DOCUMENT RESUME

ED 396 922 SE 058 527

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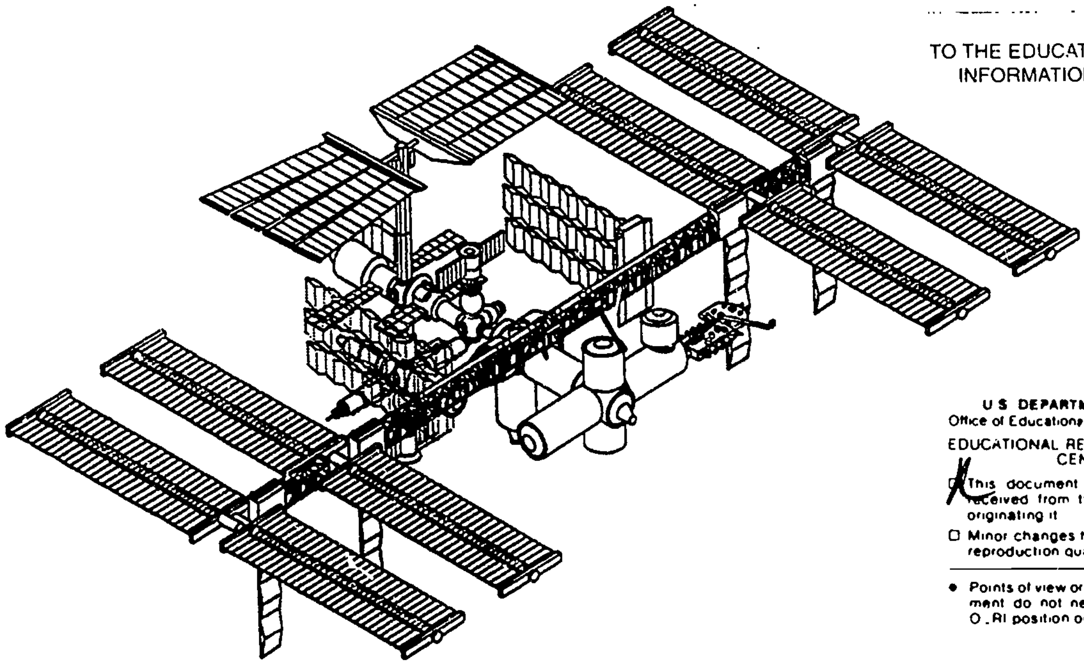
TITLE	International Space Station: 6-8 Hands-on Science and Math Lesson Plans.
INSTITUTION	Boeing Co., Huntsville, AL.
PUB DATE	Mar 96
NOTE	44p.
AVAILABLE FROM	The Boeing Company, P.O. Box 240002 JW-54, Huntsville, AL 35824.
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Cooperative Learning; Hands on Science; Intermediate Grades; Junior High Schools; Lesson Plans; Mathematics Instruction; *Science Activities; Science Process Skills; Space Exploration; *Space Sciences; Spectroscopy

ABSTRACT

These lesson plans, designed for grades 6-8, have been developed to provide a guide to hands-on experience in science and math. They focus on an International Space Station and are designed for use with students working in groups. The three lesson plans highlighting the importance of the scientific method are: (1) International Space Station identification (crosswords puzzle, observations, data, and conclusions); (2) Crystallography (triclinic, tetragonal, hexagonal, isometric, orthorhombic, monoclinic); and (3) Spectral Analysis (complete visible spectrum, lithium spectrum, helium spectrum). A fact sheet for the International Space Station is also included. (JRH)

International Space Station

6-8 Hands-on Science and Math Lesson Plans



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Level (Grades 6-8)

International Space Station

Level (Grades 6-8)

Dear Educator:

International Space Station will inspire a new generation of Americans to explore and achieve, while pioneering new methods to teach and motivate the next generation of scientists, engineers, entrepreneurs, and explorers.

> Space science is a catalyst for academic achievement. Enrollment trends of U.S. college students majoring in science and engineering track closely with the funding trends of the U.S. space program.
>
> NASA is a leader in the development of virtual reality and telepresence technologies, giving students the same benefits they would get from actual presence on the space station and interaction with real astronauts.
>
> Astronauts and cosmonauts serve as role models, capturing the imagination of future leaders and encouraging more students to study science and engineering.
>
> In addition to lessons from Space, students of the future will have experiments on the space station and will conduct them from their classrooms on the ground. Students will transmit and receive data, manipulate equipment remotely, and evaluate the experiments through interpretation of the data.
>
> With the international focus, students will absorb broad lessons in the value of cooperation as we work with partners in Russia, Europe, Japan, and Canada.

Space station already influences American students. Teachers and communities across the nation are using space station concepts in the classroom. The idea of living and working in Space continues to spark interest. With these lesson plans the Space Station Partners for Educational Advancement join with educators in an effort to encourage our children to pursue their dreams. International Space Station, the next step in space exploration, will motivate, stimulate, and capture our children's imagination.

Space Station Partners
for Educational Advancement

International Space Station

Level (Grades 6-8)

Dear Teacher:

This material has been developed to provide a guide to hands-on experiences in science and math. The lesson plans are written to be used by the students in groups of two to four people in a lab-type activity. The lesson activities are outlined using the scientific method. All questions should be used to lead the students to explore a subject, and the activities should be open ended.

Each lab session should begin with a brief discussion of the Theory/Information section of the lesson plan. The teacher should feel free to adjust the information and activities to meet the needs of the students.

These plans are intended to be used by students. The teacher will actively participate by moving among the students to help each group to organize, supply materials, provide information, and answer questions.

Pat Armstrong
Writer/Teacher

Introduction

Level (Grades 6-8)

Introduction to the National Aeronautics and Space Administration (NASA) and the United States Space Station Program.

The National Aeronautics and Space Administration (NASA) is an independent federal agency with headquarters in Washington, D.C. This federal agency does nonmilitary research into problems of flight within and beyond Earth's atmosphere. In 1958 the Space Act Agreement established the National Aeronautics and Space Administration. Since that time NASA has experimented with rockets, unmanned probes and satellites, manned missions including the Apollo moon missions, and the Space Shuttle flights.

The United States Space Station Program is also under the direction of the National Aeronautics and Space Administration. After the first Space Shuttle flew in April of 1981, a space station was considered to be the next logical step in human space flight. In May 1982, the Space Station Task Force was formed and produced a space station concept.

In 1984 after many studies, President Reagan committed the nation to the goal of developing a space station with permanent human occupancy within the decade. At that time he also stressed international participation, and NASA invited other countries to work with the United States to develop a space station. Finally in September of 1988, Japan, Canada and 9 of the 13 nations involved with the European Space Agency (ESA) agreed to work together on the Space Station Program. The nine European Space Agency members are Belgium, Denmark, France, Italy, the Federal Republic of Germany, the Netherlands, Norway, Spain and the United Kingdom.

In 1992, President Clinton asked NASA to redesign the station to lower the cost. NASA, with the help of aerospace contractors such as The Boeing Company, began working on the redesign. During the planning, it was decided that members of the Russian Space Agency would help with the new space station.

The Human Tended Capability, the first phase of space station, will be completed in 1998 after the Assembly Flights. This first phase includes the laboratory module. The final phase, Permanent Human Capacity, is scheduled for 2002. The station is designed to operate for at least 10 years.

The space station will support six crew members. The crew will serve for 90 days, and then they will be replaced by another crew of six. The crew will be rotated four times each year. Crew members involved in long-duration microgravity studies may serve six months or more before they return to Earth.

Introduction (Continued):

Level (Grades 6-8)

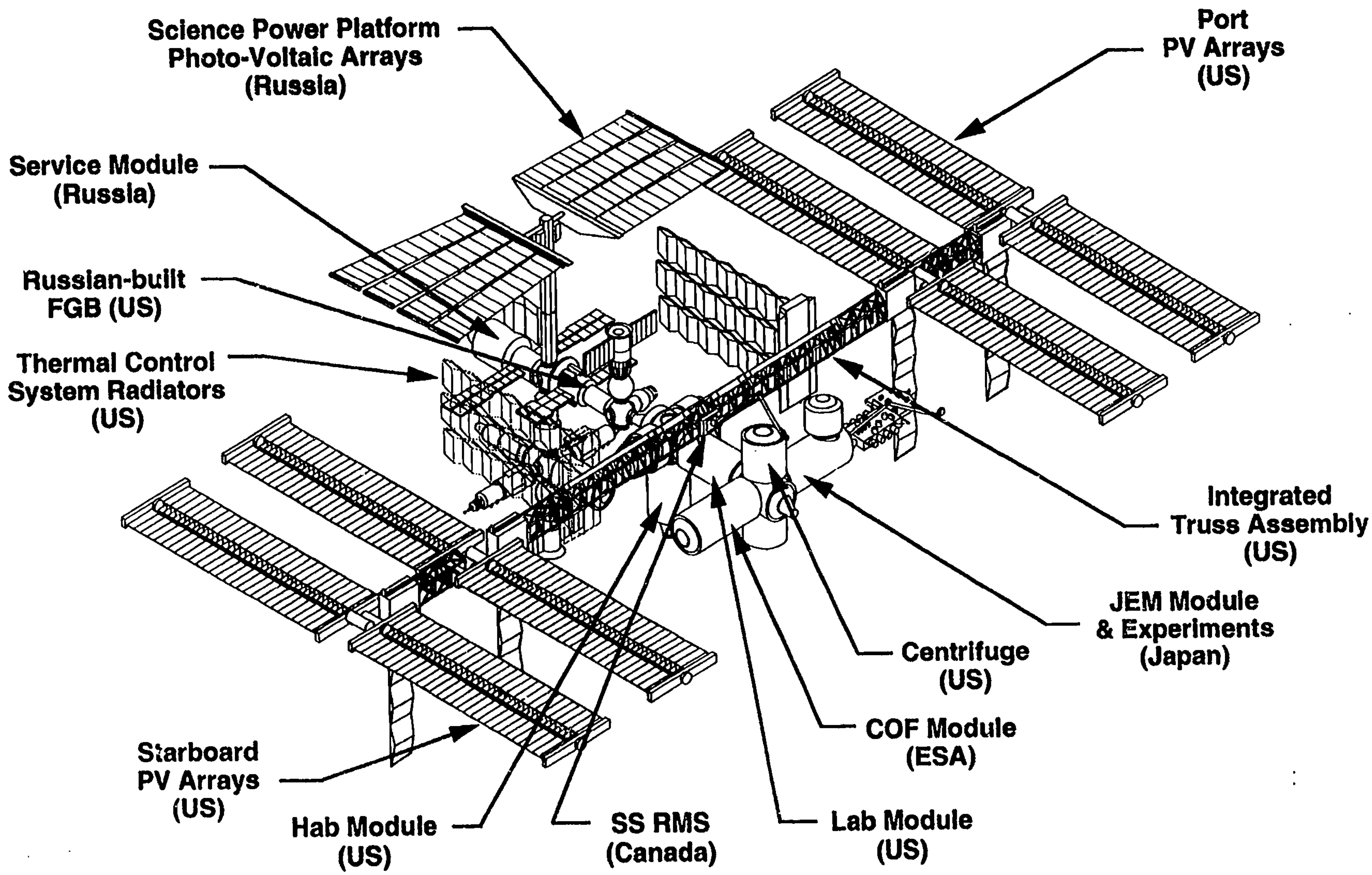
Introduction to the National Aeronautics and Space Administration (NASA) and the United States Space Station Program.

The space station will travel at a speed of about 29,000 kilometers per hour (18,000 miles per hour), and it will complete one orbit every 90 minutes. The station will operate at an altitude of 335 to 460 kilometers (208 to 285 statute miles). This is about the distance from New York City to Washington, D.C.

The space station will be a permanent Earth orbiting laboratory. By observing and collecting information from the space station, scientists will learn more about our home planet, Earth. By collecting information, conducting experiments, and manufacturing materials on orbit, they will develop new processes and technologies. The biological studies done on orbit also hold great promise for the development of new medicines and the understanding of various diseases such as anemia, diabetes, osteoporosis, and cancer.

The space station is needed to help humans continue to explore Space. The station will encourage international cooperation in science and technology and make it possible for scientists to perform long-duration space research in materials and life sciences. While building the station, scientists and engineers will also learn more about building, maintaining, and operating advanced human tended and automated space systems.

A well-equipped, continuously functioning, permanent space station will allow scientists to make more efficient use of time spent on orbit. The space station will provide scientists more time to study and experiment in microgravity, more power for equipment, and more room to work, and more crew members to do the work.



International Space Station Assembly Complete

International Space Station Fact Sheet

Level (Grades 6-8)

- **End to End Width (wingspan)** _ 361 feet (110 meters)
- **Length** _____________ 290 feet (88 meters)
- **Weight** _____________ 443 tons (886,000 pounds)
- **Operating Altitude** _______ 220 miles (average)
- **Inclination** ____________ 51.6 degrees to the Equator
- **Atmosphere** ___________ 14.7 pounds per square inch (same as Earth)
- **Crew Size** ___________ 6

- **Canadian Mobile Servicing System** - includes a 55-foot robot arm with 125-ton payload capability. It also includes a mobile transporter which can be positioned along the truss for robotic assembly and maintenance operations.

- **Russian FGB** - includes the energy block, contingency fuel storage, propulsion, and multiple docking points. The 42,600-pound element, built in Russia, but purchased by the United States, will be launched on a Proton vehicle.

- **Russian Service Module** - provides life support and utilities, thrusters, and habitation functions (toilet, hygiene facilities). The 46,300-pound element will be launched on a Proton vehicle.

- **Science Power Platform (SPP)** - will provide power (20 kw) and heat rejection for Space Station science and operations. The SPP will be launched on a Russian Zenit rocket. It could potentially be assembled and serviced by a European robotic arm.

- **Crew Transfer Vehicles** - include two modified Russian Soyuz TM capsules. The Soyuz CTV can normally accommodate a crew of three, or a crew of two when returning an ill or injured crew member and medical equipment.

- **Progress Cargo Vehicles**- carry reboost propellant (up to 6,000 pounds) to the Space Station about four times a year.

- **7 Laboratories**

  2 U. S. - a laboratory and a Centrifuge Accommodation Module (CAM)
  1 ESA Columbus Orbital Facility (COF)
  1 Japanese Experiment Module (JEM)
  3 Russian Research Modules

- U. S., European and Japanese laboratories together provide 33 International Standard Payload Racks; additional science rack space is available in the three Russian laboratory modules.

- The JEM has an exposed platform, or "back porch" attached to it with 10 mounting spaces for experiments which require direct contact with the Space environment. The JEM also has a small robotic arm for payload operations on the exposed platform.

International Space Station Fact Sheet (Continued):

Level (Grades 6-8)

- **U. S. Habitation Module** - includes a 55-foot robot arm with 125-ton payload capability. It also includes a mobile transporter which can be positioned along the truss for robotic assembly and maintenance operations.
- **Italian Mini Pressurized Laboratory Module (MPLM)** - will be used to carry all the pressurized cargo and payloads launched on the Space Shuttle. It is capable of delivering 16 International Standard Payload Racks.
- **U. S. Nodes** - Node 1 is for storage space only. Node 2 contains racks of equipment used to convert electrical power for use by the international partners.
- **Total Pressurized Volume** - 46,200 cubic feet
- **External Sites** - there are four locations on the truss for mounting experiments for looking down at Earth, up into Space, or for direct exposure to Space
- **Power** - 110 kw (approximately 46 kw for research)

There are four large U. S. photovoltaic modules; each module has two arrays, each 112 feet long by 39 feet wide. Each module generates approximately 23 kw. They rotate to face the Sun, which provides maximum power to the station.

Schedule	Date	Payload
First U S. Element Launch	November 1997	FGB
First Russian Element Launch	April 1998	Service Module
Continuous Human Presence	May 1998	Soyuz
U S. Lab Launch	November 1998	U. S. Pressurized Lab
Japanese Lab Launch	March 2000	JEM Pressurized Lab
ESA Lab Launch	February 2001	Attached Pressurized Module
Centrifuge Launch	October 2001	Centrifuge Accommodation Module
Habitation Module Launch	February 2002	U. S. Habitation Module
Assembly Complete/Continuous Full Crew	June 2002	Crew Transport Vehicle (CTV)

Transportation

• Total Space Shuttle flights (1997 - 2002)	27	
Assembly		21
Utilization/Outfitting		6
• Total Russian flights	44	
Assembly		15
Crew Transport		10
Reboost (propulsion)		19
• Total Space Shuttle flights (Ariane 5)	1	
• Launch Vehicle for CTV	1	

International Space Station Identification

Level (Grades 6-8)

THEORY/INFORMATION

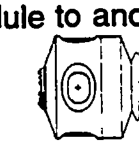
The International Space Station is a permanent orbiting science institute in Space capable of performing long-duration research in materials and life sciences in a nearly gravity-free environment. This spaceship will orbit 335-460 kilometers (208-285 statute miles) above the Earth. This station is to be used as a permanent laboratory where astronauts live and work. A crew of six astronauts will live and work at this institute for 90 days . At the end of a mission, another crew will come to the station, and the first group will return to Earth. NASA plans four missions each year. The first phase of the space station will be placed on orbit in 1998, and the whole station should be in place and operating in 2002. (See Space Station drawing page vi, and Facts Sheets vii and viii.)

Some of the most important parts of the space station are the **truss**, **photovoltaic arrays**, **laboratory modules**, **nodes**, **habitat module**, **thermal radiators**, **centrifuge**, **remote manipulator system**, **service module**, and **progress resupply vehicle**. A description of some of these parts follows:

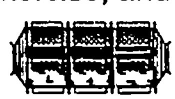
A. A **truss** (trus) is a backbone-like structure located on the outside of the station. Other parts of the station are attached to this structure. 

B. The **photovoltaic arrays** (phō'to•vol•tā'ic ar•rāy') are sets of solar panels grouped together in big sheets. These arrays collect light from the Sun and use it to make electricity to power the machines and equipment on the space station. 

C. The **laboratory modules** (lab'o•ra•tō•ry mod'ūles) are filled with equipment used for studying processes, manufacturing materials, and doing experiments. The crew works in these modules. 

D. **Nodes** (nōdes) attach one module to another, and they are used as passageways so that the astronauts can go from one module to another. The nodes are also used for some experiments and for storage. 

E. The astronauts will live in the **habitat module** (hab'i•tat mod'ūle). They will cook, eat, clean, sleep, bathe, exercise, and relax in this module.



International Space Station Identification (Continued):

Level (Grades 6-8)

THEORY/INFORMATION

F. Thermal **radiators** (rā´di • ā • tŏr) are panels attached to the outside of the space station. These radiators are used to get rid of the extra heat created by the machines and equipment on the station.

G. The **centrifuge** (cen´ tri • fūge) is a piece of equipment that can spin experiments. It will be used to simulate gravity for plant and animal research.

H. The Canadian Mobile Servicing System includes a **robot arm** (ro´ bŏt ārm). The arm is used to load, unload, experiment, assemble and repair outside the space station. * For details see International Space Station Fact Sheet, pages vii & viii.

OBJECTIVE

The student will identify at least eight parts of the space station.

QUESTION

What are the major parts of the space station? What does each part do?

MATERIALS

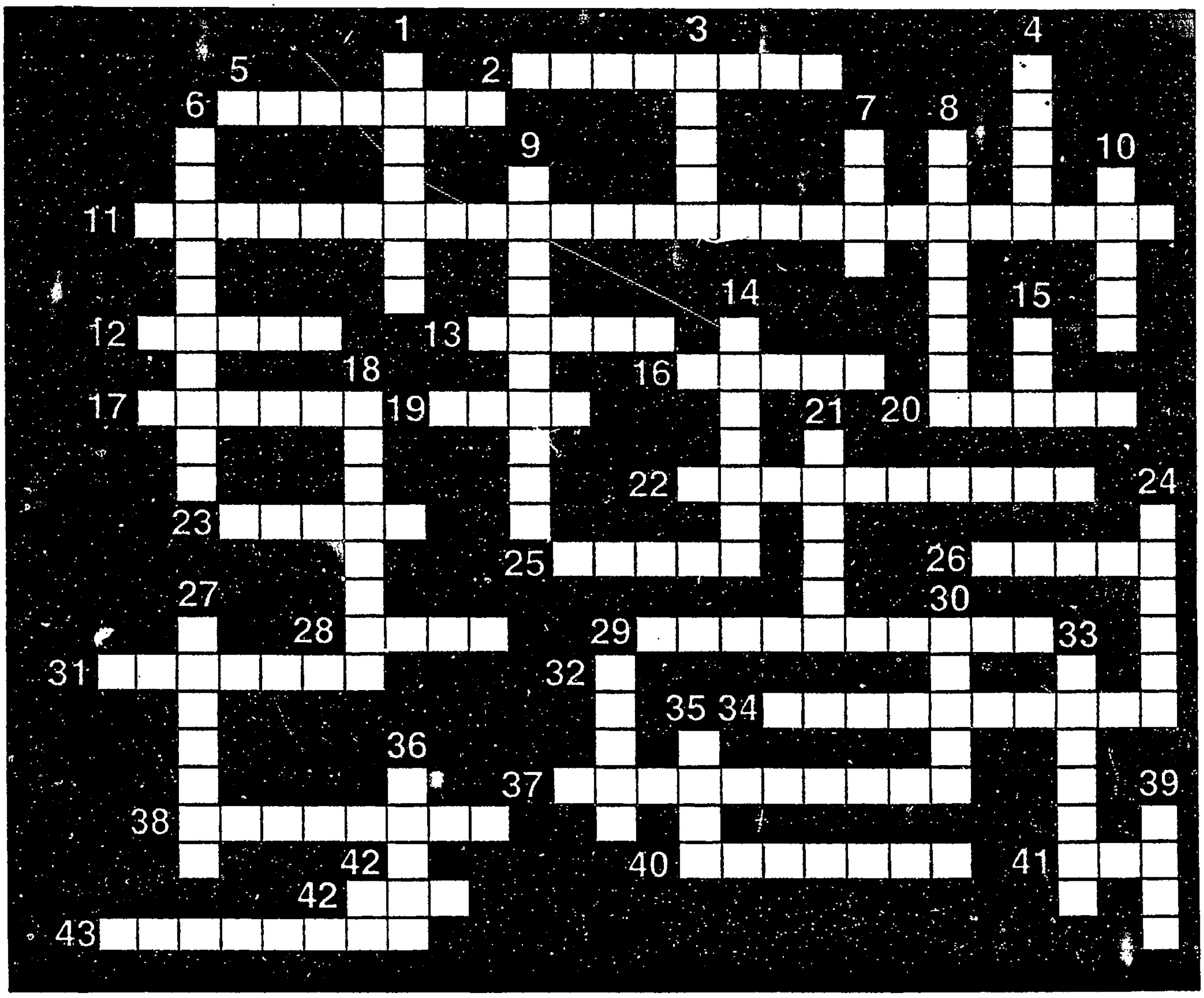
1 - Pencil
International Space Station Fact Sheet, pages vii & viii.
International Space Station Crosswords Puzzle, page 3.
International Space Station Observations, Data and Conclusions, page 6.

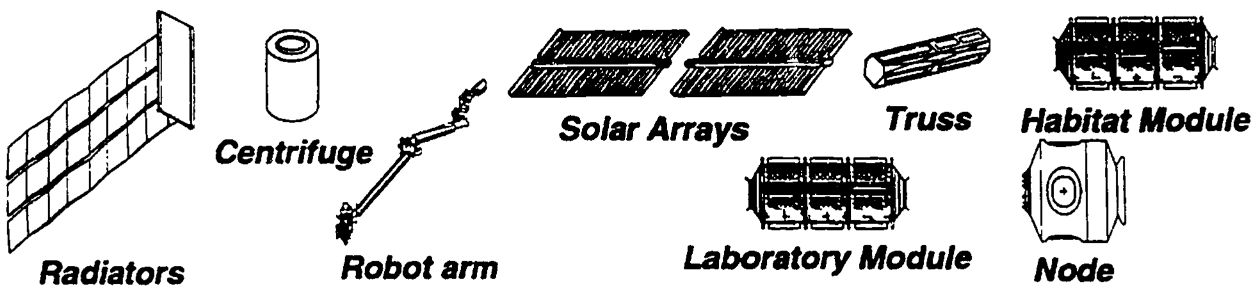
PROCEDURES

1. Find the crosswords puzzle on page 3.
2. Choose a partner and complete the puzzle. Hint: The Introduction, the International Space Station Fact Sheets, and Lesson 1 are helpful.
3. After you have completed the puzzle, ask your teacher for an answer key and check all answers.
4. Use all lesson materials to complete "Observations, Data, and Conclusions" on page 6.
5. Turn in any of the lesson materials requested by the teacher.

International Space Station Puzzle

Level (Grades 6-8)





International Space Station Puzzle Clues

Level (Grades 6-8)

ACROSS

2. Solids in which the particles are arranged in a regular, repeating pattern
5. The simplest type of pure substance
11. A large, permanently operating space facility to be built by eighteen cooperating nations
12. 5,280 feet, twice
13. A member of the European Space Agency
16. Supplies and equipment on orbit in space station
17. The latest member to join the International Space Station Program
19. A storage area on space station
20. The third planet from the Sun
22. Gases that surround a planet or star
23. Passageways to connect one module of space station to another
25. A coating to protect materials against heat or aging
26. Beyond Earth's atmosphere
28. Complex machinery used to preserve life is called the ______ support system.
29. Fuel used to launch and steer space station
31. A member of the European Space Agency
34. A test to develop, new materials, products, equipment, and technologies
37. A place to conduct experiments
38. The number of nations working together to build the International Space Station, subtract five.
40. Material, product, equipment, and technology used everyday by ordinary people, but discovered or developed while planning and building space station.
41. European Space Agency
42. Space station is designed to operate for ________ years.
43. Panel attached to the outside of the space station to help get rid of the extra heat created by the machines on the station

International Space Station Puzzle Clues

Level (Grades 6-8)

DOWN

1. A member of the European Space Agency
3. A backbone-like structure used to attach various parts of the space station
4. The path the space station travels around the Earth
6. A piece of equipment that spins and provides artificial gravity for life science experiments
7. The group of people that work on the space station
8. The elevation of the space station above the Earth
9. A large remote controlled crane-like piece of equipment used to do work outside the space station. Hint: _ _ _ _ _ i c _ _ _
10. A kind of energy used to operate space station
14. The space station module in which the crew will sleep, eat, and bathe
15. The Russian space station
18. The time spent putting the pieces of the space station together is called the ______________ time
21. A cylinder-shaped section of the space station that can be used as a laboratory or living area
24. Quality or amount of heaviness
27. The force that tends to draw all bodies in the Earth's atmosphere toward the center of the Earth
30. A set of photovoltaic or solar panels
32. A partner in the development of the International Space Station
33. A facility used to conduct tests
35. Twice, 2,000 pounds
36. 100 centimeters
39. The National Aeronautics and Space Administration
42. The study of Earth from Space is called Mission ____ Planet Earth.

OBSERVATIONS, DATA, AND CONCLUSIONS

1. What is the name of the new space station?

2. How many countries will cooperate to build the station? Name them.

3. When will the station be completely operational?

4. What part of space station will provide power to run the equipment and machinery on the station?

5. What is the backbone-like part of the space station called?

6. On space station, what is the name of the place where people will bathe, sleep, eat and live? How many of these are on space station?

7. What is the name of a module used for conducting experiments and research? How many of these modules are on space station? Which nations will provide them?

8. If you are on orbit and a module gets to hot for comfort, you cannot open a door or window to cool the area. What part of space station is designed to get rid of excess heat ?

9. What is the name of the hallways that connect the individual parts of the space station?

10. What piece of equipment spins experiments?

THEORY/INFORMATION

The International Space Station will serve as a continuously orbiting lab for research in a near gravityless environment. The microgravity of Space provides a unique environment for growing crystals. Crystals grown in Space are larger and more perfect than those grown on Earth. These Space-grown crystals are studied to better understand the structure of the molecules of various substances. Crystal studies contribute to better understanding and new developments in agriculture, biology, medicine, electronics, metallurgy, chemistry, materials, processes, and yet to be discovered uses.

Space-grown Crystals.....

Space-grown protein crystals are studied. Proteins are the building blocks of living things, and microbiologist study their structure to determine their functions. Proteins are more easily identified and studied if they can be observed in their crystal form. Space-grown crystals are used by microbiologists to develop treatments and medicines for human beings. Biologist and agricultural scientists study protein crystals to better understand animals and plants. These studies contribute to the health and preservation of many species both domestic and wild.

The study of crystals is called crystallography. Crystals are molecules arranged in the highest degree of order, the solid state. How crystals grow from gases and liquids is called crystallization. Some substances change from one state of matter to another because they become cooler or hotter. As liquids, and sometimes gases, become solids, a strange phenomenon takes place. From wild disorder, molecules or atoms of a substance join together into precise rows and columns. This neatly ordered array of molecules or atoms is a crystal. Each different mineral or protein has its own unique crystal form. The crystal form of each is determined by the kinds of atoms in the molecule of the mineral or protein and how these atoms cling together.

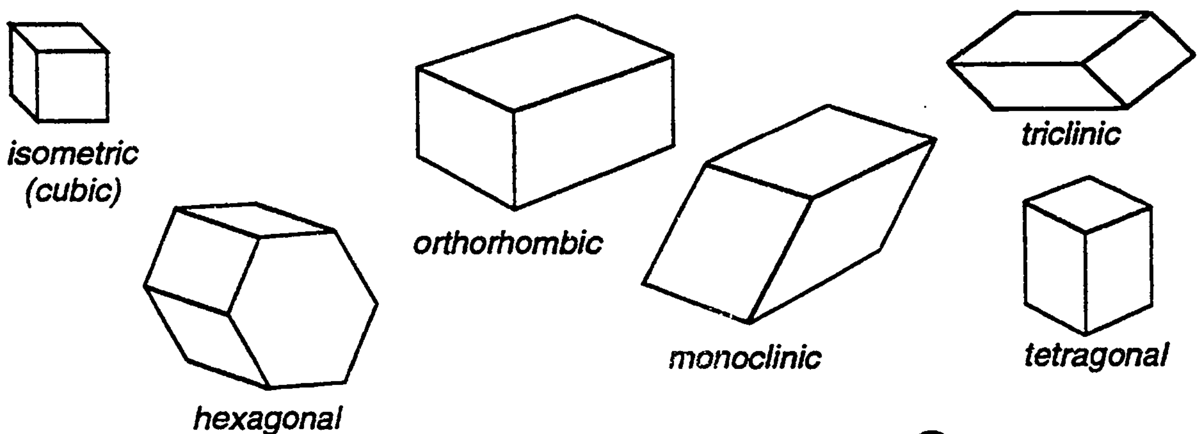
Crystals formed from liquids and gases begin on a microscopic level. The smallest bit of a crystal forms when a few molecules lock together in a pattern that repeats itself again and again. Crystallographers call this bit of crystal a unit cell. Most crystals are too small to be seen with the naked eye. As soon as liquids start to solidify, thousands of crystals form at the same time. Usually a single unit cell does not get the chance to become large before it stops growing.

THEORY/INFORMATION

The size, shape, and internal structure of crystals grown on Earth are often limited or deformed. Crystal shapes are distorted when they are crowded against each other or against a container. The structure of the crystal is also distorted by the effects of gravity and small currents of air caused by uneven heating or cooling. Protein crystals may be affected by the changes in the temperature, the pH balance, the addition of other minerals, the concentration of proteins, or changes in the environment.

People have always been fascinated by crystals. Early scientists attempted to classify crystals into groups called systems. The crystal classification systems are based on the number of the flat surfaces or faces and the angles at which adjoining faces meet. Some crystal systems studied by both physical and life scientists include: isometric (cubic), orthorhombic, tetragonal, monoclinic, triclinic, and hexagonal.

Crystal Systems



OBJECTIVE

The student will construct and identify at least five crystal systems. The student will list at least two examples of each.

QUESTION

What are crystal systems? How are crystals grown on Earth different from those grown in Space?

MATERIALS

- 6 Crystal System Model Sheets (See pages 11, 13, 15, 17, 19, & 21).
- 1 Pair Scissors
- 1 Roll Transparent tape
- 1 Pencil
- 1 Magnifier (Optional)
- 1 Pinch of salt (Optional)

Crystallography

Level (Grades 6-8)

PROCEDURES

1. Find six Crystal System Model Sheets.
2. Cut out the crystal patterns.
3. Fold the patterns into 3 dimensional shapes.
4. Tape each shape together to form a model crystal system.
5. The students may stack the crystals together according to shape. If the model crystals are folded correctly, the edges should fit together to form a solid substance made up of the individual crystals.
6. Optional: Use a magnifier and observe salt crystals. Observe other crystals in your environment.

OBSERVATIONS, DATA, AND CONCLUSIONS

1. Complete the following table.

System Name	Number Faces	Number Edges	Examples
Isometric (Cubic)			
Orthorhombic			
Tetragonal			
Monoclinic			
Triclinic			
Hexagonal			

2. Why is it difficult to grow high quality crystals on Earth?

3. Why are crystals grown in Space better than those grown on Earth?

Observations, Data, and Conclusions (Continued)

4. Why are crystals important? How are they used?

5. Optional: What is the shape of a salt crystal? Salt belongs in which crystal system?

6. Optional: What other crystals did you observe? What systems did you observe?

Home Science Project

Grow Crystals

Materials:

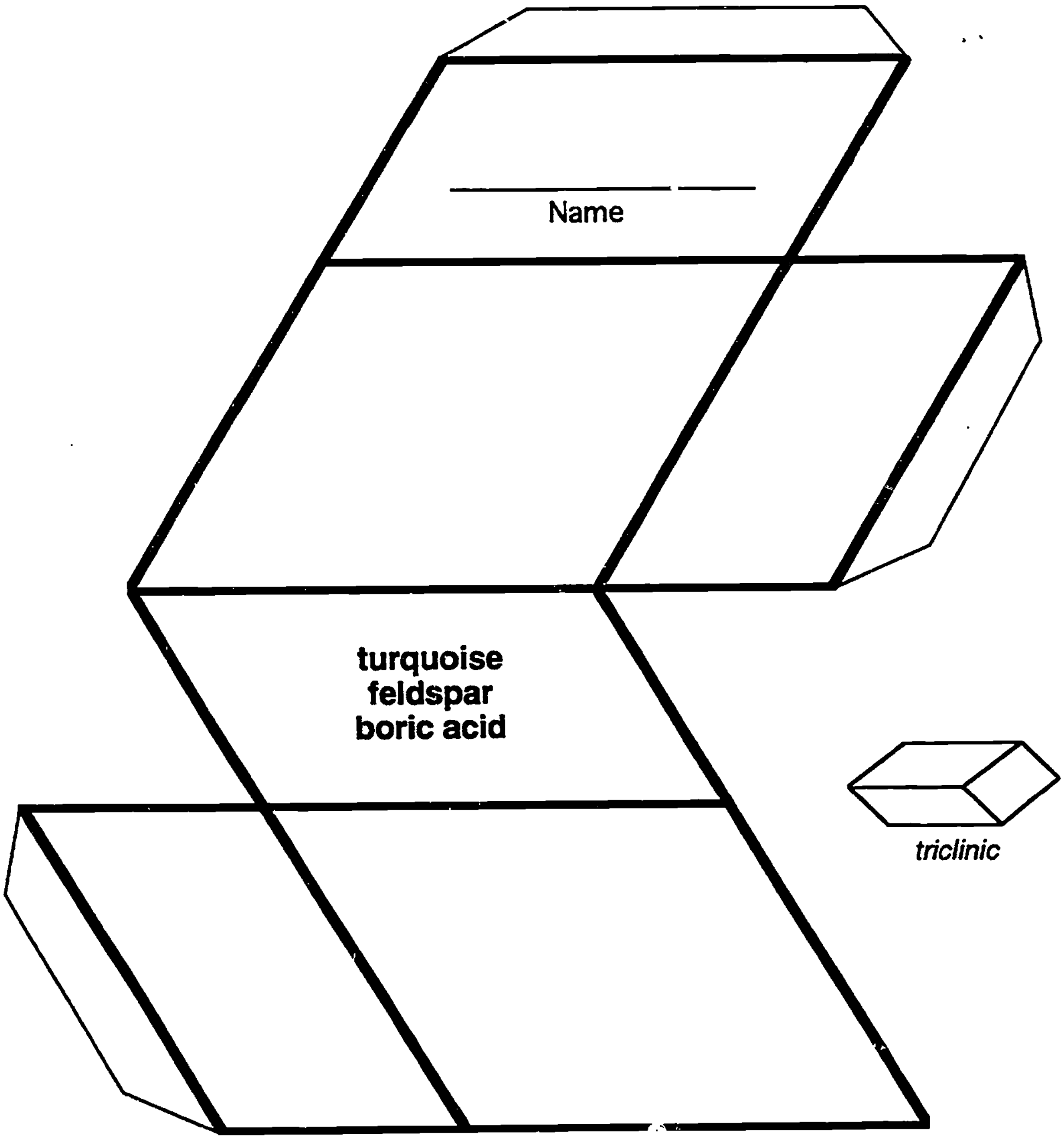
6 Tablespoons	Laundry bluing
6 Tablespoons	Water
6 Tablespoons	Salt
1 Tablespoons	Ammonia (Use regular ammonia not sudsy).
1	Charcoal briquette (Substitute pieces of building brick).
1	Bowl
1	Measuring spoon
1	Glass jar for mixing
1	Food coloring
1	Magnifying glass

Measure and mix the water, laundry bluing, and salt in a glass. Add the ammonia. Break the briquette into three or four pieces and put them into the bowl. Pour the mixture over the charcoal pieces. In a couple of hours crystals will begin to grow. When the crystals begin, sprinkle food coloring on the pieces of charcoal.

If the humidity is high, the crystals will grow slowly. Do not move or shake the bowl. The crystals towers are fragile, and they will collapse. Use the magnifying glass to observe the crystals as they form.

Crystallography

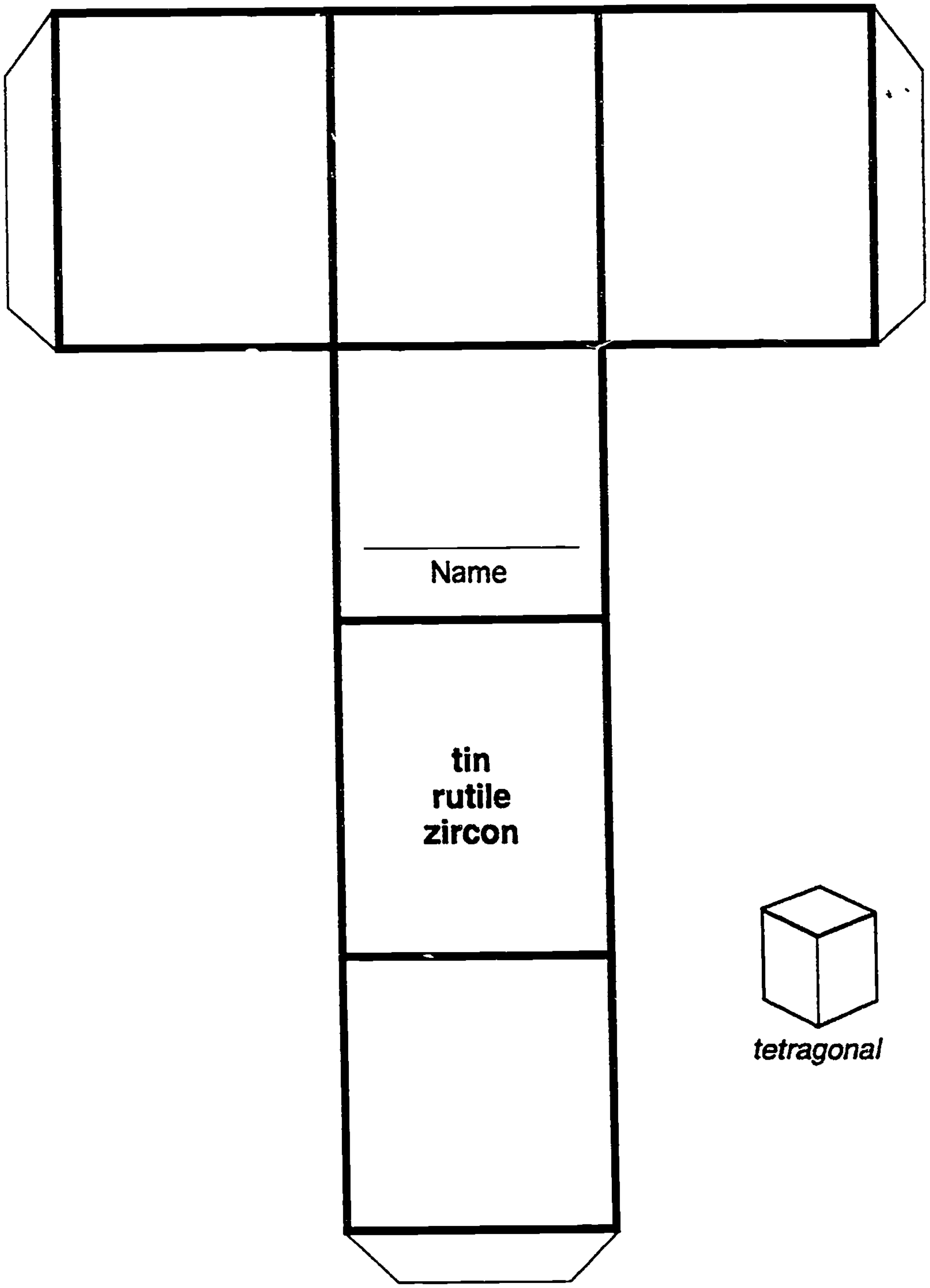
Level (Grades 6-8)



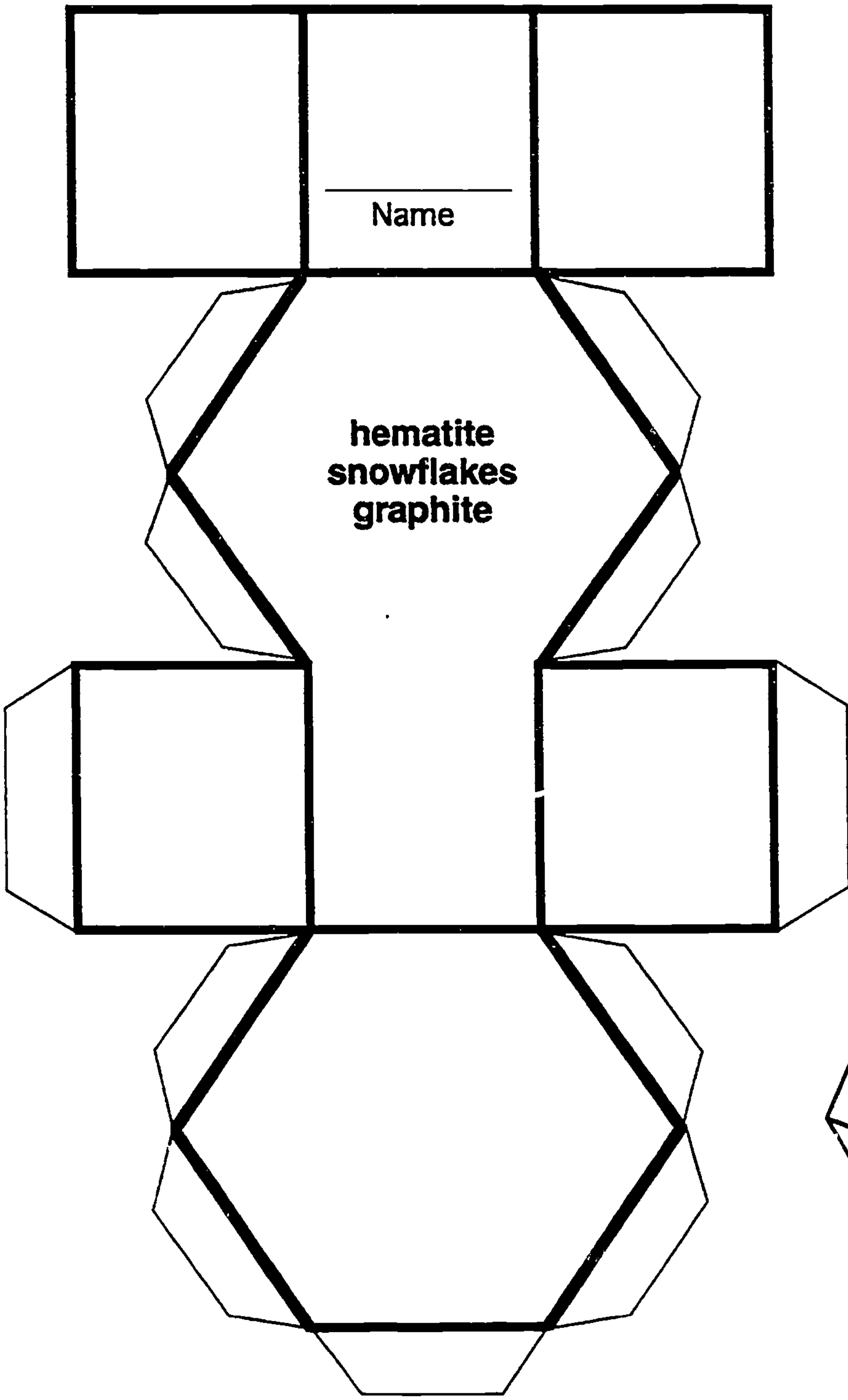
triclinic

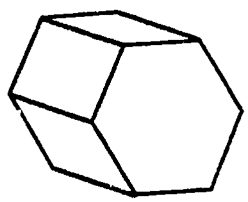
Crystallography

Level (Grades 6-8)



tetragonal

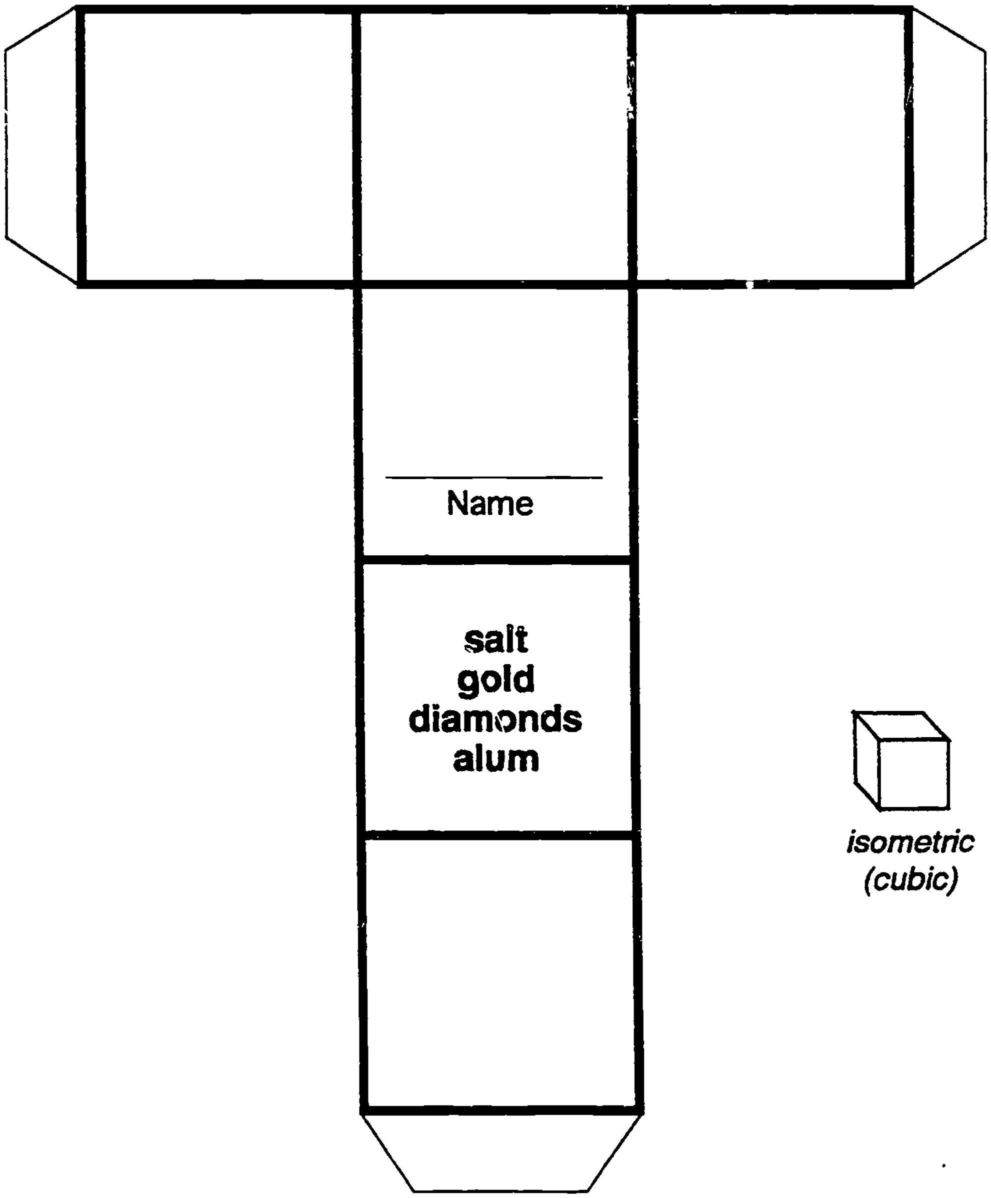




hexagonal

Crystallography

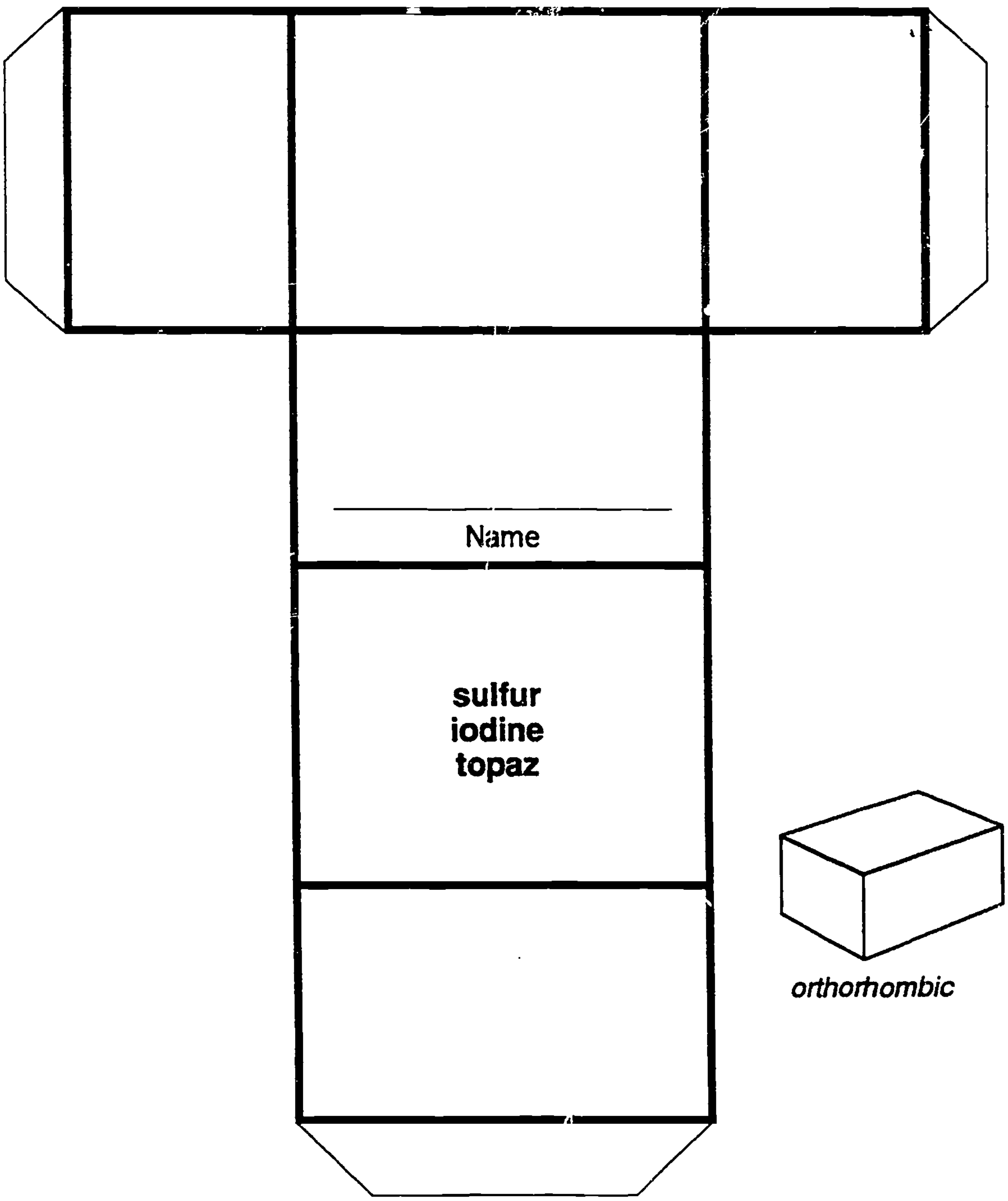
Level (Grades 6-8)



isometric (cubic)

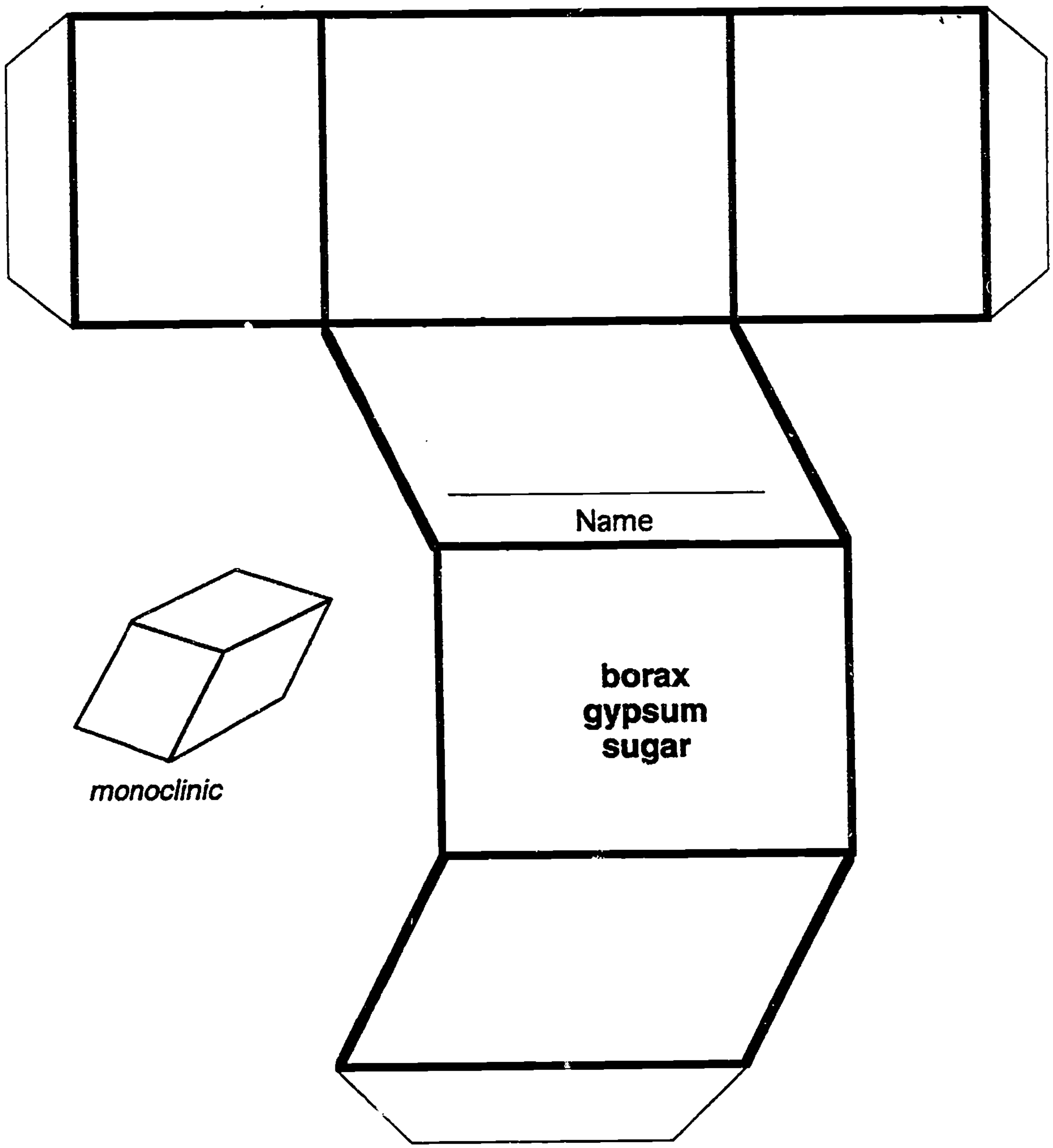
Crystallography

Level (Grades 6-8)



orthorhombic

Crystallography



Spectral Analysis - The study of substances or bodies through an analysis of their spectra.

Level (Grades 6-8)

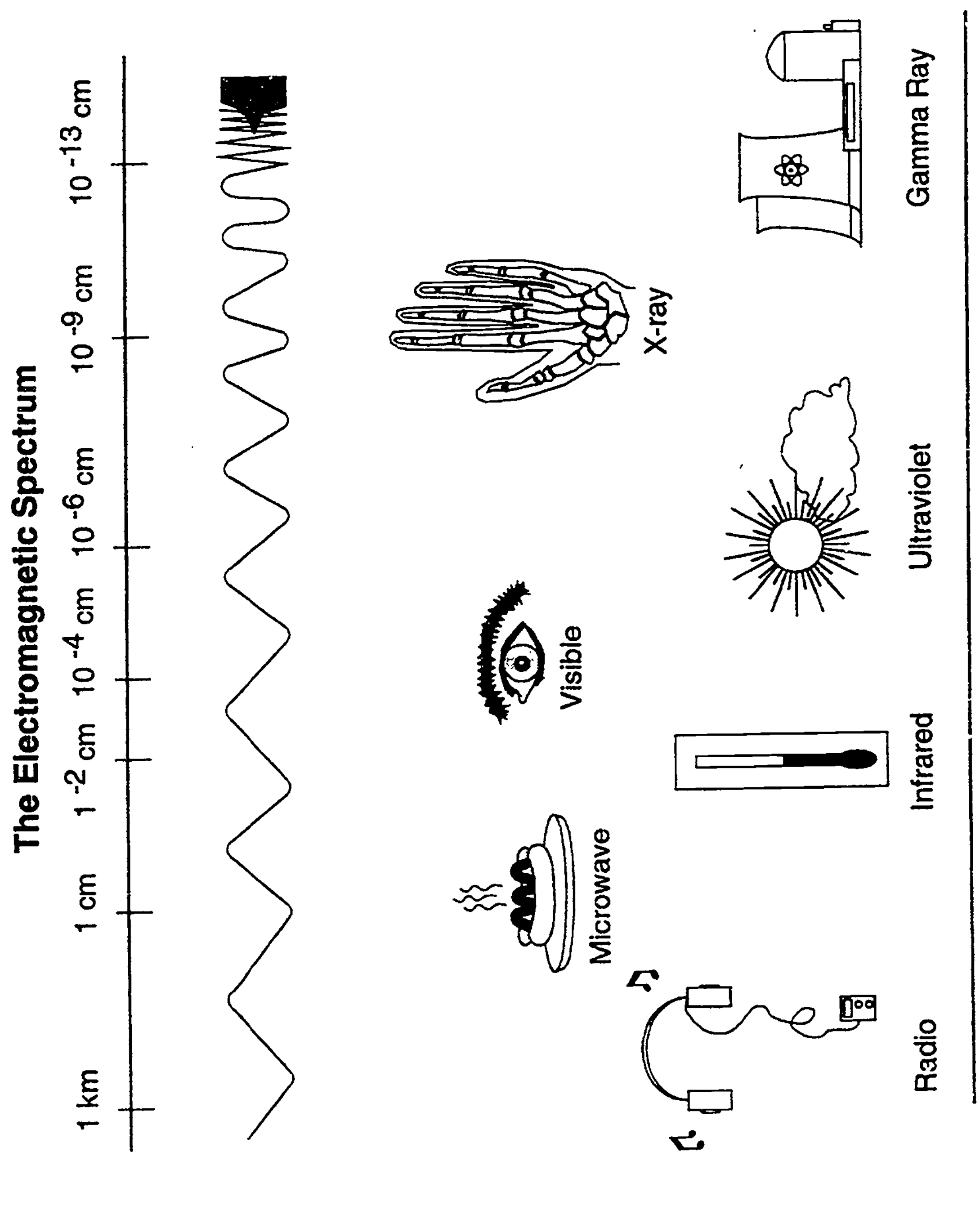
THEORY/INFORMATION

The International Space Station is a science laboratory that orbits 335 - 460 kilometers (208 to 265 miles) above the Earth. At this altitude the space station is beyond most of the effects of the gases, water vapor, dust, ash, and the pollution of the Earth's atmosphere. At this altitude the station is also far enough away from the Earth to view the planet from a global perspective. Astronomers can use the space station to collect more information about the Universe. Earth scientists and life scientists can study the Earth's processes, life forms, and their ever changing relationships.

From the International Space Station, astronomers will take measurements of the various wavelengths of energy that radiates from objects in Space. By analyzing this energy scientists can identify the elements that are present on the surface of the objects. The extremely sensitive measuring instruments used by scientists can be attached to space station for data collection or testing. At times these instruments will be deployed from the station aboard satellites.

From the International Space Station, scientists will also focus their instruments on our home planet to observe the processes at work on and around Planet Earth. From this position they can use instruments to collect information about the visible as well as the invisible wavelengths of the electromagnetic spectrum. Scientists analyze all the wavelengths of radiant energy to search for patterns. The study of the visible color bands produced by various kinds of spectrometers is called spectral analysis. Scientists studying the visible wavelengths find that elements give off energy. Each element produces its own unique pattern or colored bands. Scientists analyze the colored patterns to identify the elements.

Special instruments are also used to record data and search for patterns in the invisible wavelengths of the electromagnetic spectrum. These patterns or spectra can be recorded as bands of colors, dark bars, graphs, or numbers. Earth scientists, metallurgists, biologists, botanists, and many other scientists collect information about the various wavelengths of energy that radiate from Earth. From space station, instruments can be used to find underground water, sample air and water pollution, and pin point objects, animals, or people. Animal herds, crops, forests, and ocean and ground water can be continuously monitored. Every 90 minutes instruments orbiting aboard space station can take readings and relay new information about plants, animals and specific sites on the Earth's surface.


The Electromagnetic Spectrum
1 km
1 cm
1 -2 cm
10 -4 cm
10 -6 cm
10 -9 cm
10 -13 cm
Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray

Spectral Analysis

Level (Grades 6-8)

OBJECTIVE

The student will construct sample spectral patterns of at least two elements. The student will also demonstrate Edwin P. Hubble's Red-Blue Shift theory.

MATERIALS

1 Pencil
1 Pack of colored pencils or crayons
1 Complete Visible Spectrum sheet
1 Lithium Spectrum sheet
1 Helium Spectrum sheet
1 Extra sheet
1 Utility knife or single-edge blade

(FOR SAFETY THE TEACHER MAY WISH TO DO ALL CUTTING.)

QUESTION

How do scientists use spectral analysis to learn more about Planet Earth and the Universe?

Procedures

1. Use colored pencils or crayons and color the Complete Visible Spectrum sheet. Observe the order of colors on this sheet.

2. Use a utility knife or single-edge blade and remove all of the black bands from the Lithium and Helium Spectrum sheets.

3. Place the Helium Spectrum sheet over the Complete Visible Spectrum sheet. Observe the pattern made by the bands of color.

4. Place the Lithium Spectrum sheet over the Complete Visible Spectrum sheet. Observe the pattern made by the bands of color.

5. Shift or move the Helium or Lithium Pattern sheets 15 columns to the right. Observe the pattern. You have just demonstrated Hubble's Red Shift theory.

6. Shift or move the Helium or Lithium Pattern sheets 15 columns to the left. Observe the pattern. You have just demonstrated Hubble's Blue Shift theory.

7. An Extra Sheet is included for students who wish to reproduce the spectra of other elements.

Data, Observations, and Conclusions

1. Observe the Complete Visible Spectrum sheet. What are the colors in the visible spectrum?

2. In nature, where could you see the colors in this order?

3. What color is located at 3,900 angstroms?

4. What color is located at 7,000 angstroms?

5. What is an angstrom?

6. How many colors are visible in the Helium Spectrum sheet?

Information: Edwin P. Hubble, an American astronomer, developed a theory about objects speeding through Space. Hubble said that objects rapidly speeding through Space cause a distortion in the wavelengths of light and the spectral pattern moves or shifts. According to Hubble, an object speeding rapidly away from Earth causes a shift toward the red or infrared end of the electromagnetic spectrum. An object that is speeding rapidly toward the Earth causes a shift toward the blue or ultraviolet end of the spectrum. Hubble called this idea Red-Blue Shift. Hubble also developed a formula to calculate the speed of an object based on the amount of red or blue shift. The faster an object is traveling the greater the shift.

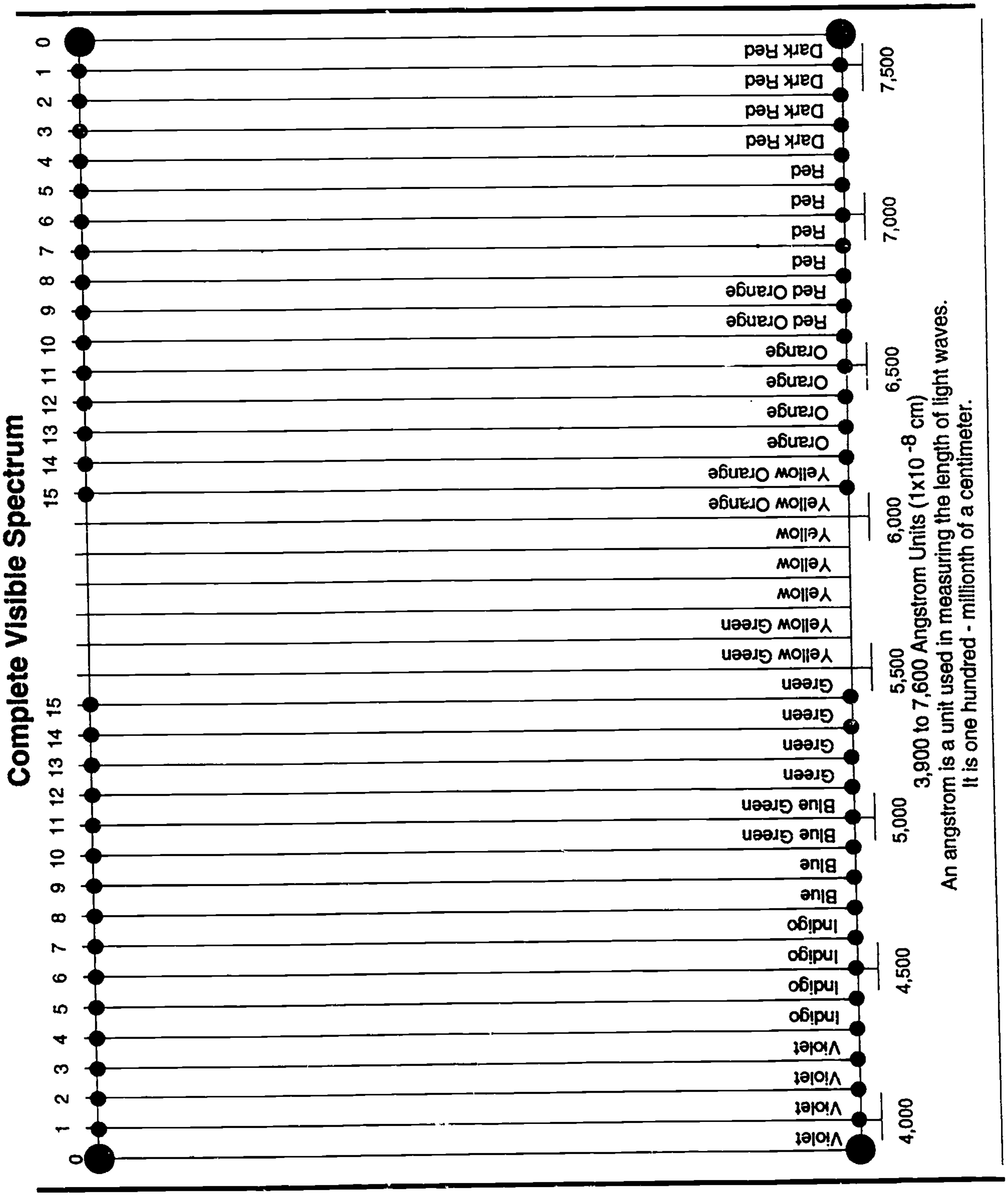
7. How does the spectrum of lithium change when the Lithium Spectrum sheet is moved or shifted 15 columns to the right? What happens to the color bands between the 6,000 and 7,000 angstroms?

8. How does the spectrum of helium change when the Helium Spectrum sheet is moved or shifted 15 columns to the left? What happens to the color bands between the 4,400 and 5,100 angstroms?

9. When the color bands shift or move out of the visible spectrum what happens?

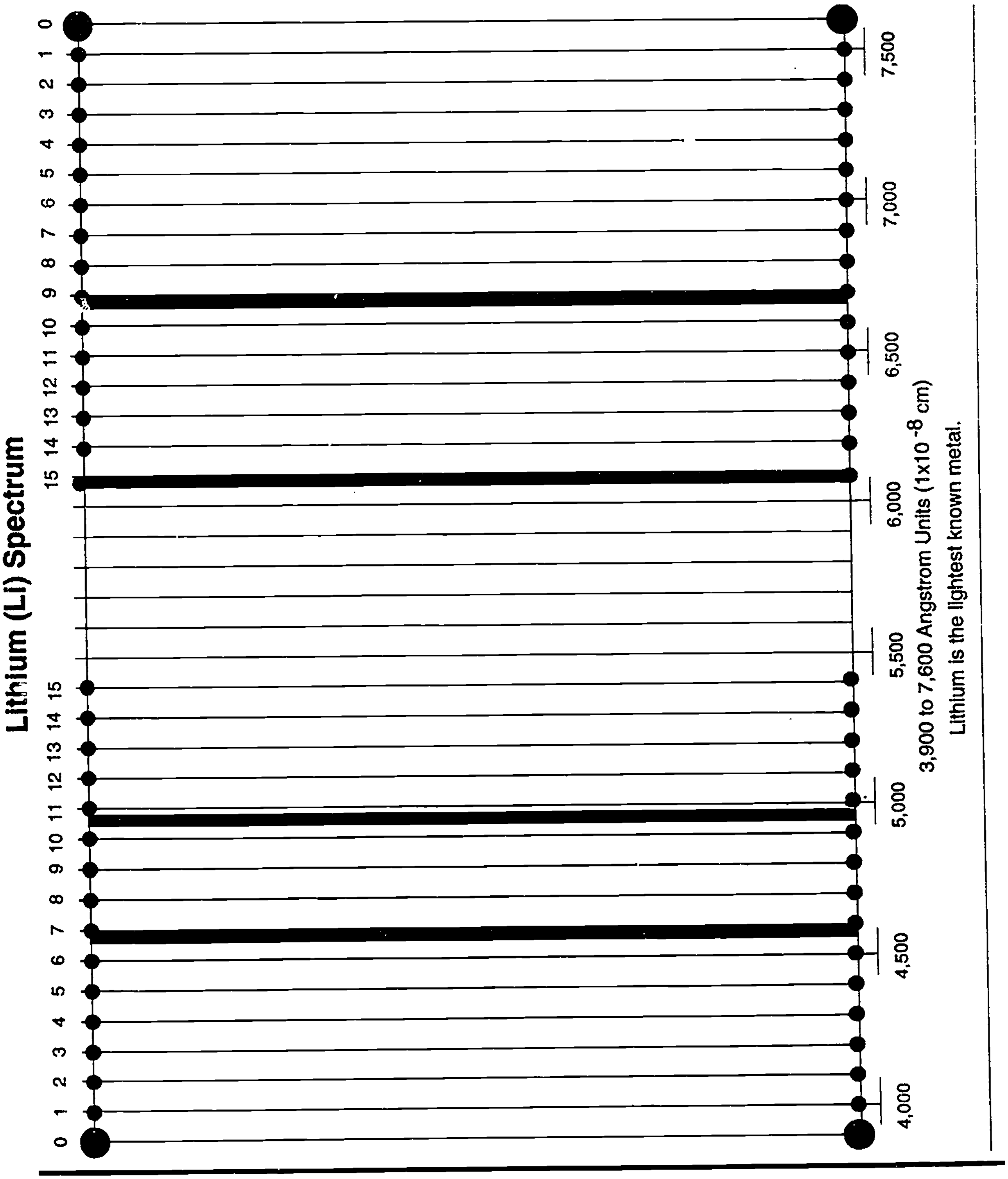
Spectral Analysis

Level (Grades 6-8)



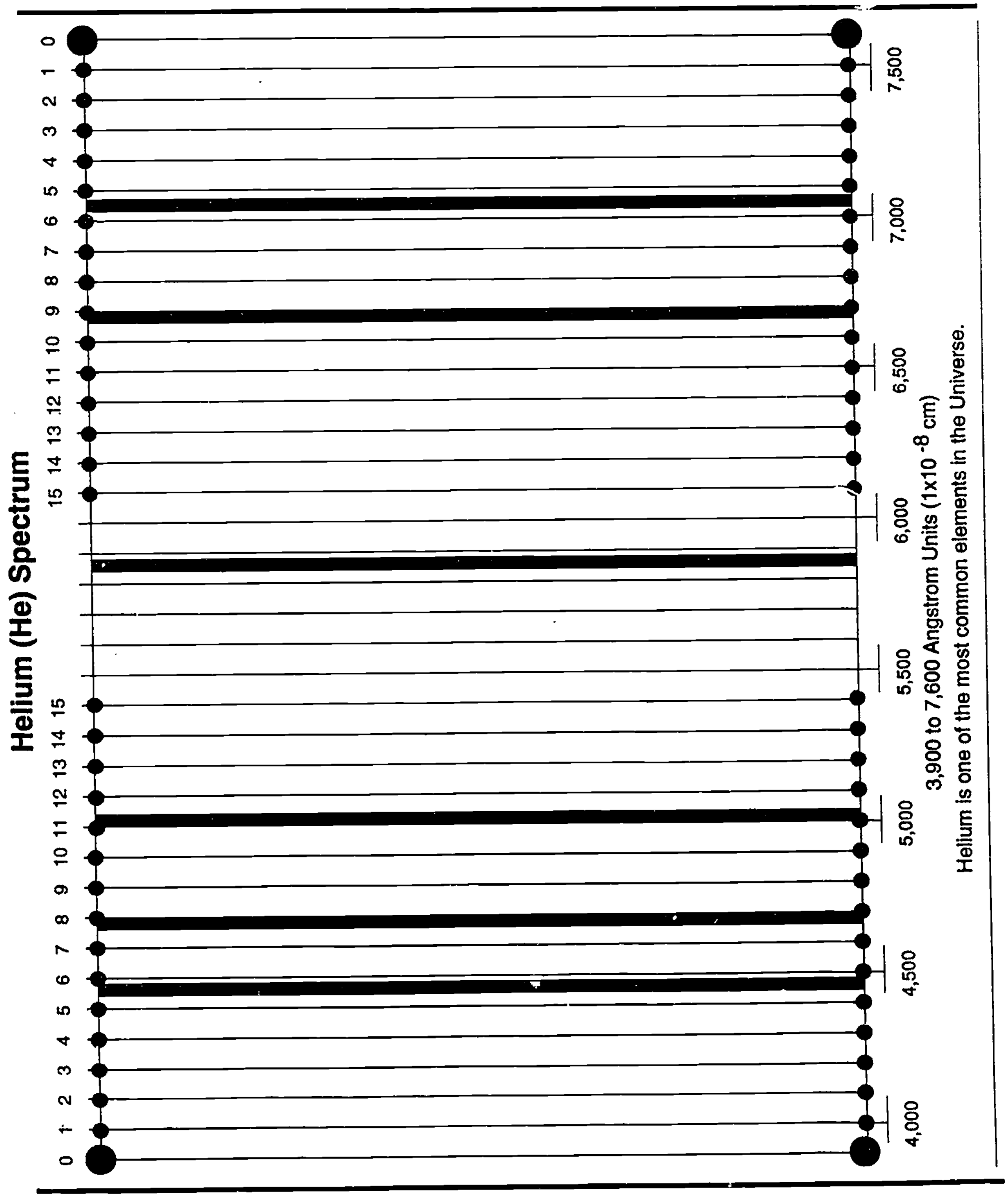
Spectral Analysis

Level (Grades 6-8)



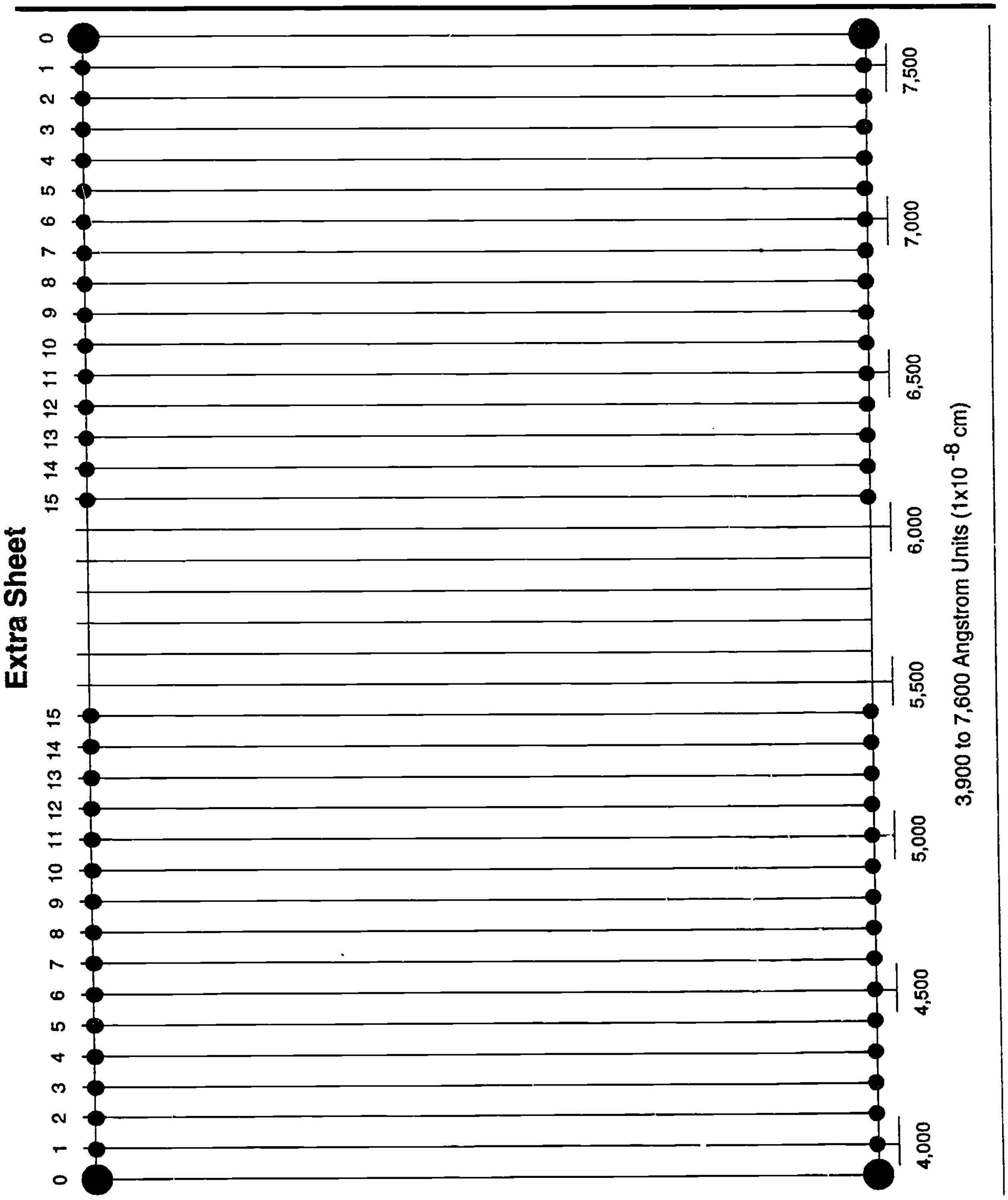
Spectral Analysis

Level (Grades 6-8)



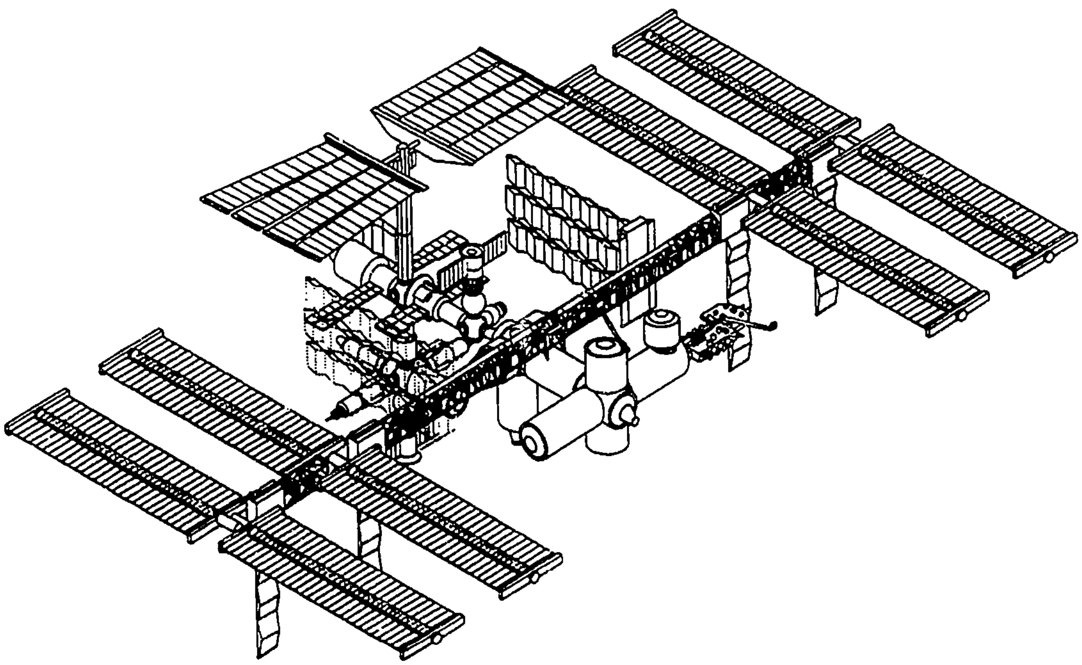
Spectral Analysis

Level (Grades 6-8)



International Space Station

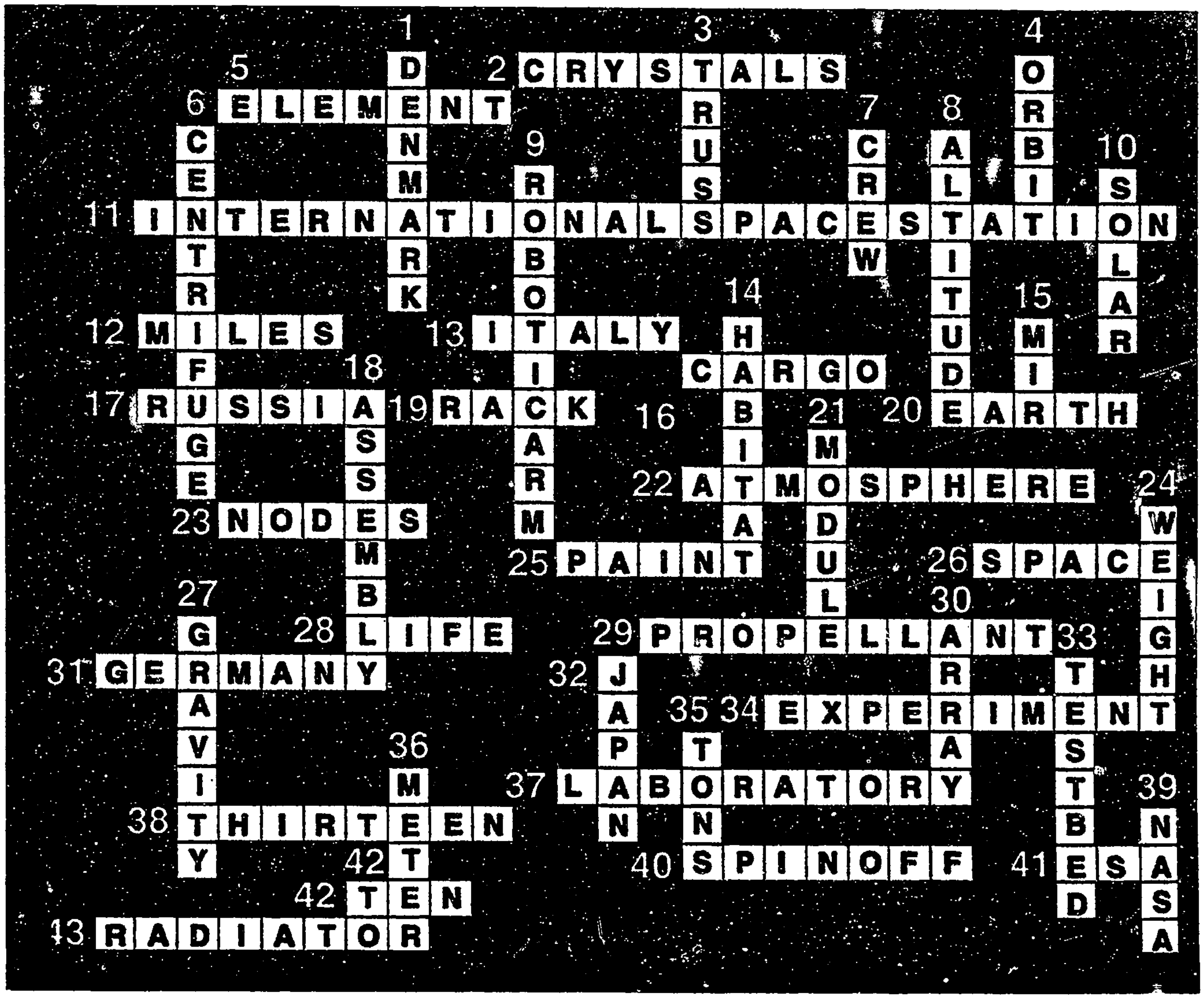
Answer Booklet
6-8 Hands-on Science and Math



Answer Booklet

Level (Grades 6-8)

Space Station Identification - Page 3



OBSERVATIONS, DATA, AND CONCLUSIONS - Page 6

1. **International Space Station** is the name of the new space station.

2. There are **eighteen** countries cooperating to build the International Space Station. The countries are **Austria, Belgium, Canada, Denmark**, the **Federal Republic of Germany, Finland, France, Great Britain, Ireland, Italy, Japan**, the **Netherlands, Norway, Russia, Spain, Sweden, Switzerland**, and the **United States.**

3. The International Space Station will be completely operational by **June 2002.**

Space Station Identification (Continued)

4. The **solar arrays** will provide the electrical power to run the equipment and machinery on space station.

5. The **truss** is the backbone-like part of the space station.

6. The crew on the completely operational space station will bathe, sleep, eat, and live in one **habitat module.**

7. The crew on the International Space Station will use the **seven laboratory modules** to conduct experiments and research. The **United States** will have **two laboratories.** The **European Space Agency** and **Japan** will have one **module each**, and **Russia** will have **three research modules.**

8. The **Thermal Control System Radiators** are designed to get rid of excess heat produced by the machines and equipment on the International Space Station.

9. The **nodes** serve as passageways or halls for the astronauts. They connect the modules of the space station together and can be used for experiments or storage areas.

10. The **centrifuge** spins life science experiments. It is used to simulate gravity for plant and animal experiments.

Answer Booklet

Level (Grades 6-8)

Crystallography - Pages 9-10

OBSERVATIONS, DATA, AND CONCLUSIONS

1. Complete the following table.

System Name	Number Faces	Number Edges	Examples
Isometric (Cubic)	6	12	salt, gold, diamonds, alum
Orthorhombic	6	12	sulfur, iodine, topaz
Tetragonal	6	12	tin, rutile, zircon
Monoclinic	6	12	borax, gypsum, sugar
Triclinic	6	12	turquoise, feldspar, boric acid
Hexagonal	8	18	hematite, snowflakes, graphite

Notice that the models of each crystal system, except the hexagonal, have the same number of faces and edges. Observe that the shapes of the models are different. The angle at which each edge meets is the factor that determines the shape of the particular crystal system.

2. On Earth the pull of gravity can cause crystals to collapse or be distorted. On Earth, crystals have to be grown in a container and the individual crystals crowd each other and stop growing while they are still small. In Space, crystals can grow while they are floating, and they do not have to crowd each other or touch the container. Uneven heating and cooling of substances on Earth can also cause small air currents that disturb the shape of crystals.

3. Crystals grown in space are larger and their shapes are more perfect. When studied by x-ray diffraction, the diffraction pattern of the Space grown crystals show fewer flaws in the internal structure.

4. Crystals are cut into tiny pieces to be used in electronic parts. Crystals are also studied to produce better man-made fibers and materials. The study of crystals in metals allows scientists to produce stronger, more dependable metals to use in machines or buildings. The study of protein crystals contributes to the understanding of the function of hundreds of proteins present in the human body. When the scientists can identify and understand the work of a specific protein, they can develop treatments or medicines to stop or start the function of the protein.

5. Optional: A salt crystal is shaped like a cube and it is a member of the isometric or cubic system.

6. Optional: Answers vary.

Answer Booklet

Level (Grades 6-8)

Spectral Analysis - Page 26

Date, Observations, and Conclusions

1. The colors in the complete visible spectrum from wave lengths of 7,600 to 3,900 angstroms are red, orange, yellow, green, blue, indigo, and violet. An easy way to remember the colors in order is the name Roy G. Biv.

2. In nature the visible spectrum can be observed in a rainbow. Red will be on top and violet will be on the bottom. The visible spectrum might also be observed when white light is refracted or diffracted as it passes through water, glass, plastic, soap bubbles, oil spots, small slits, tiny pin holes, and cloth or metal screens.

3. The color violet corresponds to wavelengths of 3,900 angstroms.

4. The color red corresponds to wavelengths of 7,000 angstroms.

5. An angstrom is a unit used in measuring the length of light waves. An angstrom is one hundred-millionth of a centimeter.

6. There are six colors or shades of color visible through the Helium Spectrum sheet. In a natural spectrum each color appears to blend into the next color, there are no apparent abrupt color changes like those produced by coloring the Complete Visible Spectrum sheet. Two wavelengths average to produce a third color between them.

7. When the Lithium Spectrum sheet is moved or shifted 15 columns to the right, the violet and blue bands of the spectrum are no longer visible. The first three bands are yellow, orange, and red. The fourth band has moved into the infrared and it is no longer visible.

8. When the Helium Spectrum sheet is moved or shifted 15 columns to the left, the first three bands move into the ultraviolet and are no longer visible. The last three bands move toward the blue end of the spectrum, and they are indigo, green and yellow green.

9. When the color bands shift or move out of the visible spectrum they can no longer be seen by the human eye. If the bands move into the red or infrared it is called Red Shift. If the bands move into the blue or ultraviolet it is called Blue Shift. Even though shifts into the infrared and ultraviolet can not be seen by humans, they can be analyzed by instruments designed to operate at those wavelengths.

Acknowledgments

This publication was produced as a part of the continuing educational activities of The Boeing Company. The following deserve thanks for their assistance:

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