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Measurements, Matter, and Crystals

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I. INTRODUCTION

Matter is described as anything that has mass and volume. What causes matter to exhibit these properties? It is also said that for anything to exist it must be able to be measured. How do we measure the various forms of matter? Why do some forms of matter combine with one another and others will not combine? This unit is intended to give the average student a basic understanding of matter and its behavior. In so doing, the student will become familiar with some laboratory techniques, terminology, and equipment used by people in the scientific community.

In many cases, our Middle School students are not exposed to any laboratory investigations or meaningful activities which will stimulate or aid in their interest and/or understanding of science.

This unit will help accomplish these goals by beginning with the study of atoms and the periodic table. We will use “A” group elements to discuss and predict chemical reactions.

We will then move to the metric system of measurement and become familiar with the units and instruments we will use for measuring matter. We will complete this section by finding the density of several objects to evaluate the students understanding of the units and the measuring instruments.

The next topic will be the “states of matter.” We will discuss the the characteristics of each state and end the study by adding heat to iced water and observing and graphing the results as it goes from the solid to liquid to gaseous state.

Solutions will then be covered and a solubility curve will be constructed using grams of potassium chlorate vs. temperature to complete this topic.

The unit will be culminated by the growing and studying of crystals.

II. MATTER AND THE ATOM

The atom is the basic part of matter and a basic understanding of its structure is probably the best place to start this unit. We should keep in mind that atoms are small and consist mainly of empty space. When atoms combine to make different molecules the spaces between molecules of different substances vary. To stress this point put 50ml. of water in a graduated cylinder and 50ml. of ditto fluid in another cylinder. Ask the students to predict the combined volumes of the liquids. The volume will not be 100ml. which will help get across the point of spaces between the molecules. The actual volume will be +98ml.

Since atoms are too small to be studied directly, models are used to describe them and their activities. The average diameter of an atom is about 2 x 10 to the minus 10 meters.

To describe the internal structure of the atom, we need to consider the proton, neutron, and electron.

The proton carries a (+)charge and is located in the nucleus along with the neutron which has a (0) charge. The electron has a (-) charge and circles the nucleus.

(figure available in print form)

There are approximately 108 elements both natural (92) and artificial with the number of protons distinguishing one element from another. An atom also has an equal number of protons and electrons which prevents it from having an electrical charge. The Periodic Table arranges the elements in an orderly fashion which aids us in understanding and predicting how they will react with one another.

Let us use symbols for the elements and think of these symbols as letters of the alphabet. Some letters can be combined to form words while others will not, just as some atoms will combine to form new substances and others will not combine.

Except for hydrogen and helium, the atoms of the lower order strive to have 8 electrons in their outer shell. This can be accomplished by lending or borrowing electrons and in some cases sharing them to stabilize there outer shell.

We will use groups IA IIA IIIA IVA VA VIA VIIA to explain a basic method of predicting a chemical reaction.

(figure available in print form)

Let us use a (+) sign for the tendency to give up electrons and a (-) sign for the tendency to borrow electrons. The roman numeral in front of the letter "A" indicate the number of electrons in the outer shell which aids us in determining their valence.

IA=+ IIA=++ IIIA=+++ IVA=++++/ÐÐÐÐ VA=ÐÐÐ VIA=ÐÐ VIIA=Ð The number of (+) or (Ð) signs will not change for an atom thus each time it enters into a chemical reaction it will have the tendency to follow the pattern of lending or borrowing the number of electrons in its group.

In order to have a chemical reaction we need something to lend and something to borrow electrons. The number of (+) signs must equal the number of (Ð) signs in the completed reaction.

When an atom loses or gains an electron it takes on an electrical charge and becomes an ion. If it loses an electron the protons outnumber the electrons and it becomes a (+) ion. If the reverse happens and it gains an electron, the electrons will out number the protons and it will become a (Ð) ion. The results of one atom becoming a (+) ion and the other a (Ð) ion causes and electrical attraction between them and a chemical reaction may occur.

Let’s combine some elements using this method. examples:

Li=+	Cl=Ð	rxn=LiCl
H=+	O=ÐÐ	
H=+		rxn=H20
Al=+++	O=ÐÐ	
Al=+++	O=ÐÐ	
	O=ÐÐ	rxn=Al2 03

Notice the number of (+) signs equal the number of (Ð) signs in each completed reaction. The subscript is determined by the number of times each atom has to be written down to balance the number of (+) and (Ð) signs to balance the reaction.

Now that we have a basic understanding of why certain atoms will combine with one another and others will not combine, let us concern ourselves the measuring of matter.

III. MATTER AND MEASUREMENT

The metric system of measurement is used in all branches of science and more experiences are needed to become more comfortable and competent with this system of measurement and some basic laboratory equipment. A good introduction to this segment is the filmstrip “A History of Measurement” by Learning Resource Company,

This filmstrip traces the early standards of measurement and the problems with these standards to the presently accepted standards of the metric system.

We will concern ourselves with the measurement of mass (grams), volume (liters), length (meters), temperature (celsius), and the prefixes kilo (1000), centi (1/100), and milli (1/1000) with our measurements.

A. MASS

Mass is the preferred term to use over weight when describing properties of matter as matter can become weightless but it does not become massless. The balance is the instrument we will use to measure mass in the middle school. The introductory assignment with the measurement of mass should involve a teacher demonstration/ explanation on the use of the balance and the introducing of the following terms: gram-beam-adjustment knob-riders-zero point.

After the introductory lesson a good homework/follow-up activity would be Lab Skill 3 from “Basic Skills in the Laboratory” by Charles E. Towne and published by Cebco Standard Publishing Company, copyright 1977.

This exercise gives the student an opportunity to practice reading the position of the riders on the beams before they begin practical application exercises.

The practical application should begin by giving students objects of known masses to help their confidence with the use of the balance. After this has been completed the massing of some common objects in metric units is also helpful.

A good way to end this section is to give the students 10 marbles and find the mass starting with a single marble and continuing with 3-5-7-9. These results then can be graphed with the number of marbles vs mass of marbles. After the graph has been constructed determine the mass of 2-4-6-8-10 marbles by interpolating the graph. Find the mass of 2-4-6-8-10 marbles on the balance and compare results. If so desired, the per cent error can be figured by actual mass of marbles minus estimated mass of marbles divided by actual mass of marble; times 100%.

(figure available in print form)

B. VOLUME

Volume will be found by using the graduated cylinder and overflow can. The easiest way is to use the displacement method even though the mathematical procedure is more accurate when used in our laboratory setting. At this point it is more important to introduce new techniques and procedures than to strive for exact answers. A good homework assignment is Lab Skill 2 in the same “Basic Skills in the Laboratory” by Charles E. Towne which helps the student understand what a meniscus is and how to read the graduated cylinder.

Continued use of the marbles for the practical application is advisable for this exercise . When using the graduated cylinder to find the volume of the marbles directly it is a good idea to put a rubber stopper in the bottom of the cylinder to prevent breakage.

As with finding the mass of marbles repeat the same procedures finding the volume of 1-3-5-7-9 marbles using the graduated cylinder and the overflow can graphing the results of volume of marbles vs number of marbles.

(figure available in print form)

Estimate the volume of 2-4-6-8-10 marbles by using the graph then measure the volumes directly and compare the results. Again the per cent error can be calculated by using the same formula as with mass.

A fun exercise is to prove the the volume of various objects such as a coffee can by using the formula V=XRXRXH. After figuring the volume mathematically, use the graduated cylinder to check the accuracy of your answer. If possible, it is best to use the vernier caliper for your measurements.

C. DENSITY

Density is the amount of mass per unit of volume. The study of density provides an opportunity to help the student better understand how the masses of atoms differ. A suggested way to start this topic is to have the student find the density of one rubber stopper and then three rubber stoppers. Repeat the same procedure but use three marbles and then eight marbles. This impresses the fact that the amount of matter does not affect the density of the object and can be used to distinguish objects of different sizes.

The evaluation of this topic can be the finding of density of some objects such as brass, lead, aluminum, rubber, and glass. After determining their densities,construct a bar graph to visualize their differences.

(figure available in print form)

D. LENGTH

The measurement of length in meters and centimeters seems to be the most common units used by middle school science students and so the emphasis will be with these units when measuring objects. After the demonstration / explanation of the meter stick and metric ruler is completed a good follow up exercise is Lab Skill 1 in "Basic Skills in the Laboratory" by Charles E. Towne.

Students should then be allowed to measure various common objects to become more familiar with their dimensions in metric units. Estimating sizes and distances is also a good activity and finding their per cent of error always adds to the fun.

Other activities could be to find their pace(amount of steps to cover 10 meters) and find distances to various places using their pace. If possible the actual distances can be measured and per cent error calculated.

Another activity could be the use of the triangulation method to find the distance to an unknown object. Again the actual distance could be found and the per cent of error calculated. (see "triangulation" at end of unit).

If you have access to vernier calipers, students enjoy working with these as their measurements are more accurate and they are learning to use a new instrument. A good source of information for the use of the caliper is "Selected Experiments for Elements of Physics" by Buchanan and Murphy. This text can probably be found at the SCSU bookstore as this was written for their Physics course.

Activities of this nature tend to keep the students interest and also aid them when confronted with similar material on standardized tests.

To evaluate this section, a good way is to have then find the density of three objects and identify them by comparing their results to a bar graph constructed by you.

Now that we have measured matter in two of the three states of matter, we will learn about the third state of matter and what separates on state from another.

Although matter exists in four states, we will concern ourselves with the three states that are familiar to us.

IV. STATES OF MATTER

The states of matter can best be described by the "Kinetic theory on matter" which basically says that all matter is made of molecules which are in constant motion and the amount of motion determines the state which will exist. Solids have a definite shape and take up a definite amount of space, liquids take up a definite amount of space but have no definite shape, and gases have no definite space or shape.

The changing of one state to another involves the adding or removing of heat which affects the molecular motion.

A good explanation of the molecular motions in the various states is found on page 324 in "Physical Science" by Ramsey, Gabriel, McGuirk, Phillips, and Watenpaugh published by Holt, Rinehart, and Winston 1986.

It uses people in a theater to show the difference between the states. It starts with people sitting in their seats watching a performance. (solid). When the performance is over they begin to leave their seats. (liquid) Finally they leave the theater and move out in all directions. (gas)

This situation could also be used to explain the molecular actions with the addition or removal of heat.

A good activity showing the effects of heat would be heating iced water until it reaches it boiling point. Plotting a graph with time vs temperature is a beneficial activity which can show the boiling point, freezing point. and melting point of water.

V. SOLUTIONS:

Solutions are classified as homogenous mixtures consisting of a solute(material being dissolved) and a solvent (material doing the dissolving) and exist as a solid, liquid, or a gas. We will devote most of our time and effort discussing the liquid solvent and solid solute method of making solutions as the main activity of this unit will involve the growing of crystals from solutions.

Not all materials can be dissolved in a substance and are said to be insoluble in that substance. If a substance can be dissolved it is said to be soluble and the solution may be saturated, saturated, or supersaturated.

Unsaturated solutions can hold more solute for that temperature and pressure while saturated solutions can no longer hold any more solute under the same conditions. When a solution contains more solute than it can normally hold at that temperature and pressure, we say it is supersaturated and is very unstable. A saturated solution is needed for the growing of crystals which we will grow from an aqueous solution of sodium chloride and water.

First let's do some experiments to see how the size of particles, temperature, and agitation affect a substances rate of solubility. In the lab manual for "Physical Science" by Louise Nolan and published by D.C. Heath and Company 1987, a good lab is available. (sample at end of unit)

After completing this exercise we will construct a solubility curve with grams of solute/100 ml water vs temperatures of 20 degrees centigrade, 40 degrees centigrade, 60 degrees centigrade, 80 degrees centigrade, and 100 degrees centigrade.

We will use potassium chlorate for our solute and mass 80 grams before adding it to the 100 ml of water. We will then add the solute to the water until it becomes saturated (particles begin to settle out) and mass the remaining solute to determine the amount added. Plot the number of grams used over the corresponding temperature and continue this until all mass/temperatures have been recorded.

(figure available in print form)

Now that that we have concluded our basic study of matter, we will move to the topic of crystals.

VI. CRYSTALS:

Crystals are defined as solids with their atoms, molecules, or ions arranged in regular patterns.

These patterns are classified into six basic shapes depending on the number of faces, or flat surfaces, that meet forming certain angles at their points of intersection.

The six crystal systems are the cubic, hexagonal, orthorhombic, monoclinic, tetragonal, and triclinic.

If more information is needed about crystal systems, it can be found in most physical science textbooks.

Most solids are crystalline to some degree which means they are made up of crystals. This means we should introduce students to crystals and allow their curiosity to aid in the understanding of some basic principles on crystals.

Due to the complexity of the study of crystals for this age group, it might be best to have the child grow some crystals and observe their behavior.

Beg, borrow, or buy “CRYSTALS—A HANDBOOK: FOR SCHOOL TEACHERS” by Elizabeth Wood for these activities.

Start out by growing salt crystals as explained in the text. After completing this exercise, depending on the interest, facilities, and materials available you might have different groups of students grow different crystals and share their experiences.

I would suggest that crystals of alum and epsom salts be grown for additional activities as alum is not hard to obtain and these crystals are easier to grow then the salt crystal while the epsom salt will allow the student to see crystals growing as long needles instead of the shapes produced by sodium chloride and alum.

Upon completion of these exercises, I would have the students exhibit their work with a written explanation on how each was grown and tell of the difficulties they encountered, if any, and how they overcame them.

I would also have them write a critique about their experience with the growing of crystals for my benefit in planning future classes.

VII. CONCLUSION:

This unit has tried to have simple but meaningful hands on activities to stimulate and motivate students with their understanding of some basic scientific principles. Although it is not necessary to do all the activities in the unit, the more that are performed the more confident and prepared the student will be with future studies in science.

BIBLIOGRAPHY STUDENT RESOURCES

Focus on Physical Science

Heimler—Price

Merrill Publishing Company—1989

Good information on atomic structure and chemical bonding.

Physical Science

Nolan

Heath—1987

Good explanation on the periodic table.

Physical Science Investigations

Bickel—Eisenford—Hogg

Houghton Mifflin—1973

Good investigations for physical science with graphing. Very well organized for freezing point, melting point, and boiling point of water.

Introduction to Physical Science

Haber—Schaim—Abegg—Dodge—Kirksey—Walter Prentice-Hall—1987

Excellent experiments but geared to the above average student.

TEACHER RESOURCES

The Nature of Solids

Holden

Columbia University Press

Good information on solids but a little difficult to understand.

Crystals and Crystal Growing

Holden and Morrison

MIT Press—1982

Good information on crystals with diagrams and explanations.

Basic Skills in the Laboratory

Charles E. Towne

Cebco Standard Publishing—1977

Good introductory activities for laboratory equipment and techniques.

Selected Experiments For Elements of Physics

Buchanan and Murphy

Southern Connecticut State University—1070

Selected Experiments For Elements of Physics

Buchanan and Murphy

Southern Connecticut State University—1970

Excellent explanation and exercises with the vernier caliper.

Crystals—A Handbook for School Teachers

Elizabeth A. Wood

1972

This book supplies information for the teacher who has little or no experience with the growing of crystals. It is geared toward students performing activities before understanding what is really happening.

This book can be purchased for $4.00 plus postage from:

Polycrystal Book Service

P.O. Box 3439

Dayton, Ohio 44401

Tel. (513) 275-2424

PLANEMETRIC MAP MAKING

Purpose ***To construct a planemetric map of an area using using simple devices.***

Goal ***The percent of error will be less than 5%.***

Constraints ***Pacing techniques—Sighting alignments***

Materials
sighting device (ruler on edge)

magnetic compass

2 stakes

paper

large board (for paper)

metric tape measure

Procedures

1. In the middle of the area to be mapped, pace off a distance over half the length of the area to be measured and place stakes at each end and refer to this as your base line.
   Decide on a scale and make the base line on your paper.
2. From point A, sight in and draw a line along your point of sight to the four boundaries.
3. Move to point B, align table and sight on the same objects. Mark only the points of intersection.
4. Connect points of intersection.
5. Using your scale, determine the distance around the perimeter.

Evaluation Determine the percent error.

section	scale	distance/scale	distance/true	% error
AB	5.0 cm	20 m	20 m	0
CD	9.0 cm	45 m	47 m	4.4%
DE	2.9 cm	11.6 cm	12.0 m	3.3%
EF	8.3 cm	33.2 cm	34.0 m	2.3%
CF	3.0 cm	12.0 m	11.5 m	4.3%

PLANEMETRIC MAP MAKING

!. Distance of base line = 20 meters

scale: 1 cm = 4 meters

(figure available in print form)

true value—calculated value

% error ——————————————— x 100%

true value

TRIANGULATION

Purpose To be able to find the distance to an object by using the triangulation method.

Goal After completing this exercise the percent of error will be less than 5%.

Constraints Pacing techniques—alignment of sighting device—scale used

Materials Protractor—sighting device—2 stakes—paper—pace knowledge—metric ruler.

Procedures

1. Using your pace, set up your base line.

(figure available in print form)

BASE LINE DISTANCE _____ METERS

2. Using your protractor, sighting device, and magnetic compass, determine the number of degrees to the object from the right and left side of your base line.

(figure available in print form)

RIGHT _____ DEGREES LEFT _____ DEGREES

3. Decide on a scale to be used for distance determination.

SCALE: _____ cm = _____ meters

4. Construct your diagram on a sheet of paper using your scaled distance for the base line and construct angles with the same degrees measured.See procedure 2 for degrees.
5. The location of the object is the point of intersection of lines of sight.
6. Measure the distance in centimeters from the vertex to the center of the base line. _____ cm

7. Using your scale, determine the number of meters to the object. _____ meters. If possible measure the actual distance and determine the percent error.

VOLUME

Purpose To introduce students to the measurement of volume with the graduated cylinder and the plotting of information on a graph.

Goal Upon completion of this exercise, 95% of the students will be able to measure objects accurately using the graduated cylinder, graph these results and predict results of other volume measurements using the same materials from a graph.

Procedures

1. Homework assignment—Lab from Cebco text or make up activity for reading a meniscus.
2. Oral evaluation of assignment.
3. Practical:
    a. Have 2 graduated cylinders set up at each lab station. One with a known amount of liquid and the other without any liquid.
    b. On an index card have the correct volume recorded then then invert the card. The student will then write the volume on a piece of paper, invert the card and check his/her answer. if having a problem, individual help will be given.
    c. On an index card, write the amount of liquid to be placed into the cylinder. Check results and give individual help if needed.
4. Have students set up a graph with number of marbles vs volume of marbles.

5. Find the volume of 1-3-5-7-9 marbles and plot this information on the graph.

Evaluation

1. Have the students predict the volume of 2-4-6-8-10 marbles. from the graph.
2. Have the students find the volume of 2-4-6-8-10 marbles.
3. Have the students find the percent error which should be less than 3%.

TRIANGULATION

Procedures

1. Base line distance = 20 meters
2. Right angle = 75 degrees Left angle = 72 degrees
3. Scale: 1 cm = 5m

4-5.

(figure available in print form)

6. 6.4 cm

7. 32.0 m

true value—scale value

% error = ———————————— x 100 %

true value

Volume of marbles in ml

(figure available in print form)
