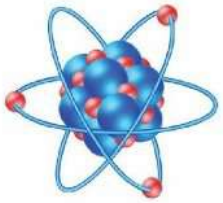
2 CHAPTER

ATOMIC STRUCTURE



After studying this chapter, students will be able to:

- Explain the structure of the atom as a central nucleus containing neutrons and protons surrounded by electrons in shells
- State that, orbits (shells) are energy levels of electrons and a larger shell implies higher ' energy and greater average distance from nucleus
- State that electrons are quantum particles with probabilistic paths whose exact paths and locations cannot be mapped (with reference to the uncertainty principle} Explain that a nucleus is made up of protons and neutrons held together by strong nuclear force
- Explain that an atomic model is an aid to understand the structure of an atom. State the relative charge and relative masses of a subatomic particles (an electron, proton and neutron)
- Interpret the relationship between a subatomic particle, their mass and charge. Illustrate the path that positively and negatively charged particles would take under the influence of a uniform Electric Field.
- Define proton number/atomic number as the number of protons in the nucleus of an atom.
- Explain that the proton number is unique to each element and used to arrange elements in periodic table
- State that radioactivity can change the proton number and alter an atom[r]s identity Define nucleon number / atomic mass as sum of number of protons and neutrons in the nucleus of an atom.
- Define isotopes as different atoms of the same element that have same number of protons but different neutrons
- State that isotopes can affect molecular mass but not chemical properties of an atom
- Determine the number of protons and neutrons of different isotopes
- Define relative atomic mass as the average mass of isotopes of an element compared to 1/1 2th of mass of an atom of Carbon-12
- State that isotopes can exhibit radioactivity
- Discuss the importance of isotopes using carbon dating and medical imaging as examples. Describe the of positive (cation) and negative (anion) ions from atoms.
- Interpret and use the symbols for atoms and ions
- Calculate relative atomic mass' bf an element from relative masses and abundance of isotopes,
- Calculate the relative mass of an isotope given relative atomic mass and abundance of all stable isotopes.

INTRODUCTION

SHORT QUESTIONS

Q.1 What are the physical states of matter/elements? (MTN 2017)*(K.B)*

Ans:

PHYSICAL STATES OF MATTER

Elements are very different from one another. All these elements are however made up of atoms. There are three physical states of matter.

Solid: A large number of elements exist as solids

Liquid: Very few are present as liquids

Gas: The rest exist as gases

Q.2 What do you know about difference between properties of elements? (MTN 2017)(K.B)

Ans:

DIFFERENCE BETWEEN ELEMENTS

Have you ever thought why these elements are so different from one another?

- Iron looks very different from gold which, in turn, is very different from aluminium or zinc.
- Iron is a heavy metal while aluminium and zinc are light metals.
- Metals are mostly lustrous while non-metals like sulphur and carbon appear dull.

Cause of difference in properties of elements

The difference in the properties of elements is due to the difference in the properties of their constituent atoms.

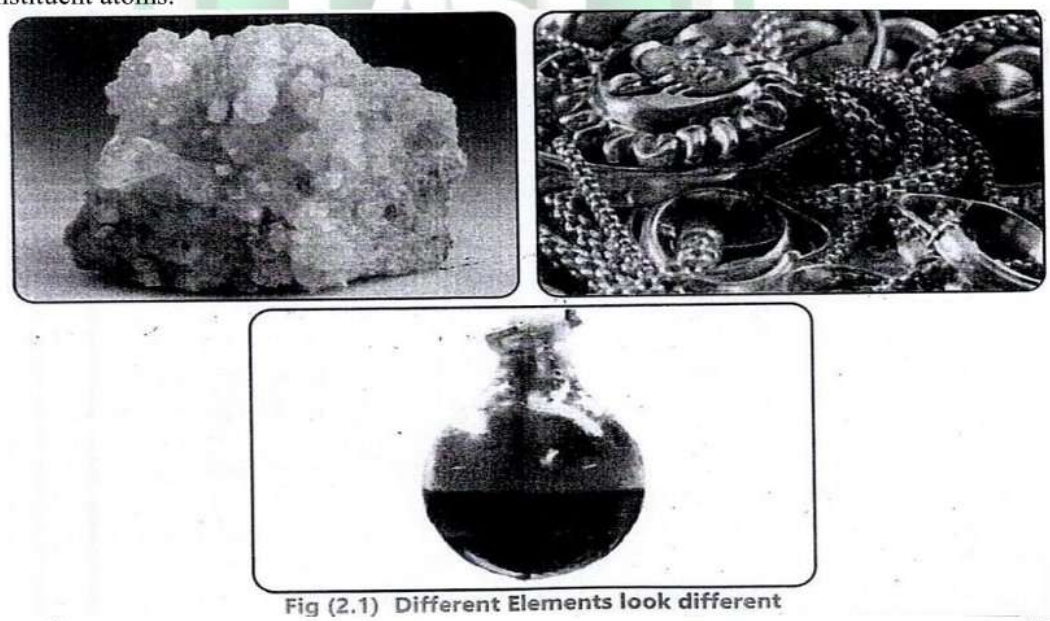


Fig (2.1) Different Elements look different

Q.3 Define matter. (K.B)

Ans:

MATTER

Definition:

*"Anything that has **mass** and **occupies space** is called matter".*

Examples:

Air, water, table, book etc.

MULTIPLE CHOICE QUESTIONS

1. The liquid state has intermolecular forces: (K.B)

(A) Strong (B) Weak

(C) Very weak (D) None of these

2. Solids are _____ and denser than liquid and gases. (K.B)

(A) Rigid (B) Soft
(C) Hard (D) Both A and C

3. Simplest state of matter is: (LHR 2014)(K.B)

(A) Solid state (B) Liquid state
(C) Gaseous state (D) Plasma state

2.1 STRUCTURE OF ATOM

LONG QUESTIONS

Q.1 What are contributions of John Dalton, William Crooks and Goldstein towards the structure of atom? (MTN 2017)(K.B)

Ans: **CONTRIBUTIONS OF JOHN DALTON, WILLIAM CROOKS AND GOLDSTEIN**

A. John Dalton atomic theory

In 1803, an English chemist, John Dalton, in his famous theory Dalton s atomic theory', proposed atoms to be indivisible. In other words, according to him, it was not possible to divide atoms to smaller particles.

B. Gas discharge tube experiment (William Crooks, John Dalton)

In the last decade of nineteenth century, a group of scientists were trying to pass electricity through gases at reduced pressure. During the course of these experiments known as **'Discharge Tube Experiments'**,

Subatomic particle

They discovered that atoms are no longer the smallest particles of matter; rather there exist particles that are even smaller than atoms. In other words, atoms are composed of:

i. **Electrons:** Negatively charged particles
ii. **Protons:** Positively charged particles
iii. **Neutron:** Neutral particles

Mass of Proton, Electron and Neutron

It was also discovered that a proton is 1836 times heavier than an electron. The mass of neutron is equal to the mass of proton.

Evidence of electron and proton

In a discharge tube, the presence of the negatively charged particles (electron) was ascertained because of their deflection towards the positive plate in an electric field. Similarly, the presence of positively charged particles (proton) was confirmed due to their deflection towards the negative plate.

Q.2 How the cathode rays were discovered? What are their major properties? (U.B+K.B)

OR

How are cathode rays produced? What are their five major characteristic?

(SGD 2016, 17, BWP 2016, MTN 2016)

OR

How was it proved that electrons are fundamental particles of an atom?

Ans: **DISCOVERY OF ELECTRONS**

William Crooks performed a series of experiments and discovered cathode rays, which led to the discovery of electron.

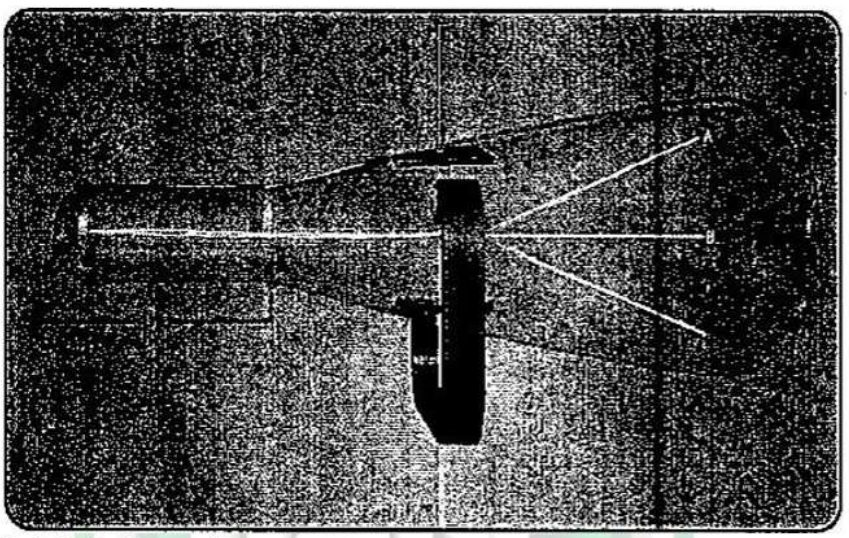
Discharge Tube Experiment

Construction of Apparatus

A discharge tube is a hard glass tube provided with two metallic electrodes and a vacuum pump to evacuate the gas present in it Fig (2.2).

Working

When a very high voltage is applied to an evacuated glass tube the glass surface behind the positive electrode started to glow, due to the rays emitted from the cathode. These rays were named as cathode rays.



Why called Cathode rays?

These rays are called cathode rays because they are produced from the surface of the cathode.

PROPERTIES OF CATHODE RAYS

In 1897, British physicist Joseph John Thomson studied the properties of cathode rays by passing Experiment them through the oppositely charged electric plates.

i. **Deflection in Electric Field**

It was observed that cathode rays bent towards the positively charged plate showing that they carry negative charge.

ii. **Deflection in Magnetic Field**

Thomson also installed two magnets on either side of the discharge tube and noticed that cathode rays were also diverted by the magnetic field.

iii. **Charge to mass (e/m) ratio**

Thomson used the findings of his experiments to calculate the mass to charge ratio of cathode rays which finally proved that cathode rays are in fact, negatively charged material particles. These particles were later named as subatomic particles of all elements.

Q.3 How the protons were discovered? Write down their properties. (U.B+K.B)
(MTN 2017, DGK 2017, RWP 2016, BWP 2017, SWL 2016, 17)

OR

Draw a labeled diagram to show the presence of protons in the discharge tube and explain how canal rays were produced.

Ans: **DISCOVERY OF PROTONS**

(A) GOLDSTEIN'S EXPERIMENT

Introduction

The presence of positively charged particles in an atom had been first observed by E. Goldstein in 1886.

Basis of Discovery of positively charged particles

It was based on the concept that atoms are electrically neutral having same number of positive and negative charges.

Gas Discharge Tube Experiments

He performed a series of experiments with a gas-discharge tube having a perforated cathode.

A new type of rays were produced from the anode which moved towards the cathode. He called these new rays as canal rays or anode rays.

PROPERTIES OF ANODE RAYS

i. **Dependence of Positive rays**

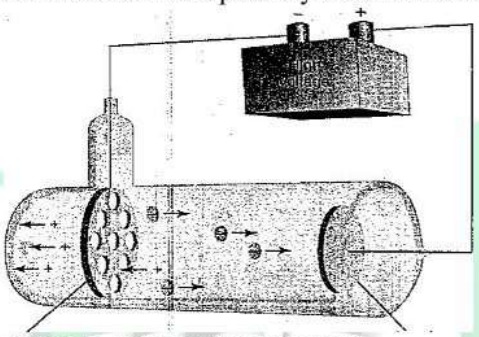
The properties of these rays seemed to vary depending on the gas used in the discharge tube. In fact what he discovered was gas ions and this also included hydrogen ion. Goldstein at that time knew nothing about its significance.

ii. **Origin of Anode Rays**

iii. A very high electrical potential of thousands of volts was applied in the discharge tube which ionized the residual gas atoms present in the tube. The positive ions thus produced travelled towards the cathode as anode or canal rays.

(B) RUTHERFORD'S EXPERIMENTS

In 1917, Rutherford performed experiments which proved that the hydrogen nucleus is present in other nuclei. Rutherford thought that a hydrogen nucleus or a proton must be the fundamental building block of all nuclei and also possibly a new fundamental particle as well.



ORIGIN OF CATHODE AND ANODE RAYS

Why cathode rays are so named?

Cathode rays are so named because they are emitted by the cathode in a discharge tube.

Origin of anode or canal rays

A very high electrical potential of thousands of volts was applied in the discharge tube which ionized the residual gas atoms present in the tube. The positive ions thus produced travelled towards the cathode as anode or canal rays.

Origin of cathode rays

When anode or canal rays collided with the cathode they knocked electrons out of its surface. This stream of electrons was called cathode rays.

Q.4 How were neutrons discovered? Write down their properties. (U.B+K.B)

(FSD 2017, RWP 2017 G-I MTN 2016)

Ans:

DISCOVERY OF NEUTRONS

Introduction

In 1933, another particle neutron was also discovered.

Experiment:

Chadwick discovered neutron, when he bombarded **alpha particles** on a **beryllium target**. He observed that **highly penetrating** radiations were produced. These radiations were called **neutron**.

$$^{9}_{4}Be + {}^{4}_{2}He \longrightarrow {}^{12}_{6}C + {}^{1}_{0}n$$

PROPERTIES OF NEUTRON

The properties of neutrons are as follows:

i. **Charge:** Neutrons **carry no charge** i.e. they are neutral.

ii. **Penetration:** They are **highly penetrating**.

iii. **Mass:** The mass of a neutron is almost the same as that of a proton.

LAST
HOPE
STUDY

Why electron, proton and neutron were given the name fundamental particles?

These three particles i.e. electron, proton and neutron were given the name fundamental particles and are shown to be present in all atoms irrespective of the fact that these atoms behave very different from one another.

Number of Particles in different atoms

It was, however, also shown that the number of these particles is different in different atoms.

Q.5 How Rutherford discovered that atom has a nucleus located at the centre of the atom? (U.B+K.B)

OR

Explain the Rutherford's atomic structure experiment and atomic model in detail.

OR

Write down postulates of Rutherford's Atomic Model.

Ans:

RUTHERFORD'S EXPERIMENT

(Gold Foil Experiment / α-Scattering Experiment / Atomic Structure Experiment).

ARRANGEMENT OF SUBATOMIC PARTICLES IN AN ATOM

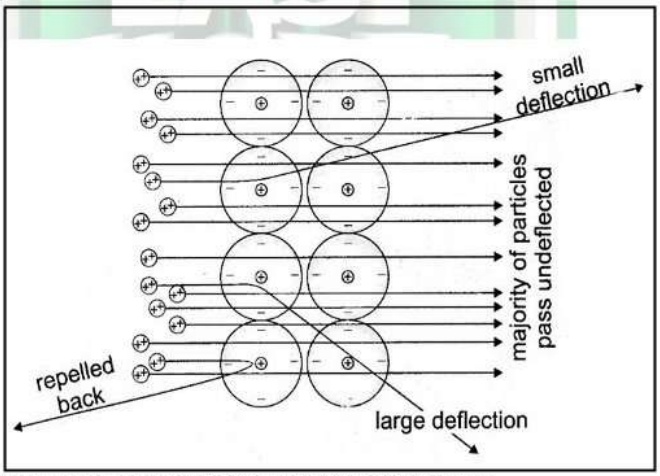
After the discovery of these particles, a very important question arose as to how these particles are arranged in a tiny place called atom. In other words, what is the structure of an atom?

Rutherford's Experiment

Lord Rutherford, in 1911, provided answer to this question, **'how the subatomic particles are arranged in a tiny place called atom".**

Experiment

He carried out a remarkable experiment in which he hit a stream of special type of particles to a very thin gold foil.



POSTULATES OF RUTHERFORD'S ATOMIC MODEL

A. Portions of Atom

From this experiment he concluded that an atom has two portions.

i. A tiny central portion which he called as **nucleus.**

ii. a relatively large area surrounding this, which he called **extra nuclear portion.**

B. Mass of Atom

It was also discovered that almost all the mass of an atom is concentrated in the nucleus, because both the heavy particles i.e. protons and neutrons are found to be present here.

C. Arrangement of Particles

(a) Location of Protons and Neutrons

In the nucleus these two particles are held together by a strong nuclear force.

(b) **Location of Electrons**

Electrons are, however, revolving around the nucleus.

Q.6 How did Bohr described the revolving of electron and probability of finding the electrons in an atom? ***(U.B+K.B)***

Ans:

BOHR'S ATOMIC THEORY

Introduction:

Neils Bohr presented another model of atom in **1913**, keeping in view the defects in Rutherford's Atomic Model.

Basis of Bohr's Atomic Theory:

The **Quantum Theory of Max Planck** was used as foundation for this model.

Location of Electrons

Electrons are, however, revolving around the nucleus in fixed circular paths called orbits or shells.

Since electron present in each shell has a fixed energy, these shells are also named as energy levels.

Probability of Finding Electrons

There is a certain probability of finding the electrons at a certain probable distance from the nucleus.

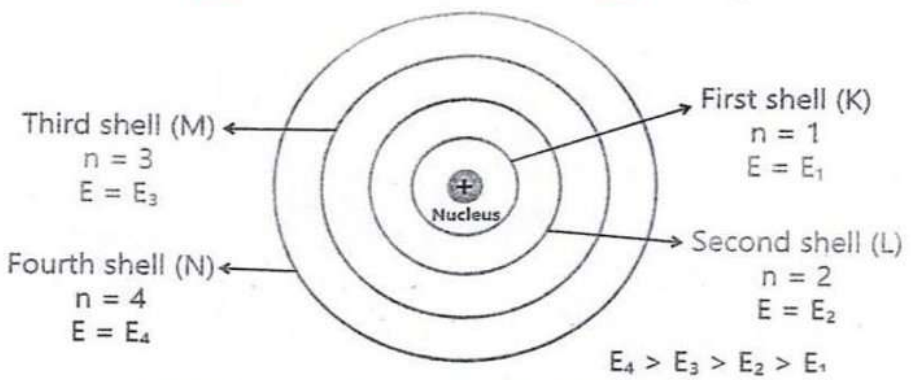


Table (2.1) Charges and Masses of Sub-Atomic Particles

PARTICLE	CHARGE	MASS
Electron	-1.6022×10^{-19} C	9.109×10^{-31} Kg
Proton	$+1.6022 \times 10^{-19}$C	1.673×10^{-27} Kg
Neutron	0.0	1.675×10^{-27} Kg

Q.7 Write a detailed note on shells and subshells. **(U.B+K.B)**

Ans:

SHELL/ORBIT/ENERGY LEVEL

*"The **circular path of an electron around the nucleus** is called shell or principal energy level".*

Examples:

K, L, M, N etc.

Explanation

First Shell

The shell which is nearest to the nucleus is called first shell or K shell and the electron present in it has a fixed value of energy.

Second Shell

The second shell will also be at a definite distance from the nucleus which will, of course, be greater than the first shell and electron present in it will also possess greater value of energy.

Third or Higher Shells

Similarly, electron may also be present in the third or higher shells.

INTERESTING INFORMATION

Although the nucleus is one hundred thousandth (1/100000) of the size of the atom, it contains more than 99.9% of th

n value	Shell	Max. number of electrons in a shell	Subshell
1	K	2	Only s
2	L	8	s, p
3	M	18	s, p ,d
4	N	32	s, p, d, f

Maximum electrons in a shell

In order to find out the number of electrons which can be accommodated in these extra nuclear shells, the scientists have devised formula called ($2n^2$) formula.

Where n can have values 1, 2, 3 and so on and they represent the number of shells.

Shells have also been named as K, L, M, N .... and so on.

K shell: $2n^2 = 2(1)^2 = 2\times1 = \mathbf{2}$

L shell: $2n^2 = 2(2)^2 = 2\times4 = \mathbf{8}$

M shell: $2n^2 = 2(3)^2 = 2\times9 = \mathbf{18}$

N shell: $2n^2 = 2(4)^2 = 2\times16 = \mathbf{32}$

- When the value of n is one (n=1), it means first or K shell and the maximum number of electrons which can be present in this shell is ($2 \times 1^2 = 2$). K shell can, however, have less than two electrons or it may not have any electron.
- Similarly, when the value of n is two (n = 2), it means second or L shell and the maximum number of electrons it can accommodate is ($2 \times 2^2 = 8$).
- Similarly, when the value of n is three (n = 3) or M shell, it can accommodate 18 electrons at the most.

This process will go on until the electrons present in an atom are finished.

Calculation of Maximum number of electrons in a shell

The **number of electron that a shell** can accommodate is given **by $2n^2$**, where **'n'** is the **shell number**.

SUB SHELL OR SUB ENERGY LEVELS

Each shell is further sub-divided into sub-shells or orbitals.

OR

*"**Each shell consists of one or more subshells or orbitals**. Each subshell is designated by a **small alphabet** called letter **s, p, d, f** etc."*

Number of Sub-Shells Present In a Shell

The number of sub-shells present in a shell is equal the value of n for that shell.

- For the first shell, (n = 1) it will, therefore, have only one sub-shell which is called s sub-shell.
- For (n = 2) there will be two sub-shells s and p. The second shell will, therefore, have two sets of sub-shells.
- The third shell (n = 3) has three sub-shells s, p and d.
- The fourth shell consists of four sub-shells s, p, d and f

n value	Shell	Subshell
1	K	Only s
2	L	s, p
3	M	s, p ,d
4	N	s, p, d, f

Maximum number of electrons Accommodated in a subshell

The maximum number of electrons which can be accommodate in subshells s, p, d and f are 2, 6, 10 and 14 respectively.

- In the first shell there are 2 electrons which shell go to (s) sub-shell.
- In the second shell, 8 electrons will be further sub-divided, s-subshell will have 2 electrons and 6 electrons will be accommodated in p sub-shell

Sub shell	Max. number of electrons in a subshell

Calculation of number of Accommodated

s	2
p	6
d	10
f	14

INTERESTING INFORMATION

SIZE OF AN ATOM

The size of an atom is so small that it is not possible to see with naked eyes. However, a transition electron microscope can be used to see atoms.

INTERESTING INFORMATION

LARGEST ATOM

The largest atom cesium is approximately nine time bigger than the smallest atom helium.

SHORT QUESTIONS

Q.1 What is Dalton's atomic theory? **(K.B)**

Ans: Answer given on page # 34

Q.2 How neutron was discovered? **(K.B)**

Ans: Answer given on page # 36

Q.3 Write down the properties of neutron. **(K.B)**

Ans: Answer given on page # 36

Q.4 Do you know any element having no neutrons in its atoms? **(K.B)**

ATOMS HAVING NO NEUTRONS

Ans: Yes the isotope of hydrogen (Protium, ${}^{1}_{0}H$) has no neutron. It has one proton in its nucleus and one electron revolving around it.

Q.5 Who discovered electron, proton and neutron? **(BWP 2016,17) (K.B)**

Ans:

DISCOVERY

Electron:

In 1897, J.J. Thomson discovered the negatively charged particles called **electrons**.

Proton:

In 1886, Goldstein discovered positively charged particles called **proton**.

Neutron:

In 1932, James Chadwick discovered the neutral particles called **neutrons**.

Q.6 How does electron differ from a neutron? **(U.B)**

Ans:

DIFFERENTIATION

The differences between electron and neutron are as follows:

Electron	Neutron
Charge	
• Electron is the negatively charged particle.	• Neutron is the neutral particle.
Location	
• Electron revolves around the nucleus.	• Neutron is present in the nucleus.
Mass	
• Mass of electron is 9.109×10^{-31} Kg	• Mass of neutron is 1.675×10^{-27} Kg.

Q.7 Give two observations of Rutherford's atomic model. **(SGD 2017 G-I) (U.B)**

Ans: Answer given on page # 37

Q.8 What is the maximum number of electrons that can be accommodated in p-subshell? **(K.B)**

Ans:

NUMBER OF ELECTRON IN P-SUBSHELL

The maximum number of electron that can be accommodated in a p subshell is 6.

Q.9 How many subshells are there in second shell? (K.B)

Ans: **NUMBER OF SUBSHELL**

There are two subshells in second shell i.e. s and p subshells.

Q.10 Why does an electron first fill 2p orbital and then 3s orbital? (U.B)

Ans: **FILLING OF ELECTRON**

Electrons are filled around the nucleus in various shells and subshells according to increasing energy. The energy of 2p orbital is less than that of 3s orbital. Therefore 2p orbital is filled first than that of 3s orbital.

Q.11 If both K and L shells of an atom are completely filled; what is the total number of electrons present in them? (U.B)

Ans: **NUMBER OF ELECTRON IN K AND L SHELL**

The maximum capacity of shells to accommodate electrons is:
K shell = 2 electrons
L shell = 8 electrons
Therefore, the total number of electrons present in K and L shell = 2+8=10 electrons.

Q.12 How many electrons can be accommodated in M shell? (U.B+K.B)

Ans: **ACCOMMODATION OF ELECTRON IN M-SHELL**

The maximum number of electrons that can be accommodated in M shell is 18. It can be calculated by the formula $2n^2$. As for M shell value 'n' is 3.
Therefore,
Maximum number of electrons in M shell = $(2n^2) = 2\times3^2 = 2\times9 = 18$ electrons.

Q.13 How many electrons will be in M shell of an atom having atomic number 15? (U.B)

Ans: **ELECTRON IN M SHELL**

Atomic number = Number of electrons =15
Electronic configuration = $1s^2, 2s^2, 2p^6, 3s^2, 3p^3$.
Therefore, M shell contains electrons = 2+3=5 electrons.

Q.14 What is maximum capacity of a shell? (LHR 2017 G-I)(U.B)

Ans: **MAXIMUM CAPACITY OF A SHELL**

The maximum capacity of a shell to accommodate electrons can be calculated by the formula = $2n^2$
Where
n = 1, 2, 3, 4 ……. and it represents the shell
Maximum capacity of K shell = 2 electrons
Maximum capacity of L shell = 8 electrons
Maximum capacity of M shell = 18 electrons
Maximum capacity of N shell = 32 electrons

MULTIPLE CHOICE QUESTIONS

1. Matter is composed of tiny indivisible particles called: (K.B)

(A) Element (B) Atom (C) Compound (D) Substance

2. Which are three fundamental particles of an atom? (K.B)

(A) Ion, radical, free radical (B) Electron, neutron, ion
(C) Electron, proton, neutron (D) Canal rays, X-rays, γ-rays

3. Atoms of the same element are: (K.B)

(A) Different (B) Alike (C) Comparable (D) Active

4. Gas discharge tube experiment was performed by: (K.B)

(A) J.J Thomson (B) Rutherford (C) Dalton (D) William Crook

5. **The pressure inside the discharge tube for the discovery of electron was kept:** **(K.B)**
(A) Very high (B) Very low (C) Moderate (D) None of these

6. **Who discovered the proton?** **(GRW 2014) (K.B)**
(A) Goldstein (B) J.J. Thomson (C) Neil Bohr (D) Rutherford

7. **The mass of proton is _____ times more than that of an electron.** **(K.B)**
(A) 1830 (B) 1840 (C) 2 (D) 3

8. **Canal rays were discovered by:** **(K.B)**
(A) Goldstein (B) Thomson (C) Dalton (D) William Crooks

9. **Canal rays travel in straight lines in a direction _____ to cathode rays.** **(U.B)**
(A) Opposite (B) Same (C) Parallel (D) None of these

10. **Canal rays carry:** **(K.B)**
(A) Positive charge (B) Negative charge (C) Neutral (D) None of these

11. **Which one of the following is produced by the bombardment of the helium particles on beryllium?** **(K.B)**
(A) Alpha particles (B) Beta particles (C) Neutron (D) Gamma rays

12. **The highly penetrating rays are:** **(U.B+K.B)**
(A) Alpha particles (B) Beta particles (C) Neutron (D) Both A and B

13. **Neutron was discovered by:** **(RWP 2017 G-II) (K.B)**
(A) Rutherford (B) Chadwick (C) Bohr (D) William Crooks

14. **Which one of the following is most penetrating?** **(Ex-2) (U.B+K.B)**
(A) Proton (B) Neutron (C) Electron (D) Alpha particles

15. **Canal rays are actually:** **(K.B)**
(A) Electrons (B) Protons (C) Neutrons (D) X-rays

16. **The concept of orbit was used by:** **(K.B)**
(A) J.J Thomson (B) Rutherford (C) Bohr (D) Planck

17. **In $\propto$-scattering experiment Rutherford used the foil made up of:** **(K.B)**
(A) Silver (B) Tin (C) Platinum (D) Gold

18. **Alpha particles are emitted by radioactive element:** **(K.B)**
(A) Carbon (B) Polonium (C) Neon (D) Vanadium

19. **According to quantum theory which type of spectrum is shown:** **(K.B)**
(A) Continuous spectrum (B) Line spectrum
(C) Emission spectrum (D) Absorption spectrum

20. **Rutherford used a thin layer of gold of thickness:** **(K.B)**
(A) 0.00004 cm (B) 0.004 cm (C) 0.0004 cm (D) 0.04 cm

21. **The p-subshell has:** **(Ex-7)(K.B)**
(A) One orbital (B) Two orbitals (C) Three orbitals (D) Four orbitals

22. **M-shell can accommodate:** **(GRW 2016 G-II, LHR 2014)(K.B)**
(A) 2 electrons (B) 8 electrons (C) 18 electrons (D) 32 electrons

23. **Which one of the following shell consist of three subshells?** **(Ex-4)(K.B)**
(A) O shell (B) N shell (C) L shell (D) M shell

24. **How many electrons can K-shell accommodate?** **(GRW 2014)(K.B)**
(A) 3 (B) 2 (C) 4 (D) 5

25. **Maximum number of electrons accommodated by N-shell is:** **(K.B)**
(A) 8 (B) 2 (C) 18 (D) 32

26. **Energy level is represented by:** **(K.B)**
(A) m (B) n (C) M (D) N

27. **A shell closest to the nucleus is of:** **(U.B)**

(A) Same energy (B) Minimum energy (C) High energy (D) Maximum energy

2.2 ATOMIC NUMBER AND MASS NUMBER

LONG QUESTIONS

Q.1 Write a detailed note on atomic number and mass number. (U.B+K.B)

Ans:

ATOMIC NUMBER AND MASS NUMBER

Fundamental particles of matter/atom

Electrons, protons and neutrons are called the fundamental particles of all types of matter. In other words, the atoms of all the elements present in this world contain same electrons, protons and neutrons.

Why atom of an element are differ from atoms of other elements?

However, an atom of one element differs from an atom of another element because it contains different number of the fundamental particles.

ATOMIC NUMBER

The number of protons present in the atoms of an element is always fixed and it is called the atomic number of that element.

Representation

Atomic number of an element is represented by Z.

No. of protons and electrons

Since an atom, as a whole, is electrically neutral, the number of electrons present in an atom will be the same as the number of protons.

Atomic number as identification number

Atomic number of an element is unique to that element and the element is identified by this number.

Significance of Atomic Number

In a periodic table of elements, the elements are arranged according to ascending order of their atomic numbers.

MASS NUMBER (NUCLEON NUMBER)

The total number of protons and neutrons present in an atom almost accounts for the total mass of that atom and hence it is called its nucleon number or mass number.

Representation

It is represented by A.

Why mass of electron is not included in mass number?

The mass of electron being very small is not included in the mass number.

Mass number as identification number

Just like atomic number, the atom of an element may also be identified from its mass number.

Example

The number of protons present in an oxygen atom is 8, so its atomic number is 8 while the total number of protons and neutrons present in it is 16, so its mass number is 16.

Symbolic representation

Information about the atomic number and the mass number is often included with the symbol of any element.

- The atomic number is written as a left subscript
- The mass number as a left superscript.

Oxygen

So, oxygen atom would be symbolized $^{16}_{8}O$

Carbon

Similarly, carbon atom symbolized as $^{12}_{6}C$ will have 6 protons and 6 neutrons.

Calculation of number of neutrons

The number of neutrons N present in an atom can be calculated if its atomic number Z and mass number (A) are known.

$N = A - Z$

Chlorine

Thus, the number of neutrons in chlorine atom, symbolized as $^{35}_{17}Cl$, can be calculated as

Number of neutrons = 35- 17 = 18

INTERESTING INFORMATION

COPERNICIUM (Cn)

Copernicium (Cn) is a synthetic element and it was discovered in 1966. This metal turns into gas at room temperature.

SAMPLE EXAMPLE 1

Calculate the number of neutrons, protons and electrons in barium Ba.

Solution **NUMERICAL**

Given data

Each barium atom will have 56 protons and 56 electrons.

Formula

The number of neutrons in boron will be calculated as follows:

N = A-Z

N = 137-56 =81

So each $^{137}_{56}Ba$ atom will have 81 neutrons, 56 protons and 56 electrons.

Number of neutron = ?

SOLVED EXAMPLE 2

Calculate the number of neutrons/ protons and electron in an atom of uranium

SOLUTION

Given data

Each uranium atom will have 92 protons and 92 electrons.

Number of neutron = ?

Formula

The number of neutrons will be calculated as follows:

N = A-Z

N = 238-92 = 146

So each $^{238}_{92}U$ atom will have 146 neutrons, 92 protons and 92 electrons.

EXERCISE

Calculate the number of neutrons; protons and electrons in the following.

$^{195}_{78}Pt$, $^{55}_{25}Mn$, $^{127}_{53}I$

Ans: **NUMBER OF NEUTRONS; PROTONS AND ELECTRONS**

Element	Number of Electron	Number of Proton	Number of Neutron
$^{195}_{78}Pt$	78	78	195 – 78 = 117
$^{55}_{25}Mn$	25	25	55 – 25 = 30
$^{127}_{53}I$	53	53	127 – 53 = 74

SHORT QUESTIONS

Q.1 How many neutrons are present in C–12 and C–13? **(BWP 2017 G-II)(U.B)**

Ans:

NUMBER OF NEUTRONS IN C–12

Number of neutrons = Mass number – atomic number
= 12 – 6 = 6 neutrons

NUMBER OF NEUTRONS IN C–13

Number of neutrons = Mass number – atomic number
= 13 – 6 = 7 neutrons

Q.2 How we can define atomic number? (BWP 2017 G-II)(U.B)

Ans:

ATOMIC NUMBER

The number of protons present in the atoms of an element is always fixed and it is called the atomic number of that element.

Representation

Atomic number of an element is represented by Z.

MULTIPLE CHOICE QUESTIONS

1. Atomic number is represented by: (FSD 2017 G-II)(K.B)

(A) Z (B) Y (C) A (D) a

2. Element with least atomic number is: (K.B)

(A) Carbon (B) Sodium (C) Hydrogen (D) Helium

3. Mass number is represented by: (FSD 2017 G-II)(K.B)

(A) Z (B) Y (C) A (D) a

2.3 ISOTOPES AND THEIR MASSES

LONG QUESTIONS

Q.1 Define isotopes. Explain the isotopes of hydrogen. (K.B)

OR

What is an isotope? Describe the isotopes of hydrogen with diagram.

Ans:

ISOTOPES

Definition

Atoms of the same element having different number of neutrons in their nuclei are called isotopes.

OR

"The **atoms of an element** that have **same atomic number** but **different mass number** are called isotopes".

All the atoms of an element must necessarily have the same atomic number, but their mass number may vary depending upon the number of neutrons present in the nucleus.

Examples

Hydrogen has **three** isotopes i.e., **protium** $\left({}_{1}^{1}\mathrm{H}\right)$, **deuterium** $\left({}_{1}^{2}\mathrm{H}\right)$ **and tritium** $\left({}_{1}^{3}\mathrm{H}\right)$.

Properties

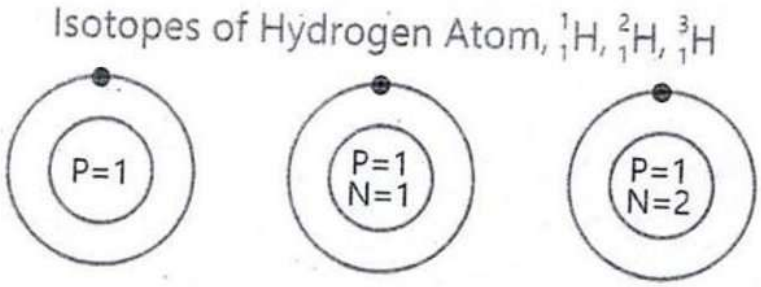
The properties of isotopes are as follows:

- They have same electronic configuration and number of protons
- They differ in the number of neutrons.
- Isotopes have **similar chemical properties** because they depend upon electronic configuration.
- They have **different physical properties** because these properties depend upon atomic masses.
- Most of the elements show isotopes.
- All isotopes of an element occupy **same position in the periodic table**.

1. ISOTOPES OF HYDROGEN

Similarly, hydrogen exists in three isotopes Hydrogen, Deuterium and Tritium represented by:

- Protium $\left({}_{1}^{1}\text{H or P}\right)$
- Deuterium $\left({}_{1}^{2}\text{H or D}\right)$
- Tritium $\left({}_{1}^{3}\text{H or T}\right)$



Atom with no neutron

${}_{1}^{1}\text{H}$ is the only atom which does not have neutron.

Chemical properties

Since the chemical properties of the elements are determined by the number of electrons, all three isotopes will show almost the same chemical behavior.

Physical properties

Although their physical properties may be different. ${}^{2}{}_{1}\text{H}$ has twice the mass of ${}^{1}{}_{1}\text{H}$ while the mass of ${}^{3}{}_{1}\text{H}$ is thrice as the mass of ${}^{1}{}_{1}\text{H}$.

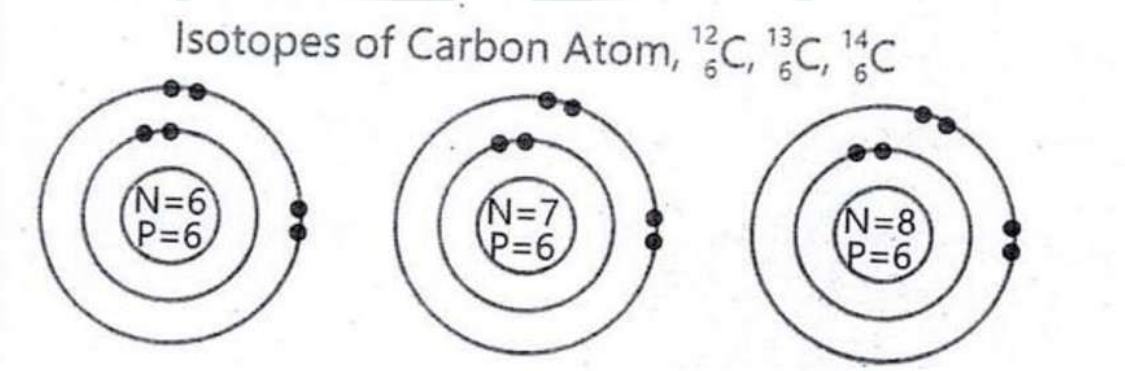
2. ISOTOPES OF CARBON

Element carbon has three isotopes as its atoms have six, seven and eight neutrons in their nuclei. These isotopes are represented as:

${}_{6}^{12}\text{C}$ ${}_{6}^{13}\text{C}$ ${}_{6}^{14}\text{C}$

Mass of isotopes of carbon:

Similarly, the masses of three different isotopes of carbon are different.



Q.2 (A) What are radioactive isotopes?
(B) Give the uses or applications of isotopes in the field of radiotherapy, medicines, archaeology and power generation. (GRW 2016 G-I) (A.B)

OR

Give the application of isotopes in the field of radiotherapy and medicines. (A.B)

Ans: (A) RADIOACTIVE ISOTOPES

Radioactivity

The emission of radioactive rays from a radioactive substance is called radioactivity.

OR

The isotopes of the same element do not have the same physical properties. Several isotopes of the same chemical elements exist whose nuclei are unstable. They emit excess energy in the form of radiation. This radiation is called radioactivity.

Radioactive isotopes

The isotope which emits energy in the form of radiations is called radioactive isotope.

Radioactive isotopes of an element

Every element has one or more radioactive isotope. Tritium $^{3}_{1}H$ is a radioactive isotope and the other two are stable and do not emit any radiation.

Radioactive decay

When a radioactive element emits radiation, it is transformed into another chemical element. This process is called radioactive decay.

This new element may be stable or may be radioactive so that it also emits radiation.

$$^{238}_{92}U \longrightarrow {}^{234}_{90}Th + \text{energy}$$

(Uranium) (Thorium)

$^{234}_{90}$Thorium is unstable and further disintegrates to give $^{231}_{91}Pa$ (Protactinium)

$$^{234}_{90}Th \longrightarrow {}^{231}_{91}Pa$$

(Thorium) (Protactinium)

$$^{210}_{83}Bi \longrightarrow {}^{206}_{81}TI + \text{energy}$$

(Bismuth) (Thallium)

INTERESTING INFORMATION

Every year , our body replaces about 98% of its atoms.

(B) APPLICATION OF RADIOACTIVE ISOTOPES

(i) Medical Imaging

Radioactive isotopes are useful in medical imaging. Doctors use them to diagnose the disease by injecting the patient with a small amount of radioactive fluid.

Example

Technetium - 99m is used for diagnostic imaging across human organs like brain, lungs, etc. Doctors use a special camera to watch how the radioactive fluid moves.

EXERCISE

1. Why does a radioactive isotope emit radiation?

Ans: **EMISSION OF RADIATION**

A radioactive isotope emits radiation because its nucleus is unstable, and by releasing radiation in the form of particles or energy, it tends to become more stable. This process is called radioactive decay.

2. Give an example of a radioactive isotope which disintegrates to give a stable atom.

Ans: **RADIOACTIVE ISOTOPE TO GIVE A STABLE ATOM**

Carbon-14 emits a beta particle and becomes the stable isotope Carbon-12.

INTERESTING INFORMATION

PROPERTIES OF GALLIUM

Gallium has many interesting properties. Its melting point is below body temperature so it is liquid at room temperature so it is liquid at room temperature. It has water like viscosity. It

does not evaporate.

(ii) Radioactive dating

Definition

Radiocarbon dating is a method for finding out the age of an historical object containing organic material with the help of radioactive isotope of carbon C.

Method

The method involves measuring the proportion of ^{14}C in a sample from a dead plant or animal like a piece of wood or a bone which provides information that can be used to calculate when an animal or plant died. The older the sample is, the less ^{14}C is to be detected.

(iii) To test strength of metals and concrete

Radioactive isotopes are used to test the strength of metals and concrete mixture.

(iv) To generate cheap nuclear power

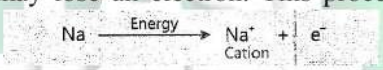
They are used to generate cheap nuclear power and to find oil fields. In medicine they are used to diagnose and treat many medical conditions and diseases, including cancer and thyroid disorders.

(v) IONIZATION OF ATOM BY RADIOACTIVE SOURCE

Radiation emitted from a radioactive source causes atoms to ionize.

Example

Radiation emitted by a radioactive element radium -226 can remove electron or electrons from the atom. However, this ionizing radiation should have enough energy to remove the tightly bound electron from the orbit of an atom. Electron can be lost because an ionizing radiation collides with the atom and forces the electron away from the atom. If an atom of sodium is hit by an ionizing radiation, it may lose an electron. This process coverts the atom into a positively charged ion (cation).



INTERESTING INFORMATION

ARTIFICIAL ISOTOPES

The same elements occur everywhere in the universe All artificial isotopes are unstable and therefore radioactive.

Q.3 Explain the relative atomic mass and atomic mass unit. (DGK 2016)(U.B+K.B)

Ans:

RELATIVE ATOMIC MASS (A_r)

The relative atomic mass of an element is thus defined as the mass of an atom of that element relative to the mass of light isotope of carbon taken as 12.

OR

"The **average mass of atoms of an element as compared to 1/12th (one-twelfth) the mass of one atom of carbon-12 isotope** is called relative atomic mass".

Exa mples

- A_r of carbon = 12 amu
- A_r of oxygen = 16 amu

Historical background

(a) Early period

Ever since the existence of atom was recognized, the chemists were trying to find out a method which would allow them to compare the masses of different atoms. It was necessary because without knowing the relative masses of atoms, we would not know in which ratio of masses we mix the reactants to carry out a chemical reaction.

(b) 1961

In 1961 the chemists adopted a new scale for the measurement of the relative masses of atoms.

Determination of masses of an element

The mass of one atom of carbon on this scale is exactly 12 and the masses of the other atoms are measured relative to this unit.

Unit of relative atomic mass (Ar)

The relative atomic masses of elements are expressed in atomic mass unit (a.m.u).

Unit mass (a.m.u)/Atomic Mass Unit:

Definition

"One atomic mass unit is **1/12th the mass of one atom of carbon 12.** The atomic mass unit is abbreviated as **amu**."

$$1 \text{ amu} = \frac{1}{12} \times \text{mass of carbon-12 atom}$$

$$1\text{a.m.u} = 1.67377 \times 10^{-27} \text{ kg}$$

Example

The mass of one atom of hydrogen-I is 1.007 a.m.u, the mass one atom of sulphur-32 is 31.972 a.m.u.

EXERCISE

Q. How would you compare the masses of the atoms of C, Mg and CI?

Ans: COMPARISON OF MASSES OF C, Mg and CI

The atomic mass of C is 12 amu, Mg is 24 amu and that of Cl is 35.5 amu. Therefore, mass of Mg is double as compared to the mass of C and mass of Cl is three times as compared to the mass of C.

CALCULATION OF RELATIVE ATOMIC MASS FROM ISOTOPE ABUNDANCE

Relative Isotopic Masses

An element usually consists of a few different isotopes with different mass numbers. These mass numbers are called relative isotopic masses.

Isotopic abundance

Each isotope will also have its own naturally occurring abundance which is called isotopic abundances.

Calculation of relative atomic mass

Relative atomic mass of an element can be calculated from the relative isotopic masses (m) and isotopic abundances (p) by the following formula.

$$\text{Relative atomic mass} = \frac{8m1p1 + m2p2 + m3p3\text{----------}}{100}$$

Krypton

The element Krypton (Kr) has five isotopes. Their relative isotopic masses and isotopic abundances are shown in the following table (2.2).

Table (2.2) Isotopic Abundances of Krypton

Relative isotope mass	Isotopic abundance
80	2.0%
82	12.0%
83	12.0%
84	57.0%
85	17.0%

SAMPLE EXAMPLE

Relative atomic mass of krypton

$$= \frac{80 \times 2.0 + 82 \times 12.o + 83 \times 12.0 + 84 \times 57.0 + 85 \times 57.0}{100}$$

$$= 83.7$$

SAMPLE EXAMPLE

Calculate the relative atomic mass of light isotope of chlorine

Relative atomic mass of chlorine

$$= \frac{Cl \times 75.77 + 37 \times 24.23}{100}$$

$$3545 = \frac{Cl \times 75.77 + 37 \times 24.23}{100}$$

$$3545 = Cl \times 75.77 + 37 \times 24.23$$
$$3545 - 896.51 = Cl \times 75.77$$
$$2648.49/75.77 = Cl$$
$$34.95 = Cl$$

Result

Relative atomic mass of light isotope of chlorine is 34.95.

EXERCISE

Q. Calculate the relative atomic mass of Lead (Pb). Isotopic abundances of isotopes are 2.0, 24.0, 22.0, 52.0 respectively.

^{203}Pb ^{206}Pb ^{207}Pb ^{208}Pb

Solution: **NUMERICAL**

Relative atomic mass of Lead

$$= \frac{204 \times 2.0 + 206 \times 24.0 + 207 \times 22.0 + 208 \times 52.0}{100}$$

Result: Thus relative atomic mass of lead is amu 20.7

SHORT QUESTIONS

Q.1 What is the relative atomic mass? How it is related to gram? (U.B+K.B)

Ans: **RELATIVE ATOMIC MASS**

Definition:

"The average mass of atoms of an element as compared to $1/12^{th}$ (one-twelfth) the mass of one atom of carbon-12 isotope is called relative atomic mass."

Unit of Relative Atomic Mass: Its unit is atomic mass unit, with symbol amu.

Atomic Mass Unit: "One atomic mass unit is $1/12^{th}$ the mass of one atom of carbon-12^{th}."

Representation in Grams: When this atomic mass unit is expressed in grams it is.

$$1 \text{ amu} = 1.673776 \times 10^{-27} \text{ Kg}$$

Q.2 Define atomic mass unit. Why is it needed? (U.B+K.B+A.B)

Ans: **Definition:**

"The mass equal to one twelfth ($1/12^{th}$) of the mass of a carbon -12 atom is called atomic mass unit."

The atomic mass unit is abbreviated as amu.

$$1 \text{ amu} = 1/12 \times \text{mass of C-12 atom}$$

The mass of one atom of carbon -12 is 12 amu.

Need of amu:

It is the unit used for the relative atomic mass. It is used to compare masses of atoms.

Q.3 Give mass of proton and neutron in amu and grams. (K.B)

Ans: Answer given on page # 44

Q.5 Is atomic mass unit a SI unit of an atomic mass? (K.B)

Ans: SI unit for the mass of a substance is kilogram. As an atom is too small to weigh in kg therefore, atomic mass is stated in very small unit i.e. atomic mass unit.

$$1 \text{ amu} = 1.673776 \times 10^{-27} \text{ Kg}$$

Q.6 What is the relationship between atomic number and atomic mass? (U.B)

Ans: $A = Z + n$

Q.7 Define relative atomic mass.

Ans:

RELATIVE ATOMIC MASS

"The **average mass of atoms of an element as compared to 1/12th (one-twelfth) the mass of one atom of carbon-12 isotope** is called relative atomic mass".

Examples:

A_r of carbon

Q.8 Explain isotopes of hydrogen. (K.B)

Ans: Answer given on page # 45

Q.9 Write the uses of isotopes in radiotherapy. (A.B)

Ans: Answer given on page # 47

Q.10 Define isotopes. Give an example: (K.B)

Ans: Answer given on page # 45

Q.11 Why isotopes of an element have same chemical properties? (U.B)

Ans: Answer given on page # 45

Q.12 How electricity is generated by U-235? (U.B+A.B)

Ans: $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{139}_{56}Ba + {}^{94}_{36}Kr + 3\,{}^{1}_{0}n + \text{energy}$

Q.13 Which element has not any neutron in its atom? (SWL 2016 G-II)(U.B+K.B)

Ans:

ELEMENT WITH NO NEUTRON

The element hydrogen (protium) has not any neutron in its atom.

Q.14 Why do the isotopes of an element have different atomic masses? (U.B)

Ans:

ISOTOPES HAVING DIFFERENT ATOMIC MASSES

The isotopes of an element have same number of electrons and protons while different number of neutrons. Therefore the isotopes of an element have different atomic masses due to different number of neutrons.

Q.15 How many neutrons are present in C-12 and C-14? (U.B+K.B)

Ans:

NUMBER OF NEUTRONS IN C-12, C-14

Number of neutrons present in C-12=12-6=6 neutrons

Number of neutrons present in C-14=14-6=8 neutrons

(The atomic number of carbon is 6).

Q.16 Which of the isotopes of hydrogen contains greater number of neutrons? (U.B+K.B)

Ans:

GREATER NUMBER OF NEUTRONS

Tritium isotope of hydrogen contains greater number of neutrons. It has 2 neutrons.

Q.17 Give one example each of the use of radioactive isotope in medicine and radiotherapy. (A.B)

Ans:

USE OF ISOTOPES IN MEDICINE AND RADIOTHERAPY

In Medicine:

The radioactive isotope iodine-131 is used as a tracer in medicine. It is used to diagnose presence of tumors in the human body.

In Radiotherapy:

Co-60 is used to treat cancer inside the body. P-32 and Sr-90 are used to treat skin cancer.

Q.19 Define nuclear fission reaction. (K.B)

Ans:

NUCLEAR FISSION

Definition:

"A reaction that involves the splitting of heavy nucleus into two or more lighter nuclei with a release of huge amount of energy is called a nuclear fission reaction."

Example:

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{139}_{56}Ba + {}^{94}_{36}Kr + 3\,{}^{1}_{0}n + \text{energy}$$

During this reaction, released neutrons continue to bombard other uranium -235 atoms.

Q.20 When U-235 breaks up, it produces a large amount of energy. How is this energy used? (A.B)

Ans:

USE OF ENERGY

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{139}_{56}Ba + ^{94}_{36}Kr + 3\,^{1}_{0}n + \text{energy}$$

In this reaction a large amount of energy is released which may be used to convert water into steam in boilers. The steam then drives the turbines to generate electricity.

Q.21 How many neutrons are produced in the fission reaction of U-235? (K.B)

Ans:

NUMBER OF NEUTRON

In the fission reaction of U-235, three neutrons are produced.

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{139}_{56}Ba + ^{94}_{36}Kr + 3\,^{1}_{0}n + \text{energy}$$

MULTIPLE CHOICE QUESTIONS

1. Which isotope of carbon is in abundance? (BWP 2016 G-I)(K.B)
(A) ^{12}C (B) ^{13}C (C) ^{14}C (D) None of these

2. Isotopes have different: (K.B)
(A) Atomic number (B) Mass number (C) Atomic volume (D) None of these

3. Number of protons in $^{238}_{92}U$ are: (U.B+K.B)
(A) 92 (B) 90 (C) 91 (D) 89

4. Isotopes have same _____ and different _____. (K.B)
(A) Mass number, atomic number (B) Atomic number, mass number
(C) Neutrons, protons (D) None of these

5. The isotope used to generate electricity in nuclear reactor is: (LHR 2017 G-II)(A.B)
(A) C-12 (B) U-235 (C) Co-60 (D) P-32

6. Uranium has number of isotopes: (LHR 2016 G-II, GRW 2016)(K.B)
(A) 1 (B) 3 (C) 4 (D) 5

7. Isotopes have different: (K.B)
(A) Number of neutron (B) Number of electron (C) Atomic volume (D) None of these

8. Which one of the following is used for diagnostic imaging in the body? (GRW 2017 G-II, FSD 2017 G-II)(A.B)
(A) Technetium-99 (B) Sr-90 (C) I-131 (D) Co-60

9. Isotopes have same: (K.B)
(A) Atomic number (B) Mass number (C) Atomic volume (D) None of these

ANSWER KEY

MULTIPLE CHOICE QUESTIONS

INTRODUCTION

1	B	**2**	D	**3**	C

2.1 STRUCTURE OF ATOM

1	B	**2**	C	**3**	B		C	5	D	6	A
7	B	**8**	A	**9**	A	10	A	11	C	12	C
13	B	**14**	B	**15**	B	16	C	17	D	18	B
19	B	**20**	A	**21**	C	22	C	23	D	24	B
25	D	**26**	B	**27**	B						

2.2 ATOMIC NUMBER AND MASS NUMBER

1	A	**2**	C	**3**	C		

2.3 ISOTOPES AND THEIR MASSES

1	A	**2**	B	**3**	A	**4**	B
5	B	**6**	B	**7**	A	**8**	A
9	A						

EXERCISE SOLUTION

MULTIPLE CHOICE QUESTIONS

Tick () the correct answer.

1. How many electrons can be accommodated at the most in the third shell of the elements?

(A) 8 (B) 18
(C) 10 (D) 32

2. What information was obtained from discharge tube experiments?

(A) Structure of atom was discovered.
(B) Neutrons and protons were discovered.
(C) Electrons and protons were discovered.
(D) Presence of nucleus in an atom was discovered.

3. Why have isotopes not been shown in the periodic table?

(A) Periodic table cannot accommodate a large number of isotopes of different elements.
(B) Some of the isotopes are unstable and they give rise to different elements
(C) All the isotopes have same atomic number; so there is no need to give them separate places.
(D) Isotopes do not show periodic behavior.

4. Which particle is present in different number in the isotopes?

(A) Electron (B) Neutron
(C)Proton (D)Both neutron and electron

5. Predict the boiling point of heavy water.

(A) 101 .4 ^{0}C (B) 98.2^{0}C
(C) 100 ^{0}C (D) 105.4^{0}C

6. What will be the relative atomic mass of hydrogen given the abundances of its two isotopes, 99.9844% and 0.0156%.

(A) 1 .0078 (B) 1.0784
(C) 1.0800 (D) 1.0700

7. How is radiocarbon dating useful for archeologists?

(A) It helps determine the age of organic matter.
(B) It helps determine the composition of matter.
(C) It helps determine the usefulness of matter.
(D) It helps determine whether the matter is radioactive or not.

8. What does keep the particles present in the nucleus intact?

(A) Particles are held together by strong nuclear force.
(B) Particles are held together by weak nuclear force.
(C) Particles are held together by electrostatic force.
(D) Particles are held together by dipolar force.

9. How do electrons keep themselves away from the oppositely charged nucleus?

(A) By keeping themselves stationary
(B) By revolving around the nucleus
(C) Due to their wave-like nature
(D) A magnetic field around the nucleus keeps them away

10. Rubidium consists of two isotopes ^{85} Rb and ^{87}Rb. The percent abundance of the light isotope is 72.2% What is the percent abundance of the heavier isotope? Its atomic mass is 85.47

(A) 15% (B) 28%
(C) 37% (D) 72%

ANSWER KEY

1	B	2	C	3	C	4	B	5	A

6	A	7	A	8	A	9	B	10	B

QUESTIONS FOR SHORT ANSWERS

2. Questions for Short Answers

Q1. Why is it said that almost all the mass of an atom is concentrated in its nucleus?

Ans: **MASS OF ATOM IN NUCLEUS**

Almost all the mass of an atom is concentrated in its nucleus because the nucleus contains protons and neutrons. These particles are significantly heavier compared to electrons that revolve around the nucleus and they have a negligible mass.

Q2. Why are elements different from one another?

Ans: **DIFFERENCE IN ELEMENTS**

Elements are different from one another because each element has a unique number of protons in the nucleus, called atomic number. This number of protons differentiate it from other atoms.

Q3. How many neutrons are present in $^{210}_{83}Bi$?

Ans: **NUMBER OF NEUTRONS IN $^{210}_{83}Bi$**

There are 127 neutrons in $^{210}_{83}Bi$.

Q4. Why is tritium (^{3}H) a radioactive element?

Ans: **TRITIUM ($^{3}_{1}H$) AS A RADIOACTIVE ELEMENT**

Tritium ($^{3}_{1}H$) is a radioactive element because it has two neutrons in its nucleus with one proton which makes it unstable. The extra neutron in tritium causes it to be radioactive.

Q5. How can an atom absorb and evolve energy?

Ans: **ABSORPTION AND EVOLUTION OF ENERGY**

Energy is either absorbed or released in the form of light and heat. The photon interacts with an electron, pushing it into a higher-**energy energy** state or lower energy state.

CONSTRUCTED RESPONSE QUESTIONS

3. Constructed Response Questions

Q1. Why does the energy of electron increase as we move from first shell to second shell?

Ans: **ENERGY OF ELECTRONS IN SHELLS**

The energy of electron increase as we move from first shell to second shell because it absorbs energy and then go to the outer shell.

Q2. Why is it needed to lower the pressure of the gas inside the discharge tube?

Ans: **LOW PRESSURE OF GAS IN THE DISCHARGE TUBE**

It is needed to lower the pressure of the gas inside the discharge tube to allow electrons to travel freely in the Gas Discharge tube without collisions with the gas molecules.

Q3. What is the classical concept of an electron? How has this concept changed with time?

Ans: **CLASSICAL CONCEPT OF AN ELECTRON**

The classical model of the electron was "a point particle with mass and charge".

CHANGE OF CONCEPT

This concept changed with time due to the quantum mechanics and it included wave-particle duality and probabilistic behavior.

Q4. Why the nuclei of the radioactive elements are unstable?

Ans: **UNSTABLE NUCLEI**

The nuclei of radioactive elements are unstable due to an imbalanced ratio of protons to neutrons. This creates an excess of internal energy within the nucleus, which causes it to emit radiations spontaneously to become more stable.

Q5. During discharge tube experiments, how did the scientists conclude that the same type of electrons and protons are present in all the elements?

Ans: **SAME TYPE OF ELECTRONS AND PROTONS**

Scientists concluded that the same type of electrons are present in all elements through discharge tube experiments because they observed that the characteristics of the cathode rays were

independent of the gas used in the tube. Similarly, properties of protons remain same for all the atoms.

DESCRIPTIVE QUESTIONS

4. Descriptive Questions

Q1. Explain the structure of a hydrogen atom.

Ans:

STRUCTURE OF A HYDROGEN ATOM

A hydrogen atom consists of a single proton in its nucleus and a single electron revolving around the nucleus. It has no neutron. Thus it is simplest atom.

Q2. How does the theory of atomic structure explain the ionization of atoms by a radioactive isotope?

Ans:

ATOMIC STRUCTURE AND IONIZATION OF ATOMS

According to theory of atomic structure, when a radioactive isotope decays, it emits ionizing radiation (like alpha, beta, or gamma rays). These radiations carry enough energy to knock out electrons of nearby atoms and make them positively charged ions.

Ionizing radiation:

The radiation which has enough energy to remove an electron from an atom is called ionizing radiation.

Q3. What is radioactivity? Explain any three applications of radioactive isotopes.

Ans:

RADIOACTIVITY

Emission of radioactive rays from a radioactive substance is called radioactivity.

Radioactive decay

When a radioactive element emits radiation, it is transformed into another chemical element. This process is called radioactive decay.

This new element may be stable or may be radioactive so that it also emits radiation.

$$^{238}_{92}\text{U} \longrightarrow {}^{234}_{90}\text{Th} + \text{energy}$$

(Uranium) (Thorium)

$^{234}_{90}$Thorium is unstable and further disintegrates to give $^{231}_{91}$Pa (Protactinium).

$$^{234}_{90}\text{Th} \longrightarrow {}^{231}_{91}\text{Pa}$$

(Thorium) (Protactinium)

$$^{210}_{83}\text{Bi} \longrightarrow {}^{206}_{81}\text{Tl} + \text{energy}$$

(Bismuth) (Thallium)

APPLICATIONS OF RADIOACTIVE ISOTOPES

(i) Medical Imaging

Radioactive isotopes are useful in medical imaging. Doctors use them to diagnose the disease by injecting the patient with a small amount of radioactive fluid.

Example

Technetium - 99m is used for diagnostic imaging across human organs like brain, lungs, etc. Doctors use a special camera to watch how the radioactive fluid moves.

(ii) Radioactive dating

Definition

Radiocarbon dating is a method for finding out the age of an historical object containing organic material with the help of radioactive isotope of carbon C.

Method

The method involves measuring the proportion of ^{14}C in a sample from a dead plant or animal like a piece of wood or a bone which provides information that can be used to calculate when an animal or plant died. The older the sample is, the less ^{14}C is to be detected.

(iii) To test strength of metals and concrete

Radioactive isotopes are used to test the strength of metals and concrete mixture.

(iv) To generate cheap nuclear power

They are used to generate cheap nuclear power and to find oil fields. In medicine they are used to diagnose and treat many medical conditions and diseases, including cancer and thyroid disorders.

Q4. Find out the relative atomic mass of mercury from the following data.

Isotope	Relative Abundance	Isotope	relative abundance
^{196}Hg	0.0146%	^{199}Hg	16.34%
^{198}Hg	10.02%	^{200}Hg	23.13%
^{201}Hg	13.22%	^{202}Hg	29.80%
^{204}Hg	6.85%		

Ans: **NUMERICAL**

Given Data:

Isotope	Relative Abundance	Isotope	relative abundance
^{196}Hg	0.0146%	^{199}Hg	16.34%
^{198}Hg	10.02%	^{200}Hg	23.13%
^{201}Hg	13.22%	^{202}Hg	29.80%
^{204}Hg	6.85%		

To Find:

Relative atomic mass of mercury = ?

Calculation:

Relative atomic mass of Mercury

$$= \frac{196x0.0146 + 198 x10.02 + 199 x16.34 + 200x23.13 + 201x13.22 + 202x29.80 + 204 x 6.85}{100}$$

$$= \frac{19938.7016}{100}$$

$$= 199.387016 \text{ amu}$$

Result: Thus relative atomic mass of mercury is 199.387016 amu

INVESTIGATIVE QUESTIONS

5. Investigative Questions.

Q1. How can scientists synthesize elements in the laboratory?

Ans: **SYNTHESIS OF ELEMENTS IN LAB**

Scientists create synthetic elements in the laboratory by using particle accelerators to "smash" together the nuclei of heavy elements with a lighter one. This process is called nuclear reaction.

Method

Nuclear reaction is often carried out by bombarding a heavy element with a lighter one in a particle accelerator.

Q2. A system just like our solar system exists in an atom. Comment on this statement.

Ans: **ATOM AS SOLAR SYSTEM**

A system just like our solar system exists in an atom. This term means atom is similar to the solar system. Nucleus of the atom is like sun and electrons are like planets of the sun which revolve around the sun in certain energy levels.

TERMS TO KNOW

Terms	Definitions
John Dalton's Idea	An English chemist, John Dalton, proposed that atoms are indivisible.
Discharge tube experiments	Discharge tube experiments showed that atoms are no longer smallest particles of matter. Rather they are made up of still smaller particles called electron, proton and neutron.
Electrons, protons and neutrons	Electrons, protons and neutrons are shown to be present in all the elements irrespective of the fact that the elements behave very differently. Different elements however, contain different number of these particles.
Discovery of Nucleus	Lord Rutherford discovered that all atoms have a central part which he named as nucleus. The protons and neutrons are present in this nucleus while the electrons are revolving around the nucleus.
Number of electron and proton	An atom being electrically neutral contains the same number of electrons and protons.
Revolving of Electrons	Electrons revolve around the nucleus in different-shells
Atomic number	The number of protons present in the nucleus of an element is called the atomic number of that element.
Mass number	The total number of protons and neutrons present in the nucleus of an element in called its mass number.
Isotopes	Isotopes are the atoms of the same element which have the same number of protons but different number of neutrons.
Properties of Isotopes	Isotopes of an element have same chemical properties but they differ in their physical properties.
Radioactive Isotopes	Isotopes of an element may be stable or radioactive. Radioactive isotopes have many useful applications in medicine.
Radioactive isotopes	Radioactive isotopes have unstable nuclei and they throw out radiation.
Relative atomic mass	Relative atomic mass of an element can be calculated from the relative isotopic