1.

A. Phase Rule: The phase rule, first announced by J. Willard Gibbs in 1876 relates the physical state of a mixture to the number of constituents in the system and to it conditions. It was also Gibbs who first called each homogeneous region in a system by the term "phase." When pressure and temperature are the state variables the rule can be written as follows:

$$F=C-P+2$$

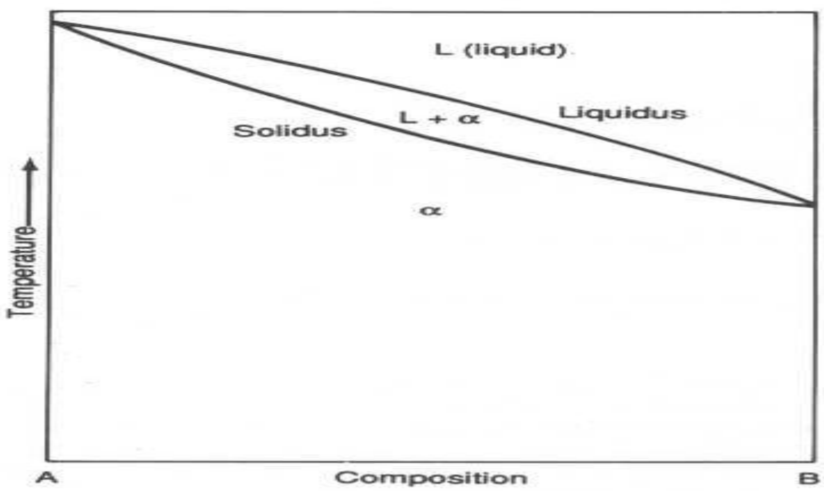
Where f is the number of independent variables (called degrees of freedom) c is the number of components, and p is the number of stable phases in the system.

Binary Diagram

If the system being considered compares two components, a composition axis must be added to the PT plot, requiring construction of a three dimensional graph. Most metallurgical problems, however, are concerned only with a fixed pressure of one atmosphere, and the graph reduces to a two-dimensional plot of temperature and composition (TX diagram).

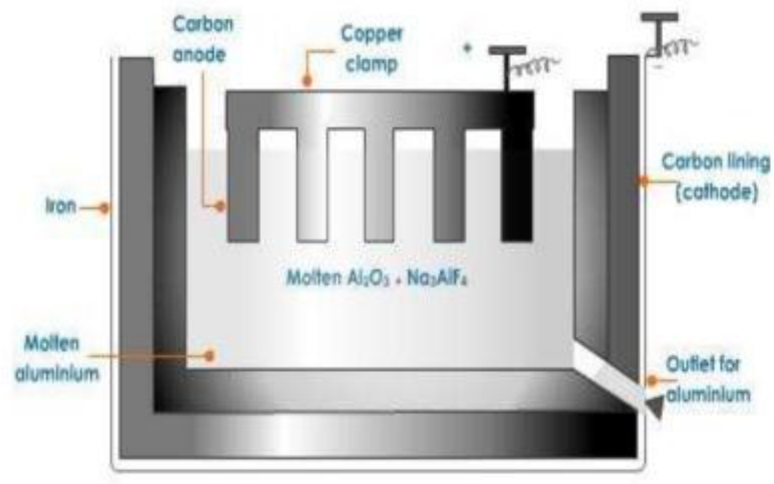
Number of components	Number of phases	Degrees of freedom	Equilibrium
2	3	0	Invariant
2	2	1	Univariant
2	1	2	Bivariant

Miscible Solids: Many systems are comprised of components having the same crystal structure, and the components of some of these system are completely miscible (completely soluble in each other) in the solid form, thus forming a *continuous solid solution.* When this occurs in a binary system, the phase diagram usually has the general appearance of that known in Fig. 3. The diagram consists of two single-phase fields separated by a two-phase field. The boundary between the liquid field and the two-phase field in Fig. 3 is called the liquids*;* that between the two-phase field and the solid field is the solidus.



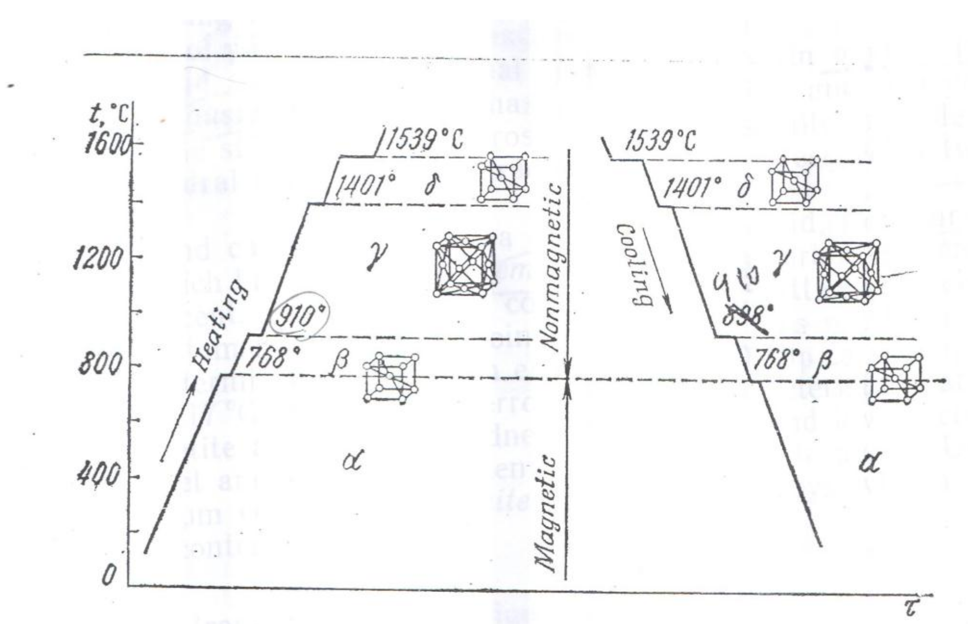
B. Aluminium can be obtained by electrolysis of pure alumina but it offers two problems. (i) Pure alumina is a poor conductor of electricity and melts at about 2000^{o}C. (ii) When fused alumina is electrolyzed at 2000^{o}C, the metal formed vapourises as its boiling point is 1800^{o}C. Aluminium is usually prepared by **Hall- Heroult** process. Alumina is fused with cryolite Na_3AlF_6. Alumina dissolves in cryolite. Cryolite lowers the temperature of the mixture. Small amount of CaF2 and AlF3 are also added to lower the temperature of the mixture. Pure alumina melts at 2000^{o} C while the mixture melts at about 9500C The charge consists of cryolite (85 %), CaF_2 (5 %), AlF_3 (5 %) and Al_2O_3 (5 %) .The electrolysis is carried out at temperature of 9500C and with a voltage of 5.5 volts in a graphite lined steel tank which acts as a cathode. The anodes are made of graphite. The Al2O3 is added from feeder at the top. Some coke is thrown on the surface of charge to control the oxidation of the metal. The electrode reactions are complicated and their exact nature is not known . The simplified mechanism of electrode reactions is given below.

C.



$Na_3AlF_3 \rightarrow 3\ NaF + AlF_3$; $4\ AlF_3 \rightarrow 4Al^{3+} + 12\ F^-$
At anode $\rightarrow 2\ Al_2O_3 + 12\ F^- \rightarrow 4\ AlF_3 + 3\ O_2 + 12\ e-$; $4C + 3O_2 \rightarrow 2\ CO_2 + 2\ CO$
At cathode $\rightarrow 4\ Al^{3+} + 12\ e- \rightarrow 4\ Al$

D. the heating and cooling curves of iron



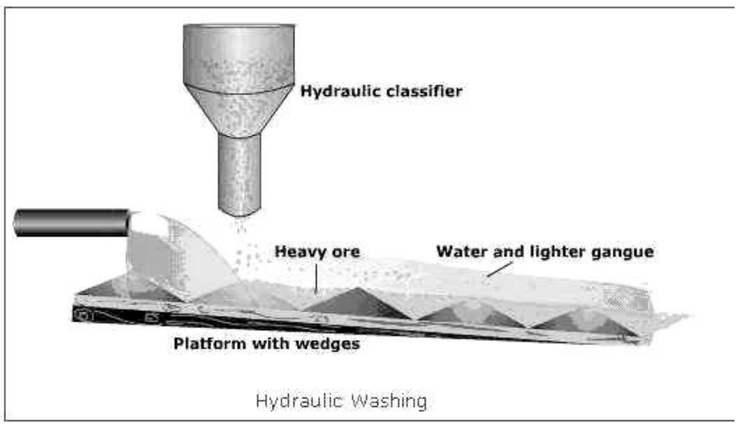
2.

A. physical methods which used in concentration of ore:

(1) Hydraulic washing (Gravity separation): In this process, the ore particles are poured over a hydraulic classifier which is a vibrating inclined table with grooves and a jet of water is allowed to flow over it. The denser ore settles in the grooves while the lighter gangue particles are washed away. This method is used for concentration of heavy oxide ores of lead, tin, iron etc. The hydraulic washing method is shown in the

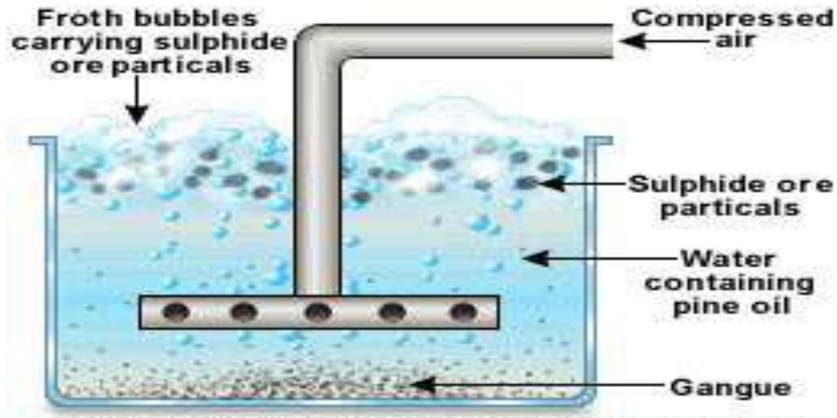
Fig.1 - Hydraulic washing

following figure.



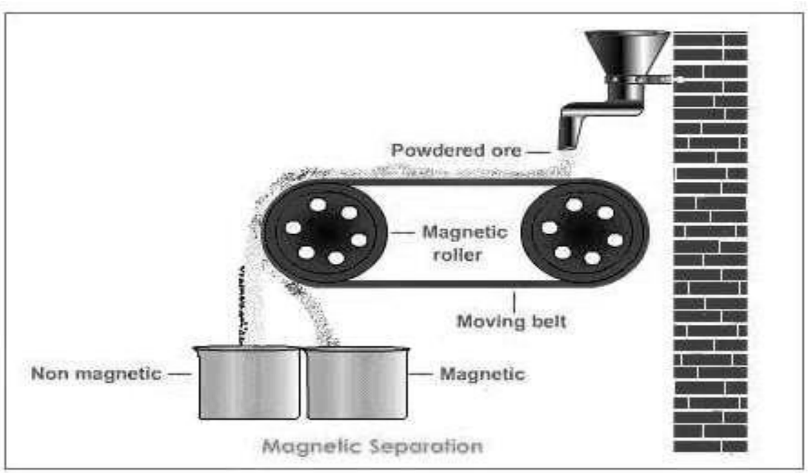
(2) **Froth floatation -** This method is especially used for sulphide ores. The method employs a mixture of water and pine oil which is made to agitate with the ore. A mixture of water, pine oil, detergent and powdered ore is first taken in a tank. A blast of compressed air is blown through the pipe of a rotating agitator to produce froth. The sulphide ore particles are wetted and coated by pine oil and rise up along with the froth (froth being lighter). The gangue particles wetted by water sink to the bottom of the tank (water being heavier). Sulphide being more electronegative attracts the covalent oil molecules. The gangue being less electronegative is attracted by the water. The froth containing the sulphide ore is transferred to another container, washed and dried. Thus sulphide ore is separated from the gangue. The froth floatation

process is shown in the following figure.



Froth floatation process for the concentration of sulphide ores.

(3) **Magnetic separation** - Magnetic ores like pyrolusite (MnO_2) and chromite ($FeO.Cr_2O_3$) are enriched by this method by making use of the difference in the magnetic properties of the ore and gangue particles. The powdered ore is dropped on to leather or brass conveyer belt, which moves over two rollers one of which is magnetic. When the ore passes over the magnetic roller, it sticks to the belt due to the force of attraction and falls nearer to magnetic roller. The gangue falls in a normal way under the influence of gravity. The magnetic ore and gangue thus form two separate heaps. Following figure shows the magnetic separation method.



1. Leaching - It means washing. In this process, the ore is washed with some suitable

reagent (solvent) so that the main metal passes into its salt solution. This solution is separated and subjected to further treatment like precipitation. It is then treated further to recover the metal. This is a chemical method of concentration.

B. the applications of aluminium in industry:

(i)Aluminium is used in making body of air-ships and motor cars.

(ii) it is used for making electrical transmission cables.

(iii) it is used in making cooking utensils.

(iv) it is used in aluminium paints.

(v) Aluminium foils are used in wrapping cigaretts, confectionary items etc.

(vi) Aluminium is used as a deoxidizer and for removing blow holes in metallurgy. (vii) It is used in thermite welding and in the aluminothermic process.

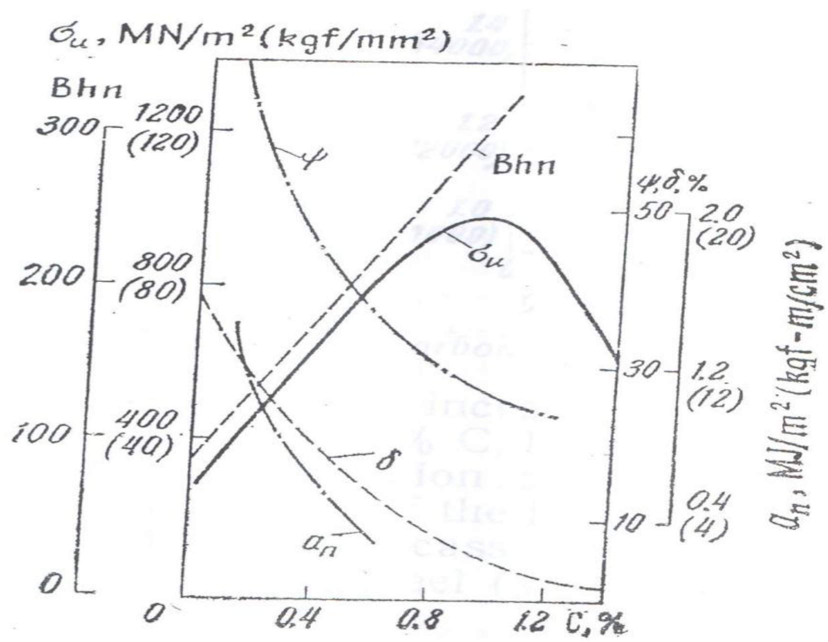
(viii) Salts of aluminium such as alum are used as mordants in dyeing industries.

3. Phase Diagram: In order to record and visualize the results of studying the effects of state variables on a system, diagrams were devised to show the relationships between the various phases that appear within the system under equilibrium conditions. As such, the diagrams are variously called constitutional diagrams, equilibrium diagrams, or phase diagrams. alloy phase diagrams are useful to metallurgists, materials engineers, and materials scientists in four major areas: (1) development of new alloys for specific application, (2) fabrication of these alloys into useful configurations, (3) design and control of heat treatment procedures for specific alloy that will produce the required mechanical, physical, and chemical properties, and (4) solving problem that arise with specific alloys in their performance in commercial applications, thus improving product predictability. In all these areas, the use of phase diagrams allows research, development, and production to be done more efficiently and cost effectively.

Q3:

A. the effect of carbon on the properties of steel

Carbon - is generally considered to be the most important alloying element in steel and can be present up to 2% (although most welded steels have less than 0.5%). Increased amounts of carbon increase hardness and tensile strength, as well as response to heat treatment (hardenability). Increased amounts of carbon will reduce weld ability. Decreases the ductility of steel, Increases the tensile strength of steel, Increases the hardness of steel, Decreases the ease with which steel can be machined, Lowers the melting point of steel, Makes steel easier to harden with heat treatments, Lowers the temperature required to heat treat steel, Increases the difficulty of welding steel. Steel with 0.2% Carbon can attain Rockwell C hardness of 49, while an 0.8% carbon steel can be hardened to Rockwell C of 65.As carbon is added, steel gets harder and becomes difficult to machine, Melting point of 0.2% carbon steel is 2800°F while 0.8% carbon steel can melt near 2,700°F. Steel are classified according to their carbon content. Carbon will dissolve into iron without producing steel at 0.026% at 1330°F. Low carbon steel or mild steel contain less than 0.3% carbon. Medium carbon steels contain carbon from 0.3 -0.55%. High carbon steel contains more than 0.5% carbon. Iron with more than 2% carbon is referred to as Cast Iron. Steels for springs must have at least 0.45 % carbon to attain required hardness.



B. Ores can be divided into four general groups as follows:

(i) Native ores - These ores contain metals in the Free State. e.g. Ag, Au, Pt, Hg, Cu etc. These are usually found associated with rock or alluvilial materials like clay, sand etc. Sometimes, lumps of pure metals are also found in them. These are termed nuggets. Iron is found in Free State as meteorites which also have 20 to 30 nickel.

(ii) Sulphurised and arsenical ores - These ores consist of sulphides and arsenides in simple and complex forms of metals. Some examples of this group are PbS, ZnS, Ag_2S, NiAs, $CuFeS_2$, $3Ag_2S$. Sb_2S_3 etc. (iii) Oxide ores - In these ores, metals are present as their oxides or oxysalts such as carbonates, nitrates, sulphates, phosphates, silicates etc. The examples include Fe_2O_3, Al_2O_3, $BeO.Al_2O_3$, MnO_2, $CaCO_3$, $FeO.TiO_2$, $NaNO_3$, $BaSO_4$, Zn_2SiO_4, $Ca_3(PO_4)_2$ etc. (iv) Halide ores - Metallic halides are very few in nature. Chlorides are more common. The examples include common salt, NaCl, Carnallite, KCI, $MgCl_2$,$6H_2O$, Fluospar, CaF_2 , Horn silver, AgCl etc.

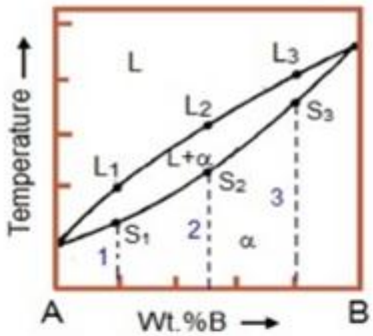
C. The names, composition and uses of three aluminium alloys

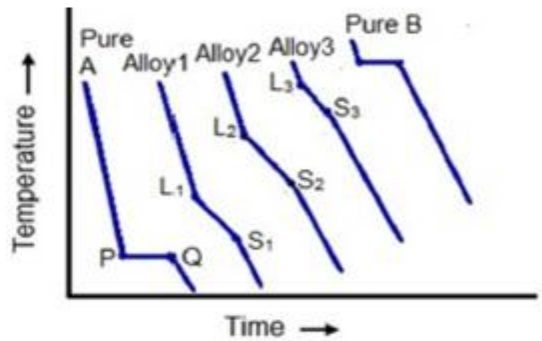
Alloys of aluminium

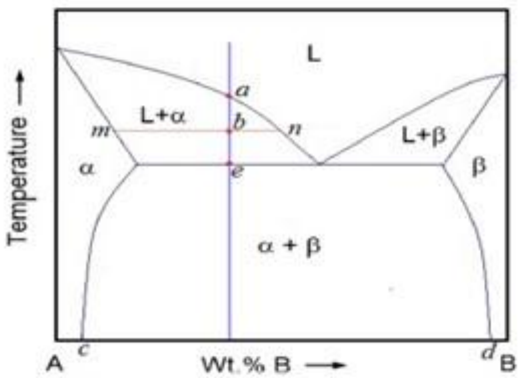
Alloy	Composition	Properties	Uses
1) Magnalium	98 % Al, 2 % Mg	Hard, tough, light, Can be excellently worked on lathe	For making balance beams, light instruments, articles
2) Duralium	95 % Al, 4 % Mn, 0.5 % Mg	Resistance to corrosion, highly ductile, light	For making airships, aeroplanes etc.
3) Aluminium Bronze	10 t0 12 % Al, 88 to 90 % Cu	Resistance to corrosion, readily fusible, strong	For making utensils, jewellery, decorative articles , coins
4) Nickeloy	95 % Al, 4% Cu, 1 % Ni	Extremely light, great mechanical strength	For making airships
5) Alnico	50% steel, 20%Al, 20% Ni, 10% Cu	-	For making permanent magnets

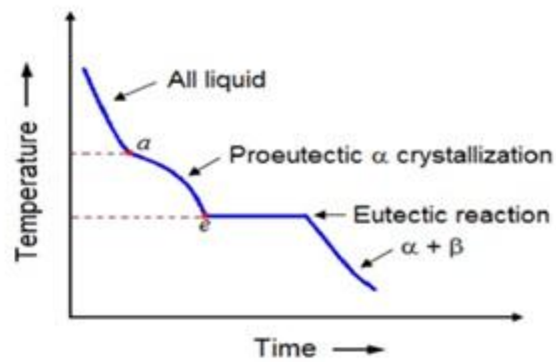
Q4:

A. Draw the cooling-time curve for binary phase diagram with and without eutectic point.

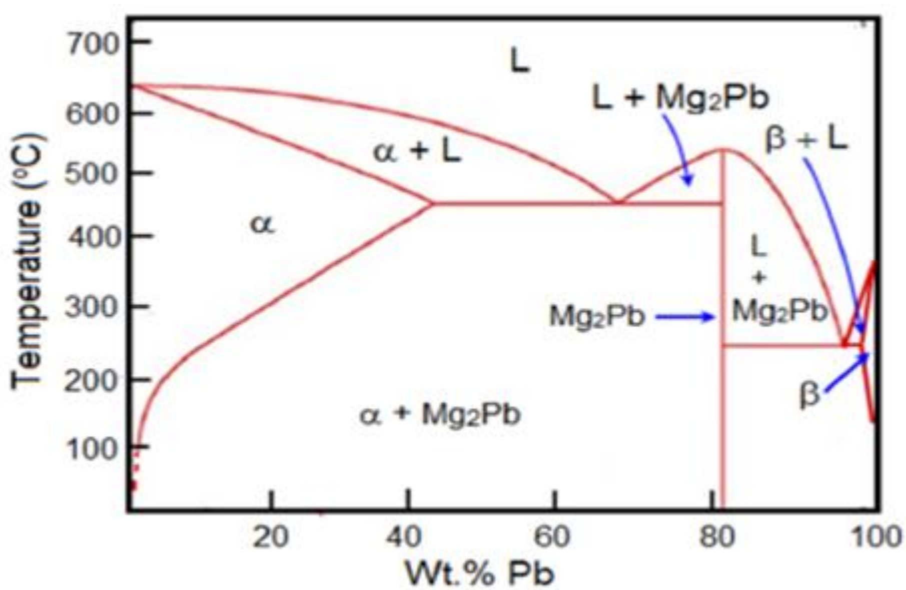




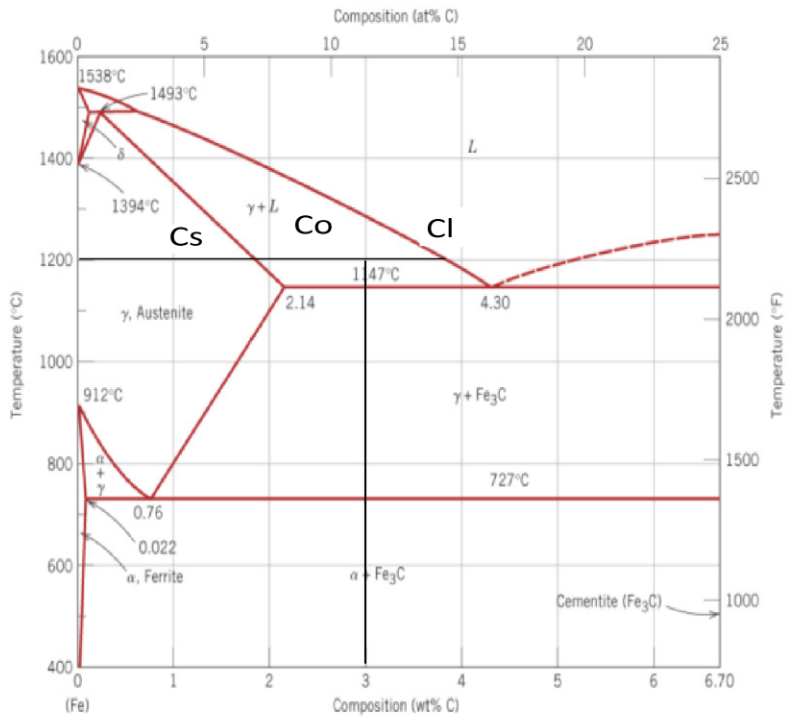


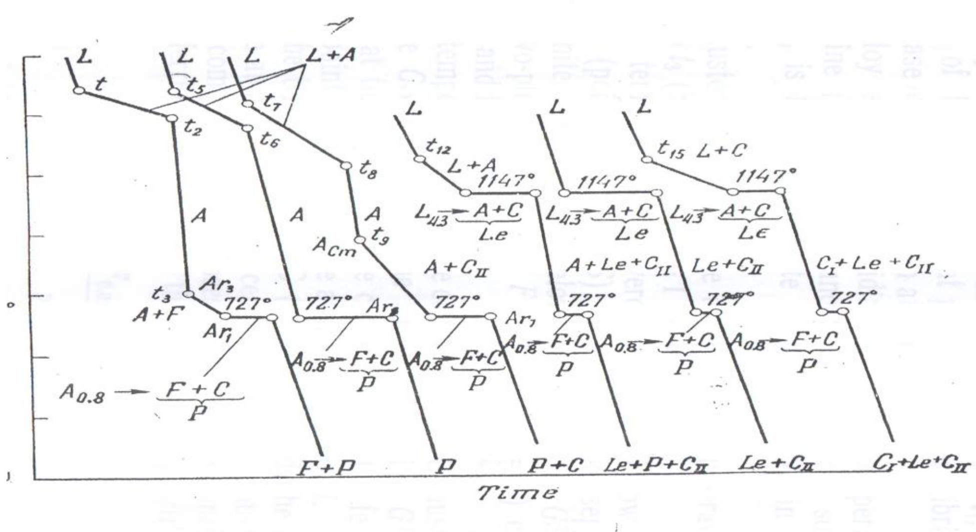


B. lead-magnesium (pb-Mg) phase diagram with show intermetallic compounds form between two metals



5. Sketch out the phase diagram of iron- carbon as binary system with 6.67% carbon and answer the following questions using iron- carbon diagram





$$f_s = \frac{MX}{XY} = \frac{C_o - C_l}{C_s - C_l} \qquad f_l = \frac{MY}{XY} = \frac{C_s - C_o}{C_s - C_l}$$

$F_S = 58\%$

$F_l = 42\%$