EXPERIMENT 0

Solutions, Electrolytes, Concentration

A. Goal

The goal of this experiment is to identify the polarity of a given solute as well as the electrolyte character of a series of solutes. The goal is also to calculate the molarity of an already prepare solution.

B. Materials

- ☐ Eight test tubes in a rack with cyclohexane,sucrose, iodine, potassium permanganate and vegetable oil
- ☐ Two electrodes connected to a lightbulb and a set of electrolytes: NaCl, sucrose, HCl, CH_3-COOH,NH_3 , CH_3-CH_2OH, and NaOH
- ☐ A 250mL beaker with 200mL of water
- ☐ evaporating dish
- ☐ unknown solution
- ☐ hot plate, stand and ring

C. Background

Solutions and composition

Solutions are homogeneous mixtures of two components. The state of the matter of both components of the mixture or their polarity affects the formation of a solution. For example, a solution will not result from mixing oil and water as they have different polar characteristics and it will form from mixing table salt and water as both are polar chemicals. At the same time, the more solute you add to a solution the more concentrated the solution will be. This section covers polarity and the composition of solutions.

What makes a solution?

Solutions are homogeneous mixtures of a solute and a solvent (see Figure **??**). Homogeneous means that if you look at the mixture you will not be able to differentiate both components and you will only see it as a whole. In a solution, the solute is the component of the mixture in less amount, whereas the solvent is the component in a larger amount. Think about mixing sugar with water. Sugar is sweet and water tasteless. When you mix both, you form a solution of sugar (solute) in water (solvent) and you will not see sugar in the solution as it is dissolved. In this particular example, sugar will be the solute in the solution, as the sugar is in less amount than water. Is important to remember that a solution is a result or mixing a solute and a solvent:

$$\boxed{\text{Solution} = \text{Solute} + \text{Solvent}}$$

Types of solutions

You can prepare different types of solutions by mixing a solid and a liquid, like when you mix sugar and water, or salt and water. You can create solutions as well by mixing two liquids or two solids. Examples are vinegar–a liquid solution of acetic acid (liquid) in water (liquid)–or steel– a solid solution that contains iron and carbon, both solids.

Empirical rules of polarity

The affinity between two chemicals is related to a concept called polarity. Molecules contain electrons and depending on the electron distribution within the molecules, molecules can be polar or non-polar. Molecules with an even electron distribution are non-polar as they have no permanent dipole moment. An example of this is H_2 molecule. Differently, HF is a polar molecule, as F concentrates more on the electron density of the molecule than H. The polar nature of substances–with a permanent dipole moment–is related to miscibility and molecules with similar polar character will mingle and mix creating a single visible phase (see Table 1). As an example, water (H_2O, polar) and methanol (CH_3OH, polar) will mix together. Differently, water (polar) and oil (non-polar) are immiscible due to their different polar nature and they will not mix. Even if the rules or polarity are based on the nature and structure of the molecule, one can use very simple empirical rules to classify molecules as polar or non-polar. These rules work in general well for the case of diatomic and very large molecules:

1. **Rule one:** Diatomic molecules made of the same element (e.g. H_2) are non-polar.
2. **Rul two:** Diatomic molecules made of different elements (e.g. HI) are polar.
3. **Rul three:**Poliatomic molecules (with more than four atoms) made of C and H (e.g. CH_4) are in general non-polar.
4. **Rul four:** Poliatomic molecules (with more than four atoms) containing C, H, and a different atom (e.g. CH_3F) are in general polar.

Mixing and polarity

A solution is formed when both the solute and the solvent mix. However, they will only mix if they have the same polarity. As an example, water (H_2O) is a polar molecule, and methanol (CH_3-OH) is too. Hence they will both mix and form a solution. If the elements of a mixture have different polarity they will not mix. An example is benzene (C_6H_6, nonpolar) and water, or for example oil (nonpolar) and water (polar).

Sample Problem 1

Classify the following molecules as polar or nonpolar: H_2, HCl, CH_3CH_3, and CH_3CH_2Cl.

SOLUTION

H_2 is a non-polar molecule, being a diatomic molecule containing two atoms of the same element. Differently HCl is polar. CH_3CH_3 is a non-polar poliatomic molecule made of C and H atoms, whereas CH_3CH_2Cl is polar.

STUDY CHECK

Classify the following molecules as polar or nonpolar: HF, Cl_2, C_2H_4, and C_2H_3Cl.

Table ?? Polarity and mixing

Solvent	Solute	Mixing?
Polar	Polar	Yes
Polar	Nonpolar	No
Nonpolar	polar	No
Nonpolar	Nonpolar	Yes

Concentration of solutions

The concentration of a solution refers to the amount of solute with respect to the amount of solution. The larger concentration the larger the number of solute particles with respect to the particles of solvent. Concentration is one of the most important properties of a solution as it affects the physical properties of a solution such as the freezing and boiling point. There are many different concentration units, such as molarity, mass percent concentration, or volume percent concentration. All these different units overall express the ratio between the particles–mass or volume–of solute and solvent.

Mass percent concentration

The mass percent (% m/m) is the amount of solute in grams per gram of solution in percent form

$$\boxed{\%m/m = \frac{\text{g of solute}}{\text{g of solution}} \times 100}$$

Volume percent concentration

The volume percent concentration (% v/v) is the volume of solute per volume of solution in percent form

$$\boxed{\%v/v = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100}$$

Mass volume percent concentration

The mass/volume percent concentration (% m/v) is the mass of solute per mL of solution in percent form.

$$\boxed{\%m/v = \frac{\text{g of solute}}{\text{mL of solution}} \times 100}$$

Molarity concentration

The molarity (M) is the moles of solute per L of solution.

$$\boxed{M = \frac{\text{moles of solute}}{\text{L of solution}}}$$

Sample Problem 2

A NaCl solution is prepared by mixing 4g of NaCl (MW=58.4g/mol) with 50 g of water until a final volume of 52mL of solution. Calculate: (a) the mass percent (m/m) concentration; (b) the molarity.

SOLUTION

(a) to calculate the mass percent (m/m) we just need the grams of solute and the grams of solution–that is four plus fifty. Both numbers are already given:

$$m/m = \frac{\text{g of solute}}{\text{g of solution}} \times 100 = \frac{\text{4 g of solute}}{\text{54 g of solution}} \times 100 = 9.2\%$$

(b) To calculate molarity we need the moles of solute and the liters of solution. We have the mL of solution, that can be converted to L: 52mL= $5.2 \times 10^{-2} L$. To calculate the moles of solute, we will use the grams of solute and the molar mass to convert this value into moles: $4g/58.4g/mol$ =0.068moles. Plugging all values into the molarity formula:

$$M = \frac{\text{moles of solute}}{\text{L of solution}} = \frac{\text{0.068 moles of solute}}{5.2 \times 10^{-2}\text{L of solution}} = 1.31M$$

STUDY CHECK

(a) A solution is prepared by mixing 8g of NaCl (MW=74g/mol) with water until a 250mL volume. Calculate the molarity; (b) A KCl solution is prepared by mixing 45g of KCl with 200g of H_2O. Calculate the percent (m/m) of the solution.

D. Procedure

1. Polarity and miscibility The goal of this mini-experiment is to identify the polarity of a given solute by mixing it with a polar and nonpolar solvent. To chemicals with the same polarity will mix with each other due to favorable interactions. Think about oil and soap, both are nonpolar chemicals and hence they mix well. Differently, chemicals with different polarity do not mix well. Think this time about water and oil. Water is polar and oil is nonpolar. Both chemicals do not mix well. By using a polar solvent (water) and a nonpolar solvent (cyclohexane) you will be able to track the polarity of a given solute by studying the miscibility of the solute with both solvents. Ultimately, polarity is due to differences in electronegativity an the existence of a permanent dipolar moment in the molecule. Small molecules (diatomic) made of different elements will always be polar, as the differences of electronegativity will not compensate with each other leading to a permanent dipole moment. Molecules made mainly of C and H will normally be nonpolar as both elements have not appreciable electronegativity differences.

Step 1: – Use eight test tubes in a rack. Four of these will be filled with 5 drops of water–a polar solvent–whereas the remaining four tubes will be filled with cyclohexane–a nonpolar solvent.

Step 2: – Add a few drops of a few crystals of the following solutes both in water and in cyclohexane. If the solute mixes with water that means it will be polar. If the solute mixes with cyclohexane that would mean it is nonpolar.

2. Electrolytes In this mini-experiment you will study the electrolyte character of a series of solutes with different nature. By means of two electrodes connected to a lightbulb you will be able to appreciate the degree these chemicals conduct electricity. If the lightbulb glows the chemical will be an electrolyte. Depending on the brightness of the glow the chemical will be a strong or weak electrolyte.

Step 1: – You or the professor will use a setup with two electrodes connected to a lightbulb. Place 20mL of the different solutions in the table below in a beaker.

Step 2: – Lower the electrodes to the solution and observe the glow.

Step 3: – Observe the glow and classify the chemical as nonelectrolyte, strong electrolyte or weak electrolyte.

3. Molarity of a solution The goal of this mini-experiment is to calculate the molarity of an already prepare solution. In order to calculate molarity, we need the moles of solute and the volume of solution. You will take a given solution volume by using a pipet. At the same time you will learn how to use a pipet–a very common chemistry measuring tool. Then you will evaporate the solution so that only the solute will remain. By weighting this solute and given the molar mass you will convert grams into moles and compute molarity.

Step 1: – Fill a 250mL beaker with 200mL of water. Set the beaker on a hot plate and start heating at medium high heat.

Step 2: – Weight an evaporating dish. Write down the mass in the table below.

Step 3: – Place the evaporating dish on top of the beaker so that it receives indirect heat. Use a metallic ring to secure the beaker.

Step 4: – Use a small beaker to measure approximately 20mL of the solution. Use a 10-mL graduated pipet to transfer exactly 10mL of the solution into the evaporating dish. Weight the evaporating dish with the solution.

Step 5: – The solution will start to dry. When the evaporating dish is completely dry, stop the heater and wait for the dish to cool down. Weight the evaporating dish with the solute.

Calculate the molarity of the solution by using the following formula:

$$M = \frac{n_{solute}}{v_{solution}}$$

STUDENT INFO

Name: ______________________ Date: ______

Pre-lab Questions

Solutions, Electrolytes, Concentration

---

1. Define electronegativity.

2. Compare the electronegativity of hydrogen and chlorine. Will HCl be polar or nonpolar?

3. Compare the electronegativity of two hydrogen atoms. Will H_2 be polar or nonpolar?

4. Classify the following chemicals as ionic, covalent, organic chemical, organic acid or organic base: NaCl, CH_3-COOH, CH_3NH_2, HF, CO.

STUDENT INFO
Name: ____________________ Date: ______

Results
EXPERIMENT

Solutions, Electrolytes, Concentration

1. Polarity and miscibility

Solute	Soluble in Water (H_2O)?	Soluble in Cyclohexane (C_6H_{10})?	Polar/Nonpolar
I_2(iodine)			
Sucrose			
$KMnO_4$(potassium permanganate)			
Vegetable oil			

2. Electrolytes

Chemical	Light intensity (No light, weak light, strong light)	Electrolyte type (Non electrolyte/weak electrolyte/strong electrolyte)	Particles in solution (Molecules/ions/Molecules+Ions)
NaCl			
Sucrose			
HCl			
CH_3-COOH			
NH_3			
CH_3-CH_2OH			
NaOH			

3. Molarity of a solution

1	Mass of the evaporating dish (g)	______
2	Volume of solution, $v_{solution}$ (L)	______
3	Mass of the evaporating dish with the solution (g)	______
3 − 1	Mass of the solution (g)	______
4	Mass of the evaporating dish with dry solute	______
4 − 1	Mass of solute, m_{Solute}	______
$(4 - 1) \times \frac{1 \text{ mol NaCl}}{58 \text{ g NaCl}}$	Moles of solute, n_{solute} (mol)	______

$M =$ ______

STUDENT INFO
Name: ______________________ Date: ______

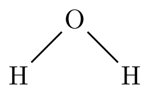
Post-lab Questions

Solutions, Electrolytes, Concentration

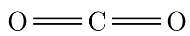
---

1. Indicate whether the following diatomic molecules are polar or nonpolar: Cl_2, N_2, O_2, HCl, HI, and HF.

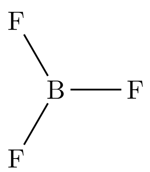
2. Given the geometry of the following small polyatomic molecules are polar or nonpolar:

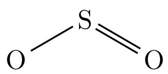


and

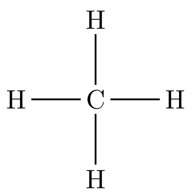


3. Given the geometry of the following small polyatomic molecules are polar or nonpolar:





and



4. Indicate whether the following chemicals are nonelectrolytes, weak electrolytes or strong electrolytes: NaF, CH_3-CH_3, $CH_3-CH_2-CH_2OH$, HF, and CH_3-CH_2-COOH.

5. Use your results to calculate the mass percent of the solution.

6. Calculate the volume of a 3M solution that contains 4 moles of solute.

7. Calculate the number of moles in 20mL of a 4M solution.