Chapter-II
Phase Equilibria

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Text Books / Reference Books

1) O. G. Palanna, Engineering Chemistry, Tata McGraw Hill Education

2) Jain P. C. and Monica Jain, Engineering Chemistry, Dhanpat Rai Publishing Company Ltd.

3) R. L. Madan, Physical Chemistry, McGraw Hill Education

4) Dara S. S., Umare S. S., Engineering Chemistry, S. Chand & Company Ltd.

Phase Rule

➤ Phase Rule was given by J. Willard Gibbs in 1875.

➤ Phase Rule is applicable to heterogeneous System.

➤ Phase Rule is very useful to understand the effect of intense variables like Temperature, Pressure or Concentration on the equilibrium between Phases (Solid, Liquid & Gas) as well as between the Chemical Constituents.

➤ Phase Rule can be used to determine the "Variance of the System" or Degree of Freedom(F) for the system.

Phase Rule can be defined as

When equilibrium between any number of phases is influenced by Temperature, Pressure and Concentration but not influenced by gravity or electrical force or mechanical force or surface action then Degree of Freedom (F) is related to Number of Components (C) and Number of Phases by following relation

$$F + P = C + 2$$

Where

✓ F = Degree of Freedom

✓ C = Number of Component

✓ P = Number of Phases

✓ 2 = Additional variables of Temperature and Pressure besides Concentration

Phase Rule at Constant Pressure

Condensed System do not have gas phase and the effect of Pressure is negligible.

Only one variable is required to define the system completely then Phase Rule at constant pressure is defined as

$$F + P = C + 1$$

It is also known as Condensed Phase Rule

Phase

A Phase is defined as any homogeneous, physically distinct and uniform in composition part of the system having same physical and chemical properties through out the system. It is denoted by "P".

Examples
Pure substances (Solid, Liquid and Gas) are made up of one chemical specie only is considered as one phase system, like Oxygen, Benzene and Ice is a One Phase System.

A system containing only liquid water is one phase system.

A system containing only liquid water and Ice is two phase system.

A system containing only liquid water, vapour and solid Ice is Three phase system.

Three phases of water

water vapour

solid ice

liquid water

(a) Thus, gases being mutually miscible in all proportions will constitute one phase only. Thus mixture of H_2 and O_2 constitutes single phase.

(b) Mixture of two completely miscible liquids has single phase.

(c) Solution of a solute in a solvent constitutes single phase such as salt solution in water.

(d) If two liquids are immiscible, they form two phases such as chloroform and water.

(e) Except solid solutions all different kinds of solids form different phases.

(f) If we keep a mixture of miscible liquids in a closed vessel, above the liquid mixture, there will be some vapors of the liquids, so the system will have two phases.

(g) At freezing point, water consists of three phases:

$$Ice(s) \rightleftharpoons Water(l) \rightleftharpoons Water\ vapor(g)$$
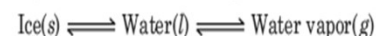
(h) A heterogeneous mixture of the type

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$
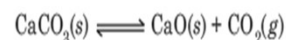
consists of three phases—two solid and one gaseous.

Component

The term component is defined as the minimum number of independent chemical constituents in terms of which the composition of each phase can be expressed by means of chemical equation. It is denoted by "C".

Examples
Total Number of Phases in water are Solid (Ice), Liquid (Water) and Gas (Water Vapour)
The composition of each phase is expressed in terms of chemical constituent i.e. Water.
Water is a One Component System.

Examples
Total Number of Phases in Sulphur are rhombic sulphur, monoclinic sulphur, Liquid sulphur, Sulphur vapour.
The composition of each phase is expressed in terms of chemical constituent i.e. Sulphur.
Sulphur is a One Component System.

Lead and Silver are miscible in all proportions in molten state.
Total number of Phases = 1
Total number of Component = 2
So to define the composition of this homogeneous molten single phase system, we need both the constituents. Therefore it is a two component system.

Decomposition of Calcium Carbonate
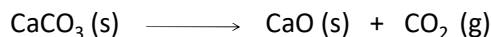
$CaCO_3$ (s) $\longrightarrow$ CaO (s) + CO_2 (g)
Total number of phases = 3
(Solid $CaCO_3$, Solid CaO and CO_2)

If the constituents chosen are CaO and CO_2

Phase		Composition		
$CaCO_3$	= CaO	+	CO_2
CaO	= CaO	+	0 CO_2
CO_2	= 0 CaO	+	CO_2

Total number of Component = 2

If the constituents chosen are $CaCO_3$ and CO_2
Phase   Composition

$CaCO_3$	=	$CaCO_3$	+	0 CO_2
CaO	=	$CaCO_3$	-	0 CO_2
CO_2	=	0 $CaCO_3$	+	CO_2

If the constituents chosen are $CaCO_3$ and CaO
Phase   Composition

$CaCO_3$	=	$CaCO_3$	+	0 CaO
CaO	=	0 $CaCO_3$	+	CaO
CO_2	=	$CaCO_3$	-	CaO

Total number of Component = 2

So to define each phase we require two components. Hence it is a <u>two component system</u>.

Decomposition of Ammonium Chloride

NH_4Cl (s) $\longrightarrow$ NH_3 (g) + HCl (g)
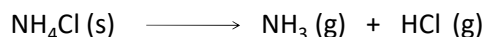
Total number of phases = 2
(Solid NH_4Cl , Homogeneous gaseous mixture of NH_3 and HCl present in same proportion in which they are present in solid NH_4Cl).

Phase rule do not distinguish between chemical compound and its constituents present in same proportion in the homogeneous mixture.
Composition of both the phases can be defined by NH_4Cl. So it is a <u>one component system</u>.

If excess NH_3 and HCl is introduced into the system then it becomes <u>two component</u> system.

Fe(s) + H_2O (g) $\leftrightarrow$ FeO (s) + H_2 (g); Find out P & C?
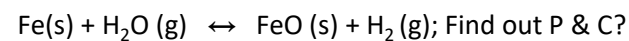
If the constituents chosen are Fe, H_2O and H_2
Phase   Composition

Fe	=	Fe	+	0 H_2O
FeO	=	FeO	+	0 H_2
H_2O	=	H_2O	+	0 Fe

Total number of Component = 3

4

(A) In a chemically reactive system where various reactions takes place between chemical species the number of components is calculated by following relationship-

$$C = S - R$$

Where, S = Number of Chemical Constituents / Species

R = Number of Chemical Reactions which chemical constituent / species can undergo

(B) When ions are also present in the system then condition of electroneutrality (Number of positive & negative charges should be equal) then the number of components is calculated by following relationship-

$$C = S - (R+1)$$

Activity

Activity-1

Explain why KCl – NaCl – H_2O should be regarded as a three component system whereas KCl – NaBr – H_2O should be regarded as a four component system.
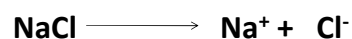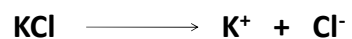
In KCl – NaCl – H_2O system

Total number of species are-

KCl, NaCl, H_2O, K^+, Na^+, Cl^-

$$S = 6$$

Total number of reaction are-

KCl $\longrightarrow$ K^+ + Cl^-
NaCl $\longrightarrow$ Na^+ + Cl^-

$$R = 2$$

$$S - (R+1) = 6 - (2+1)$$

$$= 3$$

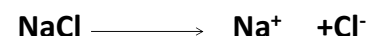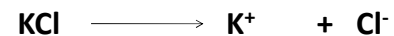Therefore KCl – NaCl – H_2O system is a 3 component system

In KCl – NaBr – H_2O system

Total number of species are-

KCl, NaBr, KBr, NaCl, H_2O, K^+, Na^+, Br^- , Cl^-

$$S = 9$$

Total number of reaction are-

KCl $\longrightarrow$ K^+ + Cl^-
NaBr $\longrightarrow$ Na^+ + Br^-
KBr $\longrightarrow$ K+ + Br^-
NaCl $\longrightarrow$ Na^+ +Cl^-
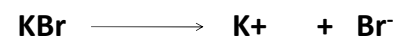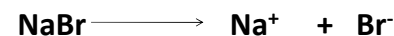
R = 4

S − (R+1)   = 9 − (4+1)

= 4

Therefore KCl − NaBr − H_2O system is a 4 component system

Degree of Freedom

The minimum number of independent variables (such as temperature, pressure and composition of phase) which must be specified in order to define the system completely is called Degree of Freedom.

It is also known as variance of the system.

If   F = 0,   System is invariant or non-variant
       F = 1,   System is univariant or monovariant
       F = 2,   System is bivariant
       F = 3,   System is trivariant

NON-VARIANT SYSTEM

Ice = Water = Vapour System

In this system there are three phases of one component (Water). These three phases can co-exist together in equilibrium at particular temperature and pressure. Any change in one of these factor results in the disappearance of one or more phases.

F   = C − P + 2
        = 1 − 3 + 2 = 0

Hence the system is invariant or non-variant.

MONOVARIANT SYSTEM

Water − Water Vapour System

This system consist of two phases of one component (Water). If the temperature is fixed the vapour pressure is also fixed and vice versa.

F   = C − P + 2
        = 1 − 2 + 2 = 1

Hence the system is univariant or monovariant.

BIVARIANT SYSTEM

For a Gas

The temperature, pressure and concentration (volume) are related to each other according to PV = RT.
So in order to define the system completely, any two factors (pressure, temperature or volume) must be fixed.

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

Hence the system is bivariant.

TRIVARIANT SYSTEM

A mixture of two or more gases is completely defined only when pressure, temperature and composition are specified. If pressure and temperature are specified then the third variable composition may be varied.
So it is necessary to specify all the three variables to define the system completely.

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

Hence the system is trivariant.

Advantages of Phase Rule

➢ Phase Rule is applicable to Chemical & Physical equilibria.

➢ Phase Rule is applicable to macroscopic system and hence no information is required regarding molecular / micro structure.

➢ We can classify equilibrium states in terms of phases, components and degree of freedom.

➢ The behaviour can be predicted under different conditions.

➢ According to phase rule different systems behaves similarly if they have same degree of freedom.

➢ Phase rule helps in deciding under a given set of conditions:
(i) Existence of equilibrium among various substances
(ii) Inter convergence of substances
(iii) Disappearance of some of the substances

Limitation of Phase Rule

➢ It is applicable only for those systems which are in equilibrium.

➢ Only three degree of freedom i.e. Pressure, Temperature and Composition are allowed to influence the system.

➢ It is consider number of phases rather than their amount.

➢ Under the same condition of temperature and pressure, all the phases of the system must be present.

Application of Phase Rule

➢ Single Component System – Water System and Carbon Dioxide System

➢ Binary Component System – Lead-Silver System

Single Component System-Water System

➢ In Single Component System the degree of freedom depends on the number of phases

Number of Component (C) = 1
By Phase Rule: F + P = C + 2
                F = 1 + 2 - P

| Phase Rule with Single Component System			
System	No. of Phases	Degree of Freedom	Remarks
Solid / Liquid / Gas	1	2	System is bivariant
Solid – Liquid Liquid – Gas Solid – Gas	2	1	System is univariant
Solid – Liquid – Gas	3	0	System is invariant

Water System

✓ In Water System the chemical compound is Water. Hence C = 1.

✓ Water System consist of three phases i.e. Ice, Liquid, Vapour.

✓ Phase diagram consist of :
(i) Stable Curves OA, OB, OC and OA'
(ii) Areas BOC, COA and BOA
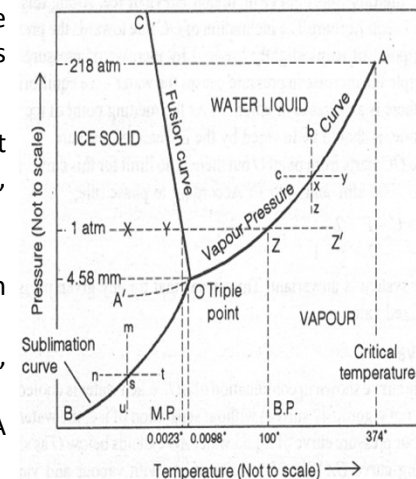
(iii) Triple Point 'O'

Study of Curves:

Curve OA

It is known as vapour pressure curve of water and represent the equilibrium between liquid water and vapour.

It starts from the point 'O' and ends at 'A', the critical temperature (374°C) beyond which the two phases merge into each other.

Along the Curve OA:
No. of Component = 1,   No. of Phases = 2
Degree of Freedom (F)   = C + 2 − P = 1 + 2 − 2   = 1
Hence the system is univariant.

Curve OB

It is known as sublimation curve of ice. This curve starts from point 'O' and extend upto the 'B' absolute zero of temperature (-273°C).

Along the curve OB for a particular temperature there can be only one value of pressure and vice versa.

The Ice = Vapour system is univariant and has one degree of freedom.

Curve OC

It is known as melting point curve or freezing point curve or fusion curve of Ice and represent the equilibrium between Ice and Liquid water. This curve shows the effect of pressure on the melting point of Ice.

The Curve OC is inclined towards pressure axis. The negative slop of curve shows that melting point of Ice is lowered with the increase in pressure.

This curve starts from point 'O' and ends upto point 'C' (2000 atmospheres and -20°C).

The Ice = Liquid water system is univariant and has one degree of freedom.

Curve OA'

The curve OA' is the continuation of curve OA and represent water (l) and water (vapour) phases are in metastable equilibrium.

It is sometime possible to cool liquid water below the point 'O' without solidification. The liquid below the freezing point is in the Super-Cooled State, which is not stable and known as metastable state

Study of Area:

The area BOC (Solid), COA (Liquid) and AOB (Vapour) represent three phases of Water.

No. of Component (C)   =   1
No. of Phases (P)   =   1
Degree of Freedom (F)   = C + 2 − P = 1 + 2 − 1
                                        =   2
Hence the system is bivariant.

Both temperature and pressure must be specified to define the state of system.

Study of Point 'O' [Triple Point]:

At triple point all the three phases of water co-exist and curve OA, OB and OC meet.
i.e.   Solid = Liquid = Vapour
So, No. of Phases   =   3

No. of Component   =   1
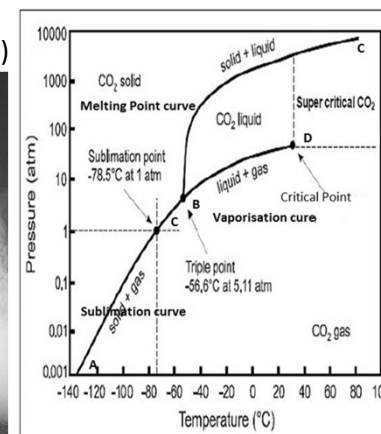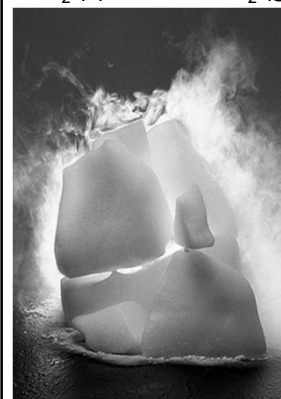Degree of Freedom (F)   = C + 2 − P = 1 + 2 − 3
                         =   0

Hence the system is invariant at the triple point 'O' (0.0098°C and 0.006 atm. or 4.58 mm Hg)

Single Component System- Carbon Dioxide

At 1 atm
CO_2 (s) ⟶ CO_2 (g)

✓ Phase Diagram of CO_2 resembles with that of H_2O with some differences.

Study of Area:

✓ The phase diagram of CO_2 has three distinct area ABD (Right Hand Side) consist of Vapour phase, Area above CBD consist of Liquid phase and Area (Left Hand Side) ABC consist of Solid Phase

Study of Curves:

Curve AB

✓ Curve AB is the sublimation curve along which Solid CO_2 is in equilibrium with Gas CO_2.
✓ Point 'C'' is known as Sublimation point (Temperature -78.5°C, Pressure 1 atm.)

Curve BD

✓ Curve BD is the vaporisation curve along which Liquid CO_2 is in equilibrium with Gas CO_2.

✓ This curve starts from Triple Point 'B' and ends at Point 'D' is known as Critical point (Temperature 31.1°C, Pressure 72.8 atm.)

Curve BC

✓ Curve BC is the fusion curve along which Solid CO_2 is in equilibrium with Liquid CO_2.

✓ This curve starts from Triple Point 'B' and ends at Point 'C'.

Study of Point 'B' [Triple Point]:

At triple point 'B' all the three phases of CO_2 co-exist and curve AB, BD and BC meet.

i.e.   Solid CO_2 = Liquid CO_2 = Gas CO_2

So, No. of Phases   =   3
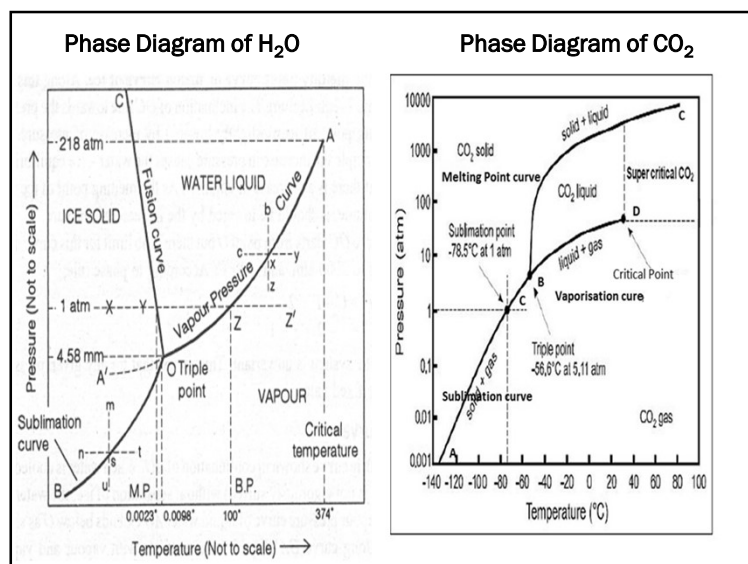
No. of Component   =   1
Degree of Freedom (F)   = C + 2 − P = 1 + 2 − 3
                            =   0

Hence the system is invariant at the triple point 'B' (-56.6°C and 5.11 atm.)

Difference in the Phase Diagram of H_2O and CO_2

✓ In CO_2 phase diagram the melting poing curve slopes away from the pressure axis.

✓ Solid CO_2 can exist in equilibrium with Liquid CO_2 only at high pressure equal to 5.11 atm. While in H_2O system Ice and Water can exist in equilibrium at low pressure.

✓ Vapour pressure of Solid CO_2 even at low temperature is very high and many time higher than that of Ice.

✓ At low atmospheric pressure CO_2 gas can be directly solidify without attending the liquid phase just by cooling to -78.5°C, this is why the Solid CO_2 is known as **Dry Ice**.

Phase Diagram of H_2O / Phase Diagram of CO_2

Binary Component System

Two component system is one in which it is possible to express the composition of each phase in terms of two substances.

Number of Phases (P)   =   1
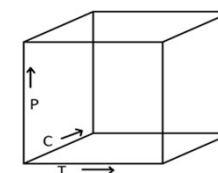Number of Components(C)   =   2
Degree of Freedom (F)   = C + 2 − P
                                         = 2 + 2 − 1   =   3

So to define the system completely three variables temperature, pressure and composition are required.

It is difficult to construct a phase diagram in two dimension.

Let us consider a system where Solid = Liquid and do not have gas phase and the effect of pressure is small on equilibrium then such a system in which vapour phase is not considered and effect of pressure is kept constant is known as **condensed system**.

At constant Pressure the degree of freedom is reduced by ONE. For condensed system Reduced Phase Rule is applicable.

i.e.   F + P =   C+1
For two component system   C = 2
          F = 2 + 1 –P
When P = 1, then F = 2 + 1 -1 = 2

Therefore Solid = Liquid equilibria are represented on temperature composition diagram.

Types of Binary Component System

Two component system is of Three types involving solid-liquid equilibria.

Type-I: Two component do not react with each other but mix with each other in molten state or in solution.
For Example: Lead-Silver System, KI-H_2O System

Type-II: Two pure component react to form a compound which is stable upto its melting point. At melting point it melts to gives a liquid of the same composition as that of solid compound. The compound formed is then said to have congruent melting point.
For Example: $FeCl_3.H_2O$ System

Type-III: Two pure component react to form a compound which is unstable upto its melting point. On heating it starts decomposing before melting point to gives a new solid and a solution with composition different from that of solid phase. The compound is said to have incongruent melting point.
For Example: Na_2SO_4-H_2O System

Eutectic Mixture
Solid solution of such two component system which has lowest melting point of all the possible mixtures of the components is known as **Eutectic mixture** and the corresponding freezing point temperature is known as **Eutectic point**.
For Example: Cu – Ag, Pb-Ag, Bi - Cd

Application of Eutectic Mixture

Alloys which are known to form eutectic mixture are used as 'Fail Safe' devices in boilers & domestic water geysers, as plug in automobiles.

Eutectic mixtures has low melting point, so they are used for joining two metal pieces together. For example Lead-Tin solders.

Eutectic mixtures of Sodium & Potassium are liquid at room temperature and are used as coolant in nuclear reactors.

Binary Component System-Lead-Silver

Phase Diagram of Lead – Silver System
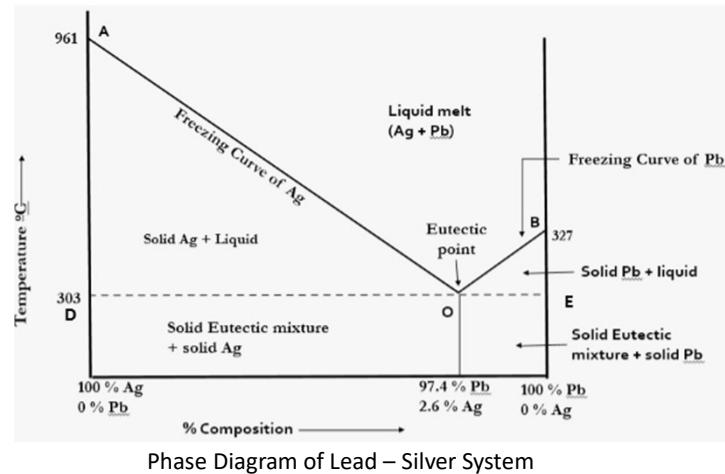
Lead & Silver are completely miscible in all proportions in their molten state, they don't react chemically and each component has the property of lowering each other's freezing point.

Various phases are
(a) Solid Lead
(b) Solid Silver
(c) Solution of Lead & Silver in molten state
(d) Vapour

Small changes of pressure has negligible effect on the equilibrium between lead and silver in solid state or in molten state and hence vapour phase will not exist.
Thus Reduced Phase Rule can be applied.
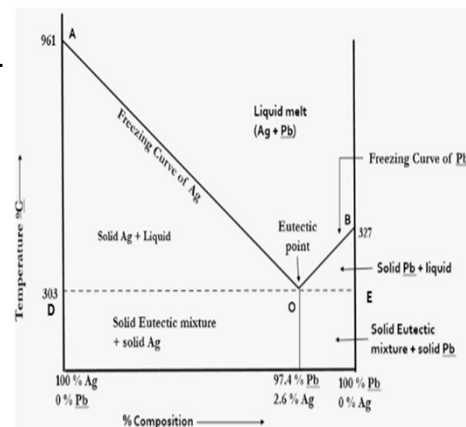
$$F = C + 1 - P$$
$$F = 2 + 1 - P$$

In Pb – Ag system, two components are present i.e. Lead & Silver. Hence C = 2

Lead – Silver system consist of

1) Curves OA and OB.

2) Areas AOD,
Area BOE,
Area above AOB,
Area below DOE.

3) Point 'O'.

Study of Curves:

Curve OA (Solid Silver ⟷ Molten Liquid)

This is called the freezing point curve of silver to which successive quantities of lead are added.

Point 'A' indicate the melting point of Pure Silver (961°C). Melting point of silver is lowered gradually by the addition of lead to it.

Along the curve OA added Lead goes into solution and separation of Silver occurs when point 'O' is reached.

At point 'O' no more Lead goes into solution as the solution becomes saturated with respect to Lead & hence the melting point of Silver do not fall.

Along the Curve OA two phases, Solid Silver and Liquid (melt) are in equilibrium. So, P = 2
No. of Component (C) = 2
By Reduced Phase Rule   F   = C + 1 –P
                                        = 2 + 1 – 2 = 1
Hence the system is univariant.

Curve OB (Solid Lead $\longleftrightarrow$ Molten Liquid)

This is called the freezing point curve of Lead to which successive quantities of Silver are added.

Point 'B' indicate the melting point of Pure Lead (327°C). Melting point of Lead is lowered gradually by the addition of Silver to it.

Along the curve OB added Silver goes into solution and separation of Lead occurs when point 'O' is reached.

At point 'O' no more Silver goes into solution as the solution becomes saturated with respect to Silver & hence the melting point of Lead do not fall.

Along the Curve OB two phases, Solid Lead and Liquid (melt) are in equilibrium. So, P = 2
No. of Component (C) = 2
By Reduced Phase Rule   F   = C + 1 –P
                                        = 2 + 1 – 2 = 1
Hence the system is univariant.

Study of Area:

Area AOD and BOE

Each area has two phases, Solid Silver + Liquid in area AOD and Solid Lead + Liquid in area BOE.
Number of Phases = 2
Number of Component = 2
Degree of Freedom = C + 1 –P = 2 + 1 – 2   = 1

Hence the system is univariant.

Area above AOB (Liquid Phase)

In this area only liquid phase is present as the temperature is above the melting point of any mixture i.e. P = 1

Number of Phases = 1
Number of Component = 2
Degree of Freedom = C + 1 –P = 2 + 1 – 1   = 2

Hence the system is bivariant.

Area below DOE (Pure Silver & Pure Lead)

In this area only solid phase is present i.e. Pure Silver and Pure Lead. So, No. of Phases (P) = 2

Number of Phases = 2
Number of Component = 2
Degree of Freedom = C + 1 –P = 2 + 1 – 2   = 1

Hence the system is univariant.

Study of Point 'O' [Eutectic Point]:

At point 'O' the curve OA and OB meets

At point 'O' all the three phases i.e. Solid Silver, Solid Lead and Fuses mass (Molten Liquid mixture) co-exist.

Number of Phases = 3
Number of Component = 2
Degree of Freedom = C + 1 –P = 2 + 1 – 3   = 0

Hence the system is invariant.

Desilverisation of Lead (Pattinson's Process)

Knowledge of Phase diagram of Lead & Silver is useful to understand the process of desilverisation of Lead and enrichment of silver in argentiferrous Lead.

In the phase diagram of Pb-Ag the curve OB represent the decrease of m.p. of Pb with different amount of Ag.

Lowering of temperature of molten liquid result in the change in the composition of the two components till constant composition (Eutectic Point "O").

If the molten liquid of argentiferrous lead is cooled gradually the solid lead will separate out. The crystalize lead is removed by wooden ladles.

Alloys

An **alloy** is a mixture of a metal with at least one other element.

Adding other elements to a metal changes its structure and also changes its properties.

The final alloy may have very different properties to the original metal.

By changing the amount of each element in an alloy, we can custom-make alloys to fit a given job.
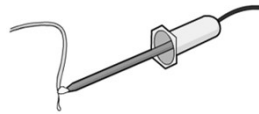
Steel: Steel is a common example of an alloy. It contains iron mixed with carbon, nickle, chromium and other elements.

Brass: An alloy of copper and zinc. It does not tarnish and is used for doors, knobs, buttons and musical instruments.

Solder: An alloy of zinc and lead. It is used in electronics to attach components to circuit boards.

Amalgam: An alloy of mercury and silver or tin. It is used in filling dental fillings because it can be shaped when warm and resist corrosion.
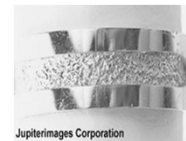
Gold: Pure gold is soft, adding small amount of other metals makes the gold hard enough to use in jewellery.
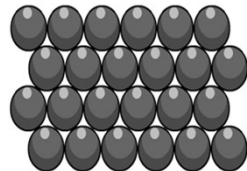Alloying of gold with different metals affects it colour
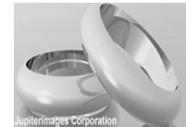
Yellow gold is an alloy of gold with copper.
White gold is an alloy of gold with nickle, platinium or palladium

The atoms in pure iron are arranged in densely-packed layers. These layers can slide over each other. This makes pure iron a very soft material.

The atoms of other elements are of different sizes. When other elements are added to iron, their atoms distort the regular structure of the iron atoms.

It is more difficult for the layers of iron atoms in steel to slide over each other and so this alloy is stronger than pure iron.

Classification of Alloy based on number of components

Binary Alloy	Ternary Alloy	Quaternary Alloy

Types of Alloys

Substitution Alloys: The atom of parent metal are replaced with the atoms of other element having roughly same size. For e.g. Bronze, Brass.

Interstitial Alloys: The atom of parent metal are replaced with the atoms of other element having different size. For e.g. Steel.

Combined Alloys: Alloys that combine the mode of formation substitution alloy and interstitial alloy. For e.g. Stainless Steel.

Properties of Alloys

Pure metals may posses useful properties like **good electrical conductivity, high tensile strength, hardness, malleable, sharp melting point, heat resistance and corrosion resistance.**

Alloys properties are different from those of its component elements.

Metal Alloys combine these beneficial properties in order to create a metal that is more useful for a particular application.

Significance of Alloying

Pure metals possess few important physical and metallic properties, such as melting point, boiling point, density, specific gravity, high malleability, ductility, and heat and electrical conductivity. These properties can be modified and enhanced by alloying it with some other metal or nonmetal, according to the need.

Alloy are made to:

Enhance the hardness of a metal: An alloy is harder than its components. Pure metals are generally soft. The hardness of a metal can be enhanced by alloying it with another metal or nonmetal.

Lower the melting point: Pure metals have a high melting point. The melting point lowers when pure metals are alloyed with other metals or nonmetals. This makes the metals easily fusible. This property is utilized to make useful alloys called solders.

Enhance tensile strength: Alloy formation increases the tensile strength of the parent metal.

Enhance corrosion resistance: Alloys are more resistant to corrosion than pure metals. Metals in pure form are chemically reactive and can be easily corroded by the surrounding atmospheric gases and moisture. Alloying a metal increases the inertness of the metal, which, in turn, increases corrosion resistance.

Modify color: The color of pure metal can be modified by alloying it with other metals or nonmetals containing suitable color pigments.

Provide better castability: One of the most essential requirements of getting good castings is the expansion of the metal on solidification. Pure molten metals undergo contraction on solidification. Metals need to be alloyed to obtain good castings because alloys expand.

Ferrous Alloys

Ferrous alloys are iron based alloys that has extensive use in wide range of industries because of its flexibility to meet strength, toughness, and impact of diverse industrial applications.

For Example: Carbon steels, Alloy steels, Stainless steels, Tool steels, Cast iron, Cast steel, Maraging steel.

Types of Ferrous Alloys

➢ Carbon steels are ferrous alloys that contain carbon and small levels of other alloying elements, such as manganese or aluminum.

➢ Alloy steels contain low to high levels of elements such as chromium, molybdenum, vanadium and nickel.

➢ Stainless steels are highly corrosion resistant, ferrous alloys that contain chromium and/or nickel additions.

➢ Cast iron, a ferrous alloy, contains high amounts of carbon. Ductile iron, gray iron and white cast iron grades are types of cast iron.

➢ Cast steel alloy grades are made by pouring molten iron into a mold.

Nichrome

Nichrome (NiCr, nickel-chrome, chrome-nickel, etc.) are alloys of nickel, chromium, and often iron (and possibly other elements or substances).

Nichrome, a non-magnetic alloy that is commonly made up of 80% nickel and 20% chromium, has very high boiling point (~1400 °C) and high corrosion resistance.

The properties of nichrome vary depending on its alloy. Any variations are due to different percentages of nickel or chromium.

Properties of Nichrome

Property	Value
Modulus of Elasticity	2.2×10^{11} Pa
Density	8400 kg·m^{-3}
Melting Point	1400°C
Electrical Resistivity at Room Temperature	$(1.0—1.5) \times 10^{-6}$ Ω·m
Specific Heat	450 J·kg^{-1}·K^{-1}
Thermal conductivity	11.3 W·m^{-1}·K^{-1}
Thermal Expansion	14×10^{-6} K^{-1}

Uses of Nichrome

❖ Any conductive wire can be used for heating, but most metals conduct electricity with great efficiency, requiring them to be formed into very thin/ delicate wires in order to create enough resistance to generate heat. Once heated, most metals then oxidize quickly, become brittle, and break when heated in air.

❖ When heated to red hot temperatures, nichrome wire, however, develops an outer layer of chromium oxide, thermodynamically stable in air, mostly impervious to oxygen, and protects the heating element from further oxidation.

❖ Nichrome is used in the explosives and fireworks industry as a bridgewire in electric ignition systems, such as electric matches and model rocket igniters. Industrial and hobby hot wire foam cutters (a tool used to cut polystyrene foam) use nichrome wire.

❖Nichrome wire is commonly used in ceramics as an internal support structure to help some elements of claysculptures hold their shape while they are still soft. Nichrome wire is used for its ability to withstand the high temperatures that occur when clay work is fired in a.

❖Nichrome wire can be used as an alternative to platinum wire for flame testing by colouring the non-luminous part of a flame to detect cations such as sodium, potassium, copper, calcium etc.

❖Nickle based superalloys are Ni base, Ni-Fe base, Ni-Co base having high concentration of Cr with Ti and Al in addition to Mo, Co, B, Fe.

Stainless Steel

Steel is an iron based alloy that contains carbon less than 1.2%.

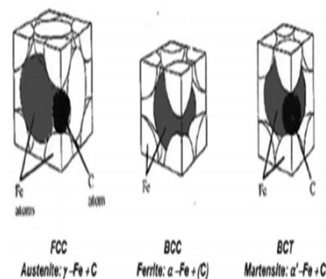When Chromium is added to steel the alloy is called Stainless Steel (12% - 30%).

Classification of Stainless Steel

Based on lattice arrangements

Ferritic (bcc)- Below 910°C is stable
Austenitic (fcc)- From 910°C to 1390°C is stable
Martenistic (bct)- Above 1390°C is stable.

FCC   BCC   BCT
Austenite: γ -Fe +C   Ferrite: α -Fe +(C)   Martensite: α'-Fe +C
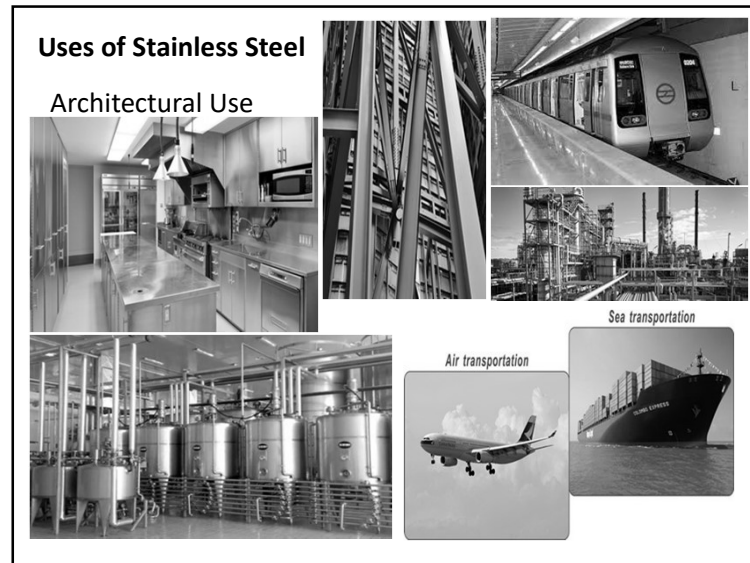
Based on Carbon content

Properties of Stainless Steel

High Oxidation Resistance.

Acid and Alkali Resistant

Poor Conductor of Electricity

High Toughness and ductility

Uses of Stainless Steel

Architectural Use

Air transportation

Sea transportation

Thank You