Unit 4: Solutions and Solubility

Solubility – the mass of a substance that will dissolve in a given volume or mass of a solvent

- if more of a substance dissolves in one solvent than in a second solvent, the substance is said to be <u>more soluble</u> in the first solvent

Soluble – a solid that dissolves in a given liquid (aq)
- solubility is greater than 1 g per 100 mL of solvent

Insoluble – a solid that does not dissolve in a given liquid (s)
- solubility is less than 0.1 g per 100 mL of solvent

Slightly Soluble – substances with solubility between 0.1 g and 1 g per 100 mL of solvent Figure 8.2 pg. 356

Precipitate – a solid that forms in solution

Unsaturated Solution – contains less than the maximum amount of solute that can dissolve in a given amount of solvent at a particular temperature

Saturated Solution – contains maximum amount of solute that can remain dissolved in a given amount of solvent at a particular temperature

Supersaturated Solution – a solution which contains more dissolved solute than it would if it were saturated ↑ temperature

change pressure

Types of Solutions

Solution – homogeneous (the same throughout) mixture of two or more substances (see table 8.1 pg. 355)

Solvent – substance that is present in larger quantity

Solute – substance that is present in smaller quantity
- dissolved in the solvent

Ex. 1 sugar water solvent – water solute – sugar

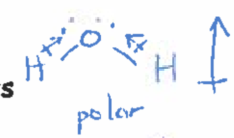
Dilute Solution – contains a relatively small amount of solute compared to the amount of solvent

Concentrated Solution – contains a relatively large amount of solute

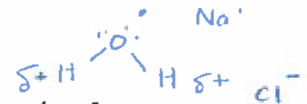
Aqueous Solution – solutions made by dissolving solutes in water

Solubility and Intermolecular Forces

- polar substances dissolve in polar solvents
- non-polar substances dissolve in non-polar solvents
- "like dissolves like"



Dipole-Dipole Attraction – the intermolecular force between oppositely charged ends of two polar molecules (molecules with dipoles)
- much weaker than an ionic or covalent bond
  e.g. **Hydrogen Bond** – a relatively strong dipole-dipole force between a positive hydrogen atom of one molecule and a highly electronegative atom (N, O, or F) in another molecule
- much stronger than ordinary dipole-dipole attraction



Ion-Dipole Attraction - the intermolecular forces between ions and polar molecules

- if ion-dipole attraction can replace the ionic bonds between the cations and anions in an ionic compound, the compound will dissolve

NaCl $[Na]^+$ $[:Cl:]^-$

- however, if the ionic bond is very strong, the compound will be less soluble in water than a compound with a weak ionic bond

Factors That Affect Solubility

Molecule Size - small molecules are often more soluble than larger molecules

Temperature

- the solubility of most solids increases with temperature
  - energy is needed to break bonds between particles in the solid - at higher temperatures, more energy is present

- the solubility of most liquids is not greatly affected by temperature
  - the bonds between particles in a liquid are not as strong as the bonds between particles in a solid - additional energy is needed

- the solubility of gases decreases with higher temperatures
  - gas particles have a great deal of kinetic energy - when they dissolve in a liquid they lose some energy (Figure 8.13 pg. 367)
  - as a result, the gas comes out of solution and is less soluble

Fig 8.13 pg. 367 pop

Pressure - the solubility of a gas is directly proportional to the pressure of the gas above the liquid

e.g. when the pressure of carbon dioxide in a pop bottle is released, the solubility of the gas in the solution decreases

- changes in pressure have little effect on solid and liquid solutions

Factors That Affect The Rate of Dissolving

Temperature - increasing the temperature increases the rate of dissolving

- the solvent molecules have greater kinetic energy, and therefore collide with the undissolved solid molecules more frequently

Agitation - agitation increases the rate of dissolving

- agitation brings fresh solvent into contact with undissolved solid

Particle Size - decreasing the size of the particles increases the rate of dissolving

- breaking up solute into smaller pieces increases the surface area that is in contact with the solvent

Activity - Launch Lab pg. 353
Title: **Layered Liquids**
Observations: Qualitative
Questions: #1-4

HW: Q#1-6 pg 358
Q#2,3,5,14 pg 370

Concentration

Concentration – the amount of solute (smaller amount) per quantity of solvent (larger amount)

A. Percentage Concentrations

1. volume/volume (V/V) percent = $\frac{\text{volume of solute (mL)}}{\text{volume of solution (mL)}} \times 100$

e.g. vinegar is 5% V/V acetic acid, which means that in a 100 mL solution of vinegar, there are 5 mL of acetic acid.

$5\%\ V/V = \frac{V_{acetic\ acid}}{V_{solution}} \times 100 \qquad 5\% = \frac{V_{acetic\ acid}}{100\ mL} \times 100$

2. Weight/weight (W/W) percent = $\frac{\text{weight of solute (g)}}{\text{weight of solution (g)}} \times 100$

e.g. In a 200 g tube of toothpaste, there are 0.486 g of dissolved sodium fluoride.

W/W concentration of NaF = $\frac{0.486\ g}{200\ g} \times 100 = 0.243\%\ w/w$

3. Weight/volume (W/V) percent = $\frac{\text{mass solute (g)}}{\text{volume of solution (mL)}} \times 100$

$1\ L = 1000\ mL$

e.g. A salt solution has 12.8 g of salt in 1 L of solution. .

W/V concentration of NaCl = $\frac{12.8\ g}{1000\ mL} \times 100$

$= 1.28\ \%\ w/v$

B. Parts per Million

- concentrations of very small quantities can be expressed in parts per million (ppm)

ppm = $\frac{\text{mass of solute (mg)}}{\text{volume of solution (L)}}$

e.g. In a 0.25 L sample of pond water, 2.2 mg of dissolved oxygen are measured.

Concentration of O_2 in ppm= $\frac{2.2\ mg}{0.25\ L}$

$= 8.8\ ppm$

e.g. $1.5\ \frac{mol}{L} = 1.5\ M$

C. Molar Concentration (Molarity)- the number of moles of solute that can dissolve in 1 L of solution (mol/L or M)

Molar concentration = $\frac{\text{amount of solute (mol)}}{\text{volume of solution (L)}}$

$\frac{mol}{L} \qquad C = \frac{n}{V}$ ← n: mol, V: L

Ex. 1 A solution contains 5.85 g of sodium chloride dissolved in 5000 mL of water. What is the concentration of the sodium chloride in mol/L?

↓ 5 L

$M_{NaCl} = 58.443\ \frac{g}{mol}$

$C_{NaCl} = 5.85\ g \times \frac{1\ mol}{58.443\ g} \times \frac{}{5\ L}$

$= 0.02\ \frac{mol}{L}$

Ex. 2 What is the concentration in mol/L of a solution that contains 49 g of sulfuric acid in 3.0 L of solution?

$M_{H_2SO_4} = 98.077\ \frac{g}{mol}$

$C_{H_2SO_4} = 49\ g \times \frac{1\ mol}{98.077\ g} \times \frac{}{3.0\ L}$

$= 0.17\ \frac{mol}{L}$

$V = 600\,mL \div 1000 = 0.6\,L$

Ex. 3 What mass of potassium hydroxide is required to prepare 600 mL of a 0.225 mol/L solution?

$M_{KOH} = 56.105\ \frac{g}{mol}$

$m_{KOH} = 0.6\,L \times \frac{0.225\,mol}{L} \times \frac{56.105\,g}{mol}$

$= 7.574\,g$

$= 8\,g$

OR

$c = \frac{n}{V}$

$n_{KOH} = c \times V$

$= 0.225\ \frac{mol}{L} \times 0.6\,L$

$= 0.135\,mol$

$m_{KOH} = 0.135\,mol \times \frac{56.105\,g}{mol}$

$= 8\,g$

Ex. 4 A solution containing 0.125 mol/L of magnesium chloride is required for an experiment. If 87.8 g of solid magnesium chloride is available, what is the maximum volume of solution that can be prepared?

$M_{MgCl_2} = 95.211\ \frac{g}{mol}$

$V_{MgCl_2} = 87.8\,g \times \frac{1\,mol}{95.211\,g} \times \frac{1\,L}{0.125\,mol}$

$= 7.38\,L$

OR

$c = \frac{n}{V}$

$V = \frac{n}{c}$

$n_{MgCl_2} = 87.8\,g \times \frac{1\,mol}{95.211\,g}$

$= 0.9222\,mol$

$V = \frac{n}{c} = \frac{0.9222\,mol}{0.125\,mol/L}$

$= 7.38\,L$

HW: #1 pg 373, #11 pg 375, #22 pg 376, #31 pg378, #41,42,44,46(tricky think of # of atoms) pg 381

PREPARING SOLUTIONS

Standard Solution (Stock Solution): Solution in which the precise concentration is known.

There are two methods of preparing standard solutions: $c = \frac{n}{V}$

1. From a solid
2. By dilution

1. FROM A PURE SOLID:

Example: Calculate the mass of copper (II) sulfate pentahydrate required to prepare 100.0 mL of a 0.5000 mol/L solution.

$V = 100.0\ mL \div 1000 = 0.1 L$ ✓ $c = 0.5\ mol/L$

1. Determine the number of moles of $CuSO_4{\cdot}5H_2O$ in the solution.

$n = c \times V$

$= (0.5 mol/L)(0.1 L)$

$= 0.05 mol$

2. Convert moles to grams.

$M_{CuSO_4 \cdot 5H_2O} = 249.682\ g/mol$

$m_{CuSO_4 \cdot 5H_2O} = 0.05 mol \times 249.682\ g/mol$

$= 12.48\ g$

3. Accurately weigh the number of grams and dilute in a volumetric flask.

OR $m_{CuSO_4 \cdot 5H_2O} = 0.1 L \times \frac{0.5 mol}{L} \times \frac{249.682\ g}{mol} = 12.48\ g$

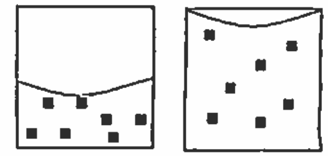
EXAMPLES:

1. What mass of sodium hydroxide is required to prepare 500.0 mL of a 10.0 mol/L cleaning solution? (2.00×10^2 g)
2. Calculate the mass of potassium permanganate required to prepare 500.0 mL of a 0.0750 mol/L solution. (5.93 g)
3. Calculate the mass of cobalt (II) chloride dihydrate required to prepare 2.00 L of a 0.100 M solution. (33.2 g)
4. What mass of barium nitrate is needed to create 100 mL of a 0.125 M solution? (3.27 g)
5. What mass of ammonium oxalate monohydrate is required to prepare 100.0 mL of a 0.250 M solution? (3.55 g)

2. DILUTIONS

A concentrated solution can be made more dilute by mixing the concentrated solution with solvent.

In dilutions the amount of solvent is increased, but the amount of solute is kept constant. This means that the original number of moles of solute and the final number of moles of solute are the same. The result is a decreased concentration, but an increased volume.



Concentrated Solution | Diluted Solution

Same number of moles of solute in each.

Therefore we can develop this formula:

$$n_c = n_d$$

$$\because n = cv$$

$$\therefore \boxed{c_c v_c = c_d v_d}$$

Where:

c_c = conc. of concentrated solution (mol/L)

v_c = vol. of concentrated solution (L)

c_d = conc. of dilute solution (mol/L)

v_d = vol. of dilute solution (L)

This formula can be rearranged to solve for anyone of these variables.

Examples

1. How much 2.0 M NaCl solution would you need to make 250 mL of 0.15 M NaCl solution? (19 mL)
2. What would be the concentration of a solution made by diluting 45.0 mL of 4.2 M KOH to 250 mL? (0.76 M)
3. What would be the concentration of a solution made by adding 250 mL of water to 45.0 mL of 4.2 M KOH? (0.64 M)
4. How much 0.20 M glucose solution can be made from 50 mL of 0.50 M glucose solution? (125 mL)

Kool-Aid *Madness*

Part 1: Making a Standard Solution from a Solid

Intro: Creating and diluting solutions requires careful practice and precise techniques. Today, your job is to create a 50 mL, 0.1 M solution of Kool-Aid using perfect technique.

Important Info:
Kool-Aid's main ingredient is sugar, a solid at room temperature:

Molecular formula: $C_{12}H_{22}O_{11}$

$M_{Kool\text{-}Aid}$:

$n_{Kool\text{-}Aid}$ =

$m_{Kool\text{-}Aid}$ =

Part 2: Making a Solution by Diluting

Often times in Chemistry we do not need concentrated solutions. In order to prepare solutions that are adequately diluted, we dilute those solutions by adding more water to a small amount of the concentrated solution.

Determine the "diluted" concentration of the solution by pipetting 10 mL of the concentrated solution (from part 1) and placing it in a new 50 mL volumetric flask. Top it up with deionized water.

prepared solution from above | pipette 10 mL | 10 mL of concentrated + deionized water to 50 mL mark

$C_{concentrated}$=

$V_{concentrated}$=

V_{dilute}=

C_{dilute}= ?