Redox

- in terms of Oxygen

Reduction
- lose O

oxidation
Gain O

ex: $Al + Fe_2O_3 \rightarrow Al_2O_3 + Fe$

Oxidation : Al

ex: $CO + ZnO \rightarrow Zn + CO_2$

Oxidation : C in CO

reduction

ex: $H_2 + CuO \rightarrow Cu + H_2O$

oxidation

- in terms of hydrogean

Reduction
gain H

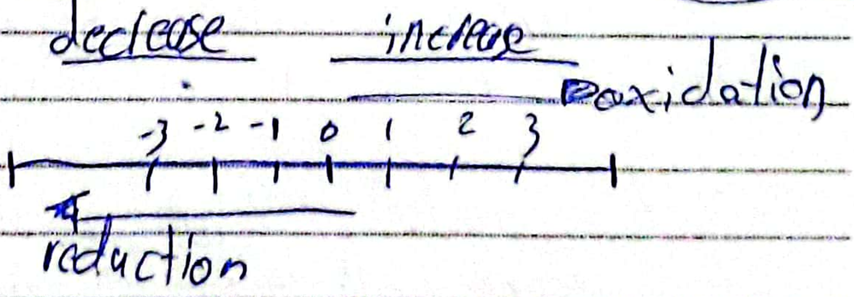
Oxidation
lose H

reduction

ex $H_2S + Cl_2 \rightarrow HCl + S$

oxidation

- oxidation state



No.

reduction $Cu^{2+} \to Cu$

Ex: $\overset{+0}{Zn} + Cu^{2+} \to Zn^{2+} + Cu$

Oxidation $Zn^{0} \to Zn^{2+}$

- Rules for oxidation

1) the oxidation state for any free element = zero .

- Mono Atomic : Na, K, Li, Ca, Cu
- Di Atomic : $H_2, O_2, N_2, F_2, Cl_2, Br_2, I_2$
- Polyatomic : P_4, S_8

2) The oxidation number of any atom in a compound form

- Grp 1 = +1 (Li, Na, K ...)
- Grp 2 = +2 (~~Be~~ Mg, Ca, Sr, Ba)
- Grp 3 = always 3+ only ~~for (F)~~ (Al)
- Grp 7 = −1 only for (F−)

3) the oxidation Number of Hydrogen (+1) except with metal in metal hydride (−1)

So (+1) if non-Metal + semi-Metal (−1) if metal

4) The oxidation state of oxygen (-2)
- except in peroxide (-1)
except in OF_2 (2+)

O^{-2} oxide

O_2^{-2} peroxide

- Any pure element has an oxidation state of zero. like Li

- Sodium oxide Na^{+1} $O^{-2} \rightarrow Na_2O^{2-}$
Sodium peroxide Na^{+1} $O_2^{2-} \rightarrow Na_2O_2$

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

- NaCl $+1 + x = 0$ so $\boxed{Cl = -1}$

- $\overset{+1}{H}Cl\overset{2-}{O}$

$+1 + x - 2 = 0$

$\boxed{x = +1}$

- $\overset{+1}{H}\overset{\pm x}{Cl}\overset{-2}{O_2}$

$+1 + x + 2(-2) = 0$

$\boxed{x = +3}$

examples

No.

- NO_3^- Nitrate ion

$N + 3(O) = -1$

$N + 3(-2) = -1$

$N - 6 = -1$

so oxidation state for (N) is +5

- ClO_4^-

$Cl + 4(O) = -1$

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

$Cl - 8 = -1$

$\boxed{Cl = 7}$

- $Cr_2O_7^{2-}$

$2Cr - 14 = -2$

$\frac{2Cr}{2} = \frac{12}{2}$

$\boxed{Cr = +6}$

No.

- find the oxidation state of each underlined species

- $\underline{Fe}_2O_3$

$2Fe + 3(-2) = 0$

$2Fe - 6 = 0$

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

$\boxed{Fe = +3}$

- $\underline{O}F_2$

~~$2F + (-2) = 0$~~

~~$2F$ [illegible] 6~~

~~$2F = 2$~~

~~$F = +1$~~

$2(-1) + O = 0$

$-2 + O = 0$

$\boxed{O = +2}$

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

$S + 4(-2) = -2$

$S - 8 = -2$

$\boxed{S = 6}$

$\boxed{S = +6}$

- V_2O_5

$2V + 5(-2) = 0$

$2V - 10 = 0$

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

$\boxed{V = +5}$

No.

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

  - Oxidation: $Al \longrightarrow Al^{3+}$

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

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

  - Oxidation: $C^{2+} \longrightarrow C^{4+}$
  - reduction: $Zn^{2+} \longrightarrow Zn$

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

  - oxidation: $S^{2-} \longrightarrow S$
  - reduction: $Cl_2 \longrightarrow Cl^{-1}$

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

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

Oxidation: $Na \longrightarrow Na^{+1}$

Reduction: $H^{+1} \longrightarrow H_2$

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

FIVE APPLE

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

oxidation : $Al \longrightarrow Al^{3+}\ (+3\acute{e})$
reduction : $\underset{(+3e^-)}{Fe^{3+}} \longrightarrow Fe$

- writting balanced half ionic equations
  1) Atoms
  2) the charge by adding és to the side with greater charge by the difference

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

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

H.O.r $\underset{+2\acute{e}}{2H^{+}} \longrightarrow H_2$

overall rxn : $2Na + 2H^{+}$

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

H.o.o $3(3Ca \longrightarrow 3Ca^{+2}\ \underline{+6\acute{e}})$
H.o.r $2(2Al^{3+} + 6\acute{e} \longrightarrow 2Al)$

$3Ca + 2Al^{+3} \longrightarrow 3Ca^{2+} + 2Al$
é gained = é lost

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

H OO $\rightarrow S^{2-} \rightarrow S + 2e'$

Hor $\rightarrow Cl_2 \rightarrow 2Cl^-$

$+2e'$

Oxidation = lose of electrons

reduction = gain of electrons

Oil Rig

oxidation is lose Reduction is gain

- overall reaction

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

H.O.O : 2(Al $\rightarrow Al^{+3}$ + e3)

H.O.R : (2H$^+ \rightarrow H_2$)

3 (+2e)

$2Al \rightarrow 2Al^{+3} + 6e$

$6H^+ + 6e \rightarrow 3H_2$

Net $2Al + 6H^+ \rightarrow 2Al^{+3} + 3H_2$

$\overset{+7}{M}n\overset{-2}{O}_4^{-1} + Fe^{2+} + H^+ \rightarrow Mn^{2+} + fe^{3+}$

$a\times5(Fe^{2+} \rightarrow fe^{3+} + (1e^-))$

reduction; $Mn^{+7} \rightarrow mn^{+2}$
$+ 5e$

$5Fe^{2+} \rightarrow 5fe^{3+} + \cancel{5e'}$

$mn^{+7} \rightarrow mn^{+2} + \cancel{5e'}$

• $5fe^{2+} + Mn^{+7} \rightarrow 5fe^{3+} + Mn^{+2}$

overall.

	reducing oxidation	oxidizing reduction
O	gain O	loose O
H	lose H	Gain H
Oxid State	↑	↓
é trasler	lose é	gain é

Oxidising agent: the substance that itself reduced and causes the other substance to be oxidized.

Reducing agent "Reduction" 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 the compound itself.

$$\overset{0}{Al} + \overset{3+}{fe_2}\overset{2-}{O_3} \longrightarrow Al_2O_3 + \overset{0}{fe}$$

Oxidation Al → Reducing agent: Al

Reduction Fe^{3+} Oxidising agent Fe_2O_3

No.

$\overset{+2\,-2}{CO} + \overset{+2}{Zn}O^{-2} \rightarrow \overset{0}{Zn} + \overset{+4\,-2}{CO_2}$

Oxidation: C^{2+} oxidat. agent ZnO

Reduction Zn^{2+}

agent CO

$\underline{\overset{+1\,-2}{H_2S} + \overset{0}{Cl_2}} \rightarrow \overset{+1\,-1}{HCl} + \overset{0}{S}$

Oxidant Cl_2

Reductant H_2S (Cion)

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

Oxidant: MnO_4^{-1} Reduction: Mn^{+7}

Reductant: Fe^{2+} Oxidation: Fe 2+

oxidising agent

1) oxygen

$\overset{0}{Fe} + \overset{0}{O_2} \rightarrow Fe_2O_3$

$S + O_2 \rightarrow SO_2$

2) Acidified pottasium manganate

$MnO_4^{-1} \rightarrow Mn^{2+}$

purple colorless

3) Acidified pottasium dichromate

$K_2Cr_2O_7/H^+$

$\overset{\boxed{+6}}{Cr}O_7^{-2} \rightarrow Cr^{\boxed{3+}}$

orange green

4) halogers

$F_2 \rightarrow F^-$

$Cl_2 \rightarrow Cl^-$

$Br_2 \rightarrow Br^-$

$I_2 \rightarrow I^-$

(in terms of electrons)

colorless solution

F_2 Yellow

Cl_2 Green yellow

Br_2 red Brown

I_2
- purple gas
- black solid
- brownred solution.

Most common reducing agent

1) Hydrogean $H_2 + CuO \rightarrow H_2O + Cu$

2) carbon and carbon monoxide

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

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

colorless red brown solution

4) Metal

- More reactive
- More likely to lose é
- More likely to oxidise
- More like to be a reducing agent

↑

K →

Na

Li

Ca

Mg

Al

C, CO

Zn

Fe

Pb

H

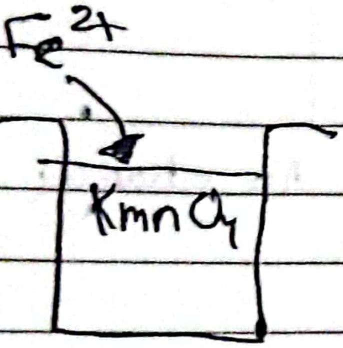
Cu

Ag

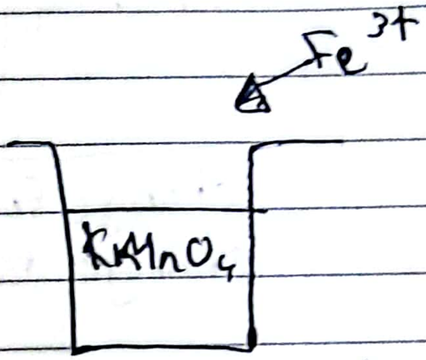
Fe^{2+} is a reducing agent
Fe^{3+} is an oxidising agent

- Record the Obsrv

1)

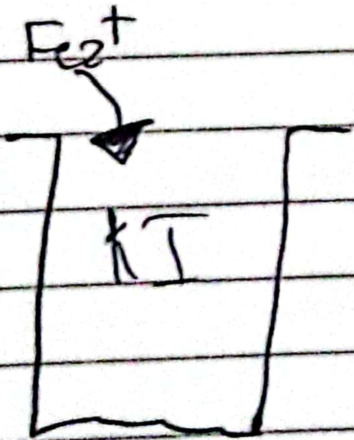


change color from purple to colorless.

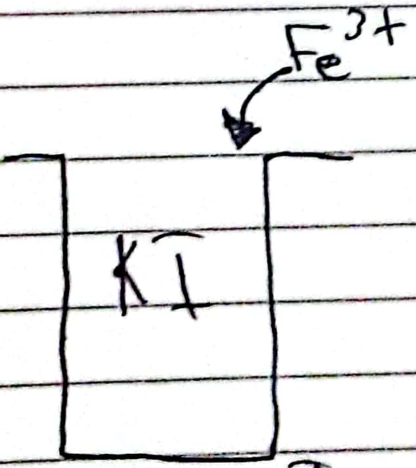


stays purple

2)



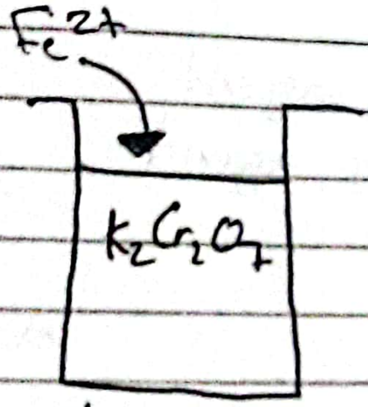
stays colorless



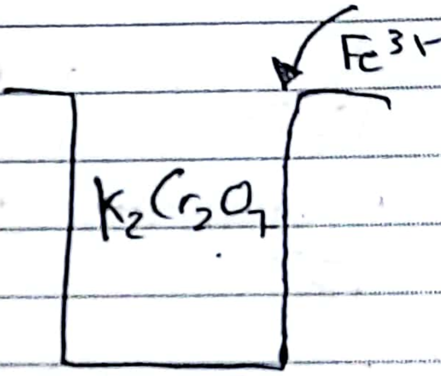
$$2I^- \longrightarrow \underbrace{I_2}_{\text{Red-Brown}} + 2e$$

No.

3)



change from
orange → green



no change

No. electrolysis

Electricity

Analysis
"Breaking down"

- Electrolysis: Breaking down chemical compounds (Ionic) when molten or ageous by passing electiricity.

• why the ionic compounds don't cond. electricity when solid?

- The ions are not free to move.

• why the ionic compounds conduct elecricity when dissolve in water on molten?

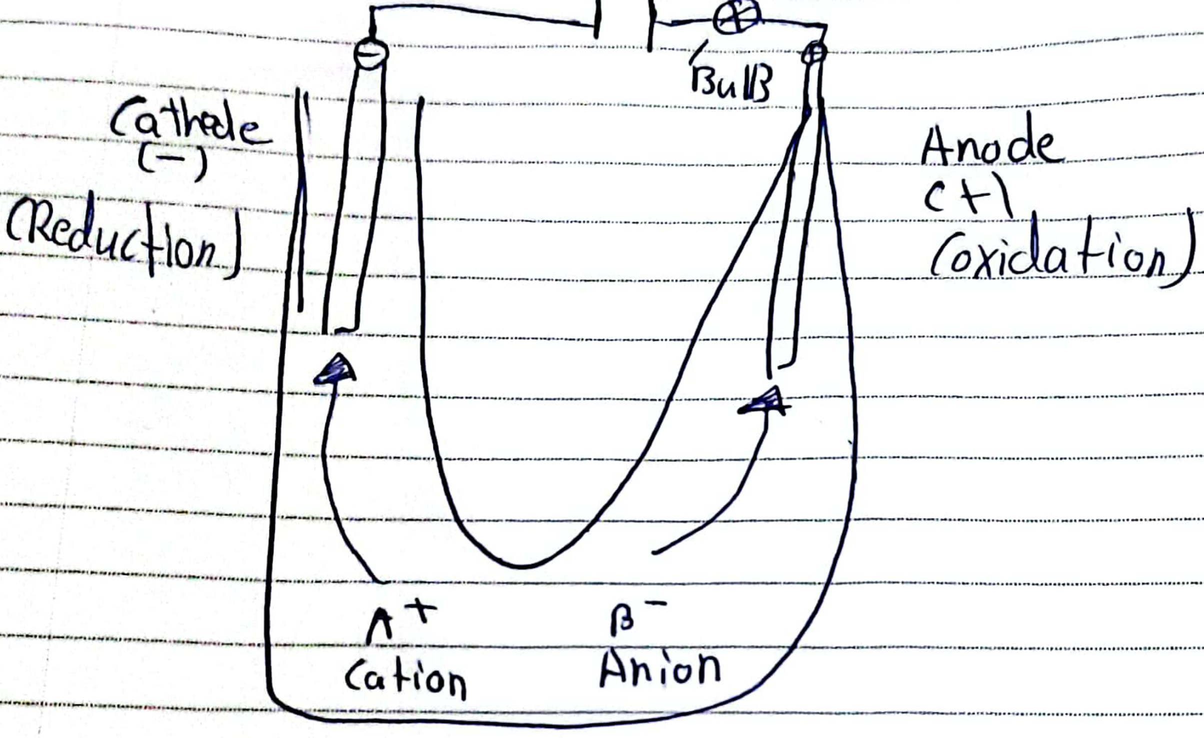
- The ions are free to move.

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

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

- Electrolyte: chemical compound that conduct electricity when molten on aq.

Electrolysis cell



- Cathode: the -ve rod that attracts the +ve [illegible] (cations) where the reduction occurs

- Anode: the +ve rod that attracts the -ve (Anions) where the oxidation occurs.

Electrolysis = discharging Ion → element

Cations reactants   Anions products

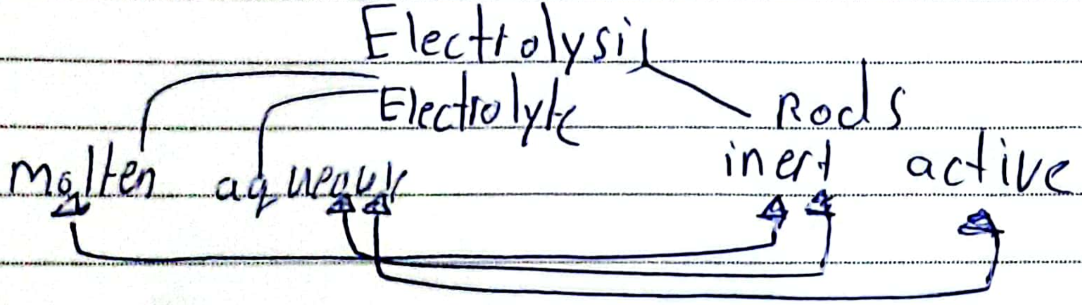
$1\acute{e} + Na^{+} \rightarrow Na$ $2F^{-1} \rightarrow F_2 + 2e$

$2\acute{e} + Mg^{2+} \rightarrow Mg$ $2Cl^{-1} \rightarrow Cl_2 + 2e$

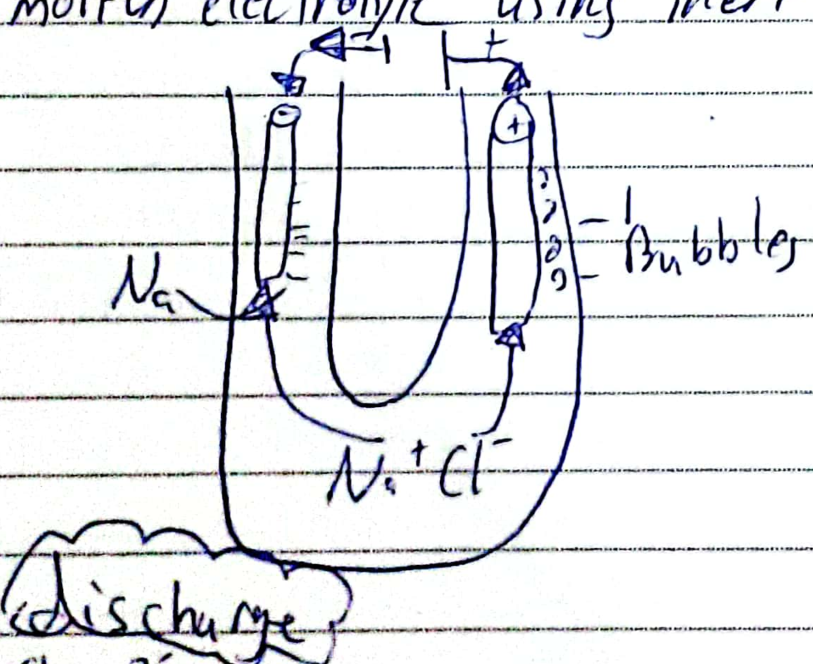
$2\acute{e} + Ca^{2+} \rightarrow$ ~~Mg~~ Ca $2Br^{-1} \rightarrow Br_2 + 2e$

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

$2e + 2H^{+} \rightarrow H_2$



- Electrolysis for molten electrolyte using inert rods (graphite)



$NaCl_{(l)}$

al: Na^{+1} Cl^{-1}

cathode   Anode

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

deposite of metal on the cathode.

$2Cl \rightarrow Cl_2 + 2\acute{e}$

Bubbles of green yellow gas.

No.

Electrolyte: Used up in molten

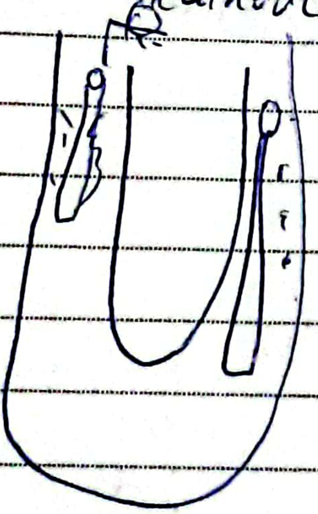
Molten Lead (II) Bromide

$+2\acute{e}\ Pb^{2+} \rightarrow Pb$ $PbBr_2$ $2Br^{-1} \rightarrow Br_2 + 2e'$

Pb^{2+} cathode

Br^{-1} Ande

deposite of metal



bubbles of red brown gas

F_2 : Yellow gas
Cl_2: green yellow gas
Br_2: Red brown gas and liquid
F_2: Solid black
gas purple
Red brown solution

Deposit of red brown Solid

$CuCl_2$

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

Cathode Anode

Bubbles of green Yellow gas

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

Electrolyte consumed.

Deposit of metal

Al_2O_3

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

Cathode Anode

Bubbles of colorless gas (dont mention name of gas.)

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

- We use graphite because good conductor and cheap, and it is inert

Electrolysis of (aq) using inert

$AB_{(aq)}$

A^{+} B^{-}

H^{+} OH^{-}

Cathode Anode

- **At the cathode**

the less reactive Ion is more likely to reduce and the more reactive metal stays in electrolyte

x because H^+ is less reactive

K^+
Na^+
Li^+
Ca^{+2}
Mg^{+2}
Al^{+3}
Zn^{+2}
$Fe^{+2,+3}$
Pb^{+2}
- H^{+1}
$Cu^{+1,+2}$
Ag^{+1}
Au^{+7}

At the anode

Always OH^- except concentrated Halide Cl^-, Br^-, I^-

- when the halide oxidize

$2Cl^- \rightarrow Cl_2 + 2e^-$

when OH^- oxidize

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

Bubbles of colorless gas

Concentrated $NaCl_{(aq)}$ graphite

Na^+ Cl^-

H^+ OH^-

cathode

$2H^+ + 2e^- \rightarrow H_2$

bubbles of ~~concentrated~~ colourless gas.

Anode

$2Cl^- \rightarrow Cl_2 + 2e$

bubbles of green yellow gas

electrolytes: $NaOH$

Blue Solution

$CuSO_4$ (aq) Graphite

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

~~Cad~~ H^+ OH^-

cathode Anode

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

~~OH~~ →

$4OH^- \rightarrow H_2O + O_2 + 4e$

- electrolyte : H_2SO_4

gas	test	results
H_2	lighted splint	pop
O_2	glowing splint	relight
Cl_2, Br_2	Damp litmus paper	turns red then bleach

No.

Dilute NaCl(aq) /graphite

Na^+ Cl^-

H^+ OH^-

Cathode Anode

$+2e\ 2H^+ \rightarrow H_2$

bubbles of colorless gas

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

bubbles of colorless gas

electrolyte : NaCl

Conc. KI

K^+ I^-

H^+ OH^-

$2H^+ + 2e^- \rightarrow H_2$

bubbles of colorless gas

$2I^- \rightarrow I_2 + 2e^-$

Red brown

Electrolyte : KOH

Conc: $CaCl_2$

Cu^{2+} Cl^-

H^+ OH^-

cathode anode

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

[deposit of red brown solid [bubbles of green yellow gas

Electrolyte: less conc: $CaCl_2$

- Concentrated sodium chloride called Brine solution

$NaCl$

Na^+ Cl^-

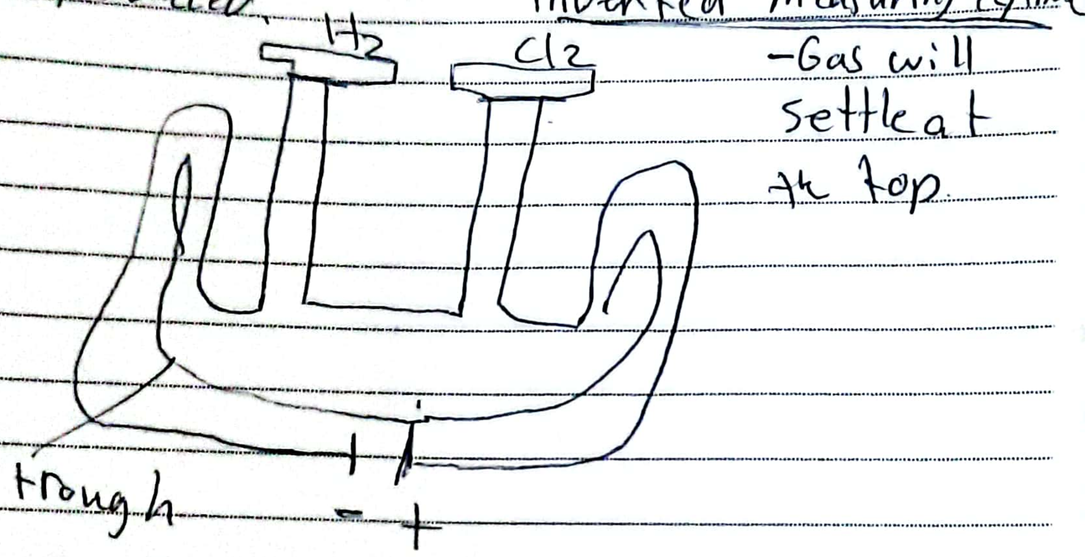
H^+ OH^-

cathode Anode

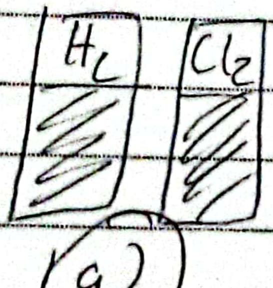
$2H^+ + 2e \rightarrow H_2$ $2Cl^- \rightarrow Cl_2 + 2e$

Electrolyte: $NaOH$

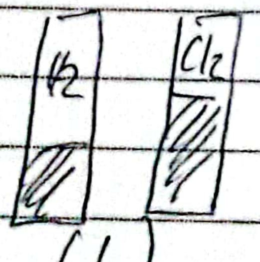
Q1) plan an exp to collect and measure the volume of H_2 and Cl_2 produced.



Q2) the final appearance of the two measuring cylinders are



(a)



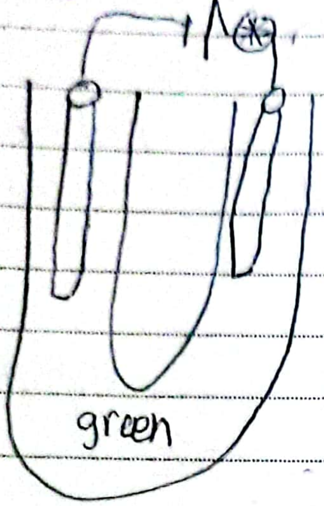
(b)

(c)

Half of OX : $2Cl^- \Rightarrow Cl_2 + 2e$
Half of RE : $2H^+ + \cancel{2e} \Rightarrow H_2$

ovr ; $2H^+ + 2Cl^- \rightarrow H_2 + Cl$
1 : 1

Q3) Brine with aniversal indicator :



☆ The Cl_2 doesn't appear immedially becusse some Cl_2 will be disolved in the solution

Observations

1-] the bulb light up

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

3] bubbles of colorless gas on the cathode

4] Around the cathode the solution beomes purple because NaOH is Alkali

5] Around the anode the solution beomes colorless scince Cl_2 bleaches.

No.

ex : conc. KI (aq) using inert graphite rod

K^+ I^-

$+2e\ 2H^+ \rightarrow H_2$ H^+ OH^- $2I^- \rightarrow I_2 + 2e$

bubbles of colorless gas

cathode Ande

red-brown solution.

ex $CuSO_4$ graphite rod

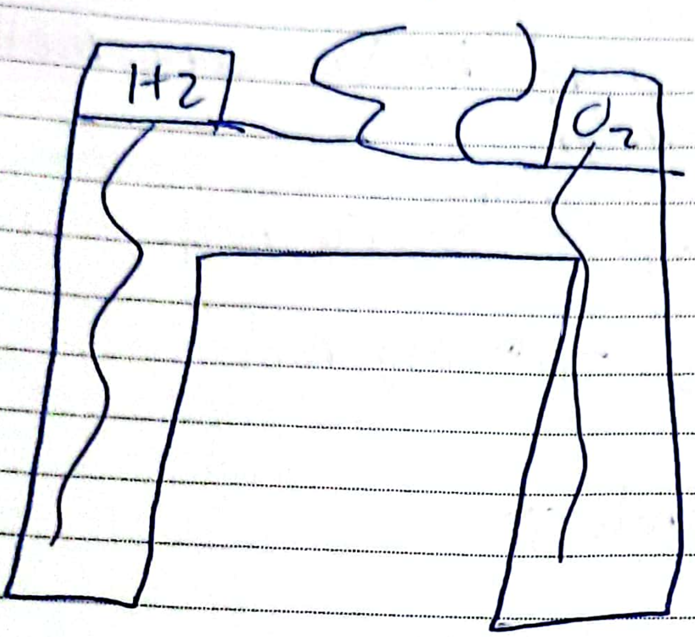
Cu^{+2} SO_4^{-2}

H^+ OH^- bubbles of colorless gas

~~electrolyte : $Cu(OH)_2$~~

elcotrolyte : H_2SO_4 (sulfuric acid)

Electrolysis for H_2SO_4 (aq)



H_2SO_4

H^+ SO_4^{-} –

H^+ OH

cathode Anode

Final appearance

cathode $2(2H^+ + 2e \rightarrow H_2)$

Anode: $4OH^- \rightarrow 2H_2O + O_2 + 4e$

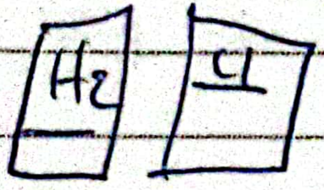
$4H^+ + \cancel{4e} \rightarrow 2H_2$

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

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

2:1

Final appearance



No. Electrolysis :

for aqueous electrolyt using active rod

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

$CuSO_{4(aq)} \xrightarrow{using}$ Cu rod

$AgNO_3 \rightarrow$ Ag rod

→ electrolysis

$CuSO_4$

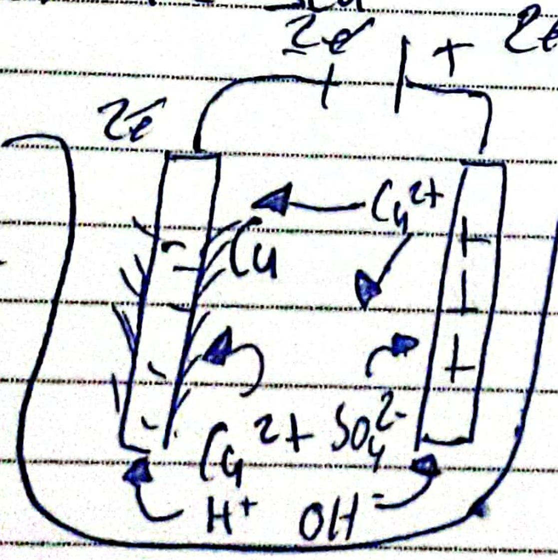
Less reactive Cu^{2+} | SO_4^{-2} ×

H^+ | OH^- × } • The anode itself oxidized.

Cathode | Anode

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

$Cu^{2+} + 2e \rightarrow Cu$ ←



→ $Cu \rightarrow Cu^{2+} + 2e$

or to cathode

- Cu^{2+} to electrolyte
- electrons in wires to replace ions

Results :

- mass of (cathode) increase due to deposit of metal ↑
- Anode: decrease in mass ↓ oxidised by lose electrons
- Electrolyte : stays the same concentration, the anode oxidised and replace the Cu^{2+} in the electrolyte with the same rate.
- Same color

aq cow /Active

electroplating ↓ → puryfing metals

- Electroplating: coating a metal with another metal using electrolysis
- why? 1) to prevent rusting
  2) more attractive

Steps to coat a metal spoon :

1- Clean the spoon from any impurities or any oxide layers using sandpaper, to ensure a good sticking

2- make the spoon the cathode

3- make the anode from (Ag)

4- the electrolyte must contain Ag^+ ex $AgNO_3$

5- turn on the circuit, be sure the spoon is fully immersed in the electrolyte.

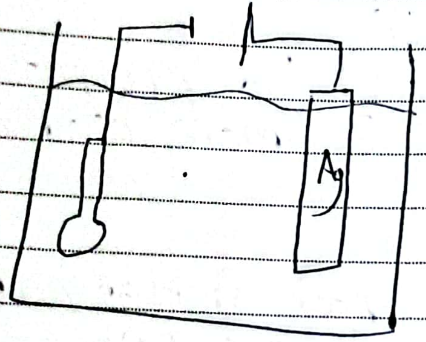
6- rotate the spoon to ensure an equal

distribution.

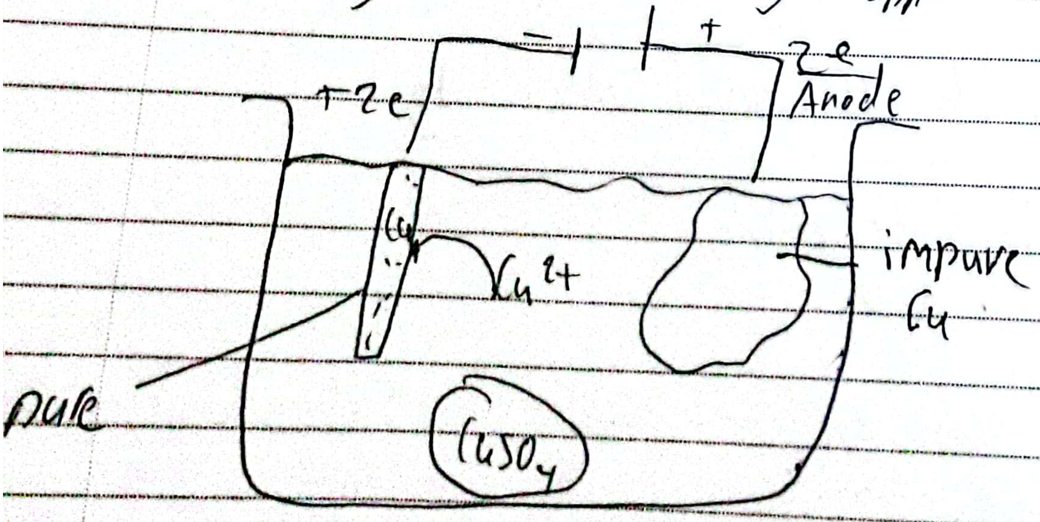
7- rinse with distilled water

8- Dry in oven

(if we didnt want the new electroplate, switch the cathode and anode.)



② puryfing metals /Refining copper.



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

* impurities

(Ag, Au) settle down (less reactive)

- if we Zn ads there it will displace Cu to $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

- Extraction of metal from their ores.

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

By molten electrolysis graphiter [K
Na
Li
Ca
Mg

Electrolysis Bauxite Al_2O_3 ← Al Al_2O_3

C, CO

Reduction by (C, CO) [Zincblend (ZnS) ← Zn (ZnS)

Hematite Fe_2O_3 ← Fe

Pb

- (H) -

H_2 less costly Copper(II) sulphide ← Cu] By H_2

Ag

Au

- Extraction of Alaminium

ore: Al_2O_3 Bauxite

- Method: Electrolysis for molten Al_2O_3 /graphite
- M.P of Al_2O_3 is about: 2000 °C

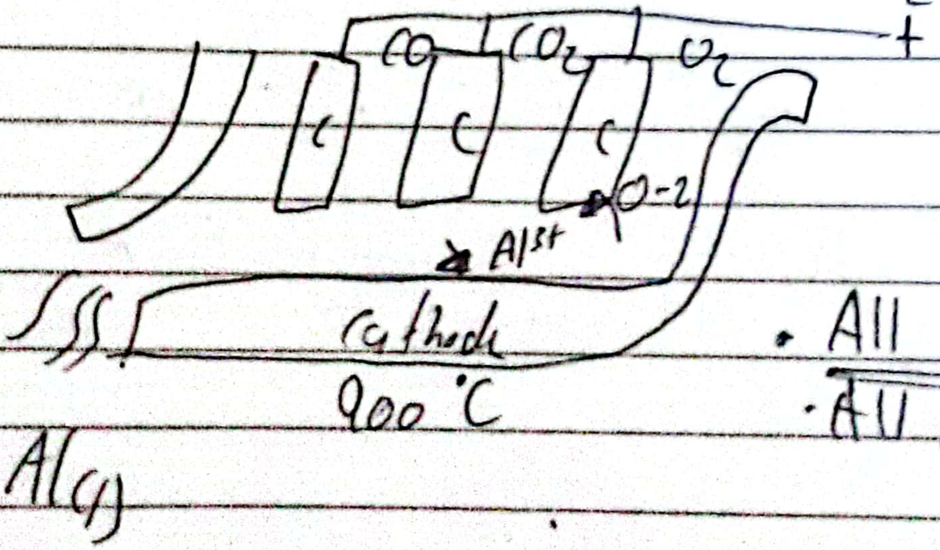
- So we dissolve Al_2O_3 in a molten cryolite Na_3AlF_6.

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

$$\begin{tikzcd} & Al_2O_3 \ (l) \arrow[dl] \arrow[dr] & \\ Al^{3+} & & O^{2-} \end{tikzcd}$$

Cathode | Anode

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



- All carbon
- All Anode rods

No.

- Gases produced At Anode

1- O_2

2. CO_2] Reaction of Rods with O_2, so we must replace them periodiclly.

3- CO

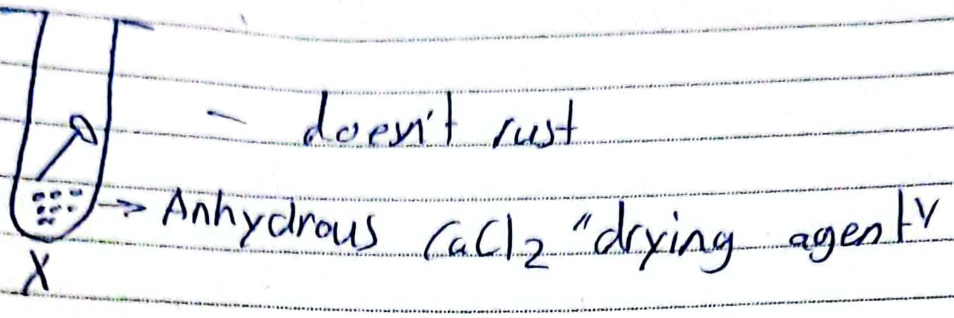
(corrosion will take place due to high temprature and reaction.)

Property	Use
- Low density	- Aircraft bodies
- Ductile	- in electrical wires
- malleable	- window frame cooking utensils
- Conduct electricity	- wires
- form an oxide layer that is not toxic. and unreactive	- food cans

- Malleable : bendy
- Ductile : wires

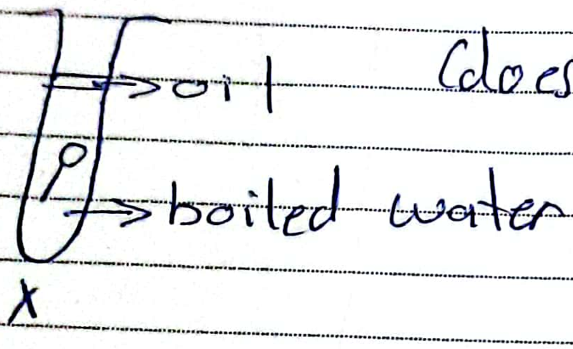
No. Rust

1)



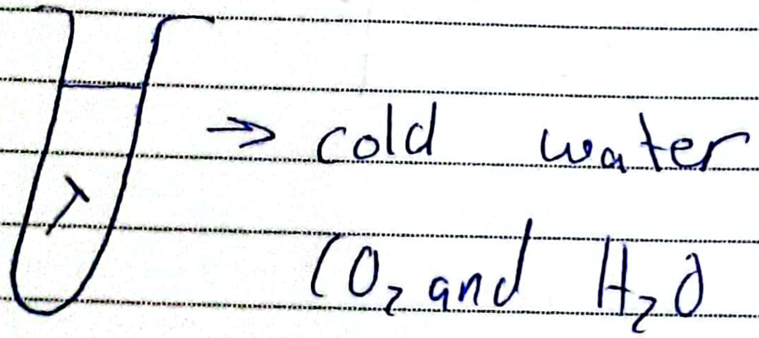
- doesn't rust

2)



(doesn't rust (no O_2))

3)



(O_2 and H_2O present)

✓

- Rust : Reaction of Iron with both O_2 and H_2O.
- it is a slow reaction 1 or 2 weeks

Q) plan an expirement 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 a known volume of water for 1week, dry them and measure the mass again, repeat the exp with the 2nd solution.

+ conclusion: the exp which cause more increase in mass, wore solution.

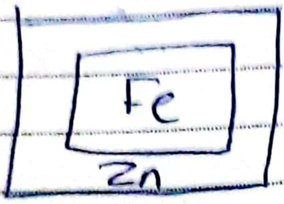
$$Fe + O_2 \xrightarrow{H_2O} \underbrace{Fe_2O_3 . aH_2O}_{\text{Brown}}$$

- How to prevent rusting

painting oiling greasing cover with plastic

" to prevent O_2 and H_2O from reaching the metal!!

Galvanising

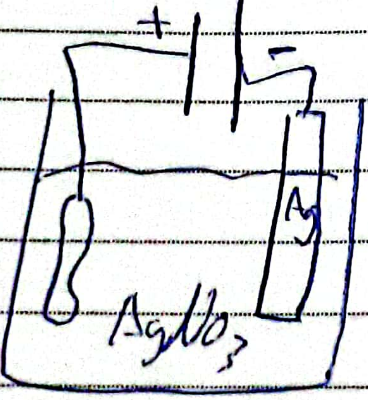


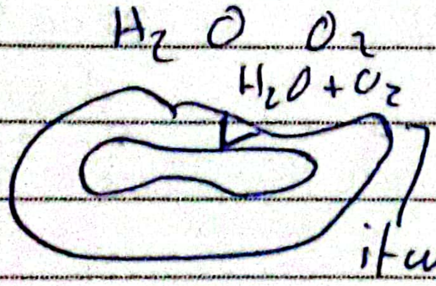
- Coating

Sacrificial protection

- Zn and Mg are more reactive than Fe more likely to oxidise, more likely to lose e^-s so Fe is less likely to rust.

electroplating

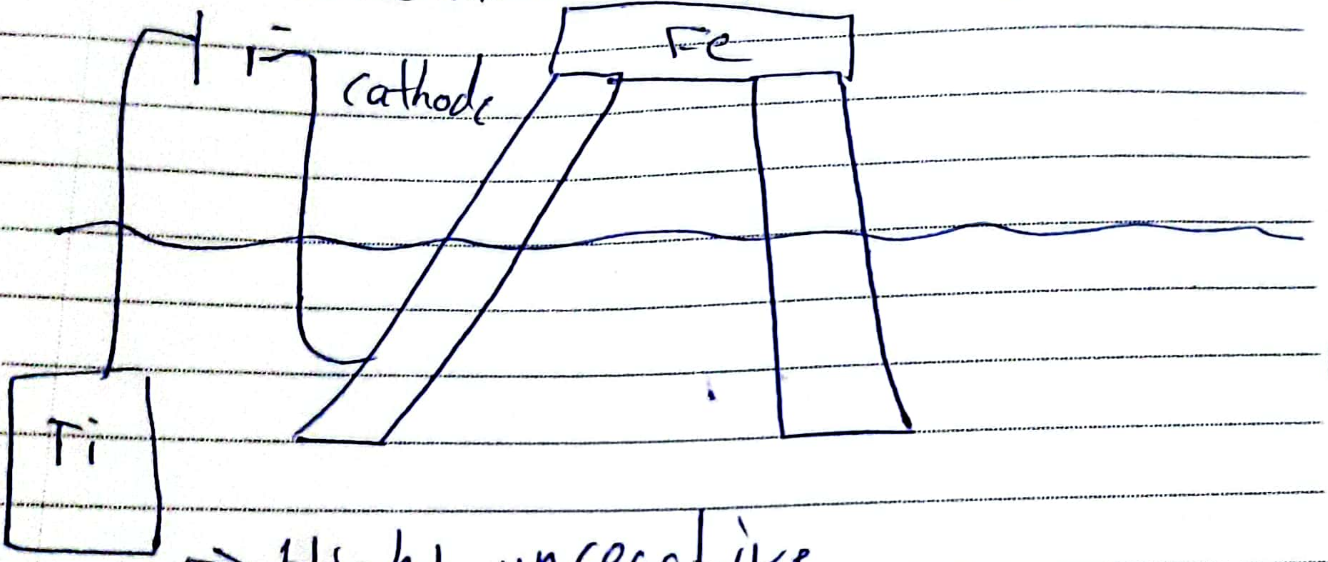




it will rust (Ag less reactive)

Dont let iron be Anode, oxidize

cathodic protecting



→ Highly unreactive

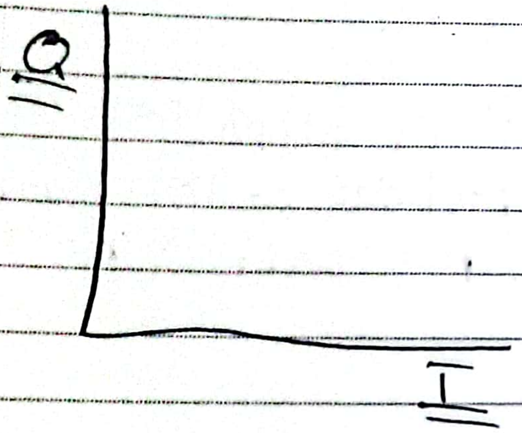
- Add magnesium blocks at the base

No. Rate of reactio

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

- Rate = $\frac{\Delta Q}{\Delta T}$

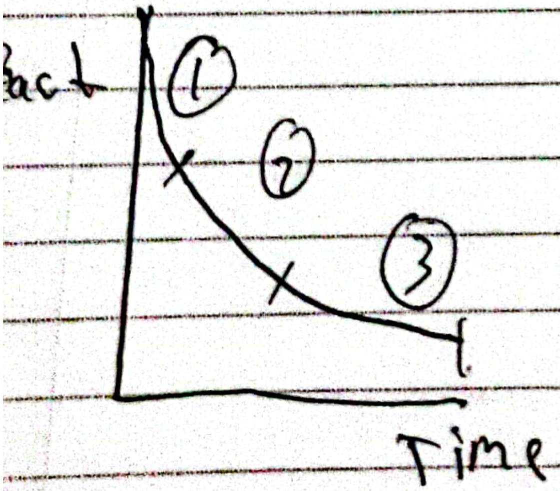
- Δmass
  Δconc
  ΔpH
  ΔVolume
  ΔTemp
  Δheight of pp
  Δligh intensity

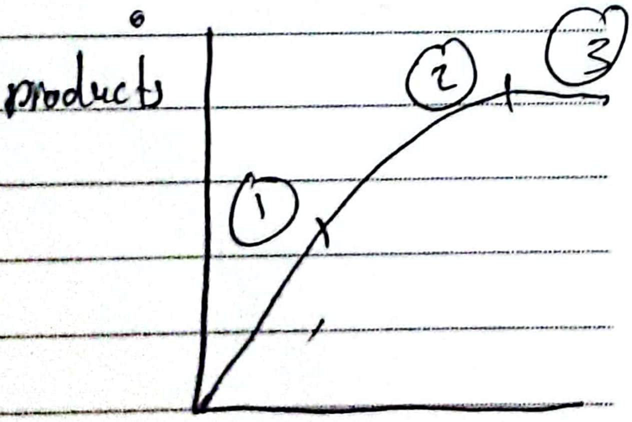


Measure rate of reaction

How fast the reactants consumed per unit time

How fast the products per unit time





No.

- Region (1)
  Fastest rate ⇒ From the graph steepest
- More amounts of reactants, so more particle so more effective collisions per unit time
- Region (2)
  Slower rate ⇒ from graph. less steep
- Less number of particles so less number of efective collisions per unit time
- Region (3)
- Reaction is over ⇒ from graph. horizantal line (gradient (0))
- no more limiting factor, no more effective collisions.

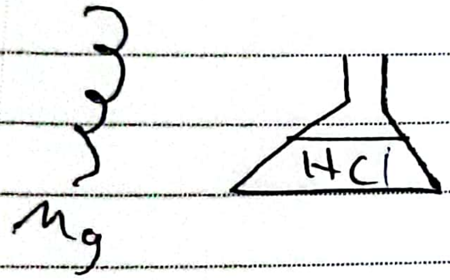
No.

- for any reaction there are three conditions

1- The reactant must be suitable

$Cu + HCl$ → no rxn

2-



- The reactant must colide

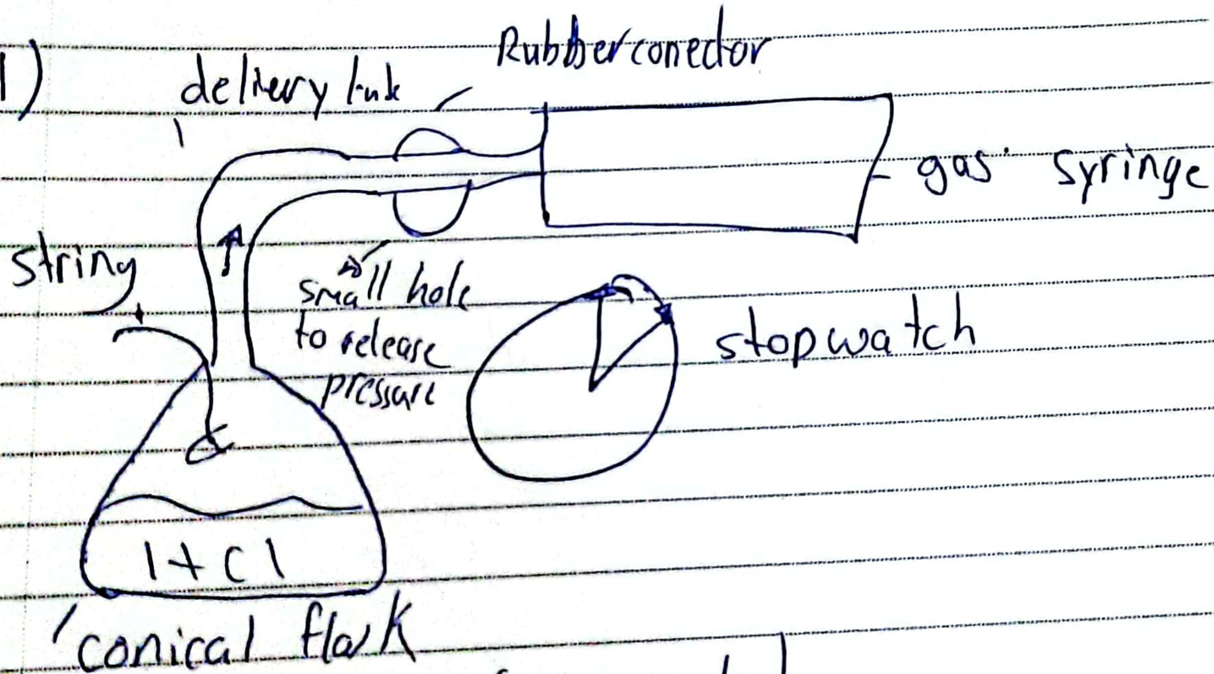
3- th collisions must be effective / min amount of energy to start th rxn, Activasion energy EA

- measuring rate of reaction

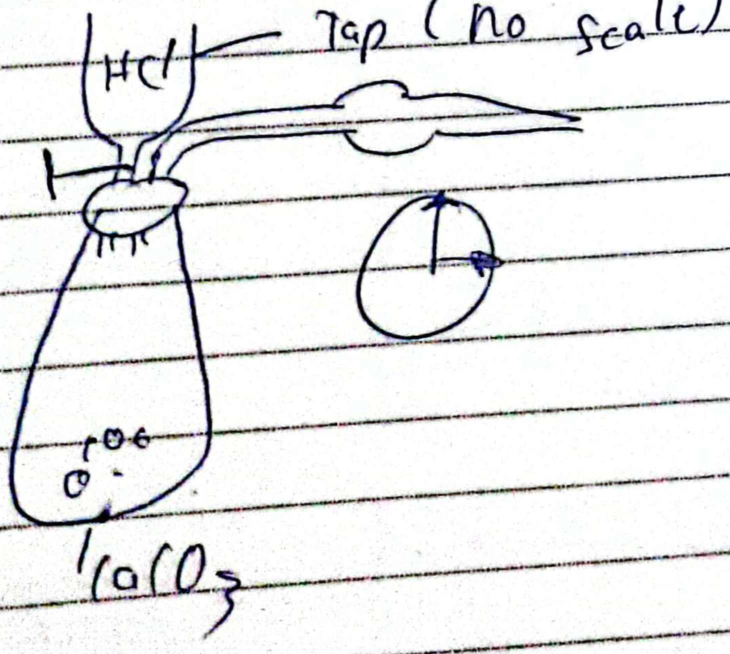
$CaCO_{3(s)} + 2HCl \rightarrow CaCl_2 + H_2O_{(l)} + CO_{2(aq)}$

1) measuring the volume of gas per unit time
2) Measure the mass of the conical flask + content per unit time.

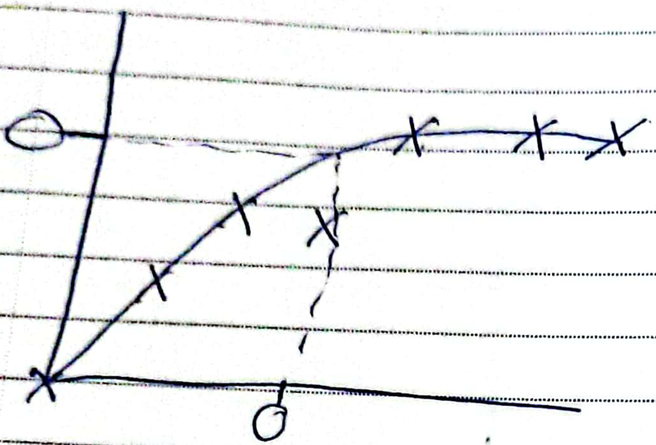
•1)



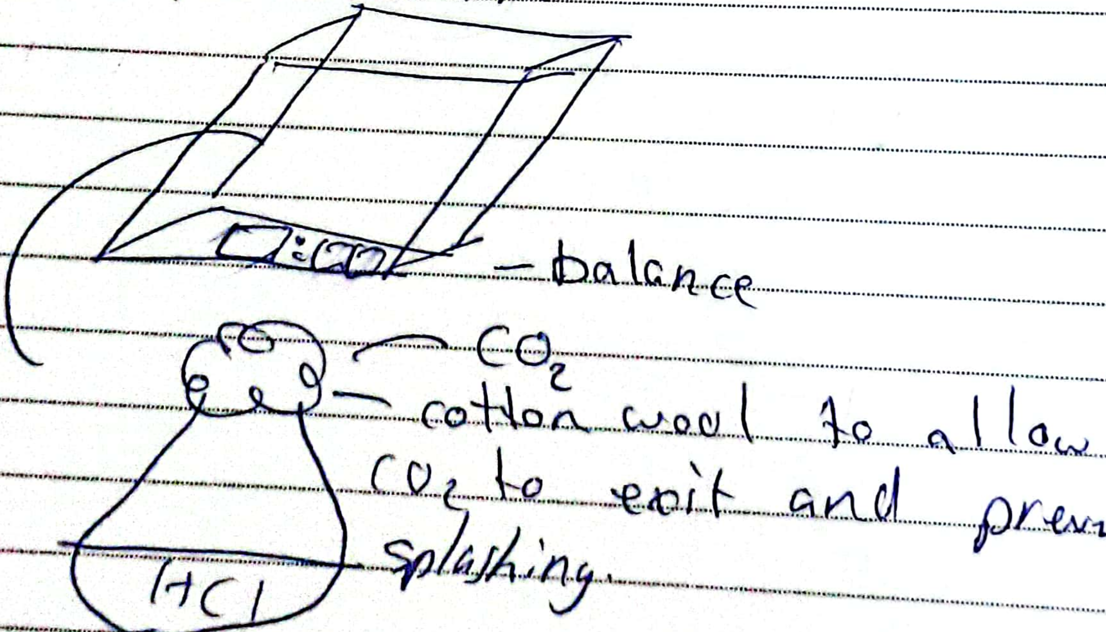
•)



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

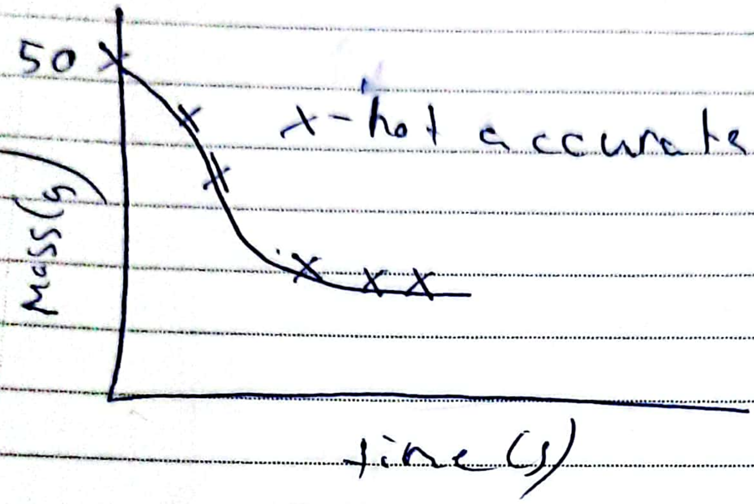


2) measure the mass of the conical flask + contents per unit time.



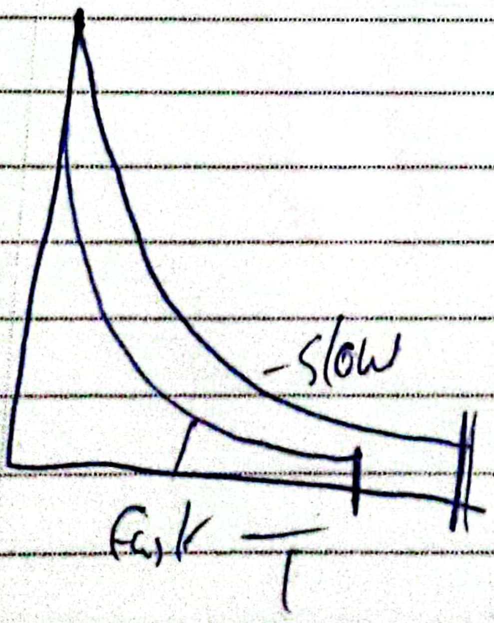
mass decrease because CO_2 escape.

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

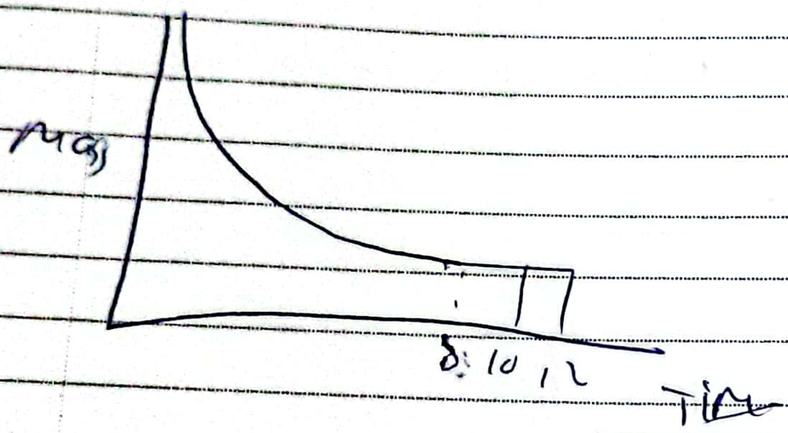


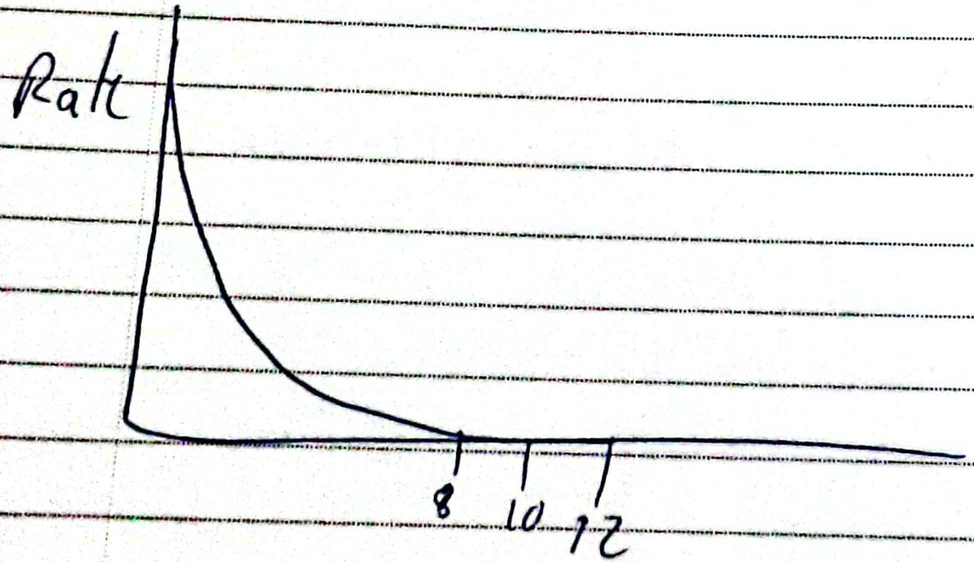
- Increasing the rate of reaction

- more product per same period of time
or same product per less time.



Q) The graph below shows how the amount of reactants change with time





)) Tempreture.

- ~~As the~~ state how the temp increases rate of Rxn

- As temp ↑ rate of reaction ↑

- explain how the temp affect rate of Rxn

- As temp increases
- particles gain more K.E so faster
- The particles will have energy equal to or greater than the (EA)
- so more effective collisions
- faster rate of reaction

(5)

state how SA affect rate of reaction.

- As th surface area increases, rate of rxn increases

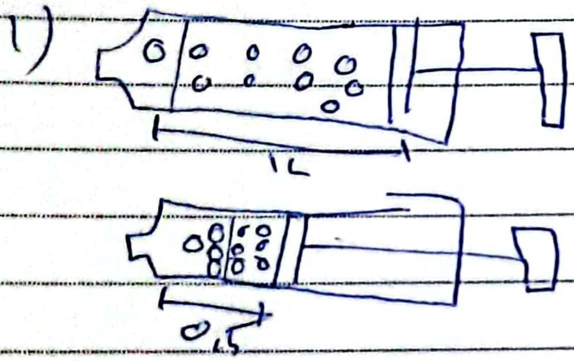
* Explain how th SA affect rate of Rxn

- At th surface area increases, rate of rxn increases. (decrease th particle size by crushing using mortar and pestile)
More particles exposed to th reaction
more effective collisions per unit time
so faster rate.

4) pressure : "only affect th gas"

Q) explain how th pressure affect rate of reaction?

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



$\frac{10 \text{ particles}}{1 \text{ litre}} = 10$

$\frac{10}{0.5} = 20$

5) light "only for photochemical reactions"

- photochemical : Reactions that need light to occur.
- eg : photosynthesis

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

- photographic films
- films coated with silver $\overset{AgCl}{\text{chloride}}$ or silver $\overset{AgBr}{\text{bromide}}$

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

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

6) catalyst
- chemical substance that speeds up th reaction without being changed or used up.

- How it provides and alternative way with lower Ea.
- more particles will have energy equal to or more than Ea
- so more effective collissions per unit time so faster rate of rxn.

- The reaction

$2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$

- 1st catalyst) - CuO
- 2nd catalyst - MnO_2

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

Take a known volume with a known ~~reaction~~ conc. of H_2O_2 measure th volume of O_2 produced per unit time at known temp. repeat exp using CuO
The exp using CuO will produce more O_2 per th same unit time.

Le chatelier principle

⇒ if th system at equil ⇌
- and any external factor disturbt th equil
- th equil can shift itself either to th forward ⇌ or backward ⇌ to return back to equil.

◎ Factors effect th position of equilibrium.

①

↑ tempshift to endo
↓ temp shift to exo.

• shift to endo

Temprature

↑↑ rate of endothermic
↑temp ↑ rate of exothermic

↓ ↓↓ rate of endothermic
↓ rate of exothermic

• shift to exo

No.

ΔH = Enthalpy change

- The sign of ΔH always represents th forward reactio →.

+ve
- gain
- endo

-ve
- lose
- Exo

$$A+B \underset{exo}{\overset{endo}{\rightleftharpoons}} C+D$$

endo

ΔH = +ve

↑Temp ↑↑ Rate of forward
Rate of Backward
↓A ↓B ↑C ↑D
- Shift forward to th endo.

↓Temp ↓rate of forward
↓rate of backward
↑A ↑B
C↓ D↓
Shif back to exo.

$\overset{exo}{\Delta H = -ve}$

$$X + W \underset{endo}{\overset{exo}{\rightleftharpoons}} Y + Z$$

↑Temp ↑ rate of forward } shift
↑ rate of backward } to endo

↑X ↑W ↓Y ↓Z

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

↑ temp: shift to endo, which is backward, so concentration of NH_3 will decrease and concentration of H_2 and N_2 would increase

No. mixture ~~of~~

→ mixture of NO_2 and N_2O_4 at equil in a sealed tube.

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

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

- Because th forward reaction is exothermic, enhanced by cooling.

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

$\Delta H = -ve$

③ pressure. less gas moles.

- As the pressure increase, the equil shift to the side with less pressure.
- As the pressure decreases - - - -
  - - - - - - - more pressure. → more gas mole

4 moles 2 moles

Q ⇒ $3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$

↑ pressure: shift forward to the side with less gas moles. ↑% NH_3

0 moles 1 mol

Q ⇒ $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

↓ pressure: shift ~~down~~ forward to the side with ~~less~~ more gas mole.

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

0 1

) $H_2CO_{3(aq)} \rightleftharpoons H_2O_{(l)} + CO_{2(g)}$

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

No.

Q) 2moles ⇌ 2moles

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

☆ changing the pressure has no effect on the position of equil.
→ scince both sides has the same no. of gas moles.

So: ① Temp (↑ increases rate) (↓ decreases rate)

↑ Temp shift ~~exo~~ endo

↓ shift to exo

② pressure

↑ pressure shift to less gas mole.

↓ pressure shift to more gas mole

∴ ↑ pressure both rates increase

↓ pressure both rates decrease.

FIVE APPLE

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

purple colorless

Q) The equil doesn't affect by increasing the pressure, why by increasing the pressure the pressure the mixture becomes more purple?

~~⇒ The~~

⇒ The I_2 molecule become 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 equil.

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

Dark brown pale brown

Q By increasing

③ concentration

React $\rightleftharpoons$ product

↑ Reactant] shift forward
↓ product

↓ reactant] shift backward
↑ product

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

- ↑A (shift forward) ↓B ↑C ↑D
- ↓B shift backward ↑A ↓C ↓D
- ↑C shift backward ↑A ↑B ↓D

↑D shift backward ↑A ↑B ↓C

- $\boxed{\text{Indicaton}}$

methyl orange $HIn_{(aq)} \rightleftharpoons H^+_{(aq)} + In^-_{(aq)}$

color (1) red — color (2) Yellow

- Add HCl (Acid): proton donor ↑H^+, shift backward, More HIn, more color (1), less In^- less color (2)
- Add NaOH: proton acceptor ↓H^+, shift forward, more In^- more color (2), less HIn less colon (1).

Q)

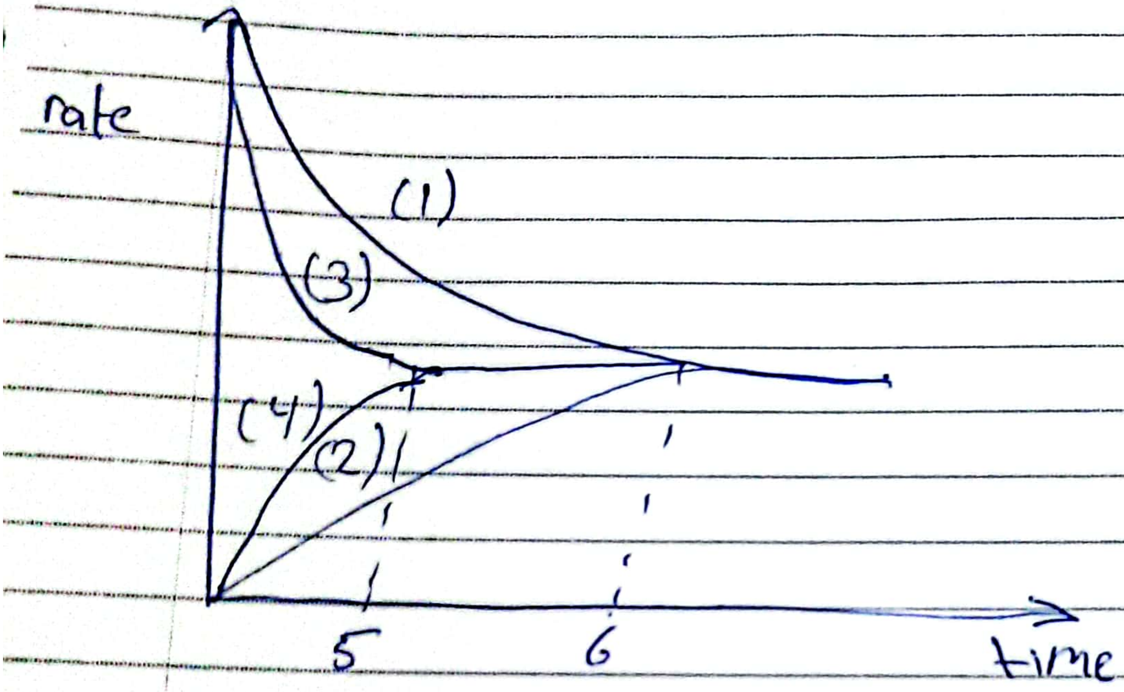
$Cr_2O_7^{-2} + Fe^{2+} + H^+ \rightleftharpoons Cr^{3+} + Fe^{3+} + H_2O$

orange — green

- Explain why 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 and backward



1) Reaction of forward reaction without catalyst.

2) ////// Backward //////

3) Rete ''' forward /// with

4) ///// Backward ///,

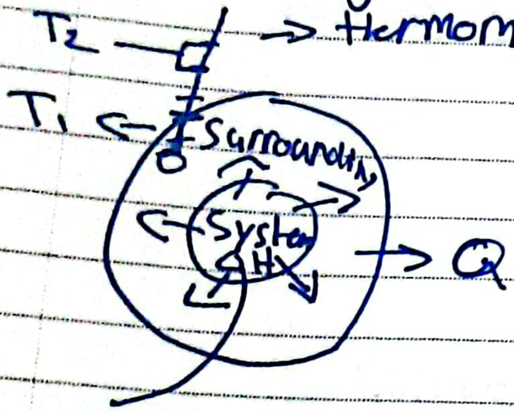
5) time taken to reach equil with catalyst.

6) ////////// without.

No. Energetics

Exothermic

- Reaction that give /release energy to the surrounding



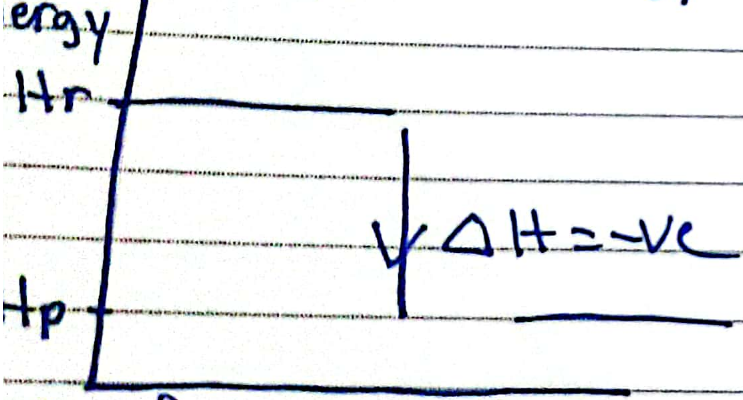
−no temp. change for the system.

- $Q = mc\Delta T$
- $T_2 > T_1$

$\Delta H = -ve$

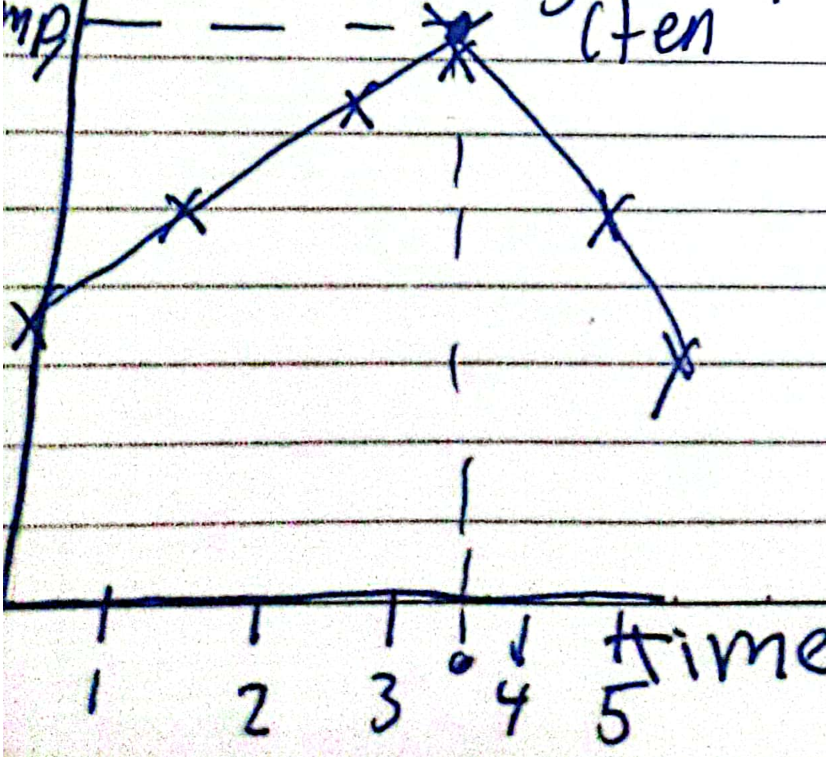
↑Q → more exo

> for system (energy level diagram) ΔT↑



- Enthalpy : Heat contents "stored energy"

→ for surrounding rxn progress



−Hr : enthalpy of reactant
−Hp : Enthalpy of product

−Reaction is over

- Draw intersection point

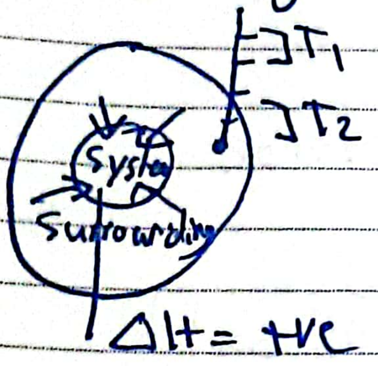
No.

- examples on Exo

1- freezing, condensation
2- Respiration
3- combustion
4- neutralization
5- displacement
6 - Voltaic cell
7- building up bonds

No. Endo

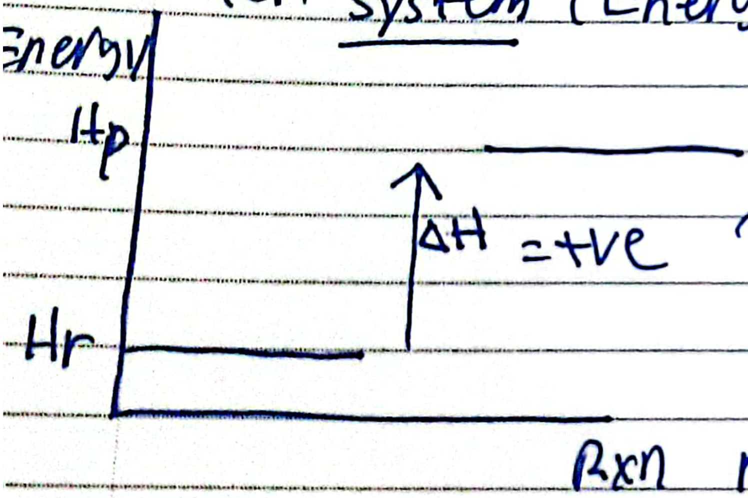
- Reaction that absorb energy from the surrounding



ΔH = +ve

- $T_2 < T_1$
- goes to the system, so temp. decrease
- $Q = mc\Delta t$
  ↳ for surrounding

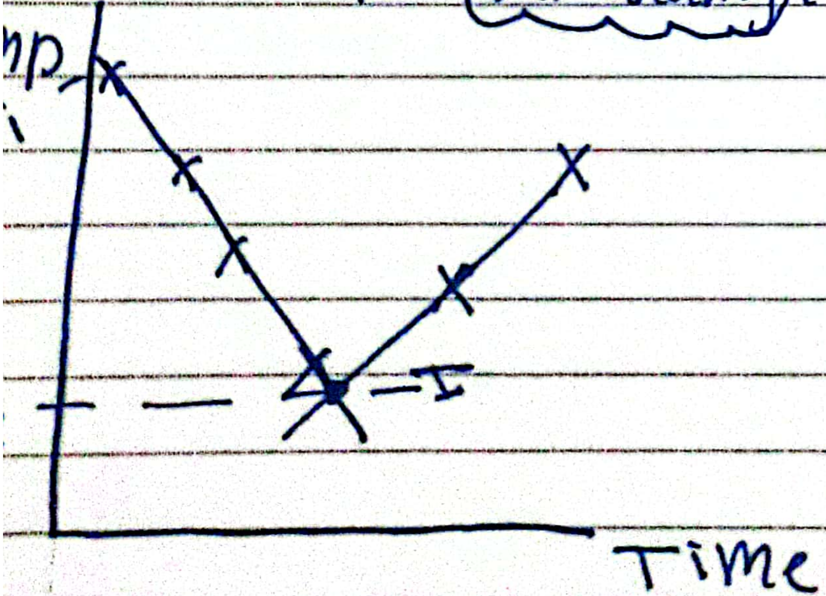
⇒ for system (Energy level diagram)



↑Q → ↑ endo.

system gain ΔT↑

for surrounding (Templeture)



$Q = mc\Delta t$

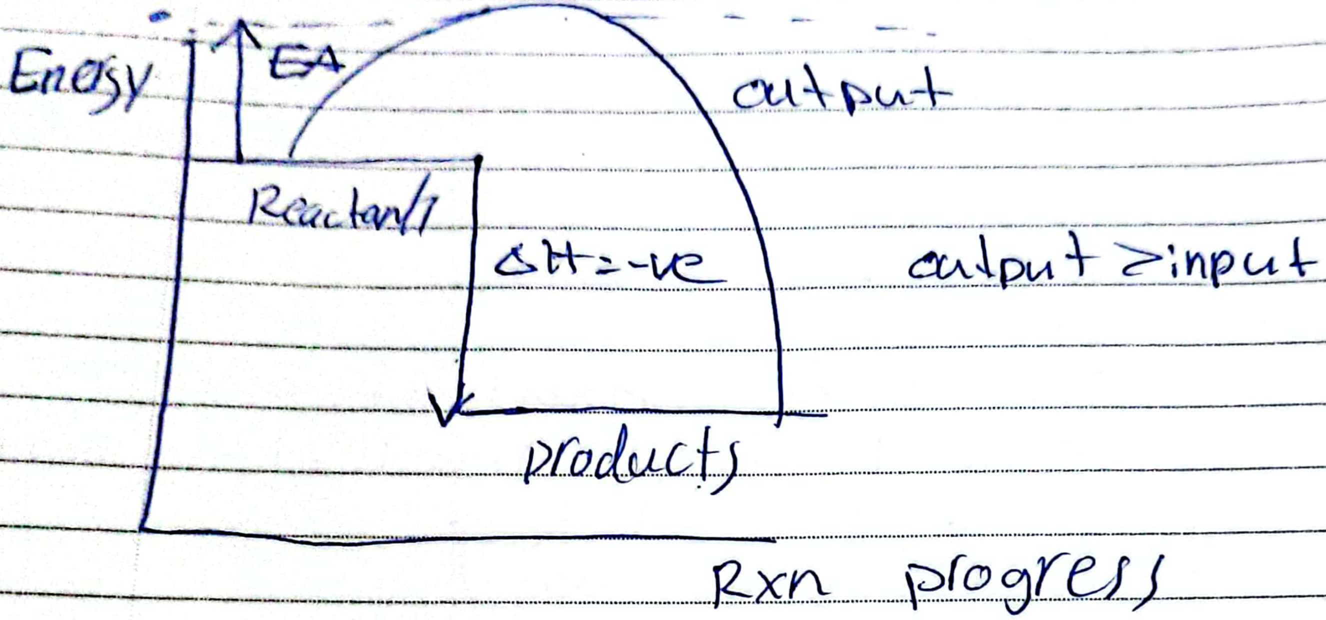
specific heat capacity 4.2 J

$(T_2 - T_1)$

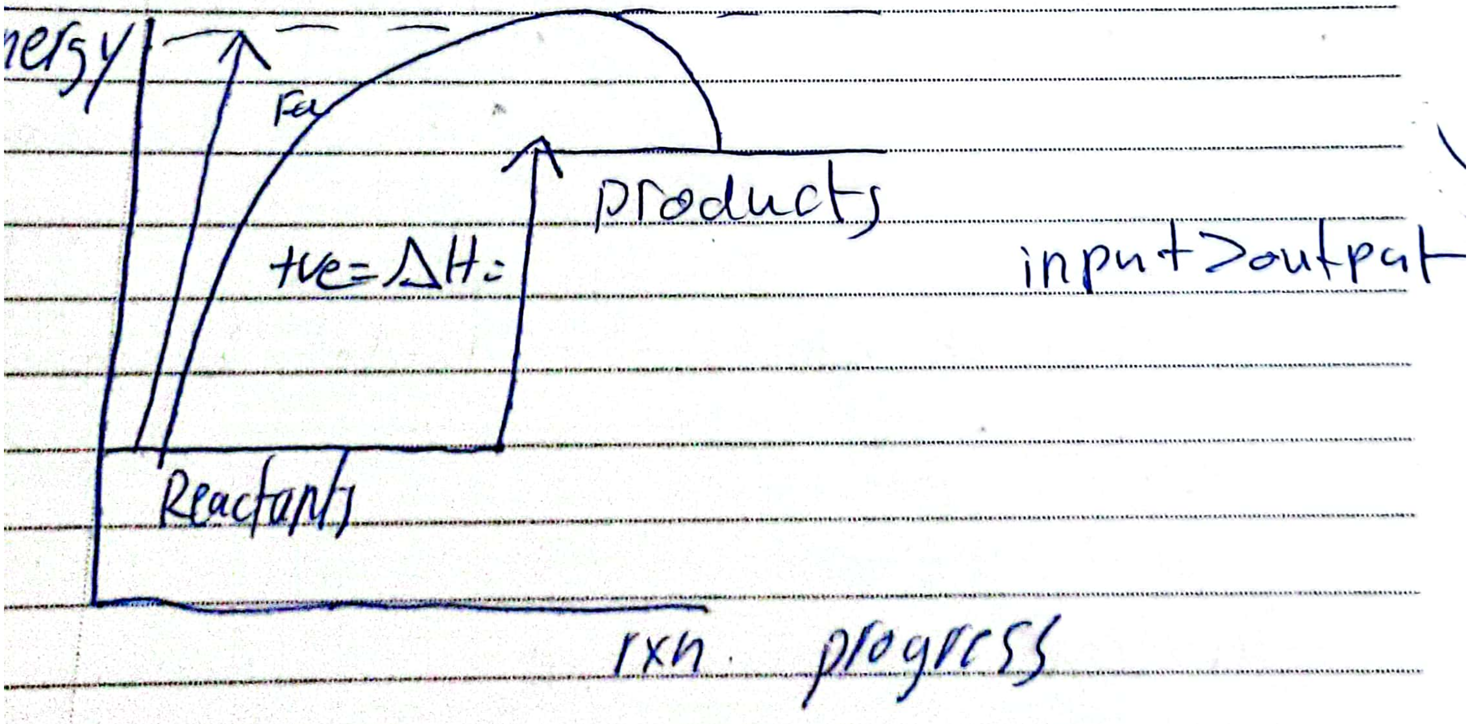
examples on endo

1- Boiling, melting
2- photosynthesis
3- thermal decomposition
4- Electrolysis
5- photographic films
6- dissolve ammonium salt
7- Breaking bonds.

→ How to express exo rxn



→ Endo



Measuring ΔH

Theoretical
→ using bond energy

practical
→ combustion, displacement, neutralization

→ using bond energy

Bond energy: amount of energy needed to break 1mol of a bond in a gas state or // // // // Released to build.

Bond	Bond energy Kj/mol
H-H	436

(should be balanced)

ΔH reaction = Σ input - Σ output

⇓ Break bonds

⇓ build bond.

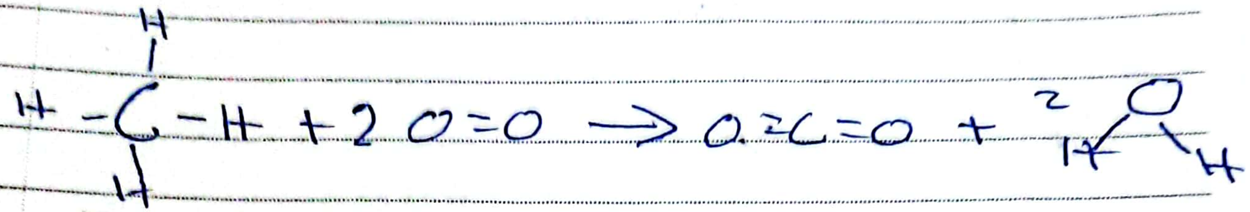
⊕ ⊖

end exo

nput>out input<output.

→ Example

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



	Bond	Bond energy
1)	C−H	413
2)	O=O	495
3)	C=O	399
4)	O−H	463

→ Bond broken

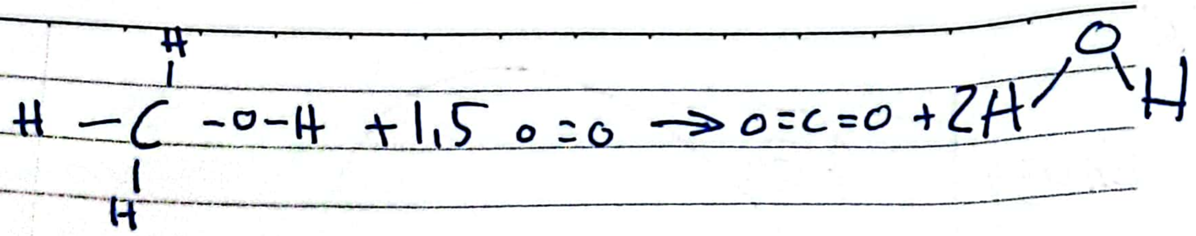
- 4x C−H → 4x413 = 1652
- 2x O=O → 2x495 = 990

→ Bond formed

→ 2 x C=O → 2x799 = 1598
→ 4x O−H → 4x 463 = 1852

- Σ input ~~+~~ total output =
  2642 − 3450 = −808 KJ
  ↓ exo

No.



$H-\underset{H}{\overset{H}{C}}-O-H + 1{,}5\ O=O \rightarrow O=C=O + 2H\overset{O}{\diagup\ \diagdown}H$

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

3x C-H
1x C-O
1x O-H
1,5 x O=O
2x C=O
4x O-H

$(3\times 413) + (1\times 358) + (1\times 463) + (1{,}5\times 495)$
$\uparrow$
Broken

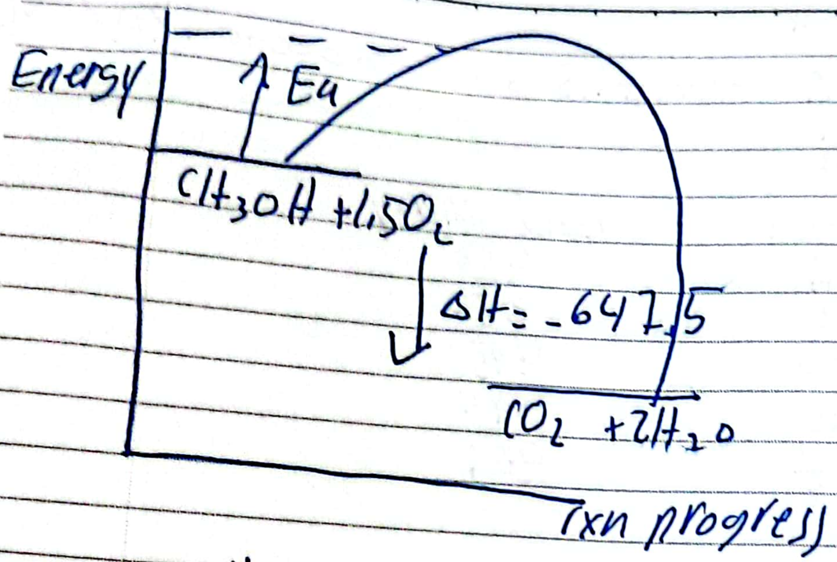
$= 2802{,}5$ kJ

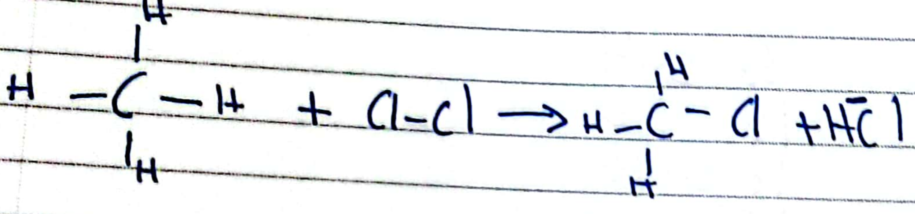
Built $(2\times 799) + (4\times 463) = \underline{3450}$
$\downarrow$

$\Delta H = \Sigma\text{input} - \Sigma\text{output}$
$2802{,}5 - 3450 = -647{,}5$ kj/mo

FIVE APPLE

No





$$H-\overset{H}{\underset{H}{C}}-H + Cl-Cl \rightarrow H-\overset{H}{\underset{H}{C}}-Cl + HCl$$

Bond broken	Bonds built
1x C-H	C-Cl
1x Cl-Cl	H-Cl

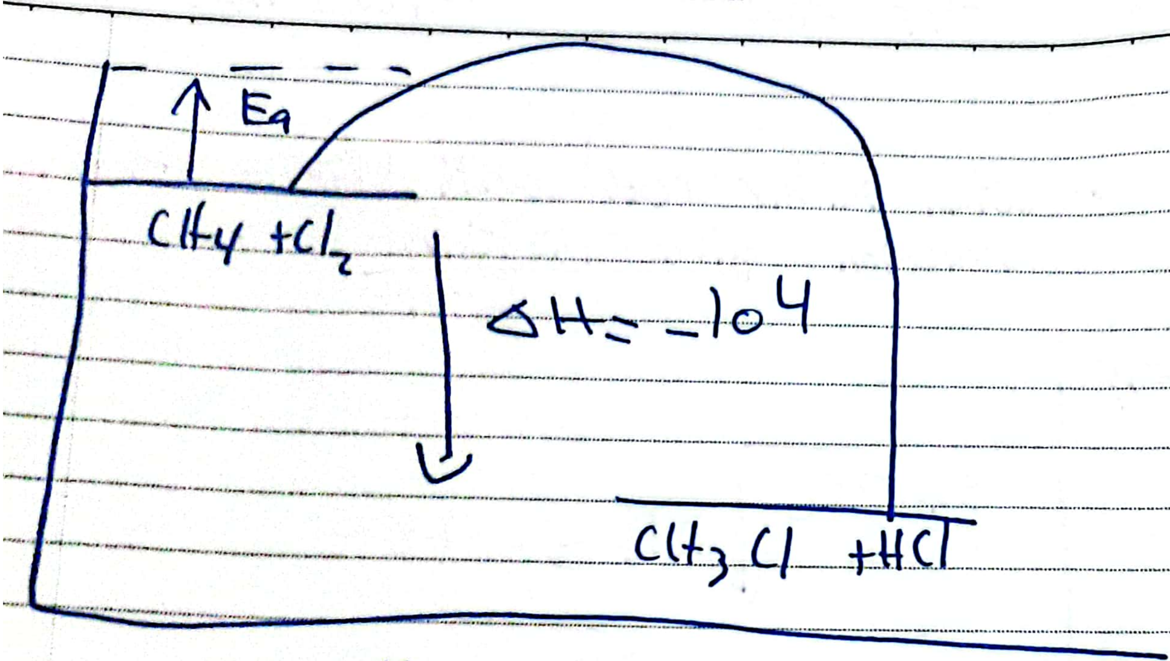
$\Delta H = \Sigma input - \Sigma output$

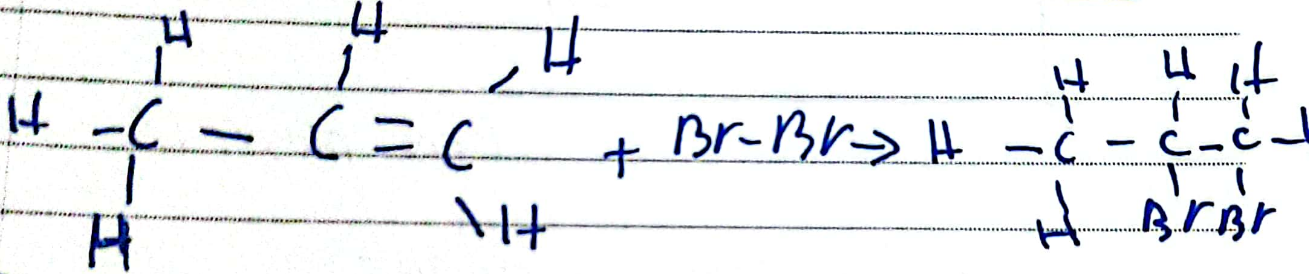
Bond	Bond energy
C-H	413
Cl-Cl	242
H-Cl	431

655-759 = (-)104 kj/mol

exo

FIVE APPLE





Bond	Bond energy
C-H	413
C-C	348
C=C	614
Br-Br	193
C-Br	278

Bond Broken		Bond build
Br-Br	193	2x C-Br
	614	C-C
	807	

$\Delta H: 807 - 900 = -93$ kJ/mol

$320 - 4x = 780 \quad 320 - 4x = 780$

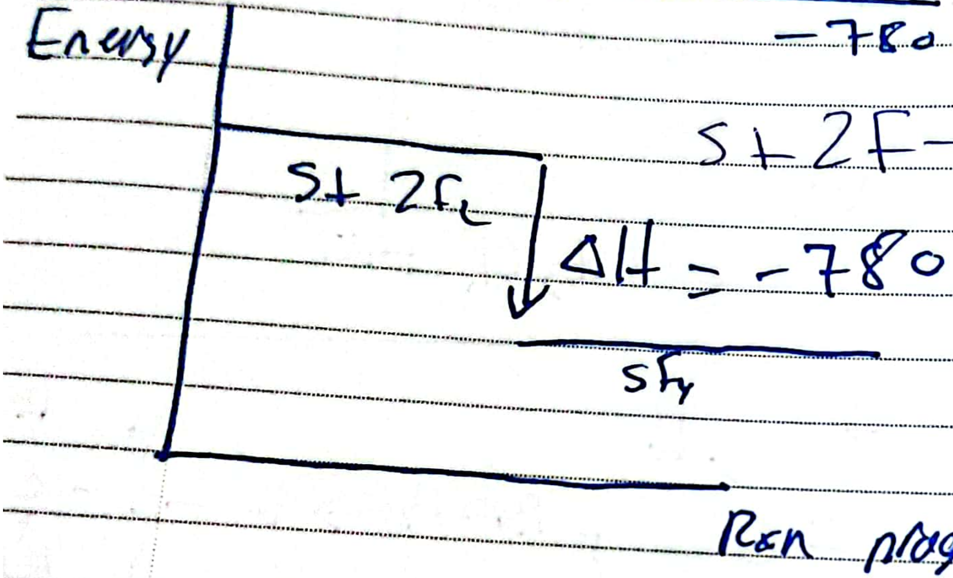
$-4x = 400$

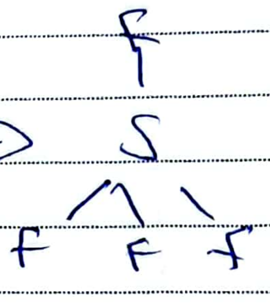
$320 - 4sf = 780$

- When sulfur react with florine the reaction give 780 kj/mol

-780

$S + 2F - F \rightarrow$





ΔH = input − output

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

$-110 = -4S-f$

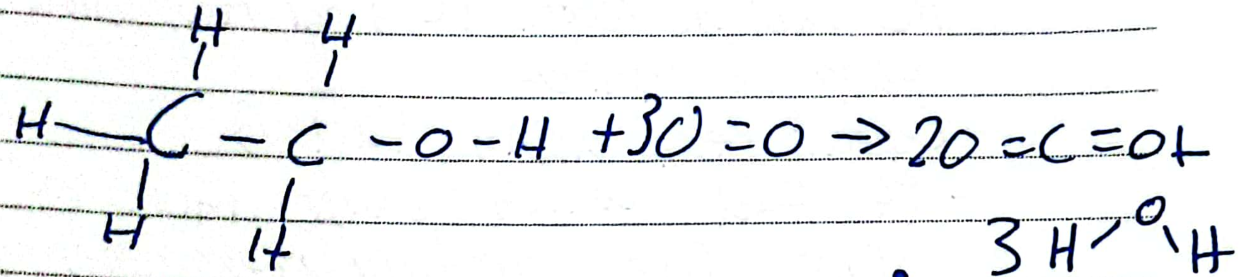
SF = 275 kj/mol

No.

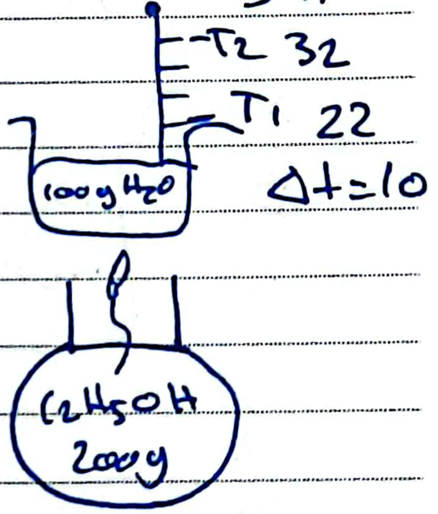
Finding ΔH (energy change) practically

combustion   displacement   neutralization

- Finding ΔH combustion :



$$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-O-H + 3O=O \rightarrow 2O=C=O + 3\,H-O-H$$



- $Q=mc\Delta T$
energy transfer

$m=100g$
$c=4.2$ → for surrounding
$\Delta t = ??$

$Q = 100 \times 4.2 \times 10 = 4200\,\underline{J} = 4{,}2\,\underline{KJ}$

$4.2\,Kj \rightarrow 2g$ of ethanol
$\boxed{96.6\,KJ/Mol}$ 1 mole $=46g$

$\Delta H = -98.6$ kj/mol

FIVE APPLE

No. Alternative resources of energy

Hydrogen fuel cell

• Test water
1) physical test b.p =100
2) chemical test:

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

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

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

- Advantages:

- Only one waste product (H_2O)
- no CO_2
- produce high amounts of energy
- generate electricity

- Disadvantages

- expensive
- hard to store and transport
- Risk of explossion

No. Industrial chemistry

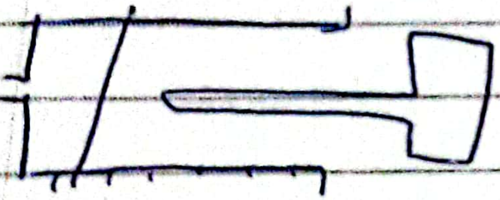
- Dealing with gases
  - Dry
  - connect
- Industry
  - NH_3 (Haber process)
  - H_2SO_4 (contact process)
  - CO_3^{-2} (carbonate cycle)
- metals
  - Al
  - Fe
  - Zn
  - Cu

→ Dealing with gas

Rxn → $\overset{\text{(wet)}}{\text{gas}}$ → dry → collect

- collect gas.

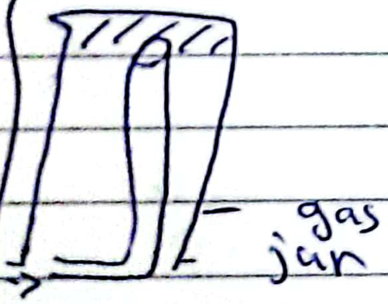
gas syringe



→ collect volume of any gas.

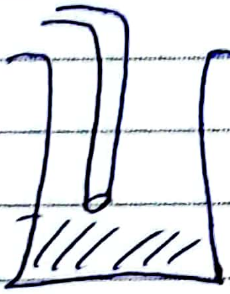
→ no mixing with oter gases.

Delivery tube



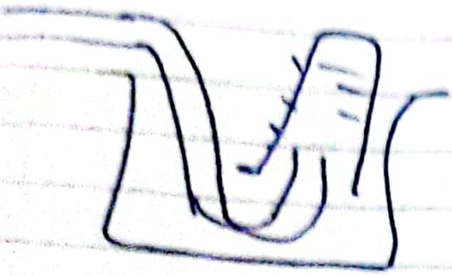
upward

→ less dense than air



→ more dense than air

× mix with air. × gas can escape



→over water.

→only for insoluble gas.

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

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

NH_3 $NH_4Cl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl + H_2O + NH_3$

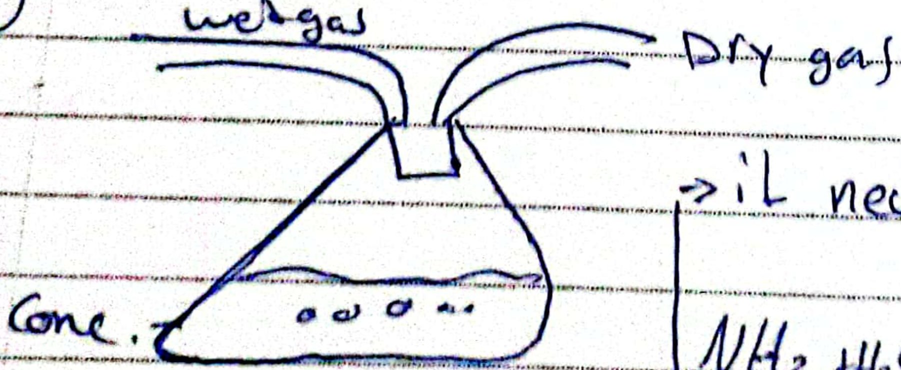
SO_2 $NaSO_3 + HCl \xrightarrow{\Delta} NaCl_{(aq)} + H_2O_{(l)} + SO_{2(g)}$

CO_2 $CaCO_{3(s)} + HCl_{(aq)} \rightarrow CaCl_2 + H_2O_{(l)} + CO_{2(g)}$

- Drying gases

concentrated
H_2SO_4

①

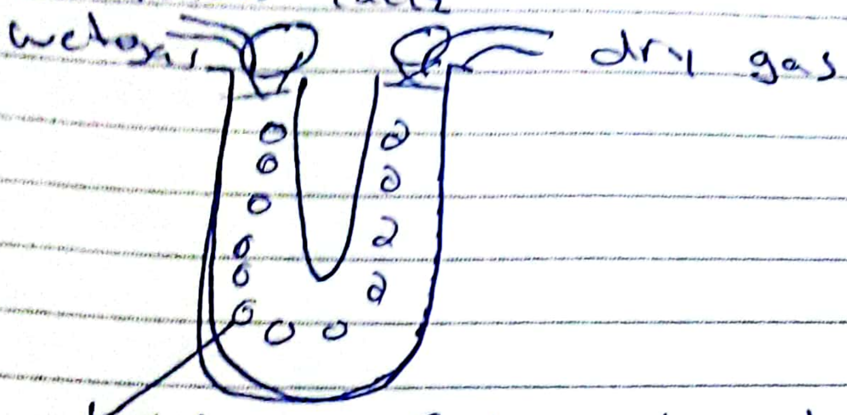


→it neutralise the H_2SO_4

$NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

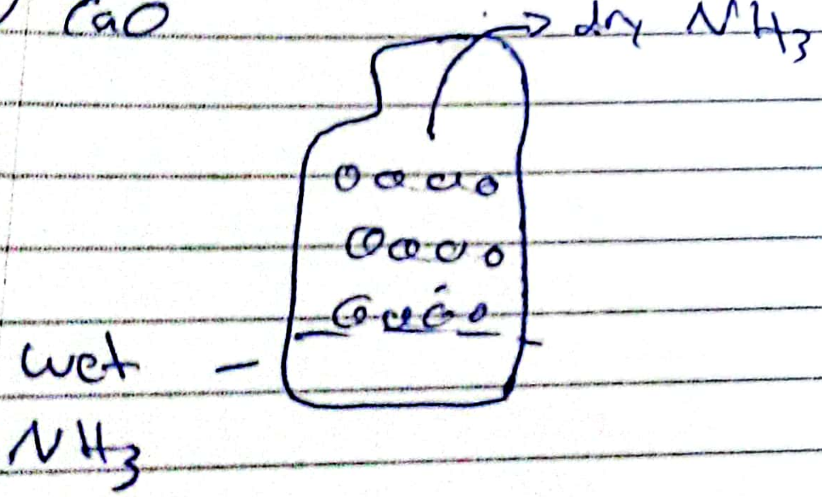
- H_2SO_4 becomes dilute
- used to dry any gas
- except NH_3

② Anhydrous $CaCl_2$



Anhydrous • $CaCl_2$ used to dry any gas except NH_3

③ CaO



No. Industrial

→ Industry of ammonia "Habe process"

$3H_{2(g)} + N_{2(g)} \xrightarrow[\text{endo}]{Fe\ \text{exo}} 2NH_{3(g)}$

How to obtain:

↑ dif b.p

1) Nitrogen - fractional distilation of liquid air.

↓ cooling under high pressure

2)
1) cracking of alkanes (organic)
2) $CH_{4(g)} + H_2O_{(g)} \rightarrow CO_{(g)} + 3H_{2(g)}$

→ Temp (400 – 450)

Temp

less than 400		more than 450	
Adv:	Dis:	ADV:	Dis
• Higher yield of NH_3 • shift forward to exo side.	• Slower rate, los K.E, less effective coll.	• faster rate	• Less yield • shift backward

→ pressure (200 ATM)

• Adv:	• Dis
→ more yield of NH_3 shift forward to less moles – faster rate	→ risk of explosion 2 expensive.

HCl
HC ll + H2O

(Cl) Cl HCl
H OH

No. Industry of H_2SO_4 (contact process)

Stage:

$$S \xrightarrow[+O_2]{\overset{(1)}{CO}} SO_2 \underset{+O_2}{\overset{(2)}{\rightleftharpoons}} SO_3 \xrightarrow{(3)} \underset{\text{(oleum)}}{H_2S_2O_7} \xrightarrow{(4)} H_2SO_4$$

{Roasting} {contact process}

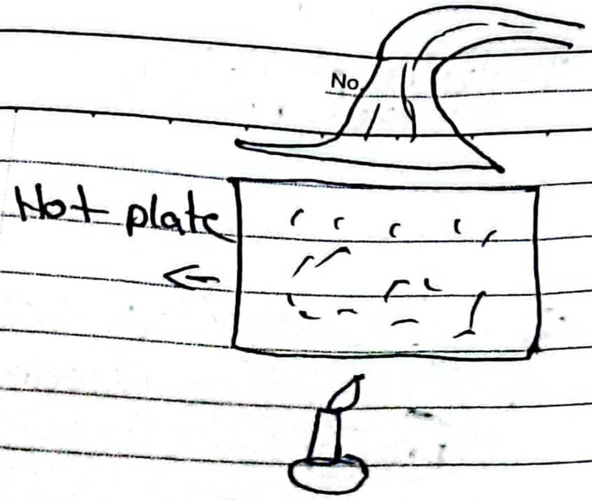
- → group 6
- → valency 2
- → yellow solid
- → S8

- Uses:
  - → medicine
  - → match
  - → Rubber
- Ore: zinc blend ZnS
  - → from fossil fuel

$$SO_3 \xrightarrow{H_2O} 2H_2SO_4$$

- Highly exo
- low yield of H_2SO_4

$H_2S_2O_7$



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

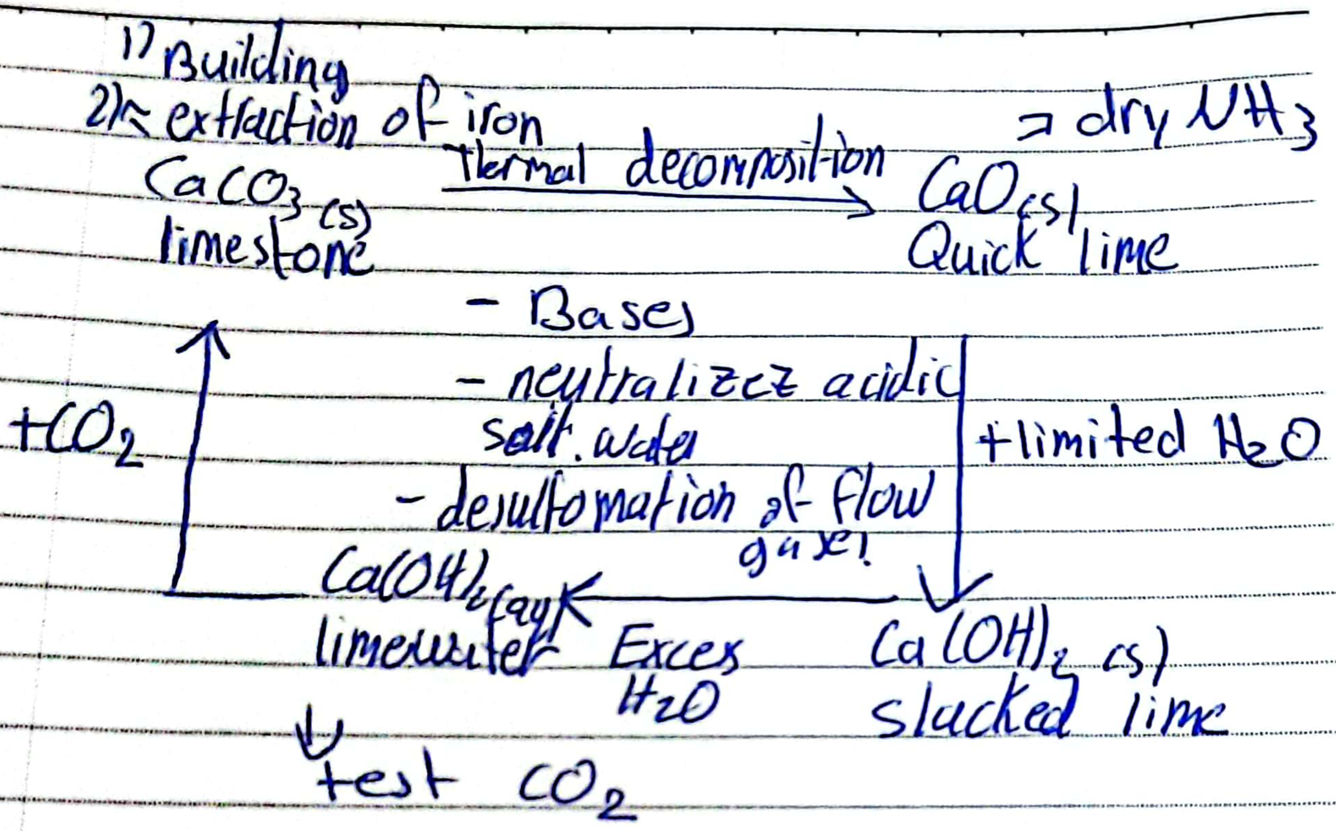
Essential conditions.

1) Temp 400-450°C
2) pressure. 2ATM " High pressure favour the ~~favour~~ forward rxn (fewer gas moles) 2 ATM gives max yield of SO_3
3) catalyst V_2O_5 Vandium (V) oxide.

⇒ SO_2 for wood pulp and food preservatives

⇒ SO_3 is dissolved in concentrated H_2SO_4 to form oleum then into water to form 2moles of H_2SO_4, used to make fertilizers.

No. Carbon cycle



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

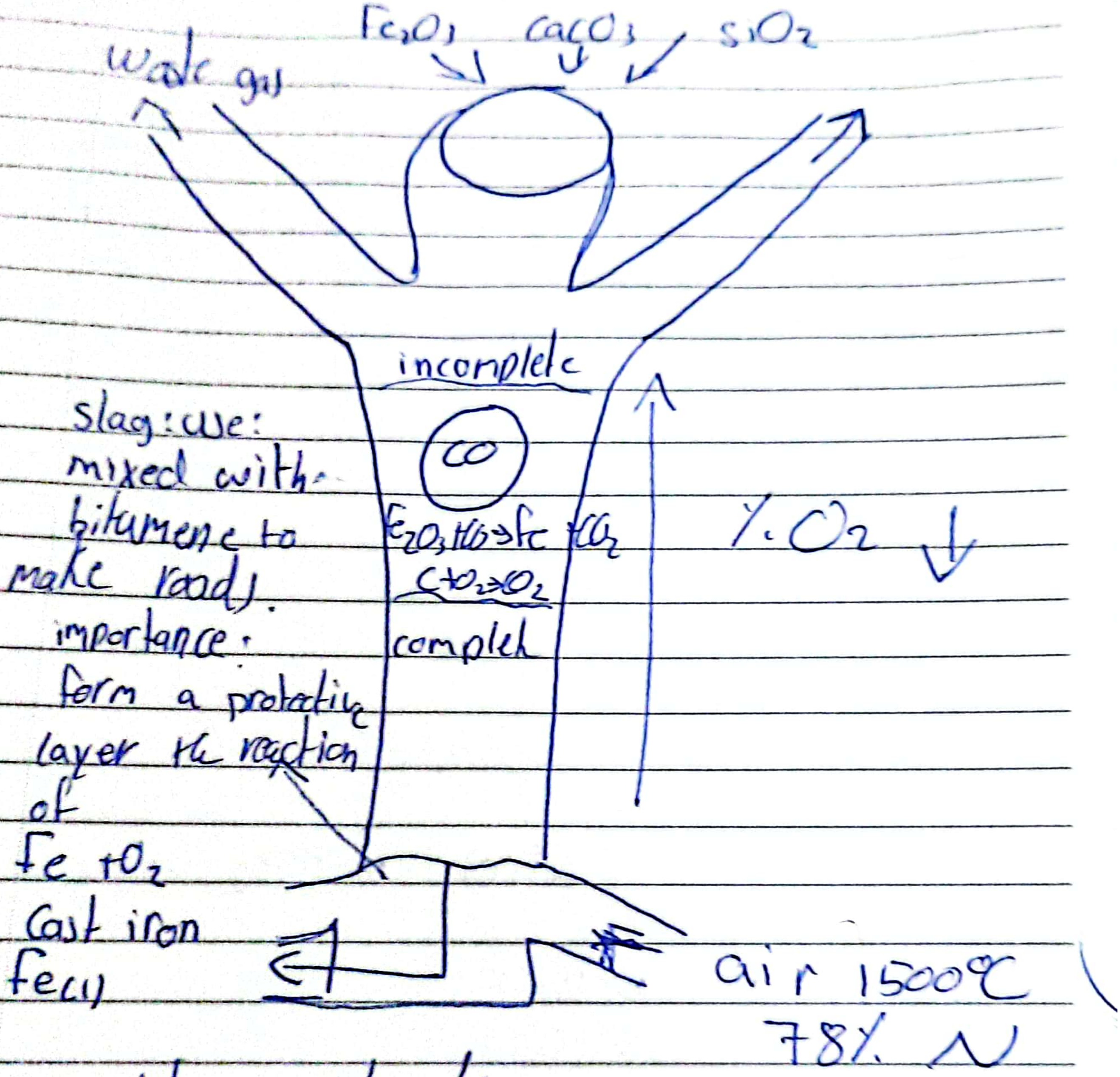
No.

Extraction of metals

K
Na
Li
Ca
Mg
Al] Electrolysis Al_2O_3
Zn
Fe hematite Fe_2O_3
Pb
H
Cu
Ag
Au
Pt

- Extraction of iron
- ore Fe_2O_3 hematite
- methode reduction by C, CO
- place blast furnace
- mixed with:
  - $CaCO_3$ 'lime stone',
  - coke 'carbon pure'
  - air 1500°C

Extraction of Iron



slag: use: mixed with bitumene to make roads.
importance: form a protective layer the reaction of $Fe + O_2$

→ complete combustion
$C + O_2 \rightarrow CO_2$ + energy

→ incomplete combustion; $2C + O_2 \rightarrow 2CO$

→ Redox; $CO_2 + C \rightarrow 2CO$

→ Redox $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

No.

→ thermal decomp: $CaCO_3 \xrightarrow{Heat} CaO + CO_2$

→ Neutralization $\underset{base}{CaO} + \underset{acid}{SiO_2} \longrightarrow \underset{\text{calcium silicate (slag) (molten)}}{CaSiO_3}$

- Carbon and carbon monoxide are reducing agents

• $\overset{\uparrow Base}{CaCO_3}$ can't neutralize $\overset{\uparrow acid}{sio2}$ (gets decomposed)

steel making "oxygen base process"

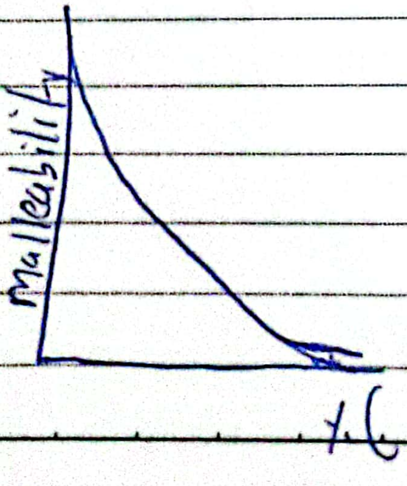
Fe

$CO_2 \uparrow \leftarrow C$ ↙ Heat O_2

$SO_2 \uparrow \leftarrow S$ ↶ CaO

$SiO_{2(s)} \uparrow \leftarrow Si$

$P_2O_{5(l)} \uparrow \leftarrow P$



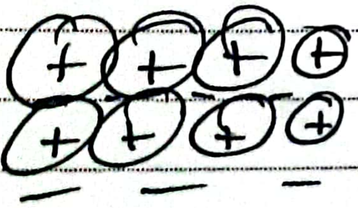
→ steel → Mild steel 0.03% C "car bodies"
→ Medium steel 0.3% C, railways
→ ~~[illegible]~~ stainless steel 3-5% C, cutter watch

- Alloy, mixture of metal with another metal or semi-metal.

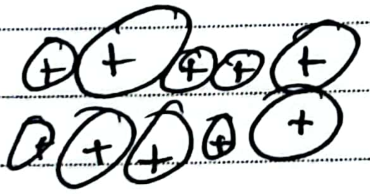
- Brass, Cu, Zn
- bronze, Cu, Sn
- steel, Fe, C, Ni, Cr

- As carbon increase), more stronger (more brittle), less malleable so stronger

metal
Cu



Brass
Cu, Zn



-harder, diff size of metals

→ As carbon ↑, it will become stronger (less malleable) but more ductile.