Intermolecular forces, acids, bases, electrolytes, net ionic equations, solubility, and molarity of ions in solution:

1. What are the different types of Intermolecular forces? Define the following terms: Vapor pressure, Boiling point, Normal boiling point, Melting point and freezing point.

**Answer:**
There are five types of Intermolecular forces
1. Ion-dipole forces
2. Ion-induced dipole forces
3. Dipole-dipole forces (Hydrogen bond is also a special type of dipole-dipole forces)
4. Dipole-induced dipole forces
5. London dispersion forces

**Vapor pressure:** When a liquid evaporates, the molecules that enter the vapor phase from liquid phase exert a pressure called the vapor pressure.

\[ \text{H}_2\text{O (l)} \rightleftharpoons \text{H}_2\text{O (g)} \]

But at equilibrium the,  \[
\frac{\text{Rate of condensation}}{\text{Rate of evaporation}} = \frac{\text{Rate of evaporation}}{\text{Rate of condensation}}
\]

That is called dynamic equilibrium
The *equilibrium vapor pressure* is the vapor pressure measured when a dynamic equilibrium exists between condensation and evaporation. More commonly, the equilibrium vapor pressure is called the vapor pressure of a liquid.

Vapor pressure depends on:
1. Temperature: High temperature, more molecules move from liquid, therefore high pressure.
2. Intermolecular forces: Due to IMF’s molecules will move into gas phase more or less easily. Strong IMF’s means less molecule can come out to the gas phase, so, less vapor pressure. On the other hand weak IMF’s means high vapor pressure. e.g. H$_2$O and H$_2$S at same temperature which will have high VP?????
   Due to H-bond H$_2$O has low VP. But, no H-bond in H$_2$S, so, high VP.

**Boiling point:** The *boiling point* is the temperature at which the (equilibrium) vapor pressure of a liquid is equal to the external pressure.

**Normal Boiling point:** The *normal boiling point* is the temperature at which a liquid boils when the external pressure is 1 atm.

**Melting point and Freezing point:** The *melting point* of a solid or the *freezing point* of a liquid is the temperature at which the solid and liquid phases coexist in equilibrium
2. Define the following terms: strong acid, strong base, weak acid, weak base, strong electrolyte, weak electrolyte, non-electrolyte, soluble, insoluble, and solubility. List the seven strong acids. Define the following types of solutions: saturated, unsaturated and supersaturated.

**Answer:**

**Strong acid:** Substance that when dissolved in water produces protons (H⁺) is called acid (defined by Arrhenius). The acid dissolves in water and dissociates 100% to produce protons (H⁺) is called strong acid. e.g. the seven strong acids are: HCl, HBr, HI, HNO₃, H₂SO₄, HClO₄ & HClO₃.

**Weak acid:** The acid dissolves in water but less than 100% dissociates to produce protons (H⁺) is called weak acid. e.g. any acid that is not one of the seven strong acid is weak acid: H₃PO₄, HClO, HClO₂, HF, H₂S, HC₂H₃O₂ etc.)

**Strong base:** Substance that when dissolved in water produces hydroxides (OH⁻) is called base (defined by Arrhenius). The base dissolves in water and dissociates 100% to produce hydroxides (OH⁻) is called strong base. e.g. Group IA metal hydroxides are strong base (i.e. LiOH, NaOH, KOH etc) and heavier GroupIIA metal hydroxides are also strong base (i.e. Ca(OH)₂, Sr(OH)₂, Ba(OH)₂).

**Weak base:** The base dissolves in water but less than 100% dissociates to produce hydroxides (OH⁻) is called weak base. e.g. ammonia (NH₃) and its derivatives (NH₂OH, (CH₃)₂NH etc.)

**Strong electrolyte:** A strong electrolyte dissolves and dissociates 100% into ions in water and conducts a strong electrical current. e.g. strong acids, strong bases and soluble ionic compounds (i.e. NaCl, KBr, Ca(Cl)₂ etc).

**Weak electrolyte:** A weak electrolyte dissolves and dissociates less than 100% into ions in water (some dissociates into ions and the rest dissolves as neutral molecules) and conducts a weak electrical current. e.g. weak acids, weak bases

**Nonelectrolyte:** A nonelectrolyte dissolves in water as neutral molecules (none dissociates into ions) and conducts no electrical current. e.g. sugar (C₁₂H₂₂O₁₁).

**Soluble:** A compound (e.g. ionic compounds or salts) is said to be soluble if it dissolves in water to a significant extent >0.1 M.

**Insoluble:** A compound (e.g. ionic compounds or salts) is said to be insoluble if it does not dissolve in water to a significant extent <=0.1 M.

**Solubility:** The amount of ionic compound or salt that must be added to a given volume of solvent to form a saturated solution is called the solubility of the ionic compound or salt.

**Saturated and supersaturated solution:**
A solution obtained when a solvent (liquid) can dissolve no more of a solute (usually a solid) at a particular temperature is called saturated solution. Normally, a slight fall in temperature causes some of the solute to crystallize out of solution. If this does not happen the phenomenon is called supercooling, and the solution is said to be supersaturated.

**Unsaturated solution:** A solution in which more solute can be dissolved.

3. What types of substances can be classified as strong electrolytes? Weak electrolytes? Non- electrolytes?

**Answer:**

Strong acids, strong bases and soluble ionic compounds are classified as strong electrolytes. Weak acids and weak bases are classified as weak electrolytes. Organic compounds that are not classified as weak acids and bases are nonelectrolytes (e.g. sugar)
5. What are the three types of equations that can be written for any chemical reaction?

**Answer:**
- **Molecular equation:** Equation shows all species with full chemical formula is called molecular equation.
- **Full or complete ionic equation:** Equation shows all species really exist in solution, that means all strong electrolytes split into ions except weak electrolytes, gases and precipitates is called full or complete ionic equation.
- **Net ionic equation:** Equation shows only the reacting species (spectator ions are cancelled out) in solution is called net ionic equation.

Note: Spectator ions are those donot actually take part in the reaction.

**Properties of Solutions and Concentration units:**

12. Define the following terms: homogeneous mixture, heterogeneous mixture, solution, colloid, and suspension?

**Answer:**
- **A mixture** is a combination of two or more substances that are not chemically united and do not exist in fixed proportions to each other. Most natural substances are mixtures.

**Homogeneous mixtures:**

The prefixes "homo"- indicate sameness, A homogeneous mixture has the same uniform appearance and composition throughout. Many homogeneous mixtures are commonly referred to as solutions.

- e.g. Corn oil is homogeneous, White vinegar is homogeneous. A sugar solution is homogeneous since only a colorless liquid is observed.

**Heterogeneous mixtures:**

The prefixes: "hetero"- indicate difference. A heterogeneous mixture consists of visibly different substances or phases. e.g a mixture of olive oil and vinegar in a salad dressing.

Particle size distinguishes homogeneous solutions from other heterogeneous mixtures. Solutions have particles which are the size of atoms or molecules - too small to be seen.

- A **colloid** is a homogeneous solution with intermediate particle size between a solution and a suspension (2-1000 nm). Colloid particles may be seen in a beam of light such as dust in air in a "shaft" of sunlight but not filterable or separable. Milk, fog, and jello are examples of colloids.

In contrast a **suspension** is a heterogeneous mixture of larger particles (>1000 nm size). These particles are visible and will settle out on standing and filterable. Examples of suspensions are: fine sand or silt in water.
A Solution is a homogeneous mixture with small solute particles (<2 nm size) (i.e. individual atoms, molecules and ions) but not filterable or separable. e.g. Sea water (NaCl/water).

Note: The substance in the smallest amount and the one that dissolves or disperses is called the SOLUTE. The substance in the larger amount is called the SOLVENT.

13. Are the following mixtures solutions? Identify the solute and solvent and the physical state of each.
   a. Soda water           b. Sea water           c. 14K gold (mixture of Au and Ag)

Answer: Yes the following mixtures are solutions

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<th>TYPES OF SOLUTIONS</th>
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<td>Solute</td>
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14. What types of substances dissolved in water more readily, nonpolar or polar substances? Why?

**Answer:** Polar substances are dissolved in water more readily, because water is a polar solvent (“like dissolves like”).

15. Which of the following would be more soluble in hexane (C₆H₁₄) than in water? Wax (C₂₀H₄₂), C₂H₅OH, CaI₂, Toluene (C₇H₈), HC₂H₃O₂, HCl, NH₃.

**Answer:** Since hexane (C₆H₁₄) is a nonpolar solvent, so, Wax (C₂₀H₄₂), Toluene (C₇H₈) will be more soluble in hexane (C₆H₁₄) than in water (“like dissolves like”).

16. Define: Molarity (M), Molality (m), Mole fraction (Xᵢ) and Mole Percent (mol%)

**Answer:**

1. **Molarity (M)**

Molarity tells us the number of moles of solute in exactly one liter of a solution. (Note that molarity is spelled with an "r" and is represented by a capital M.)

We need two pieces of information to calculate the molarity of a solute in a solution:

- The moles of solute present in the solution.
- The volume of solution (in liters) containing the solute.

To calculate molarity we use the equation:

\[
\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in liters}}
\]

2. **Molality (m)**

Molality (m), tells us the number of moles of solute dissolved in exactly one kilogram of solvent. (Note that molality is spelled with two "l"s and represented by a lower case m.)

We need two pieces of information to calculate the molality of a solute in a solution:

- The moles of solute present in the solution.
- The mass of solvent (in kilograms) in the solution.

To calculate molality we use the equation:

\[
\text{Molality} = \frac{\text{moles of solute}}{\text{mass of solvent in kilograms}}
\]
3. Mole Fraction ($X$)

The mole fraction ($X$), of a component in a solution is the ratio of the number of moles of that component to the total number of moles of all components in the solution.

To calculate mole fraction, we need to know:

- The number of moles of each component present in the solution.

The mole fraction of A, $X_A$, in a solution consisting of A, B, C, ... is calculated using the equation:

$$X_A = \frac{\text{moles of A}}{\text{moles of A} + \text{moles of B} + \text{moles of C} + \cdots}$$

To calculate the mole fraction of B, $X_B$,

$$X_B = \frac{\text{moles of B}}{\text{moles of A} + \text{moles of B} + \text{moles of C} + \cdots}$$

4. Mole percent (mol%)

When the mole fraction composition of a mixture is expressed on a percentage basis, we call it a mole percent (mol%). Mole percent is obtained by multiplying the mole fraction by 100%.

i.e. $\text{mol\% of A} = X_A \times 100 \ \text{mol \%}$