

Topic 1: Classification of Solids (50 MCQs)

Level 1: Basic / Conceptual (Q1–Q15)

Q1. Which of the following is an amorphous solid?

- a) Diamond
- b) NaCl
- c) Glass
- d) Graphite

Q2. Ionic solids are generally:

- a) Good conductors of electricity in solid state
- b) Hard and brittle
- c) Low melting point
- d) Soft and malleable

Q3. Molecular solids are held together by:

- a) Ionic bonds
- b) Covalent bonds
- c) Van der Waals forces
- d) Metallic bonds

Q4. Diamond is an example of:

- a) Ionic solid
- b) Covalent solid
- c) Molecular solid
- d) Metallic solid

Q5. Which of the following solids has a definite melting point?

- a) Amorphous solids
- b) Crystalline solids
- c) Both
- d) None

Q6. Which of the following is a metallic solid?

- a) NaCl
- b) Fe
- c) I₂
- d) Ice

Q7. Characteristics of crystalline solids include:

- a) Long-range order
- b) Definite shape
- c) Sharp melting point
- d) All of the above

Q8. Amorphous solids do not have:

- a) Short-range order
- b) Long-range order

- c) Molecules
- d) Atoms

Q9. Ionic solids are generally:

- a) Soft
- b) Brittle
- c) Conductors in solid state
- d) Malleable

Q10. Which of the following is covalent network solid?

- a) NaCl
- b) Diamond
- c) Iodine
- d) Copper

Q11. Graphite conducts electricity because:

- a) It has mobile protons
- b) It has delocalized electrons
- c) It has ionic bonds
- d) It has hydrogen bonds

Q12. Which of the following is a molecular solid?

- a) Diamond
- b) I₂
- c) NaCl
- d) SiC

Q13. Amorphous solids are sometimes called:

- a) Supercooled liquids
- b) Crystalline solids
- c) Covalent solids
- d) Ionic solids

Q14. Which type of solids is soluble in water but not in nonpolar solvents?

- a) Molecular solids
- b) Ionic solids
- c) Metallic solids
- d) Covalent solids

Q15. Which property is common to all crystalline solids?

- a) Brittle
- b) Malleable
- c) Long-range periodic arrangement of particles
- d) Poor conductor in molten state

Level 2: Moderate / Calculation / Application (Q16–Q40)

Q16. Lattice energy depends on:

- a) Charge of ions and size
- b) Density of solid

- c) Molar mass
- d) Temperature

Q17. Ionic solids conduct electricity:

- a) In solid state
- b) In molten state
- c) Both solid and molten
- d) Never

Q18. Diamond is very hard because:

- a) Weak van der Waals forces
- b) 3D covalent network
- c) Ionic bonding
- d) Metallic bonding

Q19. If an ionic solid has high lattice energy, it will have:

- a) Low melting point
- b) High melting point
- c) Poor stability
- d) Softness

Q20. Among the following, which has the lowest melting point?

- a) NaCl
- b) Diamond
- c) I₂
- d) MgO

Q21. Which solid will conduct electricity in molten state but not in solid?

- a) NaCl
- b) Diamond
- c) I₂
- d) Graphite

Q22. Ionic solids are brittle because:

- a) Layers can slide easily
- b) Electrostatic repulsion between like charges causes fracture
- c) Weak bonds
- d) No long-range order

Q23. The hardness of diamond is due to:

- a) Ionic bonds
- b) Metallic bonds
- c) Covalent bonding in 3D network
- d) Weak van der Waals forces

Q24. Which solid is malleable and ductile?

- a) NaCl
- b) Copper
- c) I₂
- d) Ice

Q25. The solubility of ionic solids increases with:

- a) Increasing lattice energy
- b) Increasing temperature
- c) Decreasing solvation energy
- d) None of the above

Q26. Covalent solids generally:

- a) Conduct electricity
- b) Are soft
- c) Are hard and brittle
- d) Have high solubility in water

Q27. Molecular solids generally have:

- a) High melting point
- b) Low melting point
- c) Conductivity
- d) Hardness

Q28. Which of the following solids has mobile electrons?

- a) NaCl
- b) Graphite
- c) Diamond
- d) I₂

Q29. Ionic solids are generally:

- a) Insoluble in water
- b) Soluble in water
- c) Soluble in nonpolar solvents
- d) None of the above

Q30. Solids with metallic bonding:

- a) Conduct in solid state
- b) Are brittle
- c) Insoluble in all solvents
- d) Soft

Q31. Amorphous solids differ from crystalline solids in:

- a) Lack of definite melting point
- b) Lack of long-range order
- c) Both (a) and (b)
- d) Electrical conductivity

Q32. Ionic solids have:

- a) Strong covalent bonding
- b) Strong electrostatic forces
- c) Weak van der Waals forces
- d) Delocalized electrons

Q33. Which is not a property of molecular solids?

- a) Low melting point
- b) Soft

- c) High electrical conductivity
- d) Poor conductor

Q34. Diamond and graphite differ in:

- a) Type of bonding
- b) Conductivity
- c) Structure
- d) All of the above

Q35. Among the following, which is least brittle?

- a) NaCl
- b) Diamond
- c) Metallic copper
- d) Ice

Q36. Ionic solids are hard because:

- a) Weak bonds
- b) Strong electrostatic interactions
- c) 3D network of covalent bonds
- d) Delocalized electrons

Q37. Covalent solids are:

- a) Conductors
- b) Insulators
- c) Always malleable
- d) Ionic

Q38. Molecular solids generally have:

- a) High solubility in water
- b) Weak intermolecular forces
- c) High melting point
- d) Ionic bonding

Q39. Conductivity of graphite arises from:

- a) Mobile ions
- b) Delocalized π -electrons
- c) Covalent bonds
- d) Ionic lattice

Q40. Ionic solids like NaCl are:

- a) Soluble in polar solvents
- b) Soluble in nonpolar solvents
- c) Poorly soluble in polar solvents
- d) Insoluble in all solvents

Level 3: Advanced / Multi-step / Olympiad-style (Q41–Q50)

Q41. Rank the following in increasing order of melting point: I₂, NaCl, MgO, Diamond.

Q42. The lattice energy of LiF is higher than NaCl because:

- a) Li^+ is smaller \rightarrow stronger attraction
- b) F^- is smaller
- c) Both
- d) None

Q43. If an ionic solid is doped with small amount of divalent cation, what type of defect forms?

Q44. Compare hardness and conductivity of diamond vs graphite.

Q45. Ionic solid XY has a lattice energy U. If radius of X increases, U changes as:

- a) Increases
- b) Decreases
- c) Remains same
- d) Cannot predict

Q46. Which is stronger: covalent network bonding or ionic bonding? Explain with examples.

Q47. Explain why metals are malleable while ionic solids are brittle.

Q48. A molecular solid has very low melting point. Explain in terms of forces.

Q49. Graphite vs diamond: explain why only graphite conducts electricity.

Q50. Given the lattice energy of NaCl = 786 kJ/mol, estimate relative lattice energy of MgO.

Answer Key – Topic 1: Classification of Solids

Q	Answer	Explanation / Formula
1	c	Glass is amorphous; lacks long-range order
2	b	Ionic solids are hard and brittle due to strong ionic bonds
3	c	Molecular solids held by van der Waals forces
4	b	Diamond = 3D covalent network
5	b	Crystalline solids have sharp melting points
6	b	Metallic solid = Fe, Cu etc.
7	d	All characteristics listed apply

Q	Answer	Explanation / Formula
8	b	Amorphous solids lack long-range order
9	b	Ionic solids brittle due to electrostatic repulsion
10	b	Diamond = covalent network
11	b	Delocalized π electrons in graphite
12	b	I ₂ = molecular solid
13	a	Supercooled liquid = amorphous solid
14	b	Ionic solids soluble in polar solvents
15	c	Long-range periodic arrangement common
16	a	Lattice energy $\propto (Q_1 \cdot Q_2)/r$
17	b	Ionic solids conduct in molten state only
18	b	Diamond 3D covalent network → very hard
19	b	High lattice energy → high melting point
20	c	I ₂ has weakest van der Waals forces → lowest MP
21	a	Ionic solids conduct when molten or in solution
22	b	Electrostatic repulsion when layers shift
23	c	Covalent bonds in 3D network → hardness
24	b	Metals are malleable and ductile due to delocalized electrons

Q	Answer	Explanation / Formula
25	b	Solubility increases with temperature for ionic solids
26	c	Covalent solids are hard and brittle
27	b	Molecular solids → weak forces → low MP
28	b	Graphite has mobile delocalized electrons
29	b	Ionic solids soluble in polar solvents
30	a	Metals conduct in solid state
31	c	Amorphous solids lack sharp MP and long-range order
32	b	Ionic solids held by strong electrostatic forces
33	c	Molecular solids are poor conductors
34	d	Diamond and graphite differ in bonding, conductivity, structure
35	c	Metallic copper is least brittle
36	b	Strong ionic bonds → hardness
37	b	Covalent solids are insulators
38	b	Weak intermolecular forces → low MP
39	b	Graphite conductivity from delocalized π -electrons
40	a	Ionic solids soluble in polar solvents
41	I ₂ < NaCl < Diamond < MgO	MP increases with bond strength: Van der Waals < ionic < covalent < highly ionic MgO

Q	Answer	Explanation / Formula
42	a	Smaller Li^+ → stronger attraction → higher lattice energy
43	Frenkel or substitutional defect depending on ion size	
44	Diamond: very hard, non-conductor; Graphite: soft, conductor	
45	b	Increasing radius decreases lattice energy ($U \propto 1/r$)
46	Covalent network stronger (diamond vs NaCl)	
47	Metals malleable due to delocalized electrons; ionic solids brittle due to charge repulsion	
48	Weak van der Waals forces → low MP	
49	Graphite has mobile π electrons → conducts; diamond does not	
50	MgO lattice energy higher due to higher charges (+2, -2)	

Topic 2: Crystal Lattice and Unit Cell (70 MCQs)

Level 1: Basic / Conceptual (Q51–Q65)

Q51. A crystal lattice is defined as:

- a) Arrangement of atoms in a molecule
- b) 3D arrangement of particles in a crystal
- c) Random arrangement of atoms
- d) Arrangement of ions in a solution

Q52. Which of the following is a primitive cubic unit cell?

- a) NaCl
- b) Polonium
- c) Diamond
- d) Cu

Q53. Number of atoms per unit cell in simple cubic lattice is:

- a) 1
- b) 2
- c) 4
- d) 8

Q54. Edge length of a cubic unit cell is 'a'. Atomic radius in simple cubic lattice is:

- a) a
- b) $a/2$
- c) $a/\sqrt{2}$
- d) $a/\sqrt{3}$

Q55. Face-centered cubic (FCC) contains how many atoms per unit cell?

- a) 1
- b) 2
- c) 4
- d) 8

Q56. Body-centered cubic (BCC) has how many atoms per unit cell?

- a) 1
- b) 2
- c) 4
- d) 8

Q57. Atomic packing factor (APF) for FCC lattice is:

- a) 0.52
- b) 0.68
- c) 0.74
- d) 0.91

Q58. In BCC lattice, atomic packing factor is:

- a) 0.52
- b) 0.68

- c) 0.74
- d) 0.91

Q59. Edge length 'a' of FCC unit cell is related to atomic radius r as:

- a) $a = 2r$
- b) $a = 4r/\sqrt{2}$
- c) $a = 2\sqrt{2} r$
- d) $a = 4r$

Q60. Number of atoms at corners in cubic unit cell is:

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

Q61. Which unit cell has maximum packing efficiency?

- a) Simple cubic
- b) BCC
- c) FCC
- d) None

Q62. Edge length of BCC unit cell in terms of atomic radius r is:

- a) $a = 2r$
- b) $a = 4r/\sqrt{3}$
- c) $a = 4r/\sqrt{2}$
- d) $a = r$

Q63. NaCl crystallizes in:

- a) FCC lattice
- b) BCC lattice
- c) Simple cubic
- d) Diamond cubic

Q64. Diamond has which type of cubic lattice?

- a) Simple cubic
- b) BCC
- c) FCC
- d) None

Q65. In FCC, number of atoms effectively present at face centers is:

- a) 1
- b) 2
- c) 3
- d) 4

Level 2: Moderate / Calculation / Application (Q66–Q105)

Q66. Edge length of simple cubic lattice = 400 pm. Calculate volume of unit cell.

- a) $6.4 \times 10^{-23} \text{ cm}^3$
- b) $6.4 \times 10^{-21} \text{ cm}^3$

- c) $6.4 \times 10^{-24} \text{ cm}^3$
- d) $6.4 \times 10^{-22} \text{ cm}^3$

Q67. If density of a cubic crystal is 8 g/cm^3 , molar mass = 56 g/mol , and number of atoms per unit cell = 2, calculate edge length.

- a) 2.86 \AA
- b) 3.15 \AA
- c) 4.01 \AA
- d) 2.45 \AA

Q68. Packing efficiency of simple cubic structure:

- a) 52%
- b) 68%
- c) 74%
- d) 90%

Q69. Density of metal with FCC structure, edge $a = 4 \text{ \AA}$, atomic mass = 58.5 g/mol , calculate density.

Q70. Number of atoms effectively present in BCC lattice:

- a) 1
- b) 2
- c) 3
- d) 4

Q71. Edge length of FCC unit cell = 4 \AA . Atomic radius = ?

- a) 1 \AA
- b) 2 \AA
- c) $\sqrt{2} \text{ \AA}$
- d) $2\sqrt{2} \text{ \AA}$

Q72. Which of the following is true for FCC lattice?

- a) 1 atom per unit cell
- b) 4 atoms per unit cell
- c) 2 atoms per unit cell
- d) 8 atoms per unit cell

Q73. Copper crystallizes in FCC. Calculate number of atoms per 1 cm^3 given edge = 361 pm .

Q74. NaCl structure is also called:

- a) Rock salt structure
- b) Zinc blende
- c) Diamond
- d) BCC

Q75. In NaCl structure, each Na^+ is surrounded by:

- a) 4 Cl^-
- b) 6 Cl^-
- c) 8 Cl^-
- d) 12 Cl^-

Q76. Coordination number in BCC = ?

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

Q77. Coordination number in FCC = ?

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

Q78. In zinc blende (ZnS) structure, coordination numbers of Zn and S are:

- a) 4, 4
- b) 6, 6
- c) 8, 8
- d) 12, 12

Q79. In CsCl structure, coordination number of Cs = ?

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

Q80. Edge length of BCC unit cell = 4.1 Å. Atomic radius = ?

Q81. Volume of FCC unit cell = ? formula in terms of r.

Q82. Number of ions in NaCl unit cell = ?

Q83. Edge length of unit cell $a = ?$, radius $r = ?$ for FCC lattice.

Q84. Calculate packing efficiency of BCC.

Q85. Metal has density 8 g/cm³, molar mass 56 g/mol, BCC structure. Find edge length.

Q86. Simple cubic lattice density formula: $\rho = ?$

Q87. Calculate number of atoms per unit volume in FCC.

Q88. Compare packing efficiencies: SC, BCC, FCC.

Q89. If NaCl edge length = 564 pm, calculate density.

Q90. Edge length of FCC lattice $a = 4\sqrt{2} r$. Verify APF = 0.74.

Q91. Number of atoms at corner in SC = ? fraction contribution per unit cell.

Q92. Contribution of atoms at face in FCC unit cell = ?

Q93. Number of atoms effectively in BCC = 1 corner + 1 body center?

Q94. For NaCl, how many Cl⁻ ions per unit cell?

- Q95. For CsCl, number of Cs⁺ ions per unit cell = ?
- Q96. Density formula in terms of Z, M, a: $\rho = ZM/Na^3$. Apply to calculate density.
- Q97. If APF = 0.74, calculate void fraction.
- Q98. Calculate number of formula units in 1 cm³ of NaCl.
- Q99. FCC lattice edge = 4 Å. Find number of atoms in 1 cm³.
- Q100. BCC lattice, edge = 3 Å. Atomic radius = ?
- Q101. Calculate edge of unit cell of KCl, M = 74.5 g/mol, density = 1.98 g/cm³, Z = 4.
- Q102. Diamond cubic unit cell has 8 atoms per unit cell. Calculate density if M = 12 g/mol, a = 3.567 Å.
- Q103. Relation of radius and edge for BCC: $a = 4r/\sqrt{3}$. Derive APF.
- Q104. For FCC, $a = 2\sqrt{2} r$. Derive APF formula.
- Q105. Fractional volume occupied by atoms in SC = ?
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Level 3: Advanced / Multi-step / Olympiad-style (Q106–Q120)

- Q106. Compare theoretical densities of BCC and FCC lattices for same element.
- Q107. Calculate number of NaCl formula units per cm³ given a = 564 pm.
- Q108. In diamond cubic structure, calculate packing efficiency.
- Q109. Show relation between atomic radius and edge length for tetrahedral void.
- Q110. Find radius of octahedral void in FCC lattice.
- Q111. Find fraction of octahedral voids filled in NaCl.
- Q112. Calculate lattice constant of CsCl given density, molar mass.
- Q113. If 10% vacancies present in metal with FCC, calculate density decrease.
- Q114. Compare densities of ZnS (zinc blende) and NaCl.
- Q115. Number of tetrahedral voids in FCC lattice with n atoms.
- Q116. Show relation: Number of octahedral voids = n (for FCC lattice with n atoms).
- Q117. Find number of atoms per cm³ for aluminum FCC lattice.
- Q118. Show that volume of unit cell for BCC = $16r^3/3\sqrt{3}$.
- Q119. Fraction of empty space in BCC lattice.
- Q120. Calculate radius of atom in FCC if edge a = 4 Å.

Answer Key: Topic 2 – Crystal Lattice and Unit Cell

Level 1: Basic / Conceptual (Q51–Q65)

Q51 – b. A crystal lattice is a 3D arrangement of particles (atoms, ions, molecules) in a crystal.

Q52 – b. Polonium crystallizes in **primitive cubic** lattice.

Q53 – a. Simple cubic (SC) has **1 atom per unit cell** (8 corners \times 1/8).

Q54 – b. For SC: $r = a/2$.

Q55 – c. FCC has **4 atoms/unit cell** (8 corners \times 1/8 + 6 faces \times 1/2).

Q56 – b. BCC has **2 atoms/unit cell** (8 corners \times 1/8 + 1 body).

Q57 – c. FCC packing efficiency = 0.74.

Q58 – b. BCC packing efficiency = 0.68.

Q59 – b. FCC: $a = \frac{4r}{\sqrt{2}}$.

Q60 – b. Cubic unit cell has 8 corner atoms.

Q61 – c. FCC has maximum packing efficiency (74%).

Q62 – b. BCC: $a = \frac{4r}{\sqrt{3}}$.

Q63 – a. NaCl crystallizes in **FCC lattice** (rock salt structure).

Q64 – c. Diamond has **FCC cubic lattice with 8 atoms/unit cell**.

Q65 – b. Face centers in FCC contribute $6 \times \frac{1}{2} = 3$ atoms.

Level 2: Moderate / Calculation / Application (Q66–Q105)

Q66 – a. Volume = $a^3 = (400 \times 10^{-12} \text{ m})^3 = 6.4 \times 10^{-29} \text{ m}^3 = 6.4 \times 10^{-23} \text{ cm}^3$.

Q67 – a. Formula: $\rho = \frac{ZM}{N_A a^3}$. Solve for a $\rightarrow 2.86 \text{ \AA}$.

Q68 – a. SC packing efficiency = 52% (Volume occupied/Unit cell volume).

Q69 – Answer: Use $\rho = \frac{ZM}{N_A a^3}$.

Q70 – b. BCC: 2 atoms/unit cell.

Q71 – b. FCC: $a = 4r/\sqrt{2} \rightarrow r = a\sqrt{2}/4 = 2\text{\AA}$.

Q72 – b. FCC has **4 atoms/unit cell**.

Q73 – Use formula: $n = \frac{N_A}{V_{\text{cell}}} \times Z$. Answer $\sim 8.5 \times 10^{22}$ atoms/cm³.

Q74 – a. NaCl = Rock salt structure.

Q75 – b. Na⁺ surrounded by **6 Cl⁻ ions** (octahedral coordination).

Q76 – b. BCC coordination number = 8.

Q77 – c. FCC coordination number = 12.

Q78 – a. ZnS (zinc blende) CN: 4, 4.

Q79 – b. CsCl CN = 8.

Q80 – b. BCC: $a = 4r/\sqrt{3} \rightarrow r = a\sqrt{3}/4 = 2.89\text{\AA}$.

Q81 – FCC unit cell volume: $V = a^3 = (2\sqrt{2}r)^3 = 16\sqrt{2}r^3$.

Q82 – NaCl unit cell contains **4 Na⁺ + 4 Cl⁻ = 8 ions**.

Q83 – FCC: $a = 2\sqrt{2}r$.

Q84 – BCC packing efficiency = 68% (Formula: $\frac{2 \times 4/3 \pi r^3}{a^3}$).

Q85 – Same as Q67. Edge length $\sim 2.86 \text{ \AA}$.

Q86 – SC: $\rho = \frac{ZM}{N_A a^3}$.

Q87 – FCC: $n/V = 4/a^3$.

Q88 – Packing efficiencies: SC = 52%, BCC = 68%, FCC = 74%.

Q89 – Use $\rho = ZM/N_A a^3 \rightarrow 2.16 \text{ g/cm}^3$.

Q90 – FCC: Verify APF = $\frac{4 \times 4/3 \pi r^3}{a^3} = 0.74$.

Q91 – SC: 8 corners $\times 1/8 = 1$ atom/unit cell.

Q92 – FCC face atoms = $6 \times 1/2 = 3$ atoms.

Q93 – BCC: 1 corner + 1 body = 2 atoms/unit cell.

Q94 – NaCl: 4 Cl⁻ ions/unit cell.

Q95 – CsCl: 1 Cs⁺ ion/unit cell.

Q96 – $\rho = \frac{ZM}{N_A a^3}$.

Q97 – Void fraction = $1 - \text{APF} = 0.26$.

Q98 – Number of formula units = $4/\text{unit cell} \times N_A/a^3$.

Q99 – FCC: Use formula n/V .

Q100 – BCC: $a = 3\sqrt{2}r \rightarrow r = a\sqrt{3}/4 = 1.3\text{\AA}$.

Q101 – Use $a = \left(\frac{ZM}{\rho N_A}\right)^{1/3}$.

Q102 – Diamond density = $\rho = 8 \times 12 / (6.022 \times 10^{23} \times 3.567^3 \times 10^{-24}) \approx 3.52 \text{ g/cm}^3$.

Q103 – BCC: $a = 4r/\sqrt{3}$, APF = $\frac{2 \times 4/3 \pi r^3}{a^3} = 0.68$.

Q104 – FCC: $a = 2\sqrt{2}r$, APF = 0.74.

Q105 – SC fractional volume = 0.52.

Level 3: Advanced / Multi-step / Olympiad-style (Q106–Q120)

Q106 – FCC density > BCC for same element due to higher packing efficiency.

Q107 – Number of NaCl formula units = $4/\text{unit cell} \times N_A/a^3 \approx 2.7 \times 10^{22}/\text{cm}^3$.

Q108 – Diamond cubic packing efficiency = 34%.

Q109 – Tetrahedral void radius $r_{tet} = 0.225r$.

Q110 – Octahedral void radius $r_{oct} = 0.414r$.

Q111 – Fraction of octahedral voids filled in NaCl = 50% (Na⁺ occupy half).

Q112 – Lattice constant of CsCl: $a = \left(\frac{ZM}{\rho N_A}\right)^{1/3}$.

Q113 – 10% vacancies \rightarrow density decreases by 10%.

Q114 – ZnS less dense than NaCl because CN smaller (4 vs 6).

Q115 – Number of tetrahedral voids = $2n$ in FCC lattice.

Q116 – Octahedral voids = n (n = number of atoms).

Q117 – Aluminum FCC: atoms per $\text{cm}^3 = 4/a^3 \times N_A \approx 6 \times 10^{22} \text{ atoms/cm}^3$.

Q118 – BCC unit cell volume = $a^3 = 16r^3/3\sqrt{3}$.

Q119 – Empty space in BCC = $1 - 0.68 = 0.32$.

Q120 – FCC: $r = a/(2\sqrt{2}) = 4/(2\sqrt{2}) = 1.414 \text{\AA}$.

Topic 3: Types of Crystalline Solids (60 MCQs)

Level 1: Basic / Conceptual (Q121–Q135)

Q121. Ionic solids are generally:

- a) Soft and low melting
- b) Hard and brittle
- c) Soft and malleable
- d) Conductive in solid state

Q122. Which of the following is an example of covalent crystal?

- a) NaCl
- b) Diamond
- c) Ice
- d) K

Q123. Metallic solids are:

- a) Poor conductors
- b) Good conductors
- c) Brittle
- d) Non-lustrous

Q124. Molecular solids are held together by:

- a) Ionic bonds
- b) Covalent bonds
- c) Intermolecular forces
- d) Metallic bonds

Q125. Diamond is:

- a) Soft
- b) Hard and has high melting point
- c) Conductive
- d) Ionic solid

Q126. Electrical conductivity of ionic solids in molten state:

- a) High
- b) Low
- c) Zero
- d) Same as in solid state

Q127. Graphite conducts electricity because:

- a) Free electrons in layers
- b) Ionic bonding
- c) Metallic bonding
- d) Hydrogen bonding

Q128. Which is a molecular solid?

- a) NaCl
- b) I₂

- c) Diamond
- d) Cu

Q129. Metallic solids are generally:

- a) Hard and brittle
- b) Malleable and ductile
- c) Low melting
- d) Poor conductors

Q130. Ionic solids are usually soluble in:

- a) Non-polar solvents
- b) Polar solvents
- c) Metals
- d) None

Q131. Covalent network solids have:

- a) Low melting points
- b) High melting points
- c) Good solubility in water
- d) Ionic bonding

Q132. Example of molecular solid:

- a) NaCl
- b) Ice
- c) Diamond
- d) Si

Q133. Graphite has:

- a) 3D network of covalent bonds
- b) Layered structure with van der Waals forces between layers
- c) Ionic bonds
- d) Metallic bonding

Q134. Ionic solids are:

- a) Hard, brittle, high melting, soluble in water
- b) Soft, low melting, insoluble
- c) Malleable
- d) Conductive in solid state

Q135. Covalent solids:

- a) Usually conduct electricity
- b) Usually poor conductors
- c) Soft and malleable
- d) Ionic

Level 2: Moderate / Calculation / Application (Q136–Q170)

Q136. NaCl lattice energy depends on:

- a) Only ionic radii
- b) Only charges

- c) Charges and ionic radii
- d) Temperature

Q137. Calculate lattice energy of KCl using Born-Lande equation: $U = \frac{N_A Z^+ Z^- e^2}{4\pi\epsilon_0 r_0} \left(1 - \frac{1}{n}\right)$

Q138. Melting point trend of ionic solids depends on:

- a) Ionic charge
- b) Ionic radii
- c) Both
- d) None

Q139. Covalent network solids have melting points:

- a) Low (<200°C)
- b) Moderate (200–500°C)
- c) High (>1000°C)
- d) Variable

Q140. Molecular solids like I₂ have melting points:

- a) Very high
- b) Moderate
- c) Low
- d) None

Q141. Electrical conductivity of metals explained by:

- a) Free electrons
- b) Ionic charges
- c) Van der Waals forces
- d) Covalent bonds

Q142. Ice is a molecular solid held by:

- a) Ionic bonds
- b) Covalent bonds
- c) Hydrogen bonding
- d) Metallic bonding

Q143. Diamond vs Graphite: Conductivity difference due to:

- a) Free electrons
- b) Ionic character
- c) Metallic bonds
- d) Hydrogen bonds

Q144. Which solid is hardest?

- a) Diamond
- b) Graphite
- c) Ice
- d) I₂

Q145. Electrical conductivity of ionic solid in solid vs molten state:

- a) Solid = 0, molten = high
- b) Both high

- c) Solid high, molten low
- d) Both zero

Q146. Covalent solids are:

- a) Good conductors
- b) Poor conductors
- c) Malleable
- d) Ionic

Q147. Molecular solids are:

- a) Soft, low melting
- b) Hard, high melting
- c) Conductive
- d) Ionic

Q148. Arrange ionic solids in increasing melting point: KCl, LiF, NaCl

Q149. Metal X with FCC lattice has melting point 1357 K. Type of bonding?

- a) Ionic
- b) Covalent
- c) Metallic
- d) Molecular

Q150. Diamond and SiO₂ are examples of:

- a) Ionic solids
- b) Molecular solids
- c) Covalent network solids
- d) Metallic solids

Q151. Which is a molecular solid with hydrogen bonding?

- a) I₂
- b) Ice
- c) NaCl
- d) Diamond

Q152. Lattice energy of MgO > NaCl because:

- a) Mg²⁺ and O²⁻ higher charges
- b) Larger radii
- c) Lower charges
- d) None

Q153. Electrical conductivity trend: metals > ionic (molten) > covalent > molecular

Q154. Graphite is a good lubricant because:

- a) Ionic bonds
- b) Metallic bonds
- c) Layered structure
- d) Covalent network

Q155. Density of molecular solid is:

- a) High
- b) Low

- c) Moderate
- d) Variable

Q156. Examples of metallic solids:

- a) Na, K, Cu, Fe
- b) NaCl, KCl
- c) Diamond
- d) I₂

Q157. Calculate lattice energy of NaCl using Born-Mayer equation.

Q158. MP of molecular solid ~ I₂: 113°C, reasoning: weak van der Waals forces

Q159. Compare MP of diamond vs graphite

Q160. Ionic solids soluble in water, insoluble in non-polar solvents: reason?

Q161. Identify types of crystalline solids from properties table

Q162. LiF lattice energy > KCl because:

- a) Smaller radii
- b) Higher charge
- c) Both
- d) None

Q163. Why metals are malleable and ductile?

Q164. Covalent solids: MP high due to:

- a) Strong covalent bonds
- b) Ionic character
- c) Metallic bonding
- d) Hydrogen bonding

Q165. Molecular solids: low electrical conductivity because:

- a) No free electrons
- b) No ions
- c) Both
- d) None

Q166. Calculate number of formula units in 1 cm³ of NaCl.

Q167. Compare density: Molecular solids vs Ionic solids

Q168. Which solid has largest band gap?

- a) Diamond
- b) Graphite
- c) Cu
- d) NaCl

Q169. Conductivity of graphite explained by:

- a) Delocalized π -electrons
- b) Ionic bonding

- c) Hydrogen bonding
- d) Van der Waals forces

Q170. Arrange solids by hardness: Diamond, Graphite, Ice, I₂

Level 3: Advanced / Multi-step / Olympiad-style (Q171–Q180)

Q171. Calculate lattice energy of MgO using Born-Landé equation; compare with NaCl.

Q172. Derive relation between lattice energy and melting point for ionic solids.

Q173. Calculate % ionic character from measured lattice energy and Born-Mayer energy.

Q174. Compare theoretical density of molecular solid vs ionic solid with same unit cell volume.

Q175. Number of octahedral and tetrahedral voids in ionic vs metallic solids.

Q176. Calculate lattice enthalpy from Kapustinskii equation for LiF.

Q177. Explain why graphite is soft and slippery while diamond is hardest.

Q178. Compare band gap of diamond vs Si vs Ge, explain trend.

Q179. Explain solubility trend of ionic solids in water vs ethanol.

Q180. Derive relation between coordination number, ionic radii, and radius ratio for ionic solids.

Answer Key: Topic 3 – Types of Crystalline Solids

Level 1: Basic / Conceptual (Q121–Q135)

Q121 – Correct option: b

Explanation: Ionic solids are generally hard and brittle due to strong electrostatic forces.

Q122 – Correct option: b

Explanation: Diamond is a covalent network solid with tetrahedral bonding.

Q123 – Correct option: b

Explanation: Metallic solids conduct electricity due to delocalized electrons.

Q124 – Correct option: c

Explanation: Molecular solids are held together by weak intermolecular forces (van der Waals, dipole-dipole, H-bonding).

Q125 – Correct option: b

Explanation: Diamond has strong covalent bonds, making it extremely hard with high melting point.

Q126 – Correct option: a

Explanation: Ionic solids conduct electricity only in molten/dissolved state, not solid state.

Q127 – Correct option: a

Explanation: Graphite conducts electricity due to free electrons in layers.

Q128 – Correct option: b

Explanation: Iodine (I₂) is a molecular solid held by van der Waals forces.

Q129 – Correct option: b

Explanation: Metals are malleable and ductile due to metallic bonding.

Q130 – Correct option: b

Explanation: Ionic solids dissolve in polar solvents like water.

Q131 – Correct option: b

Explanation: Covalent network solids have high melting points due to strong covalent bonds.

Q132 – Correct option: b

Explanation: Ice is a molecular solid held by hydrogen bonds.

Q133 – Correct option: b

Explanation: Graphite has layers held by weak van der Waals forces.

Q134 – Correct option: a

Explanation: Ionic solids: hard, brittle, high melting, soluble in water.

Q135 – Correct option: b

Explanation: Covalent solids are generally poor conductors (no free electrons/ions).

Level 2: Moderate / Calculation / Application (Q136–Q170)

Q136 – Correct option: c

Explanation: Lattice energy depends on ionic charges and radii (Born-Landé equation: $U = \frac{N_A Z^+ Z^- e^2}{4\pi\epsilon_0 r_0} (1 - \frac{1}{n})$).

Q137 – Formula: $U = \frac{N_A Z^+ Z^- e^2}{4\pi\epsilon_0 r_0} (1 - \frac{1}{n})$

Explanation: Substitute K⁺, Cl[–] charges, r₀ and Madelung constant.

Q138 – Correct option: c

Explanation: Ionic solids: higher charge & smaller ionic radius → higher melting point.

Q139 – Correct option: c

Explanation: Covalent network solids: very high MP (>1000°C) due to strong bonds.

Q140 – Correct option: c

Explanation: Molecular solids have low melting points due to weak van der Waals forces.

Q141 – Correct option: a

Explanation: Metals conduct due to free electrons.

Q142 – Correct option: c

Explanation: Ice is molecular solid held by H-bonding.

Q143 – Correct option: a

Explanation: Diamond has no free electrons → insulator; graphite has delocalized π-electrons → conductor.

Q144 – Correct option: a

Explanation: Diamond is hardest solid due to 3D covalent network.

Q145 – Correct option: a

Explanation: Ionic solids: non-conductive as solids; conduct in molten solution.

Q146 – Correct option: b

Explanation: Covalent solids: no free electrons/ions → poor conductivity.

Q147 – Correct option: a

Explanation: Molecular solids: soft, low melting due to weak intermolecular forces.

Q148 – Correct option: LiF < NaCl < KCl → Reason: melting point increases with lattice energy (smaller ions → higher lattice energy).

Q149 – Correct option: c

Explanation: Metals (FCC lattice) have metallic bonding.

Q150 – Correct option: c

Explanation: Diamond and SiO₂ are covalent network solids.

Q151 – Correct option: b

Explanation: Ice is molecular solid with H-bonding.

Q152 – Correct option: a

Explanation: MgO lattice energy higher due to higher charges (Mg^{2+} , O^{2-}) vs NaCl (Na^+ , Cl^-).

Q153 – Trend: Metals > ionic (molten) > covalent > molecular.

Q154 – Correct option: c

Explanation: Graphite is slippery due to weak interlayer forces.

Q155 – Correct option: b

Explanation: Molecular solids have low density.

Q156 – Correct option: a

Explanation: Na, K, Cu, Fe are metallic solids.

Q157 – Formula: Born-Mayer equation: $U = \frac{N_A Z^+ Z^- e^2}{4\pi\epsilon_0 r_0} \left(1 - \frac{\rho}{r_0}\right)$.

Q158 – Correct option: Low MP due to weak van der Waals forces.

Q159 – Diamond > Graphite MP

Explanation: Diamond has strong 3D covalent bonds; graphite has weak interlayer bonds.

Q160 – Ionic solids soluble in polar solvents due to ion-dipole interactions.

Q161 – Identify solids from table using properties like MP, conductivity, hardness.

Q162 – Correct option: a

Explanation: LiF lattice energy higher due to smaller ions → stronger electrostatic attraction.

Q163 – Metals malleable/ductile because delocalized electrons allow layers to slide.

Q164 – Correct option: a

Explanation: High MP due to strong covalent bonds.

Q165 – Correct option: c

Explanation: Molecular solids lack free electrons and ions → poor conductivity.

Q166 – Formula: Number of formula units $n = \frac{\text{density} \times \text{unit cell volume} \times N_A}{M}$.

Q167 – Molecular solids lower density vs ionic solids due to weak forces and lower packing.

Q168 – Correct option: a

Explanation: Diamond has largest band gap (~5.5 eV).

Q169 – Correct option: a

Explanation: Conductivity of graphite due to delocalized π -electrons.

Q170 – Hardness order: Diamond > Graphite > Ice > I₂.

Level 3: Advanced / Multi-step / Olympiad-style (Q171–Q180)

Q171 – Formula: Born-Landé equation, calculate $U(\text{MgO})$ and $U(\text{NaCl})$, $\text{MgO} > \text{NaCl}$ due to higher charge.

Q172 – Relation: $T_m \propto U$ (higher lattice energy \rightarrow higher melting point).

Q173 – % ionic character: Use measured lattice energy vs theoretical, Born-Mayer equation.

Q174 – Density: $\rho = \frac{ZM}{N_A a^3}$, compare molecular vs ionic solids.

****Q175 – Octahedral voids = n , tetrahedral voids = $2n$ in FCC/metallic solids.**

Q176 – Kapustinskii equation:

$U = K \frac{Z^+ Z^-}{r^+ + r^-} \left(1 - \frac{d}{r^+ + r^-}\right)$, calculate for LiF.

Q177 – Graphite soft vs diamond hard: Layered structure vs strong 3D covalent bonding.

Q178 – Band gap trend: Diamond (5.5 eV) > Si (1.1 eV) > Ge (0.67 eV), decrease with increasing atomic size.

Q179 – Solubility trend: Ionic solids dissolve in polar solvents due to ion-dipole interaction; low solubility in non-polar.

Q180 – Radius ratio relation: r_c/r_a = function of CN, defines ionic structure.

Topic 4: Imperfections in Solids (50 MCQs)

Level 1: Basic / Conceptual (Q181–Q195)

Q181. A vacancy defect occurs when:

- a) An ion is missing from its lattice site
- b) An extra ion occupies an interstitial site
- c) An ion moves to the surface
- d) The lattice is perfect

Q182. Frenkel defect involves:

- a) Cation missing from lattice
- b) Cation displaced to interstitial site
- c) Anion displaced to interstitial site
- d) Vacancies in both cation and anion sublattice

Q183. Schottky defect involves:

- a) Cation vacancy only
- b) Anion vacancy only
- c) Equal number of cation and anion vacancies
- d) Interstitial cation

Q184. Imperfections in solids:

- a) Always reduce density
- b) Can increase or decrease density
- c) Have no effect on density
- d) Only occur at high temperature

Q185. Non-stoichiometric defects are mainly found in:

- a) Ionic solids
- b) Molecular solids
- c) Covalent solids
- d) Metallic solids

Q186. Which defect increases the electrical conductivity of AgCl?

- a) Frenkel
- b) Schottky
- c) Metal excess
- d) None

Q187. Cation interstitial defect is called:

- a) Schottky
- b) Frenkel
- c) Metal deficiency
- d) None

Q188. Which solid commonly shows Frenkel defect?

- a) NaCl
- b) ZnS

- c) KCl
- d) CsCl

Q189. Which solid commonly shows Schottky defect?

- a) NaCl
- b) ZnS
- c) AgCl
- d) KBr

Q190. Metal excess defect is due to:

- a) Cation interstitial
- b) Anion vacancy
- c) Both
- d) None

Q191. Color in NaCl doped with Tl^+ is due to:

- a) Vacancy defect
- b) Interstitial defect
- c) Frenkel defect
- d) Schottky defect

Q192. Which defect decreases density?

- a) Schottky
- b) Frenkel
- c) Metal excess
- d) Interstitial

Q193. Frenkel defect affects:

- a) Density
- b) Electrical conductivity
- c) Both
- d) None

Q194. Defects in solids are generally:

- a) Always harmful
- b) Useful in conductivity and color
- c) Only harmful
- d) Do not affect properties

Q195. Presence of defects makes solids:

- a) More brittle
- b) More ductile
- c) Have altered optical/electrical properties
- d) Perfect crystals

Level 2: Moderate / Calculation / Application (Q196–Q220)

Q196. Fraction of Schottky defects at temperature T :

$$\frac{n}{N} = \exp\left(-\frac{E_s}{2kT}\right)$$

Where n = number of defects, N = total ions, E_s = energy to form defect.

Q197. Number of Frenkel defects in 1 mol of ZnS if defect formation energy = 2 eV at 300 K.

Q198. Schottky defects decrease density: explain.

Q199. Frenkel defect does not change density: explain.

Q200. Calculate fraction of Schottky defects in NaCl at 1000 K ($E_s = 2\text{eV}$).

Q201. Which defect increases conductivity in AgBr?

Q202. Metal excess defect arises due to:

- a) Anion vacancies
- b) Cation interstitial
- c) Both
- d) None

Q203. In AgCl, color is due to:

- a) F-center (electron trapped in anion vacancy)
- b) Cation vacancy
- c) Frenkel defect
- d) Schottky defect

Q204. Number of defects in 1 cm^3 of NaCl crystal at 500 K (Schottky).

Q205. Calculate density change of NaCl due to Schottky defects.

Q206. Which defect can cause solid to become semiconducting?

Q207. Estimate fraction of Frenkel defects in ZnS at 300 K ($E_f = 1.8\text{eV}$).

Q208. In ionic solids, Frenkel defects are more common for:

- a) Small cations
- b) Large cations
- c) Small anions
- d) Large anions

Q209. Schottky defects are common in:

- a) NaCl
- b) CsCl
- c) ZnS
- d) KBr

Q210. F-center contributes to:

- a) Color
- b) Conductivity
- c) Density change
- d) Hardness

Q211. Calculate number of F-centers in 1 mole of NaCl doped with KCl.

Q212. Frenkel defect formation involves:

- a) Vacancy + interstitial
- b) Only vacancy
- c) Only interstitial
- d) None

Q213. Explain why density of ZnS (Frenkel) is nearly unchanged.

Q214. Schottky defect formation energy in NaCl = 2 eV, calculate fraction of defects at 600 K.

Q215. Metal deficiency defect example: Cu₂O.

Q216. Calculate total defects in 0.1 mol NaCl at 700 K (Schottky).

Q217. Effect of defects on lattice energy.

Q218. Explain how metal excess defect occurs due to anion vacancies.

Q219. Density of ionic solid with 0.01% Schottky defects.

Q220. Compare electrical conductivity of perfect and defected ionic solids.

Level 3: Advanced / Multi-step / Olympiad-style (Q221–Q230)

Q221. Derive expression for fraction of Schottky defects:

$$\frac{n}{N} = \exp\left(-\frac{E_s}{2kT}\right)$$

Q222. Derive fraction of Frenkel defects:

$$\frac{n}{N} = \exp\left(-\frac{E_f}{kT}\right)$$

Q223. Calculate number of defects per cm³ in NaCl at 800 K (Schottky, $E_s = 2\text{eV}$).

Q224. Calculate F-center concentration required to produce yellow color in NaCl.

Q225. Explain why Frenkel defect common in ZnS, not NaCl.

Q226. Calculate change in density of AgCl due to Schottky defect at 500 K.

Q227. Derive relation between lattice energy and defect formation energy.

Q228. For 1 mole ZnS, calculate number of Frenkel defects at 350 K ($E_f = 1.9\text{eV}$).

Q229. Estimate total vacancies in 1 kg NaCl crystal at 600 K (Schottky).

Q230. Explain effect of Schottky and Frenkel defects on electrical and optical properties.

Answer Key: Topic 4 – Imperfections in Solids

Level 1: Basic / Conceptual (Q181–Q195)

Q181 – Correct option: a

Explanation: Vacancy defect occurs when an ion is missing from its lattice site.

Q182 – Correct option: b

Explanation: Frenkel defect: cation moves from lattice site to interstitial site, creating a vacancy-interstitial pair.

Q183 – Correct option: c

Explanation: Schottky defect: equal number of cation and anion vacancies.

Q184 – Correct option: b

Explanation: Defects can increase or decrease density depending on type (Schottky decreases, Frenkel almost unchanged).

Q185 – Correct option: a

Explanation: Non-stoichiometric defects are mainly in ionic solids due to variable oxidation states or metal excess/deficiency.

Q186 – Correct option: c

Explanation: Metal excess defect introduces free electrons → increases conductivity in AgCl.

Q187 – Correct option: b

Explanation: Cation interstitial defect is called Frenkel defect.

Q188 – Correct option: b

Explanation: ZnS (ionic solid with small cations) commonly shows Frenkel defect.

Q189 – Correct option: a

Explanation: NaCl commonly shows Schottky defect.

Q190 – Correct option: c

Explanation: Metal excess defect arises due to both anion vacancies and cation interstitials.

Q191 – Correct option: a

Explanation: Color in NaCl doped with Ti^{+} is due to F-center (electron trapped in anion vacancy).

Q192 – Correct option: a

Explanation: Schottky defects decrease density because ions are missing.

Q193 – Correct option: b

Explanation: Frenkel defect increases conductivity slightly but does not affect density significantly.

Q194 – Correct option: b

Explanation: Defects are useful for conductivity, color, and catalytic properties.

Q195 – Correct option: c

Explanation: Defects alter optical, electrical, and mechanical properties of solids.

Level 2: Moderate / Calculation / Application (Q196–Q220)

Q196 – Formula: Fraction of Schottky defects:

$$\frac{n}{N} = \exp\left(-\frac{E_s}{2kT}\right)$$

Where n = number of vacancies, N = total ions, E_s = energy to form Schottky defect, k = Boltzmann constant.

Q197 – Correct option: Use:

$$n = N \exp\left(-\frac{E_f}{kT}\right)$$

Q198 – Explanation: Schottky defect reduces density because ions are missing from lattice.

Q199 – Explanation: Frenkel defect does not change density as ion moves from lattice to interstitial site.

Q200 – Example calculation:

$$n/N = \exp(-2 \text{ eV} / 2 \times 8.617 \times 10^{-5} \text{ eV/K} \times 1000 \text{ K}) \approx 3.17 \times 10^{-6}$$

Q201 – Correct option: a

Explanation: Metal excess defect introduces free electrons → conductivity increases.

Q202 – Correct option: c

Explanation: Metal excess defect arises due to both cation interstitials and anion vacancies.

Q203 – Correct option: a

Explanation: F-center: electron trapped in an anion vacancy → color (yellow in NaCl).

Q204 – Formula:

$$n = N \exp\left(-\frac{E_s}{2kT}\right)$$

N = number of ions per cm^3 .

Q205 – Density change formula:

$$\rho_{\text{defected}} = \rho_{\text{perfect}} \left(1 - \frac{n}{N}\right)$$

Q206 – Correct option: defects creating free electrons

Explanation: Metal excess or F-centers can cause semiconducting behavior.

Q207 – Formula:

$$n/N = \exp(-E_f/kT)$$

Substitute $E_f = 1.8\text{eV}$, $T = 300\text{K}$, $k = 8.617 \times 10^{-5} \text{ eV/K}$.

Q208 – Correct option: a

Explanation: Frenkel defect common for small cations (e.g., Zn^{2+}) which can move to interstitials.

Q209 – Correct option: a

Explanation: Schottky defect is common in NaCl, KCl (large ions, stoichiometric).

Q210 – Correct option: a

Explanation: F-center contributes to color of crystals.

Q211 – Formula: Number of F-centers:

$$n = xN_A \quad \text{for } x \text{ mole fraction of dopant}$$

Q212 – Correct option: a

Explanation: Frenkel defect involves vacancy + interstitial pair.

Q213 – Explanation: Density of ZnS (Frenkel) is nearly unchanged as cation moves from lattice to interstitial.

Q214 – Example:

$$n/N = \exp(-2 \text{ eV}/2 \times 8.617 \times 10^{-5} \text{ eV/K} \times 600 \text{ K}) \approx 1.78 \times 10^{-4}$$

Q215 – Correct option: Cu₂O

Explanation: Metal deficiency defect example due to cation vacancies.

Q216 – Use formula in Q196 to calculate total defects.

Q217 – Explanation: Defects reduce lattice energy slightly due to missing ions.

Q218 – Explanation: Anion vacancy leaves extra electrons → metal excess defect.

Q219 – Formula:

$$\rho = \rho_0 \left(1 - \frac{n}{N}\right)$$

Q220 – Explanation: Defected ionic solids conduct better (metal excess, F-centers) than perfect crystals.

Level 3: Advanced / Multi-step / Olympiad-style (Q221–Q230)

Q221 – Fraction of Schottky defects derivation:

Start with Boltzmann probability: $n/N \propto \exp(-E_s/2kT)$.

Q222 – Fraction of Frenkel defects derivation:

$$n/N = \exp(-E_f/kT)$$

Q223 – Example calculation:

$$n = N \exp(-E_s/2kT), \quad \text{Substitute NaCl parameters, } T=800 \text{ K, } E_s = 2eV$$

Q224 – F-center concentration for color: Use number of electrons per cm³ required to absorb visible light ($\sim 10^{18}/\text{cm}^3$).

Q225 – Explanation: Frenkel defect common in ZnS due to small cation size; NaCl cations too large → Schottky.

Q226 – Formula:

$$\Delta\rho = \rho_0 - \rho_{\text{defected}} = \rho_0 \frac{n}{N}$$

Q227 – Lattice energy vs defect energy: Higher lattice energy → fewer defects.

Q228 – Frenkel defects in 1 mol ZnS:

$$n = N_A \exp(-1.9/(8.617 \times 10^{-5} \times 350)) \approx 5 \times 10^{15}$$

Q229 – Vacancies in 1 kg NaCl at 600 K: Convert mass → moles → N → use Schottky fraction.

Q230 – Effect on properties: Schottky lowers density, Frenkel increases conductivity slightly, F-centers give color.

Topic 5: Packing in Solids (50 MCQs)

Level 1: Basic / Conceptual (Q231–Q245)

Q231. Atomic packing factor (APF) is defined as:

- a) Volume of atoms per unit cell / total volume of unit cell
- b) Volume of unit cell / volume of atoms
- c) Density \times volume
- d) Number of atoms per unit cell

Q232. Simple cubic structure has:

- a) APF = 0.52
- b) APF = 0.68
- c) APF = 0.74
- d) APF = 1

Q233. Coordination number of BCC lattice is:

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

Q234. Coordination number of FCC lattice is:

- a) 6
- b) 8
- c) 12
- d) 14

Q235. Number of atoms in simple cubic unit cell:

- a) 1
- b) 2
- c) 4
- d) 8

Q236. Number of atoms in BCC unit cell:

- a) 1
- b) 2
- c) 4
- d) 8

Q237. Number of atoms in FCC unit cell:

- a) 2
- b) 4
- c) 6
- d) 8

Q238. Hexagonal close packed (HCP) has:

- a) Coordination number 6
- b) Coordination number 8

- c) Coordination number 12
- d) Coordination number 14

Q239. APF of FCC and HCP is:

- a) 0.52
- b) 0.68
- c) 0.74
- d) 1

Q240. Voids in cubic unit cell are:

- a) Tetrahedral and octahedral
- b) Only tetrahedral
- c) Only octahedral
- d) None

Q241. Simple cubic packing efficiency is:

- a) 52%
- b) 68%
- c) 74%
- d) 100%

Q242. In BCC, atoms touch along:

- a) Edge
- b) Face diagonal
- c) Body diagonal
- d) None

Q243. In FCC, atoms touch along:

- a) Edge
- b) Face diagonal
- c) Body diagonal
- d) None

Q244. Number of octahedral voids per atom in FCC:

- a) 0.5
- b) 1
- c) 2
- d) 4

Q245. Number of tetrahedral voids per atom in FCC:

- a) 1
- b) 2
- c) 4
- d) 8

Level 2: Moderate / Calculation / Application (Q246–Q270)

Q246. Calculate APF of simple cubic:

$$\text{APF} = \frac{\text{Volume of atoms in unit cell}}{\text{Volume of unit cell}}$$

Q247. Calculate radius of atom in BCC unit cell of edge a:

$$\sqrt{3}a = 4r$$

Q248. Calculate radius of atom in FCC unit cell of edge a:

$$\sqrt{2}a = 4r$$

Q249. Calculate density of a metal with FCC lattice:

$$\rho = \frac{ZM}{N_A a^3}$$

Where Z = number of atoms per unit cell, M = molar mass, a = edge length, N_A = Avogadro number.

Q250. Number of atoms in unit cell if 1 mole of simple cubic metal occupies 10 cm³:

Q251. Determine coordination number for HCP: 12

Q252. Calculate APF of BCC.

Q253. Calculate fraction of voids in FCC.

Q254. Calculate number of tetrahedral voids per cm³ for FCC crystal of NaCl.

Q255. Find number of octahedral voids in 1 mol of FCC metal.

Q256. Calculate density of K in BCC lattice; given edge length and molar mass.

Q257. Determine radius of atom in HCP if c/a = 1.633.

Q258. Calculate edge length of FCC copper given atomic radius.

Q259. Calculate mass of 1 unit cell of FCC aluminum.

Q260. Determine packing efficiency for HCP.

Q261. Number of atoms per unit volume in BCC lattice with given edge a.

Q262. Number of voids per unit volume in FCC with given edge.

Q263. Relation between radius and edge in simple cubic: $a = 2r$

Q264. Relation between radius and edge in BCC: $\sqrt{3}a = 4r$

Q265. Relation between radius and edge in FCC: $\sqrt{2}a = 4r$

Q266. Number of atoms in HCP unit cell: 6

Q267. Calculate density of FCC metal with given parameters.

Q268. Find fraction of unoccupied space in BCC.

Q269. Calculate number of tetrahedral voids per atom in HCP.

Q270. Compare APF of SC, BCC, FCC, and HCP.

Level 3: Advanced / Multi-step / Olympiad-style (Q271–Q280)

Q271. Derive APF formula for FCC:

$$\text{APF} = \frac{4 \times \frac{4}{3}\pi r^3}{a^3}, \quad a = \frac{4r}{\sqrt{2}}$$

Q272. Derive APF formula for BCC:

$$\text{APF} = \frac{2 \times \frac{4}{3}\pi r^3}{a^3}, \quad a = \frac{4r}{\sqrt{3}}$$

Q273. Derive volume of HCP unit cell and APF using $c/a = 1.633$.

Q274. Calculate edge length of unit cell given density and molar mass of FCC metal.

Q275. Calculate number of atoms per cm^3 in BCC crystal.

Q276. Determine radius of atom if FCC metal has density 8 g/cm^3 and molar mass 64 g/mol .

Q277. Calculate fraction of tetrahedral and octahedral voids in HCP lattice.

Q278. Derive relation between number of voids and packing efficiency.

Q279. Determine total void volume in 1 cm^3 of FCC crystal.

Q280. Multi-step: Given a metal with BCC lattice, calculate density, edge, radius, and void fraction.

Answer Key: Topic 5 – Packing in Solids

Level 1: Basic / Conceptual (Q231–Q245)

Q231 – Correct option: a

Explanation: $APF = \text{Volume occupied by atoms in a unit cell} \div \text{Total volume of unit cell}$.

Q232 – Correct option: a

Explanation: Simple cubic: 1 atom/unit cell, edge a , $APF = 0.52$.

Q233 – Correct option: c

Explanation: BCC coordination number = 8 (each atom touches 8 neighbors along body diagonals).

Q234 – Correct option: c

Explanation: FCC coordination number = 12 (each atom touches 12 neighbors along face diagonals).

Q235 – Correct option: a

Explanation: Simple cubic has 8 corner atoms $\times 1/8 = 1$ atom/unit cell.

Q236 – Correct option: b

Explanation: BCC: 8 corners $\times 1/8 + 1$ body center = 2 atoms/unit cell.

Q237 – Correct option: b

Explanation: FCC: 8 corners $\times 1/8 + 6$ face atoms $\times 1/2 = 4$ atoms/unit cell.

Q238 – Correct option: c

Explanation: HCP coordination number = 12.

Q239 – Correct option: c

Explanation: Close-packed structures (FCC & HCP) $APF = 0.74$.

Q240 – Correct option: a

Explanation: Cubic crystals have tetrahedral and octahedral voids.

Q241 – Correct option: a

Explanation: Packing efficiency SC = 52%.

Q242 – Correct option: c

Explanation: In BCC, atoms touch along the body diagonal: $\sqrt{3}a = 4r$.

Q243 – Correct option: b

Explanation: In FCC, atoms touch along face diagonal: $\sqrt{2}a = 4r$.

Q244 – Correct option: b

Explanation: Number of octahedral voids per atom in FCC = 1.

Q245 – Correct option: c

Explanation: Number of tetrahedral voids per atom in FCC = 2.

Level 2: Moderate / Calculation / Application (Q246–Q270)

Q246 – Correct option:

$$\text{APF (SC)} = \frac{1 \times \frac{4}{3}\pi r^3}{(2r)^3} = 0.52$$

Q247 – Correct option:

$$\text{BCC: } \sqrt{3}a = 4r \Rightarrow r = \frac{\sqrt{3}}{4}a$$

Q248 – Correct option:

$$\text{FCC: } \sqrt{2}a = 4r \Rightarrow r = \frac{\sqrt{2}}{4}a$$

Q249 – Correct option:

$$\rho = \frac{ZM}{N_A a^3}, \quad Z = 4 \text{ for FCC}$$

Q250 – Correct option: Solve using $n = \text{total atoms} = \frac{N_A \text{ moles}}{\text{atoms/unitcell}}$.

Q251 – Correct option: 12

Q252 – Correct option:

$$\text{APF (BCC)} = \frac{2 \times \frac{4}{3}\pi r^3}{a^3} = 0.68$$

Q253 – Correct option:

$$\text{Void fraction (FCC)} = 1 - 0.74 = 0.26$$

Q254 – Correct option: Number of tetrahedral voids = $2 \times$ number of atoms/unit volume.

Q255 – Correct option: Number of octahedral voids = $1 \times$ number of atoms/unit volume.

Q256 – Correct option: Use $\rho = \frac{ZM}{N_A a^3}$ and solve for density.

Q257 – Correct option:

HCP: $c/a = 1.633, r = a/2$

Q258 – Correct option: Edge length $a = \frac{4r}{\sqrt{2}}$ for FCC.

Q259 – Correct option: Mass = $4 \times (M/N_A)$ for FCC unit cell.

Q260 – Correct option: HCP packing efficiency = 0.74

Q261 – Correct option: Number of atoms per unit volume = Z / a^3 (BCC)

Q262 – Correct option: Number of voids = total void fraction \times volume/unit cell.

Q263 – Correct option: SC: $a = 2r$

Q264 – Correct option: BCC: $\sqrt{3}a = 4r$

Q265 – Correct option: FCC: $\sqrt{2}a = 4r$

Q266 – Correct option: HCP: 6 atoms/unit cell

Q267 – Correct option: Density: $\rho = \frac{ZM}{N_A a^3}$

Q268 – Correct option: Fraction of unoccupied space in BCC = $1 - 0.68 = 0.32$

Q269 – Correct option: Number of tetrahedral voids per atom in HCP = 2

Q270 – Correct option: APF: SC = 0.52, BCC = 0.68, FCC = 0.74, HCP = 0.74

Level 3: Advanced / Multi-step / Olympiad-style (Q271–Q280)

Q271 – Correct option:

$$\text{APF (FCC)} = \frac{4 \times \frac{4}{3}\pi r^3}{a^3}, \quad a = \frac{4r}{\sqrt{2}} \Rightarrow \text{APF} = 0.74$$

Q272 – Correct option:

$$\text{APF (BCC)} = \frac{2 \times \frac{4}{3}\pi r^3}{a^3}, \quad a = \frac{4r}{\sqrt{3}} \Rightarrow \text{APF} = 0.68$$

Q273 – Correct option:

$$\text{HCP: APF} = \frac{6 \times \frac{4}{3}\pi r^3}{\text{volume of hexagonal prism}} = 0.74$$

Q274 – Correct option:

$$a = \left(\frac{ZM}{\rho N_A} \right)^{1/3} \quad \text{for cubic cells}$$

Q275 – Correct option: Number of atoms/cm³ = Z / a^3 (convert a in cm)

Q276 – Correct option: Solve $\rho = \frac{ZM}{N_A a^3}$ for $a \rightarrow r = a\sqrt{2}/4$

Q277 – Correct option: HCP: Tetrahedral voids = 2 per atom, octahedral voids = 1 per atom

Q278 – Correct option: Void fraction = $1 - \text{APF}$

Q279 – Correct option: Total void volume = void fraction \times total volume

Q280 – Correct option: Multi-step: Use relations: BCC: $a = 4r/\sqrt{3}$, $Z = 2$, $\rho = ZM/(N_A a^3)$, void fraction = 0.32

Topic 6: Stoichiometry of Solids (60 MCQs)

Level 1: Basic / Conceptual (Q281–Q295)

Q281. The stoichiometry of a solid refers to:

- a) The crystal structure
- b) Ratio of ions/atoms in the compound
- c) Density of the solid
- d) Unit cell type

Q282. Non-stoichiometric compounds are those:

- a) With exact ratio of elements
- b) With variable composition
- c) That are amorphous
- d) That have no defects

Q283. Schottky defect involves:

- a) Interstitial atom
- b) Vacancy of cation and anion
- c) Dislocation of ions
- d) Excess atom

Q284. Frenkel defect involves:

- a) Cation in interstitial site
- b) Anion in interstitial site
- c) Vacancy of both cation and anion
- d) No defect

Q285. NaCl shows which type of defect commonly?

- a) Frenkel
- b) Schottky
- c) Both
- d) None

Q286. ZnS shows which type of defect commonly?

- a) Frenkel
- b) Schottky
- c) Both
- d) None

Q287. Number of formula units per unit cell in FCC NaCl:

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

Q288. Stoichiometric ratio is affected by:

- a) Temperature
- b) Pressure

- c) Defects
- d) Both a & c

Q289. A cation vacancy affects:

- a) Color
- b) Electrical conductivity
- c) Stoichiometry
- d) All

Q290. Non-stoichiometric oxide:

- a) FeO
- b) NaCl
- c) ZnS
- d) KCl

Q291. Formula unit is:

- a) Same as molecule
- b) The simplest ratio of ions in unit cell
- c) Number of atoms per unit cell
- d) Density

Q292. FCC structure of NaCl has how many Na^+ ions in unit cell?

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

Q293. FCC structure of NaCl has how many Cl^- ions in unit cell?

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

Q294. Non-stoichiometry can result from:

- a) Metal deficiency
- b) Metal excess
- c) Both
- d) None

Q295. Vacancy defect increases:

- a) Density
- b) Conductivity (ionic)
- c) APF
- d) Coordination number

Level 2: Moderate / Calculation / Application (Q296–Q330)

Q296. Calculate number of formula units per unit cell for NaCl.

Q297. Calculate density of NaCl given edge length and molar mass.

- Q298. Calculate fraction of cation vacancies in non-stoichiometric NaCl.
- Q299. Determine fraction of anion vacancies in FeO (non-stoichiometric).
- Q300. Given 1 cm^3 of ZnS with Frenkel defects, calculate number of cations displaced.
- Q301. For FCC NaCl, calculate number of Na^+ ions at corners, edges, faces.
- Q302. Calculate density of FeO considering 0.05 fraction of Fe vacancies.
- Q303. Calculate molecular formula of non-stoichiometric Fe_{1-x}O .
- Q304. Calculate density of KCl in CsCl type unit cell.
- Q305. Determine number of formula units in HCP ZnS.
- Q306. Calculate percentage of Schottky defects in NaCl sample to reduce density by 1%.
- Q307. Number of formula units per BCC unit cell in CsCl.
- Q308. Calculate theoretical density of CsCl.
- Q309. Calculate number of vacancies per cm^3 if 0.01% Schottky defects present.
- Q310. Fractional occupancy of cation site in FeO.
- Q311. Determine stoichiometry from X-ray data (given unit cell contents).
- Q312. Calculate number of ions in 1 mol of NaCl (FCC).
- Q313. Determine effect of Frenkel defect on density of ZnS.
- Q314. Calculate total vacancies in 1 g NaCl with 0.1% defect.
- Q315. Determine formula of FeO_{1-x} from defect data.
- Q316. Calculate density of AgBr with given Schottky defect fraction.
- Q317. Number of vacancies to reduce density by 0.5% in KCl.
- Q318. Determine number of displaced cations in Frenkel defect for 1 cm^3 sample.
- Q319. Given density, calculate edge length of NaCl unit cell.
- Q320. Calculate radius ratio and stability for ionic crystal.
- Q321. Calculate formula units per unit cell in ZnS (Zinc blende).
- Q322. Calculate mass of unit cell for FCC NaCl.
- Q323. Determine stoichiometry of Fe_{1-x}O from given density.
- Q324. Calculate density of ZnS from unit cell parameters.
- Q325. Determine fractional vacancy of cation in non-stoichiometric oxide.

- Q326. Calculate total vacancies per mole for Schottky defect.
- Q327. Calculate density of ionic crystal with vacancies.
- Q328. Determine effect of Schottky defect on stoichiometry ratio.
- Q329. Number of formula units in FCC KBr.
- Q330. Calculate vacancy fraction for given defect percentage in NaCl.
-

Level 3: Advanced / Multi-step / Olympiad-style (Q331–Q340)

- Q331. Given density decrease of 0.5% in NaCl, calculate fraction of Schottky defects.
- Q332. Multi-step: For FeO_{1-x} with $x = 0.05$, calculate actual formula unit and density.
- Q333. Derive formula for density of ionic crystal considering Schottky defects.
- Q334. Derive formula for density considering Frenkel defects.
- Q335. Given X-ray data, calculate number of formula units in unit cell of ZnS.
- Q336. Calculate total mass of unit cell in FeO_{1-x} with vacancies.
- Q337. Determine stoichiometry of non-stoichiometric KCl sample with vacancy data.
- Q338. Calculate density of non-stoichiometric NaCl given unit cell dimension and vacancy fraction.
- Q339. Multi-step: For FCC crystal with defects, determine molar mass, density, and defect fraction.
- Q340. Advanced: For ZnS (HCP) with Frenkel defect, calculate number of displaced cations and effect on stoichiometry.

Answer Key: Topic 6 – Stoichiometry of Solids

Level 1: Basic / Conceptual (Q281–Q295)

Q281 – Correct option: b

Explanation: Stoichiometry of solids refers to the ratio of ions/atoms in a compound.

Q282 – Correct option: b

Explanation: Non-stoichiometric compounds have variable composition due to defects or metal deficiency/excess.

Q283 – Correct option: b

Explanation: Schottky defect is a paired cation and anion vacancy maintaining electrical neutrality.

Q284 – Correct option: a

Explanation: Frenkel defect occurs when a cation leaves its normal position and occupies an interstitial site.

Q285 – Correct option: b

Explanation: NaCl commonly shows Schottky defect.

Q286 – Correct option: a

Explanation: ZnS commonly shows Frenkel defect due to small cation size.

Q287 – Correct option: c

Explanation: FCC NaCl has 4 formula units/unit cell ($Z = 4$).

Q288 – Correct option: d

Explanation: Stoichiometry can be affected by temperature (thermal defects) and lattice defects.

Q289 – Correct option: d

Explanation: Cation vacancies affect color, conductivity, and stoichiometry.

Q290 – Correct option: a

Explanation: FeO is a non-stoichiometric oxide due to Fe deficiency.

Q291 – Correct option: b

Explanation: Formula unit = simplest ratio of ions in the unit cell.

Q292 – Correct option: a

Explanation: FCC NaCl has 4 Na^+ ions/unit cell.

Q293 – Correct option: a

Explanation: FCC NaCl has 4 Cl^- ions/unit cell.

Q294 – Correct option: c

Explanation: Non-stoichiometry arises from metal deficiency or excess.

Q295 – Correct option: b

Explanation: Vacancy defects reduce density but increase ionic conductivity.

Level 2: Moderate / Calculation / Application (Q296–Q330)

Q296 – Correct option: $Z = 4$ (FCC), NaCl has 4 formula units per unit cell.

Q297 – Correct option:

$$\rho = \frac{ZM}{N_A a^3}$$

$Z = 4$, M = molar mass, a = edge length, N_A = Avogadro's number.

Q298 – Correct option: Fraction of cation vacancies = number of cation vacancies / total cations \times 100%.

Q299 – Correct option: $\text{FeO}_{1-x} \rightarrow x$ = fractional cation vacancies.

Q300 – Correct option: Number of cations displaced = $2 \times$ number of formula units (Frenkel defect).

Q301 – Correct option: Na^+ ions in FCC: $8 \text{ corners} \times 1/8 + 6 \text{ faces} \times 1/2 = 4$ ions/unit cell.

Q302 – Correct option:

$$\rho = \frac{ZM(1-f)}{N_A a^3}, f = \text{fraction of defects}$$

Q303 – Correct option: Fe_{1-x}O , x = fraction of Fe vacancies.

Q304 – Correct option: CsCl type: $Z = 1$, density formula: $\rho = \frac{ZM}{N_A a^3}$.

Q305 – Correct option: HCP ZnS has 2 formula units/unit cell.

Q306 – Correct option: % Schottky defects = $\frac{\text{density loss}}{\text{original density}} \times 100$.

Q307 – Correct option: CsCl (BCC) $Z = 1$ formula unit/unit cell.

Q308 – Correct option:

$$\rho = \frac{ZM}{N_A a^3}, Z = 1, M = \text{molar mass}$$

Q309 – Correct option: Vacancies/ cm^3 = % defects \times total ions/ cm^3 .

Q310 – Correct option: Fractional occupancy = $1 - x$ (where x = fraction of missing ions).

Q311 – Correct option: From X-ray data, Z = number of formula units/unit cell \rightarrow molecular formula = $Z \times$ simplest ratio.

Q312 – Correct option: Number of ions in 1 mol NaCl = $2 \times N_A$.

Q313 – Correct option: Frenkel defects displace cations \rightarrow negligible change in density.

Q314 – Correct option: Total vacancies = % defect \times total formula units in sample.

Q315 – Correct option: $\text{FeO}_{1-x} \rightarrow$ calculate actual number of Fe atoms/unit cell.

Q316 – Correct option: Density $= \rho = \frac{ZM(1-f)}{N_A a^3}$, f = Schottky defect fraction.

Q317 – Correct option: Vacancies = 0.5% \times total formula units.

Q318 – Correct option: Displaced cations = 2 \times number of formula units (Frenkel).

Q319 – Correct option: Edge length $a = \left(\frac{ZM}{\rho N_A} \right)^{1/3}$.

Q320 – Correct option: Radius ratio r_+/r_- determines coordination number and structure.

Q321 – Correct option: FCC ZnS: $Z = 4$ formula units/unit cell.

Q322 – Correct option: Mass of unit cell = $Z \times M / N_A$.

Q323 – Correct option: Fractional vacancy = $1 - (\rho_{\text{actual}} / \rho_{\text{theoretical}})$.

Q324 – Correct option: Density = mass/unit cell volume = $Z M / (N_A a^3)$.

Q325 – Correct option: Fractional cation vacancy = number of missing cations / total cations.

Q326 – Correct option: Total vacancies/mole = % defect $\times N_A$.

Q327 – Correct option: Density decreases: $\rho = \frac{ZM(1-f)}{N_A a^3}$.

Q328 – Correct option: Schottky defect reduces cation/anion ratio \rightarrow affects stoichiometry.

Q329 – Correct option: FCC KBr: $Z = 4$ formula units/unit cell.

Q330 – Correct option: Fraction of vacancies = % defect / 100.

Level 3: Advanced / Multi-step / Olympiad-style (Q331–Q340)

Q331 – Correct option: Fraction of Schottky defects $f = \Delta\rho/\rho = 0.005$.

Q332 – Correct option: For FeO_{1-x} with $x = 0.05$:

- $Z = 4$ (FCC),
- actual Fe atoms/unit cell = $4 \times (1 - x) = 3.8$,
- density $= \rho = \frac{ZM(1-x)}{N_A a^3}$.

Q333 – Correct option: $\rho = \frac{ZM(1-f)}{N_A a^3}$ for Schottky defects.

Q334 – Correct option: $\rho = \frac{ZM}{N_A a^3}$, Frenkel defects reduce cation occupancy but negligible change in density.

Q335 – Correct option: $Z =$ total formula units = $2 \times (1 + 1)$ for ZnS HCP (X-ray data).

Q336 – Correct option: Mass/unit cell = $(Z \times M \times (1 - f)) / N_A$.

Q337 – Correct option: Fractional cation vacancy \rightarrow actual stoichiometry = $K_{1-x}Cl$.

Q338 – Correct option: Density = $\rho = \frac{ZM(1-f)}{N_A a^3}$.

Q339 – Correct option: Multi-step: compute molar mass, Z, density, defect fraction \rightarrow adjust for vacancies.

Q340 – Correct option: Number of displaced cations = $2 \times$ formula units/unit cell, effect: stoichiometry remains nearly same, density slightly decreases.

Topic 7: Electrical and Magnetic Properties of Solids (50 MCQs)

Level 1: Basic / Conceptual (Q341–Q355)

Q341. Conductivity of metals arises due to:

- a) Free electrons
- b) Ionic vacancies
- c) Atomic vibrations
- d) Interstitial defects

Q342. Band gap of insulators is typically:

- a) 0–1 eV
- b) 1–3 eV
- c) >4 eV
- d) Negative

Q343. Intrinsic semiconductors are:

- a) Pure, no impurities
- b) Doped with acceptors
- c) Doped with donors
- d) Amorphous

Q344. Extrinsic semiconductors are:

- a) Pure
- b) Doped
- c) Ionic
- d) Metallic

Q345. n-type semiconductor has:

- a) Holes as majority carriers
- b) Electrons as majority carriers
- c) No carriers
- d) Equal electrons and holes

Q346. p-type semiconductor has:

- a) Electrons as majority carriers
- b) Holes as majority carriers
- c) No carriers
- d) Equal electrons and holes

Q347. Magnetic property where susceptibility is negative:

- a) Paramagnetism
- b) Diamagnetism
- c) Ferromagnetism
- d) Ferrimagnetism

Q348. Curie temperature is:

- a) Temperature below which ferromagnet becomes paramagnetic
- b) Temperature above which diamagnet becomes paramagnetic

- c) Melting point of metal
- d) Temperature of maximum conductivity

Q349. Antiferromagnetic materials have:

- a) Parallel alignment of spins
- b) Anti-parallel alignment of spins
- c) Random spins
- d) Only one unpaired electron

Q350. Ferrimagnetic materials have:

- a) Complete cancellation of magnetic moments
- b) Partial cancellation of magnetic moments
- c) No magnetic moments
- d) Only paramagnetic behavior

Q351. Electrical conductivity of semiconductors increases with:

- a) Temperature
- b) Decrease in temperature
- c) Pressure
- d) Magnetic field

Q352. Doping of silicon with group V element forms:

- a) p-type
- b) n-type
- c) Insulator
- d) Metal

Q353. Doping of silicon with group III element forms:

- a) n-type
- b) p-type
- c) Metal
- d) Intrinsic

Q354. Fermi level of intrinsic semiconductor lies:

- a) Near conduction band
- b) Near valence band
- c) Midway between conduction and valence band
- d) Below valence band

Q355. Band theory explains:

- a) Electrical conductivity
- b) Magnetic properties
- c) Defects in solids
- d) Packing in solids

Level 2: Moderate / Calculation / Application (Q356–Q380)

Q356. Calculate intrinsic carrier concentration of silicon at 300 K given band gap 1.12 eV.

- Q357. Determine conductivity of intrinsic semiconductor given $n = p = 10^{10} \text{ cm}^{-3}$, $e = 1.6 \times 10^{-19} \text{ C}$, $\mu_e = 1350 \text{ cm}^2/\text{V}\cdot\text{s}$, $\mu_h = 480 \text{ cm}^2/\text{V}\cdot\text{s}$.
- Q358. Find Fermi energy of intrinsic silicon at 300 K.
- Q359. Calculate resistivity of doped silicon given carrier concentration and mobility.
- Q360. Determine number of free electrons in 1 cm^3 of n-type Si with 10^{15} cm^{-3} donor atoms.
- Q361. Compute hole concentration in p-type Si given acceptor concentration 10^{16} cm^{-3} .
- Q362. Band gap energy of semiconductor given conductivity at two temperatures.
- Q363. Energy of photon required to excite electron from valence to conduction band in Ge ($E_g = 0.66 \text{ eV}$).
- Q364. Calculate Curie constant of a paramagnetic substance given μ_{eff} and N .
- Q365. Determine susceptibility of paramagnetic material using Curie's law: $\chi = C/T$.
- Q366. Calculate Bohr magneton value for electron.
- Q367. Compute saturation magnetization of ferromagnet given magnetic moment per atom and number of atoms.
- Q368. Determine magnetization of paramagnetic substance at given field H and temperature T .
- Q369. Calculate energy required to flip spin in antiferromagnetic material.
- Q370. Compute fraction of ionization for extrinsic semiconductor at room temperature.
- Q371. Determine Fermi energy shift for n-type doping.
- Q372. Calculate electrical conductivity change in intrinsic semiconductor when temperature doubles.
- Q373. Determine Curie temperature given susceptibility vs. temperature data.
- Q374. Calculate magnetic moment per formula unit for ferrimagnetic Fe_3O_4 .
- Q375. Find number of electrons in conduction band of intrinsic Si at 400 K.
- Q376. Compute density of states at conduction band edge.
- Q377. Determine energy gap from temperature-dependent conductivity graph.
- Q378. Calculate effective mass of electron in semiconductor given density of states.
- Q379. Determine mobility of carriers from conductivity and carrier concentration.
- Q380. Compute total magnetization in a sample with mixed ferro- and antiferromagnetic regions.
-

Level 3: Advanced / Multi-step / Olympiad-style (Q381–Q390)

- Q381.** Multi-step: Determine intrinsic carrier concentration, Fermi level, and conductivity of Si at 350 K.
- Q382.** Given band structure diagram, calculate electron and hole densities.
- Q383.** Compute total magnetic moment of NiO (antiferromagnet) with given spin configuration.
- Q384.** Multi-step: Calculate magnetization and susceptibility of a ferrimagnetic solid at $T < T_C$.
- Q385.** Determine Fermi energy shift for both n- and p-type doped semiconductors.
- Q386.** Advanced: Calculate energy difference between conduction band edge and donor level.
- Q387.** Multi-step: Compute electrical conductivity of intrinsic semiconductor including temperature dependence.
- Q388.** Determine Curie-Weiss constant from magnetic susceptibility data.
- Q389.** Advanced: Compute fractional occupancy of donor levels in extrinsic semiconductor.
- Q390.** Multi-step: Given H , T , and μ_{eff} , compute magnetization, susceptibility, and Curie temperature.

Answer Key: Topic 7 – Electrical and Magnetic Properties

Level 1: Basic / Conceptual (Q341–Q355)

Q341 – Correct option: a

Explanation: Metals have free electrons in the conduction band, which carry current.

Formula: $\sigma = n e \mu$ (conductivity)

Q342 – Correct option: c

Explanation: Insulators have a large band gap (>4 eV) preventing electron flow.

Q343 – Correct option: a

Explanation: Intrinsic semiconductors are pure; conductivity arises from thermally excited electrons.

Q344 – Correct option: b

Explanation: Extrinsic semiconductors are doped to increase conductivity.

Q345 – Correct option: b

Explanation: n-type has electrons as majority carriers due to donor doping.

Q346 – Correct option: b

Explanation: p-type has holes as majority carriers due to acceptor doping.

Q347 – Correct option: b

Explanation: Diamagnetic materials have negative susceptibility ($\chi < 0$).

Q348 – Correct option: a

Explanation: Curie temperature (T_C) is the temperature above which ferromagnets become paramagnetic.

Q349 – Correct option: b

Explanation: Antiferromagnetic materials have anti-parallel spin alignment resulting in zero net magnetization.

Q350 – Correct option: b

Explanation: Ferrimagnetic materials have partial cancellation of magnetic moments (e.g., Fe_3O_4).

Q351 – Correct option: a

Explanation: Semiconductors conduct better at higher temperatures due to thermal excitation of electrons.

Q352 – Correct option: b

Explanation: Group V dopants (P, As) provide extra electrons → n-type.

Q353 – Correct option: b

Explanation: Group III dopants (B, Al) create holes → p-type.

Q354 – Correct option: c

Explanation: Fermi level of intrinsic semiconductor lies midway between conduction and valence bands.

Q355 – Correct option: a

Explanation: Band theory explains conduction in metals, semiconductors, and insulators.

Level 2: Moderate / Calculation / Application (Q356–Q380)

Q356 – Correct option: Use formula for intrinsic carrier concentration:

$$n_i = \sqrt{N_c N_v} e^{-E_g/2kT}$$

Q357 – Correct option:

$$\sigma = e(n\mu_e + p\mu_h)$$

$$n = p = 10^{10} \text{ cm}^{-3}, \mu_e = 1350 \text{ cm}^2/\text{V}\cdot\text{s}, \mu_h = 480 \text{ cm}^2/\text{V}\cdot\text{s}$$

Q358 – Correct option: Fermi energy for intrinsic semiconductor:

$$E_F = E_i = \frac{E_c + E_v}{2} + \frac{3}{4}kT \ln(m_h^*/m_e^*)$$

Q359 – Correct option: Resistivity:

$$\rho = \frac{1}{\sigma} = \frac{1}{e(n\mu_e + p\mu_h)}$$

Q360 – Correct option: Free electrons \approx donor concentration ($n \approx N_D$).

Q361 – Correct option: Hole concentration = acceptor concentration ($p \approx N_A$).

Q362 – Correct option: Use temperature-dependent conductivity:

$$\sigma = \sigma_0 e^{-E_g/2kT}$$

Q363 – Correct option: Photon energy required:

$$E = h\nu = E_g$$

Q364 – Correct option: Curie constant:

$$C = \frac{\mu_0 N \mu_{\text{eff}}^2}{3k_B}$$

Q365 – Correct option: Magnetic susceptibility:

$$\chi = \frac{C}{T}$$

Q366 – Correct option: Bohr magneton:

$$\mu_B = \frac{e\hbar}{2m_e} \approx 9.27 \times 10^{-24} \text{ A}\cdot\text{m}^2$$

Q367 – Correct option: Saturation magnetization:

$$M_s = \frac{\text{magnetic moment per atom} \times \text{number of atoms}}{\text{volume}}$$

Q368 – Correct option: Paramagnetic magnetization:

$$M = \chi H$$

Q369 – Correct option: Energy to flip spin:

$$E = 2\mu B$$

Q370 – Correct option: Fractional ionization of donors:

$$n = \frac{N_D}{1 + \frac{1}{2}e^{(E_D - E_F)/kT}}$$

Q371 – Correct option: Fermi energy shift for n-type:

$$E_F = E_i + kT \ln(N_D/n_i)$$

Q372 – Correct option: Conductivity change with temperature: $\sigma \propto e^{-E_g/2kT}$

Q373 – Correct option: Curie temperature: temperature where $\chi \rightarrow \infty$ in Curie-Weiss law:

$$\chi = \frac{C}{T - \theta}$$

Q374 – Correct option: Magnetic moment per formula unit Fe_3O_4 : sum of moments of Fe^{2+} and Fe^{3+} ions.

Q375 – Correct option: Number of electrons in conduction band: $n_i^2 = n \times p \rightarrow n = \sqrt{n_i^2}$

Q376 – Correct option: Density of states at conduction band edge:

$$g_c(E) = \frac{8\pi\sqrt{2}(m_e^*)^{3/2}}{h^3} \sqrt{E - E_c}$$

Q377 – Correct option: Energy gap from conductivity graph using slope:

$$\sigma = \sigma_0 e^{-E_g/2kT}$$

Q378 – Correct option: Effective mass of electron from density of states:

$$m_e^* = \left(\frac{h^2}{2\pi k_B T} \right) (N_c)^{2/3}$$

Q379 – Correct option: Carrier mobility:

$$\mu = \frac{\sigma}{ne}$$

Q380 – Correct option: Total magnetization: sum of contributions from ferro- and antiferromagnetic regions.

Level 3: Advanced / Multi-step / Olympiad-style (Q381–Q390)

Q381 – Correct option: Compute n_i , E_F , σ using formulas:

$$n_i = \sqrt{N_c N_v} e^{-E_g/2kT}, \quad E_F = E_i, \quad \sigma = e(n\mu_e + p\mu_h)$$

Q382 – Correct option: Electron density:

$$n = \int_{E_c}^{\infty} g_c(E) f(E) dE$$

Hole density:

$$p = \int_{-\infty}^{E_v} g_v(E) [1 - f(E)] dE$$

Q383 – Correct option: Total magnetic moment = sum of unpaired spins considering anti-parallel alignment.

Q384 – Correct option: Magnetization and susceptibility using sublattice model for ferrimagnets.

Q385 – Correct option: Fermi energy shifts:

$$E_F(n) = E_i + kT \ln(N_D/n_i), \quad E_F(p) = E_i - kT \ln(N_A/n_i)$$

Q386 – Correct option: Energy difference conduction band – donor level:

$$E_C - E_D \approx kT \ln(N_D/n)$$

Q387 – Correct option: Temperature-dependent conductivity:

$$\sigma(T) = e(n(T)\mu_e + p(T)\mu_h)$$

Q388 – Correct option: Curie-Weiss constant: slope of $1/\chi$ vs. T plot:

$$C = \text{slope} \times (T - \theta)$$

Q389 – Correct option: Fractional occupancy of donor levels:

$$f_D = \frac{1}{1 + \frac{1}{2} e^{(E_D - E_F)/kT}}$$

Q390 – Correct option: Multi-step: Compute M , χ , and T_C using Curie-Weiss law and sublattice magnetization formulas.

Topic 8: Other Important Concepts (XRD, Bragg's Law, etc.) – 60 MCQs

Level 1: Basic / Conceptual (Q391–Q405)

Q391. X-rays are suitable for diffraction studies because their wavelength is comparable to:

- a) Atomic radii
- b) Bond lengths ($\sim \text{\AA}$)
- c) Crystal lattice spacing
- d) Molecular size

Q392. Bragg's law is:

- a) $n\lambda = 2d \sin \theta$
- b) $\lambda = d \sin \theta$
- c) $n\lambda = d \cos \theta$
- d) $\lambda = 2d \tan \theta$

Q393. In XRD, the first-order reflection corresponds to:

- a) $n = 1$
- b) $n = 2$
- c) $n = 0$
- d) $n = \lambda$

Q394. Miller indices (hkl) denote:

- a) Atomic positions
- b) Planes in crystal lattice
- c) Number of unit cells
- d) Crystal density

Q395. Powder diffraction is used for:

- a) Single crystal only
- b) Polycrystalline sample
- c) Amorphous solids
- d) Liquids

Q396. Laue method is suitable for:

- a) Determining orientation of single crystals
- b) Powder analysis
- c) Magnetic properties
- d) Electrical conductivity

Q397. Debye-Scherrer method is used to:

- a) Measure resistivity
- b) Determine crystal structure of powdered sample
- c) Measure band gap
- d) Study magnetization

Q398. In Bragg's law, $\lambda = 1.54 \text{ \AA}$ corresponds to:

- a) Visible light
- b) UV light
- c) Cu-K α X-rays
- d) Gamma rays

Q399. XRD patterns provide information about:

- a) Crystal lattice type
- b) Interplanar spacing
- c) Orientation of planes
- d) All of the above

Q400. Constructive interference occurs when:

- a) Path difference = $n\lambda$
- b) Path difference = $\lambda/2$
- c) Path difference = 0
- d) Path difference = $n\lambda/2$

Q401. The angle θ in Bragg's law is measured between:

- a) Incident beam and crystal plane
- b) Reflected beam and crystal plane
- c) Incident beam and detector
- d) Reflected beam and incident beam

Q402. X-ray diffraction can distinguish:

- a) Amorphous from crystalline solids
- b) Metals from semiconductors
- c) Ferromagnetic from diamagnetic materials
- d) Insulators from conductors

Q403. The interplanar spacing d for (100) plane in cubic lattice with lattice parameter a :

- a) a
- b) a^2
- c) $a/\sqrt{2}$
- d) $a/\sqrt{1}$

Q404. For (111) plane in cubic lattice, $d =$

- a) $a/\sqrt{1}$
- b) $a/\sqrt{2}$
- c) $a/\sqrt{3}$
- d) $a/2$

Q405. X-ray diffraction intensity is maximum when:

- a) $\theta = 0$
- b) Bragg's condition satisfied
- c) Random angle
- d) Crystal is amorphous

- Q406.** Calculate interplanar spacing d for cubic crystal, $a = 4 \text{ \AA}$, plane (110).
- Q407.** First-order Bragg reflection for Cu-K α $\lambda = 1.54 \text{ \AA}$, $d = 2 \text{ \AA}$. Find θ .
- Q408.** Determine Miller indices for plane with spacing $d = 2 \text{ \AA}$ in cubic lattice $a = 4 \text{ \AA}$.
- Q409.** Powder diffraction shows peak at 30° . Determine d for $\lambda = 1.54 \text{ \AA}$.
- Q410.** Calculate angle for second-order reflection ($n = 2$) for $d = 1.5 \text{ \AA}$, $\lambda = 1.54 \text{ \AA}$.
- Q411.** d -spacing in tetragonal lattice, $a = 3 \text{ \AA}$, $c = 5 \text{ \AA}$, plane (101).
- Q412.** Volume of cubic unit cell, $a = 4 \text{ \AA}$.
- Q413.** Calculate radius of atom in simple cubic lattice, $a = 3.6 \text{ \AA}$.
- Q414.** Packing efficiency of FCC lattice.
- Q415.** Number of atoms per unit cell in BCC lattice.
- Q416.** d -spacing for (200) plane in cubic crystal, $a = 4 \text{ \AA}$.
- Q417.** Find lattice parameter a from XRD data, $\theta = 20^\circ$, $n = 1$, $\lambda = 1.54 \text{ \AA}$, plane (100).
- Q418.** Determine density of crystal given unit cell parameters and atomic mass.
- Q419.** Calculate Bragg angle for (111) plane, $a = 4 \text{ \AA}$, $\lambda = 1.54 \text{ \AA}$.
- Q420.** Determine plane spacing for orthorhombic lattice, $a = 2 \text{ \AA}$, $b = 3 \text{ \AA}$, $c = 4 \text{ \AA}$, plane (101).
- Q421.** Compute 2θ for strongest peak in FCC crystal for Cu-K α .
- Q422.** Powder diffraction line broadening can estimate:
- Crystallite size
 - Lattice defects
 - Both a & b
 - None
- Q423.** Determine crystal system from d -spacing ratios.
- Q424.** Calculate number of unit cells in 1 g of NaCl ($a = 5.64 \text{ \AA}$).
- Q425.** XRD can detect strain in crystals due to:
- Shift in peak position
 - Broadening of peaks
 - Both
 - None
- Q426.** Calculate interplanar spacing for hexagonal crystal: $a = 2 \text{ \AA}$, $c = 4 \text{ \AA}$, plane (101).
- Q427.** Determine θ for given d in tetragonal lattice.
- Q428.** Debye-Scherrer radius of diffraction ring for $\theta = 15^\circ$, $R = 6 \text{ cm}$, $\lambda = 1.54 \text{ \AA}$.
- Q429.** Compute lattice constant from XRD peak for cubic crystal.

- Q430. Calculate angle between two planes (h1k1l1) and (h2k2l2) in cubic lattice.
- Q431. Determine maximum diffraction angle for first-order reflection.
- Q432. Find nearest-neighbor distance in FCC lattice.
- Q433. Calculate atomic radius for BCC crystal, $a = 3.2 \text{ \AA}$.
- Q434. Determine packing fraction for simple cubic lattice.
- Q435. Compute Bragg angle for orthorhombic plane with given spacing.
- Q436. Find d-spacing for plane in hexagonal close-packed (HCP) lattice.
- Q437. Estimate lattice constant from multiple diffraction peaks.
- Q438. Determine Miller indices for plane perpendicular to given vector.
- Q439. Calculate 2θ for given d and λ in tetragonal crystal.
- Q440. Determine number of formula units in unit cell for given density and lattice parameter.
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Level 3: Advanced / Multi-step / Olympiad-style (Q441–Q450)

- Q441. Multi-step: Determine lattice parameter from multiple XRD peaks in cubic crystal.
- Q442. Compute interplanar spacing for triclinic lattice plane.
- Q443. Determine Bragg angles for multiple reflections of FCC crystal.
- Q444. Estimate crystallite size using Scherrer formula:
- $$D = \frac{K\lambda}{\beta \cos \theta}$$
- Q445. Find plane indices from observed XRD d-spacing ratios.
- Q446. Calculate strain in lattice from XRD peak shift.
- Q447. Determine density of crystal with given formula units per unit cell and lattice parameters.
- Q448. Compute 2θ for mixed cubic planes in FCC lattice.
- Q449. Multi-step: Identify unknown crystal system from XRD pattern.
- Q450. Calculate θ for highest intensity diffraction peak in BCC crystal.

Answer Key: Topic 8 – Other Important Concepts (XRD, Bragg's Law, etc.)

Level 1: Basic / Conceptual (Q391–Q405)

Q391 – Correct option: c

Explanation: X-ray wavelengths ($\sim 1 \text{ \AA}$) are comparable to interplanar spacing in crystals, allowing diffraction.

Q392 – Correct option: a

Explanation: Bragg's law: $n\lambda = 2d \sin \theta$ describes constructive interference from crystal planes.

Q393 – Correct option: a

Explanation: First-order reflection corresponds to $n = 1$ in Bragg's law.

Q394 – Correct option: b

Explanation: Miller indices (hkl) define orientation of crystal planes.

Q395 – Correct option: b

Explanation: Powder diffraction is used for polycrystalline samples.

Q396 – Correct option: a

Explanation: Laue method determines orientation of single crystals.

Q397 – Correct option: b

Explanation: Debye-Scherrer method is used for crystal structure analysis of powdered samples.

Q398 – Correct option: c

Explanation: Cu-K α X-rays have $\lambda \approx 1.54 \text{ \AA}$.

Q399 – Correct option: d

Explanation: XRD provides information about lattice type, interplanar spacing, and plane orientation.

Q400 – Correct option: a

Explanation: Constructive interference occurs when path difference = $n\lambda$.

Q401 – Correct option: a

Explanation: θ is angle between incident beam and crystal plane.

Q402 – Correct option: a

Explanation: XRD distinguishes amorphous and crystalline solids.

Q403 – Correct option: d

Explanation: For cubic lattice, $d = a/\sqrt{h^2 + k^2 + l^2}$. For (100), $d = a/\sqrt{1} = a$.

Q404 – Correct option: c

Explanation: For (111) plane, $d = a/\sqrt{1+1+1} = a/\sqrt{3}$.

Q405 – Correct option: b

Explanation: Maximum intensity occurs when Bragg condition is satisfied.

Level 2: Moderate / Calculation / Application (Q406–Q440)

Q406 – Correct option: $d = a/\sqrt{(h^2+k^2+l^2)} = 4/\sqrt{(1+1+0)} = 2.828 \text{ \AA}$

Q407 – Correct option: $n\lambda = 2d \sin \theta \rightarrow \sin \theta = n\lambda / 2d = 1 \times 1.54 / 2 \times 2 \rightarrow \theta \approx 22.6^\circ$

Q408 – Correct option: Use $d = a/\sqrt{(h^2+k^2+l^2)} \rightarrow$ solve for hkl.

Q409 – Correct option: $d = \lambda / (2 \sin \theta) = 1.54 / (2 \sin 30^\circ) = 1.54 / 1 = 1.54 \text{ \AA}$

Q410 – Correct option: $\theta = \arcsin(n\lambda/2d) = \arcsin(2 \times 1.54 / (2 \times 1.5)) \approx 64.16^\circ$

Q411 – Correct option: $d = 1 / \sqrt{[(h^2+k^2)/a^2 + l^2/c^2]} = 1 / \sqrt{[(1+0)/9 + 1/25]} \approx 0.86 \text{ \AA}$

Q412 – Correct option: $V = a^3 = 4^3 = 64 \text{ \AA}^3$

Q413 – Correct option: $r = a/2 = 3.6/2 = 1.8 \text{ \AA}$ (simple cubic)

Q414 – Correct option: Packing efficiency (FCC) = 0.74 = 74%

Q415 – Correct option: BCC has 2 atoms/unit cell

Q416 – Correct option: $d = a/\sqrt{(h^2+k^2+l^2)} = 4/\sqrt{(4+0+0)} = 2 \text{ \AA}$

Q417 – Correct option: $a = n\lambda / 2 \sin \theta = 1 \times 1.54 / 2 \sin 20^\circ \approx 2.24 \text{ \AA}$

Q418 – Correct option: Density $\rho = (Z M) / (N_A a^3)$

Q419 – Correct option: $d = a/\sqrt{3} = 4/\sqrt{3} \approx 2.309 \text{ \AA} \rightarrow \theta = \arcsin(\lambda/2d) \approx 19.5^\circ$

Q420 – Correct option: $d = 1 / \sqrt{[(h^2/a^2) + (k^2/b^2) + (l^2/c^2)]} = 1 / \sqrt{[(1/4) + (0/9) + (1/16)]} \approx 1.72 \text{ \AA}$

Q421 – Correct option: For FCC, strongest peak corresponds to (111) plane, $2\theta = 2 \arcsin(\lambda/2d)$

Q422 – Correct option: c) Both (crystallite size and defects)

Q423 – Correct option: Compare d-spacing ratios to theoretical ratios for crystal systems

Q424 – Correct option: Number of unit cells = mass / (Z M/N_A)

Q425 – Correct option: c) Both (strain causes shift and broadening)

Q426 – Correct option: Hexagonal: $\frac{1}{d^2} = \frac{4}{3} \frac{h^2+hk+k^2}{a^2} + \frac{l^2}{c^2} \rightarrow d \approx 1.59 \text{ \AA}$

Q427 – Correct option: $\theta = \arcsin(n\lambda/2d)$

Q428 – Correct option: $R = \lambda L / 2d \sin \theta$ (radius from Debye-Scherrer formula)

Q429 – Correct option: $a = \sqrt{(h^2+k^2+l^2)} \lambda / 2 \sin \theta$

Q430 – Correct option: $\cos \varphi = (h_1 h_2 + k_1 k_2 + l_1 l_2) / (\sqrt{(h_1^2 + k_1^2 + l_1^2)} \times \sqrt{(h_2^2 + k_2^2 + l_2^2)})$

Q431 – Correct option: $\theta_{\max} = \arcsin(\lambda/2d_{\min})$

Q432 – Correct option: Nearest-neighbor distance FCC = $a/\sqrt{2}$

Q433 – Correct option: $r = \sqrt{3} a / 4$ (BCC)

Q434 – Correct option: Packing fraction simple cubic = 0.52

Q435 – Correct option: $\theta = \arcsin(n\lambda/2d)$

Q436 – Correct option: d-spacing HCP: $\frac{1}{d^2} = \frac{4}{3} \frac{h^2+hk+k^2}{a^2} + \frac{l^2}{c^2}$

Q437 – Correct option: Lattice constant from multiple peaks using $d_{hkl} = a / \sqrt{(h^2+k^2+l^2)}$

Q438 – Correct option: Miller indices (hkl) perpendicular to vector [uvw] satisfy $hu + kv + lw = 0$

Q439 – Correct option: $\theta = \arcsin(n\lambda/2d)$

Q440 – Correct option: Number of formula units = $\rho \times a^3 \times N_A / M$

Level 3: Advanced / Multi-step / Olympiad-style (Q441–Q450)

Q441 – Correct option: Solve for a using multiple Bragg peaks: $a = \sqrt{(n\lambda / 2 \sin \theta)}$

Q442 – Correct option: Use general triclinic spacing formula:

$$\frac{1}{d^2} = \frac{1}{V^2} [\dots]$$

Q443 – Correct option: Use FCC allowed reflections: (111), (200), (220), (311), etc. $\rightarrow 2\theta = 2 \arcsin(n\lambda/2d_{hkl})$

Q444 – Correct option: Scherrer formula: $D = K \lambda / (\beta \cos \theta)$

Q445 – Correct option: Compare measured d-spacing ratios with theoretical ratios to get (hkl)

Q446 – Correct option: Strain $\epsilon = \Delta d / d = \Delta \theta / \tan \theta$

Q447 – Correct option: $\rho = Z M / N_A a^3$

Q448 – Correct option: 2θ for mixed planes: calculate individual $d_{hkl} \rightarrow \theta = \arcsin(n\lambda/2d)$

Q449 – Correct option: Use d-spacing ratios, peak positions, and allowed reflections \rightarrow identify crystal system

Q450 – Correct option: For BCC, highest intensity: plane (110), $\theta = \arcsin(\lambda / 2d_{110})$