



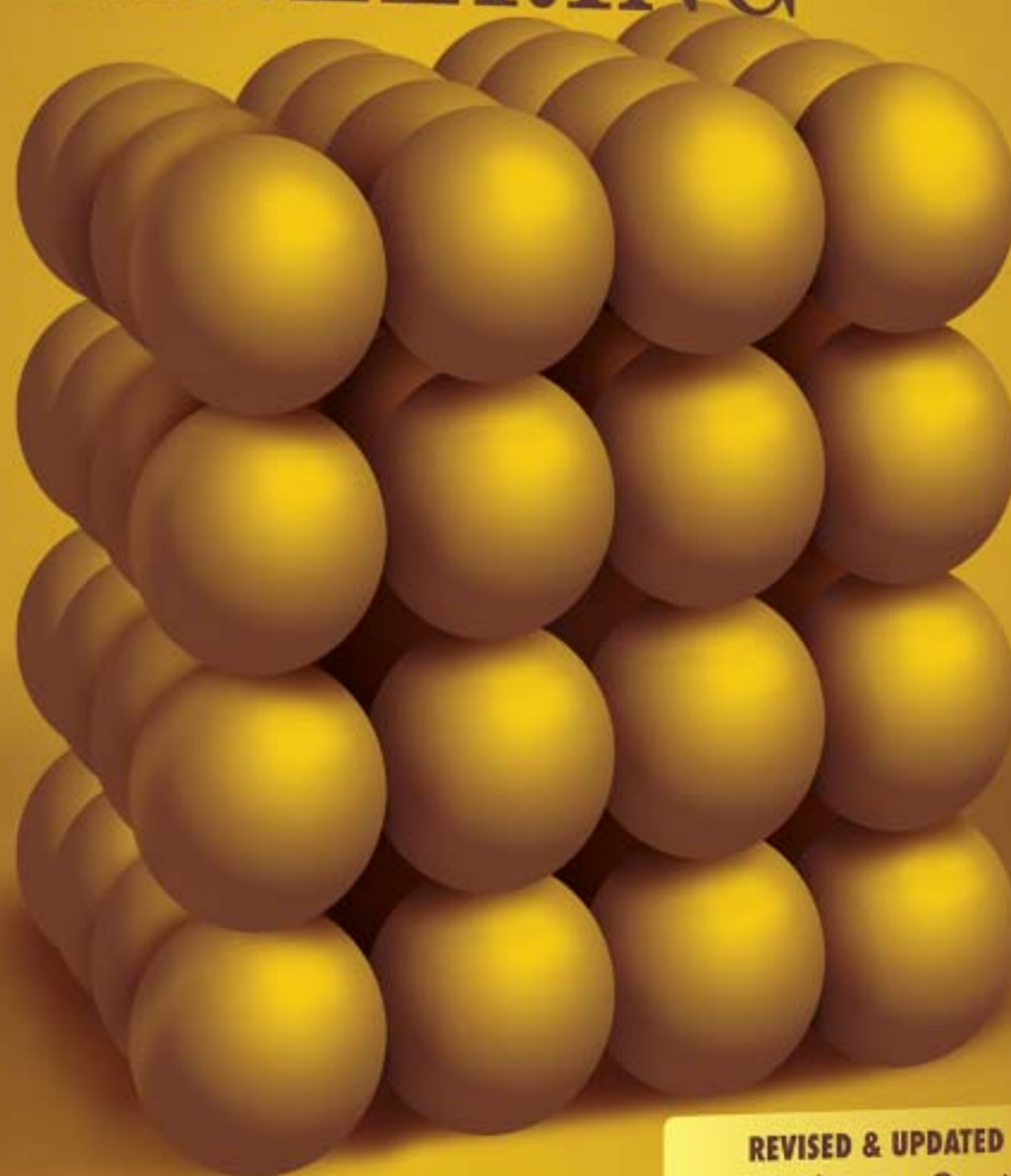
ESE 2019
Prelims Paper - I



IES MASTER
PUBLICATION

BASICS OF MATERIAL SCIENCE AND ENGINEERING

BASICS OF
MATERIAL
SCIENCE &
ENGINEERING



REVISED & UPDATED
520+ Objective Questions

ESE 2019
Prelims Paper - I

Basics of
Material Science
and
Engineering

New Pattern
for
UPSC ESE Exam



Office : F-126, (Lower Basement), Katwaria Sarai, New Delhi-110016 • **Phone** : 011-26522064
Mobile : 8130909220, 9711853908 • **E-mail**: info@iesmasterpublications.com, info@iesmaster.org
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F-126, (Lower Basement), Katwaria Sarai, New Delhi-110016

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E-mail : info@iesmasterpublications.com, info@iesmaster.org

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PREFACE

Materials are the spinal chord of technology. An Engineer, regardless of which discipline he/she belongs to, must have sound understanding of basic concept of Material Science.

This understanding of materials enables the engineers to select the most appropriate materials and use them with greatest efficiency whilst causing minimum pollution in their extraction, refinement and manufacturing.

Favourable and warm reception which the 1st and 2nd Edition got from the student is a matter of great satisfaction for me. This book has been written after intensive study of the probable topics in material science from where questions are expected. Based on the pattern and trend of questions asked in UPSC examinations; all the necessary concepts and information have been compiled in simple and lucid form.

This book primarily aimed at explaining the basic concept of "Material Science" for student preparing for ESE. The treatment of each chapter is such as to start from the fundamentals and build up to the level of ESE.

This book is divided into "Twelve Chapters" plus One Annexure. The first two chapter deal with the basic concept of atom, chemical bonding, Various Related Theories to Bonding and Crystal Structure. The Chapter 3 and 4 describes the phase diagram, Heat treatment and mechanical properties of material. Chapter 5 discusses the various type of alloy. Chapter 6 discusses the semiconductor and its related terms. Chapter 7, 8, 9 describes the magnetic and dielectric properties, conductivity and superconductivity, optical and thermal properties of material. Chapter 10 deals with modern material which include polymer, ceramic and composite. Chapter 11 includes Miscellaneous and advance material and Chapter 12 has been added in this addition which discusses fundamental of corrosion and its prevention. The Annexure given at end serves as a ready reckoner, covering short and brief description of properties of various important material in the periodic table and short notes on metallurgical extraction, for a distraction free learning.

This book contains several student friendly features. No prior knowledge is expected of the student except school level physics and chemistry. Important points, which are important from examination point of view, are highlighted in the chapters and at the end of the chapter these are given as **Point to be Remembered**. Good number of practice questions are provided at the end of every chapter. So, as a topic is finished, students test their understanding in the language asked in the UPSC exam. The spin given to the concepts, tests the ability of the students to derive the correct answer, which facilitate the students to acquire necessary confidence. Students may generally not require any additional study and may be reasonably confident that all the probable questions and topics covered in this book. Apart from the aforesaid, UPSC sample Paper Questions and Questions asked in ESE-2017-18 paper are discussed after the completion of relevant topics.

All care has been taken to make the understanding of this subject more clear and interesting. My special thanks to the entire IES MASTER Team for their continuous support in bringing out this book. Hope this will suffice the need of students who are preparing for Engineering Services Examination. All comments and suggestions for further improvement of the book are welcome and will be appreciated.

Bipin Thakur
IES Master Publication
New Delhi, 2018

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1

Atomic Structure and Radioactivity

1.1 INTRODUCTION

- 1.1 Introduction
- 1.2 Atomic Model
- 1.3 Basic Term and their Definition
- 1.4 Fundamental Components of Atoms
- 1.5 The Energy-Band Theory
- 1.6 Periodic Table
- 1.7 Atomic Bonding
- 1.8 Bond Characteristic
- 1.9 Radio Activity

All substances contain matter which can exist in three states solid liquid or gas. The constituent particles are held in different ways in these states of matter and they exhibit their characteristic properties. Matter can also be classified into elements, compounds or mixtures. An element contains particles of only one type which may be atoms or molecules. The compounds are formed where atoms of two or more elements combine in a fixed ratio to each other. Mixtures occur widely and many of the substances present around us are mixtures.

This chapter consider several fundamental and important concept namely atomic structure and it's related theory, electron configuration, periodic table, types of bonds that hold together the atoms comprising a solid and finally radioactivity at the end.

1.2 ATOMIC MODEL

The concept of atom was given by early Greek philosophers. In Greek the word atom means indivisible. In 1804, Dalton put forward his atomic theory, thereafter in 1815. Prout found that atomic weights of most elements were simple multiple of atomic weight of hydrogen atom but increase of time this has been discarded because it was found that certain elements have fraction atomic weight. According to modern concept, an atom is composed of a nucleus which is surrounded by electrons.

1.2.1 Dalton's Atomic Theory

The **Dalton's atomic theory** states that atoms are building blocks of matter.

According to Dalton's atomic theory:

- ◀ Matter consists of indivisible atoms
- ◀ All the atoms of a given element have identical properties including identical mass. Atoms of different elements differ in mass.
- ◀ Compounds are formed when atoms of different elements combine in a fixed ratio.

Draw back

- ◀ It can explain the laws of chemical combination by weight but it fails to explain Gay-Lussac's law gaseous volume.

- ◀ Distinction between the ultimate particles of an element and the smallest particle of a compound, both of which are made of atoms, could not be made.
- ◀ It assumes that atoms of same element are like and have same mass. But this is not true for isotopes (two or more atoms with same atomic number but different atomic mass called isotopes).
- ◀ ${}^{12}_6\text{C}$, ${}^{13}_6\text{C}$, ${}^{14}_6\text{C}$ have atoms of different mass.
 ${}^1_1\text{H}$, ${}^2_1\text{H}$, ${}^3_1\text{H}$ have atoms of different masses.

1.2.2 Avogadro's Hypothesis

Before Avogadro, Berzelius was the first who have been talking about atom. **As per Berzelius assumed "equal volumes of different gases under identical conditions of temperature and pressure contain the same number of atoms"** (The word atom was at that time used for both elements and compounds as molecule was not thought of)." As per this theory if 1 atom of H_2 combines with $1/2$ atom of O_2 . Then this **process allows atom to be divisible. This is against Dalton's atomic theory. Hence, Berzelius hypothesis was discarded.** Failure led to assume that gases exist in polyatomic state and ultimate particles which can exist in the free state were defined as molecule. Avogadro's hypothesis is based on molecules:

"Equal volume of all gases under the same conditions of temperature and pressure contain the same number of molecule".

The conclusion withdrawn by this theory are as follows:

- ◀ The word molecule and made the distinction between atoms and molecules.
- ◀ Molecules of hydrogen, chlorine, oxygen, nitrogen and fluorine are diatomic.
- ◀ Molecular weight = $2 \times$ vapour density.
- ◀ One gram-molecular mass (molecular weight) has volume 22.4 L ($22.4 \times 10^{-3} \text{ m}^3$) at NTP (pressure = 1 atm and $T = 273.15 \text{ K}$)

Example 1.1

Consider the following statements :

Statement (I) : Atoms can neither be created nor destroyed.

Statement (II) : Under similar conditions of temperature and pressure, equal volumes of gases do not contain an equal number of atoms. **[ESE-2018]**

Choose the correct option :

- (a) I and II are correct
- (b) Only I is correct
- (c) Only II is correct
- (d) None of the statement is correct.

Ans. (b)

1.2.3 Thomson's Atomic Model

J.J. Thomson, proposed that an atom possesses a spherical shape (radius approximately 10^{-10}m) in which the positive charge is uniformly distributed. The electrons are embedded into it in such a manner as to give the most stable electrostatic arrangement.

- ◀ Atom is a sphere filled with positively charged matter distributed uniformly with sufficient electrons embedded in it to balance positive charge, hence atom is electrically neutral.
- ◀ The electrons possess vibratory motion about their equilibrium position and causes emission of light.

Drawbacks of the Model

Thomson's model did not explained

- (i) Scattering of α -particle incident on metal foil.
- (ii) Emission of spectral lines by the atoms.

1.2.4 Rutherford's Atomic Model

Rutherford did his famous α -particle scattering experiment. On the basis of his observations, Rutherford proposed the nuclear model of atom. According to this:

- (i) The positive charge and most of the mass of the atom were densely concentrated in extremely small region. This very small portion of the atom was called **nucleus** by Rutherford.
- (ii) The nucleus is surrounded by electrons that move around the nucleus with a very high speed in circular paths called **orbits**.
- (iii) Electrons and the nucleus are held together by electrostatic forces of attraction.

Drawbacks of Rutherford's Atomic Model

A revolving electron must be continuously accelerating due to change in direction of motion. According to electromagnetic theory, an accelerating charge particle possesses centripetal acceleration and there would be continuous loss in energy of the revolving electron. Thus, the electron must move along a spiral path of decreasing radius and ultimately fall into the nucleus.

Questions

1. According to Thomson's plum pudding model, an atom consists of
 - (a) A nucleus of negative charge with protons around
 - (b) A sphere of negative charge seasoned with enough number of proton plums.
 - (c) A heavy sphere of positive charge seasoned with enough number of electron plums to make it electrically neutral
 - (d) None of these
2. When an electron 'jumps' from an energy level to a lower one, the energy released is usually
 - (a) absorbed by the nucleus
 - (b) emitted as a photon
 - (c) emitted as light
 - (d) emitted as a continuous electromagnetic wave
3. The radiation emitted by a heated gas of hydrogen atoms contains
 - (a) all wavelengths
 - (b) one specific wavelength
 - (c) a set of discrete values of wavelength
 - (d) None of the above
4. The emission of radiation from a gas of atoms occurs when
 - (a) an electron is spiralling towards the nucleus
 - (b) an electron jumps between two energy levels
 - (c) the wavelength of an electron changes
 - (d) None of the above
5. The principal quantum number n may have only the values
 - (a) 0, 1, 2,...
 - (b) 0, ± 1 , ± 2 , ± 3 ,...
 - (c) 1, 2, 3,...
 - (d) None of the above
6. The angular momentum quantum number l may take only the values
 - (a) 0, 1, 2, ..., $(n - 1)$
 - (b) 0, 1, 2, 3, ..., n
 - (c) 1, 2, 3, ..., n
 - (d) 1, 2, 3, ..., $(n - 1)$
7. The magnetic quantum number m may have only the values
 - (a) 0, ± 1 , ± 2 , ..., l
 - (b) 0, ± 1 , ± 2 , ..., $\pm n$
 - (c) 0, ± 1 , ± 2 , ..., $\pm (l - 1)$
 - (d) 0, ± 1 , ± 2 , ..., $\pm (n - 1)$
8. How many quantum numbers are needed to define the wave function of an electron moving in two dimensions (excluding spin)?
 - (a) one
 - (b) two
 - (c) three
 - (d) four
9. Pauli's exclusion principle states that, within one atom
 - (a) no more than two electrons may have the same energy
 - (b) the spins of the electrons interact so as to become parallel if possible
 - (c) no two electrons may have the same four quantum numbers
 - (d) there are only two values for the quantum number m_s
10. The maximum number of electrons in the L shell ($n = 2$) is
 - (a) 4
 - (b) 6
 - (c) 8
 - (d) 14
11. The maximum number of electrons allowed in the 4d subshell is
 - (a) 14
 - (b) 10
 - (c) 8
 - (d) 4
12. The lithium atom, which contains three electrons, has the structure
 - (a) $1s^2 2s^1$
 - (b) $1s^2 2p^1$
 - (c) $1s^1 2p^2$
 - (d) $2s^2 2p^1$
13. The atomic number of the element whose outermost electron fills the 3s subshell exactly is
 - (a) 13
 - (b) 8
 - (c) 10
 - (d) 12
14. Equal moles of the substance are present in

(1) 1.6g CH_4	(2) 1.7 g NH_3
(3) 1.8 g H_2O	(4) 1.2g Mg

 - (a) 1, 2
 - (b) 2, 3
 - (c) 1, 2 and 3
 - (d) 1, 2, 3 and 4
15. The difference between A and Z is a result of the presence in the nucleus of
 - (a) electrons
 - (b) protons
 - (c) photons
 - (d) neutrons

16. The electronegativity of an element is a measure of
- the excess of electrons over protons
 - the number of electrons in the valence shell
 - the strength with which electrons are attracted to the atom
 - None of the above
17. Consider the following statements :
- A characteristic of the structure of metallic atoms is that
- their outermost orbital of electrons is nearly complete and they attract electrons from other atoms
 - their atoms are smaller and more compact than those of non-metallic elements
- Which of the above statements is/are correct?
- 1 only
 - 2 only
 - Both 1 and 2
 - Neither 1 nor 2
18. Total number of electrons that can be accommodated in various electron states in a valence band of a given solid is equal to
- atomic number of the solid
 - half the number of atoms in the solid
 - the number of atoms in the solid
 - twice the number of atoms in the solid
19. Solid material chemical bonds are
- Ionic, molecular and fusion
 - Covalent, fusion and fission
 - Ionic, covalent and molecular
 - Fission, molecular and ionic
20. Hydrogen bonds are stronger than
- Van der Waals bonds
 - Metallic bonds
 - Ionic bonds
 - Covalent
21. Particles that most effects material propertis
- Nuetrons
 - Protons
 - Electrons
 - Valence electrons
22. Metallic solids are held together by
- the attraction between the ion cores
 - the attraction between ion cores and the electrons
 - electrons shared between adjacent pairs of atoms
 - None of the above
23. Two group atoms may be covalently bonded by
- direct transfer of electron
 - sharing of electrons from each other
 - a completed octet of electrons from the two atoms
 - a single bond
24. Van der Waals bonding is prominent
- between molecular ions
 - between ionic molecules
 - when there are no valence electrons available to form primary bonds
 - None of the above
25. Van der Waals bonding is a result of
- attraction between magnetic dipoles
 - attraction between saturated covalent bonds
 - attraction between electrostatic dipoles
 - None of the above
26. Hydrogen bonds play a part in bonding
- water of hydration to a salt
 - solid methane (CH_4)
 - CO_2
 - None of the above
27. Solid CO_2 has a low sublimation point because
- the carbon-oxygen bonds are covalent
 - the intermolecular bonding is due to ionic forces
 - there are no spare electrons for bonding the molecules to one another
 - None of the above
28. Find out correct statements among following :
- Double bond cause less repulsion than single bond.
 - Shape of the molecule is determined by repulsions between all the electron pairs.
 - Shape and size of MO depends upon shape and size of two atomic orbitals that combine each other
- I, II and III
 - II and III
 - I and III
 - I and II
29. An electrically balanced atom has 30 protons in its nucleus and 2 electrons in its outermost shell. The materials made of such atom is

- (a) a conductor (b) an insulator
(c) a semiconductor (d) a superconductor
30. In which of the following pairs do the two species resemble each other most closely in chemical properties?
(a) ${}^1_1\text{H}$ and ${}^2_1\text{H}$ (b) ${}^{16}_8\text{O}$ and ${}^{16}_8\text{O}^{2-}$
(c) ${}^{24}_{12}\text{Mg}$ and ${}^{24}_{12}\text{Mg}^{2+}$ (d) ${}^{14}_7\text{N}$ and ${}^{14}_7\text{N}^{3-}$
31. The bond formed by oscillatory dipole is
(a) Covalent bond (b) Dipole
(c) Dispersion bond (d) Hydrogen bond
32. Which of the bond is available in three state of metal?
(a) Metallic (b) Ionic
(c) Covalent (d) Hydrogen
33. The mole is
(a) The molecular weight of a substance in grams
(b) The amount of a substance whose mass is numerically equal to its molecular weight
(c) The amount of a substance whose volume is equal to that of 1 gram of hydrogen gas at standard temperature and pressure
(d) None of the above
34. The total energy of the electron is
(a) the difference between its kinetic and potential energies
(b) the sum of its kinetic and potential energies
(c) the product of its kinetic and potential energies
(d) None of the above
35. Electron sea exists in
(a) Polar bonds (b) Ionic bond
(c) Covalent bond (d) Metallic bond
- Each of the sentences in **Questions 58-68** consists of an assertion followed by a reason.
- (a) If both assertion and reason are true statements and the reason is a correct explanation of the assertion.
(b) If both assertion and reason are true statements but the reason is not a correct explanation of the assertion.
(c) If the assertion is true but the reason contains a false statement.
(d) If the assertion is false but the reason contains a true statement.
36. **Assertion** : The hydrogen atom in its ground state can emit radiation
Reason : The electron can make a transition to a higher energy level.
37. **Assertion** : Hydrogen gas at normal temperatures does not emit light.
Reason : The radiation that is emitted has wavelengths too short to be visible.
38. **Assertion** : The ground state of the helium atom is $1s^2$.
Reason : This is the lowest energy state.
39. **Assertion** : The electronic structure $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5 4d^2$ does not normally occur in a real atom.
Reason : The subshells have been filled in the wrong order.
40. **Assertion** : The elements in any one group of the periodic table are chemically similar.
Reason : They all contain the same number of electrons in the outermost subshell.

ANSWER KEY

1. (c)	8. (b)	15. (d)	22. (b)	29. (a)	36. (d)
2. (b)	9. (c)	16. (c)	23. (b)	30. (a)	37. (b)
3. (c)	10. (c)	17. (d)	24. (c)	31. (a)	38. (b)
4. (b)	11. (b)	18. (a)	25. (c)	32. (b)	39. (a)
5. (c)	12. (a)	19. (c)	26. (a)	33. (b)	40. (a)
6. (a)	13. (d)	20. (a)	27. (c)	34. (b)	
7. (a)	14. (c)	21. (d)	28. (b)	35. (d)	

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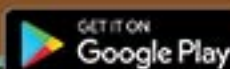
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