Redox

Redox

Reduction | Oxidation.

→ in term of

① oxygen (lose O) (Gain O)

reduction: Fe in Fe_2O_3

× $Al + Fe_2O_3 \longrightarrow Al_2O_3 + Fe$

oxidation: Al

reduction: Zn in ZnO

× $CO + ZnO \longrightarrow Zn + CO_2$

oxidation: C in CO

reduction: Cu in CuO

× $H_2 + CuO \longrightarrow Cu + H_2O$

oxidation: H_2

→ in term of ② Hydrogen reduction gain H oxidation: lose H

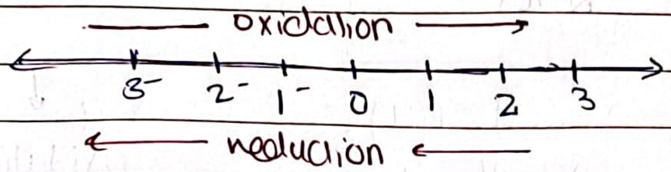
reduction: Cl_2

* $H_2S + Cl_2 \longrightarrow HCl + S$

oxidation: S in H_2S

→ in term of ③ Oxidation state

Reduction: decrease
Oxidation: increase



× Displac. → redox ✓
× redox → displ. ✗
J Gr

reduction $Cu^{+2} \rightarrow Cu^{0}$

× $Zn^{0} + Cu^{+2} \longrightarrow Zn^{+2} + Cu$

oxidation: $Zn^{0} \rightarrow Zn^{+2}$

Rules for oxidation state :-

1- the oxidation state for any free element → zero

monoatomic :	Diatomic :	polyatomic :
Na, K, Li Na, Cu, Ca.	H_2, O_2, N_2 $F_2, Cl_2, Br_2,$	P_4 S_8

2- The oxid no. of any atom in a compound from :-

Group 1 = +1 Li, Na, K, Rb, Cs, Fr
" 2 = +2 Mg, Ca, Sr, Ba
" 3 = +3 always +3 only for Al
" 7 = −1 " −1 " " (F)

constants

3- The oxidation no. of hydrogen (+1)
× exept with Metal in Metal hydride (−1)

$\overset{+1}{C}H_4$, $N\overset{+1}{H}_3$, $\overset{+1}{Na}\overset{-1}{H}$, $\overset{+2}{Ca}\overset{-1}{H_2}$

4 The oxidation state of oxygen (−2)

exept in peroxide (−1)

" " F^{n} OF_2 (2+)

O^{-2} oxide

O_2^{-2} peroxide

- sodium oxide $Na^{+1}\ O^{-2} \longrightarrow Na_2\boxed{O}^{2-}$
- sodium peroxide $Na^{+1}\ O_2^{-2} \longrightarrow Na_2\boxed{O_2}^{-1}$

- H_2O (water) (−2)
- H_2O_2 (hydroegen peroxide) (−1)

- Calcium oxide $Ca^{+2}\ O^{-2} \rightarrow CaO$
- Calcium peroxide $Ca^{+2}\ O_2^{-2} \rightarrow CaO_2$

5- The sum of all oxidation state in a compound = 0

in an ion = change of this ion.

- $Na\underline{Cl}$ →

$$+1 + x = 0$$
$$\underline{-1 \qquad\quad -1}$$
$$\boxed{x = -1}$$

- $H\underline{Cl}O$ →

$$+1 + x - 2 = 0$$
$$x - 1 = 0$$
$$\underline{+1 \qquad +1}$$
$$\boxed{x = +1}$$

- $\underline{N}H_3$ →

$$x + 3(+1) = 0$$
$$x + 3 = 0$$
$$\underline{-3 \qquad -3}$$
$$\boxed{x = -3}$$

C. – $\underline{N}O$ = $x - 2 = 0$

$+2 \quad +2$

$\boxed{x = +2}$

– $\underline{N}_2O_5$ = $2(N) + 5(-2) = 0$

$2N - 10 = 0$

$+10 \quad +10$

$\frac{2N}{2} = \frac{10}{2} = \boxed{N = 5}$

– $H_2\underline{S}$ $2(+1) + S = 0$

$+2 + S = 0$

$-2 \quad -2$

$\boxed{S = -2}$

– $H_2\underline{S}O_4$ $2(+1) + S + 4(-2) = 0$

$2 + S - 8 = 0$

$S - 6 = 0$

$+6 \quad +6$

$\boxed{S = +6}$

– $\underline{S}O_3$ $S + 3(-2) = 0$

$S - 6 = 0$

$+6 \quad +6$

$\boxed{S = +6}$

– $\underline{N}O_3^{-1}$ $N + 3(-2) = -1$

$N - 6 = -1$

$+6 \quad +6$

$\boxed{N = +5}$

- $\underline{Mn}O_4^{-1}$

$Mn + 4(-2) = -1$

$Mn - 8 = -1$

$+8 \quad +8$

$\boxed{Mn = +7}$

- $\underline{S}O_3^{-2}$

$S + 3(-2) = -2$

$S - 6 = -2$

$+6 \quad +6$

$\boxed{S = +4}$

- $\underline{Cr}_2O_7^{-2}$

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

$2Cr - 14 = -2$

$+14 \quad +14$

$\frac{2Cr}{2} = \frac{+12}{2} = \boxed{Cr = 6}$

* Find the oxidation state of each underline species:-

$\underline{Fe}_2O_3$

→ ~~F~~ $2(Fe) + 3(-2) = 0$

$2Fe - 6 = 0$

$+6 \quad +6$

$\frac{2Fe}{2} = \frac{6}{2}$

$\boxed{Fe = 3}$

$\underline{O}F_2$

→ $O + 2(-1) = 0$

$O - 2 = 0$

$+2 \quad +2$

$\boxed{O = +2}$

$\underline{S}O_4^{-2}$

→ $S + 4(-2) = -2$

$S - 8 = -2$

$+8 \quad +8$

$\boxed{S = +6}$

$\underline{V}_2O_5$

→ $2(V) + 5(-2) = 0$

$2V - 10 = 0$

$+10 \quad +10$

$\frac{2V}{2} = \frac{10}{2}$

$\boxed{V = 5}$

$\underline{P}O_4^{3-}$

→ $P + 4(-2) = -3$

$P - 8 = -3$

$+8 \quad +8$

$\boxed{P = +5}$

$\underline{Cr}O_4^{2-}$

→ $Cr + 4(-2) = -2$

$Cr - 8 = -2$

$+8 \quad +8$

$\boxed{Cr = +6}$

C.

CO	CO_2	CO_3^{2-}
→ $C - 2 = 0$	→ $C + 2(-2) = 0$	→ $C + 3(-2) = -2$
$+2 \quad +2$	$C - 4 = 0$	$C - 6 = -2$
$\boxed{C = +2}$	$+4 \quad +4$	$+6 \quad +6$
	$\boxed{C = 4}$	$\boxed{C = +4}$

* $\overset{0}{Al} + \overset{+3}{Fe_2}\overset{-2}{O_3} \longrightarrow \overset{+3}{Al_2}\overset{-2}{O_3} + \overset{0}{Fe}$

Oxidation:- $Al^0 \rightarrow Al^{+3}$
Reduction:- $Fe^{+3} \rightarrow Fe^0$

* $\overset{+2}{C}\overset{-2}{O} + \overset{+2}{Zn}\overset{-2}{O} \longrightarrow \overset{0}{Zn} + \overset{+4}{C}\overset{-2}{O_2}$

oxidation:- $C^{+2} \rightarrow C^{+4}$
Reduction:- $Zn^{+2} \rightarrow Zn^0$

* $\overset{+1}{H_2}\overset{-2}{S} + \overset{0}{Cl_2} \longrightarrow \overset{+1}{H}\overset{-1}{Cl} + \overset{0}{S}$

oxidation: $S^{-2} \rightarrow S^0$
reduction: $Cl^0 \rightarrow Cl^{-1}$

* $\overset{+7}{Mn}\overset{-2}{O_4}{}^{-1} + \overset{+2}{Fe}{}^{+2} + \overset{+1}{H}{}^{+1} \longrightarrow \overset{+2}{Mn}{}^{+2} + \overset{+3}{Fe}{}^{+3} + \overset{+1}{H_2}O^{-2}$

Oxidation: $Fe^{+2} \rightarrow Fe^{+3}$
reduction: $Mn^{+7} \rightarrow Mn^{+2}$

* $\overset{+6}{Cr_2}\overset{-2}{O_7} + \overset{+2}{Sn^{+2}} + \overset{+1}{H^+} \rightarrow \overset{+3}{Cr^{+3}} + \overset{+4}{Sn^{+4}} + \overset{+1}{H_2}\overset{-2}{O}$

Oxidation: $Sn^{+2} \rightarrow Sn^{+4}$
Reduction: $Cr^{+6} \rightarrow Cr^{+3}$

* $\overset{+1}{Ag}\overset{+5}{N}\overset{-2}{O_3} + \overset{+1}{Na}\overset{-1}{Cl} \rightarrow \overset{+1}{Ag}\overset{-1}{Cl} + \overset{+1}{Na}\overset{+5}{N}\overset{-1}{O_3}$

NOT REDOX → DISPLACEMENT

* $\overset{0}{Na} + \overset{+1}{H}\overset{-1}{Cl} \rightarrow \overset{+1}{Na}\overset{-1}{Cl} + \overset{0}{H_2}$

Reduction: $H^{+1} \rightarrow H^0$
Oxidation: $Na^0 \rightarrow Na^{+1}$

* $\overset{+1}{H_2}\overset{-1}{O_2} \rightarrow \overset{+1}{H_2}\overset{-2}{O} + \overset{0}{O_2}$

↓ peroxide

3-9-2202/Sal.

Redox

$\overset{0}{Al} + \overset{+3}{Fe_2}\overset{-2}{O_3} \longrightarrow \overset{+3}{Al_2}\overset{-2}{O_3} + \overset{0}{Fe}$

Half of oxidation:- $Al^{0} \longrightarrow Al^{+3} \cancel{+3\bar{e}}$

Half of reduction:- $Fe^{+3} \cancel{+3\bar{e}} \longrightarrow Fe^{0}$

* Overall rxn :- $Al^{0} + Fe^{+3} \longrightarrow Al^{+3} + Fe^{0}$

⇒ writing balanced half ionic equation:-

1) Atoms.
2) the charge by adding ē's to the side with greater charge by the difference.

→ $\overset{0}{Ca} + \overset{+2}{Zn}\overset{-1}{Cl_2} \longrightarrow \overset{+2}{Ca}\overset{-1}{Cl_2} + \overset{0}{Zn}$

H.O.O:- $Ca \longrightarrow Ca^{+2} + \cancel{2\bar{e}}$

H.O.R:- $Zn^{+2} + \cancel{2\bar{e}} \longrightarrow Zn^{0}$

* overall rxn: $Ca^{0} + Zn^{+2} \longrightarrow Ca^{+2} + Zn^{0}$

→ $\overset{0}{Na} + \overset{+1}{H}\overset{-1}{Cl} \longrightarrow \overset{+1}{Na}\overset{-1}{Cl} + \overset{0}{H_2}$

H.O.O:- $(2Na^{0} \longrightarrow 2Na^{+1} + \overset{2}{\cancel{1}}\bar{e}) * 2$

H.O.R:- $2H^{+} + \cancel{2\bar{e}} \longrightarrow H_2^{0}$

overall rxn:- $2Na^{0} + 2H^{+} \longrightarrow 2Na^{+} + H_2^{0}$

→ $\overset{0}{Ca} + \overset{+3}{Al}\overset{-1}{Cl_3} \longrightarrow \overset{+2}{Ca}\overset{-1}{Cl_2} + \overset{0}{Al}$

H.O.O :- $(3Ca^0 \longrightarrow 3Ca^{+2} + \overset{6}{\cancel{2}}\bar{e}) * 3$
H.O.R :- $(2Al^{+3} + \underset{6}{\cancel{3}}\bar{e} \longrightarrow 2Al^0) * 2$

Overall rxn :- $3Ca^0 + 2Al^{+3} \longrightarrow 3Ca^{+2} + 2Al^0$

→ $H_2\overset{2-}{S} + \overset{0}{Cl_2} \longrightarrow \overset{+1}{H}\overset{-1}{Cl} + \overset{0}{S}$

H.O.O :- $S^{-2} \longrightarrow S^0 \cancel{+ 2\bar{e}}$
H.O.R :- $Cl_2^0 \cancel{+ 2\bar{e}} \longrightarrow 2Cl^{-1}$

Overall rxn :- $S^{-2} + Cl_2^0 \longrightarrow S^0 + 2Cl^{-1}$

Reactants ⟶ products

oxidation ⟶ $\bar{e}$ " lose $\bar{e}$ "
reduction $\bar{e}$ ⟶ " gain $\bar{e}$ "

reduction
OIL RIG → gain $\bar{e}$
Oxidation is lose $\acute{e}$ is

→ $\overset{0}{Al} + \overset{+1}{H}\overset{-1}{Cl} \longrightarrow \overset{+3}{Al}\overset{-1}{Cl_3} + \overset{0}{H_2}$

H.O.O :- $(\overset{2}{Al^0} \longrightarrow 2Al^{+3} + \overset{6}{\cancel{3}}\bar{e}) * 2$
H.O.R :- $(\underset{6}{\cancel{2}}H^{+1} + \underset{6}{\cancel{2}}\bar{e} \longrightarrow 3H_2^0) * 3$

overall rxn :- $2Al^0 + 6H^+ \longrightarrow 2Al^{+3} + 3H_2^0$

$\overset{+7}{Mn}\overset{-2}{O_4}^{-1} + \overset{+2}{Fe} + \overset{+1}{H} \longrightarrow \overset{2+}{Mn} + \overset{3+}{Fe} + \overset{+1}{H_2}\overset{-2}{O}$

H.O.O:- $(5Fe^{+2} \longrightarrow 5Fe^{+3} + \overset{5}{\cancel{1}}\bar{e}) * 5$
H.O.R: $Mn^{+7} \cancel{+5\bar{e}} \longrightarrow Mn^{+2}$

overall rxn:- $5Fe^{+2} + Mn^{+7} \longrightarrow 5Fe^{+3} + Mn^{+2}$

$\longrightarrow$ $\overset{+6}{Cr_2}O_7 + Sn^{2+} + H^{+} \longrightarrow Cr^{+3} + Sn^{4+} + \overset{+1}{H_2}\overset{-2}{O}$

H.O.O:- $(^{3}Sn^{+2} \longrightarrow 3Sn^{+4} + \overset{6}{\cancel{2}}\bar{e}) * 3$
H.O.R:- $(2Cr^{+6} \underset{6}{\cancel{+3\bar{e}}} \longrightarrow 2Cr^{+3}) * 2$

overall rxn: $3Sn^{+2} + 2Cr^{+6} \longrightarrow 3Sn^{+4} + 2Cr^{+3}$

Oxidising Agent and Reducing Agent.

	(reducing agent) Oxidation	(oxidising Agent) Reduction
O	gain O	lose O
H	lose H	gain H
oxid. state	↑	↓
ē transfer	lose ē	gain ē

- Oxidising agent "oxidant" :- the substance that itself reduced and causes the other substance to be oxidise.

- Reducing agent "reductant":- the substance that itself oxidised and causes the other substance to be reduced.

* if The substance is an ion in a compound, the agent is in he compound itself.

- $\overset{0}{Al} + \overset{+3}{Fe_2}\overset{-2}{O_3} \longrightarrow \overset{+3}{Al_2}\overset{-2}{O_3} + \overset{0}{Fe}$

oxidation: Al^{0} oxidising agent: Fe_2O_3
reduction: Fe^{3+} reducing agent: Al

- $\overset{+2}{C}\overset{-2}{O} + \overset{2+}{Zn}\overset{-2}{O} \longrightarrow \overset{0}{Zn} + \overset{+4}{C}\overset{-2}{O_2}$

oxidation:- C^{2+} oxidising agent: ZnO
reduction:- Zn^{+2} reducing agent. CO

- $\overset{+1}{H_2}\overset{2-}{S} + \overset{0}{Cl_2} \longrightarrow \overset{+1}{H}\overset{-1}{Cl} + \overset{0}{S}$

oxidation:- S^{-2} oxidising agent: Cl_2
reduction!- Cl_2^{0} reducing agent, H_2S

- $MnO_4^{-1} + Fe^{2+} + H^{+} \longrightarrow Mn^{2+} + Fe^{3+} + H_2O$

oxidising agent, MnO_4^{-1} reducing agent: Fe^{+2}

* Most common oxidising agent :-

① Oxygen

→ $\overset{0}{Fe} + \overset{0}{O_2} \longrightarrow \overset{3+}{Fe_2}\overset{-2}{O_3}$

→ $\overset{0}{S} + O_2 \longrightarrow \overset{+4}{S}\overset{2-}{O_2}$

② Acidify potassium manganate ($KMnO_4^{-1}$ / H^+)

→ $MnO_4^{-1} \longrightarrow Mn^{+2}$

(+7)	(+2)
purple	colorless

③ Acidify potassium dichromate ($K_2Cr_2O_7$ / H^+)

$Cr_2O_7^{2-} \longrightarrow Cr^{3+}$

(+6)	(+3)
orange	green

④. Halogens

$2\bar{e}$	$F_2 \longrightarrow$	$2F^-$	yellow
$2\bar{e}$	$Cl_2 \longrightarrow$	$2Cl^-$	green-yellow
$2\bar{e}$	$Br_2 \longrightarrow$	$2Br^-$	red-brown
$2\bar{e}$	$I_2 \longrightarrow$	$2I^-$	purple gas black solid red-brown sol (aq.

* **Most common reducing agent:-**

① Hydrogen.

$$\overset{0}{H_2} + \overset{2}{Cu}\overset{-1}{O} \longrightarrow \overset{+2}{H_2}\overset{-2}{O} + \overset{0}{Cu}$$

② Carbon and carbon monoxide

$$\overset{0}{C} + \overset{3+}{Fe_2}O_3 \longrightarrow \overset{0}{Fe} + \overset{+2}{C}\overset{-2}{O}$$

$$\overset{+2}{C}\overset{-2}{O} + \overset{2+}{Zn}\overset{-2}{O} \rightarrow \overset{0}{Zn} + \overset{+4}{C}\overset{-2}{O_2}$$

③ Iodide

$$I^-_{(aq)} \rightarrow I_{2\,(aq)} + 2\bar{e}$$

colorless red-brown

④ Metals

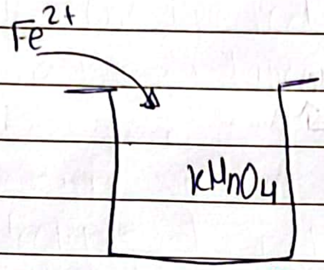
→ Metal's more reactive, more likely to lose e-
→ more likely to oxidise.
→ " " to be a reducing agent.

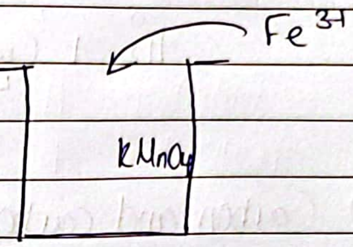
k → strongest reducing agent.
Ag → weakest " "

Ag^+ → strongest oxidising agent
k^+ → weakest " "

Q. Fe^{2+} is a reducing agent
Fe^{3+} · an oxidising agent
→ Record the observation in each of the following reaction.

①

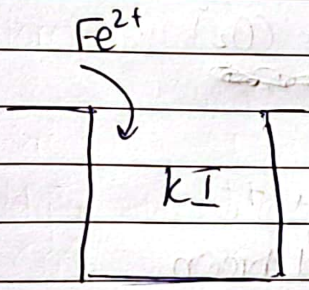


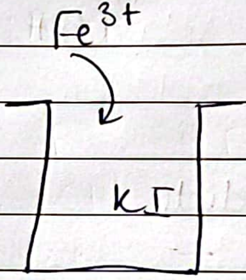


→ change color from purple to colorless

→ stays purple

②



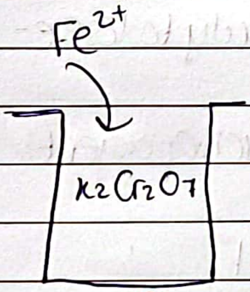


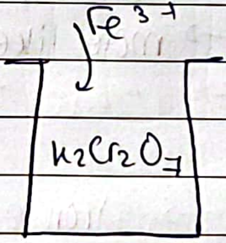
→ stays colorless

$2I^- \rightarrow I_{2(aq)} + 2e^-$
red-brown

$$\underbrace{Fe^{3+} + \overset{\downarrow}{I^-} \rightarrow Fe^{2+}}_{\uparrow} + I_2$$

③





→ change from orange to green.

→ no change

Wed | 7-9-2202

Electrolysis

Electricity — Analysis (Breaking down)

* Electrolysis: breaking down chemical compounds (ionic) when molten or aqueous by passing electricity.

* Why the ionic compound don't conduct electricity when solid?
→ the ions are not free to move.

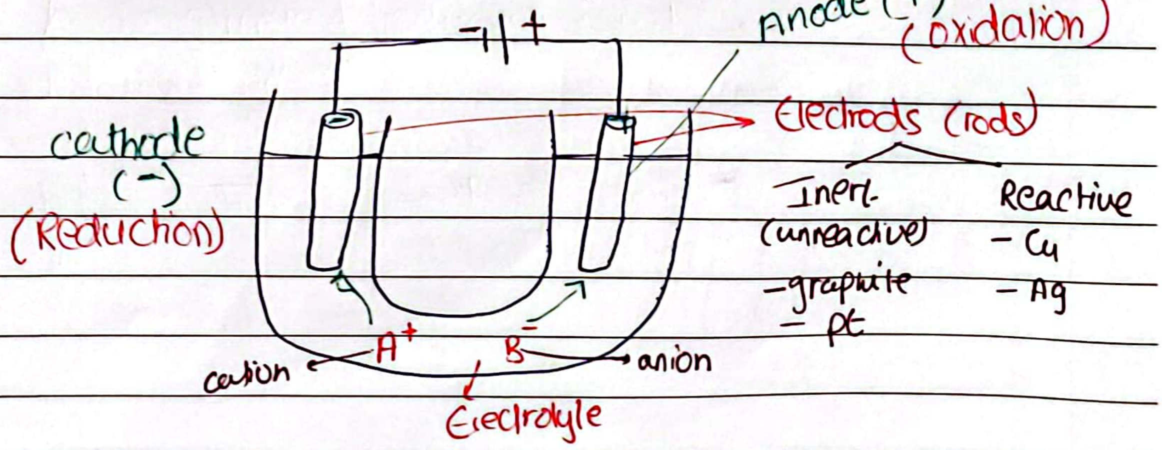
* Why the ionic compounds conduct electricity when dissolve in water or being mollen?
→ the ions are free to move.

$$NaCl_{(s)} \xrightarrow{heat} Na^+_{(L)} + Cl^-_{(L)}$$

$$NaCl_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + Cl^-_{(aq)}$$

* Electrolyte: chemical compound that conduct electricity when mollen or aqueous.

Electrolysis Cell



- * **Cathode** :- the -ve rod that attracts the +ve ions (cations) where the reduction occurs.

- * **Anode**: the +ve rod that attracts the -ve ions (anion). where the oxidation occurs.

- Electrolysis = Discharging
  Ion to element

Cations:-	Anions:-
$1\acute{e} + Na^{+} \longrightarrow Na$	$2F^{-1} \longrightarrow F_2 + 2\acute{e}$
$2\acute{e} + Mg^{2+} \longrightarrow Mg$	$2Cl^{-1} \longrightarrow Cl_2 + 2\bar{e}$
$2\acute{e} + Ca^{2+} \longrightarrow Ca$	$2Br^{-1} \longrightarrow Br_2 + 2\acute{e}$
$3\bar{e} + Al^{3+} \longrightarrow Al$	$2I^{-1} \longrightarrow I_2 + 2\acute{e}$
$2\bar{e} + H^{+} \longrightarrow H_2$	$2O^{2-} \longrightarrow O_2 + 2\acute{e}$

10-9-2202 | Sat.

Electrolysis

- Electrolysis for Molten electrolyte using Inert rods (graphite).

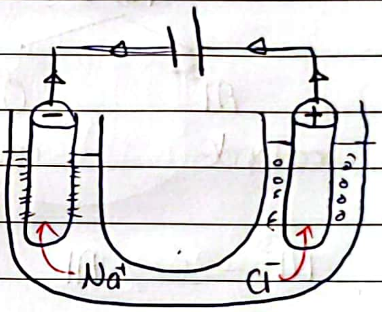
$NaCl_{(l)}$

Total ions Na^+ — cathod

Cl^- — anode → $2Cl^- \rightarrow Cl_2 + 2e^-$ bubbles of green-yellow gas.

$Na^+ + 1e^- \rightarrow Na$

Deposit of metal



→ Electrolyte: used up

→ $NaCl_{(l)} \xrightarrow{electricity} Na + Cl_2$

Molten lead (II) Bromide

$PbBr_{2\,(l)}$

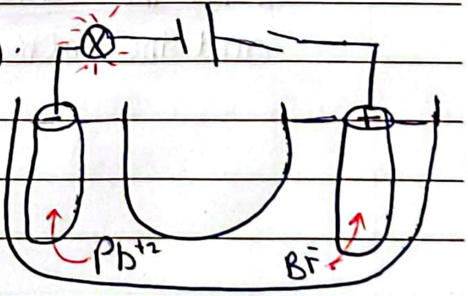
Pb^{2+} — cathod

Br^- — anode → $2Br^- \rightarrow Br_2 + 2e^-$ Bubbles of red-brown gas

$Pb^{2+} + 2e^- \rightarrow Pb$

Deposit of metal

- Bulb lights on (another observation).



- Electrolyte: used up.

C.

1) $CuCl_2$

Cu^{2+} cathod — Cl^- anode → $2Cl^- \rightarrow Cl_2 + 2\acute{e}$

bubbles of green-yellow gas

$Cu^{2+} + 2\acute{e} \rightarrow Cu$

Deposit of red-brown solid

Electrolyte : consume

Al_2O_3

Al^{3+} cathode — O^{2-} anode → $2O^{2-} \rightarrow O_2 + 4\acute{e}$

$Al^{3+} + 3\acute{e} \rightarrow Al$

Electrolyte : used up.

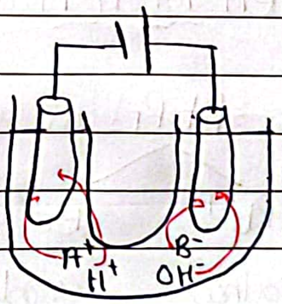
- Electrolysis for aqueous electrolyte using Inert.

$AB_{(aq)}$

A^+ — B^-

H^+ — OH^-

cathode — anode



* At the cathode :- less reactive more likely to reduce and the more reactive stays in the electrolyte.

X
K^+
Na^+
Li^+
Ca^{2+}
Mg^{2+}
Al^{3+}
Zn^{2+}
$Fe^{2+,3+}$
Pb^{2+}
$2é + H^{+1} \rightarrow H_2$
$Cu^{+1,+2}$
Ag^{+1}
Au^{+1}

At the ~~cathode~~ anode :- Always OH^- exept concentrated halide (Cl^-, Br^-, I^-)

* when the halide oxidise
$2Cl^- \rightarrow Cl_2 + 2é$

∝ when OH oxidise
$4OH^- \rightarrow 2H_2O + O_2 + 4é$

Ex:- concentrated
$NaCl_{(aq)}$ | graphite

Na^+, H^+ — cathode
Cl^-, OH^- — anode

$\rightarrow {}_2Cl^- \rightarrow Cl_2 + 2é$
bubbles of yellow-green gas.

$+2é \; {}_2H^+ \rightarrow H_2$
bubbles of colorless gas

Electrolyte : NaOH (left)

$CuSO_{4\,(aq)}$ / graphite

Cu^{2+}, H^+ — cathode
SO_4^{2-}, OH^- — anode

$\rightarrow 4OH^- \rightarrow 2H_2O + O_2 + 4é$
bubbles of colorless gas.

$2é + Cu^{2+} \rightarrow Cu^\circ$
deposit of red-brown solid.

Electrolyte : H_2SO_4

Dilute $NaCl_{(aq)}$ / graphite

Na^+ Cl^-

$\boxed{H^+}$ $\boxed{OH^-}$

cathod anode

$2\acute{e} + {}_2H^+ \rightarrow H_2$
Bubbles of colorless gas

$4OH^- \rightarrow {}_2H_2O + O_2 + 4\acute{e}$
Bubbles of colorless gas (glowing splint → relight)

Electrolyte: $NaCl_{(aq)}$ (more concentrated)

Concentrated $KI_{(aq)}$ / graphite

K^+ $\boxed{I^-}$

$\boxed{H^+}$ OH^-

Electrolyte: KOH

$2\acute{e} + 2H^+ \rightarrow H_2$
Bubbles of colorless gas

$2I^- \rightarrow I_2 + 2\acute{e}$
red-brown sol.

concentrated $CuCl_2$ / graphite

$\boxed{Cu^{2+}}$ $\boxed{Cl^-}$

H^+ OH^-

$2\acute{e} + Cu^{2+} \rightarrow Cu$
Deposit of red-brown solid

${}_2Cl^- \rightarrow Cl_2 + 2\acute{e}$
bubbles of green yellow gas

[illegible] → electrolyte: less conc. $CuCl_2$

Concentrated sodium chloride called Brine Solution

NaCl

Na^+ Cl^-

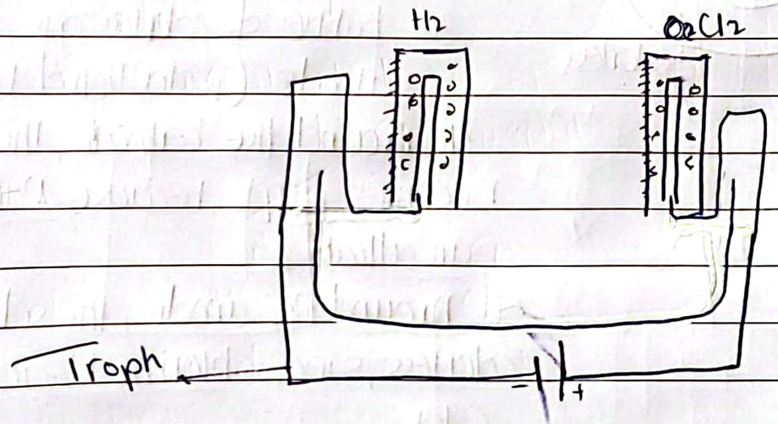
H^+ OH^-

cathod anode

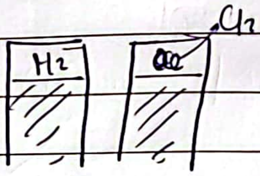
Electrolyte: NaOH

$2e^- + 2H^+ \to H_2$ $2Cl^- \to Cl_2 + 2e^-$

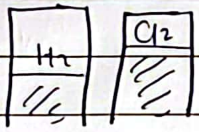
Q.1 → plan an exp. to collect and measure the volume of H_2 and O_2 produced. Inverted measuring cylinder.



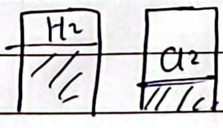
Q.2 the final appearance of the 2 measuring cylinders are:



(a)



(b)



(c)

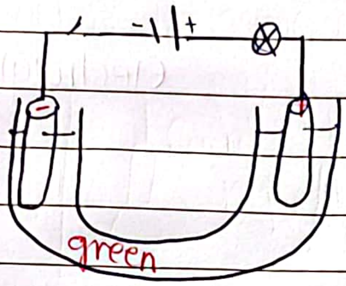
H.O.O:- $2Cl^- \to Cl_2 + 2e^-$

H.O.R:- $2e^- + 2H^+ \to H_2$ Answer is (a)

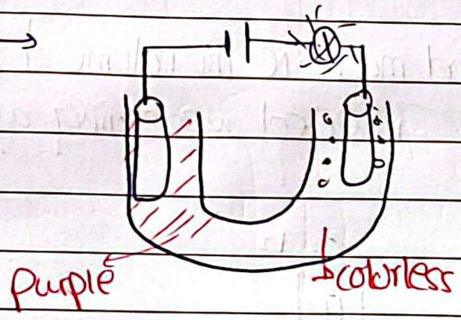
overall:- $2Cl^- + 2H^+ \to Cl_2 + H_2$

$(1 : 1) \to$ ratio

Q3 Brine with universal indicator:-



→



Observations:-

1- the bulb lights up.

2- bubbles of green-yellow gas on the anode (oxidation of Cl^-)

3- bubbles of colorless gas on the cathode (reduction of H^+)

4- Around the cathode, the sol. becomes purple, because NaOH is an alkali.

5- Around the anode, the sol. becomes colorless, since chlorine bleach the color.

* the chlorine not immodietly appears as H_2 produce?

→ since Cl_2 dissolve in sol.

- ## Electrolysis for $H_2SO_{4(aq)}$

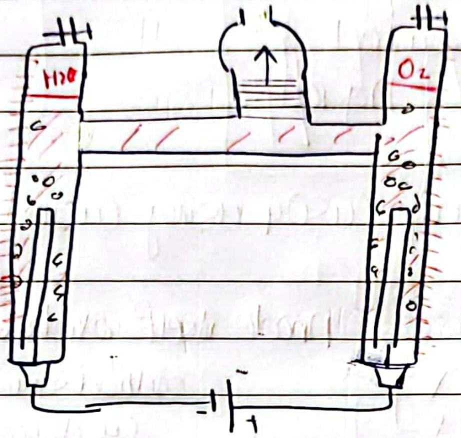
H_2SO_4

H^{+1} SO_4^{2-}

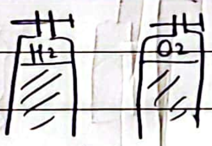
H^+ cathode $\rightarrow H_2$

$OH^- \rightarrow O_2$ anode

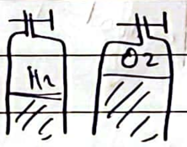
HOFF-man



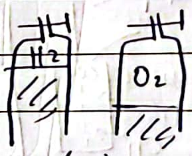
Q.2. the final appearance :-



(a)



(b)



(c)

check dinal

$$(4\cancel{2}H^+ + 4\cancel{2}e^- \rightarrow 2H_2) \times 2$$

$$4OH \rightarrow 2H_2O + O_2 + \cancel{4e^-}$$

overall $\rightarrow$ $4H^+ + 4OH \rightarrow 2H_2O + 2H_2 + O_2$

2 : 1

C. - Electrolysis for aqueous electrolyte using active rod:

* the rod must be the same metal ion in the electrolyte.

→ $CuSO_{4(aq)}$ ⟶ Cu rod

→ $AgNO_{3(aq)}$ ⟶ Ag rod.

- Electrolysis for aqueous $CuSO_4$ using Cu rod:-

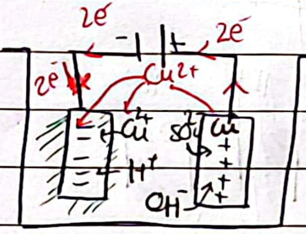
$CuSO_4$

Cu^{2+} $\quad$ SO_4^{2-} ✗

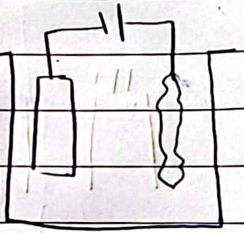
H^+ $\quad$ OH^- ✗ → Anode itself oxidise

cathod $\quad$ anode

* cathod's mass ↑
  Cu deposit
* Anode's mass ↓
  oxidised by lose é's



- anode must be impure Cu
- cathod → pure Cu



cathode $\quad$ Anode

$2é + Cu^{2+} \rightarrow Cu$ $\quad$ $Cu \rightarrow Cu^{2+} + 2é$

why the color of the sol. didn't change

→ Electrolyte stays the same concentrated!

→ the anode oxidised and replace the Cu^{2+} in the electrolyte within same rate.

Note: - Using Carbon → graphite.

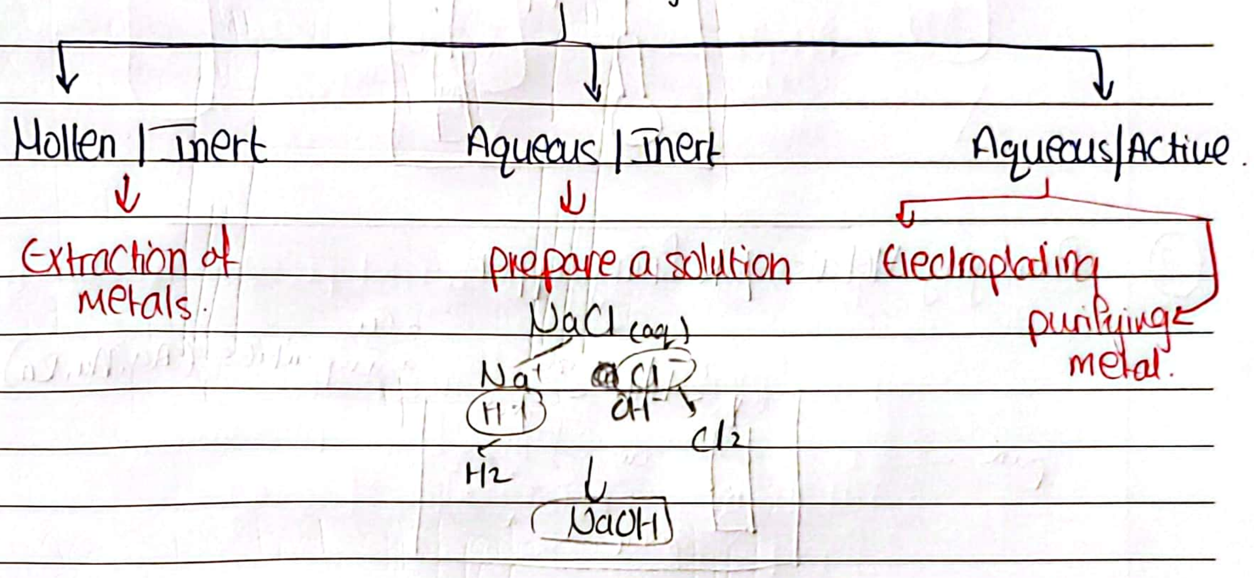
- $CuSO_4$ → eli bidal H_2SO_4 (sulfenic acid)

→ then blue to colorless.

17-9-2202

Electrolysis

Applications on electrolysis



- Electroplating:-
  → coating a metal with another metal using electrolysis

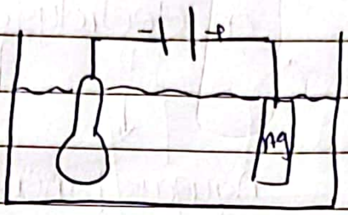
  * why? → ① to prevent rusting.
  ② more attractive.

→ How to electroplate a metal spoon with silver?

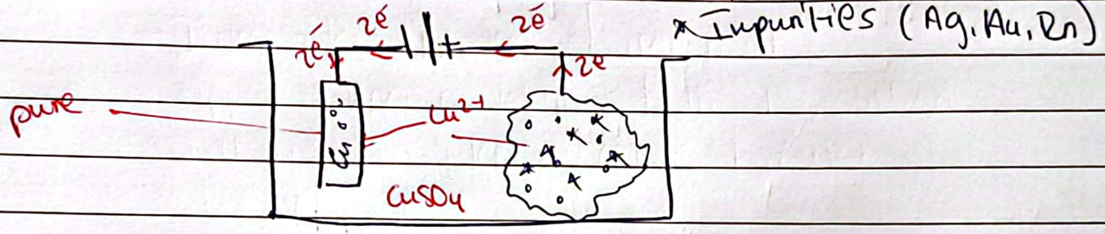
1- Clean the spoon from any impurities as oxide layer, using sand paper, to ensure a good sticking.

2- Make the spoon the cathode (-ve)
3- the anode must be Ag.
4- the electrolyte must contain Ag^+ eg. $AgNO_{3(aq)}$ → taken aq.
5- Turn on the circuit "be sure that the spoon is fully immersed in the electrolyte"

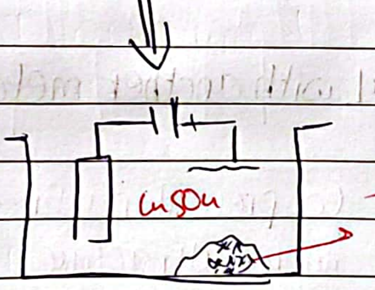
6- Rotate the spoon to ensure an equal distribution
7- Rinse with distilled water.
8- Dry in oven



② Purifying Metals / Refining copper :-



$2\acute{e} + Cu^{2+} \rightarrow Cu$ $Cu \rightarrow Cu^{2+} + 2\acute{e}$



Impurities
Au, Ag → settle down (less reactive)
$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

Extraction of Metals from their ores:-

* The method of extraction depends on the position of metal in reactivity series.

K
Na
Li
Ca
Mg
→ Electrolysis (Molten) graphite.
Bauxite Al_2O_3 ← Al
C, CO
Zinc Blende ZnS ← Zn
Hematite Fe_2O_3 ← Fe] → reduction by C, CO
Pb
H
Copper (II) Sulphide CuS ← Cu] → reduction by H_2
Ag
Au

- Extraction of Aluminium:-

Ore: Al_2O_3 Bauxite

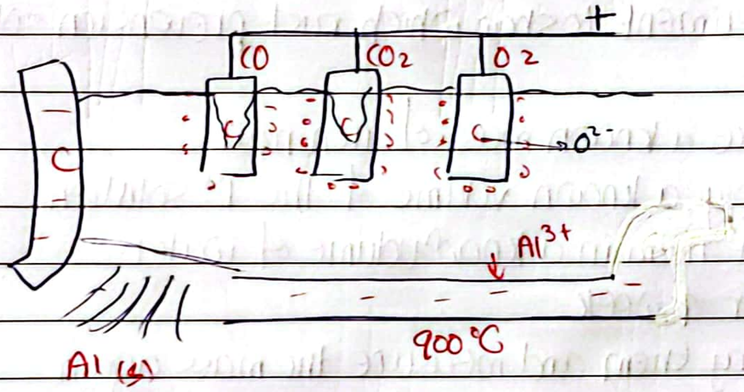
Method: Electrolysis for molten Al_2O_3 / graphite

* m.p of Al_2O_3 is about 2000 °C

⇒ so we dissolve Al_2O_3 in a molten cryolite Na_3AlF_6

→ ① to lower m.p to 900 °C, so less cost.

→ ② to increase the electrical conductivity.



Al_2O_3

Al^{3+} O_3^{2-}

Cathode Anode

$3\acute{e} + Al^{3+} \rightarrow Al$ $2O^{2-} \rightarrow O_2 + 4\acute{e}$

* Gases produced at anode:- 1- O_2

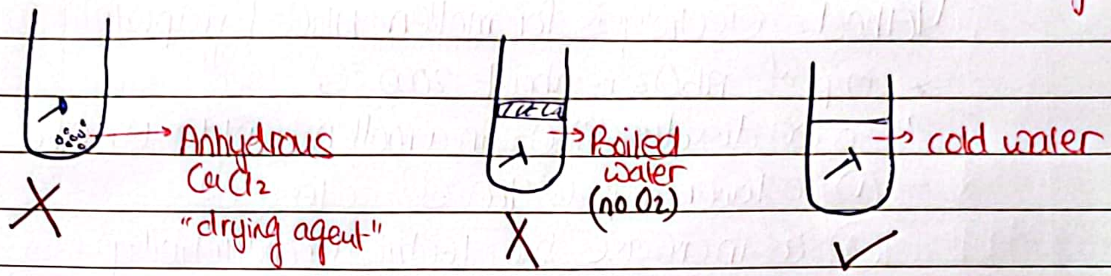
2- CO_2 } reaction of rods with O_2

3- CO so we must replace them periodically.

Property:-	Use:-
1- low density	- in aircraft bodies
2- Ductile	- electrical wires.
3- Malleable	- window frame / cooking utensils
4- conducts electricity	- wires
5- Form an oxide layer which is non-toxic	- Food cans.

Rust :- reaction of iron with both O_2 and H_2O

slow reaction 6-7 days



- Plan an experiment to show which rust prevension solution is better.

→ Take a known mass of iron nail.
→ Apply a known volume of the 1st solution.
→ Put them in a know volume of water.
→ For 1 week
→ Dry them and measure the mass again.
→ Repeat the experiment, with the 2nd solution.
→ Conclusion :- the exp. which cause more increase in mass, worse sol.

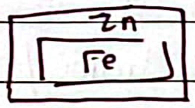
- How to prevent rusting :-

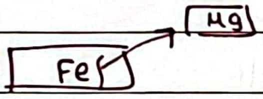
① Painting ② Oiling ③ Grasing

* prevent O_2 + H_2O from reaching the iron

④ Cover with plastic.

⑤ Galvanizing ⑥ Sacrificial protection



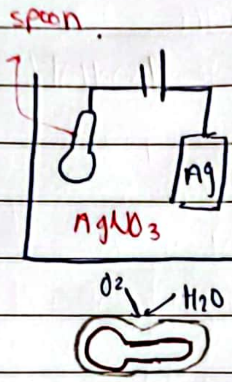


coating with Zn

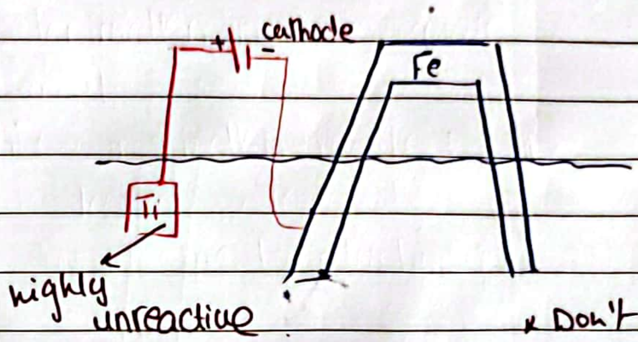
Zn + Mg → more reactive than Fe
→ more likely to oxidise
→ " " " lose é
→ so Fe is less likely to rust.

→ connecting to ~~Zn~~ Mg

⑦ Electroplating



⑧ Cathodic Protection

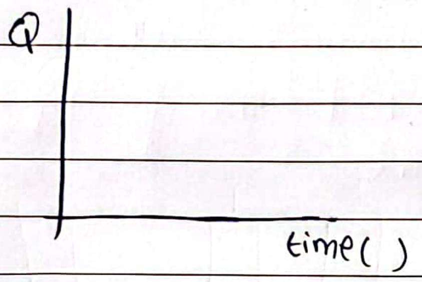


× Don't make Fe the anode

Rate of Reaction

$$\text{Rate} = \frac{\text{change in a quantity}}{\text{change in time}}$$

$$\text{rate} = \frac{\Delta Q}{\Delta t}$$

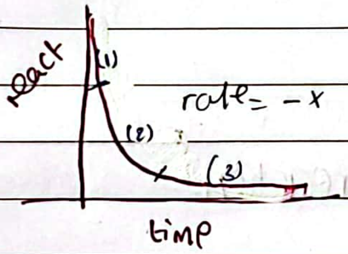


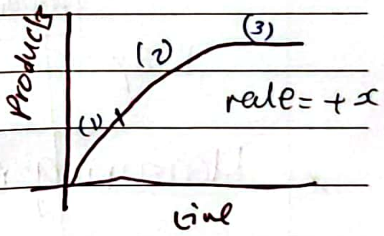
- $\frac{\Delta \text{mass}}{\Delta \text{time}}$
- $\frac{\Delta \text{conc.}}{\Delta \text{time}}$
- $\frac{\Delta \text{pH}}{\Delta \text{time}}$
- $\frac{\Delta \text{volume}}{\Delta \text{time}}$
- $\frac{\Delta \text{temp}}{\Delta \text{time}}$
- $\frac{\Delta \text{weight of ppt}}{\Delta \text{time}}$
- $\frac{\Delta \text{light intensity}}{\Delta \text{time}}$

Measure the rate of reaction

How Fast the reactants consumed per unit time

How ~~Fast~~ the products Produced per unit time





region (1): fastest rate ⇒ from the graph (steepest)

At the beginning of reaction:-

- more amount of reactants.
  - more particles
  - more effective collisions per unit time.

region (2): slower rate ⇒ from the graph (less steep)

- less no. of particles
- so less no. of effective collisions per unit time

region (3): reaction is over ⇒ gradient = 0 (horizontal)

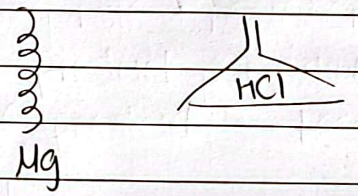
- no more limiting factor.
- so no more effective collisions

For any chemical reaction these are the main conditions:-

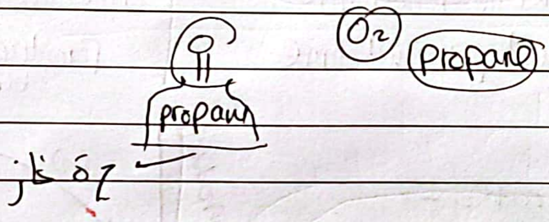
① The reactant must be suitable

$Cu + HCl \longrightarrow$ no rxn

② The reactant must collide



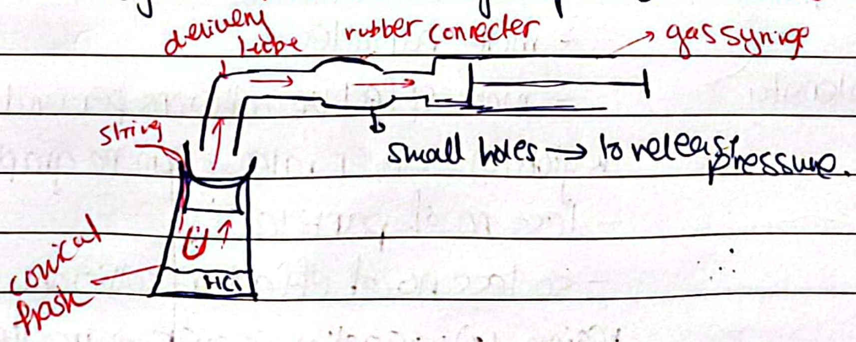
③ The collisions must be effective (minimum amount of energy to start the rxn. Activation Energy. Energy Ea.)

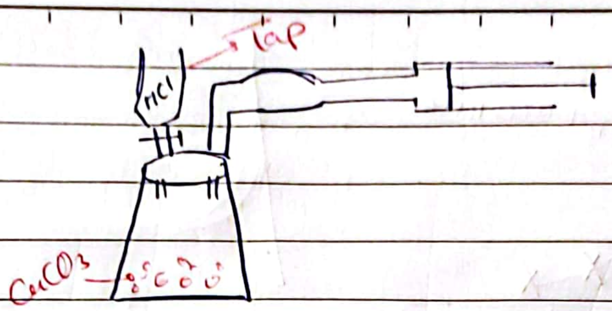


* Measuring rate of reaction:-

$$CaCO_{3(s)} + 2HCl \longrightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

① Measuring the volume of gas per unit time.



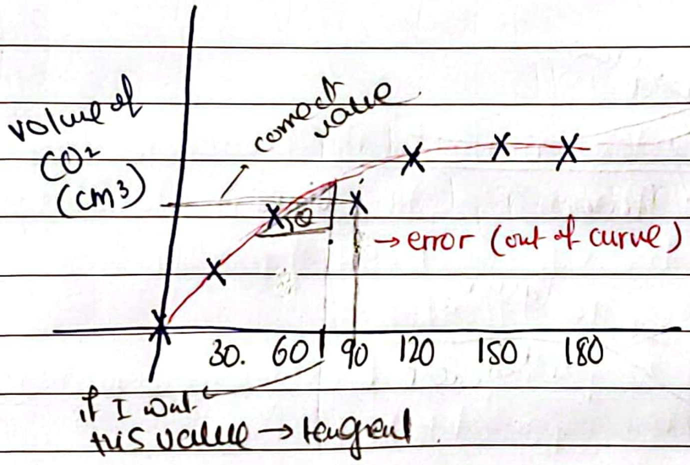


× more reliable method ⇒ measure short time interval.

reaction is over

time (s)	0	30	60	90	120	150	180
volume of CO_2 (cm^3)	0	10	15	17	17.5	17.5	17.5

+10 +5 +2 +0.5 0.5



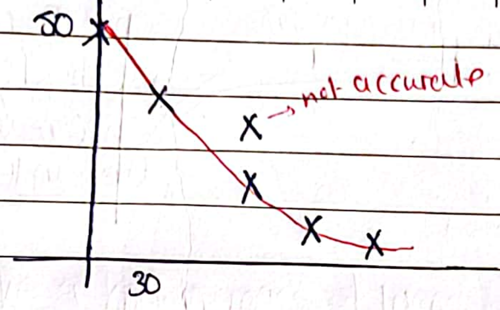
② Measure mass of conical flask+contents per unit time.

→ cotton wool → allow CO_2 to escape + prevent splashing

mass ↓ because CO_2 escapes.

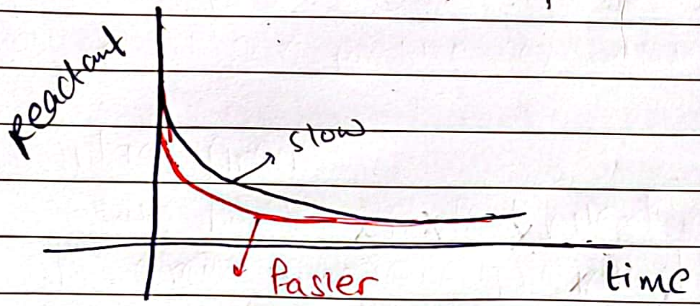
reaction is over.

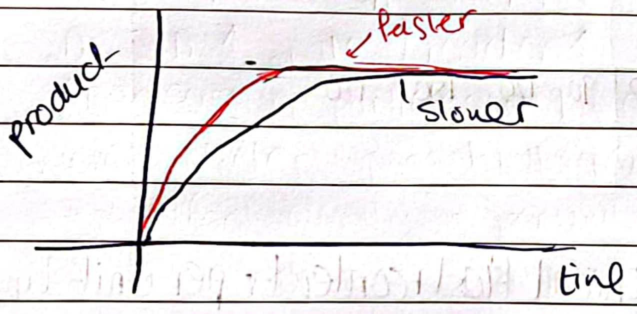
time (s)	0	30	60	90	120	150	180
mass (g)	50	40	35	33	32.5	32.5	32.5



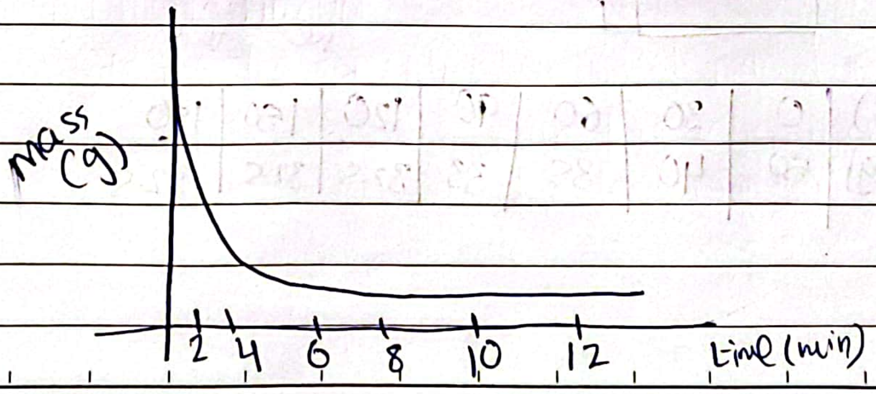
* Increasing rate of reaction:-

More product per same period of time]
same product ∴ less time] → steeper curve

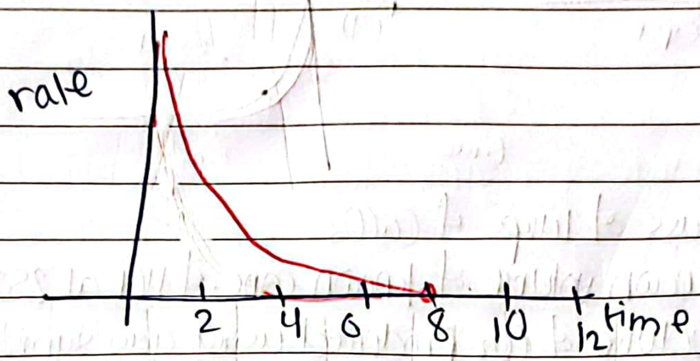




Q. The graph below shows how the amount of reactant changes with time.



Draw rate Vs time graph for this reaction:-



- Factors that effect rate of reaction:-

① Temperature. ④ Pressure
② S.A ⑤ light intensity
③ Conc. / amount ⑥ Catalyst.

① Temperature:-

* State how the temp. affect rate of reaction.

As the temp increases, the rate of reaction increases.

* Explain how the temp. affect rate of reaction.

As the temp increases, the particles gain K.E so move faster, the particles will have energy equal to or greater than Ea (activation energy) so more effective collisions per unit time, so faster rate of reaction.

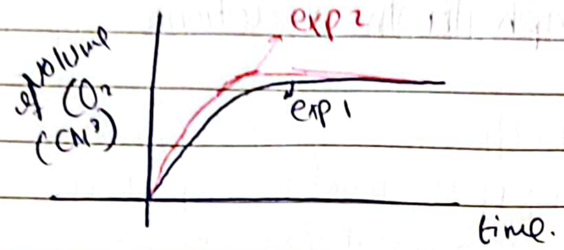
* plan an exp. to show how temp. affect rate of reaction..

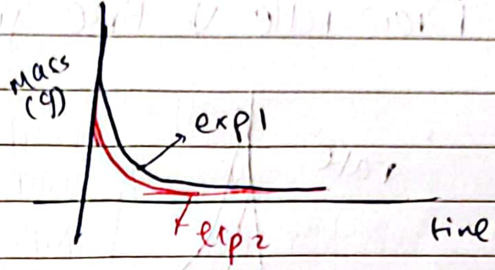
$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

Exp 1: m = 20g lumps
V HCl = 0.1 dm³
M HCl = 1 mol/dm³
Temp = 25°C

Exp 2: m = 20g " lumps
V HCl = 0.1 dm³
M HCl = 1 mol/dm³
Temp = 50°C.

C.





- Take a known mass of lumps of $CaCO_3$.
- Add them to a known volume of known conc. of HCl at 25°C.
- Measure the volume of CO_2 produced using gas syringe per unit time.
- Repeat the exp. at 50°C.
- The exp. at 50°C produce CO_2 with less time.

② Surface Area:-

* State how the S.A affect rate of reaction.

As the ~~rate~~ S.A increases, the rate of reaction increases.

* Explain how S.A affect rate of reaction

- As S.A ↑, rate of reaction ↑
- (Decrease the particle size by crushing using morter + pestile)
- more particles exposed to the reaction.
- more effective collisions per unit time.
- So faster rate.

* Plan an exp. to show how S.A affect rate of reaction.

same, exp 2 → temp → 25°C
exp 2 → Powder not lumps.

③ Concentration "Amount":-

* State how the concentraction affects rate of reaction.

As the conc. increases, rate of reaction increases.

* Explain how the conc. affect rate of reaction.

- As the conc. increase.
- More particles
- More effective collisions per unit time

- So faster rate of reaction

needed = 0.005
add = 0.05

- plan an exp

0.01 → 0.04

$^{0.02}CaCO_3 + 2\underset{(limiting)}{\overset{0.01}{HCl}} \rightarrow CaCl_2 + H_2O + CO_2$ n = 0.005, V = 0.12

Exp1 = mass of $CaCO_3$ = 2g lumps, Mr = 100

V HCl = 0.1 dm^3

M HCl = 0.1 Mol/dm^3

Temp = 25°C

Exp 2 = mass of $CaCO_3$ = 2g lumps

V HCl = 0.1 dm^3

$\boxed{M\ HCl = 0.2\ Mol/dm^3}$

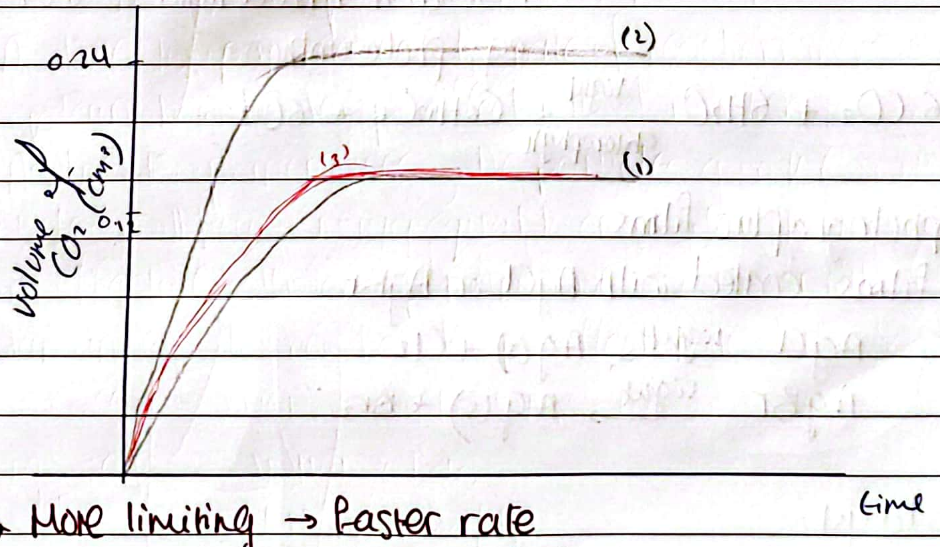
Temp = 25°C

Exp 3 = mass of $\boxed{CaCO_3 = 4g}$ lumps

V = 0.1 dm^3

M = 0.1 dm^3

Temp = 25°C

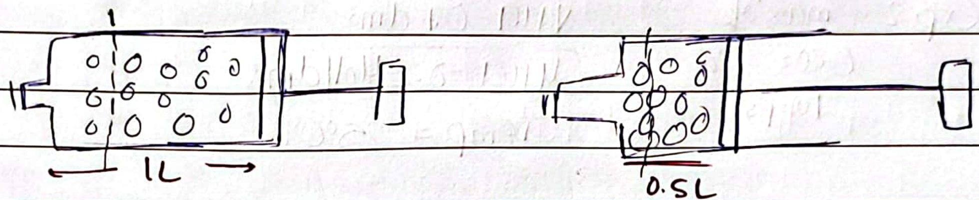


- More limiting → faster rate, more product
- More excess → faster rate.

④ pressure : "only affect the gas"

- Explain how the pressure affect the rate of reaction :-

As the pressure increases by reducing the volume.
so more particles per unit volume, so more effective collisions per unit time
so faster rate of reaction.



$\frac{10 \text{ particles}}{1L} = 10$ $\frac{10 \text{ particles}}{0.5L} = 20$

⑤ light: "only for photochemical reaction"

reaction that need light to occur
eg: photosynthesis

$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$

* photographic films

⇒ films coated with AgCl or AgBr

$AgCl \xrightarrow{\text{light}} Ag_{(s)} + Cl_2$

$AgBr \xrightarrow{\text{light}} Ag_{(s)} + Br_2$

⑥ Catalyst:

chemical substance that speeds up the reaction without being used up.

How? it provides an alternative way
with lower Ea
so more particles will have energy equal
to or more Ea
so more effective collisions per unit time.
so faster rate of rxn.

the reaction

$$H_2O_2 \xrightarrow[②\,MnO_2]{①\,CuO} 2H_2O + O_2$$

① plan an exp to show that CuO is a catalyst for this reaction.

1- Take a known volume with a known conc. of H_2O_2

2- Measure volume of O_2 per unit time.

at known temp.

3- Repeat same volume using CuO

– the exp using CuO will produce more O_2 per the same unit time.

② plan an exp to show which of the 2 catalyst is better CuO or MnO_2

same as Q1 + same mass of catalyst.

conc: the exp which produce more O_2 per same unit time, used better catalyst.

③ Plan an exp. to show that CuO not used up during the reaction.

1- measure mass of CuO

2- add to H_2O_2 until no more fizzes.

3- filter the mixture.

4- Dry the solid in oven.

5- remeasure the mass.

× same initial + final mass.

Reversible Reactions

Types of chemical rxn

one way

Reactants $\xrightarrow{\text{forward}}$ products

$CaCO_{3(s)} + HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

$Mg + HCl \rightarrow MgCl_2 + H_2$

* Reactant must be suitable.

both ways

Reactants $\underset{\text{backward}}{\overset{\text{forward}}{\rightleftharpoons}}$ products

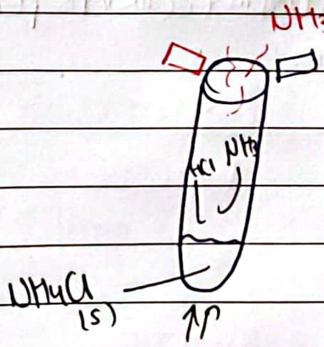
$NH_4Cl_{(s)} \rightleftharpoons NH_{3(g)} + HCl_{(g)}$

$CaCO_3 \rightleftharpoons Ca + CO_{2(g)}$

$3H_{2(g)} + NH_{2(g)} \rightleftharpoons 2NH_{3(g)}$

$NH_4Cl_{(s)} \xrightarrow{\Delta} NH_{3(g)} + HCl_{(g)}$

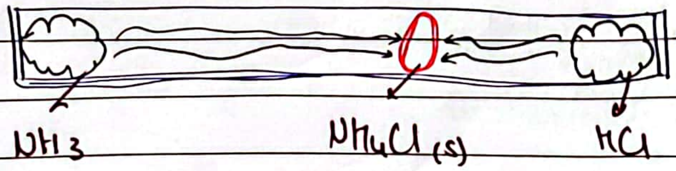
Ammonium Chloride — Ammonia — hydrogen chloride



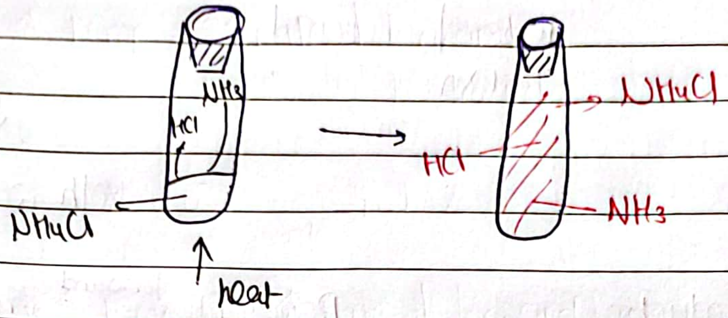
Q. which damp litmus paper will change its color first, why? (3)

⇒ the damp red litmus paper changes to blue. First because $NH_{3(aq)}$ is an alkali and lighter than $HCl_{(aq)}$ which is acidic.

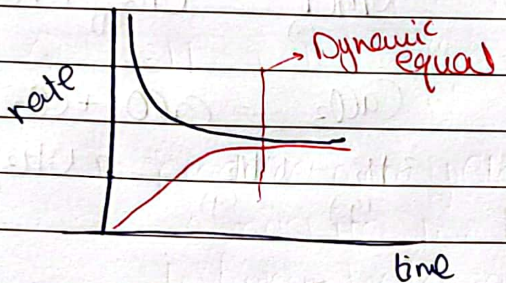
$HCl_{(g)} + NH_{3(g)} \rightarrow NH_4Cl_{(s)}$



$NH_4Cl_{(s)} \rightleftharpoons NH_{3(g)} + HCl_{(g)}$

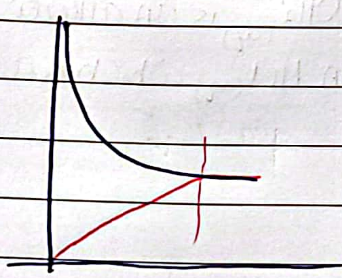


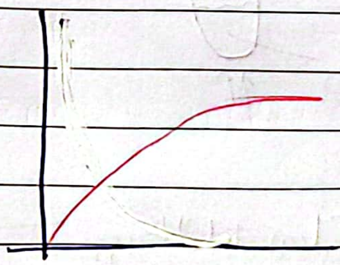
In terms of rate:

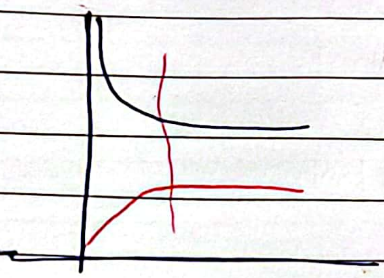


- rate of forward ↓
  - less reactants
  - so less particles
  - less effective collisions per unit time
- rate of backward ↑
  - more products
  - " particles
  - " effective collisions per unit time

In terms of conc:







Le Chatelier Principle:-

- if the system at equal ⇌ and any external factor distrubt
- the equal can shift itself either to the forward → to return back to the equil or: backward ←

- Factors that affect position of equilibrium:-

① Temp:-

K --- Endo + Exo

↑ Temp shift to Endo
↓ " " " Exo

↑ Temp ↑ rate
↓ " ↓ "

② Pressure

↑ Pressure, shift to less gas mole.

↓ Pressure, shift to more gas mole.

↑ Pressure, ↑↑ rate of less gas mole
↑ rate of more gas mole

↓↓ Pressure ↓ rate of less ---
↓ rate of more ---

③ Concentration

↑R
↓P } → shift forward

↓R
↑P } → shift backward

① Temperature

↑ Temp ↑↑ rate of endo
↑ " " exo
shift to endo

↓ Temp ↓↓ rate of endo
↓ " " exo
shift to exo

ΔH
Enthalpy change

+ve
gain
Endo

-ve
lose
Exo

the sign of ΔH is always represent the forward reaction

$A + B \underset{exo}{\overset{endo}{\rightleftharpoons}} C + D$ $\Delta H = \overset{endo}{+ve}$

↑ Temp ↑↑ rate of forward ↓A ↓B ↑C ↑D
↑ " " backward

$X + W \underset{endo}{\overset{exo}{\rightleftharpoons}} Y + Z$ $\Delta H = \overset{exo}{-ve}$

↑ Temp ↑ rate of forward } shift to endo ↑X ↑W ↓Y Z↓
↑↑ " " backward

Q. $3H_2 + N_2 \underset{endo}{\overset{exo}{\rightleftharpoons}} 2NH_3$ $\Delta H = \overset{exo}{-ve}$

To produce more yield of NH_3:-
→ we must use low temp.
→ to favour the forward reaction which is exothermic.

Q. $2SO_2 + O_{2(g)} \underset{endo}{\overset{exo}{\rightleftharpoons}} 2SO_{3(g)}$ $\Delta H = \overset{exo}{-ve}$.

	rate of forward	rate of back	% SO_3
↑ Temp	increase	increase	decrease
↓ Temp	decrease	decrease	increase.

- Mixture of NO_2 and N_2O_4 at equil in a sealed mixture.

$2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$
dark brown pale brown

- if we put this sealed tube in a cold water bath, the mixture becomes paler? why?

→ because forward reaction is exothermic enhanced by cooling.

② Pressure

→ As the pressure increases, the equil shift to the side with low pressure. with less gas moles

→ " " " decreases, " " " " " " with high pressure with high gas moles.

- $\overbrace{3H_{2(g)} + N_{2(g)}}^{4\ moles} \rightleftharpoons \overbrace{2NH_{3(g)}}^{2\ moles}$

↑ Pressure, shift to the side with less gas moles ↑ NH_3

↓ Pressure, " " " " " more " "

- $\overbrace{CaCO_{3(s)}}^{0} \rightleftharpoons \overbrace{CO_{(s)} + CO_{2(g)}}^{1}$

↓ pressure, shift to the side with more gas mole

↑ " , " " " " " less " "

- $\overbrace{H_2CO_{3(aq)}}^{0} \rightleftharpoons \overbrace{H_2O_{(l)} + CO_{2(g)}}^{1}$

↓ pressure, shift to the side with more gas moles.

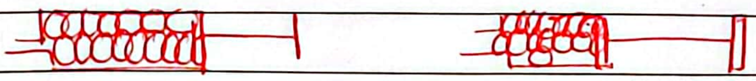
- $\overbrace{H_{2(g)} + I_{2(g)}}^{2} \rightleftharpoons \overbrace{2HI_{(g)}}^{2}$

⇒ Changing the pressure has no effect on the position of equilibrium since both sides has the same no. of gas moles.

Q. $\underset{purple}{H_{2(g)} + I_{2(g)}} \rightleftharpoons \underset{colorless}{2HI_{g}}$

the equil doesn't affect by increasing the pressure

→ why by increasing the pressure the mixture becomes more purple.



the I_2 molecules becomes closer to each other, so the color seems to be darker.

Q. Sealed tube contains mixture of $NO_{2(g)}$ and $N_2O_{4(g)}$ at equilibrium?

$$\underset{\text{darker brown}}{2NO_{2(g)}} \rightleftharpoons \underset{\text{paler brown}}{N_2O_4}$$

by increasing the pressure, the color of mixture:-

a) becomes paler then gas darker.
[✓ b)] " darker " " parler
c) " paler and stays paler.
d) " darker " " darker.

③ Concentration

React. ⇌ products

↑ Reactant
↓ Product } → shift Forward

↓ Reactant
↑ Product } shift backward.

$$A + B \rightleftharpoons C + D$$

↑[A] shift forward ↓B ↑C ↑D
↓[B] " backwards ↑A ↓C ↓D
↑[C] " " ↑A ↑B ↓D

Indicator:-

methyl orange

$$\underset{\substack{\text{color (1)}\\\text{red}}}{HIn_{(aq)}} \rightleftharpoons H^+_{(aq)} + \underset{\substack{\text{color (2)}\\\text{yellow}}}{In^-_{(aq)}}$$

Add HCl : proton donor ↑H^+ shift backword

more HIn more color (1)

less In^- less " (2)

Add NaOH : proton accepter ↓H^+ shift forward

more In^- more color (2)

less HIn less " (1)

Q. The reversible reaction below at equilibrium :

$$\underset{\text{orange}}{Cr_2O_7^{-2}} + Fe^{2+} \rightleftharpoons \underset{\text{green}}{Cr^{3+}} + Fe^{3+} + H_2O$$

→ Explain by adding HCl to the rxn mixture the color of the mixture becomes green ?

→ HCl is an acid (proton donor)

→ more H^+

→ shift forward

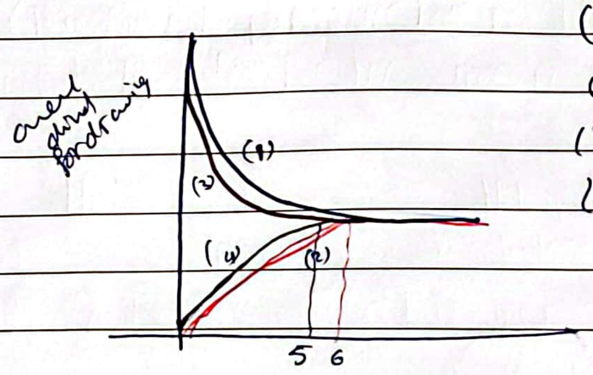
→ more Cr^{3+} more green)

→ less $Cr_2O_7^{2-}$ less orange

* Catalyst :

has no effect on the position of equilibrium

since it speeds up the rate of forward + backward.



(1) → rate of forward reaction without catalyst

(2) " " backward " " "

(3) → " " forward with catalyst

(4) → " " backward " "

(5) → time taken to reach equil with catalyst

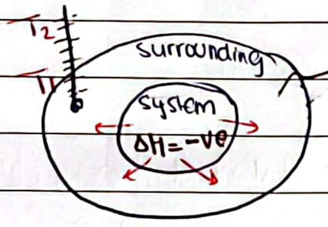
(6) → " " " " " without catalyst

Energetics

Exothermic

Reactions that give out (release) energy to the surrounding.

$T_2 > T_1$

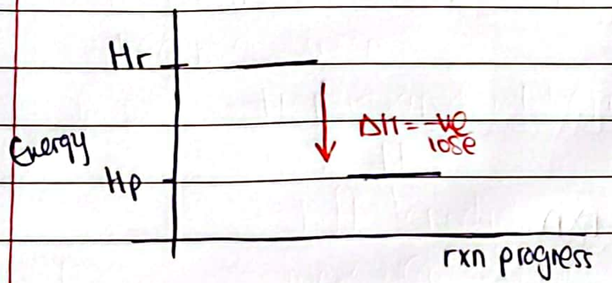


→ $Q = mc\Delta t$

كل ما قلت ال energy تكون more stable
، ، زادت " ، less "

Enthalpy: Heat contents "stored energy"

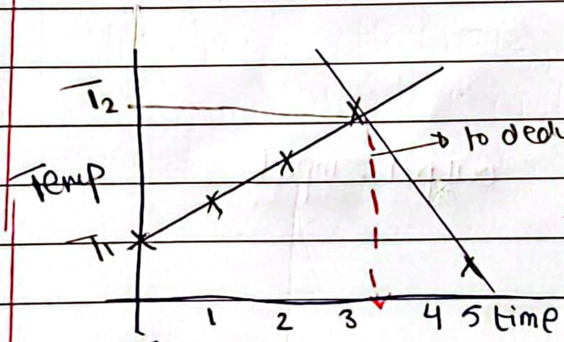
For system (energy level diagram)



H_r: enthalpy of reactants

H_p: enthalpy of products

For surrounding (Temp diagram)



Reaction is over → so return back to room temp.

→ to deduce when reaction is over → by doing 2 intersecting lines

→ $Q = mc\Delta t$ → change in temp (°C)

energy transfer (J) ← Q

mass (g) ← m

specific heat capacity ← c

↑Q more exothermic

∝ ↑Δt

Examples on Exo: -

1- Freezing, condensation.   7- Building up bonds.

2- Respiration

3- Combustion

4- Neutralization

5- Displacement

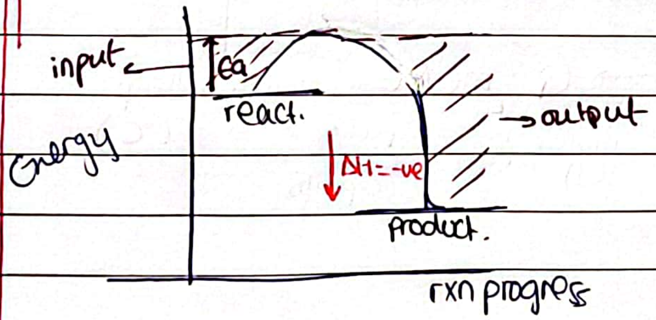
6- Voltic cell

- How to express exothermic rxn.

① Reactants $\longrightarrow$ products $\Delta H = -ve$

② Reactants $\longrightarrow$ products + energy

③ Profile diagram

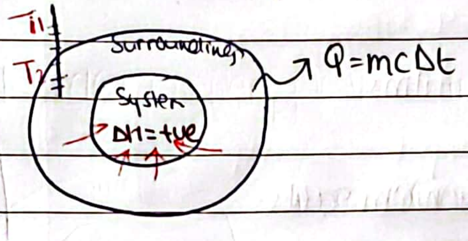


output > input

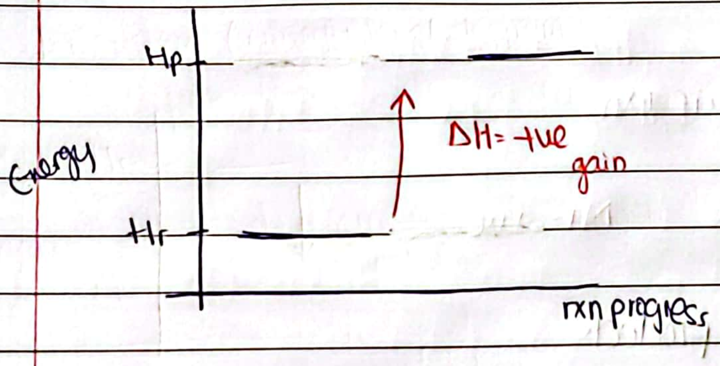
Endothermic

Reactions that absorb (take in) energy from the surrounding.

$T_1 > T_2$

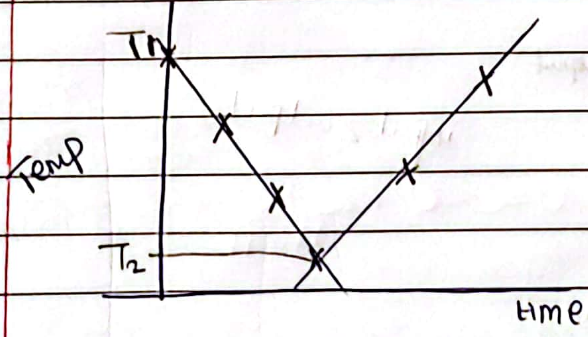


For system (energy level diagram)



For surrounding (Temp diagram)

→ $Q = mc\Delta t$



↑ Q more endothermic
← more Δt

- Examples on endo:-

1- Boiling, Melting

2- Photosynthesis.

3- Thermal Decomposition.

4- Electrolysis

5- Photographic films

6 Dissolve ammonium salts

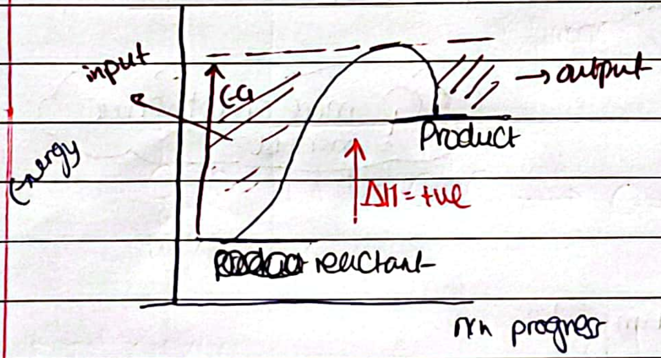
7- Breaking down bonds

- How to express endothermic rxn.

① Reactants ⟶ products $\Delta H = +ve$

② Reactants + energy ⟶ products

③ Profile diagram



input > output.

Measuring ΔH Reaction

Theoretical — Using Bond Energy

Experimental — combustion, Displacement, neutralization

* ΔH reaction using bond energy:-

→ Bond Energy:- amount of energy needed to break 1 mol of energy in gaseous state.
" " " released to build " " " " " "

Bond	Energy bond kj/mol
H-H	436

$H-H_{(g)} + 436\ kj/mol \rightarrow H_{(g)} + H_{(g)}$

$H_{(g)} + H_{(g)} \rightarrow H-H_{(g)} + 436\ kj/mol$

→ ΔH reaction = Σ input − Σ output
to break down bonds in react. — to build bonds in products

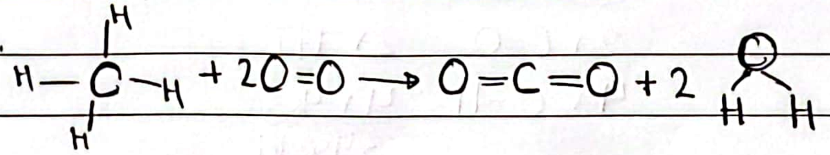
+ endo: input > output

− exo: input < output

- to use this equation.

① Balanced equation.
② covalent structure.
③ Bond Energy.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$



$CH_4 + 2\,O=O \rightarrow O=C=O + 2\,H_2O$

Bond	Bond energy
C-H	413
O=O	495
C=O	799
O-H	463
C-O	358

Bond Broken	Bond Formed
$4 \times C-H \Rightarrow 4 \times 413$	$2 \times C=O \Rightarrow 2 \times 799$
$2 \times O=O \Rightarrow 2 \times 492$	$4 \times O-H \Rightarrow 4 \times 463$ +
2642 kj	3450 kj

$\Delta H = \Sigma \text{input} - \Sigma \text{output}$

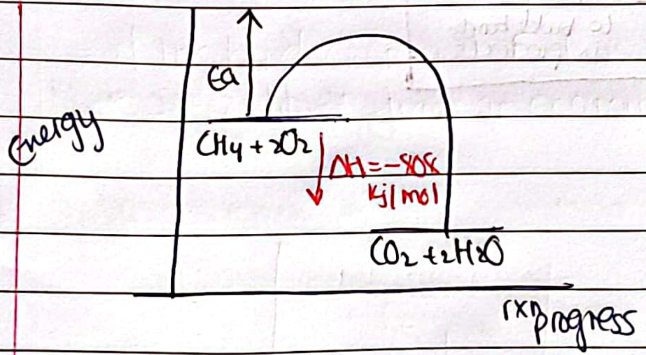
$= 2642 - 3450$

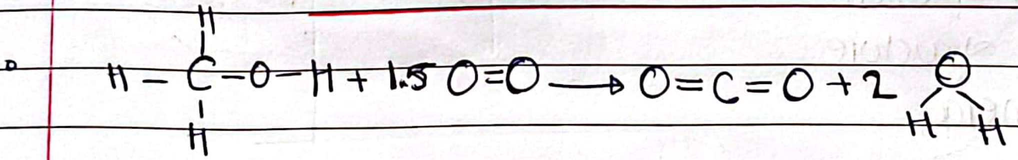
$= -808$ kj/mol   input < output

exo

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + 808$ kj/mol

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$ $\Delta H = -808$ kj/mol.





$H-\overset{H}{\underset{H}{C}}-O-H + 1.5\, O=O \longrightarrow O=C=O + 2\, H_2O$

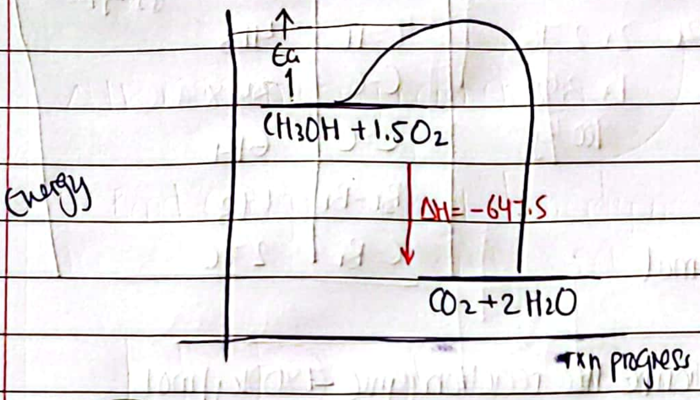
Bond Broken:		Bond Build:	
$3 \times C-H$	3×413	$2 \times C=O$	2×799
$1 \times C-O$	1×358	$4 \times O-H$	4×463
$1 \times O-H$	1×463		3450 kj
$1.5 \times O-O$	1.5×495		
	2802.5 kj		

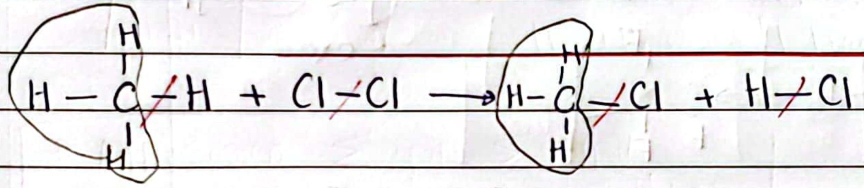
$\Delta H = \Sigma input - \Sigma output$

$= 2802.5 - 3450$

$= -647.5$ kj/mol

exo





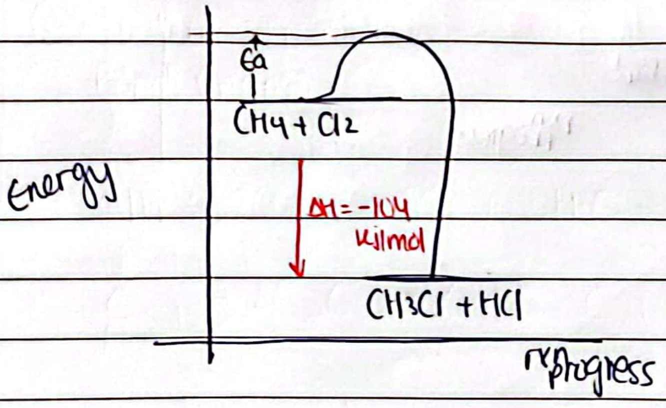
$$H-\underset{H}{\overset{H}{C}}-H + Cl-Cl \longrightarrow H-\underset{H}{\overset{H}{C}}-Cl + H-Cl$$

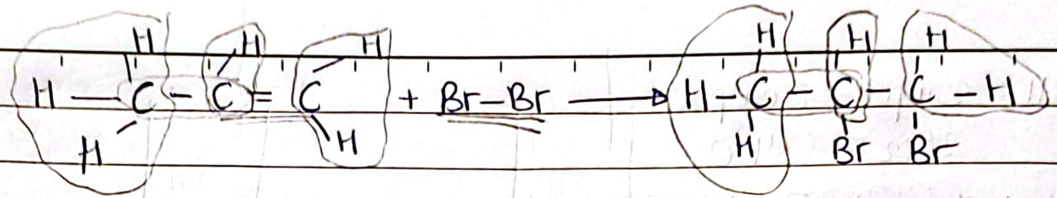
Bond Broken		Bond Formed	
1 × C–H	413	1 × C–Cl	328
1 × Cl–Cl	242	1 × H–Cl	431
	655 kj		957 kj

Bond	Bond Energy kj/mole
C–H	413
Cl–Cl	242
H–Cl	431
C–Cl	328

→ $\Delta H = 655 - 957 = -104$ kj/mol

exo





$$H_3C-CH=CH_2 + Br-Br \longrightarrow H_3C-CHBr-CH_2Br$$

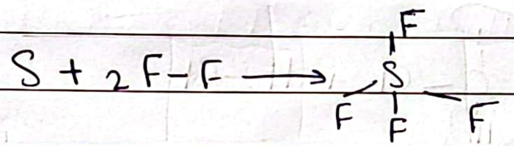
Bond Broken		Bond formed	
Br–Br	193	2×C–Br	2×276
C=C	614	C–C	1×348
	807 kj		900 kj

Bond	Bond Energy kj/mole
C-H	413
C-C	348
C=C	614
Br-Br	193
C-Br	276

$\Delta H = 807 - 900 = -93$ kj/mol

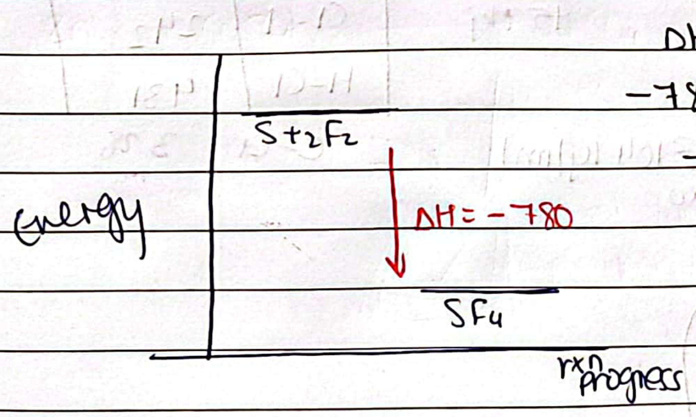
- when sulfer react with fluorine the reaction give −780 kj/mol.

exo



$$S + 2F-F \longrightarrow SF_4$$

→ if the bond energy of F–F is 160 kj/mol. find the bond energy of S–F ? And draw an energy level of diagram.



ΔH = input − output

$-780 = (2 \times 160) - 4 \times S-F$

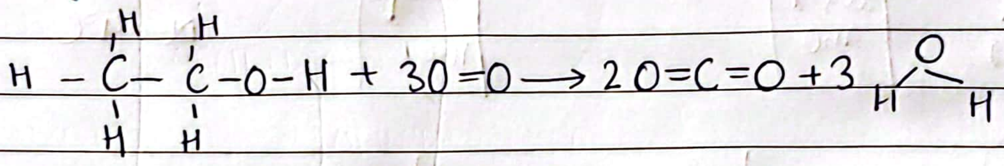
$-1100 = -4\,S-F$

$S-F = 275$ kj/mol.

Finding ΔH (energy change) practically.

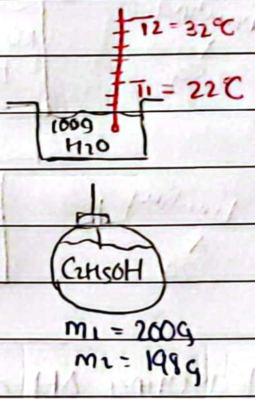
Combustion | Displacement | Neutralization

Finding ΔH combustion :-



$$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-O-H + 3O=O \longrightarrow 2O=C=O + 3H_2O$$

$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$



→ $Q = mc\Delta t \Rightarrow \Delta t = \frac{Q}{mc}$

Energy transfer = 100 × 4.2 × 10

= 4200J ≈ 4.2 kj

$4.2\ kj \xrightarrow[\text{from}]{\text{Produced}} 2g\ C_2H_5OH$

ΔH $96.6\ kj/mol \xleftarrow{\quad} 1\ \text{mole} = 46g\ C_2H_5OH$

ΔH = − 96.6kj/mol.

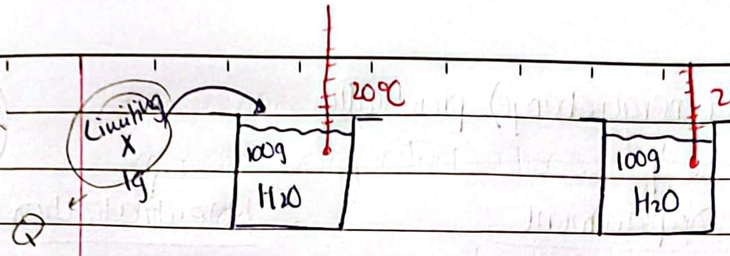
* Two fuels A and B, plan an experiment to show which one produce more energy ?

- Take a known mass of water with known initial temp. in a copper can.
- ″ ″ ″ ″ Fuel A
- Ignite the fuel, and record final mass and final temp. of water.
- Repeat exp. using fuel B.

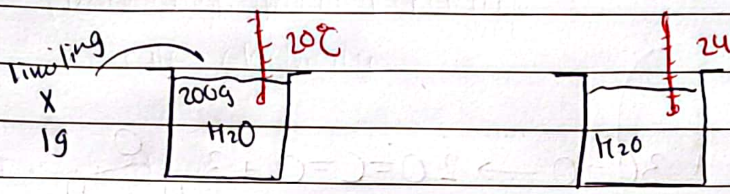
Conclusion: The fuel which cause more temp. rise per gram of fuel, produce more energy.

↑Q Δt↑

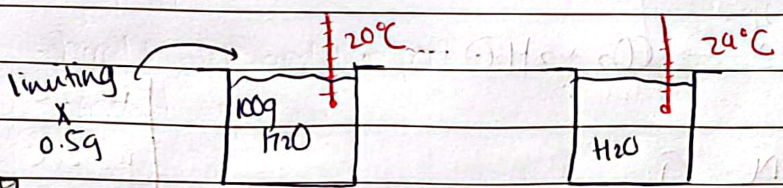
↑m Δt↓



ΔT = 8°C

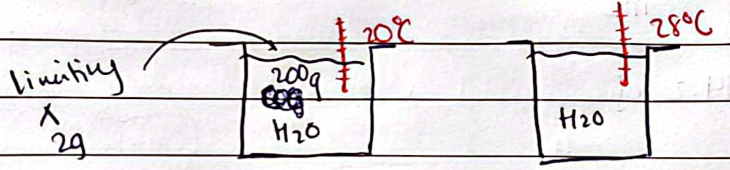


ΔT = 4°C



ΔT = 4°C

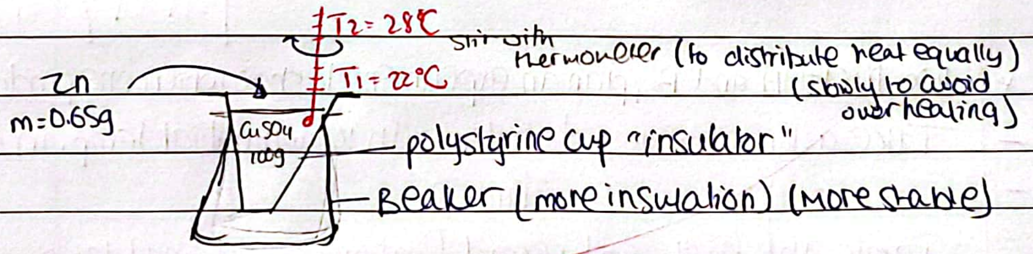
Ex on displ.



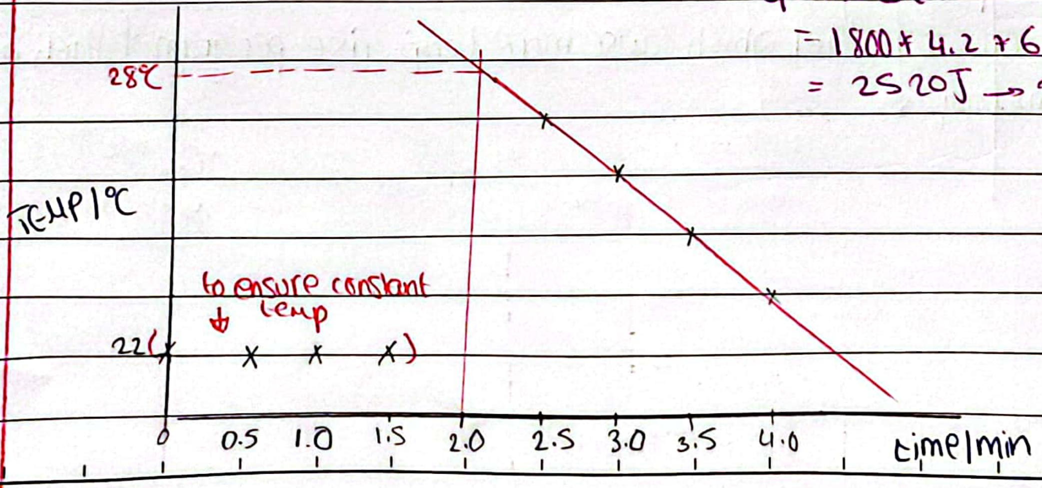
ΔT = 8°C

- Measuring ΔH displacement:-

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

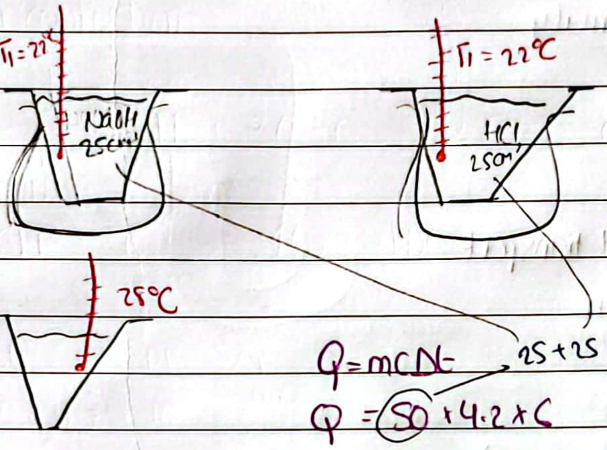


Q = mcΔt
= 100 × 4.2 × 6
= 2520J → 2.52kj



- Measuring ΔH neutralization:

$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(s)}$



specific heat capacity = 4.2 °C/

d = 1g/cm³

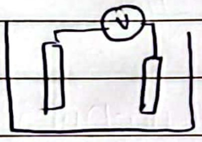
$Q = mc\Delta t$

$Q = \boxed{50} \times 4.2 \times 6$ ← 25 + 25

$= 1260\ J$

Alternative Resources of Energy

- voltaic cell
- Hydrogen fuel cell
- Uranium
  old style



- Hydrogen fuel cell

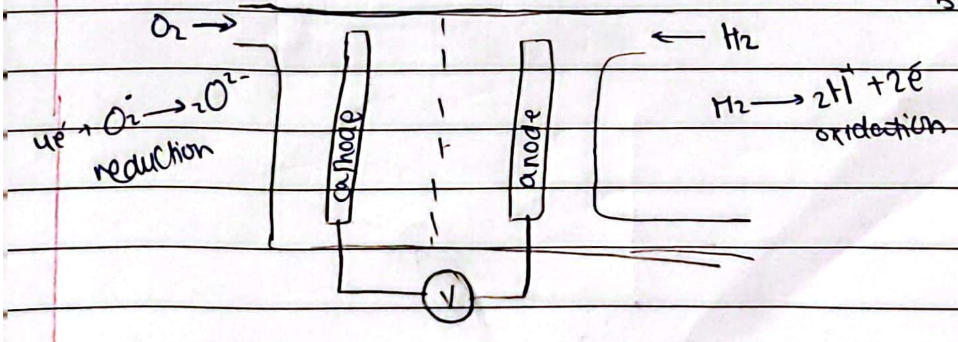
$2\overset{0}{H_2} + \overset{0}{O_2} \longrightarrow 2\overset{+1}{H_2}\overset{2-}{O}$

test water:

- physical test: b.p = 100°C
- chemical:

① $CuSO_{4(s)} + 3H_2O \rightleftharpoons CuSO_4.5H_2O$
white → blue

② $CoCl_2 + 6H_2O \rightleftharpoons CoCl_2.6H_2O$
blue → pink



Advantages -

- only one waste product. (H_2O)
- No CO_2
- Produce high amount of energy.
- generates electricity.

Disadvantages:

- expensive
- hard to store and transport.
- risk of explosion

Industrial Chemistry

- Dealing with gases
  - Dry
  - collect
- Industry of
  - NH_3 — Haber process
  - H_2SO_4 — contact process
  - CO_3^{2-} — carbonate cycle
- Extraction of metals
  - Al
  - Fe
  - Zn
  - Cu

① Dealing with gas

Rxn → wet gas → dry → collect.

* collect gas:-

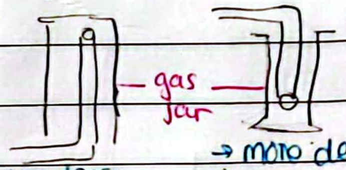
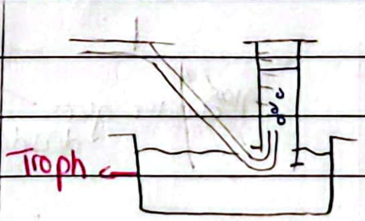
O_2 // $H_2O_{2(aq)} \xrightarrow{CuO} H_2O_{(l)} + O_{2(g)}$

H_2 // $Mg_{(s)} + HCl_{(aq)} \rightarrow MgCl_{(aq)} + H_{2(g)}$

NH_3 // $NH_4Cl_{(aq)} + NaOH_{(aq)} \xrightarrow{\Delta} NaCl_{(aq)} + H_2O_{(l)} + NH_{3(g)}$

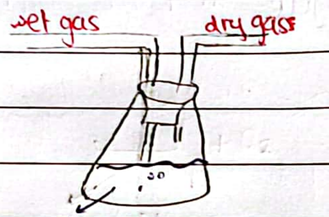
SO_2 // $Na_2SO_3 + HCl \xrightarrow{\Delta} NaCl_{(aq)} + H_2O_{(l)} + SO_{2(g)}$

CO_2 // $CaCO_{3(s)} + HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

Gas syringe	Delivery tube	Over water
	upward delivery / downward delivery  → less dense than air / → more dense than air	
- used to collect and measure the volume of any gas. - no mixing with other	- mix with air - can escape	- Only for insoluble gas

Drying Gases:-

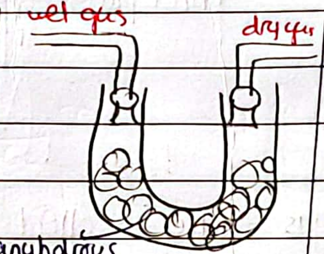
Concentrated H_2SO_4



conc. H_2SO_4 (becomes dilute)

-used to dry any gas except NH_3 → it neutralise the H_2SO_4. $NH_3 + H_2SO_4 \rightarrow \underset{\text{chemical}}{(NH_4)_2SO_4}$

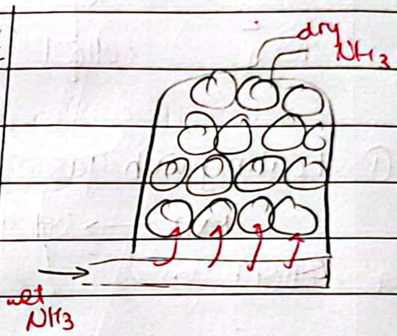
Anhydrous $CaCl_2$



anhydrous $CaCl_2$

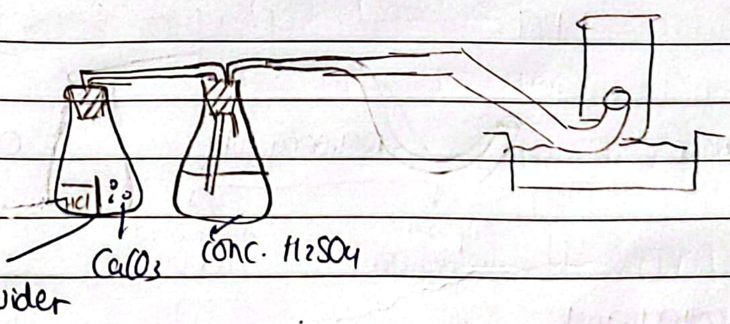
-used to dry any gas except ammonia

Calcium oxide



Q. Draw a suitable apparatus use to collect and measure volume of CO_2 gas from

$CaCO_{3(s)} + HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$ (CO_2 insoluble)



Industry of ammonia "Haber process" ⇒ prepare fertilizers

$$3H_{2(g)} + N_{2(g)} \xrightarrow{Fe} 2NH_{3(g)} \quad \Delta H = -ve.$$

How to obtain:-

① Nitrogen :- Fractional distillation of liquid air

⇓ Different b.p

⇓ cooling under high pressure.

② Hydrogen :- cracking of alkanes (organic)

2- $CH_{4(g)} + H_2O_{(g)} \rightarrow CO_{2(g)} + 3H_{2(g)}$

78% N_2
21% O_2
0.9% Ar
0.03% CO_2
0.01% H_2
0.06% others

Essential Conditions:-

1- Temp. 400-450°C

400°C — 450°C

less than:-

Adv:- - higher yield of NH_3
- shift forward to the exo Side

Disadv:- - slower rate
particles lose k.E, so less effective collisions per unit time.

more than: Disadv: - less yield
- shift backward to the endo side

Adv: faster yield

2- Pressure 200 atm

Adv:- - more yield of NH_3
shift forward to the side with fewer gas moles.
- faster rate

Disadv:-
- risk of explosion.
- expensive.

3- Fe catalyst

add excess H_2 and N_2
return back to convecter
Remove NH_3 immediatly
By cooling

Uses of ammonia:-

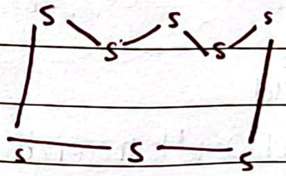
1- Fertilizers.
2- Cleaning detergents.
3- Smelling salts

* Industry of H_2SO_4 Contact Process

Stages:- $S \xrightarrow[+O_2]{(1)} SO_2 \xrightarrow[+O_2]{(2)} SO_3 \xrightarrow{(3)} H_2S_2O_7 \xrightarrow{(4)} H_2SO_4$

Roasting　　contact process　　oleum

- group (VI)
- valency 2
- yellow solid
- S_8



* SO_2 cause acid rain

* uses of SO_2

$SO_3 \xrightarrow{H_2O} H_2SO_4$
- Highly exothermic
- produce low yield of H_2SO_4

$SO_3 \xrightarrow{H_2SO_4} H_2S_2O_7 \xrightarrow{H_2O} H_2SO_4$

Uses: medicine
match
rubber

ore: * zinc blende ZnS
* from fossil fuel

→ Contact:-

$$\overbrace{2SO_{2(g)} + O_{2(g)}}^{3} \underset{endo}{\overset{V_2O_5 \quad exo}{\rightleftharpoons}} \overbrace{2SO_3}^{2} \qquad \Delta H = -ve$$

Essential conditions:

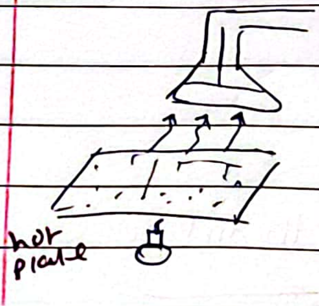
1- Temp 400 - 450°C

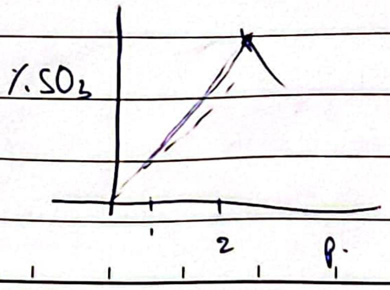
2- Pressure 2 atm "high pressure favour the forward rxn" (fewer gas moles)

2 atm gives max. yield of SO_3

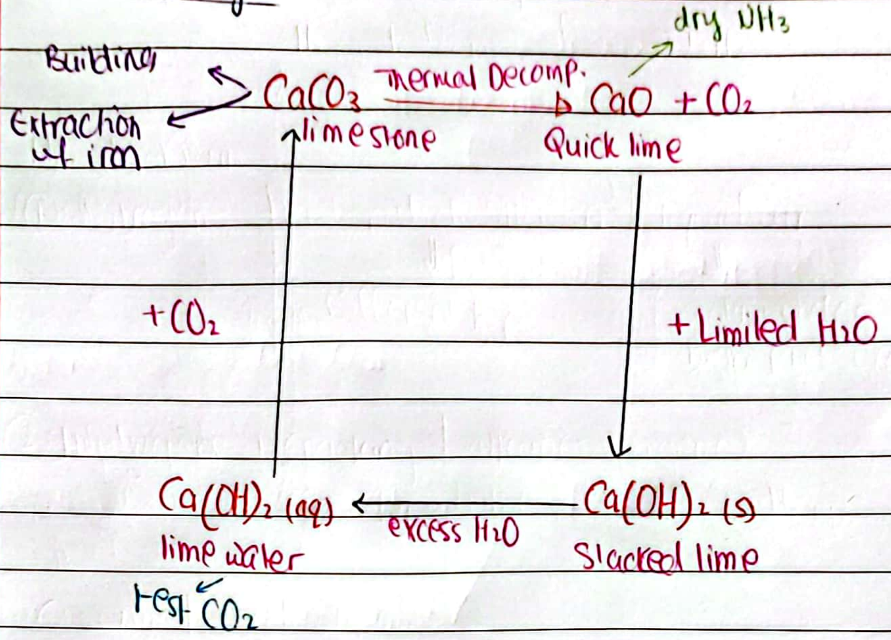
3- Catalyst V_2O_5 vanadium(V) oxide

→ Roasting

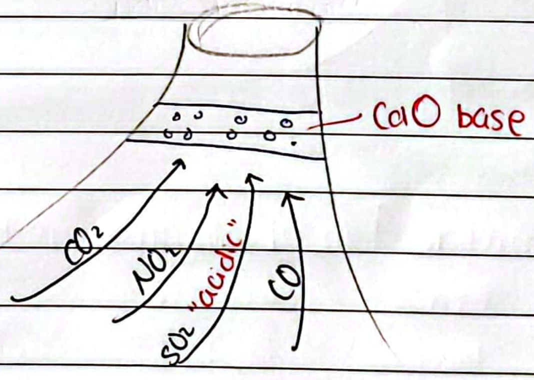




Carbonate Cycle:-



$$* \; Ca(OH)_{2\,(aq)} + CO_2 \longrightarrow CaCO_{3\,(s)} + H_2O$$



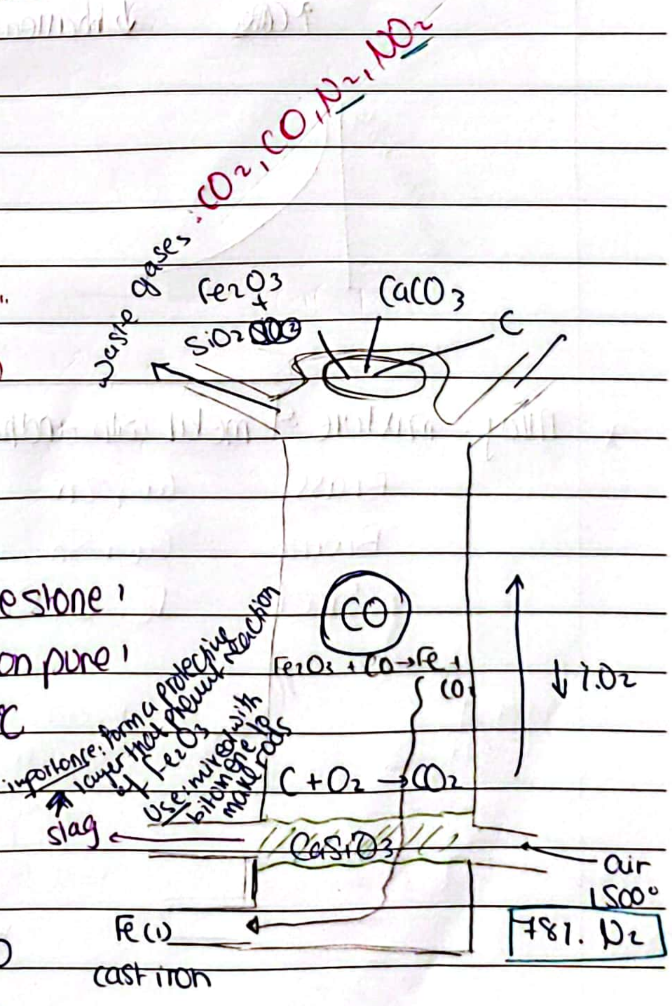
Extraction of Metals :-

K
Na
Li
Ca
Al] electrolysis Al_2O_3
C, CO
reduction by C, CO 'blast furnace' [Zn] ⇝ zinc blonde ZnS not included
Fe] Hematite, Fe_2O_3
Pb
H
Cu] Reduction by 'H_2' not included
Ag
Au
Pt

* Extraction of iron :-

ore : Fe_2O_3 "Hematite"
method : reduction by C, CO
place : blast furnace

Raw material : Fe_2O_3 mixed with
$CaCO_3$ 'limestone'
coke 'carbon pure'
air 1500 °C



redox • complete combustion : $C + O_2 \rightarrow CO_2$
redox • incomplete " : $2C + O_2 \rightarrow 2CO$
redox $CO_2 + C \rightarrow 2CO$
redox $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

Thermal Decomp.

$CaCO_3 \xrightarrow{heat} CaO + CO_2$

$CaO + SiO_2 \longrightarrow CaSiO_3$

base acid calcium silicate

slag

Steel Making "Oxygen Base Process"

cast iron

Fe

hot O_2

$CO_2 \uparrow$ ← C

$SO_2 \uparrow$ — S

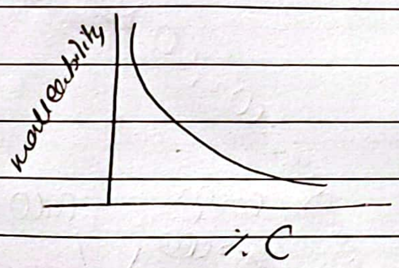
$SiO_{2(s)}$ ← Si

$P_2O_{5(s)}$ ← P

CaO

Steel % C in Steel
- mild steel 0.03% C "car bodies"
- medium steel 0.3% C "railways"
- stainless steel 3-5% C "cutters" watch

↑ C% ↓ malleability

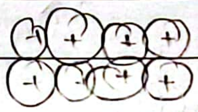


* Alloy: mixture of metal with another metal or semi-metal.

Brass	Cu, Zn
Bronze	Cu, Sn
Steel	Fe, C, Ni, Cr

Metal
Cu

Brass
Cu, Zn



harder
diff. size of metals

Extraction of zinc:

ore: zinc blende ZnS
method: reduction by C, CO
place: blast furnace

> C, CO and H_2 can only reduce the less reactive metal from its oxide

Step 1: Roasting with hot oxygen

$$ZnS + O_2 \longrightarrow ZnO + SO_2$$

Step 2:

$$C + O_2 \longrightarrow CO_2$$

$$2C + O_2 \longrightarrow 2CO$$

$$CO_2 + C \longrightarrow 2CO$$

$$CO + ZnO \longrightarrow Zn\cancel{CO} + CO_2$$

Temp inside furnace 1500°C
and b.p of zinc is 907 °C

→ so it produced as pure gas must condense.
and the other impurities since they have high b.p stay in the furnace.