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CONTENTS

ELECTRONICS ENGINEERING

Objective Practice Sets

Materials Science

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CHAPTER

Materials Science

Introduction to Engineering Materials

Q.1 Material science deals with
(a) solid materials (b) molten metals
(c) gases and liquids (d) solids and vapours

Q.2 A unit cell is
(a) an agglomerated structure.
(b) the basic building block of crystal.
(c) the smallest group of atoms which when regularly repeated forms the crystal.
(d) a cube containing the largest number of atoms.

Q.3 **Assertion (A) :** A unit cell is analogous to a brick used in the building construction.
Reason (R) : A unit cell is defined as the basic structural part in the composition of materials.
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

Q.4 Consider the following statements:
1. The crystal directions of a family must be parallel to one another.
2. Crystal directions and crystal plane are denoted by the Miller indices.
3. In cubic crystals, a crystal plane and a crystal direction normal to it have different indices.
4. The effective number of lattice points in unit cell is highest in case of face centered cubic space lattice.

Which of the statements given above is/are correct?
(a) 2, 3 and 4 (b) 2 and 4
(c) 1, 2 and 3 (d) 4 only

Q.5 Consider the following statements associated with the atomic structure and chemical bonding:
1. Covalent bond is non-directional.
2. The metallic bond is directional and generally weaker than ionic and covalent bonds.
3. Free electrons are responsible for the high thermal and electrical conductivities of metals.
4. The order of occupation of quantum states by electrons is determined by the Pauli exclusion principle, the Hund's rule, and the minimum energy criterion.
5. The bond energy is related to the enthalpy of atomization of the solid.

Which of the statements given above are correct?
(a) 2, 3 and 5 (b) 1, 2 and 4
(c) 3, 4 and 5 (d) 1, 3 and 5

Q.6 The Miller indices of a plane are proportional to
(a) the reciprocal of numerical parameters of the intercepts
(b) the square of unit cell dimensions
(c) the intercepts of the planes on the coordinate axes
(d) interplaner spacing

Q.7 What is the Miller indices (h, k, l) of a plane whose intercepts are a, $b/2$ and $3c$ on x, y and z axes respectively in a simple cubic unit cell?
(a) (3, 1, 6) (b) (6, 3, 1)
(c) (1, 3, 6) (d) (3, 6, 1)

Q.8 The forces involved in the chemical bonding are
(a) Pauli's forces (b) Newton's forces
(c) Plank's forces (d) Coulomb's forces

Q.9 The atomic diameter of an FCC crystal (lattice parameter is a) is
(a) $\frac{a\sqrt{2}}{2}$ (b) $\frac{a\sqrt{2}}{4}$
(c) $\frac{a\sqrt{3}}{4}$ (d) $\frac{a}{2}$

Q.10 A material is most stable when its potential energy is
(a) maximum (b) infinite
(c) minimum (d) zero

Q.11 Total number of electrons that can be accommodated in various electron states in a valence band of a given solid is equal to
(a) atomic number of the solid
(b) half the number of atoms in the solid
(c) the number of atoms in the solid
(d) twice the number of atoms in the solid

Q.12 Consider the following statements:
Secondary (or Molecular) bonds are
1. The attraction forces exist between atoms or molecules.
2. Stronger than primary bonds.
3. Can be divided as electrostatic bonds.
4. Weaker than primary bonds.

Which of the above statements is /are correct?
(a) 1 only (b) 2 and 3 only
(c) 1 and 4 only (d) 1, 2, 3 and 4

Q.13 The geometrical configuration of one molecule of C_{60}-buckminsterfullerene contains
(a) 12 hexagons and 20 pentagons of Carbon atoms.
(b) 20 hexagons and 12 pentagons of Carbon atoms.
(c) 20 hexagons and 20 pentagons of Carbon atoms.
(d) 12 hexagons and 12 pentagons of Carbon atoms.

Q.14 Assuming the Fermi level E_f to be independent of temperature, E_f may be defined as the level with an occupancy probability of
(a) 0% (b) 50%
(c) 75% (d) 100%

Q.15 If (n) is lattice points per unit cell of the cubic system, (N) and (M) are the Avogadro's number and atomic weight, respectively, and (ρ) is the density of the element, then the lattice constant (a) is
(a) $\left(\frac{M\rho}{nN}\right)^{1/3}$ (b) $\left(\frac{NM}{n\rho}\right)^{1/3}$
(c) $\left(\frac{nM}{N\rho}\right)^{1/3}$ (d) $\left(\frac{N\rho}{nM}\right)^{1/3}$

Q.16 Consider the following statements in respect of energy bands in a solid.
1. Energy bands at high energy have more width than those bands at low energy.
2. Low energy bands correspond to valence electrons.
3. There are always some energy bands that are not filled.

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) only 2 (d) 1 and 3

Q.17 Lattice constants and angles of Triclinic crystal are:
(a) $a = b = c$, $\alpha = \beta = \gamma \neq 90°$.
(b) $a = b \neq c$, $\alpha = \beta = 90°$, $\gamma = 120°$.
(c) $a \neq b \neq c$, $\alpha = \gamma = 90° \neq \beta$.
(d) $a \neq b \neq c$, $\alpha \neq \beta \neq \gamma \neq 90°$.

Q.18 The crystal structure of an element is face centered cubic with cube side length 'a'. The atomic packing fraction and radius of atom in terms of cube side will be respectively.
(a) $\frac{\pi}{3\sqrt{3}}, \frac{a}{2\sqrt{2}}$ (b) $\frac{\pi}{3\sqrt{2}}, \frac{a}{2\sqrt{3}}$
(c) $\frac{\pi}{3\sqrt{2}}, \frac{a}{2\sqrt{2}}$ (d) $\frac{\pi}{3\sqrt{3}}, \frac{a}{2\sqrt{3}}$

Q.19 Consider the following statements:
1. An increase in BCC iron volume is observed when heated due to change of BCC iron to FCC iron.
2. If the dislocation density in the crystal is high, it results in high mechanical strength of crystal.
3. Ionic crystals are hard and corrosive both in nature.

Which of the above given statements are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

Q.20 What type of defect causes F-centers in a crystal?
(a) Stoichiometric defect
(b) Metal excess defect due to anion vacancies
(c) Metal excess defect due to extra cations
(d) Frenkel defect

Q.21 Point imperfections, during interaction with each other,
(a) lower their total energy
(b) are not affected at all
(c) are thermodynamically stable
(d) both (b) and (c)

Q.22 If there are six electrons in the *d* orbital of a transition metal, the number of unpaired electrons are

(a) 6 (b) 5
(c) 4 (d) 0

Q.23 A material has a face-centered cubic structure with an ionic radius of 1.06 Å. Calculate the inter planar separation for (110) planes.

(a) 3.119 Å (b) 1.731 Å
(c) 2.119 Å (d) 1.499 Å

Q.24 What is the packing fraction of a BCC (body-centered cubic) unit cell?

(a) $\frac{\sqrt{3}\pi}{16}$ (b) $\frac{\sqrt{3}\pi}{8}$
(c) $\frac{\sqrt{3}\pi}{12}$ (d) $\frac{\sqrt{2}\pi}{8}$

Q.25 Match **List-I** with **List-II** and select the correct answer using the code given below the lists:

List-I	List-II
A. Carbon (Diamond)	1. Conducting
B. Silicon	2. Semiconducting
C. Tin (Grey)	3. Insulating
D. Lead	

Codes:

	A	B	C	D
(a)	3	2	1	1
(c)	1	2	1	3
(c)	3	1	2	1
(d)	1	1	2	3

■■■■

Answers Introduction to Engineering Materials

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

Explanations Introduction to Engineering Materials

1. (a)

The scope of material science is generally restricted to the study of solid materials, and that too only to those which are useful as engineering materials.

2. (c)

When many unit cells repeat in a three-dimensional space, a crystal is obtained. The structure of a crystal is same as that of a repeating unit cell.

3. (a)

A unit cell is defined as the basic structure part in the composition of materials. It is analogous to a brick used in the building construction. So, Assertion is correct and Reason is correct explanation of it.

4. (b)

- The crystal directions of a family are not necessarily parallel to one another. Hence, statement-1 is not correct.
- Statement-2 is correct.
- In cubic crystals, a crystal plane and a crystal direction normal to it have the same indices. Hence, statement-3 is not correct.
- The effective number of lattice points in unit cell is highest i.e. 4 in case of face-centered cubic space lattice. In case of simple cubic it is 1 and in case of BCC it is 2. Hence, statement-4 is correct.

5. (c)

- The sharing of electrons between neighbouring atoms results in a covalent bond, which is directional. Hence, statement-1 is not correct.

- The metallic bond is non-directional and generally weaker than ionic and covalent bonds. Thus, statement-2 is not correct.
- Free electrons are responsible for the high thermal and electrical conductivities. Hence, statement-3 is correct.
- Statement-4 is correct.
- The magnitude of the energy released, when two atoms come together from a large distance of separation to the equilibrium distance, is called the bond energy. It is related to the enthalpy of atomization of the solid. Hence, statement-5 is correct.

6. (a)

Miller indices are expressed as a reciprocal of intercepts made by the plane on the three rectangular x, y and z respectively.

7. (d)

The intercepts C_1 (along x-axis) = a,
C_2 (along y-axis) = $b/2$,
and C_3 (along z-axis) = $3c$

Therefore, $p = \frac{c_1}{a} = \frac{a}{a} = 1$

$$q = \frac{c_2}{b} = \frac{b/2}{b} = \frac{1}{2}$$

and $$r = \frac{c_3}{c} = \frac{3c}{c} = 3$$

$\therefore$ $$h = \frac{1}{p} = \frac{1}{1} = 1$$

$$k = \frac{1}{q} = \frac{1}{1/2} = 2$$

and $$l = \frac{1}{r} = \frac{1}{3}$$

Hence, $(h, k, l) = \left(1, 2, \frac{1}{3}\right) = \frac{1}{3}(3, 6, 1) = (3, 6, 1)$

(Since Miller indices is always an integer)

8. (d)

Bonding is the nature of a material to hold the atoms together. In materials, atoms are arranged systematically. Coulomb's force, both attractive and repulsive, work on them. The net force out of these two opposite natured forces, are responsible for the bonding.

9. (a)

In FCC crystal, diagonal of each face

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

(Where, r = radius of each atom)

The atomic diameter of an FCC crystal

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

10. (c)

A material is most stable when its potential energy is minimum.

11. (a)

Atomic number represents the total number of valence electrons present in various energy state in valence band.

12. (c)

Secondary or molecular bonds are either ion-dipole interaction, dipole-dipole interaction or Van der Waals are weaker than primary bonds (ionic, covalent).

13. (b)

It contains 20-hexagons and 12-pentagons of carbon atoms.

14. (b)

Fermi-Dirac probability function $F(E)$ is given by

$$F(E) = \frac{1}{1 + e^{(E-E_F)/kT}}$$

where, E_F = Fermi level

if $E = E_F$ then $F(E) = \frac{1}{2}$ for any value of temperature. Thus, the fermi level represents the energy state with 50% probability of being filled if no forbidden band exists.

15. (c)

$\because$ $$\rho = \frac{nM}{Na^3} \Rightarrow a^3 = \frac{nM}{N\rho}$$

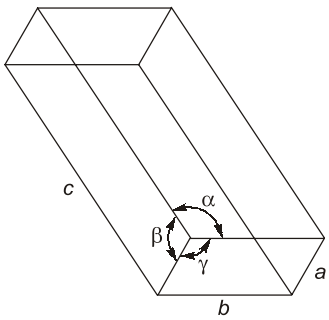
$$a = \left(\frac{nM}{N\rho}\right)^{1/3}$$

where, M = Atomic weight
ρ = Density of element
n = Lattice point per unit cell
N = Avogadro's number
a = Lattice constant

16. (d)

- Bands of higher energy are splitted into more bands as outermost level splits first and inner level splits after.
- Partially filled band refer to free or valence electrons possessing higher energy.
- Valence band is the highest range of electron energies in which electrons are normally present at zero temperature.
- Some energy bands like conduction band may be unfilled.

17. (d)



Triclinic
$a \neq b \neq c$
$\alpha \neq \beta \neq \gamma$

18. (c)

Atomic packing fraction for face centre cubic structure : $\frac{4 \times \text{Volume of atom}}{\text{Volume of cube}}$

For face centered cube

No. of atoms per unit cell:

$$\frac{1}{8} \times 8 + 6 \times \frac{1}{2} = 4$$

For face centered cubic system,

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

Where r is atomic radius and a is cube side length

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

$$\therefore \text{Atomic packing fraction} = \frac{4 \times \frac{4}{3}\pi\left(\frac{a}{2\sqrt{2}}\right)^3}{a^3}$$

$$= 4 \times \frac{4}{3}\pi \times \frac{a^3}{8 \times 2\sqrt{2}\, a^3} = \frac{\pi}{3\sqrt{2}}$$

19. (b)

If dislocation density is high, mechanical strength of material decreases.

20. (b)

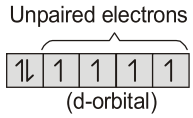
F-centers are non-stoichiometric defect where electrons are trapped in anion vacancies and produced by the exposure of an alkali metal halide crystal to the alkali metal vapour.

21. (d)

Point imperfections are imperfect point-like regions in the crystal. These defects are of one or two atomic diameters only. Hence, these are called two-dimensional defects.

Point imperfections of different types interact with each other and in doing so lower the total energy. These are thermodynamically stable.

22. (c)



The number of unpaired electrons = 4

23. (c)

∵ In a face-centred cubic structure

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

$$r = 1.06 \text{ Å}$$

$$\therefore \quad a = \frac{4r}{\sqrt{2}} = \frac{4 \times 1.06}{\sqrt{2}} = 2.998 \text{ Å}$$

∴ Inter planar separation for (111) planes is

$$d = \frac{a}{\sqrt{1^2 + 1^2 + 0^2}}$$

$$= \frac{2.998}{\sqrt{2}} = 2.119 \text{ Å}$$

24. (b)