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Crystals in the World around Us

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As a teacher of Special Education, one of the biggest problems I am faced with is how to motivate the student. This is a challenge that is not easily met since motivation is precisely one of the areas where they are more seriously lacking. One of the worst moments a teacher faces, I think, is when he is in front of the class demonstrating something only to be met with blank expressions. What to do? How to reach into those minds and share something meaningful? The magic of science may be a tool to help awaken some interest!

Science is the magic of our modern world. What person has not been fascinated by the wonders of science? With its test-tubes, rockets, telescopes, microscope, chemistry-sets, the atom and Milky-Way, etc. Even the special-ed. child will be lured into tinkering with these magic tools.

Using crystals as the springboard I propose to let our children have a taste of being the scientist by letting him do the experiments and asking the questions. This program intends to be a hands-on experience where the students will grow a number of crystals, ask questions and experiment. A log will, optionally, be kept by the students on the progress of their experiments. At the end of the program the students will have a display showing their crystals in various stages of development. Additionally, the students will have models of crystals to take home. The students will also have some understanding about the forces that shape crystals into their particular forms as well as having criteria in identifying crystals.

The program will touch on the building blocks of matter and how they unite to create the great diversity that we see all around us. Students will get an appreciation of size through a little comparative math. Comparing, for example, the difference between an ant and an elephant will cause raised eye-brows and laughter.

Learning could and, whenever possible, should be fun. This will make the lesson easier to assimilate. To this end we will spend some time tracing, cutting, coloring, and pasting patterns into shapes, mobiles and other forms of decorations. This will reinforce the lesson as well as create an enjoyable activity.

Finally, the group will tour the neighborhood and make field trips to find out more about crystals , where they are found and how they affect our lives through technology.

OUTLINE

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IV MOLECULAR STRUCTURE OF CRYSTALS
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   B. Bonds.
   C. Molecular Patterns.
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V. FUN WITH SHAPES

Tracing, cut-outs, mobiles, coloring, repeating-patterns, free-form, more . . .

VI. FUN WITH NUMBERS

A. Introducing the Metric System.

B. The Powers of Ten.

C. Illuminating Comparisons.

1. The Atom and the Graine of Sand.
2. The Ant and the Elephant.
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VII. EXPLORING CRYSTALS IN THE WORLD AROUND US

A. In the Home.

B. In the Neighborhood.

1. Museums.
2. Out of doors (field trips).
3. In our neighborhood.

VIII. REFERENCES, RESOURCES and BIBLIOGRAPHY

1. INTRODUCTION

A. The Elements

It is not positively known how we got here but one of the more popular beliefs is that billions of years ago the earth was an exceedingly hot, coalescing place. It was so hot, in fact, that there were no recognizable features; nc mountains, oceans or land. The earth was one limitless, luminescent ocean of magma. After many millions of years the earth eventually cooled down and everything that we know of today separated out of this very hot soup that we call magma.

Today, billions of years later, the earth is still a very hot and inhospitable place only a few miles below our feet. There the earth is still hot, boiling magma, fiery and violent. Occasionally this magma will erupt to the surface through some crevice or volcanic explosion and rudely remind us about exactly where it is that we are living on.

Most of the earth is made up of magma. Magma is melted rock. It is made up mostly of silicon and oxygen. Earth's crust has ninety-two elements all of which are present in magma. Some of these you find a lot of; others are rare. Of all the elements only about twelve are abundant enough to make up an important part of the earth's crust. Some of these are:

Earth's Most Abundant Elements [1]

Oxygen	0	46%
Silicon	Si	27%
Aluminum	Al	8%
Iron	Fe	5%
Calcium	Ca	3%
Sodium	Na	2.8%
Potassium	K	2.5%
Magnesium	Mg	2.0%

B. The Minerals

Minerals come from nature. They crystallize from magma or are deposited from solution. Minerals are made from elements. From minerals we get crystals. Crystals are solid mineral bodies. They have a definite shape and volume and their atoms are arranged in fixed, regularly repeating patterns.

When most of us think of crystals we may have in mind gems and the more dramatic crystal forms. The field of crystals is surprisingly large, however. It includes items one would never guess are categorized as crystals. For example, all metals are crystals. Rocks, trees and bones are also considered crystals. Glass, something many layman might consider a crystal, is one of the rare items not a crystal. That is so because its molecular structure is not in a fixed, regularly repeating pattern. A crystal, therefore, is defined by its fixed, regularly repeating internal structure. It was only with the advent of X-rays that this structure was confirmed. This regularly repeating structure is also what is responsible for the great outward beauty of crystals.

II. GROWING THE CRYSTALS

Most of the following material has been gathered from Elizabeth Woods, Crystals A Handbook for Teachers. The reader is referred to that source for more detailed procedure and further experiments.

Growing crystals is one of the more interesting and pleasurable parts of this curriculum. This is a hands-on experience where the students grow their own crystals from solution. We grow crystals from salt solution because they are readily available and the process is not dangerous. Growing a crystal from a melt, for example, would be much more dangerous.

A. Equipment and Procedure

Salt (table salt, sodium

chloride, NaCl)

Sugar

Water

Borax

Alum(Ammonium alum)

Equipment Cup, glass or other container Measuring cup Teaspoon, thread or thin string Magnifying glass Tweezers or forceps Microscope slides Candle or match flame Source of heat to boil water refrigerator

B. Sodium Chloride

Growing the crystals and observing their growth. Put 3 teaspoonfuls of salt into—cup water. Stir well. Let the mixture stand overnight. Next morning the mixture will appear clear. Pour clear solution into a shallow glass or cup being careful not to stir up any material from the bottom. This process is called *decanting* . Let clear solution stand, uncovered, for a few days.

The solution is now *saturated* . As the saturated solution stands and the solvent evaporates, it may become *supersaturated* . In the case of a supersaturated solution, the addition of the tiniest bit of *solute* (crystal) will cause *precipitation* of the excess solute in the bottom of the vessel.

As the first crystals appear examine them with a magnifying glass. Watch it change from day to day.

Question What forces cause the solution to solidify in the form of little cubes? It is an amazing fact that out of a formless solution such ordered form should come out!

a. What to do with the crystal

1. An exhibit could be made showing the development at various stages. The sequence from small to large will show how the crystal keeps its form.
2. Break them. Tap the crystals with a hammer or something heavy. This may cause them to break along plane surfaces parallel to the surface. These may still be broken into smaller pieces and retain their cubic form. This is called *cleavage* .
3. Place a crystal on a glass slide and place a drop of water on it, watching it with a magnifying glass as it dissolves in the water.

a .If you allow the water to once again evaporate the salt crystals will again appear.

b. Lessons from this section

1. A salt crystal grows by adding salt to itself from the water solution of salt that surrounds it and that it grows with shiny faces which are at right angles to each other, provided its growth is not obstructed.
2. Cleavage shows that within the crystal one direction is not like every other. The kind and arrangement of atoms, ions or molecules in a crystal determine its shape and other properties.
3. Decanting was used as a method of separating a liquid from a solid.

C. Borax

Borax forms crystals very quickly. It is used as a cleaning agent and sold in paper boxes just like soap. It is harmful if swallowed. Borax is much more soluble in hot water than in cold water.

1. Growing the crystals and observing their growth.
   Add one teaspoonful of borax to 1/2 cup of very hot water, stirring the mixture until the borax has dissolved completely. After this has cooled, many beautiful little crystals will grow.
2. Do the same things you did with the sodium chloride crystals to the borax crystals. One crystal could be taken out of solution, dried, tied with a thread and used for a seed to be suspended in a satiated solution. It is best to have the seed near the bottom of the container. Compare the shape of the borax crystals with that of the salt crystals.
3. Lessons from this section:
   Some crystals, such as borax, grow faces that do not meet at right angles. Borax and salt have different shapes

D. Sugar

1. Growing the crystals
   Sugar forms a thick syrup and the molecules do not move very well making it hard to form the proper crystal pattern. It is important to let the solution stay warm thus allowing the molecules proper mobility. To promote growth the following directions should be observed: heat one cup of sugar and 1/2 cup of water gently, with constant stirring, until all the sugar dissolves and the solution is clear. Put this in a jar and cover it but do not screw it down tightly. The jar must be kept warm for many days. It could be placed over the pilot light of a gas stove. A little water escapes because the lid is not tight. Slowly crystals will grow with the beautiful form of the water crystals.
2. What to do with the crystals
   All the suggestions made with the salt and borax crystals could also be made with the sugar crystals. You can also compare the crystals.
3. Lessons from this section
   Sugar crystals differ in the rate of growth, and in shape. The particles that form the crystals must be free to move to allow them to get together to form the crystals. The sugar crystal solution is so viscous(thick) that it slows down this motion making it harder for these crystals to grow.

E. Alum(Ammonium alum)

1. Growing the crystals

Put 4 teaspoonfuls of alum powder in 1/2 cup of hot water. Stir. After the powder dissolves the solution will clear. Put a light cover, such a piece of paper, over the container, to keep the dust out. As the water evaporates, beautiful alum crystals will appear. Compare these crystals with the others.

2. What to do with the crystals

   a. Arrange a growth sequence exhibit.

   b. Break them to find out if they have cleavage.

   c. Use one as a seed crystal.

3. Lessons from this section

Alum crystals are unlike salt or sugar crystals in several different ways. They grow large more quickly. They show a different shape. They do not show cleavage. The alum crystals have a new property: color. Each substance has its own form and properties.

III. IDENTIFYING CRYSTALS

After growing several crystals and investigating some of their properties, students may have whetted their curiosity and may want to investigate further. They might want to know how crystals are classified or what makes them valuable. The following are some criteria used by minerologist in identifying crystals. Students can use these same steps in the classroom to identify crystals supplied to them by their teacher or some mineral found on a field trip or a rock that they may have at home and want to know what it is.

The procedure outlined below can be found in any general book on minerals. Some of this information comes from Alan Holden's books (see bibliography).

A. Properties of Crystals

There are many ways used in identifying crystals. Some are easily identified by their appearance. Others are identified by their smell (sulfur-P, taste (salt), or by how they sound when tapped. The quickest way to identify a mineral is by its appearance and feel. After one becomes familiar with a crystal one can often identify it again upon seeing it. In order to be more accurate you should test it. There is a good test that has been devised to determine a mineral's identity. A mineral is tested in the following order:. Luster, hardness, streak, heft(relative weight), and the shape that the crystal has.

1. Luster

Luster refers to the way light is reflected from the mineral surface, There are two types of luster, metallic and nonmetallic. If it looks like a metal, it has metallic luster. Pyrite and galena have metallic luster. Nonmetallic luster is dull, pearly, silky, glassy or brilliant. [2] Diamond has a brilliant luster. Nonmetallic luster may also be transparent.

2. Hardness

This is one of the more useful properties. Hardness is a mineral's resistance to being scratched. The harder mineral always scratches the softer mineral. Frederick Mohs, a German Mineralogist, worked out a scale of hardness used in mineral identification. The minerals are arranged in order of increasing hardness. Each mineral is assigned a number between one and ten. A mineral with a higher number will always scratch a mineral with a lower number.

Moh's Scale of Hardness

1-Talc	6-Orthoclase
2-Gypsum	7-Quartz
3-Calcite	8-Topaz
4-Flourite	9-Corundum
5-Apatite	10-Diamond

The hardness of an unkown mineral is found by scratching its edge against the surface of each reference mineral. If the reference mineral scratches the unknown then the reference mineral is harder than the unknown. If the unknown scratches a reference mineral then the unknown is harder. If they do not scratch each other then they have the same hardness. The number of hardness can be compared to the known list of mineral hardness in order to arrive at a possible identification. A table will be included at the end of this paper which will give samples.

3. Streak

Can you streak the mineral? Streak is the color of the powdered mineral. This is a useful property in identifying minerals that have color streak other than white. Too many minerals have the streak of white. In this case streak is not helpful. To find the streak(color) rub the unknown across a piece of unglazed porcelain. The color on the porcelain is the streak. A sample list in the Appendix will give the streak of some minerals. In this way the possible list of the unknown will be narrowed.

4. Shape

What is the shape of the mineral? Shape refers to the geometric pattern. Is the rock cubed, rectangular, hexagonal, pointed, etc. This refers to the ideal crystal arrangement and is not always apparent. The shape of the crystal is classified in one of six crystal systems. The shape of an unknown can be compared with the models of the crystal systems below.

CRYSTAL SYSTEM [3]

(figure available in print form)

5. Cleavage or Fracture

Does the mineral have any broken surfaces? Whether a mineral cleaves or fractures is also useful in determining its identity. Minerals cleave if they break along smooth, flat planes. Cleavage planes may meet in angles that form geometric patterns similar to the crystal patterns. A fracture is a break along an irregular surface. A hammer and a sharp edge may be necessary. In some cases, mica for instance, you might be able to cleave the mineral with your hands.

6. Color

This property is useful in identifying a limited number of minerals as most minerals are mixed.

7. Specific Gravity

Is the mineral heavy? This is useful in recognizing heavy-minerals and jewels. Specific gravity refers to the ratio of the mineral's mass to the mass of an equal amount of water. For example, galena(a lead mineral) has a specific gravity of 7.5. This means that a one cubic centimeter sample of galena is seven and a half times heavier then an equal amount of water. Heavy minerals can be roughly judged by picking the mineral up and tossing it in your hand, hence, heft.

8. Special Property

Does the mineral have some unique or special property?

Some minerals have some unique property by which they can be identified. For example, you can taste halite(salt), smell sulfur and tap jade for the bell like ring. Test your mineral for any of these.

9. Activities in identifying Minerals

Materials Needed

Mineral samples
Glass (for water displacement)
Streak plate
White paint
Brush (small)
Ink (black)
Magnifying glass
Pan balance
Graduated cylinder

Water Recording Chart
(figure available in print form)

Procedure

a. Paint a small circle on each sample.
b. Put a number on each rock
c. Find the luster, hardness, streak, shape, cleavage-fracture, color, specific gravity and any special property for each sample. Record these on a chart like the one on the previous page.

Findings

a. Were you able to identify any of the samples?
b. Which tests were hard and which easy?
c. Which property is most useful in identifying?

Follow-Up If you are having difficulty with this activity a fascinating way to reinforce this is by visiting the Peabody Museum. There is a large computer-type machine which the public is encouraged to use. By supplying some information the computer will zero-in until it identifies the unknown mineral. One merely supplies the properties the computer does the rest.

VII. THE MOLECULAR ARRANGEMENTS OF CRYSTALS

A. Atoms and Electrons

If we had a superpowerful microscope and could zoom into the atom and molecule to see how they are arranged and how they hold themselves together what would we see? What does an atom or molecule really look like? An Atom is the smallest particle of an element that can exist alone or in combination. It is super-small; so small in fact, that we cannot see it even with the most powerful microscope in the world. Years ago scientist used to imagine that atoms were shaped pretty much like our solar system is shaped; with its nucleus like the sun and its electrons like the planetary system. There are big differences not only in size but also in charges. Whereas the proton and electron attract each other, like the sun and planets, the electrons repel each other. The planets pull each other. The atom's oppositely charged particles, electron and proton, pull each other and keep the atom's overall charge at zero. This is the electrostatic force which is much greater then the gravitational forces. An atom has as many electrons around it as it has protons. Here the charge is zero. This is not the case with an ion. An ion is an atom that has either lost an electron or captured an extra electron. Thus an ion always has a charge, positive or negative.

Electrons arrange themselves around the atoms in orbits or shells. Each shell can receive only a limited number of electrons. For example the inner shell can hold no more than two electrons. The next shell can hold no more than eight electrons. Once a particular shell is filled then any new electrons must start on the next level or shell.

In this diagram the inner dark circle represents the nucleus and the outer circles are the shells with the electrons.The number is the limit of electrons in that shell.

(figure available in print form)

In this diagram the inner dark circle represents the nucleus and the outer circles are the shells with the electrons. The number is the limit of electrons in that shell.

In the above representation the atom has three complete electron shells for a total of 18 electrons. The number of electrons that an atom has is also its identifying atomic number. In this case the atom (element) with atomic number 18 is Argon. The Periodic Table of Elements is arranged numerically. Hydrogen is assigned atomic number one because it has only on electron. Helium is number two because because it has two electrons and so forth.

Some atoms like to have stability. This means that they like having their shells filled. They tend to do this by either gaining or losing electron with other atoms in whose proximity they may happen to be in. Thus, for example, chlorine, lacking one electron to fill its outermost occupied shell, might tend to pick up that electron from, say, sodium in whose proximity it happens to be in. Sodium, with only one electron in its outermost occupied shell might easily lose that electron in order to leave that shell empty and expose the filled shell beneath as its outermost occupied shell. The diagram below demonstrates this more clearly: [5]

(figure available in print form)

Atoms combine in this way to gain stability and in the process create new compounds. In this case the ions of chlorine and sodium combine to form sodium chloride, common table salt.

B. Crystal Forms

In a free flowing solution the ions, atoms or molecules attract each other until they bond. They will continue bonding, linking up layer after layer until they have no more room to grow or the solution is no longer saturated. You may have many crystals in a solution growing at the same time. These crystals may eventually meet. Where they meet and join, called the grain boundary, they stop growing as individual crystals but may continue growing as a polycrystal.

In this diagram four crystals are growing against each other. The dotted lines are the layers of ions, atoms or molecules. The grain boundary is evident. [4]

(figure available in print form)

Nearly all rocks are made up of crystals. The different kinds of crystals can often be distinguished from each other. This is especially true if the rock is polished.

Metal objects are made up of interlocking crystals. Sometimes you can clearly see their boundaries. For example in the zinc coating of galvanizes garbage cans. Polished brass door knobs often show their grain boundaries.

Few substances are not crystalline in nature. One of these is glass. Window glass and volcanic glass are examples. There is a glassy candy that comes with nuts in it that is another example. In these cases the solutions are cooled too quickly to allow the molecules to move into their proper crystalline structure. The molecules become frozen, locked into a patternless structure. It is conceivable that after many years (millions?) the molecular pull will rearrange the molecules into their proper places and the glass will then revert to a crystalline form. This is the reason why very old glass is not found.

VI. Fun With Shapes

Copying, drawing, cutting, shaping,coloring, etc. is a natural outgrowth of working with crystals and a nice diversion from the routine academic work. It will re-inforce some of the new crystal's concepts in a fun way. There is something engrossing about these geometrical forms. Hang them up in the room; they make a great attraction. The kids will love to take them home. You can quiz them on names of forms, the number of sides(the names will give them a clue, for example, the octahedron, like the octopus, has eight side), and some crystals that may take that form.

The patterns in this section, and many others, can be found in many general books on crystals. There is a very beautiful book of Escher's drawings, Kaleidiocycles(see bibliography), that has very beautiful patterns with step-by-step instructions on making them. The reader is encouraged to pursue this further, if he finds his class response positively to this. This section is a small sample of the kinds of shapes available in this area. Have fun!

This figure combines a hexagonl prism with 2 hexagonal pyramids.

(figure available in print form)
This shape resembles the large quartz crystal.
(figure available in print form)
A right triangular prism
(figure available in print form)
You can make a right triangular prism by folding up this figure.

This prism has a triangular base and its side are at right angles to the base

(figure available in print form)
You can cut and fold up this shape to make a right hexagonal prism. This is made from 6 rectangles and two hexagrams. The beryl crystal has the shape of a right hexagonal prism.
(figure available in print form)
From this shape we make the regular dodecahedron. The dodecheron has 12 sides.

You cn easily make this figure by drawing one regular pentagon and carefully tracing the others from it on paper. Paste the final figure on cardboard.

(figure available in print form)
This shape is a regular tetrahedron with its 4 corners cut off equally.
(figure available in print form)
This shpe will give you an octahedron. Draw this shape then cut, crease and fold to form the three dimensional solid.
(figure available in print form)
From this figure we can malke a cube.

VI. FUN WITH NUMBERS

A. Introducing the Metris System

The teacher should make an effort to have the students familiarize themselves with the metric system. For this any elementary book on math should suffice. The U.S. is lagging behind the rest of the world in converting to the metric system. This is an unreasonable position. There is a great beauty and convenience in working with this system. The American system, on the other hand, is one filled unnecessarily with difficulty. It is not so easy to remember that a yard is divided into three feet, the foot into twelve inches and the inch into sixteenths. It would be a lot easier working with the metric system which uses only multiples of tens. There is beauty and simplicity here. Instead of saying 12 inches in a foot and 5280 feet in a mile we would say 1000 millimeters to the meter and 1000 meters to the kilometer. These measurements are good not only for distances but for weights and volumes as well. Instead of using ounces and pounds (lbs.) one would use grams and kilos. Instead of pints, quarts and gallons we would use the liter. The American system seems one arbitrarily arrived at making it difficult to remember.

B. The Powers of Ten

In working with numbers there is a particular notation, called the scientific notation, that is useful and lends a certain beauty in working with very large or very small numbers. The system works briefly as follows:

10 multiplied by itself a certain number of times to reach an intended number, say 100 is 10x10 = 10^2; 10x10x10 = 10^3 or 1000. Multiplying a number by itself produces a power of that number; 10^3 is read as "ten to the third power". It is much easier and clearer to write or say 10^{14} than 100,000,000,000 or one hundred trillion. We even run out of names when it gets that high. The small number written above is called an exponent. These numbers10-2 (powers) can also be written as a negative. We can have 10^{-2} or 10^{-3} etc. Instead of a number multiplying itself a certain number of times, this shows that the number will divide itself a certain number of times.

(figure available in print form)
or 0.001, etc.

You can multiply one power of ten with another simply by adding their exponents:

10^6 x10^3 = 10^9 Subtracting the exponents is equivalent to division:

07 Ö 10^5 Ð 10^2 All numbers, not just numbers that are exact powers of ten, like 100 or 1000, can be written with the help of exponential notation. The number 4000 is 4x10^3; 186,000 is 1.86x10^5.

There is a delightful movie called, The Powers of Ten.

This video is available in New Haven(see bibliography). The teacher should show this in class for a good demonstration of the powers of exponents. The students will also get a concrete idea on size, from the unimaginably big to the unimaginably small. The movie is also out in book form.

Following are a few examples of size comparison to help make the concept of size more concrete and palatable for the student. The teacher can, with the participation of the class, arrive at other interesting examples.

C. Illuminating comparisons

1. The ant and the elephant
    If an ant were 3mm long and an elephant were 3m and if the ant became as big as the elephant how big would the elephant become proportionally?

ant is 3mm	elephant is 3m
3mmx 1000 (elephant	so,

is 1000 times longer than ant since 1m is 1000 times more than 1mm)	3mx1000 (same number you multiply ant by) = 3000m or

roughly 2 miles This elephant, then, would be about the size of a small city.

2. If a drop of water were to grow as large as a basketball and the basketball grew proportionally how big would the basketball grow to be?

drop of water is	Basketball is about
about 1mm	300mm
1mmx300	300mmx300
=300mm	=90000mm or

= 9000 m or about 100 feet

3. If one million one dollar bills were stacked up one on top of the other how high would the pile reach?

1 dollar is about 0.1mm

(figure available in print form)

4. If the Earth were the size of a basketball and the sun were proportionally small, how big would the Sun be? The diameter of the Earth is about 8,000 miles. The Sun's diameter is about 800,000 miles. That makes the Sun's a basketball

This is a very graphic demonstration of how the Earth's size compares with the Earth.

5. How many atoms are there on the head of a pin?

(figure available in print form)

across. This is only in one direction! In order to find the area we would have to multiply this number by itself;, 1,000,000 x 1,000,000 =1,000,000,000,000 or 1 trillion atoms. This is only the surface area! In order to find the volume, which would be the head of the pin, then we would have to multiply it again by itself or 1,000,000 x 1,000,000 x 1,000,000 or, 1,000,000,000,000,000,000. A staggering number! Enough to make the mind reel.

VII. EXPLORING CRYSTALS IN THE WORLD AROUND US

A. In Museums

1. Displays of Rocks and Minerals

Museums usually have very beautiful collections of rocks and minerals. A trip to the museum is a good way to find out more about crystals and look at some fine specimen. New Haven's Peabody Museum has a very good collection of rocks. It also has the computer, mentioned previously, which will help one identify an unknown crystal. By supplying some of the crystal's properties the computer will attempt to pinpoint the name of the crystal.

2. The Museum Staff

This is a good source of information as well as a possible resource for the classroom. They may even know the best locations to find crystals.

B. Out of Doors

1. Igneous Rocks. These have been crystallized from the molten condition. Minerals that commonly make up igneous rocks are: quartz, feldspar, mica and hornblende.

2. Sedimentary Rocks

Form when layers of fragments, deposited by rivers and streams, are hardened into rocks. This material originally came from igneous rocks. Quartz is the commonest mineral in sedimentary rocks.

3. Metamorphic Rocks

These are formed from igneous and sedimentary rocks by heat and pressure, deep within the earth. When limestone is metamorphosed, marble results. Metamorphism of shale produces slate.

4. Snow

This is perhaps the prettiest of all crystals. Each flake may be a single crystal. They may come down in clumps, however. Look at them through a magnifying glass and delight the children. What kinds of shapes do they have? Draw their patterns.

C. Walking through the Neighborhood

1. Streets and Buildings

Exploring crystals and walking down the street may be revealing. The sidewalks themselves and curbs may be made of slate, a natural mineral. The buildings may be made of limestone with marble or polished igneous rock. Polished rock will reveal other crystals contained in the rock. One can walk around trying to identify some of these and how they are used.

2. Drugstores

These are a source of crystals. Many of the crystals (salts) mentioned in this paper may be found there. The druggist may be of assistance. Talk to him.

D. Crystals in Technology

Crystals are becoming more and more pervasive in our technologically dependent society. Computers need the crystal chips as do rockets, planes, boats, appliances, watches, toys, greeting cards (the singing ones), t.v., radio, etc., etc. This is an interesting list and one the class can enlarge.

VIII. ANNOTATED BIBLIOGRAPHY

Crystals and Light: An Introduction to the Optical

Crystallography, E. Wood, D. Van Nostrand Company, Inc. Princeton, N.J.

A nicely illustrated book on crystals and their appearance in crossed-polarized light. Gives an account of symmetry in general and crystals and their properties. Talks about X-rays and optical techniques in investigating

M.C. Escher Kaleidocycles: 17 models of Escher graphics and the story of how they were devised. D.Schattschneider and W.Walker, Tarquin Publications 1978.

A very beautifully illustrated book showing Eschers work and developed into a colorful set of three-dimensional models the reader can make for himself. The three dimensional models are each illustrated with Escher's magical, repeating patterns.

Powers of Ten: About the Relative Size of Things in the Universe. P.M.Morrison and P.Morrison and the Office of Charles and Ray Eams.

A beautiful collection of pictures illustrating relationships of size among objects in our universe. Makes sterile numbers come alive in stunning, concrete pictures. Shows a relationship between very small things and very large things. Shows the powers of ten with clarity. Children will get an appreciation of size.

The Dancing WuLi Masters: An Overview of the New Physics, G.Zukav, Bamtam New Age Books 1979.

A great book that explains recent breakthroughs of science understandable for the layperson.

Light and Color , R.D. Overheim and D.L. Wagner. John Wiley & Sons, Inc. N.Y. 1982

The emphasis of this book is on color, how light is produced and how the eye-brain system registers it. The emphasis is scientific although they try to explain it to the non-scientific person.

Gems made by Man , K. Nassau. Chilton Book Company, Radnor Penn. The story of mans effort to duplicate gems. The efforts of the scientist who toiled to create perfection not just imitation, but synthetic gemstones with the same chemical composition, crystal structure and appearance as naturally occurring diamonds, rubies, sapphires, emeralds, opals and other precious stones.

The process of crystal growth is discussed and how to distinguish natural stones from synthetic ones.

The book is beautifully illustrated with colorful pictures and is an asset in helping to identify crystals. Dictionary of Physics, edited by Valerie H.Pitt. Penguin Books 1986. A handy, good resource book for teachers, especially science teachers. Gives good illustrations and definitions. Handy to have in the classroom as the need for it will always arise.

Man-made Crystals , J.E. Arems, Smithsonian Institution Press, Washington, D.C. 1973

A beautifully illustrated book showing all the man-made gems and the uses for these in today's technological world. Relies minimally on technical language and explanations.

Shapes , Space and Symmetry. A.Holden, Columbia University Press, N.Y. 1971.

A book that examines the nine regular solids. Has many mesmeric pictures and geometrical solids. Gives some guidelines in how to design and make these shapes.

Notes

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1. *Rocks and Minerals* , Martin, A. and Parker, B.M.. New York Golden Press, 1974 2. Ibid. p. 80 3. Ibid. R. 94 4. See E. Wood's book, *A Handbook for Teachers, Crystals* . 5. *The Nature of Solids* , A. Holden, Columbia University Press.

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Students Reading list

Crystals , R.A. Wohlrabe, J.B. Lippincott Co. N. Y.

An introduction to crystals on a very elementary level. Many step-by-step procedures on drawing crystals.

Earth Treasure: Rocks and Minerals, I. T. Comfort. Prentice Hall, Inc. N. J.

A basic introduction to geology for young students. Easy to to follow and concise.

Salt , A. Goldin, R. Galster. Thomas Y. Crowell Co. N.Y. Very simple experiments with salt to find out about its properties. Nicely and simply illustrated.

The Shapes of Water , A. Goldin. Doubleday and Co. Inc. N.Y. Many safe and easy easy experiments with crystals for children.

For Adults

Color Underground , The Mineral Picture Book, L. Boltin and J.S. White Jr., Charles Scribner's Sons, N.Y.

A beautiful book with color pictures. Cheap and thin.

Minerals and Rocks in Color , J.F. Kirkaldy, Brandford Press. Many good photos and drawings. Good reference book. Very general on geology. Paperback.

Rocks and Minerals , P.E. Desautels.

A collection series A beautiful book! Outstanding pictures of crystals. Little or no technical language required. Good for students.

Crystals-A Handbook for Teachers , E. Wood, Commission on Crystallographic Searching of the International Union of Crystallography, 1972

Crystals and Crystal Growing , A. Holden and P. Morrison, The MIT Press Cambridge, Miss, London, England

The Nature of Solids , A. Holden, Columbia University Press New York/and London.