

Phase Equilibria

Poosa PREMNATH

①

Applications of phase diagrams

- (i) Development of new alloys
- (ii) Fabrication of these alloys into useful configurations
- (iii) Design & control of heat treatment procedures to produce the required mechanical properties of alloys.
- (iv) Solve problems pertaining to certain alloys to improve commercial performance.

Definition of Phase Rule

When a heterogeneous system in equilibrium with any no. of phases is not influenced by gravity, electrical, magnetic forces or by surface action, but rather only by temperature, pressure & concentration, then

THE DEGREE OF FREEDOM OF THE SYSTEM IS RELATED TO THE NO. OF COMPONENTS (C) & PHASES (P) BY THE RELATION: $F = C - P + 2$

Phase (P): A UNIFORM, PHYSICALLY DISTINCT AND MECHANICALLY SEPARABLE part of the system which ~~has distinct~~ is separated from the rest of the system by distinct PHYSICAL BOUNDARIES.

Examples:

1. GASES: gases are miscible in all proportions
 \Rightarrow a single phase

2. LIQUIDS:

2.1 Miscible & immiscible

① Miscible \Rightarrow a single phase (alcohol in water)

Note: alcohol in water in an ^{closed} open system

\Rightarrow 2 phases (1 liquid phase + 1 vapour phase)

② Immiscible \Rightarrow water & oil = 2 phases

benzene & water = 2 phases

benzene & water in a closed system = 3 phases
(2 liquid + 1 vapor phase)

2.2 saturated vs. unsaturated solutions

- (i) unsaturated solution of glucose in water : 1 phase
 (ii) saturated solution of glucose in water : 2 phases (solid + liquid phase)

2.3 density | order of addition

Consider a system of x, y, z .
 ① ② ③

x, y are immiscible w/ each other

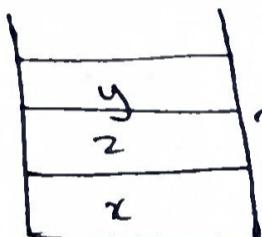
x, z are miscible

y, z are immiscible

$$\rho_z < \rho_x$$

substances are added in the order x, z, y

$$\text{No. of phases} = ?$$

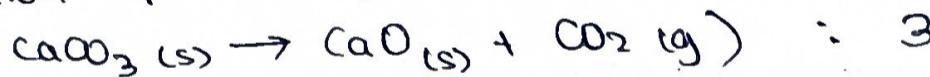


\Rightarrow There are 2 phases.

3. SOLIDS: n no. of phases $\Leftrightarrow n$ solids

(i) mixture of sugar & salt : 2

(ii) decomposition of calcium carbonate:



(iii) water : 3 phases (solid, liquid, gas)

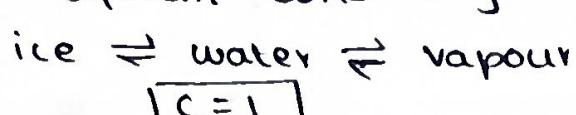
(iv) Mohr's salt : $\text{FeSO}_4 (\text{NH}_4)_2 \text{SO}_4 \cdot 6\text{H}_2\text{O} : 1$

(v) rhombic sulphur \rightleftharpoons monoclinic sulphur : 2 phases

COMPONENT (C) : The minimum no. of chemically independent species required to define each phase of the system completely by means of chemical equations.

Examples:

1. Water system consisting of 3 phases:



2. Allotropic forms of sulphur: rhombic sulphur
 monoclinic sulphur
 sulphur vapour
 liquid sulphur

$$\boxed{C=1}$$

3. Aqueous NaCl: $\boxed{C=2}$

4. Saturated NaCl in a closed system: NaCl
 water
 water vapour } consider to be
 $\Rightarrow \boxed{C=2}$

* Formula to calculate components : $\boxed{C = N - E}$

C = components

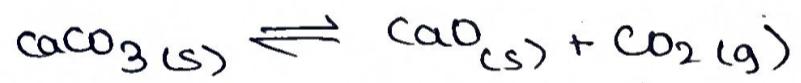
N = no. of chemically independent species (constituents)

E = eqns. representing the equilibrium of the system.

Examples

Decomposition of CaCO_3

(i) CASE 1: a closed system



$N = 3$ (CaCO_3 , CaO & CO_2)

$E = 1$ (1 eqn)

$$C = N - E$$

$$= 3 - 1$$

$$\boxed{C=2}$$

(ii) CASE 2: open system

$N = 2$ (CaCO_3 , CaO , CO_2 is mixed w/ air, no longer chemically independent)

$$E = 0$$

$$C = N - E$$

$$\boxed{C=2}$$

since there is no water, CaCO_3 cannot dissolve; there cannot be any dissolution

(iii) CASE 3: Random mixing (chemically inactive)

$$N = 3$$

$$E = 0$$

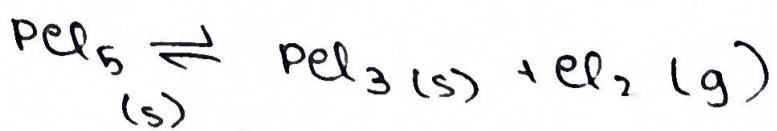
$$C = N - E$$

$$\boxed{C=3}$$

Components = constituents
 in the $\text{NaCl}, \text{KCl}, \text{H}_2\text{O}$ case, since there's water, dissolution occurs.

② Decomposition of PbI_5

(4)

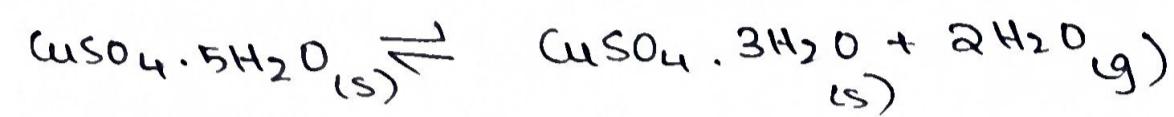


$$N = 3$$

$$E = 1$$

$$C = 2$$

③ Removal of water from copper sulphate pentahydrate



$$N = 3$$

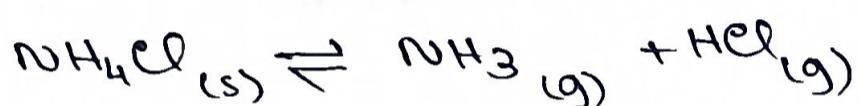
$$E = 1$$

$$C = 2$$

(4)

Decomposition of ammonium chloride

Case 1 closed system, chemically reactive



$$N = 3 \quad (\text{NH}_4\text{Cl}, \text{NH}_3, \text{HCl})$$

$$E = 1 + 1 = 2$$

↓ → physical eq. where $[\text{NH}_3] = [\text{HCl}]$
 chemical eq. i.e. partial pressures are equal.

$$C = 3 - 2$$

$$\boxed{C = 1}$$

Case 2 in an open vessel

$$N = 3$$

$E = 1$ (partial pressures are no longer the same)

$$C = 3 - 1$$

$$\boxed{C = 2}$$

Case 3 random mixture (chemically inactive)

$$N = 3$$

$$E = 0$$

$$\boxed{C = 3}$$

Case 4 : decomposition in a closed

vessel w/ some NH_3 and HCl already present

$$\Rightarrow N = 3$$

$$E = 1$$

$$\boxed{C = 2}$$

Partial pressures will not be equal

5

b) Reaction of Fe w/ water (g)



$$N = 4$$

$$E = 1 \quad (\text{only chem eq})$$

$$C = 3$$

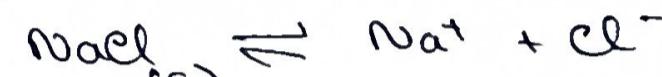
5) glucose in water (open system)

$$N = 2$$

$$E = 0$$

$$C = 2$$

6) NaCl in water (open sys.)



$$N = 4 \quad (\text{Na}^+, \text{Cl}^-, \text{H}_2\text{O}, \text{NaCl (s)})$$

$$E = 1 + 1 = 2$$

\downarrow \rightarrow electrical eq.
chem eq.

$$C = 2$$

7) KCl - NaCl - H₂O (non-reactive system)

$$N = 6 \quad (\text{K}^+, \text{Cl}^-, \text{Na}^+, \text{H}_2\text{O}, \text{KCl}, \text{NaCl})$$

$$E = 2 + 1 = 3 \quad \text{KCl} \rightleftharpoons \text{K}^+ + \text{Cl}^-$$

$$\downarrow \quad \downarrow \quad \text{NaCl} \rightleftharpoons \text{Na}^+ + \text{Cl}^-$$

chem eq. electrical eq.

$$C = 6 - 3$$

$$C = 3$$

8) NaCl - KBr - H₂O (chemically reactive)

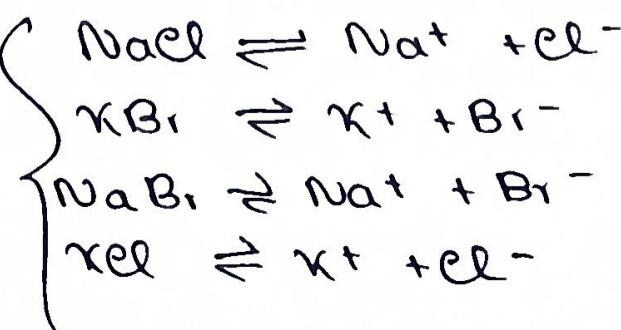
$$N = 9$$

$$(\text{NaCl}, \text{KBr}, \text{H}_2\text{O}, \text{Na}^+, \text{Cl}^-, \text{K}^+, \text{Br}^-, \text{NaBr}, \text{KCl})$$

$$E = 1 + 4 = 5$$

\downarrow
electrical eq.

\downarrow
chemical eq.



$$C = 4$$

5. Degree of Freedom / Variance (F): The minimum no. of independent variables like pressure, temperature, composition or concentration which must be specified in order to define a system completely.

e.g. (i) water at room temp:

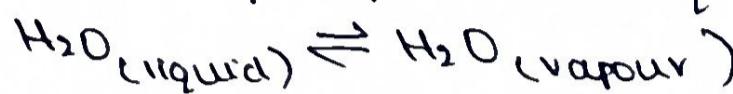
$$C = 1$$

$$P = 1$$

$$F = C - P + 2$$

$F = 2$ (both temp & pressure must be specified to determine the phase) bivariant

(ii) water w/ 2 phases in equilibrium



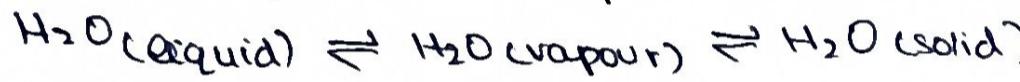
$$C = 1$$

$$P = 2$$

$$F = C - P + 2 = 1 - 2 + 2$$

$F = 1$ univariant

(iii) water w/ all three phases in equilibrium



$$C = 1$$

$$P = 3$$

$$F = C - P + 2$$

$F = 0$ invariant

Work out table 4.1

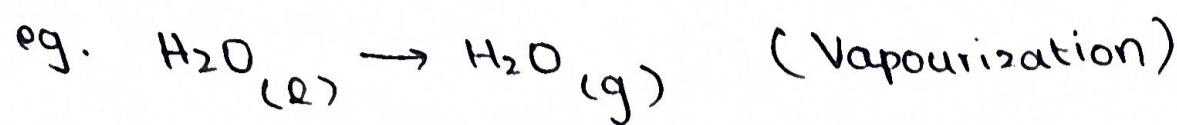
Merits of the Phase Rule

- useful in metallurgy
- predict behaviour of a sys. under diff. conditions of pressure, temperature & concentration.
- can classify the equilibrium state of a sys.
- applicable to macroscopic systems
- systems w/ a diff. degree of freedom behave differently, sys. w/ the same degree of freedom behave in a similar fashion.

Limitations of Phase Rule

- can only be applied to heterogenous systems in equilibrium
- must take utmost care in deciding the no. of phases, even a small amt of another phase (say, an impurity) must be considered.
- all the phases in the sys. must be under the same pressure, temp, composition
- like thermodynamics, it does not give any info on the rate of change

Phase Reaction : A reaction which brings out a change in the phase of the system is called a phase reaction.



however, $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ is not a phase reaction

Phase Diagram : graphical representation of a phase reaction

Types (i) P-T diagram : used for a 1 component system (isoplethal)

(ii) T-C diagram : used for a 2 component system (isobar)

(iii) P-C diagram : isotherm , used for a 2 component system

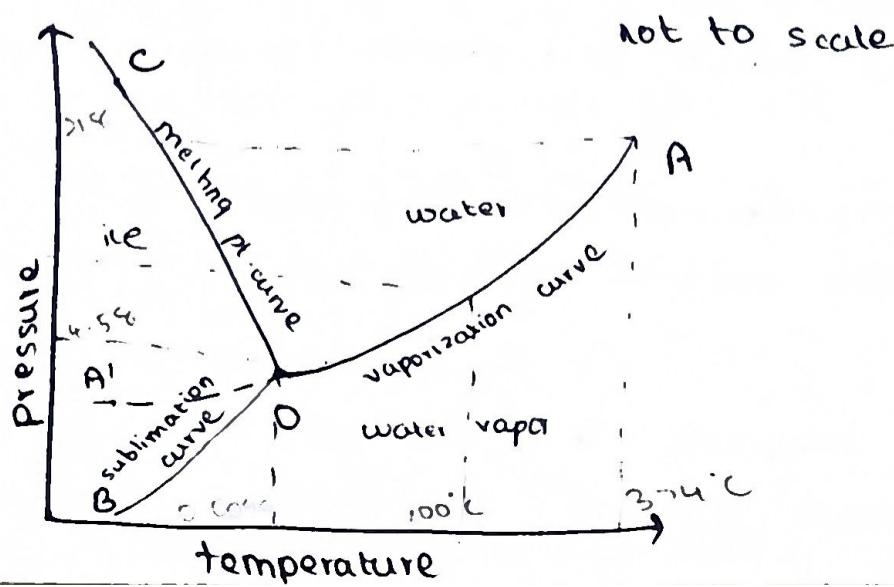
Uses of phase diagrams

1. To predict & understand the behaviour of the phases at equilibrium
2. To predict the formation of eutectic alloys on cooling the homogeneous liquid
3. To study low melting eutectic alloys
4. alloy design & material development.

One Component System

Water System

- a single component system as there exists only 1 chemically independent species
- On subjecting to heat, there is a change of phase.
- Both pressure & temperature are required to specify the 3 diff states of water, at diff. points



Areas AOB, AOC, BOC

only a single phase exists at a time

AOB \rightarrow water vapor

AOC \rightarrow water

BOC \rightarrow ice

By the phase rule: $F = C - P + 2$

$$F = 1 - 1 + 2$$

$$\boxed{F = 2} \quad (\text{bivariant})$$

\Rightarrow Both temperature & pressure are required to define a region completely in this region.

Curves: along the curves, 2 phases exist

$$C = 1 \quad F = C - P + 2$$

$$P = 2 \quad F = 1 - 2 + 2$$

$$\boxed{F = 1} \rightarrow \text{univariant}$$

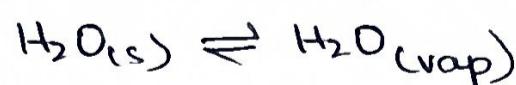
Only 1 parameter, either temperature or pressure is required to describe the system completely.

(i) Vaporization Curve: OA

- ends abruptly at 374°C (critical temperature - temperature above which vapor can never be liquified) how much ever pressure is applied.
- above 374°C , vapour & liquid coexist.

(ii) Sublimation Curve: OB

- solid & vapour phase are in equilibrium



- lower limit = -273°C , beyond which both phases merge w/ each other.

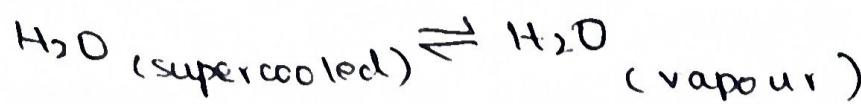
(iii) Melting curve: OC

- solid & liquid phase are in equilibrium with each other.
- OC is inclined to the pressure axis \Rightarrow melting pt decreases w/ increase in pressure.

\Rightarrow liquid state is more compact than the solid state, to be inferred by tilting towards Y axis.

(iv) Metastable Curve (OA')

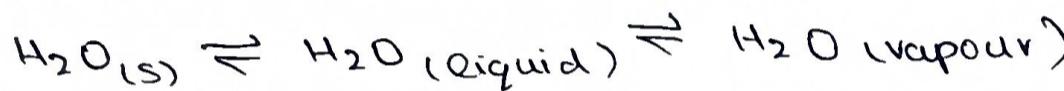
As water is more compact than ice, it is possible to cool water below 0°C without it solidifying. Here supercooled water is in equilibrium with the vapor phase.



- However, this metastable equilibrium is very fragile. Even the slightest disturbance, like stirring, destroys the equilibrium.
- Note: The pressure of the metastable condition is greater than the sublimation pressure, and the metastable curve always lies above the sublimation curve.

Triple point of Water

- all three phases are in equilibrium



$$\text{here } P = 3$$

$$\Rightarrow F = C - P + 2 \\ = 1 - 3 + 2$$

$$\boxed{F = 0} \rightarrow \text{invariant}$$

$$\left. \begin{array}{l} \text{i.e both temp \& pressure are constant.} \\ T = 0.0098^{\circ}\text{C} \\ P = 4.58 \text{ mm} \end{array} \right\}$$

Reduced / Condensed phase rule

- A system in which only the solid and liquid phases are considered, and the gas phase is ignored is called a condensed system.
- Since pressure is kept a constant, the phase rule becomes $F = C - P + 1$.
- For eg. in the case of a solid - liquid equilibrium of an alloy, there is no gas phase, and the effect of pressure is negligible. The reduced / condensed phase rule is used here.

Need for the Condensed Phase Rule : In a α component sys, with only a minimum no. of phases, ($P=1$), the degree of freedom would be :

$$\begin{aligned} F &= C - P + 2 \\ &= 2 - 1 + 2 \\ &= 3 \end{aligned}$$

This means that 3 variables would be necessary to define the system: pressure, temperature & composition.

- In order to represent this diagram, three axes would be required, leading to a 3-D diagram
- This cannot be represented on paper: as a result, one of the variables is taken to be a constant.

Classification of a Two Component System

1. Simple eutectic formation
2. Compound eutectic formation
 - a. w/ a congruent melting pt.
 - b. w/ an incongruent melting pt.

1. Simple eutectic system

- A binary system w/ 2 substances, immiscible in the solid state, but miscible in the molten state, which do not react chemically w/ each other.
~~do not react chemically w/ each other~~
- Among the different mixtures of the 2 substances, the mixture w/ the lowest melting point is called as a eutectic mixture. eg. Lead - silver system.

2. Compound eutectic formation

- congruent melting pt. A 2 component sys. of 2 solids which has a definite composition.
- It has a congruent melting pt; it melts at a constant temp, has the same composition in both the solid & the molten state.
eg. Zn-Mg
- All normal pts = congruent melting pts, as the composition of the solid & liquid phase is the same.

Characteristics: (i) no decomposition of the compound formed, fairly stable.
(ii) compound having a congruent melting pt. will separate out as a new solid phase from the solution.
(iii) The phase diagram shows a hump in the middle w/ eutectic on either side. The presence of a hump indicates the formation of a compound in between components in the solid phase.

A well defined hump indicates that the compound is stable, melting pt. is maximum.

11

- Sometimes, more than 1 compound is formed \Rightarrow multiple humps

Incongruent melting Point

- If the compound formed in a 2 component solid system, decomposes at a temperature below its melting point, the compound has an incongruent melting pt.
- A new solid phase is formed w/ composition different from that of the original. e.g. sodium - bismuth system.
(e.g. sodium - bismuth system)

Formation of a solid - solution system

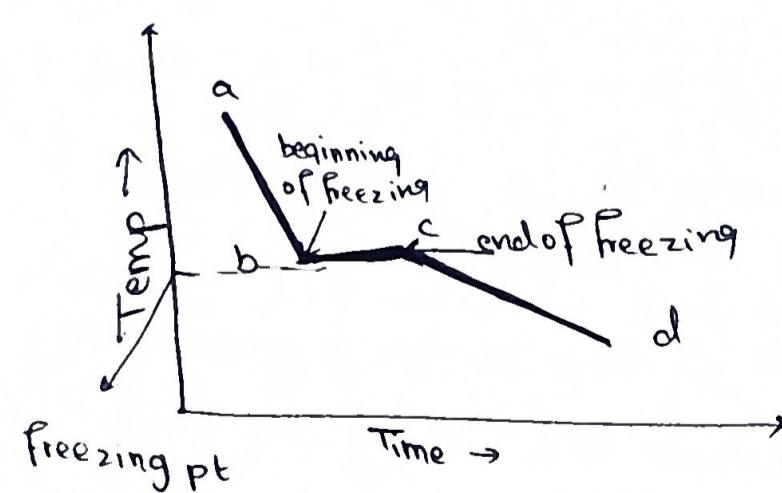
- A 2-component system of solids completely miscible in the solid and the liquid state.
- They form a solid soln. where mixing happens at atomic levels.
condition: atomic radii of the 2 solids must not differ by more than 15%. e.g. Cu - Ni system.

Thermal Analysis

A graph plotted between temperature & time is called a cooling curve.

During thermal analysis, a pure substance is melted into a liquid state, and is slowly cooled. Temperature is noted at regular intervals.

Cooling Curve of a pure Substance



Explanation:

- Along ab, temp. falls rapidly with time.
- b is the freezing pt. of the substance, the solid substance starts separating out.
- Crystallization is an exothermic process, if the rate of cooling & the rate of crystallization are the same, then there is no change of temperature along bc, i.e., it is parallel to the X-axis.

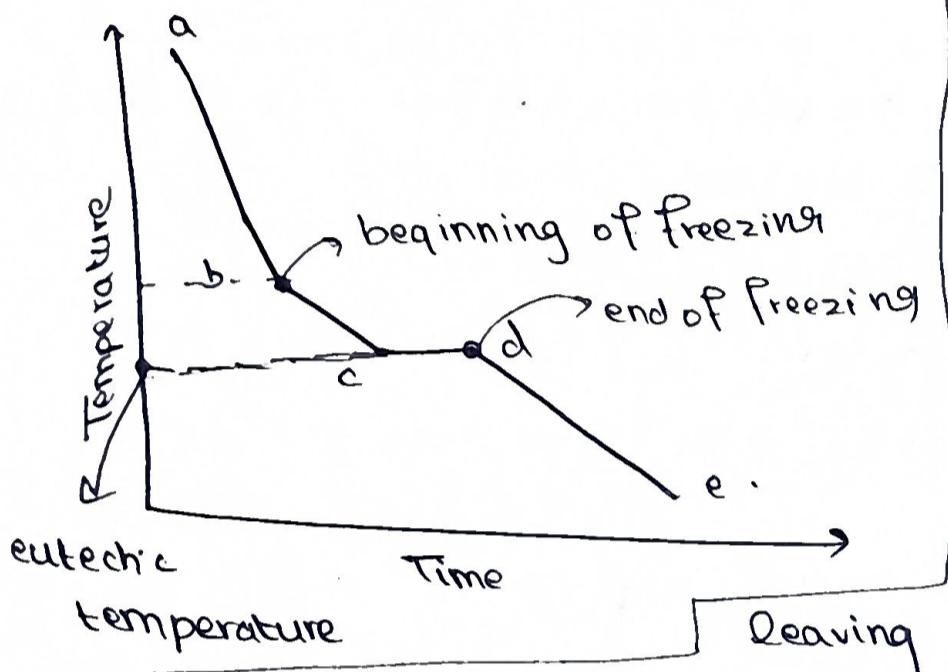
Newton's law of cooling

- If an impurity is added, the freezing pt. decreases.

Thermal Analysis of a Two-Component System

The thermal analysis of a 2 component system is carried out by cooling a mixture of 2 solids, completely miscible in the liquid state.

The temperature is noted at periodic intervals.



- Consider a mixture of A & B. A is the major component, and B is the impurity.
- When the mixture is cooled, there is a rapid decrease in temp.
- The first break occurs at b, when A starts crystallizing out, leaving behind B.

- However, the temperature will not remain constant as A crystallizes, because during the crystallization of A, the quantity of impurity B, increases. This further decreases the freezing pt. of A.
- After A completely solidifies, at eutectic temperature 'c', B starts crystallizing out.
- This time, the temperature remains a constant, because there is no other metal in the liquid state.
- Along 'de', the solidified system cools as per Newton's Law of Cooling.

∴ There are 3 breaks in the cooling curve of a 2 component system

- (i) First break - when at the freezing pt. of the major component
- (ii) Second break - at the eutectic pt., when the impurity (B) starts crystallizing.
- (iii) Third break : when the mixture is completely solidified.

Applications of cooling curves

1. melting pt & eutectic temperature can be found out
2. The phase diagram can be drawn
3. The percentage of the compounds can be found out.

Eutectic system: A binary system which is miscible in all proportions in the liquid phase. (eutectic = easy melting) eg. Ag-Pb system

uses of eutectic systems: (i) to find the alloy composition
(ii) to prepare solders to join metal pieces together

Eutectic mixture: a solid solution of 2 or more components which has the lowest melting point of all possible mixtures of the components.

eutectic point : minimum freezing pt. of the eutectic mixture

characteristics: (i) eutectic temperature is non-variant (has a specific temp and composition)

- (ii) is the lowest possible melting pt. of the system
- (iii) if the liquid is cooled below the eutectic point, both components solidify immediately, without any change in composition of the liquid phase.
- (iv) can maintain its temperature over long periods.

applications: (i) fire alarms
(ii) automatic sprinklers
(iii) safety devices in boilers

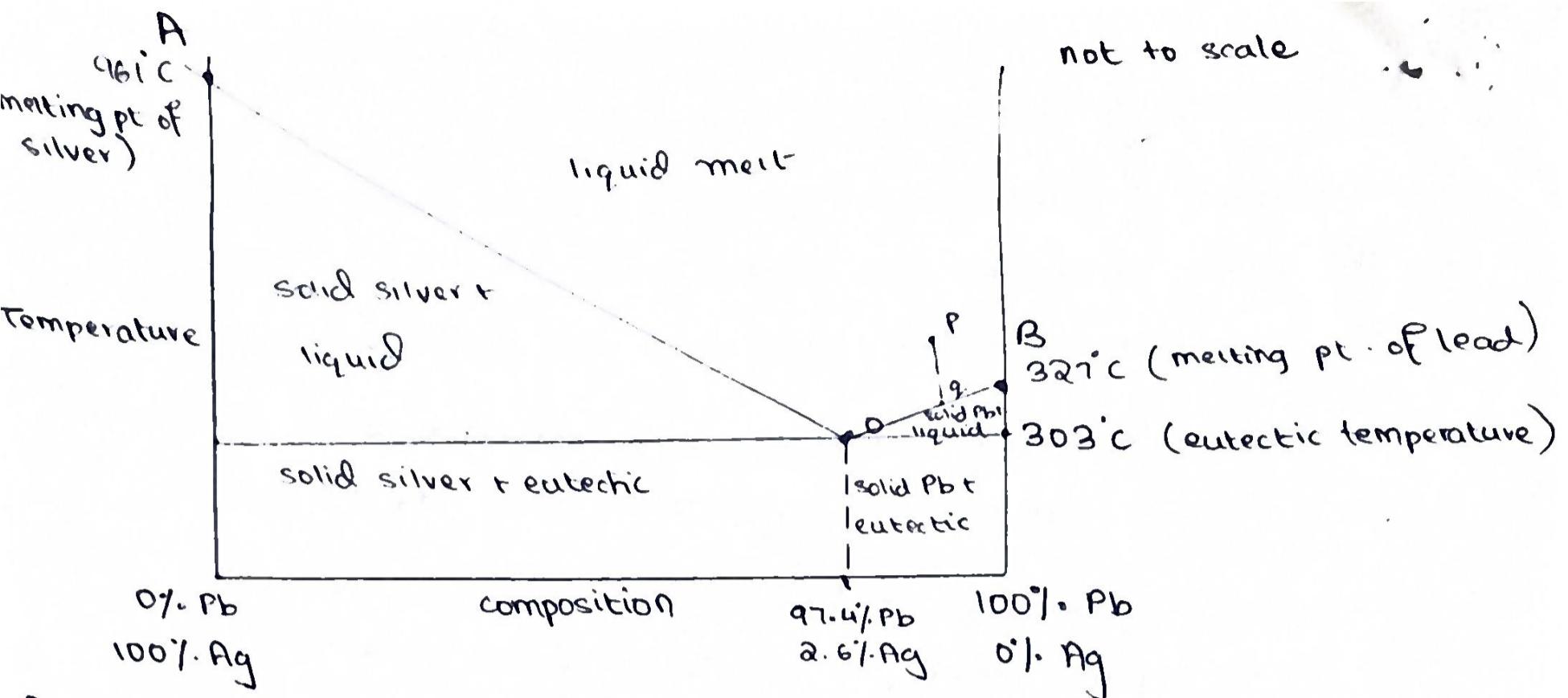
Two Component System: Binary Alloy System (or) Simple Eutectic System

Lead-Silver System

Given Data: melting points silver = 96°C
 lead = 327°C

eutectic temperature = 303°C

eutectic composition \Rightarrow lead = 97.4%
silver = 2.6%.



Areas (i) above AOB = a homogeneous solution of Ag + Pb.

$$P=1$$

applying the condensed phase rule: $F = C - P + 1$

$$= 2 - 1 + 1$$

$$\boxed{F = 2} \Rightarrow \text{bivariant}$$

(ii) below AO, BO and O

below AO : solid silver + liquid

below BO : solid lead + liquid

below O : solid silver / lead + eutectic mixtures

Lines (i) AO : freezing curve of Ag

as lead is added, melting pt. of Ag decreases, Ag crystallizes out

$\text{solid Ag} \rightleftharpoons \text{liquid melt}$

$$P=2$$

$$F = C - P + 1$$

$$F = 2 - 2 + 1$$

$$\boxed{F = 1} \text{ univariant}$$

(ii) BO : freezing curve of Pb

as silver is added, melting pt. of Pb decreases, Pb crystallizes out

$\text{solid Pb} \rightleftharpoons \text{liquid melt}$

$$P=2$$

$$F = C - P + 1$$

$$\boxed{F = 1} \text{ univariant}$$

Eutectic pt O: solid Ag + solid Pb \rightleftharpoons melt

$$P=3 \quad F = C - P + 1$$

$$F = 2 - 3 + 1 \quad \boxed{F = 0} \Rightarrow \text{invariant}$$

eutectic composition: $Pb = 97.4\%$,
 $Ag = 2.6\%$.

Pattinson's process: Argentiferous lead has a small proportion of Ag (0.1%). When heated to a temp. above the melting pt, the sys. consists only of liquid melt (P). It is cooled till g, where Pb begins to crystallize out, soln. contains more & more Ag. The melt gets richer & richer in silver till pt. O, where Ag sol. is 2.6%. The process of raising the relative proportion of silver in the alloy is called Pattinson's process.

CHEMISTRY ASSIGNMENT

PHASE EQUILIBRIA

POOJA PREMENDATH

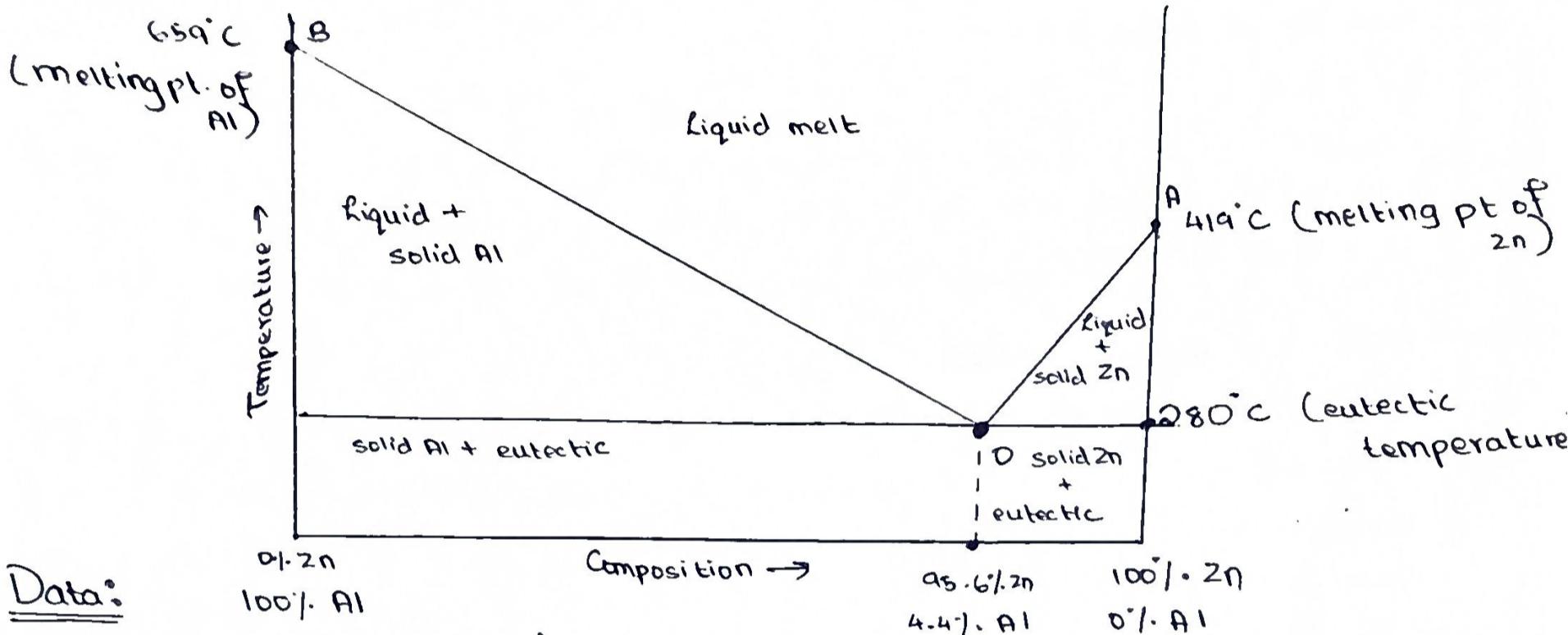
S01

ROLL NO. 211D152

15

1. Phase diagram of Zn-Al system

not drawn to scale



Data:

0% Zn
100% Al

Composition →

95.6% Zn
4.4% Al

100% Zn
0% Al

Melting point: Zn - 419°C
Al - 659°C

Eutectic temperature: 280°C

Eutectic composition: Zn - 95.6%
Al - 4.4%.

Explanation

Areas 1. above AD_B: Zn, Al are in a homogenous liquid solution.

$$\Rightarrow P = 1$$

based on the condensed phase rule,

$$F = C - P + 1$$

$$= 2 - 1 + 1$$

$$\boxed{F = 2} \Rightarrow \text{bivariant}$$

2. below AD_B, BO & O

below AD = solid zinc and liquid melt

below BO = solid aluminium and liquid melt

below O = solid zinc/aluminium & eutectic compound.

$$P = 2$$

Lines: BO = freezing curve of Al

addition of Zn lowers melting pt

here said Al \rightleftharpoons liquid melt

$$\Rightarrow P = 2, C = P = 2$$

$$\begin{aligned} \therefore F &= C - P + 1 \\ &= 2 - 2 + 1 \\ \boxed{F = 1} \Rightarrow &\text{ univariant} \end{aligned}$$

AO: Freezing curve of Zn
addition of Al reduces melting pt
 $\text{solid Zn} \rightleftharpoons \text{liquid melt}$

$$P = 2, C = 2$$

$$\begin{aligned} F &= C - P + 1 \\ &= 2 - 2 + 1 \end{aligned}$$

$$\boxed{F = 1} \Rightarrow \text{univariant}$$

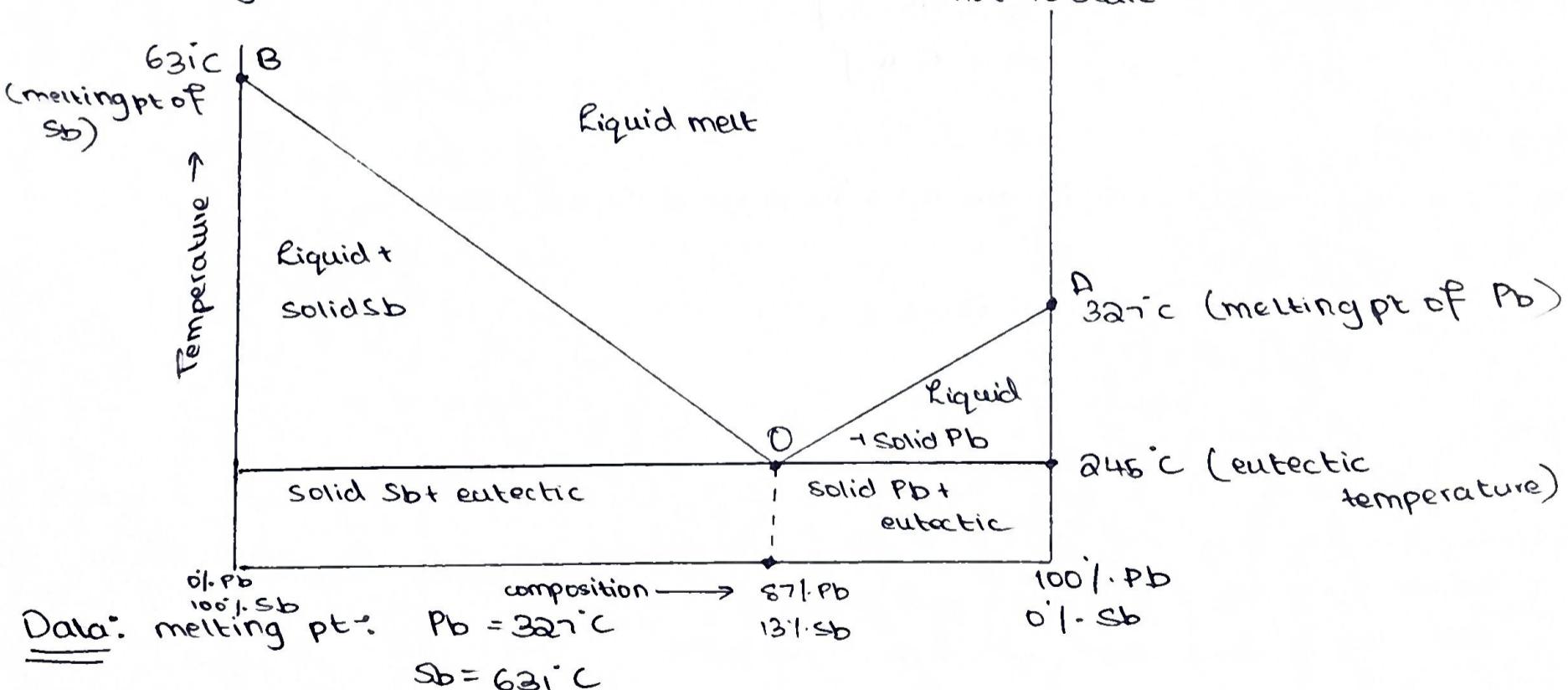
eutectic pt D: 3 phases coexist
 $\text{solid Zn} \rightleftharpoons \text{solid Al} \rightleftharpoons \text{liquid melt}$

$$P = 3, C = 2$$

$$\begin{aligned} F &= C - P + 1 \\ &\cancel{= 2 - 3 + 1} \\ &= 2 - 3 + 1 \end{aligned}$$

$$\boxed{F = 0} \Rightarrow \text{invariant}$$

2. Phase diagram of Pb - Sb system



$$\text{eutectic temperature} = 245^\circ\text{C}$$

$$\text{eutectic composition} = 87\% \text{ Pb} \pm 13\% \text{ Sb}$$

Explanation: Areas

1. area above AOB : Pb, Sb are in a homogenous liquid solution.

$$P = 1 \quad C = 2$$

$$F = C - P + 1$$

$$= 2 - 1 + 1$$

$$\boxed{F = 2} \Rightarrow \text{bivariant}$$

2. area below AO, BO & O

area below AO = solid Pb & liquid melt

area below BO = solid Sb & liquid melt

area below O = solid Pb | Sb & eutectic compound

$$P = 2$$

Lines AD : A = melting pt of Pb

as Sb is added, melting pt. decreases

solid Pb \rightleftharpoons liquid melt

$$P = 2 \quad C = 2$$

$$F = C - P + 1$$

$$= 2 - 2 + 1$$

$$\boxed{F = 1} \Rightarrow \text{univariant}$$

BO : B = melting pt. of Sb

as Pb is added, melting pt. decreases

solid Sb \rightleftharpoons liquid melt

$$P = 2 \quad C = 2$$

$$F = C - P + 1$$

$$= 2 - 2 + 1$$

$$\boxed{F = 1} \Rightarrow \text{univariant}$$

eutectic pt O: 3 phases coexist

solid Sb \rightleftharpoons solid Pb \rightleftharpoons liquid melt

$$P = 3$$

$$C = 2$$

$$F = C - P + 1$$

$$= 2 - 3 + 1$$

$$\boxed{F = 0} \Rightarrow \text{invariant}$$

→ κ Two component system congruent melting pt.

Zinc-magnesium system

Data:

$$\text{melting pts: } \text{Zn} = 419^\circ\text{C}$$

$$\text{Mg} = 650^\circ\text{C}$$

$$\text{MgZn}_2 = 590^\circ\text{C}$$

Zn-MgZn₂ system

$$\text{eutectic composition} = \text{Zn: 79\%} \\ \text{MgZn}_2: 21\%$$

$$\text{eutectic temperature} = 380^\circ\text{C}$$

$$\text{melting pt Zn} = 419^\circ\text{C}$$

$$\text{overall composition: } \text{Zn} = 66.66\% \\ \text{Mg} = 33.34\%$$

Mg-MgZn₂ system

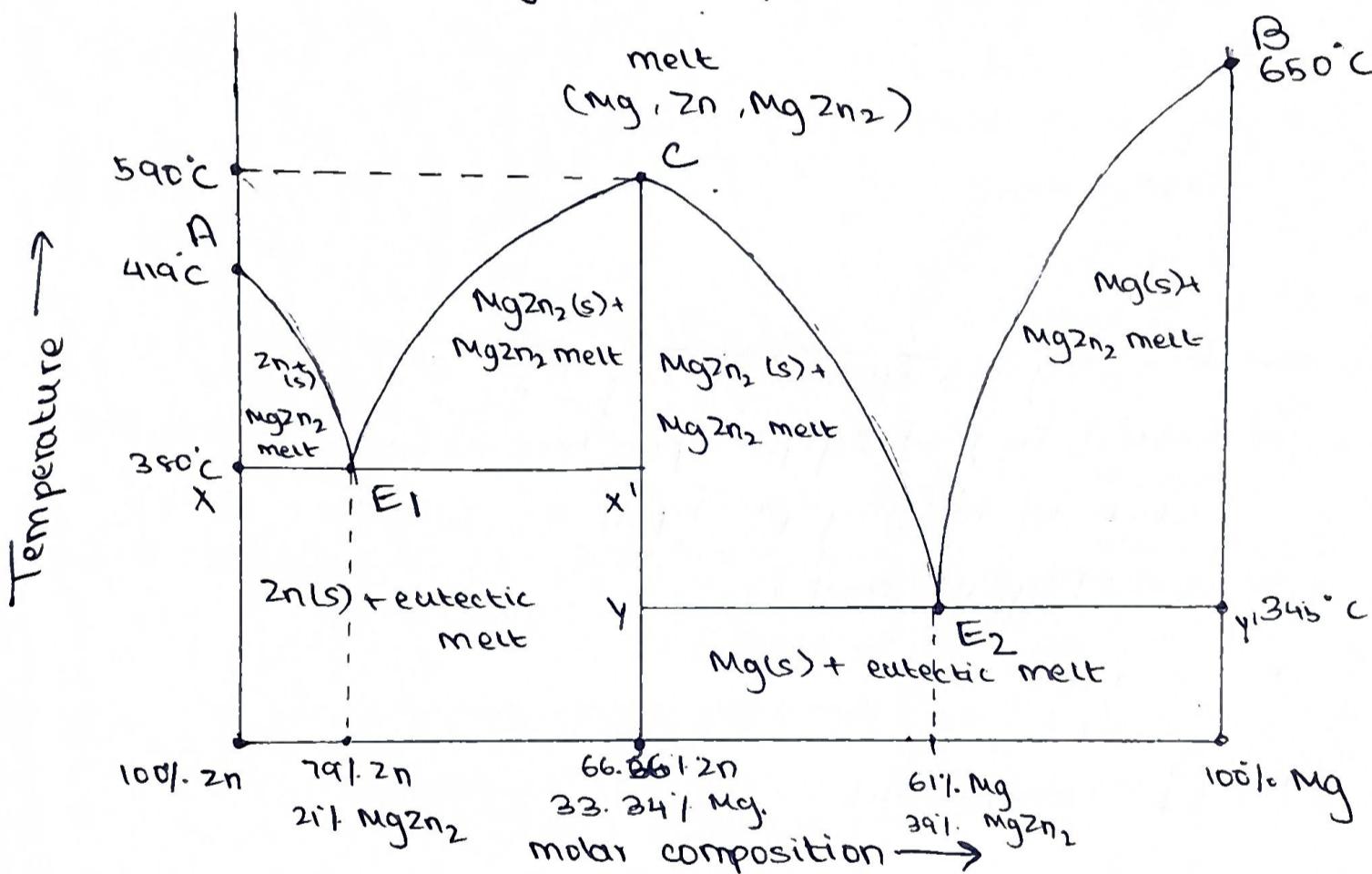
$$\text{eutectic composition}$$

$$\text{Mg: 61\%}$$

$$\text{MgZn}_2: 39\%$$

$$\text{eutectic temperature} = 345^\circ\text{C}$$

$$\text{melting pt Mg} = 650^\circ\text{C}$$



The phase diagram of the Mg-Zn system can be thought of as a simple phase diagram.

Left side = Zn, ZnMg₂ system

Right side = Mg, ZnMg₂ system

Explanation:

Left side = Zn, ZnMg₂ system

1. curve AE₁

→ freezing pt. curve of Zn

here, $\text{Zn(s)} \rightleftharpoons \text{MgZn}_2 \text{ melt}$

P=2

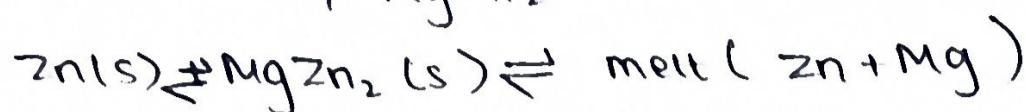
$$F = C - P + 1 = 2 - 2 + 1$$

$$F = 1 \quad \text{univariant}$$

2. eutectic point E₁

temp = 380°C

composition = 79% Zn
21% Mg₂n₂



P = 3

$$F = C - P + 1$$

$$F = 2 - 3 + 1$$

$F = 0$ nonvariant

Right side of the phase diagram

curve BE₂ : freezing curve of Mg



$$P = 2 \quad F = C - P + 1$$

$$F = 2 - 2 + 1$$

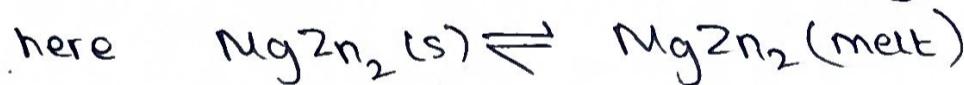
$F = 1 \Rightarrow$ univariant

2. curve E₁CE₂

CE₁, CE₂ are the melting pt. curves of Mg₂n₂

CE₁ shows the reduction in melting pt upon the addition of Zn

CE₂ shows the reduction in melting pt. upon the addition of Mg



$$P = 2 \quad F = C - P + 1$$

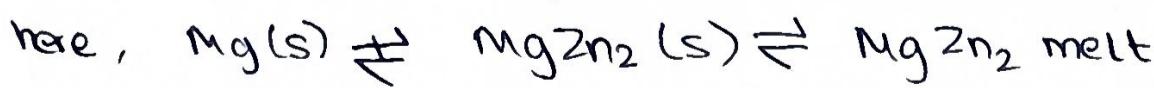
$$= 2 - 2 + 1$$

$F = 1 \Rightarrow$ univariant

3. eutectic pt E₂

temp = 345°C

composition = 39% Mg₂n₂
61% Mg



$$P = 3 \quad F = C - P + 1$$

$$F = 2 - 3 + 1$$

$F = 0$ nonvariant

4. pt C = congruent melting pt @ 590°C

Mg₂n₂ melts sharply w/o change in composition

composition: Zn = 66.66% Mg = 33.34%