Chapter 12: The Chemistry of Solids

MULTIPLE CHOICE

1. The bonding in solid-state metals can be described as __________

   a. nonexistent.
   b. a covalent network.
   c. an electron sea.
   d. highly directional.
   e. ionic.

   ANS: C DIF: Easy REF: 12.1
   OBJ: Identify the characteristics of bonding in metals. MSC: Factual

2. Metal solids are good conductors of electricity because __________

   a. they are easily ionized.
   b. their valence electrons are not localized.
   c. they are easily reduced and oxidized.
   d. they can be drawn into wires.
   e. they are ductile.

   ANS: B DIF: Medium REF: 12.1
   OBJ: Identify the key characteristics of band theory. MSC: Factual

3. Band theory of bonding in solids __________

   a. is an extension of molecular orbital theory.
   b. describes bonds as rubber bands.
   c. does not apply to any type of solid other than metals.
   d. explains bond formation in metals, but not their physical properties.
   e. All of the above are correct.

   ANS: A DIF: Medium REF: 12.1
   OBJ: Identify the key characteristics of band theory. MSC: Factual

4. Electrical and thermal conductivity in metals __________

   a. is explained by a dipolar coupling model.
   b. is explained by band theory.
   c. is explained by matrix isolation techniques.
   d. is explained by temporary ionization.
   e. is a function of the level of contamination by excess electrons.

   ANS: B DIF: Medium REF: 12.1
   OBJ: Identify the key characteristics of band theory. MSC: Factual

5. The molecular orbital description for metal bonding is different from that for diatomic molecules in that __________

   a. there are no antibonding orbitals in the metal bonding description.
   b. quantum theory no longer applies as the orbitals are continuous.
   c. the orbitals are so close in energy that they are referred to as bands.
   d. the increased number of electrons results in each bond being stronger.
   e. All the above are true.

   ANS: C DIF: Difficult REF: 12.1
   OBJ: Identify the key characteristics of band theory. MSC: Factual

6. Molecular orbital theory can be applied __________

   a. only to two adjacent metal atoms.
   b. only to a few metal atoms that are very close to each other.
   c. to any number of metal atoms.
   d. to nonmetals only—not to metals.

e. to nonmetals and ionic bonds only—not to metals.

ANS: C DIF: Medium REF: 12.1
OBJ: Identify the key characteristics of band theory. MSC: Conceptual

7. Which of the following elements are semiconductors?

C, Si, Ge, Sn

a. C and Si only
b. Si and Ge only
c. Ge and Sn only
d. None of these elements are semiconductors unless a dopant is added.
e. All of these elements are semiconductors.

ANS: B DIF: Easy REF: 12.2
OBJ: Identify elements that act as semiconductors. MSC: Factual

8. The band structure of semiconductors differs from that of metal conductors in that __________

a. metal bands are relatively empty while semiconductor bands are nearly full.
b. metal bands are nearly full while semiconductor bands are relatively empty.
c. metal conduction bands are lower in energy than valence bands while semiconductor conduction bands are higher in energy than valence bands.
d. metal conduction bands are higher in energy than valence bands while semiconductor conduction bands are lower in energy than valence bands.
e. valence bands in metals are either partially empty or overlap with conduction bands while these bands in semiconductors are separated by a small gap.

ANS: E DIF: Difficult REF: 12.2
OBJ: Identify the relationship between valence and conductance bands in semiconductors.
MSC: Factual

9. When silicon is doped with gallium, electrical conduction increases because __________

a. gallium has fewer valence electrons than silicon so holes are created in the valence band of silicon.
b. gallium has more valence electrons than silicon so electrons are added to the conduction band of silicon.
c. gallium causes electrons to be transferred from the valence band of silicon to the conduction band of silicon.
d. gallium causes electrons to be transferred from the conduction band of silicon to the valence band of silicon.
e. gallium is a better conductor of electricity than silicon.

ANS: A DIF: Medium REF: 12.2
OBJ: Describe how conductivity in semiconductors can be increased MSC: Conceptual

10. Which of the following can be used to increase the conductivity of any semimetal?

I. Adding an element with one additional valence electron
II. Adding an element with one fewer valence electron
III. Lowering the temperature

a. I only
b. II only
c. III only
d. I and II only
e. I, II and III.

ANS: D DIF: Easy REF: 12.2
OBJ: Identify elements that act as semiconductors. MSC: Factual

11. When Si is doped with P, it produces a(n) __________ -type semiconductor.

a. p
d. np

b. n
c. q
e. No semiconductor will be produced.

ANS: B DIF: Easy REF: 12.2
OBJ: Determine the type of a particular semiconductor. MSC: Applied

12. When Ge is doped with Ga, it produces a(n) __________ -type semiconductor.

a. p
b. n
c. q
d. np
e. No semiconductor will be produced.

ANS: A DIF: Easy REF: 12.2
OBJ: Determine the type of a particular semiconductor. MSC: Applied

13. Which element would be used to dope silicon to produce a p-type semiconductor?

a. boron (B)
b. carbon (C)
c. aluminum (Al)
d. phosphorus (P)
e. germanium (Ge)

ANS: C DIF: Easy REF: 12.2
OBJ: Determine a suitable element for creating a particular type of semiconductor.
MSC: Applied

14. Which element would be used to dope germanium to produce an n-type semiconductor?

a. Ga
b. Sn
c. Si
d. As
e. Cu

ANS: D DIF: Easy REF: 12.2
OBJ: Determine a suitable element for creating a particular type of semiconductor.
MSC: Applied

15. Light-emitting diodes are semiconductors that emit light when a current is passed through them. What is the key factor that must be changed to change the wavelength of the emitted light in an LED?

a. the width of the valence band
b. the width of the conduction band
c. the width of the band gap
d. the magnitude of the current
e. the type of semiconductor (p vs. n)

ANS: C DIF: Easy REF: 12.2
OBJ: Identify how a semiconductor can be used to generate light. MSC: Factual

16. GaAs and $AlGaAs_2$ are examples of __________ semiconductors.

a. light-emitting diode (LED)
b. sound-emitting
c. np
d. non-
e. dual voltage

ANS: A DIF: Easy REF: 12.2
OBJ: Identify common LED materials. MSC: Factual

17. The two types of closest-packed lattices are __________

a. cubic closest-packed and face-centered cubic.
b. cubic closest-packed and hexagonal closest-packed.
c. cubic closest-packed and random closest-packed.
d. cubic closest-packed and pyramidal closest-packed.
e. simple cubic and hexagonal closest-packed.

ANS: B DIF: Easy REF: 12.3
OBJ: Identify the meaning of closest-packed, hexagonal closest-packed, and cubic-closest packed.

MSC: Factual

18. The face-centered cubic structure is also known as __________

a. cubic closest-packed.
b. hexagonal closest-packed.
c. square closest-packed.
d. spherical closest-packed.
e. none of the above as it is not a closest-packed pattern.

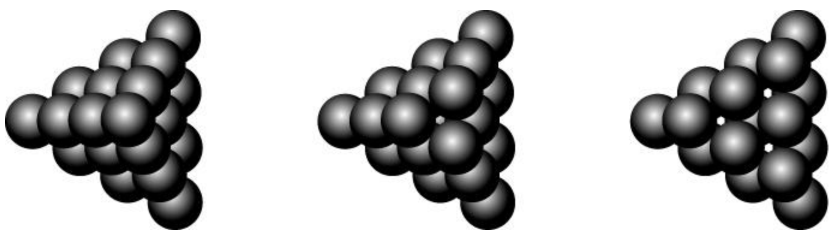
ANS: A DIF: Easy REF: 12.3
OBJ: Identify the meaning of closest-packed, hexagonal closest-packed, and cubic-closest packed.
MSC: Factual

19. A cubic closest-packed structure has hexagonally arranged layers of atoms in the series __________

a. ababab.
b. abcabcabc.
c. abcbabcbabcba.
d. abacabacaba.
e. aaaaaa.

ANS: B DIF: Easy REF: 12.3
OBJ: Identify the meaning of closest-packed, hexagonal closest-packed, and cubic-closest packed.
MSC: Factual

20. At a historic Civil War battleground, a stack of cannonballs looked like the picture below on the far left. Removing the top cannonball resulted in the middle view, and removing the next layer resulted in the view on the right. What sort of packing was used in stacking the cannonballs?



a. cannonball closest-packed
b. hexagonal closest-packed
c. cubic closest-packed
d. random packed
e. body-centered closest-packed

ANS: C DIF: Medium REF: 12.3
OBJ: Differentiate between hexagonal and cubic closest-packed structures.
MSC: Applied

21. Pure solid metals __________

a. do not crystallize.
b. are amorphous.
c. often crystallize in closest-packed structures.
d. often crystallize in very complex unit cells.
e. are like liquids with the nuclei flowing through a sea of electrons.

ANS: C DIF: Medium REF: 12.3
OBJ: Identify common examples of packing in metallic crystals. MSC: Factual

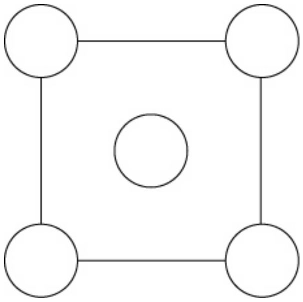
22. Which is *not* true about a crystallographic unit cell?

a. It repeats throughout a crystalline structure in three dimensions.
b. It fills all the space in the crystalline lattice.
c. Its dimensions can be measured with X-rays.
d. It always has corners with 90° angles.
e. It represents the smallest repeating unit in the crystal.

ANS: D DIF: Easy REF: 12.3

OBJ: Identify the meaning of a unit cell. MSC: Conceptual

23. In the sodium chloride unit cell, the chloride ions form a cube in which each side is arranged like the following figure. The circles represent the positions of the chloride ions on one square face of the cube. All the other faces are the same. What is the name of this unit cell?



a. cubic
b. chloride-centered cubic
c. face-centered cubic
d. x-face cubic
e. body-centered cubic

ANS: C DIF: Easy REF: 12.3
OBJ: Identify common types of unit cells. MSC: Factual

24. How many nearest neighbor atoms are there around each atom in a simple cubic unit cell?

a. 4
b. 6
c. 8
d. 10
e. 12

ANS: B DIF: Medium REF: 12.3
OBJ: Identify the number of nearest neighbors around each atom in a unit cell.
MSC: Applied

25. How many nearest neighbor atoms are there around each atom in a face-centered cubic unit cell?

a. 4
b. 6
c. 8
d. 10
e. 12

ANS: E DIF: Medium REF: 12.3
OBJ: Identify the number of nearest neighbors around each atom in a unit cell.
MSC: Applied

26. How many nearest neighbor atoms are there around each atom in a body-centered cubic unit cell?

a. 4
b. 6
c. 8
d. 10
e. 12

ANS: C DIF: Medium REF: 12.3
OBJ: Identify the number of nearest neighbors around each atom in a unit cell.
MSC: Applied

27. Polonium crystallizes in a simple cubic pattern. How many polonium atoms are in each unit cell?

a. 1
b. 2
c. 3
d. 4
e. 5

ANS: A DIF: Medium REF: 12.3
OBJ: Determine the number of atoms in a unit cell. MSC: Applied

28. Iron crystallizes in a body-centered cubic pattern. How many iron atoms are in each unit cell?

a. 1
b. 2
c. 4
d. 8
e. 9

ANS: B DIF: Medium REF: 12.3
OBJ: Determine the number of atoms in a unit cell. MSC: Applied

29. Copper crystallizes in a face-centered cubic pattern. How many copper atoms are in each unit cell?

a. 2
b. 4
c. 8
d. 12
e. 14

ANS: B DIF: Medium REF: 12.3
OBJ: Determine the number of atoms in a unit cell. MSC: Applied

30. Which unit cell contains the most atoms?

a. fcc
b. bcc
c. cubic
d. both fcc and bcc
e. None of the above, as fcc, bcc, and cubic contain the same number of atoms.

ANS: A DIF: Medium REF: 12.3
OBJ: Determine the number of atoms in a unit cell. MSC: Applied

31. If a body-centered cubic unit cell has a volume of 1.447×10^8 pm^3, what must be the dimension of the cube's edge?

a. 1.131×10^8 pm
b. 110 pm
c. 1.20×10^4 pm
d. 525 pm
e. 367 pm

ANS: D DIF: Easy REF: 12.3
OBJ: Interconvert volume and edge length of cubic unit cells. MSC: Applied

32. The alpha form of polonium (Po) crystallizes as a simple cubic unit cell with an edge length of 335 pm. What is the atomic radius of polonium?

a. 84 pm
b. 168 pm
c. 335 pm
d. 175 pm
e. 808 pm

ANS: B DIF: Easy REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

33. Aluminum (Al) crystallizes as a face-centered unit cell with an edge length of 404 pm. What is the atomic radius of aluminum?

a. 143 pm
b. 202 pm
c. 286 pm
d. 175 pm
e. 808 pm

ANS: A DIF: Medium REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

34. Iron (Fe) crystallizes as a body-centered unit cell with an edge length of 287 pm. What is the atomic radius of iron?

a. 99 pm
b. 114 pm
d. 143 pm
e. 256 pm

c. 124 pm

ANS: C DIF: Difficult REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

35. The alpha form of polonium (Po) has a density of 9.196 g/cm^3 and crystallizes in a simple cubic structure. What is the atomic radius of polonium?

a. 119 pm
b. 168 pm
c. 266 pm
d. 335 pm
e. 419 pm

ANS: B DIF: Difficult REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

36. Aluminum (Al) has a density of 2.70 g/cm^3 and crystallizes in a face-centered cubic structure. What is the unit-cell edge length?

a. 2.47×10^{-3} pm
b. 40.0 pm
c. 405 pm
d. 321 pm
e. 255 pm

ANS: C DIF: Difficult REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

37. Gold (Au) has a face-centered cubic structure with a unit cell edge length of 407.8 pm. What is the calculated value of the density of gold based on this information?

a. 15.78 g/cm^3
b. 19.28 g/cm^3
c. 9.64 g/cm^3
d. 4.82 g/cm^3
e. 11.6 g/cm^3

ANS: B DIF: Medium REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

38. Iron (Fe) has a density of 7.874 g/cm^3 and crystallizes in a body-centered cubic structure. What is the atomic radius of iron?

a. 99 pm
b. 114 pm
c. 124 pm
d. 143 pm
e. 255 pm

ANS: C DIF: Difficult REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

39. If a face-centered cubic unit cell has a volume of 1.447×10^8 pm^3 and the ions at the corners touch the ion on the face, what must be the ion's radius?

a. 186 pm
b. 388 pm
c. 4243 pm
d. 125 pm
e. 1050 pm

ANS: A DIF: Difficult REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

40. Gold has a face-centered cubic structure with a unit cell edge length of 407.8 pm. What is the density of each individual gold atom?

a. 21.44 g/cm^3
b. 26.20 g/cm^3
c. 13.1 g/cm^3
d. 6.55 g/cm^3
e. 19.28 g/cm^3

ANS: B DIF: Difficult REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

41. Which of the following unit cells has the lowest packing efficiency?

a. simple cubic
b. face-centered cubic
c. body-centered cubic
d. both face-centered and body-centered cubic
e. Simple, face-centered, and body-centered cubic all have the same packing efficiency.

ANS: A DIF: Medium REF: 12.3
OBJ: Compare packing efficiencies of common unit cells. MSC: Conceptual

42. Which of the following unit cells has the highest packing efficiency?

a. simple cubic
b. face-centered cubic
c. body-centered cubic
d. both face-centered and body-centered cubic
e. Simple, face-centered, and body-centered cubic all have the same packing efficiency.

ANS: B DIF: Medium REF: 12.3
OBJ: Compare packing efficiencies of common unit cells. MSC: Conceptual

43. Which of the following can be varied to change the physical properties of an alloy?

I. The elements used
II. The proportions used
III. The type of hole each element occupies

a. I only
b. II only
c. III only
d. I and II only
e. I, II, and III

ANS: D DIF: Easy REF: 12.3
OBJ: Identify how the properties of alloys can be manipulated. MSC: Conceptual

44. Which of the following refers to an alloy in which the composition of the elements is constant?

a. intermetallic
b. interstitial
c. stoichiometric
d. substitutional
e. homogeneous

ANS: A DIF: Easy REF: 12.3
OBJ: Identify a substitutional alloy, interstitial alloy, or intermetallic compound.
MSC: Conceptual

45. Which of the following refers to an alloy in which the composition is variable and the elements have comparable radii?

a. intermetallic
b. interstitial
c. stoichiometric
d. substitutional
e. homogeneous

ANS: D DIF: Easy REF: 12.3
OBJ: Identify the meaning of a substitutional alloy, interstitial alloy, or intermetallic compound.
MSC: Conceptual

46. Which of the following refers to an alloy in which the composition of the elements is variable and one element must have a much smaller radius than the other?

a. intermetallic
b. interstitial
c. stoichiometric
d. substitutional
e. inhomogeneous

ANS: B DIF: Easy REF: 12.3
OBJ: Identify the meaning of a substitutional alloy, interstitial alloy, or intermetallic compound.
MSC: Conceptual

47. In a two-component alloy the more abundant metal can be thought of as the solvent while the less abundant metal can be thought of as the solute. Which of the following would *not* change the orientation of atoms in the solvent's unit cell?

I. a solute with the same atomic radius as the solvent
II. a solute that was sufficiently small to fit into holes in the solvent's unit cell
III. a solvent that was sufficiently small to fit into holes in the solute's unit cell

a. only I
b. only II
c. only III
d. I or II
e. I, II, or III

ANS: D DIF: Difficult REF: 12.4
OBJ: Identify key characteristics of metals in substitutional alloys. MSC: Conceptual

48. Bronze that is composed of 10% tin and 90% copper is __________

a. a substitutional alloy.
b. an interstitial alloy.
c. a doped semiconductor.
d. a colloidal alloy.
e. an intermetallic compound.

ANS: A DIF: Medium REF: 12.4
OBJ: Identify common substitutional, intermetallic, and interstitial alloys.
MSC: Factual

49. In comparing the density of bronze composed of 20% tin to the density of pure copper, __________

a. the density of the bronze is higher.
b. the density of the bronze is lower.
c. the density of the bronze is the same.
d. the density of the bronze depends on whether the tin or the copper occupies holes.
e. It cannot be determined as only the 1:1 intermetallic compound of tin and copper has ever been observed.

ANS: A DIF: Medium REF: 12.4
OBJ: Identify common properties associated with alloys. MSC: Conceptual

50. The higher the carbon content in steel, __________

a. the stronger and more malleable it is.
b. the stronger and more brittle it is.
c. the weaker and more malleable it is.
d. the weaker and more brittle it is.
e. Any of these, depending on the formula of the interstitial compound.

ANS: B DIF: Easy REF: 12.4
OBJ: Identify common properties associated with alloys. MSC: Factual

51. In addition to carbon and iron, stainless steel contains __________

a. teflon and polyethylene.
b. gold and silver.
d. chromium and nickel.
e. platinum.

c. copper and nickel.

ANS: D DIF: Easy REF: 12.4
OBJ: Identify common substitutional, intermetallic, and interstitial alloys.
MSC: Factual

52. Stainless steel is less susceptible to rusting than iron because __________

a. it is coated with plastic.
b. the metals other than iron in the alloy are oxidized more easily, forming protective oxides.
c. the carbon within the alloy polymerizes to form a protective film.
d. the silicon within the alloy oxidizes to form a protective silicate layer.
e. the intermetallic compound formed is less reactive.

ANS: B DIF: Medium REF: 12.4
OBJ: Identify common properties associated with alloys. MSC: Factual

53. Aluminum alloys are more desirable than steel in some applications because of their relatively __________

a. low density.
b. low cost.
c. high luster.
d. high warmth to touch.
e. high conductivity.

ANS: A DIF: Medium REF: 12.4
OBJ: Identify common properties associated with alloys. MSC: Factual

54. Aluminum is resistant to corrosion because of __________

a. its positive oxidation potential.
b. its low density.
c. the formation of a protective surface film of aluminum oxide.
d. the formation of a protective surface film of aluminum nitride.
e. its lack of reactivity toward oxygen.

ANS: C DIF: Easy REF: 12.4
OBJ: Identify common properties associated with alloys. MSC: Factual

55. Which of the following elements are found as a covalent network solid?

I. beryllium
II. carbon
III. phosphorus
IV. sulfur

a. I and II
b. I and III
c. II and III
d. II and IV
e. III and IV

ANS: C DIF: Easy REF: 12.5
OBJ: Identify common covalent network solids. MSC: Factual

56. Which two of the following elements are *not* found as a covalent network solid?

I. beryllium
II. carbon
III. phosphorus
IV. sulfur

a. I and III
b. I and II
c. I and IV
d. II and III
e. II and IV

ANS: C DIF: Easy REF: 12.5

OBJ: Identify common covalent network solids. MSC: Factual

57. Different structural forms of the elements are called __________

a. polymers.
b. allotropes.
c. isotopes.
d. isoforms.
e. polymorphs.

ANS: B DIF: Easy REF: 12.5
OBJ: Identify the meaning of allotrope. MSC: Factual

58. The most common allotrope of carbon is __________

a. coal.
b. graphite.
c. soot.
d. diamond.
e. carbon steel.

ANS: B DIF: Easy REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Factual

59. The hybridization of atomic orbitals in diamond is __________

a. none, since it is the element.
b. *sp*.
c. sp^2.
d. sp^3.
e. dsp^3.

ANS: D DIF: Medium REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Factual

60. The bond order in diamond is __________

a. 1.
b. 1.33.
c. 1.5.
d. 2.
e. 3.

ANS: A DIF: Medium REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Factual

61. How many carbons are bonded to each carbon in graphite?

a. 1
b. 2
c. 3
d. 4
e. some have 2 and some have 3

ANS: C DIF: Easy REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Factual

62. Which of these is the best conductor of electricity?

a. diamond
b. graphite
c. water
d. glass
e. fullerene

ANS: B DIF: Easy REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Conceptual

63. The sheet structure of carbon is __________

a. diamond.
b. graphite.
d. industrial diamond.
e. rolled carbon steel.

c. fullerene.

ANS: B DIF: Medium REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Factual

64. Researchers at the University of Texas at Austin prepared a *linear* allotrope of carbon in 1998. What is the hybridization of its atomic orbitals?

a. sp
b. sp^2
c. sp^3
d. dsp^3
e. Cannot be determined from the information provided.

ANS: A DIF: Difficult REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Conceptual

65. Would you expect the *linear* allotrope of carbon to conduct electricity? (Fragments of it were first prepared and characterized in 1998.)

a. No, the linear carbon chains would have no free electrons for carrying electricity.
b. Yes, this allotrope would be ionic and would therefore conduct electricity.
c. No, linear carbon chains would easily break under any electrical potential difference.
d. Yes, electrons can move through the delocalized π network.
e. No, only metals conduct electricity.

ANS: D DIF: Difficult REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Conceptual

66. As an analog of graphite, a material composed of boron and nitrogen (B–N) has been prepared. Why do these elements make a good substitute for the element in graphite?

I. They are all elements with electrons in the 2*p* subshell.
II. The sum of the valence electrons of one boron atom and one nitrogen atom is the same as the number of valence electrons on two carbon atoms.
III. Boron and nitrogen have suitable 2*p* orbital overlap.

a. I only
b. II only
c. III only
d. I and II only
e. I, II, and III

ANS: E DIF: Difficult REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Conceptual

67. Boron nitride, BN, is solid under standard conditions. Which of the following structures would you expect it to most resemble?

a. S_8
b. white phosphorus
c. graphite
d. carbon dioxide
e. kaolinite

ANS: C DIF: Difficult REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Conceptual

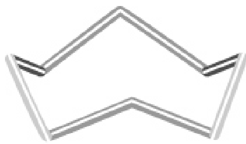
68. An approximately spherical allotrope of carbon containing 60 or 70 atoms is __________

a. spherohexadecalene and spheroheptadecalene.
b. spheralene-60 and spheralene-70.

c. fullerene.
d. graphitolene.
e. soccerene.

ANS: C DIF: Easy REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Factual

69. Which of the following figures best represents a common structure within crystalline sulfur? (A sulfur atom lies at each vertex.)

a. 

b. 

c. 

d. 

e. None of these as sulfur is a network covalent solid.

ANS: A DIF: Medium REF: 12.5
OBJ: Identify the allotropes of nonmetals along with their structures, properties, and relative abundances.
MSC: Factual

70. Which of the following is true regarding the attractive force that holds sodium chloride in the solid state?

I. It is electrostatic.
II. It is termed ionic bonding.
III. It depends on the distance between the sodium and chloride.
IV. It only operates between adjacent sodium and chloride.

a. I and II only
b. II and III only
c. I, II, and III only
d. II and IV only
e. I–IV are all true statements.

ANS: C DIF: Easy REF: 12.6
OBJ: Identify the meaning of an ionic solid. MSC: Factual

71. Compare the packing efficiency of face-centered cubic gold and face-centered cubic sodium chloride.

a. The efficiency of packing in the gold unit cell is higher.
b. The efficiency of packing in the sodium chloride unit cell is higher.
c. The efficiencies of packing in the two lattices are the same.
d. Packing efficiencies cannot be defined for one or both of these.
e. There is no way to compare without further information.

ANS: B DIF: Difficult REF: 12.6
OBJ: Compare packing efficiencies of common unit cells. MSC: Conceptual

72. Why does a pure metal *not* crystallize in a fluorite or antifluorite unit cell?

a. They can and do.
b. These unit cells require two types of atoms or ions with differing radii.
c. Pure metals do not crystallize; they are amorphous.
d. The atoms in pure metals move about in a sea of electrons.
e. The radius of the metal is too large.

ANS: B DIF: Difficult REF: 12.6
OBJ: Compare unit cells for ionic solids and metals. MSC: Conceptual

73. In the solid-state structure of sodium chloride, the closest distance between the centers of ions is observed __________

a. between adjacent sodium ions on the edge of the unit cell.
b. between adjacent chloride ions on the edge of the unit cell.
c. between adjacent sodium ions on the face and one corner of the unit cell.
d. between adjacent chloride ions on the face and one corner of the unit cell.
e. between all adjacent sodium and chloride ions.

ANS: E DIF: Easy REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Factual

74. The face-centered cubic unit cell has __________ tetrahedral holes.

a. 0
b. 1
c. 4
d. 8
e. 12

ANS: D DIF: Easy REF: 12.6
OBJ: Identify the number and arrangement of octahedral, tetrahedral, and cubic holes in a unit cell.
MSC: Factual

75. A face-centered cubic unit cell has a(n) __________ in its center.

a. tetrahedral hole
b. octahedral hole
c. atom
d. square planar hole
e. cubic hole

ANS: B DIF: Medium REF: 12.6
OBJ: Identify the number and arrangement of octahedral, tetrahedral, and cubic holes in a unit cell.
MSC: Factual

76. A face-centered cubic unit cell contains __________ octahedral holes.

a. 1
b. 4
c. 8
d. 13
e. 13

ANS: B DIF: Easy REF: 12.6
OBJ: Identify the number and arrangement of octahedral, tetrahedral, and cubic holes in a unit cell.
MSC: Factual

77. A tetrahedral hole in a crystal lattice is defined as __________

a. one-half of an octahedral hole.
b. the space between any number of atoms having tetrahedral edges.
c. the space between a cage of sp^3 hybridized atoms such as in diamond.
d. the space between a cluster of four adjacent atoms arranged in a tetrahedron.
e. a large hole having four flat sides arranged in a tetrahedral shape.

ANS: D DIF: Difficult REF: 12.6
OBJ: Identify the number and arrangement of octahedral, tetrahedral, and cubic holes in a unit cell.
MSC: Factual

78. How many tennis balls will fit within the interstitial holes between a truckload of basketballs perfectly placed in a closest-packed arrangement? Assume that the tennis balls have a radius that is 20% that of a basketball.

a. equal number of tennis balls and basketballs
b. twice as many tennis balls as basketballs
c. three times as many tennis balls as basketballs
d. four times as many tennis balls as basketballs
e. five times as many tennis balls as basketballs

ANS: B DIF: Difficult REF: 12.6
OBJ: Identify the number and arrangement of octahedral, tetrahedral, and cubic holes in a unit cell.
MSC: Applied

79. Which of the following contribute to the arrangement of ions in the unit cells of an ionic solid?

I. The empirical formula
II. The relative radii of the ions
III. The shape of polyatomic ions

a. I and II only
b. II and III only
c. I and III only
d. I only
e. I, II, and III

ANS: E DIF: Medium REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Conceptual

80. In the cubic closest-packed structure of sodium chloride, what ions are touching or nearly touching?

I. Sodium ions and sodium ions
II. Chloride ions and chloride ions
III. Sodium ions and chloride ions

a. I only
b. II only
c. III only
d. II and III only
e. I and III only

ANS: D DIF: Medium REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Factual

81. A rock salt structure has smaller ions in __________

a. cubic holes.
b. tetrahedral holes.
c. hexagonal holes.
d. octahedral holes.
e. the usual atomic positions in the unit cell, i.e., not in holes.

ANS: D DIF: Medium REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Factual

82. In the unit cell of sphalerite, __________

a. all of the octahedral holes are filled with cations.
b. half of the octahedral holes are filled with cations.
c. all of the tetrahedral holes are filled with cations.
d. half of the tetrahedral holes are filled with cations.
e. cations occupy standard atomic positions in the unit cell, i.e., not the holes.

ANS: D DIF: Easy REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Factual

83. If half of the tetrahedral holes in a face-centered cubic unit cell are filled, what must be the stoichiometry of the ionic compound, written as nonhole sites : hole sites in lowest terms?

a. 2:1
b. 1:1
c. 1:2
d. 4:1
e. 2:3

ANS: B DIF: Medium REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Applied

84. In fluorite, __________

a. cations are smaller than the anions, and there are two cations for every anion.
b. anions are smaller than the cations, and there are two anions for every cation.
c. cations are smaller than the anions, and there are two anions for every cation.
d. anions are smaller than the cations, and there are two cations for every anion.
e. anions and cations are the same size.

ANS: C DIF: Difficult REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Factual

85. In antifluorite structures, __________

a. cations are smaller than the anions, and there are two cations for every anion.
b. anions are smaller than the cations, and there are two anions for every cation.
c. cations are smaller than the anions, and there are two anions for every cation.
d. anions are smaller than the cations, and there are two cations for every anion.
e. anions and cations are the same size.

ANS: A DIF: Difficult REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Factual

86. If a salt has a face-centered cubic (fcc) unit cell and a 1:2 cation:anion stoichiometry with cations occupying the fcc positions, then the anions fill all the __________ holes.

a. cubic
b. octahedral
c. tetrahedral
d. octahedral and tetrahedral
e. cubic, octahedral, and tetrahedral

ANS: C DIF: Difficult REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Conceptual

87. A salt with the formula AB has a ratio of its ions' radii A/B = 0.28. Which structure is it likely to adopt?

a. rock salt
b. sphalerite
c. fluorite
d. cubic
e. There is insufficient data to determine the structure.

ANS: B DIF: Easy REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Conceptual

88. What is the likely unit cell for ionic compounds of 1:1 stoichiometry in which the *difference* in the radii is only about 25% or less?

a. rock salt
b. sphalerite
c. fluorite
d. cubic
e. antifluorite

ANS: A DIF: Medium REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Applied

89. The center of a cubic hole is found __________

a. at the center of a simple cubic lattice.
b. on the edges of a simple cubic lattice.

c. on the faces of a body-centered cubic lattice.
d. at the center of a face-centered cubic lattice.
e. at eight sites within a face-centered cubic lattice.

ANS: A DIF: Easy REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Factual

90. A ceramic is a chemically resistant and heat-resistant solid produced by heating __________

a. compounds containing cerium.
b. clays.
c. sand and water.
d. any compound containing aluminum and sulfur.
e. mixtures containing yttrium and barium.

ANS: B DIF: Easy REF: 12.7
OBJ: Identify the meaning of a ceramic. MSC: Factual

91. Firing of a kaolinite clay object to make a ceramic results in __________

a. loss of water but not SiO_2.
b. loss of SiO_2 but not water.
c. loss of water and SiO_2.
d. loss of neither water nor SiO_2.

ANS: C DIF: Medium REF: 12.7
OBJ: Identify the meaning of a ceramic. MSC: Factual

92. Silicon dioxide exists as __________

a. a covalent network solid.
b. a metallic solid.
c. a semimetallic solid.
d. a molecular solid.
e. all the above

ANS: A DIF: Medium REF: 12.7
OBJ: Identify common polymorphs of silicon dioxide. MSC: Factual

93. Substances like silicon dioxide that can have the same empirical formula but different crystal structures and properties are termed __________

a. allotropes.
b. allopmorphs.
c. isomorphs.
d. isotopes.
e. polymorphs.

ANS: C DIF: Medium REF: 12.7
OBJ: Identify the meaning of polymorph. MSC: Factual

94. Glass is a term used to describe any solid that is __________

a. crystalline.
b. amorphous.
c. a liquid crystal.
d. a crystalline liquid.
e. transparent.

ANS: B DIF: Easy REF: 12.7
OBJ: Identify common polymorphs of silicon dioxide. MSC: Factual

95. The thermal and electrical insulating qualities of ceramics can be explained by __________

a. significant band gaps.
b. small band gaps.
c. Cooper pairs.
d. the Meissner effect.
e. the low conductivity of positively charged holes.

ANS: A DIF: Medium REF: 12.7
OBJ: Identify key characteristics of the band structure of insulators. MSC: Factual

96. Ceramic insulators __________

a. do not have a band structure.
b. have a band structure, but no electrons are in these bands.
c. have two half-filled bands neither of which is capable of conducting electricity.
d. have a full band that is well separated in energy from an empty band.
e. do not exist as all ceramics are good thermal and electrical conductors

ANS: D DIF: Difficult REF: 12.7
OBJ: Identify key characteristics of the band structure of insulators. MSC: Factual

97. Superconductivity involves the formation of __________

a. electron tunnels.
b. phase-matched electron waves.
c. Cooper pairs.
d. electron yokes.
e. Meissner couples.

ANS: C DIF: Easy REF: 12.7
OBJ: Identify the meaning of a Cooper pair. MSC: Factual

98. Why are ceramic superconductors not currently practical for widespread transmission of electricity?

I. They are relatively expensive in comparison to metals.
II. They require extremely cold temperatures.
III. They are brittle and lack ductility.

a. I only
b. II only
c. III only
d. I and II only
e. I, II, and III

ANS: E DIF: Medium REF: 12.7
OBJ: Identify the key characteristics of superconductivity. MSC: Factual

99. What similarities are there in the motion of electrons about an atom and electrons being conducted in a superconducting ceramic?

a. The electrons move in circular orbits.
b. Two electrons move in opposite directions but with the same path.
c. The electrons move without loss of kinetic energy.
d. The electrons move in all directions at once like light.
e. The electrons move in Cooper pairs.

ANS: C DIF: Difficult REF: 12.7
OBJ: Identify the key characteristics of superconductivity. MSC: Conceptual

100. The Meissner effect is __________

a. the repulsion of a superconductor by a magnetic field.
b. the scattering of electrons in ceramics.
c. the tunneling of electrons through a solid.
d. the acceleration of electrons in a particle accelerator.
e. the superconduction of materials below their critical temperature.

ANS: A DIF: Medium REF: 12.7
OBJ: Identify the meaning of the Meissner effect. MSC: Factual

101. The property of superconducting ceramics that makes them a potential technology for levitating trains is __________

a. antigravity.
b. the Meissner effect.
c. Brownian motion.
d. resistive heating.
e. Cooper pairing of yttrium and barium.

ANS: B DIF: Medium REF: 12.7
OBJ: Identify the meaning of the Meissner effect. MSC: Factual

102. Yttrium–barium–copper oxides are ceramics with __________

a. photovoltaic properties.
b. superstitial substitution sites.
c. superconductivity at moderately low temperatures.
d. liquid crystalline properties.
e. All of the above.

ANS: C DIF: Easy REF: 12.7
OBJ: Identify common superconducting materials. MSC: Factual

103. Just as visible light is diffracted by the finely spaced grooves on a CD, electromagnetic radiation in the __________ range has the appropriate wavelength to be diffracted by atoms and electron density in a crystalline lattice.

a. UV-A
b. UV-B
c. X-ray
d. gamma-ray
e. microwave

ANS: C DIF: Easy REF: 12.8
OBJ: Identify the meaning of X-ray diffraction. MSC: Factual

104. X-ray diffraction (XRD) makes use of the Bragg equation in which θ is the __________

a. wavelength of the X-ray.
b. the distance between layers of identical particles in the lattice.
c. the angle of incidence of the X-ray beam.
d. the dimension of the unit cell.
e. angle of diffraction of the X-ray beam.

ANS: C DIF: Easy REF: 12.8
OBJ: Identify the meanings of the angles of incidence, refraction, and diffraction.
MSC: Factual

105. If an X-ray with a wavelength of 154 pm is diffracted at an angle $2\theta = 14.6°$, according to the Bragg equation ($n\lambda = 2\ d \sin\theta$), what is the distance between layers of the crystal that give rise to this diffraction? Assume $n = 1$ in this problem.

a. 610.9 pm
b. 305.5 pm
c. 606.0 pm
d. 1212 pm
e. 198.1 pm

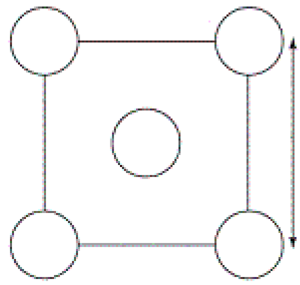
ANS: C DIF: Medium REF: 12.8
OBJ: Determine the angle of incidence, wavelength, spacing d, or order n from the other three.
MSC: Applied

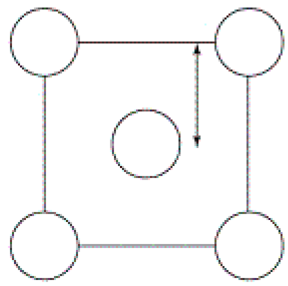
106. In an XRD analysis using a wavelength of 154 pm, a crystalline sample of a layered $VO(PO_4)(H_2O)$ structure gave peaks at 24.2°, 36.3°, and 48.4°. What is likely to be the value of the distance between the layers?

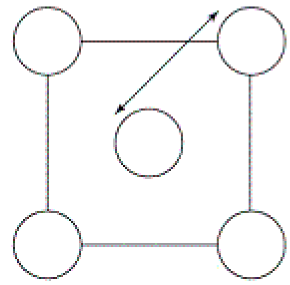
a. 731 pm
b. 367 pm
c. 103 pm
d. 188 pm
e. 55.1 pm

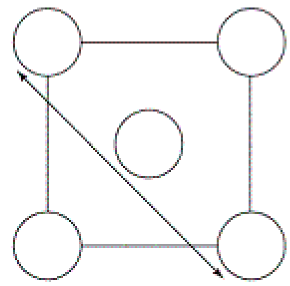
ANS: A DIF: Difficult REF: 12.8
OBJ: Determine the angle of incidence, wavelength, spacing d, or order n from the other three.
MSC: Applied

107. The XRD scan of the face-centered cubic (fcc) structure of sodium chloride showed that there was a distance of 562.8 pm between "layers of ions." Given that the fcc unit cell has a volume of $178.26 \times 10^{-24}\ cm^3$, to which distance does the 562.8 pm correspond?

a. 

b. 

c. 

d. 

ANS: A DIF: Difficult REF: 12.8
OBJ: Determine the angle of incidence, wavelength, spacing d, or order n from the other three.
MSC: Applied

SHORT ANSWER

1. According to band theory, when the lower energy __________ band overlaps with the higher energy __________ band, the material will act as a __________ of electricity.

   ANS:
   valence, conduction, conductor

   DIF: Easy REF: 12.1
   OBJ: Identify the relationship between valence and conductance bands in metals.
   MSC: Factual

2. According to band theory, when the lower energy __________ band is separated from the higher energy __________ band by a small band gap, the material will act as a __________ of electricity.

   ANS:
   valence, conduction, semiconductor

   DIF: Easy REF: 12.2
   OBJ: Identify the relationship between valence and conductance bands in semiconductors.
   MSC: Factual

3. According to band theory, when the lower energy __________ band is separated from the higher energy __________ band by a large band gap, the material will act as a __________ of electricity.

   ANS:
   valence, conduction, nonconductor

   DIF: Easy REF: 12.7
   OBJ: Identify the relationship between valence and conductance bands in insulators.
   MSC: Factual

4. In a simple cubic cell there is/are __________ atom(s), in a face-centered cubic cell there is/are __________ atom(s), and in a body-centered cubic cell there is/are __________ atom(s).

ANS:
1, 4, 2

DIF: Easy REF: 12.3 OBJ: Determine the number of atoms in a unit cell.
MSC: Factual

5. For an alloy composed of two elements whose composition can be variable, if the radii of the two elements are approximately the same, the alloy is most likely to be a(n) __________ alloy, while if the radii are significantly different, the alloy is most likely to be a(n) __________ alloy.

ANS:
substitutional, interstitial

DIF: Easy REF: 12.4
OBJ: Identify the meaning of a substitutional alloy, interstitial alloy, or intermetallic compound.
MSC: Factual

6. Graphite and diamond are examples of __________ solids; sulfur and white phosphorus are examples of __________ solids; and sodium chloride and zinc sulfide are examples of __________ solids.

ANS:
network covalent, molecular, ionic

DIF: Easy REF: 12.5 | 12.6 OBJ: Classify a solid as network covalent, molecular, or ionic.
MSC: Factual

7. In ionic solids, one ion often occupies holes in the unit cell defined by the other ion. In a simple cubic cell, what are the types of holes that are found and the number of holes of each type?

ANS:
type: cubic; number: 1

DIF: Easy REF: 12.3 | 12.6
OBJ: Identify the number and arrangement of octahedral, tetrahedral, and cubic holes in a unit cell.
MSC: Factual

8. In ionic solids, one ion often occupies a hole in the unit cell defined by the other ion. In a face-centered cubic cell, what are the types and numbers of each hole?

ANS:
type: tetrahedral; number: 8; type: octahedral; number: 12

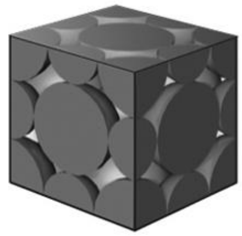
DIF: Medium REF: 12.3 | 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Factual

9. In ionic solids, one ion often occupies a hole in the unit cell defined by the other ion. In a body-centered cubic cell, what are the types and numbers of each hole?

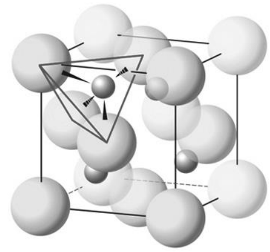
ANS:
type: octahedral; number: 6

DIF: Difficult REF: 12.3 | 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Applied

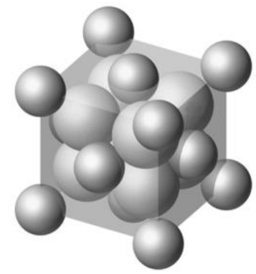
10. Consider the three unit cells below for ionic solids. In each unit cell, one of the ions is arranged in one of the standard unit cell structures while the other is found between these sites. What are the names of the minerals associated with each of these structures? I __________; II __________; III __________.



I
In addition to the ions shown, there is another at the very center of the unit cell



II
There are 14 large and 4 small ions depicted.



III
There are 14 small and 8 large ions depicted.

ANS:
rock salt (halite), sphalerite, fluorite

DIF: Medium REF: 12.6
OBJ: Identify and compare various structures for ionic compounds. MSC: Factual

11. In the Bragg equation, θ refers to the angle of __________ or __________and 2θ refers to the angle of __________.

ANS:
incidence, reflection, diffraction

DIF: Easy REF: 12.8
OBJ: Identify the meanings of the angles of incidence, refraction, and diffraction.
MSC: Factual

12. When Si is doped with P, it produces a(n) __________ -type semiconductor.

ANS:
n

DIF: Easy REF: 12.2 OBJ: Determine the type of a particular semiconductor.
MSC: Applied

13. When Ge is doped with Ga, it produces a(n) __________ -type semiconductor.

ANS:
p

DIF: Easy REF: 12.2 OBJ: Determine the type of a particular semiconductor.
MSC: Applied

14. The alpha form of polonium (Po) crystallizes as a simple cubic unit cell with an edge length of 335 pm. What is the atomic radius of polonium in picometers?

ANS:
168 pm

DIF: Easy REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

15. The alpha form of polonium (Po) has a density of 9.196 g/cm^3 and crystallizes in a simple cubic structure. What is the atomic radius of polonium in picometers?

ANS:
168 pm

DIF: Difficult REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

16. If a face-centered cubic unit cell has a volume of 1.447×10^8 pm^3 and the ions at the corners touch the ion on the face, what must be the ion's radius in picometers?

ANS:
186 pm

DIF: Difficult REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

17. Aluminum (Al) crystallizes as a face-centered unit cell with an edge length of 404 pm. What is the atomic radius of aluminum in picometers?

ANS:
143 pm

DIF: Medium REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

18. Aluminum (Al) has a density of 2.70 g/cm^3 and crystallizes in a face-centered cubic structure. What is the unit cell edge length in picometers?

ANS:
405 pm

DIF: Difficult REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

19. Gold (Au) has a face-centered cubic structure with a unit cell edge length of 407.8 pm. What is the calculated value of the density of gold in g/cm^3 based on this information?

ANS:
19.3 g/cm^3

DIF: Medium REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

20. Gold has a face-centered cubic structure with a unit cell edge length of 407.8 pm. What is the density *of each individual gold atom* in g/cm^3?

ANS:
26.2 g/cm^3

DIF: Difficult REF: 12.3
OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
MSC: Applied

21. If a body-centered cubic unit cell has a volume of 1.447×10^8 pm^3, what must be the dimension of the cube's edge in picometers?

    ANS:
    525 pm

    DIF: Easy REF: 12.3 OBJ: Interconvert volume and edge length of cubic unit cells.
    MSC: Applied

22. Iron (Fe) crystallizes as a body-centered unit cell with an edge length of 287 pm. What is the atomic radius of iron in picometers?

    ANS:
    126 pm

    DIF: Difficult REF: 12.3
    OBJ: Interrelate unit cell type, atomic radius, cell dimensions, and density.
    MSC: Applied