MODULE
DOES SIZE MATTER IN CHEMISTRY?

MODULE TOPIC:
Analysis of particle size of solutes on the rate of dissolution in a solvent

RATIONALE:
Science curriculum is guided by research findings in the laboratory. It helps the students to sharpen their analytical skills by providing them with new opportunities for intellectual investigation. The present topic deals with particle size of matter and its importance in chemistry in the field of pharmaceutical and other industries. This investigation will enable the students to understand different topics in chemistry such as chemical reactions, solutions, catalysts, measurement and mathematical operations.

LEARNING OBJECTIVES:
After completion of this activity, students will be able to:
1. Calculate the surface area and volume of different sized materials.
2. Classify particles into different sizes
3. Define the following terms: reactant, product, catalyst, solution, solvent, solute and solubility
4. Compare the rate of solubility with different sized particles

NJ STANDARDS & INDICATORS
5.1.8.B2. Design and conduct investigations incorporating the use of a control.
5.1.8.B3. Collect, organize, and interpret the data that result from experiments.
5.6.6.A3. Describe the properties of mixtures and solutions, including concentration and saturation.
5.6.12.B1. Explain that the rate of reactions among atoms and molecules depends on how often they encounter one another and that the rate is affected by nature of reactants, concentration, pressure, temperature, and the presence of a catalyst.

MATERIALS:
Activity 1: Modeling clay, metric ruler, calipers with metric markings, pencil, and calculator

Activity 2: Anhydrous calcium chloride pellets of different sizes, 500 ml beaker, graduated cylinder, magnetic stirrer.

LIST OF HAND OUTS:
Lecture notes about chemical reactions and solutions
Activity 1: All equations for calculation of surface areas and volumes of cube, rectangular box, sphere and cylinder.
Procedure for conducting the experiment and post lab questions

Activity 2: List of materials needed for the experiment, post lab questions

BACKGROUND INFORMATION:

Particle size of matter plays a vital role in many chemical and pharmaceutical processes. In the pharmaceutical industry drugs are made into fine powder for easy dissolution and in the chemical industry catalysts are used in the powder form for maximum surface interaction between the reactant molecules to produce greater product yield. Surface interactions are widely studied to improve pharmaceutical products.(ref) Among the different geometric shapes, a sphere has the smallest surface area for a given volume. Maximizing surface area is important for making the catalysts work. A sphere can be an ideal shape for this. If we shrink the volume of a sphere by a factor of 1000, the surface area goes down only by a factor of 100. That means when catalysts are in the form of small spheres, they can speed up the reactions tremendously. This is one of the promises of nanoparticles. They are minuscule bits of materials that have special properties the same material in larger sizes does not. The first activity helps the students to understand how nanoparticles may be more effective by investigating how the ratio of surface area to volume is affected by shape changes. The second activity helps them to organize their thoughts and design an experiment to prove the relation between particle size and rate of dissolution of a solute in a solvent.

APPROXIMATE TIME:

2 to 5 days (2x44 min lecture, 2 lab periods(2x88 min) for activities)

CLASSROOM ACTIVITIES

Day 1-3: Lecture and discussion on chemical reactions, catalysts and solutions
Day 4: Lab activity 1 by students and teacher
Day 5: Lab activity 2 by students

SAMPLE QUESTIONS TO ELICIT CLASS DISCUSSION:

1. What is a chemical reaction? Give examples
2. What is the difference between reactants and products in a chemical reaction?
3. What is a catalyst? Give examples
4. What are the factors affecting rate of a chemical reaction?
5. What are nanoparticles?
6. Which shape is better to make catalysts? Why?
5. What is a solution?
6. What is the difference between solute and solvent?
7. What is solubility?
8. What are the factors affecting solubility of a solute in a solvent?
9. What are the uses of catalysts?
10. Name some of the cleaner uses of energy?
11. How can we improve technology to produce cleaner energy?

Activity 1 :

The Surface Area-to-Volume Ratio of Nanoparticles

Aim: This lab is designed to help you understand how nanoparticles may be more effective by investigating how the surface area-to-volume ratio of a substance is affected as its shape changes. Nanoparticles are important in chemistry due to its effectiveness as catalysts in chemical reactions. Catalysts are substances that increase the speed of a chemical reaction without itself undergoing any change. Understanding how catalysts work involves studying chemical reactions at the molecular and atomic scale. For this reason, catalysis can be considered one of the earliest forms of nanoscale science.

Background information

Among the many geometric shapes, sphere has the smallest surface area encompassing a given volume. That is important if we want to limit the material exposed to an environment or build the largest enclosure with a given amount of material. Maximizing surface area is vital to making catalysts work. A sphere can be an ideal shape for this. If we shrink the volume of a sphere by a factor, say 1000, the surface area goes down by only a factor of 100. That means if we make spheres smaller, some materials can do amazing things. That is one of the promises of nanoparticles, minuscule bits of material that have properties the same material in larger sizes does not. Nanoparticles, the first real commerical breakthrough in nanotechnology are now found in everything from paint to tennis balls.

Materials

- 8.5 inch x 11 inch sheet of waxed paper
- modeling clay, the size of a walnut
- metric ruler
- calipers, with metric markings
- pencil
- calculator
- (Note : No special safety instructions for this lab)

Formulas to calculate the surface area and volume of different shapes:

Volume of a rectangular box = length x width x height

Volume of a sphere = $4/3\ \pi\ (\text{radius})^3$

Volume of a cylinder = π x height x $(\text{radius})^2$

Surface area of a cube = length x width x number of sides

Surface area of a box $(4 \times \text{length} \times \text{width})_{\text{front face}} + (2 \times \text{length} \times \text{width})_{\text{side face}}$

Surface area of a sphere = $4\ \pi\ (\text{radius})^2$

Surface area of cylinder = $2\ \pi\ (\text{radius}) + 2\ \pi$ x radius x height

Pre lab Questions

1) What happens during a chemical reaction?
2) What is the difference between reactants and products?
3) What are the factors affecting the rate of a reaction?
4) What is the role of catalyst in a reaction?
5) What factors affect whether an industry can inexpensively make a product or whether the product would cost more to make?

PROCEDURE

1) Place a wax paper on top your desk. For each of the steps below, be sure to use all of the clay. Do not remove any clay between measurements.

2) Press the clay into a cube.

3) Use the ruler to measure the size of each side. Write each measurement in the table below.

4) Press the clay into a flat, rectangular box.

5) Use the ruler to measure the size of each side. Write the measurement in the table below.

6) Roll the clay into a ball.

7) Use the calipers to measure the ball's diameter. Write your measurement in the table below.

8) Roll the clay into a cylinder.

9) Use the calipers to measure the diameter of the cylinder. Write your measurement in the table below.

10) Use the ruler to measure the length of the cylinder. Write your measurement in the table below.

Data Table 1 (Measurements should in centimeters with correct significant digits)

Length of the cube	=
Length of Rectangular box	=
Width of rectangular box	=
Height of the rectangular box	=
Radius of the sphere	=
Height of the cylinder	=
Radius of the cylinder.	=

11) Calculate the volume of each shape using the given formulas. Write your answers in the table below

Volume of the cube	
Volume of the sphere	
Volume of the rectangular box	
Volume of the cylinder	

12) Calculate the surface area (A) of each shape using the given formulas. Write your answers in the table below.

Surface area of the cube	
Surface area of the sphere	
Surface area of the rectangular box	
Surface area of the cylinder	

13) For each shape, calculate divide the surface area by the volume and write this ratio in the table below.

Data Table 2

Ratio of surface area to volume of the cube	
Ratio of surface area to volume of the sphere	
Ratio of surface area to volume of the rectangular box	
Ratio of surface area to volume of the cylinder	

Post Lab Questions

1) What are the surface areas of cube, sphere, rectangular box and cylinder in your experiment?

2) What are the volumes of cube, sphere, rectangular box and cylinder in your experiment?

3) Which shape had the smallest surface area-to-voume radio?

4) Which shape had the largest surface area-to-volume ratio?

5) Of the shapes you tested, which shape would you recommend as the most reactive catalyst? Explain.

6) Why are manufacturers interested in using nanoparticles for catalysts?

7) One of the sources of clean energy is fuel cells in which hydrogen combines with oxygen. The product of this reaction is steam and energy. One of the reactants in this reaction, hydrogen, is not easy to make. Many oil refineries use a platinum catalyst to make hydrogen. But platinum is too costly. The metal Nickel is another cheaper option. If you use nickel metal, what shape do you prefer the nanoparticles of nickel to make them more reactive? Explain

Activity 2: Students will be given anhydrous calcium chloride pellets of different sizes. They have to separate them into different sizes using sieves. Using water as the solvent, they have to dissolve a definite amount of solute in the solvent. Compare the rate of solubility with different sized particles and answer the post lab questions:
Materials provided: 1L beaker, graduated cylinders, balance, timer, magnetic stirrer, distilled water, sieves of three different sizes(US standard Sieve # 5 = 4 mm, sieve # 10= 2 mm and sieve # 20 = 0.85mm)

1. What is the surface area of different sized particles?
2. What is the solubility of anhydrous calcium chloride in water?
3. Based on the graph, what happens to the rate of dissolution when particle size increases?
4. Based on the answer#3, what is your conclusion about particle size and rate of dissolution? Explain your answer

Homework activity

1. Read the chapter about chemical reactions and catalyst and make notes.
2. Read about solutions and define the following terms: solution, solute, solvent, saturated solution, solubility, factors affecting solubility
3. Conduct an internet research and write a four paragraph essay on role of catalysts in clean energy production. Your research should focus on catalysts in the form of nanoparticles.
4. Using the collected lab data, plot a graph.
5. Calculate the experimental values using the collected data.
6. Prepare a lab report explaining the effect of particle size on the rate of dissolution of a solute in a solvent
7. Answer post lab questions provided

Parameters to evaluate student work

1. Answering all questions with relevant information with correct calculations and units of measurement- A grade
2. Answering all questions with most of the correct answers and most units- B grade
3. Answering maximum questions with some correct answers and some missing units- C grade

Lecture notes on solutions

A **Solution** is a homogeneous mixture of two or more substances.
Eg : Salt solution
Sugar solution

A solution consisting of two components is called a binary solution. The major component is called **solvent** and the minor component is called **solute**.

Depending upon the physical nature of the solvent and solute, we can have different types of solutions.

Solvent	**Solute**	**Examples**
Liquid	Solid	Salt solution
Liquid	Liquid	Alcohol in water
Liquid	Gas	Aerated Drinks (soda)
Solid	Solid	Alloys
Solid	Liquid	Hg in Silver (amalgams)
Solid	Gas	Hydrogen in palladium
Gas	Solid	Smoke, Sublimation of Iodine
Gas	Liquid	Fog
Gas	Gas	Air

Solution in which the solvent is water is called **aqueous solution.**

Solubility & factors affecting solubility.
Solubility is the term used to describe how much solute can be dissolved in a given amount of solvent. When the maximum amount of solute is dissolved in solution, it is called a *Saturated Solution.*

Two factors affecting solubility are
1) **Temperature:** The solubility of molecular and ionic solids increases with temperature. But in the case of gases, the solubility decreases with increase in temperature.
2) **Pressure:** The solubility of a gas in a liquid increases as the pressure of the gas over the solution increases. This is called *Henry's law.*

Factors affecting the rate of dissolving
1. Surface area of the solute: Greater the surface area of the solid, faster the dissolution
2. Stirring: increases the surface interactions
3. Temperature: When temperature increases, solvent particles move faster thereby increasing the interactions with the solute particles.

Chemical reactions

A **chemical reaction** is a chemical change in which new substances (products) are produced from starting substances (reactants). Chemical reactions are represented by chemical equations, in which an arrow separates the reactants and products.

Reactants → Products

Eg: $C + O_2 \rightarrow CO_2$

How Reactants are Transformed into Products?

When chemical reactions occur, bonds in the reactant molecules break, and new bonds are formed to create the products. The bond-breaking process always requires an input of energy, and the bond-making process always gives off energy. The energy for the bond breaking process comes from collisions between the reactant molecules.

Catalysts: Substances that speed up a chemical reaction without itself undergoing any chemical change. Ex: Enzymes are biological catalysts.

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