# ENGG*2120 Materials Science
# Assignments: Chapter 4 Answers

1. Define the three types of imperfections in solids?
Ans:

Three types of imperfection in solids are:-
1. Point Defects
2. Planer Defects
3. Interfacial Defects

2. Define the followings:
a) Vacancy b) self interstitial and c) solid solution

Ans:

**Vacancy:**
The simplest of the point defects is a vacancy, or vacant lattice site, one normally occupied from which an atom is missing

**Self interstitial:**
A self-interstitial is an atom from the crystal that is crowded into an interstitial site, a small void space that under ordinary circumstances is not occupied.

**Solid solution:**
The addition of impurity atoms to a metal will result in the formation of a solid solution and/or a new *second phase,* depending on the kinds of impurity, their concentrations, and the temperature of the alloy.

3. Write the conditions for the solid solution of two materials?
Ans:

1. **Atomic size factor:** Appreciable quantities of a solute may be accommodated in this type of solid solution only when the difference in atomic radii between the two atom types is less than about ±15%. Otherwise the solute atoms will create substantial lattice distortions and a new phase will form.

2. **Crystal structure:** For appreciable solid solubility the crystal structures for metals of both atom types must be the same.

3. **Electro-negativity:** The more electropositive one element and the more electronegative the other, the greater is the likelihood that they will form an intermetallic compound instead of a substitutional solid solution.

4. **Valences**: Other factors being equal, a metal will have more of a tendency to dissolve another metal of higher valency than one of a lower valency.

4. Calculate the fraction of atom sites that are vacant for lead at its melting temperature of 327°C (600 K). Assume an energy for vacancy formation of 0.55 eV/atom

Ans:

In order to compute the fraction of atom sites that are vacant in lead at 600 K, we must employ equation following equation:-

$$\frac{N_v}{N} = \exp\left(-\frac{Q_v}{kT}\right)$$

Substituting in above equation, $Q_V$ = 0.55 eV/atom. Thus,

$$\frac{N_v}{N} = \exp\left(-\frac{Q_v}{kT}\right) = \exp\left[-\frac{0.55\, eV/atom}{(8.62\times 10^{-5}\, eV/atom\text{-}K)(600\, K)}\right]$$

$$= 2.41 \times 10^{-5}$$

5. Calculate the activation energy for vacancy formation in aluminum, given that the equilibrium number of vacancies at 500°C (773 K) is $7.57 \times 10^{23}$ $m^{-3}$. The atomic weight and density (at 500°C) for aluminum are, respectively, 26.98 g/mol and 2.62 $g/cm^3$

Ans:

Upon examination of Equation $\frac{N_v}{N} = \exp\left(-\frac{Q_v}{kT}\right)$ all parameters besides $Q_V$ are given except $N$, the total number of atomic sites.

However, $N$ is related to the density, ($\rho_{Al}$), Avogadro's number ($N_A$), and the atomic weight ($A_{Al}$) according to Equation

$$N = \frac{N_A \rho_{Al}}{A_{Al}}$$

$$= \frac{(6.022 \times 10^{23} \text{ atoms/mol})(2.62 \text{ g/cm}^3)}{26.98 \text{ g/mol}}$$

$$= 5.85 \times 10^{22} \text{ atoms/cm}^3 = 5.85 \times 10^{28} \text{ atoms/m}^3$$

Now, taking natural logarithms of both sides of Equation

$$\frac{N_v}{N} = \exp\left(-\frac{Q_v}{kT}\right)$$

$$\ln N_v = \ln N - \frac{Q_v}{kT}$$

and, after some algebraic manipulation

$$Q_v = -kT \ln\left(\frac{N_v}{N}\right)$$

$$= -\left(8.62 \times 10^{-5} \text{ eV/atom-K}\right)(500°\text{C} + 273 \text{ K}) \ln\left[\frac{7.57 \times 10^{23} \text{ m}^{-3}}{5.85 \times 10^{28} \text{ m}^{-3}}\right]$$

$$= 0.75 \text{ eV/atom}$$

6. Calculate the composition, in weight percent, of an alloy that contains 218.0 kg titanium, 14.6 kg of aluminum, and 9.7 kg of vanadium.

Ans:

The concentration, in weight percent, of an element in an alloy may be computed using a modified form of Equation

$$C_1 = \frac{m_1}{m_1 + m_2 + m_3} \times 100$$

For this alloy, the concentration of titanium ($C_{Ti}$) is just

$$C_{Ti} = \frac{m_{Ti}}{m_{Ti} + m_{Al} + m_V} \times 100$$

$$= \frac{218 \text{ kg}}{218 \text{ kg} + 14.6 \text{ kg} + 9.7 \text{ kg}} \times 100 = 89.97 \text{ wt\%}$$

Similarly, for aluminum

$$C_{Al} = \frac{14.6 \text{ kg}}{218 \text{ kg} + 14.6 \text{ kg} + 9.7 \text{ kg}} \times 100 = 6.03 \text{ wt\%}$$

And for vanadium

$$C_V = \frac{9.7 \text{ kg}}{218 \text{ kg} + 14.6 \text{ kg} + 9.7 \text{ kg}} \times 100 = 4.00 \text{ wt\%}$$

7. Two metal specimens, A and B, have ASTM grain size numbers of 3 and 8, respectively. Which specimen has the larger grain size?

A. Grain size A <Grain size B

B. Grain size A >Grain size B

Ans: B

8. The surface energy of a single crystal depends on crystallographic orientation. Does this surface energy increase or decrease with an increase in planar density? Why?
Ans:

The surface energy of a single crystal depends on the planar density (i.e., degree of atomic packing) of the exposed surface plane because of the number of unsatisfied bonds. As the planar density increases, the number of nearest atoms in the plane increases, which results in an increase in the number of satisfied atomic bonds in the plane, and a decrease in the number of unsatisfied bonds. Since the number of unsatisfied bonds diminishes, so also surface energy decrease. (That is, surface energy decreases with an increase in planar density).

9. Briefly describe a twin and a twin boundary.
Ans:

A twin boundary is an interface such that atoms on one side are located at mirror image positions of those atoms situated on the other boundary side. The region of material between these boundaries is appropriately termed a twin.

10. For each of the following stacking sequences found in FCC metals, cite the type of planar defect that exists:

(a) . . . A B C A B C B A C B A . . .

(b) . . . A B C A B C B C A B C . . .

Now, copy the stacking sequences and indicate the position(s) of planar defect(s) with a vertical dashed line.

Ans:

(a) The interfacial defect that exists for this stacking sequence is a twin boundary, which occurs at the indicated position.


The stacking sequence on one side of this position is mirrored on the other side.

(b) The interfacial defect that exists within this FCC stacking sequence is a stacking fault, which occurs between the two lines.


Within this region, the stacking sequence is HCP.

11. Determine the ASTM grain size number if 25 grains per square inch are measured at a magnification of 600.

Ans:

This problem asks that we determine the ASTM grain size number if 8 grains per square inch are measured at a magnification of 600. In order to solve this problem we make use of Equation

$$N_M\left(\frac{M}{100}\right)^2 = 2^{n-1}$$

Where, $N_M$ = the number of grains per square inch at magnification $M$, and $n$ is the ASTM grain size number. Solving the above equation for $n$, and realizing that $N_M = 8$, while $M = 600$, we have

$$n = \frac{\log N_M + 2\log\left(\frac{M}{100}\right)}{\log 2} + 1$$

$$= \frac{\log 8 + 2\log\left(\frac{600}{100}\right)}{\log 2} + 1 = 9.2$$

12. Does the grain size number n in equation $N = 2^{n-1}$ increase or decrease with size? Why?

Ans:

Taking logarithms of Equation $\mathbf{N = 2^{n-1}}$ and then rearranging such that the grain size number $n$ is the dependent variable leads to the expression

$$n = 1 + \frac{\log N}{\log 2}$$

Thus, $n$ increases with increasing $N$. But as $N$ (the average number of grains per square inch at a magnification of 100 times) increases the grain size decreases. In other words, value of $n$ *increases* with decreasing grain size.

13. Cite the relative Burgers vector–dislocation line orientations for edge, screw, and mixed dislocations.

Ans:
The Burgers vector and dislocation line are perpendicular for edge dislocations, parallel for screw dislocations, and neither perpendicular nor parallel for mixed dislocations.