RG
Ram Govind Yadav
CHEMISTRY EDUCATOR

PHYSICAL

CH 07

The Solid State — Unit Cells, Packing & Defects

07

Types of solids, crystal systems, counting atoms in unit cells, close packing and voids, packing efficiency, density numericals, ionic structures, defects, and electrical and magnetic properties — with every numerical type solved, an exam trap gallery, graded MCQs and a one-page revision sheet.

WHAT YOU WILL BE ABLE TO DO

- Classify solids as crystalline or amorphous and as molecular, ionic, metallic or covalent
- Count atoms per unit cell and relate edge length to radius for sc, bcc and fcc
- Calculate packing efficiency and density, and find formulas from void occupation
- Describe the NaCl, CsCl, ZnS and CaF_2 structures and use radius ratios
- Explain Schottky, Frenkel and non-stoichiometric defects, semiconductors and magnetic types

INSIDE

A The big picture
B Crystalline and amorphous solids
C Classification of crystalline solids
D Crystal lattices and unit cells
E Counting atoms in a unit cell
F Close packing and voids
G Density of a unit cell
H Ionic structures

HOW TO USE THESE NOTES

IN ONE LINE The core idea of a section	**KEY IDEA** The concept to remember	**EXAM TRAP** Where marks are usually lost
SOLVED EXAMPLE Worked step by step	**CHECK YOURSELF** Quick self-test	**MEMORY HOOK** A line that sticks

SECTION A

The big picture

A

Count, relate, calculate.

IN ONE LINE

A crystal is a unit cell repeated in three dimensions; counting the atoms that belong to one cell and relating the edge length to the atomic radius gives density, packing efficiency and formula.

Question type	What you need
Atoms per cell (Z)	Corner ⅛, edge ¼, face ½, body 1
Radius from edge	sc: a = 2r; bcc: √3a = 4r; fcc: √2a = 4r
Density	$d = ZM / (a^3 N_a)$
Formula of a compound	Which ions sit in which voids, and what fraction
Defect type	Does density change? Does the ratio of ions change?

THINK OF IT LIKE THIS

Stack oranges at a fruit stall. However you start, the neatest pile has each orange touching 12 others and fills 74% of the space; the gaps left over are of two sizes — small ones between four oranges and larger ones between six. Every close-packed metal and many ionic crystals are built exactly like that pile.

SECTION B

Crystalline and amorphous solids

B

Long-range order or only short-range order.

Property	Crystalline	Amorphous
Shape	Definite, regular	Irregular
Order	Long-range	Short-range only
Melting	Sharp m.p.	Softens over a range

Property	Crystalline	Amorphous
Cleavage	Clean, flat faces	Irregular surfaces
Heat of fusion	Definite	Not definite
Physical properties	Anisotropic (differ with direction)	Isotropic
Examples	NaCl, quartz, diamond, ice	Glass, rubber, plastics, quartz glass

- Glass is called a **supercooled liquid** (pseudo-solid): very old window panes are slightly thicker at the bottom.
- Heating and slow cooling can make an amorphous solid crystalline (old glass turns milky).
- Quartz (crystalline) and quartz glass (amorphous) are both SiO_2 — same composition, different order.

SECTION C

Classification of crystalline solids

C

What holds the particles together decides the properties.

Type	Particles	Forces	Examples	Properties
Molecular — non-polar	Molecules	Dispersion forces	Ar, CCl_4, H_2, I_2, CO_2	Soft, very low m.p., insulators
Molecular — polar	Molecules	Dipole–dipole	HCl, SO_2	Soft, low m.p., insulators
Molecular — H-bonded	Molecules	Hydrogen bonds	H_2O (ice)	Hard, low m.p., insulators
Ionic	Ions	Electrostatic	NaCl, MgO, ZnS, CaF_2	Hard, brittle, high m.p.; conduct when molten or dissolved
Metallic	Cations in a sea of electrons	Metallic bonding	Fe, Cu, Ag, Mg	Malleable, ductile, conductors
Covalent network	Atoms	Covalent bonds	Diamond, SiO_2, SiC, AlN; graphite	Very hard, very high m.p.; insulators (graphite conducts)

CHECK YOURSELF

C1 Why is glass called a supercooled liquid?

C2 Classify ice, SiC and brass by type of solid.

Answers at the end of the chapter.

SECTION D

Crystal lattices and unit cells

D

Seven shapes, fourteen lattices.

Crystal system	Edges	Angles	Bravais lattices	Example
Cubic	a = b = c	α = β = γ = 90°	sc, bcc, fcc (3)	NaCl, Cu, ZnS
Tetragonal	a = b ≠ c	α = β = γ = 90°	simple, body-centred (2)	SnO_2, TiO_2
Orthorhombic	a ≠ b ≠ c	α = β = γ = 90°	simple, body, face, end (4)	KNO_3, $BaSO_4$, rhombic S
Hexagonal	a = b ≠ c	α = β = 90°, γ = 120°	simple (1)	Graphite, ZnO, Mg
Rhombohedral	a = b = c	α = β = γ ≠ 90°	simple (1)	Calcite, HgS
Monoclinic	a ≠ b ≠ c	α = γ = 90°, β ≠ 90°	simple, end-centred (2)	Monoclinic S, $Na_2SO_4{\cdot}10H_2O$
Triclinic	a ≠ b ≠ c	α ≠ β ≠ γ ≠ 90°	simple (1)	$K_2Cr_2O_7$, $CuSO_4{\cdot}5H_2O$, H_3BO_3

KEY IDEA

7 crystal systems, 14 Bravais lattices. The triclinic system is the least symmetric (all edges and angles different); cubic is the most symmetric.

SECTION E

Counting atoms in a unit cell

E

Shared atoms count only for the fraction inside.

Position	Shared by	Contribution
Corner	8 cells	⅛
Edge centre	4 cells	¼
Face centre	2 cells	½
Body centre	1 cell	1

Cubic cell	Atoms per cell (Z)	Relation of a and r	Coordination number	Packing efficiency
Simple (sc)	8 × ⅛ = 1	a = 2r	6	52.4%
Body-centred (bcc)	8 × ⅛ + 1 = 2	√3 a = 4r	8	68%
Face-centred (fcc / ccp)	8 × ⅛ + 6 × ½ = 4	√2 a = 4r	12	74%

SOLVED EXAMPLE 01 — FORMULA FROM POSITIONS

In a cubic cell, A atoms are at the corners and B atoms at the face centres. One corner atom is missing. Find the formula.

SOLUTION

1. A: 7 corners × ⅛ = 7/8.
2. B: 6 faces × ½ = 3.
3. A : B = 7/8 : 3 = 7 : 24.

ANSWER A_7B_{24}.

SOLVED EXAMPLE 02 — PACKING EFFICIENCY OF BCC

Show that the packing efficiency of a bcc lattice is 68%.

SOLUTION

1. Z = 2; body diagonal $\sqrt{3}a = 4r \rightarrow a = 4r/\sqrt{3}$.
2. Volume of atoms = $2 \times (4/3)\pi r^3 = 8.38r^3$.
3. Cell volume $a^3 = (4r/\sqrt{3})^3 = 12.32r^3$.
4. Efficiency = 8.38 / 12.32.

ANSWER ≈ 0.68 → 68%.

SECTION F

Close packing and voids

F

How spheres stack, and the gaps they leave.

- **In two dimensions:** square packing (CN 4) or hexagonal packing (CN 6, more efficient).
- **In three dimensions:** placing a third layer over the holes of the second gives two patterns. **ABAB… = hcp** (Mg, Zn); **ABCABC… = ccp = fcc** (Cu, Ag, Au, Al). Both have CN 12 and 74% efficiency.
- **Tetrahedral void:** surrounded by 4 spheres. **Octahedral void:** surrounded by 6 spheres.

- For N spheres in close packing: **N octahedral voids and 2N tetrahedral voids.** In an fcc cell (4 atoms): 4 octahedral voids (body centre + 12 edge centres × ¼) and 8 tetrahedral voids (inside, near each corner).

Radius ratio r^+/r^-	Coordination number	Void / shape	Example
0.155 – 0.225	3	Triangular planar	B_2O_3
0.225 – 0.414	4	Tetrahedral	ZnS
0.414 – 0.732	6	Octahedral	NaCl
0.732 – 1.000	8	Cubic	CsCl

SOLVED EXAMPLE 03 — FORMULA FROM VOIDS

Oxide ions form ccp; Al^{3+} ions occupy two-thirds of the octahedral voids. Find the formula.

SOLUTION

1. N oxide ions → N octahedral voids.
2. Al^{3+} = ⅔N.
3. Al : O = ⅔ : 1 = 2 : 3.

ANSWER Al_2O_3.

SOLVED EXAMPLE 04 — TWO KINDS OF VOID

Atoms of Y form ccp; X occupies all tetrahedral voids and Z half the octahedral voids. Formula?

SOLUTION

1. Per N atoms of Y: 2N tetrahedral, N octahedral.
2. X = 2N; Z = N/2.
3. Y : X : Z = 1 : 2 : ½ = 2 : 4 : 1.

ANSWER X_4Y_2Z (X : Y : Z = 4 : 2 : 1).

CHECK YOURSELF

C3 How many tetrahedral voids are there in one fcc unit cell?

C4 Radius ratio of a salt is 0.52. What coordination number do you expect?

Answers at the end of the chapter.

SECTION G

Density of a unit cell

G

The single formula behind most numericals.

$$d = Z\,M / (a^3\,N_a)$$

Z = atoms (or formula units) per cell; M in g mol^{-1}; a in cm (1 pm = 10^{-10} cm); $N_a = 6.022 \times 10^{23}$

SOLVED EXAMPLE 05 — DENSITY OF COPPER

Copper is fcc with a = 361 pm. Find its density. (Cu = 63.5 g mol^{-1})

SOLUTION

1. Z = 4; a = 3.61×10^{-8} cm → $a^3 = 4.70 \times 10^{-23}$ cm^3.
2. $d = 4 \times 63.5 / (4.70 \times 10^{-23} \times 6.022 \times 10^{23}) = 254 / 28.3$.

ANSWER d ≈ 8.97 g cm^{-3} (measured 8.96).

SOLVED EXAMPLE 06 — NUMBER OF ATOMS IN A SAMPLE

An element (bcc, a = 288 pm) has density 7.2 g cm^{-3}. How many atoms are in 208 g of it?

SOLUTION

1. $a^3 = (2.88 \times 10^{-8})^3 = 2.39 \times 10^{-23}$ cm^3.
2. Mass of one cell = $7.2 \times 2.39 \times 10^{-23} = 1.72 \times 10^{-22}$ g, containing 2 atoms.
3. Atoms = $(208 / 1.72 \times 10^{-22}) \times 2$.

ANSWER ≈ 2.42×10^{24} atoms.

SOLVED EXAMPLE 07 — FINDING THE CELL TYPE

An element of molar mass 60 g mol^{-1} has a cubic cell of edge 400 pm and density 6.23 g cm^{-3}. Find Z and the cell type.

SOLUTION

1. $Z = d\,a^3\,N_a / M = 6.23 \times (4.00 \times 10^{-8})^3 \times 6.022 \times 10^{23} / 60$.
2. $= 6.23 \times 6.40 \times 10^{-23} \times 6.022 \times 10^{23} / 60 = 4.0$.

ANSWER Z = 4 → face-centred cubic.

SOLVED EXAMPLE 08 — RADIUS FROM EDGE LENGTH

Silver is fcc with a = 408.6 pm. Find the atomic radius.

SOLUTION

1. $\sqrt{2}\,a = 4r \rightarrow r = \sqrt{2} \times 408.6 / 4 = 1.414 \times 408.6 / 4$.

ANSWER r ≈ 144.4 pm.

SECTION H

Ionic structures

H

Four structures cover most questions.

Structure	Anions	Cations	CN (cation : anion)	Formula units per cell	Examples
Rock salt (NaCl)	fcc (ccp)	All octahedral voids	6 : 6	4	NaCl, KCl, MgO, AgCl
Caesium chloride	Simple cubic	Cube centre	8 : 8	1	CsCl, CsBr, TlCl
Zinc blende (ZnS)	fcc (ccp)	Half the tetrahedral voids	4 : 4	4	ZnS, CuCl, AgI
Fluorite (CaF_2)	Ca^{2+} fcc; F^- in all tetrahedral voids	—	8 : 4	4	CaF_2, BaF_2, $SrCl_2$
Antifluorite (Na_2O)	O^{2-} fcc; Na^+ in all tetrahedral voids	—	4 : 8	4	Na_2O, K_2O, Li_2O

KEY IDEA

Pressure and temperature change the structure. High pressure raises the coordination number (NaCl, 6:6 → CsCl type, 8:8); high temperature lowers it (CsCl, 8:8 → NaCl type, 6:6 at about 760 K).

SOLVED EXAMPLE 09 — EDGE LENGTH OF NACL

Na^+ = 95 pm and Cl^- = 181 pm. Assuming the ions touch along the edge, find the edge length of the NaCl cell.

SOLUTION

1. In rock salt, $a = 2(r^+ + r^-)$.
2. $a = 2 \times (95 + 181)$.

ANSWER a = 552 pm.

SECTION I

Imperfections in solids

I

Real crystals are never perfect.

Defect	What happens	Density	Found in
Vacancy	Lattice site empty	Decreases	Non-ionic solids, on heating
Interstitial	Extra particle in a void	Increases	Non-ionic solids
Schottky	Equal numbers of cations and anions missing	Decreases	NaCl, KCl, CsCl, AgBr (similar-size ions)
Frenkel	A smaller ion (usually the cation) moves to an interstitial site	Unchanged	ZnS, AgCl, AgBr, AgI (large size difference)

- **AgBr shows both** Schottky and Frenkel defects.
- Schottky defects in NaCl: about 10^6 pairs per mole at room temperature.
- **Impurity defects:** adding $SrCl_2$ to NaCl — each Sr^{2+} replaces two Na^+, leaving one cation vacancy. $CdCl_2$ in AgCl behaves the same way.
- **Metal excess by anion vacancies (F-centres):** heating NaCl in Na vapour creates Cl^- vacancies filled by electrons, which absorb light — NaCl turns yellow, LiCl pink, KCl violet.
- **Metal excess by interstitial cations:** ZnO turns yellow on heating as it loses oxygen: $ZnO \rightarrow Zn^{2+} + \frac{1}{2}O_2 + 2e^-$; Zn^{2+} and electrons occupy interstitial sites.
- **Metal deficiency:** FeO is really about $Fe_{0.95}O$ — some Fe^{2+} are missing and others become Fe^{3+} to keep the crystal neutral.

SOLVED EXAMPLE 10 — IMPURITY VACANCIES

NaCl is doped with 10^{-3} mol % $SrCl_2$. Find the concentration of cation vacancies per mole of NaCl.

SOLUTION

1. 10^{-3} mol % = 10^{-5} mol of $SrCl_2$ per mol of NaCl.
2. Each Sr^{2+} creates one cation vacancy.
3. Vacancies = $10^{-5} \times 6.022 \times 10^{23}$.

ANSWER **6.02×10^{18} vacancies per mole.**

CHECK YOURSELF

C5 Which defect lowers the density of a crystal?

C6 Why does ZnO turn yellow on heating?

Answers at the end of the chapter.

SECTION J

Electrical properties

J

Conductors, insulators and semiconductors.

- **Band theory:** in metals the valence band is partly filled or overlaps the conduction band — conductors. In insulators a wide forbidden gap separates them. In semiconductors the gap is small, so conductivity **increases with temperature**.
- **n-type:** Si or Ge doped with a group 15 element (P, As). The fifth electron is free → negative carriers.
- **p-type:** Si or Ge doped with a group 13 element (B, Al, Ga). An electron-deficient "hole" → positive carriers.
- A p–n junction is a diode (rectifier); n–p–n and p–n–p arrangements make transistors.
- **Compound semiconductors:** 13–15 (InSb, AlP, GaAs) and 12–16 (ZnS, CdS, CdSe, HgTe).

SECTION K

Magnetic properties

K

Unpaired electrons and how they line up.

Type	Alignment of magnetic moments	Examples
Diamagnetic	No unpaired electrons; weakly repelled	H_2O, NaCl, C_6H_6
Paramagnetic	Unpaired, randomly oriented; weakly attracted	O_2, Cu^{2+}, Fe^{3+}, Cr^{3+}
Ferromagnetic	Domains aligned in one direction; strongly attracted, permanent magnets	Fe, Co, Ni, Gd, CrO_2
Antiferromagnetic	Equal moments aligned opposite; net zero	MnO
Ferrimagnetic	Unequal moments aligned opposite; net moment	Fe_3O_4, ferrites $MgFe_2O_4$, $ZnFe_2O_4$

- Heating a ferromagnetic or ferrimagnetic solid above its Curie temperature makes it paramagnetic (Fe_3O_4 above 850 K).
- CrO_2 is used in audio and video cassette tapes.

SECTION L

Advanced problems

L

Each needs two ideas from the chapter.

SOLVED EXAMPLE 11 — Fe^{3+} IN A NON-STOICHIOMETRIC OXIDE

A sample of ferrous oxide has the formula $Fe_{0.93}O$. What percentage of the iron is present as Fe^{3+}?

SOLUTION

1. Let x = Fe^{3+} per formula unit; Fe^{2+} = 0.93 − x.
2. Charge balance with one O^{2-}: 3x + 2(0.93 − x) = 2 → x = 0.14.
3. Fraction Fe^{3+} = 0.14 / 0.93.

ANSWER About 15% of the iron is Fe^{3+}.

SOLVED EXAMPLE 12 — NEAREST-NEIGHBOUR DISTANCE

Iron is bcc with a = 286.6 pm. Find the distance between nearest neighbours and the atomic radius.

SOLUTION

1. In bcc the nearest atoms touch along the body diagonal: distance = √3a / 2.
2. = 1.732 × 286.6 / 2 = 248.2 pm.
3. r = half of that.

ANSWER Nearest-neighbour distance ≈ 248.2 pm; r ≈ 124.1 pm.

SOLVED EXAMPLE 13 — VOIDS AND FORMULA WITH TWO CATIONS

In a ccp lattice of oxide ions, A^{2+} occupies one-eighth of the tetrahedral voids and B^{3+} half of the octahedral voids. Find the formula.

SOLUTION

1. N oxide ions → 2N tetrahedral and N octahedral voids.
2. A^{2+} = 2N/8 = N/4; B^{3+} = N/2.
3. A : B : O = ¼ : ½ : 1 = 1 : 2 : 4. Check charge: +2 + 2(+3) − 8 = 0.

ANSWER AB_2O_4 — the spinel structure (e.g. $MgAl_2O_4$).

SOLVED EXAMPLE 14 — EDGE LENGTH FROM DENSITY

KCl has the rock-salt structure and density 1.98 g cm^{-3}. Find the edge length. (KCl = 74.5 g mol^{-1})

SOLUTION

1. Z = 4 formula units.
2. $a^3 = ZM / (d\ N_a) = 4 \times 74.5 / (1.98 \times 6.022 \times 10^{23}) = 2.50 \times 10^{-22}$ cm^3.
3. $a = (2.50 \times 10^{-22})^{1/3}$ cm = 6.30×10^{-8} cm.

ANSWER a ≈ 630 pm.

SECTION M

Exam trap gallery

M

Where marks are lost in this chapter.

✗ TRAP 01 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Simple cubic has 8 atoms per cell.	1 atom (8 × ⅛).
WHY Each corner atom is shared by 8 cells.	

✗ TRAP 02 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
For fcc, a = 2r.	fcc: √2a = 4r (a = 2√2 r); a = 2r is simple cubic.
WHY In fcc the atoms touch along the face diagonal.	

✗ TRAP 03 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
hcp is more efficient than ccp.	Both are 74% with CN 12.
WHY Only the stacking order differs.	

✗ TRAP 04 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
There are N tetrahedral voids for N atoms.	2N tetrahedral, N octahedral.
WHY A tetrahedral void is formed by 4 spheres in two layers.	

✗ TRAP 05 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Frenkel defects lower the density.	Frenkel: unchanged. Schottky: lower.
WHY In Frenkel no ion leaves the crystal.	

✗ TRAP 06 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Schottky defects occur in AgCl.	AgCl shows Frenkel; AgBr shows both.

WHY Large size difference favours Frenkel.

✗ TRAP 07 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Forgetting to convert pm to cm in $d = ZM/a^3N_a$.	1 pm = 10^{-10} cm; cube after converting.

WHY Otherwise the answer is off by 10^{30}.

✗ TRAP 08 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Silicon doped with boron is n-type.	p-type (holes).

WHY Boron has only three valence electrons.

✗ TRAP 09 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
CsCl is body-centred cubic.	It is simple cubic with a two-ion basis (Cl^- at corners, Cs^+ at centre).

WHY A true bcc needs identical particles at corners and centre.

✗ TRAP 10 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
In CaF_2, F^- forms the fcc lattice.	Ca^{2+} forms the fcc lattice; F^- fill all tetrahedral voids.

WHY Antifluorite (Na_2O) is the reverse.

✗ TRAP 11 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Conductivity of semiconductors falls with temperature.	It rises; that of metals falls.

WHY More electrons cross the small band gap.

✗ TRAP 12 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Fe_3O_4 is ferromagnetic.	Fe_3O_4 is ferrimagnetic.

WHY Unequal opposing moments.

MEMORY HOOK

"8 corners × ⅛ = 1; add 1 for bcc; add 3 for fcc."

"sc 52, bcc 68, fcc 74."

"N octahedral, 2N tetrahedral."

"Schottky shrinks density; Frenkel keeps it."

SECTION N

Practice MCQs

Levels: Easy, Moderate, Tough.

Q01 Atoms per unit cell in fcc: [EASY]

(a) 1 (b) 2
(c) 4 (d) 6

Q02 Coordination number in ccp: [EASY]

(a) 6 (b) 8
(c) 10 (d) 12

Q03 Packing efficiency of simple cubic: [EASY]

(a) 52.4% (b) 68%
(c) 74% (d) 80%

Q04 An example of an amorphous solid: [EASY]

(a) quartz (b) NaCl
(c) glass (d) diamond

Q05 Number of Bravais lattices: [EASY]

(a) 7 (b) 12
(c) 14 (d) 32

Q06 Frenkel defect is shown by: [EASY]

(a) NaCl (b) KCl
(c) AgCl (d) CsCl

Q07 Schottky defect causes density to: [EASY]

(a) increase (b) decrease
(c) remain same (d) double

Q08 In bcc, the relation between a and r is: [MODERATE]

(a) a = 2r (b) √2a = 4r
(c) √3a = 4r (d) a = 4r

Q09 Number of tetrahedral voids in a ccp arrangement of N atoms: [MODERATE]

(a) N (b) 2N
(c) N/2 (d) 4N

Q10 Coordination number of Na^+ in NaCl: [MODERATE]

(a) 4 (b) 6
(c) 8 (d) 12

Q11 Coordination numbers in CaF_2 (Ca^{2+} : F^-): [MODERATE]

(a) 4 : 8 (b) 8 : 4
(c) 6 : 6 (d) 8 : 8

Q12 Si doped with As gives: [MODERATE]

(a) p-type (b) n-type
(c) intrinsic (d) insulator

Q13 MnO is: [MODERATE]

(a) ferromagnetic (b) paramagnetic
(c) antiferromagnetic (d) ferrimagnetic

Q14 Crystal system with $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90°$: [MODERATE]

(a) tetragonal (b) orthorhombic
(c) monoclinic (d) triclinic

Q15 NaCl heated in Na vapour turns yellow because of: [MODERATE]

(a) Frenkel defects (b) F-centres
(c) interstitial Na^+ (d) Schottky defects only

Q16 A radius ratio of 0.30 suggests a coordination number of: [MODERATE]

(a) 3 (b) 4
(c) 6 (d) 8

Q17 Oxide ions in ccp with M in ⅔ of octahedral voids gives: [MODERATE]

(a) MO (b) M_2O_3
(c) M_3O_2 (d) MO_2

Q18 $Fe_{0.95}O$ contains: [MODERATE]

(a) only Fe^{2+} (b) Fe^{2+} and Fe^{3+}
(c) Fe^{2+} and Fe (d) only Fe^{3+}

Q19 Copper (fcc, a = 361 pm) has a density of about: [TOUGH]

(a) 4.5 g cm^{-3} (b) 8.97 g cm^{-3}
(c) 17.9 g cm^{-3} (d) 2.24 g cm^{-3}

Q20 Under high pressure NaCl changes to a structure with CN: [TOUGH]

(a) 4 (b) 6
(c) 8 (d) 12

Q21 A^+ ions at the corners and B^- at the body centre of a cube. Formula and CN of A^+: [TOUGH]

(a) AB, 8 (b) AB_2, 6
(c) A_2B, 4 (d) AB, 6

Q22 An element (M = 60, a = 400 pm, d = 6.23 g cm^{-3}) has Z: [TOUGH]

(a) 1 (b) 2
(c) 4 (d) 6

Q23 Packing efficiency of bcc: [TOUGH]

(a) 52.4% (b) 68%
(c) 74% (d) 90%

Q24 Doping NaCl with 10^{-3} mol % $SrCl_2$ gives cation vacancies per mole: [TOUGH]

(a) 6.02×10^{18} (b) 6.02×10^{20}
(c) 6.02×10^{16} (d) 6.02×10^{23}

Q25 Fe_3O_4 above 850 K becomes: [TOUGH]

(a) ferromagnetic (b) paramagnetic
(c) diamagnetic (d) antiferromagnetic

Answer key with explanations

Q01 **(c) 4** — 8 × ⅛ + 6 × ½.

Q02 **(d) 12** — Close packing.

Q03 **(a) 52.4%** — Least efficient.

Q04 **(c) glass** — Short-range order only.

Q05 **(c) 14** — Fourteen.

Q06 **(c) AgCl** — Large size difference.

Q07 **(b) decrease** — Ions leave the crystal.

Q08 **(c) √3a = 4r** — Atoms touch along the body diagonal.

Q09 **(b) 2N** — Two per atom.

Q10 **(b) 6** — Octahedral voids.

Q11 **(b) 8 : 4** — Fluorite.

Q12 **(b) n-type** — Extra electron from group 15.

Q13 **(c) antiferromagnetic** — Opposing equal moments.

Q14 **(b) orthorhombic** — Three unequal edges, right angles.

Q15 **(b) F-centres** — Electrons in anion vacancies.

Q16 **(b) 4** — 0.225 – 0.414.

Q17 **(b) M_2O_3** — ⅔ : 1.

Q18 **(b) Fe^{2+} and Fe^{3+}** — Charge balance for missing Fe^{2+}.

Q19 **(b) 8.97 g cm^{-3}** — $d = ZM/a^3N_a$ with Z = 4.

Q20 **(c) 8** — CsCl type.

Q21 **(a) AB, 8** — CsCl type.

Q22 **(c) 4** — $Z = da^3N_a/M$.

Q23 **(b) 68%** — Z = 2, √3a = 4r.

Q24 **(a)** $6.02 \times 10^{18} - 10^{-5}$ mol × N_a.

Q25 **(b) paramagnetic** — Above its Curie temperature.

Check-yourself answers

C1 It has short-range order like a liquid and flows extremely slowly; it does not melt sharply.

C2 Ice: molecular (H-bonded); SiC: covalent network; brass: metallic.

C3 Eight.

C4 6 (0.414 – 0.732, octahedral).

C5 Schottky (and vacancy) defects.

C6 It loses oxygen: Zn^{2+} ions and electrons occupy interstitial sites; the electrons absorb blue light.

QUICK REVISION

One-page revision

Read this page the night before the exam.

Types of solid

- Crystalline: sharp m.p., anisotropic
- Amorphous: glass, rubber; isotropic
- Molecular, ionic, metallic, covalent
- 7 systems, 14 Bravais lattices

Unit cells

- sc 1, bcc 2, fcc 4 atoms
- sc a = 2r; bcc √3a = 4r; fcc √2a = 4r
- CN 6, 8, 12
- Efficiency 52.4, 68, 74%

Packing and voids

- hcp ABAB; ccp ABCABC; both 74%
- N octahedral, 2N tetrahedral
- Radius ratio 0.225 / 0.414 / 0.732
- fcc cell: 4 octa, 8 tetra voids

Density and structures

- $d = ZM / (a^3 N_a)$; pm → cm
- NaCl 6:6, 4 f.u.; CsCl 8:8, 1 f.u.
- ZnS 4:4; CaF_2 8:4; Na_2O 4:8
- Pressure ↑ CN; temperature ↓ CN

Defects

- Schottky: density ↓ (NaCl, KCl)
- Frenkel: density same (AgCl, ZnS)
- AgBr both; $SrCl_2$ in NaCl → vacancies
- F-centres; ZnO yellow; $Fe_{0.95}O$

Electrical and magnetic

- n-type: group 15 dopant; p-type: group 13
- Semiconductor σ rises with T
- Ferro Fe Co Ni CrO_2; antiferro MnO
- Ferri Fe_3O_4; Curie T → paramagnetic

END OF NOTES · RAMGOVINDYADAV.COM