CH 6 Chemical Reactions

Saturday, 10 January 2026 6:29 PM

CH 6

- Rate of reaction
- Equilibrium
- Redox
- Physical & chemical change

Redox

- Reduction
- oxidation

Oxidation	Reduction
→ loss of $\bar{e}$	Gain of $\bar{e}$
→ gain of oxygen	loss of oxygen
→ loss of hydrogen	Gain of Hydrogen
→ Increase in oxidation number	decrease in oxidation number

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

Oxidation Number: is a number given to an element in a compound that shows if it has lost or gained electron.

Transition elements → Variable oxidation states.

Iron (II) oxide

Rules to find oxidation number

*(1) oxidation number for uncombined form (not in the compound form) = 0

$\overset{0}{Cl_2} + \overset{0}{H_2} \longrightarrow 2HCl$

(2) $\overset{+1}{H}$ $\overset{-2}{O}$

(3) sum of oxidation number in a compound = 0

H_2O

$2H + O$

$2(+1) + (-2)$

$+2 - 2 = 0$

(4) Sum of oxidation number in polyatomic ion is equal to charge of the ion.

SO_4^{-2} → Polyatomic ion

Increase in oxidation number ↑

+5
+4
+3
+2
+1
0
-1

$SO_4 = -2$

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

$S - 8 = -2$

(+) redox

-2 ↓
-3 decrease. $S = -2 + 8$
-4 in oxidation
-5 number. $S = +6$

endergetic

$KMnO_4 = 0$ $\qquad MnO_4^{-1}$

$K_2Cr_2O_7 = 0$ $\qquad NO_3^{-1}$ ✓

$2K + 2Cr + 7O = 0$ $\qquad NH_3$, NO,

$2(+1) + 2Cr + 7(-2) = 0$

$2Cr - 12 = 0$ $\qquad FeCl_3$

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

$Cr = +6$

oxidation numbers

red

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

oxid

oxidised

✓ $\overset{0}{Cl_2} + \overset{+1}{K}\overset{-1}{Br} \rightarrow \overset{+1}{K}\overset{-1}{Cl} + \overset{0}{Br_2}$

redn

reduc $\qquad$ oxidised

O.A $\qquad$ R.A

O. A (oxidising Agent)

oxidises others but reduce itself

Potassium manganate $KMnO_4$ purple → Colourless

$K_2Cr_2O_7$ orange → Green Colour

H_2O_2

R.A (Reducing Agent)

which reduces other and itself get oxidised

eg KI

O.A + O.A → No $\qquad$ $I_{2(s)}$ purple

Base + Base → NO $\qquad$ $I_{2(s)}$ Greyish black

Acid + Acid → NO

oxid

$\overset{+1}{K}\overset{-1}{I}_{(aq)} + H_2SO_{4(aq)} + H_2O_{2(aq)} \rightarrow \overset{0}{I_2}_{(aq)} + K_2SO_{4(aq)} + H_2O_{(l)}$

R.A $\qquad$ colourless $\qquad$ red Brown

O.A.

red

KI $\qquad$ NaI $\qquad$ $H\overset{-1}{I} \rightarrow \overset{0}{I_2}$

Signs

Redox | chemical energetics

$Na_2Cr_2O_7 = 0$

$2Na + 2Cr + 7O = 0$

$2(+1) + 2Cr + 7(-2) = 0$

+6

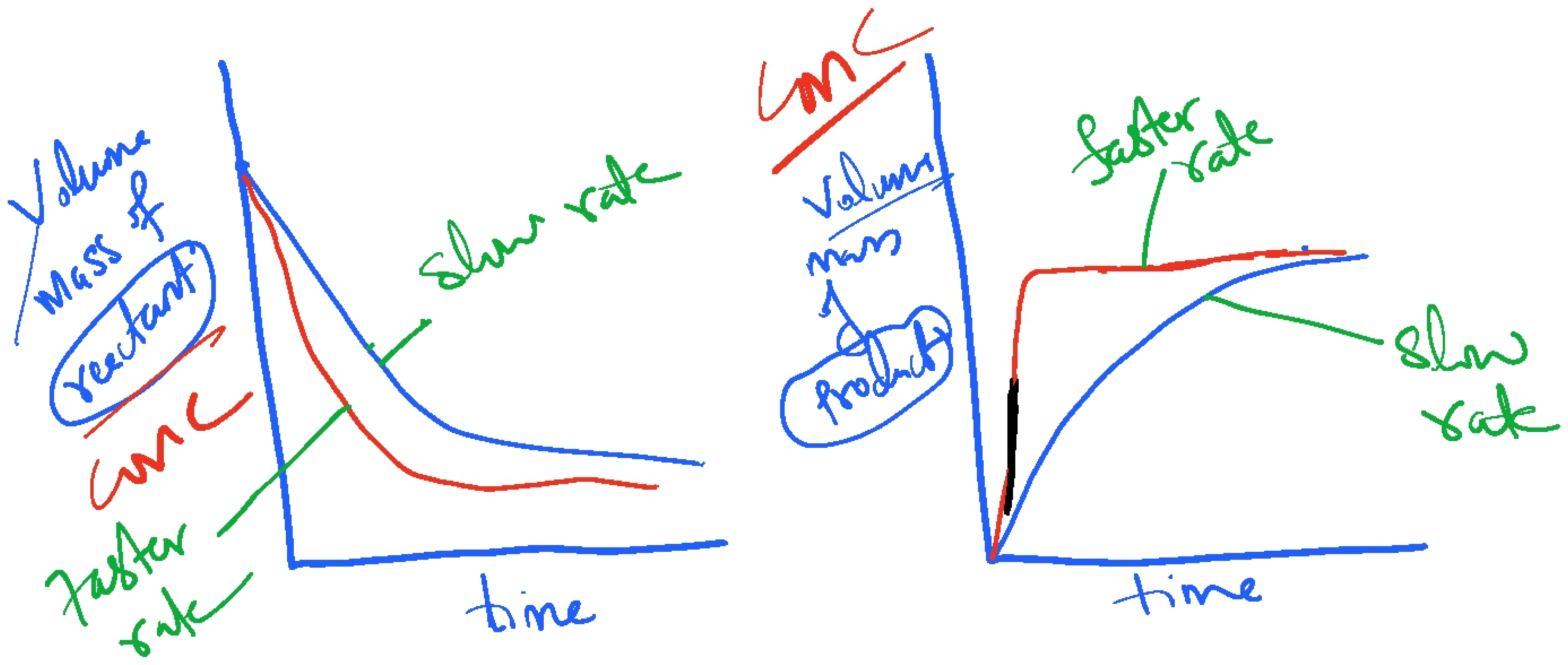
$+2 + 2Cr - 14 = 0$

$2Cr - 12 = 0$

$\frac{2Cr}{2} = \frac{+12}{2}$ → +6

Rate of Reaction

Apparatus: stopwatch

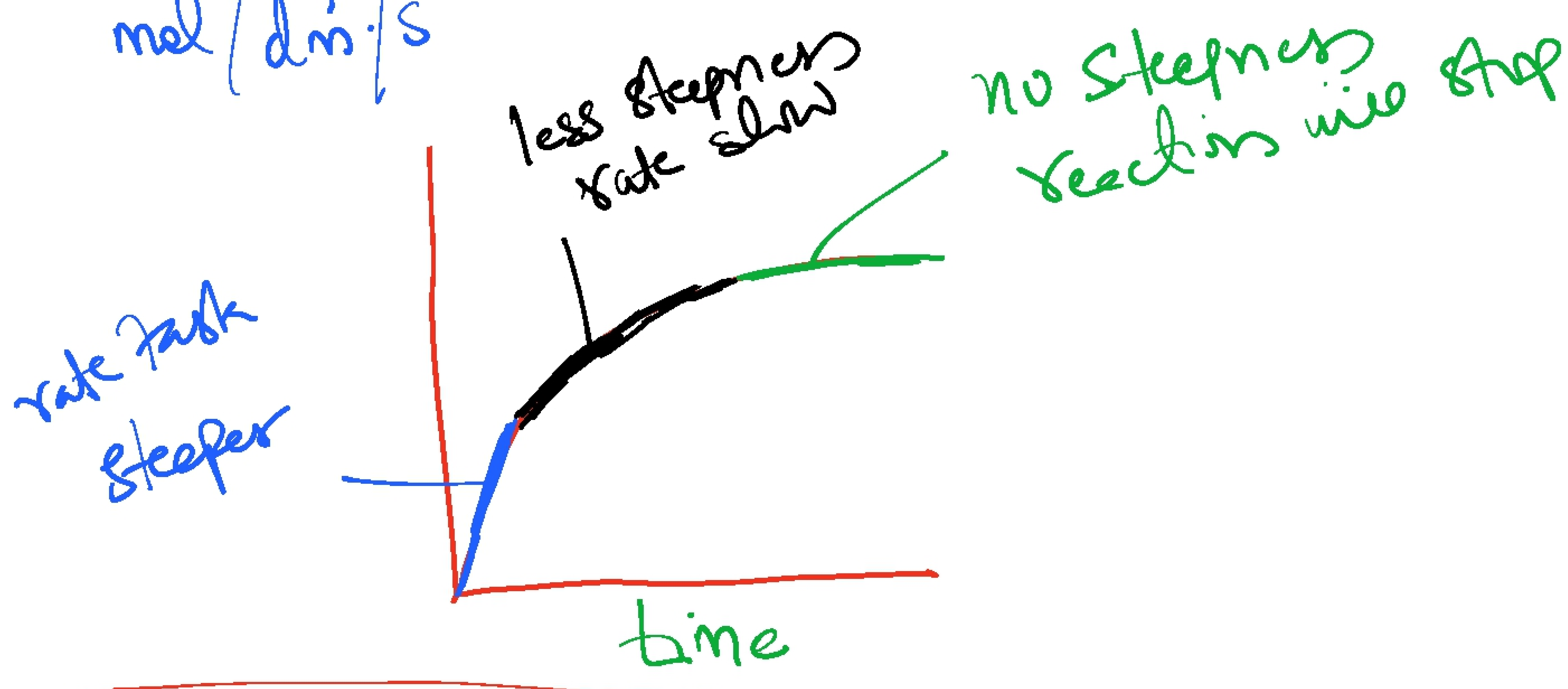


Steeper the graph → faster will be the rate of reaction

$\text{rate} = \frac{\text{Concentration of Reactant}}{\text{time}} = \frac{mol/dm^3}{s} = mol \cdot dm^{-3} \cdot s^{-1}$

$\text{rate} = \frac{\text{Conc of Product}}{\text{time}} =$

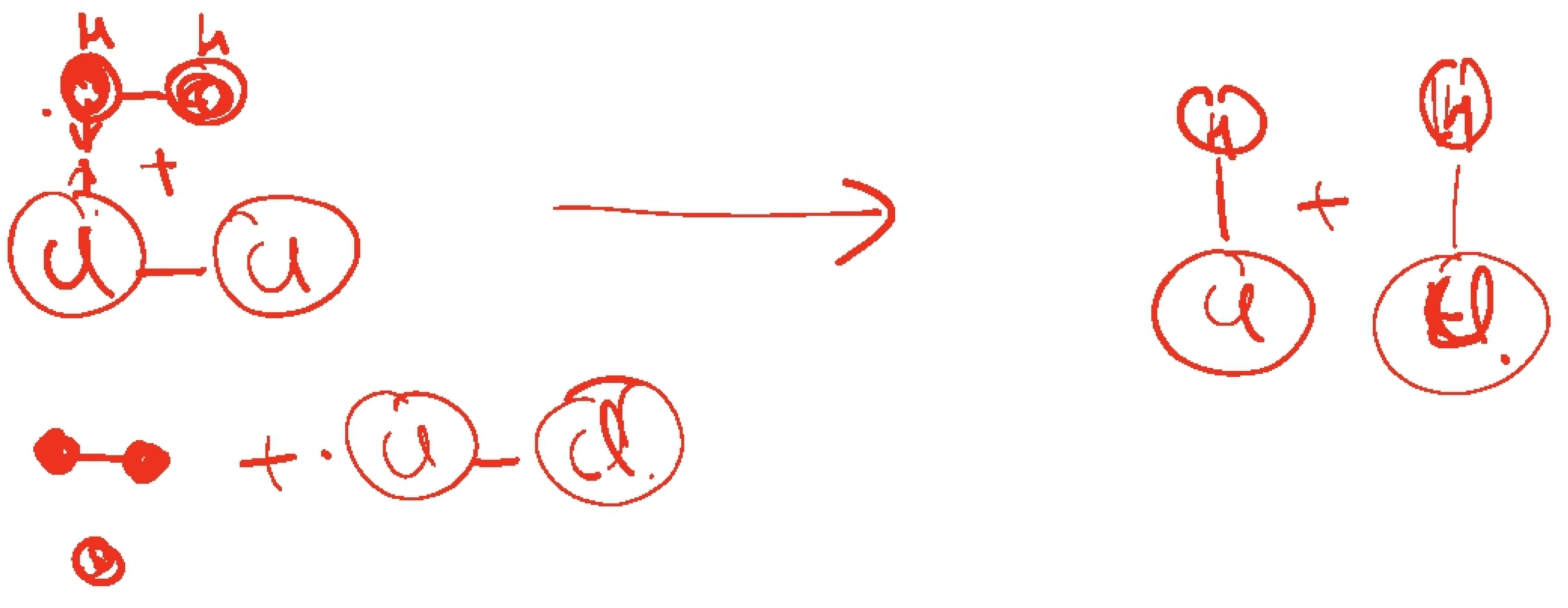
mol / dm³ / s



Collision theory

→ Particles must do collision before forming product.

(1) → Particles must have sufficient energy to react
*(2) → Particles must be properly oriented to each other



Factors affecting rate of Reactions

All factors are directly proportional to rate of reaction

- Concentration
- Pressure
- Surface Area
- Temp
- Catalyst

① Concentration

$CaCO_3 + HCl \rightarrow CaCl_2 + CO_2 + H_2O$ (0.2 mol/dm³, 0.1 mol/dm³)

Rate of reactions ∝ Conc.

More concentration means more effective collision per unit volume

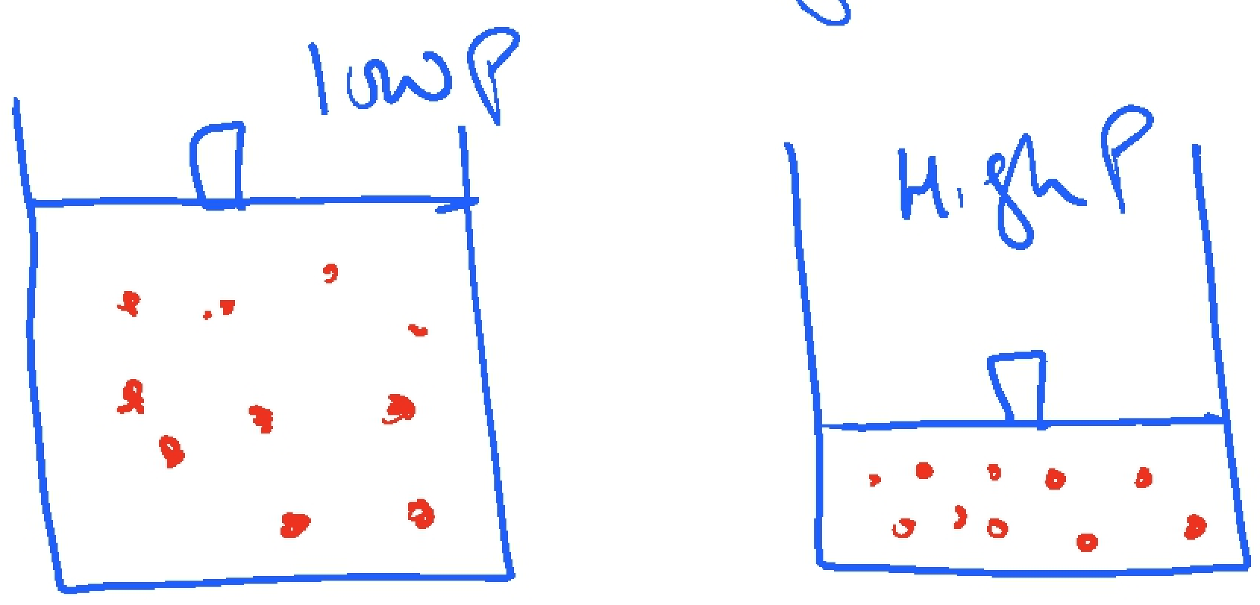
effective collision | fruitful collision | successful collision → give product

Higher Conc
↓
More reactants in a given volume
↓
Increase frequency of collisions
↓
more successful collision per unit time

3 Marks

② Pressure → only in Gases

Rate of reaction ∝ Pressure

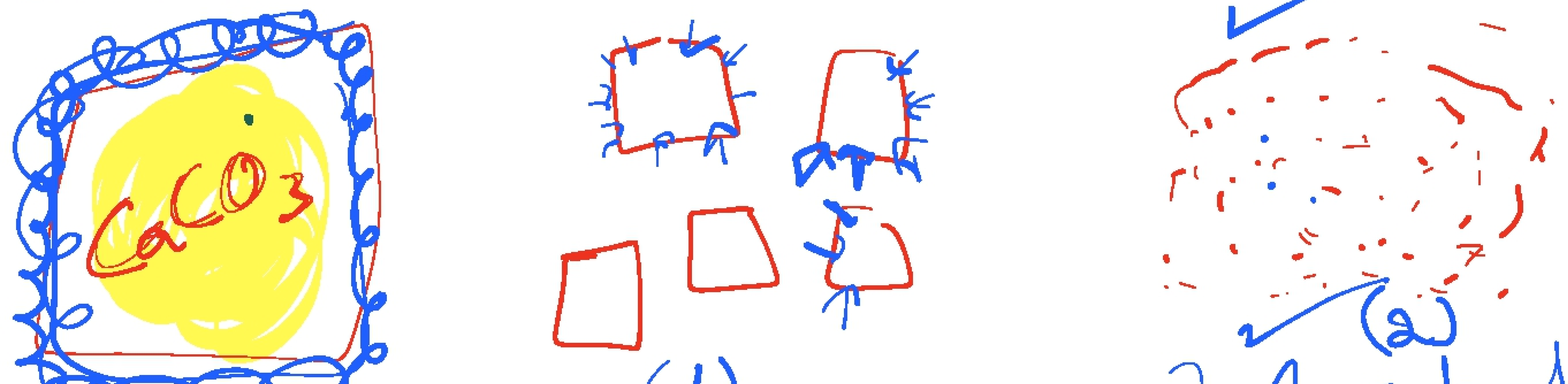


High P
↓
gas particles close together
↓
Increasing frequency of collision
↓

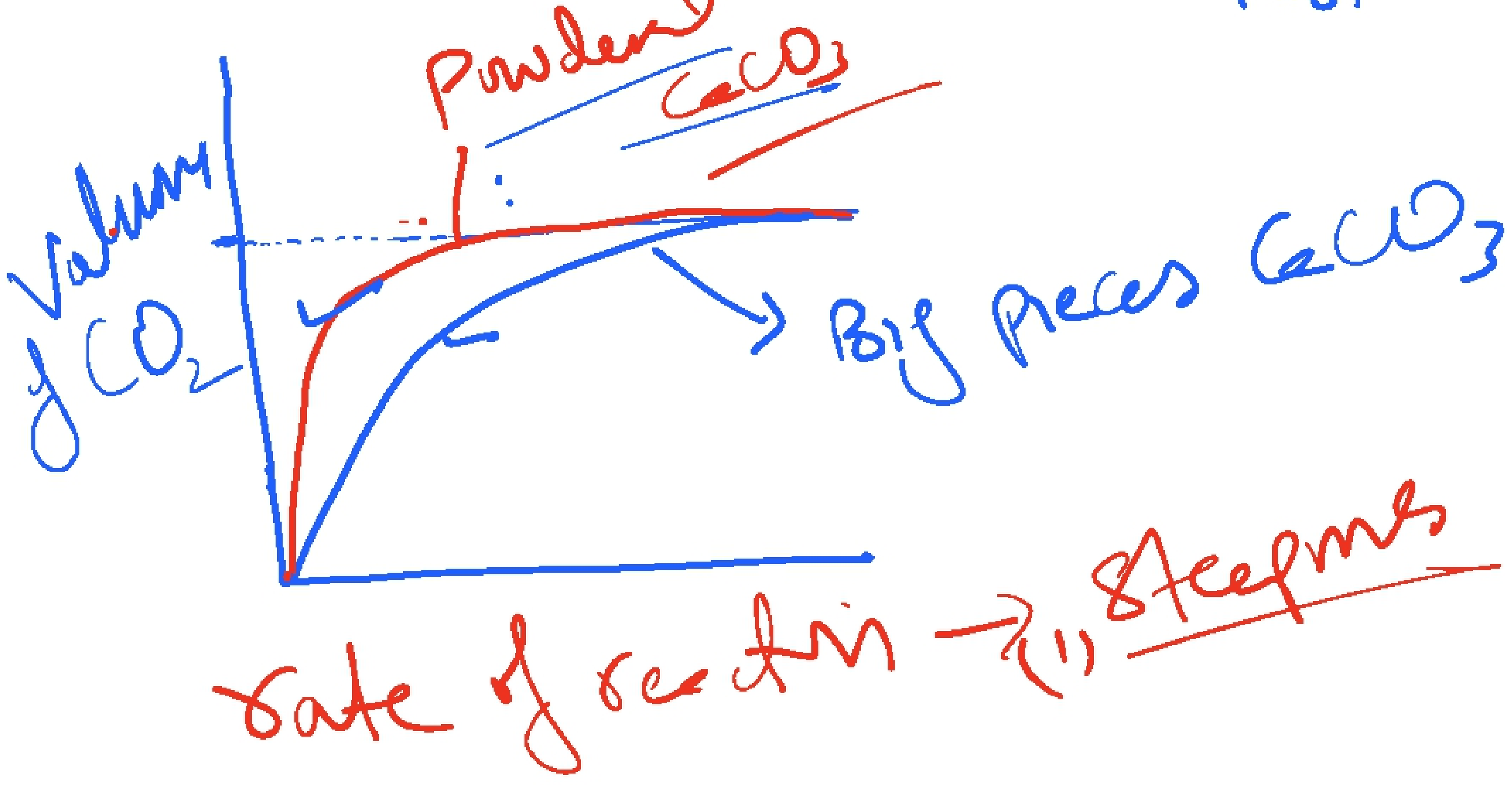
higher rate.

③ Surface Area → (Solid only)

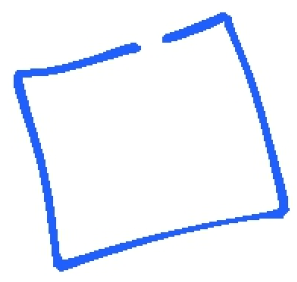
$CaCO_3 + HCl \to CaCl_2 + H_2O + CO_2$



Fast rate of reaction



rate of reaction → (1) steepness

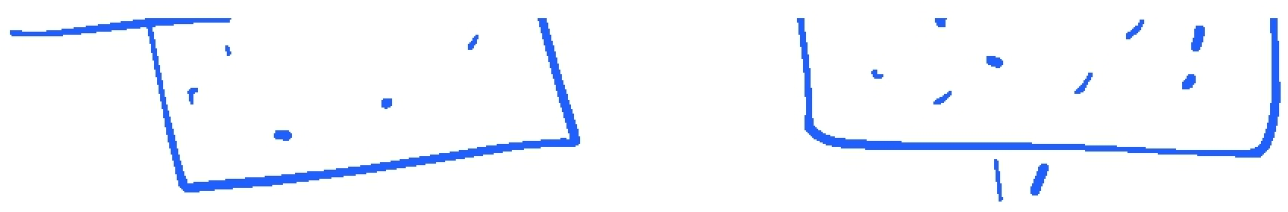


High surface area
↓
expose the solid particles to other reactants
↓
increase frequency of collision
↓
Higher rate

④ Temperature

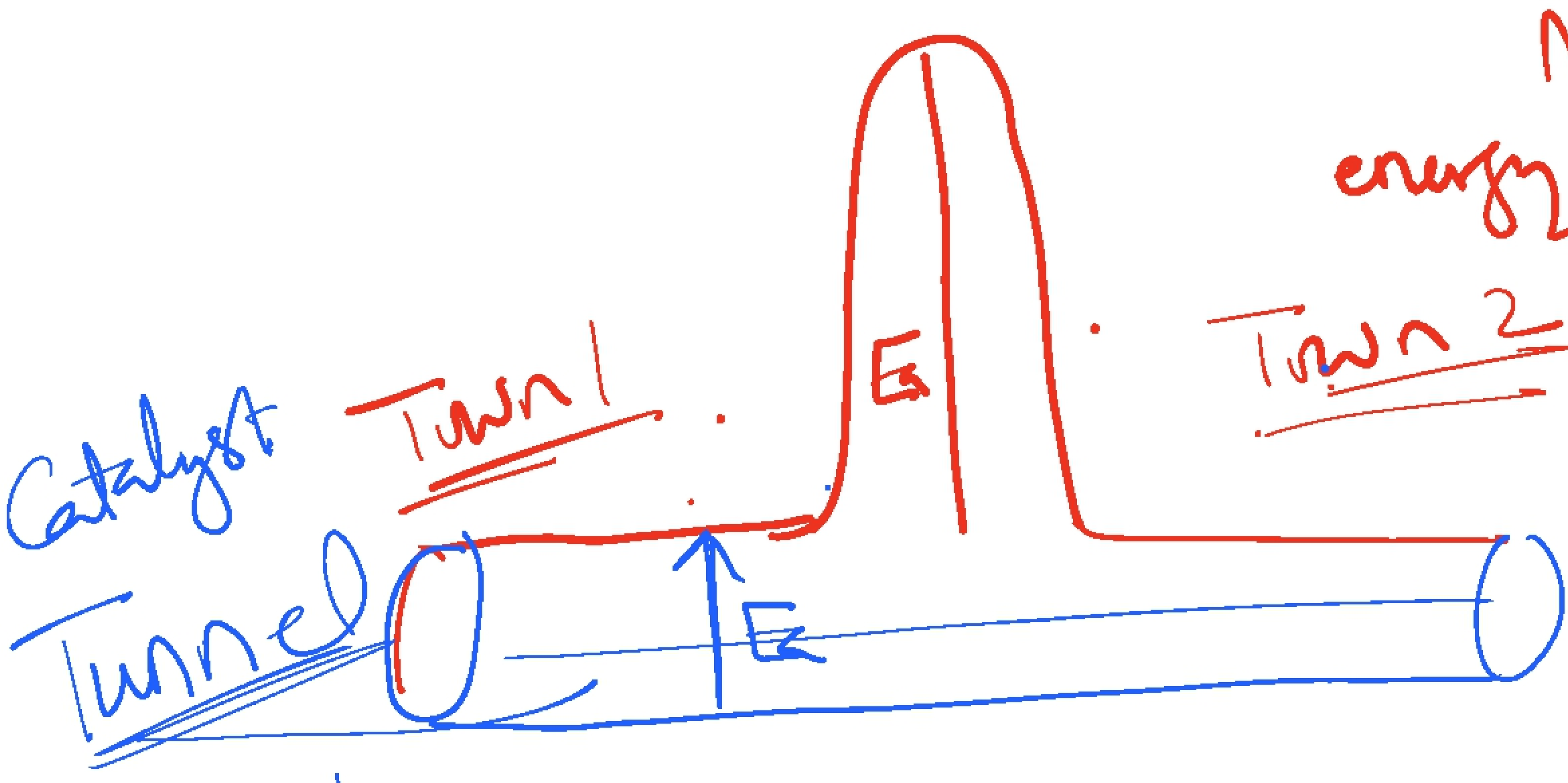
(1) Increasing temp → Increases K.E → More successful collision

Increasing temp will make the more particles energy greater their activation energy



(1) { Increase K.E
↓
Molecules will move faster
↓
more frequent collisions
↓
(2) → More particles will have energy > Ea.

Minimum amount of energy needed to start the reaction

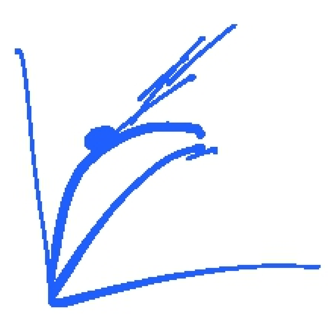


catalyst (2)

Catalyst: a substance that speeds up a chemical reaction (1) without being changed in reaction (2)

~~Collision theory:~~

Catalyst increases the rate of reaction and is unchanged at the end of reaction. Catalyst decreases the Ea.



Enzyme → Biological catalyst

High (PH) & Temp may affect the

enzyme activity so it becomes denatured

Investigating The rate of Reaction

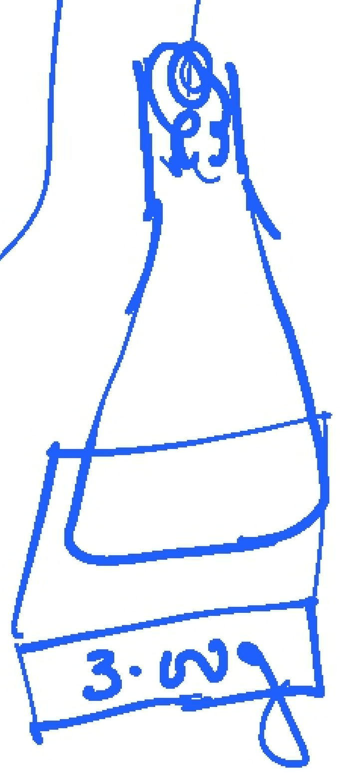
Change in Mass of R / P

→ Balance

_ Mouth of the flask

cotton wool

is placed to prevent any substance spilling out



Measuring volume of gas formed

→ gas syringe (Collection of small volume of gas) / Inverted measuring cylinder (for large volume)

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

$Mg + 2HCl \rightarrow MgCl_2 + H_2$ ✗

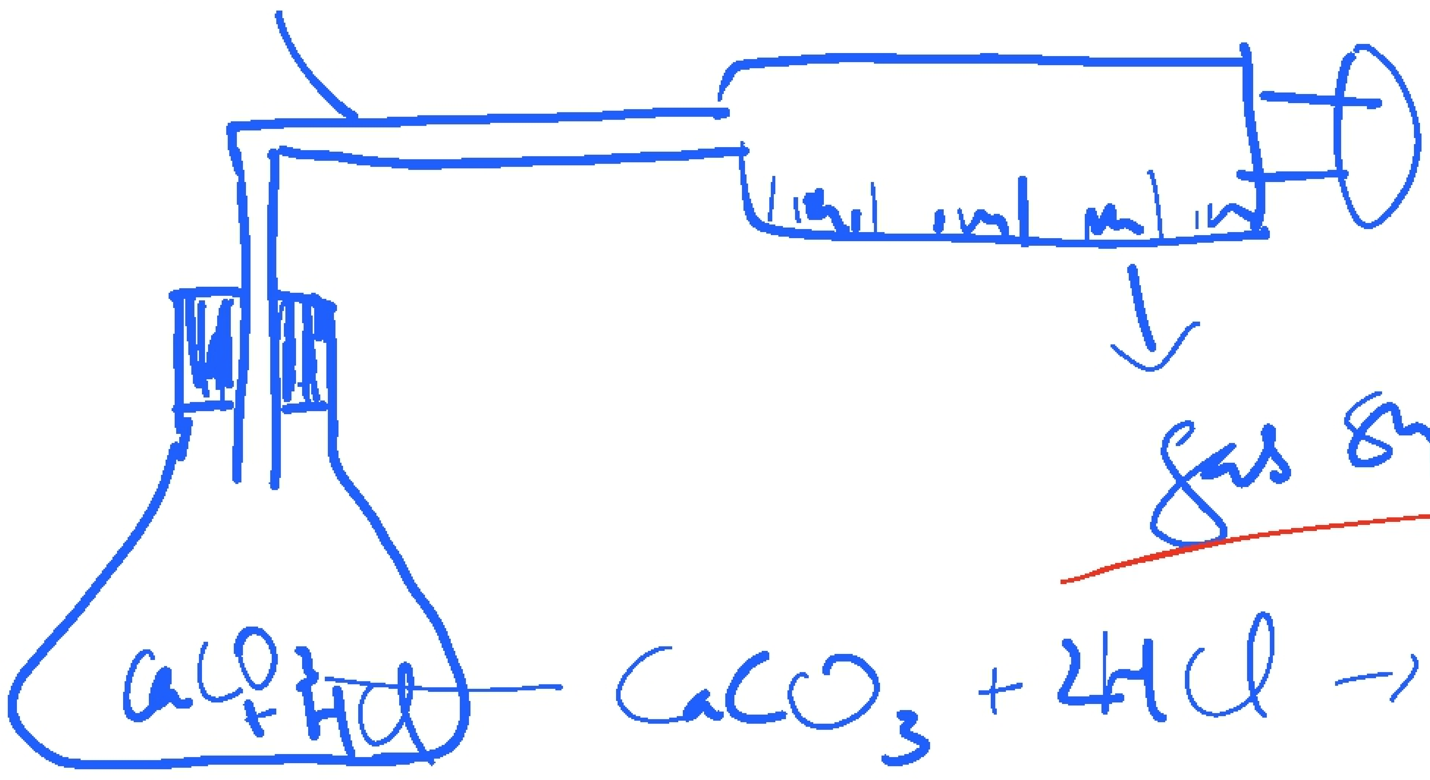
because H_2 mass is negligibly small.

This method is not affective if your reaction is releasing H_2

observations (1) No more bubbles

(2) mass will be constant

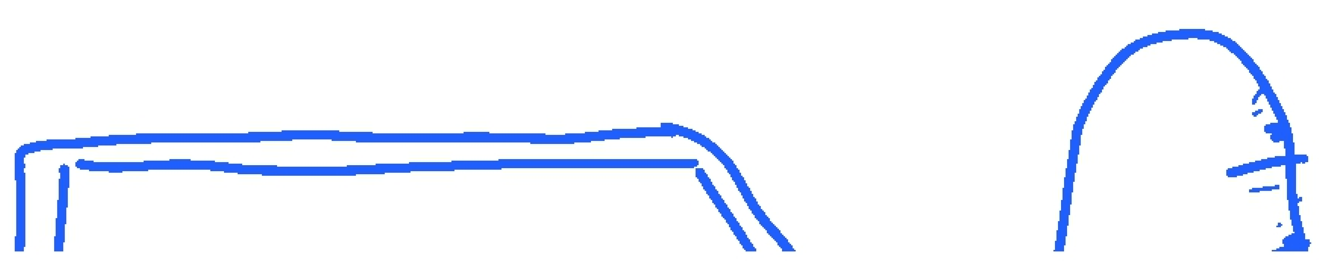
More reliable Method



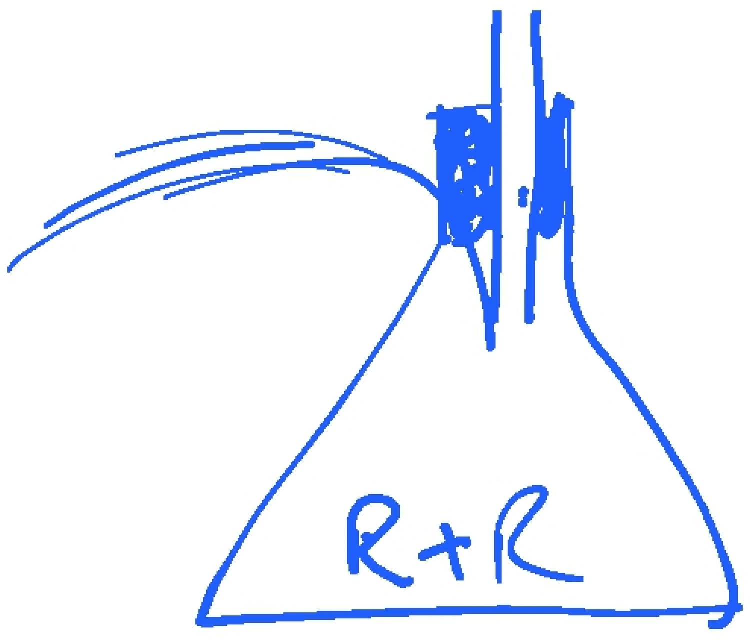
use to measure small amount of gas

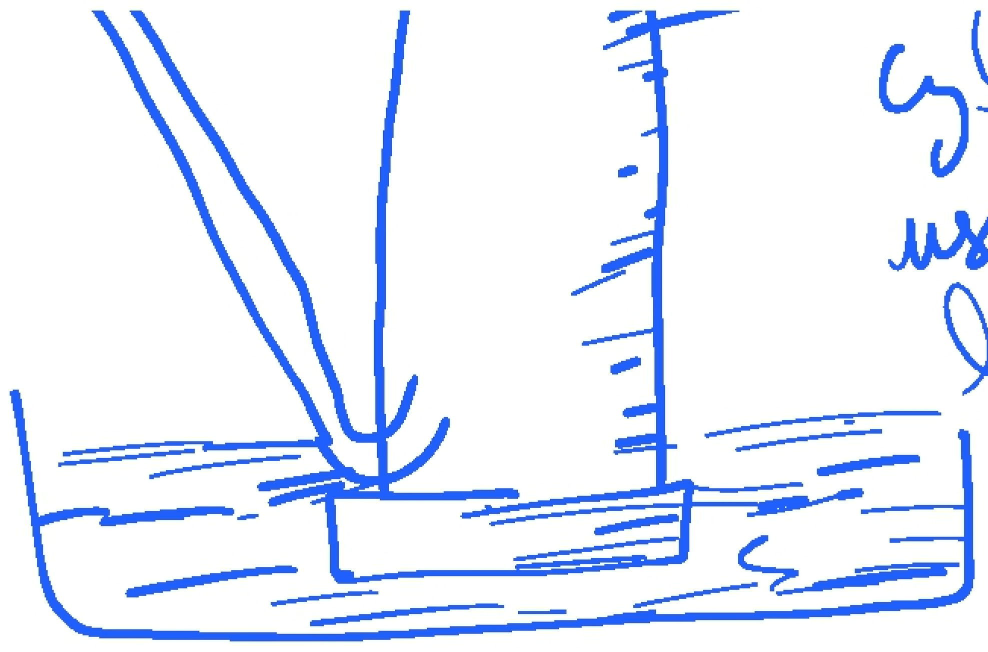
$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

Rate of reaction = $\frac{\text{Volume of gas Produced}}{\text{time}}$



Inverted measuring ... is





cylinder use to measure large volume of gas.

inaccurate

→ gas leaked out

Physical and chemical change

Physical: Alter the appearance of substance without changing its chemical composition

→ Melting ice

→ dissolving sugar in H_2O

Chemical: New substance is formed with different chemical composition.

→ Rusting of iron

→ Frying an egg

→ Burning of wood.

Signs that a chemical reaction has taken place

(1) Colour change

(2) Bubbles formation

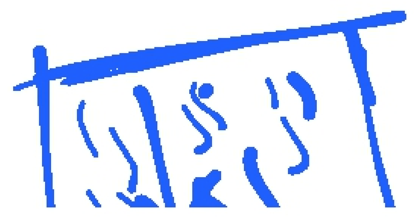
(3) Change in temperature

(4) formation of new odor

(5) Formation of precipitate

310

Chemical Equilibrium



Conditions for equilibrium

(1) System must be closed

* (2) Rate of forward reaction must be equal to reverse reaction

* (3) Concentration of reactants and products remain constant.

Reversible Reactions

$\rightleftharpoons$ forward / reverse

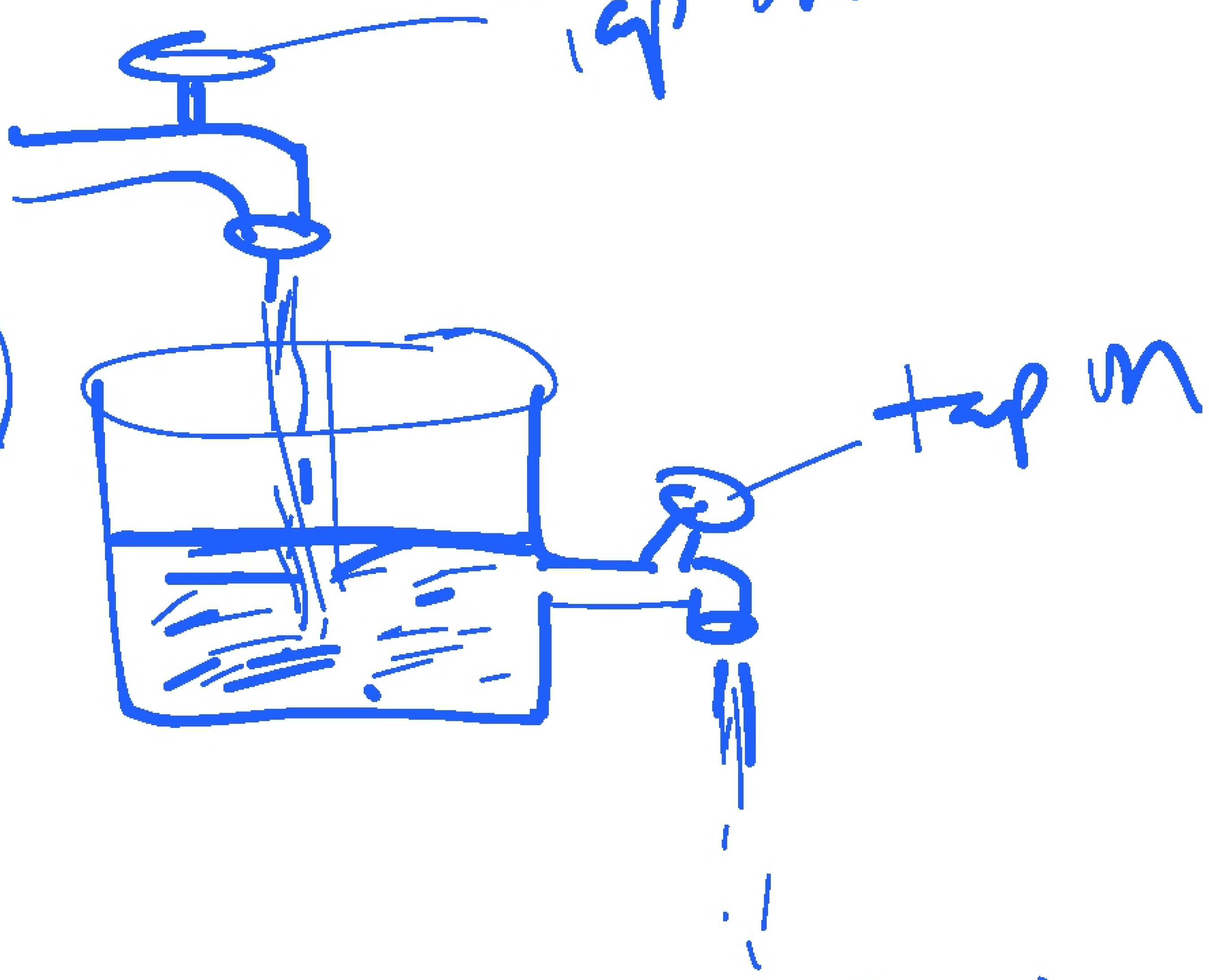
$NaOH + HCl \rightarrow NaCl + H_2O$

Dynamic equilibrium

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

R (reactants) / P (product)

	N_2	H_2	NH_3
t=0	100 mol/dm³	100 mol/dm³	0 mol/dm³
t: 5 min	90 mol/dm³	90 mol/dm³	10 mol/dm³
t: 5 min	80 mol/dm³	80 mol/dm³	20 mol/dm³
t: 5 min	75 mol/dm³	75 mol/dm³	25 mol/dm³
t: 5 min	75 mol/dm³	75 mol/dm³	25 mol/dm³
t: 5 min	//	//	//



Reversible reactions have dynamic equilibrium and

→ never stops and incomplete reactions

Hydrated Compounds (reversible reactions)

They have water molecule in their structure e.g $CuSO \cdot 5H_2O$, $CoCl_2 \cdot 6H_2O$

Anhydrous Compounds

hydrated compound when lose water.

of crystallization

Hydrated $\rightarrow$ Anhydrous

$$\underset{\text{Blue}}{CuSO_4 \cdot 5H_2O} \underset{\text{exothermic}}{\overset{\text{endothermic heat}}{\rightleftharpoons}} \underset{\text{white}}{CuSO_4} + 5H_2O$$

$$\underset{\text{Pink}}{CoCl_2 \cdot 6H_2O} \underset{\text{exothermic}}{\overset{\text{endothermic heat}}{\rightleftharpoons}} \underset{\text{Blue}}{CoCl_2} + 6H_2O$$

Factors Affecting Equilibrium in Reversible Reactions

- Concentration
- Pressure
- Temperature
- Catalyst

① Concentration

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

Increase N_2 (Reactant conc) → forward direction
right side

Decrease N_2 (Reactant con) → reverse direction
left side

Increasing NH_3 (Product conc) → reverse direction
left side

Decreasing NH_3 (") → forward direction
Right side

(2) Pressure (only gases) $V \propto \frac{1}{P}$

$V \propto n$ (number of moles)

$1N_2 + 3H_2 \rightleftharpoons 2NH_3$

4V (2V)

Increase the Pressure. low volume / low moles

Decrease in Pressure high volume / high moles

↑P

$H_2 + I_2 \rightleftharpoons 2HI$

2V 2V

it remains same

↓P $2SO_2 + O_2 \rightarrow 2SO_3$

$2SO_2 + O_2 \rightleftharpoons 2SO_3$

③ Temperature

Exothermic Process favour low temp
Endothermic Process favour high temp

Decrease temp

$N_2 + 3H_2 \underset{endo}{\overset{exo}{\rightleftharpoons}} 2NH_3$ — exothermic, ΔH = negative

forward reaction is exo/endo

Increase temp

Increase temp

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

Increase temp

$2SO_2 + O_2 \underset{endo}{\overset{exo}{\rightleftharpoons}} 2SO_3$ ΔH = -ive

Increase Temp

$C + D \rightleftharpoons E$ ΔH = +ive

Fatima → forward
Rameen → forward
Sakina → forward

NH_3 — Haber Process

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

Conc H_2SO_4 — Contact Process

$2SO_2 + O_2 \rightleftharpoons 2SO_3$

Choosing the optimum conditions

So when manufacturing ammonia, it is best to:

- use high pressure, and remove ammonia, to improve the yield
- use a moderate temperature, and a catalyst, to get a decent rate.

The conditions: a summary

$$N_2 + 3H_2 \underset{\text{endothermic}}{\overset{\text{exothermic}}{\rightleftharpoons}} 2NH_3$$

4 molecules → 2 molecules

to improve the yield:

- a pressure of 200 atmospheres (or 20 000 kilopascals)
- remove ammonia

for a reasonable rate:

- 450 °C
- use a catalyst (iron)

Obtaining the reactants

nitrogen

Air is nearly 80% nitrogen, and 20% oxygen. The oxygen is removed by burning hydrogen:

$$2H_2\,(g) + O_2\,(g) \longrightarrow 2H_2O\,(l)$$

That leaves mainly nitrogen, and a small amount of other gases.

hydrogen

- It is usually made by reacting **natural gas** (methane) with steam:

$$CH_4\,(g) + 2H_2O\,(g) \xrightarrow{\text{catalyst}} CO_2\,(g) + 4H_2\,(g)$$

- It is also made by **cracking hydrocarbons** from petroleum. For example:

$$\underset{\text{ethane}}{C_2H_6\,(g)} \xrightarrow{\text{catalyst}} \underset{\text{ethene}}{C_2H_4\,(g)} + H_2\,(g)$$

The conditions used in the Contact process

The key reaction in the Contact process is reversible, as in the Haber process. So the factory faces the same challenge: to increase the yield.But once again, the issues of **speed**, **safety**, and **cost** must be considered.

How to improve the yield

Here again is the key reaction:

Here again is the key reaction:

$$2SO_2\,(g) + O_2\,(g) \underset{\text{endothermic}}{\overset{\text{exothermic}}{\rightleftharpoons}} 2SO_3\,(g)$$

3 molecules 2 molecules

Applying what we know already, these will increase the yield:

- a low temperature, since the forward reaction is exothermic
- high pressure, since there are fewer molecules on the right
- remove the product, to lower its concentration so that more will for

The graph on the right shows how yield falls as the temperature rises.

The chosen conditions

In fact the first two conditions above would make the process unprofitable for the manufacturer. So here are the actual conditions used:

- 450 °C. The catalyst is essential, but is inactive below 400 °C, and works better at higher temperatures. So 450 °C is a compromise
- 2 atmospheres (or 200 kilopascal) of pressure. This is low, but the yield is acceptable. Raising the pressure further would cost more
- removal of the sulfur trioxide – safely – by dissolving it in sulfuric acid
- the catalyst of vanadium(V) oxide.

Not a closed system

- When a reversible reaction takes place in a closed system, no particles escape.
- So the reversible reaction reaches equilibrium, and will *never* go to completion.
- In the Contact process – and the Haber process – the system is not closed. The aim is to *prevent* equilibrium being established!
- Instead, the product is removed, and unreacted gas(es) are recycled, to get as high a yield as possible.