Solutions

Types of solutions

- A ***solution*** is a homogeneous mixture of two or more substances.
- The two main components of a solution are the ***solute*** and the ***solvent***.
  - Solute is present in the smaller amount
  - The solvent is present in the larger amount.
- Any phase of matter can dissolve into any other phase.

Types of solutions

- Gases
  - Gases dissolved in gases (air)
  - Liquids dissolved in gases (humid air)
  - Solids dissolved in gases (moth balls)
- Liquids
  - Gases in liquids (air dissolved in water)
  - Liquids in liquids (ethanol in water)
  - Solids in Liquids (salt in water)
- Solids
  - Gases in solids (H_2 in Pt)
  - Liquids in solids (Hg/Ag amalgam)
  - Solids in solids (Cr in Fe alloy)

Terminology

- Solubility – The maximum amount of solute that will dissolve in a solvent.
- Saturated – A solution is that is at the solubility limit.
- Unsaturated – Anything less than saturated.
- Supersaturated – A solution that contains more than the solubility limit.

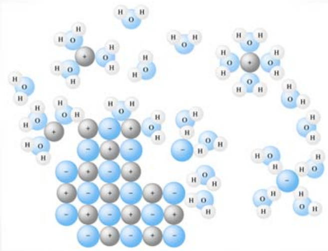
Terminology

- Dilute – A solution that contains relatively little solute.
- Concentrated – A solution that contains a relatively large amount of solute.
  - Can also mean a saturated solution, especially when applied to acids.
- Aqueous solution – A solution in which water is the solvent.

Solution formation

- Ionic solids dissolving in water
  - The polar water molecules are attracted to the ions in the solid.
  - The ions are attracted to each other and the water molecules
  - If the attraction between the water molecules and the ions is greater than that between the ions the substance will dissolve.

Solution formation



Solution Formation

- For covalent compounds, the relative strengths of the intermolecular forces determines whether or not a solution forms.
- "like dissolves like"

Concentration Units

- Concentration is the amount of solute in a given amount of either solution or solvent
- Percentage units

$$\%\left(\tfrac{m}{m}\right) = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$

$$\%\left(\tfrac{m}{v}\right) = \frac{\text{g of solute}}{\text{mL of solution}} \times 100$$

$$\%\left(\tfrac{v}{v}\right) = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100$$

Other concentration units

- ppm – Parts per million $ppm = \frac{parts}{whole} \times 10^6$
- ppb – Parts per billion $ppb = \frac{parts}{whole} \times 10^9$
- These units have the same possibilities as the percentage (parts per hundred) units.
  - ppm(m/m), ppm(m/v), ppm(v/v), etc.

Concentration Units

- Molarity

$$M = \frac{\text{mol solute}}{\text{L solution}}$$

- Molarity can be used as a conversion factor between number of moles of solute and volume of solution.

Dilution of solutions

- A solution can be made less concentrated by ***dilution***.
- Dilution is a process where solvent is added to a solution without changing the number of moles of solute. This lowers the concentration.
- It is important to remember that the number of moles of solute is constant.

Dilution

- Because the number of moles is constant, we can express it mathematically as: $n_i = n_f$
- We can find the number of moles from the volume of the solution and its molarity: $M_i V_i = M_f V_f$
- This equation is valid ***only*** for dilutions.

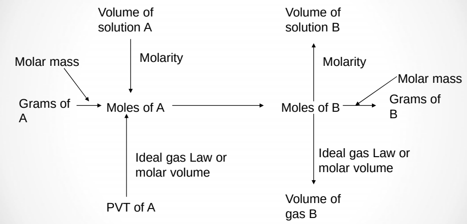
13

Molarity and Chemical Equations

- The volume and molarity of a solution give us a new way to calculate the number of moles of a reactant.
- Once we have the number of moles of reactant we can use the mole-to-mole relationships from the balanced chemical equation to calculate values of other quantities.
- We can now construct a complete "map" of chemical calculations.

14

Map of Chemical Calculations



15

Example

- According to the reaction:
  $3\ Ca(OH)_2 + 2\ H_3PO_4 \rightarrow 6\ H_2O + Ca_3(PO_4)_2$
  If 23.56 mL of 0.4436 M $Ca(OH)_2$ reacts with excess phosphoric acid, what mass of Calcium Phosphate is produced?

$$?\ \text{g}\ Ca_3(PO_4)_2 = 23.56\ \text{mL}\ Ca(OH)_2\ \text{sol'n} \times \frac{0.4436\ \text{mol}\ Ca(OH)_2}{1000\ \text{mL}}$$

$$\times \frac{1\ \text{mol}\ Ca_3(PO_4)_2}{3\ \text{mol}\ Ca(OH)_2} \times \frac{310.18\ \text{g}\ Ca_3(PO_4)_2}{1\ \text{mol}\ Ca_3(PO_4)_2}$$

$$= 1.081\ \text{g}\ Ca_3(PO_4)_2$$

16