CHAPTER 2. NATURE OF MATERIALS

2.1. See Section 2.2.1.

2.2. See Section 2.1.

2.3. See Section 2.1.1.

2.4. See Section 2.1.1.

2.5. See Section 2.1.2.

2.6. See Section 2.2.1.

2.7. See Section 2.1.2.

2.8. See Section 2.2.1.

2.9. See Section 2.2.1.

2.10. If the atomic masses and radii are the same, then the material that crystalizes into a lattice with a higher APF will have a larger density. The FCC structure has a higher APF than the BCC structure.

2.11. For the face-center cubic crystal structure, number of equivalent whole atoms in each unit cell = 4
By inspection the diagonal of the face of a FCC unit cell = 4r
Using Pythagorean theory:

$(4r)^2 = a^2 + a^2$

$16r^2 = 2a^2$

$8r^2 = a^2$

$a = 2\sqrt{2}r$

2.12. a. Number of equivalent whole atoms in each unit cell in the BCC lattice structure = **2**

b. Volume of the sphere = $(4/3)\,\pi\, r^3$

Volume of atoms in the unit cell = $2 \times (4/3)\,\pi\, r^3 = (8/3)\,\pi\, r^3$

By inspection, the diagonal of the cube of a BCC unit cell

$= 4r = \sqrt{a^2 + a^2 + a^2} = a\sqrt{3}$

a = Length of each side of the unit cell = $\frac{4r}{\sqrt{3}}$

c. Volume of the unit cell = $\left[\frac{4r}{\sqrt{3}}\right]^3$

$$APF = \frac{volume \quad of \quad atoms \quad in \quad the \quad unit \quad cell}{total \quad unit \quad volume \quad of \quad the \quad cell} = \frac{(8/3)\pi.r^3}{(4r/\sqrt{3})^3} = \mathbf{0.68}$$

2.13. For the BCC lattice structure: $a = \frac{4r}{\sqrt{3}}$

Volume of the unit cell of iron = $\left[\frac{4r}{\sqrt{3}}\right]^3 = \left[\frac{4x0.124x10^{-9}}{\sqrt{3}}\right]^3$ = **2.348 x 10^{-29} m^3**

2.14. For the FCC lattice structure: $a = 2\sqrt{2}r$

Vol. of unit cell of aluminum = $(2\sqrt{2}r)^3 = (2\sqrt{2}x0.143)^3$ =0.06616725 nm^3 = **6.6167x10^{-29} m^3**

2.15. From Table 2.3, copper has an FCC lattice structure and r of 0.1278 nm

Volume of the unit cell of copper =$(2\sqrt{2}r)^3 = (2\sqrt{2}x0.1278)^3$ = **0.04723 nm^3 = 4.723 x10^{-29} m^3**

2.16. For the BCC lattice structure: $a = \frac{4r}{\sqrt{3}}$

Volume of the unit cell of iron = $\left[\frac{4r}{\sqrt{3}}\right]^3 = \left[\frac{4x0.124x10^{-9}}{\sqrt{3}}\right]^3$ = 2.348 x 10^{-29} m^3

Density = $\rho = \frac{nA}{V_C N_A}$

n = Number of equivalent atoms in the unit cell = 2
A = Atomic mass of the element = 55.9 g/mole
N_A= Avogadro's number = 6.023 x 10^{23}

$$\rho = \frac{2x55.9}{2.348x10^{-29}x6.023x10^{23}}$$ = 7.904 x 10^6 g/m^3 = **7.904 Mg/m^3**

2.17. For the BCC lattice structure: $a = \frac{4r}{\sqrt{3}}$

Vol. of the unit cell of molybdenum = $\left[\frac{4r}{\sqrt{3}}\right]^3 = \left[\frac{4x0.1363x10^{-9}}{\sqrt{3}}\right]^3$ = 3.119 x 10^{-29} m^3

$$\rho = \frac{nA}{V_C N_A} = \frac{2x95.94}{3.119x10^{-29}x6.023x10^{23}}$$ = 10.215 x 10^6 g/m^3= **10.215 Mg/ m^3**

2.18. For the BCC lattice structure: $a = \frac{4r}{\sqrt{3}}$

Volume of the unit cell of the metal = $\left[\frac{4r}{\sqrt{3}}\right]^3 = \left[\frac{4x0.128x10^{-9}}{\sqrt{3}}\right]^3$ = 2.583 x 10^{-29} m^3

$$\rho = \frac{nA}{V_C N_A} = \frac{2x63.5}{2.583x10^{-29}x6.023x10^{23}} = 8.163 \text{ x } 10^6 \text{ g/m}^3 = \mathbf{8.163\ Mg/\ m^3}$$

2.19. For the FCC lattice structure: $a = 2\sqrt{2}r$

Volume of unit cell of the metal = $(2\sqrt{2}r)^3 = (2\sqrt{2}x0.132)^3$ =0.05204 nm^3 = 5.204x10^{-29} m^3

$$\rho = \frac{nA}{V_C N_A} = \frac{4x42.9}{5.204x10^{-29}x6.023x10^{23}} = 5.475 \text{ x } 10^6 \text{ g/m}^3 = \mathbf{5.475\ Mg/\ m^3}$$

2.20. For the FCC lattice structure: $a = 2\sqrt{2}r$

Volume of unit cell of aluminum = $(2\sqrt{2}r)^3 = (2\sqrt{2}x0.143)^3$ =0.06616725 nm^3 = 6.6167x10^{-29} m^3

Density = $\rho = \frac{nA}{V_C N_A}$

For FCC lattice structure, n = 4

A = Atomic mass of the element = 26.98 g/mole

N_A= Avogadro's number = 6.023 x 10^{23}

$$\rho = \frac{4x26.98}{6.6167x10^{-29}x6.023x10^{23}} = 2.708 \text{ x } 10^6 \text{ g/m}^3 = \mathbf{2.708\ Mg/m^3}$$

2.21. $\rho = \frac{nA}{V_C N_A}$

For FCC lattice structure, n = 4

$V_c = \frac{4x63.55}{8.89x10^6x6.023x10^{23}}$ = 4.747 x 10^{-29} m^3

APF = 0.74 = $\frac{4x(4/3)\pi.r^3}{4.747x10^{-29}}$

r^3 = 0.2097 x 10^{-29} m^3

r =0.128 x 10^{-9} m = **0.128 nm**

2.22. a. $\rho = \frac{nA}{V_C N_A}$

For FCC lattice structure, n = 4

$V_c = \frac{4x40.08}{1.55x10^6x6.023x10^{23}}$ = 1.717 x 10^{-28} m^3

b. APF = 0.74 = $\frac{4x(4/3)\pi.r^3}{1.717x10^{-28}}$

$r^3 = 0.7587 \times 10^{-29}$ m^3

r =0.196×10^{-9} m = **0.196 nm**

2.23. $\frac{\rho_1}{\rho_2} = \frac{n_1 A_1 V_{c2} N_A}{V_{c1} N_A n_2 A_2} = \frac{n_1 V_{c2}}{n_2 V_{c1}}$

$\frac{8.87}{\rho_2} = \frac{2 x (\frac{4r}{\sqrt{3}})^3}{4x(2r\sqrt{2})^3}$

$\rho_2 = 32.573 \ g/cm^3$

2.24. See Section 2.2.2.

2.25. See Section 2.2.2.

2.26. See Section 2.2.2.

2.27. See Figure 2.14**.**

2.28. See Section 2.2.5.

2.29. m_t = 100 g

P_B = 65 %

P_{lB} = 30 %

P_{sB} = 80 %

From Equations 2.4 and 2.5,

$m_l + m_s = 100$

$30\ m_l + 80\ m_s = 65 \times 100$

Solving the two equations simultaneously, we get:

m_l = mass of the alloy which is in the liquid phase = **30 g**

m_s = mass of the alloy which is in the solid phase = **70 g**

2.30. m_t = 100 g

P_B = 45 %

P_{lB} = 17 %

P_{sB} = 65 %

From Equations 2.4 and 2.5,

$m_l + m_s = 100$

$17\ m_l + 65\ m_s = 45 \times 100$

Solving the two equations simultaneously, we get:

m_l = mass of the alloy which is in the liquid phase = **41.67 g**

m_s = mass of the alloy which is in the solid phase = **58.39 g**

2.31. $m_t = 100$ g
$P_B = 60$ %
$P_{lB} = 25$ %
$P_{sB} = 70$ %
From Equations 2.4 and 2.5,
$m_l + m_s = 100$
$25\ m_l + 70\ m_s = 60 \times 100$
Solving the two equations simultaneously, we get:
m_l = mass of the alloy which is in the liquid phase = **22.22 g**
m_s = mass of the alloy which is in the solid phase = **77.78 g**

2.32. $m_t = 100$ g
$P_B = 40$ %
$P_{lB} = 20$ %
$P_{sB} = 50$ %
From Equations 2.4 and 2.5,
$m_l + m_s = 100$
$40\ m_l + 50\ m_s = 40 \times 100$
Solving the two equations simultaneously, we get:
m_l = mass of the alloy which is in the liquid phase = **33.33 g**
m_s = mass of the alloy which is in the solid phase = **66.67 g**

2.33. a. Spreading salt reduces the melting temperature of ice. For example, at a salt composition of 5%, ice starts to melt at -21°C. When temperature increases more ice will melt. At a temperature of -5°C, all ice will melt.

b. **-21°C**

c. **-21°C**

2.34. See Section 2.3.

2.35. See Section 2.3.

2.36. See Section 2.4.