Project on

Saturated Solutions: Measuring Solubility

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CERTIFICATE

This is to certify that the Project titled 'Saturated solutions: Measuring Solubility' was completed under my guidance and supervision by Roll No. _________ a student of XII SCI, Faith Academy within the stipulated time as prescribed by the CBSE.

Mrs. Sasheela Jose Head, Department of Chemistry
Faith Academy New Delhi

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Parichay Saxena
Roll NO :

Objective:

The goal of this project is to measure the solubilities of some common chemicals:

- Table salt (NaCl)
- Epsom salts ($MgSO_4$)
- sugar (sucrose, $C_{12}H_{22}O_{11}$).

Introduction

A good part of the substances we deal with in daily life, such as milk, gasoline, shampoo, wood, steel and air are mixtures. When the mixture is *homogenous,* that is to say, when its components are intermingled evenly, it is called a solution. There are various types of solutions, and these can be categorized by state (gas, liquid, or solid).

The chart below gives some examples of solutions in different states. Many essential chemical reactions and natural processes occur in liquid solutions, particularly those containing water *(aqueous* solutions) because so many things dissolve in water. In fact, water is sometimes referred to as the *universal solvent.* The electrical charges in water molecules help dissolve different kinds of substances. Solutions form when the force of attraction between solute and solvent is greater than the force of attraction between the particles in the solute.

Two examples of such important processes are the uptake of nutrients by plants, and the chemical weathering of minerals. Chemical weathering begins to take place when carbon dioxide in the air dissolves in rainwater. A solution called carbonic acid is formed. The process is then completed as the acidic water seeps into rocks and dissolves underground limestone deposits.

Sometimes, the dissolving of soluble minerals in rocks can even lead to the formation of caves.

Types of Solutions

	State of Solute	State of Solvent	State of Solution
Air, natural gas	gas	gas	gas
Alcohol in water, antifreeze	liquid	liquid	liquid
Brass, steel	solid	solid	solid
Carbonated water, soda	gas	liquid	liquid
Sea water, sugar solution	solid[1]	liquid	liquid
Hydrogen in platinum	gas	solid	solid

If one takes a moment to consider aqueous solutions, one quickly observes that they exhibit many interesting properties. For example, the tap water in your kitchen sink does not freeze at exactly 0°C. This is because tap water is not pure water; it contains dissolved solutes. Some tap water, commonly known as *hard water,* contains mineral solutes such as calcium carbonate, magnesium sulfate, calcium chloride, and iron sulfate. Another interesting solution property is exhibited with salt and ice.

Another example comes from the fact that salt is spread on ice collected on roads in winters. When the ice begins to melt, the salt dissolves in the water and forms salt water. The reason is that with the adition of salt the melting point of water increases and as aresult the snow melts away faster.

Even some organisms have evolved to survive freezing water temperatures with natural "antifreeze." Certain arctic fish have blood containing a high concentration of a specific protein. This protein behaves like a solute in a solution and lowers the freezing point of the blood. Going to the other end of the spectrum, one can also observe that the boiling point of a solution is affected by the addition of a solute. These two properties, namely freezing-point depression and boiling-point elevation, are called *colligative* properties (properties that depend on the number of molecules, but not on their chemical nature).

Removing snow from blocked roads. Before manually removing it, salt is spread on the snow cover to ease the job.

Basic Concepts

A saturated solution is a mixture in which no more solute can be practically dissolved in a solvent at a given temperature. It is said practical because theoretically infinite amount of solute can be added to a solvent, but after a certain limit the earlier dissolved solute particles start rearranging and come out at a constant rate. Hence overall it appears that no solute is dissolved after a given amount of solute is dissolved. This is known as a saturated solution.

In an unsaturated solution, if solute is dissolved in a solvent the solute particles dissociate and mix with the solvent without the re-arrangement of earlier dissolved solute particles.

Solubility depends on various factors like the Ksp of the salt, bond strength between the cation and anion, covalency of the bond, extent of inter and intramolecular hydrogen bonding, polarity, dipole moment etc. Out of these the concepts of H-bonding, covalency, ionic bond strength and polarity play a major role if water is taken as a solvent.

Also physical conditions like temperature and pressure also play very important roles as they affect the kinetic energy of the molecules.

Materials and Equipment

To do this experiment following materials and equipment are required:

- Distilled water
- Metric liquid measuring cup (or graduated cylinder)
- Three clean glass jars or beakers
- Non-iodized table salt ($NaCl$)
- Epsom salts ($MgSO_4$)
- Sugar (sucrose, $C_{12}H_{22}O_{11}$)
- Disposable plastic spoons
- Thermometer
- Three shallow plates or saucers
- Oven
- Electronic kitchen balance (accurate to 0.1 g)

Experimental Procedure

Determining Solubility

1. Measure 100 mL of distilled water and pour into a clean, empty beaker or jar.

2. Use the kitchen balance to weigh out the suggested amount (see below) of the solute to be tested.
   a. 50 g Non-iodized table salt (NaCl)
   b. 50 g Epsom salts ($MgSO_4$)
   c. 250 g Sugar (sucrose, $C_{12}H_{22}O_{11}$)

3. Add a *small* amount of the solute to the water and stir with a clean disposable spoon until dissolved.

4. Repeat this process, always adding a small amount until the solute will no longer dissolve.

5. Weigh the amount of solute remaining to determine how much was added to the solution.

6. Try and add more solute at the same temperature and observe changes if any.

7. Now heat the solutions and add more solute to the solutions.

Observations:

Salt	Amount of salt dissolved in 100mL water to make saturated solution.	Moles dissolved
NaCl (Non-iodized common salt)	**36.8 grams**	**0.7**
$MgSO_4$	**32.7 grams**	**0.255**
$C_{12}H_{22}O_{11}$ (sucrose)	**51.3 grams**	**0.15**

Adding more solute at the same temperature to the saturated solutions yielded no significant changes in NaCl and Epsom salt. Howerver at all temperatures the saturation point of sucrose could not be obtained exactly as due to the large size of the molecule the solution became thick and refraction was more prominent. Neglecting this observation in the room for error, the experiments agreed with the theory.

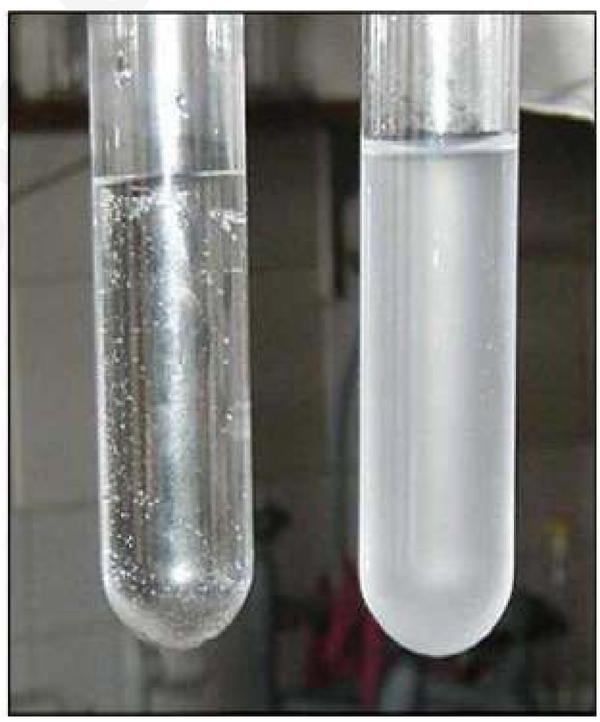
Adding more solute to heated solutions increased the solubility in all the 3 cases. The largest incrrease was shown by NaCl, followed by Epsom salt and sucrose. These facts too agreed with the theory as at high temperatures the kinetic enery of molecules increases and the collisions are more effective.

Conclusions:

The solubility of NaCl is the highest as it an ionic salt and easily dissociates in water. Also since the size of both the cation and anion are small, the collisions are more and hence probability of dissociation is high. The solubility of $MgSO_4$ is also high as it is also an ionic salt, but due to a larger anion, collisions are not very effective. The solubility of $C_{12}H_{22}O_{11}$ is the least as it a very large molecule due to which hydrogen bonding with the water molecules is not very effective. Also due to the large number of carbon and oxygen atoms, inter molecular H-bonding is more dominant than intramolecular H-bonding.

Solution of NaCl (actual photo)

Solution of scucrose



$MgSO_4$ solution (unsaturated and

Precautions:

1. While adding the solute to the solvent, the solution should be stirred slowly so as to avoid the formation of any globules.
2. Stirring should not be vigorous as the kinetic energy of the molecules might change due to which solubility can increase.
3. While stirring, contact with the walls of the container should be avoided as with every collision, an impulse is generated which makes the dissolved solute particles rearrange themselves. As a result solubility can decrease.
4. The temperature while conducting all the three experiments should be approximately same.

^ 5. Epsom salt should be first dried in order to remove the water of crystallization ($MgSO_4.7H_2O$).

Result:

The saturated solutions of NaCl, MgSO4 and C12H22O11 were made and observed. The observations agreed with the related theory within the range of experimental error.

Bibliography:

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