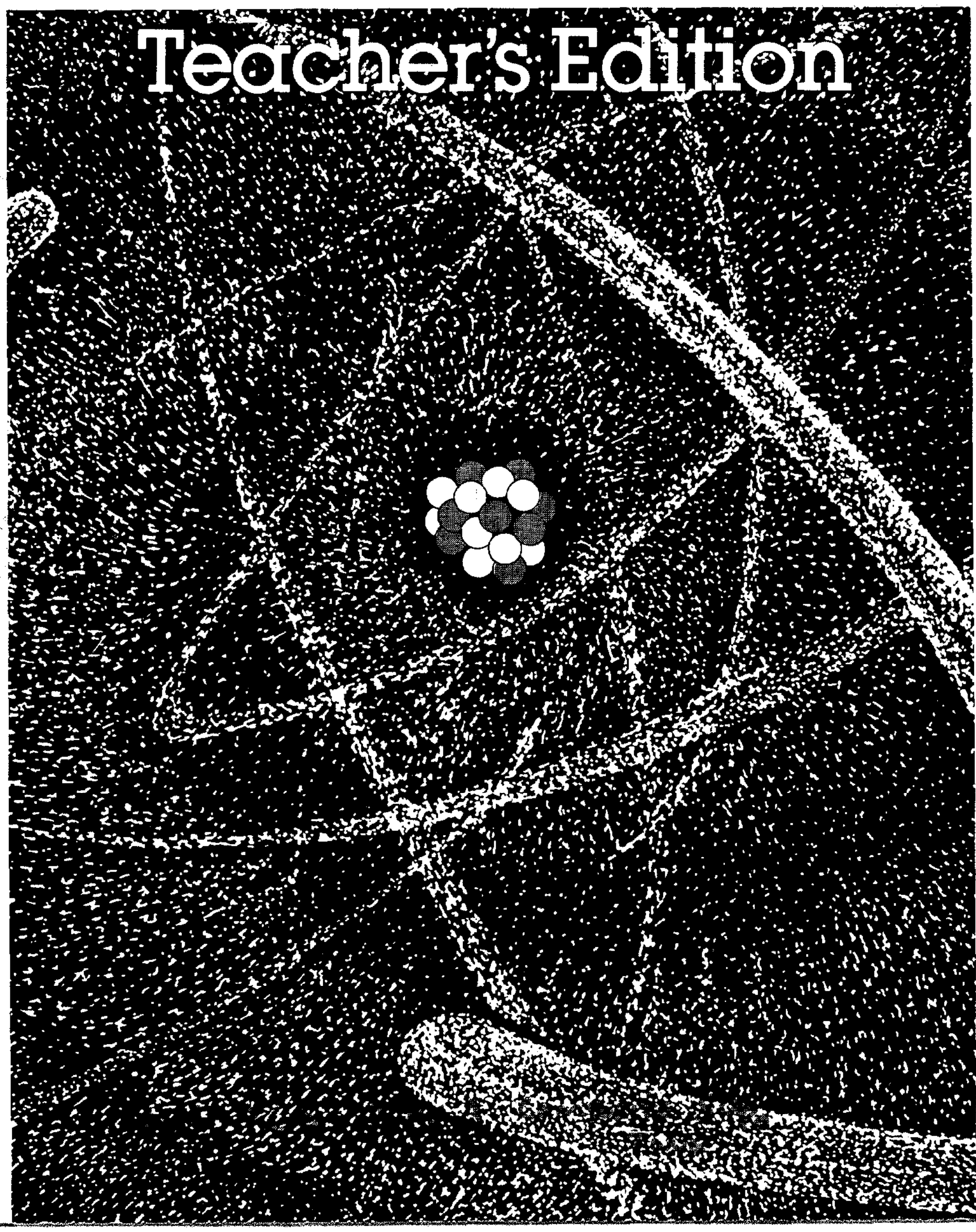
DOE/NE-0073

Nuclear Energy & Electricity

The Harnessed Atom

U.S. Department of Energy
Assistant Secretary, Nuclear Energy ■ Office of Program Support



Note: This publication is missing the pages for the Review Exercise for Unit 2 – Lesson 2

DOE/NE-0073

Nuclear Energy & Electricity

The Harnessed Atom

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

THE HARNESSED ATOM

Nuclear Energy and Electricity

TEACHER GUIDE

Introduction

The Harnessed Atom is a nuclear energy curriculum for grades 6 through 8. The kit contains written text and a filmstrip, review exercises, and activities for the students.

This Teacher Guide contains suggestions for using the materials, including ideas for a learning center. The guide is designed to help teachers in scheduling and planning lessons that teach concepts as well as develop basic skills. Also included here are discussion questions, answers to review exercises and activities, a list of materials, and a list of additional resources. Teachers using the materials should remember to insist that students follow safety rules and use proper equipment in doing activities.

The Teacher Guide is designed to be inserted in a binder. This format will enable the teacher to remove pages for making photocopies, dittos, or transparencies and will also make it easy to add supplemental pages if desired.

TABLE OF CONTENTS

			Page
Evaluation Form			iii
Equipment List			1
Order Form			4
Schedule			5
Additional Resources			9
Pretest			13
Unit 1	**Energy and Electricity**		
	Introduction		17
	Learning Objectives		17
	Lesson 1	Energy Review	19
		Review Exercise	21
		The Good Old Days	25
		Cryptoglyphics	27
		Which Has More Heat Energy?	29
	Lesson 2	Electricity Review	31
		Review Exercise	33
		Make a Motor	35
		How to Read an Electric Meter	37
Unit 2	**Understanding Atoms and Radiation**		
	Introduction		41
	Learning Objectives		41
	Lesson 1	Atoms and Isotopes	43
		Review Exercise	47
		The Mystery Box	51
		Name That Isotope	53
		Atom Model	57
		Periodic Table of the Elements	59
	Lesson 2	Radiation and Radioactive Decay	61
		Review Exercise	65
		Flip Out!	67
		The Cloud Chamber	69
	Lesson 3	Detecting and Measuring Radiation	71
		Review Exercise	73
		Using a Geiger Counter	75
	Lesson 4	Background Radiation	79
		Review Exercise	81
		Computing Your Personal Radiation Dose	85
		Background Radiation Crossword Puzzle	87
	Lesson 5	The Uses of Radiation	89
		Review Exercise	91
		Uses of Radiation	95
		Radiography	97
	Lesson 6	Fission, Chain Reactions, and Fusion	99
		Review Exercise	101
		Simulation of Fission Chain Reaction	105
	Additional Lesson:	The Atomic Pioneers	107
		Atomic Pioneers Time Line	109
		The Atomic Pioneers	111

TABLE OF CONTENTS

Unit 3 The Franklin Nuclear Powerplant
Introduction 121
Learning Objectives 121
Lesson 1 Planning the Franklin Nuclear Powerplant 123
Review Exercise 125
Selecting a Site for a Nuclear Powerplant 127
The Effect of Heat on Brine Shrimp 131
Lesson 2 How the Reactor Works 135
Review Exercise 137
Word Search 141
Controlling the Speed of a Nuclear Chain Reaction 143
Lesson 3 Producing Electricity at Franklin 147
Review Exercise 149
Locating Nuclear Powerplants in the United States 153
Model of Franklin 157
Lesson 4 Franklin's Fuel 161
Review Exercise 163
Scrambled Fuel Terms 165
Separating Salt from Sand 167
Lesson 5 Franklin's Waste 169
Review Exercise 171
The Nuclear Fuel Cycle 175
Nuclear Waste Cube 179
Lesson 6 Franklin's Safety System 181
Review Exercise 183
Safety Systems All around Us 185
Containment System Eggstraordinary! 187
Lesson 7 Other Reactors 189
Review Exercise 191
Types of Nuclear Powerplants 195
Nuclear Power around the World 205
Lesson 8 "The Harnessed Atom" Filmstrip 207

Unit 4 Addressing the Issues
Introduction 209
Learning Objectives 209
Lesson 1 Energy and Money 211
Review Exercise 213
Supply and Demand 217
Percent of Electricity Produced by Nuclear Powerplants 219
Lesson 2 Safety 221
Review Exercise 223
Nucleoglyphics 227
Selecting a Permanent Waste Repository Site 229
Lesson 3 Energy Decision Making 239
Review Exercise 241
Nuclear Energy—Benefits and Problems 243
Posttest 245
Appendix: A Learning Center 249

THE HARNESSED ATOM EVALUATION

In order to evaluate The Harnessed Atom, the Department of Energy needs information from teachers who have used it in their classrooms.

We would appreciate it if you would fill in the form below and return it to:

THE HARNESSED ATOM
U.S. Department of Energy
300 South Tulane Avenue
Oak Ridge, Tennessee 37830

THE HARNESSED ATOM EVALUATION FORM

Please Print

Name ______________________________
School ______________________________
Street Address ______________________________
City ____________________ State ______ Zip __________

1. Number of students in each grade who studied *The Harnessed Atom.*

   Grade 6 ______ Grade 7 ______ Grade 8 ______ Other ______ (Please specify)

2. Total number of classes to whom you taught *The Harnessed Atom.* ______

3. What do you think was the reaction of most of your students to *The Harnessed Atom* (in comparison to other units you have taught)?

   ______ Very Positive ______ Positive ______ Negative ______ Very Negative

4. What was your overall reaction to *The Harnessed Atom?*

   ______ Very Positive ______ Positive ______ Negative ______ Very Negative

5. Will you teach *The Harnessed Atom* again?

   ______ Yes ______ No

6. Comments/Suggestions for improvement:

EQUIPMENT LIST

A complete list of equipment needed to do all the activities found in *The Harnessed Atom* is listed below. The amounts are calculated for one class of 30 students working in pairs.

Materials	Amount Needed for 30 Students	Unit-Lesson in Which Used
aluminum foil	one roll	1-1
balance	1	1-1
blotter paper	15	2-2
books, heavy	15	2-5
box, large, with transparent top or clear plastic for a cover	1	2-6
boxes, 2 small identical boxes	15	2-1
brine shrimp eggs	one vial	3-3
candles, birthday	300	1-1, 3-2
cheesecloth	one package	3-4
coat hanger or stiff wire	15	1-1
colored pencils (optional)	60	2-2
containers:		
aluminum pie pans	15	3-2
beakers or plastic cups	90	3-1, 3-3
glass baking dish	1	3-1
heat resistant glass or stainless steel pans	4	3-1
jars, small transparent with lids (baby food jars)	15	2-2
tin cans, small	15	1-1
trash	1	2-5
cookie sheet or heat resistant glass beaker	15	3-4
copper wire, enameled (90 cm #20)	15	1-2
corks	15	1-1
D-cell batteries	15	1-2
dominoes	several boxes	3-2
dry ice or CO_2 fire extinguisher	1	2-2
eggs, raw	15	3-6
ethyl alcohol, pure	50 ml	2-2
eye droppers	15	3-1
felt tip markers	10	1-1
flashlights	15	2-2
Geiger counters	10	2-3
gloves or tongs	1 pair	2-2, 2-6
glue	several bottles to share	3-1
goggles, safety	30	2-2
graph paper (optional)	30 sheets	2-2

EQUIPMENT LIST

hammers	10	1-2
hot plate	1	3-1, 3-4
magnets (1 inch)	30	1-2, 2-1
magnifying glasses	15	3-4
matches	30	1-1
matches, wooden	15 boxes	3-2
meter sticks	2	3-6
modeling clay	3 packages	3-2
mousetraps (snap-spring type)	30	2-6
paper—sheets of 8-1/2" by 11"	75	3-6
paper clips	30	1-2, 2-5
peanuts	15	1-1
pennies	1 roll	2-2, 2-5
ping-pong balls	61	2-6
plastic sheet (4' x 6')	1	3-6
pliers	5	1-2
Polaroid 4x5 Land film (pocket type 57) 3000 speed	15	2-5
pot holders	15	3-1, 3-4
radioactive sources such as:		2-2, 2-3, 2-5
cloisonné jewelry		
commercially available radioactive sources		
gas lantern mantles		
salt substitute containing potassium		
luminescent clock face		
orange-glazed ovenware		
rollers, art	3	2-5
rulers, Metric or English	15	1-1, 3-1, 3-2
salt	5 boxes	3-4
salt, non-iodized or ocean mix	1 box	3-1
sand	30 cups	3-4
sandpaper pieces, fine	15	1-2
scales	10	2-1
scissors	30	3-3
screen (pieces for sifting sand)	15	3-4
shielding materials such as:		2-3
aluminum foil		
brick		
glass pane		
jar of water		
paper		
piece of wood		
sheet of lead		

spray paint:		
flat black	2 cans	2-2
orange	2 cans	2-1
red	2 cans	2-1
stop watches	3	3-2
straight pins	15	1-1
styrofoam balls (4 cm)	135	2-1
styrofoam blocks (2 cm x 10 cm)	45	2-1
styrofoam squares	15	2-2
tape:		
black electrical	1 roll	2-1
clear	1 roll	3-6
masking	2 rolls	1-1, 1-2, 2-2
thermometers	15	1-1, 3-1
thumbtacks or screws	30	1-2
tongs	1	2-2, 2-6
toothpicks	1 box	2-1
walnut pieces	15	1-1
water	2 gallons	3-1, 3-4
wood, 10cm x 10cm pieces	15	1-2
Any 3: BBs		2-1
bolts		2-1
magnets		2-1
marbles		2-1
moth balls		2-1
onions		2-1
packet of seeds		2-1
pieces of chalk		2-1
ping-pong balls		2-1
sleigh bells		2-1
small blocks of wood		2-1
tennis balls		2-1

ORDER FORM: "THE NUCLEAR FUEL CYCLE" FILMSTRIP

To order the filmstrip, "The Nuclear Fuel Cycle," for Lesson 8, Unit 3 of *The Harnessed Atom*, please complete the order form. Send order to: Discovery Shop, American Museum of Science and Energy, 300 South Tulane Avenue, Oak Ridge, Tennessee 37830.

Please enclose $2.50 for each filmstrip. All orders must be prepaid by check or money order. Purchase orders are accepted from school systems.

Please print or type:

Name ______________________________

Street ______________________________

City, State, Zip ______________________________

Description	Quantity	Price Each	Total Price
"The Nuclear Fuel Cycle" Filmstrip		$2.50	

Schedule

The Harnessed Atom is composed of 18 lessons and a filmstrip. Some lessons will take longer than one day to complete if all of the activities are assigned. There are class activities for each lesson which expand the lesson and further explore some of the concepts. The activities that require extra time and/or equipment are listed as extended learning opportunities. A suggested schedule for 28 class periods is given here. You may want to design a schedule of your own as well.

Recommended Schedule

Day 1
Pretest
Reading Unit 1, Lesson 1
Discussion questions, Lesson 1
Assign homework, The Good Old Days

Day 2
Review Exercise, Lesson 1
Discussion, The Good Old Days
Cryptoglyphics
Extended learning: Which Has More Heat Energy, a Peanut or a Walnut?

Day 3
Review Cryptoglyphics
Reading Unit 1, Lesson 2
Discussion questions, Lesson 2
Review Exercise, Lesson 2

Day 4
How to Read An Electric Meter
Extended learning: Make a Motor

Day 5
The Mystery Box
Reading Unit 2, Lesson 1
Discussion questions, Lesson 1
Review Exercise, Lesson 1

Day 6
Name That Isotope
Periodic Table of the Elements
Extended learning: The Atom Model

Day 7
Reading Unit 2, Lesson 2
Discussion questions, Lesson 2
Review Exercise, Lesson 2

Day 8
Flip Out!
Extended learning: The Cloud Chamber

Day 9
Reading Unit 2, Lesson 3
Discussion questions, Lesson 3
Review Exercise, Lesson 3
Extended learning: Using a Geiger Counter

Day 10
Reading Unit 2, Lesson 4
Discussion questions, Lesson 4
Review Exercise, Lesson 4
Computing Your Personal Radiation Dose

Day 11	Background Radiation Crossword Puzzle Reading Unit 2, Lesson 5 Discussion questions, Lesson 5 Review Exercise, Lesson 5
Day 12	Uses of Radiation Extended learning: Radiography Reading Unit 2, Lesson 6 Discussion questions, Lesson 6 Extended learning: Simulation of Fission Chain Reaction
Day 13	Reading Unit 3, Lesson 1 Discussion questions, Lesson 1 Review Exercise, Lesson 1
Day 14	Selecting a Site for a Nuclear Powerplant Extended learning: The Effect of Heat on Brine Shrimp
Day 15	Reading Unit 3, Lesson 2 Discussion questions, Lesson 2 Review Exercise, Lesson 2 Word Search Extended learning: Controlling the Speed of a Nuclear Chain Reaction
Day 16	Reading Unit 3, Lesson 3 Discussion questions, Lesson 3 Review Exercise, Lesson 3
Day 17	Locating Nuclear Powerplants in the United States Model of Franklin
Day 18	Reading Unit 3, Lesson 4 Discussion questions, Lesson 4 Review Exercise, Lesson 4 Scrambled Fuel Terms Extended learning: Separating Salt from Sand
Day 19	Reading Unit 3, Lesson 5 Discussion questions, Lesson 5 Review Exercise, Lesson 5 The Nuclear Fuel Cycle Extended learning: Nuclear Waste Cube
Day 20	Reading Unit 3, Lesson 6 Discussion questions, Lesson 6 Review Exercise, Lesson 6 Safety Systems All Around Us Extended learning: Containment System Eggstrodinary!
Day 21	Reading Unit 3, Lesson 7 Discussion questions, Lesson 7 Review Exercise, Lesson 7 Types of Nuclear Powerplants

Day 22	Nuclear Powerplants Around the World Filmstrip: "The Harnessed Atom"
Day 23	Reading Unit 4, Lesson 1 Discussion questions, Lesson 1 Review Exercise, Lesson 1 Supply and Demand
Day 24	Percent of Electricity Produced by Nuclear Powerplants Reading Unit 4, Lesson 2 Discussion questions, Lesson 2
Day 25	Review Exercise, Lesson 2 Nucleoglyphics Extended learning: Selecting a Permanent Waste Repository Site
Day 26	Reading Unit 4, Lesson 3 Discussion questions, Lesson 3 Review Exercise, Lesson 3 Nuclear Energy—Benefits and Problems
Day 27	Review & Makeup Day
Day 28	Posttest Evaluation of *The Harnessed Atom*

Additional Resources

This list is provided to aid teachers in locating supplies for activities described in this Teachers' Kit and to enable them to find additional information about nuclear energy. This is not an exhaustive or comprehensive list. Reference to any specific commercial product or organization does not imply its endorsement.

Alternative Energy Sources: Experiments You Can Do. 32 pp., $1.00, Charles Edison Fund, 101 South Harrison Street, East Orange, NJ 07018.

The Amazing Energy Expedition: A Play to Read and Act Out (reprint from the 10/82 and 11/82 issues of **Ranger Rick's Nature Magazine**). 15 pp., $1.00, National Wildlife Federation, 1412 16th Street, NW, Washington, DC 20036.

The Atom — A Closer Look (16 mm color film, 30 min., 1981). American Nuclear Society, 555 North Kensington Avenue, La Grange Park, IL 60525.

The Electric Timeline (teacher resource). 47 pp., Edison Electric Institute, 1111 19th Street, NW, Washington, DC 20036.

Electricity (by David Macaulay). 1983, 47 pp., Free, Tennessee Valley Authority, Director of Information, 400 West Summit Hill Drive, Knoxville, TN 37902. (Single copy requests only.)

Electricity (student resource booklet), 20 pp.,**Electricity, — Electric Safety and Electricity - Generation/Transmission** (teacher kit). Duke Power Company, 422 South Church Street, P. O. Box 33189, Charlotte, NC 28242.

Electricity from Nuclear Fission and **Electricity from Nuclear Fusion** (teacher resource). Electric Power Research Institute, Communications Services Department, P. O. Box 10412, Palo Alto, CA 94022.

Electricity from Nuclear Energy (student resource booklet). 25 pp., 75¢, Westinghouse Strategic Information and Education Programs, Monroeville Nuclear Center, Monroeville, PA 15146.

Electricity from Power Plant to You (10 activities with teacher's guide). Baltimore Gas and Electric Co., 1100 Gas and Electric Building, P. O. Box 1475, Baltimore, MD 21203. (Within service area only.)

Energy Factsheets (teacher resource). $2.50, League of Women Voters, 1730 M Street, NW, Washington, DC 20036.

The Energy Future Today. Free, U.S. Department of Energy, Technical Information Center, P.O. Box 62, Oak Ridge, TN 37830.

Energy Source Energy Education Program (10 lessons with planned curriculum). The Energy Source Program, 5505 E. Carson Street, Suite 250, Lakewood, CA 90713. **Power Switch** (grades 5-6, $35). **Energy Crunch** (junior high science, $24 for teacher pack, $50 for student materials).

Films (industry produced). Free, Modern Talking Picture Service, 5000 Park Street North, St. Petersburg, FL 33709.

Filmstrips, videotapes, and computer software for loan. American Nuclear Society, Public Communications Department, 555 North Kensington Avenue, La Grange Park, IL 60525.

How Nuclear Plants Work. 6 pp., 10¢, Atomic Industrial Forum, Inc., Public Affairs and Information Program, 7101 Wisconsin Avenue, Bethesda, MD 20814.

Into the Atom (film). Modern Talking Picture Service, 5000 Park Street North, St. Petersburg, FL 33709.

Know Nukes: A Nuclear Power Issues Curriculum Project (booklet of lessons and exercises). 45 pp., $4.00, Antioch/New England Graduate School, Roxbury Street, Keene, NH 03431.

Additional Resources

Lifestyles in an Electric Economy (teacher resource). Edison Electric Institute, 1111 19th Street, NW, Washington, DC 20036.

Managing Nuclear Waste. 6 pp., 10¢, Atomic Industrial Forum, Inc., Public Affairs and Information Program, 7101 Wisconsin Avenue, Bethesda, MD 20814.

Microcomputer programs. National Science Teachers Association, Special Publications, 1742 Connecticut Avenue, NW, Washington, DC 20009. Programs include: **Power Grid** $59, **Energy Conversion** $35, **Electricity Bill** $35, **Personal Energy Inventory** $45, **House Energy Savings** $45. Programs suitable for Apple II and Radioshack TRS 80.

Nuclear Energy Facts — Q & A (teacher resource). American Nuclear Society, Public Communications Department, 555 North Kensington Avenue, La Grange Park, IL 60525.

Nuclear Energy Glossary. 20 pp., 60¢, Westinghouse Strategic Information and Education Programs, Monroeville Nuclear Center, Monroeville, PA 15146.

Nuclear Experiments You Can Do ... From Edison. 75¢, Thomas Alva Edison Foundation, 2100 West Ten Mile Road, Southfield, MI 48075.

The Nuclear Kit (teacher kit with transparencies and posters). Free within service area, Alabama Power Company, P. O. Box 2641, Birmingham, AL 35291.

Nuclear Power: Answers to Your Questions (teacher resource). 48 pp., Edison Electric Institute, 1111 19th Street, NW, Washington, DC 20036.

Nuclear Power Plant Model Kit (cardstock model of a nuclear powerplant with detailed assembly instructions printed in English. Recommended for use as special project for particularly interested and motivated students 14 years old and older.) Free to schools or other educational bodies, Kraftwerk Union Aktiengesellschaft, Public Relations Division, Postfach: 3220, 8620 Erlangen, West Germany.

A Nuclear Power Primer: Issues for Citizens (teacher reference). 80 pp., $4.50, League of Women Voters Education Fund, 1730 M Street, NW, Washington, DC 20036.

Nuclear Power Quick Reference IV. Single copies free, General Electric Company, c/o Marketing Communication, 175 Curtner Avenue, San Jose, CA 95125.

Nuclear Reactor Safety. 6 pp., 10¢, Atomic Industrial Forum, Inc., Public Affairs and Information Program, 7101 Wisconsin Avenue, Bethesda, MD 20814.

Nuclear Waste Disposal: Closing the Circle (teacher resource). Atomic Industrial Forum, 7101 Wisconsin Avenue, Bethesda, MD 20814.

The Nuclear Waste Primer (A handbook for Citizens). 90 pp., $5.95, Distributed for the League of Women Voters by Schocken Books, 62 Cooper Square, New York, NY 10003.

Nuclear Waste: Toward a Solution (teacher resource). Atomic Industrial Forum, 7101 Wisconsin Avenue, Bethesda, MD 20814.

Protecting Nuclear Power Plants (teacher resource). Atomic Industrial Forum, 7101 Wisconsin Avenue, Bethesda, MD 20814.

Questions Kids Ask About Energy (student resource). 43 pp., $1.00, Westinghouse Strategic Information and Education Programs, Monroeville Nuclear Center, Monroeville, PA 15146.

Additional Resources

Radiation (booklet), 12 pp., 75¢, Westinghouse Strategic Information and Education Programs, Monroeville Nuclear Center, Monroeville, PA 15146.

Radiation — A Fact of Life. American Nuclear Society, 555 North Kensington Avenue, La Grange Park, IL 60525.

Radiation — A Fact of Life (teacher resource). 14 pp., International Atomic Energy Agency, Wagramerstrasse 5, A-1400, P. O. Box 100, Vienna, Austria.

Radiation: Measure for Measure (pamphlet). Atomic Industrial Forum, 7101 Wisconsin Avenue, Bethesda, MD 20814.

Radiation ... Naturally (film). Available from Modern Talking Picture Service, see Films listing.

Shipping Nuclear Fuel: Safety in Motion (teacher resource). Atomic Industrial Forum, 7101 Wisconsin Avenue, Bethesda, MD 20814.

Teacher Kit on Nuclear Power (reference). Atomic Industrial Forum, Attn: Publications Office, 7101 Wisconsin Avenue, Bethesda, MD 20814.

Uranium: Energy for the Future (teacher resource). Atomic Industrial Forum, 7101 Wisconsin Avenue, Bethesda, MD 20814.

Working with the Atom — Careers for You. 40 pp., Atomic Industrial Forum, 7101 Wisconsin Avenue, Bethesda, MD 20814.

You and Your Electric Company — Answers to Your Questions (teacher resource). 37 pp., Edison Electric Institute, 1111 19th Street, NW, Washington, DC 20036.

In the blank that precedes each question, write the letter of the answer that *best* completes each statement.

____ 1. Which of the following is a secondary energy source?

a. electricity.
b. solar energy.
c. tidal energy.
d. fossil fuel energy.

____ 2. In the United States, most electricity is produced by using steam to turn the blades of a ________.

a. turbine.
b. windmill.
c. generator.
d. flywheel.

____ 3. Which of the following produces and sells electricity to the public?

a. a franchise.
b. a turbine.
c. a generator.
d. a utility.

____ 4. The main difference between a nuclear powerplant and other kinds of powerplants is that at a nuclear powerplant ________.

a. steam is used to turn the turbine.
b. electricity is made by the generator.
c. the heat used to make the steam is produced by fissioning atoms.
d. water is used for cooling.

____ 5. Alpha, beta, and gamma are types of ____________.

a. atoms.
b. molecules.
c. radiation.
d. elements.

____ 6. Radioactive atoms throw off particles and/or rays in a process called ________

a. half-life.
b. decay.
c. fission.
d. fusion.

____ 7. Distance, shielding, and time affect the amount of exposure to ____________.

a. electricity.
b. molecules.
c. elements.
d. radiation.

____ 8. An instrument that is used to detect and measure radiation is a ____________.

a. Geiger counter.
b. telescope.
c. microscope.
d. seismograph.

____ 9. Splitting the atom to release energy is called ________________.

a. fusion.
b. fission.
c. generation.
d. division.

____ 10. When you get a sunburn, it is the result of too much exposure to ___________.

a. heat.
b. low atmospheric pressure.
c. radiation.
d. high atmospheric pressure.

____ 11. When hydrogen isotopes are joined together to form a new atom and release energy, it is called ________________.

a. fission.
b. permutation.
c. cogeneration.
d. fusion.

____ 12. The element now used as fuel in most nuclear powerplants is ______________.

a. cadmium.
b. uranium.
c. thorium.
d. helium.

____ 13. An example of a nuclear reaction is ____________________.

a. an atom of sodium combines with an atom of chlorine to form a molecule of table salt.
b. a neutron is added to the nucleus of a uranium-235 atom, causing it to become unstable and split apart.
c. an atom of sulfur combines with two atoms of oxygen, forming a molecule of sulfur dioxide.
d. an atom of oxygen combines with two atoms of hydrogen to form a molecule of water.

____ 14. Thirteen percent of our electricity is generated by using ______________.

a. coal.
b. nuclear fission.
c. wind energy.
d. solar cells.

____ 15. The Nuclear Regulatory Commission (NRC) ________________.

a. is a State Government agency.
b. is the utility that builds all U.S. nuclear powerplants.
c. is responsible for licensing nuclear powerplants.
d. sells uranium to utilities.

____ 16. What kind of energy is released by unstable isotopes?

a. electricity.
b. static.
c. motion.
d. radiation.

____ 17. The process of increasing the percent of uranium-235 in reactor fuel is ________.

a. reprocessing.
b. recycling.
c. milling.
d. enriching.

____ 18. The reason that we isolate nuclear waste from the environment is that it is ______.

a. very flammable.
b. expensive.
c. radioactive.
d. biodegradable.

____ 19. At a nuclear powerplant, fission takes place in the ________________.

a. steam-generator.
b. reactor.
c. control rods.
d. turbine.

____ 20. The coolant/moderator of a nuclear powerplant slows down ________________.

a. neutrons.
b. protons.
c. electrons.
d. nuclei.

____ 21. Most of the United States' low-level radioactive wastes come from ____________.

a. hospitals and industry.
b. nuclear powerplants.
c. fossil fuel powerplants.
d. NASA's space program.

____ 22. When the control rods are slowly lowered into the core of the reactor, ________.

a. more neutrons are available to cause fission.
b. the nuclear chain reaction slows down.
c. the nuclear chain reaction speeds up.
d. the temperature in the core increases.

____ 23. After being used in the reactor, nuclear fuel is ________________.

a. not radioactive.
b. slightly radioactive.
c. highly flammable.
d. highly radioactive.

____ 24. A reactor that can make more fuel than it uses is a ________________.

a. high temperature gas-cooled reactor.
b. pressurized water reactor.
c. boiling water reactor.
d. breeder reactor.

____ 25. The spent fuel pool is where ________________.

a. nuclear fission takes place.
b. water is heated to make steam and generate electricity.
c. water from the cooling tower is collected.
d. used fuel is stored.

Introduction

This is the first of four units that comprise *The Harnessed Atom*. It presents review information on energy and electricity necessary for understanding nuclear energy. The intent is to provide correct and easily understood information for the students.

Unit 1 includes a pretest for the entire kit that will measure students' knowledge of the subject before they begin the unit. Suggested demonstrations and activities are included that require students to use skills in following directions, interpreting, observing, computing, recording, and interviewing. Also included are review exercises to help reinforce students' understanding of basic energy and electricity concepts. These activities are designed to increase the basic knowledge which students acquire from the student reader.

The format of the Teacher Guide will allow you to remove the activity and review exercise pages for making ditto copies, photocopies, or transparencies.

Instructions for using *The Harnessed Atom* in a learning center are given in Appendix B.

Learning Objectives

The materials, activities, and exercises in this unit are developed from the following learning objectives.

Lesson 1 Energy Review

Students will be able to:

- ☐ recognize energy
- ☐ identify primary energy sources
- ☐ identify secondary energy sources
- ☐ classify energy types as kinetic energy
- ☐ classify energy types as potential energy
- ☐ classify energy forms (e.g., mechanical, chemical, thermal, electrical, nuclear)
- ☐ describe energy conversion

Lesson 2 Electricity Review

Students will be able to:

- ☐ identify electricity
- ☐ describe electricity production
- ☐ describe electric utilities
- ☐ define utility regulation
- ☐ generate a paragraph describing the reasons for regulating utilities

Lesson Plans

1. Gather materials.

- ☐ pretest
- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "The Good Old Days"
- ☐ class activity "Cryptoglyphics"
- ☐ class activity "Which Has More Heat Energy, a Peanut or a Walnut?"

peanut	straight pin	walnut
small tin can	cork	coat hanger or stiff wire
aluminum foil	balance	thermometer
candle	masking tape	matches
felt tip marker	ruler	

2. Administer the pretest for the entire kit.

1. a	6. b	11. d	16. d	21. a
2. a	7. d	12. b	17. d	22. b
3. d	8. a	13. b	18. c	23. d
4. c	9. b	14. b	19. b	24. d
5. c	10. c	15. c	20. a	25. d

3. Introduce vocabulary.

Introduce the vocabulary words by listing them on the chalkboard and pronouncing them correctly. Definitions can be found in the glossary at the end of the student reader.

chemical energy	inefficient	potential energy
conservation	kinetic energy	primary energy sources
efficient	mechanical energy	radiant energy
electrical energy	nonrenewable	renewable
electricity	nuclear energy	secondary energy sources
energy	photosynthesis	thermal energy
energy conversions	plutonium	uranium
fossils fuels		

4. Read Lesson 1 in student reader. (Page 3 in the student reader.)

Tell the students that this lesson will review what energy is and how we use it.

5. After students have read Lesson 1, the following questions may be used for class discussion.

a. What are some examples of how *primary sources* produce energy? (Coal can heat a home, Sun heats water, and gasoline [fossil fuel] makes a car move.)

b. Why are wind and running water considered *secondary energy sources* that come from the Sun? (Sun warms air, warm air rises; cooler air moves in to take its place. This movement of air is the wind. Heat from the Sun also creates water vapor which falls as rain.)

c. *Kinetic energy* is energy in action. Name some forms which kinetic energy can take. (Mechanical, thermal, electrical)

d. Pretend that you have just ordered your favorite meal of a hamburger, fries, and a soft drink. Can you explain how each of the *six forms of energy* might have been used to prepare the meal? (There are hundreds of possible answers. Mechanical energy helped refrigerate the meat, freeze the ice, and transport the food to the restaurant. Workers used chemical energy to power their bodies to bring you your food. Thermal energy was used to cook the food. Electrical energy was used to light the restaurant and to run many machines. Radiant energy was used by the potato plant. Nuclear energy may have been used to generate electricity; it also powers the Sun, which provides radiant energy to grow the cow's food.)

e. Many kinds of *energy conversions* occur every day. Can you name some? (Electricity to heat, light, or mechanical motion; chemical energy in food to thermal energy; kinetic energy of wind to electrical energy by turning a generator.)

f. An automobile gets 25 miles to a gallon of gas. Assuming all other factors are the same, what would the mileage be if the *energy conversion* factor were 100 percent instead of 25 percent? (It would be much better — 100 miles per gallon.) What other factors affect the miles per gallon? (Speed, starting and stopping, tire inflation, weight in the car)

6. Assign and discuss the review exercise for Lesson 1. (Page 8 in the student reader.)

Two copies of the exercise have been provided—one with answers and a clean copy for your use to make copies.

7. Assign class activity "The Good Old Days."

Additional activities:

- o Tape interviews.
- o Invite an informative older person to visit the classroom to answer questions.
- o Have students bring in energy-related devices of yesterday and display them.

8. Assign class activity "Cryptoglyphics."

9. Assign class activity "Which Has More Heat Energy, A Peanut or a Walnut?"

Review how to read a thermometer and how to use a balance. There are several kinds of balances, but the same general rules apply.

- o Carry the balance by holding it with two hands at the base.
- o Be sure to set the balance on a level surface.
- o Be sure the balance registers zero before using it.
- o The teacher, not the student, should adjust the balance.

The following questions may be used when discussing the activity.

1. Which nut raises the water temperature more? How much? (Answers will vary.)

2. Why must you be careful to measure equal amounts of the nuts and the water?
(To get accurate results. It takes more heat to affect a larger amount of H_2O. If one nut were larger, it would burn longer and give off more heat simply because it is bigger.)

3. What specific form of potential energy do the peanut and the walnut represent? (Chemical)

4. Burning the peanut and the walnut represents an energy conversion from (potential) energy to (kinetic) energy.

LESSON 1 REVIEW EXERCISE

A. List the two basic types of energy.

1. ______________________ 2. ______________________

B. List the five primary energy sources.

1. ______________________ 2. ______________________

3. ______________________ 4. ______________________

5. ______________________

C. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1.	Energy cannot be created or destroyed.	T F
2.	Fossil fuels originally got their energy from the Sun.	T F
3.	Automobiles are energy efficient.	T F
4.	Kinetic energy is stored energy.	T F
5.	In any energy conversion process, some energy is lost.	T F

D. The following are examples of potential energy. Tell how to convert each example into kinetic energy.

1. A lump of coal ______________________

____

2. Water held behind a dam ______________________

____

3. A coiled spring ______________________

____

4. A flashlight battery ______________________

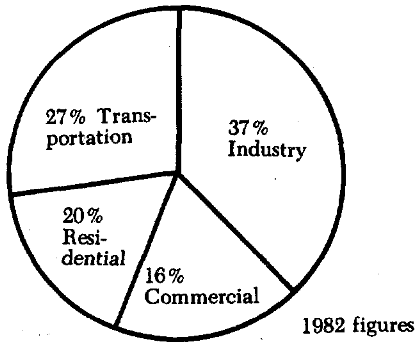
____

5. An apple ______________________

____

(Continued on next page)

E. Where we get our energy and how we use it.



The chart above divides our energy use into four groups.

1. In what group do we use the most energy? ______________________

2. What ranks second? ______________________

3. In what ways do you use energy in the transportation and residential groups? ______________________

____

____

4. Where do you have the most opportunity to cut down on your energy consumption?

____

____

Which of the groups below use energy when the following types of work are done? Check the box or boxes in the appropriate columns.
(The first one is done for you.)

	Industry	Transportation	Commercial	Residential
1. Drive to a hamburger stand		✓		
2. Take a hot bath				
3. Fly an airplane				
4. Switch on an air-conditioner				
5. Buy a new baseball				
6. Ride a school bus				
7. Blow dry your hair at home				
8. Buy a frozen pizza				
9. Ride a motor bike				
10. Manufacture a motor bike				

LESSON 1 REVIEW EXERCISE

A. List the two basic types of energy.

1. kinetic
2. potential

B. List the five primary energy sources.

1. fossil fuels
2. geothermal
3. nuclear
4. solar
5. tidal

C. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

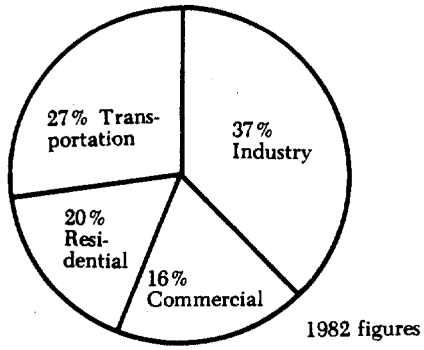
1. Energy cannot be created or destroyed. T F
2. Fossil fuels originally got their energy from the Sun. T F
3. Automobiles are energy efficient. (inefficient) T F
4. Kinetic energy is stored energy. (Kinetic energy is energy in motion. Potential energy is stored energy.) T F
5. In any energy conversion process, some energy is lost. T F

D. The following are examples of potential energy. Tell how to convert each example into kinetic energy.

1. A lump of coal When a lump of coal is burned, the potential energy it contains is converted to kinetic energy.
2. Water held behind a dam When water held behind a dam is released, potential energy is converted to kinetic energy.
3. A coiled spring The potential energy in a coiled spring is converted to kinetic energy when the spring uncoils.
4. A flashlight battery The potential energy stored in a flashlight battery is converted to kinetic energy when the flashlight is turned on.
5. An apple The potential energy in an apple is converted to kinetic energy by the body of the person who eats the apple.

(Continued on next page)

E. Where we get our energy and how we use it.



The chart above divides our energy use into four groups.

1. In what group do we use the most energy? industry
2. What ranks second? transportation
3. In what ways do you use energy in the transportation and residential groups? driving, getting from one place to another; heating or cooling; cooking; washing clothes; using hair dryers
4. Where do you have the most opportunity to cut down on your energy consumption?
   transportation
   residential

Which of the groups below use energy when the following types of work are done? Check the box or boxes in the appropriate columns.
(The first one is done for you.)

	Industry	Transportation	Commercial	Residential
1. Drive to a hamburger stand		✓		
2. Take a hot bath				✓
3. Fly an airplane		✓		
4. Switch on an air-conditioner				✓
5. Buy a new baseball			✓	
6. Ride a school bus		✓		
7. Blow dry your hair at home				✓
8. Buy a frozen pizza			✓	
9. Ride a motor bike		✓		
10. Manufacture a motor bike	✓			

THE GOOD OLD DAYS?

Interview someone (like a grandparent or neighbor) who is old enough to remember what life was like before we used so much oil, natural gas, and electricity. Ask him or her the following questions. You may even think of other questions yourself.

1. What kinds of lights did you use in your home?__________

   How was it heated?__________

2. What fabrics were clothes made of? Was clothing harder or easier to take care of?__________

   ____

3. What sort of washing machine did you have?__________

4. What kind of stove (and what kind of fuel) did your family use for cooking?__________

   ____

5. Did you have a refrigerator? How did you keep your food fresh?__________

   ____

6. How was food packaged when it came from the store?__________

   What did milk come in?__________ Was your milk delivered?__________

   How?__________

7. What sort of soap did you use?__________

   Did it clean as well as the cleaners we have now?__________

8. How was your water heated for bathing and laundry?__________

   ____

9. Did your family have a car?__________ If not, how did you travel? How did you get to school?

   ____

10. Did you have a radio?__________ What did it look like?__________

    __________ Did you go to the movies?__________

    What kinds of entertainment did you enjoy?__________

    ____

(Continued on next page)

Think up as many questions of your own as you can and ask them during the interview.

To close the interview, ask the following two questions and write the answers on the lines.

A. In what ways is life more enjoyable for you now that we have electricity, plastics, detergents, and other oil and natural gas products?

B. In what ways did you like the "good old days" better?

CRYPTOGLYPHICS

A famous archaeologist has discovered some hieroglyphics (ancient writing) on a clay tablet. He found a clue that told him the tablet was about conservation and the sources of energy. Can you figure out the words on the tablet?

∯	Σ	Π	Φ	Ψ	Δ	↖	Ω	Θ	Ξ	Σ	Π
C	O	N	S	E	R	V	A	T	I	O	N

1. Λ Σ Σ ϑ

   ___ ___ ___ ___

2. ξ Ω Φ Σ Υ Ξ Π Ψ

   ___ ___ ___ ___ ___ ___ ___ ___

3. Ω Θ Σ § Ξ ∯

   ___ ___ ___ ___ ___ ___

4. Π Γ ∯ Υ Ψ Ω Δ

   ___ ___ ___ ___ ___ ___ ___

5. ∯ Σ Ω Υ

   ___ ___ ___ ___

6. Σ Ξ Υ

   ___ ___ ___

7. Γ Δ Ω Π Ξ Γ §

   ___ ___ ___ ___ ___ ___ ___

8. Λ Ξ Π ϑ

   ___ ___ ___ ___

9. Ψ Π Ψ Δ ξ ∫

   ___ ___ ___ ___ ___ ___

10. ‖ Γ Ψ Υ

    ___ ___ ___ ___

11. ‖ Ξ Φ Φ Ξ Σ Π

    ___ ___ ___ ___ ___ ___ ___

12. Φ Σ Υ Ω Δ

    ___ ___ ___ ___ ___

13. ‖ Γ Φ Ξ Σ Π

    ___ ___ ___ ___ ___ ___

14. ξ Ψ Σ Θ ≈ Ψ Δ § Ω Υ

    ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

15. Φ Γ Π

    ___ ___ ___

16. Λ Ω Θ Ψ Δ

    ___ ___ ___ ___ ___

CRYPTOGLYPHICS

A famous archaeologist has discovered some hieroglyphics (ancient writing) on a clay tablet. He found a clue that told him the tablet was about conservation and the sources of energy. Can you figure out the words on the tablet?

∯	Σ	Π	Φ	Ψ	Δ	↖	Ω	Θ	Ξ	Σ	Π
C	O	N	S	E	R	V	A	T	I	O	N

1. Λ Σ Σ ϑ
   W O O D
2. ξ Ω Φ Σ Υ Ξ Π Ψ
   G A S O L I N E
3. Ω Θ Σ § Ξ ∯
   A T O M I C
4. Π Γ ∯ Υ Ψ Ω Δ
   N U C L E A R
5. ∯ Σ Ω Υ
   C O A L
6. Σ Ξ Υ
   O I L
7. Γ Δ Ω Π Ξ Γ §
   U R A N I U M
8. Λ Ξ Π ϑ
   W I N D
9. Ψ Π Ψ Δ ξ ∫
   E N E R G Y
10. ‖ Γ Ψ Υ
    F U E L
11. ‖ Ξ Φ Φ Ξ Σ Π
    F I S S I O N
12. Φ Σ Υ Ω Δ
    S O L A R
13. ‖ Γ Φ Ξ Σ Π
    F U S I O N
14. ξ Ψ Σ Θ ≈ Ψ Δ § Ω Υ
    G E O T H E R M A L
15. Φ Γ Π
    S U N
16. Λ Ω Θ Ψ Δ
    W A T E R

WHICH HAS MORE HEAT ENERGY, A PEANUT OR A WALNUT?

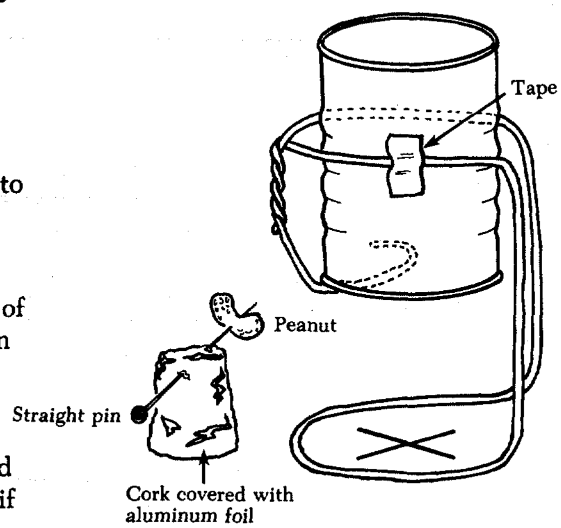
This experiment illustrates energy conversion. All food has varying amounts of energy that we use in our bodies for heat and motion. By eating and digesting food, we are actually using the energy of the Sun that the plants have stored.

Materials

½ shelled peanut
one piece of walnut the same weight as the peanut
cork covered with aluminum foil
small tin can
wire coat hanger or stiff wire
ruler
felt tip marker
thermometer
straight pin
balance
candle
matches
masking tape

Directions:

1. Bend coat hanger to make a frame for the tin can.
2. Fill the tin can ¾ full of cold water. Draw a mark on the outside of the can to show the waterline.
3. Measure the temperature of the water and record it on the chart.
4. Put small can on the stand you have made. Tape it, if you need to.
5. Weigh the peanut first. Then weigh an equal amount of walnut.



6. Put the cork and peanut under the can. The peanut should be 2 cm from the can. Bend the frame to lower or raise the can.
7. Use a match to light the candle. Set fire to the peanut by using a candle. Make sure you do not hold the candle flame beneath the can because this will affect your results.
8. Record the water temperature after the peanut has burned.
9. Repeat the experiment, this time using the walnut.

PEANUT			WALNUT		
Temperature of Water			Temperature of Water		
Cold	Heated	Change	Cold	Heated	Change

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Make a Motor"

80 cm #20 *enameled* copper wire	2 pieces of *enameled* copper wire for connecting	pliers
fine sandpaper	10 cm x 10 cm piece of wood	hammer
thumbtacks or screws		magnets (1 inch)
paper clips		masking tape
		1 D-cell battery

- ☐ class activity "How to Read an Electric Meter"

2. Discuss "The Good Old Days" assignment.

3. Introduce vocabulary.

Introduce the vocabulary words by listing them on the chalkboard and pronouncing them correctly. Definitions can be found in the glossary at the end of the student reader.

biomass	generate	turbine
electricity	generator	utility
electrons	regulate	

4. Read Lesson 2 in student reader. (Page 10 in student reader.)

5. After students have read Lesson 2, the following questions may be used for class discussion.

a. Name some of the ways we use *electricity*. (We use electricity to cool and heat our homes, schools, offices; to provide light; to run appliances; and to run machines in factories.)

b. How quickly can you find ten ways you used *electricity* starting from the time you woke up this morning? (Answer will vary but will probably include such things as alarm clocks, toasters, hot water heaters, electric lights, refrigerators, microwave ovens, heaters, electric blankets, air conditioners, television sets, radios, etc.)

c. What *energy sources* can we use to make electricity? (coal, oil, uranium, water)

d. What special circumstances does an *electric utility* operate under? (It must have a supply of electricity ready when the customers need it. If the temperature drops 20° due to a cold wave, people will need more electricity for heat. The company must also plan ahead to decide how much electricity the community will need several years from now because of construction time for powerplants.)

6. Assign and discuss the review exercise for Lesson 2. (Page 14 in student reader.)

Depending upon the grade level of your class, you may put the following list of words on the board for students to choose answers from for Section A.

7. Introduce class activity "Make a Motor."

This activity will usually take an entire period. The activity illustrates energy conversion—the chemical energy in the battery is converted to mechanical energy in the motor.

You may want to make a motor before class begins for use as a demonstrator. Magnets can be purchased at a radio supply store; the motor will usually work better with more than one magnet. Students will need to test the armature to be sure it spins before attaching it to the battery. To make the armature, they should wrap the wire around two fingers. Explain that the ends of the wire need to be sandpapered so that the wires will make good contact. This activity requires patience, but students usually feel very satisfied when they succeed. If the motor does not work the first time, problems to check for are: failure to sand off the enamel coating; unbalanced armature; not making good contact with the battery.

Questions that you may want to ask the class are:

1. The battery has potential energy in what form? (Chemical)

2. Does this activity illustrate energy conversion? Why or why not? [Yes. Chemical (potential) energy changes to mechanical (kinetic) energy.]

3. What secondary energy source do we rely on most to run our machines and motors? (Electricity)

8. Assign class activity "How to Read an Electric Meter."

Two copies of the exercise have been provided—one with answers and a clean copy for your use to make copies.

Questions to ask the class:

How would you compare the electric meter to an odometer in an automobile? (An odometer measures mileage in units of 10 much like an electric meter measures electricity use.)

Would there be some days when the electricity used would be higher than other days? Why? (More electricity would be needed for heating or cooling during very hot or very cold weather, etc.)

LESSON 2 REVIEW EXERCISE

A. Circle the letter of the best answer for each item.

1. Which one of these energy sources is not used in the United States to produce electricity?
   a. water   c. tidal energy
   b. uranium   d. coal

2. Most powerplants make electricity by heating water to produce ________________.
   a. oil   c. electrons
   b. steam   d. heat energy

3. The steam made at the powerplant turns a ________________________.
   a. windmill   c. bolt
   b. turbine   d. steel rod

4. How many electric power companies are there in the United States?
   a. about 250   c. about 1,000
   b. about 400   d. about 2,000

5. What is the name of the utility that supplies electricity to your community?

   ____

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Electricity is the flow of electrons, usually through a wire. T F
2. Many electric utilities may sell electricity to the same town. T F
3. Meters keep track of how much electricity you use. T F
4. Demand for electricity is always the same. T F
5. State and local governments regulate utilities because a utility is allowed to be the only electric power company in the area. T F

C. List three reasons why governments regulate utilities.

____

____

____

____

____

LESSON 2 REVIEW EXERCISE

A. Circle the letter of the best answer for each item.

1. Which one of these energy sources is not used in the United States to produce electricity?
   a. water c. tidal energy
   b. uranium d. coal

2. Most powerplants make electricity by heating water to produce ______________.
   a. oil c. electrons
   b. steam d. heat energy

3. The steam made at the powerplant turns a ______________________________.
   a. windmill c. bolt
   b. turbine d. steel rod

4. How many electric power companies are there in the United States?
   a. about 250 c. about 1,000
   b. about 400 d. about 2,000

5. What is the name of the utility that supplies electricity to your community?

   ____

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Electricity is the flow of electrons, usually through a wire. T F
2. Many electric utilities may sell electricity to the same town. (one utility only) T F
3. Meters keep track of how much electricity you use. T F
4. Demand for electricity is always the same. (Demand changes constantly.) T F
5. State and local governments regulate utilities because a utility is allowed to be the only electric power company in the area. T F

C. List three reasons why governments regulate utilities.

Utilities provide an essential service to customers. Electric utilities must provide electricity as it is needed and in the amounts needed. This electricity production requires a large investment from the company. Therefore, each utility is assigned a specific area to serve and no other utility serves the same area. Governments feel that it is important to regulate utilities so that they will charge fair rates to their customers.

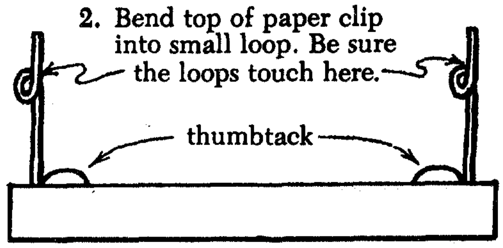
MAKE A MOTOR

Materials

80 cm # 20 enameled copper wire	hammer
fine sandpaper	pliers
paper clips	2 pieces of enameled copper wire to connect motor and battery
thumbtacks or screws	10 cm × 10 cm piece of thin wood
masking tape	1 D-cell battery
magnets (1")	

I. MAKE A FRAME

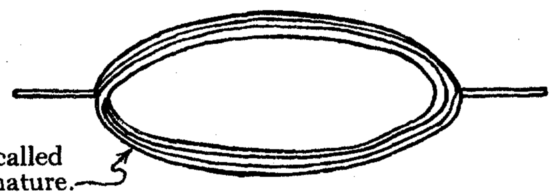
1. Bend large end of paper clip up.
2. Bend top of paper clip into small loop. Be sure the loops touch here.



3. Attach the loops to the board with the thumbtacks holding down the paper clip through the end that was not bent up.

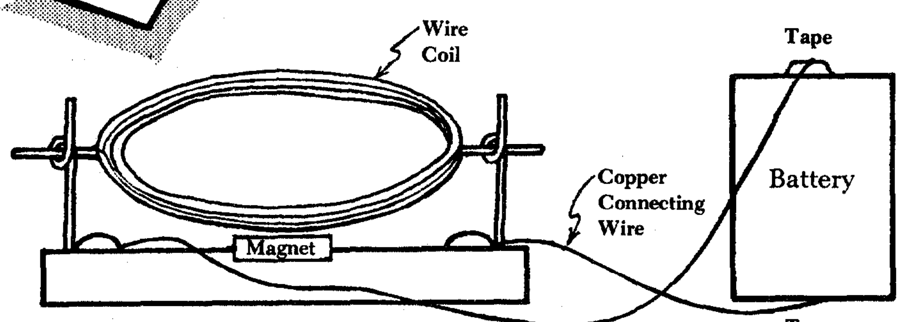
II. MAKE AN ARMATURE

4. Make the 80 cm of copper wire into a coil. Be sure the ends of the wire stick out at the center of the coil. Sandpaper the enamel coating off the ends of the armature.



5. Make sure the ends of the wire are long enough to fit between the paper clips, resting in the small loops you made.

III. PUT THE MOTOR TOGETHER



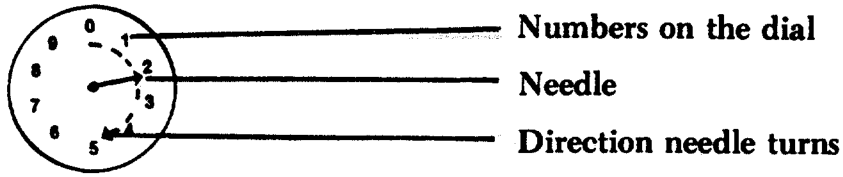
6. Sand the enamel coating off each end of each connecting wire.
7. Attach one end of each connecting wire to the thumbtack part of the frame. Attach the other end of each wire to the battery as shown.
8. Put the magnet under the armature.
9. Gently spin the armature to get the motor started.

Note: You may need to press the wire to the battery with your fingertips to make sure there is good contact.

HOW TO READ AN ELECTRIC METER

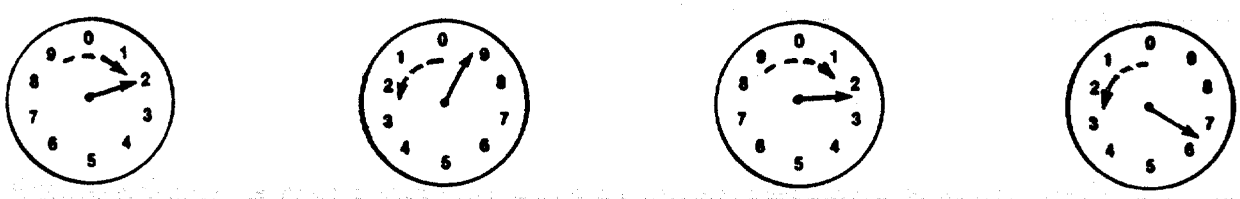
The amount of electricity you use is measured by a **meter** attached to your house or apartment. An electricity meter has dials on which needles point to the number of kilowatt-hours of electricity that you have used. One of the dials on the meter will look like this:

Dial



Study the illustration below.

This dial counts units of 1000 kilowatt-hours each.	This dial counts units of 100 kilowatt-hours each.	This dial counts units of 10 kilowatt-hours each.	This dial counts single kilowatt-hours.



Dial A clockwise direction	**Dial B** counterclockwise direction	**Dial C** clockwise direction	**Dial D** counterclockwise direction

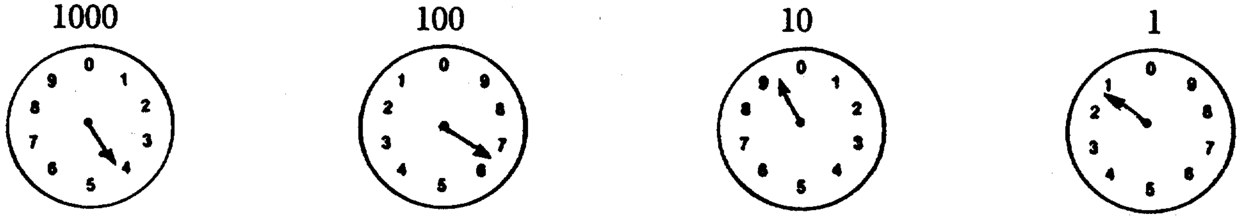
As the needle turns in a clockwise or counterclockwise direction, it counts one unit of electricity used.

The number of units counted is the last number passed by the needle. For instance, Dial D has just passed 6.

Study the illustration carefully to notice that several dials are needed to count the total number of units of electricity used in a home. The reason for the four dials is that each dial can count only ten units, so each dial as explained will count a unit of a different size.

Study the meter below. Fill in the blanks beneath each dial.

1000	100	10	1



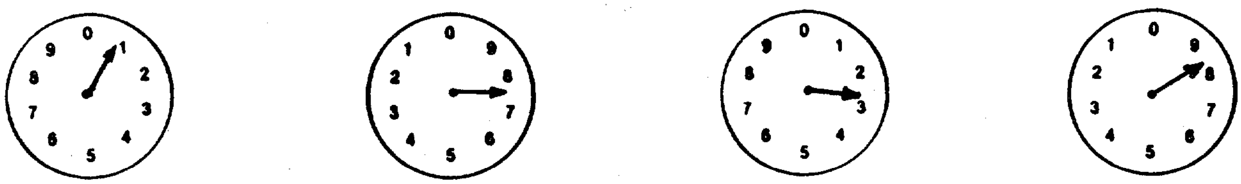
means ____________ kilowatt-hours	means ____________ kilowatt-hours	means ____________ kilowatt-hours	means ____________ kilowatt-hours

According to your calculations, this meter shows that a total of

____________________ kilowatt-hours have been used.

(Continued on next page)

This meter reads ________________ kilowatt-hours.



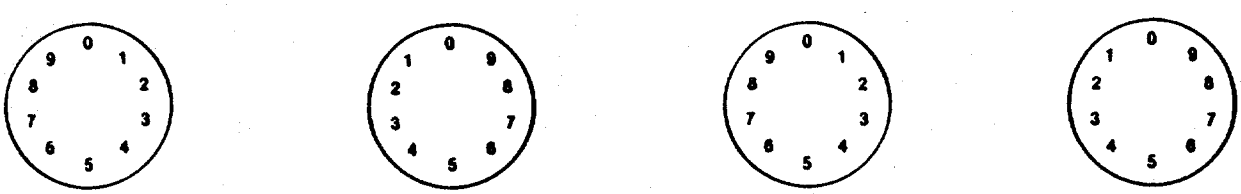
This meter reads ________________ kilowatt-hours.

This meter reads ________________ kilowatt-hours.

1. Find the meter in your home. Use the blank dials below to record the readings for two days.

Day 1 

This meter reads ________________ kilowatt-hours.

Day 2 

This meter reads ________________ kilowatt-hours.

2. Subtract the reading for Day 1 from the reading for Day 2. ________________ Day 2

— ________________ Day 1

Total kilowatt-hours used ________________

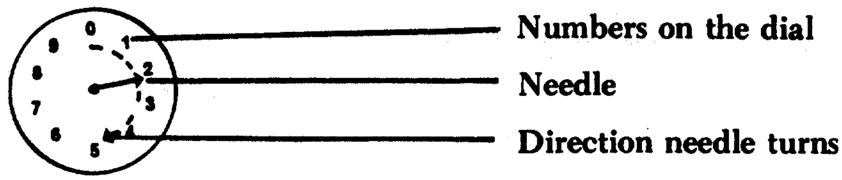
3. * Select one person in the class to call the electric company to see how much one kilowatt hour costs.

How much did one day's electricity cost? ________________

HOW TO READ AN ELECTRIC METER

The amount of electricity you use is measured by a meter attached to your house or apartment. An electricity meter has dials on which needles point to the number of kilowatt-hours of electricity that you have used. One of the dials on the meter will look like this:

Dial



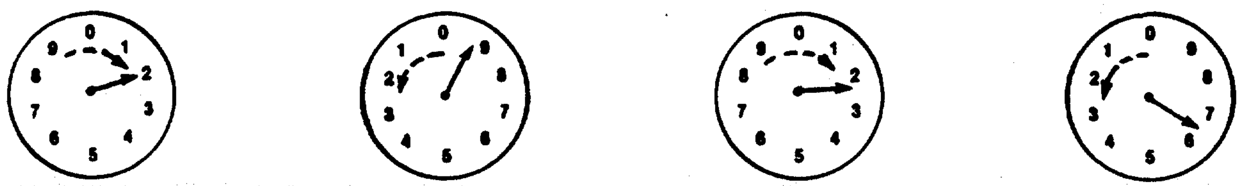
Study the illustration below.

This dial counts units of 1000 kilowatt-hours each.

This dial counts units of 100 kilowatt-hours each.

This dial counts units of 10 kilowatt-hours each.

This dial counts single kilowatt-hours.



Dial A clockwise direction

Dial B counterclockwise direction

Dial C clockwise direction

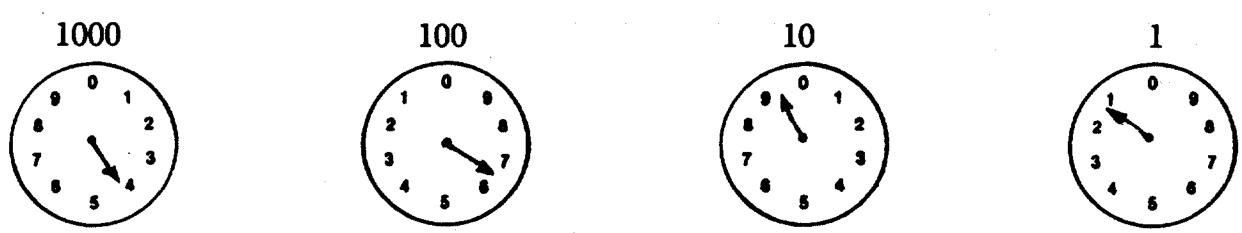
Dial D counterclockwise direction

As the needle turns in a clockwise or counterclockwise direction, it counts one unit of electricity used.

The number of units counted is the last number passed by the needle. For instance, Dial D has just passed 6.

Study the illustration carefully to notice that several dials are needed to count the total number of units of electricity used in a home. The reason for the four dials is that each dial can count only ten units, so each dial as explained will count a unit of a different size.

Study the meter below. Fill in the blanks beneath each dial.



means 4000 kilowatt-hours

means 600 kilowatt-hours

means 90 kilowatt-hours

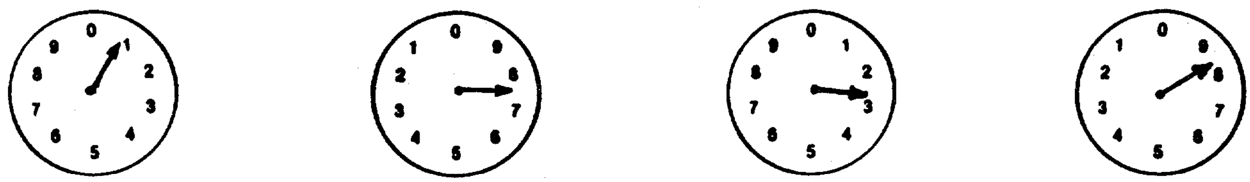
means 1 kilowatt-hours

According to your calculations, this meter shows that a total of

4691 kilowatt-hours have been used.

(Continued on next page)

This meter reads 4481 kilowatt-hours.



This meter reads 0728 kilowatt-hours.

This meter reads 2379 kilowatt-hours.

1. Find the meter in your home. Use the blank dials below to record the readings for two days.

Day 1 

This meter reads ______________ kilowatt-hours.

Day 2 

This meter reads ______________ kilowatt-hours.

2. Subtract the reading for Day 1 from the reading for Day 2. ______________ Day 2

— ______________ Day 1

Total kilowatt-hours used ______________

3. * Select one person in the class to call the electric company to see how much one kilowatt hour costs.

How much did one day's electricity cost? ______________________________

Introduction

This is the second of the four units that comprise *The Harnessed Atom*. It is a science-oriented unit, providing the basic information necessary for understanding nuclear energy, including radioactivity and radiation. The intent is to provide correct and easily understood information for your students.

Unit 2 includes suggested demonstrations and activities that require students to use and develop skills in observing, measuring, computing, and predicting. Also included are review exercises to help reinforce your students' understanding of basic scientific concepts.

The format of the teacher guide will allow you to remove the activity and review exercise pages for making ditto copies, photocopies, or transparencies.

Learning Objectives

The materials, activities, and review exercises in this unit are developed from the following learning objectives.

Lesson 1 Atoms and Isotopes

Students will be able to:

- ☐ describe the basic structure of matter
- ☐ describe the hierarchy in the structure of matter
- ☐ identify molecules, atoms, and atomic particles
- ☐ describe elements
- ☐ identify isotopes of elements
- ☐ demonstrate the use of the periodic table

Lesson 2 Radiation and Radioactive Decay

Students will be able to:

- ☐ describe radiation
- ☐ describe radioactive decay
- ☐ describe shielding
- ☐ describe half-life
- ☐ classify the types of ionizing radiation (e.g., alpha, beta, gamma)
- ☐ demonstrate how to compute half-lives

Lesson 3 Measuring and Using Radiation

Students will be able to:

- ☐ describe the units of measure for radiation (e.g., millirems)
- ☐ define radiation dose
- ☐ explain reduction of exposure to radiation (e.g., time, distance, shielding)
- ☐ describe instruments and devices for detecting radiation, including film badges and Geiger counters
- ☐ describe the effects that radiation can have on people
- ☐ identify labels for hazardous materials

Lesson 4 Background Radiation

Students will be able to:

- ☐ identify the sources of background radiation
- ☐ assess the extent of the contribution of background radiation to annual radiation dose
- ☐ define cosmic rays
- ☐ identify the sources of manmade radiation
- ☐ describe safety standards for radiation exposure
- ☐ explain why background radiation is different in different locations

Lesson 5 Uses of Radiation

Students will be able to:

- ☐ tell how x rays work
- ☐ describe labeling and tracing
- ☐ identify the uses of radiation in science, medicine, and industry
- ☐ identify the role of radioactive materials in electric power production

Lesson 6 Fission, Chain Reactions, and Fusion

Students will be able to:

- ☐ describe fission, chain reactions, and fusion
- ☐ classify nuclear fission and nuclear fusion
- ☐ classify chemical and nuclear reactions

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "The Mystery Box"

2 small identical boxes (cigar boxes work well)	Any 3: bolt	ping-pong ball
scales	marble	BBs
magnet	small block of wood	sleigh bell
	onion	piece of chalk
	tennis ball	moth balls
	packet of seeds	magnet

- ☐ class activity "Name That Isotope"
- ☐ class activity "Atom Model"

3 blocks of styrofoam (2 cm x 10 cm)	toothpicks
9 styrofoam balls (4 cm in diameter)	black electrical tape
red and orange spray paint (water base)	

2. Do the demonstration "The Mystery Box" on direct and indirect observations.

You may divide the class into small groups of 4 or 5 students and let each group do the activity, or you may want to do the demonstration yourself. The groups may explain their reasoning and open their boxes before the entire class. Discuss direct and indirect observation. Direct observation is observing something yourself. Indirect observation is deciding about something by observing its properties and effects without seeing the object itself. An example of a direct observation is a person seeing a bear. An example of indirect observation is a person on a camping trip discovering his backpack ripped open, claw marks on a tree, large paw prints on the ground, and saying "A bear probably did this." Ask the class to explain how indirect observation applies to the study of atoms. You may want to tell the students that they will be learning more about how we know about atoms as they work on this unit.

3. Introduce vocabulary.

Introduce vocabulary words by listing them on the chalkboard and pronouncing them correctly. Definitions can be found in the glossary at the end of the student reader.

atom	isotopes	radioactive decay
chemical reaction	molecule	radiation
electrons	neutrons	uranium
elements	nucleus and nuclei	
emitting	protons	

(If you do "The Mystery Box" activity, add indirect observation to the vocabulary list.)

4. Read Lesson 1 in student reader. (Page 17 in the student reader.)

Explain that this lesson covers concepts about atoms and isotopes.

Why is the number of naturally occurring elements smaller than the number of elements on the periodic table? We know for certain that 92 elements exist in nature. Physical evidence indicates that at least two others are present from time to time because they are part of the decay chain of some naturally occurring elements. Students may become confused because the periodic table indicates 103 elements. The reason for the discrepancy is that scientists have produced small amounts of very heavy elements in the laboratory.

5. After students have read Lesson 1, the following questions may be used for class discussion.

a. If atoms are so small that we can't see them, how do we know they really exist? (Scientists learn about atoms through indirect observation. They study the properties of atoms that can be measured in some way. We study other phenomena the same way. For example, we can't see the wind, but we can see it blow leaves about, and therefore we know it exists. We know its properties and its effects.)

b. If an atom is considered the smallest unit of matter, how can we say that atoms are made of smaller particles such as protons, electrons, and neutrons? (The atom is the smallest part of matter which retains all of the chemical characteristics of an element. Electrons, protons, and neutrons are fundamental particles which make up the atoms of all elements.

c. Why are protons used to identify elements? (The number of protons in an atom is used to identify an element because all isotopes of an element have the same number of protons.)

d. What is the difference between an atom and a molecule? (A molecule can be a combination of several atoms of the same element or of different elements. For example, a molecule of hydrogen gas is made of 2 hydrogen atoms. A molecule of oxygen gas is made of 2 oxygen atoms. A molecule of water is made of 2 hydrogen atoms combined with 1 oxygen atom, H_2O. A molecule is always made of atoms; atoms are not made of molecules.)

e. How do isotopes differ from one another? (Isotopes of a specific element differ from one another in the number of neutrons in their nuclei. They have the same number of protons in their nuclei and, therefore, they have the same chemical properties but not the same atomic weight. They are all atoms.)

f. Why is the atomic weight sometimes a fraction? (The atomic weight is the average of the weights of the isotopes of an atom.)

6. Assign and discuss the review exercise for Lesson 1. (Page 20 in the student reader.)

Depending upon the grade level of your class, you may put the following list of words on the board for students to choose answers from for Section A.

atom	electron	isotopes	molecule	neutron	nucleus	proton

Two copies of the exercise have been provided—one with answers and a clean copy for your use to make copies.

7. Assign the activity on "Name That Isotope."

Review rounding off numbers with the class and do the first example as a group.

Also discuss the steps involved in filling in the names of isotopes. Be sure students know they have to use the list of elements and their symbols to find the isotope symbol, that they use the symbol to find the correct box for the element on the periodic table, and that they add the number of protons and neutrons to identify the isotopes.

If you would like to do more work on the periodic table, a crossword puzzle is included. (See Number 10).

8. Introduce class activity "Atom Model."

9. To further explore the topic. You might assign finding the names of the subatomic particles as a research topic to students who are very interested in the subject of atoms.

Mention the difference in the large number of neutrons in uranium, radium, and plutonium versus the much smaller number of neutrons in carbon, helium, and gold. Why does the large number of neutrons make these elements unstable and radioactive? (The large number of neutrons makes it difficult for the atom to hold itself together.) Any element above lead in the periodic table is unstable. An analogy would be that it is like going into the grocery store to pick up a few items. As you walk through the aisles, you see more and more things that you need. Soon your grocery cart is too full and some items fall out of it. Lead could be the full grocery cart and any element above lead is a cart that is too full.

10. An additional activity.

A crossword puzzle, "Periodic Table of the Elements," is included here.

LESSON 1 REVIEW EXERCISE

A. Select the word that best fits the definition given.

1. ____________________ the smallest unit of matter that has all the characteristics of an element
2. ____________________ the bundle consisting of protons and neutrons, which is found in the center of an atom
3. ____________________ atoms of an element containing the same number of protons, but different numbers of neutrons
4. ____________________ a part of an atom with a positive charge
5. ____________________ a part of an atom with a negative charge

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Unstable isotopes can change from one form to another by emitting particles and rays. T F
2. An atom is identified by the number of protons in its nucleus. T F
3. Protons and electrons together make up the nucleus of an atom. T F
4. Atoms are so small that humans cannot see them. T F
5. Atoms combine to form molecules. T F

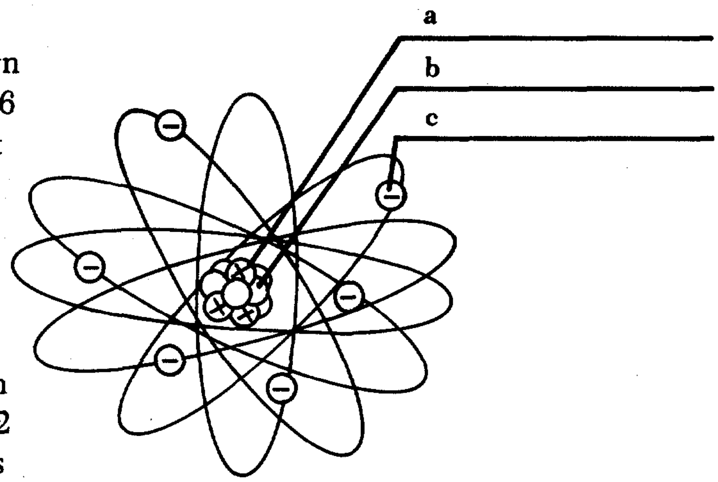
C. Using the periodic table, tell which elements make the molecules of the following substances.

1. H_2SO_4 ____________________ ____________________ ____________________
2. $C_6H_{12}O_6$ ____________________ ____________________ ____________________
3. KOH ____________________ ____________________ ____________________
4. $AgNO_3$ ____________________ ____________________ ____________________
5. $ZnCl_2$ ____________________ ____________________

(Continued on next page)

D. Models

1. Label the model of the carbon atom shown below. An atom of carbon has 6 protons, 6 neutrons, and 6 electrons. Remember that protons have a positive (+) charge, electrons have a negative (−) charge, and neutrons have no electrical charge.



2. Draw a model of a helium atom. An atom of helium has 2 protons, 2 electrons, and 2 neutrons. Show protons as ⊕, electrons as ⊖, and neutrons as ○.

THE MYSTERY BOX

How can you study something you can't see?

Materials	
2 small identical boxes (cigar boxes work well)	scales
magnet	3 mystery items

Directions: Try to guess the contents of the mystery box.

Try to guess the shape of the objects in the box

by tilting it...

and rattling it.

What shapes do you think are inside?

	☐	Test box weight
(minus) −	☐	Empty box weight
	☐	Weight of the objects

Now hold a magnet to the box.
Are any of the objects magnetic?

Describe the objects you think are inside.

1. ______________________________

2. ______________________________

3. ______________________________

Now open the box and check them with your description.

Other ideas to explore:

1. Can you think of other ways to investigate things without seeing them? (This is called indirect observation.) ______________________________

____

2. What other instruments might have helped you guess what was in the box? ______________

____

3. Think of other examples of indirect observation. ______________________________

____

THE MYSTERY BOX

How can you study something you can't see?

Materials	
2 small identical boxes (cigar boxes work well)	scales
magnet	3 mystery items

Directions: Try to guess the contents of the mystery box.

Try to guess the shape of the objects in the box

by tilting it...

and rattling it.

What shapes do you think are inside?

	[ ]	Test box weight
(minus) ▭	[ ]	Empty box weight
	[ ]	Weight of the objects

Now hold a magnet to the box.
Are any of the objects magnetic?

Describe the objects you think are inside.

1. ______

2. ______

3. ______

Now open the box and check them with your description.

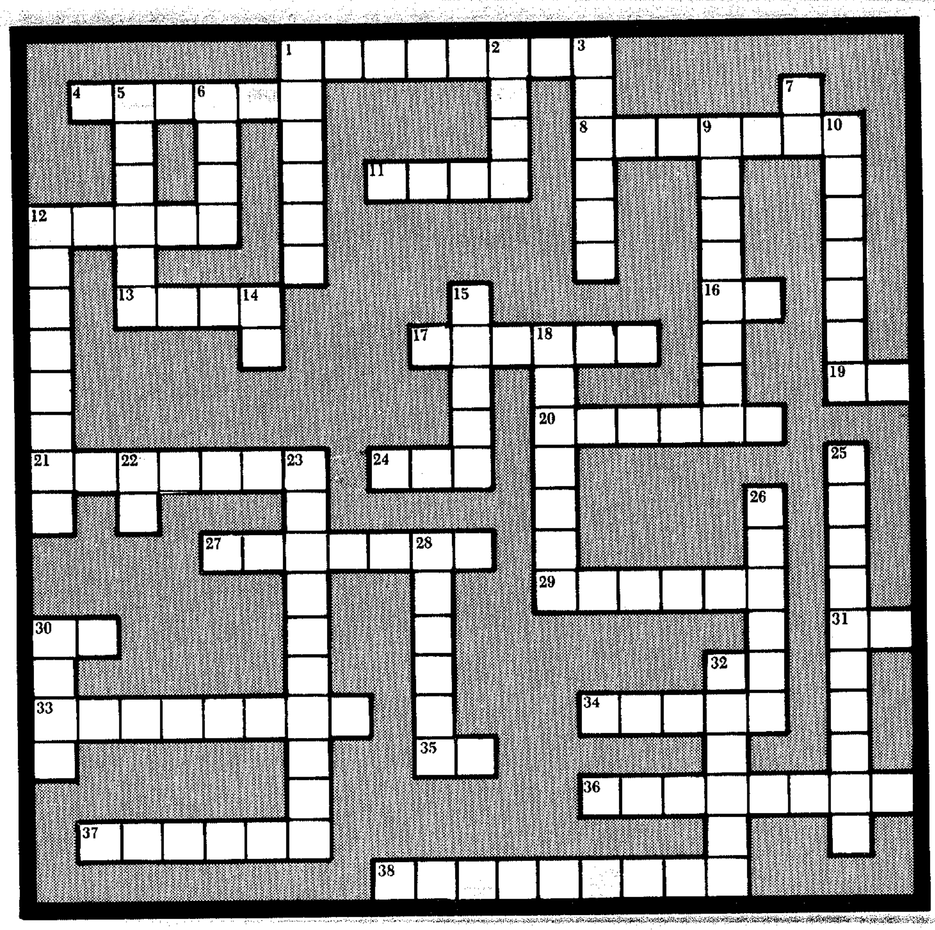
Other ideas to explore:

1. Can you think of other ways to investigate things without seeing them? (This is called indirect observation). by observing the effects that things have on their environments

2. What other instruments might have helped you guess what was in the box? x-ray machine

3. Think of other examples of indirect observation. tire tracks found in mud; animal tracks; wilting plants (no rain)

PERIODIC TABLE OF THE ELEMENTS



Directions:
Use the periodic table of the elements to do the crossword puzzle.

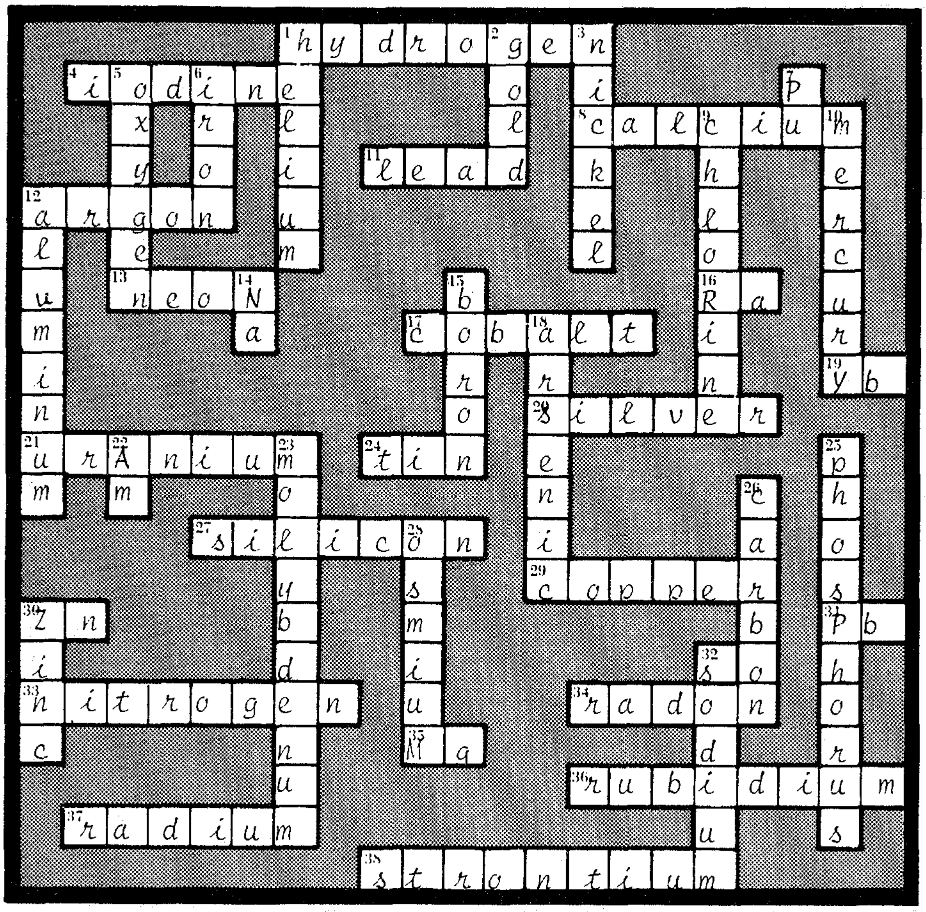
Across

1. H
4. I
8. Ca
11. Pb
12. Ar
13. Ne
16. Symbol for radium
17. Co
19. Symbol for ytterbium
20. Ag
21. U
24. Sn
27. Si
29. Cu
30. Symbol for zinc
31. Symbol for lead
32. Do, Re, Me, Fa, ________, La, Ti, Do
33. N
34. Rn
35. Symbol for magnesium
36. Rb
37. Ra
38. Sr

Down

1. He
2. Au
3. Ni
5. O
6. Fe
7. Symbol for plutonium
9. Cl
10. Hg
12. Al
14. Symbol for sodium
15. B
18. As
22. Symbol for americium
23. Mo
25. P
26. C
28. Os
30. Zn
32. Na

PERIODIC TABLE OF THE ELEMENTS



Directions:
Use the periodic table of the elements to do the crossword puzzle.

Across
1. H
4. I
8. Ca
11. Pb
12. Ar
13. Ne
16. Symbol for radium
17. Co
19. Symbol for ytterbium
20. Ag
21. U
24. Sn
27. Si
29. Cu
30. Symbol for zinc
31. Symbol for lead
32. Do, Re, Me, Fa, ________, La, Ti, Do
33. N
34. Rn
35. Symbol for magnesium
36. Rb
37. Ra
38. Sr

Down
1. He
2. Au
3. Ni
5. O
6. Fe
7. Symbol for plutonium
9. Cl
10. Hg
12. Al
14. Symbol for sodium
15. B
18. As
22. Symbol for americium
23. Mo
25. P
26. C
28. Os
30. Zn
32. Na

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Flip Out"

1 roll of pennies	colored pencils (optional)	graph paper (optional)

- ☐ class activity "The Cloud Chamber"

small transparent container with lid	block of dry ice or CO_2 fire extinguisher	blotter paper
flat black spray paint	flashlight	masking tape
radioactive source	pure ethyl alcohol	gloves or tongs

2. Introduce vocabulary.

Introduce vocabulary words by listing the words on the chalkboard and pronouncing them correctly. Definitions can be found in the glossary at the end of the student reader.

alpha	gamma	radioactive decay
beta	half-life	radioactivity
decay chain	ionizing radiation	shielding
electromagnetic wave	radiation	unstable isotopes
emit	radioactive	

3. Read Lesson 2. (Page 22 in the student reader.)

Explain to the students that they will be reading about radiation and the types of radiation.

4. The following questions may be used for class discussion.

a. Why are elements that break apart called *unstable*? (They are called unstable because they stabilize themselves by emitting gamma rays or change into another element by emitting alpha and beta particles.)

b. How do things become less *radioactive* as time goes by? (Unstable elements break down bit by bit [emitting alpha and beta particles and gamma rays]. Each unstable element also loses its radioactivity at a different rate that is defined by its half-life. A material made up of a quantity of an unstable isotope is radioactive and emits alpha and beta particles or gamma rays. The rate at which the material loses radioactivity is determined by its half-life. Half-lives range from very small fractions of a second to several billion years.)

c. How can we use *half-lives* to determine the age of ancient objects? (Because we know the half-lives of various isotopes, we are sometimes able to figure out how long they have been present in certain objects, and thus determine the age of those objects. Carbon-14 is especially useful because carbon is deposited in most living things, and when those living organisms die, they no longer take up carbon. The decay of the carbon-14 can then be evaluated in order to estimate the age of the object in question.)

d. What materials are best for *shielding*? (Denser materials are more effective for stopping radiation. This is because the radiation has more matter with which to collide. Water is often used because it is convenient and abundant.)

e. Gamma radiation, a powerful type of radiation emitted from some radioactive isotopes, has no weight. What other types of particles or waves do you come in contact with that have no weight? (Examples include light waves and sound waves, as well as TV and radio waves.)

f. You bought 10 lbs. of the rare isotope iridium-191 for $5 million. The next day chemical tests show that the iridium-191 has changed into a worthless compound. Have you been cheated? What happened? (It is difficult to know whether you have been cheated. However, iridium-191 has a half-life of 4.9 seconds and would decay into another different substance quite rapidly. In fact, because they have short half-lives, many radioisotopes used in medicine and science must be rushed to hospitals and laboratories in order to be used before they decay.)

5. Assign and discuss the review exercise for Lesson 2. (Page 26 of the student reader.)

Depending upon the grade level of your class, you may put the following list of words on the board for students to choose answers from for Section A.

decay	electrons	energy	half-life	isotopes	radiation

6. Do the class activity "Flip Out."

Two copies of the activity have been provided—one with answers and a clean copy for your use to make copies.

You should flip a coin each time to determine whether heads or tails is "out."

To get accurate results, ask who got heads and tails before you announce which is out. This is necessary because students like to continue playing.

Another interesting demonstration to illustrate half-life of iodine-131 is to fold a piece of paper in half to illustrate one-half the radioactivity lost in eight days. Fold in half again for half of that radioactivity lost in eight more days. Continue the folding.

1. What shape of line do you get? *A steep curve with a flat bottom.*
2. After five turns, how many students are out? ______

   Why isn't this amount half of the total? *It was one-half after the first flip.*
3. Will the number of students out always be one-half the number of students who flipped? *No*

   Why or why not? *This is an average. Just as radioactive decay is random, so is flipping a coin.*

7. Introduce the class experiment "The Cloud Chamber."

The class experiments are designed to enrich the concepts in the student reader. The experiment should be done by groups of four or five students. If the groups are much larger, everyone may not really get a chance to see the "tracks" from the radioactive source. Cloud chamber kits are available from science supply houses for about $3-$5. Dry ice may be obtained where fire extinguishers are refilled. A CO_2 fire extinguisher may also be used instead of dry ice (Blowing it through a burlap bag makes less mess). You may want to tape the blotter paper to hold it together. You may use a small glass jar with a lid and use the lid as the bottom in place of the small transparent container.

Other sources of radiation:

- ☐ Cut out one numeral from the clock face of an old luminescent clock and staple it to a cork.
- ☐ Uranium ore (samples are available from The Nucleus, Inc., 461 Laboratory Road, Oak Ridge, TN 37830).
- ☐ Gas lantern mantle (doesn't work as well as a commercial source).

Questions for discussion after this activity:

1. Because you could not actually see the radiation, what kind of observation did you experience? (Indirect observation)
2. What is actually happening to the radioactive source? (It is decaying.)
3. What radiation "footprints" did you see? Describe them. (Answer will vary. Descriptions are given on the lab sheet.)

While observing the cloud chamber, the students should look for alpha, beta, and gamma radiation. They should understand that they are not seeing the radiation itself, but the tracks of atom pieces that the atoms are throwing out in order to break down. This activity can lead to a review discussion of radiation, half-life, and decay.

LESSON 2 REVIEW EXERCISE

A. Select the word which best fits the definition given.

_______________ 1. energy released by unstable isotopes

_______________ 2. atoms of an element with the same number of protons, but different numbers of neutrons

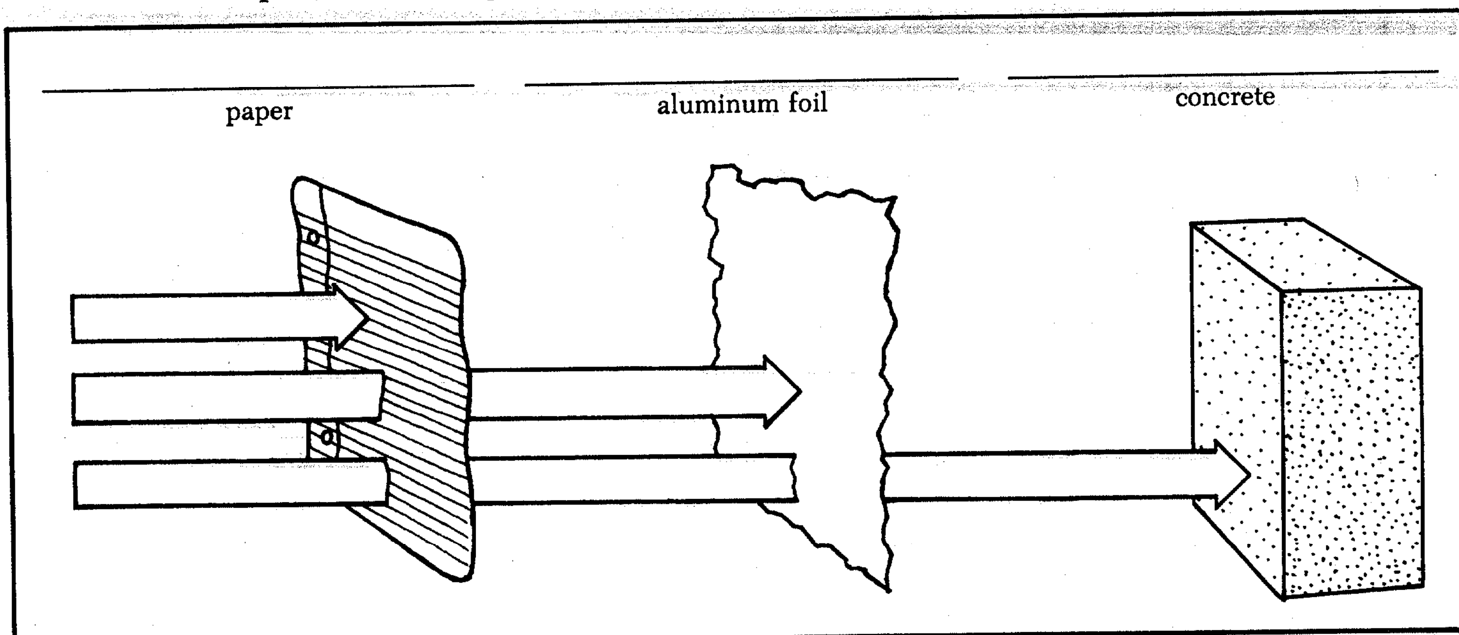
_______________ 3. process of becoming more stable and less radioactive as time passes

_______________ 4. amount of time it takes for a material to lose half its radiation

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1.	Radiation is a form of energy.	T F
2.	Radioactive isotopes emit radiation.	T F
3.	Gamma radiation can be stopped by paper.	T F
4.	Aluminum foil is a shielding material that will stop gamma radiation.	T F
5.	Alpha and beta radiations are tiny bits of atoms.	T F
6.	Gamma radiation is a type of electromagnetic wave.	T F

C. Match alpha, beta, and gamma radiation with the materials that can stop them.



D. A radioactive substance contains 1,000 radioactive atoms. The half-life of the element is 10 years. At the end of 30 years, approximately how many of the atoms in the sample will still be radioactive? _______________

E. Challenge Question
If a quantity of a radioactive substance has lost 7/8 of its radioactivity in 30 seconds, what is its half-life? _______________

LESSON 2 REVIEW EXERCISE

A. Select the word which best fits the definition given.

radiation ______ 1. energy released by unstable isotopes

isotopes ______ 2. atoms of an element with the same number of protons, but different numbers of neutrons

decay ______ 3. process of becoming more stable and less radioactive as time passes

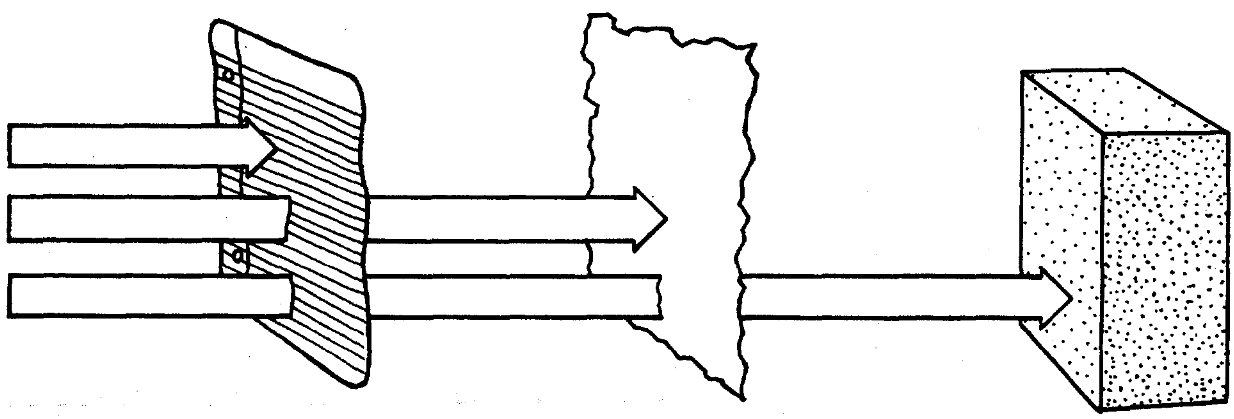
half-life ______ 4. amount of time it takes for a material to lose half its radiation

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Radiation is a form of energy. T F
2. Radioactive isotopes emit radiation. T F
3. Gamma radiation can be stopped by paper. (concrete) T F
4. Aluminum foil is a shielding material that will stop gamma radiation. (lead or beta) T F
5. Alpha and beta radiations are tiny bits of atoms. T F
6. Gamma radiation is a type of electromagnetic wave. T F

C. Match alpha, beta, and gamma radiation with the materials that can stop them.

alpha	beta	gamma
paper	aluminum foil	concrete

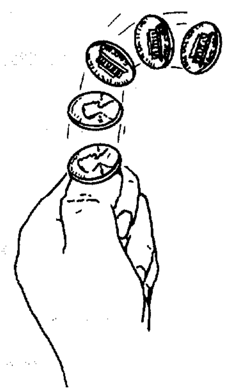


D. A radioactive substance contains 1,000 radioactive atoms. The half-life of the element is 10 years. At the end of 30 years, approximately how many of the atoms in the sample will still be radioactive? 125--At the end of 10 years 500 will still be radioactive. At the end of 20 years, 250 will be radioactive. At the end of 30 years, 125 will be radioactive.

E. Challenge Question

If a quantity of a radioactive substance has lost 7/8 of its radioactivity in 30 seconds, what is its half-life? 10 seconds. At the end of 1 half-life, 1/2 the radiation remains. At the end of 2 half-lives, 1/4 the radiation remains. At the end of 3 half-lives, 1/8 of the radiation remains; 7/8 has been lost. Divide 30 seconds by 3.

FLIP OUT!



Materials

- 1 roll of pennies
- colored pencils (optional)
- graph paper (or use the graph below)

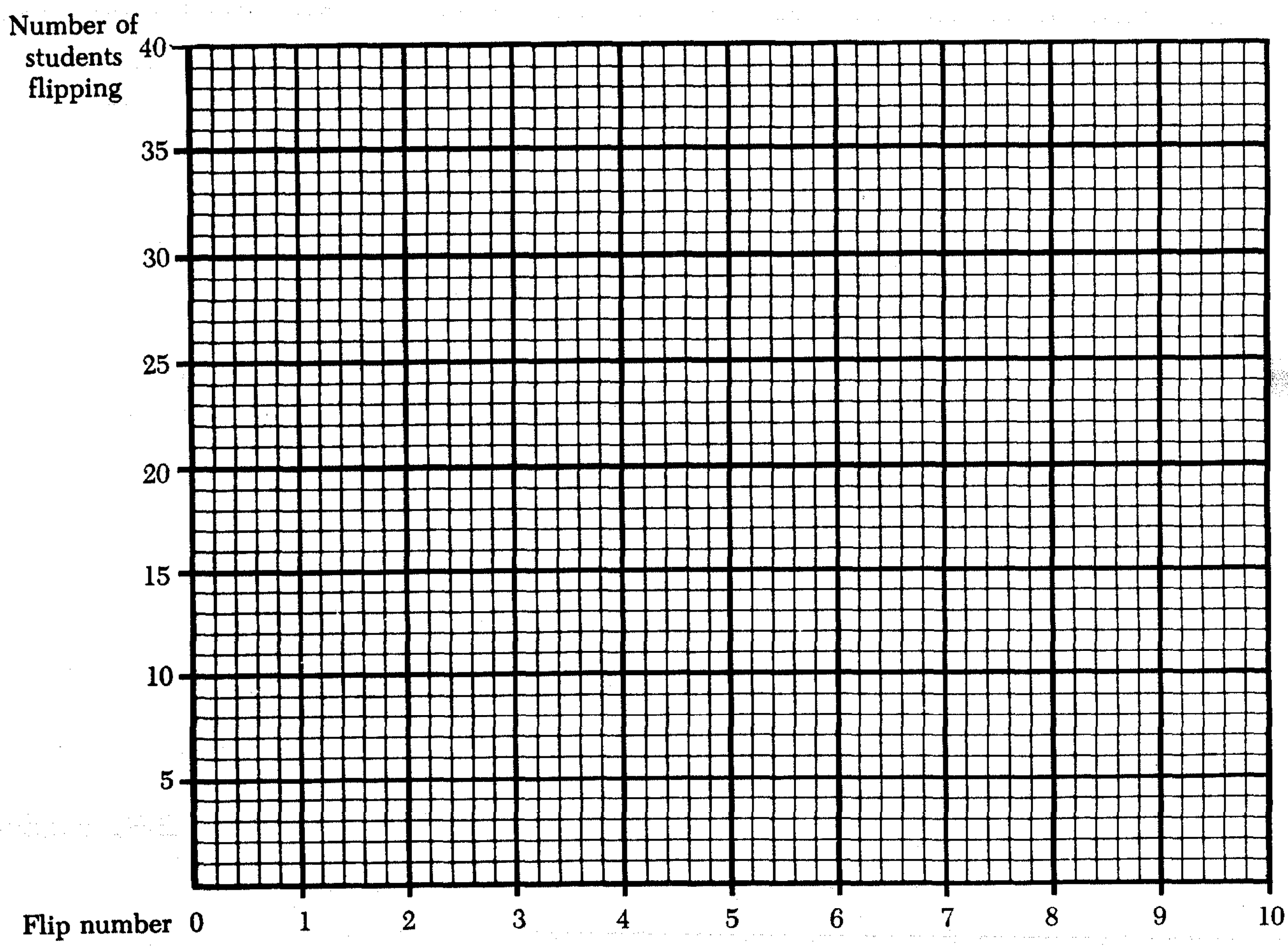
In this activity, the class will simulate radioactive decay and show how the half-life of an imaginary element can be determined.

Directions:

In this activity, everybody has a penny. The teacher and students flip the pennies. Everyone whose penny matches the teacher's flip has "decayed," while those whose penny is different are still "radioactive."

Each time, those who have "decayed" are out. Count the number out and record the results on the chalkboard. Then those who are still playing flip again. Continue until everyone is out. Then plot the results on the graph below.

It is fun for the class to do this several times through, each time recording the results on the chalkboard. Using a different color to graph each "decay" will differentiate among them.



(Continued on next page)

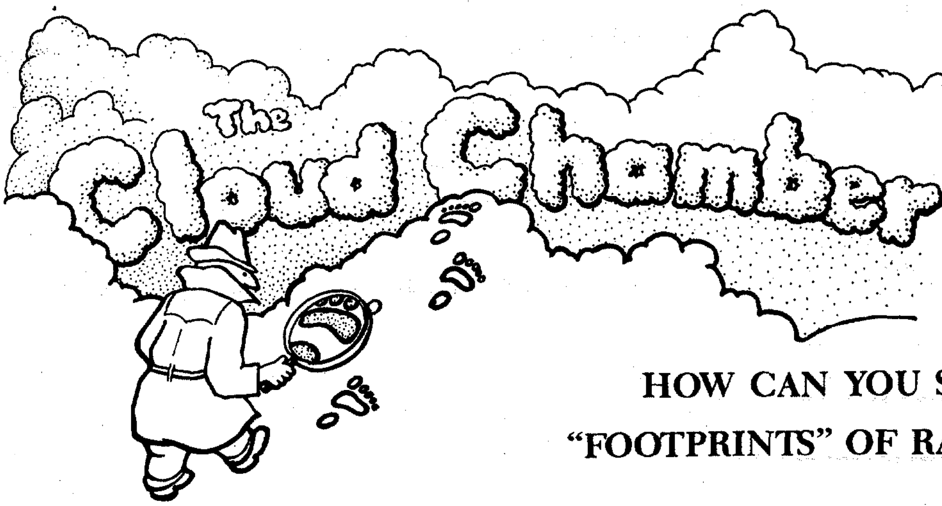
1. What shape of line do you get?________________________________

2. After five turns, how many students are out?________________________________

   Why isn't this amount half of the total?________________________________

3. Will the number of students out always be one-half the number of students who flipped?______

   Why or why not?________________________________



HOW CAN YOU SEE THE "FOOTPRINTS" OF RADIATION?

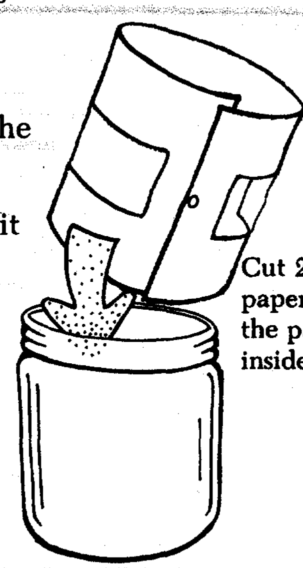
While radiation cannot be seen, the cloud chamber allows you to see the tracks it leaves in a dense gas.

Materials	
small transparent container with transparent lid	masking tape
flat black spray paint	block of dry ice
blotter paper	styrofoam square
pure ethyl alcohol	flashlight
radioactive source	gloves or tongs to handle the dry ice

First, paint the bottom of the container with black paint and let it dry. Then cut the blotter paper into a strip about as wide as the height of the container. Cut two windows in the strip, as shown, and place it against the inside of the container.

Directions:

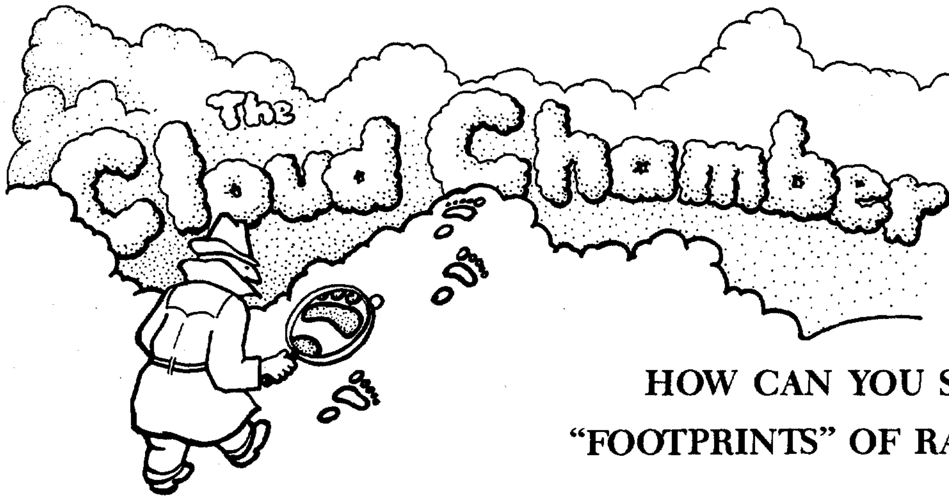
1. Pour enough alcohol into the cloud chamber so that it covers the bottom of the container. The blotter paper will absorb most of it.
2. Place the radioactive source in the cloud chamber and seal the lid with tape.
3. Place the cloud chamber on the dry ice to super chill it. Wait about 5 minutes. Darken the room. Shine the flashlight through the windows of the chamber while looking through the lid. You should see "puffs" and "trails" coming from the source. These are the "footprints" of radiation, as it travels through the alcohol vapor. The vapor condenses as the radiation passes through. This is much like the vapor trail left by high flying jets.
4. Do you see radiation in the cloud chamber? ____________



Cut 2 "windows" in paper strip and wrap the paper around the inside of the container.

OTHER IDEAS TO EXPLORE: Try to identify these footprints
—**ALPHA**—sharp tracks about 1 cm long
—**BETA**—thin tracks 3 cm to 10 cm long
—**GAMMA**—faint, twisting and spiraling tracks

CAUTION
Dry ice should be handled very carefully! It can burn unprotected skin.



HOW CAN YOU SEE THE "FOOTPRINTS" OF RADIATION?

While radiation cannot be seen, the cloud chamber allows you to see the tracks it leaves in a dense gas.

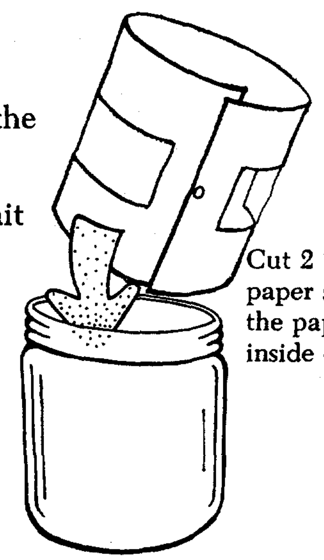
Materials

small transparent container with transparent lid	masking tape
flat black spray paint	block of dry ice
blotter paper	styrofoam square
pure ethyl alcohol	flashlight
radioactive source	gloves or tongs to handle the dry ice

First, paint the bottom of the container with black paint and let it dry. Then cut the blotter paper into a strip about as wide as the height of the container. Cut two windows in the strip, as shown, and place it against the inside of the container.

Directions:

1. Pour enough alcohol into the cloud chamber so that it covers the bottom of the container. The blotter paper will absorb most of it.
2. Place the radioactive source in the cloud chamber and seal the lid with tape.
3. Place the cloud chamber on the dry ice to super chill it. Wait about 5 minutes. Darken the room. Shine the flashlight through the windows of the chamber while looking through the lid. You should see "puffs" and "trails" coming from the source. These are the "footprints" of radiation, as it travels through the alcohol vapor. The vapor condenses as the radiation passes through. This is much like the vapor trail left by high flying jets.
4. Do you see radiation in the cloud chamber? No-You see the "footprints."



Cut 2 "windows" in paper strip and wrap the paper around the inside of the container.

OTHER IDEAS TO EXPLORE: Try to identify these footprints
—**ALPHA**—sharp tracks about 1 cm long
—**BETA**—thin tracks 3 cm to 10 cm long
—**GAMMA**—faint, twisting and spiraling tracks

CAUTION

Dry ice should be handled very carefully! It can burn unprotected skin.

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Using a Geiger Counter"

Geiger counter Radioactive sources such as: gas lantern mantle salt substitute containing potassium cloisonné jewelry orange-glazed ovenware commercially available source from science supply house luminescent clock face	Shielding materials such as: paper aluminum foil brick jar of water piece of wood glass pane sheet of lead

2. Introduce vocabulary.

Introduce the vocabulary words before the students read the lesson. Definitions can be found in the glossary at the end of the student reader.

adverse	Geiger counters	rem
curie	millirem	roentgen
discernible	rad	time, distance, shielding
film badge	radiation dose	

3. Assign Lesson 3 in the student reader. (Page 27 in the student reader.)

4. The following questions may be used for class discussion when students have completed the assigned reading.

a. Why do we measure *radiation dose*? (We measure radiation dose because exposure to too much radiation can be harmful to people. In fact, the Federal Government has set limits on how much exposure to radiation a worker may receive. Workers who are around areas where there are radioactive substances are checked very carefully to protect their health.)
NOTE: You may be able to get a film badge from the local hospital radiology lab, county agricultural agent, or State university. People who work in occupations that require film badges would be a good local resource.

b. When you use a *Geiger counter* to determine how radioactive a substance is, why is it important to know what the background radiation level is? (You need to know the background radiation level so that you don't add that count to the reading of the substance you're testing.)

c. Has anyone you know ever been helped or harmed by *radiation*? (Answers to this question will depend on the experiences of your students. They are most likely to mention such things as medical and dental x rays and cancer treatments as having been helpful. For harmful effects, they are likely to mention sunburn or maybe even skin cancer.)

d. Why is it necessary to have a standard *symbol* for marking places where radiation may be present? (It is important to have a standard symbol for radioactive substances because they can be dangerous. The symbol warns people to use caution—just the way other symbols warn people to use caution with poisons, flammable materials, and so on.)

e. If you found a package by the highway that was marked with the *radiation hazard symbol,* what should you do? (In the first place, such an occurrence is highly unlikely because a great deal of care is always used in shipping or transporting any radioactive substance. The best thing to do would be to notify the highway patrol or police department. The package itself would have been prepared very carefully for shipment because strict regulations govern shipping such substances. Therefore, the package would probably not be dangerous to you, but you should let trained personnel handle it.)

f. How can *time, distance,* and *shielding* help you to prevent sunburn? (Limit the amount of time that you are in the Sun; stay out of the Sun during the middle of the day when the Sun is directly overhead; wear protective clothing, hats, and sunscreen.)

5. Assign and discuss the review exercise for Lesson 3. (Page 31 in the student reader.)

Depending upon the grade level of your class, you may put the following list of words on the board for students to choose answers from for Section A.

isotopes	distance	Geiger counter	millirems	shielding
time	150-200	5,000	50,000	100,000

6. Introduce class activity "Using a Geiger Counter."

A possible source of a Geiger counter is your local civil defense or emergency response officer, a local utility, a college or university, a firehall, or hospital radiology lab.

LESSON 3 REVIEW EXERCISE

A. Select the term which best fits the statement.

1. To reduce exposure to radiation, we limit the amount of ______________________ we are near radioactive substances.
2. To avoid exposure to radiation, we keep as great a ______________________ away from radioactive substances as possible.
3. Thick leaded glass is used as ______________________ to protect workers from exposure to radiation.
4. The effect radiation has on people is measured in ______________________.
5. The average annual radiation dose that most Americans receive is ________________ millirems.
6. Any radiation dose less than ______________________ millirems is considered low-level.
7. A radiation dose of over ________________ millirems will usually cause radiation sickness.
8. A ______________________ is used to detect radiation.

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Photographic film can detect radiation. T F
2. The average person receives 5,000 millirems a year as natural background radiation. T F
3. The period of time over which we receive radiation determines how strongly it will affect us. T F
4. Radioactive materials are the only hazardous materials that must be labeled. T F
5. It is easy to hear radiation, although we cannot feel it or see it. T F

C. Make a sketch or drawing for the symbol for radiation.

D. List two places where you might see this label.

1. ____

2. ____

LESSON 3 REVIEW EXERCISE

A. Select the term which best fits the statement.

1. To reduce exposure to radiation, we limit the amount of ___time___ we are near radioactive substances.
2. To avoid exposure to radiation, we keep as great a ___distance___ away from radioactive substances as possible.
3. Thick leaded glass is used as ___shielding___ to protect workers from exposure to radiation.
4. The effect radiation has on people is measured in ___millirems___.
5. The average annual radiation dose that most Americans receive is ___150-200___ millirems.
6. Any radiation dose less than ___5,000___ millirems is considered low-level.
7. A radiation dose of over ___100,000___ millirems will usually cause radiation sickness.
8. A ___Geiger counter___ is used to detect radiation.

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true

1. Photographic film can detect radiation. T F
2. The average person receives 5,000 millirems a year as natural background radiation. (150-200 millirems a year from all sources) T F
3. The period of time over which we receive radiation determines how strongly it will affect us. T F
4. Radioactive materials are the only hazardous materials that must be labeled. T F
(also chlorine, gasoline, pressurized gases)
5. It is easy to hear radiation, although we cannot feel it or see it. T F
(cannot hear, see, feel, or smell radiation)

C. Make a sketch or drawing for the symbol for radiation.

D. List two places where you might see this label.

1. hospitals, laboratories
2. trucks, containers, nuclear powerplants

USING A GEIGER COUNTER

How radioactive are different materials?

Materials

Geiger counter
Radioactive sources such as:
- gas lantern mantle
- cloisonné jewelry
- orange-glazed ovenware
- commercially available source from science supply house
- luminescent clock face

Shielding materials such as:
- paper
- aluminum foil
- brick
- jar of water
- piece of wood
- glass pane
- sheet of lead

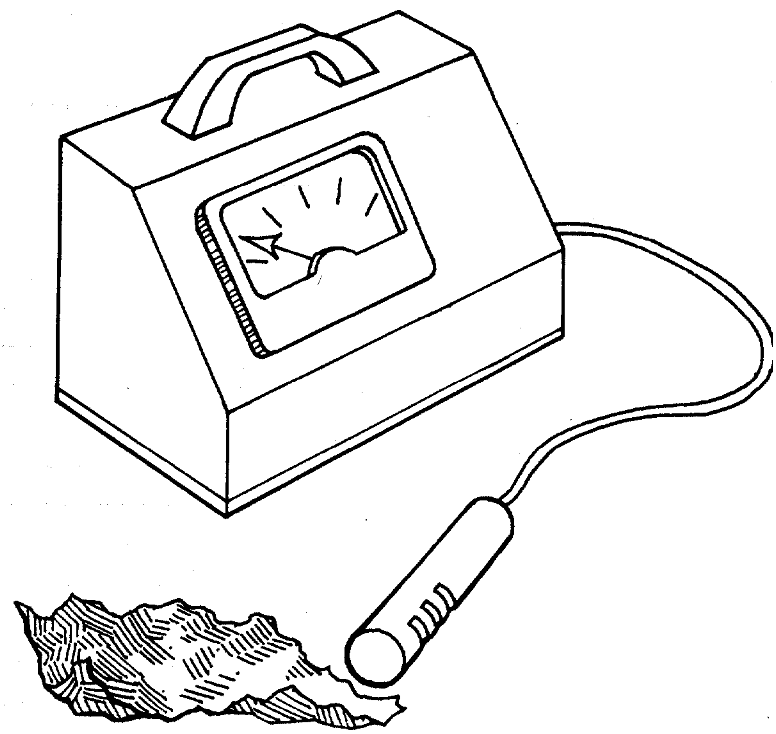
Directions:

1. One at a time, test each item that is a source of radioactivity by placing the source 2 inches from the Geiger counter probe. Use the chart on the back of this sheet to record your readings. Which item has the highest reading? ________________

   The lowest? ____________________

2. Place the radioactive source which had the highest reading 2 inches from the Geiger counter probe. One at a time, test each of your shielding materials by placing them between the source and the counter. Use the chart on the back of this sheet to rate each of the materials. Do you think the density of the shield is important?________

   Why? ____________________________



(Continued on next page)

Other ideas to explore:

1. What happens when the radioactive source is moved further from the Geiger counter?__________
2. Will less radiation be counted if you pass the source quickly by the counter?__________
3. How do doctors and dentists shield themselves when taking x rays?__________
4. Why is it important that all materials be measured at exactly the same spot with the probe at the same distance?__________

Source	Geiger Counter Reading

Shielding Material	Geiger Counter Reading

USING A GEIGER COUNTER

How radioactive are different materials?

Materials

Geiger counter
Radioactive sources such as:
- gas lantern mantle
- cloisonné jewelry
- orange-glazed ovenware
- commercially available source from science supply house
- luminescent clock face

Shielding materials such as:
- paper
- aluminum foil
- brick
- jar of water
- piece of wood
- glass pane
- sheet of lead

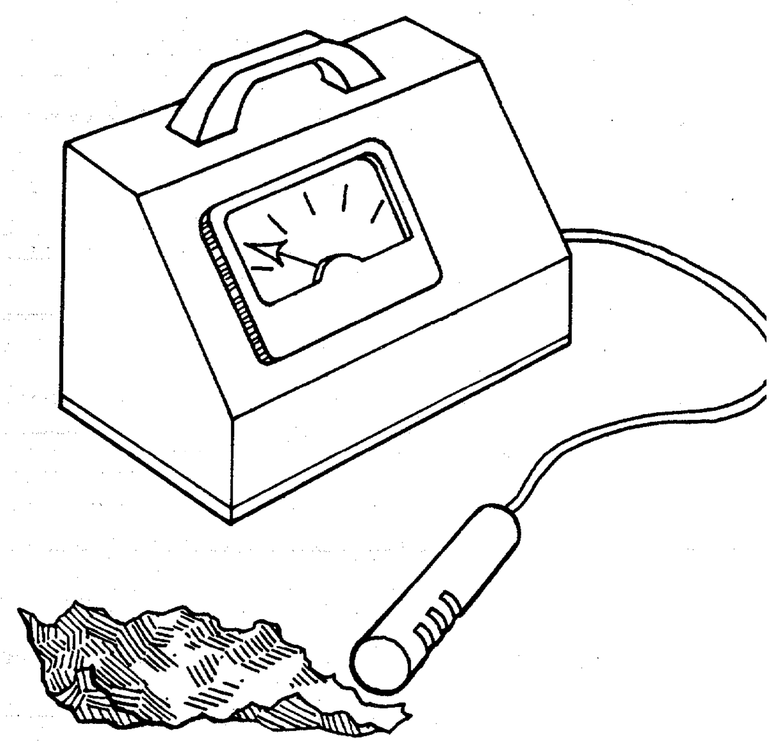
Directions:

1. One at a time, test each item that is a source of radioactivity by placing the source 2 inches from the Geiger counter probe. Use the chart on the back of this sheet to record your readings. Which item has the highest reading? ______________

   The lowest? ______________

2. Place the radioactive source which had the highest reading 2 inches from the Geiger counter probe. One at a time, test each of your shielding materials by placing them between the source and the counter. Use the chart on the back of this sheet to rate each of the materials. Do you think the density of the shield is important? Yes

   Why? The more dense the shielding, the more radiation it stops.



(continued on next page)

Other ideas to explore:

1. What happens when the radioactive source is moved further from the Geiger counter? Less effect
2. Will less radiation be counted if you pass the source quickly by the counter? Yes
3. How do doctors and dentists shield themselves when taking x rays? Stepping behind protective barriers that serve as shielding. Leaving the room.
4. Why is it important that all materials be measured at exactly the same spot with the probe at the same distance? All materials are measured at the same spot so conditions will be the same for all materials. The different materials are the variables.

Source	Geiger Counter Reading

Shielding Material	Geiger Counter Reading

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Computing Your Personal Radiation Dose"
- ☐ class activity "Background Radiation Crossword Puzzle"

2. Introduce vocabulary.

Introduce the vocabulary words by listing them on the chalkboard and pronouncing them correctly. Definitions can be found in the glossary at the end of the student reader.

background radiation	cosmic rays

3. Read Lesson 4 in the student reader. (Page 32 in the student reader.)

Explain that this lesson covers ways of measuring radiation and uses of radiation in science, industry, and medicine.

4. The following questions may be used for discussion when the students have completed the assigned reading.

a. Is *background radiation* dangerous to our health? (This is a very hard question to answer. Even experts disagree. But most experts agree that there is little, if any, danger from the background radiation which is always present in our environment and always has been because it is part of nature. There may be a cumulative effect of background radiation, somewhat like the effect of growing old. The average annual exposure from background radiation in the United States is 150 millirems.)

b. Is *radiation* from *nuclear powerplants* dangerous to our health? (Most experts agree there is little danger of radiation from nuclear powerplants. Many safety systems at these plants protect the public. Readings taken at nuclear powerplants show little or no increase of radiation above background radiation.)

c. Why would flying in a *jet airplane* expose you to *radiation*? (Radiation comes from the Sun and outer space. The clouds and air that surround Earth help protect us by shielding us from some of the rays. When people fly in planes, they lose some of the protection of the clouds and air.)

d. Why is some of your *food* a source of *radiation*? (Because naturally radioactive elements such as potassium are present in some foods, eating them contributes radiation to your body. The internal exposure from radioactivity in foods is about ¼ of the exposure we get from external background radiation.)

5. Assign and discuss the review exercise for Lesson 4. (Page 36 in the student reader.)

6. Assign "Computing Your Personal Radiation Dose."

This could be assigned for homework so that parents could help with the answers.

7. Assign the "Background Radiation Crossword Puzzle."

LESSON 4 REVIEW EXERCISE

A. Fill in the blanks below.

1. Name three sources of natural background radiation.

___

___

___

2. Name three sources of manmade radiation.

___

___

___

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Radiation exists in nature. T F
2. People who live at sea level are exposed to more background radiation than people who live at high altitudes. T F
3. Nuclear and coal-fired powerplants contribute to manmade background radiation. T F
4. A large source of background radiation is cosmic rays from outer space. T F
5. Most of the radiation the average American is exposed to comes from nuclear powerplants. T F
6. The human body is naturally radioactive. T F

C. Compute the average background radiation level for a person living in the States listed below.
Use the amounts given on the map on p. 32 and add 80 for manmade radiation.

Oregon ___
Utah ___
Vermont ___
Iowa ___
Alabama ___
Oklahoma ___
Maryland ___
Nevada ___
The State you live in___

D. Explain how where you live affects the amount of exposure you receive from natural background radiation.

LESSON 4 REVIEW EXERCISE

A. Fill in the blanks below.

1. Name three sources of natural background radiation.

   outer space, rocks, soil, plants, animals, foods, people

2. Name three sources of manmade radiation.

   medical and dental x rays

   coal-fired and nuclear powerplants

   building materials such as bricks

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Radiation exists in nature. T F
2. People who live at sea level are exposed to more background radiation than people who live at high altitudes. (high altitude receives more) T F
3. Nuclear and coal-fired powerplants contribute to manmade background radiation. T F
4. A large source of background radiation is cosmic rays from outer space. T F
5. Most of the radiation the average American is exposed to comes from nuclear powerplants. (greatest source is natural background) T F
6. The human body is naturally radioactive. T F

C. Compute the average background radiation level for a person living in the States listed below.

Use the amounts given on the map on p. 32 and add 80 for manmade radiation.

Oregon	117 + 80 = 197	Oklahoma	119 + 80 = 199
Utah	142 + 80 = 222	Maryland	101 + 80 = 181
Vermont	116 + 80 = 196	Nevada	128 + 80 = 208
Iowa	118 + 80 = 198	The State you live in	
Alabama	105 + 80 = 185		

(Continued on next page)

D. Explain how where you live affects the amount of exposure you receive from natural background radiation. *The amount of radioactive material in the rocks and soil and the altitude of the place where you live will affect the amount of natural background radiation you are exposed to as a result of where you live.*

COMPUTING YOUR PERSONAL RADIATION DOSE

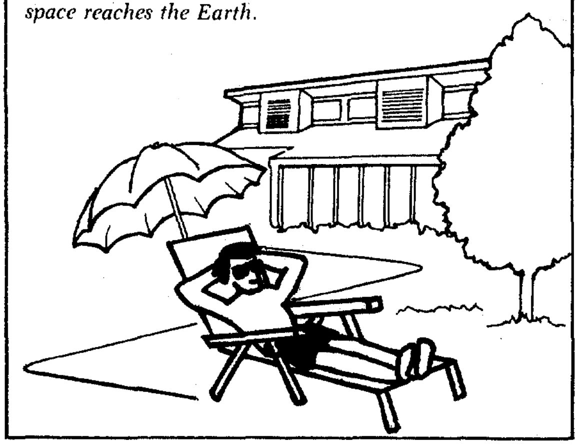
Calculate how much radiation you receive each year.

Radiation is energy or tiny particles given off by certain kinds of energetic atoms. We live in a radioactive world. Radiation is all about us and is part of our natural environment. It comes from the surface of the Earth, from outer space, and from rocks and plants. Even your body is radioactive.

We also get radiation from man-made things like bricks, x-ray machines, and smoke alarms.

Tiny amounts of radiation are measured in units called millirems. The average American receives about 150 to 200 millirems a year from all sources.

Radiation from the Sun and outer space reaches the Earth.



As you probably know, large amounts of radiation can be harmful. Science has been studying radiation for nearly a century. This research has not found any harmful effects from small amounts of radiation. Just to be on the safe side, though, strict laws protect the public from even small amounts of manmade radiation.

How much radiation do you receive?

Take this quiz to find out how much radiation you receive each year.

Radiation from the Sun and outer space reaches the Earth. 28

Some radiation is stopped by the atmosphere. Look up the elevation of the place where you live and add 1 for every 100 feet above sea level. ____

(Examples: Pittsburgh is 1,200 feet, so add 12.
Denver is 5,300 feet, so add 53.
Atlanta is 1,050, so add 10.)

Building materials are radioactive. If your house is:
brick or concrete, add 70. ____
wood, add 30. ____

Ground radiation (U.S. average). 26

Water, food, air radiation (U.S. average). 28

For each person that you spend 8 hours per day with, add 0.1. ____

Nuclear weapons testing fallout. 5

Add 14 for each dental x ray you've had this year. ____

For each 1,500 miles you've flown in a jet airplane during the year, add 1. ____

If you live within 5 miles of a nuclear or coal-fired powerplant, add 0.3. ____

If you live more than 5 miles from a nuclear or coal-fired powerplant, add 0. ____

YOUR YEARLY TOTAL ____

What three sources contribute the most?________________

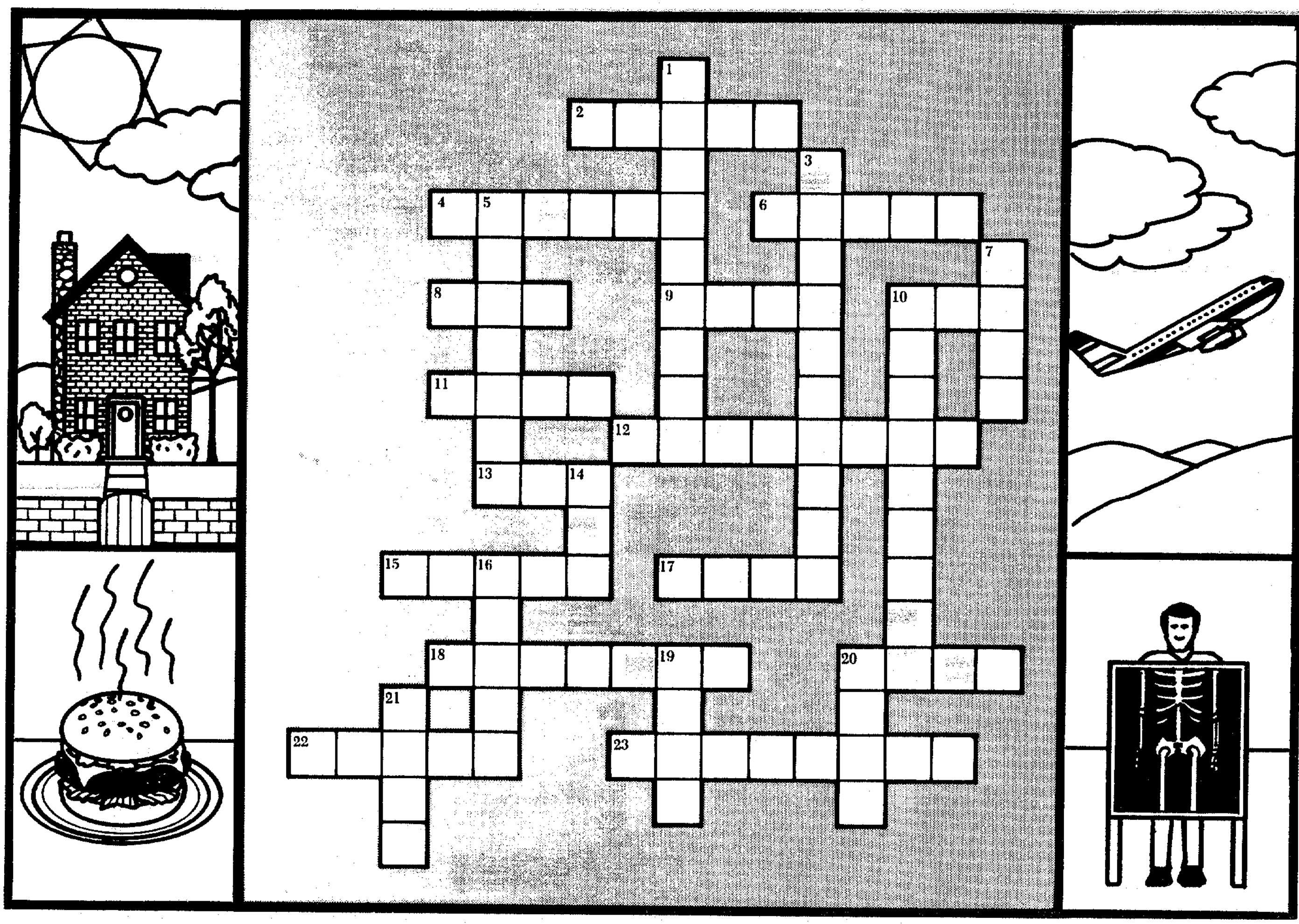
____

The least?________________

What sources surprise you the most?________________

____

BACKGROUND RADIATION CROSSWORD PUZZLE



ACROSS

2 You can receive between 50 and 100 millirems a year from living in a ______________ house.

4 A country where background radiation can be unusually high is ______________.

6 The most penetrating type of radiation is ______________.

8 A unit of radiation measurement.

9 Type of modern music.

10 A ______________ instructor works in the mountains in the winter.

11 The smallest indivisible unit of matter.

12 Types of atoms of an element that have different numbers of neutrons.

13 1,000 millirems = 1 ______________.

15 In order to become stable, an isotope must ______________.

17 A house made of ______________ gives off between 30 and 50 millirems of radiation in a year.

18 We can generate electricity by splitting ______________ atoms.

20 Scrambled ______________.

22 Background radiation comes from outer ______________.

23 The amount of time it takes for an isotope to lose half of its radiation is its ______________.

DOWN

1 Units that measure the effect of radiation on people.

3 Natural radiation that is found everywhere.

5 At a nuclear powerplant, fission takes place in a ______________.

7 An animal that lives in water.

10 Time, distance, and ______________ can protect people from radiation.

14 The 5th month of the year.

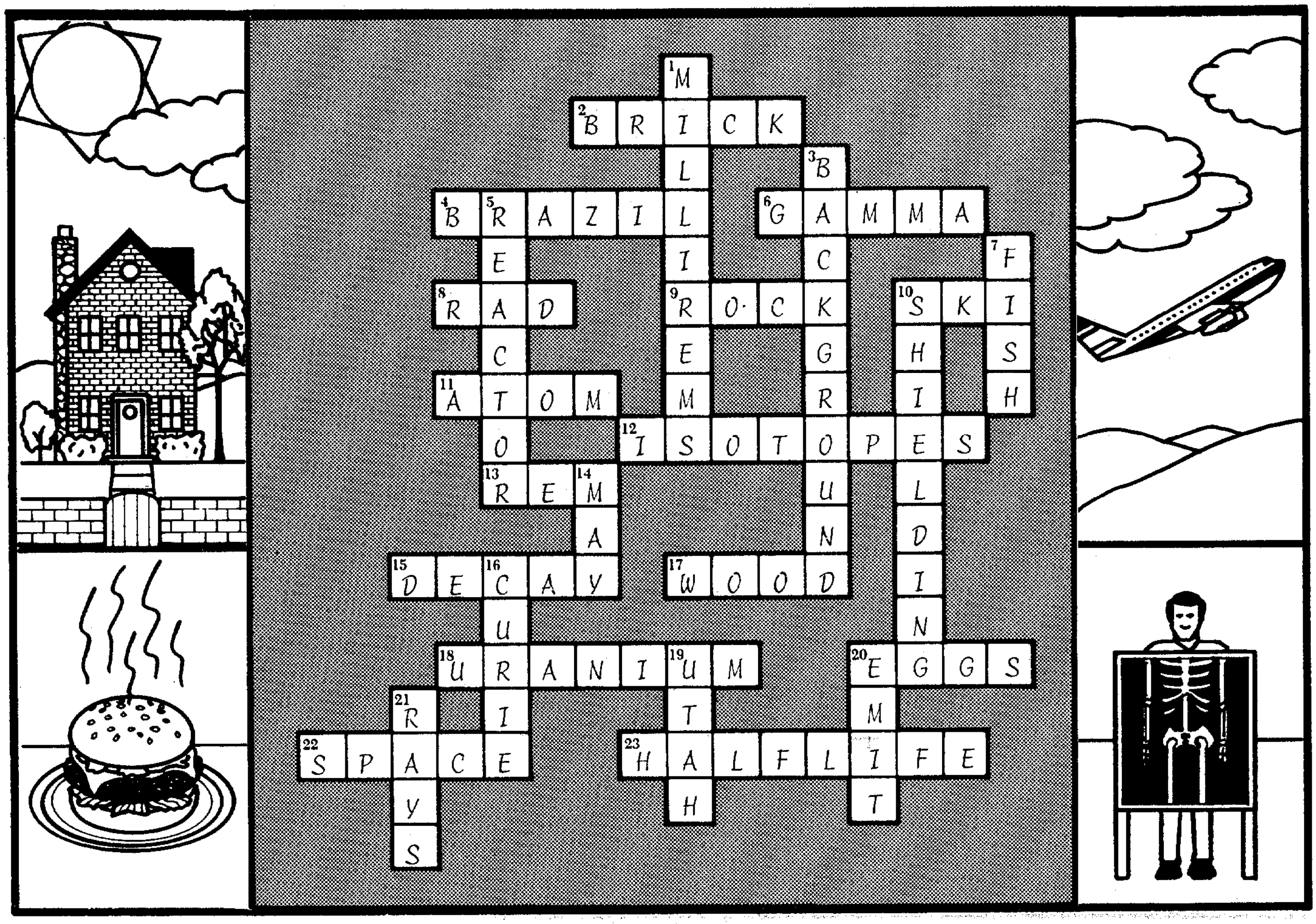
16 A measure of radiation named for a famous French scientist.

19 A State where there are deposits of uranium.

20 To give off.

21 Cosmic ______________ are the main source of background radiation.

BACKGROUND RADIATION CROSSWORD PUZZLE



ACROSS

2 You can receive between 50 and 100 millirems a year from living in a __________ house.

4 A country where background radiation can be unusually high is __________.

6 The most penetrating type of radiation is __________.

8 A unit of radiation measurement.

9 Type of modern music.

10 A __________ instructor works in the mountains in the winter.

11 The smallest indivisible unit of matter.

12 Types of atoms of an element that have different numbers of neutrons.

13 1,000 millirems = 1 __________.

15 In order to become stable, an isotope must __________.

17 A house made of __________ gives off between 30 and 50 millirems of radiation in a year.

18 We can generate electricity by splitting __________ atoms.

20 Scrambled __________.

22 Background radiation comes from outer __________.

23 The amount of time it takes for an isotope to lose half of its radiation is its __________.

DOWN

1 Units that measure the effect of radiation on people.

3 Natural radiation that is found everywhere.

5 At a nuclear powerplant, fission takes place in a __________.

7 An animal that lives in water.

10 Time, distance, and __________ can protect people from radiation.

14 The 5th month of the year.

16 A measure of radiation named for a famous French scientist.

19 A State where there are deposits of uranium.

20 To give off.

21 Cosmic __________ are the main source of background radiation.

1. Review "Computing Your Personal Radiation Dose."

If this activity was a homework assignment, it can be reviewed.

2. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Uses of Radiation"
- ☐ class activity "Radiography"

Polaroid 4x5 Land film (packet type 57) 3000 speed	trash container	book
	radioactive source	paper clips
	roller	penny or other small objects

3. Introduce vocabulary.

activation analysis	hormones	rubidium
carbon dating	labeling	scintillation counter
CAT scanner	radiography	
electroscope	radioactive isotopes	

4. Assign Lesson 5 in the student reader. (Page 38 in the student reader.)

5. Use the following questions for class discussion after the students read Lesson 5.

a. How can we use *radioactive isotopes* to detect illness? (By replacing a few regular atoms with radioactive isotopes in substances like hormones, foods, or drugs, we are able to trace the path they take through our bodies as well as through other animals and plants. Instruments can be used to trace the isotopes through the body, or parts of the body, to find problems.)

b. How can we use *radiation* to *detect* a weakness in the construction of a building? (X rays can be used to see into many metals and machines to help us find flaws we cannot see on the outside. This is called radiography.)

c. Have you ever had a broken bone *x-rayed*? Teeth x-rayed? How did this help the doctor or dentist treat you? (The doctor or dentist was able to see exactly what the problem was and then know how to treat it.)

d. Do you think the *additional radiation* received when people have medical *x rays*, about 80 millirems/year, is worth the benefits they receive? (Answers will vary.)

e. Are there advantages to using *radiation* instead of pesticides to *control* pests, such as insects? (Radiation can be used to control pests by sterilizing male insects that have been raised in captivity and then released into the environment. These insects will not be able to produce offspring. Therefore, the number of insects will be reduced. This would help to reduce the need for adding chemicals to the environment.)

f. Make up a crime story in which the villain is caught by using *carbon dating* and *activation analysis*. (Answers will vary.)

6. Assign and discuss the review exercise for Lesson 5. (Page 43 in student reader.)

Depending upon the grade level of your class, you may put the following list of words on the board for students to choose answers from for Section A.

dating	CAT scanners	denser	electricity
label	pacemakers	radiography	thinner
x rays			

7. Introduce "Uses of Radiation" activity.

8. Introduce "Radiography."

LESSON 5 REVIEW EXERCISE

A. Select the term that best fits the blank space.

1. Our bones are ______________________ than our skin.
2. Doctors and dentists use ________________________ to see inside our bodies.
3. We can use radioactive materials to ___________________ different substances and then see where they go in our bodies or our environment.
4. We use radioactive materials to help us generate ________________________.
5. ____________________ helps us find invisible defects in metal objects.
6. Carbon ___________________ helps us find the age of artifacts.
7. Devices called ___________________ help people's hearts keep beating.

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Dentists use x rays to polish people's teeth.	T	F
2. More than 80 nuclear powerplants are currently operating in America.	T	F
3. Activation analysis helps police solve crimes.	T	F
4. George de Hevesy discovered celery in his leftovers.	T	F
5. Radiation can be used to determine the correct volume to fill cartons and boxes.	T	F

C. List four uses for x rays.

1. ____
2. ____
3. ____
4. ____

(Continued on next page)

D. Tell how the following segments of our society use radioactive materials.

construction ______________________________

archaeology ______________________________

agriculture ______________________________

medicine ______________________________

electric utilities ______________________________

Which of these uses occur in your community ?______________________________

List any additional uses of radioactive materials in your community.

____

____

____

LESSON 5 REVIEW EXERCISE

A. Select the term that best fits the blank space.

1. Our bones are denser than our skin.
2. Doctors and dentists use x rays to see inside our bodies.
3. We can use radioactive materials to label different substances and then see where they go in our bodies or our environment.
4. We use radioactive materials to help us generate electricity.
5. Radiography helps us find invisible defects in metal objects.
6. Carbon dating helps us find the age of artifacts.
7. Devices called pacemakers help people's hearts keep beating.

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Dentists use x rays to polish people's teeth. (to check for dental caries) T F
2. More than 80 nuclear powerplants are currently operating in America. T F
3. Activation analysis helps police solve crimes. T F
4. George de Hevesy discovered celery in his leftovers. (radioisotopes, not celery) T F
5. Radiation can be used to determine the correct volume to fill cartons and boxes. T F

C. List four uses for x rays.

1. To "see" inside our bodies; to check for broken bones.
2. To treat some cancers.
3. To check the strength of things we build.
4. To check the contents of baggage at airports.

(Continued on next page)

D. Tell how the following segments of our society use radioactive materials.

construction Builders x-ray welds to be sure they are done correctly.

archaeology The age of artifacts can be determined through carbon dating.

agriculture Better plants have been developed. Insects can be sterilized.

medicine X rays are used to diagnose. Radiation is used to treat some cancers. Radioisotopes are used to diagnose.

electric utilities Radioactive materials are fissioned to produce heat, which is converted to steam.

Which of these uses occur in your community ? ______

List any additional uses of radioactive materials in your community.

______

______

______

USES OF RADIATION

Directions:

Match the correct sentence with the number in the appropriate balloon in the cartoons shown below.

A) The radiograph shows a crack in this valve.__________

B) Can you guess my age?__________

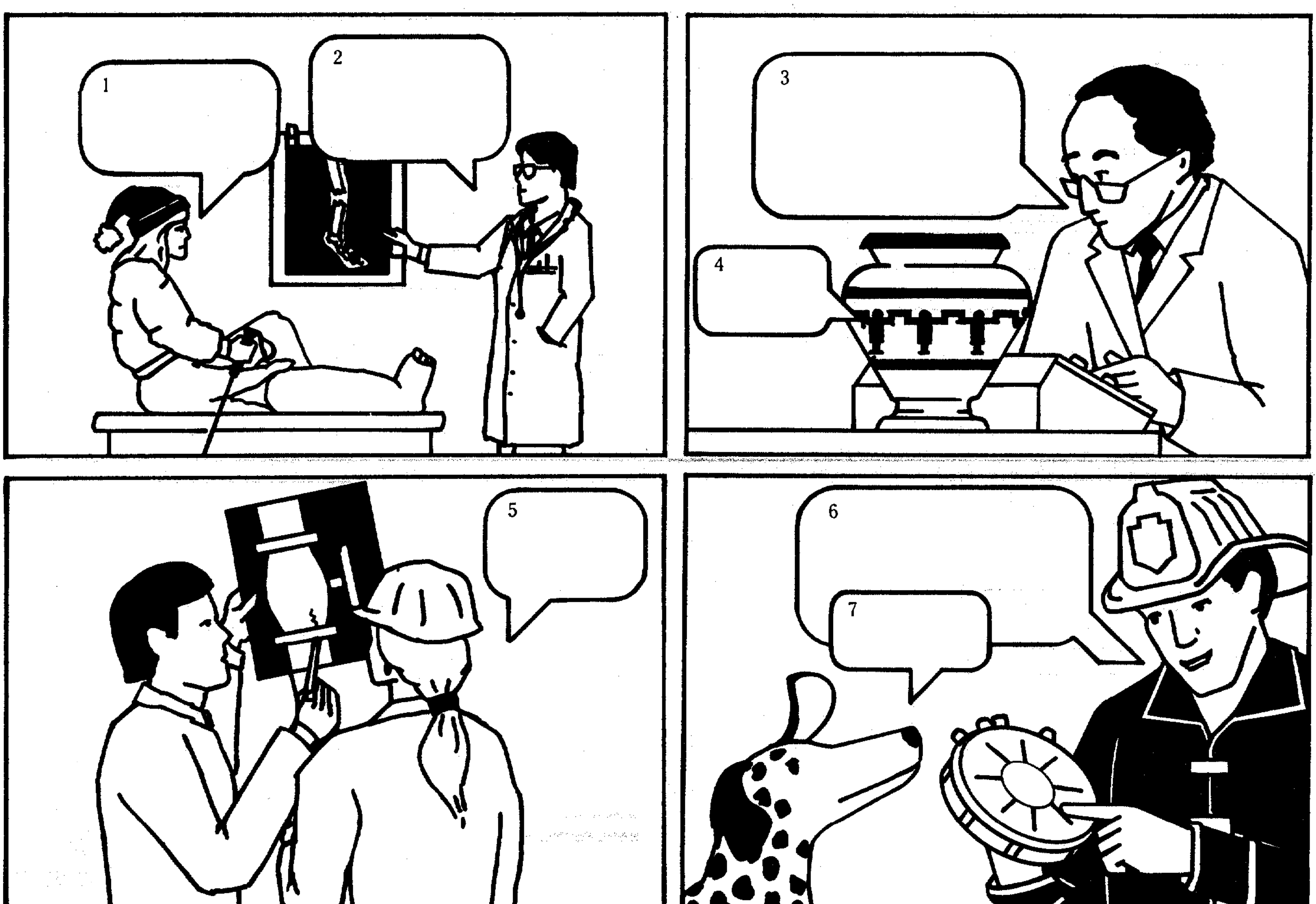
C) Some smoke detectors use a tiny radioactive source.__________

D) Carbon dating indicates this vase is over 3,000 years old.__________

E) Bow wow wow!__________

F) I'll never try a triple back flip again, Doctor.__________

G) This x ray clearly shows a fractured fibula.__________



USES OF RADIATION

Directions:

Match the correct sentence with the number in the appropriate balloon in the cartoons shown below.

A) The radiograph shows a crack in this valve. 5

B) Can you guess my age? 4

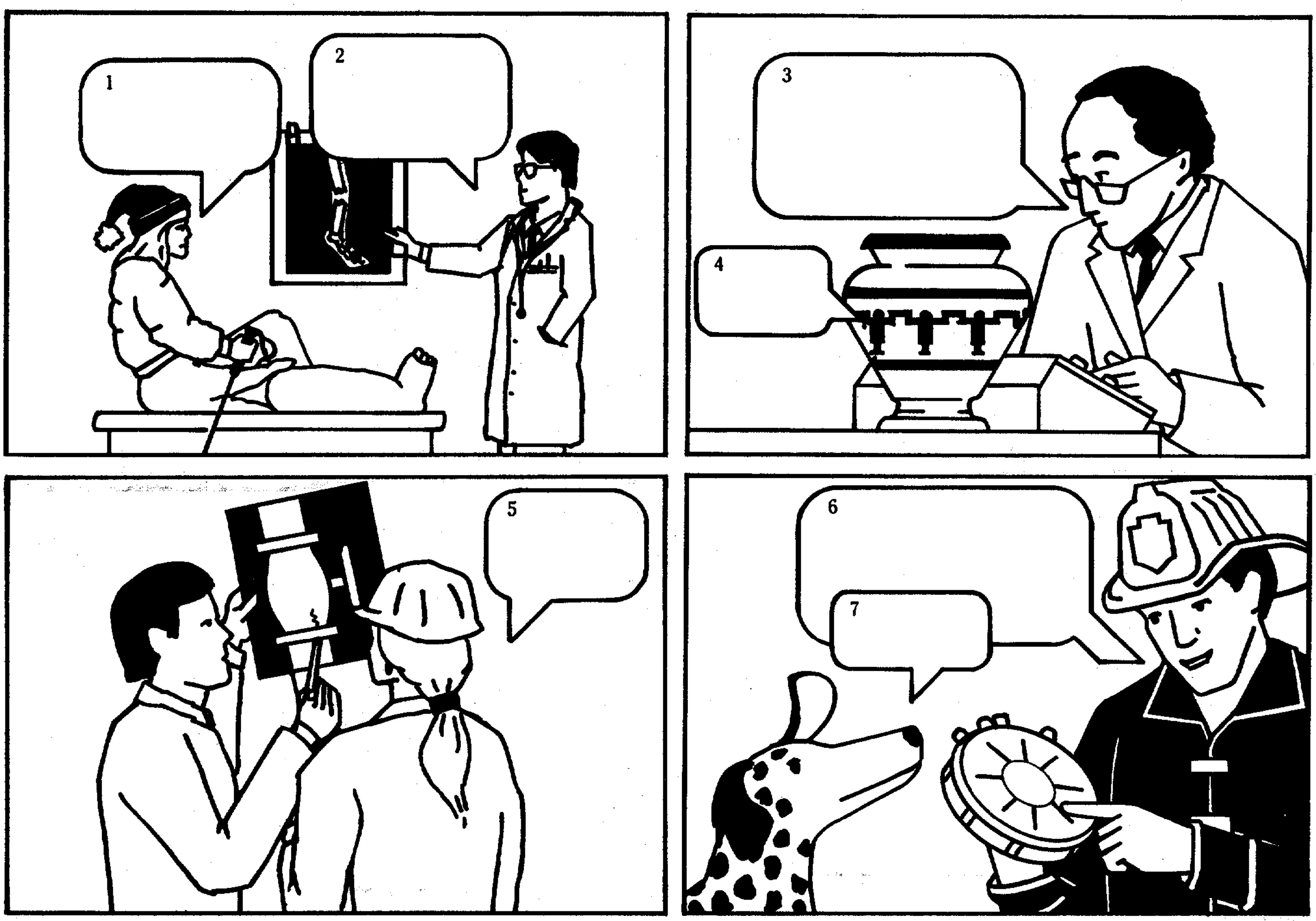
C) Some smoke detectors use a tiny radioactive source. 6

D) Carbon dating indicates this vase is over 3,000 years old. 3

E) Bow wow wow! 7

F) I'll never try a triple back flip again, Doctor. 1

G) This x ray clearly shows a fractured fibula. 2



RADIOGRAPHY

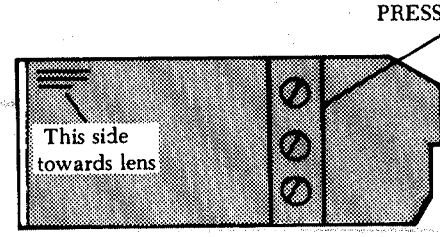
Can you make a photograph using radiation?

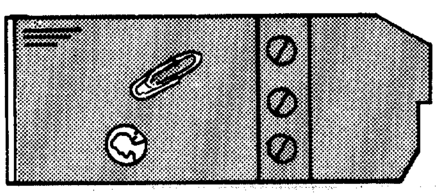
This experiment demonstrates one of the many practical applications of radiation as a tool in science, medicine, and industry.

Materials

trash container	roller
Polaroid 4x5 Land film (packet type 57), 3000 speed	book
	paper clips
radioactive source, such as a lantern mantle	penny or other small objects

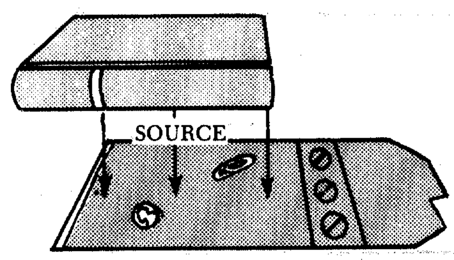
1. Place a film square on a table with side reading "This side towards lens" facing up. Be sure you do not push down on the area indicated.

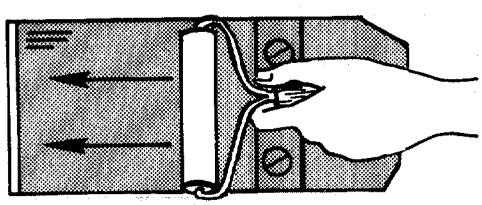




2. Arrange the paper clips and penny on the film square.

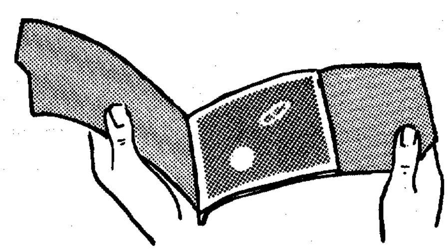
3. Now place the source on top of the objects and hold in place with a book. If you use a lantern mantle, fold it in half, and then in half again. Do not mash the section indicating "Do not press here." Expose for at least 30 minutes. For best results, leave overnight.





4. Be very careful developing your photo. Do not touch the chemicals. Develop your photo by starting just behind the section indicating "Do not press here" and firmly roll the roller over the film once. This will release the developing fluid and spread it evenly over the film.

5. Peel back the paper. **Do not** touch the chemicals. Immediately discard the paper in the trash container. Look carefully at your photograph. Can you see the objects?



Other Ideas to Explore: How does a doctor use this technique? A dentist? See if your doctor will give your class an old x ray. If you live near a large airport, see if you can get permission to watch your suitcase or purse go through the scanner.

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Simulation of Fission Chain Reaction"

large box with transparent top or clear plastic for a cover	ping-pong balls
mousetraps (snap-spring type)	long-handle tongs

2. Introduce vocabulary.

deuterium	fusion	plasma
fission	nuclear chain reaction	tritium
fission products		

3. Have students read Lesson 6 in the student reader. (Page 45 in the student reader.)

4. Use the following questions for discussion after the students read Lesson 6.

a. What is the main difference between *nuclear fission* and *nuclear fusion*? (In nuclear fission, energy is released when the nucleus of an atom is split apart. In nuclear fusion, energy is released when the nuclei of two atoms are forced together, or fused.)

b. Why aren't we using *fusion* to produce electricity? (Scientists have not yet learned to keep fusion reactions going for a long enough time to be able to use the reactions to make electricity. Fusion is still in the research stage.)

c. What is the difference between a *chemical reaction* and a *nuclear reaction*? (In a chemical reaction, two or more atoms combine to form molecules, but the atoms themselves are not changed. In a nuclear reaction, the atoms themselves change. The reaction in a chemical reaction takes place in the electrons; in a nuclear reaction, the reaction is in the nucleus.)

5. Assign and discuss the review exercise for Lesson 6. (Page 49 in the student reader.)

Depending upon the grade level of your class, you may put the following list of words on the board for students to choose answers from for Section A.

chain reaction	electron	fission	fusion	neutron	proton	uranium

6. Do the class demonstration "Simulation of Fission Chain Reaction."

This demonstration is also shown in the film, "The Atom—A Closer Look" by Walt Disney Productions. A large box from an appliance store is a good size. Cut holes in sides and cover with plastic wrap. Use the box upside down so that the top is closed and the bottom is open. Set mousetraps and then set box over them.

Another idea to demonstrate the concept of a chain reaction is to stand 12 matches one-quarter inch apart in clay in an aluminum pan. Light the first match and the others will flame up in a chain reaction.

LESSON 6 REVIEW EXERCISE

A. Select the term that best fits the definition given.

_______________ 1. nuclear reaction in which an atom is split apart

_______________ 2. sequence of atoms fissioning and releasing neutrons that cause additional atoms to fission

_______________ 3. particle of an atom that flies off when a uranium atom is split

_______________ 4. type of atoms split apart in nuclear powerplant to produce heat

_______________ 5. nuclear reaction in which two atoms are joined together

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Fission occurs when the nuclei of certain atoms are hit by neutrons. T F
2. When fission occurs, energy is released as heat. T F
3. A nuclear chain reaction occurs when electrons from fissioning atoms hit other atoms. T F
4. In a nuclear reaction, the atom is changed. T F
5. Fusion takes place under conditions of extreme cold. T F
6. In a nuclear powerplant, fission is used to heat water to make steam. T F

C. Circle the letter of the best answer for each item.

1. In today's nuclear powerplants, the fuel used is _______________.
   a. helium c. uranium
   b. proton d. tritium

2. Nuclear fusion uses _______________ for fuel.
   a. petroleum c. oxygen
   b. hydrogen isotopes d. uranium

3. A uranium-235 atom splits when a(n) _______________ hits its nucleus.
   a. atom c. electron
   b. proton d. neutron

(Continued on next page)

D. Label the following reactions as **chemical** or **nuclear**. Remember that in chemical reactions, atoms of various elements combine with one another to form molecules. In nuclear reactions, the atoms themselves change, often forming new elements.

_______________ 1. An atom of sodium combines with an atom of chlorine to form a molecule of table salt.

_______________ 2. A neutron is added to the nucleus of a uranium-235 atom, causing it to become unstable and split apart.

_______________ 3. An atom of sulfur combines with two atoms of oxygen, forming a molecule of sulfur dioxide.

_______________ 4. An atom of oxygen combines with two atoms of hydrogen to form a molecule of water.

_______________ 5. Deuterium and tritium atoms are forced together, releasing energy, an atom of the element helium, and a neutron.

LESSON 6 REVIEW EXERCISE

A. Select the term that best fits the definition given.

fission 1. nuclear reaction in which an atom is split apart

chain reaction 2. sequence of atoms fissioning and releasing neutrons that cause additional atoms to fission

neutron 3. particle of an atom that flies off when a uranium atom is split

uranium 4. type of atoms split apart in nuclear powerplant to produce heat

fusion 5. nuclear reaction in which two atoms are joined together

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Fission occurs when the nuclei of certain atoms are hit by neutrons. T F
2. When fission occurs, energy is released as heat. T F
3. A nuclear chain reaction occurs when electrons from fissioning atoms hit other atoms. (neutrons, not electrons) T F
4. In a nuclear reaction, the atom is changed. T F
5. Fusion takes place under conditions of extreme cold. (extreme heat) T F
6. In a nuclear powerplant, fission is used to heat water to make steam. T F

C. Circle the letter of the best answer for each item.

1. In today's nuclear powerplants, the fuel used is ____________________.
   a. helium
   b. proton
   c. uranium
   d. tritium

2. Nuclear fusion uses ____________________ for fuel.
   a. petroleum
   b. hydrogen isotopes
   c. oxygen
   d. uranium

3. A uranium-235 atom splits when a(n) ____________________ hits its nucleus.
   a. atom
   b. proton
   c. electron
   d. neutron

(Continued on next page)

D. Label the following reactions as **chemical** or **nuclear**. Remember that in chemical reactions, atoms of various elements combine with one another to form molecules. In nuclear reactions, the atoms themselves change, often forming new elements.

chemical 1. An atom of sodium combines with an atom of chlorine to form a molecule of table salt.

nuclear 2. A neutron is added to the nucleus of a uranium-235 atom, causing it to become unstable and split apart.

chemical 3. An atom of sulfur combines with two atoms of oxygen, forming a molecule of sulfur dioxide.

chemical 4. An atom of oxygen combines with two atoms of hydrogen to form a molecule of water.

nuclear 5. Deuterium and tritium atoms are forced together, releasing energy, an atom of the element helium, and a neutron.

SIMULATION OF FISSION CHAIN REACTION

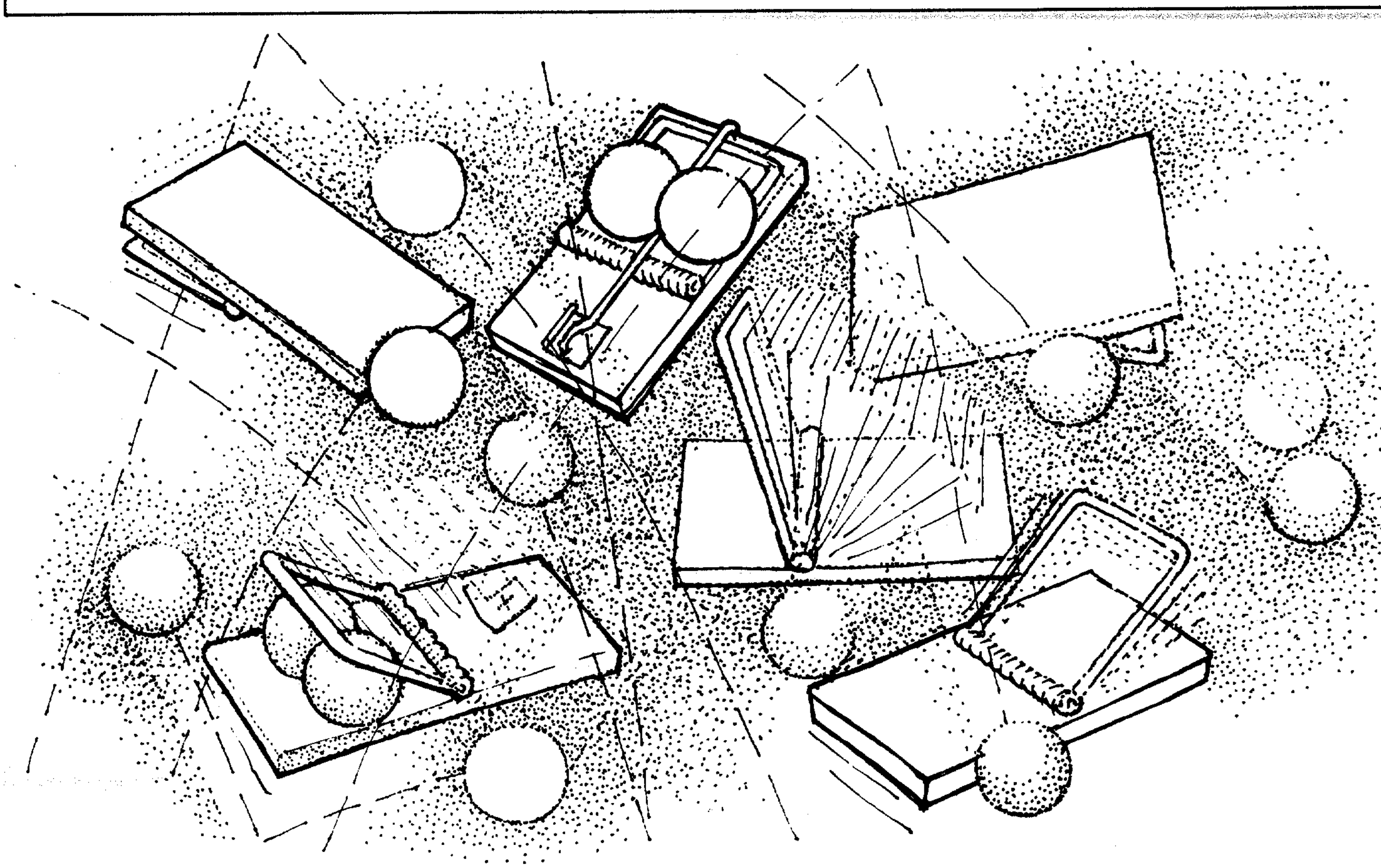
Materials

large box with transparent top or clear plastic for a cover
mousetraps (snap-spring type)
ping-pong balls
long-handled tongs

Directions:

Set the box where it can be easily viewed.
Set the mousetraps. Using the tongs, **carefully** place the traps in the bottom of the box.
Carefully place two ping-pong balls on each trap, using the tongs.
Move the cover in place.
Drop one ping-pong ball under the cover.

Note of Caution: Because there is a danger that the mousetraps could go off accidentally, it is better if this demonstration is done by the teacher.



Learning Objective

The student will be able to describe the sequential development of theories concerning the atom and nuclear energy.

Background Information

During the early 1900s, many scientists worked together to discover the knowledge vital to the development of nuclear energy. Each succeeding discovery brought atomic science closer to modern physics. Albert Einstein's theory of relativity, Ernest Rutherford's and Neil Bohr's theories about atomic structure, and Otto Hahn's and Lise Meitner's discovery of fission of the uranium atom moved the world into the atomic age.

Some of the scientists who contributed to this work are listed below.

Henri Becquerel	Democritus	Otto Hahn
Neils Bohr	Albert Einstein	Lise Meitner
Marie Curie	Enrico Fermi	Ernest Rutherford
Pierre Curie		

Studying these scientists can benefit students by illustrating:

1. How scientists use the scientific method.
2. The teamwork that was required to discover nuclear energy and how teamwork is needed in modern science.
3. The role that women can have and have had in science.
4. How many of the most remarkable scientific discoveries have been made by accident, albeit helped by close observation.
5. An understanding that science is always subject to change.
6. An appreciation of the history of science.

Suggested Activities

1. **Library research work.** Write a report on the work of one of the scientists listed above.
2. **Class play.** A script is provided for additional reading or for a class play. The play can be as simple as students reading the parts aloud in class. Students can also bring in a few props for their characters and prepare illustrations for some of the scientific concepts (e.g., Bohr's atom model).
3. **Atomic Pioneers Time Line.** This can be done as a class discussion activity.
4. **A filmstrip.** Students can draw pictures to illustrate the script and photograph them to make a filmstrip. Your media center may have a camera and copy stand designed for making filmstrips. Students can read the script to make an audiotape to accompany the filmstrip.

The following questions may be used for class discussion.

a. Some scientific discoveries are *unexpected occurrences*: you might even call them accidents. Can you name a discovery from "The Atomic Pioneers" when the scientist was surprised by the results of the experiment? (With unfamiliar circumstances, the scientist, after thinking about the problem, will often believe or expect that a particular result will occur. Sometimes something entirely unexpected happens. Becquerel did not expect the uranium salt to emit radiation spontaneously. Rutherford was very surprised when he found that almost all of an atom's mass was concentrated in the center of the atom. Fermi was surprised that the uranium atom split into two.)

b. Why is it important to keep *good notes* of what you do during your experiment? (Each step should be carefully recorded as the experiment is performed. Then, when you get the result, you will be able to tell how you accomplished it. And you will be able to achieve the same result again by following your notes.)

c. *Scientific discoveries* by one scientist often lead to another scientist's taking up the work and adding to the first discovery. Can you name some examples? (Curie became interested in Becquerel's work with radiation; Bohr became interested in Rutherford's work on the structure of the atom; Meitner and Hahn became interested in Fermi's work and discovered the atom could be split.)

d. What *discovery* do you think was the most important and why? (Answers will vary. This should encourage discussion among students.)

e. When did scientists first begin to think that we might be able to *use the energy from atoms*? (When they began to think that a chain reaction was possible, they began to think we might be able to use the energy from fission. Nuclear energy could never be a reality if they had to keep firing neutrons from some source at the uranium atoms to break them up. But, if the uranium atom released neutrons as it split up, then these neutrons could go on and break up other nuclei. With the chain reaction would come the release of a lot of energy.)

ATOMIC PIONEERS TIME LINE

Directions: Arrange the events in the correct order by writing the items listed below on the lines given.

- Rutherford discovers that most of an atom is empty space. (1909)
- Becquerel discovers uranium naturally gives off some kind of radiation. (1896)
- Enrico Fermi achieves the first sustained nuclear chain reaction. (1942)
- Marie Curie names radioactivity. (1899)
- Lise Meitner and Otto Hahn understand the experiments with uranium in which the atom splits. (1938)
- Marie and Pierre Curie discover radium. (1898)
- Neils Bohr develops the theory of atomic structure. (1913)
- Albert Einstein develops an equation stating that matter and energy are the same thing.

1890

Sport of basketball invented by James Naismith. (1891)

1895 ______

______

1900 ______

Wright brothers make first flight at Kitty Hawk. (1903)

1905 ______

______

1910 Boy Scouts and Camp Fire begin. (1910)

______

1915 First telephone talk from N.Y. to San Francisco is made by Alexander Graham Bell and Thomas A. Watson. (1915)

1920 Women's Voting Rights Amendment passes. (1920)

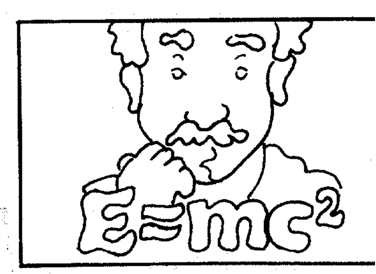
1925

Robert Goddard invents first rocket using liquid fuel. (1926)

Martin Luther King is born. (1929)

1930

First NFL Championship—Chicago Bears 23, New York Giants 21. (1931)



1935 Elvis Presley is born. (1935)

______

1940

Pearl Harbor is bombed. (1941)

______

1945 World War II ends. (1945

CLASS ACTIVITY

ATOMIC PIONEERS TIME LINE

Directions: Arrange the events in the correct order by writing the items listed below on the lines given.

- Rutherford discovers that most of an atom is empty space. (1909)
- Becquerel discovers uranium naturally gives off some kind of radiation. (1896)
- Enrico Fermi achieves the first sustained nuclear chain reaction. (1942)
- Marie Curie names radioactivity. (1899)
- Lise Meitner and Otto Hahn understand the experiments with uranium in which the atom splits. (1938)
- Marie and Pierre Curie discover radium. (1898)
- Neils Bohr develops the theory of atomic structure. (1913)
- Albert Einstein develops an equation stating that matter and energy are the same thing. (1905)

1890
— Sport of basketball invented by James Naismith. (1891)

Becquerel discovers uranium naturally gives off some kind of radiation. (1896)

1895

Marie and Pierre Curie discover radium. (1898)

1900

Marie Curie names radioactivity. (1899)

— Wright brothers make first flight at Kitty Hawk. (1903)

1905 *Albert Einstein develops an equation stating that matter and energy are the same thing. (1905)*

Rutherford discovers that most of an atom is empty space. (1909)

1910 Boy Scouts and Camp Fire begin. (1910)

Neils Bohr develops the theory of atomic structure. (1913)

1915 First telephone talk from N.Y. to San Francisco is made by Alexander Graham Bell and Thomas A. Watson. (1915)

1920 Women's Voting Rights Amendment passes. (1920)

1925
— Robert Goddard invents first rocket using liquid fuel. (1926)

— Martin Luther King is born. (1929)

1930
— First NFL Championship—Chicago Bears 23, New York Giants 21. (1931)

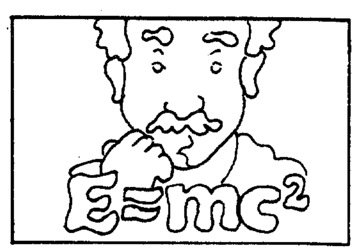
1935 Elvis Presley is born. (1935)

Lise Meitner and Otto Hahn understand the experiments with uranium in which the atom splits. (1938)

1940
— Pearl Harbor is bombed. (1941)

Enrico Fermi achieves the first sustained nuclear chain reaction. (1942)

1945 World War II ends. (1945)



The Atomic Pioneers

1 The Atomic Pioneers

2 (JENNIFER): Hi, Mark. Where are you going?

(MARK): I'm on my way to the library. We're studying atoms and radiation, and I need some facts about them.

(JENNIFER): Do you mind if I come along? I've got the same assignment for Mr. Brown's class.

3 (MARK): These books should help a lot. Let's see...radiation— Henri Becquerel...Albert Einstein...Madam Marie Curie... I wonder what they did?

4 (CURIE): Hello, Mark and Jennifer. Perhaps I can help you.

(JENNIFER): Wow! Who are you?

(CURIE): I am Madam Marie Curie. I know a lot about radiation. In fact, I discovered several radioactive elements.

5 (MARK): Say, it would be great if you would help us. We have a lot of questions. Where does radiation come from? How did you discover those elements?

(CURIE): Well, why don't you come with me and see what we can find out?

6 (CURIE): Let's start with Democritus, a Greek philosopher from the 4th century B.C., who believed that everything was made of tiny particles that were so small no one could see them.

7 (CURIE): These particles were grouped together in different ways to form different substances. However, these particles could never change or break apart. Democritus called these particles atoms.

8 (MARK): It's still all Greek to me. Why did he call them atoms?

(CURIE): From the Greek word "atomos," which means indivisible. It was over 2000 years before we found out more about atoms. Now, come with me to Paris in 1896 and meet a friend of mine, Henri Becquerel.

9 (CURIE): Hello, Monsieur Becquerel. I'd like you to meet my friends, Mark and Jennifer. They are learning about radiation.

(BECQUEREL): Well, let me tell you about an interesting discovery that I made.

10 (BECQUEREL): I had been testing substances that glowed in the dark after being exposed to sunlight. This intrigued me.

(JENNIFER): What did you think was happening?

(BECQUEREL): I wasn't sure, but I thought the sun was having an effect.

11 (BECQUEREL): I wrapped some photographic plates in thick black paper that light could not go through. Then I placed a piece of uranium salt on each plate. I meant to expose them to the sun, but it was a cloudy day.

12 (BECQUEREL): So, I put the plates away in a drawer. When I developed the plates a few days later, I found silhouettes of the uranium salt. The uranium gave off radiation spontaneously! And the radiation was more penetrating than light. It could pass through black paper that could stop light.

13 (MARK): It wasn't what you expected, was it?

(BECQUEREL): No, it wasn't. You could say that by accident I discovered that uranium naturally gives off some kind of radiation. Sunlight really had nothing to do with what was happening.

14 (MARK): That discovery was pretty important, wasn't it?

(CURIE): Yes, it was. And this discovery that uranium is naturally radioactive sparked the interest of several other scientists, including me.

15 (CURIE): In 1899, I decided to study the type of rays that Becquerel had discovered almost 2 years earlier. I studied many elements and finally found that the element thorium also gave off radiation spontaneously.

16 (CURIE): My husband, Pierre, and I called this property radioactivity.

(JENNIFER): Why did you decide to call it that?

(CURIE): It was radiating activity and we combined these two words to radioactivity.

17 (CURIE): At this time, Pierre gave up his own research to study the nature of radioactivity with me. One day as I worked with a piece of uranium ore called pitchblende, I noticed that it gave off a radiation much stronger than the radiation from uranium and thorium.

18 (CURIE): To continue our research, Pierre and I used our life's savings to buy every ounce of pitchblende we could find. We also needed a larger laboratory than the little room where we had been working.

19 (CURIE): The only space large enough was an old woodshed in the courtyard of the School of Physics where Pierre was teaching. The shed was cold and damp. It had no floor, and on rainy days the roof leaked. It was far from an ideal laboratory.

20 (CURIE): Even so, at the end of 4 years of research, Pierre and I had treated several tons of pitchblende and had obtained one-tenth of a gram of pure radium salt. The study of radium became my life's work.

21 (CURIE): When Pierre was killed in an accident, I succeeded him as professor of physics at the Sorbonne, a university in Paris. I became the first woman ever to teach there.

(JENNIFER): That's a good accomplishment.

(CURIE): Thank you, Jennifer. Scientists around the world wondered about the radiation given off by uranium and other radioactive elements. Perhaps the scientist who did the most to answer these new questions was Ernest Rutherford.

22 (CURIE): Here he is now. Mr. Rutherford, can we talk to you about some of your discoveries?

(RUTHERFORD): Certainly! While I was working at the University of Montreal in Canada, I found that different types of radiation are made of different particles.

23 (RUTHERFORD): One type of radiation that I called alpha is made of fast-moving particles charged with positive electricity.

24 (RUTHERFORD): I found a second kind of particle charged with negative electricity that I called beta. I recognized that beta particles were electrons.

25 (RUTHERFORD): Other scientists working during this time discovered a third type of radiation called gamma. I thought that some elements could change spontaneously into other elements by emitting these different types of radiation.

(JENNIFER): I don't understand what you mean.

26 (RUTHERFORD): When an element changes by emitting radiation, the change takes place in the nucleus of the atom. This can change the atom into one or two entirely different elements.

(JENNIFER): Oh... Could you give me an example?

27 (RUTHERFORD): All right. When a radium atom breaks down, it gives off an alpha particle and gamma waves and it changes into an element called radon. This kind of change is called decay. So we say that radium decays into radon.

28 (CURIE): Another of Mr. Rutherford's later experiments helped us understand how atoms are put together. Why don't you tell Mark and Jennifer about it?

(RUTHERFORD): First, remember that earlier scientists thought that atoms were tiny, solid dots. Then we began to suspect that this was not true.

29 (RUTHERFORD): My experiment proved that an atom has all of its positive charge and virtually all of its mass concentrated in a tiny spot at its center. This meant that atoms are not solid. In fact, most of an atom is empty space.

(JENNIFER): You mean like Mark's head?

(MARK): Thanks a lot.

(JENNIFER): I couldn't resist. Go on, Mr. Rutherford.

30 (RUTHERFORD): Well, actually you're right, Jennifer. As you know, everything is made of atoms. And if atoms are mostly empty space, all the things we see around us, which look solid, have a lot of empty space. My laboratory table, this wall, and even our heads and bodies are examples. My idea changed our thoughts about how atoms are put together.

31 (CURIE): Now that you've heard about Mr. Rutherford's contributions, you'll see why he is known as the "father of nuclear science."

32 (CURIE): Next, the Danish physicist Neils Bohr used Rutherford's model of the nucleus of an atom to explain how atoms are put together. Bohr worked with Rutherford in Manchester, England in 1912. There Bohr worked out a mathematical explanation of how the electrons move around the nucleus.

33 (CURIE): Bohr's description of the structure of an atom is often considered the foundation of modern atomic physics. His model showed that all atoms are like small solar systems.

34 (CURIE): Scientists agreed that alpha, beta, and gamma radiation must come from atoms. Yet, because of this new information about the structure of atoms, it became apparent that atoms were not indivisible, as Democritus and many others had thought.

35 (CURIE): Scientists began to suspect that atoms must contain large amounts of energy that hold these tiny pieces together. Some scientists began to talk of the immense store of energy locked up in atoms and of the amount of work that this energy could do.

(MARK): So how did we learn to unlock the atom's energy?

(CURIE): To answer this, we must talk to Albert Einstein. When Dr. Einstein was only 26 years old, he discovered some of the fundamental concepts of physics. . . Hello, Albert.

36 (EINSTEIN): Hello, Marie. Who is with you?

(CURIE): These are my friends, Mark and Jennifer. We are learning about radiation and energy. They are interested in hearing about your work.

(EINSTEIN): It is a little complicated, so listen carefully.

37 (EINSTEIN): I thought that mass could change into energy, and energy into mass.

(JENNIFER): Excuse me, Dr. Einstein. What is mass?

38 (EINSTEIN): Mass is anything that takes up space and has weight.

39 (EINSTEIN): I expressed the relationship between energy and mass in the equation $E = mc^2$.

40 (EINSTEIN): E stands for energy, m for mass, and c^2 for the speed of light multiplied by itself. The key to this formula is in the quantity c^2.

41 (EINSTEIN): The speed of light is always 186,000 miles per second.

42 (EINSTEIN): And this number multiplied by itself becomes 34,596,000,000.

43 (EINSTEIN): According to my equation, the weight of a mass must be multiplied by this number in order to find the amount of energy that would be equal to this mass. As you can see, the result is an incredible amount of energy.

44 (CURIE): In other words, Dr. Einstein's equation said that matter and energy are the same thing in two different forms.

Yet the equation doesn't tell how to convert matter into energy. But the formula showed scientists that a virtually endless source of energy exists. They just had to find out how to release it.

45 (EINSTEIN): And they found the answer in nature. The energy that holds the atoms together also powers the universe. Matter changing into energy powers our Sun and all the stars.

(MARK): But how did scientists learn to control this energy?

(CURIE): That's a good question. And it puzzled scientists for several years.

46 (CURIE): In the early 1930s an Italian physicist, Enrico Fermi, was working on the problem. Let's ask him.

(FERMI): As part of an experiment, I was bombarding uranium atoms with slow neutrons. And the results I was getting were puzzling. More radiation was being emitted than I expected.

47 (FERMI): My interpretation was that some uranium nuclei had been absorbing neutrons and changing into unknown heavier elements. But I was not sure that this was the answer.

48 (CURIE): Otto Hahn and Lise Meitner, chemists in Germany, repeated the Fermi experiment in Berlin. They also found more radiation was being emitted than was expected. When they examined the bombarded uranium, to their own astonishment, and everyone else's, they found barium, which has a much lighter nucleus than uranium.

(JENNIFER): What was happening?

(CURIE): Let's ask Lise Meitner about her experience.

49 (MEITNER): During the time I spent in Sweden, I discussed the problem with my nephew, Otto Frisch. Since Democritus, we had all taken it for granted that heavy nuclei, such as uranium, could not be split.

50 (MEITNER): But, what if some uranium nuclei that had 92 protons split into two lighter atoms after being bombarded with neutrons? The break-up could release radiation and produce barium (with 56 protons) and a gas called krypton (with 36 protons). This could be the reason for the unexpected appearance of barium in Fermi's and our experiments.

51 (MARK): Wait a minute. Why did they think there was krypton?

(JENNIFER): Mark, 92 protons minus 56 protons leaves 36 protons. Dr. Meitner just said that krypton has 36 protons. Isn't that right, Madame Curie?

(CURIE): Mais oui.* The protons add up.

52 (MEITNER): I gave the name fission to the process because that means splitting apart.

(CURIE): It was at this stage that scientists began to think that the tremendous energy released when atoms split could be put to use.

53 (MEITNER): Using Einstein's formula, we calculated that the expected energy released by splitting each uranium nucleus would be about 200 million electron volts.

(MARK): But how could we use nuclear energy if we had to fire single neutrons at single atoms to break them up?

54 (CURIE): Nature again provided the key because some atoms release extra neutrons when they split. And if the uranium atom did release neutrons as it split...

55 (CURIE): then these neutrons could break up other atoms that also release extra neutrons. This would cause a chain reaction.

56 (CURIE): By 1940 Neils Bohr and Enrico Fermi were in the United States. And they had decided that such a chain reaction might work. Fermi decided to try.

(FERMI): I knew we had to slow down the neutrons to give them more opportunity to strike the nucleus of the atoms. Neutrons generally go too fast. But we used blocks of graphite to slow them.

57 (FERMI): In a squash court at the University of Chicago, we built a structure using 6 tons of uranium, 50 tons of uranium oxide, and 400 tons of graphite blocks. Today, this would be called a nuclear reactor.

58 (FERMI): On December 2, 1942 we tested our peculiar device and achieved the first sustained nuclear chain reaction. The nuclear age had begun.

* (pronounced "may wee." Means "of course" in French.)

59 (CURIE): I've told you a long story. Fermi's chain reaction was the last piece in the puzzle of understanding how we get energy from atoms. Science was on the threshold of harnessing this energy.

60 (MARK): Gee, Madame Curie, thank you. We've really enjoyed your story and learned a lot. My teacher will be really surprised when she gets my "A" paper!

61 The end.

Introduction

This is the third of four units that comprise *The Harnessed Atom*. This unit explains the processes of a nuclear powerplant as it converts the heat from nuclear fission to electricity. The intent is to provide correct and easily understood information for the students.

Unit 3 includes suggested demonstrations and activities that require students to use and develop skills in map reading, decision making, interpreting, measuring, observing, model making, ordering in sequence, and working in groups. Also included are review exercises to help reinforce the students' understanding of basic scientific concepts.

The format of the Teacher Guide will allow you to remove the activity and review exercise pages for making ditto copies, photocopies, or transparencies. Instructions for using *The Harnessed Atom* in a learning center are given in Appendix A.

Learning Objectives

The materials, activities, and review exercises in this unit are developed from the following learning objectives.

Lesson 1 Planning the Franklin Nuclear Powerplant

Students will be able to:

- ☐ discuss factors a utility must consider in deciding whether to build a powerplant
- ☐ discuss factors a utility must consider in deciding what type of powerplant to build
- ☐ explain why a utility must get a license to build a nuclear powerplant
- ☐ arrange in sequence the steps involved in getting a construction permit
- ☐ describe characteristics of a site that would be appropriate for building a nuclear powerplant
- ☐ describe the types of studies conducted before a construction permit is granted
- ☐ identify the U.S. Government agency responsible for licensing nuclear powerplants

Lesson 2 How the Reactor Works

Students will be able to:

- ☐ identify the parts of a reactor—fuel assemblies, control rods, coolant/moderator, and pressure vessel
- ☐ explain how control rods work

Lesson 3 Producing Electricity at Franklin

Students will be able to:

- ☐ explain the process of heat transfer
- ☐ describe how water moves heat through a powerplant
- ☐ describe the movement of steam through a powerplant
- ☐ discuss what takes place in a cooling tower

Lesson 4 Franklin's Fuel

Students will be able to:

- ☐ describe the processes of uranium mining, milling, enrichment, and fuel fabrication
- ☐ identify fuel pellets, fuel rods, fuel assemblies

Lesson 5 Franklin's Waste

Students will be able to:

- ☐ classify low-level waste and high-level waste
- ☐ describe disposal of low-level waste
- ☐ describe how high-level waste will be isolated
- ☐ describe how waste will be transported
- ☐ discuss the safety measures used in transportation of waste
- ☐ discuss the pros and cons of dismantling a powerplant immediately upon shutdown or waiting several years before dismantling

Lesson 6 Franklin's Safety Systems

Students will be able to:

- ☐ describe how the following systems protect people and the environment from radiation: containment building, pressure vessel, metal fuel rods, spent fuel pool, monitors
- ☐ explain two backup safety systems of a nuclear powerplant
- ☐ identify four requirements nuclear powerplant operators must satisfy in order to get and keep their jobs

Lesson 7 Other Reactors

Students will be able to:

- ☐ identify and describe boiling water reactors, high temperature gas-cooled reactors, breeder reactors, and liquid metal fast breeder reactors

Lesson 8 Filmstrip "The Harnessed Atom"

Students will be able to:

- ☐ distinguish features of each process required to use nuclear energy to make electricity

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Selecting a Site for a Nuclear Powerplant"
- ☐ class activity "The Effect of Heat on Brine Shrimp"

6 clear containers of equal size (beakers, plastic cups, etc.)	hatching container (glass baking dish works well)	heat resistant glass or stainless steel container
brine shrimp eggs (available at pet shops)	hot plate	ruler
eyedropper	ocean mix salts or non-iodized table salt	thermometer
	pot holder	

2. Introduce vocabulary.

Before students read Lesson 1, you may wish to introduce vocabulary words by listing them on the chalkboard and pronouncing them correctly. Definitions can be found in the glossary at the end of the student reader.

construction permit	environmentalists	physicists
economists	hazardous	pollute
economy	hearings	pollution
engineers	licenses	utility
environmental	nuclear fission	uranium

3. Read Lesson 1 in student reader. (Page 53 in the student reader.)

4. After students have read Lesson 1, the following questions may be used for class discussion.

a. How might someone who lives in a state that has no *nuclear powerplants* get some electricity from nuclear powerplants? (Sometimes a utility buys electricity from utilities in neighboring states; these states may use nuclear powerplants to generate electricity.)

b. Why might a *utility* decide to build a new powerplant? (A utility is responsible for supplying its customers with the electricity they need or want. Therefore, a utility must try to anticipate future needs of the area it serves. If predictions based on studies they conduct show that it will not be possible to supply the amount of electricity that will be needed using existing powerplants, they may decide to build additional ones. Some factors that indicate there will be increasing need or demand for electricity are population growth and new or expanding businesses and industries. Students should understand that a utility is trying to anticipate future needs.)

c. What could be the effects on a community or region if a *utility* cannot *supply* as much electricity as people want? (Companies will only locate in places where there is enough electricity for their needs. If a utility cannot supply as much electricity as people or businesses want at prices they can afford, it could affect the number of jobs that are available. If there are not enough jobs, people may choose to move away.)

d. If the utility that serves your area decided to build a *new powerplant*, what type do you think they would select? (Answers will vary, but should reflect availability and cost of fuel, including transportation of fuel, costs of construction and operation, safety, environmental effects, as well as some indication of regional attitudes toward various types of powerplants.)

e. What things are considered in deciding *where to build a nuclear powerplant*? (A site for a nuclear powerplant requires access to water. The area must be free from earthquakes. The site should be located where supplies and fuel can be delivered; it is helpful to be near railroad tracks for this reason. The site should be in a lightly populated area for safety reasons. And the site should not be one where valuable historical objects would be lost if the plant were built. The plant should be located where it will have a minimum effect on the environment.)

f. What *other types of industries* should be located in lightly populated areas? Why? (Any industry that presents a possible hazard to the public in the event of an accident should be located in a lightly populated area. Industries that produce or use large amounts of toxic chemicals or industries that produce, use, or store explosives such as firecrackers or natural gas should be in lightly populated areas. Industries that manufacture or use poisonous gases such as chlorine or isocyanate should be away from highly populated areas. Also, industries that produce large amounts of traffic or noise should be located away from large groups of people.)

g. Why does the U.S. Government require a powerplant to get a *license* before beginning to build a nuclear powerplant? (The U.S. Government requires a license to ensure that the powerplant will be safe in design and to ensure protection of the public and environment.)

h. Over the last 100 years, what changes have increased the demand for electric power? What predictions would you make about changes in our future electrical needs? (In the last 100 years, a multitude of appliances have been invented. Industry also has witnessed many new electrical machines that have increased production. The electric light also cannot go unmentioned. As to our future energy needs, it is difficult to speculate. Answers will vary. But one example might be the invention of an efficient electric car. This could increase electricity demand dramatically.)

i. Is there a suitable location for a nuclear powerplant in your area? (Answers will vary.)

5. Assign and discuss the review exercise for Lesson 1. (Page 60 in the student reader.)

Two copies of the exercise have been provided: one with answers and a clean copy for use in making copies.

6. Assign the activity "Selecting a Site for a Nuclear Powerplant."

7. Introduce class activity "The Effect of Heat on Brine Shrimp."

12. Answers to questions on activity sheet.

    a. Manmade heat is a pollutant because it changes the natural environment.

    b. Answers will vary.

    c. Because heated water will be put into the river, it is important to make sure the organisms in the river can tolerate the temperature increases.

    d. Yes. The major difference between a coal-fired plant and a nuclear plant is the fuel. Both produce waste in the form of heated water as a by-product of producing electricity.

    e. Yes. The food chain would be broken.

LESSON 1 REVIEW EXERCISE

A. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. About one-third of our energy resources are used to produce electricity. T F
2. Nuclear powerplants supply 13 percent of the electricity we use in the United States. T F
3. Some of the electricity used in States where no nuclear powerplants are located may still come from nuclear powerplants. T F
4. Sometimes a utility may need to buy electricity from a neighboring utility in order to supply all the electricity its customers want. T F
5. A construction permit to build a nuclear powerplant is issued by the State where it is located. T F
6. The part of the U.S. Government that is responsible for licensing nuclear powerplants is the Department of Energy. T F
7. It is important to check the powerplant site for historic objects before construction begins. T F
8. There are strict requirements that regulate the effects that building a nuclear powerplant may have on the environment. T F
9. At public meetings, local people may testify about building a nuclear powerplant. T F
10. A utility may build a nuclear powerplant without a construction permit. T F

B. Number the events in the order in which they occur.

______ Utility decides to build a nuclear powerplant.

______ Construction begins.

______ Utility selects preferred site for powerplant.

______ Public hearings are held.

______ NRC issues construction permit.

LESSON 1 REVIEW EXERCISE

A. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. About one-third of our energy resources are used to produce electricity. T F
2. Nuclear powerplants supply 13 percent of the electricity we use in the United States. T F
3. Some of the electricity used in States where no nuclear powerplants are located may still come from nuclear powerplants. T F
4. Sometimes a utility may need to buy electricity from a neighboring utility in order to supply all the electricity its customers want. T F
5. A construction permit to build a nuclear powerplant is issued by the State where it is located. (Issued by Nuclear Regulatory Commission) T F
6. The part of the U.S. Government that is responsible for licensing nuclear powerplants is the Department of Energy. (Nuclear Regulatory Comm.) T F
7. It is important to check the powerplant site for historic objects before construction begins. T F
8. There are strict requirements that regulate the effects that building a nuclear powerplant may have on the environment. T F
9. At public meetings, local people may testify about building a nuclear powerplant. T F
10. A utility may build a nuclear powerplant without a construction permit. (must have) T F

B. Number the events in the order in which they occur.

__1__ Utility decides to build a nuclear powerplant.
__5__ Construction begins.
__2__ Utility selects preferred site for powerplant.
__3__ Public hearings are held.
__4__ NRC issues construction permit.

SELECTING A SITE FOR A NUCLEAR POWERPLANT

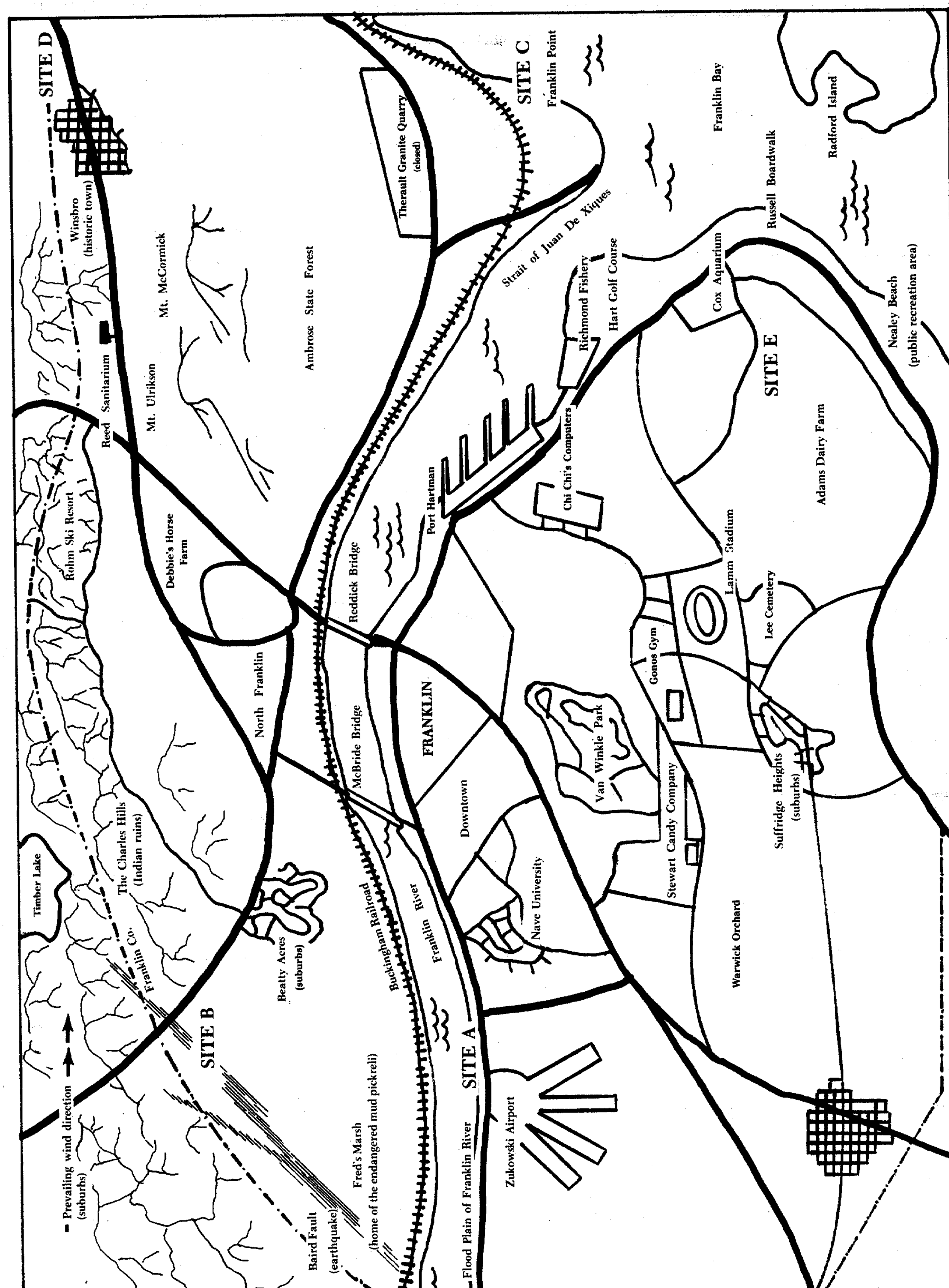
Using the map provided, fill in the blanks which apply for each of the possible powerplant sites. Then select the site that you think is best. Write a paragraph explaining why you selected this site and why you did not select each of the other sites.

If this site is selected	Site A	Site B	Site C	Site D	Site E
supplies could be easily delivered by railroad					
plenty of water would be available to the plant					
the plant would be downwind from centers of population					
the plant would be built on stable land					
the plant would be away from centers of population					
no historical objects would be lost by building a powerplant					

SELECTING A SITE FOR A NUCLEAR POWERPLANT

Using the map provided, fill in the blanks which apply for each of the possible powerplant sites. Then select the site that you think is best. Write a paragraph explaining why you selected this site and why you did not select each of the other sites.

If this site is selected	Site A	Site B	Site C	Site D	Site E
supplies could be easily delivered by railroad			✓		
plenty of water would be available to the plant	✓		✓		✓
the plant would be downwind from centers of population			✓	✓	✓
the plant would be built on stable land			✓	✓	✓
the plant would be away from centers of population			✓		✓
no historical objects would be lost by building a powerplant	✓	✓	✓		✓

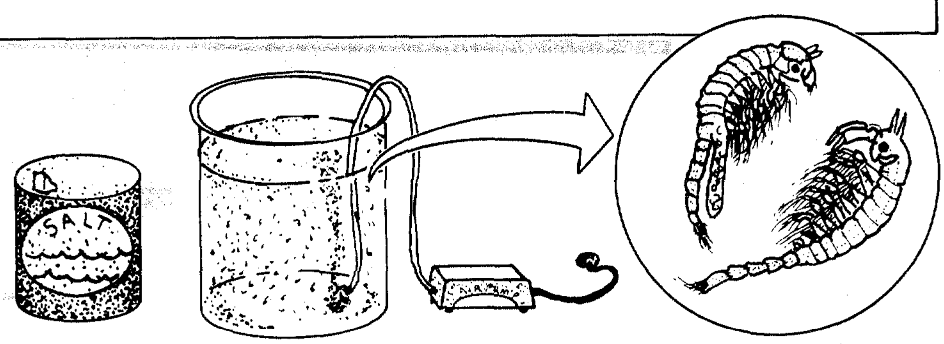


SITE A
SITE B
SITE C
SITE D
SITE E
Prevailing wind direction
(suburbs)
Timber Lake
The Charles Hills
(Indian ruins)
Franklin Co.
Baird Fault
(earthquake)
Fred's Marsh
(home of the endangered mud pickrel)
Beatty Acres
(suburbs)
Buckingham Railroad
Franklin River
Flood Plain of Franklin River
Zukowski Airport
Rohm Ski Resort
Reed Sanitarium
Winsbro
(historic town)
Mt. Ulrikson
Mt. McCormick
Ambrose State Forest
Debbie's Horse Farm
North Franklin
McBride Bridge
Reddick Bridge
Port Hartman
FRANKLIN
Downtown
Nave University
Van Winkle Park
Stewart Candy Company
Warwick Orchard
Gonos Gym
Chi Chi's Computers
Therault Granite Quarry
(closed)
Strait of Juan De Xiques
Richmond Fishery
Hart Golf Course
Franklin Point
Franklin Bay
Cox Aquarium
Russell Boardwalk
Radford Island
Nealey Beach
(public recreation area)
Adams Dairy Farm
Lamm Stadium
Lee Cemetery
Suffridge Heights
(suburbs)

THE EFFECT OF HEAT ON BRINE SHRIMP

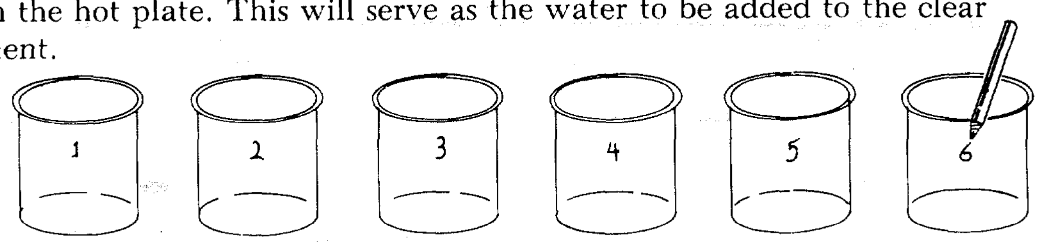
Materials

- 6 clear containers of equal size (beakers, plastic cups, etc.)
- brine shrimp eggs (available at pet shops)
- hatching container (glass baking dish works well)
- eyedropper
- ocean mix salts or non-iodized table salt
- thermometer
- heat resistant glass or stainless steel container
- hot plate
- pot holder
- ruler



Directions:
Day 1

The day before you do the experiment, prepare the brine shrimp as instructed on the brine shrimp package. Allow a full 24 hours for the shrimp to hatch. Prepare another container of salt water with the same salt concentrations as the hatching container. Use a glass or stainless steel pan that can be heated on the hot plate. This will serve as the water to be added to the clear containers for the experiment.

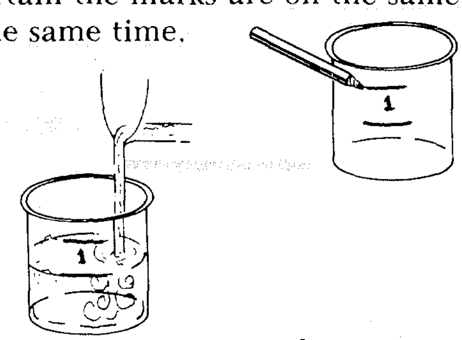


Day 2

1. Label the clear containers 1 through 6. Container 1 will serve as the control.

2. Mark two lines on the container, one about halfway to the top and one 3 centimeters or 1 inch from the top of each container, making certain the marks are on the same side on each container so they can both be seen at the same time.

3. Pour saltwater to the first mark on each container.

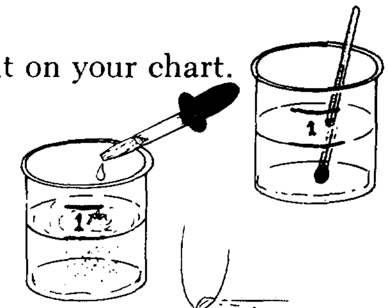


(Continued on next page)

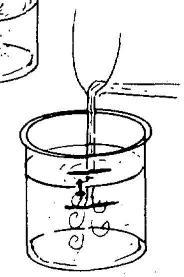
4. Measure the water temperature in each container and record it on your chart.

5. Add two eyedroppers full of brine shrimp to each container.

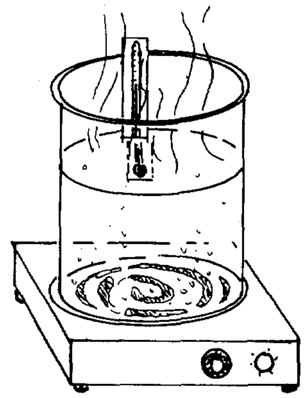
6. Observe the activity level of the shrimp in each container and record the information on your chart.



7. Slowly pour saltwater from the pan to the top line of Container 1. Remember this is your control.

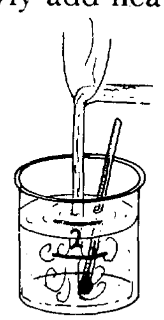


8. Heat the saltwater in the pan slowly, measuring the temperature increase with a thermometer.



9. When the temperature has increased 10°F, slowly add heated water to the top line of Container 2.

10. Check the temperature in Container 2 again. On your chart, record the temperature of the water in Container 2 **after** the heated water has been added.



11. Observe the activity level of the shrimp and record the information on your chart.

12. Follow steps 9, 10, and 11 as follows:

Container 3 at 20°F increase
Container 4 at 30°F increase
Container 5 at 40°F increase
Container 6 at 50°F increase

On the back of your worksheet, write a paragraph discussing your results and answer the following questions.

a. Why is adding heated water to a river or lake termed thermal pollution?

b. At what temperature increase did you note a change in the brine shrimp activity?

c. Why do you think an environmental impact study is done for the river adjacent to a nuclear powerplant?

d. Would coal-fired powerplants release heated waste water into the river? Why or why not?

e. Could the killing off of such small organisms as brine shrimp have any further impact on the environment? Why or why not?

Brine Shrimp Worksheet

Before Thermal Pollution	Cont. 1	Cont. 2	Cont. 3	Cont. 4	Cont. 5	Cont. 6
Temperature						
Activity of Shrimp (high, low, none)						

After Thermal Pollution	Cont. 1	Cont. 2	Cont. 3	Cont. 4	Cont. 5	Cont. 6
Temperature						
Activity of Shrimp (high, low, none)						

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Word Search"
- ☐ class activity "Controlling the Speed of a Nuclear Chain Reaction"

aluminum pie pan or some other nonflammable container	stop watch	1 box long kitchen matches
dominoes	metric ruler or English unit ruler	1 box birthday candles
	modeling clay	

2. Introduce vocabulary.

Before the students read Lesson 2, introduce vocabulary words by listing the words on the chalkboard and pronouncing them correctly. Definitions can be found in the glossary at the end of the student reader.

boron	coolant/moderator	nuclei
cadmium	fuel assemblies	nucleus
chain reaction	fuel pellets	pressure vessel
containment building	fuel rods	reactor
control rods	neutrons	

3. Read Lesson 2 in student reader. (Page 61 in the student reader.)

4. The following questions may be used for class discussion.

a. Why is it important to design a nuclear powerplant so that the water in *one loop* or set of pipes cannot mix with water from *any other loop* or set of pipes? (Because the water in the reactor becomes slightly radioactive, it cannot be allowed to mix with water in the third loop [cooling loop] because it would cause that water to become radioactive also. In addition, water in the first loop is treated to prevent corrosion or deposits of minerals. Water in the cooling tower loop is treated to prevent animals such as Asiatic clams from entering the powerplant where they might clog up the pipes as they grow. In other words, water used in one loop is treated differently from water used in other loops.)

b. How does *slowing down the neutrons* make a chain reaction more likely? (When neutrons are moving too fast, they fly past atoms and do not cause fission. If they are slowed down, they are more likely to be "captured" by an atom, thus causing the atom to fission.)

c. Why are *control rods* made of substances such as cadmium and boron? (Cadmium and boron can capture neutrons more readily than most other metals; their atoms present a larger target. Scientists call the ability of an atom to absorb neutrons its "neutron capture cross section." This is the effective area that the atom presents for neutron capture. They measure this ability in units called "barns." An aluminum atom has a neutron capture cross-section of one barn, whereas cadmium is about 23,000 barns. Limiting the number of neutrons available for fission by the use of cadmium or boron control rods allows powerplant operators to control the speed of a chain reaction.)

d. Why is *uranium fuel* formed into ceramic pellets? (Using uranium in a ceramic form contributes to safety because in this form the fuel can resist the effects of heat and corrosion in the reactor. Preventing the fuel from corroding or melting keeps radioactive material from being dispersed in the water, thus becoming harder to contain in one place. It is also easier to keep the fuel in the proper position for fission.)

e. What three things does water do in a nuclear powerplant? (It serves as the coolant, moderator, and heat transfer medium.)

5. **Assign and discuss the review exercise for Lesson 2.** (Page 67 in the student reader.)

6. **Assign the "Word Search" activity.**

7. **Introduce the activity "Controlling the Speed of a Nuclear Chain Reaction."**

LESSON 2 REVIEW EXERCISE

A. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

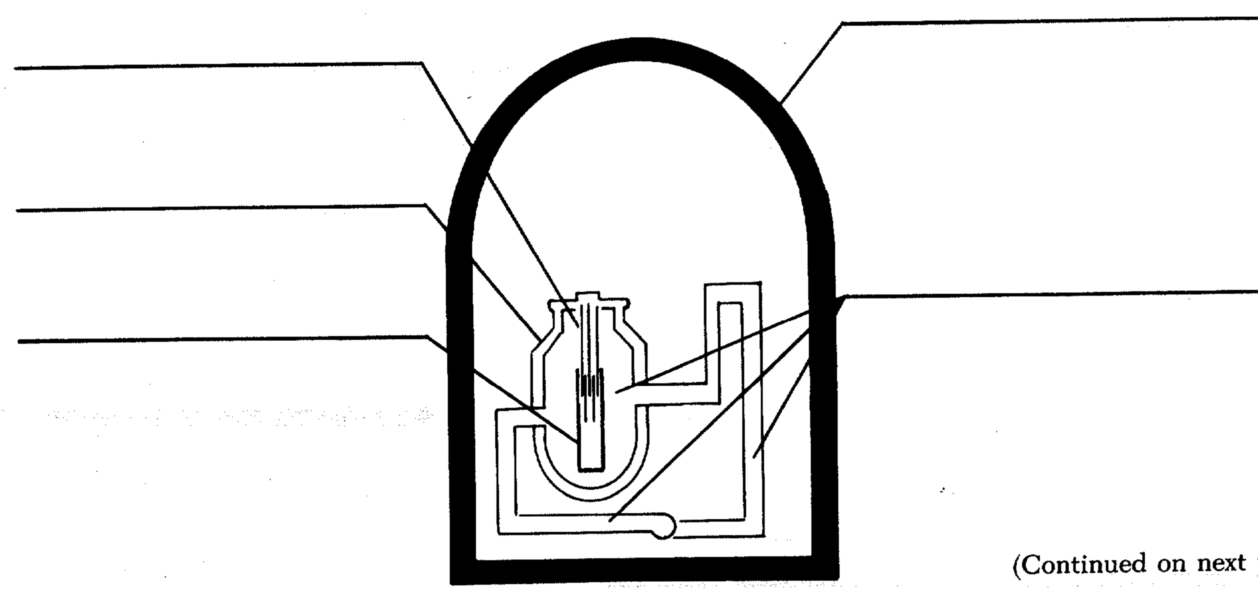
1. A uranium fuel pellet is about the size of your fingertip. T F
2. Before it is used in the reactor, the uranium in the fuel rods is very radioactive. T F
3. To speed up a chain reaction, control rods are lowered into the reactor core. T F
4. Control rods regulate the speed of a chain reaction by absorbing neutrons that could otherwise cause fission. T F
5. The faster neutrons move, the more likely they are to cause uranium-235 atoms to fission. T F
6. Purified treated water is used to keep the core of the reactor from becoming too hot. T F
7. Fission takes place inside the steam-generator. T F
8. In a nuclear powerplant, boron is used in the fuel rods. T F
9. The fuel assemblies, control rods, coolant/moderator, and pressure vessel make up the reactor core. T F
10. The water from the reactor and the water in the steam-generator that is turned into steam never mix. T F

B. Label the following parts of the reactor.

fuel assemblies
pressure vessel

control rods

coolant/moderator
containment building



(Continued on next page)

C. Arrange the following phrases in the correct order. Then draw a diagram that illustrates the sentence you have made.

causing the nucleus to split apart
a neutron
releasing energy and more neutrons
strikes the nucleus of a uranium-235 atom

____

____

____

D. Your goal is to keep the temperature inside the reactor at 900°F. If the temperature reaches 950°F, do you raise or lower the control rods?

____

If the temperature is 800°F, do you raise or lower the control rods?

____

E. How many fuel pellets would normally be installed in the Franklin Plant? ______________

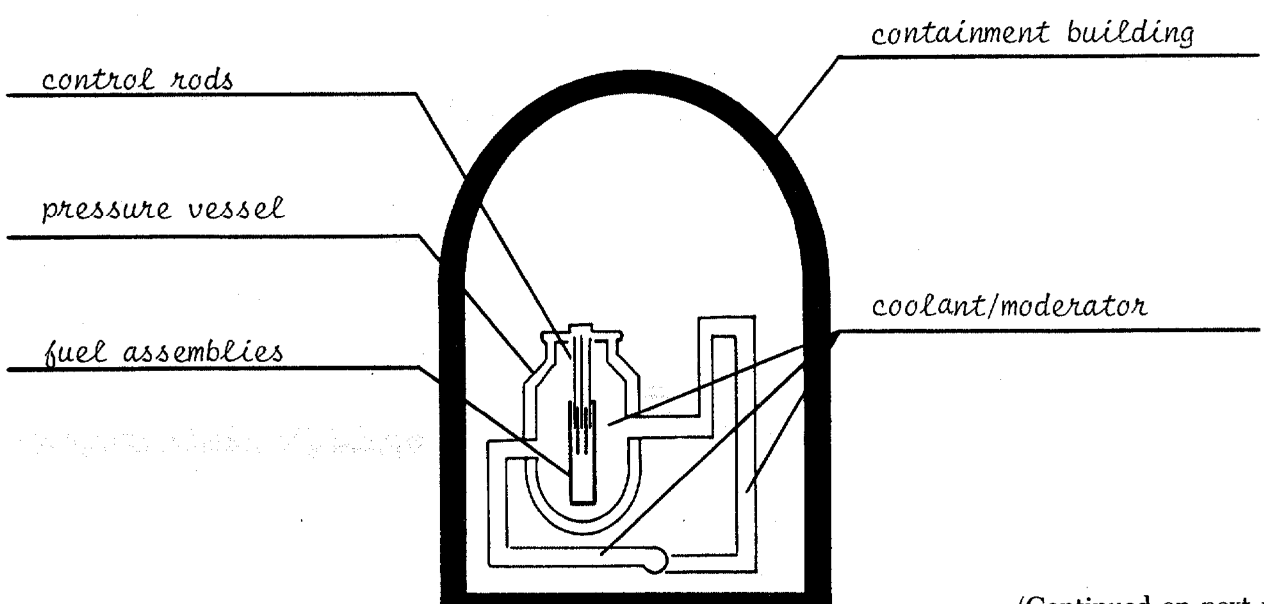
LESSON 2 REVIEW EXERCISE

A. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. A uranium fuel pellet is about the size of your fingertip. T F
2. Before it is used in the reactor, the uranium in the fuel rods is very radioactive. (not very radioactive) T F
3. To speed up a chain reaction, control rods are lowered into the reactor core. (raised) T F
4. Control rods regulate the speed of a chain reaction by absorbing neutrons that could otherwise cause fission. T F
5. The faster neutrons move, the more likely they are to cause uranium-235 atoms to fission. (slower) T F
6. Purified treated water is used to keep the core of the reactor from becoming too hot. T F
7. Fission takes place inside the steam-generator. (inside the reactor) T F
8. In a nuclear powerplant, boron is used in the fuel rods. (control rods) T F
9. The fuel assemblies, control rods, coolant/moderator, and pressure vessel make up the reactor core. T F
10. The water from the reactor and the water in the steam-generator that is turned into steam never mix. T F

B. Label the following parts of the reactor.

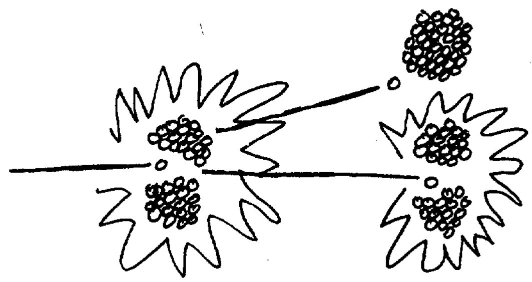
fuel assemblies pressure vessel	control rods	coolant/moderator containment building



(Continued on next page)

C. Arrange the following phrases in the correct order. Then draw a diagram that illustrates the sentence you have made.

causing the nucleus to split apart
a neutron
releasing energy and more neutrons
strikes the nucleus of a uranium-235 atom



A neutron strikes the nucleus of a uranium-235 atom causing the nucleus to split apart, releasing energy and more neutrons.

D. Your goal is to keep the temperature inside the reactor at 900°F. If the temperature reaches 950°F, do you raise or lower the control rods?

lower

If the temperature is 800°F, do you raise or lower the control rods?

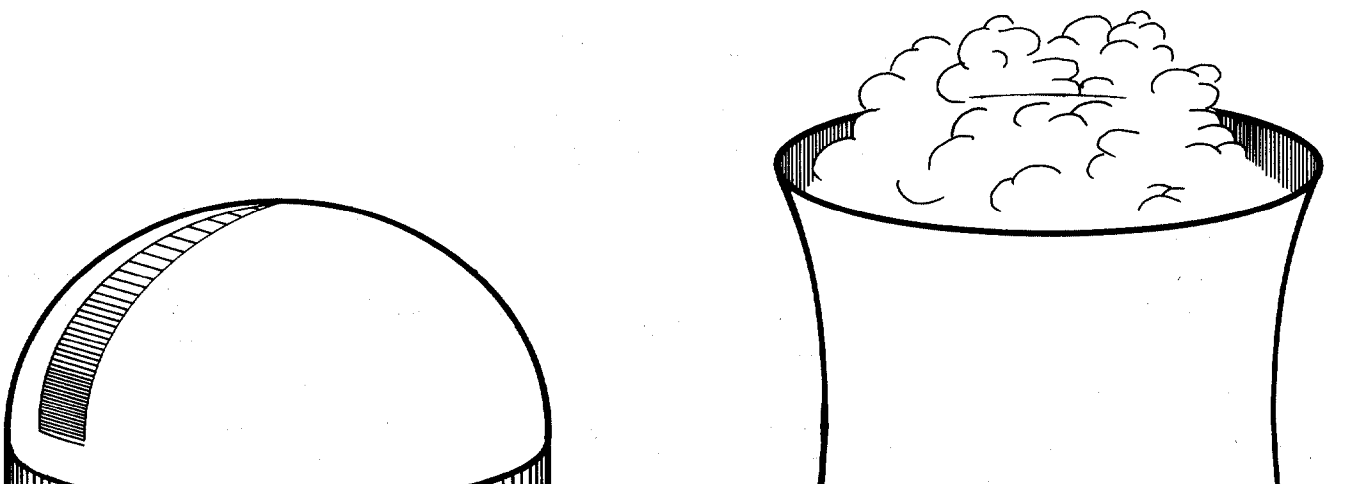
raise

E. How many fuel pellets would normally be installed in the Franklin Plant? 7,536,000

WORD SEARCH

Words about Franklin's reactor are hidden in the puzzle below. See if you can find:

boron	moderator
chain reaction	neutrons
coolant	nucleus
fission	pressure vessel
fuel rods	reactor
generator	steam

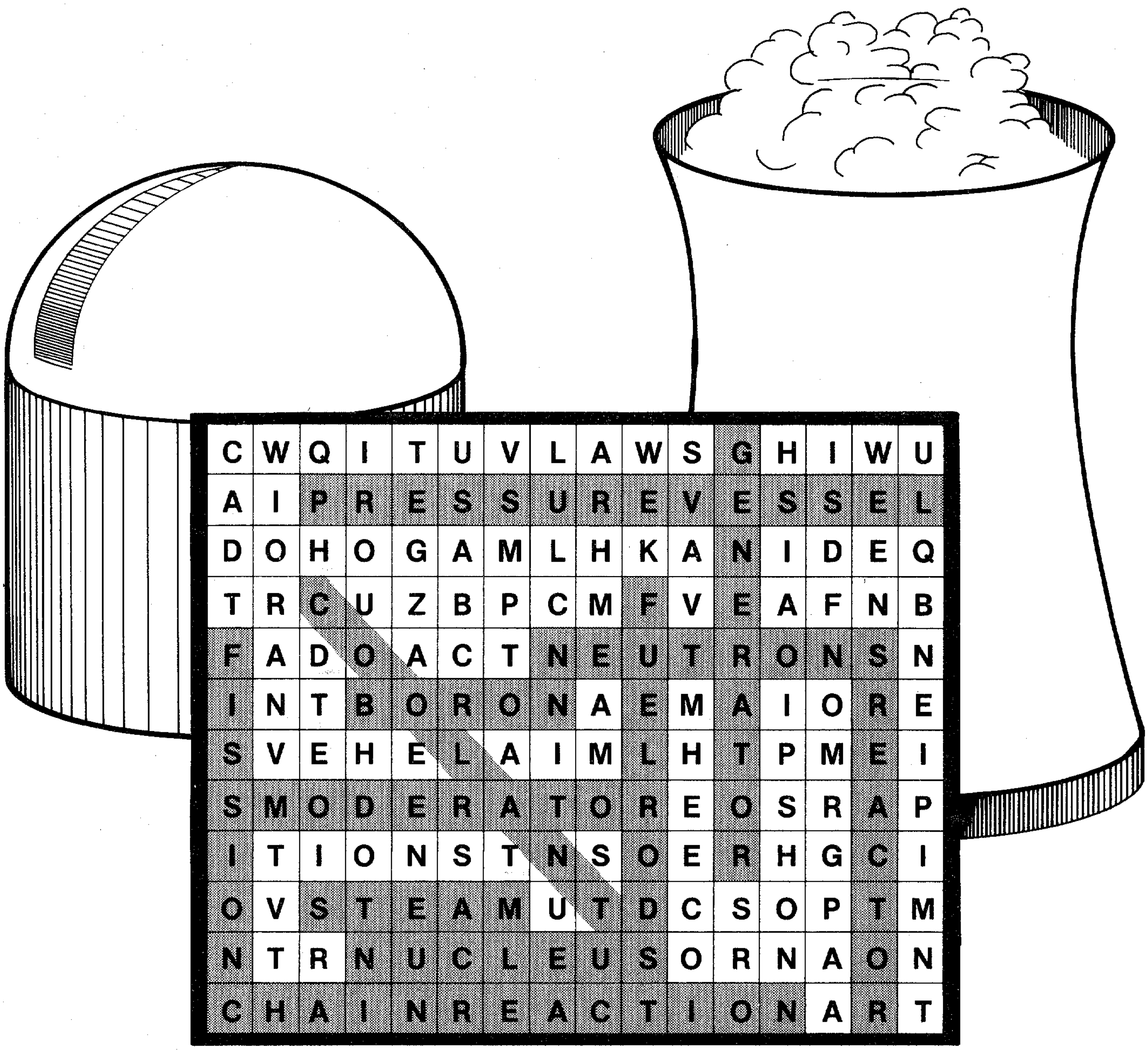


C	W	Q	I	T	U	V	L	A	W	S	G	H	I	W	U
A	I	P	R	E	S	S	U	R	E	V	E	S	S	E	L
D	O	H	O	G	A	M	L	H	K	A	N	I	D	E	Q
T	R	C	U	Z	B	P	C	M	F	V	E	A	F	N	B
F	A	D	O	A	C	T	N	E	U	T	R	O	N	S	N
I	N	T	B	O	R	O	N	A	E	M	A	I	O	R	E
S	V	E	H	E	L	A	I	M	L	H	T	P	M	E	I
S	M	O	D	E	R	A	T	O	R	E	O	S	R	A	P
I	T	I	O	N	S	T	N	S	O	E	R	H	G	C	I
O	V	S	T	E	A	M	U	T	D	C	S	O	P	T	M
N	T	R	N	U	C	L	E	U	S	O	R	N	A	O	N
C	H	A	I	N	R	E	A	C	T	I	O	N	A	R	T

WORD SEARCH

Words about Franklin's reactor are hidden in the puzzle below. See if you can find:

boron	moderator
chain reaction	neutrons
coolant	nucleus
fission	pressure vessel
fuel rods	reactor
generator	steam



C	W	Q	I	T	U	V	L	A	W	S	G	H	I	W	U
A	I	P	R	E	S	S	U	R	E	V	E	S	S	E	L
D	O	H	O	G	A	M	L	H	K	A	N	I	D	E	Q
T	R	C	U	Z	B	P	C	M	F	V	E	A	F	N	B
F	A	D	O	A	C	T	N	E	U	T	R	O	N	S	N
I	N	T	B	O	R	O	N	A	E	M	A	I	O	R	E
S	V	E	H	E	L	A	I	M	L	H	T	P	M	E	I
S	M	O	D	E	R	A	T	O	R	E	O	S	R	A	P
I	T	I	O	N	S	T	N	S	O	E	R	H	G	C	I
O	V	S	T	E	A	M	U	T	D	C	S	O	P	T	M
N	T	R	N	U	C	L	E	U	S	O	R	N	A	O	N
C	H	A	I	N	R	E	A	C	T	I	O	N	A	R	T

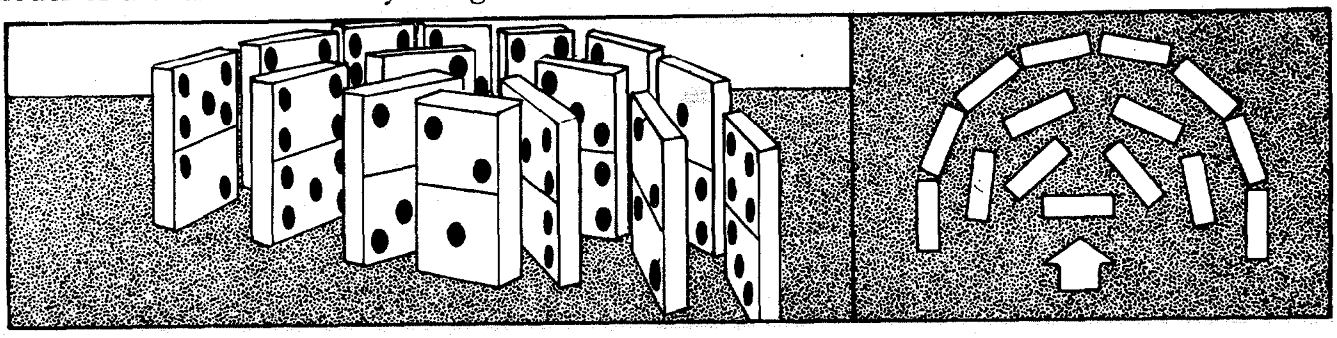
CONTROLLING THE SPEED OF A NUCLEAR CHAIN REACTION

Part One

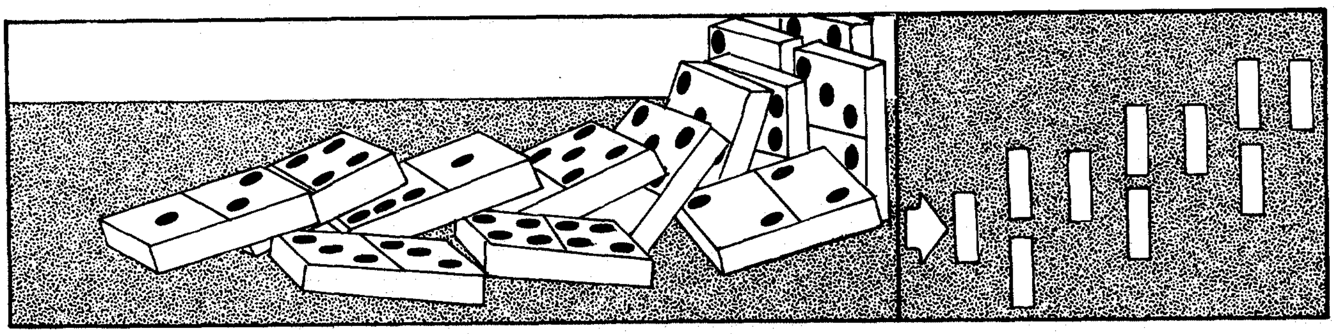
Materials	stop watch dominoes

Directions:

In theory, a nuclear chain reaction can take place very rapidly. Each time an atom fissions, two neutrons are released and these neutrons can each cause a new atom to fission. We can make a model of a chain reaction by using dominoes.



1. Place the dominoes in an order that allows each falling domino to strike two additional dominoes. By toppling the first domino, you can quickly see the effect of an uncontrolled chain reaction.



2. Now set the dominoes up again, but this time, for each domino that hits another domino, one domino should fall without hitting another domino. This models a controlled chain reaction.
3. The object of controlling a chain reaction is to release a steady amount of energy over a prolonged period of time. You may want to use a stopwatch to time the seconds it takes for different setups to fall.

Other Ideas to Explore:

Are there other ways to control the domino reaction? What might they be?

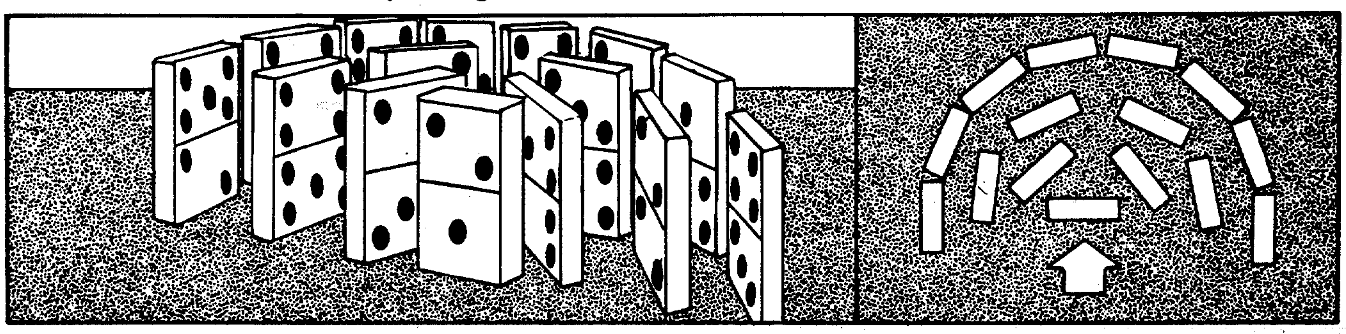
CONTROLLING THE SPEED OF A NUCLEAR CHAIN REACTION

Part One

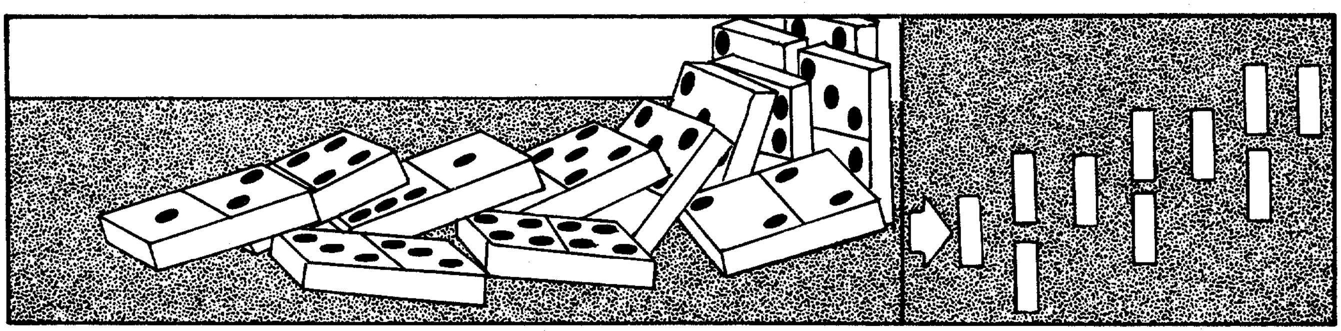
Materials	stop watch dominoes

Directions:

In theory, a nuclear chain reaction can take place very rapidly. Each time an atom fissions, two neutrons are released and these neutrons can each cause a new atom to fission. We can make a model of a chain reaction by using dominoes.



1. Place the dominoes in an order that allows each falling domino to strike two additional dominoes. By toppling the first domino, you can quickly see the effect of an uncontrolled chain reaction.



2. Now set the dominoes up again, but this time, for each domino that hits another domino, one domino should fall without hitting another domino. This models a controlled chain reaction.
3. The object of controlling a chain reaction is to release a steady amount of energy over a prolonged period of time. You may want to use a stopwatch to time the seconds it takes for different setups to fall.

Other Ideas to Explore:

Are there other ways to control the domino reaction? What might they be?
(Different set-ups, distances in between, etc.)

CONTROLLING THE SPEED OF A NUCLEAR CHAIN REACTION

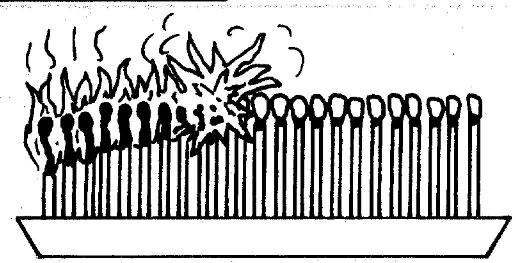
Part Two

Generally, when you light a row of matches, they will ignite within a very short period of time and quickly release all of their heat. However, there are ways to control the reaction.

Materials

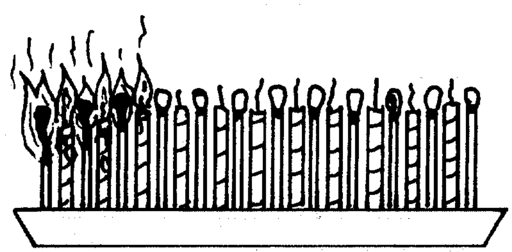
aluminum pie pan or some other nonflammable container	1 box of long kitchen matches
stop watch	ruler
	modeling clay
	1 box of birthday candles

CAUTION: This activity should be done with adult supervision.



Directions:

1. For safety, place the clay in the pie pan.
2. Arrange 25 matches side by side in the clay, leaving ¼ in. or ½ cm between each set of two matches.



3. Light the first match and measure the amount of time that it takes for all the matches to burn out.
4. Record your results.
5. Arrange candles and matches side by side in the clay, alternating candles and matches and leaving ¼ in. or ½ cm between each set.
6. Light the first match and measure the amount of time it takes for all the matches to burn out.
7. Record your results.

Questions:

1. In what way is the effect the candles have in this demonstration similar to the effect the control rods have in a nuclear reactor?

2. Can you think of any other way to control the speed at which the matches burn?

CONTROLLING THE SPEED OF A NUCLEAR CHAIN REACTION

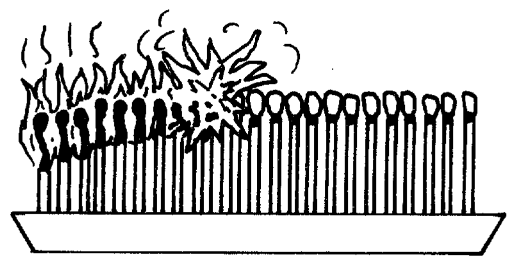
Part Two

Generally, when you light a row of matches, they will ignite within a very short period of time and quickly release all of their heat. However, there are ways to control the reaction.

Materials

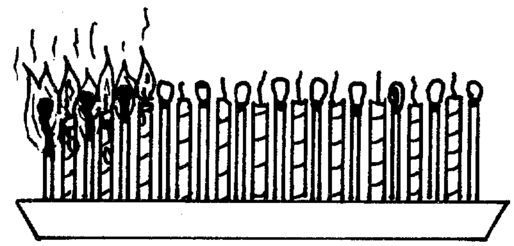
aluminum pie pan or some other nonflammable container	1 box of long kitchen matches
stop watch	ruler
	modeling clay
	1 box of birthday candles

CAUTION: This activity should be done with adult supervision.



Directions:

1. For safety, place the clay in the pie pan.
2. Arrange 25 matches side by side in the clay, leaving ¼ in. or ½ cm between each set of two matches.



3. Light the first match and measure the amount of time that it takes for all the matches to burn out.
4. Record your results.
5. Arrange candles and matches side by side in the clay, alternating candles and matches and leaving ¼ in. or ½ cm between each set.
6. Light the first match and measure the amount of time it takes for all the matches to burn out.
7. Record your results.

Questions:

1. In what way is the effect the candles have in this demonstration similar to the effect the control rods have in a nuclear reactor? *The candles slow down the rate at which the matches ignite and release all their energy. In a similar manner, the control rods in a nuclear reactor slow down the rate at which atoms fission and release energy.*
2. Can you think of any other way to control the speed at which the matches burn? *Dip the lower part of the matches in water. Dip the matches in wax. Treat the matches with flame retardant substance.*

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Locating Nuclear Powerplants in the United States"
- ☐ class activity "Model of Franklin"

paste, optional	scissors

2. Introduce vocabulary.

Introduce the vocabulary words before the students read the lesson. Definitions can be found in the glossary at the end of the student reader.

baffles	cooling tower	turbine
condenser	pressurized water reactor	

3. Read Lesson 3 in student reader. (Page 69 in the student reader.)

4. The following questions may be used for class discussion when students have completed the assigned reading.

a. Are there any similarities between the way your body cools you down and the way a *cooling tower* works? (One way we cool down is by sweating—we perspire and we loose heat when our heated perspiration is evaporated. When you sweat, and a breeze comes up, you begin to cool down and feel more comfortable. The baffles inside the cooling tower also cool by evaporation; they provide a lot of surface area from which cooling water can be evaporated.)

b. Are there any types of powerplants that do not use *heat* to produce electricity? (Hydroelectric powerplants turn their turbines with water that has been held back by a dam. Photovoltaic cells can convert the Sun's energy directly to electricity. Wind generators use a generator and wind turbine to convert the energy in wind into electricity. However, powerplants that use coal, natural gas, oil, uranium, or geothermal energy all heat water to produce electricity and over half of the electricity in the United States is still generated by using coal.)

c. The core of a *pressurized water reactor* like Franklin is kept under pressure in order to keep the water in the core from turning into a gas (steam). Can you think of other devices that use pressure? How? (Your family may own a pressure cooker that uses the same scientific principles that are used in the reactor core. By not allowing the boiling hot water in the pressure cooker to turn into gas, the water in a pressure cooker becomes very hot and can cook food much more quickly. Hospitals use similar devices [called autoclaves] to sterilize medical equipment. In addition, by pressurizing certain gases, like oxygen, we can keep them in a liquid form. This allows us to store large amounts of these gases in a small area. You may have seen tanks of pressurized gas on the backs of divers, who breathe it under water, or on trailers where it is used to hold gas for cooking.)

d. Why do cake mixes have *high-altitude* instructions, which often tell the cook to bake cakes longer at high altitudes? (There is less air pressure at high altitudes because there is less air. As a result, water, which boils at 212° Fahrenheit [100° Celsius] will boil at 203° Fahrenheit [95° Celsius] at 7,920 feet in altitude.)

e. On a hot summer day the street may become so hot that it will burn your feet, but if you spray *water* on the road, you can walk on it. Why is this? (The water evaporates and cools the road.)

f. Could a powerplant the size of Franklin (which is able to supply electricity to a city of 500,000 people) *provide electricity* to everyone in your community? (Divide 500,000 by the population. If the answer is greater than 1, the Franklin plant could provide electricity to everyone. If less than 1, it is the fraction of people in the community that a plant the size of Franklin could supply with electricity. You may also want to do this calculation for the population of your State, the United States, another country, or even for the world. It is important to bear in mind, however, that not all countries use as much electricity as we do in the United States.)

g. What is the difference between *removing heat and cooling*? (Removing heat and cooling are actually the same thing. In the reactor, some loops perform dual functions. For instance, the first loop in a pressurized water reactor cools the reactor, but it puts this heat to good use in the second loop where it produces steam.)

h. Why can't the *steam* that comes out of the turbine be *used again*? (The steam coming into the turbine is under high pressure and contains a lot of potential energy. After it hits the blades of the turbine, the potential energy is changed to kinetic energy and the steam loses a lot of pressure. It is physically difficult and expensive to pump the low pressure steam back to the heat source to be reheated. So the steam is condensed back into water, which is easily pumped back to the heat source.)

i. Are there any places in your *home* that use *heat transfer*? (Water heater, refrigerator, stove, air conditioner.)

5. Assign and discuss the review exercise for Lesson 3. (Page 74 in student reader.)

Depending upon the grade level of your class, you may choose to put the following list of words on the board for students to choose answers from for Section A.

fission	pressure	removed
fusion	pressurized	steam
liquid		

6. Assign the activity "Locating Nuclear Powerplants in the United States."

7. Introduce the class activity "Model of Franklin."

LESSON 3 REVIEW EXERCISE

A. From the reading, select the word that best fits the statement.

1. Nuclear powerplants produce heat energy through ____________.

2. Although water reaches very high temperatures in the reactor, it does not turn to steam because it is under ____________.

3. Franklin is called a ____________ water reactor, or PWR.

4. When it takes on heat from the first loop, water in the second loop turns to ____________.

5. The water in the third loop is pumped to the cooling tower to have most of its heat ____________.

B. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. The way that nuclear powerplants convert heat energy into electrical energy is basically the same as in most other powerplants. T F

2. The electrical energy of the spinning turbine is changed into mechanical energy in the generator. T F

3. Water from the powerplant's different loops never mixes together. T F

4. Heat always flows from a hot object into a cool object. T F

5. Most of the water in the cooling tower evaporates and goes into the atmosphere. T F

(Continued on next page)

C . Arrange the following steps in order by writing the correct numbers from the diagram below in the spaces.

______ In the second loop water turns to steam.

______ In the condenser, the second loop transfers some of its heat to the third loop. When the steam in the second loop loses its heat energy, it turns back into water.

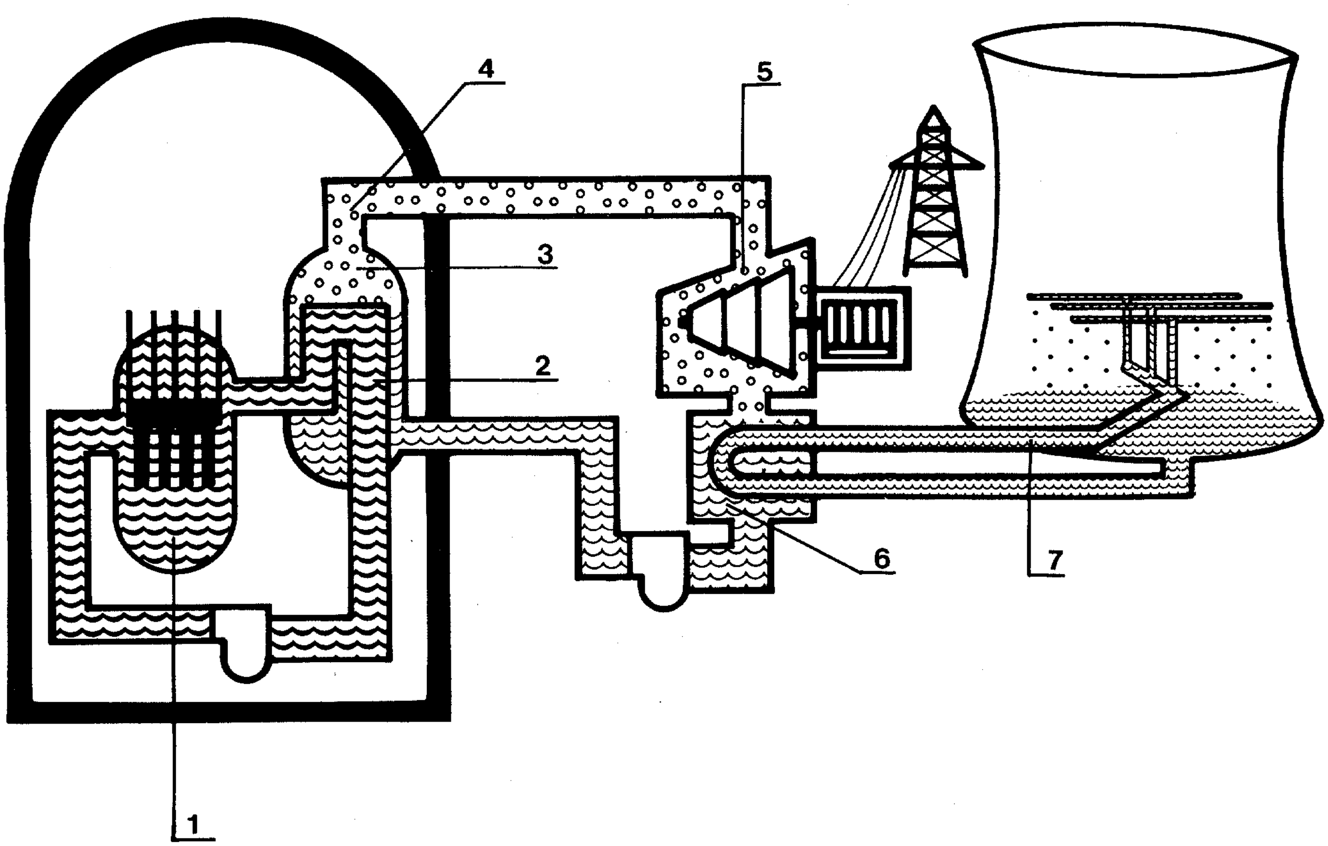
______ Water in the first loop moves to the steam-generator.

______ The second loop carries steam to the turbine, causing the turbine to spin. The mechanical energy of the spinning turbine is changed into electrical energy in the generator.

______ The water in the third loop is pumped to the cooling tower to have some of its heat removed.

______ Water circulates through the reactor core where heat from fission is transferred to the water.

______ Inside the steam-generator the first and second loops meet. The heat in the first loop transfers to the second loop.



LESSON 3 REVIEW EXERCISE

A . From the reading, select the word that best fits the statement.

1. Nuclear powerplants produce heat energy through fission.

2. Although water reaches very high temperatures in the reactor, it does not turn to steam because it is under pressure.

3. Franklin is called a pressurized water reactor, or PWR.

4. When it takes on heat from the first loop, water in the second loop turns to steam.

5. The water in the third loop is pumped to the cooling tower to have most of its heat removed.

B . Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. The way that nuclear powerplants convert heat energy into electrical energy is basically the same as in most other powerplants. T F

2. The electrical energy of the spinning turbine is changed into mechanical energy in the generator. (mechanical converted to electrical) T F

3. Water from the powerplant's different loops never mixes together. T F

4. Heat always flows from a hot object into a cool object. T F

5. Most of the water in the cooling tower evaporates and goes into the atmosphere. (returned to third loop) T F

C . Arrange the following steps in order by writing the correct numbers from the diagram below in the spaces.

__4__ In the second loop water turns to steam.

__6__ In the condenser, the second loop transfers some of its heat to the third loop. When the steam in the second loop loses its heat energy, it turns back into water.

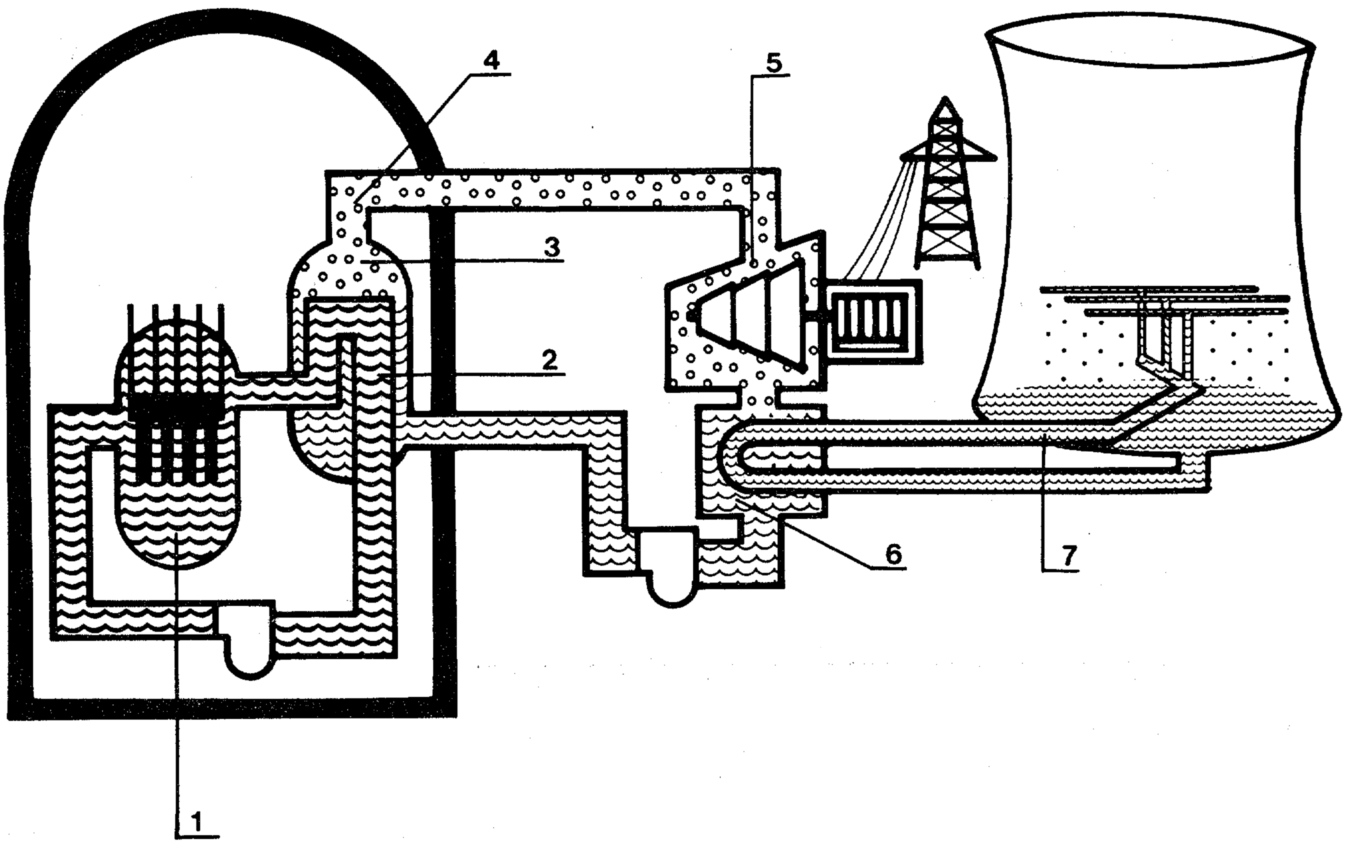
__2__ Water in the first loop moves to the steam-generator.

__5__ The second loop carries steam to the turbine, causing the turbine to spin. The mechanical energy of the spinning turbine is changed into electrical energy in the generator.

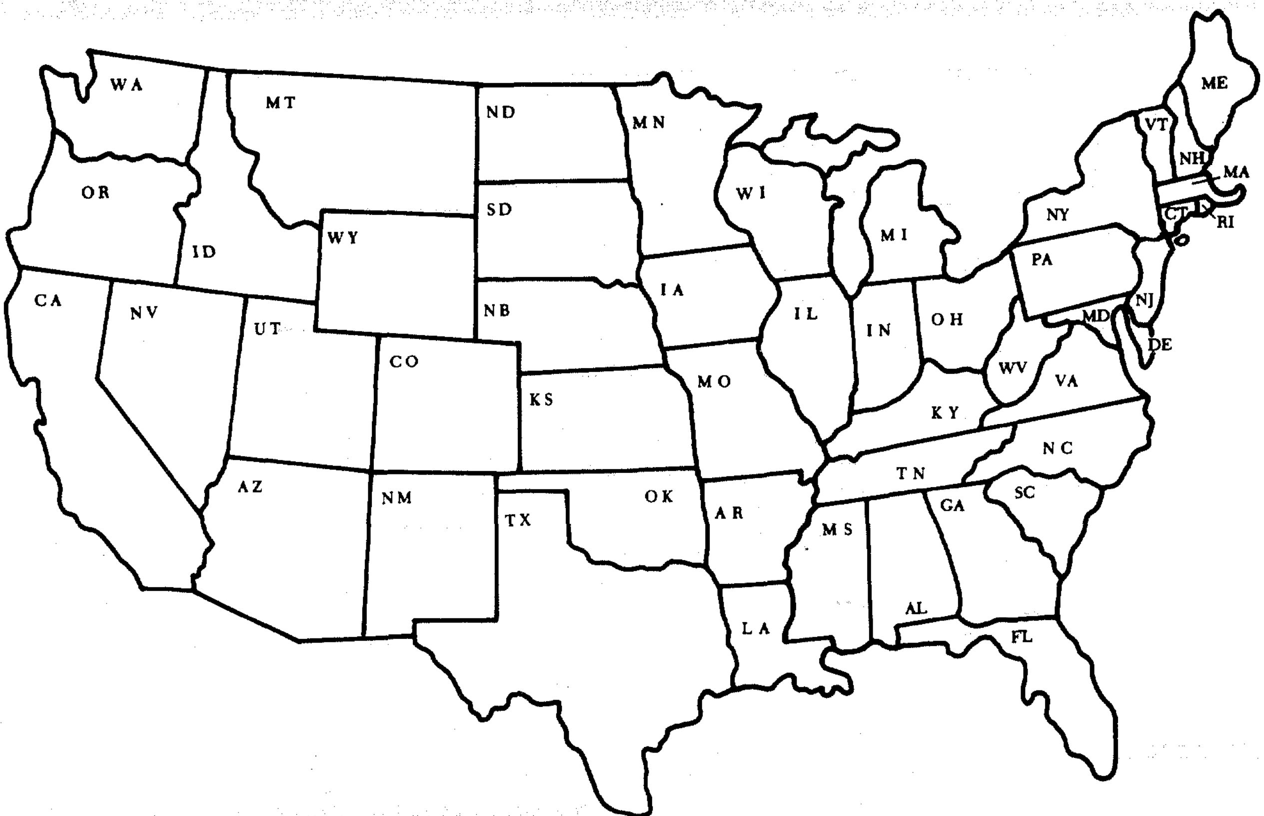
__7__ The water in the third loop is pumped to the cooling tower to have some of its heat removed.

__1__ Water circulates through the reactor core where heat from fission is transferred to the water.

__3__ Inside the steam generator the first and second loops meet. The heat in the first loop transfers to the second loop.



LOCATING NUCLEAR POWERPLANTS IN THE UNITED STATES



1. Indicate how many nuclear powerplants are located in each State by writing the number in the correct place on the map.

2. For the State you live in, indicate approximately where each nuclear powerplant is located by writing a, b, c, d, or e in the correct place on the map.

3. For the State you live in, write the name of each nuclear powerplant and its location on the blank that corresponds to the letter on the map.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

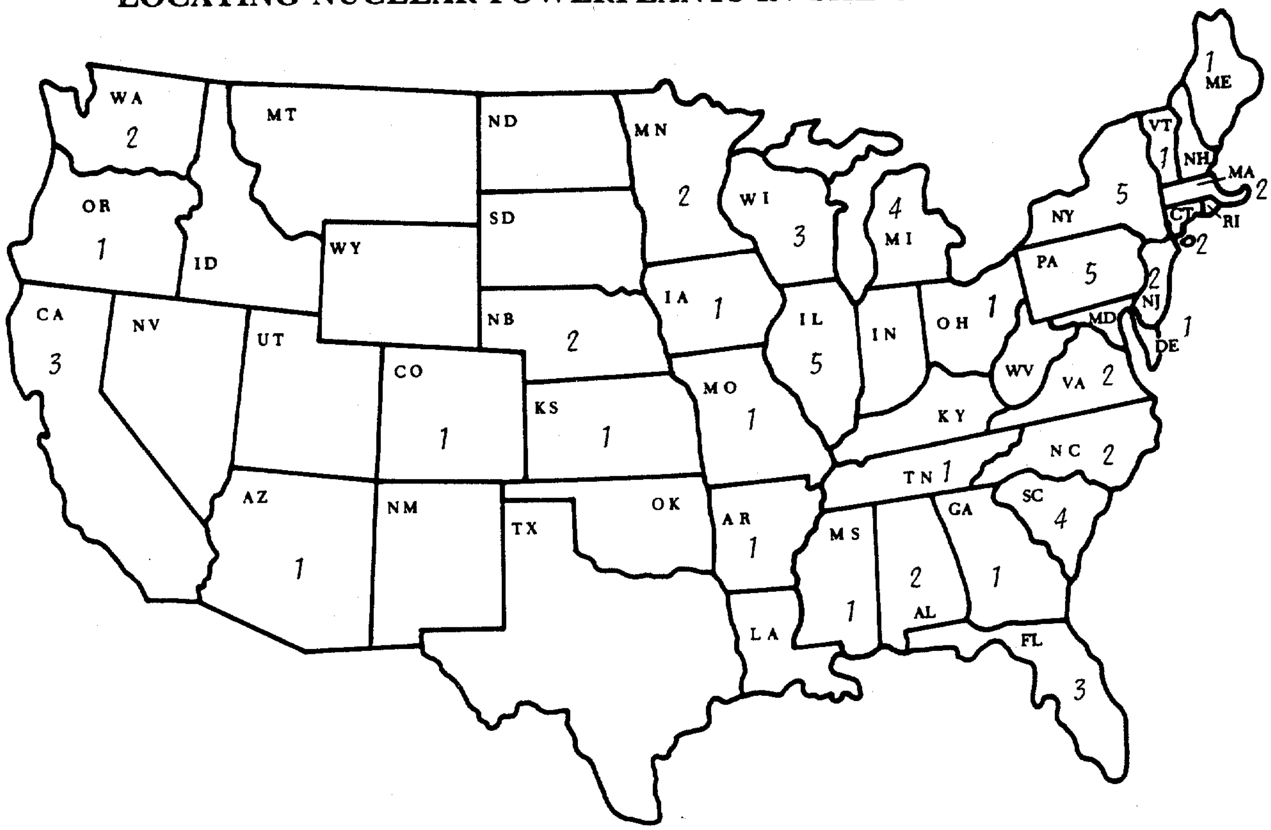
4. Which three States have the most nuclear powerplants?

   ____

   ____

   ____

LOCATING NUCLEAR POWERPLANTS IN THE UNITED STATES



1. Indicate how many nuclear powerplants are located in each State by writing the number in the correct place on the map.

2. For the State you live in, indicate approximately where each nuclear powerplant is located by writing a, b, c, d, or e in the correct place on the map.

3. For the State you live in, write the name of each nuclear powerplant and its location on the blank that corresponds to the letter on the map.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

   e. ____________________

4. Which three States have the most nuclear powerplants?

   New York

   Pennsylvania

   Illinois

NUCLEAR POWERPLANTS IN THE UNITED STATES

STATE	NAME OF POWERPLANT	LOCATION OF POWERPLANT
Alabama	Joseph M. Farley Browns Ferry	Dothan Decatur
Arizona	Palo Verde	Wintersburg
Arkansas	Arkansas Nuclear One	Russellville
California	Diablo Canyon Rancho Seco San Onofre	Diablo Canyon Clay Station San Clemente
Colorado	Fort St. Vrain	Platteville
Connecticut	Haddam Neck Millstone	Haddam Neck Waterford
Florida	Crystal River Turkey Point St. Lucie	Red Level Florida City Fort Pierce
Georgia	Edwin I. Hatch	Baxley
Illinois	Dresden Zion Quad-Cities La Salle Byron	Morris Zion Cordova Seneca Byron
Iowa	Duane Arnold	Palo
Kansas	Wolf Creek	Burlington
Maine	Maine Yankee	Wiscasset
Maryland	Calvert Cliffs	Lusby
Massachusetts	Pilgrim Yankee	Plymouth Rowe
Michigan	Big Rock Point Palisades Donald C. Cook Enrico Fermi	Charlevoix South Haven Bridgman Newport
Minnesota	Monticello Prairie Island	Monticello Red Wing
Mississippi	Grand Gulf	Port Gibson
Missouri	Callaway	Fulton
Nebraska	Cooper Fort Calhoun	Brownville Fort Calhoun
New Jersey	Oyster Creek Salem	Toms River Salem
New York	Indian Point James A. FitzPatrick Nine Mile Point Robert E. Ginna Shoreham	Buchanan Scriba Scriba Ontario Brookhaven

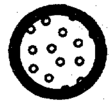
NUCLEAR POWERPLANTS IN THE UNITED STATES

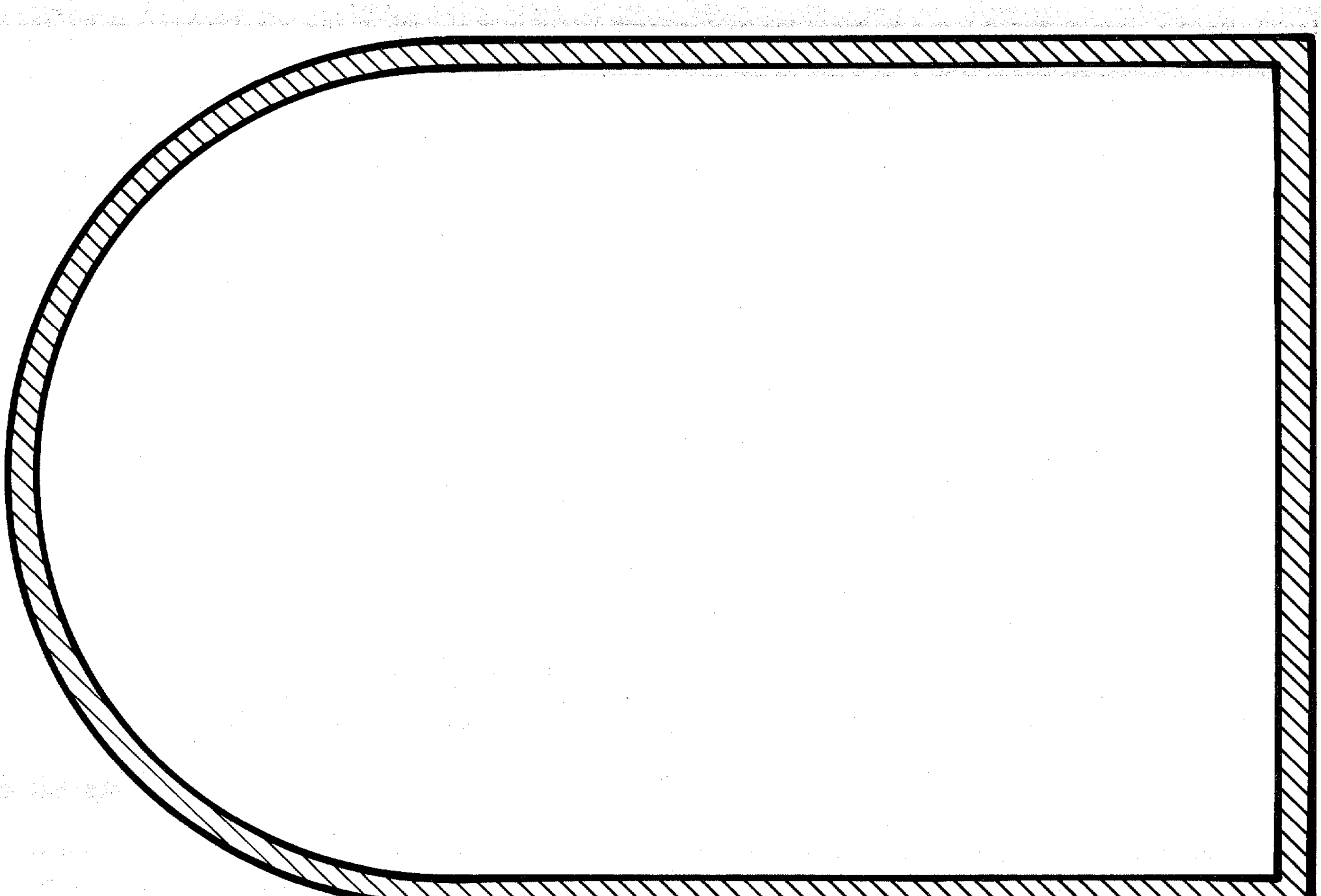
STATE	NAME OF POWERPLANT	LOCATION OF POWERPLANT
North Carolina	Brunswick William McGuire	Southport Cowans Ford Dam
Ohio	Davis-Besse	Oak Harbor
Oregon	Trojan	Prescott
Pennsylvania	Beaver Valley Three Mile Island Susquehanna Peach Bottom Limerick	Shippingport Middletown Berwick Lancaster Pottstown
South Carolina	H. B. Robinson Oconee Virgil C. Summer Catawba	Hartsville Seneca Jenkinsville Lake Wylie
Tennessee	Sequoyah	Daisy
Vermont	Vermont Yankee	Vernon
Virginia	Surry North Anna	Gravel Neck Mineral
Washington	Hanford WPPSS	Richland Richland
Wisconsin	La Crosse Point Beach Kewaunee	La Crosse Two Creeks Carlton

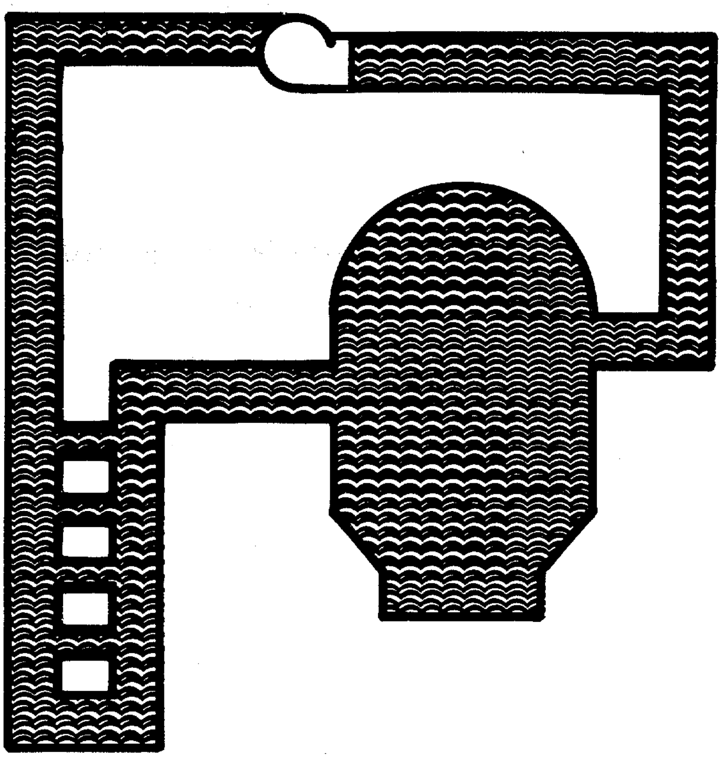
NOTE: The list above represents all commercial nuclear powerplants operating in the United States as of September 1985. You may want to see if any additional powerplants have been started up in your State by checking with your local utility.

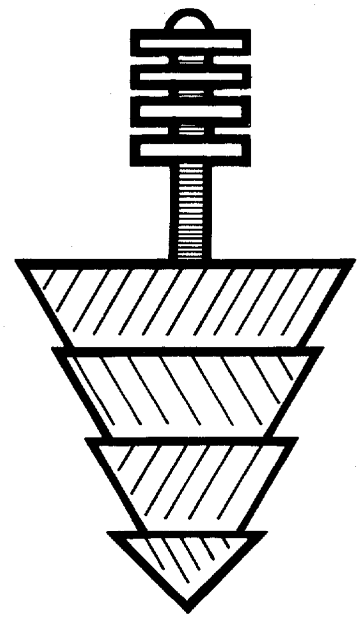
MODEL OF FRANKLIN

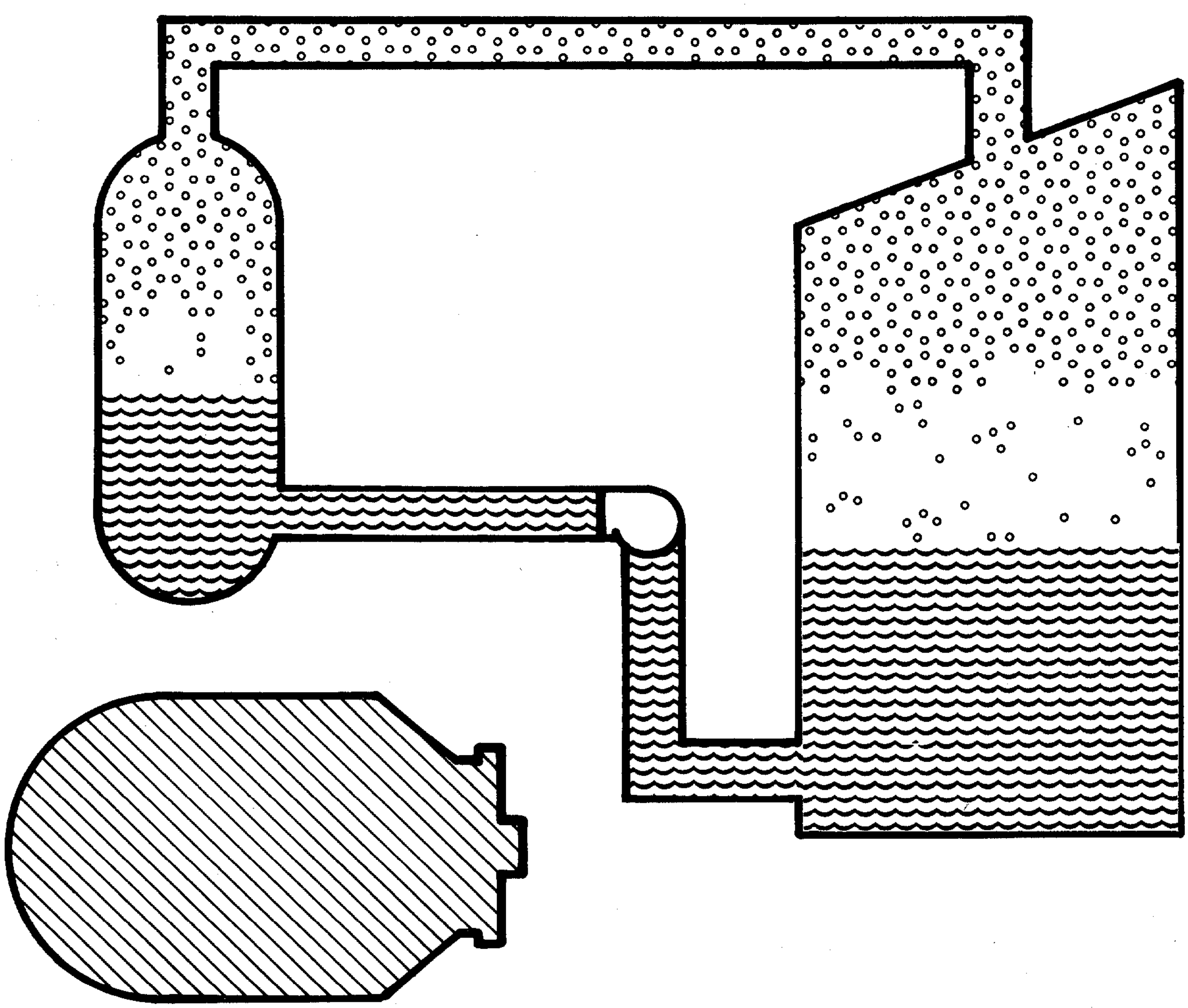
Make a model of a pressurized water nuclear powerplant like Franklin by cutting the pieces out and arranging them in the correct order. Several pieces may be placed on top of other pieces in your model.

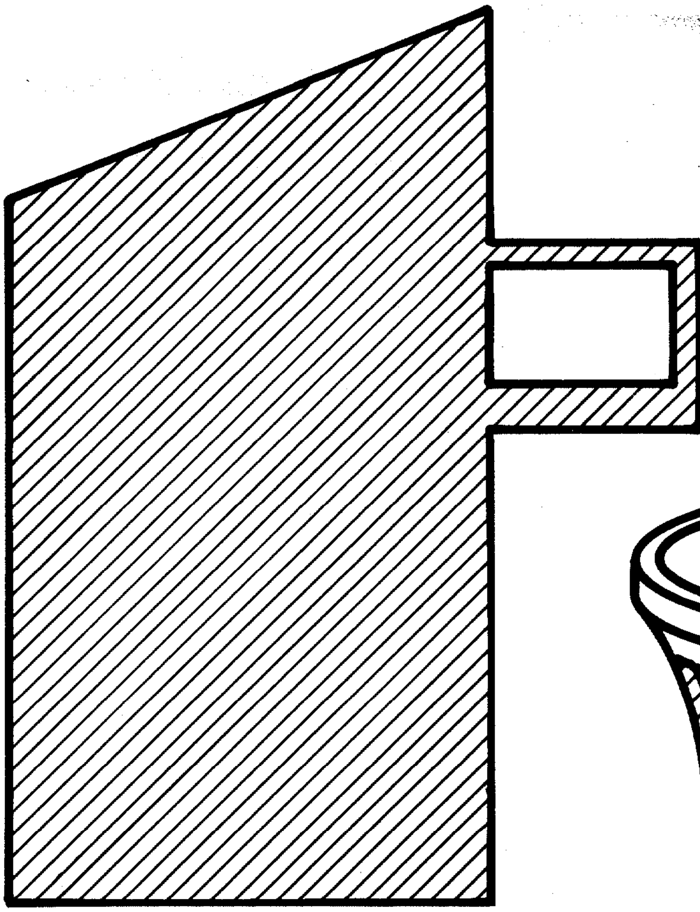
 = pressurized water  = steam  = water

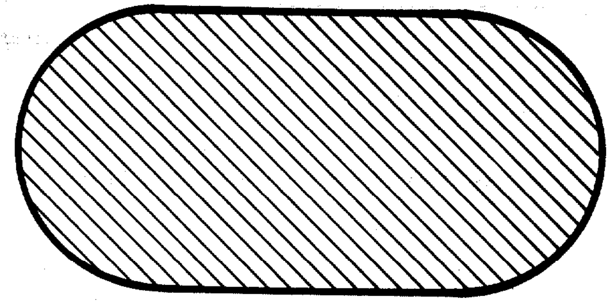


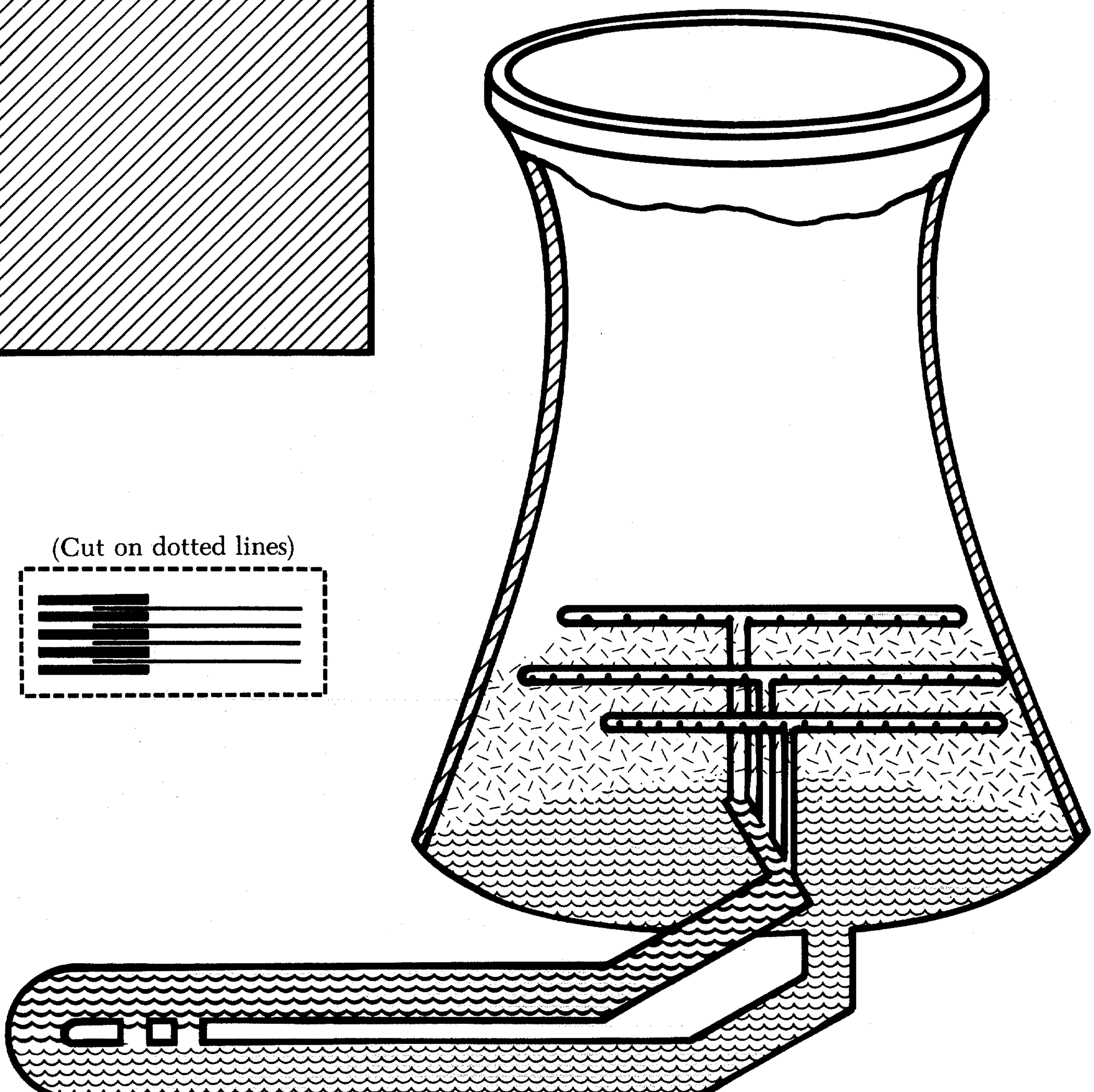












(Cut on dotted lines)

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Scrambled Fuel Terms"
- ☐ class activity "Separating Salt from Sand"

1/2 cup salt	cookie sheet or heat resistant beaker	screen
1/2 cup sand	pot holder	2 cups or glasses of water
cheesecloth or other cloth	hot plate	magnifying glass

2. Introduce vocabulary.

Introduce the vocabulary words by listing them on the chalkboard and pronouncing them correctly. Definitions can be found in the glossary at the end of the student reader.

ceramic	mill tailings	uranium hexafluoride
conversion plant	radon	uranium milling
fuel fabrication plant	reclamation	yellowcake
gaseous diffusion plant	uranium	
habitat	uranium enrichment	

3. Read Lesson 4 in student reader. (Page 76 in the student reader.)

4. The following questions may be used for class discussion after the students have completed the assigned reading.

a. Do most *fuels* have to be treated before they can be used? (Kerosene, gasoline, and heating oil are produced from crude oil by a series of processing steps called refining. Crude oil is refined to produce kerosene, gasoline, and heating oil by using a series of chemical conversions. Coal is cleaned and ground to the consistency of talcum powder before it is used in a coal-fired powerplant. A distinctive odor is added to natural gas so people can detect its presence. In fact, we wash, cook, and carefully prepare food, our own fuel. As with other fuels, the food value can vary with the treatment.)

b. Why is it important to *restore land* after it has been mined? (If land is left dug up, it will erode and the plants and animals that lived there will not be able to return and live there again. The eroded soil can also cloud streams, while the water that runs off concentrates and collects acidic and toxic elements that were already present in small amounts in the soil. This is called leaching, and it can poison a stream for miles below where mining took place.)

c. Do the ores of metals other than uranium have to be *milled*? (Yes. Few metals are found in their pure form. Generally, they must be extracted from the rock they are found in before they may be used.)

d. Name other substances that contain slightly different amounts of one of their parts, just as uranium can be *enriched* to contain different concentrations of U-235. (Milk is one example. We vary the amount of cream [butter fat] in milk, giving us skim milk, 2 percent milk, and whole milk. But it is still milk. Gasoline is refined to different octane levels. We have 8-, 12-, 14-, and 24-carat gold. We have bituminous, anthracite, and lignite coal.)

e. What are some of the reasons uranium fuel is put in a *ceramic* form? (The ceramic form of the uranium fuel simplifies fuel fabrication, holds its shape at reactor temperatures, contains [holds] the fission products produced in the reactor, and has a minimal effect on the integrity of the fuel rod at reactor temperatures. This question was asked in the discussion questions in Lesson 2; however, it seems to be a difficult concept and you may want to reiterate it.)

f. What are some *nonrenewable* resources that you use in your life? Are there any *renewable resources* that you use? (Nonrenewable resources include fossil fuels such as gasoline, heating oil, and natural gas. In addition, although we have hundreds of years of reserves of coal and uranium, our supplies of these fuels are also nonrenewable. Renewable resources include solar power, wind, water, wood, and tidal power.)

g. How can 1 pellet of *uranium fuel* release as much energy as 2,000 lbs. of *coal*? (Within 1 pellet of uranium fuel, there are millions of atoms that can be fissioned. Because the forces that hold the nucleus of an atom together are much stronger than the forces that bind electrons and molecules together, splitting uranium provides much more energy than burning coal.)

5. Assign and discuss the review exercise for Lesson 4. (Page 80 in the student reader.)

You may choose to put the following list of words on the board for students to choose answers from for Section A.

high pressure	reclamation	uranium-235
high temperatures	uranium	uranium-238
radon		

Answers to Part C. (Answers will vary but should reflect the concepts indicated.)

1. It takes about one ton of uranium ore to produce 4 to 5 pounds of uranium.
2. The expected lifetime of a nuclear powerplant is 40 years.
3. There are 690,000 tons of recoverable uranium ore in the United States.
4. Uranium-235 is used in fission.
5. Most uranium in uranium ore is U-238.
6. A uranium fuel pellet is equal to 2,000 pounds of coal.
7. A uranium fuel pellet is equal to 126 gallons of oil.
8. A fuel pellet is about ¾ inch long.
9. Powerplants require uranium that is at least 3 percent U-235.
10. Less than 1 percent of the atoms in uranium ore are U-235 atoms.

6. Assign the class activity "Scrambled Fuel Terms."

7. Assign the class activity "Separating Salt from Sand."

Answers to "Other ideas to explore":

1. Yes.
2. Filters separate the larger heavier particles. Filters separate the U-238 during enrichment. Uranium is dissolved in acid as salt is dissolved in water.
3. Salt dissolves in water. Sand does not.

LESSON 4 REVIEW EXERCISE

A. From the reading, select the word that best fits the statement.

1. For fuel, a nuclear powerplant uses enriched ____________________.

2. To protect the environment when mining is finished, the land is replanted and restored in a process called ____________________.

3. At a fuel fabrication plant, enriched uranium is made into a ceramic material that can withstand ____________________ ____________________.

4. Mill tailings produce a small amount of radioactive gas called ____________________.

5. Before it can be used as a reactor fuel, uranium has to be treated to increase the concentration of uranium-____________________.

B. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Rocks that contain a lot of uranium are called uranium ores. T F

2. There is an unlimited supply of uranium in the United States. T F

3. Milled uranium is called yellowcake because it looks like flour. T F

4. Less than 1 percent of the atoms in ordinary yellowcake are uranium-235 atoms. T F

5. Although a uranium pellet is small, it can release a lot of energy. T F

C. Write a sentence explaining how each of the following numbers relates to uranium or nuclear energy.

1. 4 to 5 pounds
2. 40 years
3. 690,000 tons
4. 235
5. 238
6. 2,000 pounds of coal
7. 126 gallons of oil
8. 3/4 inch
9. 3 percent
10. 1 percent

LESSON 4 REVIEW EXERCISE

A. From the reading, select the word that best fits the statement.

1. For fuel, a nuclear powerplant uses enriched uranium.

2. To protect the environment when mining is finished, the land is replanted and restored in a process called reclamation.

3. At a fuel fabrication plant, enriched uranium is made into a ceramic material that can withstand high temperatures.

4. Mill tailings produce a small amount of radioactive gas called radon.

5. Before it can be used as a reactor fuel, uranium has to be treated to increase the concentration of uranium-235.

B. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Rocks that contain a lot of uranium are called uranium ores. T F

2. There is an unlimited supply of uranium in the United States. T F
   (supply is limited)

3. Milled uranium is called yellowcake because it looks like flour. T F
   (because it is yellow)

4. Less than 1 percent of the atoms in ordinary yellowcake are uranium-235 atoms. T F

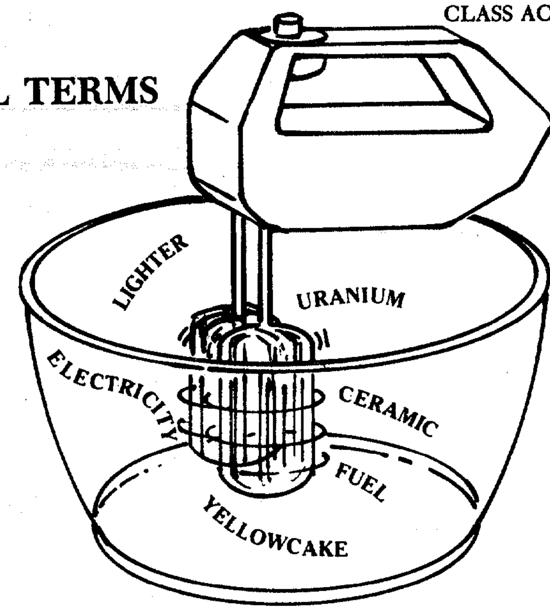
5. Although a uranium pellet is small, it can release a lot of energy. T F

C. Write a sentence explaining how each of the following numbers relates to uranium or nuclear energy.

Answers are located in the teacher guide (page 162).

1. 4 to 5 pounds
2. 40 years
3. 690,000 tons
4. 235
5. 238
6. 2,000 pounds of coal
7. 126 gallons of oil
8. 3/4 inch
9. 3 percent
10. 1 percent

SCRAMBLED FUEL TERMS



Unscramble the fuel terms in the paragraphs below. Write the unscrambled word on the blank line that corresponds to the number given.

Franklin Nuclear Powerplant uses (1) **arunumi** for fuel. Many steps are required to prepare the fuel for use in the powerplant. First, rocks containing this metal must be (2) **demin.** Then the rocks are crushed and poured into an acid, which dissolves the uranium. When the dissolved uranium is dried, a powder called (3) **ewlocyelak** is left. This process of removing the fuel from the rocks is called (4) **mauruni limginl.**

Most of the atoms in yellowcake are uranium-238 atoms, but powerplants like Franklin use uranium that is at least 3 percent uranium-235. Before the yellowcake can be treated to increase the percentage of uranium-235 atoms, it is converted to a gas called (5) **miraunu fehrulaxoied.** This process takes place at a (6) **rencovosin tlnap.**

The converted gas is shipped to a (7) **saguseo fudisonif** plant. Here, the gas is pumped through filters that contain very tiny holes. Because it is a tiny bit (8) **ghiterl,** uranium-235 moves through the holes more easily than uranium-238. The process of increasing the concentration of uranium-235 is (9) **mirnechten.**

The final step in preparing the fuel for the powerplant is to make the fuel into a (10) **raeccim** material, which is formed into small, barrel-shaped pellets. The pellets are stacked in metal rods that are bundled together into (11) **leuf seblimsesa.** The uranium in the pellets is the fuel used at the powerplant to make (12) **ciletreticy.**

1. ____________________ 2. ____________________

3. ____________________ 4. ____________________

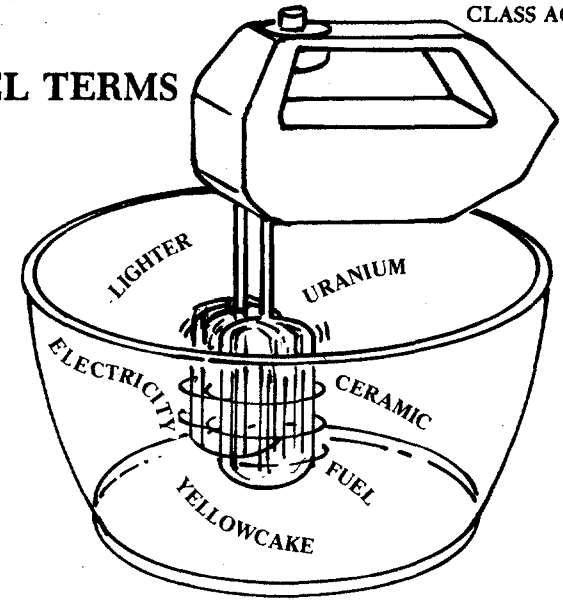
5. ____________________ 6. ____________________

7. ____________________ 8. ____________________

9. ____________________ 10. ____________________

11. ____________________ 12. ____________________

SCRAMBLED FUEL TERMS



Unscramble the fuel terms in the paragraphs below. Write the unscrambled word on the blank line that corresponds to the number given.

Franklin Nuclear Powerplant uses (1) **arunumi** for fuel. Many steps are required to prepare the fuel for use in the powerplant. First, rocks containing this metal must be (2) **demin.** Then the rocks are crushed and poured into an acid, which dissolves the uranium. When the dissolved uranium is dried, a powder called (3) **ewlocyelak** is left. This process of removing the fuel from the rocks is called (4) **mauruni limginl.**

Most of the atoms in yellowcake are uranium-238 atoms, but powerplants like Franklin use uranium that is at least 3 percent uranium-235. Before the yellowcake can be treated to increase the percentage of uranium-235 atoms, it is converted to a gas called (5) **miraunu fehrulaxoied.** This process takes place at a (6) **rencovosin tlnap.**

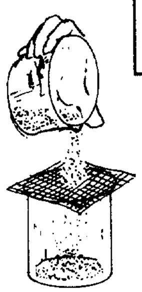
The converted gas is shipped to a (7) **saguseo fudisonif** plant. Here, the gas is pumped through filters that contain very tiny holes. Because it is a tiny bit (8) **ghiterl,** uranium-235 moves through the holes more easily than uranium-238. The process of increasing the concentration of uranium-235 is (9) **mirnechten.**

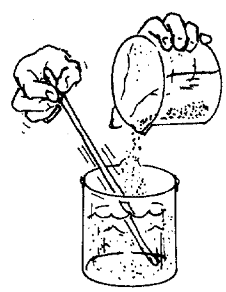
The final step in preparing the fuel for the powerplant is to make the fuel into a (10) **raeccim** material, which is formed into small, barrel-shaped pellets. The pellets are stacked in metal rods that are bundled together into (11) **leuf seblimsesa.** The uranium in the pellets is the fuel used at the powerplant to make (12) **ciletreticy.**

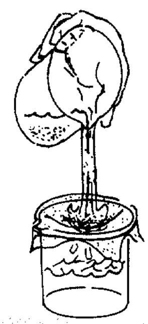
1. uranium
2. mined
3. yellowcake
4. uranium milling
5. uranium hexafluoride
6. conversion plant
7. gaseous diffusion
8. lighter
9. enrichment
10. ceramic
11. fuel assemblies
12. electricity

SEPARATING SALT FROM SAND

Materials	½ cup salt	pot holder
	½ cup sand	hot plate
	cheesecloth or other cloth	screen
	cookie sheet or heat resistant beaker	two glasses
		magnifying glass
		water

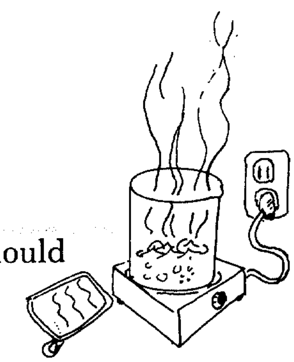






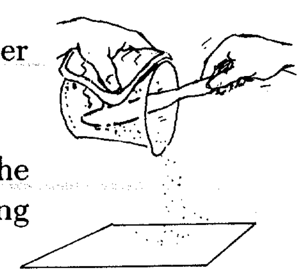
Directions:

Mix clean sand with ½ cup of salt.



1. Sift the sand and salt mixture through a screen. This should eliminate larger pieces of sand and gravel.

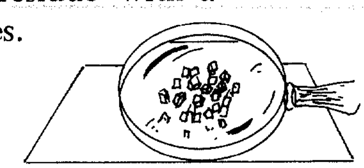
2. Pour the remaining sand and salt mixture into a container of water and mix thoroughly. Let the mixture set until the solids have settled to the bottom.



3. Slowly strain the water through the cheesecloth and into another glass.

4. Pour small amounts of the water onto a cookie sheet or into the beaker and heat it on the hot plate. Use a potholder to avoid burning yourself.

5. After the water has been evaporated, scrape the residue from the cookie sheet or sides of the beaker. Look at the residue with a magnifying glass. The cubes you see are salt particles.



Other ideas to explore:

1. Could you sift out the salt by using smaller and smaller screens?
2. How is this separation process similar to the way that uranium is extracted from the ore in which it is found?
3. Why is there salt in the water instead of sand?

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "The Nuclear Fuel Cycle"
- ☐ class activity "Nuclear Waste Cube"

scissors, glue, or tape

2. Introduce vocabulary.

contamination	low-level waste	spent fuel
decommissioned	repository	spent fuel casks
high-level waste	simulate	spent fuel pool
isolated		

3. Read Lesson 5 in student reader. (Page 81 in the student reader.)

4. The following questions may be used for class discussion after the students read Lesson 5.

a. Would a very small leak of *radioactive waste* from a nuclear waste repository be detected? Why or why not? (Yes, radiation can be easily detected with devices similar to Geiger counters.)

b. How would immediate *detection* of even a very small leak of *radioactive waste* differ from leak detection of other types of industrial toxic wastes? (Because radioactivity can be easily detected with Geiger counters, it would be easier to detect than most other types of hazardous or toxic waste. Leaks of hazardous or toxic wastes other than radioactive wastes are often detected by smell, color, or sensitive chemical analytical methods which take time to perform. An amount of a radioactive substance too small to detect by ordinary means such as smell, color, chemical analysis, etc., would still contain enough radioactive atoms to be readily detected by a Geiger counter.)

c. Why are there special sites for *disposal of low-level waste*? (There are special sites for disposal of radioactive waste because this type of waste must be isolated from the environment. Burning it could release radioactivity to the environment. Because these wastes will not remain radioactive for thousands of years and are not highly radioactive, they do not need to be put into permanent repositories.)

d. Why have some States formed coalitions to support a single *nuclear waste site* that would serve several States? (The Nuclear Waste Policy Act passed by the U.S. Congress in 1982 requires each State to provide for disposal of the low-level waste produced within its borders. Consequently, States may have their own waste sites, or enter into agreements with other States to share a single site.)

e. Why is there controversy over the selection of a *high-level nuclear waste disposal site*? (The Nuclear Waste Policy Act of 1982 requires that disposal sites for high-level waste be built. Because the waste that will be stored at these sites is highly radioactive and will remain radioactive for thousands of years, some people do not want it to be located near them. They are worried that some of the radioactive material may somehow be released into the environment from the repositories.)

f. How would it affect health care in your State if there were no *low-level waste disposal site* available? (If no low-level waste site is available, radioactive materials may not be used in the State. Many medical procedures that require the use of radioactive materials would be eliminated or prohibited. Radioactive materials could not be used to diagnose or treat diseases. However, x rays could still be taken because they do not produce low-level radioactive waste.)

g. Name some examples of artifacts we find at ancient cities. How could scientists who design *waste repositories* use the information about these ancient items? (Bones and ceramic materials endure a very long time without breaking down. Scientists use similar materials to stabilize the waste.)

h. Describe some *special packaging containers* that you encounter in everyday life. Are they specially built to protect the contents or keep the contents from getting in contact with the environment? (Packages that protect the contents include egg cartons, plastic over clothes from the cleaners, styrofoam, cardboard around electric components, etc. Packages that keep the contents from getting in contact with the environment include bottles of insecticide, cans of drain cleaner, and plastic garbage bags.)

5. **Assign and discuss the review exercise for Lesson 5.** (Page 87 in the student reader.)

You may choose to write the following words on the board for students to choose from for Section A.

disposal	low-level waste	spent fuel
high-level waste	repository	spent fuel pool

6. **Introduce the class activity "The Nuclear Fuel Cycle."**

7. **Introduce the class activity "Nuclear Waste Cube."**

You might want to have students stack cubes for their family's share, the class' share, etc. Using an almanac or atlas to get population figures, students could do math problems with how the waste from particular cities would fit into a specific space.

LESSON 5 REVIEW EXERCISE

A. From the reading, select the word that best fits the definition given.

__________________ 1. Waste that is only slightly radioactive and gives off small amounts of radiation.

__________________ 2. Powerplant waste that is very radioactive.

__________________ 3. One form of high-level waste.

__________________ 4. Permanent storage facility for high-level nuclear waste.

__________________ 5. Place where the spent fuel cools down and also begins to lose most of its radioactivity through radioactive decay.

B. Circle the letter of the best answer for each item.

1. The problem with nuclear powerplant waste is
   - A. there is a large amount of waste.
   - B. some of the waste is radioactive.
   - C. the waste is flammable.
   - D. all of the above.
2. Most radioactive waste from a nuclear powerplant is
   - A. low-level.
   - B. high-level.
   - C. ceramic.
   - D. spent fuel.
3. Low-level waste is usually
   - A. burned at high temperatures.
   - B. dumped in a sanitary landfill.
   - C. sealed in steel drums and buried at special sites.
   - D. disposed of by each state according to its own regulations.
4. About one-third of Franklin's fuel assemblies are replaced with new ones
   - A. once a month.
   - B. once every 6 months.
   - C. once a year.
   - D. once every 5 years.
5. Transportation of spent fuel assemblies involves
   - A. a series of tests to make sure the casks that will be used really work.
   - B. careful loading and inspection for proper installation of the spent fuel cask.
   - C. training of the truck driver in the hazards of radioactive materials, transportation regulations, and emergency procedures.
   - D. all of the above.

(Continued on next page)

C. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. A spent fuel cask protects its contents and also protects people and the environment from the fuel it holds. T F
2. After shutdown, the longer you wait to dismantle a nuclear powerplant, the less it costs. T F
3. The largest percentage of low-level radioactive waste in the United States comes from nuclear powerplants. T F
4. After 1 year in a spent fuel pool, the spent fuel will have lost 25 percent of its radioactivity. T F
5. High-level wastes will be isolated from underground water supplies. T F
6. In a test, the contents of a spent fuel cask remained intact when hit by a train engine traveling at 80 miles per hour. T F
7. High-level waste must be isolated from the environment for thousands of years. T F

LESSON 5 REVIEW EXERCISE

A. From the reading, select the word that best fits the definition given.

low-level waste	1.	Waste that is only slightly radioactive and gives off small amounts of radiation.
high-level waste	2.	Powerplant waste that is very radioactive.
spent fuel	3.	One form of high-level waste.
repository	4.	Permanent storage facility for high-level nuclear waste.
spent fuel pool	5.	Place where the spent fuel cools down and also begins to lose most of its radioactivity through radioactive decay.

B. Circle the letter of the best answer for each item.

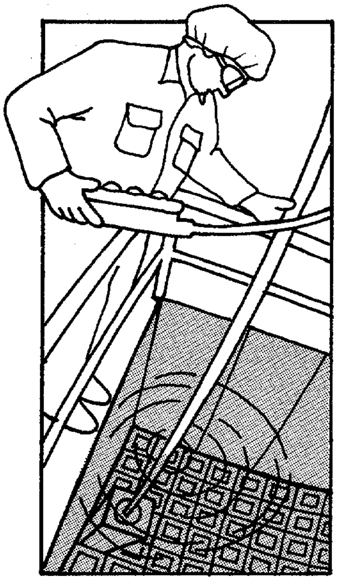
1. The problem with nuclear powerplant waste is
   A. there is a large amount of waste.
   B. some of the waste is radioactive.
   C. the waste is flammable.
   D. all of the above.
2. Most radioactive waste from a nuclear powerplant is
   A. low-level.
   B. high-level.
   C. ceramic.
   D. spent fuel.
3. Low-level waste is usually
   A. burned at high temperatures.
   B. dumped in a sanitary landfill.
   C. sealed in steel drums and buried at special sites.
   D. disposed of by each state according to its own regulations.
4. About one-third of Franklin's fuel assemblies are replaced with new ones
   A. once a month.
   B. once every 6 months.
   C. once a year.
   D. once every 5 years.
5. Transportation of spent fuel assemblies involves
   A. a series of tests to make sure the casks that will be used really work.
   B. careful loading and inspection for proper installation of the spent fuel cask.
   C. training of the truck driver in the hazards of radioactive materials, transportation regulations, and emergency procedures.
   D. all of the above.

(Continued on next page)

C. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

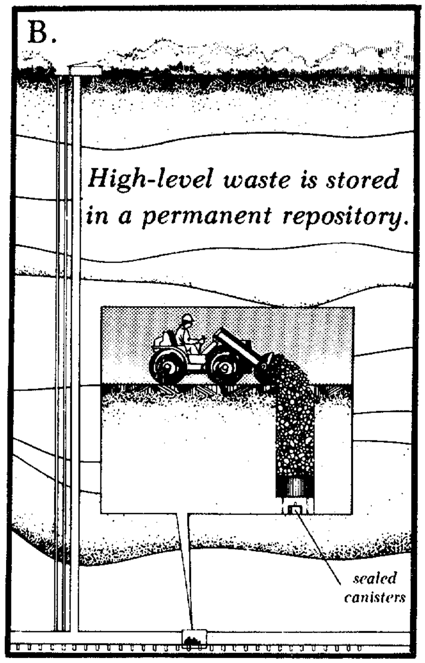
1. A spent fuel cask protects its contents and also protects people and the environment from the fuel it holds. T F
2. After shutdown, the longer you wait to dismantle a nuclear powerplant, the less it costs. T F
3. The largest percentage of low-level radioactive waste in the United States comes from nuclear powerplants. (*hospitals and industry*) T F
4. After 1 year in a spent fuel pool, the spent fuel will have lost 25 percent of its radioactivity. (*80 percent*) T F
5. High-level wastes will be isolated from underground water supplies. T F
6. In a test, the contents of a spent fuel cask remained intact when hit by a train engine traveling at 80 miles per hour. T F
7. High-level waste must be isolated from the environment for thousands of years. T F

The Nuclear Fuel Cycle
(See Next Page)



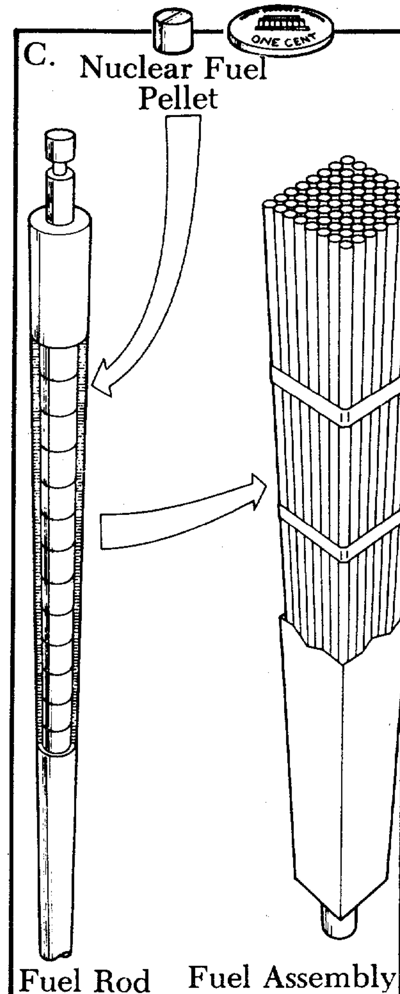
Spent fuel is stored in a spent fuel pool.

B.



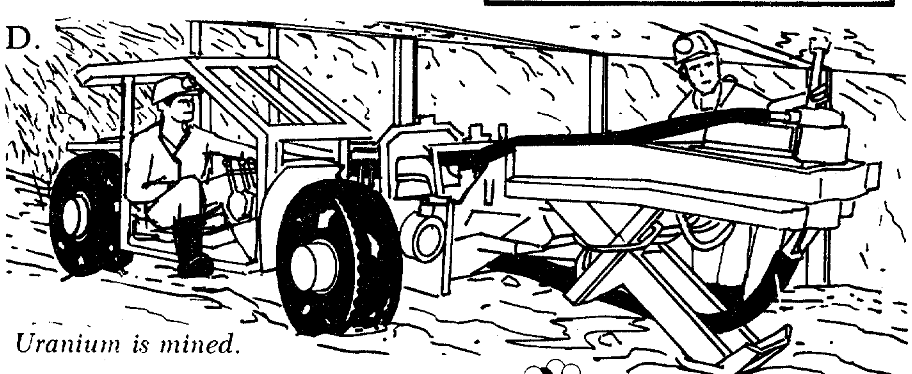
High-level waste is stored in a permanent repository.

C.



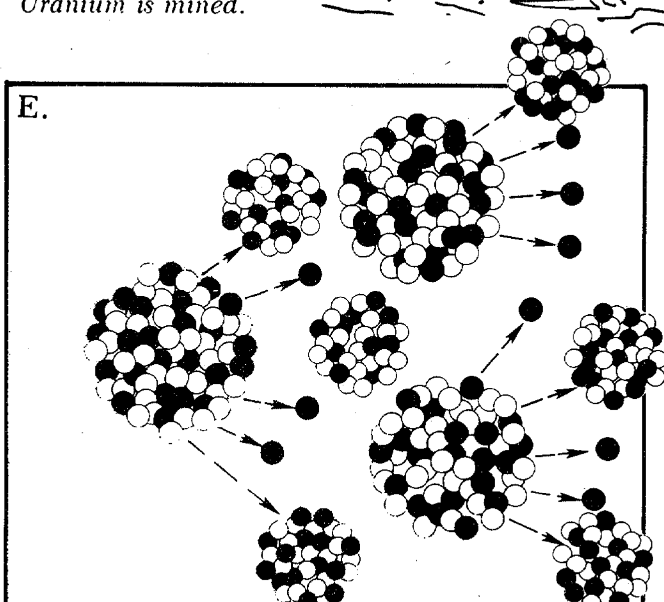
Uranium fuel pellets are placed in rods, which are placed into fuel assemblies.

D.



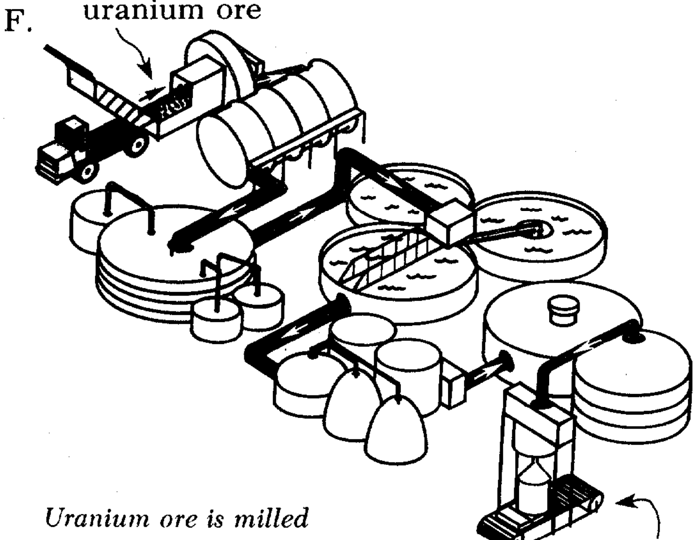
Uranium is mined.

E.



Uranium fissions to produce heat energy.

F.

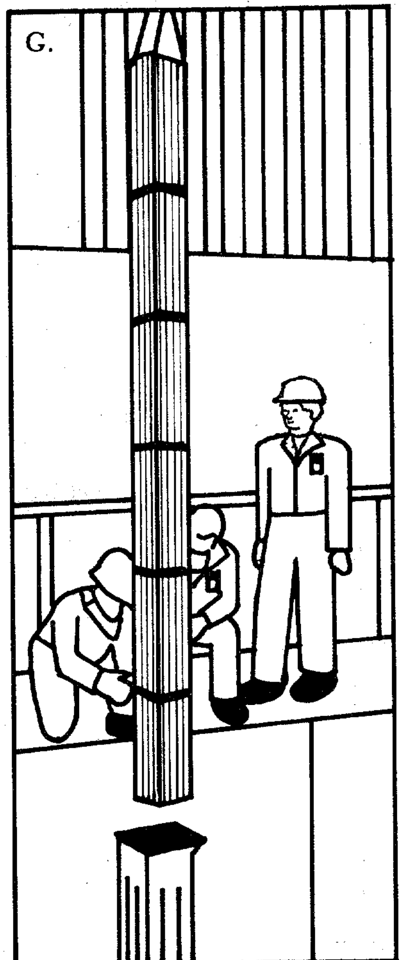


Uranium ore is milled and turned into yellowcake.

Directions: Arrange the pictures in the correct order by placing their letters in the blanks provided.

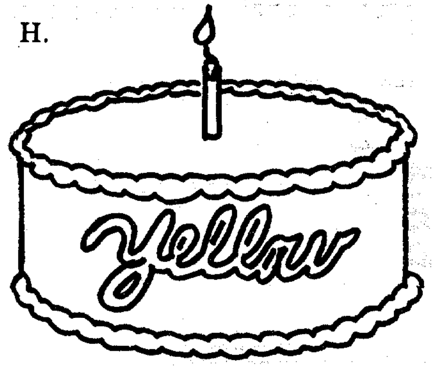
1. ______	3. ______	5. ______	7. ____	9. ______	11. ______
2. ______	4. ______	6. ______	8. ______	10. ______	12. ______

G.



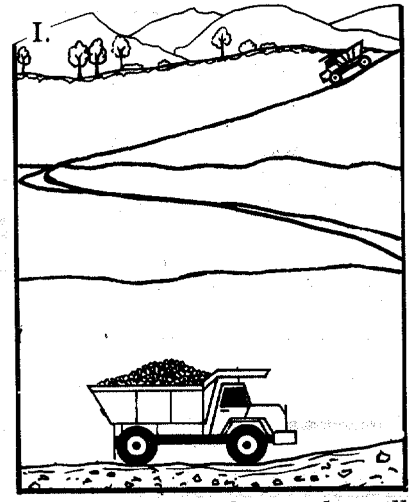
Fuel assemblies are lowered into the reactor core.

H.



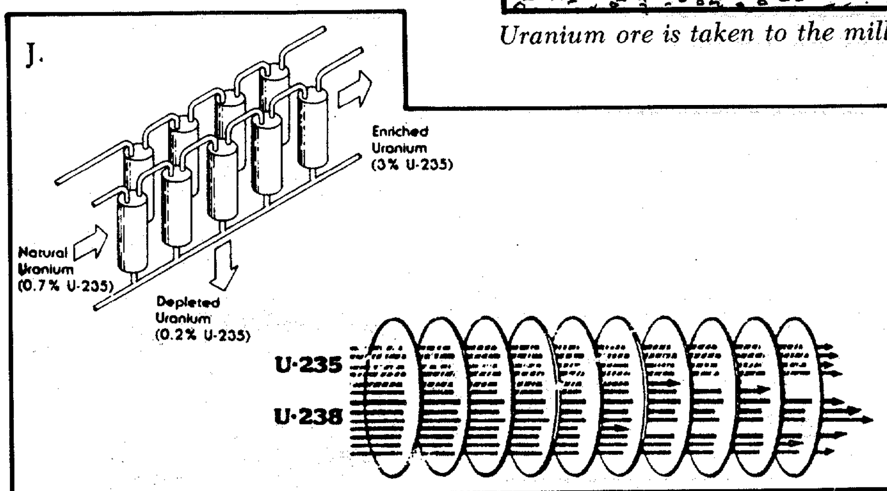
Yellowcake is taken to a conversion plant.

I.



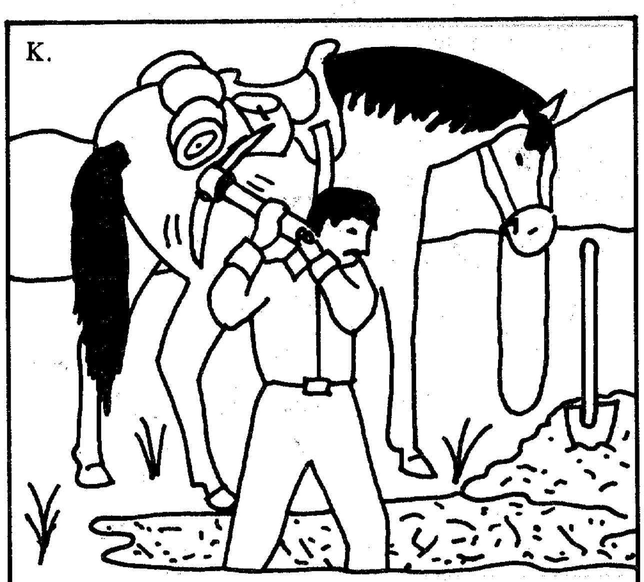
Uranium ore is taken to the mill.

J.



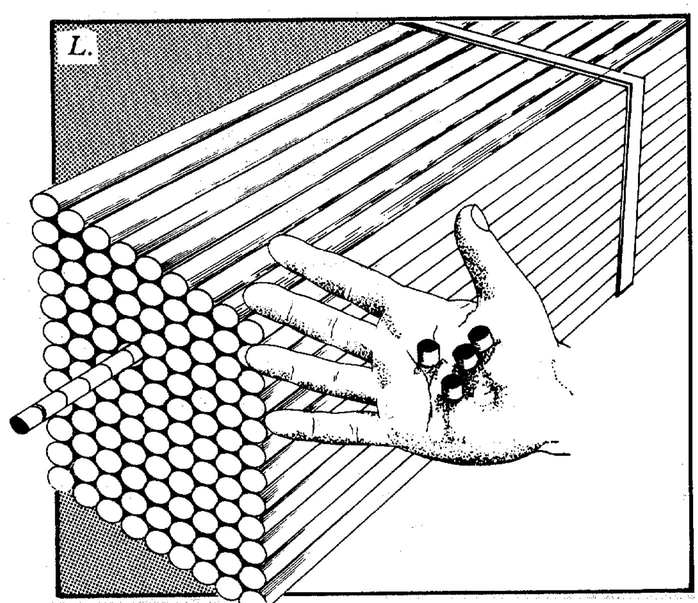
Uranium is enriched so that it contains about 3 percent U-235.

K.



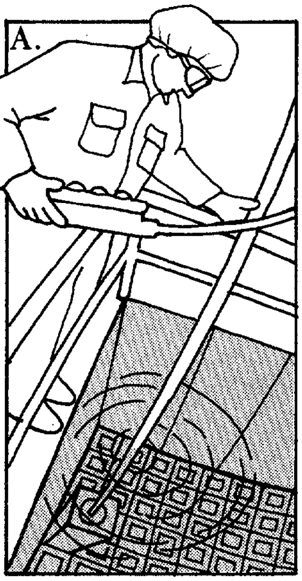
Prospecting for uranium deposits.

L.



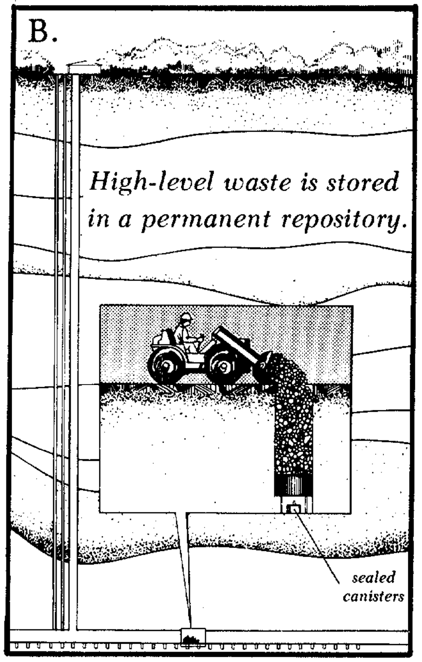
Uranium is formed into ceramic fuel pellets about the size of a fingertip.

A.



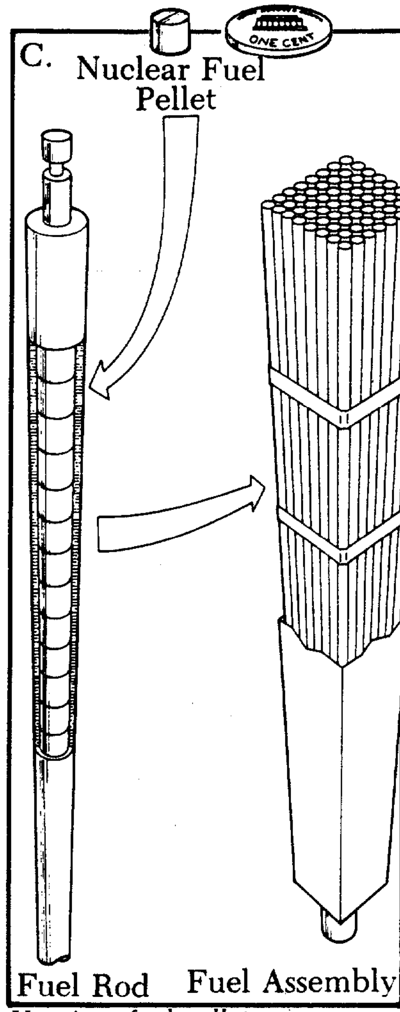
Spent fuel is stored in a spent fuel pool.

B.



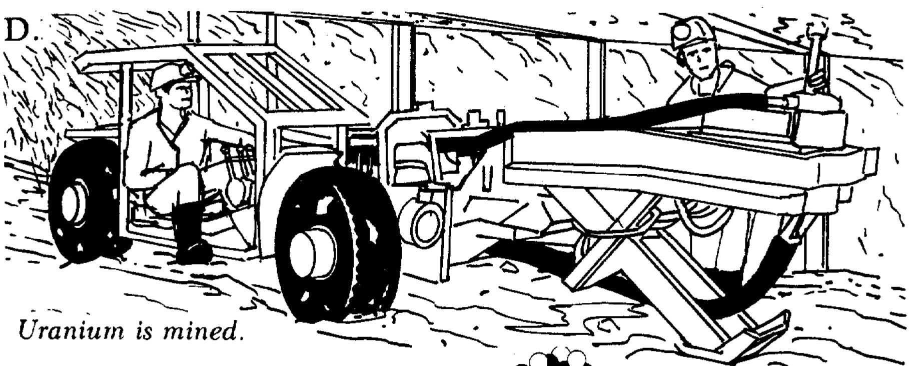
High-level waste is stored in a permanent repository.

C.



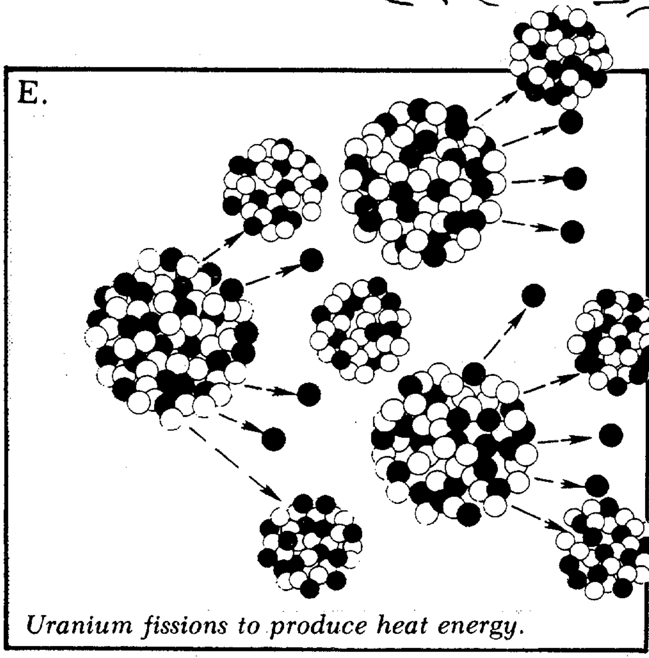
Uranium fuel pellets are placed in rods, which are placed into fuel assemblies.

D.



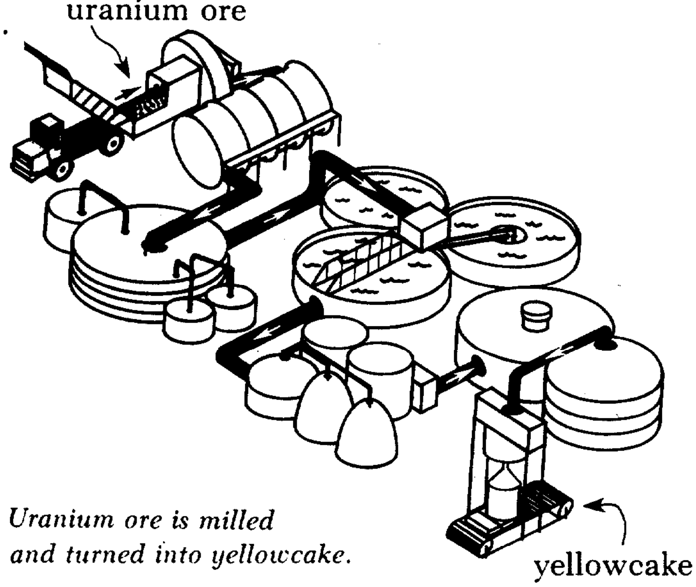
Uranium is mined.

E.



Uranium fissions to produce heat energy.

F.



Uranium ore is milled and turned into yellowcake.

Directions: Arrange the pictures in the correct order by placing their letters in the blanks provided.

1. K 3. I 5. H 7. L 9. G 11. A

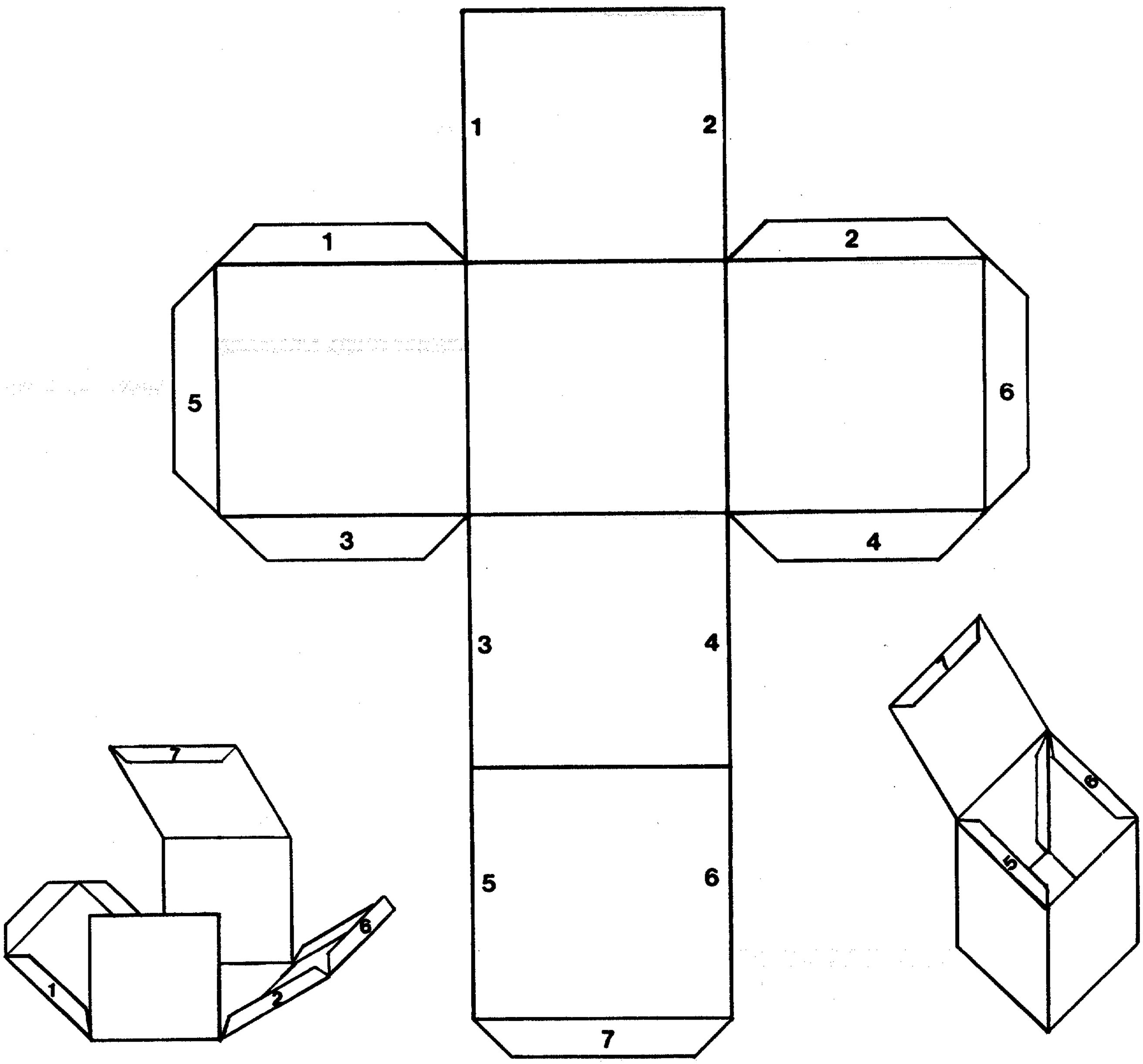
2. D 4. F 6. J 8. C 10. E 12. B

NUCLEAR WASTE CUBE

Materials	scissors glue or tape

Directions:

Using the diagram as a guide, cut out and fold the pattern to make a cube.



In the United States, one person's share of high-level radioactive waste from nuclear powerplants for a 20-year period could be placed inside the cube. This is the amount of waste that would be left over after all usable materials had been recycled.

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Safety Systems All Around Us"
- ☐ class activity "Containment System Eggstraordinary"

one raw egg	1.0 meter of tape	meter stick
5 sheets of 8-1/2" by 11" paper	plastic sheet	

2. Introduce vocabulary.

backup safety systems	monitors	safety systems
control room	operating license	

3. Read Lesson 6 in student reader. (Page 89 in the student reader.)

4. Use the following questions for discussion after the students read Lesson 6.

a. What type of high school courses do you think a student would need to take if he or she wanted to be an *operator in a nuclear powerplant*? (Because working as an operator in a nuclear powerplant requires some technical knowledge, a student preparing for this field should take science and advanced math courses. For a reference source, you might use "Working With the Atom—Careers for You" that is listed in the additional resources list.)

b. Why do you think the *Nuclear Regulatory Commission (NRC)* has such strict standards for nuclear powerplant operators? (Strict standards for nuclear powerplant operators are required to assure the safety of the public and to protect the environment.)

c. What happens to a utility if the NRC finds a violation of *safety standards*? Have you ever read of any instance in the paper or heard of any instances on the news in which a utility violated safety standards? (Part 1—If the NRC finds that a utility has violated safety standards, the utility can be fined, or the NRC can even revoke the license of the utility. Part 2—Answers may vary.)

d. Do you think the *safety regulations* imposed by the NRC are too strict or not strict enough? Why? (Answers will vary.)

e. Think of some examples of *backup safety systems* used in everyday life. (Emergency exits, emergency light on building, fire escape, understudy, extra reed or string for musical instrument, spare racket or tire or bulb, manual can opener)

f. Why must workers pass through *metal detectors* in order to enter or exit a powerplant site? (Metal detectors are used for security purposes and to ensure that all materials in the reactor area are accounted for.)

g. What is a *monitor*? How are monitors used in a nuclear powerplant? Name two monitors in your home. (A monitor is a person or device that observes the environment and then warns or instructs. Monitors in a nuclear powerplant keep track of many different activities within the plant and provide information to the plant operators through television screens, alarms, meters, computer print-outs, etc. Monitors in your home are thermostats in ovens, water heaters, and furnaces; smoke detectors; and burglar alarms.)

h. In what way could you apply the old adage, "A chain is only as strong as its weakest link" to Franklin's *safety systems*? (Answers will vary, but one possible example is that every small safety detail must be observed in order to have total safety.)

5. Assign and discuss the review exercise for Lesson 6. (Page 93 in the student reader.)

You may choose to write the following list of words on the board for students to choose from for Section A.

backup safety systems	metal fuel rods	reactor core
containment building	monitoring systems	security measures
control room	pressure vessel	spent fuel pool
diesel electric generators		

6. Class activity "Safety Systems All Around Us."

You may want to divide students into groups of four or five students each. Assign each group one of the situations and have them list the "safety systems" that they can think of that would protect them in each situation.

Following is a list of the kinds of things the students might think of. (You and the students will be able to think of many more.)

traffic laws
regulations regarding licensing of drivers, car inspections, etc.
traffic lights
stop signs
crosswalks
crossing guards
turn signals
lights on dashboard of car (e.g., door ajar, seat belt, battery charge, oil pressure)
seat belts
horn
mirrors on car
emergency brake in car
brakes
back exit door in a bus
smoke alarms
burglar alarms
locks and keys
fuse box or circuit breakers
microwave ovens and clothes washers or dryers will stop if you open doors while the machine is running
heaters that turn off when tilted
insulation for electrical wires
fireplace screens
handrails (banisters) on stairs
health inspector
safety goggles
mirror on a boat
horn on a boat
life preservers
lighthouse
drawbridge warning lights and bells
lifeguards
railroad crossing warning lights, bells, and gates
fog horns
life boats
steel-toed shoes
film badges to wear when working with x rays and nuclear materials
fire laws
doors that open out in stores, shopping centers, etc.

7. Class activity "Containment System Eggstraordinary!"

LESSON 6 REVIEW EXERCISE

A. From the reading, select the word which best fits the definition given.

__________________ 1. This is the most radioactive place in the powerplant.

__________________ 2. This is the building where the reactor is located.

__________________ 3. With its 9-inch-thick steel walls and the water inside, this helps to contain the radiation within the reactor.

__________________ 4. These provide a physical barrier and keep the uranium fuel pellets in the proper position.

__________________ 5. Spent fuel is submerged here in water that blocks radiation and cools the fuel.

__________________ 6. This system can detect problems as soon as they begin to develop.

__________________ 7. Located in a reinforced concrete building beside the containment building, this room is Franklin's brain.

__________________ 8. These would supply electricity to the control room, safety systems, and backup systems if the powerplant could not generate electricity.

__________________ 9. Identification badges, television monitors, alarm devices, magnetic cards, and high barbed wire fences are examples.

__________________ 10. Unexpected changes in temperature, radiation, or pressure would be detected by monitors or people, or computers would immediately activate them.

B. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. All backup safety systems in nuclear powerplants are tested regularly to make sure they are working correctly. T F
2. Once the highly trained operators finish their training and begin work, they do not have to return to school. T F
3. The containment building is strong enough to withstand earthquakes, storms, floods, and even the crash of a large airplane. T F
4. As a normal part of operation, the ceramic fuel pellets melt at extremely high temperatures. T F
5. In any industry there are possible hazards. T F

LESSON 6 REVIEW EXERCISE

A. From the reading, select the word which best fits the definition given.

reactor core	1.	This is the most radioactive place in the powerplant.
containment building	2.	This is the building where the reactor is located.
pressure vessel	3.	With its 9-inch-thick steel walls and the water inside, this helps to contain the radiation within the reactor.
fuel rods	4.	These provide a physical barrier and keep the uranium fuel pellets in the proper position.
spent fuel pool	5.	Spent fuel is submerged here in water that blocks radiation and cools the fuel.
monitoring system	6.	This system can detect problems as soon as they begin to develop.
control room	7.	Located in a reinforced concrete building beside the containment building, this room is Franklin's brain.
diesel electric generators	8.	These would supply electricity to the control room, safety systems, and backup systems if the powerplant could not generate electricity.
security measures	9.	Identification badges, television monitors, alarm devices, magnetic cards, and high barbed wire fences are examples.
backup safety systems	10.	Unexpected changes in temperature, radiation, or pressure would be detected by monitors or people, or computers would immediately activate them.

B. Indicate whether the following statements are true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. All backup safety systems in nuclear powerplants are tested regularly to make sure they are working correctly. T F
2. Once the highly trained operators finish their training and begin work, they do not have to return to school. (spend 1/5 of working hrs. in school) T F
3. The containment building is strong enough to withstand earthquakes, storms, floods, and even the crash of a large airplane. T F
4. As a normal part of operation, the ceramic fuel pellets melt at extremely high temperatures. (pellets do not melt) T F
5. In any industry there are possible hazards. T F

SAFETY SYSTEMS ALL AROUND US

There are many safety systems in our everyday lives. See how many you can list for each of the places given. An example is given for each place. Some of the safety systems may be used for more than one place. You may include regulations or laws in your lists.

In a bus or car Seat belts	At school Fire alarms
On a boat Life jackets	On an airplane Seat belts
In a science lab, shop class, home economics class, or gym class (pick one) Safety goggles	At home Smoke detectors

SAFETY SYSTEMS ALL AROUND US

There are many safety systems in our everyday lives. See how many you can list for each of the places given. An example is given for each place. Some of the safety systems may be used for more than one place. You may include regulations or laws in your lists.

In a bus or car	At school
Seat belts *Traffic laws* *Regulations regarding licensing of drivers, car inspections* *Traffic lights* *Stop signs* *Crosswalks* *Crossing guards* *Turn signals* *Warning lights on dashboards* *Horn, brakes, back exit on bus*	Fire alarms *Fire drills* *Crossing guards* *Smoke alarms* *Sprinkler systems* *Doors that open out* *Design of exit doors so that they will open from inside if locked* *School rules*
On a boat	**On an airplane**
Life jackets *Mirror on boat* *Running light (colored)* *Horn.* *Flotation devices* *Fog horns* *Lighthouses* *Buoys to mark channels* *Maps*	Seat belts *Warning lights* *Running lights* *Emergency door* *Safety drill* *Oxygen masks* *Design of plane* *No smoking rules* *Exit slides* *Flotation cushions*
In a science lab, shop class, home economics class, or gym class (pick one)	**At home**
Safety goggles *Safety rules* *Potholders* *Fire extinguishers* *Vent hoods (to remove fumes)* *Heat resistant glass* *Protective equipment in sports*	Smoke detectors *Burglar alarms* *Locks and keys* *Fuse box* *Circuit breakers* *Doors of washers, dryers, microwave ovens that will stop the machine if door opens* *Insulation for electrical wires* *Handrails or banisters* *Fireplace screens*

CONTAINMENT SYSTEM EGGSTRAORDINARY

Materials

EACH TEAM	ENTIRE CLASS
One raw egg	plastic sheet
5 sheets of 8-½" by 11" paper	meter stick
1.0 meter of tape	

Directions:

Scientists, engineers, and architects work together to design and build a nuclear powerplant that will assure the safety of the public and the environment. One of their main objectives is to contain the radiation produced by fissioning atoms.

To help you understand the skill and difficulty involved in structuring a containment system, you and a partner will design and build a containment apparatus for the protection of an egg. Your package design will be tested by dropping it from a high location under the direction of your teacher.

Procedure:

1. Using the materials provided, each team will construct a containment apparatus. Be certain to think and make a plan before you start. You will not be given additional materials.

2. Mark your package so that it can be recognized.

3. When all teams have completed their packages, one team member will drop your team's egg package in the area designated by the teacher. The dropping height will be 2.0 meters. Eggs that survive the fall have been contained safely.

1. **Gather materials.**

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Types of Nuclear Powerplants"
- ☐ class activity "Nuclear Power Around the World"

2. **Introduce vocabulary.**

Introduce the vocabulary words before the students read the lesson. Definitions can be found in the glossary at the end of the student reader.

boiling water reactor BWR	high temperature gas-cooled reactor HTGR	LMFBR
breeder reactor	liquid metal fast breeder reactor	pressurized water reactor PWR
graphite		sodium
helium		uranium carbide

3. **Read Lesson 7 in student reader.** (Page 94 in the student reader.)

4. **Use the following questions for class discussion after the students read Lesson 7.**

a. How is it possible for *uranium-238* to become *plutonium-239*? (When uranium-238 takes on a neutron, its atomic weight increases to 239 and it subsequently decays to plutonium-239. You may recall that chemical reactions do not change the nature of an element, but nuclear reactions and radioactive decay can change one element into another, which is what happens.)

b. How is it possible for the *breeder reactor* to make more fuel than it uses? (Because it turns non-fuel uranium-238 into plutonium-239, which can be used as fuel, the breeder makes more fuel than it consumes. This is nice because there is much more uranium-238 in the world than uranium-235. Some scientists have likened the breeder's ability to make its own fuel to a realization of the ancient dream of the Medieval alchemist, who wanted to make gold from lead.)

c. Why does an *HTGR* use graphite for a moderator? (The HTGR is a gas-cooled reactor operating at temperatures that are too high to use water. Graphite serves as a structural material for the reactor and as a moderator. The original reactors used graphite for moderators and were air cooled.)

d. Why is sodium used as a coolant in the cooling loop of the *breeder reactor*? (Unlike water, sodium is not a moderator, and sodium will not slow down the fast neutrons, which are needed to "breed" the uranium-238 isotopes. Beyond this, because metals conduct heat better than water, sodium [a metal] is a more efficient heat transfer agent.)

e. Why do *boiling water reactors* not have steam generators? (The main reason is that water boils and turns to steam in the pressure vessel of a BWR and this steam goes directly to the turbine generator.)

5. Assign and discuss the review exercise for Lesson 7. (Page 100 in the student reader.)

You may choose to write the following list of words on the board for your students to choose from for Section A.

blanket	HTGR	helium
electricity	LMFBR	uranium-235
fuel	light water reactors	uranium-238

6. Assign "Types of Nuclear Powerplants" activity.

7. Assign "Nuclear Power Around the World" activity.

LESSON 7 REVIEW EXERCISE

A. From the reading, select the word that best fits the statement.

1. A breeder reactor produces more ________________ than it uses.

2. The outer layer of the breeder reactor core is called a fuel ________________.

3. Bricks made of graphite and uranium carbide are stacked to form the core of the ________________.

4. PWRs and BWRs are both ________________ ________________ ________________.

5. The main difference between HTGRs and light water reactors is that HTGRs use ____________ gas instead of water as a coolant in the first loop.

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Control rods in the BWR come in from the bottom.	T	F
2. There are several different types of nuclear powerplants.	T	F
3. BWRs do not have steam-generators.	T	F
4. Breeder reactors require enriched uranium for fuel.	T	F
5. Graphite is a neutron moderator.	T	F

(Continued on next page)

C. Answer the following questions.

1. Explain why adding a neutron to uranium-238 would turn it into plutonium-239.

2. If there is a nuclear powerplant near you, what type is it?

LESSON 7 REVIEW EXERCISE

A. From the reading, select the word that best fits the statement.

1. A breeder reactor produces more *fuel* than it uses.

2. The outer layer of the breeder reactor core is called a fuel *blanket*.

3. Bricks made of graphite and uranium carbide are stacked to form the core of the *HTGR*.

4. PWRs and BWRs are both *light* *water* *reactors*.

5. The main difference between HTGRs and light water reactors is that HTGRs use *helium* gas instead of water as a coolant in the first loop.

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. Control rods in the BWR come in from the bottom.	T	F
2. There are several different types of nuclear powerplants.	T	F
3. BWRs do not have steam-generators.	T	F
4. Breeder reactors require enriched uranium for fuel. *(use plutonium for fuel)*	T	F
5. Graphite is a neutron moderator.	T	F

(Continued on next page)

C. Answer the following questions.

1. Explain why adding a neutron to uranium-238 would turn it into plutonium-239.

   Adding a neutron increases the total number of neutrons in the nucleus by 1. The extra neutron makes the nucleus unstable. The neutron breaks down by emitting beta radiation and changing into a proton. This changes the actual element and thus uranium-238 can change to plutonium-239.

2. If there is a nuclear powerplant near you, what type is it? ____________________

TYPES OF NUCLEAR POWERPLANTS

A. Complete the table below.

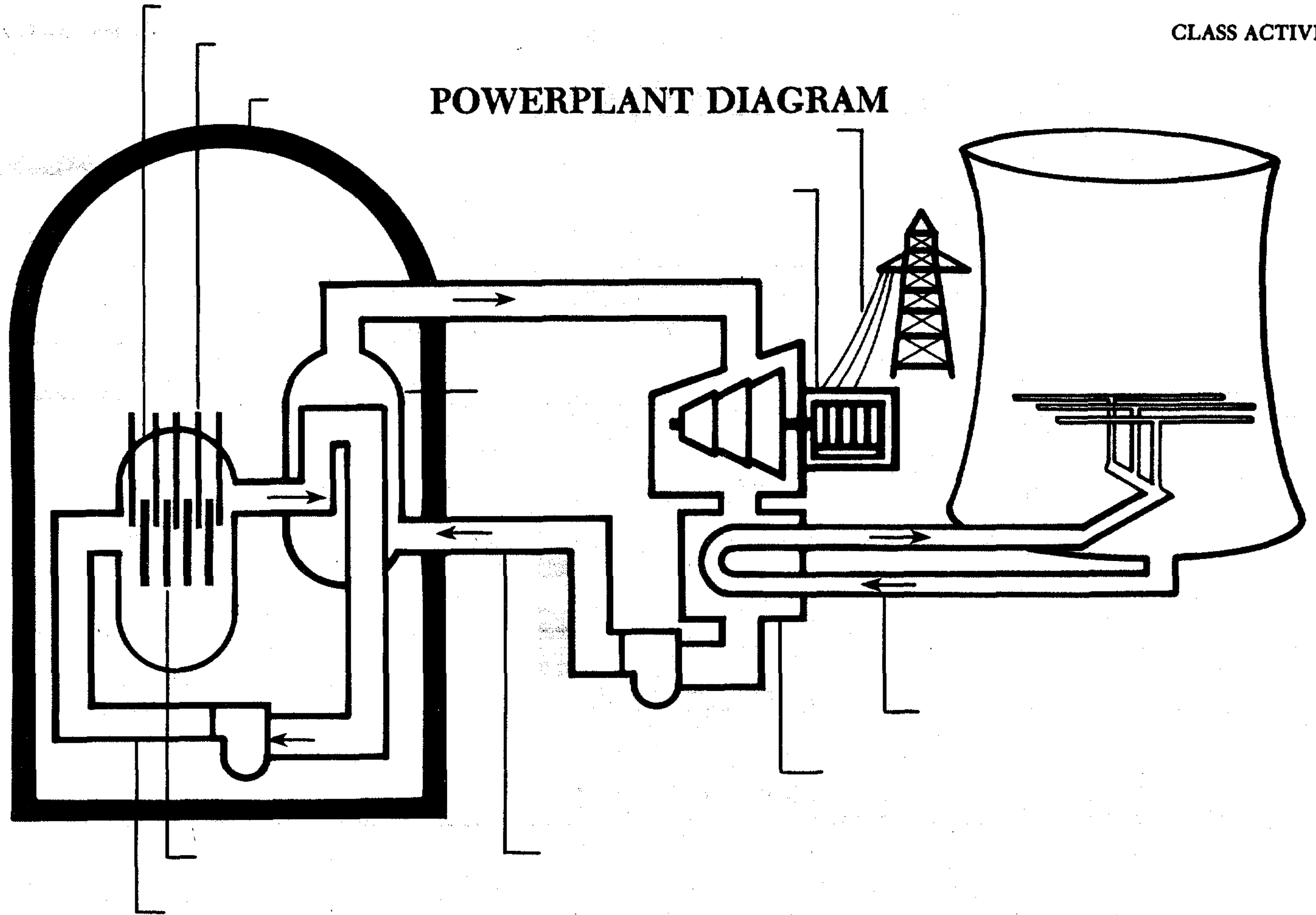
	Pressurized Water Reactor	Liquid Metal Fast Breeder Reactor	Boiling Water Reactor	High Temperature Gas-Cooled Reactor
Abbreviation				
Fuel				
Coolant				
Moderator				
Number in the U.S.				
Turbines turned by				

TYPES OF NUCLEAR POWERPLANTS

A. Complete the table below.

	Pressurized Water Reactor	Liquid Metal Fast Breeder Reactor	Boiling Water Reactor	High Temperature Gas-Cooled Reactor
Abbreviation	PWR	LMFBR	BWR	HTGR
Fuel	U-235	U-238 Pu-239	U-235	uranium carbide
Coolant	water	sodium	water	helium gas
Moderator	water		water	graphite
Number in the U.S.	50		30	1
Turbines turned by	steam	steam	steam	steam

POWERPLANT DIAGRAM

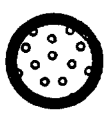


Pressurized Water Reactor (PWR)

A. Identify the powerplant parts by writing the number of the correct powerplant part on the blank.

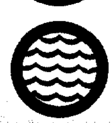
1. reactor	5. steam-generator	9. first water loop
2. control rods	6. turbine-generator	10. second water loop
3. cooling water loop	7. transmission lines	11. nuclear fuel
4. containment building	8. condenser	

B. Color the separate loops using a different color for each loop. Use the following symbols to show what is in the loop or part of the loop.

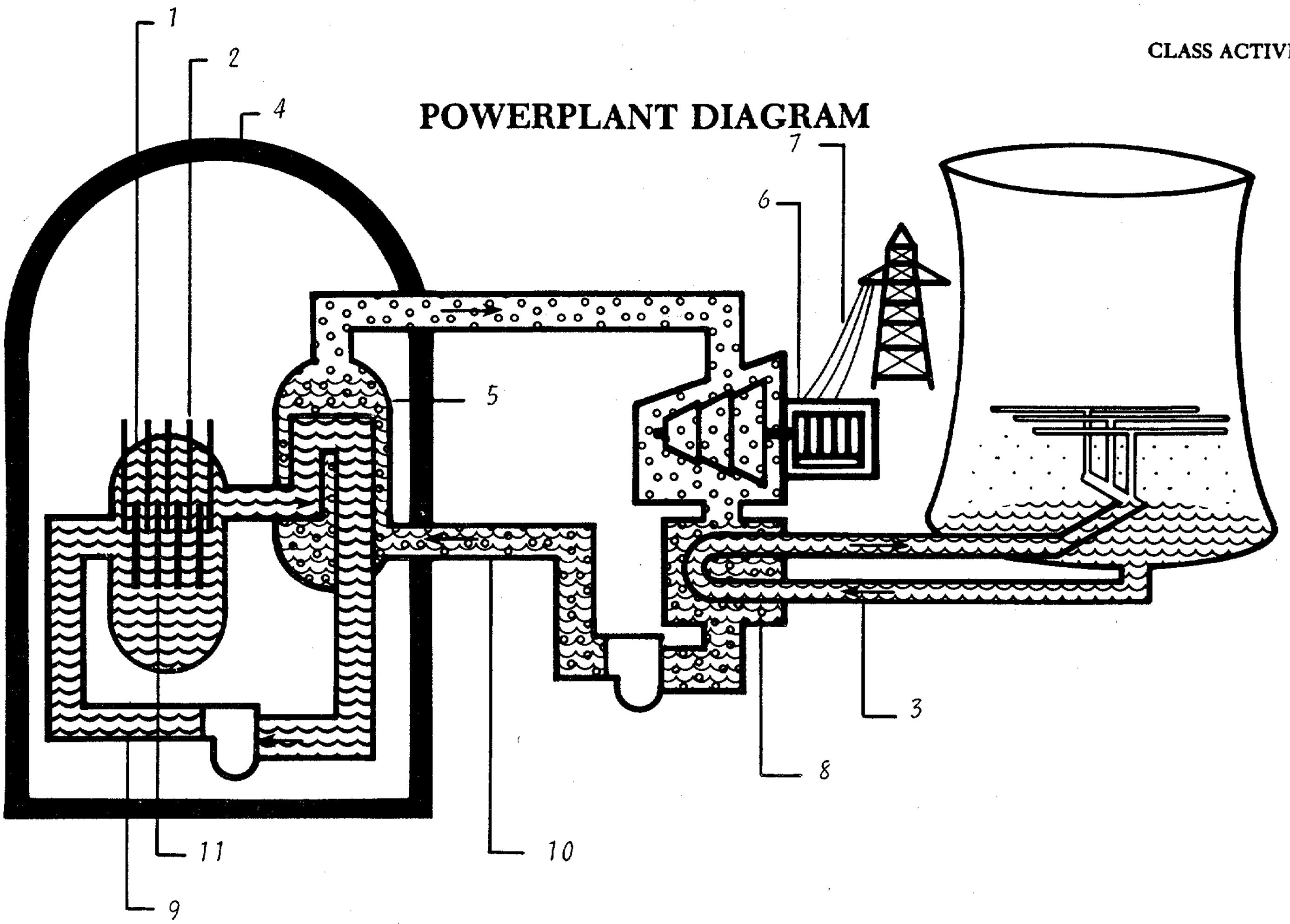
 = steam

 = steam converted back to water

 = cooling water

 = water in first loop

POWERPLANT DIAGRAM

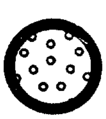


Pressurized Water Reactor (PWR)

A. Identify the powerplant parts by writing the number of the correct powerplant part on the blank.

1. reactor	5. steam-generator	9. first water loop
2. control rods	6. turbine-generator	10. second water loop
3. cooling water loop	7. transmission lines	11. nuclear fuel
4. containment building	8. condenser	

B. Color the separate loops using a different color for each loop. Use the following symbols to show what is in the loop or part of the loop.

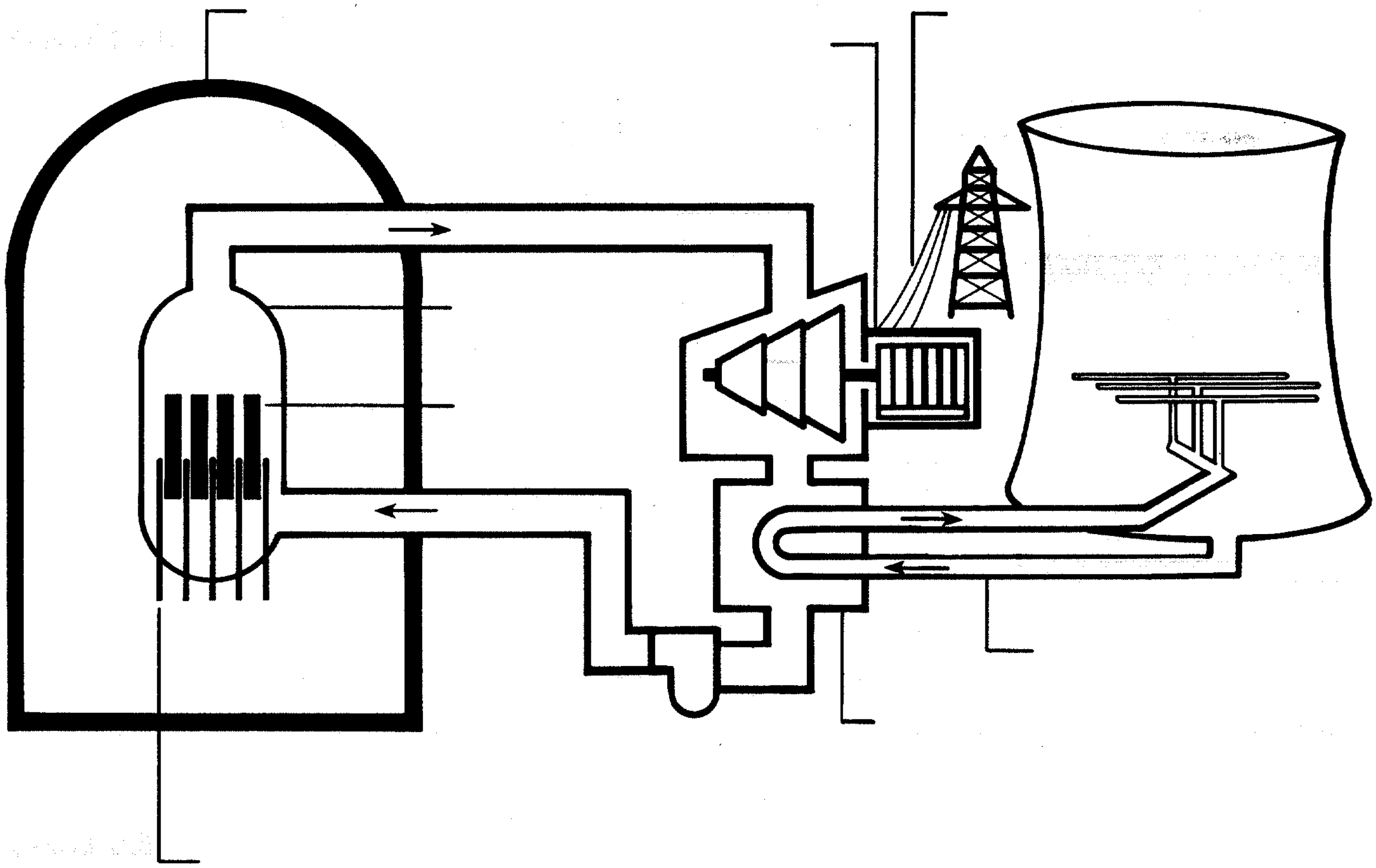
 = steam

 = steam converted back to water

 = cooling water

 = water in first loop

POWERPLANT DIAGRAM

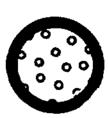


Boiling Water Reactor (BWR)

A. Identify the powerplant parts by writing the number of the correct powerplant part on the blank.

1. containment building	4. cooling water loop	7. condenser
2. turbine-generator	5. transmission lines	8. nuclear fuel
3. control rods	6. reactor	

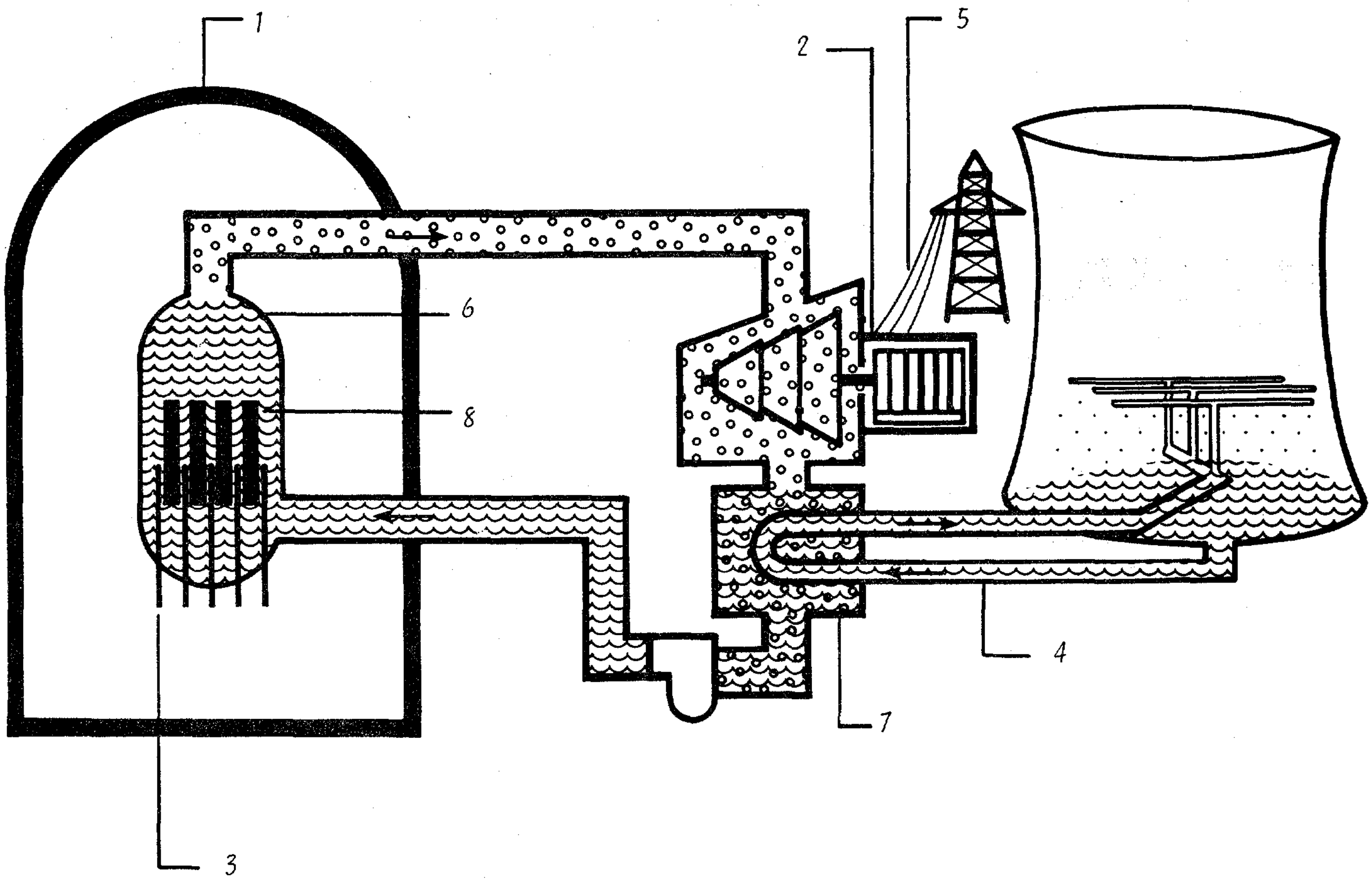
B. Color the separate loops using a different color for each loop. Then use the following symbols to show what is in each loop or part of a loop.

 = steam

 = water

 = steam converted back to water

POWERPLANT DIAGRAM

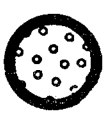


Boiling Water Reactor (BWR)

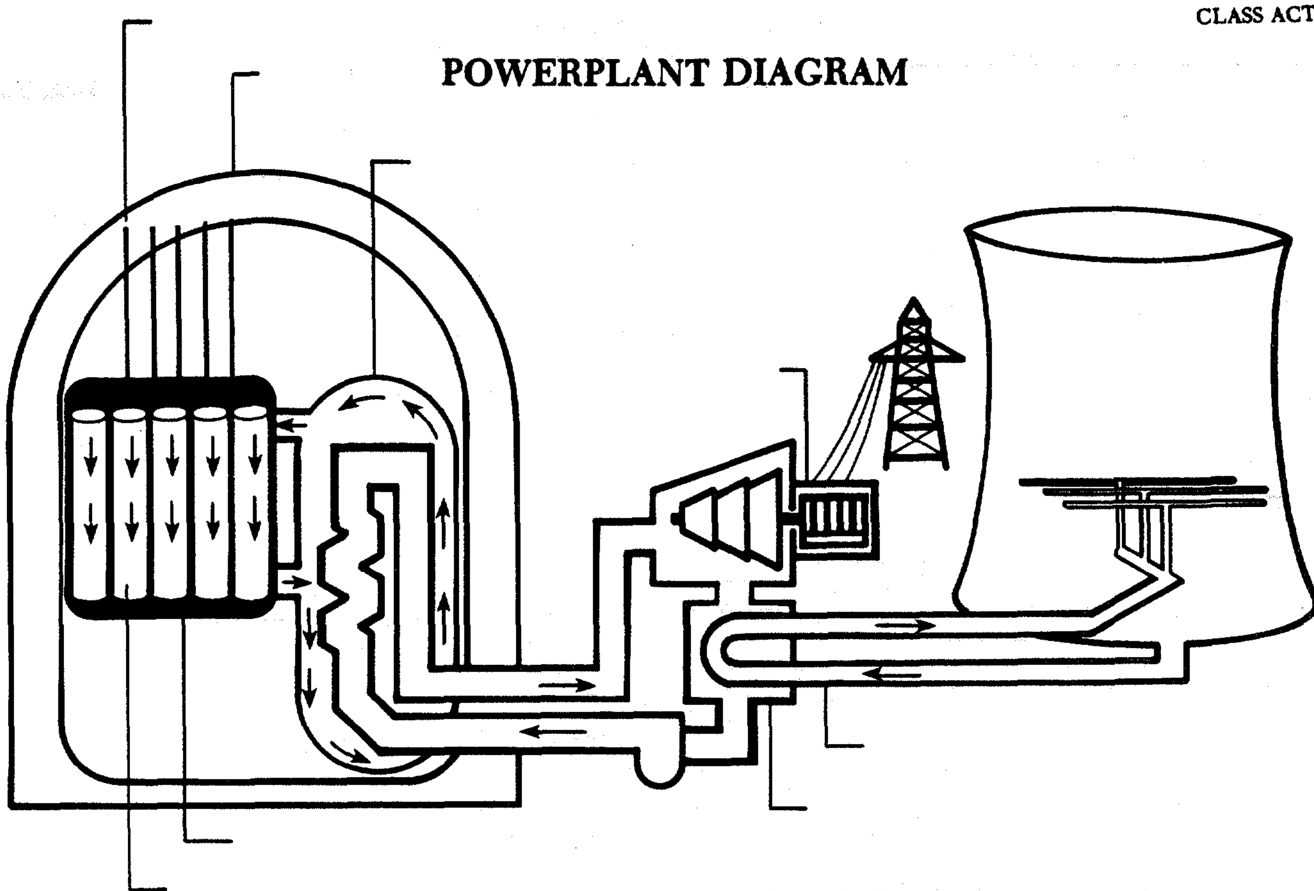
A. Identify the powerplant parts by writing the number of the correct powerplant part on the blank.

1. containment building
2. turbine-generator
3. control rods
4. cooling water loop
5. transmission lines
6. reactor
7. condenser
8. nuclear fuel

B. Color the separate loops using a different color for each loop. Then use the following symbols to show what is in each loop or part of a loop.

 = steam  = water  = steam converted back to water

POWERPLANT DIAGRAM

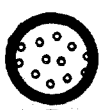


High Temperature Gas-Cooled Reactor (HTGR)

A. Identify the powerplant parts by writing the number of the correct powerplant part in the blank.

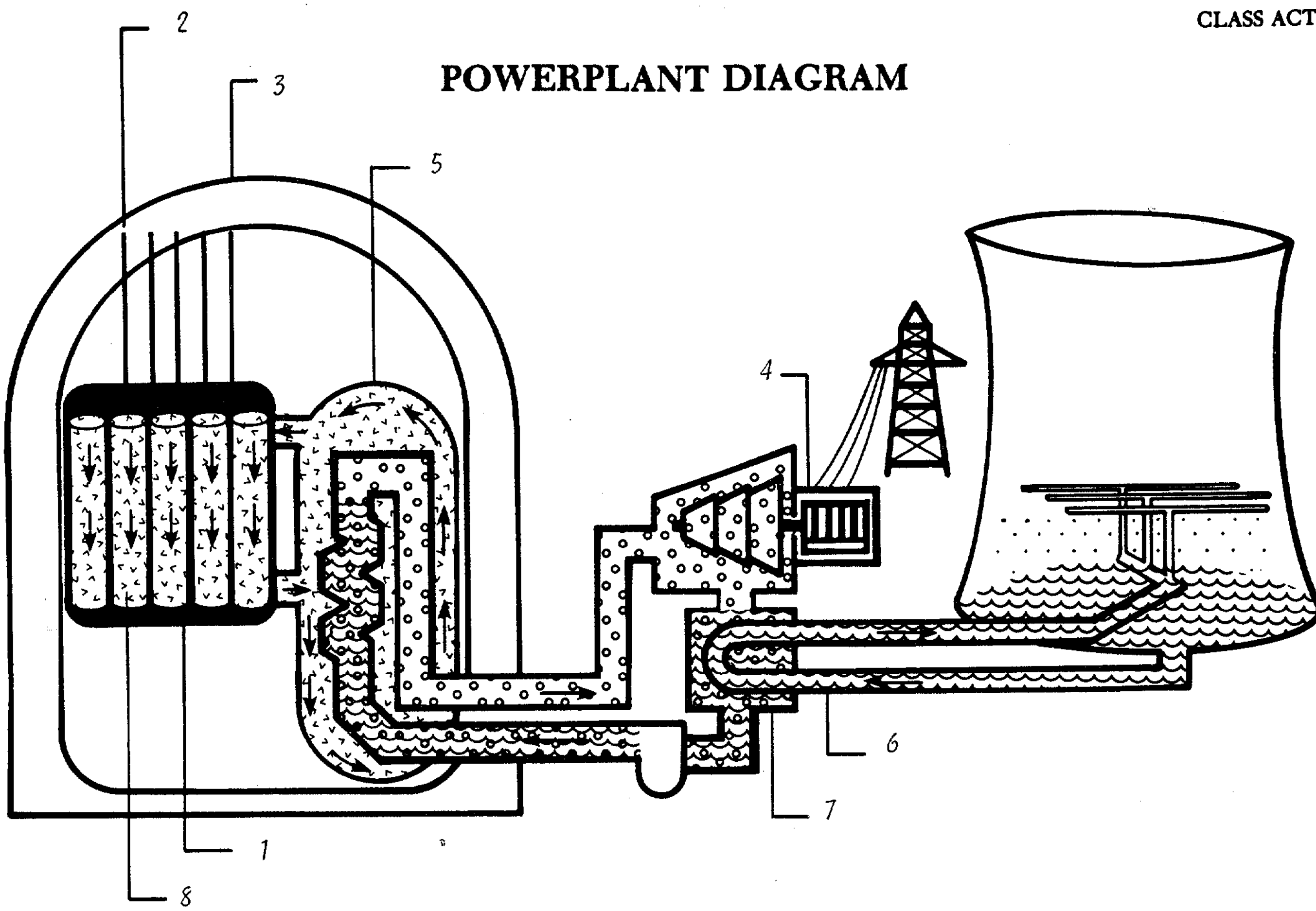
1. reactor	4. turbine-generator	7. condenser
2. control rods	5. steam-generator	8. nuclear fuel
3. containment building	6. cooling water	

B. Color the separate loops using a different color for each loop. Use the following symbols to show what is in each loop or part of a loop.

 = steam  = helium gas  = steam converted back to water

 = cooling water

POWERPLANT DIAGRAM

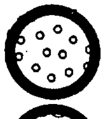


High Temperature Gas-Cooled Reactor (HTGR)

A. Identify the powerplant parts by writing the number of the correct powerplant part in the blank.

1. reactor
2. control rods
3. containment building
4. turbine-generator
5. steam-generator
6. cooling water
7. condenser
8. nuclear fuel

B. Color the separate loops using a different color for each loop. Use the following symbols to show what is in each loop or part of a loop.

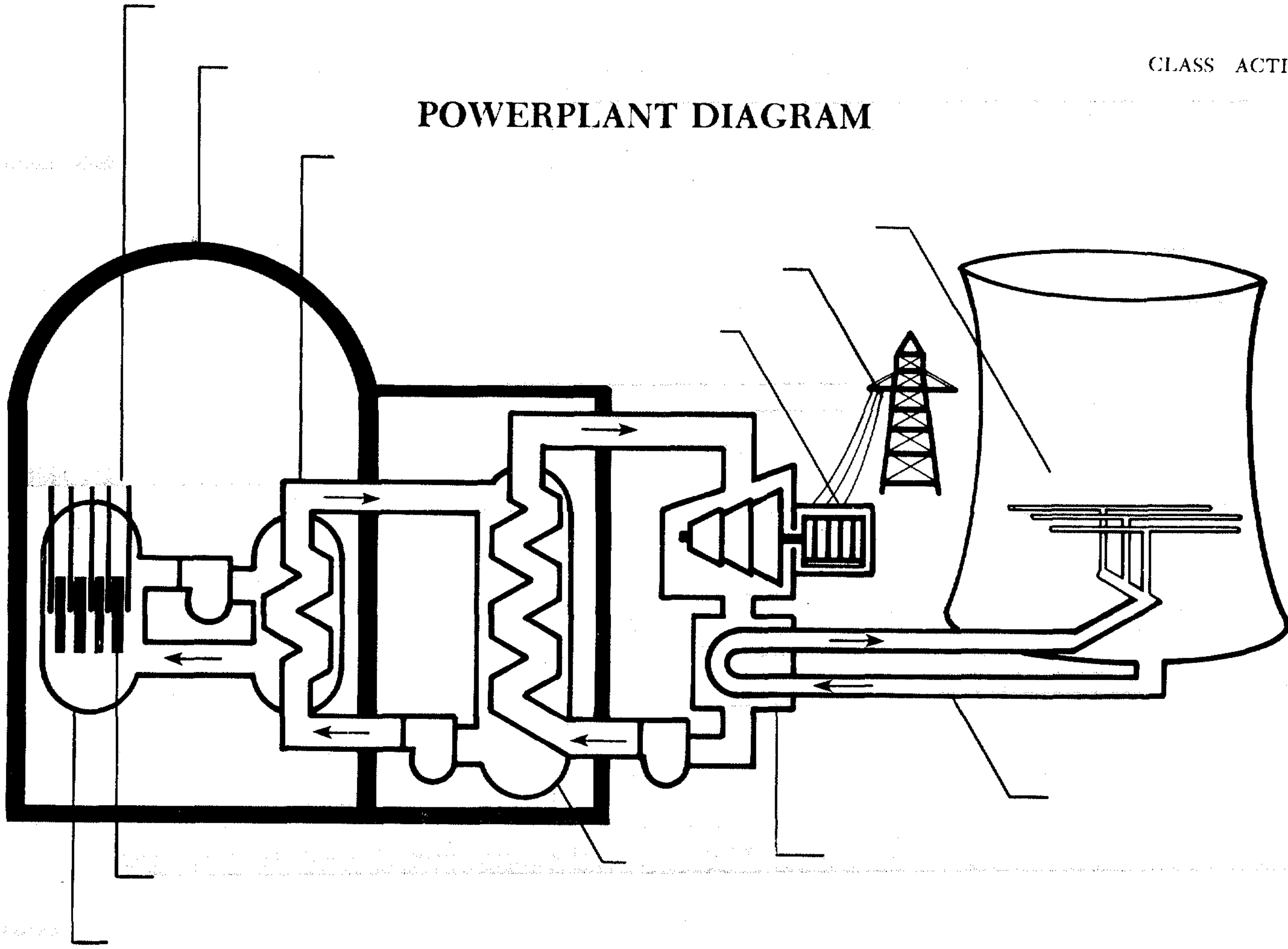

= steam


= helium gas


= steam converted back to water


= cooling water

POWERPLANT DIAGRAM

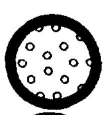


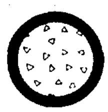
Liquid Metal Fast Breeder Reactor (LMFBR)

A. Identify the powerplant parts by writing the number of the correct powerplant part in the blank.

1. reactor
2. cooling loop
3. turbine-generator
4. condenser
5. control rods
6. steam-generator
7. cooling tower
8. containment building
9. heat exchanger
10. transmission lines
11. nuclear fuel

B. Color the separate loops using a different color for each loop. Then use the following symbols to show what is in each loop or part of a loop.

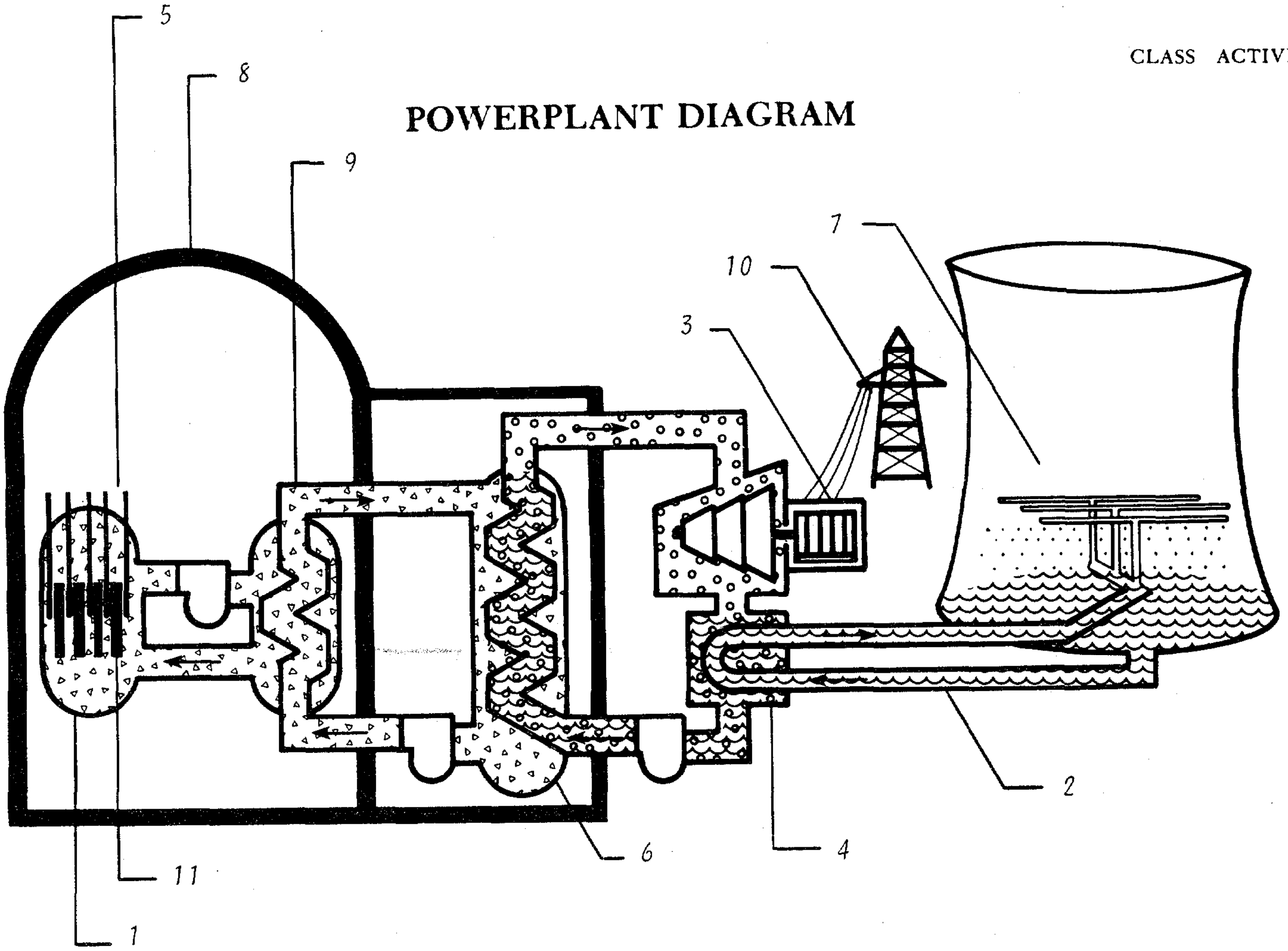
 = steam

 = sodium

 = steam converted back to water

 = cooling water

POWERPLANT DIAGRAM

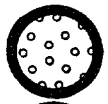


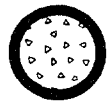
Liquid Metal Fast Breeder Reactor (LMFBR)

A. **Identify the powerplant parts by writing the number of the correct powerplant part in the blank.**

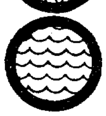
1. reactor
2. cooling loop
3. turbine-generator
4. condenser
5. control rods
6. steam-generator
7. cooling tower
8. containment building
9. heat exchanger
10. transmission lines
11. nuclear fuel

B. Color the separate loops using a different color for each loop. Then use the following symbols to show what is in each loop or part of a loop.

 = steam

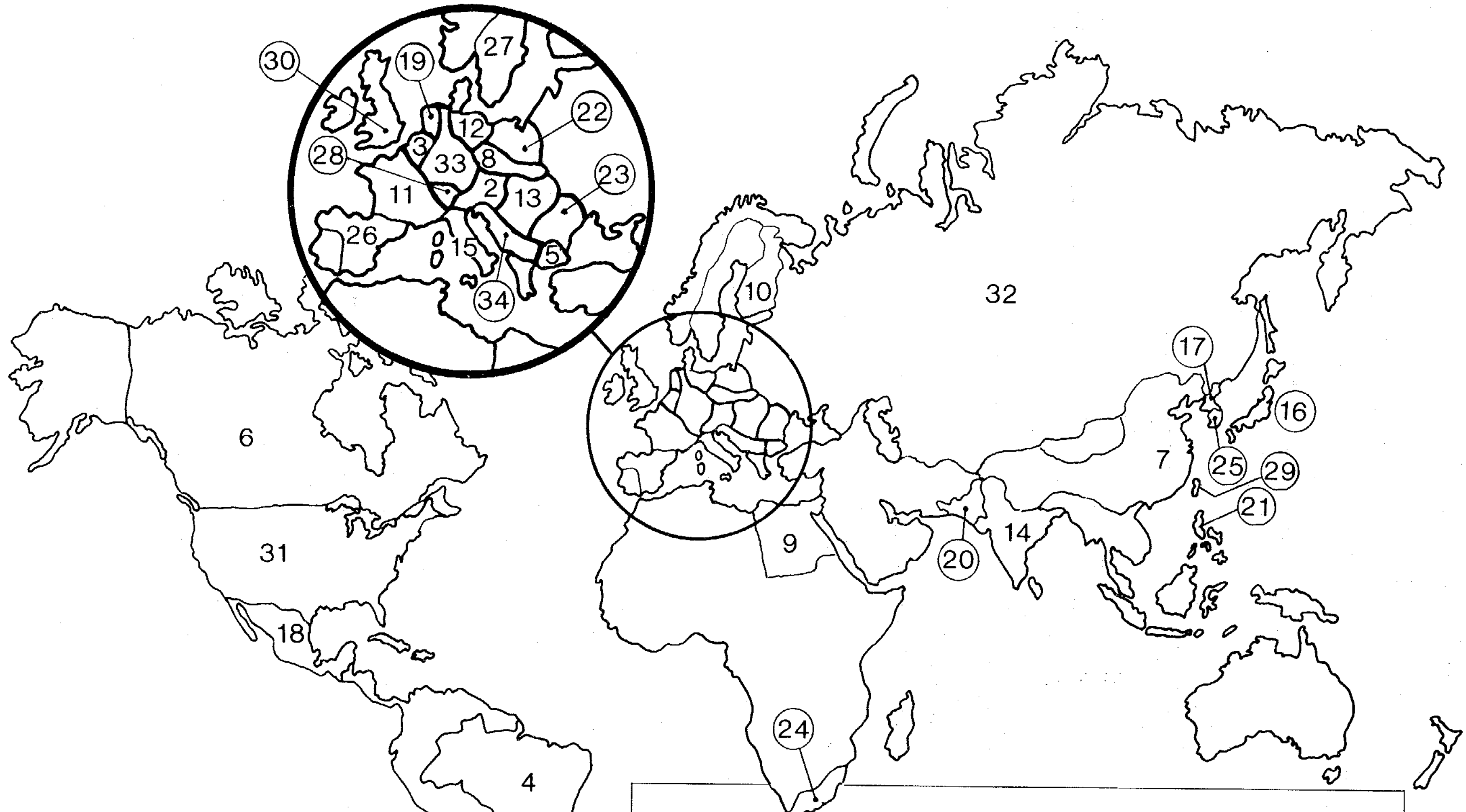
 = sodium

 = steam converted back to water

 = cooling water

Nuclear Power Around the World

Directions: Using colored pencils complete the legend on the map below; then color the countries on the map, matching them to your legend.



COUNTRIES WHERE NUCLEAR POWERPLANTS ARE LOCATED

1	Argentina	10	Finland	19	The Netherlands	27	Sweden
2	Austria	11	France	20	Pakistan	28	Switzerland
3	Belgium	12	East Germany	21	Philippines	29	Taiwan
4	Brazil	13	Hungary	22	Poland	30	United Kingdom
5	Bulgaria	14	India	23	Romania	31	United States
6	Canada	15	Italy	24	South Africa	32	USSR
7	China	16	Japan	25	South Korea	33	West Germany
8	Czechoslovakia	17	Korea	26	Spain	34	Yugoslavia
9	Egypt	18	Mexico				

This filmstrip reviews the processes of using uranium as a fuel to generate electricity and illustrates the relationship between different stages of the fuel cycle. The filmstrip can provide students with a "visit" to a nuclear powerplant and to other facilities involved in preparing fuel through pictures of actual plants in operation.

Filmstrip Summary

Uranium can be used for fuel in nuclear powerplants to make electricity. The process begins when uranium is mined and milled. The milled uranium, called yellowcake, is taken to a conversion plant where it is purified and mixed with fluoride, making uranium hexafluoride. This uranium hexafluoride is shipped to a gaseous diffusion plant where the percentage of uranium-235 in the uranium hexafluoride is increased from less than 1 percent to 3 percent. Enriched uranium is then taken to a fuel fabrication plant, where it is made into ceramic pellets. These fuel pellets are stacked one on top of the other and sealed in metal fuel rods. These fuel rods are gathered into fuel assemblies. In this form, the uranium is ready to be used as fuel in a nuclear powerplant.

The fuel assemblies are lowered into the reactor core. When uranium-235 fissions, it releases neutrons that can cause additional uranium atoms to fission. Once the chain reaction has started, control rods are used to regulate the speed of the nuclear chain reaction. After about one year, the assemblies are changed out or rotated. At this time, about one-third of the fuel assemblies are taken out. The spent fuel assemblies are currently stored in the plant's spent fuel pool. The Nuclear Waste Policy Act of 1982 provides a plan for building and using long-term storage facilities, called repositories, where highly radioactive spent fuel may be safely stored.

The nuclear chain reaction produces a great deal of heat energy. Water, kept under pressure so it will not boil and turn to steam, is pumped from the pressure vessel into steam generators. Inside these steam generators, heat is taken from the water that passed through the pressure vessel (the first loop), and is transferred to water in a second loop. Water in the second loop turns to steam. This steam is channeled to the turbine. The hot steam causes the turbine to spin, and the spinning turbine rotates an enormous electric generator, which produces electrical energy. Outside the plant this electricity is transferred to our homes and offices.

Introduction

This is the fourth of the four units that comprise *The Harnessed Atom*. It is an issues-oriented unit, providing the basic information necessary to make decisions about energy sources. The intent is to provide correct and easily understood information for the students.

Unit 4 includes suggested demonstrations and activities that require students to use and develop skills in computing, graphing, writing, map reading, interpreting, decision making, interviewing, and data collection. Also included are review exercises to help reinforce the students' understanding of basic scientific concepts.

The format of the Teacher Guide will allow you to remove the activity and review exercise pages for making ditto copies, photocopies, or transparencies.

Learning Objectives

The materials, activities, and review exercises in this unit are developed from the following learning objectives.

Lesson 1 Energy and Money

Students will be able to:

- ☐ describe the relationship of supply and demand
- ☐ explain the energy crisis
- ☐ discuss the factors a utility considers before building a powerplant
- ☐ identify the types of costs of building a powerplant

Lesson 2 Safety

Students will be able to:

- ☐ describe the safety features of a nuclear powerplant
- ☐ discuss safety concerns about nuclear power
- ☐ explain disposal of spent fuel

Lesson 3 Energy Decision Making

Students will be able to:

- ☐ describe the decision making process
- ☐ define risk assessment
- ☐ discuss the problems in energy decision making
- ☐ discuss the risks and benefits of nuclear energy

1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Supply and Demand"
- ☐ class activity "Percent of Electricity Produced by Nuclear Powerplants"

2. Introduce vocabulary.

Before students read Lesson 1, introduce vocabulary words by listing them on the chalkboard and pronouncing them correctly. Definitions can be found in the glossary at the end of the student reader.

construction costs	fuel costs	services
economics	goods	standard of living
embargoes	interest	supply and demand
energy crisis	operating costs	

3. Read Lesson 1 in student reader. (Page 105 in the student reader.)

4. After students have read Lesson 1, the following questions may be used for class discussion.

a. Have you bought anything recently that had its price affected by *supply and demand*? (There are some examples at toy stores, such as certain brands of dolls and games. Other examples can include such things as fruit and vegetables which change price as they come in and out of season, and certain brands of clothing that suddenly become popular.)

b. Do you know of any other countries where the *standard of living* is different than in the United States? (The answers to this question will vary widely from class to class, depending on the students' backgrounds and socioeconomic conditions. Places in the news can provide excellent examples; for instance, a country that is suffering from famine, or a country that is thriving because of new wealth could be discussed.)

c. Compare the projected *costs* that utilities use when they decide what type of powerplant to build with the costs your family considers when purchasing an automobile. (The types of costs are similar; for instance, an automobile has the cost of purchase, which is analogous to the construction costs of a powerplant; the cost of fuel [gasoline or diesel for automobiles, and coal, nuclear, or other fuels for powerplants]; and operation costs such as new tires, oil changes, and repairs for a car, which can be compared to the operating costs at the powerplant. When we buy automobiles, we often consider all of these types of costs.)

d. Can anyone in the class remember the *energy crisis*? What were their experiences when this was going on? (Answers will vary a great deal. Most middle school students may not recall the embargo at all; others may have waited in long gas lines, or even had a parent lose a job. If the class cannot remember anything, they may want to ask their parents, or have the teacher provide some of her or his personal stories.)

e. Suppose you were going to build a fort/tree house, go-cart, model, doll house, or stereo cabinet. What are some of the *decisions* you would have to make? (In order to build something for yourself, you will probably first place some kind of value on the project. How do you intend to use it? Is it only for fun? These questions may help you decide how much money you can spend. You must decide where to build the project, if it must be moved, where it will be used ultimately. You must decide if the project is temporary or permanent. This helps you to decide on the quality of the materials that are to be used. Other decisions will be color, size, special features, and cleaning up during and after construction.)

5. Assign and discuss the review exercise for Lesson 1. (Page 110 in the student reader.)

6. Assign the activity on "Supply and Demand."

Discuss in your class ways in which Mr. Smith's customers might respond to their gasoline supply problems.

7. Introduce "Percent of Electricity Produced by Nuclear Powerplants" activity.

Percentages from Energy Information Administration *Monthly Energy Review*, November, 1984, p. 83. All percentages have been rounded off to the nearest .5 percent. The percentage for 1984 is based on 11 months, January—November.

LESSON 1 REVIEW EXERCISE

A. Indicate whether the following costs are construction costs, fuel costs, or operating costs.

_______________ 1. Mining uranium.

_______________ 2. Decommissioning the powerplant.

_______________ 3. Building the powerplant.

_______________ 4. Doing the environmental studies needed before the powerplant can be built.

_______________ 5. Milling uranium ore.

_______________ 6. Replacing old fuel assemblies.

_______________ 7. Paying the powerplant workers.

_______________ 8. Updating training of powerplant workers.

_______________ 9. Making repairs and paying for general upkeep.

_______________ 10. Enriching the uranium.

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. America has a low standard of living. T F

2. Supply and demand dictate the value of a good or service. T F

3. OPEC stands for the Organization of Petroleum Exporting Countries. T F

4. Demand is how much of something is available. T F

5. Most experts say that we must use coal or nuclear power to produce the electricity that we need for the next few decades. T F

(Continued on next page)

C. Complete the following story with the appropriate words from the list below. You may use words more than once, or you may not use them at all.

supply	standard of living	demand
service	goods	image

The Spiders are America's newest and most popular rock and roll band, and everyone wants to hear their music. You could say that they are in ____________________. But the Spiders will only give their concerts in small auditoriums because they don't like the sound in large stadiums. This tends to limit the ____________________ of tickets to their concerts. In fact, people have been known to pay $100.00 for a single ticket!

"We consider playing a concert as performing a ____________________. It is our job and we want to do it well," the Spiders' lead singer Bob recently told our music reporter. "After we record them, records become ____________________, and they can be sold like orange juice or steam irons. Selling 8 million records has really improved our popularity. As a result, there is more ____________________ for our group's music than before."

LESSON 1 REVIEW EXERCISE

A. Indicate whether the following costs are construction costs, fuel costs, or operating costs.

fuel 1. Mining uranium.

operating 2. Decommissioning the powerplant.

construction 3. Building the powerplant.

construction 4. Doing the environmental studies needed before the powerplant can be built.

fuel 5. Milling uranium ore.

fuel 6. Replacing old fuel assemblies.

operating 7. Paying the powerplant workers.

operating 8. Updating training of powerplant workers.

operating 9. Making repairs and paying for general upkeep.

fuel 10. Enriching the uranium.

B. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. America has a low standard of living. (high) — T **F**

2. Supply and demand dictate the value of a good or service. — **T** F

3. OPEC stands for the Organization of Petroleum Exporting Countries. — **T** F

4. Demand is how much of something is available. — T **F**
(Demand is how much is wanted.)

5. Most experts say that we must use coal or nuclear power to produce the electricity that we need for the next few decades. — **T** F

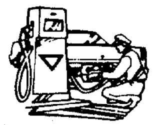
(Continued on next page)

C. Complete the following story with the appropriate words from the list below. You may use words more than once, or you may not use them at all.

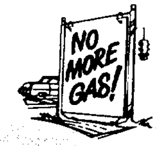
supply	standard of living	demand
service	goods	image

The Spiders are America's newest and most popular rock and roll band, and everyone wants to hear their music. You could say that they are in ___demand___. But the Spiders will only give their concerts in small auditoriums because they don't like the sound in large stadiums. This tends to limit the ___supply___ of tickets to their concerts. In fact, people have been known to pay $100.00 for a single ticket!

"We consider playing a concert as performing a ___service___. It is our job and we want to do it well," the Spiders' lead singer Bob recently told our music reporter. "After we record them, records become ___goods___, and they can be sold like orange juice or steam irons. Selling 8 million records has really improved our popularity. As a result, there is more ___demand___ for our group's music than before."



SUPPLY AND DEMAND



Finish the story by filling in the blanks. Words are listed that may be used for some of the answers. Some words may be used more than once. The other answers can be found by working arithmetic problems.

Possible Answers

supply   demand   shortage   surplus   raised   lowered

Mr. Smith, a gasoline station owner, received 200 gallons of gasoline each week. His 20 regular customers were used to buying all the gas they needed from him. Although some weeks some people bought more and some people bought less, the average customer bought 10 gallons a week. The total demand for gasoline each week at the station was (1) ____________ gallons. As you know, Mr. Smith's supply was (2) ____________ gallons. Everybody was pretty happy about the whole thing. The supply was equal to the (3) ________________.

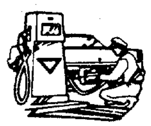
Mr. Smith charged $1.00 a gallon for gasoline, a price that was about the same as that charged by the other station in town. Each regular customer spent an average of (4) ____________ each week. Mr. Smith received (5) ____________ for the 200 gallons of gasoline he sold. When the other station reduced its price per gallon by a penny, four of Mr. Smith's regular customers deserted him and went across the street. He was still getting a delivery of 200 gallons a week, but now the demand was only (6) ____________ gallons. He had (7) ____________ gallons left over. This unbought quantity of gasoline is called a (8) ________________. To get rid of the extra gasoline, Mr. Smith (9) ________________ his price. His sixteen remaining regular customers bought up the (10) ________________ and took a few more pleasure trips into the city.

Several weeks later, Mr. Smith and the other station each received only 100 gallons of gasoline. Their suppliers were short of gasoline that week. Their customers' demands were still the same, so the pumps soon became empty. Halfway through the week, Mr. Smith had a (11) ________________ of gasoline. The sign in front of the station said, "No More Gas!" Also, by charging $1.00 a gallon, he didn't make enough to pay the costs of his station.

The next week he raised the price to $1.25 a gallon. The station across the street raised its price to $1.30 and his regular customers came back. Even at the higher price, most of his customers still had to buy gas to drive to work and do errands, so he sold all 100 gallons to his regular customers. He received (12) ____________ from selling the 100 gallons. The average amount of gas each customer used was (13) ____________ gallons. The average amount each of the 20 regular customers spent was (14) ____________.

Some of Mr. Smith's customers wanted to drive as much as they usually had, which required 10 gallons of gas. At the new prices, 10 gallons of gas cost (15)____________. Because they were on a fixed budget, these customers couldn't afford to spend more than $10.00 a week for gas. Some of the other station's customers came over to Mr. Smith's station, and the demand was greater than the (16)__________. Mr. Smith (17)__________ his gasoline prices again. Mr. Smith's customers weren't so happy anymore.

CLASS ACTIVITY



SUPPLY AND DEMAND

Finish the story by filling in the blanks. Words are listed that may be used for some of the answers. Some words may be used more than once. The other answers can be found by working arithmetic problems.

Possible Answers

supply demand shortage surplus raised lowered

Mr. Smith, a gasoline station owner, received 200 gallons of gasoline each week. His 20 regular customers were used to buying all the gas they needed from him. Although some weeks some people bought more and some people bought less, the average customer bought 10 gallons a week. The total demand for gasoline each week at the station was (1) 200 gallons. As you know, Mr. Smith's supply was (2) 200 gallons. Everybody was pretty happy about the whole thing. The supply was equal to the (3) demand.

Mr. Smith charged $1.00 a gallon for gasoline, a price that was about the same as that charged by the other station in town. Each regular customer spent an average of (4) $10.00 each week. Mr. Smith received (5) $200.00 for the 200 gallons of gasoline he sold. When the other station reduced its price per gallon by a penny, four of Mr. Smith's regular customers deserted him and went across the street. He was still getting a delivery of 200 gallons a week, but now the demand was only (6) 160 gallons. He had (7) 40 gallons left over. This unbought quantity of gasoline is called a (8) surplus. To get rid of the extra gasoline, Mr. Smith (9) lowered his price. His sixteen remaining regular customers bought up the (10) surplus and took a few more pleasure trips into the city.

Several weeks later, Mr. Smith and the other station each received only 100 gallons of gasoline. Their suppliers were short of gasoline that week. Their customers' demands were still the same, so the pumps soon became empty. Halfway through the week, Mr. Smith had a (11) shortage of gasoline. The sign in front of the station said, "No More Gas!" Also, by charging $1.00 a gallon, he didn't make enough to pay the costs of his station.

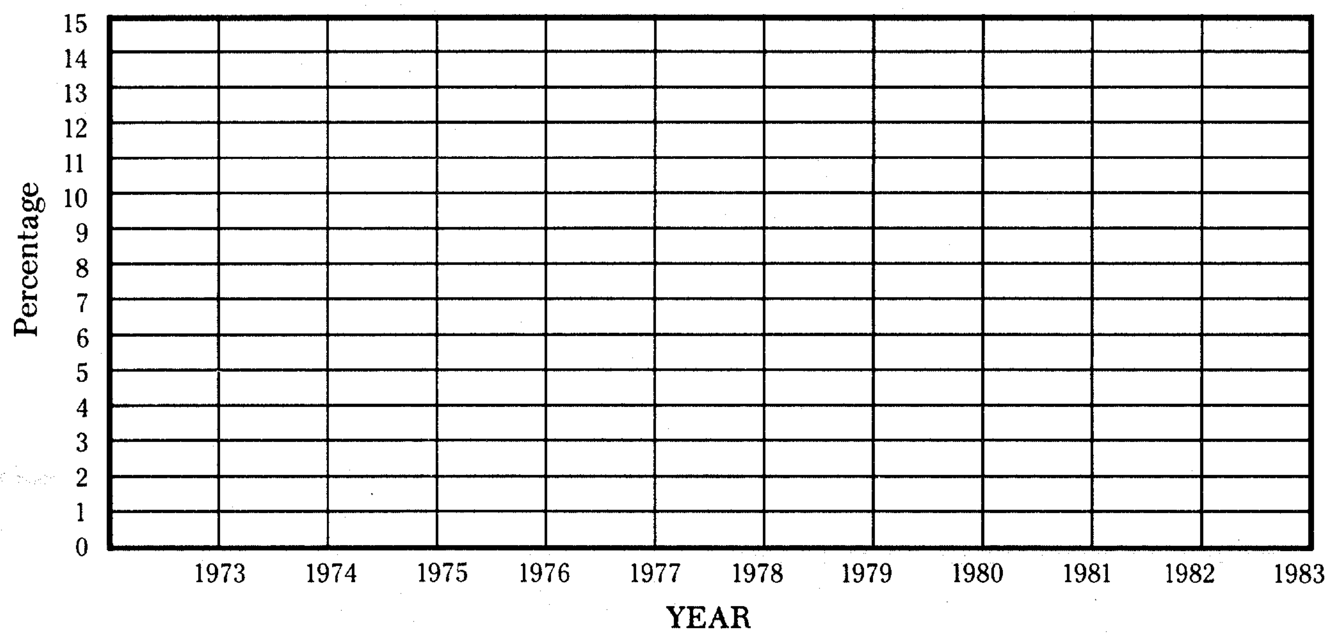
The next week he raised the price to $1.25 a gallon. The station across the street raised its price to $1.30 and his regular customers came back. Even at the higher price, most of his customers still had to buy gas to drive to work and do errands, so he sold all 100 gallons to his regular customers. He received (12) $125.00 from selling the 100 gallons. The average amount of gas each customer used was (13) 5 gallons. The average amount each of the 20 regular customers spent was (14) $6.25.

Some of Mr. Smith's customers wanted to drive as much as they usually had, which required 10 gallons of gas. At the new prices, 10 gallons of gas cost (15) $12.50. Because they were on a fixed budget, these customers couldn't afford to spend more than $10.00 a week for gas. Some of the other station's customers came over to Mr. Smith's station, and the demand was greater than the (16) supply. Mr. Smith (17) raised his gasoline prices again. Mr. Smith's customers weren't so happy anymore.

PERCENT OF ELECTRICITY PRODUCED BY NUCLEAR POWERPLANTS

1973 - 1983

Directions: The percentages of the electricity produced by nuclear powerplants in the United States from 1973 - 1983 are given below. Graph the data given. Then in a sentence or two explain what the graph shows.

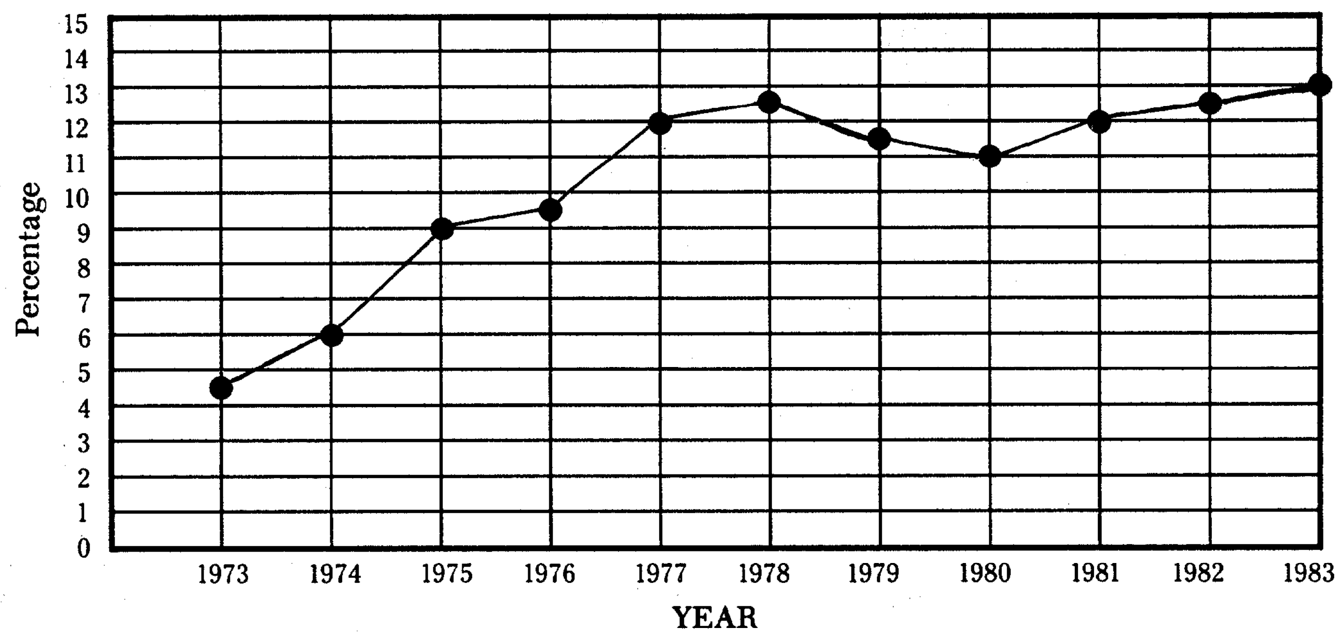


1973	4.5%	1977	12.0%	1981	12.0%
1974	6.0%	1978	12.5%	1982	12.5%
1975	9.0%	1979	11.5%	1983	13.0%
1976	9.5%	1980	11.0%		

PERCENT OF ELECTRICITY PRODUCED BY NUCLEAR POWERPLANTS

1973 - 1983

Directions: The percentages of the electricity produced by nuclear powerplants in the United States from 1973 - 1983 are given below. Graph the data given. Then in a sentence or two explain what the graph shows.



1973	4.5%	1977	12.0%	1981	12.0%
1974	6.0%	1978	12.5%	1982	12.5%
1975	9.0%	1979	11.5%	1983	13.0%
1976	9.5%	1980	11.0%		

The graph shows that the percentage of electricity produced by nuclear powerplants has risen from 4.5% in 1973 to 13% in 1983. Only in 1979 and 1980 did the percent of electricity from nuclear powerplants decline.

1. **Gather materials.**

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Nucleoglyphics"
- ☐ class activity "Selecting a Permanent Waste Repository Site"

2. **Have students read Lesson 2 in the student reader.** (Page 112 in the student reader.)

3. **The following questions may be used for class discussion after the students have read Lesson 2.**

a. Name some other industries that have strict *safety regulations*. What are some of these regulations and how are they helpful? (A few suitable answers might include transportation, especially the airlines, which are required to have many types of safety features ranging from seat belts to expensive radar and navigation equipment. Other examples include industries that work with explosives and hazardous materials.)

b. Discuss some of the ways that we could keep future generations from uncovering *nuclear waste repositories*. (One way that has been suggested is to make permanent signs that would warn people in a universal picture-language. Students will come up with ideas of their own.)

c. What are some examples of *backup safety systems* that you use in your day-to-day life? (There are many—e.g., emergency brake on car, back door on school bus, emergency lighting in public places.)

d. Discuss some well known disasters in history. Ask students if they have any ideas about how these disasters could have been prevented or alleviated by using *safety systems*? (This is a broad question that has many answers, and could even be assigned as an extra credit paper. Some well known disasters include the Hindenburg explosion in 1937, which was caused by using hydrogen gas in the Zepplin and could have been prevented by using helium; the Titanic, which hit an iceburg in 1912 causing 1,503 people to lose their lives. If the Titanic had better safety systems (e.g., enough life raft space for its passengers), many lives could have been spared. For more information, *The World Almanac* sites many different disasters.)

4. **Assign and discuss the review exercise for Lesson 2.** (Page 116 of the student reader.)

5. **Assign the "Nucleoglyphics" activity.**

6. **Introduce the activity "Selecting a Permanent Waste Repository Site."**

LESSON 2 REVIEW EXERCISE

A. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. The accident at Three Mile Island released large amounts of high-level radiation to the environment. T F

2. Radioactive materials used in nuclear powerplants cannot explode like the materials used in nuclear weapons. T F

3. Uranium fuel becomes highly radioactive in the reactor core. T F

4. Powerplant sites in the United States are located inside large cities so the electricity is close to the customer. T F

5. High-level nuclear waste repositories will be located deep in sandy soils. T F

6. The average American receives less than 1 percent of his or her total radiation exposure from the nuclear power industry. T F

7. High-level nuclear waste can remain radioactive for thousands of years. T F

8. After it is removed from the reactor, nuclear waste becomes less radioactive. T F

9. Every safety-related system in a nuclear powerplant has at least one backup safety system. T F

10. The United States is the only country in the world planning to store high-level radioactive wastes in geologic repositories. T F

(Continued on next page)

B . Complete the following story with the appropriate words from the list given. You may use some words in the list twice, while you may not need to use some words at all.

backup	public	safety
barriers	radioactive	sites
environment	radioactivity	technical

The ____________________ of the public is a main concern at nuclear powerplants. These powerplants have many ____________________ systems that are designed to make sure that the ____________________ materials powerplants produce are never released into the ____________________. The building where the reactor is located and many other reactor parts are designed to serve as ____________________ that keep radioactivity inside the reactor. In addition, every system that is necessary for safe operation must have a ____________________ system that can perform the same function if necessary.

C. List three aspects of nuclear powerplants that cause some people to worry.

1. ____
2. ____
3. ____

D. List three safety features that make nuclear powerplants safe.

1. ____
2. ____
3. ____

LESSON 2 REVIEW EXERCISE

A. Indicate whether each statement is true (T) or false (F) by circling the correct letter. If the statement is false, correct it to make it true.

1. The accident at Three Mile Island released large amounts of high-level radiation to the environment. (*not into the environment*) T F

2. Radioactive materials used in nuclear powerplants cannot explode like the materials used in nuclear weapons. T F

3. Uranium fuel becomes highly radioactive in the reactor core. T F

4. Powerplant sites in the United States are located inside large cities so the electricity is close to the customer. (*lightly populated areas*) T F

5. High-level nuclear waste repositories will be located deep in sandy soils. (*stable rock formations*) T F

6. The average American receives less than 1 percent of his or her total radiation exposure from the nuclear power industry. T F

7. High-level nuclear waste can remain radioactive for thousands of years. T F

8. After it is removed from the reactor, nuclear waste becomes less radioactive. T F

9. Every safety-related system in a nuclear powerplant has at least one backup safety system. T F

10. The United States is the only country in the world planning to store high-level radioactive wastes in geologic repositories. T F
(*Many countries are planning geologic repositories.*)

(Continued on next page)

B . Complete the following story with the appropriate words from the list given. You may use some words in the list twice, while you may not need to use some words at all.

backup	public	safety
barriers	radioactive	sites
environment	radioactivity	technical

The ___safety___ of the public is a main concern at nuclear powerplants. These powerplants have many ___safety___ systems that are designed to make sure that the ___radioactive___ materials powerplants produce are never released into the ___environment___. The building where the reactor is located and many other reactor parts are designed to serve as ___barriers___ that keep radioactivity inside the reactor. In addition, every system that is necessary for safe operation must have a ___backup___ system that can perform the same function if necessary.

C. List three aspects of nuclear powerplants that cause some people to worry.

1. radiation, radioactive materials, contamination of environment
2. waste disposal
3. terrorists could steal the fuel

D. List three safety features that make nuclear powerplants safe.

1. backup systems
2. containment systems
3. monitoring systems

POWERPLANT SAFETY

P O W E R P L A N T — S A F E T Y

∯ Σ ω π Δ ∯ Θ Ε Ω θ — Λ Ε Φ π θ Γ

Directions: Decipher the coded words by using the symbols given with POWERPLANT SAFETY.

1. _ _ _ _ _ _ _ _ _
Δ Ε Ξ Λ̣ Ε θ Λ̣ Σ Ω

2. _ _ _ _ _ _
ξ Ε γ α ψ ∯

_ _ _ _ _ _ _
Λ Γ Λ θ π ϑ Λ

3. _ _ _ _ _ _ _ _
Λ π γ ψ Δ Λ̣ θ Γ

4. _ _ _ _ _ _ _
ξ Ε Δ Δ Λ̣ π Δ

5. _ _ _ _ _   _ _ _ _
Λ ∯ π Ω θ   φ ψ π Θ

6. _ _ _ _ _ _ _ _ _ _ _
π Ω ∫ Λ̣ Δ Σ Ω ϑ π Ω θ

7. _ _ _ _ _ _ _ _ _ _ _
γ Σ Ω θ Ε Λ̣ Ω ϑ π Ω θ

8. _ _ _ _ _
ω Ε Λ θ π

9. _ _ _ _ _ _ _ _
δ π Σ Θ Σ δ Λ̣ γ

10. _ _ _ _ _ _ _ _ _ _
Δ π ∯ Σ Λ Λ̣ θ Σ Δ Γ

11. _ _ _ _ _ _ _ _ _ _
θ π γ λ Ω Σ Θ Σ δ Γ

12. _ _ _ _ _ _ _ _ _
ϑ Λ̣ Θ Θ Λ̣ Δ π ϑ Λ

NUCLEOGLYPHICS

CLASS ACTIVITY

P O W E R P L A N T   S A F E T Y

∯ Σ ω π Δ ∯ Θ E Ω θ   Λ E Φ π θ Γ

Directions: Decipher the coded words by using the symbols given with POWERPLANT SAFETY.

1. r a d i a t i o n
Δ E Ξ Ʌ̇ E θ Ʌ̇ Σ Ω

2. b a c k u p
ξ E γ α ψ ∯

s y s t e m s
Λ Γ Λ θ π ϑ Λ

3. s e c u r i t y
Λ π γ ψ Δ Ʌ̇ θ Γ

4. b a r r i e r
ξ E Δ Δ Ʌ̇ π Δ

5. s p e n t   f u e l
Λ ∯ π Ω θ   φ ψ π Θ

6. e n v i r o n m e n t
π Ω ∫ Ʌ̇ Δ Σ Ω ϑ π Ω θ

7. c o n t a i n m e n t
γ Σ Ω θ E Ʌ̇ Ω ϑ π Ω θ

8. w a s t e
ω E Λ θ π

9. g e o l o g i c
δ π Σ Θ Σ δ Ʌ̇ γ

10. r e p o s i t o r y
Δ π ∯ Σ Λ Ʌ̇ θ Σ Δ Γ

11. t e c h n o l o g y
θ π γ λ Ω Σ Θ Σ δ Γ

12. m i l l i r e m s
ϑ Ʌ̇ Θ Θ Ʌ̇ Δ π ϑ Λ

SELECTING A PERMANENT WASTE REPOSITORY SITE

Choose six team leaders from the class, divide the class into six groups, and as a class complete the following list. If you run out of class members, fill in the blanks with names of other teachers and students or even with names of your favorite celebrities. After the class has finished the list, transfer the names to the essay and the first map. When this is complete, the class should break into the teams and site a repository by using the maps and information provided in the essay.

Use last names only!

Your Classroom			Student	18.	______
Teacher's Name	1.	______	Student	19.	______
Team Leader	2.	______	Student	20.	______
Team Leader	3.	______	Student	21.	______
Team Leader	4.	______	Student	22.	______
Team Leader	5.	______	Student	23.	______
Team Leader	6.	______	Student	24.	______
Team Leader	7.	______	Student	25.	______
Student	8.	______	Student	26.	______
Student	9.	______	Student	27.	______
Student	10.	______	Student	28.	______
Student	11.	______	Student	29.	______
Student	12.	______	Student	30.	______
Student	13.	______	Student	31.	______
Student	14.	______	Student	32.	______
Student	15.	______	Student	33.	______
Student	16.	______	Student	34.	______
Student	17.	______	Student	35.	______

1 ________________land is an imaginary country that is about one-fourth the size of Australia. It is divided into six areas, called provinces. 1 ________________ land's provinces include the 2 ________________ Territory, 3 ________________, 4 ________________land, 5 ________________'s Ford, 6 ________________, and 7 West ________________. Nuclear powerplants are in wide use throughout the country; in fact, over 50 percent of 1 ________________land's electricity is provided in this fashion. As a result, the people in 1 ________________land have started to consider where they should build a repository for high-level radioactive wastes that their nuclear powerplants generate.

Many different things must be considered before siting the repository. These include the type of rock formations, the risk of earthquake damage, population density, the distance from powerplants and cities for transportation and safety, as well as environmental, social, and economic factors.

The types of suitable rock formations in 1 ________________land include: (a) granite, a very hard rock made of quartz crystals and other minerals; (b) tuff, a chalky rock with a hardened sponge-like structure; (c) basalt, a hard black/grey rock with the texture of a blackboard; and (d) salt domes, which are enormous underground columns of rock salt that are between 2 to 5 miles wide and that extend deep into the earth.

Each province has one possible repository site. For convenience, they are shown in the table below:

Province		Site
2 ________________ Territory	=	8 ________________ Mesa
3 ________________	=	9 ________________ Basin
4 ________________land	=	10 ________________ Shore
5 ________________'s Ford	=	11 ________________ Valley
6 ________________	=	Charles Hills
7 West ________________	=	12 ________________ Bay

The people of 1 ____________________land all agree that they need a repository. However, they do not all agree about where it should be located. For example, almost all areas in 3 ____________________ risk some earthquake damage. There is excellent fishing in 26 ____________________ Lakes, as well as 27 ____________________ Lake. People in 28 ____________________ville, 1 ____________________land's largest city, are very opposed to having the repository built on the islands where the city is located.

Social and economic factors also enter in. Most provinces are prosperous; however, 2 ____________________ Territory and 3 ____________________ suffer some social and economic hardships that may be measured by using such things as unemployment, family income, average education, and health of the citizens.

The table below gives the average unemployment figures for the main cities in 1 ____________________land:

Unemployment figures for each city reveal the general economic conditions of the province where the city is located. Building a repository in a province that has a high unemployment level would benefit the people living there because it would provide jobs.

City		Percent Unemployment
28 ____________________ville	=	8%
29 ____________________burg	=	34%
30 ____________________	=	28%
31 New ____________________	=	9%
32 Port ____________________	=	12%
Franklin	=	8%
33 ____________________	=	6%

The environment and natural beauty must also be considered before a repository site can be selected. For example 13 ____________________ National Park and 14 ____________________ Bird Sanctuary are both located in the northwest corner of 2 ____________________ Territory. 6 ____________________ Province is the home of the 15 ____________________ National Park, which is located in a natural area where such endangered species as the 16 ____________________ lemur, 17 ____________________ golden monkey, and the 18 ____________________ goat can be found. In addition, the endangered mud pickreli lives further south, on the shore of the Franklin River. 3 ____________________ Province is where the 19 ____________________ Indian Reservation is located. In the mountains to the south, the endangered 18 ____________________ goat roams. 4 ____________________land is for the birds. 20 ____________________ Bird Sanctuary in located on 21 ____________________ Island in the far northeast corner of 1 ____________________land, and this Sanctuary is home to 22 ____________________ flamingo, which is one of the two endangered species found in 4 ____________________land. The other is the 23 ____________________ whale, which lives offshore along the border of 4 ____________________land and 5 ____________________ Ford on the border it shares with 6 ____________________.

Between the two eastern seashore national parks are the scenic 34 ____________________ Shoals, where 1 ____________________ land's finest beaches are found. All of these places are special to certain groups of people. And as a result, many people worry about siting the repository near such places, even though the impact would most likely be very minor.

SELECTING A PERMANENT WASTE REPOSITORY SITE

Fill in the matrix below. The matrix will help your group decide which site is the most appropriate for a nuclear waste repository.

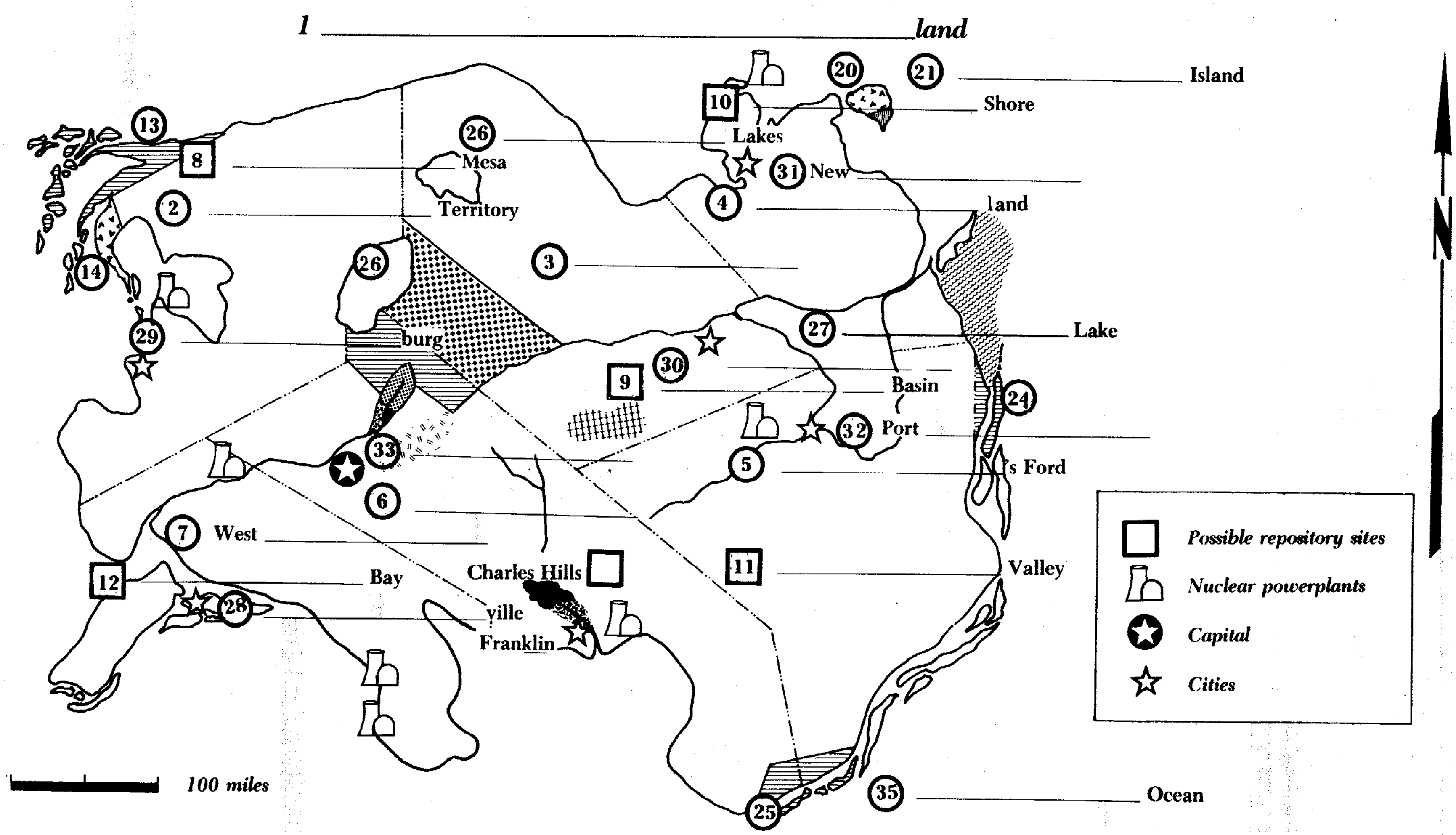
If this site is selected	8 **Mesa**	9 **Basin**	10 **Shore**	11 **Valley**	**Charles Hills**	12 **Bay**
Endangered species would not be displaced.						
The repository would be located 50 miles from large cities.						
The repository would be located in the appropriate type of rock formation.						
The repository would run little risk of earthquake damage.						
The repository could help a depressed economy.						
The repository would not be located in National Parks, recreation areas, or on other important lands.						

SELECTING A PERMANENT WASTE REPOSITORY SITE

Fill in the matrix below. The matrix will help your group decide which site is the most appropriate for a nuclear waste repository.

If this site is selected	8 Mesa	9 Basin	10 Shore	11 Valley	Charles Hills	12 Bay
Endangered species would not be displaced.	✓		✓	✓		✓
The repository would be located 50 miles from large cities.	✓			✓		
The repository would be located in the appropriate type of rock formation.	✓			✓	✓	✓
The repository would run little risk of earthquake damage.	✓		✓	✓	✓	✓
The repository could help a depressed economy.	✓	✓		✓		
The repository would not be located in National Parks, recreation areas, or on other important lands.		✓	✓	✓	✓	✓

The boxes checked will depend on the opinions of the group doing the activity.



mud pickreli

22 ____________________ Flamingo

17 ____________________ Golden Monkey

18 ____________________ Goat

23 ____________________ Whale

14 ____________________ Bird Sanctuary

20 ____________________ Bird Sanctuary

19 ____________________ Indian Reservation

16 ____________________ Lemur

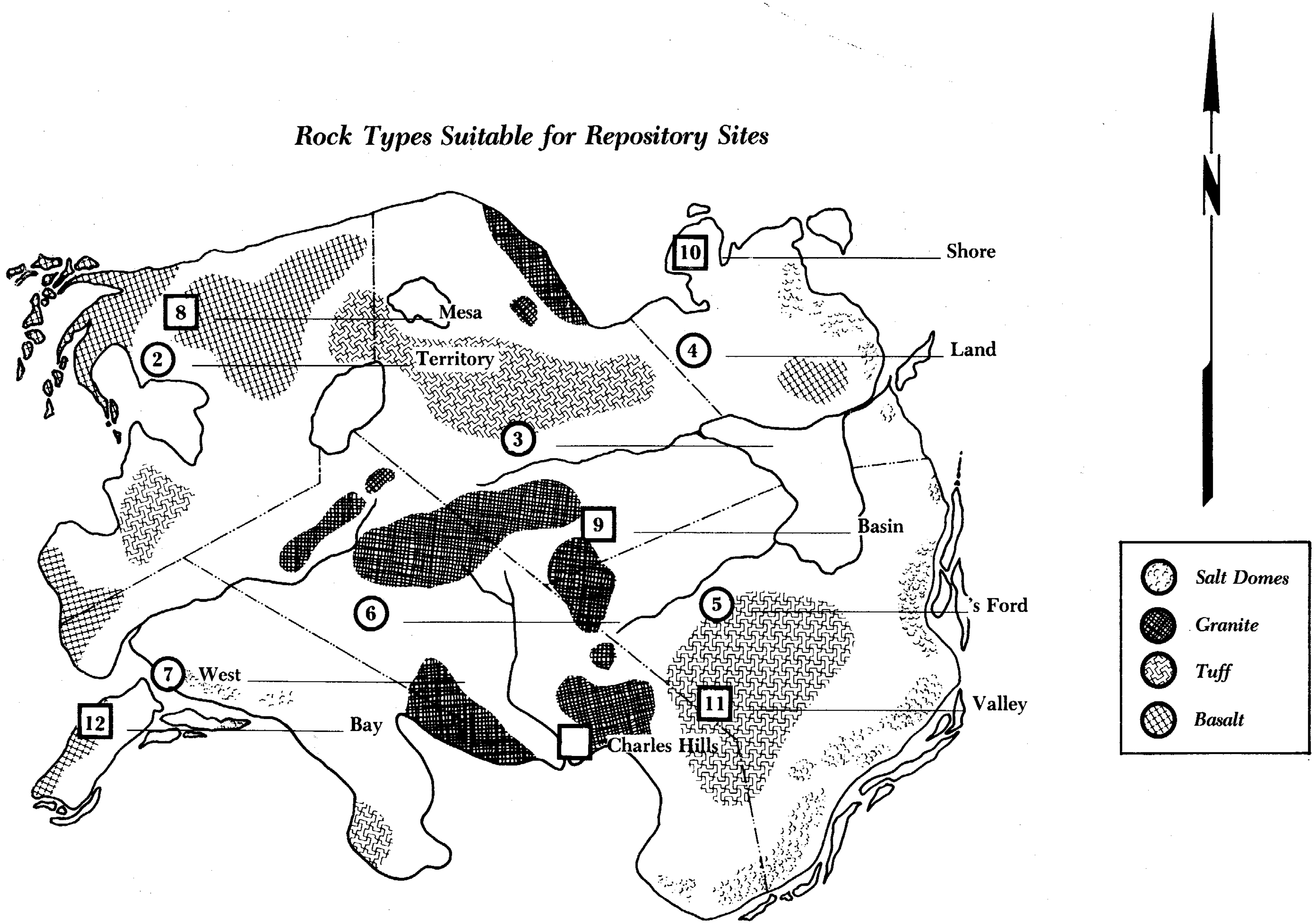
13 ____________________ National Park

15 ____________________ National Park

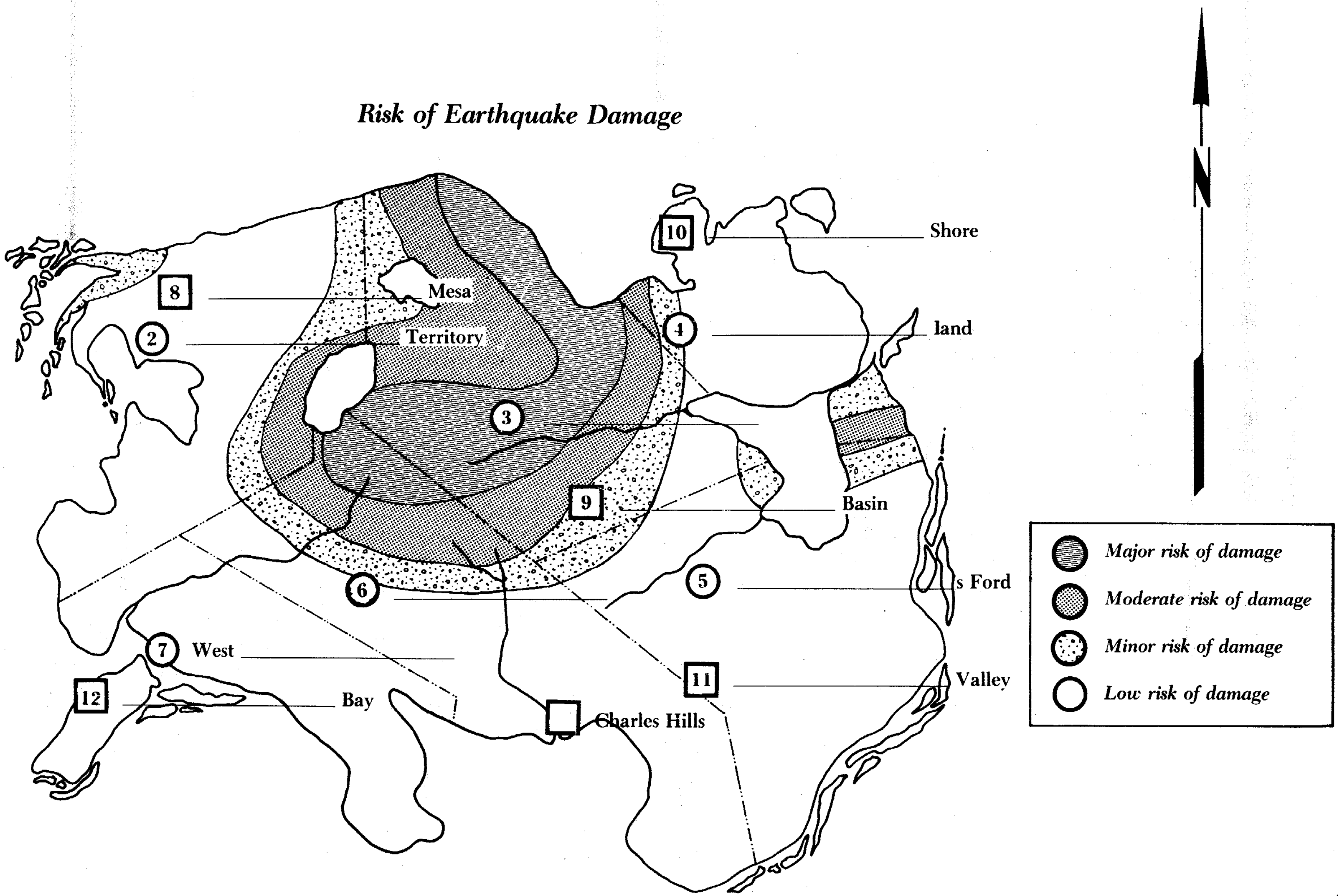
24 ____________________ National Park

25 ____________________ National Park

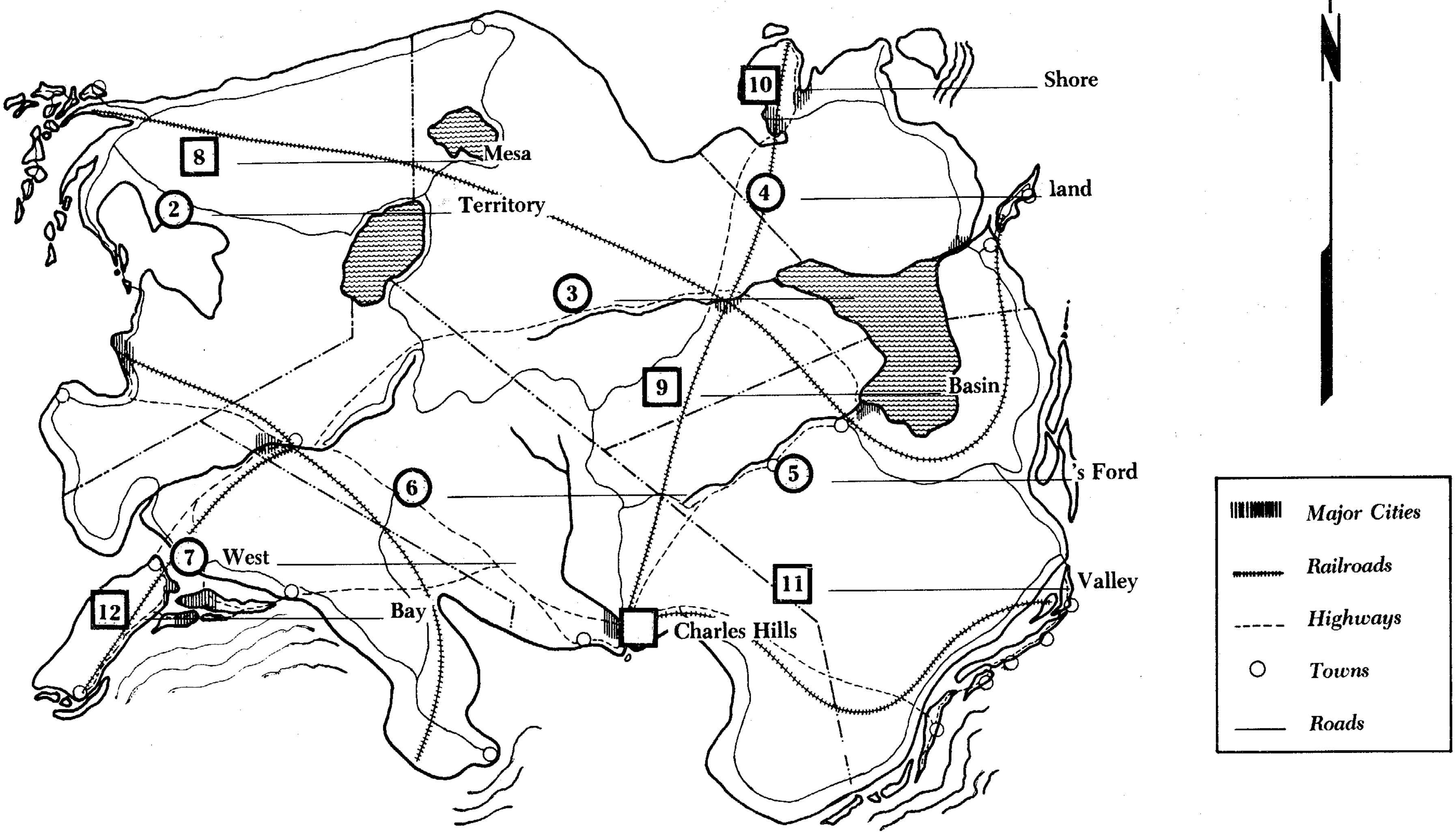
Rock Types Suitable for Repository Sites



Risk of Earthquake Damage



Population Distribution



1. Gather materials.

- ☐ student reader for each student
- ☐ review exercise for each student
- ☐ class activity "Nuclear Energy—Benefits and Problems"

2. Introduce vocabulary.

Introduce the vocabulary word before the students read the lesson. The definition can be found in the glossary at the end of the student reader.

risk assessment

3. Read Lesson 3 in student reader. (Page 118 in the student reader.)

4. The following questions may be used for class discussion when students have completed the assigned reading.

a. What should the *role of nuclear energy be in our future*? (Answers to this question will vary widely, but the discussion should help students to form constructive opinions. Students should be encouraged to express their own opinions.)

b. What are some examples of other topics where you can use the *decision-making techniques* that were outlined in Lesson 3? (Students' answers will vary.)

c. What are some of the *risks* that you take each day? What are some of the risks that you take on a weekly or monthly basis? (Students' answers will vary.)

d. What are some examples of things that people think are more *risky* than they actually are? (Students' answers will vary.)

e. What are some of the things that people think are safe, but that actually involve some *risks*? (Students' answers will vary.)

f. Why is the United States *using more electricity* as opposed to other energy sources? (Remember that electricity is a secondary energy source as opposed to uranium, fossil fuels, or solar power, which are primary energy sources. We are using more electricity partly because it can be produced from a number of energy sources. Also, the power lines for moving electricity to points of use are already in place.)

5. Assign and discuss the review exercise for Lesson 3. (Page 122 in the student reader.)

You may choose to put the following list of words on the board for students to choose answers from for Section B.

automobiles	fusion converters	trains
benefits	oil	uranium
coal	risk assessment	water power
electricity	risks	

6. **Assign the question "What are the risks and benefits of nuclear energy?"**

   This question ends the reading assignment in Lesson 3 (p. 120). It can be used for group discussion or as a written assignment.

7. **Assign the activity "Nuclear Energy—Benefits and Problems."**

8. **Review all materials.**

9. **Administer the posttest.**

1. c	6. b	11. d	16. c	21. b
2. c	7. d	12. c	17. a	22. c
3. d	8. b	13. b	18. c	23. b
4. d	9. a	14. b	19. b	24. d
5. a	10. d	15. a	20. a	25. c

LESSON 3 REVIEW EXERCISE

A. Name six energy sources and then identify a problem involved in using each source as a fuel to make electricity.

Energy Source	Problem
1. ______________________	______________________
2. ______________________	______________________
3. ______________________	______________________
4. ______________________	______________________
5. ______________________	______________________
6. ______________________	______________________

B. From the reading, select the word that best fits the statement.

1. Most experts predict that in the future the United States will rely on ______________ and ______________ to produce electricity.
2. In making decisions, many people balance the ______________ and the ______________.
3. Many people were afraid to use ______________, ______________, and ______________ when they were first invented.
4. An area of science called ______________ ______________ studies and compares the hazards of different industries.

C. What are three steps that can be used to help make an informed decision?

1. ____
2. ____
3. ____

LESSON 3 REVIEW EXERCISE

A. Name six energy sources and then identify a problem involved in using each source as a fuel to make electricity.

	Energy Source	Problem
1.	coal	hazardous to mine, air pollution
2.	uranium	hazardous to mine, radioactive waste
3.	water	building dams affects rivers and floods land
4.	oil	limited supply, foreign dependence, air pollution
5.	wind and sun	useful only when wind blows and sun shines
6.	solar cells	hazardous to mine and process materials

B. From the reading, select the word that best fits the statement.

1. Most experts predict that in the future the United States will rely on coal and uranium to produce electricity.
2. In making decisions, many people balance the benefits and the risks.
3. Many people were afraid to use automobiles, trains, and electricity when they were first invented.
4. An area of science called risk assessment studies and compares the hazards of different industries.

C. What are three steps that can be used to help make an informed decision?

1. define the problem
2. gather information
3. evaluate the information

NUCLEAR ENERGY — BENEFITS AND PROBLEMS

The following is a list of benefits and problems associated with nuclear powerplants. A key word or phrase in each item is printed in bold type. Read the list and put a (B) in the blank if it is a benefit, a (P) if it is a problem.

______ Less need for mining and **TRANSPORT** of fuel

______ No **POLLUTANTS** from burning fuel

______ Less reliance on **IMPORTED FUEL**

______ Could be targets for **TERRORISTS**

______ The fuel **COST** of a nuclear powerplant is lower than fuel costs for fossil fuel plants

______ Reactors produce **LESS WASTE** than fossil fuel plants do

______ Higher **COST TO BUILD**

______ Large amounts of **PLUTONIUM** could lead to spread of nuclear weapons

______ Possibility of **RADIATION ESCAPING**

______ **RADIOACTIVE WASTE** must be handled and disposed of safely for thousands of years

Now that you have identified the problem areas, look at the arguments below. Each one concerns a problem area and offers arguments for (PRO) and against (CON) expansion of nuclear energy. Complete the arguments by inserting a KEY WORD (in capitals above) into the blanks for each problem area.

PRO: The ______________________ is made into a type of glass or ceramic, put into special containers, and stored in places like salt beds which have been undisturbed for millions of years.

CON: It takes thousands of years for the ______________________ to lose its radioactive properties. We cannot ensure safe disposal for thousands of years and future societies may be hurt.

PRO: In more than 20 years of commercial nuclear powerplant operation, no one has suffered any ill effects brought on by ______________________.

CON: There's always a chance that an accident or mechanical malfunction could present the danger of ______________________.

PRO: Regulations and safeguards can be strictly enforced to keep the ______________________ out of the hands of terrorists. This radioactive waste is usually sealed in an unbreakable capsule right after the fuel processing.

CON: Just 10 pounds of radioactive ______________________ is enough to make an atom bomb.

NUCLEAR ENERGY — BENEFITS AND PROBLEMS

The following is a list of benefits and problems associated with nuclear powerplants. A key word or phrase in each item is printed in bold type. Read the list and put a (B) in the blank if it is a benefit, a (P) if it is a problem.

__B__ Less need for mining and **TRANSPORT** of fuel

__B__ No **POLLUTANTS** from burning fuel

__B__ Less reliance on **IMPORTED FUEL**

__P__ Could be targets for **TERRORISTS**

__B__ The fuel **COST** of a nuclear powerplant is lower than fuel costs for fossil fuel plants

__B__ Reactors produce **LESS WASTE** than fossil fuel plants do

__P__ Higher **COST TO BUILD**

__P__ Large amounts of **PLUTONIUM** could lead to spread of nuclear weapons

__P__ Possibility of **RADIATION ESCAPING**

__P__ **RADIOACTIVE WASTE** must be handled and disposed of safely for thousands of years

Now that you have identified the problem areas, look at the arguments below. Each one concerns a problem area and offers arguments for (PRO) and against (CON) expansion of nuclear energy. Complete the arguments by inserting a KEY WORD (in capitals above) into the blanks for each problem area.

PRO: The __radioactive waste__ is made into a type of glass or ceramic, put into special containers, and stored in places like salt beds which have been undisturbed for millions of years.

CON: It takes thousands of years for the __radioactive waste__ to lose its radioactive properties. We cannot ensure safe disposal for thousands of years and future societies may be hurt.

PRO: In more than 20 years of commercial nuclear powerplant operation, no one has suffered any ill effects brought on by __radiation escaping__.

CON: There's always a chance that an accident or mechanical malfunction could present the danger of __radiation escaping__.

PRO: Regulations and safeguards can be strictly enforced to keep the __plutonium__ out of the hands of terrorists. This radioactive waste is usually sealed in an unbreakable capsule right after the fuel processing.

CON: Just 10 pounds of radioactive __plutonium__ is enough to make an atom bomb.

In the blank that precedes each question, write the letter of the answer that *best* completes each statement.

____ 1. Which one of the following is NOT a primary energy source?

a. solar energy.
b. fossil fuel energy.
c. electrical energy.
d. nuclear energy.

____ 2. Most electricity in the United States is produced by using ______________ to turn turbine-generators.

a. coal.
b. oil.
c. steam.
d. uranium.

____ 3. The government regulates utilities because ______________________________.

a. a utility provides an essential service.
b. it would be wasteful and costly for more than one utility to serve an area.
c. a utility must provide its product or service at a cost people can afford to pay.
d. all of the above.

____ 4. Nuclear powerplants are different from other kinds of powerplants. This is because at nuclear powerplants ______________________________.

a. pollution is released into the atomsphere.
b. water is boiled to produce steam.
c. electricity is produced.
d. the heat used to make the steam is produced by fissioning atoms.

____ 5. The type of radiation that can be stopped by a piece of notebook paper is ____.

a. alpha.
b. beta.
c. gamma.
d. X.

____ 6. The amount of time it takes for a quantity of radioactive material to lose half of its radioactivity is its ______________________.

a. atomic number.
b. half-life.
c. radiation ratio.
d. radiation life.

____ 7. You can protect yourself from radiation by ____________________.

a. going up to a higher elevation.
b. increasing the time you are exposed.
c. increasing water intake.
d. getting further away from the radiation source.

____ 8. We CANNOT detect ionizing radiation with ____________________.

a. Geiger counters.
b. our senses.
c. photographic plates.
d. film badges.

____ 9. Fission is ____ to release energy.

a. splitting the nucleus of an atom.
b. joining the nuclei of two atoms.
c. splitting the electron of an atom.
d. joining the electrons of two atoms.

____ 10. A suntan is the result of exposure to ____________________.

a. atmospheric conversion.
b. evaporation.
c. heat.
d. radiation.

____ 11. The joining together of hydrogen isotopes to form a new atom and release energy is called ____________________.

a. combination.
b. generation.
c. fission.
d. fusion.

____ 12. In today's nuclear powerplants the primary fuel used is ____________________.

a. helium.
b. deuterium.
c. uranium.
d. tritium.

____ 13. A neutron added to the nucleus of a uranium-235 atom, causing it to become unstable and split apart, is an example of a ________________.

a. chemical reaction.
b. nuclear reaction.
c. electrical reaction.
d. mechanical reaction.

____ 14. In America we generate what percent of our electricity by using nuclear fission?

a. 5%
b. 13%
c. 33%
d. 42%

____ 15. The U.S. Government agency responsible for licensing and overseeing the construction and operation of nuclear powerplants is the __________.

a. Nuclear Regulatory Commission (NRC).
b. Department of Energy (DOE).
c. U.S. Congress.
d. Senate Committee on Energy.

____ 16. Energy given off or released by unstable isotopes is called ________________.

a. electricity.
b. conversion.
c. radiation.
d. chemistry.

____ 17. Uranium is enriched to ________________.

a. increase the percent of uranium-235 atoms.
b. decrease the percent of uranium-235 atoms.
c. increase the percent of uranium-238 atoms.
d. decrease the percent of uranium-238 atoms.

____ 18. Because waste from a nuclear powerplant is radioactive, we ______________.

a. burn it at high temperatures.
b. freeze it.
c. bury it in suitable rock formations for thousands of years.
d. isolate it for 10 years until it loses all of its radioactivity.

____ 19. The reactor, which is the heart of a nuclear powerplant, is where ____________.

a. electricity is generated.
b. fission takes place.
c. heated water is cooled.
d. steam turns the turbine.

____ 20. So that they will produce a nuclear chain reaction, neutrons are slowed down by ____________________.

a. a moderator.
b. an accelerator.
c. a decelerator.
d. fuel rods.

____ 21. In the United States, low-level nuclear wastes ____________________.

a. come mainly from nuclear powerplants.
b. make up the largest part of radioactive wastes from a nuclear powerplant.
c. make up only a small fraction of the radioactive wastes from a nuclear powerplant.
d. are not produced at nuclear powerplants.

____ 22. When the control rods are slowly raised from the core of the reactor ____________.

a. there are fewer neutrons available to cause fission.
b. the nuclear chain reaction slows down.
c. the nuclear chain reaction speeds up.
d. the temperature in the core decreases.

____ 23. Before it is used in the reactor, nuclear fuel is ____________________.

a. not radioactive.
b. slightly radioactive.
c. highly flammable.
d. highly radioactive.

____ 24. A breeder reactor ____________________.

a. is a fusion reactor.
b. uses sodium for fuel.
c. enriches uranium.
d. makes more fuel that it uses.

____ 25. Submerging spent fuel in the spent fuel pool ________________.

a. keeps the fuel moist so it will not dry out and flake apart.
b. transfers the radiation into the water, where it can be filtered out.
c. provides shielding while the fuel begins the process of radioactive decay.
d. heats the water in the reactor's first loop.

Appendix A
The Harnessed Atom as a Learning Center

The Harnessed Atom teacher kit is ideal for adaptation to the learning center concept. A learning center is an effective way to present the concepts introduced in *The Harnessed Atom* curriculum and provide the necessary materials for individualized instruction. A learning center can provide enrichment materials to all students in a classroom who are engaged in a common unit of study.

Classroom learning centers can be developed in all shapes and sizes. They can range from materials in a cardboard box to a table with several chairs and media equipment. Teachers can be creative and offer a challenge to students in developing the learning center for their classrooms. However, in order to contribute to learning in the classroom environment, each learning center should include:

a. *instructions* to explain what the students are to do. These instructions should be simple and clearly stated, displayed at the center, and discussed with the class before the learning center is used.

b. a statement of the *purpose* of the center so that students understand what is expected of them.

c. *furniture, materials, and media* that students need to accomplish their work at the center, conveniently arranged.

d. *task cards* to provide students with learning alternatives ranging from simple to complex and from concrete to abstract. A selection of several tasks will allow students to choose those that fit their abilities, interests, and learning styles.

e. *procedures* for evaluation that are discussed with students in advance. Students may provide their own evaluation and check their own progress.

Suggestions for a Management System for the Learning Center

To manage the learning center you will need:

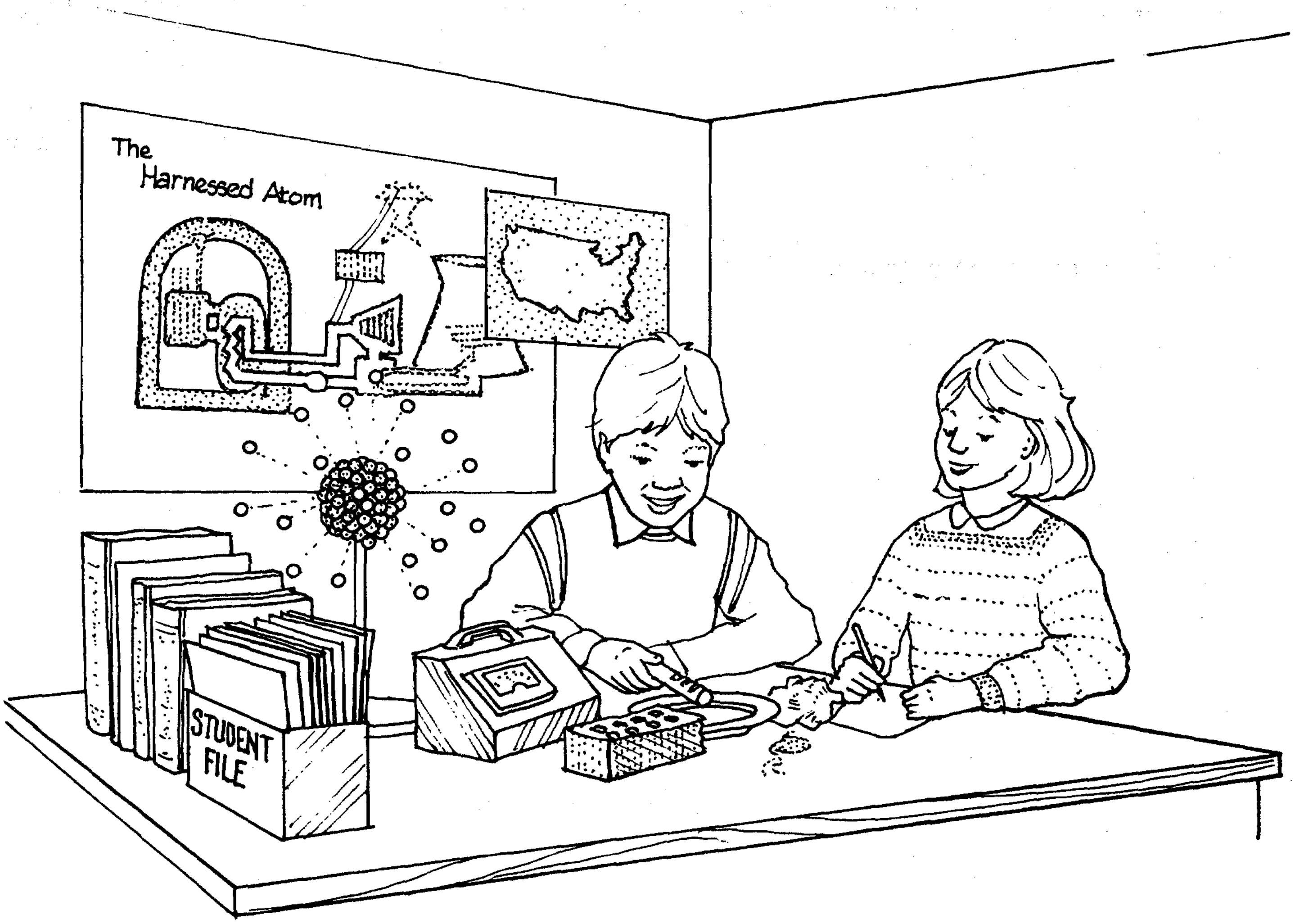
- ☐ a schedule that shows when each student or group of students use the center;
- ☐ a chart that lists each learning task, application, product, and evaluation for each lesson. (Student names can be listed under each heading as they complete that step.);
- ☐ a file folder for each student for management information; and
- ☐ a task card for each student.

Task cards for Units 1, 2, 3, and 4 have been provided in this appendix.

Arranging the Learning Center in the Classroom

When you set up your learning center, keep in mind that each center needs the following:

- ☐ convenient furniture arrangement;
- ☐ space for materials, supplies, and equipment;
- ☐ a place to display student products;
- ☐ a variety of multi-media materials on the topic.



Learning Center Bibliography

Change for children. Kaplan, Kaplan, Madsen, and Taylor. Goodyear Publishing Company, Pacific Palisades, California. 1973. (If you are beginning at "square one.")

Instructor's big idea book. The Instructor Publication's Publications, Inc., Dansville, New York 14437. (750 do-its and use-its—game boards, puzzles, reproducible work sheets, task cards, cartoons, etc.)

Nooks, crannies, and corners. Center stuff for nooks, crannies, and corners. Cornering creative writing. Pumpkins, pinwheels, and peppermint packages. Forte, Pangle, and Tupa. Incentive Publications, Inc., Post Office Box 12522, Nashville, Tennessee 37212. (Learning centers, games, activities, and ideas for elementary classrooms.)

One at a time all at once: the creative teacher's guide to individualized instruction without anarchy. Jack E. Blackburn and W. Conrad Powell. Goodyear Publishing Company, Pacific Palisades, California. 1976. (Lots of ideas for creating classroom learning centers.)

Thumbs up. Deb Holmes and Tom Christie. Good Apple, Inc., Box 299, Carthage, Illinois 62321. (For units: this collection contains a complete assortment of pictures, teacher and student introductions, beginning activities, background information, creative activities, contract, and closing activities for each of 19 topics.)

Unit 1, Lesson 1 **Energy Basics**

Date:____________________
Student:____________________

Vocabulary: Spelling of italicized words __________________ % Correct
Definitions of words __________________ % Correct
Usage in sentences __________________ % Correct

Comprehension:
1) Write a brief comparison of primary and secondary sources of energy.
2) Draw and label an illustration of one form of energy conversion.
3) Give an example not used in the student reader for potential and kinetic energy.
4) Review Exercise—Lesson 1.
5) "Cryptoglyphics."

Application: "Which Has More Heat Energy, a Peanut or a Walnut?"

Product: Conduct an interview using "The Good Old Days."

Evaluation: ____

CONTRACT Circle your choice: A B C Sign: ____________________

C 75% correct on the Vocabulary in this lesson.
Complete #1, #4, and #5 of the Comprehension selections.
Complete the Application "Which Has More Heat Energy, a Peanut or a Walnut?"
Complete the Product.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #1, #2, #4, and #5 of the Comprehension selections.
Complete the Application "Which Has More Heat Energy, a Peanut or a Walnut?"
Complete the Product. Do two interviews.
Write a comparison of the energy needs that would fit the lifestyles of a rural family to that of a large city family.
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all five of the Comprehension selections.
Complete the Application "Which Has More Heat Energy, a Peanut or a Walnut?"
Complete the Product. Do two interviews.
Using your imagination, describe a new source of energy.
Write a self-evaluation judging your performance and achievement.

Unit 1, Lesson 2 **Electricity Basics**

Date:____________________
Student:____________________

Vocabulary: Spelling of italicized words ____________% Correct
Definitions of words ____________% Correct
Usage in sentences ____________% Correct

Comprehension:
1) Write a short paragraph in your own words that tells about the production of electricity.
2) Write a paragraph explaining why the Government regulates utilities.
3) Tell what part electrons play in the electricity process.
4) Review Exercise—Lesson 2.

Application: "Make a Motor."

Product: "How to Read an Electric Meter."

Evaluation: ____

CONTRACT Circle your choice: A B C Sign:____________________

C 75% correct on the Vocabulary in this lesson.
Complete #3 and #4 of the Comprehension selections.
Choose a partner and build a motor.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #2, #3, and #4 of the Comprehension selections.
Choose a partner and build a motor.
Complete "How to Read an Electric Meter."
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all four of the Comprehension selections.
Choose a partner and build a motor.
Complete "How to Read an Electric Meter."
Read your home electric meter daily for two weeks. Record the kilowatt-hours daily.
Write a self-evaluation judging your performance and achievement.

Unit 2, Lesson 1 **Atoms And Isotopes**

Date:____________________
Student:____________________

Vocabulary: Spelling of italicized words ____________% Correct
Definitions of words ____________% Correct
Usage in sentences ____________% Correct

Comprehension: 1) Using information given on the periodic table, draw a model of the atomic structure of three elements.
2) Review Exercise—Lesson 1.
3) "Name That Isotope."

Application: "The Mystery Box."

Product: "Atom Model."

Evaluation: ____________________

CONTRACT Circle your choice: A B C Sign:____________________

C 75% correct on the Vocabulary in this lesson.
Complete one of the Comprehension selections.
Prepare and conduct the "Mystery Box" exercise for another student.
Build and label one model of an atom of an element of your choice.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete two of the Comprehension selections.
Organize and conduct two "Mystery Box" exercises.
Build and label two models of atoms (of display quality).
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all three Comprehension selections.
Organize and conduct four "Mystery Box" exercises; make a bar-graph of the results.
Build and label two models of atoms (of display quality).
Pretend you have just discovered a new element. Write a description of its characteristics from its placement on the periodic table.
Write a self-evaluation judging your performance and achievement.

Unit 2, Lesson 2 — **Radiation And Radioactive Decay**

Date:____________________________
Student:____________________________

Vocabulary: Spelling of italicized words ____________________% Correct
Definitions of words ____________________% Correct
Usage in sentences ____________________% Correct

Comprehension:
1) Write a sentence or two that explains radiation to a classmate.
2) Name the three main kinds of radiation and tell how they differ.
3) Make a poster illustrating "half-life" for the library.
4) Review Exercise—Lesson 2.

Application: With a partner, build a cloud chamber using the directions on the activity sheet.

Product: "Flip Out!"

Evaluation: ____

CONTRACT — Circle your choice: A B C — Sign:________________

C 75% correct on the Vocabulary in this lesson.
Complete #1 and #4 of the Comprehension selections.
Participate in the class activity, "Flip Out."
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #1, #2, and #4 of the Comprehension selections.
With a partner, build a cloud chamber.
Participate in the class activity, "Flip Out."
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all four of the Comprehension selections.
With a partner, build a cloud chamber.
Participate in the class activity, "Flip Out."
Research "Carbon Dating" and tell why it is useful to society.
Write a self-evaluation judging your performance and achievement.

Unit 2, Lesson 3

Measuring And Using Radiation

Date:____________________
Student:____________________

Vocabulary: Spelling of italicized words ______________% Correct
Definitions of words ______________% Correct
Usage in sentences ______________% Correct

Comprehension: 1) List three ways that could reduce radiation doses for a person.
2) Explain what has happened when an atom loses an electron.
3) Discuss two ways to recognize radiation.
4) Review Exercise—Lesson 3.

Application: "Using A Geiger Counter."

Product: Research and write a one-page biographical sketch on Henri Becquerel or Madame Curie.

Evaluation: ____

CONTRACT Circle your choice: A B C Sign:____________________

C 75% correct on the Vocabulary in this lesson.
Complete #1 and #4 of the Comprehension selections.
Complete the activity, "Using A Geiger Counter."
Write a one page biographical sketch on Henri Becquerel or Madame Curie.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #1, #3, and #4 of the Comprehension selections.
Complete the activity, "Using A Geiger Counter."
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all four of the Comprehension selections.
Complete the activity, "Using A Geiger Counter."
Research how electron microscopes work. Make a poster to display your findings. You may consult with a mentor.
Write a self-evaluation judging your performance and achievement.

Unit 2, Lesson 4 **Background Radiation**

Date:____________________
Student:____________________

Comprehension: 1) Discuss ways to reduce the amount of radiation people receive from the natural background.
2) Review Exercise—Lesson 4.
3) Complete the "Background Radiation Crossword Puzzle."

Application: "Computing Your Personal Radiation Dose."

Product: Interview a person whose occupation involves the use of radioactive materials or do library research and write a report about an occupation involving the use of radioactive materials.

Evaluation: ____________________

CONTRACT Circle your choice: A B C Sign:__________

C 75-85% correct on Lesson 4 Review Exercise.
Complete #1 of the Comprehension selections.
Complete the class activity, "Computing Your Personal Radiation Dose."
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on Lesson 4 Review Exercise.
Complete all of the Comprehension selections.
Complete the class activity, "Computing Your Personal Radiation Dose."
Complete the Product.
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on Lesson 4 Review Exercise.
Complete all of the Comprehension selections.
Complete the class activity, "Computing Your Personal Radiation Dose."
Research suntan screens. Write to a manufacturer for information. Discuss why suntan screens are important to use.
Write a self-evaluation juding your performance and achievement.

Unit 2, Lesson 5 **Uses of Radiation**

Date:____________________
Student:____________________

Vocabulary: Use the two italicized words correctly in a paragraph on the uses of radiation.

Comprehension: 1) Organize a group of four students and discuss the benefits received when knowledge of radiation is put to use.
2) Review Exercise—Lesson 5.
3) "Uses of Radiation."

Application: "Radiography."

Product: Create an 8-1/2" x 11" cartoon illustrating exposure to radiation from food, the Sun, or other people.

Evaluation: ____

CONTRACT Circle your choice: A B C Sign:____________________

C 100% correct on the Vocabulary in this lesson.
Complete #2 of the Comprehension selections.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

B 100% correct on the Vocabulary in this lesson.
Complete all three of the Comprehension selections.
Complete the class activity, "Radiography."
Complete the Product.
Write a self-evaluation judging your performance and achievement.

A 100% correct on the Vocabulary in this lesson.
Complete all three of the Comprehension selections.
Complete the class activity, "Radiography."
Complete the Product.
Find out about the safety regulations for the use of x-ray equipment. (Contact a local hospital x-ray technician.)
Write a self-evaluation judging your performance and achievement.

Fission, Chain Reactions, And Fusion

Unit 2, Lesson 6

Date:____________________
Student:____________________

Vocabulary: Spelling of italicized words ____________% Correct
Definitions of words ____________% Correct
Usage in sentences ____________% Correct

Comprehension:
1) Review Exercise—Lesson 6.
2) Explain the difference between fission and fusion.
3) Construct models of the hydrogen, deuterium, and tritium atoms.
4) Draw and color models of the hydrogen, deuterium, and tritium atoms.

Application: "Simulation Of Fission Chain Reaction."

Product: Make a poster of the completed "Atomic Pioneer Time Line." Make an oral presentation in a history class or for a youth organization.

Evaluation: ____

CONTRACT   Circle your choice: A B C   Sign:____________

C 75-84% correct on the Vocabulary in this lesson.
Complete #1 and #4 of the Comprehension selections.
Complete the Application, "Simulation Of Fission Chain Reaction."
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #1, #2, and #3 of the Comprehension selections.
Complete the Application, "Simulation Of Fission Chain Reaction."
Complete the information for "Atomic Pioneer Time Line." Look up one of the pioneers in the encyclopedia and tell the class what you found out about that person.
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all four of the Comprehension selections.
Complete the Application, "Simulation Of Fission Chain Reaction."
Complete the Product.
Design a game using the information on the "Atomic Pioneer Time Line." Practice with classmates.
Write a self-evaluation judging your performance and achievement.

Unit 3, Lesson 1 — **Planning The Franklin Nuclear Powerplant**

Date:________________________
Student:________________________

Vocabulary: Spelling of italicized words ________________% Correct
Definitions of words ________________% Correct
Usage in sentences ________________% Correct

Comprehension:
1) Write a paragraph discussing what things are considered before choosing the best site for building a nuclear powerplant.
2) Write a paragraph explaining what things the utility that serves your area would consider if they decided to build a new powerplant. What type of powerplant do you think they would select? Explain your answer.
3) Ask five people what type of powerplant they think their utility would decide to build. Make a chart giving the age, sex, occupation, and answer of each person.
4) Review Exercise—Lesson 1.

Application: Choose one partner and complete the Activity "The Effect of Heat on Brine Shrimp."

Product: "Selecting a Site for a Nuclear Powerplant."

Evaluation: ____

____

CONTRACT — Circle your choice: A B C — Sign ________________

C 75-84% correct on the Vocabulary in this lesson.
Complete #1 and #4 of the Comprehension selections.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #1, #3, and #4 of the Comprehension selections.
Complete the Application.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on Vocabulary in this lesson.
Complete all five of the Comprehension selections.
Complete the Application.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

Unit 3, Lesson 2 **How the Reactor Works**

Date:__________________
Student:__________________

Vocabulary: Spelling of italicized words ______________% Correct
Definitions of words ______________% Correct
Usage in sentences ______________% Correct

Comprehension:
1) Using the information on page 63, calculate how many fuel pellets are used in Franklin's reactor core.
2) Write a paragraph explaining the function of each of the four main parts of the reactor.
3) "Word Search."
4) Review Exercise—Lesson 2.

Application: "Controlling the Speed of a Chain Reaction, Part One."
"Controlling the Speed of a Chain Reaction, Part Two."

Evaluation: ______________________________

CONTRACT Circle your choice: A B C Sign______________

C 75-84% correct on the Vocabulary in this lesson.
Complete #3 and #4 of the Comprehension selection.
Complete the class activity "Controlling the Speed of a Chain Reaction, Part One."
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #2, #3, and #4 of the Comprehension selection.
Complete the class activity "Controlling the Speed of a Chain Reaction Part One."
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all four of the Comprehension selections.
Complete both Part One and Part Two of the class activity "Controlling the Speed of a Chain Reaction."
Write a self-evaluation judging your performance and achievement.

Unit 3, Lesson 3

Producing Electricity At Franklin

Date:____________________
Student:____________________

Vocabulary: Spelling of italicized words ____________________% Correct
Definitions of words ____________________% Correct
Usage in Sentences ____________________% Correct

Comprehension:
1) Write a paragraph describing the similarities between the way your body cools you down and the way a cooling tower works.
2) Look in the yellow pages of your telephone directory to find the population of your community. Calculate to decide if Franklin could supply electricity to everyone in your community. Show your math.
3) Make a model of a pressurized water reactor out of modeling clay.
4) Review Exercise—Lesson 3.

Application: "Model of Franklin."

Product: "Locating Nuclear Powerplants in the United States."

Evaluation: ____

CONTRACT Circle your choice: A B C Sign____________________

C 75-84% correct on the Vocabulary in this lesson.
Complete #4 of the Comprehension selection.
Complete the Application.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the vocabulary in this lesson.
Complete #1, #2, and #4 of the Comprehension selection.
Complete the Application.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the vocabulary in this lesson.
Complete all four Comprehension selections.
Complete the Application.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

Unit 3, Lesson 4 **Franklin's Fuel**

Date:____________________

Student:____________________

Vocabulary: Spelling of italicized words ________________% Correct
Definitions of words ________________% Correct
Usage in sentences ________________% Correct

Comprehension:
1) Do library research and then write a paragraph explaining some of the environmental damage that can happen if land is not restored after mining uranium or other ores.
2) "Scrambled Fuel Terms."
3) Use a reference book to learn if your State has uranium ore deposits. If so, list where the deposits are located in your State. Write an evaluation of where most uranium ore deposits are found in the United States.
4) Review Exercise—Lesson 4.

Application: "Separating Salt from Sand."

Product: Design and draw an 8-1/2" by 11" poster comparing the energy released by 1 uranium fuel pellet with the energy released by 126 gallons of oil; 2,000 pounds of coal; and 5,000 pounds of wood.

Evaluation: ________________________________

CONTRACT Circle your choice: A B C Sign________________

C 75-84% correct on the Vocabulary in this lesson.
Complete #2 and #4 of the Comprehension selections.
Complete the Application.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #1, #2, and #4 of the Comprehension selections.
Complete the Application.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all four of the Comprehension selections.
Complete the Application.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

Unit 3, Lesson 5 **Franklin's Waste**

Date:____________________
Student:____________________

Vocabulary: Spelling of italicized words ________________% Correct
Definitions of words ________________% Correct
Usage in sentences ________________% Correct

Comprehension:
1) "The Nuclear Fuel Cycle."
2) Write a paragraph describing how health care in your State would be affected if there were no low-level waste disposal site available.
3) Write a paragraph explaining why the U.S. Congress felt it was important to pass the Nuclear Waste Policy Act.
4) Review Exercise—Lesson 5.

Product: "Nuclear Waste Cube."

Evaluation: ____

CONTRACT Circle your choice: A B C Sign________________

C 75-84% correct on Vocabulary in this lesson.
Complete #1 and #4 of the Comprehension selections.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #1, #3, and #4 of the Comprehension selections.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all four of the Comprehension selections.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

Unit 3, Lesson 6 **Franklin's Safety Systems**

Date:____________________

Student:____________________

Vocabulary: Spelling of italicized words ____________________% Correct

Definitions of words ____________________% Correct

Usage in sentences ____________________% Correct

Comprehension: 1) Write a paragraph discussing why or why not industries of any type should be required to follow safety rules. Include industries in your community that should follow safety rules.

2) "Safety Systems All Around Us."

3) Review Exercise—Lesson 6.

Application: "Containment System Eggstraordinary!"

Evaluation: ____

CONTRACT Circle your choice: A B C Sign____________________

C 75-84% correct on the Vocabulary in this lesson.
Complete #2 and #3 of the Comprehension selections.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #2 and #3 of the Comprehension selections.
With a partner, design and make a containment apparatus as explained in the Application "Containment System Eggstraordinary."
Participate with partners in class competition to determine the best design.
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all three of the Comprehension selections.
Design and make your own containment apparatus as explained in the Application "Containment System Eggstraordinary."
Participate as an individual in class competition to determine the best design.
Write a self-evaluation judging your performance and achievement.

Unit 3, Lesson 7 **Other Reactors**

Date:____________________
Student:____________________

Vocabulary: Spelling of italicized words ________________% Correct
Definitions of words ________________% Correct
Usage in sentences ________________% Correct

Comprehension:
1) "Types of Nuclear Powerplants."
2) Review Exercise—Lesson 7.
3) Write a paragraph explaining why an HTGR uses graphite for a moderator.
4) Write a paragraph explaining why sodium is used as a coolant in the cooling loop of the breeder reactor.
5) Write a paragraph stating your opinion on why other nations have breeder reactors providing commercial electricity while the United States does not.

Application: "Nuclear Power Around the World."

Evaluation: ____
____

CONTRACT Circle your choice: A B C Sign____________________

C 75-84% correct on the Vocabulary in this lesson.
Complete #1 and #2 of the Comprehension selections.
Complete the Application.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #1, #2, #3, and #4 of the Comprehension selections.
Complete the Application.
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all five of the Comprehension selections.
Complete the Application.
Write a self-evaluation judging your performance and achievement.

Unit 4, Lesson 1 **Energy and Money**

Date:____________________
Student:____________________

Vocabulary: Spelling of italicized words ________________% Correct
Definitions of words ________________% Correct
Usage in sentences ________________% Correct

Comprehension: 1) Review Exercise—Lesson 1.
2) "Supply and Demand."
3) Write a paragraph comparing the projected costs that utilities use when they decide what type of powerplant to buy with the costs a family should consider when purchasing an automobile.

Application: Interview an adult about the energy crisis that occurred in 1973. Write a paragraph about your interview including the questions you asked and the responses.

Product: "Percent of Electricity Produced by Nuclear Powerplants."

Evaluation:____

CONTRACT Circle your choice: A B C Sign________________

C 75-84% correct on the Vocabulary in this lesson.
Complete #1 and #2 of the Comprehension selections.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

B 85-90% correct on the Vocabulary in this lesson.
Complete #1 and #2 of the Comprehension selections.
Complete the Application.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

A 91-100% correct on the Vocabulary in this lesson.
Complete all three of the Comprehension selections.
Complete the Application.
Complete the Product.
Write a self-evaluation judging your performance and achievement.

Unit 4, Lesson 2 **Safety**

Date:________________
Student:________________

Comprehension:
1) "Nucleoglyphics."
2) Review Exercise—Lesson 2.
3) Write a paragraph discussing some well known disasters in history. Include some ideas about how these disasters could have been prevented or alleviated by using safety systems. *The World Almanac* may be used as a reference book.
4) Write a paragraph telling your views on the status of nuclear energy safety.
5) Write a paragraph explaining what types of materials scientists often find as evidence of early peoples. Include what significance this has in selecting the form the high-level waste is in when stored.

Application: Design some ways to keep future generations from uncovering nuclear waste repositories. Discuss these ideas in a paragraph. Remember that these repositories must remain isolated for thousands of years.

Product: "Selecting a Permanent Waste Repository Site."

Evaluation:________________

CONTRACT Circle your choice: A B C Sign________________

C Complete #2 and #4 of the Comprehension selections.
Participate in the Product class activity.
Write a self-evaluation judging your performance and achievement.

B Complete #1, #2, and #4 of the Comprehension selections.
Complete the Application.
Participate in the Product class activity.
Write a self-evaluation judging your performance and achievement.

A Complete all five of the Comprehension selections.
Complete the Application.
Participate in the Product class activity.
Write a self-evaluation judging your performance and achievement.

Unit 4, Lesson 3 **Energy Decision Making**

Date:________________
Student:________________

Vocabulary: Use the italicized word correctly in a paragraph explaining what the word means.

Comprehension:
1) Write a paragraph discussing your opinion on what the role of nuclear energy should be in our future.
2) Review Exercise—Lesson 3.
3) Think of a problem that needs a decision. Organize a group of two other students and use the three steps that can help make an informed decision. Outline your steps completely on paper and state your groups' decision.
4) Write a paragraph explaining why it is difficult to make a decision about which energy source to use today and in the future.

Application: "Nuclear Energy—Benefits and Problems."

Evaluation: ____

CONTRACT Circle your choice: A B C Sign________________

C 100% correct on the Vocabulary in this lesson.
Complete #1 and #2 of the Comprehension selections.
Complete the Application.
Write a self-evaluation judging your performance and achievement.

B 100% correct on the Vocabulary in this lesson.
Complete #1, #2, and #4 of the Comprehension selections.
Complete the Application.
Write a self-evaluation judging your performance and achievement.

A 100% correct on the Vocabulary in this lesson.
Complete all 4 of the Comprehension selections.
Complete the Application.
Write a self-evaluation judging your performance and achievement.

☆U.S. GOVERNMENT PRINTING OFFICE: 1986-156-765