Solid State

Solid State Characteristics

1. Solid state is denser than the liquid and gaseous states of the same substance. Which of the following is an exception to this rule?

a) Mercury

b) Carbon dioxide (dry ice)

c) Ice

d) NaCl

Ans : c

Explanation: The density of ice is about 0.92 g/cm^3 while that of water is 1 g/cm^3. Mercury has density 14.184 g/cm^3 as solid and 13.69 g/cm^3 as liquid. Carbon dioxide has density 1.56 g/cm^3 as solid and 1.10 g/cm^3 as liquid. NaCl has density 2.71 g/cm^3 as solid and 1.556 g/cm^3 in molten state. Therefore only ice has lesser density as a solid than as a liquid.

2. Which of the following can be used to describe a crystalline solid?

a) Heterogeneous, anisotropic

b) Homogeneous, anisotropic

c) Heterogeneous, isotropic

d) Homogeneous, isotropic

Ans : b

Explanation : Homogeneity refers to uniformity in composition, which is a characteristic property of crystalline solids. Isotropy is when the values of physical properties do not change with direction throughout the body of the solid. Crystalline solids are anisotropic because the composition of the solid changes with direction, hence the physical properties also change with direction.

3. When a single substance can crystallize in two or more forms under different conditions provided, it is called as _________

a) Polymorphous

b) Isomorphous

c) Semimorphous

d) Multimorphous

Ans : a
Explanation : Isomorphous is when two or more substances have the same crystal structure. Polymorphous is when a single substance can crystallize in two or more forms depending upon the conditions.

4. Which of the following is an amorphous solid?

a) Quartz

b) Quartz glass

c) Graphite

d) Salt (NaCl)

Ans : b
Explanation : Quartz glass does not have a perfectly ordered structure, hence it is classified as an amorphous solid. The rest are crystalline solids due to ordered structures.

5. Amorphous solids are actually super cooled liquids.

a) True

b) False

Ans : a
Explanation : Amorphous solids behave like fluids and flow very slowly under the influence of gravity. Hence, they are said to be super cooled liquids.

6. Which type of solid structure melts at a definite, sharp melting point?

a) All types of solids

b) No type of solid

c) Amorphous solids

d) Crystalline solids

Ans : d
Explanation : Crystalline solids have a perfectly ordered structure which collapses

immediately at a specific temperature. Amorphous solids melt over a range of temperatures, not one specific value.

7. Which of the following describes a general solid?

a) Compressible

b) Incompressible

c) Fluid

d) Semi-compressible

Ans : b
Explanation : The intermolecular forces of attraction in a solid are very strong, making it incompressible. Gases are highly compressible, while liquids are semi-compressible. Fluid is a property of a substance that can 'flow'.

8. _________ is the basic repeated structural unit of a crystalline solid.

a) Monomer

b) Molecule

c) Unit cell

d) Atom

Ans : c
Explanation : Crystalline solids are composed of many small crystals, each of which is called a unit cell. It is a specific term. Monomer is the basic unit for a polymer, and atoms make up molecules, which can further arrange themselves to form solids, liquids or gases.

9. Which of the following statements is true for an amorphous solid?

a) Long range order is present

b) Short range order is present

c) There is no orderly arrangement

d) Complete order is present at lower temperatures

Ans : b
Explanation : For an amorphous solid there is short range order present which is independent of the temperature. Long range order is present in crystalline solids.

10. Sulfur exists in two polymorphic forms ____________ and ______________

a) rhombic and monoclinic

b) rhombic and triclinic

c) hexagonal and triclinic

d) hexagonal and monoclinic

Ans : a
Explanation : There are two polymorphous structures of sulfur, rhombic and monoclinic. Polymorphous structures occur when a single substance can crystallize in two or more forms depending upon the conditions.

Amorphous and Crystalline Solids

1. In polar molecular solids, the molecules are held together by ________

a) dipole-dipole interactions

b) dispersion forces

c) hydrogen bonds

d) covalent bonds

Ans : a

Explanation : Molecular solids are solids that are collections of molecules held together by intermolecular forces. In polar molecules such as HCl, So2, etc., the molecules are held together by dipole-dipole interactions.

2. Diamond is an example of _______

a) solid with hydrogen bonding

b) electrovalent solid

c) covalent solid

d) glass

Ans : c

Explanation : The solids in which constituent particles are attached to each other by covalent bonds are called covalent solids. Diamond, graphite, silicon, SiC, AIN, quartz are examples of covalent solids.

3. Silicon is found in nature in the forms of ________

a) body-centered cubic structure

b) hexagonal-closed packed structure

c) network solid

d) face-centered cubic structure

Ans : c

Explanation : Silicon due to its catenation property form network solid. Catenation is the ability of an atom to form bonds with other atoms of the same element. The compounds of silicon are reactive and not stable.

4. Which one of the following are the dimensions of cubic crystal?

a) $a = b \neq c$

b) $a = b = c$ and $\alpha = \beta \neq \gamma = 90$

c) $a = b = c$ and $\alpha = \beta = \gamma = 90$

d) $a \neq b = c$ and $\alpha = \beta \neq \gamma = 90$

Ans : c

Explanation : The dimensions of a cubic crystals are $a = b = c$, $\alpha = \beta = \gamma = 90$.

5. Which of the following is not a crystal system?

a) Cubic

b) Trigonal

c) Triclinic

d) Hexaclinic

Ans : d

Explanation : Hexaclinic is not a crystal system. Their crystal system are cubic, tetragonal, rhombohedral or trigonal, orthorhombic or rhombic, monoclinic, triclinic and hexagonal.

6. In face-centred cubic cell, a unit cell is shared equally by __________

a) four unit cells

b) two unit cells

c) one unit cell

d) six unit cells

Ans : d

Explanation : The unit cell in which atoms are present at corners as well as faces of unit cell is known as face-centred cubic unit cell. In face-centred cubic cell, a unit cell is shared equally by six unit cells.

7. The unit cell with $a \neq b \neq c$ and $\alpha=\beta=\gamma=90$ refers to __________ crystal system.

a) hexagonal

b) trigonal

c) triclinic

d) orthorhombic

Ans : d

Explanation : In orthorhombic crystal system, all three axes are unequal in length and all are perpendicular to one another. It is also called as rhombic crystal system. Topaz, barite are some examples of orthorhombic crystals.

8. Which is the most unsymmetrical crystal system?

a) Triclinic crystal system

b) Cubic crystal system

c) Hexagonal crystal system

d) Trigonal crystal system

Ans : a

Explanation : Most unsymmetrical crystal system is triclinic in which all three axes are unequal in length none is perpendicular to another. Triclinic unit cells has the least symmetrical shape of all unit cells. Turquoise is an example of triclinic crystal.

9. In the simple cubic cell, each corner atom is shared by __________

a) eight unit cells

b) one unit cell

c) two unit cells

d) six unit cells

Ans : a

Explanation : The unit cell in which the constituent atoms are present only at the corner is known as simple cubic cell. It is also referred to as a primitive cubic cell. In the simple cubic cell, each corner atom is shared by eight different unit cells.

10. The points which shows the position of atoms in crystal are called as _________

a) crystal lattice

b) crystal parameters

c) bravais lattice

d) lattice point

Ans : d

Explanation : The point at which the atoms may be present on the unit cell is termed as lattice point. It shows the position of atoms in crystal.

11. The unit cell with $a \neq b \neq c$ and $\alpha = \gamma = 90$, $\beta \neq 90$ refers to __________crystal system.

a) cubic

b) tetragonal

c) monoclinic

d) triclinic

Ans : c

Explanation : In monoclinic crystal system, all the three axes are unequal in length and two axes are perpendicular to each other. Gypsum and borax are examples of monoclinic crystals.

12. Which type of solid crystals will conduct heat and electricity?

a) Ionic

b) Covalent

c) Molecular

d) Metallic

Ans : d

Explanation : Metallic crystals consist of metal cations surrounded by a sea of mobile valence electrons. These electrons are capable of moving through the entire crystal. The metallic crystals conduct heat and electricity due to the presence of these mobile electrons in them.

13. Which is not a characteristic of crystalline solids?

a) They undergo a clean cleavage

b) They are true solids

c) They are isotropic

d) They have sharp melting points

Ans : c

Explanation : Amorphous solids are isotropic that is they have identical properties in all directions, whereas crystalline solids are anisotropic that is they have different properties in different directions.

14. Which of the following is a characteristic of amorphous solid?

a) They are true solids

b) They have sharp melting points

c) They undergo clear cleavage

d) They are isotropic

Ans : d

Explanation : Amorphous solids are isotropic that is they have identical properties in all directions. The remaining options are the characteristics of crystalline solids.

15. Solids are classified as ___________

a) crystalline and ionic solids

b) metallic and amorphous solids

c) molecular and covalent solids

d) crystalline and amorphous solids

Ans : d

Explanation : Based on their crystal structures, solids are classified as crystalline and amorphous solids. In crystalline solids, the constituent particles are arranged in a regular manner. In amorphous solids, the constituent particles are not arranged in any regular manner.

16. Quartz is an example of ___________

a) molecular solids

b) ionic solids

c) covalent solids

d) metallic solids

Ans : c

Explanation : Quartz is a common example of covalent solids. In covalent solids, the constituent particles are attached to each other by covalent bonds. Diamond, graphite, silicon are other examples of covalent solids.

17. Solid carbon dioxide is an example of ________

a) metallic crystal

b) covalent crystal

c) ionic crystal

d) molecular crystal

Ans : d

Explanation : Solid CO_2 is an example of molecular crystal. These solids have molecules as their constituent particles. These solids may be bonded by vander waals' forces or by dipole-dipole attraction or by strong hydrogen bonds. H_2, Cl_2 , I_2 are some examples of molecular solids.

Classification of Crystalline Solids

1. Which of the following consists of either atoms or molecules formed by non polar covalent bonds?

a) Non polar molecular solid

b) Metallic solid

c) Polar molecular solid

d) Ionic solid

Ans : a

Explanation : Non polar molecular solids consists of either of the atoms or molecules formed by non polar covalent bonds. Metallic solids and ionic solids consist of free mobile electrons and ions respectively. Whereas polar molecular solids are formed by polar covalent bonds.

2. Polar molecular solids are _________

a) bad conductors of electricity

b) good conductors of electricity

c) solid at room temperature

d) brittle

Ans : a

Explanation : In polar molecular solids, the molecules are formed by covalent bonds and held together by strong dipole-dipole interaction. Therefore, polar molecular solids are non-conductors of electricity.

3. The molecules in polar molecular solid are held together by _________

a) dipole-dipole interaction

b) london forces

c) ionic bond

d) metallic bond

Ans : a

Explanation : The force responsible for holding together the molecules of polar molecular solids is dipole-dipole force of attraction. Polar molecular solids are non-conductors of electricity.

4. Which of the following tend to be volatile liquids or soft solids at room temperature and pressure?

a) Non polar molecular solids

b) Metallic solids

c) Polar molecular solids

d) Hydrogen bonded molecular solids

Ans : d

Explanation : In hydrogen bonded molecular solid, the intermolecular forces are strong hydrogen bonds. Hence, it tends to be volatile liquids or soft solids at room temperature and pressure.

5. Which type of solids are formed by three-dimensional arrangement of cations and anions bound by strong electrostatic force?

a) Polar molecular solids

b) Ionic solids

c) Covalent solids

d) Metallic solids

Ans : b

Explanation : Ionic solids are made up of three dimensional arrangement of cations and anions bound by strong electrostatic force.

6. Which of the following is non-conductor of electricity at solid state but can conduct electricity in the molten state or when dissolved in water?

a) Non polar molecular solids

b) Metallic solids

c) Ionic solids

d) Hydrogen bonded molecular solids

Ans : c

Explanation : Ionic Solids, when dissolved in water, tend to separate cations and the anions which allows the solution to conduct electricity. Also, they have high melting and boiling points.

7. Which of the following is an orderly collection of positive ions surrounded and held together by a sea of electrons?

a) Gas

b) Non-metal

c) Metal

d) Metalloids

Ans : c

Explanation : Metal is said to be an orderly collection of positive ions surrounded and held together by a sea of delocalized electrons. These delocalized electrons are mobile and are responsible for the conduction of electricity.

8. Which of the following are responsible for high electrical and thermal conductivity of a metal?

a) Ions

b) Covalent bonds

c) Free H+ ions

d) Free and mobile electrons

Ans : d

Explanation : Each atom of a metal gives one or more electrons towards the sea of mobile electrons it is surrounded by which ultimately contributes to the electrical and thermal conductivity of the metal.

9. Which of the following is not a characteristic of metals?

a) Lustre

b) Ductile

c) Malleable

d) Brittle

Ans : d

Explanation : Metals are lustrous, ductile and malleable. They cannot be brittle. Non-metals tend to be brittle in their solid state.

10. Which type of crystalline solid is also called as giant molecules?

a) Ionic solids

b) Covalent solids

c) Polar molecular solids

d) Metallic solids

Ans : b

Explanation : Covalent solids consists of a long chain of covalent bonds between the adjacent molecules throughout the crystal. Hence, they are called giant molecules. They are hard and brittle in nature.

Crystal Lattices and Unit Cells

1. Which of the following is regarded as the 'repeatable entity' of a 3D crystal structure?

a) Unit cell

b) Lattice

c) Crystal

d) Bravais Index

Ans : a

Explanation : Unit cell is the smallest entity of a crystal lattice which, when repeated in space (3 dimensions) generates the entire crystal lattice. Lattice comprises of the unit cells which hold all the particles in a particular arrangement in 3 dimensions. Crystal is a piece of homogenous solid and Bravais indices are used to define planes in crystal lattices in the hexagonal system.

2. Which of the following unit cells has constituent particles occupying the corner positions only?

a) Body-centered cell

b) Primitive cell

c) Face centered cell

d) End-centered cell

Ans : b

Explanation : According to classification of unit cells, a primitive unit cell is one which has all constituent particles located at its corners. BCC has one particle present at the center including the corners. FCC has an individual cell shared between the faces of adjacent cells. End centered cells have cells present at centers of two opposite faces.

3. What is the coordination number of a body-centered unit cell?

a) 6

b) 12

c) 8

d) 4

Ans : c

Explanation : Coordination number of a unit cell is defined as the number of atoms/ions that surround the central atom/ion. In the case of BCC, the central particle is surrounded by 8 particles hence, 8.

4. Which of the following arrangements of particles does a simple cubic lattice follow?

a) ABAB

b) AABB

c) ABCABC

d) AAA

Ans : d

Explanation : Simple cubic lattice results from 3D close packing from 2D square-packed layers. When one 2D layer is placed on top of the other, the corresponding spheres of the second layer are exactly on top of the first one. Since both have the same, exact arrangement it is AAA type.

5. If a crystal lattice has 6 closed-pack spheres, what the number of tetrahedral voids in the lattice?

a) 12

b) 6

c) 36

d) 3

Ans : a

Explanation : For a crystal lattice, if there are N close-packed spheres the number of tetrahedral voids are 2N and number octahedral voids are N. For N=6, number of tetrahedral voids = $2 \times 6 = 12$.

6. Which of the following possess anisotropic nature within their structure?

a) Hair wax

b) Snowflakes

c) Polythene

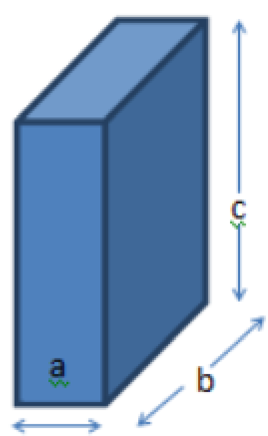
d) Crystal glass

Ans : b

Explanation : Crystalline solids possess anisotropic nature within their structure. Anisotropy is the directional dependence of a property. Meaning, a property within the crystal structure will have different values when measured in different directions. Snowflake is a crystalline solid whereas the rest are amorphous solids.

7. Identify the dimensional relation for the unit cell illustrated below.

Find the dimensional relation for the unit cell from the given diagram



a) $a = b = c$

b) $a = b \neq c$

c) $a \neq b \neq c$

d) $a \neq b = c$

Ans : c

Explanation : The given figure represents an orthorhombic unit cell. Experimentally, it is determined that for orthorhombic unit cells $a \neq b \neq c$. All sides are unequal. It results from extension of cube along two pairs of orthogonal sides by two distinct factors.

8. A compound is formed by atoms of elements A occupying the corners of the unit cell and an atom of element B present at the center of the unit cell. Deduce the formula of the compound.

a) AB_2

b) AB_3

c) AB_4

d) AB

Ans : d

Explanation : The description is of a BCC. For BCC, each atom at the corner is shared by 8 unit cells. One atom at the center wholly belongs to the corresponding unit cell.

Therefore, total number of atoms of A present=1/8 x 8=1

Total number of atoms of B present=1

Therefore, A:B=1:1 implying the formula of the compound is AB.

9. Atoms of element X form a BCC and atoms of element Y occupy 3/4th of the tetrahedral voids. What is the formula of the compound?

a) X_2Y_3

b) X_3Y_2

c) X_3Y_4

d) X_4Y_3

Ans : a

Explanation : The number of tetrahedral voids form is equal to twice the number of atoms of element X. Number of atoms of Y is 3/4th the number of tetrahedral voids i.e. 3/2 times the number of atoms of X. Therefore, the ratio of numbers of atoms of X and Y are 2:3, hence X_2Y_3.

10. What is the total volume of the particles present in a body centered unit cell?

a) $8\pi r^3$

b) $8/3\pi r^3$

c) $16/3\pi r^3$

d) $32/3\pi r^3$

Ans : b

Explanation : Since particles are assumed to be spheres and volume of one sphere is $4/3\pi r^3$, total volume of all particles in BCC = $2 \times 4/3\pi r^3 = 8/3\pi r^3$ since a BCC has 2 particles per cell.

11. If the aluminum unit cell exhibits face-centered behavior then how many unit cells are present in 54g of aluminum?

a) 1.2042×10^{24}

b) 5.575×10^{21}

c) 3.011×10^{23}

d) 2.4088×10^{24}

Ans : c

Explanation: Atomic mass of Al = 27g/mole (contains 6.022×10^{23} Al atoms)
Since it exhibits FCC, there are 4 Al atoms/unit cell.
If 27g Al contains 6.022×10^{23} Al atoms then 54g Al contains 1.2044×10^{24} atoms.
Thus, if 1 unit cell contains 4 Al atoms then number of unit cells containing 1.2044×10^{24} atoms=$(1.2044 \times 10^{24} \times 1)/4 = 3.011 \times 10^{23}$ unit cells.

12. What is the radius of a metal atom if it crystallizes with body-centered lattice having a unit cell edge of 333 Pico meter?

a) 1538.06 pm

b) 769.03 pm

c) 288.38 pm

d) 144.19 pm

Ans : d

Explanation : For body-centered unit cells, the relation between radius of a particle 'r' and edge length of unit cell 'a' is given as $\sqrt{3}/4a=r$

On substituting the values we get r = $\sqrt{3}/4 \times 333$ pm = 144.19 pm is the radius of the metal atom.

13. How many parameters are used to characterize a unit cell?

a) Six

b) Three

c) Two

d) Nine

Ans : a

Explanation : A unit cell is characterized by six parameters i.e. the three common edge lengths a, b, c and three angles between the edges that are α, β, γ. These are referred to as inter-axial lengths and angles, respectively. The position of a unit cell can be determined by fractional coordinates along the cell edges.

14. What is each point (position of particle) in a crystal lattice termed as?

a) Lattice index

b) Lattice point

c) Lattice lines

d) Lattice spot

Ans : a

Explanation : Each point of the particle's position is referred to as 'lattice point' or 'lattice site'. Every lattice point represents one constituent particle which may be an atom, ion or molecule.

15. If a metal forms a FCC lattice with unit edge length 500 pm. Calculate the density of the metal if its atomic mass is 110.

a) 2923 kg/m^3

b) 5846 kg/m^3

c) 8768 kg/m^3

d) 1750 kg/m^3

Ans : b

Edge length (a) = 500 pm = 500 x 10^{-12} m

Atomic mass (M) = 110 g/mole = 110 x 10^{-3} kg/mole

Avogadro's number (N_A) = 6.022 x 10^{23}/mole

z = 4 atoms/cell

The density, d of a metal is given as d=$\frac{zM}{a^3 N_A}$

On substitution, d=$\frac{4\times110\times10^{-3}}{(500\times10^{-12})^3\times6.022\times10^{23}}$=5846 kg/m^3.

Number of Atoms in a Unit Cell

1. In primitive unit cubic cell, only _______ of an atom (or ion or molecule) belongs to a particular unit cell.

a) 1/4th

b) 1/3rd

c) 1/8th

d) 1/2nd

Ans : c

Explanation : In primitive unit cubic cell, each atom at the corner is shared between 8 adjacent unit cells. Thus, only 1/8th of an atom (or ion or molecule) belongs to a particular unit cell.

2. The total number of atoms in one unit cell of primitive unit cubic cell is ______ atom(s).

a) 1

b) 8

c) 4

d) 2

Ans : a

Explanation : In primitive cubic unit cell, atoms are present only at the corner of the cell. Thus, in actual, only 1/8th of an atom (or ion or molecule) belongs to a particular unit cell. Hence, the total number of atoms in primitive cubic unit cell = 8 × 1/8 = 1 atom.

3. The total number of atoms in one unit cell of body-centered unit cubic cell is ______ atoms.

a) 4

b) 3

c) 8

d) 2

Ans : d

Explanation : In body-centered cubic unit cell, one atom is present at each of the corners and one atom at its body center.

• 8 corners × 1/8th of an atom = 1

• 1 body-centered atom

Thus, the total number of atoms in body-centered cubic unit cell: 1+1=2 atoms.

4. The total number of atoms in one unit cell of face-centered unit cubic cell is ______ atoms.

a) 2

b) 6

c) 4

d) 8

Ans : c

Explanation : In face-centered cubic unit cell, atoms are present at each of the corners and at the centre of the face of the cube.

• 8 corners × 1/8th of an atom = 1

• 6 faces × 1/2 of an atom = 3

Thus, the total number of atoms in face-centered cubic unit cell: 1+3=4 atoms.

Close Packed Structures

1. In ______ constituent particles are closely packed leaving the least amount of vacant spaces.

a) plasma

b) liquids

c) solids

d) gases

Ans : c

Explanation : In solids, the constituent particles tend to be closely packed due to strong forces between them. Hence, solids are stable and have a definite shape.

2. What is the coordination number for one-dimensional close packing?

a) 2

b) 1

c) 4

d) 6

Ans : a

Explanation : In one-dimensional close packing, the constituent particles are assumed to be arranged in a row. Thus, each constituent particle comes in contact with 2 of its neighbors and thereby giving the coordination number 2.

3. In how many ways, can the two-dimensional close packed structure be generated?

a) 3

b) 2

c) 1

d) 5

Ans : b

Explanation : Two-dimensional close packed structure can be generated using the one-dimensional close packed structures. This can be done in 2 ways:

• By placing one row of one-dimensional structure below another in such a way that the spheres are one below the another.

• By placing one row of one-dimensional structure below another such that spheres of second row fit in the depressions of the first row.

4. What is the coordination number for a two-dimensional square close packed structure?

a) 8

b) 4

c) 6

d) 2

Ans : b

Explanation : In a two-dimensional square close packed structure, each sphere is in contact with 4 of its adjacent spheres. Hence, it has coordination number 4.

5. What is the coordination number for a two-dimensional hexagonal close packed structure?

a) 4

b) 8

c) 12

d) 6

Ans : d

Explanation : In a two-dimensional hexagonal close packed structure, each sphere is in direct contact with 6 of its adjacent spheres. Hence, it has coordination number 6.

6. Voids in two-dimensional hexagonal close packed structure are ___________ in shape.

a) circular

b) rectangular

c) triangular

d) hexagonal

Ans : c

Explanation : Two-dimensional hexagonal close packed structure are formed when one row of a one-dimensional structure is placed below another in such a way that spheres of second row fit in the depressions of the first row and thereby creating triangular voids between them.

Packing Efficiency

1. What does the ratio 'space occupied/total space' denote?

a) Packing factor

b) Packing efficiency

c) Particle fraction

d) Packing unit

Ans : a

Explanation : Packing factor is a fraction of total space of the unit cell occupied by the constituent particles.

2. What is the dimensional formula of packing fraction?

a) $M^0L^3T^0$

b) $M^0L^0T^0$

c) ML^0T^0

d) $M^0L^2T^0$

Ans : b

Explanation : Packing fraction is a dimensionless quantity which is the ratio of space occupied to total crystal space available. Since both the quantities have the same units the ratio renders dimensionless.

3. Arrange the types of arrangement in terms of decreasing packing efficiency.

a) BCC < Simple cubic < CCP

b) HCP < CCP < BCC

c) HCP < BCC < Simple cubic

d) CCP < BCC < HCP

Ans : c

Explanation : HCP and CCP have the highest packing efficiency of 74% followed by BCC which is 68%. The simple cubic structure has a packing efficiency of 54%.

4. If the body-centered unit cell is assumed to be a cube of edge length 'a' with spherical particles of radius 'r' then how is the diameter, d of particle and surface area, S of the cell related?

a) $S = 32d^4/3$

b) $S = 2d^2$

c) $S = 4d^2$

d) $S = 8d^2$

Ans : d

Explanation: For BCC unit cell the relation between radius of a particle 'r' and edge length of unit cell, a, is r = $\frac{\sqrt{3}}{4}$a.
We know that diameter, d = 2r = $\frac{\sqrt{3}}{2}$a
Implying $d^2 = \frac{3}{4}a^2$
Therefore, $4d^2/3=a^2$
Multiplying by 6 on both sides gives $S = 6a^2 = 8d^2$, where S is the surface area of the cube = $6a^2$.

5. Which of the following metals would have the highest packing efficiency?

a) Copper

b) Potassium

c) Chromium

d) Polonium

Ans : a

Explanation : Copper metal bears face-centered unit cells in its crystal structure. Potassium and chromium both have body-centered unit cells whereas polonium is the only known metal to bear a simple cubic structure. FCC structure has the highest efficiency.

6. "The packing efficiency can never be 100%". Is this true or false?

a) False

b) True

Ans : b

Explanation : Packing efficiency can never be 100% because in packing calculations all constituent particles filling up the cubical unit cell are assumed to be spheres.

7. What are the percentages of free space in a CCP and simple cubic lattice?

a) 52% and 74%

b) 48% and 26%

c) 26% and 48%

d) 74% and 52%

Ans : c

Explanation : The packing efficiency in CCP and simple cubic lattice are 74% and 52%, respectively. Hence the corresponding free spaces will be 100% – 74% = 26% and 100% – 52% = 48%.

8. How many atoms surround the central atom present in a unit cell with the least free space available?

a) 4

b) 6

c) 8

d) 12

Ans : d

Explanation : FCC, CCP and HCP are unit cells with least free space available i.e. highest packing efficiency. The coordination number of given cells are 12.

9. If metallic atoms of mass 197 and radius 166 pm are arranged in ABCABC fashion then what is the surface area of each unit cell?

a) 1.32×10^{6} pm^{2}

b) 1.32×10^{-18}pm^{2}

c) 2.20×10^{5} pm^{2}

d) 2.20×10^{-19} pm^{2}

Ans : a

Explanation: ABCABC arrangement is found in CCP.
In closed cubic packing, relation between edge length of unit cell, a, and radius of particle, r, is given as $a=2\sqrt{2}r$.
Surface area (S.A.) = $6a^2$
From the relationship,
$a^2 = 8r^2$
S.A. = $6a^2 = 48r^2$
When r = 166 pm, S.A. = 48(166pm) = 1.32×10^6 pm^2.

10. If copper, density = 9.0 g/cm^3 and atomic mass 63.5, bears face-centered unit cells then what is the ratio of surface area to volume of each copper atom?

a) 0.0028

b) 0.0235

c) 0.0011

d) 0.0323

Ans : b

Explanation: Density, d of unit cell is given by d = $\frac{zM}{a^3 N_A}$

Given,

Density, d = 9.0 g/cm^3

Atomic mass, M = 63.5 g/mole

Edge length = a

N_A = Avogadro's number = 6.022 x 10^{23}

z = 4 atoms/cell

On rearranging the equation for density we get a^3 = $\frac{zM}{dN_A}$

Substituting the given values:

a^3 = $\frac{4 \times 63.5}{9 \times 6.022 \times 10^{23}}$

Therefore, a = 360.5 pm

The relation of edge length 'a' and radius of particle 'r' for FCC packing i.e. a = $2\sqrt{2}$r.

On substituting the value of 'a' in the given relation, r = $\frac{360.5}{2\sqrt{2}}$=127.46 pm

Now, for spherical particles volume, V = $4\pi r^3/3$ and surface area, S = $4\pi r^2$

Required ratio = S/V=$4\pi r^2/(4\pi r^3/3)$ = 3/r (after simplifying)

Thus, S/V = 3/127.46 = 0.0235.

Calculations Involving Unit Cells Dimensions

1. Aluminium crystallises in a face-centred cubic lattice. The edge length of the unit cell of aluminium is 4.05 x 10^{-10}m. What is the density of aluminium? (Atomic mass of Al=27)

a) 2700 kg m^{-3}

b) 3000 kg m^{-3}

c) 2400 kg m^{-3}

d) 2100 kg m^{-3}

Ans : a

Explanation: Given,

Atomic mass (M)=27 amu

For FCC structure, Z=4

Avogadro's number (N_0) = 6.02 x 10^{23}

Edge length of the Al unit cell (a)= 4.05 x 10^{-10}m

The density of aluminium (ρ) = (Z x M)/(a^3 X N_0)

= (4 x 27)/((4.05 x 10^{-10}) ^{3} x 6.02 x 10^{23})

= 2700 kg m^{-3}.

2. Gold (atomic mass 197 u) crystallises in a face-centred unit cell. What is its atomic radius if the edge length of the gold unit cell is 0.407 x 10^{-9}m?

a) 0.115 nm

b) 0.144 nm

c) 0.235 nm

d) 0.156 nm

Ans : b

Explanation : Given,

Edge length of the Gold unit cell (a) = 0.407 x 10^{-7}m

For FCC unit cell, the atomic radius (r) = a/(2√2)

= 0.407 x 10^{-9}/(2√2)

= 0.144 nm.

3. A metal X has a BCC structure with nearest neighbor distance 365.9 pm. What is metal X if its density is 1.0016 g cm^{-3}?

a) Aluminum

b) Magnesium

c) Sodium

d) Potassium

Ans : c

Explanation: Given,
Nearest neighbor distance (d) = 365.9 pm
Density (ρ) = 1.51 g cm^{-3}
For the BCC structure, nearest neighbor distance (d) is related to the edge length (a) as d= $\left(\frac{\sqrt{3}}{2}\right)$ x a
Or a= $\left(\frac{2}{\sqrt{3}}\right)$ x d = 2/1.732 x 365.9 = 422.5 pm
For BCC structure, Z=2
We know, (ρ) = (Z x M)/(a^3 x N_0)
Or M = (ρ x a^3 x N_0)/Z
= (1.0016 x 10^6 x (422.5 x 10^{-12})^3 x 6.02 x 10^{23})/2
= 23 amu
Therefore, the given metal X is Sodium.

4. Lithium forms a BCC lattice with an edge length of 350 pm. The experimental density of lithium is 0.53 g cm^{-3}. What is the percentage of missing lithium atoms? (Atomic mass of Lithium = 7 amu)

a) 97.7%

b) 95.4%

c) 4.6%

d) 2.3%

Explanation: Given,
Edge length (a) = 350 pm = 3.5 x 10^{-8} cm
Atomic mass (M) = 7 amu
Avogadro's number (N_0) = 6.02 x 10^{23}
Density (ρ) = (Z x M)/(a^3 x N_0)
= (2 x 7)/((3.5 x 10^{-8})^3 x 6.02 x 10^{23})
= 0.542 g cm^{-3}
% of lithium atoms occupied = (Experimental density/Theoretical density) x 100
= 0.53/0.542 x 100
= 97.7%
% of unoccupied lattice sites = 100 – 97.7
= 2.3%.

5. An element with cell edge of 288 pm has a density of 7.2 g cm^{-3}. What type of structure does the element have if it's atomic mass M=51.8 g mol^{-1}?

a) Body-Centred Cubic (BCC)

b) Face-Centred Cubic (FCC)

c) Simple Cubic

d) Hexagonal Closed Packing (HCP)

Ans : a

Explanation: Given,
Edge length (a) = 288 pm
Density (ρ) = 7.2 g cm^{-3}
Atomic mass (M) = 51.8 g mol^{-1}
Avogadro's number (N_0) = 6.02×10^{23}
We know, (ρ) = ($Z \times M$)/($a^3 \times N_0$)
Or Z =($\rho \times a^3 \times N_0$)/M = ($7.2 \times (288 \times 10^{-10})^3 \times 6.02 \times 10^{23}$)/51.8
Z = 2
Therefore, the element has Body-Centred Cubic (BCC) type of structure.

6. The radius of an atom of an element is 55 pm. What is the edge length of the unit cell if it is body-centred cubic?

a) 144.6 pm

b) 163.4 pm

c) 127.0 pm

d) 123.5 pm

Ans : c

Explanation : Given,

Interionic radius (r) = 55 pm

Edge length (a) =?

For BCC, r = (3√4) x a

Or a = (43√) x r= 4 x 55/1.732 = 127 pm.

7. An element of density 8.0 g/cm3 forms an FCC lattice with unit cell edge of 300 pm. Calculate the number of atoms present in 0.5kg of the element.

a) 95 x 1023 atoms

b) 93.59 x 1023 atoms

c) 92.59 x 1023 atoms

d) 91.38 x 1023 atoms

Ans : c

Explanation: Given,
Density (ρ) = 8.0 g/cm^3
For FCC structure, Z = 4
Avogadro's number (N_0) = 6.02 x 10^{23}
Edge length of the unit cell (a) = 300 x 10^{-10} cm
The density of the element (ρ) = (Z x M)/ (a^3 x N_0)
Therefore, the Molar Mass (M) = (ρ x a^3 x N_0)/(Z)
= (8.0 x 6.02 x 10^{23} x 27.0 x 10^{-24}) /4
= 32.508 g.
Therefore, 32.508 g of the element contains 6.02 x 10^{23} atoms.
500 g of the element would contain = (6.02 x 10^{23} x 500)/ 32.508 = 92.59 x 10^{23} atoms.

8. A metal crystallizes into two cubic phases BCC and FCC. The ratio of densities of FCC and BCC is equal to 1.5. Calculate the difference between the unit cell lengths of the FCC and BCC crystals if the edge length of the FCC crystal is equal to 4.0 Å.

a) 0.5 Å

b) 0.37 Å

c) 0. 28 Å

d) 0.73 Å

Ans : b

Explanation: Given,

Edge length of FCC crystal (a_{FCC}) = 4.0 Å

For FCC structure, Z = 4

For BCC structure, Z=2

Avogadro's number (N_0) = 6.02 x 10^{23}

The density of a crystal (ρ)=(Z x M)/(a^3 x N_0)

Therefore, the ratio of Densities= ρ_{FCC}/ρ_{BCC} = (Z_{FCC} x a^3_{BCC}) / (Z_{BCC} x a^3_{FCC})

1.5 = (4 x $(a_{BCC})^3$) / (2 x $(4 \times 10^{-10})^3$)

$(a_{BCC})^3$ = (1.5 x 2 x 64 x 10^{-30})/ 4 = 48 x 10^{-30}

Therefore a_{BCC} = 3.63 Å

Difference in Unit Cell Length = 4.0 – 3.63 = 0.37 Å.

9. If the radius of a Chloride ion is 0.154 nm, then what is the maximum size of a cation that can fit in each of its octahedral voids?

a) 1.15 x 10^{-1} nm

b) 1.21 x 10^{-1} nm

c) 1.18 x 10^{-1} nm

d) 1.13 x 10^{-1} nm

Ans : d

Explanation : Given,

Radius of Chloride ion (r^-) = 0.154 nm

Let radius of cation = r^+

For Octahedral Voids, r^+ / r^- = 0.732 (for maximum value of the size of the cation)

Therefore, r^+ = 0.732 x 0.154 = 1.13 x 10^{-1} nm.

10. Rubidium Chloride (RbCl) has NaCl like structure at normal pressures. If the radius of the Chloride ion is 1.54 Å, what is the unit cell edge length for RbCl? (Assuming anion-anion contact)

a) 4.25 Å

b) 4.78 Å

c) 4.32 Å

d) 5.14 Å

Ans : c

Explanation: Given,

Radius of Chloride ion (r^-) = 0.154 nm

Distance between the centres of the Chloride ions = 2 x 0.154 = 0.308 nm

Let the edge length of cube = a

Distance between Rb^+ and Cl^- ions = a/2

Therefore, the distance between Cl^- ions = $(2 \times (a/2)^2)^{1/2}$

$0.308 = (2 \times (a/2)^2)^{1/2}$

$0.094864 = 2 \times (a/2)^2$

$0.047432 = (a/2)^2$

$0.218 = (a/2)$

a = 0.432 nm = 4.32 Å.

Imperfections in Solids

1. What kind of order is present in a solid for it to be a perfectly crystalline solid?

a) Long range order

b) Short range order

c) No order

d) Both, short range and long range order

Ans : d

Explanation : Only short range order is a feature of amorphous solids. Crystalline solids exhibit both short and long range order. Crystalline solids are formed by repetitive arrangement of unit cells.

2. State whether true or false: The number of defects in a crystal can be minimized by carrying out the process of crystallization at a slow rate.

a) True

b) False

Ans : a

Explanation : All big crystals have some or the other defects in the arrangement of their constituents. An ideal crystal does not exist. These defects are more if the crystallization process occurs at a faster rate. Hence, slowing down the process minimizes the defects. It is akin to starting with one crystal (unit) and adding to it from all sides to create a bigger crystal. Defects are produced due to some irregularity in this arrangement.

3. In a crystal, if a fault exists in the arrangement at a point, it is called as _________

a) space defect

b) single defect

c) point defect

d) primary defect

Ans : c

Explanation : When there is a fault in the arrangement of a constituent particle such as an atom, ion or molecule, and the fault exists at a point in the lattice structure, it is called as a point defect.

4. In which type of point defect are the cations and anions absent in stoichiometric proportions?

a) Schottky defect

b) Frenkel defect

c) Impurity defect

d) The given situation does not occur for any point defect.

Ans : a

Explanation : A vacancy defect is when an atom, ion or molecule is absent from its position in the lattice. When this occurs for ionic solids, it is called a Schottky defect. Cations and anions are found to be absent in stoichiometric proportion so that the electrical neutrality of the crystal is maintained.

5. Schottky defects are observed in solids with cations and anions of similar sizes. Which of the following compounds, therefore, is NOT likely to have a Schottky defect?

a) NaCl

b) AgCl

c) CsCl

d) KCl

Ans : b

Explanation : There is a considerable size difference between Ag cation and Cl anion. Hence a Frenkel defect is more likely to occur than a Schottky defect.

6. Impurity defect is a type of point defect. It can occur __________

a) in one way, as substitution impurity defect

b) in one way, as interstitial impurity defect

c) in two ways, as substitution impurity defect or as interstitial impurity defect

d) in two ways, as vacant impurity defect or as interstitial impurity defect

Ans : c

Explanation : An impurity defect occurs when a regular ion is replaced by some other type of ion, e.g. Na^+ is replaced by K^+. If the replacement occurs in the place of the regular cation, it is called a substitution impurity defect. If the replacement occurs in an interstitial position, it is called an interstitial impurity defect.

7. Stainless steel is a/an ________ alloy.

a) vacant

b) interstitial

c) substitution

d) pure

Ans : b

Explanation : Stainless steel is an interstitial alloy. Carbon atoms are introduced into interstitial spaces of iron lattice as an impurity. Further alloying sees the introduction of nickel, chromium in the interstitial spaces.

Solid State Electrical Properties

1. Metals are good conductors of heat and electricity. This property is conferred by _______ bonds.

a) covalent

b) ionic

c) metallic

d) hydrogen

Ans : c

Explanation : Metallic bonds are formed between positive metal ions and the sea of delocalized electrons. This bond is stronger than covalent and ionic bonds. Due to the mobility of electrons, conduction of heat and electricity is feasible.

2. Which of the following properties holds true for a metalloid?

a) Poor conductors of heat and electricity

b) Malleable

c) Ductile

d) Non-brittle

Ans : a

Explanation : Metalloids have properties intermediate to those of metals and non-metals. They are non-malleable, non-ductile and brittle. They are poor conductors of heat and electricity as compared to metals, but are better conductors than non-metals.

3. According to the band theory, increase in number of atoms participating in crystal formation leads to ________ in number of molecular orbitals containing electrons.

a) decrease

b) increase

c) no change

d) either increase or decrease, depending upon the size of the atoms

Ans : b

Explanation : The band theory assumes that atomic orbitals of the atoms of the crystal combine to form molecular orbitals which are spread over the whole crystal structure. Hence, the number of atoms is directly proportional to the number of molecular orbitals formed.

4. For a metallic crystal, which band do the delocalized electrons occupy?

a) Conduction band

b) Valence band

c) Both, conduction and valence bands

d) There are no delocalized electrons

Ans : a

Explanation : A metallic crystal has valence electrons in the valence band and free moving, delocalized electrons in the conduction band. For a metal, these two bands are very close to each other.

5. A substance containing one band completely filled with electrons and other band completely empty, but with a possibility of the empty band becoming populated, behaves as a ________

a) metal

b) non-metal

c) semiconductor

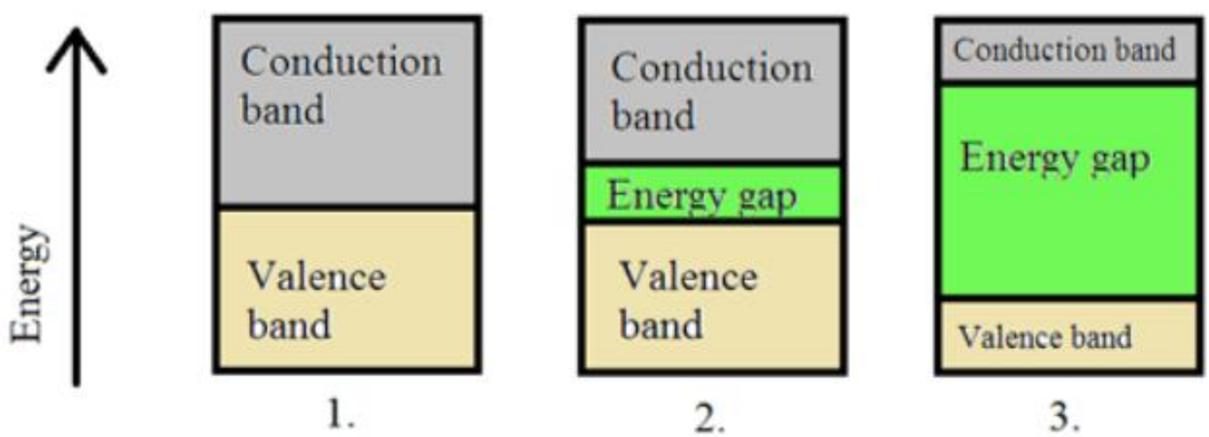
d) metal and non-metal

Ans : c

Explanation : Semiconductors have completely filled valence bands and completely empty conduction bands. The energy gap between the two bands is relatively small and can be overcome by supplying heat, which excites some electrons to the conduction band, thus allowing the conduction of electricity.

6. Label the diagram correctly.

Find type of metal and semiconductor from given diagram



a) 1-Non metal, 2-Semiconductor, 3-Metal

b) 1-Semiconductor, 2-Non metal, 3-Metal

c) 1-Metal, 2-Semiconductor, 3-Non metal

d) 1-Metal, 2-Non metal, 3-Semiconductor

Ans : c

Explanation : Energy gap is very less (may even be absent) for metals, very huge for non metals and intermediate (small) for semiconductors.

Solid State Magnetic Properties

1. Which among the following compounds can show the properties of a Ferroelectric substance?

a) $BaTiO_3$

b) $PbZrO_3$

c) MnO_2

d) CrO_2

Ans : a

Explanation : At the Curie temperature (around 120 ºC) paraelectric $BaTiO_3$ transforms into a ferroelectric structure. Ferroelectricity is the characteristic of certain substances that possess a spontaneous electric field which can be reversed by applying an external electric field.

2. All Ferroelectrics are pyroelectrics.

a) True

b) False

Ans : a

Explanation : Pyroelectricity is the ability of certain materials to generate a temporary potential difference when heated or cooled. Ferroelectrics form a subset of Pyroelectrics. Hence, all Ferroelectrics are Pyroelectrics.

3. All Ferroelectrics are piezo electrics.

a) True

b) False

Ans : a

Explanation : Piezoelectrics are substances whose polarization changes under the influence of stress. Ferro electric substances are considered as Piezoelectric since their polarization can change under the influence of an electric field.

4. Which among the following compounds is Antiferroelectric?

a) NiO

b) V_2O_3

c) $PbZrO_3$

d) Fe_3O_4

Ans : c

Explanation : In the given list: NiO and V_2O_3 are antiferromagnetic substances, Fe_3O_4 is Ferrimagnetic and $PbZrO_3$ is antiferroelectric. Antiferroelectric materials are those materials having ions which can polarize without external field (spontaneous polarization).

5. Which among the following statements is correct?

a) NaCl is a paramagnetic substance

b) Paramagnetic substances behave like an insulator

c) Cobalt is an Antiferromagnetic substance

d) On heating, ferrimagnetic substanceslose ferrimagnetism

Ans : d

Explanation : On heating, ferrimagnetic substances become paramagnetic and hence, lose their ferromagnetism. NaCl is diamagnetic in nature. Cobalt is a ferromagnetic substance.

6. What is the correct order of magnetic strength among the following elements?

a) Fe > Co > Ni > Cu

b) Fe > Ni > Co > Cu

c) Cu > Ni > Co > Fe

d) Cu > Fe > Ni > Co

Ans : a

Explanation : Magnetic strength depends on the number of unpaired electrons possessed by the element. Iron, Cobalt, Nickel and Copper have 4, 3, 2 and 1unpaired electron respectively. Hence, the correct order of magnetic strength is: Fe > Co > Ni > Cu.

7. Which of the following elements have a negative value of magnetic susceptibility?

a) Iron

b) Oxygen

c) Aluminium

d) Nitrogen

Ans : d

Explanation : Only Diamagnetic substances show a negative value of magnetic susceptibility. In the given list: oxygen and aluminium are paramagnetic, iron is ferromagnetic and nitrogen is diamagnetic. Therefore, Nitrogen has a negative value of magnetic susceptibility.

8. Which of the following is not Anti-ferromagnetic?

a) MnO

b) Mn_2O_3

c) MnO_2

d) Mn

Ans : d

Explanation : MnO, Mn_2O_3, and MnO_2 are Anti-ferromagnetic. Mn is paramagnetic in nature. Paramagnetism is when a substance is weakly attracted to a magnetic field.

9. In which of the following magnetic properties of elements does the magnetic susceptibility increase on increasing the temperature?

a) Paramagnetism

b) Anti-ferromagnetism

c) Ferromagnetism

d) Diamagnetism

Ans : b

Explanation : On increasing the temperature, the magnetic susceptibility of diamagnetic substances do not change, that of paramagnetic and ferromagnetic substances decrease and that of antiferromagnetic substances increase.

10. What is the temperature, above which a ferromagnetic substance shows no ferromagnetism called?

a) Curie temperature

b) Néel temperature

c) Critical temperature

d) There exists no such temperature

Ans : a

Explanation : The Néel temperature or magnetic ordering temperature is the temperature above which an antiferromagnetic material becomes paramagnetic. The Critical temperature of a gas is the temperature above which it cannot be liquefied by pressure alone. The temperature above which a ferromagnetic substance shows no ferromagnetism is called Curie temperature.