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Crystals: What Are They and What Holds Them Together

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Introduction

Crystals have changed the world a lot. Crystals occur widely in nature and they are used a great deal in modern technology. Crystals are everywhere. The purpose of designing a unit on “Crystals What Are They And What Holds Them Together” is to help students learn about crystals and their structure.

The unit will deal with what is a crystal, the three states of matter: their properties, structure, ions and salts, and crystal growth.

The students will do some hands on activities with crystal creations, such as crystal on a string and snowflakes. The students will make several crystal system models. The unit will explain that a crystal does not suddenly spring into being; it grows into being.

The unit will deal with two methods of growing crystals. One method is by preparing a saturated solution and the other is growing crystal by evaporation. Both methods have advantages and disadvantages that will be discussed.

The unit can be taught to students in grades five through eight. The science and math teachers are encouraged to use a team teaching approach. Other features that will be included in the unit are content, lesson plans, resources, and a bibliography.

What Is Matter?

Matter is what the world is made of. All materials consist of matter. All matter has its own set of properties or characteristics. Some properties of matter such as color, size, and shape can be observed easily; other properties cannot be observed quite so easily. Properties that can be determined without changing the substance into a new kind of substance are called physical properties. Changes that do not produce a new kind of substance are called physical changes. During a physical change, the physical properties of a substance are altered, but the substance remains the same kind of matter.

Two Basic Properties: Mass and Volume

Mass is the most important physical property of matter in an object. The kilogram is the basic unit of mass in the metric system. For example, there is more matter in a large pool than in a child's play pool. So a large pool has more mass than a child's play pool. To measure small units of mass, we use the gram. One kilogram is equal to 1000 grams. Volume is another important property of matter. Volume is the amount of space an object takes up. Volume is expressed in units called liters (1), milliliters (ml) and cubic centimeters (cm^3). One liter is equivalent to 1000 cubic centimeters.

Using the two physical properties of mass and volume, you can define matter as anything that has mass and volume.

Density

Density is the mass per unit volume of a substance. The following formula can be used to find the density of an object. Density is mass/volume. Mass is usually expressed in grams, and volume in milliliters or cubic centimeters. Thus density is g/ml or g/cm^3. So we can compute the density of a 1-centimeter cube taken from the planet Mars with a mass of 3.96 grams. The average density of mass would be: Density=3.96g (mass)/1 cm^3 (volume)=3.96 g/cm^3. The density of water is 1g/cm^3, while the density of gold is 19.32g/cm^3.

The Three States Of Matter

On the earth, matter can exist in three states. The states of matter are solid, liquid, and gas. A solid has a definite shape. A liquid takes on the shape of its container. A gas does not have a definite volume or a definite shape. A gas fills all the space in a container, regardless of the shape or the size.

Most materials can take any of the three forms, with no change in their chemical composition. Steam, water, and ice are common names for the three forms taken by a single material.

The best way to picture the difference in the states of matter is to think about water which can be changed into a solid by freezing it to produce ice, melting it to produce a liquid, and heating it to produce a vapor or gas.

In order to understand the states of matter, you must know something about molecules. The different substances that exist are made up of small particles. A molecule is the smallest part of any substance that still has all of the properties of that substance. The behavior of solids, liquids, and gases can be explained in terms of the arrangement and movement of molecules.

In the solid, atoms are close together. They vibrate but cannot move past one another. In the liquid the atoms are almost as closely packed as in the solid, but they can move past one another. In the gas the atoms are widely separated, and can move almost independently.

Figure 1.1 The Three States of Master

(figure available in print form)

Molecules Are Small: How Small?

The kinetic theory gives us a clear idea of how molecules in a gas are affected by changes in temperature, volume and pressure and how they change from one state of matter to another. There are other things that we know about molecules; we can calculate their speed, their number, their size and their relative weights with a considerable degree of accuracy. The speed of a molecule will depend upon the temperature; it will also be affected by collisions with other molecules. The molecules in a gas will move at a wide range of speeds. The average is high; it is something like 1,000 miles an hour for oxygen molecule at 0°C. Heavy molecules move more slowly than light ones at the same temperature.

It is easy for us to grasp a figure like 1,000 miles an hour since airplanes have already reached speeds several times greater than that rate. It is harder to have a clear understanding of the very large number of molecules and their extremely small size. For example, in every cubic inch of air about us there are some 500,000,000,000,000,000,000 molecules. Suppose these were apportioned, share and share alike, among all the people of the world. Suppose also that the United Nations offered each person five cents per million for his share, provided he counted his molecules accurately. Would it be worth your while to turn in your share to the UN? The answer would be yes and no. The amount to which you would be entitled would be a respectable $8,500. But if a machine counted your molecules at the rate of three per second, day and night, you would have to wait something like 1,750 years, before you received your money according to *The Book of Popular Science* , Other Facts About Molecules, volume 1, p. 172.

The great Italian Chemist Count Amadeo Avogadro (1776-1856) calculated that 18 grams of water, which is a little more than half an ounce have 602,000,000,000,000,000,000,000 molecules. This huge figure is known as Avog adro's number; it has proved to be valuable in many calculations. It may be abbreviated to read 6×10^{23} would be 6 with 23 zeros after it or 602 with 21 zeros after it.. 6×10^{23} is 602 with 21 zeros after it.

We calculate the volume of a single water molecule by using Avogadro's number. We assume that the molecules are so closely packed in liquid water that the amount of empty space is negligible in comparison to the volume of the molecules themselves. Hence we may divide the total volume of water in 18 grams by the total number of molecules (6×10^{23}) in order to find the volume of one molecule which is about 0.000,000,000,000,000,000,000,03 cubic centimeters, or 3×10^{23} cubic centimeters. This calculation is in terms of the molecules of a liquid. The individual water molecule remains unchanged; it will have the same volume in the gaseous and solid states that it had in the liquid state.

Avogadro's hypothesis is that "equal" volumes of gases at the same temperature and pressure contain equal number of molecules. This means that at a given temperature and pressure, if 6×10^{23} molecules of water vapor occupy 50 liters, then 50 liters of any other gas, such as oxygen, for example will contain 6×10^{23} molecules.

There is still more to be learned about molecules. You may want to investigate later how they are transformed in nature, and how man deliberately changes their patterns to produce a large number of useful chemicals.

Inside the Atom

Atoms are made up of even smaller particles called subatomic particles. There are three particles that make up atoms. They are electrons, protons, and neutrons. Protons and neutrons are tiny specks that have almost the same mass. Protons are particles that carry a positive electric charge. Neutrons are particles that have no charge, which means that they are electrically neutral. Together these two kinds of particles make up the nucleus, the center of the atom. All around the outside of the atom are electrons moving around the nucleus like insects swarming around a street light. In an ordinary uncharged atom there are exactly as many electrons as protons, and there is just as much positive as negative charge.

As small as the atom is, it possesses mass. We cannot weigh an atom as we would weigh flour, or potatoes. The reading of the most delicate scale at our disposal would not be affected in the slightest if we added a thousand atoms to one of its trays. We can weigh an individual atom by indirect methods. We know, for example, that an oxygen atom weighs .000,000,000,000,000,000,000,026 grams. We call the absolute weight of the oxygen atom, because we consider it by itself and not in relation to the weight of the other atoms.

We use the relative weight or atomic weight to compare atoms. For example, we take an isotope of carbon as the basic unit of the system of atomic weights and give it the value of 12,000. When we weigh equal volumes of carbon 12 and hydrogen, we find that the carbon is about 11.905 times as heavy as hydrogen. In the atomic scale, hydrogen has the value of 12,000 divided by 11.905, or 1.008 (1.00797, to be more exact.)

Using the appropriate methods, we can compute the ratio between the weights of all atoms, which are listed in the Periodic Table. There are ninety-two naturally occurring atoms. For example the sulfur atom is 2.672 times heavier than the carbon atom; its atomic weight is 2.672 x 12 or 32.064. The weight of each atom is the sum total of the weights of each of the subatomic particles of which the atom consists. They are held within the atom by electrical forces. When we say that they are held together, we do not mean that they are closely packed. We mean that they occupy very little of the space within the atom since matter is made up of atoms. In spite of the fact that most of the mass of the atom is in the nucleus, the proton and neutron are extremely tiny. In a pound of any substance you think of iron, gold, cork or air as something like having 270,000,000,000,000,000,000,000,000 protons and neutrons.

Atoms are very small in size and in general we have no exact picture of their structure. However, models of atoms have been constructed to help people understand the basic structure and behavior of atoms. See figure 2

(figure available in print form)
(Figure 2. Drawing of a planetary model of an aluminum atom. According to this model, the electrons travel in fixed paths.

Electrons are found in a region called the electron cloud. This represents the space in which electrons are likely to be found. Within the electron clouds, electrons are arranged in energy levels closest to the nucleus. Electrons with higher energy are found in energy levels farther from the nucleus. See figure 3

(figure available in print form)
Figure 3. Drawing of an electron cloud model of an aluminum atom.

What Are Crystals?

Sometimes when a mineral is forming in the earth’s crust, it grows into a particular geometric shape. The shape of a crystal results from the way the atoms or molecules of a mineral come together as the mineral is forming. So, each mineral has its own crystal shape. This solid body have a characteristic internal structure and is enclosed by symmetrically arranged plane surfaces, intersecting at definite and characteristic angles.

Fashioned snowflakes, flawless diamonds with glittering facets, the almost perfect cubes of salt grains are all fine examples of crystals bodies with a pattern of flat surfaces that meet at definite angles. The universe is full of almost all nonliving substances in the solid state form crystals. Crystals are ice, snow, sugar, salt and sulfur; in metals like gold, silver, copper, iron and mercury; in precious stone like zircon, emerald, topaz, ruby, and sapphire.

A specific crystal is a collection of fundamental building blocks with atoms and molecules arranged in a unique and always repeated regular space arrangement. Nature has grown crystals over a long span of geological time. The smooth, hard surfaces of a crystal are not shaped by the tools of man.

The Inner Structure

The external differences between crystals are based on differences in internal structure. The particles of matter within a crystal are arranged in a framework called a crystal lattice. There are four types of structural units in crystal lattices. They are small molecules, giant molecules, ions or electrically charged molecules and atoms.

Crystals Made Up Of Small Molecules

In substances like ice, iodine and solid carbon dioxide or dry ice, the structural units of the crystal lattice are small molecules. These are held together by rather weak electrical forces. There is much space between the molecules and the crystals are light in weight. That is why ice is lighter than liquid water, though both substances are built up of the very same water molecules. It is important to know that ice is unique because if ice would sink, life in the ocean would be at stake. Fish and other aquatic life will freeze. Usually, crystals in which small molecules are the structural units have low melting points; they are good insulators and are relatively soft. In some cases the bonds between the molecules are so weak that the solid will change into a gas without first becoming a liquid. This is what happens in the case of dry ice which is solid carbon dioxide.

Crystals Made Up Of Giant Molecules

Some crystals consist of giant molecules. These may be built up in one, two, or three dimensions. Asbestos is a good example of a substance that forms one dimensional giant molecule. The asbestos giant molecule consists of a long chain of atoms; this accounts for the fibrous structure of the mineral. The molecules are set side by side; they are linked together by weak forces of attraction.

The giant molecules of graphite, made up entirely of carbon atoms, are two-dimensional; they are joined together in flat hexagonal plates which lie parallel to each other. See figure 4. The bonds between layers are weak in comparison with those within the hexagons; hence one layer slips easily over the one beneath it. That is why graphite is one of the best lubricants known.

The diamond is a giant molecule built up in three dimensions. Diamond consists exclusively of carbon atoms. Each atom is bonded to four neighboring atoms, which are grouped about it at equal distances. See figure 5, for example, the carbon atom A is bonded to carbon atom B,C,D, and E. B,C,D, and E are each bonded to other atoms in the same way. Since the distances between the atoms in this type of giant molecule are equal, the bonds are of equal strength. The results is a very rigid formation. The diamond is the hardest substance known and it is very difficult to cleave or split it. It has a high melting point; is a good insulator and is transparent.

(figure available in print form

Figure 4. Show the giant molecules of graphite, made up of carbon atoms, form parallel layers of flat, joined hexagonal plates. The bonds between layers are shown by dotted lines in the diagram.

(figure available in print form)

Figure 5. Shows how the atoms of giant diamond molecules are grouped. A,B,C,D and E are carbon atoms.

Crystals Made Up Of Ions

In salts, the unit making up the crystal is an ion, an electrically charged molecule or atom. Each atom has a nucleus or central core made up chiefly of protons, each with a positive electrical charge, and neutrons, which have no charge. Around this central core revolve the electrons, each of which has a negative charge. Normally the charge of an atom is neutral; which means that there will be as many negative charges as there are positive charges. If an atom loses an electron, it has one excess positive charge; it becomes a positive ion. If an atom gains an electron, it has one excess negative charge; it becomes a negative ion. Look at what happens when sodium, normally a metal, and chlorine, normally a gas react to form the solid called sodium chloride, NaCl, which is table salt. Each sodium atom transfers an electron to a chlorine atom. The sodium atom becomes a positive ion since it now has an excess positive charge. Each chlorine atom acquires a single excess negative charge; it is now a negative ion.

Ions with unlike charges attract each other, the chlorine ions will attract the sodium ions; but will hold off the other chlorine ions since ions with like charges repel each other. As a result of the attraction between the oppositely charged particles, each chlorine ion will surround itself with six sodium ions; each sodium ion will surround itself with six chlorine ions. See figure 6

This pattern will be repeated throughout the crystal. Figure 7 shows positive ions (Na^+) and negative chlorine ions (cl-), closely packed together in a crystal lattice of table salt.

Substances that have the ionic type of lattice have moderate insulating properties and high melting points. They are hard, but they can be split along definite lines.

(figure available in print form)

Figure 6. Shows ions (NA+) and negative (clÐ), closely packed together in the crystal lattice table salt.

(figure available in print form)

Figure 7.

Crystals Made Up of Electrically Neutral Atoms

In metals, the atom is the structural unit in the formation of a crystal. The atoms may be thought of as spheres having the same diameter and packed together as closely as possible. To illustrate one arrangement, let us imagine that fifteen billiard balls are racked up to form the base, or foundation layer. See figure 8. Six more are set on top of the first layer of balls; then another ball is placed on the second layer. This shows the closest packing possible in a cube. Iron, lead, gold, silver, and aluminum assume this kind of pattern. There are several other arrangements of atoms in metallic crystal lattices. Lattices of this kind are opaque; they have moderate harness; they have high melting points; they are the best conductors of heat and electricity. These qualities make metals very useful.

(figure available in print form)

Figure 8. Shows how atoms (viewed from above) are packed in the crystal lattice of various metals, such as iron, lead, gold, silver and aluminum.

The Internal Structure Of A Crystal Affects Its Properties

The variation in internal structure shown by different crystals have a direct bearing upon their properties. Different crystals have different lines of cleavage, which are lines along which they split most readily. They conduct heat at different rates. They react differently to magnetic and electrical forces. A few crystals, like those of the mineral Iceland spar, allows only light waves that vibrate in parallel planes to pass through them. This effect is called plane polarized light. For example, try to pass a knife blade between the pages of a closed book. This will be possible only if the knife blade is held parallel to the pages. The book in this case would correspond to the Iceland spar crystal; the knife would correspond to one of the parallel planes in which the light would vibrate.

If a light is allowed to pass through a selected crystal of quartz, the plane of polarized light is twisted to the plane to the same angle to the left. Crystal of the first type are called right-handed, those of the second type, left handed.

The fact that different crystals will rotate the plane of polarized light in different directions forms a reliable means of identifying certain substances. For example, sugars in solution will rotate the planes of light through different angles; the angle of rotation will identify each sugar in question.

Lab Activity: Growing Crystals

There are two simple methods for growing crystals. They can easily be grown from solution and evaporation. A crystal never loses its ability to grow whereas a living cell does. Dry crystals remain dormant. They will always grow more when placed in a solution which is growing similar crystals. A crystal needs substance to grow from. Where there is no substance, for example at points where crystals come in contact, the crystal stops growing. Crystals will now grow from any solution of its own substance. A crystal growing in a drop of solution will begin to dissolve again if a drop of water is added to the drop of solution. The crystal will again start to grow when this added drop of water has evaporated. Crystals are very choosy about the conditions under which they grow.

Two Methods Of Growing Crystals

There are two general methods which are convenient for growing certain crystals. In both, you suspend a seed crystal by a thread in a jar of solution. In one, the sealed jar method, you supersaturate, or make more highly concentrated than the normal saturated solution and seal the jar to keep water from evaporating. The seed will grow as excess salt in the solution slowly crystallizes on it.

In the other method, growing by evaporation, you start with a saturated solution, a solution that is completely filled, and permit it to slowly evaporate. The jar is not sealed, but the top reduces, the rate of evaporation and keeps dust out of the solution. The crystal grows as water evaporates.

In both these methods even temperatures are important because temperature changes alter the amount by which the solution is supersaturated. Refer to growing crystals in the book, *Crystals Insects* , *and Unknown Objects* , by John McGavack Jr. and Donald P. LaSalle, Page 143.

The first step in either method is to make a saturated solution, one that is saturated at the temperature at which the crystals will grow. Making saturated solutions requires time and patience. Refer to recipes for crystal growing in the book *Crystal and Crystal Growing* by Alan Holden and Phyllis Singer, pages 108 to 119.

Both methods of growing crystals have advantages and disadvantages. The evaporation method allows a progressive supersaturated of solution. This allow you to get back all of the solid in the form of a single crystal. The rate of evaporation is hard to control. It depends on the humidity of the environment and how often casual drafts remove the evaporated moisture. Since evaporation takes place at the surface of the solution, the supersaturation tends to be greatest there and factitious or artificial seeds often form at the surface and may drop on the desired crystal. In the sealed jar method, supersaturating the solution by cooling it below its saturation temperature is only as effective as your control of the temperature of the environment. As the crystal grows, the supersaturation declines, and then automatically provides the slower growth rate usually desirable for larger crystals. The amount of material which can be deposited from the solution is limited to that amount originally dissolved in the saturated solution when it was made. Probably the quickest way of growing crystals is by use of the sealed jar method. For more information on crystal growing, refer to the unit developed by Lois R. VanWagner on “More Than Meets the Eye: The Story of Crystals”, Crystals in Science and Technology, Yale New Haven Teachers Institute, 1989.

Epilog

This unit is not designed to answer all of the questions you may have about crystals or crystal growing. It is designed to serve as a motivational device for teachers and students who are interested in learning about crystals. The success of this unit relies heavy on activities used or developed by the teacher. As you explore different activities, perhaps you will better understand general information about matter, and atoms and how they relate to crystals and other fascinating things in our universe.

The unit will allow you to formulate and investigate many of your own questions and concerns. It is designed so that the classroom teacher can best determine on a day-to-day basis your discussions, findings, and opinions.

Remember, you are using the unit on “Crystals What Are They And What Holds Them Together”, as a vehicle to get students to practice all forms of expression and to help develop improved work skills in dealing with unfamiliar problems. The final goal is not just to know facts about crystals, but to help students in their work with crystals to develop a process. This process will lead to a method of thinking and a scheme through which they learn to organize their own personal experiences.

This is the desire and motivation of which inspires me to share this unit with you. There are six other units written by New Haven Teachers on crystals. You may refer to “Crystals In Science and Technology”, Yale New Haven Teachers Institute, 1989; as a resources in studying this unit.

Lesson Plan I

Learning More About Atoms

Objective The student will learn more about the characteristics of the atom.

Activities

1. Display a chart of the atoms. Periodic Chart and note a few of the general characteristics such as, symbols and atomic number.
2. Examine the Periodic Chart of the Elements. What information can be obtained from it? Where are the metals located? Where are the gases in the chart? Can the chart tell something about the size of atoms? There are many other good questions which can be a part of this activity with the Periodic Chart.
3. Construct models of an atom. Select a simple one first. Remember that this is a model and does not have to be identical to the atom in every respect.

Lesson Plan II

Objective The student will be introduced to the basic techniques and procedures which they will follow in their study of crystal growth.

Materials Needed: Inexpensive microscopes, microscope slides, salt and sugar.

Procedure Place some salt on a microscope slide and look at it through the microscope. Describe what you see. Draw a picture of what you see. Next place some sugar on a microscope slide and look at it through the microscope. Describe what you see. Draw a picture of what you see.

Discussion When these substances are dissolved in water they seem to disappear. We know the substances salt and sugar have not been destroyed, for the water tastes salty or sweet. If the water is evaporated the solid substances will be restored.

Follow Up Make a small solution of salt and water. Place a drop of this solution on a microscope slide, use a toothpick. Observe the drop through the microscope as it evaporates. Describe what you see. Repeat using a small solution of sugar and water. Describe what you see.

Lesson Plan III

Objective The student will learn how a crystal will grow.

Observations

1. Do you think crystals will grow from any solution of its own substances. Add a drop of water to a drop of solution you are watching grow under the microscope. What happened?
2. When there is no longer any material for crystals to grow from, and they have stopped growing, do crystals ever lose their ability to grow more?
3. Place a drop of salt solution on a microscope slide and watch the crystals grow as you look at them through the microscope. Drop into the solution a few crystals of salt. Do these crystals grow or disappear?
4. Do crystals ever lose their ability to grow?

Discussion Crystals will not grow from any solution of its own substance. A crystal growing in a drop of solution will begin to dissolve again and again if a drop of water is added to the drop of solution under the microscope. The crystal will again start to grow when this added drop of water has evaporated. Crystals are choosy about the conditions under which they will grow. When there is no longer suitable and sufficient material for a crystal to grow from, and it has stopped growing, the crystal does not lose it capacity to grow. A dry crystal never loses its ability to grow.

Lesson Plan IV

Objective The student will learn to formulate questions and concerns about his/her observations.

Observation Solutions have been made of the substances you viewed earlier. Place a drop of one solution on a microscope slide, use a toothpick, and watch the drop through the microscope as it slowly evaporates. For each solution try answering the following questions:

1. Do you see crystals right away?

2. Do you see them in a half a minute? A minute? More?
3. How fast do the crystals grow?
4. How large to they get?
5. Where do crystals start to grow in the drop?
6. Are the shapes familiar? Compare them with the ones you saw in activity I.

7. Why do the crystals seem to stop growing?

Lesson Plan V

Crystals On A String

Objective The students will observe how some crystals are formed.

Materials Needed A hot plate or other heat source, a kettle, a spoon for stirring, about 500 g of sugar, alum, salt, three fruit jars, water, three pencils, three paper clips, string and scissors.

Procedure Tie a l5cm length of string to the middle of a pencil.
Then tie a paper clip onto the string's other end. Place the pencil across the top of a jar, so that the paper clip hangs in the middle of the jar. If the clip hangs down too far, wind the string around the pencil until you find the correct position. The string and paper clip will act as seeds for the crystals. Pour 250 ml of water into the water, stirring it until it dissolves. Keep adding sugar until no more will dissolve in the water. Now pour the solution into one of the prepared jars, submerging the paper clip. Put the jar in a place where it will not be disturbed and observe it for the next several weeks, watching crystals form on the string. Because sugar crystallizes slowly, the formations will be small if the jar is moved at all. Repeat the procedure using salt and then alum. The alum will crystallize immediately; salt takes a little longer, usually overnight. Have your students observe the crystals with a magnifying glass and under a microscope. Can they see the same shape repeated again and again? How are they alike? How are they different? Why?

Discussion The crystals that the class is creating are formed chemically by putting simple substances into supersaturated solutions using heat and evaporation to change them from liquids to solids. All elements have their own unique crystalline shapes, and they will always form these shapes when solidifying. For example, salt always forms cubes when it crystallizes. This experiment is taken from Nona Whipple and Sherry Whitemore, Science and Children, "crystal Creations: Crystals On A String", January 1989, page 16.

Teacher Reading List

A. Holden, “The Nature Of Solids” Paperback. An introduction to the basic principles needed to understand the properties of solid. Readers with little Science background may find parts of this text somewhat technical.

A. Holden and P. Morrison, “Crystals and Crystal Growing”. Paperback. A simple discussion of crystals and some of their properties. This book contains some nice discussions of simple experiments which could be done with a class.

F.H. Pough, “A Field Guide To Rocks and Minerals”. Paperback. An introduction to aology and the methods of identifying minerals. Some nice color photos.

E.A. Wood, “Crystals—A Handbook For School Teachers”. Paperback. A concise discussion of a number of simple experiments which can be done in class. Simpler than Holden and Morrison with primary emphasis on the experiments.

E.A. Wood, “Crystals and Light” (1977). Paperback. An excellent introduction to the optical properties of crystals.

Teacher Resource List

Computer Materials

“The Great Physical Science Knowledge Race”, Grade Level: 7th to 9th. Appropriate for School Use-covers the topics of sound and light, electricity, magnetism, motion and force, chemical properties, atomic structure, the periodic table, and acids and bases. Includes back-up disk. Apple (FM48AP), Price $85.00.

“Chemicals Of Life I: The Structure Of Matter”, Grade Level: 7th to l2th, Appropriate for School Use-Discusses the study of molecules, models of atoms, ions and charges, and ion and covalent bonding. Upon completion of this program, students should be able to determine the number of atoms in a compound, calculate the total electrical charge of an atom and explain ion formation oxidation states, stable octets, use the periodic table and describe bonding. Requires IBM PC color display or equivalent. IBM (IBMOlPC), Price $65.00.

Field Trip

Peabody Museum—The Hall of Minerals and Rocks is an excellent resource to take groups of students to learn about geology and mineralogy through the use of the fine exhibits and hand samples. There are museum instructors from the Public Education Department, available to provide educational instructions to classes as they relate to the school’s curriculum. Contact Mrs. Willa S. Hemingway at 432-3775.

The museum is located at 170 Whitney Avenue and corner of Sachem Street.

Scientific Companies That Publish Handy Science Catalogs, Newsletters And Other Freebies

“Workshop For Learning Things”, 5 Bridge Street, Watertown, MA. 02172. Has simple science equipment including inexpensive microscopes.

"Science Service", 1719 North Street, N.W., Washington, D.C., Produces many inexpensive small kits and materials, each kit features a related science topic. Order from Things of Science, RD #1, Box 1305, Newtown, PA. Ask company to send their catalog.

"Curriculum Innovations", 501 Lake Forest Avenue, Highwood, IL. 60040, educational periodicals for classroom use. Ask the company to send periodicals that relate to molecules, atoms, and elements, etc.

"Field Enterprise", Merchandise Mart Plaza, Chicago, IL. 60654. Has excellent free reprints from World Book Encyclopedia. Also published Science Year among other useful science books.

Student Reading List

Asimov, Isaac, *Building Blocks of the Universe* , N.Y., Abelard Schuman, rev. ed., 1961; 280 pp. For beginners. Tells who discovered elements; how they were discovered; how they got names, their uses.

Berry, James, *Exploring Crystals* , N.Y., Crowell-Collier, 1969; 104 pp. Gives simple elements of crystal form and structure and some of the applications of crystallography; includes home and classroom experiments, with instructions.

Frisch, Otto R., *The Nature of Matter* . N.Y., Dutton, 1972; 216 pp. Simple introduction to atomic theory and subatomic particles.

Wohlrable, Raymond A., *Crystals* , Phila., Lippincott, 1962; 128 pp. Simple, well illustrated discussion of crystals from snowflakes to transistors; has directions for growing crystals.

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