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# Redox

| Reduction | Oxidation |
| --- | --- |
| lose O | gain O |

oxidation →
-3 -2 -1 0 1 2 3
← reduction

In terms of :-

| | Reduction | Oxidation |
| --- | --- | --- |
| 1) oxygen | lose O | gain O |
| 2) Hydrogen | gain : H | lose H |
| 3) oxidation state | decrease | increase |

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 $CO_2$

reduction: ~~Cu in CuO~~ ~~Zn in ZnO~~ Cu in CuO

$H_2 + CuO \longrightarrow Cu + H_2O$

oxidation $H_2$

---

reduction : $Cl_2$

$H_2S + Cl_2 \longrightarrow HCl + S$

oxidation: S in $H_2S$

reduction: Cu

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

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

## Rules for oxidation state

1) the oxidation state for any free element = zero

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

2) the oxidation number of any atom in a compound from

group 1 = +1

group 2 = +2

group 3 = +3 always +3 only for Al

group 7 = −1 always −1 only for F

3) oxidation number of Hydrogen (+1) except with metal in metal hydride (−1).

$\overset{+1}{CH_4}$, $N\overset{+1}{H_3}$, $\overset{+1}{Na}\overset{-1}{H}$, $\overset{+2}{Ca}\overset{-1}{H_2}$

4) oxidation state of oxygen (−2)

except in peroxide (−1)

except in $OF_2$ (2+)

$O^{2-}$ oxide $\quad O_2^{-2}$ peroxide

Sodium oxide $Na^{+1}$ $O^{-2} \longrightarrow Na_2\overset{-2}{O}$

Sodium peroxide $Na^{+1}$ $O_2^{-2} \longrightarrow Na_2\overset{-1}{O_2}$

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$\overset{2-}{H_2O}$ — water

$H_2\overset{-1}{O_2}$ — Hydrogen peroxide

Calcium oxide: $Ca^{+2}$ $O^{-2}$ → CaO

calcium peroxide: $Ca^{+2}$ $O_2^{-1}$ → $CaO_2$

5) the sum of all oxidation state
in a compound = 0
in an ion = charge of this ion

$\overset{+1}{Na}Cl$ : $+1+x=0 = \boxed{x=-1}$

$\overset{+1}{H}Cl\overset{2-}{O}$ : $+1+x=0 = x-1=0 = \boxed{x=+1}$

$\overset{+1}{H}Cl\overset{-2}{O_2}$ : $+1+x+2(-2)=0 = 1+x-4=0 = \boxed{x=+3}$

$N\overset{+1}{H_3}$ : $N+3(+1)=0 = N+3=0 = \boxed{N=-3}$

$NO^{-2}$ : $N+(-2)=0 = \boxed{N=+2}$

$N_2\overset{-2}{O_5}$ : $2N+5(-2) = 2N-10 = \frac{2N}{2}=\frac{10}{2} = \boxed{N=+5}$

$H_2SO_4$ : $2(+1)+S+4(-2)=0 = 2+S-8=0 = S-6=0 = \boxed{S=+6}$

$\overset{-1}{H_2}S$ : $2H+S=0 = 2+S=0 = \boxed{S=2}$

$SO_3 = S+3(-2) = S-6=0$ $\boxed{S=-6}$

$NO_3^{-1}$ : $N+3(-2)=-1 = N-6=-1$, $+6$ $+6$ $= \boxed{N=+5}$

$MnO_4^{-1}$ : $Mn-8=-1$, $+8$ $+8$ $= \boxed{Mn=+7}$

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$SO_3^{-2}$ $S - 6 = -2$ (+6, +6) $= \boxed{S = +4}$

$Cr_2O_7^{-2}$ $2(Cr) - 14 = -2$ (+14, +14) $= \frac{2Cr}{2} = \frac{+12}{2}$ $\boxed{Cr = +6}$

Q - find the oxidation ~~time~~ state of each underlined species

$Fe_2O_3$ $2Fe + -6 = 0$ (+6, +6) $= \frac{2Fe}{2} = \frac{6}{2}$ $= \boxed{Fe = 3}$

$OF_2$ $O + -2 = 0$ (+2, +2) $= \boxed{O = 2}$

$SO_4^{-2}$ $S + -8 = -2$ (+8, +8) $= \boxed{S = +6}$

$V_2O_5$ $2V + -10 = 0$ (+10, +10) $= \frac{2V}{2} = \frac{10}{2}$ $= \boxed{V = +5}$

$PO_4^{-3}$ $P + -8 = -3$ (+8, +8) $= \boxed{P = +5}$

$CrO_4^{-2}$ $Cr + -8 = -2$ (+8, +8) $= \boxed{Cr = +6}$

$CO$ $C + -2 = 0$ (+2, +2) $= \boxed{C = +2}$

$CO_2$ $C + -4 = 0$ (+4, +4) $= \boxed{C = +4}$

$CO_3^{-2}$ $C + -6 = -2$ (+6, +6) $= \boxed{C = +4}$

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0 +3 −2 → +3 −2 0

* $Al + Fe_2O_3 \longrightarrow Al_2O_3 + Fe$

oxidation : $Al \longrightarrow Al^{+3}$

reduction : $Fe^{+3} \longrightarrow Fe$

+2 −2 +2 −2 → 0 +4 −2

* $CO + ZnO \longrightarrow Zn + CO_2$

oxidation : $C^{+2} \longrightarrow C^{+4}$

reduction: $Zn^{+2} \longrightarrow Zn$

+1 −2 0 → +1 −1 0

* $H_2S + Cl_2 \longrightarrow HCl + S$

oxidation: $S^{-2} \longrightarrow S$

reduction: $Cl_2^{0} \longrightarrow Cl^{-1}$

+7 −2 +2 +1 → +2 +3 +1 −2

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

oxidation: $Fe^{+2} \longrightarrow Fe^{+3}$

reduction: $Mn^{+7} \longrightarrow Mn^{+2}$

+6 −2 +2 +1 → +3 +4 +1 −2

* $Cr_2O_7^{-2} + Sn^{+2} + H^{+} \longrightarrow Cr^{+3} + Sn^{+4} + H_2O$

oxidation: $Sn^{+2} \longrightarrow Sn^{+4}$

reduction: $Cr^{+6} \longrightarrow Cr^{+3}$

+1 5+ −2 +1 −1 → +1 −1 +1 5+ −2

* $AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$ (Not redox)

~~oxidation:~~

~~reduction:~~

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writing balanced half ionic equation:-

1) atoms

2) the change: by adding é s to the side with greater charge by the difference.

0 2+ -1 2+ -1 0

$Ca + ZnCl_2 \longrightarrow CaCl_2 + Zn$

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

H.O.R $Zn^{+2} 2é \longrightarrow Zn$

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

-2 0 -1 0

$H_2S + Cl_2 \longrightarrow HCl + S$

H.O.O $S^{-2} \longrightarrow S + 2é$

H.O.R $Cl_2 + 2é \longrightarrow 2Cl$

overall rxn : $S^{-2} + Cl_2 \longrightarrow S + 2Cl$

0 +1 -1 +1 -1 0

$Na + HCl \longrightarrow NaCl + H_2$

H.O.O $(Na \longrightarrow Na^{+1} + 1é) \times 2$

H.O.R $2H + 2é \longrightarrow H_2$

overall rxn: $2Na + 2H^{+1} \longrightarrow 2Na^{+1} + H_2$

0 +1 -1 3+ -1 0

$Al + HCl \longrightarrow 2AlCl_3 + H_2$

H.O.O $(Al^0 \longrightarrow Al^{+3} + 3é)$

H.O.R $(2H^{+1} + 2é \longrightarrow H_2)$

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

0 +3 -1 +2 -1 0

$Ca + AlCl_3 \longrightarrow CaCl_2 + Al$

H.O.O $(Ca \longrightarrow Ca^{+2} + 2e^-) \times 3$

H.O.R $(Al^{+3} + 3é \longrightarrow Al) \times 2$

overall rxn $3Ca + 2Al^{+3} \longrightarrow 3Ca^{+2} + 2Al$

Oxidation $\longrightarrow$ lose é reduction $\longrightarrow$ gain é OIL RIG

+7 -2 -1 2+ + +2 3+ +1 -2

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

H.O.O $(Fe^{2+} \longrightarrow Fe^{+3} + 1é) \times 5$

H.O.R $Mn^{+7} + 5é \longrightarrow Mn^{+2}$

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

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

H.O.O $(Sn^{+2} \longrightarrow Sn^{+4} + 6e^-) \times 3$

H.O.R $(Cr^{+6} + 6e^- \longrightarrow Cr^{+3}) \times 2$

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

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## oxidising agent and redusing agent

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 substances to be reduced.

If the substance is an ion in a compound the agent is the compound itself.

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

oxidation Al — reducing agent Al

reduction $Fe^{+3}$ — oxidising agent $Fe_2O_3$

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

oxidation $C^{+2}$ — reducing agent CO

reduction $Zn^{+2}$ — oxidising agent ZnO

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

oxidation $Cl_2$ reducing agent $Cl_2$ — reductant: $H_2S$

reduction $S^{-2}$ oxidising agent $H_2S$

$\overset{+7}{MnO_4^{-1}} + Fe^{2+} + H^{+} \longrightarrow Mn^{+2} + Fe^{+3} + H_2O$

oxidising agent $MnO_4^{-1}$ — reductant $Fe^{2+}$

oxidation: $Fe^{+2}$ — reduction: $Mn^{+7}$

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most common oxidising agent

1) oxygen $\overset{0}{Fe} + \overset{0}{O_2} \rightarrow \overset{+3}{Fe_2}\overset{-2}{O_3}$ $\overset{0}{S} + \overset{0}{O_2} \rightarrow \overset{+4}{S}\overset{-2}{O_2}$

2) Acidify pottassium manganate $KMnO_4 / H^+$ $MnO_4^{-1} \rightarrow Mn^{+2}$
(+7) purple → (+2) colorless

3) Acidify potassium dichromate $K_2Cr_2O_7 / H^+$ $Cr_2O_7^{-2} \rightarrow Cr^{+3}$
(+6) orange → (+3) green

4) Halogens $2\bar{e} + Cl_2 \rightarrow 2Cl^-$ (green → yellow)
$2\bar{e} + Br_2 \rightarrow 2Br^-$ (red brown)
$2\bar{e} + I_2 \rightarrow 2I^-$
colorless solution
purple gas / red brown solution.

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most common reducing agent

1) Hydrogen

2) carbon and carbon monoxide $\overset{0}{C} + \overset{+3}{Fe_2}O_3 \rightarrow \overset{0}{Fe} + \overset{2+}{C}O$ $\overset{+2}{Zn}O + CO \rightarrow CO_2 + \overset{0}{Zn}$

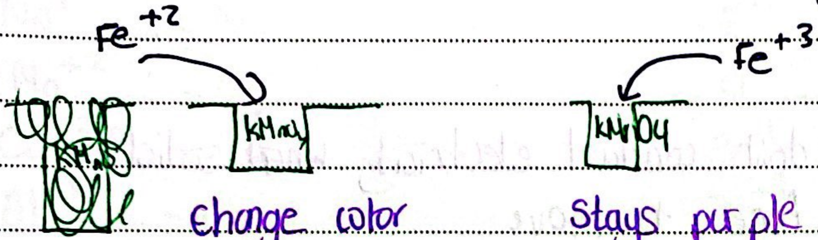
3) ~~Metals~~ iodide $2I^- \rightarrow I_2 + 2\bar{e}$
colorless red-brown.

4) metals K, Na, Li, Ca, Mg, Al, (C, CO), Zn, Fe, Pb, H, Cu, Ag

As you go up the reactivity series metals get more reactive, more likely to lose ē, more likely to oxodise, more likely to be a reducing agent.

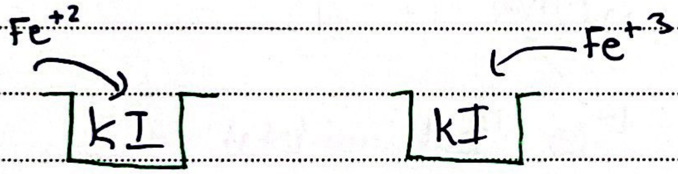
Q:- $Fe^{2+}$ is a reducing agent
$Fe^{+3}$ is an oxidising agent
Record the observation in each of the following reaction

1)



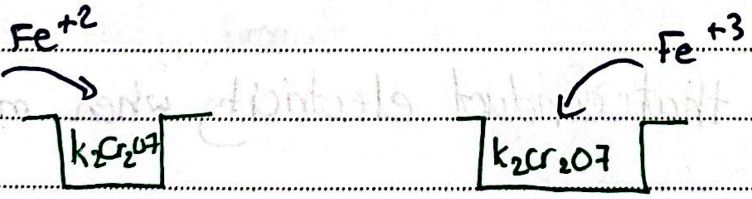

Change color from purple to colorless — Stays purple

2)




Stays colorless — red brown

3)




change color from orange to green — no change

# Electrolysis

Electro | lysis
electricity | Analysis "Breakdown"

Electrolysis: Breaking down chemical ~~reaction~~ compound (Ionic) when molten or aqueous by passing electricity

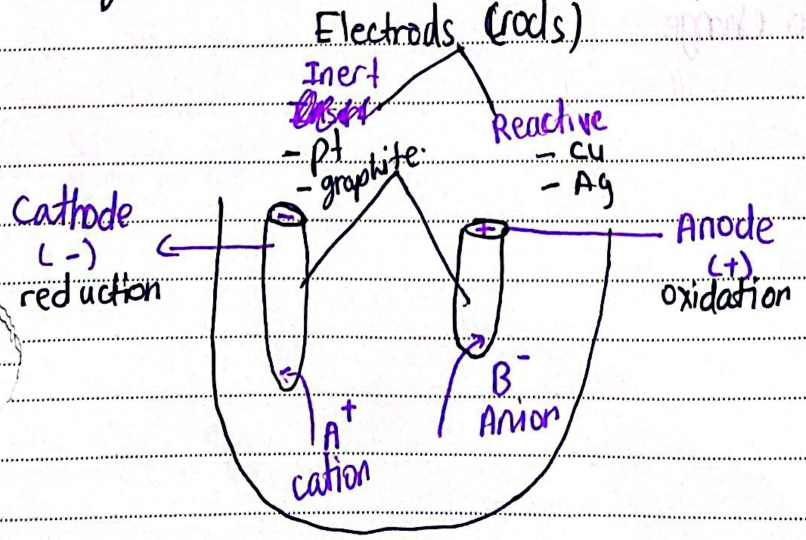
- why ~~are the~~ ionic compounds don't conduct electricity when solid?
  the ions are not free to move

- why the ionic compounds conduct electricity when dissolve in water or being molten?
  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 molten or aqeous.




Cathode: the -ve rod that attracts the +ve Ions where the reduction occurs.

Anode: the +ve rod that attracts the -ve ions where the oxidation occurs.

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Electrolysis = discharge Ion → element

| | |
|---|---|
| K | Cu |
| Na | Ag |
| Li | Au |
| Ca | |
| Mg | |
| Al | |
| Zn | |
| Fe | |
| Pb | |
| H | |

cations

$1\bar{e} + Na^{+} \rightarrow Na$

$2\bar{e} + Mg^{+2} \rightarrow Mg$

$2\bar{e} + Ca^{+2} \rightarrow Ca$

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

$2\bar{e} + 2H^{+} \rightarrow H^{2}$

Anions

$2F^{-1} \rightarrow F_2 + 2\bar{e}$

$2Cl^{-1} \rightarrow Cl + 2\bar{e}$

$2Br^{-1} \rightarrow Br_2 + 2\bar{e}$

$2I^{-1} \rightarrow I_2 + 2\bar{e}$

$2O^{-2} \rightarrow O_2 + 4\bar{e}$

Electrolysis for molten electrolyte using Inert rods (graphite)

$NaCl_{(L)}$

total ion $Na^{+1}$ $Cl^{-1}$

Cathode anode

Electrolyte: used up.

$\bar{e} + Na^{+1} \rightarrow Na$ $\quad {}_2Cl^{-1} \rightarrow Cl_2 + 2\bar{e}$ (bubbles of green yellow gas)

molten lead (II) bromide

$PbBr_2 (l)$

total ion $Pb^{+2}$ $Br^{-1}$

cathode Anode

Electrolyte: used up.

$2\bar{e} + Pb^{+2} \rightarrow Pb$ (deposite of metals) $\quad {}_2Br^{-1} \rightarrow Br_2 + 2\bar{e}$ (Bubbles of red brown gas)

$CuCl_2$

$Cu^{+2}$ $Cl^{-1}$

Cathode Anode

Electrolyte: used up.

$2\bar{e} + Cu^{+2} \rightarrow Cu$ $\quad {}_2Cl^{-1} \rightarrow Cl_2 + 2\bar{e}$

deposite of metals bubbles of green yellow gas.

/ /

$Al_2O_3$ (l) / graphite

Electrolyte: used up

| cathode | Anode |
|---|---|
| $Al^{+3}$ | $O^{-2}$ |
| $3\bar{e} + Al^{+3} \rightarrow Al$ | $2O^{-2} \rightarrow O_2 + 4\bar{e}$ |
| deposite of metals | bubbles of colorless gas |

## At the anode.

Always $OH^-$ except concentrated halide ($Cl^-$, $Br^-$, $I^-$)

when the halide oxidise

$2Cl^- \rightarrow Cl_2 + 2\bar{e}$

when $OH^-$ oxidise

$4OH \rightarrow 2H_2O + O_2 + 4\bar{e}$ → Bubbles of colorless gas.

Concentrated NaCl / graphite

Electrolyte: NaOH

| cathode | anode |
|---|---|
| $Na^{+1}$, $H^+$ | $Cl^-$, $OH^-$ |
| $2\bar{e} + 2H^+ \rightarrow H_2$ | $2Cl^- \rightarrow Cl_2 + 2\bar{e}$ |
| bubbles of colorless gas | bubbles of green yellow gas. |

/ /

$CuSO_4(aq)$ / graphite

Electrolyte: ~~dil~~ $H_2SO_4$

$Cu^{+2}$      $SO_4^{-2}$

$H^+$      $OH^-$

Cathode      Anode

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

---

dilute $NaCl_{(aq.)}$ / graphite

Electrolyte: $NaCl$

$Na^+$      $Cl^-$

$H^+$      $OH^-$

Cathode      Anode

$2\bar{e} + 2H^+ \rightarrow H_2$      $4OH^- \rightarrow 2H_2O + O_2 + 4\bar{e}$

bubbles of colorless gas      bubbles of colorless gas

---

Concentrated $KI_{(aq.)}$ / graphite

Electrolyte: $KOH$

$K^+$      $I^-$

$H^+$      $OH^-$

cathode      Anode

$2\bar{e} + 2H^+ \rightarrow H_2$      $2I^- \rightarrow I_2 + 2\bar{e}$

bubbles of colorless gas      ~~bubbles of~~ red brown ~~gas~~

/ /

Concentrated $CuCl_{2(aq)}$ /graphite

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

$H^+$ $OH^-$

cathode Anode

$2\bar{e} + Cu^{+2} \rightarrow Cu$ $2Cl^- \rightarrow Cl_2 + 2\bar{e}$

deposit of red brown bubbles of green yellow gas

Concentrated sodium chloride called brine solution.

$NaCl_{(aq)}$ Electrolyte: NaOH

$Na^+$ $Cl^-$

$H^+$ $OH^-$

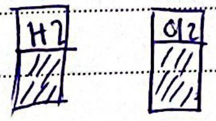
cathode Anode

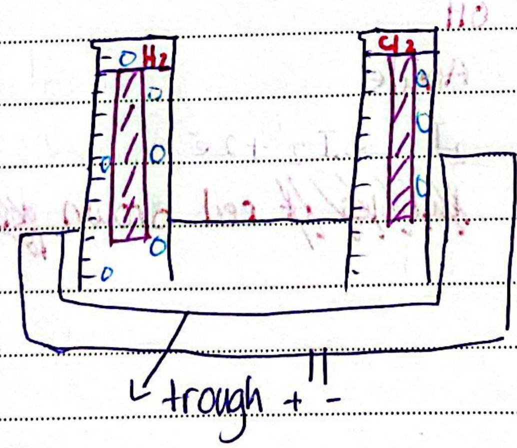
$2\bar{e} + 2H^+ \rightarrow H_2$ $2Cl^- \rightarrow Cl_2 + 2\bar{e}$

colorless gas bubbles of green yellow gas

Q1: plan an experiment to collect and measure the volume of $H_2$ and $Cl_2$ produced

the final appearance of the two measuring cylinders.



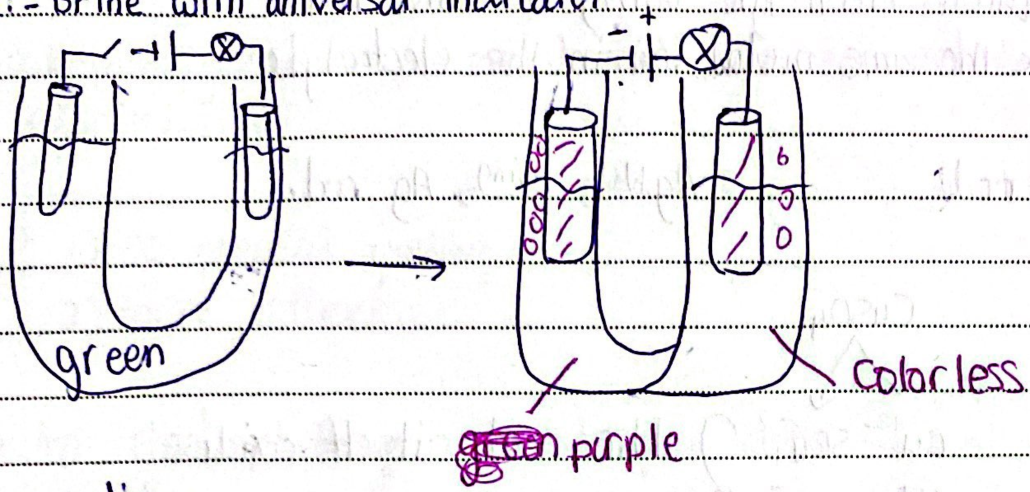

half of oxide: $2Cl^- \rightarrow Cl_2 + 2\bar{e}$

half of reduction: $2H^+ + 2\bar{e} \rightarrow H_2$

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

1 : 1

Q2:- Brine with universal indicator




· observation:-

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 ~~anode~~ cathode the solution becomes purple because NaOH is an alkali.

5 - Around the anode the solution becomes colorless since $Cl_2$ bleaches the col

* The $Cl_2$ not immediatly appear as $H_2$ produce? Some $Cl_2$ dissolve in solution.

/ /

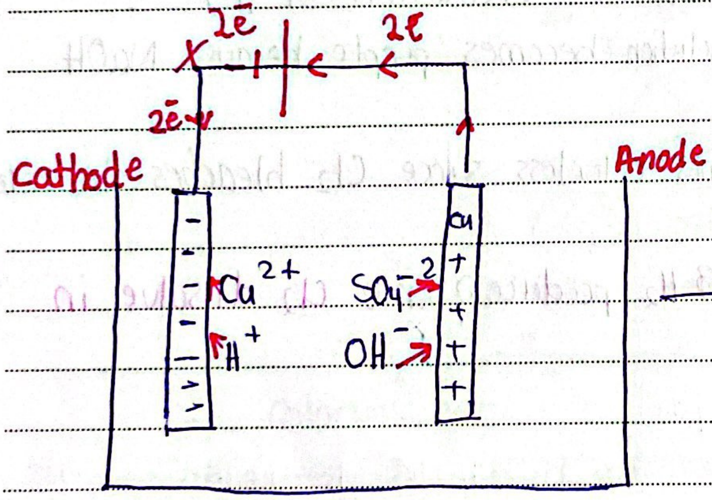
Electrolysis for aqueous electrolyte using an active rod.
* the rod must be the same metal ion in the electrolyte.

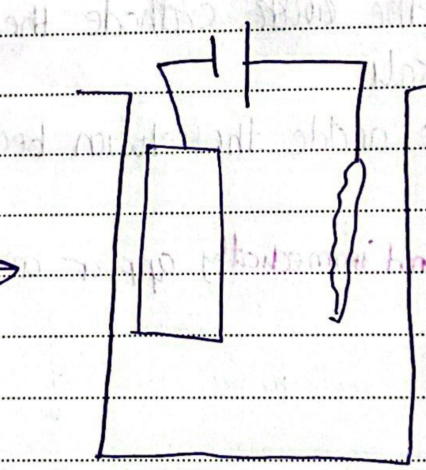
$CuSO_4$ $\xrightarrow{using}$ Cu rod          $AgNO_3$ $\xrightarrow{using}$ Ag rod.

$CuSO_4$

$Cu^{+2}$  $SO_4^{-2}$
$H^+$  $OH^-$
Cathode  Anode } the anode itself oxidise

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



| Cathode | Anode |
|---|---|
| ↑ mass | ↓ mass |
| cu deposite | oxidise by losing ēs. |

* Electrolyte:-
- stays the same concentration
* the anode oxidised and replace the $Cu^{+2}$ in the electrolyte with the same rate.

/ /

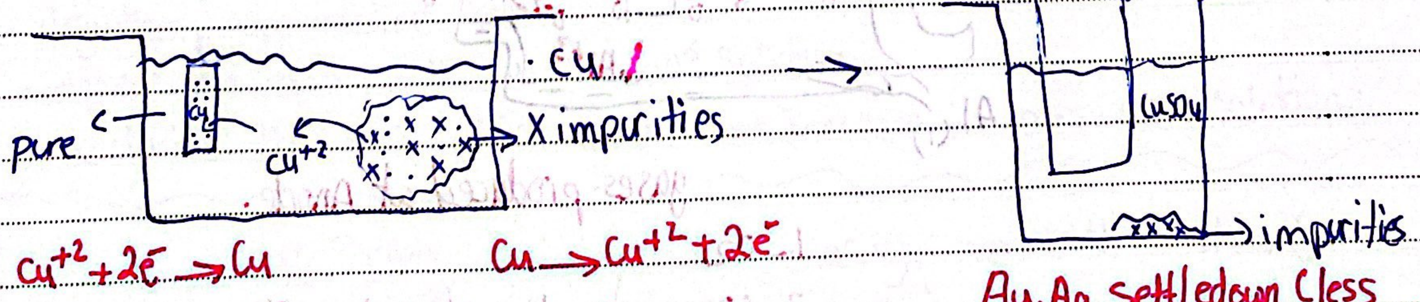
Electroplating: coating a metal with another metal using electrolysis or electricity

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 a sand paper to insure a good sticking.

2- make the spoon the cathode
3- The Anode must be Ag
4- the ~~element~~ electrolyte must ~~be~~ contain Ag eg. $AgNO_3$
5- turn on the ccut be sure that the spoon is fully immersade in the electrolyte.
6- Rotate the spoon to insure ~~the~~ an equal distribution.
7- rinse the distiled water
8- dry in oven.

② purifying metals / Refinning copper




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

Au, Ag settledown (less reactive)

$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

Extraction of metals from its (ores)

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

Electrolysis / molten / graphite

| | | | |
|---|---|---|---|
| K | reduction by | Zn | → ($ZnS$) Zincblende |
| Na | C, CO | Fe | → ($Fe_2O_3$) Hemutite |
| Li | | pb | |
| Ca | | H | |
| Mg | | [Cu] | → ($CuS$) Copper(II) sulphide. |
| Al | | Ag | |
| Cl | | Au | |
| | | reduction by $H_2$ | |

Al → Bauxite ($Al_2O_3$)

Extraction of aluminium

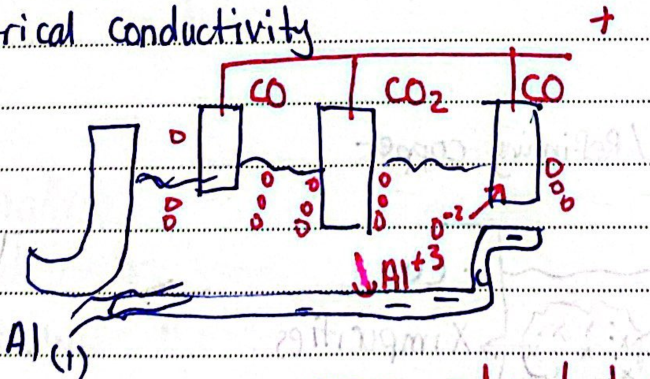
Ore: $Al_2O_3$ Bauxite

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 $Na_3AlF_6$

- to lower the m.p to 900°c so less cost
- to increase the electrical conductivity




gases produced at Anode.

1- $O_2$

2- $CO_2$ ] reaction of rods with $O_2$, so we

3- CO ] must ~~reduce~~ replace them periodically.

/ /

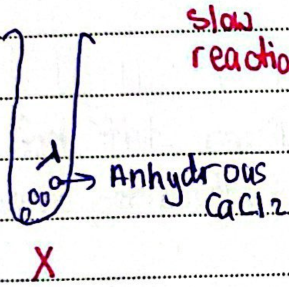
| property | use |
| --- | --- |
| - low density | Aircraft bodies |
| - ductiles | electrical wires |
| - malleable | window frame / cooking utensils. |
| - conduct electricity | wires |
| form an oxide layer which is not toxic. | Food cans |

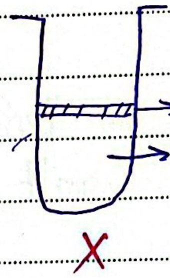
← for aluminium

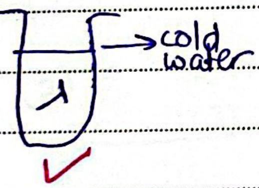
reaction of iron from both $O_2$ and $H_2O$

Rust ↗ → slow reaction

$Fe + O_2 \xrightarrow{H_2O} Fe_2O_3.nH_2O$ (brown)




plan an experiment to show which rust prevention solution is better

- Take a known mass of Iron nail, apply a known volume of the first solution.
- put them in ~~the first solution~~ a known volume of water for 1 week.
- dry them and measure them again.
- repeat the experiment with the 2nd solution.

conclusion: the exp. which cause more increase in mass worse solution.

How to prevent rusting: - paintings, oiling, greasing, cover with plastic. (to prevent $O_2$ and $H_2O$ from reaching the iron.)

For long term: - galvanizing, Sacrificial protection

galvanizing ↓ coat with zinc

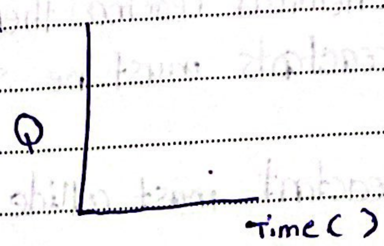
Sacrificial protection ↓ connecting with magnesium

/ /

1) Zn and Mg are more reactive than Fe. 2) more likely to oxidise. 3) more likely to lose $\bar{e}$. 4) So Fe is less likely to rust.

# Rate of reaction

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

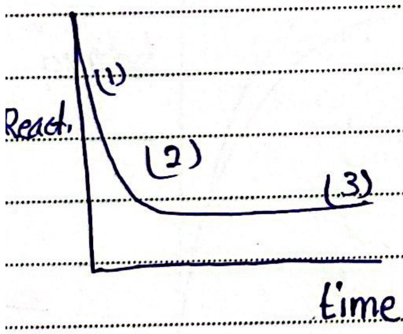



| | | | | | |
|---|---|---|---|---|---|
| $\frac{\Delta \text{mass}}{\Delta \text{Time}}$ | $\frac{\Delta \text{conc}}{\Delta \text{Time}}$ | $\frac{\Delta \text{pH}}{\Delta \text{Time}}$ | $\frac{\Delta \text{volume}}{\Delta \text{Time}}$ | $\frac{\Delta \text{Temp.}}{\Delta \text{Time}}$ | $\frac{\Delta \text{height of ppt}}{\Delta \text{Time}}$ |

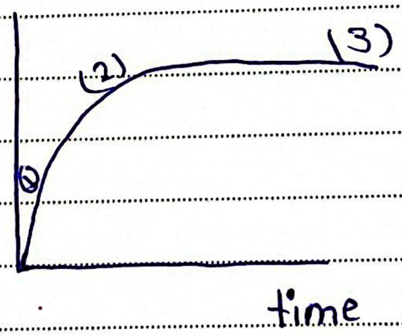
measure the rate of reaction

How fast the reactants consumed per unit time.

How fast the product produced per unit time.




products



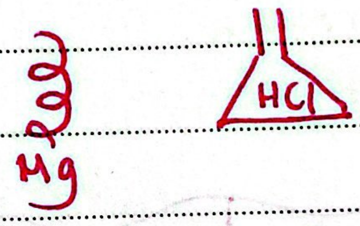

region (1): fastest rate ⇒ from the graph, steepest, More amount of reactants more particles, more effective collisions per unit time.

region (2)
slower rate ⇒ from the graph, less steep, less number of particles, so less number of effective collisions / unit time.

region (3)
reaction is over ⇒ gradient = 0, no more limitting factor so no more effective collisions.

for any chemical reaction there are three main Conditions :-

1) the reactants must be suitable $Cu + HCl \rightarrow$ no rxn

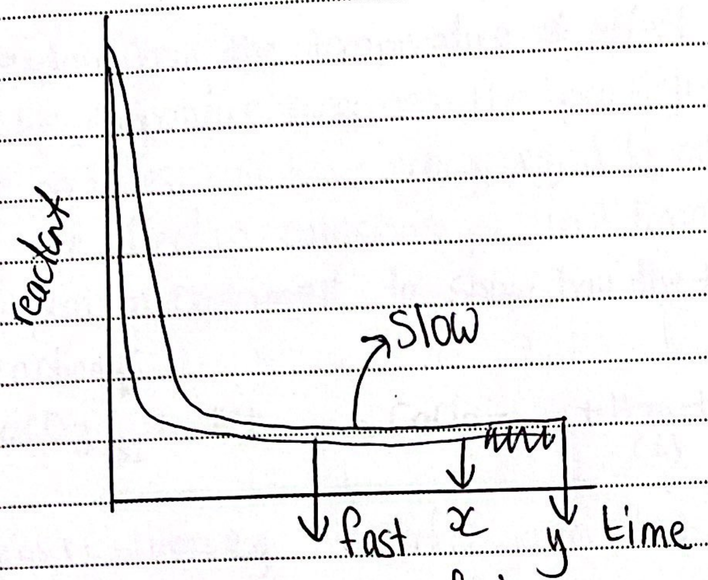
2) the reactant must collide 

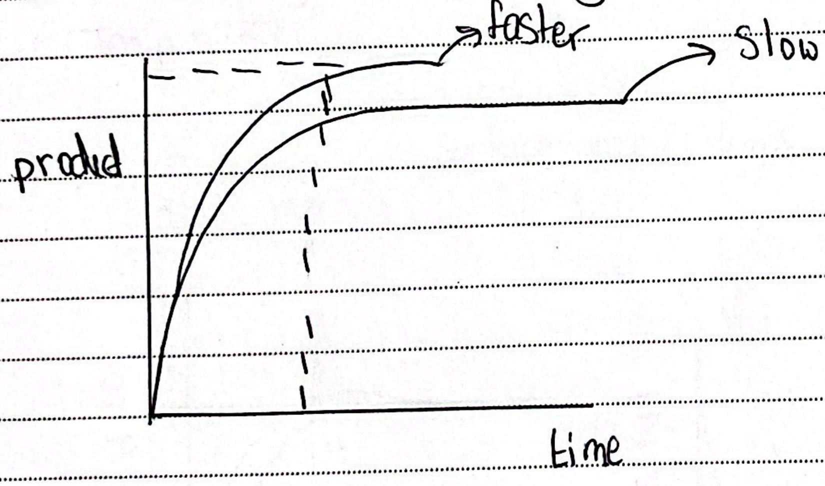
3) the collisions must be effective/min amount of energy to start the rxn (activation energy)

propane and $O_2$

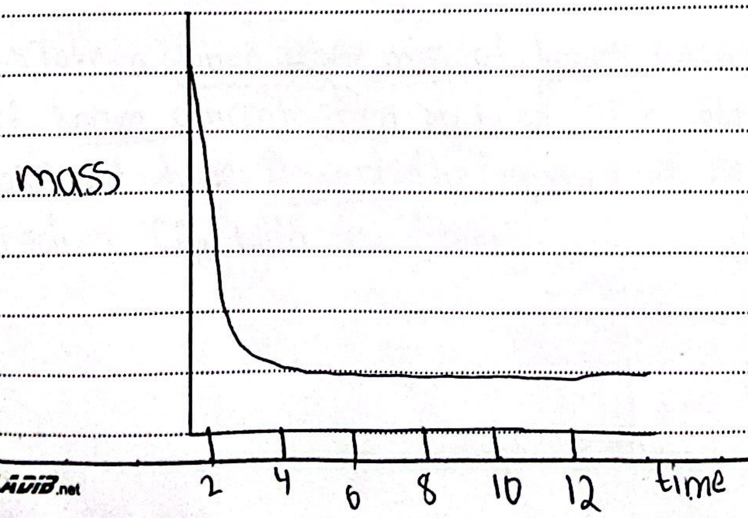
Increasing rate of reaction
- → more product per same period
- → Same product per less time

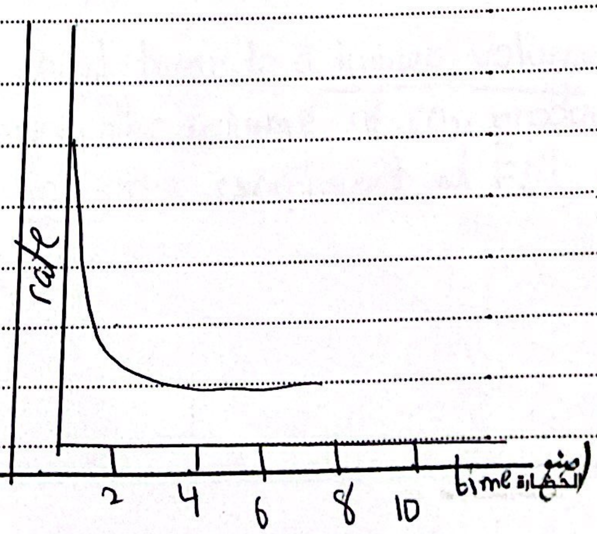
] steeper curve




- The graph shows how the amount of reactant changes with time



/ /

① Temperature

*State how the temperature affect the rate of reaction.

AS the temperature increase, rate of reaction increases.

*explain how the temperature ~~of~~ affect the rate of reaction

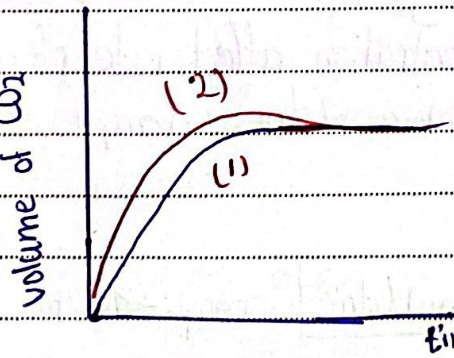
As the temperature increases the particles gain k.E so move faster particles, the particles will have energy equal to or greater than the activation energy (Ea). So more effective collisions per unit time so faster rate of reaction.

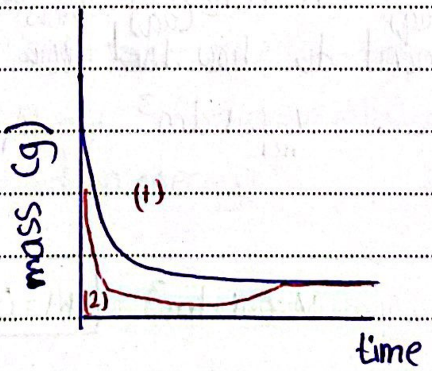
* plan an experiment to show how the temperature affect the rate of reaction.

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

exp 1 mass: 2g Surface area: Lumps $V_{HCl} = 0.1 dm^3$ $M_{HCl} = 1 mol/dm^3$
Temp = 25°c

exp 2 mass: 2g Surface area: lumps $V_{HCl} = 0.1 dm^3$ $M_{HCl} = 1 mol/dm^3$
Temp: 50°c




*Take a known ~~volume~~ mass of lumps $CaCO_3$, add them to a known volume of known concentration HCl at 25°C. Measure the volume of $CO_2$ produced per unit time. Repeat the experiment at 50°c, the experiment at 50°c produce $CO_2$ with less time.

2) Surface area

* State how the surface area affect the rate of reaction.

As the surface area increases rat of reaction increases

* explain how the surface area affect the rate of reaction

As the surface area increases more particles exposed to the reaction, more effective collisions per unit time so faster rate.

3) concentration "amount"

* State how the concentration affect the rate of reaction

As the concentration increases the rate of reaction increases.

* explain how the concentration affect the rate of reaction

As the concentration increase, more particles so more effective collision per unit time so faster rate of reaction.

need 0.005 (add 0.02)

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

(HCl: 0.01, 0.01; n = 0.005, V = 0.12)

* plan an experiment to show that how concentration affect rate of rxn.

exp 1 mass: 2g, $V_{HCl} = 0.1\ dm^3$, $M_{HCl} = 0.1\ mol/dm^3$, Temp = 25°C

Surface area = lumps

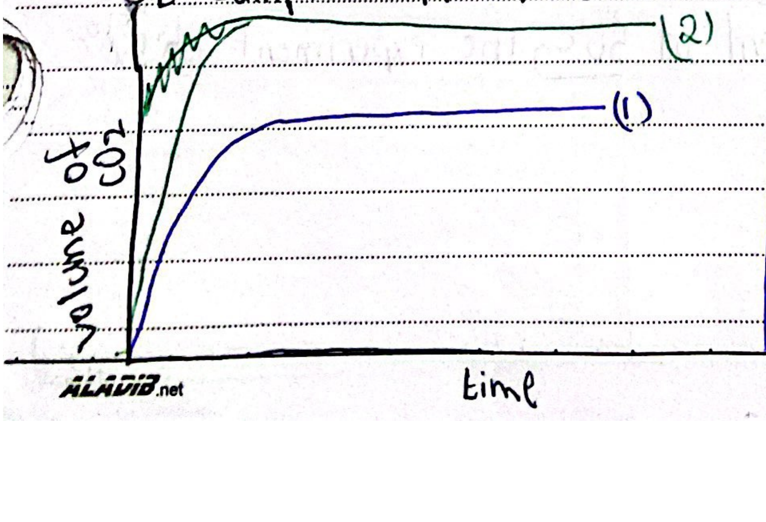
Mr = 100

exp 2 mass: 2g, $V = 0.1\ dm^3$, $M = 0.2\ mol/dm^3$, Temp = 25°C

S.E = Lumps

exp 3 mass: 4g, $V = 0.1\ dm^3$, Temp: 25°C

S.E = Lumps, $M = 0.1\ mol/dm^3$




more limitting → faster rate, more product.

more excess → faster rate.

/ /

4) pressure:- "only affect the gas"

* explain how the pressure ~~decreases~~ affect the rate of reaction

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

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

5) Light "only for photochemical reaction" reaction that need light to occur

$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$ eg:- photosynthesis.

eg 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 rate of reaction without being used up.

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

↓ activation energy.

The reaction $2H_2O_{2(aq)} \xrightarrow[\text{② } MnO_2]{\text{① } CuO} 2H_2O_{(l)} + O_{2(g)}$

1) plan an experiment show that CuO is a catalyst for this reaction.

Known volume with a known conc. of $H_2O_2$, measure the volume of $O_2$ produced per unit time. Repeat the exp. using CuO. The experiment using CuO will produce more $O_2$ per unit time

↓ the same

2) plan an experiment to show ~~That~~ which of the two catalyst is better $CuO$ or $MnO_2$

Same as Q1 + Same mass of catalyst.

measure the mass of copper oxide ($CuO$) add to $H_2O_2$ until no more fizzes, filter the mixture. Dry the solid in oven, remeasure the mass-

* Same intial and final mass.

3) plan an experiment to show that $CuO$ is not used up during the reaction.

# Reversible reaction

## Types of chemical reaction

**one way**

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

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

$Mg + HCl \rightarrow MgCl_2 + H_2$

**both ways.**

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

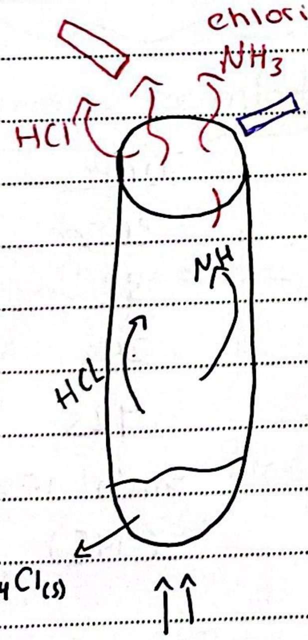
$NH_4Cl_{(s)} \rightleftharpoons NH_{3(g)} + HCl_{(g)}$

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

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

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

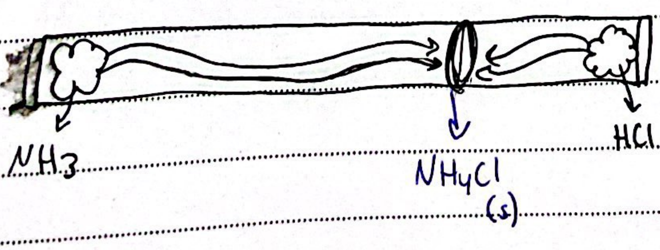
Ammonium chloride — Ammonia — Hydrogen chloride



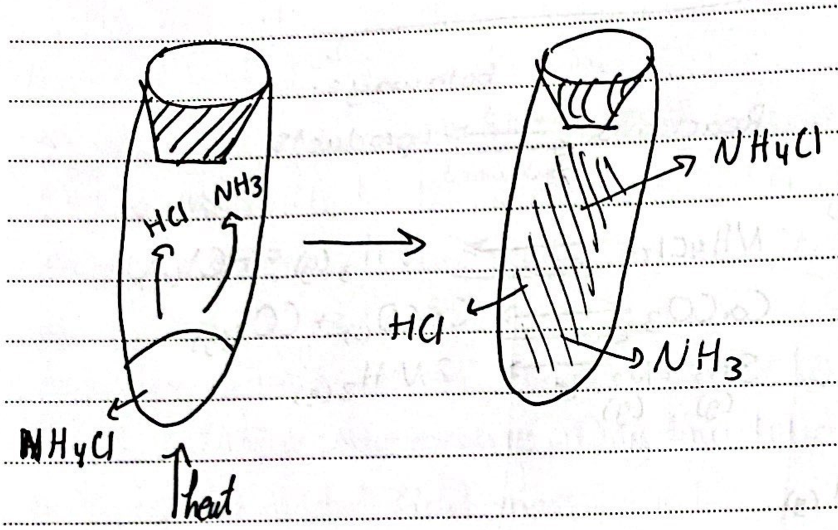

Q:- which damp litmus paper will change its color first, why? [3]

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

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



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

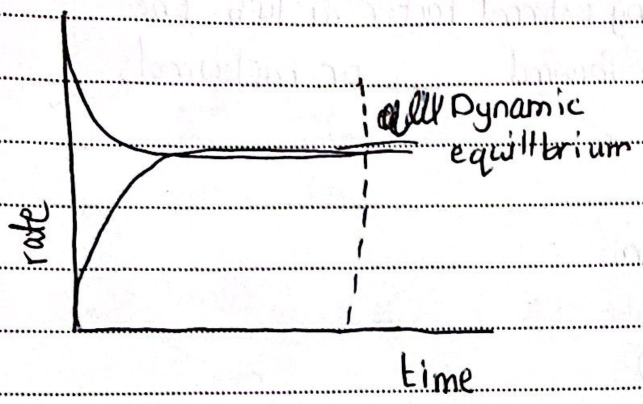



Experiment

| volume of $Na_2S_2O_3$ | $H_2O$ | HCl | Time |
|---|---|---|---|
| 50 | 0 | 10 | 30 sec |
| 40 | 10 | 10 | 32 s |
| 35 | 15 | 10 | 39 s |
| 30 | 20 | 10 | 42 s |
| 10 | ~~25~~ 40 | 10 | 3 min 15 s (195) |

/ /

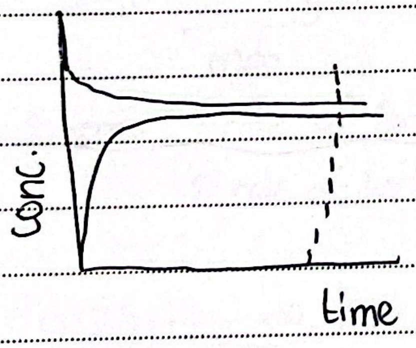
In terms of rate.

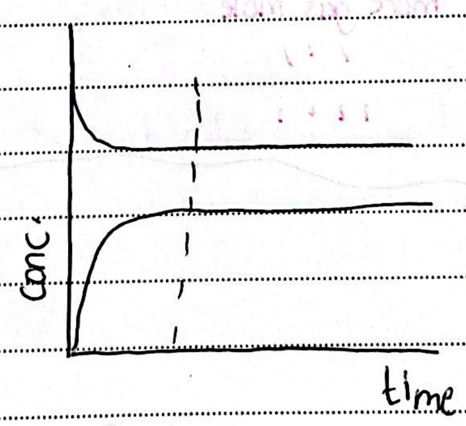


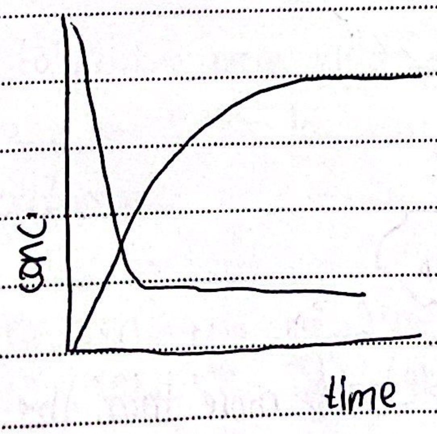

the rate of forward decrease, less reactants so less particles, so less effective collisions per unit time. As for the rate of Backward ↑ decreases, more products so more effective collisions ↓ and more particles per unit time

in terms of concentration

Just know the definition

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Le Chatelier principle,

if the system at equillibrium ⟶ and any external factor disturb the equil. the equil. can shift itself either ⇄ to the forward ⟶ or backwards ⟵ to retern back to the equillbrium.

Factors that affect the position of equilibrium

| ① Temp | ② pressure | ③ concentration |
| --- | --- | --- |
| ⇅ endo & exo | ↑ pressure shift to less gas mole. | |
| ↑ temp shift to endo | ↓ pressure shift to more gas mole. | |
| ↓ temp shift to exo | | |

↑ pressure ↑ rate of less gas mole
↑ rate of more gas mole

↓ pressure ↓ " " " " " "
↓ " " " " " " "

① Temperature :-

- ↑ temperature ↑ ↑ rate of endothermic
↑ rate of exothermic
Shift to endo

↓ temperature ↓ ↓ rate of endothermic
↓ rate of exothermic
Shift to exo

Biased towards the endo, So it increases or decreases the endo more than the exo.

/ /

$\Delta H$ =
Enthalpy change
+ve gain Endo
-ve lose Exo

the sign of $\Delta H$ always represents the forward reaction

- $A+B \underset{exo}{\overset{endo}{\rightleftharpoons}} C+D$   $\Delta H = +ve \rightarrow$ endo   ↑ temp ↑ ↑ rate of forward
↑ rate of backward
A↓ B↓ C↑ D↑

~~endo~~

↓ temp   ↓ rate of forward   A↑ B↑ C↓ D↓
↓ rate of backward

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

↑ temp   ↑ rate of forward   ↑x ↑w ↓y ↓z
↑ rate of backward

Q: $3H_{2(g)} + N_{2(g)} \underset{endo}{\overset{exo}{\rightleftharpoons}} 2NH_{3(g)}$   $\Delta H = -ve$ (exo)

to produce more yield (product) of $NH_3$
we must use low temperature to favour the forward reaction which is the exothermic.

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

| | rate of forward | rate of backward | % $SO_3$ |
|---|---|---|---|
| ↑ temp | increase | increase | decrease |
| ↓ temp | decrease | decrease | increase |

- mixture of $NO_2$ and $N_2O_4$ at equilibrium in a sealed tube.

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

dark brown — pale brown

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

Because the forward reaction is exothermic enhanced by cooling.

② pressure

As the pressure increase the equilibrium shift to the side with less pressure with less gas mole.

As the pressure decrease the equilibrium shift with more pressure with more gas mole.

ex. $3H_{2(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$ (4 moles → 2 moles)

↑ pressure. shift forward to the side with less gas mole. ↑ % $NH_3$.

ex. $H_2CO_{3(aq)} \rightleftharpoons H_2O_{(l)} + CO_{2(g)}$ (0 → 1)

↓ pressure. shift forward. total side with more gas mole.

ex. $CaCO_{3(g)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

↓ pressure. shift forward to the side with more gas mole.

↑ pressure shift backward to the side with less gas mole.

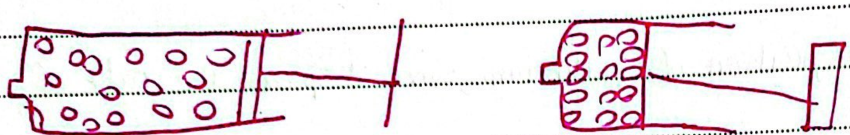
2 mole                2 mole

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

purple          colorless

Changing the pressure has no affect on the position at equilibrium. Since both sides has the same no. of gas moles

the equilibrium 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.

③ concentration :- [redacted]

Reactant $\rightleftharpoons$ products

↑ reactant, ↓ product } shift forward          ↓ reactants, ↑ product } shift backward

* $A+B \rightleftharpoons C+D$

↑[A] shift forward ↓B ↑C ↑D

↓[B] shift backward ↑A ↓C ↓D

↑[C] shift backward ↑A ↑B ↓D

Ex. Indicator : $HIn_{(aq)} \rightleftharpoons H^+_{(aq)} + In^-_{(aq)}$

color 1 red          color 2 yellow

add HCl : proton donor ↑$H^+$ shift backward (more HIn more color 1, less $In^-$ less color 2)

add NaOH : proton accepter ↓$H^+$ shift forward (More $In^-$ more color 2, HIn less color 1

/ /

Q:- the reversible reaction below is at equilibrium

$Cr_2O_7^{-2} + Fe^{+2} + H^+ \rightleftharpoons Cr^{3+} + Fe^{+3} + H_2O$

orange — green

Explain why by adding HCl to the reaction mixture the color of the mixture becomes green?

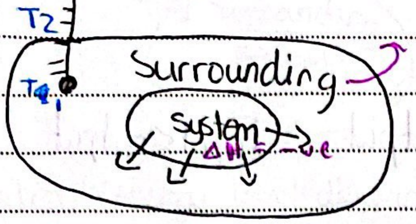
HCl is an acid (proton donor) so more $H^+$, shift forward, more $Cr^{3+}$ so more green and less $Cr_2O_7^{-2}$ so less orange.

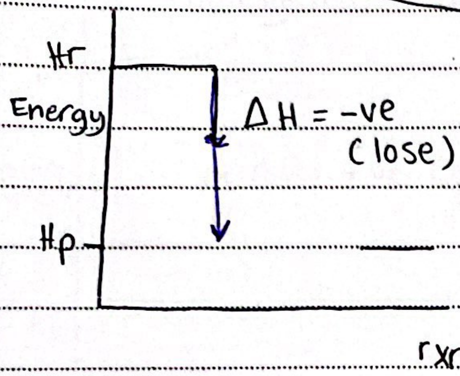
*catalysts has no effect on the position of equilibrium, since it speeds the rate of forward and backward


1: Rate of forward reaction without using catalyst
2: Rate of backward reaction without using catalyst
3: Rate of forward reaction with catalyst
4: Rate of backward reaction with catalyst
5: time taken to reach equilibrium with catalyst
6: time taken to reach equilibrium without catalyst.

# Energetics

Exothermic: reactions that give out energy to the surrounding

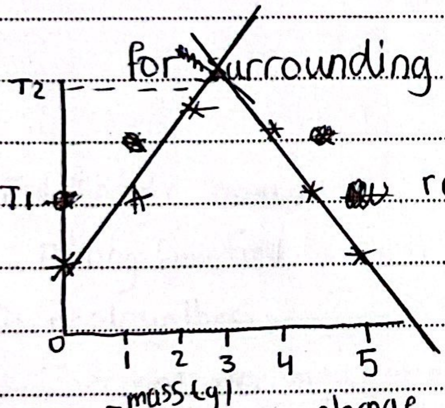



← for system (level energy of diagram)

Enthalpy: Heat contents "stored energy" → Hr enthalpy of reactant, Hp enthalpy of product

for surrounding (temp diagram)




reaction is over so return back to room temp

↑ more exothermic
↑ ΔT

$Q = mc\Delta T$ → change in Temp °C

Q ↓ energy transfer = J

m: mass (g)

c ↘ specific heat capacity 4.2 J/g.°C

Examples:-

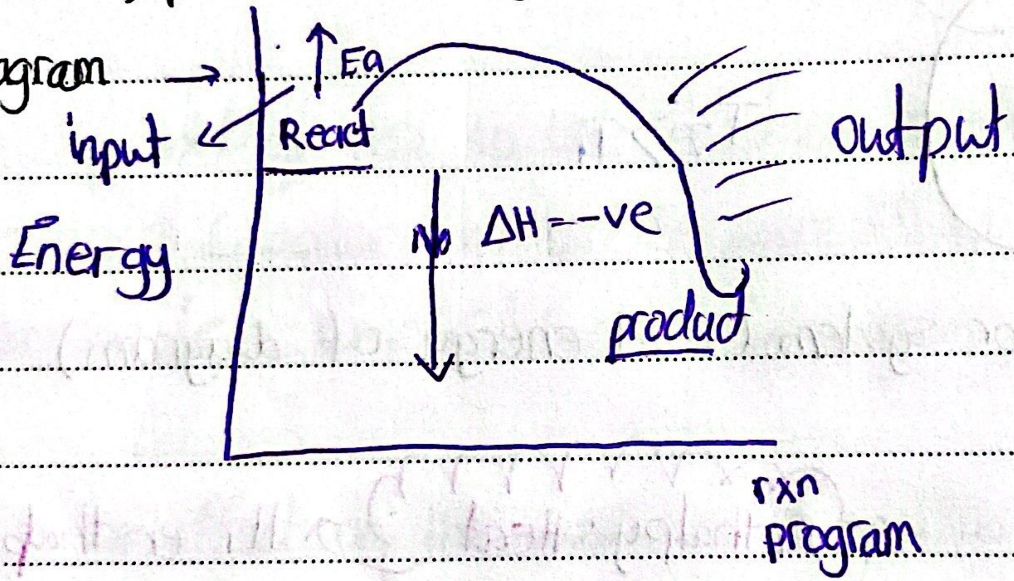
1- Freezing, condensation
2- respiration
3- combustion
4- neutralization
5- displacement
6- voltic cell
7- building up bonds

How to express exothermic rxn

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

② Reactants ⟶ products + Energy

③ profile diagram →

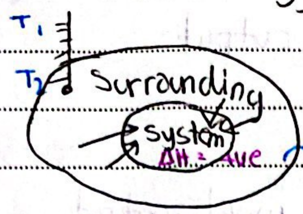



input < output

/ /

Endothermic : reactions that absorb energy from the surrounding

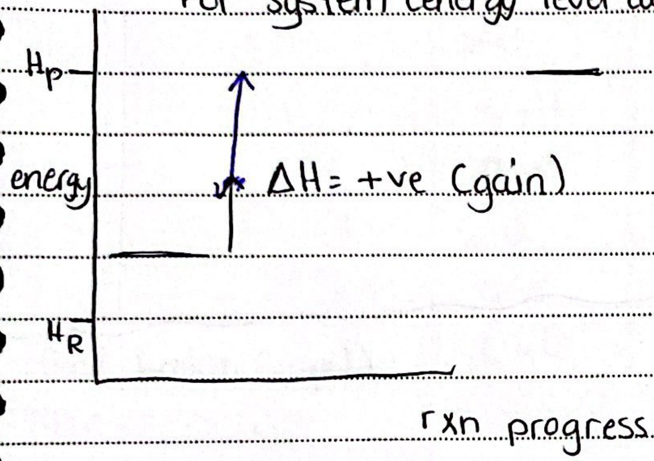
$T_1 > T_2$



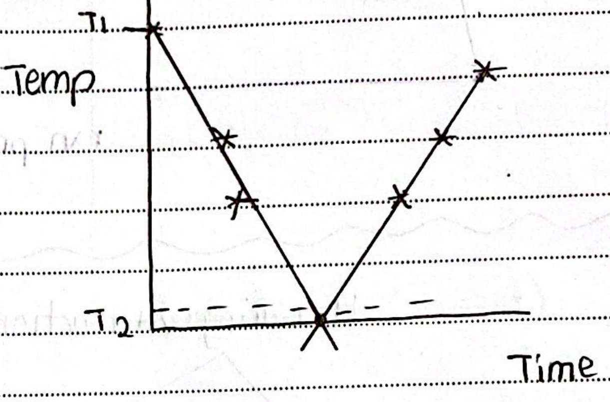

→ $Q = mc\Delta T$

* put the thermometer in the surrounding as the temperature is constant.

For system (energy level diagram)




For surrounding (temperature diagram)




$Q = mc\Delta T$

↑ Q , more endothermic
↑ ΔT

Endothermic examples :-

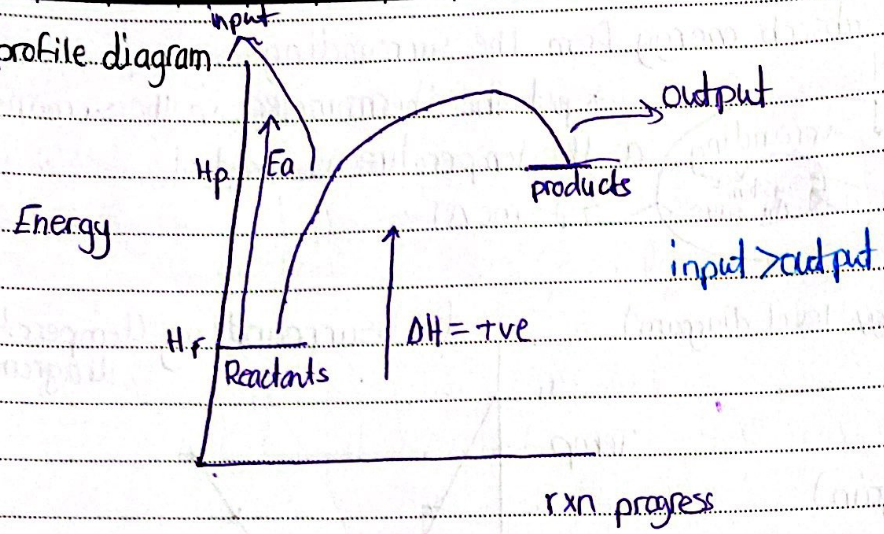
1- Boiling , melting
2- photosynthesis
3- Thermal decomposition
4- electrolysis
5- photographic films
6- dissolving ammonium salts
7- breaking down bonds.

* How to express endothermic reaction.

① Reactants → products ΔH = +ve

② Reactants → products
↓
+ energy

③ profile diagram




Measuring ΔH reaction

- theorotical — using bond energy
- experimental — displacement, neutralization, combustion

ΔH reaction using bond energy:-

Bond energy: the amount of energy needed to break 1 mol of a bond in gaseous state.

| bond | bond energy kJ/mol |
|---|---|
| H-H | 436 |

$H-H_{(g)}$ +436 kJ/mol → $H_{(g)} + H_{(g)}$

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

$$\Delta H_{reaction} = \sum input - \sum output$$

(Σ = sum)

- Σ input: to break down bonds in reactant
- Σ output: to build up bonds in products

+ (endo) input > output

− (exo) input < output

to use this equation:-

① balanced equation

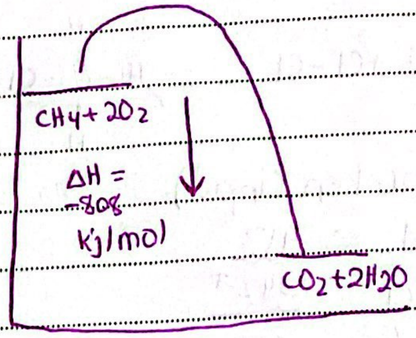
② covalent structure

③ bond energy

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

covalent bond:

$H-C(H)(H)-H + 2O{=}O \longrightarrow O{=}C{=}O + 2\,H-O-H$




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

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

Bond broken (input)

$4 \times C-H \Rightarrow 4 \times 413$

$2 \times O=O \Rightarrow 2 \times 495$ +

2642 kj

Bond formed (output)

$2 \times C=O \Rightarrow 2 \times 799$

$4 \times O-H \Rightarrow 4 \times 463$ +

3450 kj

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

$2642 - 3450 = \ominus 808$ kj/mol   input < output

exo

---

$H-C(H)(H)-O-H + 1.5\,O{=}O \longrightarrow O{=}C{=}O + 2\,H-O-H$

bond broken (input)

$3 \times C-H \Rightarrow 3 \times 413$

$1 \times C-O$   $1 \times 358$

$1 \times O-H$   $1 \times 463$ +

$1.5 \times O=O$   $1.5 \times 495$

2802.5 kj

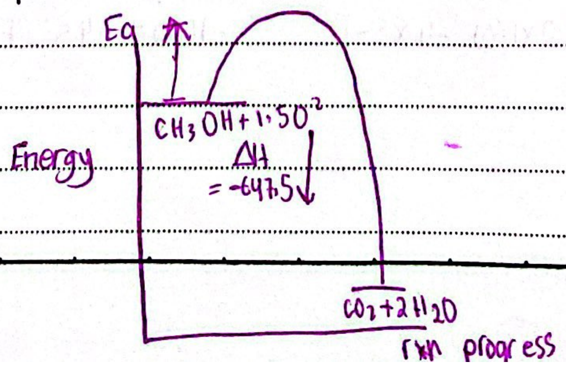
bond formed (output)

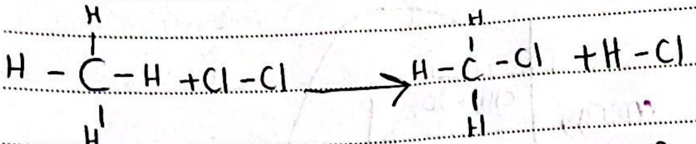
$2 \times C=O \Rightarrow 2 \times 799$

$4 \times O-H$   $4 \times 463$ +

3450 kj

$\Delta H = \Sigma input - \Sigma output = 2802.5 - 3450 = \ominus 647.5$ kj/mol (exo)





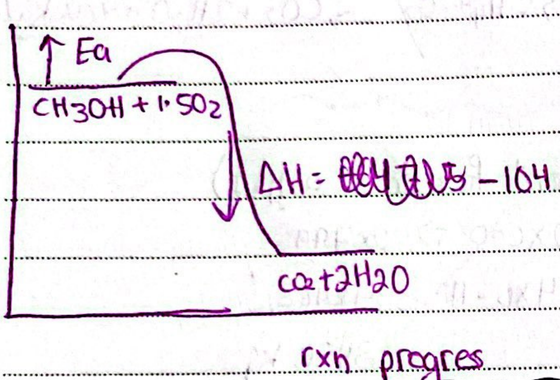
Bond broken (input)

1 × C–H ⇒ 413
1 × Cl–Cl ⇒ 242 +
655 kj

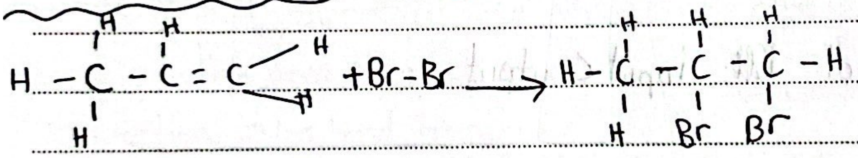
Bond build (output)

1 × C–Cl ⇒ 328 +
1 × H–Cl ⇒ 431
759 kj

$\Delta H = \Sigma input - \Sigma \Delta output = 655 - 759 = -104$ kj/mol (exo)




| Bond | Bond energy kj/mol |
|---|---|
| C–H | 413 |
| Cl–Cl | 242 |
| H–Cl | 431 |
| C–Cl | 328 |
| | |
| C–C | 348 |
| C=C | 614 |
| Br–Br | 193 |
| C–Br | 276 |
| | |
| | |



Bond broken

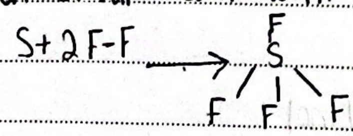
Br–Br ⇒ 193 +
C=C ⇒ 348
541 kj

Bond build

2 × C–Br ⇒ 2 × 276
C–C 348 +
900 kj

ΔH = 541 - 900 = -359 kg/mol

when sulfur react with florine the reaction give 780 kj/mol



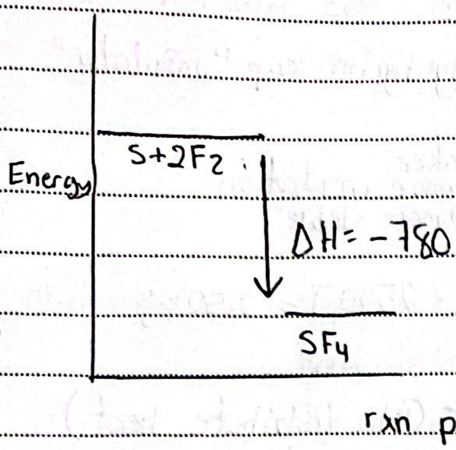
if the bond energy of F-F is 160 kj/mol. Find the bond energy of S-F)

ΔH = input - output = -780 = (2×160) - 4×S-F = -1100 = -4 S_F

S-F = 275 kj/mol.

/ / ☺

② Draw an energy level diagram:-




$Q = mc\Delta T = \Delta T = \frac{Q}{mc}$

* Finding ΔH (energy change) practically:-

- combustion
- displacement
- neutralization

Finding combustion

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

For surrounding

$Q = mc\Delta T = 100 \times 4.2 \times 10 = 4200\ J \approx 4.2\ kj$

4.2 kj ⟶ 2g (ethanol)

?? ⟵ 46g

= −96.6 kj/mol

| ΔH = −96.6 kj/mol |

Q1) Two fuels A and B, plan an experiment to show which one produces more energy?

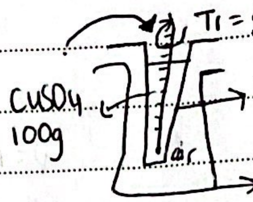
- Take a known ~~volume~~ mass of water with known intial temperature in a copper can.
- Take a known mass of fuel A. Ignite the fuel and record the final mass and final temperature of water.
- repeat the experiment using fuel B.
- The fuel which cause more ~~energy~~ temperature per gram of fuel produces more energy.

/ /

Measuring ΔH (displacement)

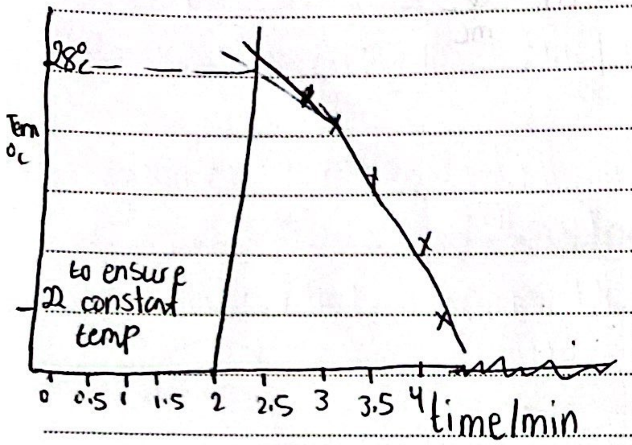
$Zn_{(s)} + CuSO_{4(aq)} \longrightarrow ZnSO_{4(aq)} + Cu_{(s)}$

Zn m = 0.65g




→ polystyrine cup "insulator"

→ beaker
1) more insulation
2) more stable



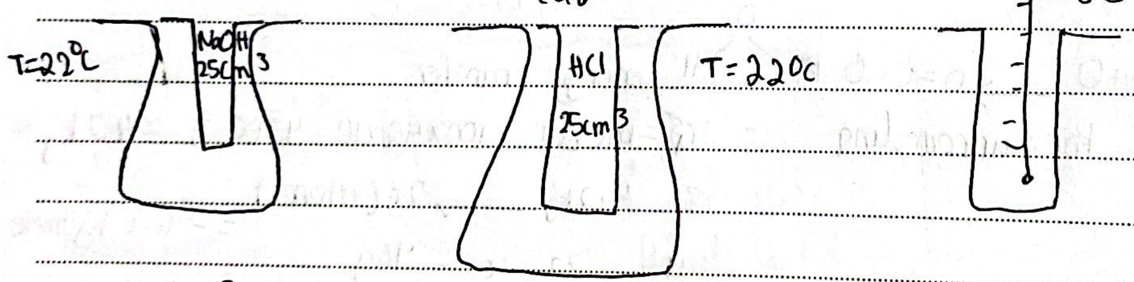

$Q = mc\Delta T = 100 \times 4.2 \times 6 = 2520\,J = 2.52\,kJ$

_ Stir with a thermometer (to distribute heat)

_ But slowly to avoid overheating.

measuring ΔH (neutralization)

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




$d = 1 g/cm^3$  $Q = mc\Delta T$ = $Q = 50 \times 4.2 \times 6 = 1260\,J$

/ /

# Alternative Resources of energy

1) Hydrogen fuel cell

$2H_2 + O_2 \rightarrow H_2O$

advantages: only one waste product
- no pollution
- produces high amount of energy
- generates electricity.

disadvantages: - expensive
- hard to transport and store
- Risk of explosion.

# Industrial chemistry

- Extraction of metals
  - Al, Zn, Fe, Cu
- Dealing with gases
  - Dry
  - Collect
- industry of
  - $NH_3$ — Haber process
  - $H_2SO_4$ — contact process
  - $CO_3^{-2}$ — carbohyd cycle

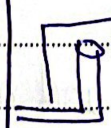
* Dealing with gases

Rxn → wet gas → dry → collect

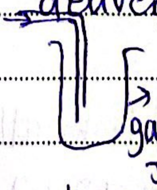
* ways of collecting gas

gas syringe
- used to collect and measure the volume of any gas
- no mixing with any gas

Delivery tube
- upward delivery
- downward delivery

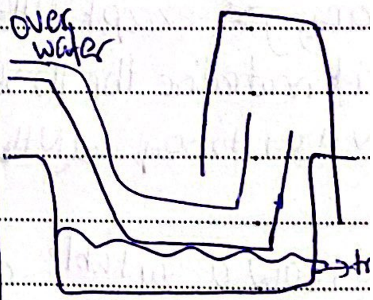


less dense than air




more dense than air

over water



*only for insoluble gases.

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

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

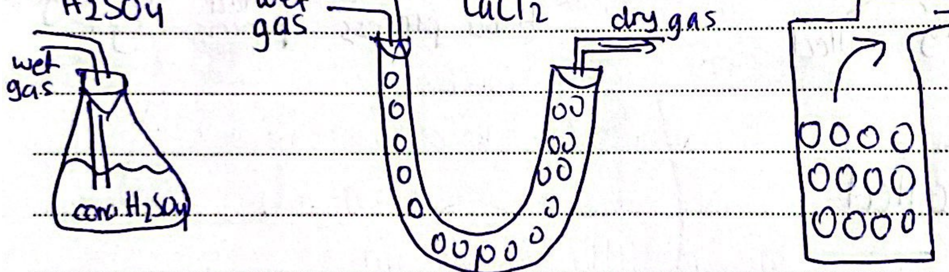
$NH_3$ $NH_4Cl_{(aq)} + NaOH \longrightarrow NaCl_{(aq)} + H_2O_{(l)} + NH_{3(aq)}$

$SO_2$ $NaSO_3 + HCl \longrightarrow NaCl_{(aq)} + H_2O_{(l)} + SO_{2(g)}$

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

*Drying reagents

concentrated $H_2SO_4$ | Anhydrous $CaCl_2$ | calcium oxide




Anhydrous $CaCl_2$ used to dry any gas

* $H_2SO_4$ becomes dilute, used to dry any gas except $NH_3$ (it neutralise the $H_2SO_4$.

$NH_3 + H_2SO_4 \longrightarrow (NH_4)_2 + SO_4$

* Draw a suitable apparatus used to collect and measure volume of dry $CO_2$ (insoluble) gas from $CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

/ /

## Industry of ammonia "Haber process" → used to prepare Fertilizers

$$3H_{2(g)} + N_{2(g)} \underset{endo}{\overset{Fe \; exo}{\rightleftharpoons}} 2NH_{3(g)} \qquad \Delta H = -ve$$

- How to obtain Nitrogen:- fractional distilation of liquid air
  - fractional distilation ⇓ different B.p
  - liquid air ⇓ cooling under high pressure

How to obtain hydrogen:- ① cracking of Alkanes, ② Methane with steam$_{(g)}$ → $CO_{(aq)} + 3H_{2(g)}$

- Essential conditions

| 1) Temperature 400-450°c | 2) pressure 200 atm |
|---|---|
| if less than 400: adv. - higher yield of $NH_3$ - shift forward to the exo side. disad. - slower rate - particles lose k.E so less effective collisions per unit time | less than 400°c:- adv:- More yield of $NH_3$ so shift forward to the side with fewer gas mole - faster rate. |
| adv. - faster rate. disad. - less yield - shift backward to the endo side. | More than 450°c:- Disad:- Risk of explosion. - Expensive |

3) Fe as a catalyst

Add excess $N_2$ and $H_2$ (return back to converter)

remove $NH_3$ immiediatly (by cooling)

Uses of Ammonia:-

1- Fertilizers 2- Cleaning detergents 3- Smelling Salts

/ /

(industry of $H_2SO_4$) contact process

Stages $S \xrightarrow[+O_2 \text{ (Roasting)}]{(1)} SO_2 \xrightarrow[+O_2 \text{ contact proces}]{(2)} SO_3 \xrightarrow{(3)} H_2S_2O_7 \text{ (oleum)} \xrightarrow{(4)} H_2SO_4$

S: Group 6, valency (2), yellow solid, $S_8$

uses: medicine, match, rubber

ore: zinc blende ZnS, from fossile fuel.

$SO_2$: causes acid rain

uses of $SO_2$: * kills bacteria (sterilization)

* paper industry (bleaching agent)

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

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

$2SO_{2(g)} + O_{2(g)} \underset{\text{endo}}{\overset{V_2O_5 \text{ exo}}{\rightleftharpoons}} 2SO_3$ $\Delta H = -ve$ (exo)

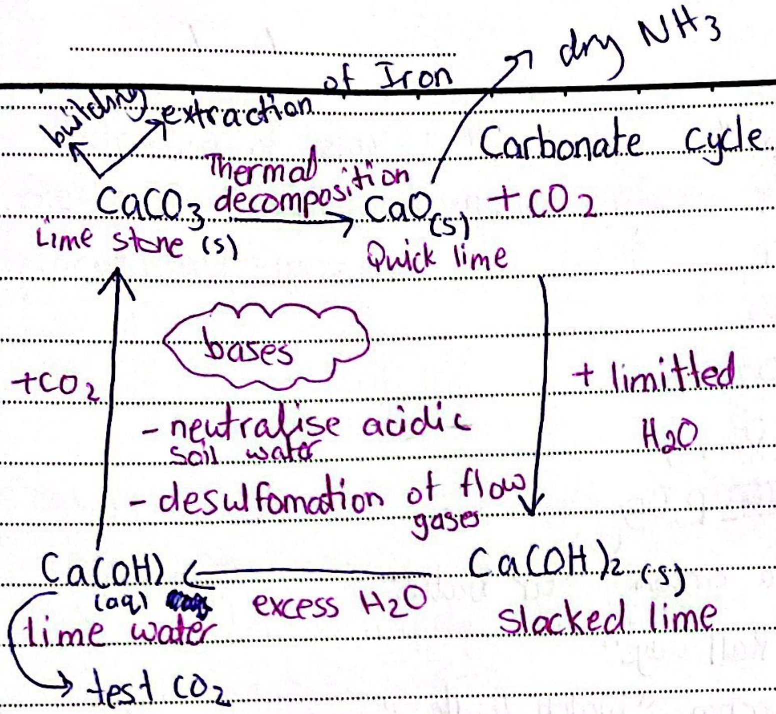
essential conditions

1) Temperature 400° – 450°c

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

3) catalyst $V_2O_5$ vanadium (V) oxide.

/ /




## Extraction of metals

Extraction of Iron

ore: $Fe_2O_3$ "Hemadite"

method of extraction: reduction by C and CO

place: Blast ~~Fur~~ furnace

Raw materials: $Fe_2O_3$ mixed with $SiO_2$ acidic impurities

$CaCO_3$ "Lime stone"

coke "carbon pure"

air 1500°c

Reactions that occur inside of the tool:-

- complete Combustion $C+O_2 \rightarrow CO_2$ (produce energy) Redox
- incomplete combustion $2C+O_2 \rightarrow 2CO$ Redox

$CO_2+C \rightarrow 2CO$ Redox

$Fe_2O_3+CO \rightarrow Fe+CO_2$ Redox

$CaCO_3 \xrightarrow{heat} CaO+CO_2$ Thermal decomposition

$CaO$ (base) $+SiO_2$ (acid) $\rightarrow CaSiO_3$ ~~carbon~~ calcium silicate slag.

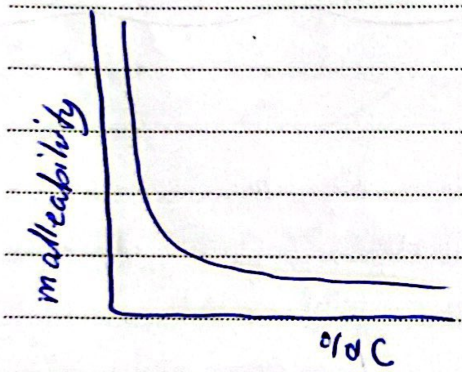
Slag is used to be mixed with bitomene to make roads.

Steel making "oxygen base process"

Cast Iron

| impurities | | |
|---|---|---|
| Fe | hot $O_2$ | Fe |
| C | | $CO_2$ |
| S | | $SO_2$ |
| Si | add a base (CaO) | $SiO_{2(s)}$ |
| P | | ~~P2O5~~ $P_2O_{5(s)}$ |

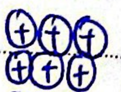
Steel:
- → Mild steel 0.03% carbon "car bodies"
- → Medium steel 0.3% "Rail ways"
- → Stainless steel 3-5% carbon "watch /cutlers"




Alloy

* Mixture of metal with another metal or semi metal
  - Brass → $Cu + Zn$
  - bronze → $Cu + Sn$
  - Steel → $Fe + C + Ni + Cr$

Metal (Cu)



same sizes so easier to slide

different sizes so harder to slide.

/ /

Extraction of zinc

ore: zinc blende ($ZnS$) method: reduction by C and $CO_2$

place: Blast furnace

C, $CO_2$ and $H_2$ can only reduce the less reactive metal only from it's oxide

step 1:- Roasting with hot oxygen $ZnS + O_2 \rightarrow ZnO + SO_2$

step 2:- ~~CO~~ $C + O_2 \rightarrow CO_2$

$2C + O_2 \rightarrow 2CO$

$CO_2 + C \rightarrow 2CO$

$CO + ZnO \rightarrow Zn + CO_2$

The temperature inside the furnace is 1500°c and the B.p of zinc is 907 so it's produced as pure gas must condense, and the other impurities Since they have high B.p stay in the furnace.