A solid solution is formed when two metals are completely soluble in liquid state and also completely soluble in solid state. In other words, when homogeneous mixtures of two or more kinds of atoms (of metals) occur in the solid state, they are known as solid solutions. The more abundant atomic form is referred as solvent and the less abundant atomic form is referred as solute. For example, sterling silver (92.5 percent silver and the remainder copper) is a solid solution of silver and copper. In this case, silver atoms are solvent atoms whereas copper atoms are solute atoms. Another example is brass. Brass is a solid solution of copper (64 percent) and zinc (36 percent). In this case copper atoms are solvent atoms whereas zinc atoms are solute atoms.

5.1 TYPES OF SOLID SOLUTIONS

Solid solutions are of two types. They are
(a) Substitutional solid solutions.
(b)Interstitial solid solutions.

5.1.1 Substitutional Solid Solutions

If the atoms of the solvent or parent metal are replaced in the crystal lattice by atoms of the solute metal then the solid solution is known as substitutional solid solution. For example, copper atoms may substitute for nickel atoms without disturbing the F.C.C. structure of nickel (Fig. 5.1a). In the substitutional solid solutions, the substitution can be either disordered or ordered.

Figure 5.1b shows disordered substitutional solid solution. Here the solute atoms have substituted disorderly for the solvent atoms on their lattice site. Fig. 5.1c shows an ordered substitutional solid solution. Here the solute atoms have substituted in an orderly manner for the solvent atoms on their lattice site.

Hume Rothery rules for the formation of substitutional solid solutions

By studying a number of alloy systems, Hume Rothery formulated certain rules which govern the formation of substitutional solid solutions. These are:
Solid solutions

(a) Substitutional solid solution  (b) Disordered substitutional  (c) Ordered substitutional

**Fig. 5.1** Solid solutions

(a) **Crystal structure factor:** For complete solid solubility, the two elements should have the same type of crystal structure i.e., both elements should have either F.C.C. or B.C.C. or H.C.P. structure.

(b) **Relative size factor:** As the size (atomic radii) difference between two elements increases, the solid solubility becomes more restricted. For extensive solid solubility the difference in atomic radii of two elements should be less than about 15 percent. If the relative size factor is more than 15 percent, solid solubility is limited. For example, both silver and lead have F.C.C. structure and the relative size factor is about 20 percent. Therefore the solubility of lead in solid silver is about 1.5 percent and the solubility of silver in solid lead is about 0.1 percent. Copper and nickel are completely soluble in each other in all proportions. They have the same type of crystal structure (F.C.C.) and differ in atomic radii by about 2 percent.

(c) **Chemical affinity factor:** Solid solubility is favoured when the two metals have lesser chemical affinity. If the chemical affinity of the two metals is greater then greater is the tendency towards compound formation. Generally, if the two metals are separated in the periodic table widely then they possess greater chemical affinity and are very likely to form some type of compound instead of solid solution.

(d) **Relative valence factor:** It is found that a metal of lower valence tends to dissolve more of a metal of higher valence than vice versa. For example in aluminium-nickel alloy system, nickel (lower valence) dissolves 5 percent aluminium but aluminium (higher valence) dissolves only 0.04 percent nickel.

### 5.1.2 Interstitial Solid Solutions

In interstitial solid solutions, the solute atom does not displace a solvent atom, but rather it enters one of the holes or interstices between the solvent atoms. An excellent example is iron-carbon system which is shown in Fig. 5.2
In this system the carbon (solute atom) atom occupies an interstitial position between iron (solvent atom) atoms. Normally, atoms which have atomic radii less than one angstrom are likely to form interstitial solid solutions. Examples are atoms of carbon (0.77 Å), nitrogen (0.71 Å), hydrogen (0.46 Å), Oxygen (0.60 Å) etc.

5.2 INTERMETALLIC COMPOUNDS

Intermetallic compounds are generally formed when one metal (for example magnesium) has chemical properties which are strongly metallic and the other metal (for example antimony, tin or bismuth) has chemical properties which are only weakly metallic. Examples of intermetallic compounds are Mg$_2$Sn, Mg$_2$Pb, Mg$_3$Sb$_2$ and Mg$_3$Bi$_2$. These intermetallic compounds have higher melting point than either of the parent metal. This higher melting point indicates the high strength of the chemical bond in intermetallic compounds.

QUESTIONS

1. Define solid solution and explain the types of solid solutions.
2. Distinguish between substitutional solid solutions and interstitial solid solutions.
3. Explain Hume-Rothary rules for the formation of substitutional solid solutions.
4. Distinguish between interstitial solid solutions and intermetallic compounds.
5. What are the factors that effect the formation of substitutional solid solutions.