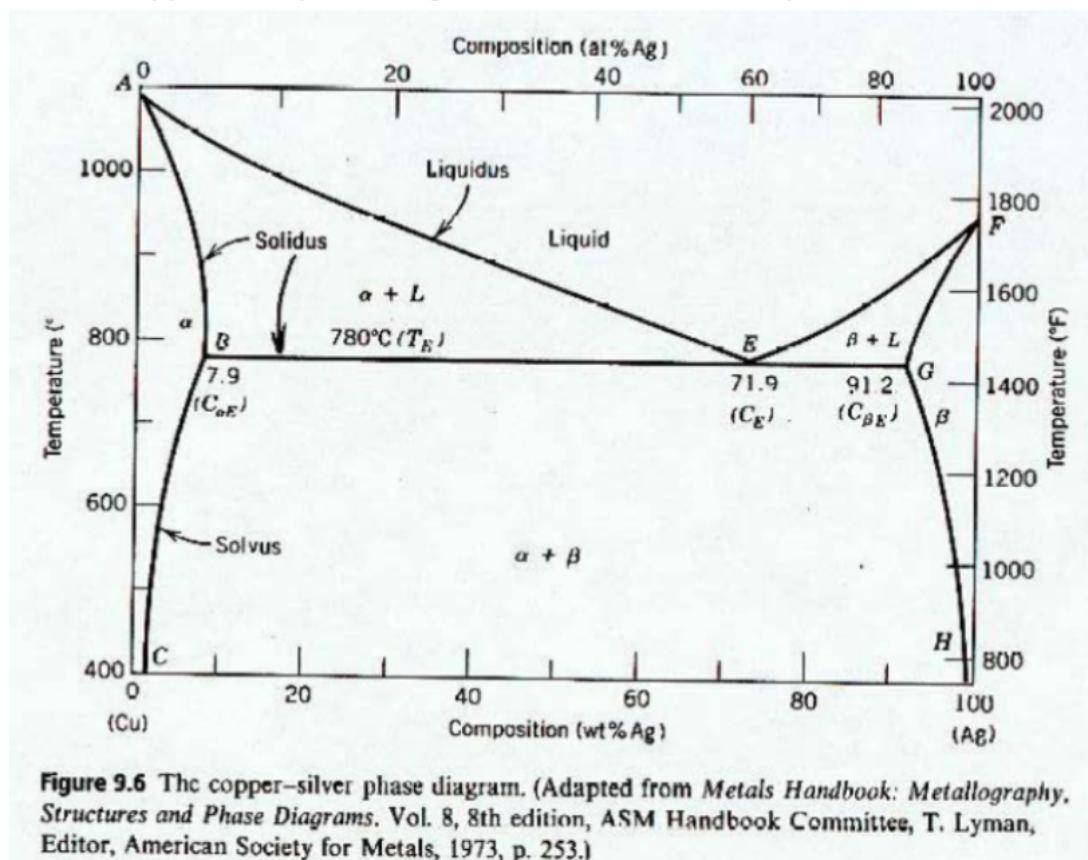


engineering / mechanical engineering / mechanical engineering questions and answers / use the copper-silver phase diagram below to answer the questions. composition (at %Ag) 0 20 40 60 80 100 2000 liquidus...

Question: Use The Copper-Silver Phase Diagram Below To An...

Use the copper-silver phase diagram below to answer the questions.



In an experiment, one selected two samples of copper-silver alloy. One sample has 40 wt% of silver and 60wt% of copper and the other has 71.9 wt% silver and 28.1wt% copper. He performed the following processes:

- 1). Heat the two materials to 1000°C, keep at the temperature for long enough time.
- 2). Drop the temperature to 850 °C and keep at this temperature for long enough time to reach to an equilibrium condition.
- 3). Quench the sampled by drop the temperature from 850 °C to 25 °C as quick as possible.

Please help him to determine:

What is the phase/s of sample one after process 1)?

- ☒ A. Liquid.

This problem has been solved!

You'll get a detailed solution from a subject matter expert that helps you learn core concepts.

See Answer

10.1 INTRODUCTION - CERAMICS

Ceramic materials are inorganic compounds of metallic and non-metallic elements, and their atoms are held together by ionic or covalent bond. These bonds are stronger than metallic bond, and accounts for their special characteristics. Ceramics are hard and brittle materials with high melting points. The distinguishing characteristics of ceramics are :

- Resistance to high temperature
- Low electrical and thermal conductivity
- Resistance to wear and corrosion
- Low ductility
- Poor conductors.

Applications of ceramics :

Ceramics are used in wide range of industrial applications. Clay based ceramics are used for sanitary work, floor tiles and other building materials. Engineering or advanced ceramics are used in electrical and electronics industries due to high electric resistivity, high dielectric strength and magnetic properties. Their capacity to retain strength at elevated temperature, make them suitable for the parts subjected to high temperature such as spark plugs. Because of their high resistance to wear, they are used for cylinder liners, bushings and bearings.

Fabrication limitations of ceramics :

- Due to brittleness, they cannot be plastically deformed to shape at room temperature.
- They can not be melted and cast into shape because of their high melting point.
- The machining of ceramic parts is costly.

Differences between ceramics and non-ceramic materials (metals and plastics) :

1. Metals are good conductors of heat and electricity whereas ceramics are generally poor conductors as plastics.
2. Metals and plastics are attacked by chemicals whereas ceramics are unaffected by most of the chemicals.
3. Ceramics can withstand high/much higher temperature than metals/plastics.
4. Metals and plastics can be easily deformed into desired shape, but it is not possible with ceramics.
5. Ceramics are harder than metals and plastics.

(Chapter-10)

As compared to metals (high ductile), ceramics are brittle i.e., possess low ductility. In metals dislocations move easily under low stresses due to non-directional nature of metallic bond, and also the dislocations are wide and Burgers vector is short in length. In contrast, ceramics lack ductility i.e., brittle due to their ionic and covalent bonds. Though ionic ceramic crystals are non-directional, yet it is difficult to move the dislocations because they are narrow and have a larger Burgers vector.

10.2 CLASSIFICATION OF CERAMIC MATERIALS

According to the characteristic features ceramic materials can be classified as :

1. Clay products (silicates)
 - Clays are mostly composed of silica and alumina ($\text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot \text{H}_2\text{O}$); used for bricks, clay pipes and building tiles.
2. Refractories
 - Special materials capable of withstanding high temperature; used for high temperature applications such as furnace walls, crucibles and moulds.
3. Glasses
 - Inorganic material that has been cooled to rigid conditions without crystallisation; used for bottles, lenses, window panes and light bulb.
4. Abrasives
 - Non metallic small hard particles capable of removing small amount of material from a surface; used as cutting tool materials.

Based on microstructure, ceramics may be crystalline, glassy (amorphous) or crystalline - glassy mix.

Based on applications, ceramics may be grouped under :

1. Traditional ceramics, and
2. Advanced or engineering ceramics.

Traditional ceramics are made from clay, silica and feldspar. They are used for building construction materials (bricks and tiles), whiteware products such as porcelain and sanitary ware.

Engineering ceramics are compounds of oxides, carbides or nitrides. Important engineering ceramics include alumina (Al_2O_3), Silica (SiO_2), silicon carbide (SiC) and Zirconia (ZrO_2).

Alumina (Al_2O_3) is used as a low dielectric constant substrate for electric packaging and houses silicon chips and for insulators in spark plugs. It is also used in dental and medical applications.

Silica (SiO_2) is an ingredient in glasses and many glass ceramics. In the form of long continuous fibers, it is used to make optical fibers for communications.

Silicon carbide (SiC) is used as a coating for metals to provide protection at high temperatures. It is also used as an abrasive in grinding wheels and as a reinforcement in both metal matrix and ceramic matrix composites.

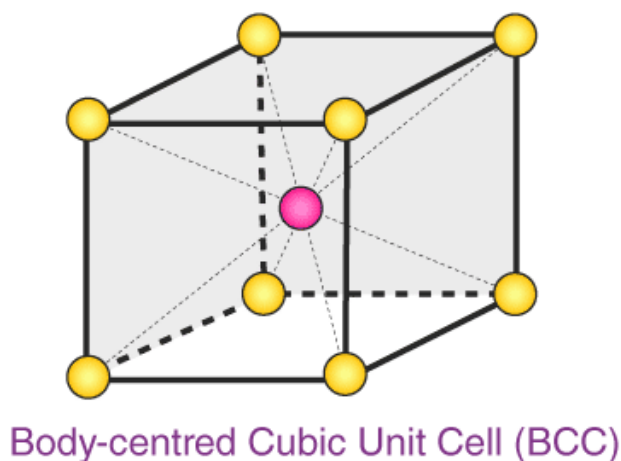
Zirconia (ZrO_2) is used to make oxygen gas sensors that are used to measure dissolved oxygen in molten steels. Zirconia is also used as refractory materials.

$$8 \times 1/8 = 1 \text{ atom.}$$

2. Body-centred Cubic Unit Cell (BCC)

A BCC unit cell has atoms at each corner of the cube and an atom at the centre of the structure. The diagram shown below is an open structure. According to this structure, the atom at the body centre wholly belongs to the unit cell in which it is present.

1. In BCC unit cell every corner has atoms.
2. There is one atom present at the centre of the structure
3. Below diagram is an open structure
4. According to this structure atom at the body centres wholly belongs to the unit cell in which it is present.



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Body centred Cubic (BCC) Unit Cell

Number of Atoms in BCC Cell:

Thus, in a BCC cell, we have:

- 8 corners \times $1/8$ per corner atom = $8 \times 1/8 = 1$ atom
- 1 body centre atom = $1 \times 1 = 1$ atom

Therefore, the total number of atoms present per unit cell = **2 atoms**.

Solved Example

Question:

Lithium metal crystallizes in a body centered cubic crystal. If the length of the side of the unit cell of lithium is 351pm, the atomic radius of the lithium will be

Solution:

In case of body centered cubic (BCC) crystal,

$$a\sqrt{3} = 4r$$

Hence, atomic radius of lithium

$$\begin{aligned} r &= \frac{a\sqrt{3}}{4} \\ &= \frac{351 \times 1.732}{4} \\ &= 151.98 \end{aligned}$$

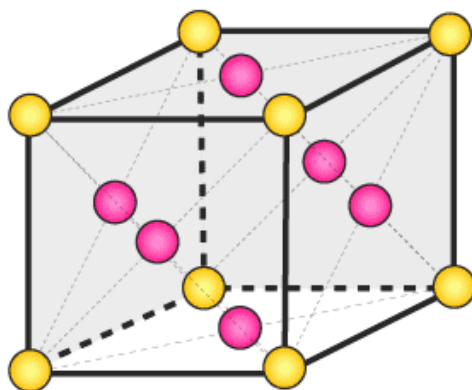
Hi there! Got any questions?
I can help you...

3. Face-centred Cubic Unit Cell (FCC)

An FCC unit cell contains atoms at all the corners of the crystal lattice and at the centre of all the faces of the cube. The atom present at the face-centered is shared between 2 adjacent unit cells and only 1/2 of each atom belongs to an individual cell.

1. In FCC unit cell atoms are present in all the corners of the crystal lattice
2. Also, there is an atom present at the centre of every face of the cube
3. This face-centre atom is shared between two adjacent unit cells
4. Only 12 of each atom belongs to a unit cell

The diagram shown below is an open structure.



Face-centred Cubic Unit Cell (FCC)

Number of Atoms in BCC Cell

- a) 8 corners \times 1/8 per corner atom = $8 \times 1/8 = 1$ atom
- b) 6 face-centered atoms \times 1/2 atom per unit cell = 3 atoms

Hence, the total number of atoms in a unit cell = 4 atoms

Thus, in a face-centred cubic unit cell, we have:

- 8 corners \times 1/8 per corner atom = $8 \times 1/8 = 1$ atom
- 6 face-centred atoms \times 1/2 atom per unit cell = 3 atoms

Therefore, the total number of atoms in a unit cell = **4 atoms**.

Volume of HCP Unit Cell

A unit cell is the smallest representation of an entire crystal. The hexagonal closest packed (HCP) has a coordination number of 12 and contains 6 atoms per unit cell. The face-centered cubic (FCC) has a coordination number of 12 and contains 4 atoms per unit cell.

Volume = area of base \times height

$$\text{Height of unit cell} = \sqrt{\frac{2}{3}}4r$$

$$\text{Area of base} = 6\sqrt{3} \times r^2$$

$$\text{Volume} = 6\sqrt{3} \times r^2 \times \sqrt{\frac{2}{3}}4r$$

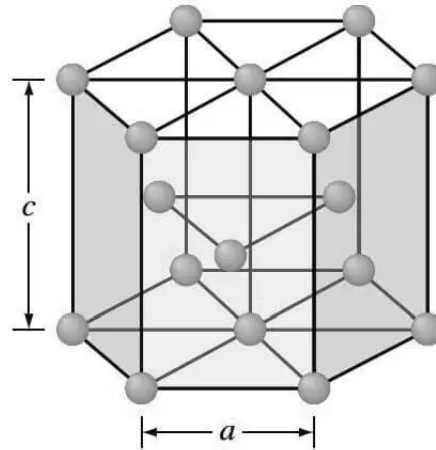
$$\text{Volume} = 24\sqrt{2}r^3$$

Hi there! Got any questions?
I can help you...

calculated from lattice constants by using the above equation, $K = \sqrt{2a/\pi}$.

3. Hexagonal Close-Packed (HCP) Crystal Structure

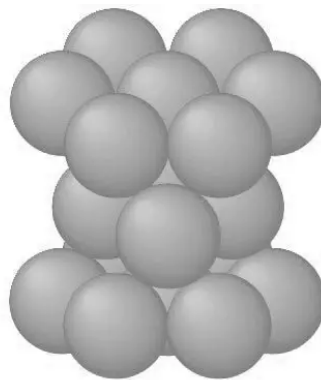
The third common metallic crystal structure is the hexagonal close-packed (HCP) structure shown below.



schematic of the HCP crystal structure

Metals do not crystallize into the simple hexagonal crystal structure because the APF is too low.

The atoms can attain lower energy and a more stable condition by forming the HCP structure as shown in the below figure.



HCP hard-sphere model

The APF of the HCP crystal structure is 0.74, the same as that for the FCC crystal structure since in both structures the atoms are packed as tightly as possible.

In both the HCP and FCC crystal structures, each atom is surrounded by 12 other atoms, and thus both structures have a coordination number of 12.

The isolated HCP unit cell, also called the primitive cell, is shown in the below figure.

Hume-Rothery rules, named after William Hume-Rothery, are a set of basic rules that describe the conditions under which an element could dissolve in a metal, forming a solid solution. There are two sets of rules; one refers to substitutional solid solutions, and the other refers to interstitial solid solutions.

Substitutional solid solution rules

For substitutional solid solutions, the Hume-Rothery rules are as follows:

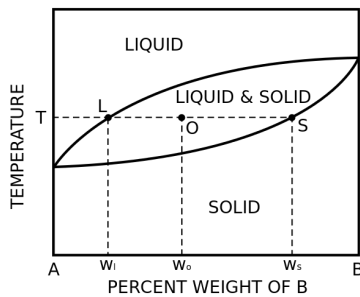
1. The atomic radius of the solute and solvent atoms must differ by no more than 15%:[1]

$$\% \text{ difference} = \left(\frac{r_{\text{solute}} - r_{\text{solvent}}}{r_{\text{solvent}}} \right) \times 100\% \leq 15\%.$$

2. The crystal structures of solute and solvent must be similar.
3. Complete solubility occurs when the solvent and solute have the same valency.^[2] A metal is more likely to dissolve a metal of higher valency, than vice versa. ^[3] ^[4] ^[5]
4. The solute and solvent should have similar electronegativity. If the electronegativity difference is too great, the metals tend to form intermetallic compounds instead of solid solutions.

This final fraction is the mass fraction of the α phase in the alloy.

Calculations



A phase diagram with tie line (LS) for a binary isomorphous system. The x dimension defines the mass fraction of elements A and B.

Binary phase diagrams

Before any calculations can be made, a *tie line* is drawn on the phase diagram to determine the mass fraction of each element; on the phase diagram to the right it is [line segment](#) LS. This tie line is drawn horizontally at the composition's temperature from one phase to another (here the liquid to the solid). The mass fraction of element B at the liquidus is given by w_B^l (represented as w_l in this diagram) and the mass fraction of element B at the solidus is given by w_B^s (represented as w_s in this diagram). The mass fraction of solid and liquid can then be calculated using the following lever rule equations:¹

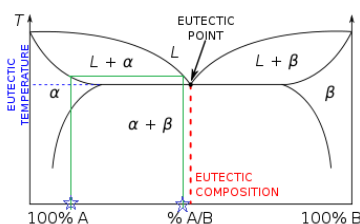
$$w^s = \frac{w_B - w_B^l}{w_B^s - w_B^l}$$

$$w^l = \frac{w_B^s - w_B}{w_B^s - w_B^l}$$

where w_B is the mass fraction of element B for the given composition (represented as w_o in this diagram).

The numerator of each equation is the original composition that we are interested in is +/- the **opposite lever arm**. That is if you want the mass fraction of solid then take the difference between the liquid composition and the original composition. And then the denominator is the overall length of the arm so the difference between the solid and liquid compositions. If you're having difficulty realising why this is so, try visualising the composition when w_o approaches w_l . Then the liquid concentration will start increasing.

Eutectic phase diagrams



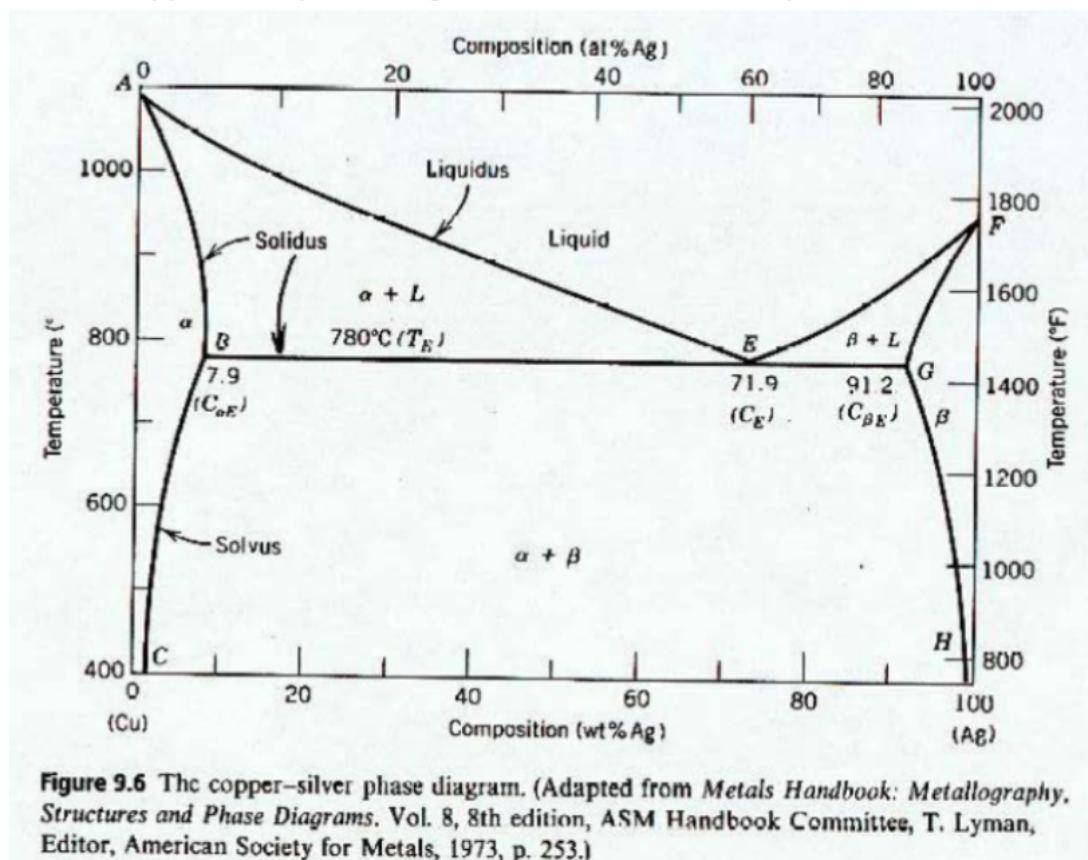
Tie line in the Alpha plus Liquid two phase region

There is now more than one two-phase region. The tie line drawn is from the solid alpha to the liquid and by dropping a vertical line down at these points the mass fraction of each phase is

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