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. This work is protected by United States copyright laws and radii are the same, then the
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have a larger density. The FCC
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f the face of a FCC unit cell = 4r dii are the same, then the material two a larger density. The FCC structure of the World Wide Web and Structure, number of equivalent effects of a FCC unit cell = 4r a larger density. The FCC strong of the work and is not permitted. The structure is not permitted. The structure is not permitted.
- **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: δ $(4r)^2 = a^2 + a^2$ $16r^2 = 2 a^2$ $8r^2 = a^2$ $a = 2\sqrt{2}r$

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 x (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 **=** 3 4*r*

c. Volume of the unit cell = 3 3 4 $\overline{}$ \rfloor $\overline{}$ L L *r total unit volume of the cell* $APF = \frac{volume \space of \space atoms \space in \space the \space unit \space cell}{total \space unit \space volume \space of \space the \space cell} = \frac{(8/3)\pi r^3}{(Ar/\sqrt{2})^3}$ 3 $(4r/\sqrt{3})$ $(8/3)\pi$. *r* $\frac{\pi r^3}{\sqrt{2}}$ = **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 m³**

- **2.14.** For the FCC lattice structure: $a = 2\sqrt{2r}$ Vol. of unit cell of aluminum = $(2\sqrt{2}r)^3 = (2\sqrt{2}x0.143)^3 = 0.06616725$ nm³ = **6.6167x10⁻²⁹ m³**
- **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 nm³ = 4.723 x10⁻²⁹ m³

2.15. From Table 2.3, copper has an FCC lattice structure and
$$
\tau
$$
 of 0.1278 nm
\nVolume of the unit cell of copper $=(2\sqrt{2}r)^3 = (2\sqrt{2}x0.1278)^3 = 0.04723 \text{ nm}^3 = 4.723 \text{ x}10$
\n2.16. For the BCC lattice structure: $a = \frac{4r}{\sqrt{3}}$
\nVolume of the unit cell of iron $= \left[\frac{4r}{\sqrt{3}}\right]^3 = \left[\frac{4x0.124 \times 10^{-9}}{\sqrt{3}}\right]^3 = 2.348 \times 10^{-29} \text{ m}^3$
\nDensity $= \rho = \frac{nA}{V_c N_A}$
\nn = Number of equivalent atoms in the unit cell = 2
\nA = Atomic mass of the element = 55.9 g/mole
\nNa = Avogadro's number = 6.023 x 10²³
\n $\rho = \frac{2x55.9}{2.348x10^{-29}x6.023x10^{23}} = 7.904 \times 10^6 \text{ g/m}^3 = 7.904 \text{ Mg/m}^3$

2.17. For the BCC lattice structure: 3 $a = \frac{4r}{r}$ Vol. of the unit cell of molybdenum = 3 3 4 $\overline{}$ \rfloor $\overline{}$ L L $\left(\frac{4r}{\sqrt{r}}\right)^5$ = 97^3 3 $4x0.1363x10$ $\overline{}$ \rfloor $\overline{}$ L L $\left[\frac{4x0.1363x10^{-9}}{2}\right]$ = 3.119 x 10⁻²⁹ m³ $V_c N$ *nA* $\rho = \frac{nA}{V_c N_A} = \frac{2x95.94}{3.119x10^{-29}x6.023x10^{23}} =$ $x10^{-29}x6.023x$ $\frac{x^{95.94}}{200 \times 0.000 \times 0.0000} = 10.215 \times 10^{6} \text{ g/m}^3 = 10.215 \text{ Mg/m}^3$

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

> Volume of the unit cell of the metal $=$ 3 3 4 $\overline{}$ $\overline{}$ $\overline{}$ L L $\left(\frac{4r}{\sqrt{r}}\right)^3$ = 97^3 3 $4x0.128x10$ $\overline{}$ 」 $\overline{}$ \mathbf{r} L $\left[\frac{4x0.128x10^{-9}}{2}\right]^{3}$ = 2.583 x 10⁻²⁹ m³

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

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

Volume of unit cell of the metal = $(2\sqrt{2}r)^3 = (2\sqrt{2}x0.132)^3 = 0.05204 \text{ nm}^3 = 5.204 \times 10^{-29} \text{ m}^3$

$$
\rho = \frac{nA}{V_c N_A} = \frac{4x42.9}{5.204 \times 10^{-29} \times 6.023 \times 10^{23}} = 5.475 \text{ N g/m}^3 = 5.475 \text{ Mg/m}^3
$$

2.20. For the FCC lattice structure: $a = 2\sqrt{2}r$ Volume of unit cell of aluminum = $(2\sqrt{2}r)^3 = (2\sqrt{2}x0.143)^3 = 0.06616725$ nm³ = 6.6167x10⁻²⁹ m³ *nA*

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

\nFor FCC lattice structure, n = 4
\nA = Atomic mass of the element = 26.98 g/mole
\nNa= Avogadro's number = 6.023 x 10²³
\n $\rho = \frac{4x26.98}{6.6167x10^{-29}x6.023x10^{23}} = 2.708 \times 10^6 \text{ g/m}^3 = 2.708 \text{ Mg/m}^3$
\n2.21. $\rho = \frac{nA}{V_c N_A}$
\nFor FCC lattice structure, n = 4⁸
\n $V_c = \frac{4x63.55}{V_c N_A} = 4.747 \times 10^{-29} \text{ m}^3$

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

For FCC lattice structure, $\vec{n} = 4e^{-\beta}$

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

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

$$
r^3 = 0.2097 \times 10^{-29} \text{ m}^3
$$

$$
r = 0.128 \times 10^{-9} \text{ m} = 0.128 \text{ nm}
$$

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

For FCC lattice structure, n = 4

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

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

\n $r^3 = 0.7587 \times 10^{-29} \text{ m}^3$
\nr = 0.196 x $10^{-9} \text{ m} = 0.196 \text{ nm}$

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

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

$$
\rho_2 = 32.573 \text{ g/cm}^3
$$

- **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.** $m_t = 100 \text{ g}$

 $P_B = 65 %$ $P_{lB} = 30 %$ $P_{sB} = 80\%$ From Equations 2.4 and 2.5, $m_l + m_s = 100$ 30 m_l + 80 m_s = 65 x 100 Solving the two equations simultaneously, we get: m_l = mass of the alloy which is in the liquid phase = **30 g** *ms* = mass of the alloy which is in the solid phase = **70 g** and 2.5, it do so and a see it is a work the work is a street when the state of the work is a street when the and is provided solely for the use of instruction in teaching their courses and particles and the student learning. But the student learning of the student learning **During or any particular and the work and beach three this work of the work and beach three this work (including on the Motor Mide Web) and a particular three order wide work (including on the Motor Mide Web) and the Worl** with the integrity of the state of the work and integrity of the work and is not permitted.

2.30. $m_t = 100 \text{ g}$

 $P_B = 45 %$ $P_{lB} = 17 %$ $P_{sB} = 65 %$ 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 *ms* = mass of the alloy which is in the solid phase = **58.39 g**

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

2.32. $m_t = 100 \text{ g}$

 $P_B = 40 %$ $P_{lB} = 20 \%$ $P_{sB} = 50 %$ From Equations 2.4 and 2.5, $m_l + m_s = 100$ $40 m_l + 50 m_s = 40 x 100$ Solving the two equations simultaneously, we get: m_l = mass of the alloy which is in the liquid phase = **33.33 g** *ms* = mass of the alloy which is in the solid phase = **66.67 g** The simultaneously, we get:
y which is in the liquid phase
by which is in the solid phase
we set the melting temperature
melt at -21°C. When temper
C, all ice will melt. and is in the liquid phase = 33
which is in the solid phase = 33
which is in the solid phase = 66.
est the melting temperature of ice
left at -21°C. When temperature
all ice will melt. simultaneously, we get:

ch is in the liquid phase = **33.33**

ich is in the solid phase = **66.67**

the melting temperature of ice. F

at -21°C. When temperature inc.

ice will melt. multaneously, we get:

is in the liquid phase = **33.33 g**

is in the solid phase = **66.67 g**

melting temperature of ice. For exactle

21°C. When temperature increases

will melt.

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 \degree C. When temperature increases more ice will melt. At a temperature of -5° C, all ice will melt. will destroy the integration of the control of the work and integration of the work and is not permitted.

b. **-21^oC**

- c. **-21^oC**
- **2.34.** See Section 2.3**.**
- **2.35.** See Section 2**.3.**
- **2.36.** See Section 2.4**.**

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