CHAPTER

11

The Solid State & Surface Chemistry

Section-A JEE Advanced/ IIT-JEE

C MCQs with One Correct Answer

1. CsBr has bcc structure with edge length 4.3. The shortest inter ionic distance in between Cs^+ and Br^- is : *(1995S)*

(a) 3.72 (b) 1.86
(c) 7.44 (d) 4.3

2. The coordination number of a metal crystallizing in a hexagonal close-packed structure is *(1999 - 2 Marks)*

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

3. In a solid '*AB*' having the *NaCl* structure, '*A*' atoms occupy the corners of the cubic unit cell. If all the face-centered atoms along one of the axes are removed, then the resultant stoichiometry of the solid is *(2001S)*

(a) AB_2 (b) A_2B
(c) A_4B_3 (d) A_3B_4

4. A substance A_xB_y crystallizes in a face centred cubic (FCC) lattice in which atoms 'A' occupy each corner of the cube and atoms 'B' occupy the centres of each face of the cube. Identify the correct composition of the substance A_xB_y *(2002S)*

(a) AB_3
(b) A_4B_3
(c) A_3B
(d) Compostion cannot be specified

5. Rate of physiorption increases with *(2003S)*

(a) decrease in temperature (b) increase in temperature
(c) decrease in pressure (d) decrease in surface area

6. Adsorption of gases on solid surface is generally exothermic because *(2004S)*

(a) enthalpy is positive (b) entropy decreases
(c) entropy increases (d) free energy increases

7. In which of the following crystals alternate tetrahedral voids are occupied? *(2005S)*

(a) NaCl (b) ZnS
(c) CaF_2 (c) Na_2O

8. Lyophilic sols are *(2005S)*

(a) Irreversible sols
(b) They are prepared from inorganic compound
(c) Coagulated by adding electrolytes
(d) Self–stabilizing

9. Among the following, the surfactant that will form micelles in aqueous solution at the lowest molar concentration at ambient condition is : – *(2008S)*

(a) $CH_3(CH_2)_{15}N^+(CH_3)_3Br^-$

(b) $CH_3(CH_2)_{11}OSO_3^-Na^+$

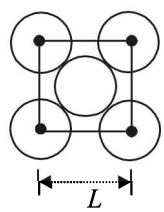
(c) $CH_3(CH_2)_6COO^-Na^+$

(d) $CH_3(CH_2)_{11}N^+(CH_3)_3Br^-$

10. Among the electrolytes Na_2SO_4, $CaCl_2$, $Al_2(SO_4)_3$ and NH_4Cl, the most effective coagulating agent for Sb_2S_3 sol is *(2009S)*

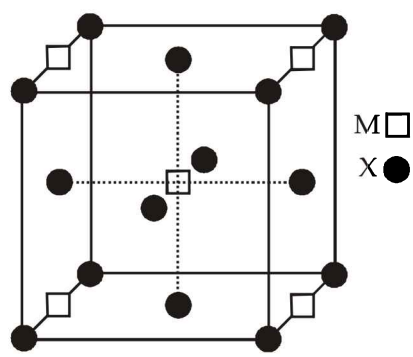
(a) Na_2SO_4 (b) $CaCl_2$
(c) $Al_2(SO_4)_3$ (d) NH_4Cl

11. The packing efficiency of the two-dimensional square unit cell shown below is : *(2010)*



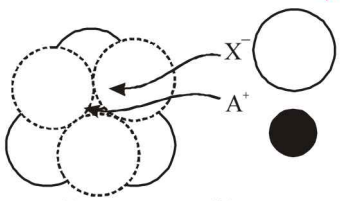
(a) 39.27% (b) 68.02%
(c) 74.05% (d) 78.54%

12. A compound M_pX_q has cubic close packing (ccp) arrangement of X. Its unit cell structure is shown below. The empirical formula of the compound is *(2012 - I)*



(a) MX (b) MX_2
(c) M_2X (d) M_5X_{14}

13. The arrangement of X^- ions around A^+ ion in solid AX is given in the figure (not drawn to scale). If the radius of X^- is 250 pm, the radius of A^+ is *(JEE Adv. 2013)*



(a) 104 pm (c) 183 pm (b) 125 pm (d) 57 pm

14. Methylene blue, from its aqueous solution, is adsorbed on activated charcoal at 25°C. For this process, the correct statement is *(JEE Adv. 2013)*

(a) The adsorption requires activation at 25°C
(b) The adsorption is accompanied by a decrease in enthalpy
(c) The adsorption increases with increase of temperature
(d) The adsorption is irreversible

D MCQs with One or More Than One Correct

1. Which of the following statement(s) is (are) correct? *(1998 - 2 Marks)*

(a) The coordination number of each type of ion in CsCl crystal is 8.
(b) A metal that crystallizes in bcc structure has a coordination number of 12.
(c) A unit cell of an inoic crystal shares some of its ions with other unit cells.
(d) The length of the unit cell in NaCl is 552 pm. (r_{Na+} = 95 pm; r_{Cl-}=181 pm).

2. The correct statement(s) regarding defects in solids is (are) *(2009S)*

(a) Frenkel defect is usually favoured by a very small difference in the sizes of cation and anion
(b) Frenkel defect is a dislocation defect
(c) Trapping of an electron in the lattice leads to the formation of F-centre
(d) Schottky defects have no effect on the physical properties of solids

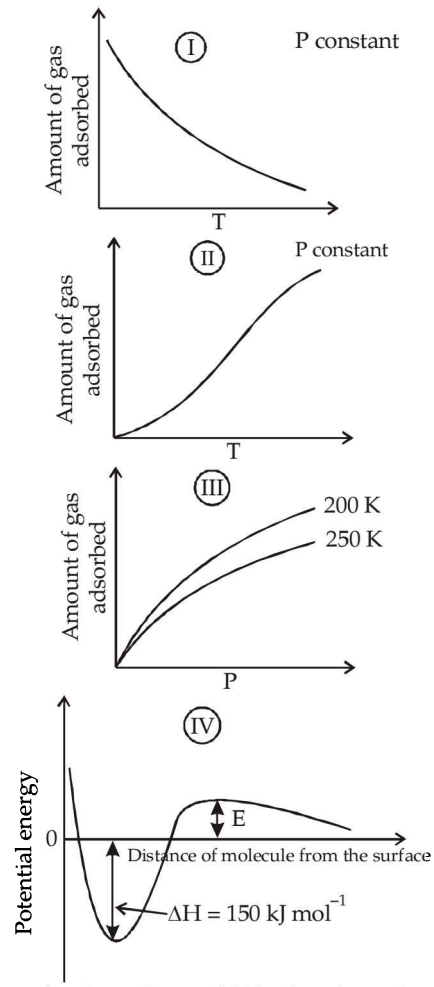
3. The correct statement(s) pertaining to the adsorption of a gas on a solid surface is (are) *(2011)*

(a) Adsorption is always exothermic
(b) Physisorption may transform into chemisorption at high temperature
(c) Physiosorption increases with increasing temperature but chemisorption decreases with increasing temperature
(d) Chemisorption is more exothermic than physiosorption, however it is very slow due to higher energy of activation

4. Choose the correct reason(s) for the stability of the **lyophobic** colloidal particles. *(2012)*

(a) Preferential adsorption of ions on their surface from the solution.
(b) Preferential adsorption of solvent on their surface from the solution.
(c) Attraction between different particles having opposite charges on their surface.
(d) Potential difference between the fixed layer and the diffused layer of opposite charges around the colloidal particles.

5. The given graphs/data I, II, III and IV represent general trends observed for different physisorption and chemisorption processes under mild conditions of temperature and presure. Which of the following choice(s) about I, II, III and IV is (are) correct ? *(2012)*



(a) I is physisorption and II is chemisorption
(b) I is physisorption and III is chemisorption
(c) IV is chemisorption and II is chemisorption
(d) IV is chemisorption and III is chemisorption

6. If the unit cell of a mineral has cubic close packed (*ccp*) array of oxygen atoms with *m* fraction of octahedral holes occupied by aluminium ions and *n* fraction of tetrahedral holes occupied by magnesium ions, *m* and *n*, respectively, are *(JEE Adv. 2015)*

(a) $\frac{1}{2}, \frac{1}{8}$ (b) $1, \frac{1}{4}$ (c) $\frac{1}{2}, \frac{1}{2}$ (d) $\frac{1}{4}, \frac{1}{8}$

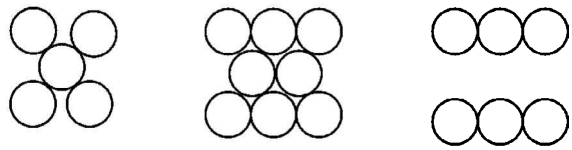
7. When O_2 is adsorbed on a metallic surface, electron transfer occurs from the metal to O_2. The true statement(s) regarding this adsorption is(are) *(JEE Adv. 2015)*

(a) O_2 is physisorbed
(b) Heat is released
(c) Occupancy of π^*_{2p} of O_2 is increased
(d) Bond length of O_2 is increased

8. The CORRECT statement(s) for cubic close packed (ccp) three dimensional structure is (are) ***(JEE Adv. 2016)***
   (a) The number of the nearest neighbours of an atom present in the topmost layer is 12
   (b) The efficiency of atom packing is 74%
   (c) The number of octahedral and tetrahedral voids per atom are 1 and 2, respectively
   (d) The unit cell edge length is $2\sqrt{2}$ times the radius of the atom

E Subjective Problems

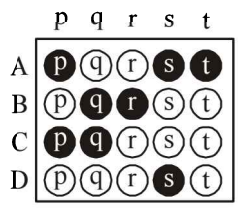
1. The density of mercury is 13.6 g/ml. Calculate approximately the diameter of an atom of mercury assuming that each atom is occupying a cube of edge length equal to the diameter of the mercury atom. ***(1983 - 3 Marks)***
2. Sodium metal crystallizes in body centred cubic lattice with the cell edge, $a = 4.29$Å. What is the radius of sodium atom? ***(1994 - 2 Marks)***
3. A metallic element crystallises into a lattice containing a sequence of layers of ABABAB..... Any packing of spheres leaves out voids in the lattice. What percentage by volume of this lattice is empty space? ***(1996 - 3 Marks)***
4. Chromium metal crystallizes with a body centred cubic lattice. The length of the unit cell edge is found to be 287 pm. Calculate the atomic radius. What would be the density of chromium in g/cm^3? ***(1997 - 3 Marks)***
5. A metal crystallises into two cubic phases, face centered cubic (FCC) and body centred cubic (BCC), whose unit cell lengths are 3.5 and 3.0 Å, respectively, Calculate the ratio of densities of FCC and BCC. ***(1999 - 3 Marks)***
6. The figures given below show the location of atoms in three crystallographic planes in a FCC lattice. Draw the unit cell for the corresponding structure and identify these planes in your diagram. ***(2000 - 3 Marks)***



7. You are given marbles of diameter 10 mm. They are to be placed such that their centres are lying in a square bound by four lines each of length 40 mm. What will be the arrangements of marbles in a plane so that maximum number of marbles can be placed inside the area? Sketch the diagram and derive expression for the number of molecules per unit area. ***(2003 - 2 Marks)***
8. 1 gm of charcoal adsorbs 100 ml 0.5 M CH_3COOH to form a monolayer, and thereby the molarity of CH_3COOH reduces to 0.49. Calculate the surface area of the charcoal adsorbed by each molecule of acetic acid. Surface area of charcoal = 3.01×10^2 m^2/gm. ***(2003 - 2 Marks)***
9. A compound AB has rock salt type structure. The formula weight of AB is 6.023 Y amu, and the closest A – B distance is $Y^{1/3}$ nm, where Y is an arbitrary number. ***(2004 - 2 Marks)***
   (a) Find the density of lattice
   (b) If the density of lattice is found to be 20 kg m^{-3}, then predict the type of defect.
10. In face centred cubic (fcc) crystal lattice, edge length is 400 pm. Find the diameter of greatest sphere which can be fit into the interstitial void without distortion of lattice. ***(2005 - 2 Marks)***
11. 20% of surface sites are occupied by N_2 molecules. The density of surface site is 6.023×10^{14} cm^{-2} and total surface area is 1000 cm^2. The catalyst is heated to 300 K while N_2 is completely desorbed into a pressure of 0.001 atm and volume of 2.46 cm^3. Find the number of active sites occupied by each N_2 molecule. ***(2005 - 4 Marks)***
12. The edge length of unit cell of a metal having molecular weight 75 g/mol is 5Å which crystallizes in cubic lattice. If the density is 2 g/cc then find the radius of metal atom ($N_A = 6 \times 10^{23}$). Give the answer in pm. ***(2006 - 6M)***

F Match the Following

Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labelled A, B, C and D, while the statements in Column-II are labelled p, q, r, s and t. Any given statement in Column-I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example :
If the correct matches are A-p, s and t; B-q and r; C-p and q; and D-s then the correct darkening of bubbles will look like the given.



1. Match the crystal system/unit cells mentioned in Column I with their characteristic features mentioned in Column II. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS. ***(2007)***

Column I	**Column II**
(A) Simple cubic and face-centered cubic parameters	(p) have these parameters, a = b = c and $\alpha = \beta = \gamma$
(B) cubic and rhombohedral	(q) are two crystal systems
(C) cubic and tetragonal	(r) have only two crystallo-graphic angles of 90°
(D) hexagonal and monoclinic	(s) belong to same crystal system

G Comprehension Based Questions

PASSAGE

In hexagonal systems of crystals, a frequently encountered arrangement of atoms is described as a hexagonal prism. Here, the top and bottom of the cell are regular hexagons and three atoms are sandwiched in between them. A space-filling model of this structure, called hexagonal close-packed (HCP), is constituted of a sphere on a flat surface surrounded in the same plane by six identical spheres as closely as possible. There spheres are then placed over the first layer so that they touch each other and represent the second layer. Each one of these three spheres touches three spheres of the bottom layer. Finally, the second layer is covered with third layer that is identical to the bottom layer in relative position. Assume radius of every sphere to be 'r'.

Answer the following questions -

1. The number of atoms in the HCP unit cell is *(2008)*
   (a) 4 (b) 6
   (c) 12 (d) 17
2. The volume of this HCP unit cell is – *(2008)*
   (a) $24\sqrt{2}r^3$ (b) $16\sqrt{2}r^3$
   (c) $12\sqrt{2}r^3$ (d) $\frac{64}{3\sqrt{3}}r^3$
3. The empty space in this HCP unit cell is *(2008)*
   (a) 74% (b) 47.6%
   (c) 32% (d) 26%

H Assertion & Reason Type Questions

Read the following statement (Assertion) and explanation (Reason) and answer each question as per the options given below :

(a) If both *assertion* and *reason* are correct, and *reason* is the correct explanation of the *assertion*.
(b) If both *assertion* and *reason* are correct, but *reason* is not the correct explanation of the *assertion*.
(c) If *assertion* is correct but *reason* is incorrect.
(d) If *assertion* is incorrect but *reason* is correct.

1. **Assertion :** In any ionic solid [MX] with Schottky defects, the number of positive and negative ions are same.
   Reason : Equal number of cation and anion vacancies are present. *(2001S)*
2. **Assertion :** Micelles are formed by surfactant molecules above the critical micellar concentration (CMC).
   Reason : The conductivity of a solution having surfactant molecules decreases sharply at the CMC. *(2007)*

I Integer Value Correct Type

1. The number of hexagonal faces that are present in a truncated octahedron is *(2011)*

Section-B JEE Main / AIEEE

1. The formation of gas at the surface of tungsten due to adsorption is the reaction of order **[2002]**
   (a) 0 (b) 1
   (c) 2 (d) insufficient data.
2. Na and Mg crystallize in BCC and FCC type crystals respectively, then the number of atoms of Na and Mg present in the unit cell of their respective crystal is
   (a) 4 and 2 (b) 9 and 14 **[2002]**
   (c) 14 and 9 (d) 2 and 4.
3. How many unit cells are present in a cube-shaped ideal crystal of NaCl of mass 1.00 g ? **[2003]**
   [Atomic masses : Na = 23, Cl = 35.5]
   (a) 5.14×10^{21} unit cells (b) 1.28×10^{21} unit cells
   (c) 1.71×10^{21} unit cells (d) 2.57×10^{21} unit cells
4. Which one of the following characteristics is **not** correct for physical adsorption ? **[2003]**
   (a) Adsorption increases with increase in temperature
   (b) Adsorption is spontaneous
   (c) Both enthalpy and entropy of adsorption are negative
   (d) Adsorption on solids is reversible
5. What type of crystal defect is indicated in the diagram below?

   $Na^+Cl^-Na^+Cl^-Na^+Cl^-$
   $Cl^-\square\ Cl^-Na^+\ \square\ Na^+$
   $Na^+Cl^-\ \square Cl^-Na^+Cl^-$
   $Cl^-Na^+Cl^-Na^+\ \square\ Na^+$ **[2004]**

   (a) Interstitial defect
   (b) Schottky defect
   (c) Frenkel defect
   (d) Frenkel and Schottky defects
6. Identify the correct statement regarding enzymes **[2004]**
   (a) Enzymes are specific biological catalysts that cannot be poisoned
   (b) Enzymes are normally heterogeneous catalysts that are very specific in their action
   (c) Enzymes are specific biological catalysts that can normally function at very high temperatures (T~1000K)
   (d) Enzymes are specific biological catalysts that possess well-defined active sites

7. An ionic compound has a unit cell consisting of A ions at the corners of a cube and B ions on the centres of the faces of the cube. The empirical formula for this compound would be **[2005]**

(a) A_3B (b) AB_3

(c) A_2B (d) AB

8. The volume of a colloidal particle, V_C as compared to the volume of a solute particle in a true solution V_S, could be

(a) $\frac{V_C}{V_S} \simeq 10^3$ (b) $\frac{V_C}{V_S} \simeq 10^{-3}$ **[2005]**

(c) $\frac{V_C}{V_S} \simeq 10^{23}$ (d) $\frac{V_C}{V_S} \simeq 1$

9. The disperse phase in colloidal iron (III) hydroxide and colloidal gold is positively and negatively charged, respectively. Which of the following statements is NOT correct ? **[2005]**

(a) Coagulation in both sols can be brought about by electrophoresis

(b) Mixing the sols has no effect

(c) Sodium sulphate solution causes coagulation in both sols

(d) Magnesium chloride solution coagulates, the gold sol more readily than the iron (III) hydroxide sol

10. Total volume of atoms present in a face-centred cubic unit cell of a metal is (r is atomic radius) **[2006]**

(a) $\frac{12}{3}\pi r^3$ (b) $\frac{16}{3}\pi r^3$

(c) $\frac{20}{3}\pi r^3$ (d) $\frac{24}{3}\pi r^3$

11. In Langmuir's model of adsorption of a gas on a solid surface **[2006]**

(a) the mass of gas striking a given area of surface is proportional to the pressure of the gas

(b) the mass of gas striking a given area of surface is independent of the pressure of the gas

(c) the rate of dissociation of adsorbed molecules from the surface does not depend on the surface covered

(d) the adsorption at a single site on the surface may involve multiple molecules at the same time

12. In a compound, atoms of element Y form ccp lattice and those of element X occupy 2/3rd of tetrahedral voids. The formula of the compound will be **[2008]**

(a) X_4Y_3 (b) X_2Y_3

(c) X_2Y (d) X_3Y_4

13. Gold numbers of protective colloids A, B, C and D are 0.50, 0.01, 0.10 amd 0.005, respectively. the correct order of their protective powers is **[2008]**

(a) D<A<C<B (b) C<B<D<A

(c) A< C<B<D (d) B<D<A<C

14. Which of the following statements is incorrect regarding physissorptions? **[2009]**

(a) More easily liquefiable gases are adsorbed readily.

(b) Under high pressure it results into multi molecular layer on adsorbent surface.

(c) Enthalpy of adsorption ($\Delta H_{adsorption}$) is low and positive.

(d) It occurs because of van der Waal's forces.

15. Copper crystallises in *fcc* with a unit cell length of 361 pm. What is the radius of copper atom? **[2009]**

(a) 127 pm (b) 157 pm

(c) 181 pm (d) 108 pm

16. The edge length of a face centered cubic cell of an ionic substance is 508 pm. If the radius of the cation is 110 pm, the radius of the anion is **[2010]**

(a) 288 pm (b) 398 pm

(c) 618 pm (d) 144 pm

17. Percentages of free space in cubic close packed structure and in body centered packed structure are respectively **[2010]**

(a) 30% and 26% (b) 26% and 32%

(c) 32% and 48% (d) 48% and 26%

18. In a face centred cubic lattice, atom A occupies the corner positions and atom B occupies the face centre positions. If one atom of B is missing from one of the face centred points, the formula of the compound is : **[2011]**

(a) A_2B (b) AB_2

(c) A_2B_3 (d) A_2B_5

19. Lithium forms body centred cubic structure. The length of the side of its unit cell is 351 pm. Atomic radius of the lithium will be : **[2012]**

(a) 75 pm (b) 300 pm

(c) 240 pm (d) 152 pm

20. According to Freundlich adsorption isotherm which of the following is correct? **[2012]**

(a) $\frac{x}{m} \propto p^0$

(b) $\frac{x}{m} \propto p^1$

(c) $\frac{x}{m} \propto p^{1/n}$

(d) All the above are correct for different ranges of pressure

21. Which of the following exists as covalent crystals in the solid state ? **[JEE M 2013]**

(a) Iodine

(b) Silicon

(c) Sulphur

(d) Phosphorus

22. The coagulating power of electrolytes having ions Na^+, Al^{3+} and Ba^{2+} for arsenic sulphide sol increases in the order : **[JEE M 2013]**

(a) $Al^{3+} < Ba^{2+} < Na^+$ (b) $Na^+ < Ba^{2+} < Al^{3+}$

(c) $Ba^{2+} < Na^+ < Al^{3+}$ (d) $Al^{3+} < Na^+ < Ba^{2+}$

23. CsCl crystallises in body centred cubic lattice. If 'a' is its edge length then which of the following expressions is correct? **[JEE M 2014]**

(a) $r_{Cs^+} + r_{Cl^-} = 3a$ (b) $r_{Cs^+} + r_{Cl^-} = \frac{3a}{2}$

(c) $r_{Cs^+} + r_{Cl^-} = \frac{\sqrt{3}}{2}a$ (d) $r_{Cs^+} + r_{Cl^-} = \sqrt{3}a$

24. Sodium metal crystallizes in a body centred cubic lattice with a unit cell edge of 4.29Å. The radius of sodium atom is approximately : **[JEE M 2015]**

(a) 5.72Å (b) 0.93Å

(c) 1.86Å (d) 3.22Å

25. 3 g of activated charcoal was added to 50 mL of acetic acid solution (0.06N) in a flask. After an hour it was filtered and the strength of the filtrate was found to be 0.042 N. The amount of acetic acid adsorbed (per gram of charcoal) is : **[JEE M 2015]**

(a) 42 mg (b) 54 mg

(c) 18 mg (d) 36 mg

26. For a linear plot of log (x/m) versus log p in a Freundlich adsorption isotherm, which of the following statements is correct? (k and n are constants) **[JEE M 2016]**

(a) Only $1/n$ appears as the slope.

(b) $\log(1/n)$ appears as the intercept.

(c) Both k and $1/n$ appear in the slope term.

(d) $1/n$ appears as the intercept.

11 The Solid State & Surface Chemistry

Section-A : JEE Advanced/ IIT-JEE

C	**1.**	(a)	**2.**	(a)	**3.**	(d)	**4.**	(a)	**5.**	(a)	**6.** (b)
	7.	(a)	**8.**	(d)	**9.**	(b)	**10.**	(c)	**11.**	(d)	**12.** (b)
	13.	(a)	**14.**	(b)							
D	**1.**	(a, c, d)	**2.**	(b, c)	**3.**	(a, b, d)	**4.**	(a, d)	**5.**	(a, c)	**6.** (a)
	7.	(b, c, d)	**8.**	(b, c, d)							
E	**1.**	2.91Å	**2.**	1.86 Å	**3.**	25.93%	**4.**	124.27 pm, 7.30 g/ml			
	5.	1.259	**7.**	(a) 25	**8.**	5×10^{-19} m^2	**9.**	(a) 5.0 kg/m^3, (b) metal excess defect			
	10.	117.16 pm	**11.**	2	**12.**	217 pm					
F	**1.**	(A - p, s); (B - p, q); (C - q); (D - q, r).									
G	**1.**	(b)	**2.**	(a)	**3.**	(d)					
H	**1.**	(a)	**2.**	(b)							
I	**1.**	8									

Section-B : JEE Main/ AIEEE

1.	(b)	**2.**	(d)	**3.**	(d)	**4.**	(a)	**5.**	(b)	**6.**	(d)	**7.**	(b)
8.	(a)	**9.**	(b)	**10.**	(b)	**11.**	(a)	**12.**	(a)	**13.**	(c)	**14.**	(c)
15.	(a)	**16.**	(d)	**17.**	(b)	**18.**	(d)	**19.**	(d)	**20.**	(d)	**21.**	(b)
22.	(b)	**23.**	(c)	**24.**	(c)	**25.**	(c)	**26.**	(a)				

Section-A JEE Advanced/ IIT-JEE

C. MCQs with One Correct Answer

1. (a) For bcc structure, atomic radius, $r = \frac{\sqrt{3}}{4}a$

$= \frac{\sqrt{3}}{4} \times 4.3 = 1.86$

Since, r = half the distance between two nearest neighbouring atoms.

$\therefore$ Shortest inter ionic distance $= 2 \times 1.86 = 3.72$

2. (a) In a hcp structure atoms are located at the corners and at centres of two hexagons placed parallel to each other ; three more atoms are placed in a parallel plane midway between these two planes. Here each atom is surrounded by 12 others and is said to have co-ordination number of 12.

3. (d) Effective number of 'A' atoms $= \left(8 \times \frac{1}{8}\right) + \left(4 \times \frac{1}{2}\right) = 3$

Effective number of 'B' atoms $= \left(12 \times \frac{1}{4}\right) + 1 = 4$

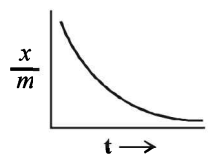
$\therefore$ Formula of the solid $= \mathbf{A_3B_4}$.

4. (a) Effective number of atoms at corners, $A = 8 \times \frac{1}{8} = 1$

Effective number of atoms at centre, $B = \frac{1}{2} \times 6 = 3$

Thus, the composition will be AB_3

5. (a) Rate of physiorsption increases with decrease of temperature



$\frac{x}{m}$ = amt of gas adsorbed per unit mass of adsorbent

t = temperature

6. **(b)** When a gas is adsorbed on the surface, the freedom of movement of its molecules becomes restricted. This causes decrease in the entropy of the gas after adsorbtion, i.e. ΔS becomes negative.

7. **(b)** In ZnS structure, sulphide ions occupy all FCC lattice points while Zn^{2+} ions are present in alternate tetrahedral voids.

8. **(d)** Lyophilic sols are self stabilizing because these sols are reversible and are highly hydrated in the solution.

9. **(b)** We know that surface acting agents (i.e. surfactants) such as soaps and detergents belong to the class of micelles. A miceller system when dissolved in water, dissociates to give ions. The anion consists of two parts. The polar groups such as (COO^- or SO_4^{--}) ion is water loving (i.e. hydrophilic) in nature. It is called head of the species. The hydrocarbon chain which is quite big in size is water repelling (i.e. hydrophobic) in nature. It is called tail of the species. The hydrocarbon chain aggregates into the micelle above the critical concentration.

NOTE : It may also be noted that the critical concentration for micelle formation decreases with increase in the molecular weight of the hydrocarbon chain of surfactant.

Here the two anions that are formed are in case of "B" (i.e. $CH_3(CH_2)_{11}OSO_3^-$) and "C" (i.e. $CH_3(CH_2)_6COO^-$)

The molecular weight of hydrocarbon chain is more in case of "B" so it has lower value of critical concentration for micelle formation in aqueous solution.

Hence the correct answer is option (b).

10. **(c)** As Sb_2S_3 is a negative sol, so $Al_2(SO_4)_3$ will be the most effective coagulant due to higher positive charge on Al (Al^{3+}) – **Hardy-Schulze rule**.

11. **(d)** Packing effieincy $= \dfrac{\text{Area occupied by effective circles}}{\text{Area of square}}$

$$= \frac{2\pi r^2}{L^2} \times 100 = \frac{2\pi r^2}{2(\sqrt{2}r)^2} \times 100 = \frac{\pi}{4} \times 100 = 78.54\%$$

12. **(b)** No. of M atoms $= \dfrac{1}{4} \times 4 + 1 = 1 + 1 = 2$

No. of X atoms $= \dfrac{1}{2} \times 6 + \dfrac{1}{8} \times 8 = 3 + 1 = 4$

So, formula $= M_2X_4 = MX_2$

13. **(a)** The arrangement given shows octahedral void arrangement-limiting radius ratio for octahedral void is

$$\frac{r_{A^+}}{r_{X^-}} = 0.414$$

$r_{A^+} = 0.414 \times r_{X^-} = 0.414 \times 250 = 103.5 \approx 104$ pm.

14. **(b)** The adsorption of methylene blue on activated charcoal is an example of physiosorption which is exothermic, multilayer and does not have energy barrier.

D. MCQs with One or More Than One Correct

1. **(a,c,d)** The crystals of CsCl has body - centred cubic unit cell. Hence, each ion in this structure has coordination number of eight.

NOTE : In case of crystals of NaCl two interpenetrating face-centred cubic lattices are present, one of these is composed entirely of Na^+ ions and the other of Cl^- ions. Each Na^+ ion is located half way between two Cl^- ions and viceversa. A unit cell of NaCl crystal has Cl^- ions at the corners as well as at the face centres and Na^+ ions are located in octahedral voids. On each edge of cubic unit cell, there are two Cl^- ions and one Na^+ ions. Hence

$$a = 2(r_{Na^+} + r_{Cl^-}) = 2(95\text{ pm} + 181\text{ pm}) = 552\text{ pm}.$$

2. **(b,c)** Frenkel defect is a dislocation effect, observed when the size of the cation and anion differ largely. F-center is created when an anion is lost from the lattice and vacancy is filled by trapping of an electron. Schottky defect changes the density of a crystalline solid.

3. **(a, b, d)**

(a) ΔH is negative for adsorption

(b) Fact based

(d) Chemical bonds are stronger than vander Waal's forces, so chemical adsorption is more exothermic.

4. **(a, d)**

5. **(a, c)** Graph (I) and (III) represent physisorption because, in physisorption, the amount of adsorption decreases with the increase of temperature and increases with the increase of pressure.

Graph (II) represent chemisorption, because in chemisorption amount of adsorption increases with the increase of temperature. Graph (IV) is showing the formation of a chemical bond, hence chemisorption.

6. **(a)** In *ccp*, O^{2-} ions are 4.

Hence total negative charge $= -8$

Let Al^{3+} ions be x, and Mg^{2+} ions be y.

Total positive charge $= 3x + 2y$

$\Rightarrow 3x + 2y = 8$

This relation is satisfied only by $x = 2$ and $y = 1$.

Hence number of $Al^{3+} = 2$.

and number of $Mg^{2+} = 1$.

$\Rightarrow n$ = fraction of octahedral holes occupied by Al^{3+}

$$= \frac{2}{4} = \frac{1}{2}$$

and m = fraction of tetrahedral holes occupied by Mg^{2+}

$$= \frac{1}{8}$$

7. **(b, c, d)** Reaction on metal surface

$$M \longrightarrow M^+ + e^-$$

$$O_2 + e^- \longrightarrow O_2^-$$

This is an example of chemisorption.

8. (b, c, d)

CCP is ABC ABC …… type packing

(A) In topmost layer, each atom is in contact with 6 atoms in same layer and 3 atoms below this layer

(B) Packing fraction $= \dfrac{4\times\frac{4}{3}\pi r^3}{\left(\frac{4r}{\sqrt{2}}\right)^3} = (0.74)$

(C) Each FCC unit has effective no of atoms = 4
Octahedral void = 4
Tetrahedral void = 8

(D) $4r = a\sqrt{2}$

E. Subjective Problems

1. Avogadro's number $= 6.023 \times 10^{23}$

At. wt. of mercury(Hg) = 200

$\because$ In 1 g of Hg, the total number of atom

$$= \frac{6.023\times10^{23}}{200} = \frac{6.023\times10^{23}}{2\times10^2}$$

$= 3.0115 \times 10^{21} = 3.012 \times 10^{21}$

Density of Mercury (Hg) = 13.6 g/c.c.

$\because$ mass of 3.012×10^{21} atoms = 1g

$$\therefore \text{mass of } 3.012\times10^{21} \text{ atoms} = \frac{1}{3.012\times10^{21}}$$

Now volume of 1 atom of mercury (Hg)

$$= \frac{1}{3.012\times10^{21}\times13.6}\text{ c.c.} = \frac{10^3\times10}{3012\times10^{21}\times136}\text{ c.c.}$$

$$= \frac{10^{-17}}{3012\times136}\text{ c.c.} = \frac{10^{-17}}{409632}\text{ c.c.} = \frac{1000000\times10^{-23}}{409632}\text{ c.c.}$$

$= 2.44 \times 10^{-23}$ c.c.

Since each mercury atom occupies a cube of edge length equal to its diameter, therefore,

diameter of one Hg atom $= (2.44\times10^{-23})^{\frac{1}{3}}$ cm

$= (24.4\times10^{-24})^{\frac{1}{3}}$ cm.

$= 2.905 \times 10^{-8}$ cm $\cong$ **2.91 Å**

2. TIPS/Formulae :

For bcc lattice, (radius), $r = \dfrac{\sqrt{3}a}{4}$

Solution

$$\therefore r = \frac{\sqrt{3}\times4.29\text{Å}}{4} = \frac{1.73\times4.29\text{Å}}{4} = \textbf{1.86 Å}$$

3. For a hcp unit cell, there are 6 atoms per unit cell. If r is the radius of the metal atoms, volume occupied by the metallic atoms $= 6\times\frac{4}{3}\times\pi\times r^3 = 6\times1.33\times\frac{22}{7}\times r^3 = 25.08\times r^3$

Geometrically it has been shown that the base area of hcp unit cell

$= 6\times\frac{\sqrt{3}}{4}\times4r^2$ and the height $= 4r\times\sqrt{2/3}$

$\therefore$ Volume of the unit cell

$= \text{Area} \times \text{height} = 6\times\frac{\sqrt{3}}{4}\times4r^2\times4r\times\sqrt{\frac{2}{3}} = 33.94\,r^3$

$\therefore$ Volume of the empty space of one unit cell
$= 33.94\,r^3 - 25.08\,r^3 = 8.86\,r^3$

$$\therefore \text{Percentage void} = \frac{8.816\,r^3}{33.94\,r^3}\times100 = \textbf{26.1\%}$$

4. For bcc lattice, $r = \dfrac{\sqrt{3}\times a}{4} = \dfrac{\sqrt{3}}{4}\times287 = \textbf{124.27 pm}$

$$\text{Now Density} = \frac{n\times\text{at.wt.}}{V\times\text{Av.No.}} = \frac{n\times\text{at. wt.}}{a^3\times\text{Av. No.}}$$

$n = 2$ for bcc; $a = 287\times10^{-10}$ cm

$$\therefore \text{Density} = \frac{2\times51.99}{(287\times10^{-10})^3\times6.023\times10^{23}} = \textbf{7.30 g/ml}$$

5. TIPS/Formulae : Density in fcc $= \dfrac{n_1\times\text{atwt.}}{V_1\times\text{No.}}$

$$\text{Density in bcc} = \frac{n_2\times\text{at.wt.}}{V_2\times\text{No.}}$$

fcc unit cell length = 3.5Å; bcc unit cell length = 3.0 Å

$$\text{Density in fcc} = \frac{n_1\times\text{at.wt.}}{V_1\times\text{Av.No.}}$$

$$\text{Density in bcc} = \frac{n_2\times\text{at.wt.}}{V_2\times\text{Av.No.}}$$

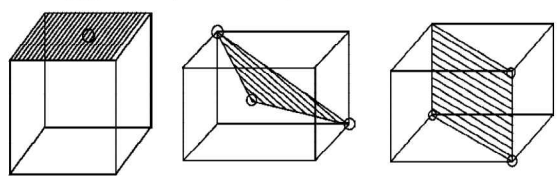
$$\therefore \frac{D_{fcc}}{D_{bcc}} = \frac{n_1}{n_2}\times\frac{V_2}{V_1}$$

n_1 for fcc = 4; Also $V_1 = a^3 = (3.5\times10^{-8})^3$

n_2 for fcc = 2; Also $V_2 = a^3 = (3.0\times10^{-8})^3$

$$\therefore \frac{D_{fcc}}{D_{bcc}} = \frac{4\times(3.0\times10^{-8})^3}{2\times(3.5\times10^{-8})^3} = \textbf{1.259}$$

6.

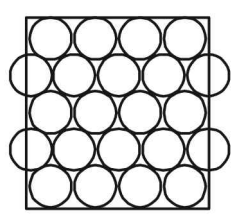


(I) (II) (III)

7. The area of square $= 4\times4 = 16\text{ cm}^2$

Again to have the maximum number of spheres the packing must be hcp.

Maximum number of spheres $= \underset{\text{full}}{14} + \underset{\text{half}}{8} = 14 + 4 = 18.$



Area $= 16\text{ cm}^2$

$$\therefore \text{Number of spheres per cm}^2 = \frac{18}{16} = 1.126$$

8. Number of moles of acetic acid in 100 ml before adding charcoal = 0.05

Number of moles of acetic acid in 100 ml after adding charcoal = 0.049

Number of moles of acetic acid adsorbed on the surface of charcoal = 0.001

Number of molecules of acetic acid adsorbed on the surface of charcoal = $0.001 \times 6.02 \times 10^{23} = 6.02 \times 10^{20}$

Surface area of charcoal = $3.01 \times 10^2\ m^2$ (given)

Area occupied by single acetic acid molecule on the surface of charcoal $= \dfrac{3.01 \times 10^2}{6.02 \times 10^{20}} = \mathbf{5 \times 10^{-19}\ m^2}$

9. (a) **TIPS/Formulae :** Density of AB $= \dfrac{Z \times M}{N_0 \times a^3}$

Here, $Z = 4$ (for fcc), $M = 6.023\ Y$,

$a = 2\ Y^{1/3}$ nm $= 2\ Y^{1/3} \times 10^{-9}$ m

Thus,

$$\text{Density} = \frac{4 \times 6.023\,Y}{6.023 \times 10^{23} \times (2Y^{1/3} \times 10^{-9})^3}$$

$$= \mathbf{5.0\ kg\ m^{-3}}$$

(b) Since the observed density (20 kg m^{-3}) of AB is higher than the calculated (5 kg m^{-3}), the compound must have **metal excess defect.** non-stocheometric defect.

10. **TIPS/Formulae :** For an octhedral void $a = 2(r + R)$

In fcc lattice the largest void present is octahedral void. If the radius of void sphere is R and of lattice sphere is r. Then,

$$r = \frac{\sqrt{2} \times 400}{4} = 141.12 \text{ pm} \qquad (a = 400 \text{ pm})$$

Applying condition for octahedral void, $2(r + R) = a$

$\therefore\ 2R = a - 2r = 400 - 2 \times 141.12$

$\therefore$ Diameter of greatest sphere = **117.16 pm**

11. $P_{N_2} = 0.001$ atm, $T = 300$ K, $V = 2.46\ cm^2$

$\therefore$ Number of N_2 molecules

$$= \frac{PV}{RT} \times N_{AV} = \frac{0.001 \times 2.46 \times 10^{-3}}{0.0821 \times 300} \times 6.023 \times 10^{23}$$

$$= 6.016 \times 10^{16}$$

Now total number of surface sites = Density × Total surface area

$$= 6.023 \times 10^{14} \times 1000 = 6.023 \times 10^{17}$$

Sites occupied by N_2 molecules $= \dfrac{20}{100} \times 6.023 \times 10^{17}$

$$= 12.04 \times 10^{16}$$

$\therefore$ No. of sites occupied by each N_2 molecule

$$= \frac{12.04 \times 10^{16}}{6.016 \times 10^{16}} \approx \mathbf{2}$$

12. **TIPS/Formulae :** For bcc ; $r = \dfrac{\sqrt{3}}{2}a$;

$$d = \frac{n \times M}{N_{Av} \times a^3} \text{ or } n = \frac{d \times N_{Av} \times a^3}{M}$$

$$\Rightarrow n = \frac{2 \times 6 \times 10^{23}\ (5 \times 10^{-8})^3}{75} = 2$$

Therefore Metal crystallizes in BCC structure and for a BCC lattice $\sqrt{3}a = 4r$

$$r = \frac{\sqrt{3}}{4}a = \frac{\sqrt{3} \times 5}{4} = 2.165\mathring{A} = 216.5 \text{ pm}$$

So the required answer is **217** pm.

F. Match the Following

1. **A-p, s; B-p,q; C-q; D-q, r.**

A→ p, s; Parameters of a cubic system are $a = b = c$ and $\alpha = \beta = \gamma = 90°$

There are three types of lattices in cubic system

These are simple, Face centred and body centred

B→ p, q ; The parameters of a Rhombohedral system are $a = b = c$; $\alpha = \beta = \gamma = 90°$

Cubic and Rhombohedral are two crystal systems. There are seven crystal systems in all

C→ q; These are two crystal systems.

D→ q, r; Hexagonal and monoclinic are two crystal systems. The parameters of these are

Hexagonal; $a = b \neq c$ and $\alpha = \beta = 90°$, $r = 120°$

Monoclinic ; $a \neq b \neq c$ and $\alpha = \gamma = 90°, \beta \neq 90°$

G. Comprehension Based Questions

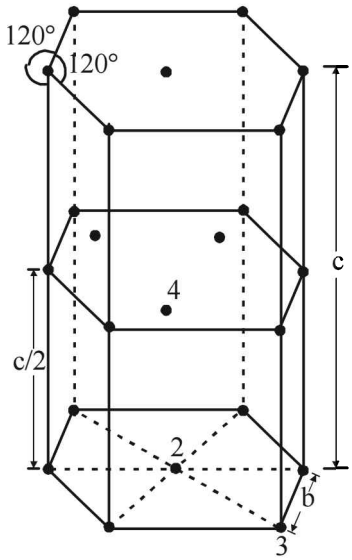
1. **(b)** In 1 unit cell of hcp, the number of atoms can be calculated as follows

Number of atoms in a unit cell of hcp

$$= 12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 = 6$$

i.e. the correct answer is option (b)

[**NOTE :** : in a hexagonal close packing (hcp) the spheres in the first and third layers are vertically aligned. (See figure below]



2. (a) The volume of hcp unit cell is given by the formula:-
Volume of hexagon = Area of base × height

$$= 6 \times \frac{\sqrt{3}}{4}(2r)^2 \times 4r\sqrt{\frac{2}{3}}$$

$$= 24\sqrt{2}\,r^3$$

i.e. the correct answer is option (a)

3. (d) In a hcp unit cell the space occupied is 74%, as calculated below

$$\text{Packing fraction} = \frac{\text{Volume of the atoms in a unit cell}}{\text{Volume of a unit cell}}$$

$$= \frac{6 \times \frac{4}{3}\pi r^3}{24\sqrt{2}\,r^3} = \frac{\pi}{3\sqrt{2}} = \frac{22}{7} \times \frac{1}{3\sqrt{2}}$$

$= 0.74$ or 74 %

$\therefore$ Empty space is HCP unit cell = (100–74)% = 26%
i.e. the correct answer is option (d).

H. Assertion & Reason Type Questions

1. (a) Schottky defect is defined as a vacancy developed for anion and cation site, so cation and anion vacancy will be same in number. Therefore an ionic solid MX with Schottky defects will still have the same number of anions and cations.

2. (b) Statement-1 is correct because the surfactant molecules aggregate to form micelles only at or above the critical micellar concentration (CMC). Although statement-2 is also correct, i.e., the conductivity of the solution having surfactant molecules decreases sharply at CMC. However, statement-2 is not the explanation for statement-1. The explantion is that "each micelle contains at least 100 molecules" and thus, with the formation of micelles, the number of ions in solution decreases and mobility of the bulkier micelle particles decreases. This, finally leads to decrease in conductivity of the solution.

Section-B JEE Main/ AIEEE

1. (b) It is zero order reaction
[**NOTE :** Adsorption of gas on metal surface is of zero order]

2. (d) In bcc - points are at corners and one in the centre of the unit cell.

Number of atoms per unit cell = $8 \times \frac{1}{8} + 1 = 2$.

In fcc - points are at the corners and also centre of the six faces of each cell.

Number of atoms per unit cell = $8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$.

3. (d) Since in NaCl type of structure 4 formula units form a cell. Number of formulas in cube shaped crystals

$$= \frac{1.0}{58.5} \times 6.02 \times 10^{23}$$

No. of unit cells present in a cubic crystal =

$$\frac{P \times a^3 \times N_A}{M \times Z} = \frac{m \times N_A}{M \times Z}$$

$$\therefore \text{units cells} = \frac{1.0 \times 6.02 \times 10^{23}}{58.5 \times 4} = 2.57 \times 10^{21} \text{ unit cells.}$$

4. (a) As adsorption is an exothermic process.
$\therefore$ Rise in temperature will decrease adsorption (according to Le-chatelier principle).

5. (b) When equal number of cations and anions are missing from their regular lattice positions, we have schottky defect. This type of defects are more common in ionic compounds with high co-ordination number and where the size of positive and negative ions are almost equal e.g. NaCl KCl etc.

6. (d) Enzymes are very specific biological catalysts possessing well - defined active sites

7. (b) Number of A ions in the unit cell. = $\frac{1}{8} \times 8 = 1$

Number of B ions in the unit cell = $\frac{1}{2} \times 6 = 3$

Hence empirical formula of the compound = AB_3

8. (a) Particle size of colloidal particle = 1mμ to 100 mμ (suppose 10 mμ)

$$V_c = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(10)^3$$

Particle size of true solution particle = 1mμ

$$Vs = \frac{4}{3}\pi(1)^3 \quad \text{hence now} \quad \frac{Vc}{Vs} = 10^3$$

9. **(b)** When oppositely charged sols are mixed their charges are neutralised. Both sols may be partially or completely precipitated.

10. **(b)** The face centered cubic unit cell contains 4 atom

$$\therefore \text{ Total volume of atoms } = 4\times\frac{4}{3}\pi r^3 = \frac{16}{3}\pi r^3$$

11. **(a)** According to Langmuir's Model of adsorption of a gas on a soild surface the mass of gas adsorbed(x) per gram of the adsorbent (m) is directly proportional to the pressure of the gas (p) at constant temperature i.e.

$$\frac{x}{m} \propto p$$

12. **(a)** From the given data, we have
Number of Y atoms in a unit cell = 4

$$\text{Number of X atoms in a unit cell } = 8\times\frac{2}{3} = \frac{16}{3}$$

From the above we get the formula of the compound as

$X_{16/3}Y_4$ or X_4Y_3

13. **(c)** For a protective colloid μ lesser the value of gold number better is the protective power.
Thus the correct order of protective power of A, B, C and D is

⇒	(A) <	(C) <	(B) <	(D)
Gold number	0.50	0.10	0.01	0.005

Hence (c) is the correct answer

14. **(c)** Adsorption is an exothermic process, hence ΔH will always be negative

15. **(a)** For *fcc* unit cell, $4r = \sqrt{2}\,a$; $r = \dfrac{\sqrt{2}\times 361}{4} = 127$ pm

16. **(d)** For an Fcc crystal

$$r_{\text{cation}} + r_{\text{anion}} = \frac{\text{edge length}}{2};\ 110 + r_{\text{anion}} = \frac{508}{2}$$

$r_{anion} = 254 - 110 = 144$ pm

17. **(b)** Packing fraction is defined as the ratio of the volume of the unit cell that is occupied by the spheres to the volume of the unit cell.
P.F. for cpp and bcc are 0.74 and 0.68 respectively.
So, the free space in ccp and bcc are 26% & 32% respectively.

18. **(d)** No. of atoms in the corners (A) $= 8\times\frac{1}{8} = 1$

$$\text{No. of atoms at face centres (B)} = 5\times\frac{1}{2} = 2.5$$

$\therefore$ Formula is $= AB_{2.5}$ or A_2B_5

19. **(d)** For BCC structure $\sqrt{3}\,a = 4r$

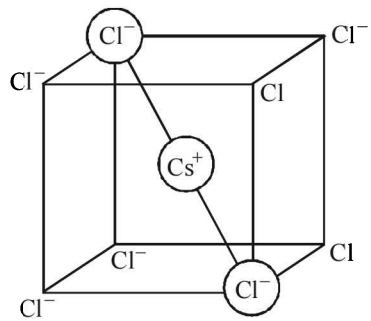
$$r = \frac{\sqrt{3}}{4}a = \frac{\sqrt{3}}{4}\times 351 = 152\,\text{pm}.$$

20. **(d)** The Freundlich adsorption isotherm is mathematically represented as $\dfrac{x}{m} = kP^{1/n}$
at high pressure $1/n = 0$. Hence, $x/m \propto P^{\circ}$
at low pressure $1/n = 1$ Hence, $x/m \propto P'$

21. **(b)** Among the given crystals only silicon is as a covalent solid.

22. **(b)** According to Hardly Schulze rule, greater the charge on cation, greater is its coagulating power for negatively charged solution. hence the correct order of coagulating power : $Na^+ < Ba^{2+} < Al^{3+}$

23. **(c)**



Relation between radius of cation, anion and edge length of the cube

$$2r_{Cs^+} + 2r_{Cl^-} = \sqrt{3}a \Rightarrow r_{Cs^+} + r_{Cl^-} = \frac{\sqrt{3}a}{2}$$

24. **(c)** In bcc the atoms touch along body diagonal

$$\therefore \quad 2r + 2r = \sqrt{3}a$$

$$\therefore \quad r = \frac{\sqrt{3}a}{4} = \frac{\sqrt{3}\times 4.29}{4} = 1.857\text{Å}$$

25. **(c)** Let the weight of acetic acid initially be w_1 in 50 ml of 0.060 N solution.

$$\text{Let the N} = \frac{w_1\times 1000}{\text{M.wt.}\times 50} \qquad (\text{Normality} = 0.06\,\text{N})$$

$$0.06 = \frac{w_1\times 1000}{60\times 50}$$

$$\Rightarrow \quad w_1 = \frac{0.06\times 60\times 50}{1000} = 0.18\,\text{g} = 180\,\text{mg}.$$

After an hour, the strength of acetic acid = 0.042 N
so, let the weight of acetic acid be w_2

$$N = \frac{w_2\times 1000}{60\times 50};\ 0.042 = \frac{w_2\times 1000}{3000}$$

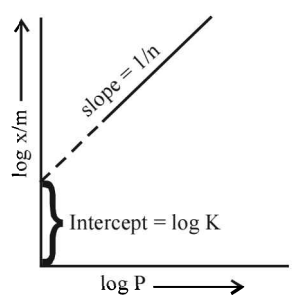
$\Rightarrow \quad w_2 = 0.126\,\text{g} = 126\,\text{mg}$
So amount of acetic acid adsorbed per 3g
$= 180 - 126\,\text{mg} = 54\,\text{mg}$
Amount of acetic acid adsorbed per g

$$= \frac{54}{3} = 18\,\text{mg}$$

26. **(a)** According to Freundlich adsorption isotherm

$$\log\frac{x}{m} = \log K + \frac{1}{n}\log P$$

Thus if a graph is plotted between log (x/m) and log P, a straight line will be obtained



The slope of the line is equal to 1/n and the intercept on log x/m axis will correspond to log K.