Chapter 2

Reactions in aqueous solution

A solution:
- The solute: The substance present in the smaller amount.
- The solvent: The substance present in the larger amount.

Substances

electrolyte
When dissolved in water the solution conducts electricity

nonelectrolyte
When dissolved in water the solution doesn't conduct electricity

* How the solutions conduct electricity ?
→ By breaking up of the compound into cations & anions.
* السؤال عن توصيل الكهرباء هي الإلكترونات السالبة والموجبة .

strong electrolyte: 100 % dissociation into ions.

$$NaCl \xrightarrow{H_2O} Na^+ + Cl^-$$

→ Ionization: The separation of acids & bases into ions.
→ Reversible reaction: The reaction can occur in both directions.

ex:

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

weak electrolyte because its ionization in water is incomplete

examples of strong electrolytes:
HCl , HNO_3 , $HClO_4$, H_2SO_4 , $NaOH$, Ionic Compounds

examples of weak electrolytes:
CH_3COOH , HF , HNO_2 , NH_3 , H_2O

Precipitation reactions:

- Percipitate: insoluble solid that separates from solution.

- Solubility: The maximum amount of solute that will dissolve in a given quantity of solvent at a specific temperature.

Write the net ionic equation when K_3PO_4 solution is mixed with $Ca(NO_3)_2$ solution.

Molecular: $2K_3PO_4 + 3Ca(NO_3)_2 \Longrightarrow 6KNO_3 + Ca_3(PO_4)_2$

Ionic: $6K^+ + 2PO_4^{2-} + 3Ca^{2+} + 6NO_3^- \Longrightarrow 6K^+ + 6NO_3^- + Ca_3(PO_4)_2$

Net ionic: $2PO_4^{2-} + 3Ca^{2+} \Longrightarrow Ca_3(PO_4)_2$ "زاب"

→ spectator ions ⟹ K^+ , NO_3^-

⇒ Molecular equation: the formulas of the compounds are written as though all species existed as molecules or whole units.

⇒ Ionic equation: shows dissolved species as free ions.

#spectator ions: ions that are not involved in the overall reaction.

Net ionic equation: shows only the species that actually take Part in the reaction.

Acids & Bases

① Acids:

→ Have a sour taste.
→ Cause color changes in plant dyes.
→ React with some metals to Produce H_2 gas.

$$2HCl + Mg \longrightarrow MgCl_2 + H_2$$

→ React with carbonates to give CO_2

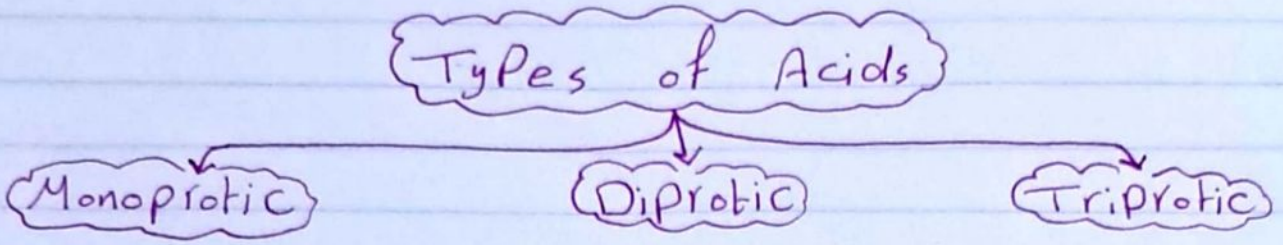
$$2HCl + CaCO_3 \longrightarrow CaCl_2 + H_2O + CO_2$$

→ Acid solutions conduct electricity

② Bases:

→ Have a bitter taste.
→ Cause color changes in plant dyes.
→ Feel slippery (soap) ملمس زلق
→ Base solutions conduct electricity.

	Arrhenius	Bronsted
Acid	A substance that ionize in water to Produce H^+ (H_3O^+)	Protor donor
Base	A substance that ionize in water to Produce (OH^-)	Proton acceptor



Neutralization reaction:

* Acid + Base ⟹ Water + salt

Q: Write the net ionic equation of:

$$H_2SO_4 + 2KOH \longrightarrow K_2SO_4 + 2H_2O_{(l)}$$

$$2H^+ + SO_4^{2-} + 2K^+ + 2OH^- \Longrightarrow 2K^+ + SO_4^{2-} + 2H_2O$$

* net ionic equation:

$$\underline{2H^+ + 2OH^- \rightleftharpoons 2H_2O}$$

* net ionic equation for all neutralization reaction.

Q: Write the net ionic equation of:

$$2HCl + Na_2CO_3 \Longrightarrow 2NaCl + H_2O_{(l)} + CO_{2\,(g)}$$

$$2H^+ + 2Cl^- + 2Na^+ + CO_3^{2-} \Longrightarrow 2Na^+ + 2Cl^- + H_2O + CO_2$$

* net ionic equation:

$$2H^+ + CO_3^{2-} \longrightarrow H_2O + CO_2$$

* spectator ions: $2Cl^-$, Na^+

* لما أكتب الـ ionic equation بعمل تأيين فقط للمواد (aq) أما الغازات (g) والسائلة (l) بخليها زي ما هي.

Oxidation-Reduction reactions: "redox"

* Oxidation reaction ⇒ Loss of electrons. أكسدة
* Reduction reaction ⇒ Gain of electrons. اختزال

$$\left.\begin{array}{l} 2Mg \longrightarrow 2Mg^{2+} + 4e^- \\ O_2 + 4e^- \longrightarrow 2O^{2-} \end{array}\right] \Rightarrow 2Mg + O_2 \longrightarrow 2MgO$$

→ Mg ⇒ Reducing agent. عامل مختزل "يفقد e^-"
→ O_2 ⇒ Oxidizing agent. عامل مؤكسد "يكتسب e^-"

electrons lost by reducing agent = electrons gained by oxidizing agent

Write the net ionic equation:

$$Zn_{(s)} + CuSO_{4(aq)} \longrightarrow ZnSO_{4(aq)} + Cu_{(s)}$$

$$Zn_{(s)} + Cu^{2+} + \cancel{SO_4^{2-}} \longrightarrow Zn^{2+} + \cancel{SO_4^{2-}} + Cu_{(s)}$$

$$\hookrightarrow Zn + Cu^{2+} \longrightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$$

Zn: reducing agent / Cu: oxidizing agent

* $H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl$ ✗
HCl is not ionic but moleeular compound

* No transfering of electrons *

* Oxidation number ⇒ The number of charges the atom would have in a molecule if electrons were transfered completely

① Free elements ⇒ Oxidation number = 0
↳ ex: Na , Be , Pb , — etc.

② In monatomic ions ⇒ The charge on the ion.
↳ ex: $Li^+ = +1$, $Fe^{3+} = +3$ ... etc.

③ Oxygen ⇒ In most compounds = -2
↳ "استثناء" - Hydrogen Peroxide ⇒ = -1 (H_2O_2)
- Peroxide ion ⇒ = -1 (O_2^{2-})

④ Hydrogen ⇒ In most compounds = +1.
↳ "استثناء" When it is bonded to metals = -1
ex: NaH , LiH

⑤ - Fluorine ⇒ Always = -1
- (Cl, Br, I) ⇒ Always negative.
↳ "استثناء" when combined with oxygen ⇒ Positive.

⑥ In neutral molecule ⇒ the sum of oxidation number = 0.
↳ $[H_2SO_4]$ ⇒ مجموع أعداد التأكسد لجميع الذرات = صفر

⑦ oxidation numbers don't have to be integers.
* يعني مش بشرط يكون عدد صحيح *
↳ ex: O_2^- ⇒ oxidation number = -1/2

* Nonmetalic elements have Positive or negative oxidation number.

* The highest oxidation number of an element can have is the groub number.

* أعلى رقم تأكسد يمكن أن يحصل عليه العنصر هو رقم مجموعته.

* ex: Cl ⇒ VII A أعلى رقم تأكسد = 7

Questions: Assign the oxidation number:

→ Li_2O ⇒ $O = -2$, $2Li = +2 \Rightarrow Li = +1$

→ HNO_3 ⇒ $O = -2$, $H = +1$

$+1 + N + (3 * -2) = 0 \Rightarrow N = +5$

→ $Cr_2O_7^{2-}$ ⇒ $O = -2$

$2Cr + (7 * -2) = -2$

$2Cr = 12 \Rightarrow Cr = +6$

→ Write the correct half-reaction:

$2Sr + O_2 \longrightarrow 2SrO$

$Sr \longrightarrow Sr^{+2} + 2e^-$ "Oxidation"

$O_2 + 4e^- \longrightarrow 2O^{2-}$ "Reduction"

Types of oxdation-reduction reactions

1 Combination reaction: تفاعلات الاتحاد

* Not all Combination reaction are redox

- ليست كل تفاعلات الاتحاد هي أكسدة واختزال

$A + B \Longrightarrow C$

[2] Decomposition reaction: تفاعلات التفكك

$$C \Longrightarrow A + B$$

[3] Combustion reaction: تفاعلات الاحتراق
↳ The reaction in which a substance reacts with oxygen. "عادة ينتج حرارة أو ضوء"

$$A + O_2 \Longrightarrow B$$

[4] Displacement reaction: تفاعلات الإحلال

$$A + BC \Longrightarrow AC + B$$

* Displacement reactions *

- Hydrogen displacement
  - Cold water
  - Acid
- Halogine displacement

In Cold Water ⇒ $2Na + H_2O \longrightarrow Na_2O + H_2$

Na, Li, K, Ca, Ba ↳ $Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2$

In Acids ⇒ $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

↳ $Mg + 2HCl \longrightarrow MgCl_2 + H_2$

* Halogine displacement:

→ Activity series of halogines $F_2 > Cl_2 > Br_2 > I_2$

* which one of these reactions take place:\

$Cl_2 + 2KBr \longrightarrow 2KCl + Br_2$ ✓

$I_2 + 2KBr \longrightarrow$ لا يحدث $Br > I$

5] Disproportione reaction:\
نفس المادة يحصل لها عملية أكسدة واختزال في نفس الوقت

$$\underline{Cl_2} + 2OH^- \longrightarrow \underline{ClO^-} + \underline{Cl^-} + H_2O$$

Oxidation

Reduction

Classify the following redox reactions:\\

- $2N_2O \longrightarrow 2N_2 + O_2$ "Decombination"
- $6\,Li + N_2 \longrightarrow 2Li_3N$ "combination"
- $Ni + Pb(NO_3)_2 \longrightarrow Pb + Ni(NO_3)_2$ "metal displacement"
- $2NO_2 + H_2O \longrightarrow HNO_2 + HNO_3$ "Disproportionation"
- $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$ "H_2 displacement"
- $Cg + F_2 \longrightarrow CgF_2$ "Combination"
- $Cg^{2+} + CO_3^{2-} \longrightarrow CgCO_3$ "precipitation"

* The Concentration : The amount of solute Present in a given amount of solvent or give amount of solution.

$$M = \text{molarity} = \frac{\text{moles of solute}}{\text{Liters of solution}} = \frac{n}{V}$$

* Question // how many grams of Potassium dichromate ($K_2Cr_2O_7$) are required to Prepare a 250 ml solution whose Concentration is 2.16 M ?

- V of solution = 250 ml $\times 10^{-3}$ = 0,25 liter
- molarity = 2,16 M

$$M = \frac{n}{V} \Rightarrow n = M * V$$
$$= 2,16 * 0,25 = 0.54 \text{ mol}$$

- $n = \frac{\text{mass}}{\text{molecular weight}} \Rightarrow \text{mass} = n * m.w$ ← الكتلة الذرية "المولية"

$$\text{mass} = 0,54 * 294.2 = 158.8 \text{ g}$$

* Question // A chemist needs to add 3.81 g of glucose to a mixture. Calculate the Volume in ml of a 2,53 M glucose solution he should use for addition.

Glucose = $C_6H_{12}O_6$

mass = 3.81 g molarity = 2,53 M

$$n = \frac{\text{mass}}{m.w} = \frac{3,81}{(6*12)+(12)+(6*16)} = 0.021 \text{ mol}$$

$$V = \frac{n}{\text{molarity}} = \frac{0.021}{2.53} = 8.36 \times 10^{-3} \ell$$
$$\hookrightarrow = 8.36 \text{ ml} \ \#$$

Dilution: The procedure for preparing a less concentrated solution from a more concentrated solution.

$$\text{Moles of solute before dilution} = \text{Moles of solute after dilution}$$

$$M_i V_i = M_f V_f$$

* Question: how would you prepare 500 ml of a 1.75 M H_2SO_4 solution starting with a 8.61 M stock solution of H_2SO_4?

$$M_i V_i = M_f V_f$$

$$1.75 * 500 = 8.61 * V_f$$

$$V_2 = \frac{1.75 * 500}{8.61} = 101.6 \text{ ml}$$

* I can prepare the solution by adding (500 - 101.6) = 398.4 ml of water.

Gravimetric Analysis:

Analytical technique based on the measurment of mass.

How to Calculate the mass using Gravimetric:

1) Dissolve the unKnown substance in water.
2) React it with Known substance to form a precipitate.
3) Filter and dry precipitate.
4) weigh precipitate.
5) Use chemical formula and mass of precipitate to detemine amount of unKnown ion.

Question\ A 0,5662g sample of an ionic compound containing chloride ions and an unknown metal is dissolved in water and treated with an excess of $AgNO_3$. If 1.0882 g of AgCl precipitate forms, what is the Percent by mass of Cl in the original compound?

* mass "AgCl" = 1.0882 g

$$n = \frac{mass}{m.w} = \frac{1.0882}{(108+35.5)} = 7.5 \times 10^{-3} \text{ mole}$$

1 mole "AgCl" $\Rightarrow$ 1 mole "Cl"

$\therefore$ n of Cl = 7.5×10^{-3} mole

mass of "Cl" = n * m.w

$= (7.5 * 10^{-3}) * (35.5) = 0,269$ g

$$\% Cl = \frac{\text{mass of "Cl"}}{\text{mass of sample}} * 100 = \frac{0.269}{0.5662} * 100$$

$$= \boxed{47.5\ \%}$$

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* Titration *

"نقطة التكافؤ"

* Equivalency Point:\ the point at which the acid has completly reacted with or been neutralized by the base.

* Indecator $\Rightarrow$ substance that have different Colors in acidic and basic media.

تغير لونها عند أو بالقرب من نقطة التكافؤ

↳ ex: Phenolphthalein $\Rightarrow$ Colorless in acidic

↓ Pink in basic solution.

"KHP" ⇒ Monoprotic acid

↳ Potassium hydrogen phthalate

Note

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* In titration problems:\\

$$aA + bB \Longrightarrow cC$$

* نطبق القانون التالي:

$$\frac{n_A}{a} = \frac{n_B}{b}$$

او

$$\frac{M_A V_A}{a} = \frac{M_B V_B}{b}$$

$$n = M * V$$

Question:\\ In a titration experiment, a student finds that 23.48ml of a NaOH solution are needed to neutralize 0.5468 g of "KHP", what is the concentration in molarity of the NaOH solution?

$$1\,NaOH + 1\,KHP \Longrightarrow \text{---}$$

$$\frac{n_{NaOH}}{1} = \frac{n_{KHP}}{1}$$

$$n_{NaOH} = M_b V_b$$

$$\hookrightarrow n_{KHP} = \frac{m}{m.w} = \frac{0.5468}{204} = 2.68 \times 10^{-3}\ mol$$

$$2.68 \times 10^{-3} = M_b V_b$$

$$\therefore M_b = \frac{2.68 \times 10^{-3}}{23.48 \times 10^{-3}} = 0.114\ M$$

Question// Caculate the concentration of the acid (or base) remaining in solution when 10.7 ml of 0.211 M HNO_3 are added to 16.3ml of 0.258M NaOH.

* $NaOH + HNO_3 \Longrightarrow NaNO_3 + H_2O$

$n_{NaOH} = (16.3 * 10^{-3}) * 0.258M = 4.2 * 10^{-3}$ mol

$n_{HNO_3} = (10.7 * 10^{-3}) * 0.211 = 2.26 * 10^{-3}$ mol

* Remaining mole of base $= (4.2 - 2.26) * 10^{-3}$

(remaining) $n_{NaOH} = 1.94 * 10^{-3}$ mol

$$M = \frac{n}{V_{Litre}} = \frac{1.94 * 10^{-3}}{(10.7 + 16.3) * 10^{-3}}$$

$M = 0.0719$ mole/litre

Question// If 30.0ml of 0.150M $CaCl_2$ is added to 15.0ml of 0.100M $AgNO_3$, What is the mass in grams of AgCl precipitate?

$CaCl_2 + 2\,AgNO_3 \longrightarrow 2\,AgCl + Ca(NO_3)_2$

n of $CaCl_2 = (30 * 10^{-3}) * 0.15$

n of $CaCl_2 = 4.5 * 10^{-3}$ mol

n of $AgNO_3 = (15 * 10^{-3}) * 0.1$

n of $AgNO_3 = 1.5 * 10^{-3}$ mol

$2\,AgNO_3 \longrightarrow 2\,AgCl$ ~~~ $\therefore 1.5\,AgNO_3 \longrightarrow 1.5\,AgCl$

mass = n * molecular weight

$= (1.5 * 10^{-3}) * (107.87 + 35.5) = 0.215$ g