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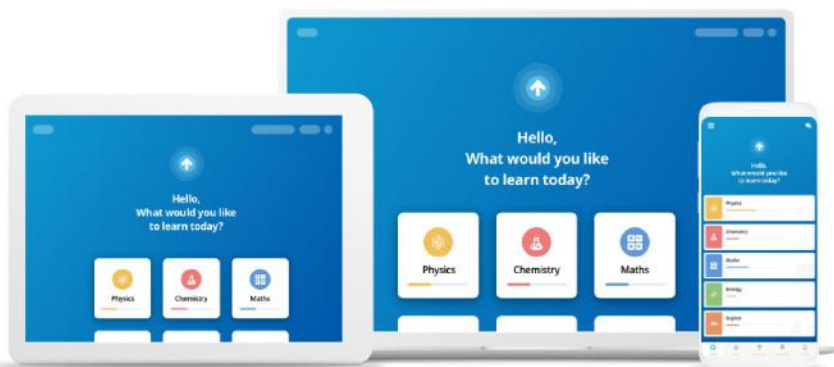
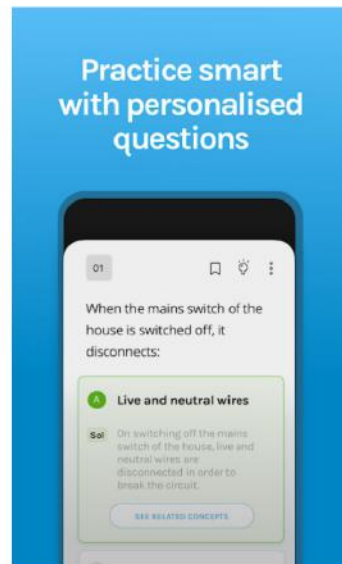
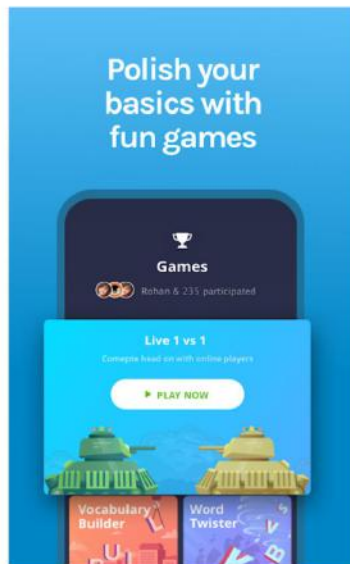
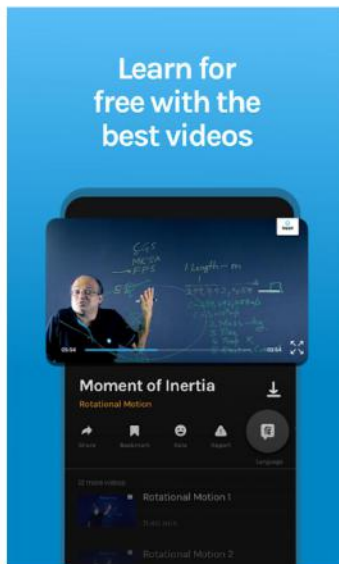
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#457378

Topic: Crystalline and amorphous solids

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

Solution

Amorphous solids have short range order with irregular shapes of constituent particles.

They have isotropic nature and melt over a range of temperature. They are sometimes called pseudo solids or super cooled liquids. They do not have definite enthalpy of fusion.

Examples of amorphous solids are glass, rubber and plastic.

#457379

Topic: Crystalline and amorphous solids

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

Solution

Quartz is crystalline solid with long range order and glass is amorphous solid (or pseudo solid or super cooled liquid) with short range order and has a tendency to flow. When quartz is heated, it can be converted into glass.

#457383

Topic: Crystalline and amorphous solids

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

(i) Tetra phosphorus decoxide (P_4O_{10}) (ii) Ammonium phosphate ($(NH_4)_3PO_4$) (iii) SiC (iv) I_2 (v) P_4 (vi) Plastic (vii) Graphite (viii) Brass (ix) Rb (x) LiBr (xi) Si

Solution

The different solids are classified below:

Ionic solids: Ammonium phosphate ($(NH_4)_3PO_4$), LiBr

Metallic solids : Brass, Rb

Molecular solids : Tetraphosphorous decaoxide (P_4O_{10}), Iodine (I_2), P_4

Network (covalent) solids: Graphite, SiC, Si

Amorphous solid : Plastics

#457385

Topic: Space lattice or crystal lattice and unit cell

(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 neighbors with which a given atom is in contact. In an ionic crystal, the coordination number of an ion refers to the number of oppositely charged ions that surround that ion.

(ii) The coordination number of atoms in a

(a) cubic close-packed structure is 12.

(b) body-centred cubic structure is 8.

#457386

Topic: Density of a cubic crystal

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

Solid water and ethyl alcohol have higher melting points due to presence of inter-molecular hydrogen bonds. Since the extent of hydrogen bonding in solid water is greater than the extent of hydrogen bonding in ethyl alcohol, the melting point of solid water is higher than the melting point of ethyl alcohol. Polar diethyl ether involves dipole-dipole interactions. Non polar methane involves weak van der Waals forces (London dispersion forces) which are weaker than dipole-dipole interactions. Hence, the melting point of methane is much lower than the melting point of diethyl ether.

Tetrahedral void is surrounded by four spheres while an octahedral void is surrounded by six spheres.

(i) Face-centred cubic

8 lattice points at corners and 6 lattice points at face centres are present in face-centred cubic.

A corner lattice point contributes one eighth to the unit cell and a lattice point at face centre contributes one half to the unit cell.

$$\text{Total number of lattice points per unit cell: } 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 1 + 3 = 4$$

(ii) Face-centred tetragonal

8 lattice points at corners and 6 lattice points at face centres.

A corner lattice point contributes one eighth to the unit cell and a lattice point at face centre contributes one half to the unit cell.

$$\text{Total number of lattice points per unit cell: } 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 1 + 3 = 4$$

(iii) Body-centred

8 lattice points at corners and 1 lattice point at body centre.

A corner lattice point contributes one eighth to the unit cell and a lattice point at body centre contributes one to the unit cell.

$$\text{Total number of lattice points per unit cell: } 8 \times \frac{1}{8} + 1 \times 1 = 1 + 1 = 2$$

#457390

Topic: Crystalline and amorphous solids

Explain

(i) The basis of similarities and differences between metallic and ionic crystals.

(ii) Ionic solids are hard and brittle.

Solution

(i) The basis of similarities and differences between metallic and ionic crystals are given below:

(a) Similarities: Both ionic and metallic crystals have electrostatic attractive forces. In ionic crystals, the forces are present between oppositely charged ions and in metallic crystals, the forces are between valence electrons and kernels.

Due to this, both crystals have high melting points. Both crystals have non directional bonds.

(b) Differences:

Ionic crystals do not conduct electricity in solid state as ions are not free to move. They conduct electricity in molten state and in aqueous solutions. Molecular crystals conduct electricity in solid state as valence electrons are free to move.

Ionic bond in ionic crystals is strong due to electrostatic attractive forces. However, in metallic crystals, the metallic bond may be weak or strong depending upon the number of valence electrons and the size of the kernels.

(ii) Ionic solids are hard due to presence of strong electrostatic attractive forces among oppositely charged ions. Due to non directional nature of ionic bond, the ionic solids are brittle.

#457391

Topic: Close packing in crystals

Calculate the efficiency of packing in case of a metal crystal for:

(i) simple cubic

(ii) body-centred cubic

(iii) face-centred cubic (with the assumptions that atoms are touching each other)

Solution

(i) The efficiency of packing in case of simple cubic unit cell is given below:

A simple cubic unit cell contains one atom per unit cell.

Also, $a = 2r$, where a is the edge length and r is the radius of atom.

Total volume of unit cell $= a^3$.

$$\text{Packing efficiency} = \frac{\text{Volume of one sphere}}{\text{Total volume of unit cell}} \times 100$$

$$\text{Packing efficiency} = \frac{\frac{4}{3}\pi r^3}{8r^3} \times 100 = 52.4\%$$

(ii) The efficiency of packing in case of body-centred cubic unit cell is given below:

A body-centred cubic unit cell contains two atoms per unit cell.

Also, $\sqrt{3}a = 4r$, where a is the edge length and r is the radius of atom.

Total volume of unit cell $= a^3$.

$$\text{Packing efficiency} = \frac{\text{Volume of two spheres}}{\text{Total volume of unit cell}} \times 100$$

$$\text{Packing efficiency} = \frac{\frac{8}{3}\pi r^3}{\frac{64}{3\sqrt{3}}} \times 100 = 68\%$$

(iii) The efficiency of packing in case of face-centred cubic unit cell (with the assumptions that atoms are touching each other) is given below:

A face-centred cubic unit cell contains four atoms per unit cell.

Also, $a = 2\sqrt{2}r$, where a is the edge length and r is the radius of atom.

Total volume of unit cell $= a^3$

$$\text{Packing efficiency} = \frac{\text{Volume of four spheres}}{\text{Total volume of unit cell}} \times 100$$

$$\text{Packing efficiency} = \frac{\frac{16}{3}\pi r^3}{16\sqrt{2}r^3} \times 100 = 74\%$$

#457393

Topic: Density of a cubic crystal

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

Solution

Density (D), number of atoms per unit cell (Z), atomic mass (M), Avogadro's number (N_0) and edge length (a) are related as below:

$$D = \frac{ZM}{N_0 a^3}$$

$$10.5 = \frac{4M}{6.023 \times 10^{23} \times (4.07 \times 10^{-8})^3}$$

$$M = 107.9 \text{ g/mol}$$

Hence, the atomic mass of silver is 107.9 g/mol.

#457395

Topic: Calculation of number of particles per unit cell of a cubic crystal system

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 that a cubic solid is made of two elements P and Q .

Atoms of Q are at the corners of the cube.

There are 8 corner atoms of Q with each one having contribution of one eight to the unit cell.

$$\text{Number of } Q \text{ atoms per unit cell} = 8 \times \frac{1}{8} = 1$$

Atom of P is at the body-centre. It contributes whole atom to the unit cell.

$$\text{Number of } P \text{ atoms per unit cell} = 1$$

The ratio of number of atoms of P to the number of atoms of Q is 1 : 1.

Hence, the formula of the compound is PQ .

Both P and Q have coordination number of 8 each.

#457396

Topic: Density of a cubic crystal

Niobium crystallises in body-centred cubic structure. If density is 8.55 g cm^{-3} , calculate atomic radius of niobium using its atomic mass 93 u .

Solution

Density (D), number of atoms per unit cell (Z), atomic mass (M), Avogadro's number (N_0) and edge length (a) are related as below:

$$D = \frac{ZM}{N_0 a^3}$$

Given $D = 8.55 \text{ g/cm}^3$ and $M = 93 \text{ u}$.

$$\text{Edge length} = a = \left(\frac{ZM}{DN_0} \right)^{1/3} = \left(\frac{2 \times 93}{8.55 \times 6.023 \times 10^{23}} \right)^{1/3} = 3.306 \times 10^{-8} \text{ cm}$$

$$\text{Atomic radius} = r = \frac{\sqrt{3}}{4} a = \frac{\sqrt{3}}{4} \times 3.306 \times 10^{-8} = 1.432 \times 10^{-8} \text{ cm} = 14.32 \text{ pm}$$

#457397

Topic: Radius ratio rules

If the radius of the octahedral void is r and radius of the atoms in close-packing is R , derive relation between r and R .

Solution

Let the radius of the octahedral void be r and radius of the atoms in close-packing be R and the edge length be a .

In the right angle triangle ABC,

$$AB = BC = a$$

For the diagonal AC,

$$AC = \sqrt{AB^2 + BC^2} = \sqrt{a^2 + a^2} = \sqrt{2}a$$

$$\text{Also, } \frac{AC}{AB} = \frac{\sqrt{2}a}{a}$$

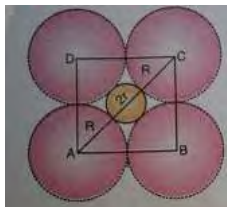
$$\text{And, } AB = 2R$$

$$AC = R + 2r + R = 2R + 2r$$

$$\therefore \frac{2R + 2r}{2R} = \sqrt{2}$$

$$r = 0.414R$$

Hence, the relation is $r = 0.414R$



#457398

Topic: Density of a cubic crystal

Copper crystallises into a fcc lattice with edge length $3.61 \times 10^{-8} \text{ cm}$. Show that the calculated density is in agreement with its measured value of 8.92 g cm^{-3} .

Solution

Copper crystallizes into a fcc lattice with edge length 3.61×10^{-8} cm.

Fcc unit cell has 4 atoms per unit cell.

Cu has atomic mass of 63.5 g/mol.

Avogadro's number is 6.023×10^{23} .

The calculated density is as below:

$$D = \frac{ZM}{a^3 N_0} = \frac{4 \times 63.5}{(3.61 \times 10^{-8})^3 \times 6.022 \times 10^{23}} = 8.97 \text{ g cm}^{-3}$$

This is close enough to the measured value of 8.92 g cm^{-3} .

#457399

Topic: Imperfections or defects in a solid

Analysis shows that nickel oxide has the formula $Ni_{0.98}O_{1.00}$. What fractions of nickel exist as Ni^{2+} and Ni^{3+} ions?

Solution

It is given that nickel oxide has the formula as $Ni_{0.98}O_{1.00}$.

As per the formula, there are 98 Ni ions for 100 oxide ions.

Out of 98 Ni ions, let x ions be in +2 oxidation state.

$98 - x$ ions will be in +3 oxidation state.

Oxide ion has -2 charge.

To maintain electrical neutrality, total positive charge on cations = total negative charge on anions.

$$2x + 3(98 - x) + 100(-2) = 0$$

$$x = 94$$

$$\text{Fraction of } Ni^{2+} \text{ ions} = \frac{94}{98} = 0.96$$

$$\text{Fraction of } Ni^{3+} \text{ ions} = \frac{98 - 94}{98} = 0.04$$

Hence, the fractions of nickel that exists as Ni^{2+} and Ni^{3+} are 0.96 and 0.04 respectively.

#457400

Topic: Electrical properties of solids

What is a semiconductor? Describe the two main types of semiconductors and contrast their conduction mechanism

Solution

Semiconductors are substances with conductance in the intermediate range of 10^{-6} to $10^4 \text{ ohm}^{-1} \text{ m}^{-1}$.

(i) n-type semiconductor: In this semiconductors, increase in conductivity is due to negatively charged electrons. For example, Si or Ge (group 14 elements) doped with P or As (group 15 elements containing 5 valence electrons).

Out of five valence electrons of group 15 elements, 4 valence electrons form covalent bonds with four neighboring Si or Ge atoms and the remaining fifth electron becomes delocalized and increases the conductivity of doped Si or Ge.

(ii) p-type semiconductor. In this semiconductors, increase in conductivity is due to positively charged holes. For example, Si or Ge (group 14 elements) doped with B, Al or Ga (group 13 elements containing 3 valence electrons). In presence of electric field, electrons move toward the positively charged plate through electron holes. However, it appears as if the electron holes are positively-charged and are moving towards the negatively-charged plate.

#457403

Topic: Electrical properties of solids

Non-stoichiometric cuprous oxide, Cu_2O can be prepared in laboratory. In this oxide, copper to oxygen ratio is slightly less than 2 : 1. Can you account for the fact that this substance is a p-type semiconductor?

Solution

Non-stoichiometric cuprous oxide, Cu_2O can be prepared in laboratory. In this oxide, copper to oxygen ratio is slightly less than 2 : 1. This substance is a p-type semiconductor. Slight difference in ratio factor corresponds to absence of Cu(I) ions from their lattice site leaving behind holes which helps in electrical conductivity.

#457404

Topic: Calculation of number of particles per unit cell of a cubic crystal system

Ferric oxide crystallises in a hexagonal close-packed array of oxide ions with two out of every three octahedral holes occupied by ferric ions. Derive the formula of the ferric oxide.

Solution

Let x represents the number of oxide ions.

Therefore, the number of octahedral voids = x

$$\text{Number of ferric ions} = \frac{2}{3}x$$

The ratio of the number of ferric ions to the number of oxide ions is $\frac{2}{3}x : x = \frac{2}{3} : 1 = 2 : 3$

Hence, ferric oxide has formula Fe_2O_3 .

#457405

Topic: Electrical properties of solids

Classify each of the following as being either a p-type or a n-type semiconductor:

(i) Ge doped with In (ii) Si doped with B

Solution

(i) Ge doped with In (ii) Si doped with B are p-type semiconductors as both B and In are trivalent impurities belonging to group 13.

#457407

Topic: Radius ratio rules

Gold (atomic radius = 0.144 nm) crystallises in a face-centred unit cell. What is the length of a side of the cell?

Solution

For fcc unit cell, $a = 2\sqrt{2}r$.

Here, a is the edge length and r is the atomic radius (0.144 nm).

$$a = 2\sqrt{2} \times 0.144 = 0.407 \text{ nm}$$

Hence, the length of a side of a cell is 0.407 nm .

#457408

Topic: Electrical properties of solids

In terms of band theory, what is the difference

(i) between a conductor and an insulator?

(ii) between a conductor and a semiconductor?

Solution

The differences are given below:

(i) Conductor and insulator

In conductor, the valence band is partially filled and it overlaps with a high energy unoccupied conduction band.

Electrons can easily flow under an applied electric field.

In case of insulator, the valence band is fully-filled and there is large energy gap between the valence band and the conduction band.

(ii) Conductor and semiconductor

In conductor, the valence band is partially filled and it overlaps with a high energy unoccupied conduction band.

Electrons can easily flow under an applied electric field.

In semiconductor, the valence band is filled and there is a small gap between the valence band and the next higher conduction band.

Some electrons can jump from the valence band to the conduction band and conduct electricity

#457410

Topic: Imperfections or defects in a solid

Explain the following terms with suitable examples:

(i) Schottky defect (ii) Frenkel defect (iii) Interstitials and (iv) F-centres

Solution

(i) Schottky defect

Some atoms or ions are missing from their normal lattice sites. Unoccupied lattice sites are called vacancies or holes.

For example, in the crystal lattice of NaCl, equal number of cations and anions are missing to maintain electrical neutrality.

(ii) Frenkel defect

An ion is missing from its normal position and occupies an interstitial site.

Due to this, vacancy defect and interstitial defect are produced.

For example, in the crystal lattice of ZnS, a zinc cation is missing from its normal position and occupies an interstitial site.

(iii) Interstitials

They are sites between lattice points.

For example, in Frenkel defect, the occupancy of interstitials cause interstitial defect.

(iv) F-centres

The electrons trapped in anion vacancies are called F-centres. They impart colour to crystal.

For example, in NaCl crystal, F-centres impart yellow colour.

#457411

Topic: Radius ratio rules

Aluminium crystallises in a cubic close-packed structure. Its metallic radius is 125 pm.

(i) What is the length of the side of the unit cell?

(ii) How many unit cells are there in 1.00 cm^3 of aluminium?

Solution

It is given that aluminium crystallises in a cubic closed packed structure.

Its metallic radius is 125 pm.

(i) For cubic close-packed structure

$$a = 2\sqrt{2}r = 2\sqrt{2} \times 125 = 354\text{ pm}$$

Here, a is the edge length of the unit cell and r is the atomic radius.

(ii) Volume of one unit cell

$$= a^3 = (354\text{ pm})^3 = 4.4 \times 10^{-23}\text{ cm}^3$$

$$(1\text{ pm} = 10^{-10}\text{ cm})$$

$$\text{Number of unit cells in } 1.00\text{ cm}^3 = \frac{1.00\text{ cm}^3}{4.4 \times 10^{-23}\text{ cm}^3} = 2.27 \times 10^{22}$$

#457413

Topic: Imperfections or defects in a solid

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

Solution

NaCl is doped with 10^{-3} mol % of SrCl_2 .

100 moles of NaCl are doped with 0.001 moles of SrCl_2 .

1 mole of NaCl is doped with $\frac{0.001}{100} = 10^{-5}$ moles of SrCl_2 or 10^5 moles of Sr^{2+} cations.

One Sr^{2+} ion creates one cation vacancy.

10^{-5} moles of Sr^{2+} will create 10^{-5} moles of cation vacancies which correspond to $10^{-5} \times 6.023 \times 10^{23} = 6.023 \times 10^{18}$ cation vacancies per mole of NaCl .

#457415

Topic: Magnetic properties of solids

Explain the following with suitable examples:

(i) Ferromagnetism

(ii) Paramagnetism

(iii) Ferrimagnetism

(iv) Antiferromagnetism

(v) 12 – 16 and 13 – 15 group compounds

Solution

(i) Ferromagnetism

Certain substances exhibit very strong magnetic property. They can be permanently magnetised. They contain large number of unpaired electrons.

Examples: Iron, cobalt, nickel, gadolinium, CrO_2 etc.

(ii) Paramagnetism

When unpaired electrons revolve in the orbitals, a net magnetic field is associated with the substance containing these unpaired electrons.

Due to presence of unpaired electrons, certain substances experiences pull in magnetic field. The number of unpaired electrons determine the extent of paramagnetism.

Examples : Oxygen,

Cu^{2+} , Fe^{3+} and Cr^{3+}

(iii) Ferrimagnetism

Unequal number of unpaired electrons are aligned in opposite directions, the net magnetic moment is not zero.

Example: Ferrite Fe_2O_3

(iv) Antiferromagnetism

Equal number of unpaired electrons are aligned in opposite directions, the net magnetic moment is zero.

Example: MnO, Mn_2O_3 and MnO_2

#457453

Topic: General introduction

Suggest the most important type of intermolecular attractive interaction in the following pairs.

(i) n-hexane and n-octane

(ii) I_2 and CCl_4

(iii) $NaClO_4$ and water

(iv) methanol and acetone

(v) acetonitrile (CH_3CN) and acetone (C_3H_6O)

Solution

The most important type of inter-molecular attractive interaction in the given pairs are given below:

(i) Van der waals interactions

(ii) Van der waals interactions

(iii) Ion dipole interactions

(iv) Hydrogen bonding

(v) Dipole dipole interactions