# Solution Chemistry

## Nature of Solutions

- solutions are **homogeneous** mixtures
- substances in solution are different from their solid, liquid or gas forms
- there should be no observable segregation of component substances

## **Types of Solutions**

- 1. Gaseous solutions
- **Ex.** Air 78%  $N_2$ , 21%  $O_2$ , 1% Ar, 0.03%  $CO_2$
- 2. Solid solutions (alloys)
- **Ex.** Sterling silver (Cu + Ag), brass (Cu + Zn), Dental amalgam (Hg + Ag), steel (Fe + C)
- 3. Liquid solutions:
  - a. liquid liquid **Ex.** vinegar
  - b. solid liquid **Ex.** salt water
  - c. gas liquid **Ex.** carbonated water in soda pop
- The substance present in the greater amount is the **solvent**
- The **solute** is the component of lesser abundance

## Polar versus Non-polar Solvents

### Molecular polarity

A dipole results when electrons are displaced to one side of the molecule **Ex.**  $H_2O$  - polar  $CCl_4$  - non-polar

### Polar versus Non-polar

**Polar** solvents tend to dissolve **polar** (and ionic) solutes **Non-polar** solvents tend to dissolve **non-polar** solutes

### Water

Solutions containing water are called **aqueous (aq)** Many important reactions (Ex. in living things) take place in aqueous solutions (Probably) the most common solvent

## Saturated and Unsaturated Solutions

- Saturated solution in which no additional solute can dissolve
- Unsaturated a solution in which additional solute can dissolve
- **Miscible** when there is no apparent limit to the solubility of one liquid in another
- **Immiscible** two liquids which do not dissolve in each other; solvation (interaction between solute and solvent particles) does not occur
- **Solubility** is a measure of the amount of solute which can dissolve in a given amount of solvent
  - o g/L, g/mL, g/g, mL/mL, are some units for this
  - adding a little at a time until saturated; or evaporating a saturated solution and measuring the mass of the solid left behind, are ways to determine solubility
  - Solubility Table defines soluble as > 0.1 mol/L @ 25°C

## **Concentration of Solutions**

Concentration describes the amount of solute in a given amount of solutions.

a) % solution	<b>X</b> g / 100 g of solution (W/W) <b>X</b> mL / 100 mL of solution (V/V)
b) <i>Molarity</i> →	# of moles of solute litres of solution made
M = n/V $n = M \times V$ V = n/M	n = # mols, V = volume (L)

- c) Dilute versus Concentrated
  - dilute solutions contain less solute per litre of solution than concentrated solutions
  - Ex. Dilute HCI: 0.1M or 0.5M Concentrated HCI: 12M

#### **Dilution Calculations**

Often solutions are made by diluting a more concentrated (stock) solution

 $n = M \times V$ Stock sol'n (conc.):  $n_1 = M_1 \times V_1$ New sol'n (dilute):  $n_2 = M_2 \times V_2$   $n_1 = n_2$ So...  $M_1 \times V_1 = M_2 \times V_2$ (# moles does not change, only M does!)

Ex. If you have 500.0 mL of 0.40 M solution, what volume of a 0.10 M solution can you make? How much water must be added?

# moles =
Vol. solution to be made =
Vol. H<sub>2</sub>O to be added =

#### OR

 $M_1 \times V_1 = M_2 \times V_2$ 

 $V_2 =$ 

**Ex.** What final concentration results when 150 mL of 0.36 M solution of  $MgSO_4$  is added to 750 mL of water?

moles MgSO<sub>4</sub> = final vol. = molarity =

OR

**Ex.** What volume of 0.50 M CuCl<sub>2</sub> stock solution is required to make 2.0 L of 0.20 M CuCl<sub>2</sub>?

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mols CuCl_2 needed = vol. = n/M =
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=

OR

0.50 M (V<sub>1</sub>) = (0.20 M)(2.0 L) so V<sub>1</sub> =

vol. of  $H_2O$  to be added =

#### Aqueous solutions of ionic substances

Ionic substances dissolve in water to form ions

**Ex.**  $\operatorname{NaCl}_{(s)} \rightarrow \operatorname{Na}_{(aq)}^{+} + \operatorname{Cl}_{(ag)}^{-}$ salt ion ion

The concentration of ions can be different from the concentrations of the salts

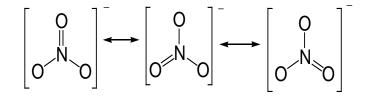
**Ex.**  $CaCl_{2(s)} \rightarrow Ca^{2+}{}_{(aq)} + 2 Cl^{-}{}_{(aq)}$  $\begin{bmatrix} CaCl_{2} \end{bmatrix} = \\ \begin{bmatrix} Ca^{2+} \end{bmatrix} = \\ \begin{bmatrix} Cl^{-} \end{bmatrix} = \end{bmatrix}$ 

This is because every mole of  $CaCl_2$  dissolves to give one mole of  $Ca^{2+}$  ions and two moles of  $Cl^{-}$  ions.

#### Examples:

Write a dissociation equation for each of the following and give the concentration of the ions:

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Ex. 0.10 M AI(NO<sub>3</sub>)<sub>3</sub>
AI(NO<sub>3</sub>)<sub>3</sub> \rightarrow AI<sup>3+</sup> + 3NO<sub>3</sub><sup>-</sup>
[AI<sup>3+</sup>] =
[NO<sub>3</sub><sup>-</sup>] =
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Ex. 0.35 M Cu(CH<sub>3</sub>COO)<sub>2</sub>

Cu(CH<sub>3</sub>COO)<sub>2</sub> \rightarrow Cu<sup>2+</sup> + 2 CH<sub>3</sub>COO<sup>-</sup>

[Cu<sup>2+</sup>] =

[CH<sub>3</sub>COO<sup>-</sup>] =

Ex. 0.25 M Na<sub>2</sub>O

Na<sub>2</sub>O \rightarrow 2 Na<sup>+</sup> + O<sup>2-</sup>

[Na<sup>+</sup>] =

[O<sup>2-</sup>] =
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### **Equation types**

Dissociation Eq<sup>n</sup>:

 $Pb(NO_3)_{2(s)} \rightarrow Pb^{2+}_{(aq)} + 2 NO_3^{-}_{(aq)}$ 

Formula Eq<sup>n</sup>:

 $Pb(NO_3)_{2(s)}$  + 2 KI<sub>(aq)</sub>  $\rightarrow$  2KNO<sub>3(aq)</sub> + PbI<sub>2(s)</sub>

Complete (Full) Ionic Eq<sup>n</sup>:

 $Pb^{2+}{}_{(aq)} + 2 NO_{3}^{-}{}_{(aq)} + 2 K^{+}{}_{(aq)} + 2I^{-} \rightarrow PbI_{2(s)} + 2 K^{+}{}_{(aq)} + 2 NO_{3}^{-}{}_{(aq)}$ 

Net Ionic Eq<sup>n</sup>:

Shows only the reaction species in a reaction in an aqueous environment (spectator ions are deleted)

 $Pb^{2+}(aq) + 2I^{-} \rightarrow PbI_{2(s)}$ 

## Qualitative Analysis

- Procedures by which a chemist decides what substances or ions are present in a sample
- Use the Solubility Table to select a reagent that gives a precipitate (ppt) with some substances but not with others
- If an anion is added to give a ppt, use an alkali metal salt of the anion (eg. Na<sup>+</sup> or K<sup>+</sup>) they will not ppt with other anions
- If adding a cation, use the nitrate salt of the cation
- Generally ppt the "easier to ppt" ion first
- **Ex.** Devise a procedure for separating a mixture of Ba<sup>2+</sup> and Pb<sup>2+</sup> by precipitating (ppt) them individually.
  - $Pb^{2+}$  ppts with Cl<sup>-</sup>, Br<sup>-</sup>, l<sup>-</sup>, and S<sup>2-</sup> but Ba<sup>2+</sup> is soluble
  - Add a reagent containing Cl<sup>-</sup>, Br<sup>-</sup>, l<sup>-</sup>, or S<sup>2-</sup>
     Ex. NaCl, KI, LiBr
  - $Pb^{2+}(aq) + 2 Br^{-}(aq) \rightarrow PbBr_{2(s)}$
  - filter off ppt; only Ba<sup>2+</sup> left
  - add a reagent containing SO<sub>4</sub><sup>2-</sup>, CO<sub>3</sub><sup>2-</sup>, PO<sub>4</sub><sup>3-</sup>, or SO<sub>3</sub><sup>2-</sup>, ions to ppt Ba<sup>2+</sup>
     Ex. Na<sub>3</sub>PO<sub>4</sub>
  - $3 \operatorname{Ba}^{2+}_{(aq)} + 2 \operatorname{PO}_{4}^{3-}_{(aq)} \rightarrow \operatorname{Ba}_{3}(\operatorname{PO}_{4})_{2(s)}$
- **Ex.** Devise a procedure to separate a mixture of  $CO_3^{2-}$  and  $CI^{-}$

## Titrations

An important analytical technique, titrations are used to determine the concentration of a substance in solution by comparing it to a solution of a known concentration; called a **standard** 

The reaction between the unknown and the standard is allowed to proceed until mole ratios like those in the balanced chemical equation are reached.

This stoichiometric point (sometimes called the equivalence point or end point) is determined using some sort of chemical indicator

Often these reactions are used with acids/bases, for acid/base titrations the end point is reached when:

## Moles of $OH^{-}$ from the base = moles of $H^{+}$ from the acid

Titrations consist of several trials; the first is an estimate, usually done quickly to get an approximate endpoint, almost always the first trial will be over the endpoint (overshot) The average volume of the second and subsequent trials are used in calculations:

### Steps to follow

- 1) Write the balanced equation (as always you can't go wrong with this)
- 2) Calculate the moles of standard used (n = M x V)
- 3) Determine the moles of unknown using the mole ratio
- 4) Calculate the unknown concentration (M = n/V)

Ex. If 10.0mL of HCl is titrated with 20.0mL of 0.40M NaOH, what is [HCl]?

NaOH (aq) + HCI (aq)  $\rightarrow$  H<sub>2</sub>O(I) + NaCI (aq)

Moles of standard (in this case NaOH) =

Moles of unknown (HCI) =

[HCI] =

- Some acids or bases produce two (or more)  $H^+$  or  $OH^-$  for each formula unit  $(H_3PO_4 \rightarrow 3 H^+ + PO_4^{3-})$ 

**Ex.** An average volume of 24.90mL of 0.100 M NaOH was required to neutralize 15.00mL of  $H_2SO_4$ . What is the concentration of the acid?

Moles of standard (in this case NaOH) = 0.100 M x 0.02490 L =  $2.49 \times 10^{-3}$ 

Moles of unknown (HCI) =

[HCI] =