Unit: 3:

Matter: (mass and occupy space)

- Gas (simplest)
- Liquid
- Solid (Most Abundant on earth)
- Plasma (Most Abundant state in universe)

Gas:

Properties:

- → Shape → not definite
- → Volume → negligible
- → IMF → Weak
- → Diffussion → Large
- → Distance → Large
- → Compressibility → Considerable
- → Expansion
- → Motion → maximum
- → Density → less

Kinetic M. Theory:

Behaviour of gases

- → Gas → tiny particles → molecule
- → Collission → Elastic
- → Pressure
  - → Collides with each other
  - → Collides with walls of container

↑Collision ∝ ↑Pressure

- → Gases → No force of attraction
- → Volume of gases → Negligible
- → Gravity → No effect

$(K.E)_{av} \propto T$

$(K.E)_{total} \propto T$

(K.E)

MCQ:

At STP maximum $(K.E)_T$?

a: 0.5 mole of N_2 b: 3×10^{23} molecule of CO_2

(c): 1 mole of H_2 d: Same

$K.E_T \propto T$

$\uparrow T \propto n \uparrow$

MCQ:

At RTP maximum $(K.E)_{avg}$?

a: CO_2 b: N_2

c: H_2 (d): Same.

→ $K.E_{avg}$ only depends upon Temperature

Kinetic Equation:

$$PV = \frac{1}{3} mN\bar{C^2}$$

$M \propto d$

Root Mean Square:

$$C_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3PV}{d}}$$

$C_{rms} \propto T \propto \frac{1}{M} \propto \frac{1}{d}$

MCQ: At RTP max C_{rms}?

a: CO_2 b: N_2 c: He (d) H_2

$\uparrow C_{rms} \propto \frac{1}{M\downarrow}$

Gas Laws: (Ideal gases)

Boyles Law:

1: $V \propto \frac{1}{P}$ (n, T)

2: $PV = K$ → depends on 'n' and 'T'

3: $P_1V_1 = P_2V_2$

different value for same gas for diff amounts or temperature.

gas $V_1 = 1dm^3$ $P_1 = 2atm$

$V_2 = ?$ $P_2 = 6atm$

$V \propto \frac{1}{P}$

→ P increased 3 time

V will decrease 3 times

$V_2 = \frac{1}{3} dm^3$ $P_2 = 6atm$

Units:

$K = P \times V$

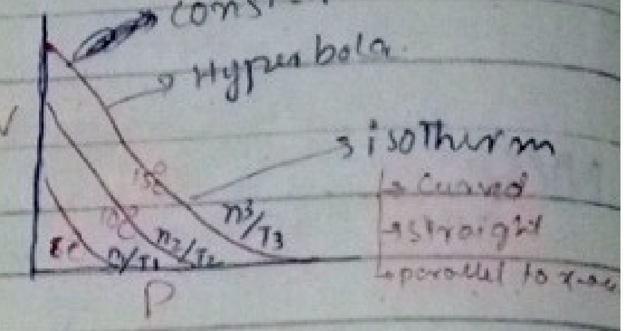
$= atm \times dm^3$

SI

$K = Nm^{-2}\ m^3$

$= Nm$

Graphical Explanation:



$n_3 > n_2 > n_1$

$T_3 > T_2 > T_1$

If 'T' or 'n' increase the isotherm will move away from

a: origin b: x-axis

c: y-axis (d) All

Charles Law:

a: $V \propto T$ $(n, P) \rightarrow$ constant → Absolute temperature

r. $\frac{V}{T} = K$ < n, P

c. $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (if T in kelvin, not T in C° X)

if $V_0 = 273$ ml

T = ↑1C°

Vol = ?

$273 \times \frac{1}{273} \Rightarrow 1$ ml ↑

Quantitative Definition:

if 1°C/1K ↑ → V ↑ $\frac{1}{273}$ times of

or 1°C/1K ↓ initial volume at 0°C

$V_t = V_0 \left(1 + \frac{t°C}{273}\right)$

V_0 = Vol at 0°C

V_t = Vol at any desire temp

t°C = Temp in celcius.

V = 273 ml at 0°C

V = ? at 273 C°

V = ? at −273 C°

273 C: Vol will become double of initial

$V_t = 273\left(1 + \frac{\cancel{273}^{1}}{\cancel{273}}\right)$

$V_t = 273(1+1)$

$= 273(2) = 546$

MCQ:

A gas has $50\,cm^3$ vol at STP at what Temp its volume will become $100\,cm^3$?

a: 0C°　　b: 273 K

(c) 546K　　d: none

: −273C°: volume will become zero

$V_t = 273\left(1 + \frac{(-273)}{273}\right)$

$V_t = 273\left(1 - \frac{273}{273}\right)$

$V_t = 273(1-1) = 0$

→ ~~K = 0C° + 273~~

546K = 0° + 273 ⇒ 546 − 273 = 0°C

273 − 0°C

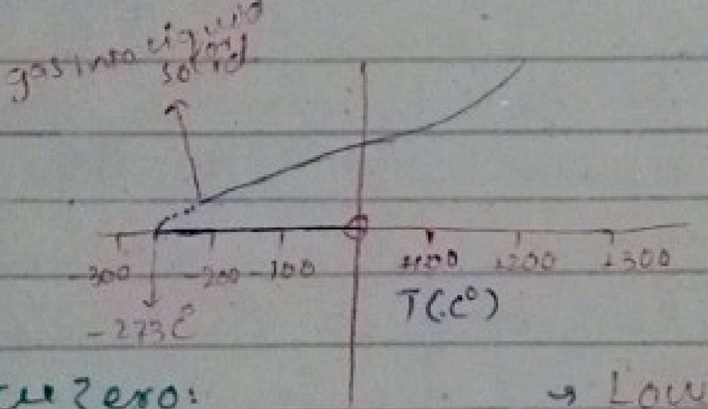
MCQ:

Vol of gas at STP is 20 ml what would be its volume at 273C°?

(a): 40 ml　　b: 20 ml

c. 273 ml　　d: 54 ml

$20\left(1 + \frac{273}{273}\right) = 40$



Absolute zero:

0K = −273.15 °C (K.E = 0 motion ceased)

= −459F°

→ Lowest possible Temp = −273C°

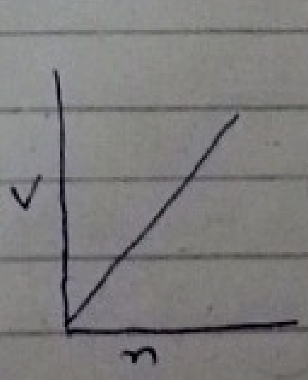
→ lowest possible T attained = 10^{-5} K

Avagadro's Law:

$V \propto n$ (P, T)

$\frac{V}{n} = K$

$\frac{V_1}{n_1} = \frac{V_2}{n_2}$



Ideal Gas Eq:

$V \propto \frac{1}{P}$

$PV = nRT$ (no of moles)

$V \propto T$

$PV = RT$ ($n = 1$)

$V \propto n$

$V \propto \frac{nT}{P}$

$V = \frac{RnT}{P}$

$PV = nRT$

What would be the new volume of certain gas when P is doubled and T is half.

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow \frac{PV_1}{T} = \frac{2P \times V_2}{T/2} \Rightarrow V_1 = 4V_2 \Rightarrow V_2 = \frac{V_1}{4}$

If P is halfed and T is doubled:

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow \frac{PV_1}{T} = \frac{P \times V_2}{2 \times 2T} \Rightarrow V_1 = \frac{V_2}{4} \Rightarrow V_2 = 4V_1$

If P and T both doubled.

$\frac{PV_1}{T} = \frac{2P \times V_2}{2T} \Rightarrow V_1 = V_2$

If P and T both halfed:

Applications Of $PV = nRT$

Conc. of gas:

$C = \frac{P}{RT}$

$C \propto \frac{n}{V}$

$C \propto P \propto \frac{1}{T} \propto n \propto \frac{1}{V}$

Density:

$d = \frac{PM}{RT}$

$d \propto P \propto M \propto \frac{1}{T}$

Mass:

$PV = nRT$

$PV = \frac{m}{M} RT$

$m = \frac{PVM}{RT}$

MCQ: CO_2 will have maximum density at?

(a) STP (1 atm) 0°C   b: RTP (1 atm) 25°C $\uparrow d \propto P \propto \frac{1}{T\downarrow}$

c: 313 K/atm 40°C   d: 323 K/atm

MCQ:

At RTP which will have max d?

a: n pentane   b: iso pentane   → molecular formula is same C_5H_{12} so mass will be same hence density will be same

c: neo pentane   (d) same

(a) 1 mole of CO_2 (44g)   c: 3×10^{23} molecules of N_2 (14g)

b: 11.212 dm^3 of O_2 (16g)   d: same.

$d \propto M$

Units of R:

	Value	P	V	nT
STP	0.0821	atm	dm^3	$mol^{-1}K^{-1}$
	62.4	torr	dm^3	$mol^{-1}K^{-1}$
	62400	torr	cm^3	$mol^{-1}K^{-1}$
	8.314	Nm^{-2}	m^3	$mol^{-1}K^{-1}$
	8.314	N	m	$mol^{-1}K^{-1}$
	8.314	J		$mol^{-1}K^{-1}$
	8.314	$\frac{1}{4.18}$ cal		$mol^{-1}K^{-1}$
	1.987	cal		$mol^{-1}K^{-1}$

physical meaning:

0.0821 atm dm^3 mol^{-1} K^{-1}

$n = 1$ $T = 1°C / 1K$

→ 0.0821 atm dm^3 → unit of energy.

→ 6.023×10^{23} molecules of any gas → 0.0821 atm dm^3

($T = 1°C / 1K$)

Ideal gas

- Follows gas laws at all T & P.
- No Force of attraction
- No liquification
- Elastic collision
- Volume of gas is negligible
- $Z = 1$
- $PV = nRT$

1 atm × 22.4 = 1 × 0.0821 × 273

22.44 = 22.44

Non-Ideal

- Follows gas laws under certain conditions (Low → P, High → T)
- Force of attraction exists
- Can liquify.
- Inelastic collision
- Volume of gas is considerable.
- $Z \neq 1$
- $PV \neq nRT$

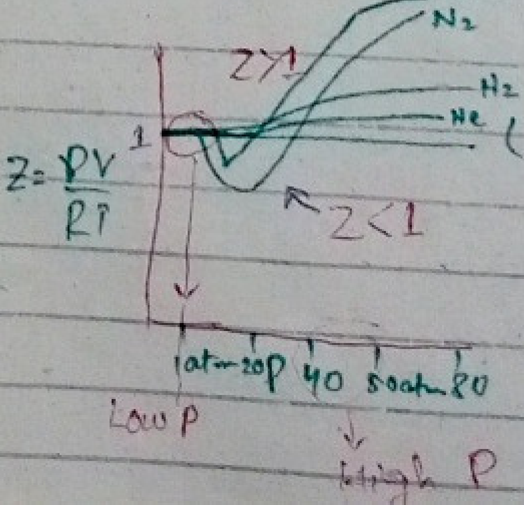
Compressibility Factor:

$$PV = nRT$$

$$Z = \frac{PV}{nRT} = 1$$

↓

$$\frac{22.4}{22.4} = 1$$



→ gases are Ideal

Ideal ∝ $\frac{1}{P}$ ∝ $\frac{1}{T}$

Non ideal ∝ P ∝ $\frac{1}{T}$

- High P
- Low T

$Z > 1$	$Z < 1$
→ Non-ideal	→ Non-Ideal
→ Positive deviation	→ Negative deviation
→ $PV > nRT$	→ $PV < nRT$
→ Forces of repulsion domination	→ Forces of attraction domination
→ Difficult to liquify	→ Easy to liquify.

Order of ideality:
$He > H_2 > N_2 > CO_2$

Order of Non ideality:
$CO_2 > N_2 > H_2 > He$

$$\text{Ideality} \propto \frac{1}{P} \propto T \propto \frac{1}{M.M}$$

$$\text{Non Ideality} \propto P \propto \frac{1}{T} \propto M.M$$

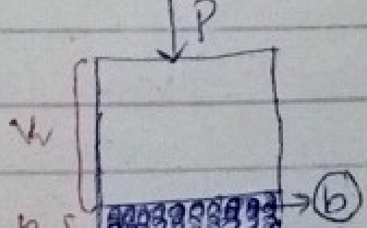
Molar mass ∝ IMF ∝ polarizability

Non-Ideality ∝ IMF ∝ Polarizability ∝ size of molecule

Wander Waal Correction: or Real Gas Eq:

$$PV = nRT$$

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$



a = force of attraction

$V_{free} = V_v - b$

b = Extended volume
= Effective volume
= Incompressible volume.

Non ideality $\propto$ a $\propto$ b $\propto$ IMF
a, b $\propto$ liq $\propto$ polar

Polar → a, b (large)
Non polar → a, b (small)

a: $a = 1, b = 0$
b: $a = 1, b = 1$
c: $a = 0, b = 0$

Units:

$$V - nb = 0$$
$$V = nb$$
$$b = \frac{V}{n}$$
$$= dm^3 mol^{-1}$$

[(S.I) $= m^3 mol^{-1}$]

$$P = \frac{an^2}{V^2}$$

$$a = \frac{P \times V^2}{n^2}$$

$$= 1 atm\ dm^3 mol^{-2}$$

[(S.I) $= Nm^{-2} \times m^6 mol^{-2}$
$= Nm^4 mol^{-2}$]

Liquids:

Force of attraction

($H_2O - H_2O$)

Intramolecular (H — O — H)
- within atom of molecule
- Strong
- Chemical properties (Bond Energy)
- Types:
  - Ionic bond
  - Covalent bond
  - Metallic bond

Intermolecular
- Among molecule
- Weak
- Physical properties (M.P↓, B.P↓, d
- Types
  - Ion dipole
  - dipole-dipole
  - dipole Induced dipole (deby)
  - London dispersion force
  - Hydrogen bonding

Types of IMF	Nature of particle	Factors	Example.
Ion dipole	Ion + polar molecule	∝ polarity (polar) ∝ Δ Electronegativity ∝ Charge↑ (Ion) / size↑	$Na^+ + H_2O$ $Cl^- + H_2O$
Dipole - Dipole (gas → week, Liquid → strong)	Polar (permanent) → usually b/w heteroatoms → Central atom from (V, VI, VII)	∝ Polarity ∝ Δ.EN ∝ 1 / Distance b/w molecule	· HCl · PH_3 · HBr · H_2S · HI
Dipole Induced Dipole	Polar + non-polar (−δ +δ) + (+) → (−δ +δ) (+δ −δ)	∝ Polarity (polar) ∝ ΔEN (polar) ∝ Size (Non-polar) ∝ Polarizability (Non-polar)	H_2O + Xe $H_2O + O_2$ $+ H_2$ $+ N_2$

→ All homoatomic gases are non-polar
→ But all heteroatomic gases are not polar.

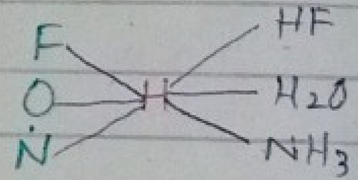
→ They depends on electron, so exist in all molecules but prominent in non-polar

L.D.F (Instantaneous dipole) (Induced dipole)	Non polar (prominent) (but also exist in all molecules)	∝ size	→ Hydrocarbons (Alkane, Alkyne, Alkene, benzene)
		∝ molar mass	
		∝ polarizability	
		∝ Atomicity	→ Xe - Xe
→ momentary forces		∝ no. of ēs	→ He - He
→ Short lived forces		∝ straight chain	
		∝ surface area	
		∝ Irregular shape	
		∝ $\frac{1}{\text{branched chain}}$	

Strength of IMF:
Ion-dp > H-B > dp-dp > LDF

Hydrogen Bonding:

→ When hydrogen is bonded with FON.



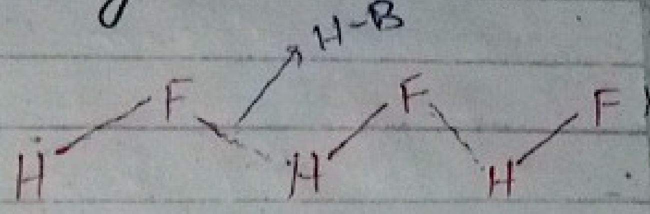
→ H.B is a extreme case of dipole-dipole forces.
→ It is also known as bridge bonding.
→ It is directional in nature.
↳ bonding will occur in specific direction.

∴ Ionic bond → Non directional
∴ Covalent bond → Directional.

It exist in;
→ Lower alcohols (In higher alcohols the non polar part 'R' will increase and LDF will come)
→ Lower Acids
→ Amine
mixture: Acetone + Chloroform

Molecule:	No. of H-bond:	No. of H atoms	No. of L.P
H_2O	2	2	2
HF	1	1	3
NH...			

Applications of H-Bonding:



∴ weak b/c of zig-zag manner.

- → Solubility
- → DNA
- → Protein
- → Paints + Dyes (Adhesive)
- → Soap + Detergents (cleansing)
- → Low Acidity (HF)

HF < HBr < HCl < HI

B.P of Hydrides:

IVA	VA	VIA	VIIA
CH_4	NH_3	OH_2	HF
SiH_4	PH_3	SH_2	HCl
GeH_4	AsH_3	SeH_2	HBr
SnH_4	SbH_3	TeH_2	HI
Pb	BiH_3	PoH_2	HAs

No Polar — B.P↑ — B.P↑ — B.P↑

B.P of IVA:
$SnH_4 > GeH_4 > SiH_4 > CH_4$

B.P of VA:
$NH_3 > SbH_3 > AsH_3 > PH_3$ ∴ NH_3 has H-bonding

B.P of VIA:
$H_2O > H_2Te > H_2Se > H_2S$

B.P of VIIA:
HF > HI > HBr > HCl.

Structure of Ice:

∴ Ice → diamond like

O → 4H → 2 (H-B), 2 (covalent B)

Ice → maximum empty space.

Density of Ice:

↳ lower than water.

100°C ⟶ 4°C ⟶ 0°C ∴ density is minimum at 0°C.

d —d↑→ Max —d↓→ Min

V —V↓→ Min —V↑→ Max

| Contraction | | Expansion |

9% V↑

$H_2O_{(liq)} \rightleftharpoons H_2O_{(ice)}$

9% V↓

MCQ: 50 ml water ⇌ Ice (vol)

a: 50 ml b: 59 ml

(c) 54.5 ml d: 46 ml.

$50 \times \frac{9}{100} \Rightarrow (4.5)$

50+4.5 = 54

100 ml water ⟶ Ice (vol)? 9% ↑

109%.

Evaporation:

→ spontaneous conversion of liquid into gas

→ surface phenomenon ∴ molecules that have high K.E will evaporate first

→ cooling process

↳ sweating.

→ Endothermic

→ Continuous at all temperatures.

Factors:

∝ Temperature ∝ branched chain

∝ Surface area

$\propto \frac{1}{\text{regular shape}}$ $\propto \frac{1}{IMF}$ $\propto \frac{1}{\text{size of molecule}}$ $\propto \frac{1}{B.P}$ $\propto \frac{1}{\text{straight chain}}$

Maximum & minimum evaporation?

a: CH_3COOH (mini)   b: C_2H_5OH 78°

c: CH_3OCH_3 34°C (max)   d: H_2O 100°C

Glycerol ($CH_2-CH-CH_2$ with OH on each carbon: OH OH OH)

Benzene

Ether

Ammonia

CCl_4

Acetone

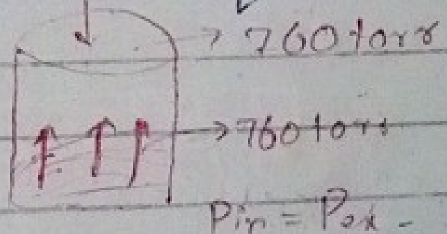
Boiling Point:

→ Internal pressure becomes equal to external ~~temperature~~ pressure.

→ K.E ⇒ max

→ Temperature → constant.

→ Heat after B.P → change state.



Evaporation
- → All Temp
- → Surface molecule
- → Cooling

B.P
- → Specific Temp
- → whole molecules
- → Heating

Factors:

$\propto$ IMF

$\propto$ External Pressure

$\propto \frac{1}{\text{Height}}$

For Water:

B.P	Pressure	Place
120°C	1489 torr	P. cooker
100°C	760 torr	sea
98°C	700 torr	Murree
72°C	323 torr	Mount everst
25°C	23.7 torr	Vacuum distilattion

Vapours Pressure:

→ Pressure exerted by vapours on its liquid.

→ In close container; otherwise vapours will escape out and no P will be exerted.

Rate of evp = Rate of condensation

[dynamic equilibrium]

↳ after this there will be VP.

Factors:

$V.P \propto T \propto \frac{1}{IMF} \propto \frac{1}{B.pt} \propto$ branch chain $\propto \frac{1}{\text{straight ch}}$

At RTP (29°C), WOF liq will max V.P?

a: $CH_2 - CH - CH_2$ (OH, OH, OH) (100°C)

b: $CH_2 - CH_2$ (OH, OH) (197.3°C)

c: H_2O

(d) C_2H_5OH (78°)

At 20°C WOf min V.P?

(a) n-pentane (5C) b: iso-pentane (5C)

c: neo-pentane (5C) d: n-butane (4C)

→ maximum

Doesnot Depend:

→ surface area

→ Volume of container

Molar Heat Of Vapourization:

1 mol of liq → gas. $\Delta H = ?$

for water $\Delta H_v = 40.7$ kJ/mol

Molar Heat of Sublimation:

1 mole of solid → gas

For I_2 $\Delta H_s = 60$ KJ/mol.

Molar Heat Of Fusion:

1 mole of solid → liq

for ice $\Delta H_f = 6.02$ KJ/mol.

$\Delta H_s > \Delta H_v > \Delta H_f$

$\Delta H_f \propto$ IMF

$\Delta H_v \propto$ IMF

Solid.

Solids on the basis of bonding?
4 types
Solids on the basis of structure?
2 types

Crystalline	Amorphous
→ Definite shape	→ No definite
→ Regular arrangement of particles	→ No regular
→ Sharp M.P	→ Wide Range
→ Anisotropic	→ Isotropic (Liq / Liq crystal)
→ Water of crystallization. $CuSO_4 \cdot 5H_2O$, $FeSO_4 \cdot 7H_2O$	→ No water of crystallization. Crystilite (small orderly parts)
→ True solids	→ Psedo solids
	→ Super cooled Liquid.

—Heat→ Liquid —Fast cooling→

NaCl → Ionic
I_2 → Molecular
Fe → Metallic
Diamond → Atomic

→ Glass
→ Rubber
→ PVC, Plastic
→ Coal tar, Coke

Characteristics Of Crystalline S.

→ Geomatrical shape (3D Arrangement)
→ M. Points (Sharp)
→ Symetry (Angle/Edge/Face)
  → Axis:] more than one ↳ Center] one.
  → Angle
  → plane

Habit:→ shape → usually grow

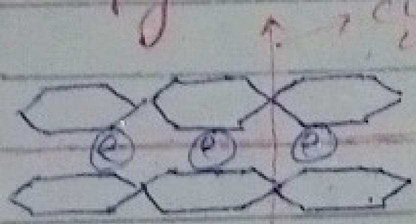
NaCl → Cubic

but if we add 10% urea then it will become octahedral.

Growth:

Saturated solution $\xrightarrow[\text{cooling}]{\text{slow}}$ Crystal formation

Anisotropy:



→ current will not conduct

→ current will conduct

} direction changed

→ cleavage plane
→ coefficient of thermal
→ Electrical conductivity
→ Thermal Conductivity.

Isomorphism: → (property)

Diff substance same shape

Isomorph → (substance)

Same	Different
• Shape	• Physical prop
• Atomic ratio.	• Chemical Prop
	• Nature of substance

1:1 NaCl, 1:1 MgO → cubic

Isomorphism occurs in?

a: Compound b: Element → Cadmium, ↳ Graphite (both are in hexagonal shape)

(c:) Both d: None

Polymorphism: (only Compounds)

Same compound in more shape
↓
Polymorphs

Same	Different
· Chemical Prop	· shape
· Nature of comp.	· Physical Property

KNO_3 → orthorohmbic / Rohmbohedral.

NaCl → Cubic / Octahedral

Allotropy: (only Elements)

∴ Polymorphism of element is allotropy.

Same Element in diff shape
↓
Allotropes

Same	Diff
→ Chemical Prop	→ Shape
→ Nature of element	→ Physical properties

C → Graphite / Diamond.

Transition Temperature:

Temp. at which two crystalline forms co exist at equilibrium.
↓

KNO_3 (Rohmbo) $\underset{}{\overset{128.5°C}{\rightleftharpoons}}$ KNO_3 (Ortho)] Polymorphism (comp)

Sn Gray (cubic) $\overset{13.2°C}{\rightleftharpoons}$ Sn White (tetragonal)] Allotropy (element)

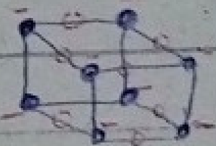
→ Below and above transition temperature only One form will exist

→ Transition temp is always less than M.P

Possible m.p of KNO_3?
a: 128.5C° (b:) >128.5C° m.p: 334C°
c: <128.5C° d: None

Transition temp exist in?
a: Isomorph b: Polymorph :: but our book didn't deal isomorph.
c: Allotropes (d): All

Crystal Lattice:
→ 3D arrangement of point particles (atoms, ions, molecules) is called crystal lattice
Atomic Ionic Molecular



Unit Cell:
→ Smallest part of crystal
→ Shape of crystal depends
→ Properties of crystal depends

Cubic: if unit cell is cubic, crystal will be cubic

{ a = b = c] sides
{ α = β = γ = 90°] angles
→ Unit cell dimensions
→ Crystallographic elements.

Crystal System:
→ Cubic: most symmetrical crystal system

$a = b = c$
$\alpha = \beta = \gamma = 90°$

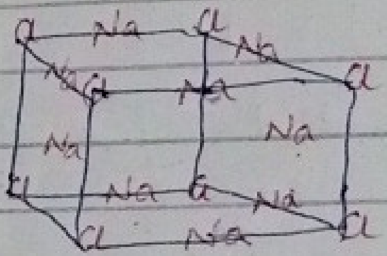
Structure of NaCl:

→ Found face crystal

→ Octahedral arrangement.

→ Distance b/w ions

Same ion	different ions
Na^+ ---- Na^+	Na^+ ---- Cl^-
Cl^- ---- Cl^-	2.815 A°
2.815 × 2	
= 5.68 A°	



location of Cl^-

Corner | face

location of Na^+:

Edge | Center

Calculation of Cl^-:

Share of Cl^- ion per corner = $\frac{1}{8}$

Share of Cl^- ion per unit cell = $\frac{1}{8} \times 8 = 1$

Share of Cl^- ion per face = $\frac{1}{2}$

Share of Cl^- ion per unit cell = $\frac{1}{2} \times 6 = 3$

Total Cl^- ion per unit cell = 3 + 1 = 4

Calculation of Na^+:

- Share of Na^+ ion per edge = $\frac{1}{4}$

Share of Na^+ ion per unit cell = $\frac{1}{4} \times 12 = 3$

Share of Na^+ ion in center = 1

Total Na^+ ion = 3 + 1 = 4

Shape of Ionic Solid:

- Electrostatic force of attraction
- Radius Ratio = $\frac{r^+}{r^-}$ (Book)
- Temperature
- Impurity.

Lattice Energy: (Ionic solids)

$NaCl_{(s)} \longrightarrow Na^+ + Cl^-$ ΔH = +787 KJ/mol (Endothermic)

or

$Na^+ + Cl^- \longrightarrow NaCl_{(s)}$ ΔH = −787 KJ/mol (Exothermic)

L.E ∝ Stability of compound

L.E ∝ M.P & B.P of compound.

Factor:

$L.E \propto \frac{\text{charge}}{\text{size}}$

Periodic Table: From L to R L.E↑ b/c Charge↑ & Size↓

From T to B L.E↓ b/c Charge↓ & Size↑

a: NaCl b) NaI (minimum) c: NaF (maximum) d: NaBr

a: NaCl (+1) b: $MgCl_2$ (+2) (c) $AlCl_3$ (+3) (maximum) d: same

Properties	Ionic	Atomic	Molecular	Metallic
Forces	Ionic bond	Covalent	Wander Waal (LDF, Dipole) H-B	metallic
Structural unit	Ions Cations Anions	Atoms	Atoms & molecules	Atoms & Free e's
M.P & B.P	High to very high	Very High	Low	Variable
Hardness & Brittleness	Hard & Brittle	Very Hard	Soft & Volatile	Variable Hardness →Malleable →Ductile
Electrical conductivity	(solid) Non-conductor (conductor) Molten	Non-conductor except graphite	Non-conductor	Very good conductor
Example	NaCl, MgF₂, AlCl₃	Carbon, SiO_2, Diamond, graphite, NO_3, BN	Polar: sugar & ice Non Polar: Dry ice, acid, I_2, P_4	metals: Fe, Ni, Co, Cr, Zn, Cu, Sn