

Q1. Define the term 'amorphous'. Give a few examples of amorphous solids.

Solution:

Amorphous solids are solids without a regular/ definitive arrangement of its constituent particles (ions, atoms or molecules) and they possess something called the short-range order i.e., a regular and periodically repeating arrangement is seen only over short distances, e.g., rubber, glass.

Q2. What makes a glass different from a solid such as quartz? Under what conditions could quartz be converted into glass?

Solution:

The arrangement of the constituent particles differentiates glass from quartz. The constituent particles in glass have a short-range order, but the constituent particles of quartz possess long range orders. Quartz is converted into glass by heating it and then rapidly cooling it.

Q3. Classify each of the following solids as ionic, metallic, molecular, network (covalent) or amorphous.

(a) Tetra phosphorus decoxide (P_4O_{10})

(b) Ammonium phosphate $(NH_4)_3PO_4$

(c) SiC

(d) I_2

(e) P_4

(f) Plastic

(g) Graphite

(h) Brass

(i) Rb

(j) LiBr

(k) Si

Solution:

Metallic: (h) Brass, (i) Rb

Molecular: (a) Tetra phosphorus decoxide (P_4O_{10}), (d) I_2 , (e) P_4 .

Ionic: (b) Ammonium phosphate $(NH_4)_3PO_4$, (j) LiBr

Amorphous: (f) Plastic

Covalent: (c) SiC, (g) Graphite, (k) Si

Q4. (i) What is meant by the term 'coordination number'?

(ii) What is the coordination number of atoms:

(a) in a cubic close-packed structure?

(b) in a body-centred cubic structure?

Solution:

(i) Coordination number is the number of nearest neighbours of a particle.

(ii)

(a) coordination number = 12

(b) coordination number = 8

Q5. How can you determine the atomic mass of an unknown metal if you know its density and the dimension of its unit cell? Explain.

Solution:

Given,

We know the dimension and density of its unit cell.

Let,

The edge length of a unit cell = a

The volume of the cell = a^3

Density = d

Atomic mass = M

Mass of unit cell = No. of atoms in unit cell \times Mass of each atom = $Z \times m$

Mass of an atom present in the unit cell, $m = M / N_a$

where N_a is the Avogadro's number.

We know,

$d = \text{Mass of unit cell} / \text{Volume of unit cell} = Zm/a^3 = Z.M / a^3 N_a$

Therefore, Atomic mass, $M = (d a^3 N_a) / Z$

Q6. 'Stability of a crystal is reflected in the magnitude of its melting points'. Comment. Collect melting points of solid water, ethyl alcohol, diethyl ether and methane from a data book. What can you say about the intermolecular forces between these molecules?

Solution:

A substance with a high melting point is more stable than a substance with a low melting point, this is because higher the melting point, stronger the intermolecular forces of attraction in that substance/crystal. Thus, implying greater stability.

The melting points of the above substances are:

Methane \rightarrow 89.34 K

Diethyl ether \rightarrow 156.85 K

Solid water \rightarrow 273 K

Ethyl alcohol \rightarrow 158.8 K

Observing the data we can say that solid water has the strongest intermolecular force and methane has the weakest.

Q7. How will you distinguish between the following pairs of terms:

(i) Hexagonal close-packing and cubic close-packing?

(ii) Crystal lattice and unit cell?

(iii) Tetrahedral void and octahedral void?

Solution:

(a) Cubic close packing: When a third layer is placed over the second layer in a manner that the octahedral voids are covered by the spheres, a layer different from the first (A) and second (B) is obtained. If we continue packing in this manner we get the cubic close packing.

Hexagonal close packing: When the third layer is placed over the second layer in a way that the tetrahedral voids are covered by the spheres, a 3D close packing is produced where spheres in each third or alternate layers are vertically aligned. If we continue packing in this order we get hexagonal close packing.

(b) Unit cell: It is the smallest 3D dimensional portion of a complete space lattice, which when repeated over and over again in different directions from the crystal lattice.
Crystal lattice – it is a regular orientation of particles of a crystal in a 3D space.

(c) Octahedral void – it is a void surrounded by 6 spheres.

Tetrahedral void – it is a void surrounded by 4 spheres.



Q8. How many lattice points are there in one unit cell of each of the following lattice?

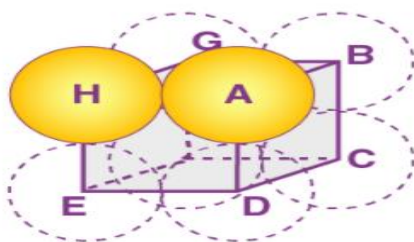
- (i) Face-centred cubic
- (ii) Face-centred tetragonal
- (iii) Body-centred

Solution:

- (i) There are 14 lattice points in face-centred cubic, 8 from the corners and 6 from the faces.
- (ii) There are 14 lattice points in face-centred tetragonal, 8 from the corners and 6 from the faces.
- (iii) There are 9 lattice points in body-centred cubic, 1 from the centre and 8 from the corners.

Simple cubic:

In a simple cubic lattice, particles are present only at the corners and they touch each other along the edge.



Let the edge length = a

Radius of each particle = r .

Thus, $a = 2r$

Volume of spheres = $\pi r^3(4/3)$

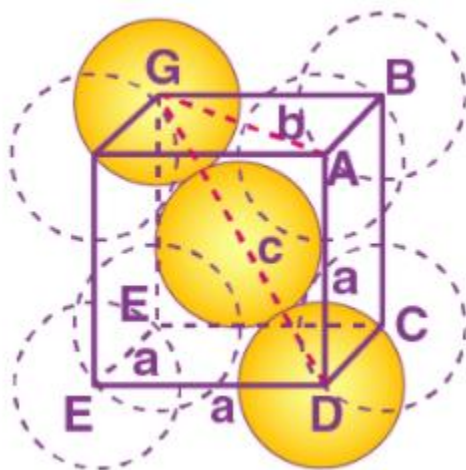
Volume of a cubic unit cell = $a^3 = (2r)^3 = 8r^3$

We know that the number of particles per unit cell is 1.

Therefore,

Packing efficiency = Volume of one particle/Volume of cubic unit cell = $[\pi r^3(4/3)] / 8r^3 = 0.524$ or 52.4%

Body-centred cubic:



From $\triangle FED$, we have:

$$b^2 = 2a^2$$

$$b = (2a)^{1/2}$$

Again, from $\triangle AFD$, we have :

$$c^2 = a^2 + b^2$$

$$\Rightarrow c^2 = a^2 + 2a^2$$

$$c^2 = 3a^2$$

$$\Rightarrow c = (3a)^{1/2}$$

Let the radius of the atom = r .

Length of the body diagonal, $c = 4r$

$$\Rightarrow (3a)^{1/2} = 4r$$

$$\Rightarrow a = 4r / (3)^{1/2}$$

$$\text{or, } r = [a (3)^{1/2}] / 4$$

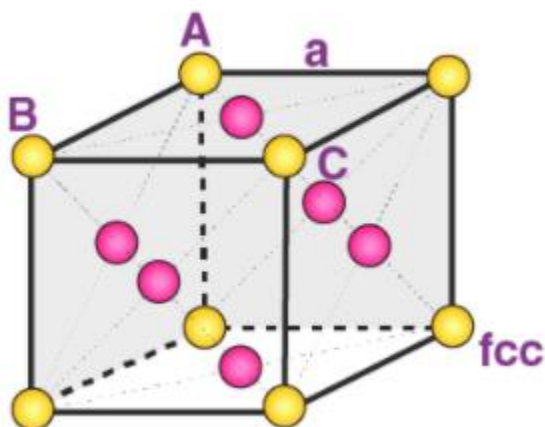
$$\text{Volume of the cube, } a^3 = [4r / (3)^{1/2}]^3$$

A BCC lattice has 2 atoms.

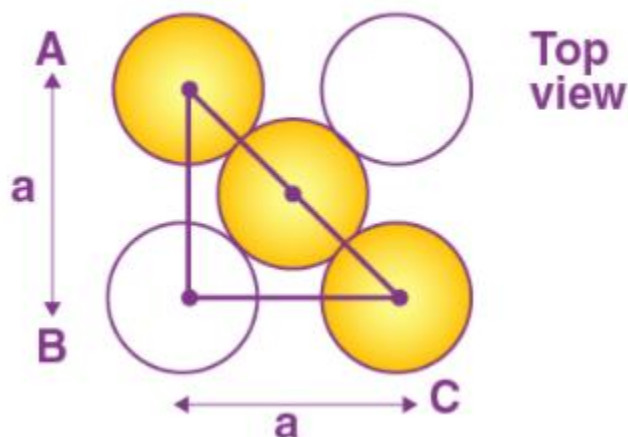
$$\text{So, volume of the occupied cubic lattice} = 2\pi r^3(4/3) = \pi r^3(8/3)$$

$$\text{Therefore, packing efficiency} = [\pi r^3(8/3)] / [\{4r/(3)^{1/2}\}^3] = 0.68 \text{ or } 68\%$$

Face-centred cubic:



Let the edge length of the unit cell = a
 let the radius of each sphere = r
 Thus, $AC = 4r$
 From the right angled triangle ABC, we have:
 $AC = (a^2 + a^2)^{1/2} = a(2)^{1/2}$



Therefore, $4r = a(2)^{1/2}$
 $\Rightarrow a = 4r / (2)^{1/2}$
 Thus, Volume of unit cell $= a^3 = \{ 4r / (2)^{1/2} \}^3$
 $a^3 = 64r^3 / 2(2)^{1/2} = 32r^3 / (2)^{1/2}$
 No. of unit cell in FCC = 4
 Volume of four spheres = $4 \times \pi r^3 (4/3)$
 Thus, packing efficiency = $[\pi r^3 (16/3)] / [32r^3 / (2)^{1/2}] = 0.74$ or 74 %

Q9. Silver crystallises in fcc lattice. If edge length of the cell is 4.07×10^{-8} cm and density is 10.5 g cm^{-3} , calculate the atomic mass of silver.

Solution:

Given:

Edge length, $a = 4.077 \times 10^{-8} \text{ cm}$

Density, $d = 10.5 \text{ g cm}^{-3}$

The given lattice is of fcc type,

Thus the number of atoms per unit cell, $z = 4$

We also know that $N_A = 6.022 \times 10^{23} / \text{mol}$

let M be the atomic mass of silver.

We know, $d = zM/a^3N_A$

$\Rightarrow M = da^3N_A / z$

$= (10.5 \times 4.077 \times 10^{-8} \times 6.022 \times 10^{23}) / 4 = 107.13 \text{ g/mol}$

Q10. A cubic solid is made of two elements P and Q. Atoms of Q are at the corners of the cube and P at the body-centre. What is the formula of the compound? What are the coordination numbers of P and Q?

Solution:

Given:

Atoms of Q occupy the corners of the cube.

\Rightarrow Number of Q atoms in a unit cell $= 8 \times 1/8 = 1$

The atom of P occupies the body centre.

\Rightarrow Number of P atoms in a unit cell $= 1$

Therefore, the ratio of the number of P atoms to the number of Q atoms;

$X : Y = 1 : 1$

Thus, the formula of the compound is PQ

And the coordination number of both the elements is 8.

Q11. Analysis shows that nickel oxide has the formula $\text{Ni}_{0.98} \text{O}_{1.00}$. What fractions of nickel exist as Ni^{2+} and Ni^{3+} ions?

Solution:

The given formula of nickel oxide is $\text{Ni}_{0.98} \text{O}_{1.00}$.

Thus, the ratio of the number of Ni atoms to the number of O atoms is,

$\text{Ni} : \text{O} = 0.98 : 1.00 = 98 : 100$

Now,

Total charge on 100 O^{2-} ions $= 100 \times (-2) = -200$

Let the number of Ni^{2+} ions $= x$.

So, the number of Ni^{3+} ions is $98 - x$.

Now,

Total charge on Ni^{2+} ions $= x(+2) = +2x$

Similarly, total charge on Ni^{3+} ions $= (98 - x)(+3) = 294 - 3x$

As, the compound is neutral, we can write:

$2x + (294 - 3x) + (-200) = 0$

$\Rightarrow -x + 94 = 0$

$\Rightarrow x = 94$

Therefore, number of Ni^{2+} ions $= 94$

And, number of Ni^{3+} ions = $98 - 94 = 4$

Thus, the fraction of nickel that exists as $\text{Ni}^{2+} = 94/98 = 0.959$

And, the fraction of nickel that exists as $\text{Ni}^{3+} = 4/98 = 0.041$

Q12. Explain the following with suitable examples:

(a) Ferromagnetism

(b) Paramagnetism

(c) Ferrimagnetism

(d) Antiferromagnetism

(e) 12-16 and 13-15 group compounds.

Solution:

(a) Ferromagnetic:

These substances (ferromagnetic substances) are strongly attracted by magnetic fields. They could be permanently magnetized even when a magnetic field is absent. Few examples of ferromagnetic substances include cobalt, iron, nickel, CrO_2 and gadolinium.

In a solid state, their metal ions come together to form small regions termed domains and each domain behaves like a tiny magnet.

In a magnetized piece of a ferromagnetic substance, these domains are randomly arranged thus, their net magnetic moment becomes zero. However, when it is kept in a magnetic field, the domains orient themselves in the direction of the field. This results in a powerful magnetic effect being produced. This orientation of domains persists even after the field is removed. Hence, the ferromagnetic substance is transformed into a permanent magnet.

Schematic alignment of magnetic moments in ferromagnetic substances:



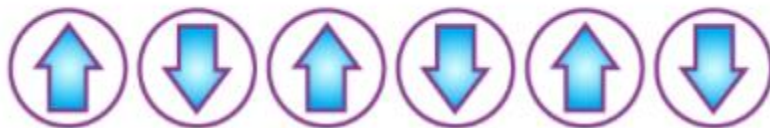
(b) Paramagnetism :

These substances (paramagnetic substances) are attracted by a magnetic field but after the removal of the field, they lose their magnetism. Examples of paramagnetic substances include Cr^{3+} , O_2 , Cu^{2+} , and Fe^{3+} . To undergo paramagnetism, a substance must possess one or more unpaired electrons. These unpaired electrons are pulled by the magnetic field, thus causing paramagnetism.

(c) Antiferromagnetism :

An antiferromagnetic substance has domain structures similar to that of ferromagnetic substances but in the opposite orientation. These oppositely-oriented domains null out each other's magnetic moments.

Schematic alignment of magnetic moments in antiferromagnetic substances



(d) Ferrimagnetism:

In these substances, the magnetic moments of the domains are oriented in parallel and anti-parallel directions and in unequal numbers. A few examples of ferromagnetic substances include ferrites like MgFe_2O_4 and ZnFe_2O_4 , Fe_3O_4 (magnetite), etc.

As compared to ferromagnetic substances these substances are weakly attracted by magnetic fields. Upon heating, they become paramagnetic.

(e) 12-16 and 13-15 group compounds:

The group 12-16 compounds are obtained by combining together group 16 and group 12 elements. Group 13-15 compounds are obtained by combining group 15 and group 13 elements. These compounds are prepared to stimulate average valence of four as in Si or Ge. Indium (III) antimonide (IrSb), gallium arsenide (GaAs) and aluminium phosphide (AlP) are some typical compounds of groups 13-15.

GaAs semiconductors provide a very minute response time and they have totally changed the designing of semiconductor devices. A few examples of group 12-16 compounds are zinc sulphide (ZnS), mercury (II) telluride (HgTe), cadmium sulphide (CdS) and cadmium selenide (CdSe). The bonds these compounds have are not perfect covalent. Their bond's ionic character depends upon the electronegativity of the two species/elements.

Q13. Why are solids rigid?

Solution:

Intermolecular forces of attraction in a solid is really strong, because of this the molecules of solids have fixed positions. Nonetheless, they still can oscillate about their mean positions. This is the reason for solids being rigid.

Q14. Why do solids have a definite volume?

Solution:

Intermolecular forces of attraction in a solid is really strong, because of this the molecules of solids have fixed positions. This makes them very rigid, thus giving them definite volumes.

Q15. Classify the following as amorphous or crystalline solids: Polyurethane, naphthalene, benzoic acid, teflon, potassium nitrate, cellophane, polyvinyl chloride, fibre glass, copper.

Solution:

Crystalline solids:

Naphthalene, potassium nitrate, benzoic acid, and copper

Amorphous solids:

Polyurethane, cellophane, Teflon, fibre glass and polyvinyl chloride.

Q16. For what reason is glass also considered a supercooled liquid?

Solution:

Just like a liquid, glass also flows from top to bottom but very slowly. For this reason, glass is also considered a supercooled liquid.

Q17. Refractive index of a solid is observed to have the same value along all directions. Comment on the nature of this solid. Would it show cleavage property?

Solution:

These solids are isotropic in nature i.e., they have the same value of physical properties in all directions. Thus, they also have the same value of refractive index along with all directions. As the solid is amorphous it will not exhibit cleavage property i.e., it will break into pieces with undefined surfaces when cut.

Q18. Classify the following solids in different categories based on the nature of intermolecular forces operating in them:

Potassium sulphate, tin, benzene, urea, ammonia, water, zinc sulphide, graphite, rubidium, argon, silicon carbide.

Solution:

Potassium sulphate → Ionic solid

Benzene → Molecular (non-polar) solid

Tin → Metallic solid

Urea → Polar molecular solid

Water → Hydrogen bonded molecular solid

Ammonia → Polar molecular solid

Zinc sulphide → Ionic solid

Rubidium → Metallic solid

Graphite → Covalent or network solid

Silicon carbide → Covalent or network solid

Argon → Non-polar molecular solid

Q19. Solid X is a really hard electrical insulator in solid and in a liquid state and it has an extremely high melting point. Identify the type of solid it is.

Solution:

The above qualities are qualities of a covalent or network solid, thus it is a covalent or network solid. The solid could be a diamond (C).

Q20. Ionic solids do not conduct electricity in the solid state but only in the molten state. Why?

Solution:

The ions of ionic solids are responsible for conducting electricity. In the solid state, however, these ions are not free to move around inside the solid because of the strong electrostatic forces. Hence, ionic solids do not conduct electricity in a solid state. Whereas, in a molten state, the ions are free to move and thus they can conduct electricity.

Q21. What kind of solids are malleable, ductile and electrical conductors?

Solution:

Metallic solids are malleable, ductile and electrical conductors.

Q22. What is the importance of 'lattice point'?

Solution:

The importance of the lattice point is that every lattice point represents a fundamental particle of a solid which could be an ion, an atom or a molecule.

Q23. What are the parameters that make up a unit cell?

Solution:

A unit cell is made up of the following parameters:

- (i) The three dimensions of a unit cell. (the three edges)
- (ii) the angles between the edges.

Q24. Differentiate between:

- (i) End-centred and face-centred unit cells.
- (ii) Monoclinic and hexagonal unit cells.

Solution:

(i)

End centred unit cell	Face-centred unit cell
<ul style="list-style-type: none">They contain particles at the corners and one in the centre of any two opposite faces.	<ul style="list-style-type: none">They contain particles at the corners and one in the centre of each face.
<ul style="list-style-type: none">Total number of particles = 2	<ul style="list-style-type: none">Total number of particles = 4

(ii)

Monoclinic unit cell	Hexagonal unit cell
$a \neq b \neq c$	$a = b \neq c$
$\alpha = \gamma = 90^\circ$	$\alpha = \beta = 90^\circ$
$\beta \neq 90^\circ$	$\gamma = 120^\circ$

Q25. A cubic unit cell has atoms at its (i) body centre, and (ii) corner, find the amount of atom each unit cell gets after share with its neighbouring unit cells.

Solution:

(i) An atom in the body centre is not shared between unit cells, thus the atom in the body centre only belongs to the unit cell it is in.

(ii) An atom in the corner is shared between 8 adjacent cells. Thus, each cell gets $1/8^{\text{th}}$ of the atom.

Q26. A molecule is in the square close-packed layer, find its two-dimensional coordination number.

Solution:

A molecule in a square close-packed layer touches four of its neighbours. Thus, its two-dimensional coordination number is 4.

Q27. Find the number of voids in 0.2 moles of a compound forming hexagonal close-packed structure. What number of these are tetrahedral voids?

Solution:

Given:

$$\text{No. of close-packed particles} = 0.2 \times 6.022 \times 10^{23} = 1.2044 \times 10^{23}$$

$$\text{Thus, no. of octahedral voids} = 1.2044 \times 10^{23}$$

$$\text{And, no. of tetrahedral voids} = 2 \times 1.2044 \times 10^{23} = 2.4088 \times 10^{23}$$

$$\text{Thus, total number of voids} = 1.2044 \times 10^{23} + 2.4088 \times 10^{23} = 3.6132 \times 10^{23}$$

Q28. A compound is made up of two elements A and B. The atoms of element B form ccp and element A's atoms take up 1/3rd of the tetrahedral voids. Find the formula of this compound.

Solution:

Given:

Atoms of element B form ccp, thus no. of atoms = n

No. of oct voids = n

No. of td voids = $2n = 2 \times n(1/3) = 2n/3$

Therefore :

The formula of the compound is A : B

$2n/3 : n$

$2:3 = A_2B_3$

Q29. Identify the lattice with the highest packing efficiency (i) hexagonal close-packed (ii) simple cubic or (iii) body-centred lattice.

Solution:

The lattice with the greatest packing efficiency is the hexagonal close-packed lattice with a packing efficiency of 74 %.

Q30. An element with a density of $2.7 \times 10^3 \text{ kg m}^{-3}$ has a molar mass of $2.7 \times 10^{-2} \text{ kg / mol}$ and it makes a cubic unit cell with an edge length of 405 pm. What kind of cubic unit cell does it have?

Solution:

Given,

Density, $d = 2.7 \times 10^3 \text{ kg m}^{-3}$

Molar mass, $M = 2.7 \times 10^{-2} \text{ kg /mol}$

Edge length, $a = 405 \text{ pm} = 405 \times 10^{-12} \text{ m} = 4.05 \times 10^{-10} \text{ m}$

We know,

Avogadro's number, $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

We also know that $d = (Z \times M)/(a^3 \times N_A)$

$\Rightarrow Z = (d \times N_A \times a^3)/M = 3.99 \sim 4$

This means that the cell is a face centered cubic.

Q31. When solids are heated what kind of defects can arise in it? Find physical property affected by it and the way it is affected.

Solution:

Heating solids produce vacancy defects in the crystal. This means that when the heat is applied to the solid, some ions or atoms leave their lattice site totally, making those sites empty. Thereby, decreasing the solid's density.

Q32. Identify the type of stoichiometric defect present in :

(i) AgBr

(ii) ZnS

Solution:

(i) Frenkel and Schottky defects are present in AgBr.

(ii) ZnS contains Frenkel defect.

Q33. If NaCl is doped with 10^{-3} mol % of SrCl_2 , what is the concentration of cation vacancies?

Solution:

When a cation of higher valence is put in an ionic solid, it starts replacing cations of lower valency such that the crystal remains electrically neutral. Thereby, creating some vacant sites. For instance, if Sr^{2+} is put in NaCl, each Sr^{2+} ion replaces two Na^+ ions. Thereby creating one vacant for every Sr^{2+} ion introduced.

Q34. Explain using an appropriate example of how ionic solids, with anionic vacancies caused due to the metal excess defect, start developing a colour.

Solution:

Let us take an example of NaCl to explain this when NaCl crystals are heated in a sodium vapor atmosphere, sodium atoms are deposited on the crystal's surface. This causes the Cl^- ions to leave their lattice sites to form NaCl with the deposited sodium atoms. In this process, the sodium atoms on the surface lose their electrons to form Na^+ ions and the released electrons move into the crystal to fill in the vacant anionic sites. These electrons absorb energy from the incoming visible light and get excited to a higher energy level. Thereby, imparting a yellow colour to the crystals.

Q35. To convert a group 14 element into an n-type semiconductor a suitable impurity is doped into it. To which group does this impurity belong?

Solution:

This impurity should belong to group 15.

Q36. Which substance would be a better choice to make a permanent magnet, ferromagnetic or ferrimagnetic. Explain your answer.

Solution:

Substances like iron, cobalt, nickel, gadolinium and CrO_2 , are known as the ferromagnetic substances and make better permanent magnets as they are attracted very strongly by the magnetic field. These substances can also be permanently magnetized. The metal ions of ferromagnetic substances, in solid-state are grouped into small regions, which are known as domains. Each domain act as a tiny magnet. Meanwhile, in a magnetized piece of a ferromagnetic substance, the domains are randomly oriented and so the magnetic moments of the domains get cancelled. Nevertheless, when the substance is placed in a magnetic field, all the domains are oriented in the direction of the magnetic field and produces a strong magnetic effect. The ordering of the domains persists even after the removal of the magnetic field. Thus, the ferromagnetic substance becomes a permanent magnet.