Chapter 4: Reactions in Aqueous Solution

4.5 Concentration of solutions

Definition: the amount of solute present in a given quantity of solvent or solution, consider the solute is a liquid or a solid and the solvent is liquid.

Molarity "Molar Concentration": number of moles of solute in one liter of solution.

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

$$M = \frac{n}{V_L}$$

Notes:

- Molarity is an intensive property
- Molarity refers to the amount of solute originally dissolved in water and does not take into account any subsequent processes, such as ionization of acid

Ex 1: Calculate the molarity of an 85 mL ethanol solution containing 1.77g of ethanol (46.0g/mol)?

Ans.: 0.45 M

$M = \frac{\text{moles}}{V(L)}$

$n = \frac{1.77}{46} = 0.038$ moles

$M = \frac{n}{V} = \frac{0.038}{0.085} = 0.45$

Ex 2: How many grams of potassium dichromate ($K_2Cr_2O_7$) (294.2 g/mol) are required to prepare a 250mL solution whose concentration is 2.16M?

Ans.: 159 g

$M = \frac{n}{V_L}$

$2.16 = \frac{n}{0.250} \Rightarrow n = 0.540$

$n = \frac{m}{MM}$

$0.540 = \frac{m}{294.2} \Rightarrow m = 158.868\,g$

Electrolyte: exist as ions in solution, such as NaCl and KCl. 1.0 M KCl solution contains 1.0 mole K^+ ions and 1.0 mole Cl^- ions and no KCl are present. (KCl is a strong electrolyte).

Nonelectrolyte: do not brake up into ions. Such as glucose 1.0M solution contains 1.0 mole glucose molecules.

Note: Elements of GIA, GIIA, and GIIIA produce ions 'Electrolyte Solutions'

Strong Electrolytes	Weak Electrolytes	Nonelectrolytes
HCl, HBr, HI	CH_3CO_2H	H_2O
HNO_3	HF	CH_3OH
$HClO_4$		C_2H_5OH
H_2SO_4		$C_{12}H_{22}O_{11}$ (sucrose)
KBr		Most compounds of carbon
NaCl		
NaOH, KOH		
Other soluble ionic compounds		

Ex.1: A 250 mL sample of solution contains 4.30 g of $CaCl_2$. Calculate the molar concentration of Cl^- in this solution?

Ans:

$M_{CaCl2} = n/V$

$= (4.30_g/111_{g/mol})/0.250_L = 0.155\ _{mol/L}$

$M_{Cl^-} = (2/1) \times 0.155 = 0.31$ mol/L

Ex.2 How many grams of Cl^- are in 300 mL of the solution in Ex.1?

Ans:

$n = MV$

$= 0.31 \times 0.3\ L = 0.093$ mol

$\gg m = n \times Mwt.$

$= 0.093 \times 35.4 = 3.3\ g$

Dilution of solutions تخفيف المحاليل

Dilution: preparing a less concentrated solution from a more concentrated one.

Q. How to prepare 1L of a 0.40M $KMnO_4$ solution from a solution of 1.0M $KMnO_4$?

Note:

- No. of moles of solute is not changing in dilution but the volume of solvent is changed.
- Since molarity is number of moles of solute in 1.0L of solution, then the number of moles is given by:

$$\frac{\text{moles of solute}}{\text{liters of solution}} \times \text{volume of solution (L)} = \text{moles of solute}$$

$$M \times V = n$$

moles before diluting = moles after diluting

In conclusion,

$$M_i V_i = M_f V_f$$

M_i , M_f initial and final concentrations of solutions in Molar(mol/L)
V_i , V_f initial and final volumes of solutions in (L)

Ex. 1: how would you prepare $2x10^2$mL of a 0.866M NaOH solution, starting with a 5.07M stock solution?

Ans.:

$M_i \times V_i = M_f \times V_f$

$5.07M \times V_i = 0.866M \times 2x10^2$ ml

$V_i = (0.866M \times 2x10^2 ml) / 5.07M$

$= 34.16$ ml (taking from stock solution to prepare NaOH solution)

Solvent added = $V_f - V_i$

Ex. 2: The molarity of "concentrated" HCl purchased for laboratory use is approximately 12.1 M. How many milliliters of this reagent should be diluted to 1.0 L to make 0.10 M HCl?

Note:

When mix two solutions you may use:

$$n1 = n2$$

$$(n_a + n_b) = n2$$

$$[(MV)_a + (MV)_b]1 = (MV)2$$

4.6 Solution Stoichiometry and chemical analysis

Titration: a solution of known concentration, called "*standard solution*", is added gradually to another solution of unknown concentration, until the chemical reaction between the two solutions is complete.

NOTE: knowing the volumes of standard and unknown solutions, along with the concentration of standard solution, this enable to calculate the concentration of unknown solution.

Sometimes, standard solutions must be "standardized" before using them in titrations; this process is accomplished by titrate the standard solution against a solution of accurately known concentration.

Ex. NaOH is standardized by using a monoprotic acid called potassium hydrogen phthalate (KHP).

$$KHC_8H_4O_4 + NaOH \rightarrow KNaC_8H_4O_4 + H_2O$$

Equivalence point: the point at which the acid has completely reacted with or been neutralized by the base.

Note: in titration of KHP with NaOH, at the equivalence point:

Moles KHP(M×V) = moles NaOH (M×V)

Indicator: substance that has distinctly different colors in acidic and basic media.

Ex. "Phenolphthaleine" (ph.ph.) as an example is colorless in acidic and neutral media, reddish pink in basic media.

In general,

$$\text{moles } H^+ = \text{moles } OH^-$$

or

$aA + bB \rightarrow Product$

$$\frac{molesA}{a} = \frac{molesB}{b}$$

Ex 1: A student finds that 0.5468g of KHP (MM=204 g/mol) is needed to completely neutralize 23.48mL of NaOH solution, calculate the molarity of NaOH solution?

$$KHP + NaOH \rightarrow KNaP + H_2O$$

Ex 2: How many milliliters of a 0.61 M NaOH are needed to neutralize 20mL of a 0.245M H_2SO_4 solution?

Ex 3: Calculate the volume of 0.5 M HCl solution needed to neutralize with 10 mL of a 0.2 M $Ba(OH)_2$?

** Redox Reactions

تفاعلات الأكسدة والاختزال ... انتقال يعني

A reaction involves transfer of electrons from one substance to another.

Remember عامل مؤكسد
Oxidizing agent: a substance that gains electrons (increasing in oxidation number) الزيادة
Reducing agent: a substance that loses electrons (decreasing in oxidation number) النقصان
عامل مختزل

Ex: for the redox reaction

$$Cu + 2Ag^+ \rightarrow Cu^{2+} + 2Ag$$

- Cu: oxidized element, Reducing agent
- Ag^+: Reduced element, oxidizing agent

Cu is considered as reducing agent (oxidized, O.N from zero to +2)

$Cu \rightarrow Cu^{2+} + 2e^-$ "oxidation"

Ag is considered as oxidizing agent (reduced, O.N from +1 to zero)

$Ag^+ + e^- \rightarrow Ag$ "reduction"

As in acid base titration, we can titrate an oxidizing agent against a reducing agent, using same procedure.

Equivalence point: a point when the reducing agent is completely oxidized by the oxidizing agent.

In redox reactions, some oxidizing agents can be used as indicators, these called "*Internal Indicator*", because they have different colors in the oxidized and reduced forms.

Ex. Dichromate and Permanganate anions...

$Cr_2O_7^- \rightarrow Cr^{3+}$

Orange yellow — green

$MnO_4^- \rightarrow Mn^{2+}$

Purple — light pink

Ex 1: $5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

In this redox reaction, 16.42mL of 0.1327M $KMnO_4$ solution is needed to oxidize 20mL of a $FeSO_4$ solution in an acidic medium. Calculate the concentration of the $FeSO_4$ solution.

Ans.:

$n_{(Fe^{2+})} = n_{(MnO_4^-)}$

$\frac{(M \times V)^+}{5} = \frac{(M \times V)^-}{1}$

$\therefore M = \frac{5(M \times V)^-}{V^+}$

$= \frac{5 \times 16.42 \text{ml} \times 0.1327 M}{20 \text{ml}}$

$= 0.545\ M$

Years Questions

1) Calculate the molarity of 6.57g of methanol (CH_3OH) in 1.50×10^2 mL of solution?

A. 13.7M B. 1.37M C. 12.05M D. 2.23M

2) Determine how many grams of sodium carbonate (Na_2CO_3) would be needed to make 2.50×10^2mL of a 0.1 M solution?

A. 2.58 g B. 2.65 g C. 4.58 g D. 5.20 g

3) You have 505 mL of a 0.125 M HCl solution and you want to dilute it to exactly 0.10 M, How much water should you add?

A. 114 ml B. 66 ml C. 78 ml D. 126 ml

4) A 46.2-mL, 0.568 M calcium nitrate $Ca(NO_3)_2$ solution is mixed with 80.5 mL of 1.396 M calcium nitrate solution. Calculate the concentration of the final solution?

A. 2.8M B. 2.2M C. 1.1M D. 0.8M

5) What volume of a 0.500 M HCL solution is needed to neutralize 10 mL of a 0.2 M $Ba(OH)_2$ solution?

A. 2 ml B. 4 ml C. 6 ml D. 8 ml

6) Calculate the volume of a 0.206M HI solution that needed to reduce 22.5mL of a 0.374M $KMnO_4$ solution?

$$10HI + 2KMnO_4 + 3H_2SO_4 \rightarrow 5I_2 + 2MnSO_4 + 8H_2O$$

A. 0.204 L B. 20.2 L C. 4.12 L D. 0.94 L

The Solution

Question No.	Answer
1	B
2	B
3	D
4	C
5	D
6	A