Chapter 2

Structure of Atoms

Major Concepts

2.1 Theories and Experiments related to Atomic Structure
2.2 Electronic Configuration
2.3 Isotopes

Time allocation	
Teaching periods	16
Assessment periods	03
Weightage	10%

Students Learning Outcomes

Students will be able to:

- Describe the contributions that Rutherford made to the development of the Atomic Theory.
- Explain how Bohr's atomic theory differed.
- Describe the structure of atom including the location of the proton, electron and neutron.
- Define isotopes.
- Compare istopes of an atom.
- Discuss the properties of the isotopes of H, C, CI, U.
- Draw the structure of different isotopes from mass number and atomic number.
- State the importance and uses of isotopes in various fields of life.
- Describe the presence of subshells I shell.
- Distinguish between shells and subshells.
- Write the electronic configuration of first 18 elements in the Periodic Table.

Introduction

Ancient Greek philosopher Democritus suggested that matter is composed of tiny indivisible particles called atoms. The name atom was derived from the Latin word 'Atomos' meaning indivisible. In the beginning of 19^{th} century John Dalton put forward Atomic Theory. According to it 'all matter is made up of very small indivisible particles called atoms'. Till the end of 19^{th} century it was considered that atom cannot be subdivided. However, in the beginning of 20^{th} century experiments performed by Goldstein, J. J. Thomson, Rutherford, Bohr and other scientist revealed that atom is made up of subatomic particles like electron, proton and neutron. Properties of these subatomic particles will be discussed in this chapter.

2.1 THEORIES AND EXPERIMENTS RELATED TO STRUCTURE OF

ATOM

According to Dalton, an atom is an indivisible, hard, dense sphere. Atoms of the same element are alike. They combine in different ways to form compounds. In the light of Dalton's atomic theory, scientists performed a series of experiments. But in the late 1800's and early 1900's, scientists discovered new subatomic particles.

In 1886, Goldstein discovered positively charged particles called **protons**. In 1897, J.J. Thomson found in an atom, the negatively charged particles known as **electrons**. It was established that electrons and protons are fundamental particles of matter. Based upon these observations Thomson put forth his "**plum pudding**" theory. He postulated that atoms were solid structures of positively charge with tiny negative particles stuck inside. It is like plums in the pudding.

J.J. Thomson (1856-1940) was a British physicist. He was awarded the 1906 Noble Prize in Physics for the discovery of electron and for his work on the conduction of electricity in gases

Cathode rays and Discovery of Electron

In 1895 Sir William Crooks performed experiments by passing electric current through gases in a discharge tube at very low pressure.

He took a glass tube fitted with two metallic electrode, which were connected to a high voltage battery. The pressure inside the tube was kept 10^{-4} atm. When high voltage current was passed through the gas, shiny rays were emitted from the cathode which travel towards the anode as shown in figure 2.1. These rays were given the name of "**cathode rays**" as these were originated from the cathode.

Sir William Crooks (1832-1919) was a British chemist and physicist. He was pioneer of vacuum tubes. He worked on spectroscopy.

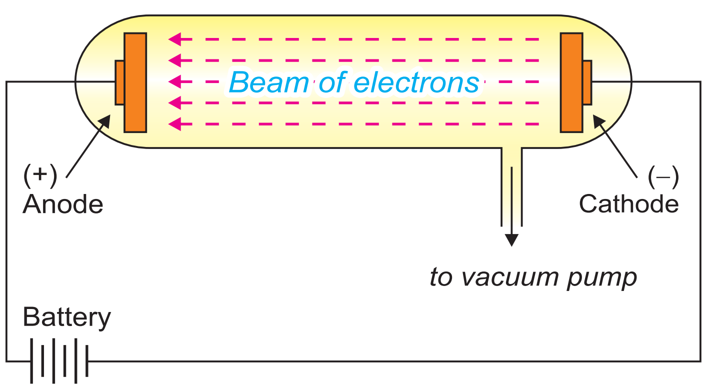


Fig 2.1 Discharge tube used for the production of cathode rays.

The cathode rays were studied in detail and their properties were determined, which are given below:

i. These rays travel in straight lines perpendicular to the cathode surface.

ii. They can cast a sharp shadow of an opaque object if placed in their path.

iii. They are deflected towards positive plate in an electric field showing that they are negatively charged.

iv. They raise temperature of the body on which they fall.

v. JJ. Thomson discovered their charge/mass (e / m) ratio.

vi. Light is produced when these rays hit the walls of the discharge tube.

vii. It was found that the same type of rays were emitted no matter which gas and which cathode was used in the discharge tube.

All these properties suggested that the nature of cathode rays is independent of the nature of the gas present in the discharge tube or material of the cathode. The fact that they cast the shadow of an opaque object suggested that these are not rays but they are fast moving material particles. They were given the name **electrons**. Since all the materials produce same type of particles, it means all the materials contain electrons. As we know materials are composed of atoms, hence the electrons are fundamental particles of atoms.

Discovery of Proton

In 1886 Goldstein observed that in addition to cathode rays, other rays were also present in the discharge tube. These rays were traveling in opposite direction to cathode rays. He used a discharge tube having perforated cathode as shown in figure 2.2. He found that these rays passed through holes present in the cathode and produced a glow on the walls of the discharge tube. He called these rays as "**canal rays**".

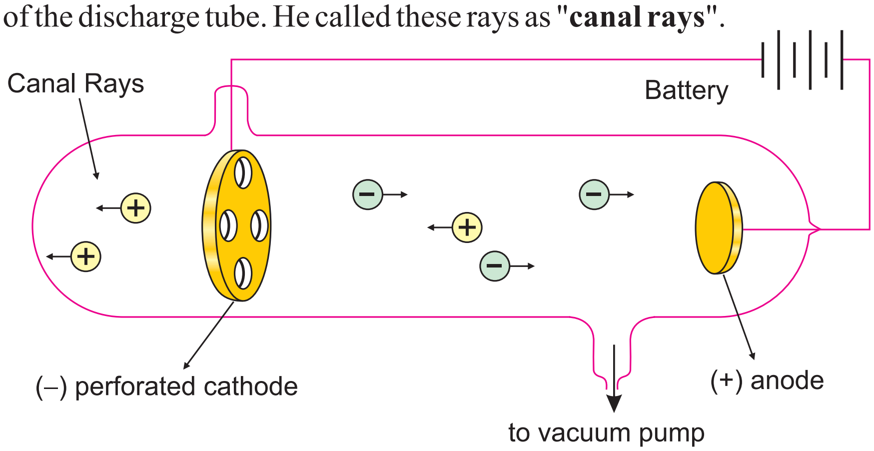


Fig 2.2 Discharge tube used for the production of canal rays.

The properties of these rays were as following:

i. These rays travel in straight lines in a direction opposite to the cathode rays.

ii. Their deflection in electric and magnetic field proved that these are positively charged.

iii. The nature of canal rays depends upon the nature of gas, present in the discharge tube.

iv. These rays do not originate from the anode. In fact these rays are produced when the cathode rays or electrons collide with the residual gas molecules present in the discharge tube and ionize them as follows:

$$M + e^{-} \longrightarrow M^{+} + 2e^{-}$$

v. Mass of these particles was found equal to that of a proton or simple multiple of it. The mass of a proton is 1840 times more than that of an electron.

Thus, these rays are made up of positively charged particles. The mass and charge of these particles depend upon the nature of the gas in the discharge tube. Hence, different gases produce different types of positive rays having particles of different masses and different charges. Keep in mind that positive particles produced by a gas will be of the same type i.e. positive rays produced by the lightest gas hydrogen contain protons.

Discovery of Neutron

Rutherford observed that atomic mass of the element could not be explained on the basis of the masses of electron and proton only. He predicted in 1920 that some neutral particle having mass equal to that of proton must be present in an atom. Thus scientists were in search of such a neutral particle. Eventually in 1932 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 are as following:

i. Neutrons carry no charge i.e. they are neutral.

ii. They are highly penetrating.

iii. Mass of these particles was nearly equal to the mass of a proton.

Test yourself 2.1

i. Do you know any element having no neutrons in its atoms?

ii. Who discovered an electron, a proton and a neutron?

iii. How does electron differ from a neutron?

iv. Explain, how anode rays are formed from the gas present in the discharge tube?

2.1.1 Rutherford's Atomic Model

Rutherford performed 'Gold Foil' experiment to understand how negative and positive charges could coexist in an atom. He bombarded *alpha* particles on a 0.00004 cm thick gold foil. Alpha particles are emitted by radioactive elements like radium and polonium. These are actually helium nuclei (He^{2+}). They can penetrate through matter to some extent.

He observed the effects of α-particles on a photographic plate or a screen coated with zinc sulphide as shown in figure 2.3. He proved that the 'plum-pudding' model of the atom was not correct.

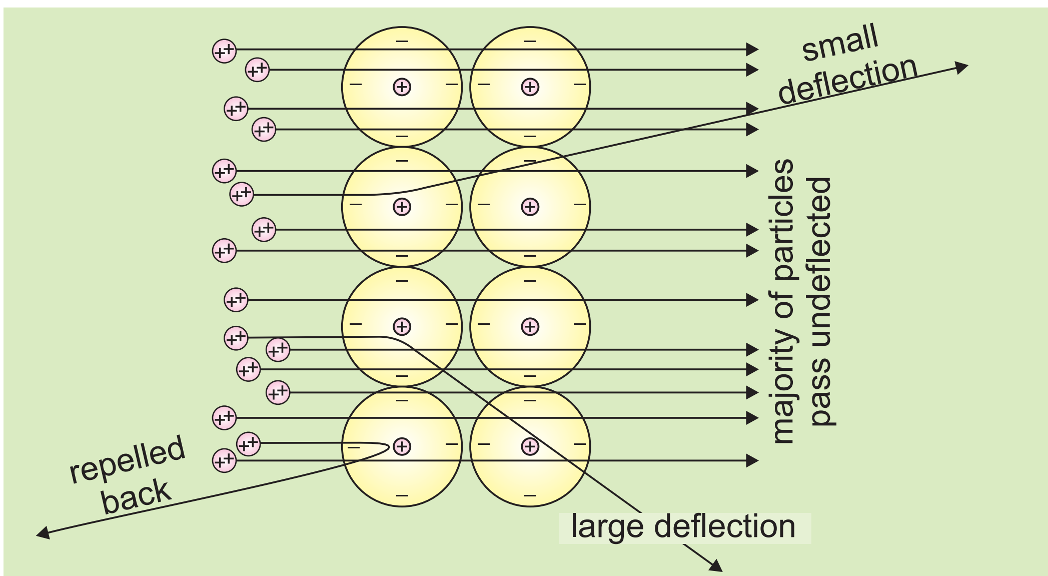


Fig 2.3 Scattering of alpha particles by the atoms of gold foil.

Observations made by Rutherford were as follows:

i. Almost all the particles passed through the foil un-deflected.

ii. Out of 20000 particles, only a few were deflected at fairly large angles and very few bounced back on hitting the gold foil.

Results of the experiment

Keeping in view the experiment, Rutherford proposed planetary model for an atom and concluded following results:

i. Since most of the particles passed through the foil undeflected, therefore most of the volume occupied by an atom is empty .

ii. The deflection of a few particles proved that there is a 'center of positive charges' in an atom, which is called 'nucleus' of an atom.

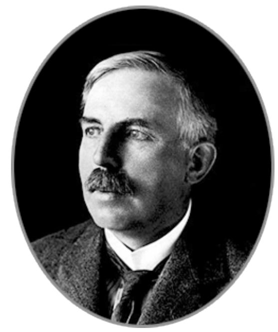
iii. The complete rebounce of a few particles show that the nucleus is very dense and hard.

iv. Since a few particles were deflected, it shows that the size of the nucleus is very small as compared to the total volume of an atom.

v. The electrons revolve around the nucleus.

vi. An atom as a whole is neutral, therefore the number of electrons in an atom is equal to the number of protons.

vii. Except electrons, all other fundamental particles that lie within the nucleus, are known as nucleons.



Rutherford was a British-New Zealand chemist. He performed a series of experiments using a - particles. He won the 1908 Noble Prize in Chemistry. In 1911, he proposed the nuclear model of the atom and performed the first experiment to split atom. Because of his great contributions, he is considered the father of nuclear science.

Defects in Rutherford's Model

Although Rutherford's experiment proved that the 'plum-pudding' model of an atom was not correct, yet it had following defects:

i. According to classical theory of radiation, electrons being the charged particles should release or emit energy continuously and they should ultimately fall into the nucleus.

ii. If the electrons emit energy continuously, they should form a continuous spectrum but in fact, line spectrum was observed.

Although the scientists had objections on the atomic model presented by Rutherford, yet it cultivated thought provoking ideas among them. They initiated the quest to answer the following questions:

i. How can an atom collapse or why are atoms stable?

ii. Why does an atom give line spectrum?

iii. Scientists considered there must be another model of atom. It indicated that Rutherford's model was not perfect.

2.1.2 Bohr's Atomic Theory

Keeping in view the defects in Rutherford's Atomic Model, Neil Bohr presented another model of atom in 1913. The Quantum Theory of Max Planck was used as foundation for this model. According to Bohr's model, revolving electron in an atom does not absorb or emit energy continuously. The energy of a revolving electron is 'quantized' as it revolves only in orbits of fixed energy, called 'energy levels' by him. The Bohr's atomic model is shown in figure 2.4.

Neil Bohr was a Danish physicist who joined Rutherford in 1912 for his post doctoral research. In 1913, Bohr presented his atomic model based upon Quantum theory. He won the 1922 Noble Prize for Physics for his work on the structure of an atom.

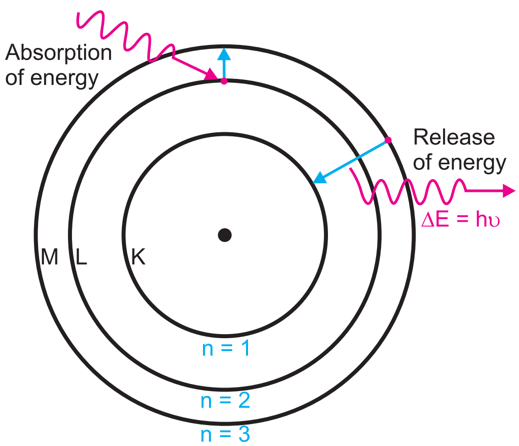


Fig 2.4 Bohr's atomic model showing orbits.

The Bohr's atomic model was based upon the following postulates:

i. The hydrogen atom consists of a tiny nucleus and electrons are revolving in one of circular orbits of radius '*r*' around the nucleus.

ii. Each orbit has a fixed energy that is quantized.

iii. As long as electron remains in a particular orbit, it does not radiate or absorb energy. The energy is emitted or absorbed only when an electron jumps from one orbit to another.

iv. When an electron jumps from lower orbit to higher orbit, it absorbs energy and when it jumps from higher orbit to lower orbit it radiates energy. This change in energy, ΔE is given by following Planck's equation

$$\triangle E = E_2 - E_1 = h\nu$$

Where, h is Planck's constant equal to 6.63×10^{-34} Js, and v is frequency of light.

v. Electron can revolve only in orbits of a fixed angular moment mvr, given as:

$$mvr = n\frac{h}{2\pi}$$

Where 'n' is the quantum number or orbit number having values 1,2,3 and so on.

Do you know?

Quantum means fixed energy. It is the smallest amount of energy that can be emitted or absorbed as electromagnetic radiation. Quanta is plural of quantum.

In 1918 Noble prize in physics was awarded to German physicist Max Planck (1858-1947) for his work on the quantum theory.

Summary of differences between two theories:

	Rutherford's Atomic Theory	Bohr's Atomic Theory
i.	It was based upon classical theory.	It was based upon quantum theory.
ii.	Electrons revolve around the nucleus.	Electrons revolve around the nucleus in orbits of fixed energy.
iii.	No idea about orbits was introduced.	Orbits had angular momentum.
iv.	Atoms should produce continuous spectrum.	Atoms should produce line spectrum.
v.	Atoms should collapse.	Atoms should exist.

Test yourself 2.2

i. How was it proved that the whole mass of an atom is located at its centre?
ii. How was it shown that atomic nuclei are positively charged ?
iii. Name the particles which determine the mass of an atom.
iv. What is the classical theory of radiation? How does it differ from quantum theory?
v. How can you prove that angular momentum is quantized?

Hint: *Let angular momentum (mvr) of 1st orbit is* $mvr = nh/2\pi$

By putting the values of h and π

$$mvr = \frac{6.63 \times 10^{-34}}{2 \times 3.14} = 1.0 \times 10^{-34}\ kg\ m^2\ s^{-1}$$

2.2 ELECTRONIC CONFIGURATION

Before discussing electronic configuration let us first understand the concept of shells and subshells.

We have learnt about the structure of atom i.e. it consists of a tiny nucleus lying in the center and electrons revolving around the nucleus. Now we will discuss how the electrons revolve around the nucleus? The electrons revolve around the nucleus in different energy levels or shells according to their respective energies (potential energy). The concept of potential energy of an electron shall be discussed in higher classes.

Energy levels are represented by 'n' values 1, 2, 3 and so on. They are designated by the alphabets K, L, M and so on. A shell closer to the nucleus is of minimum energy. Since K shell is closest to the nucleus, the energy of shells increases from K shell onwards. Such as:

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N shell can accommodate 32 electrons.

As we know there is a slight difference between the energies of the subshells within a shell, therefore, filling of electrons in subshells of a shell is such as that V subshell is filled first and then its *p* subshell and then other subshells are filled. The maximum capacity of subshells to accommodate electrons is:

'*s*' subshell can accommodate 2 electrons.

'*p*' subshell can accommodate 6 electrons.

Let us write the electronic configuration of the elements and their ions with the help of a few examples. Keep in mind, we should know three things:

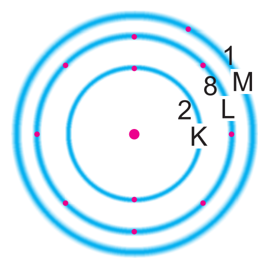
i. The number of electrons in an atom.

ii. The sequence of shells and subshells according to the energy levels.

iii. The maximum number of electrons that can be placed in different shells and subshells.

Example 2.1

Write the electronic configuration of an element having 11 electrons.



Solution:

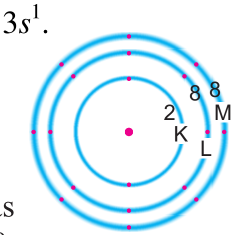
Keep in mind that all electrons do not have the same energy. Therefore, they are accommodated in different shells according to increasing energy and capacity of the shell. First of all, the electrons will go to K shell which has minimum energy. It can accommodate 2 electrons. After this, electrons will go to L shell that can accommodate 8 electrons. Thus K and L shells have accommodated 10 electrons. The remaining 1 electron will go to M shell, the outermost shell of maximum energy in this case. The electronic configuration will be written as: K L M

2, 8, 1,

But it is not necessary to write the subshells. Therefore, it is simply written as 2,8 and 1. Further distribution of electrons in subshells will be: $1s^2$, $2s^2$, $2p^6$, $3s^1$.

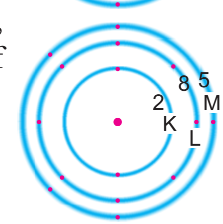
Example 2.2

Write down the electronic configuration of Cl^- *ion*



Solution:

We know that chlorine has 17 electrons and chloride ion (Cl^-) has 17 + 1 = 18 electrons. Its electronic configuration will be 2, 8, 8, which is presented in the figure. The further distribution of electrons in subshells will be $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$.



Example 2.3

An element has 5 electrons in M shell. Find out its atomic number.

Solution:

When there are 5 electrons in M shell, it means K and L shell are completely filled with their maximum capacity of 10 electrons. Hence the electronic configuration of the element is: K L M

2, 8, 5, or just 2, 8, 5

So the total number of electrons is 2 + 8 + 5 = 15

As we know, the number of electrons in an atom is equal to its atomic number. Therefore, atomic number of this element is 15.

2.2.2 The electronic configuration of first 18 elements

The sequence of filling of electrons in different subshells is as following:

$$1s^2, 2s^2, 2p^6, 3s^2, 3p^6 \ldots\ldots$$

Where number represents the shell number, while letters (s and p) represent subshells. The superscript shows the number of electrons in a subshell. The sum of superscripts number is the total number of electrons in an atom. i.e. atomic number of an element. The electronic configuration of first 18 elements is shown in the Table 2.1

Table 2.1 Electronic Configuration of First Eighteen Elements

Element	Symbol	Atomic Number	Electronic Configuration
Hydrogen	H	1	$1s^1$
Helium	He	2	$1s^2$
Lithium	Li	3	$1s^2, 2s^1$
Beryllium	Be	4	$1s^2, 2s^2$
Boron	B	5	$1s^2, 2s^2, 2p^1$
Carbon	C	6	$1s^2, 2s^2, 2p^2$
Nitrogen	N	7	$1s^2, 2s^2, 2p^3$
Oxygen	O	8	$1s^2, 2s^2, 2p^4$
Fluorine	F	9	$1s^2, 2s^2, 2p^5$
Neon	Ne	10	$1s^2, 2s^2, 2p^6$
Sodium	Na	11	$1s^2, 2s^2, 2p^6, 3s^1$
Magnesium	Mg	12	$1s^2, 2s^2, 2p^6, 3s^2$
Aluminium	Al	13	$1s^2, 2s^2, 2p^6, 3s^2, 3p^1$
Silicon	Si	14	$1s^2, 2s^2, 2p^6, 3s^2, 3p^2$
Phosphorus	P	15	$1s^2, 2s^2, 2p^6, 3s^2, 3p^3$
Sulphur	S	16	$1s^2, 2s^2, 2p^6, 3s^2, 3p^4$
Chlorine	Cl	17	$1s^2, 2s^2, 2p^6, 3s^2, 3p^5$
Argon	Ar	18	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6$

Test yourself 2.3

i.	*How many the maximum number of electrons that can be accommodated in a p-sub shell?*
ii.	*How many subshells are there in second shell?*
iii.	*Why does an electron first fill 2p orbital and then 3s orbital?*
iv.	*If both K and L shells of an atom are completely filled; how many total number of electrons are present in them?*
v.	*How many electrons can be accommodated in M shell?*
vi.	*What is the electronic configuration of a hydrogen atom?*
vii.	*What is atomic number of phosphorus? Write down its electronic configuration.*
viii.	*If an element has atomic number 13 and atomic mass 27; how many electrons are there in each atom of the element?*
ix.	*How many electrons will be in M shell of an atom having atomic number 15,*
x.	*What is maximum capacity of a shell?*

2.3 ISOTOPES

2.3.1 Definition

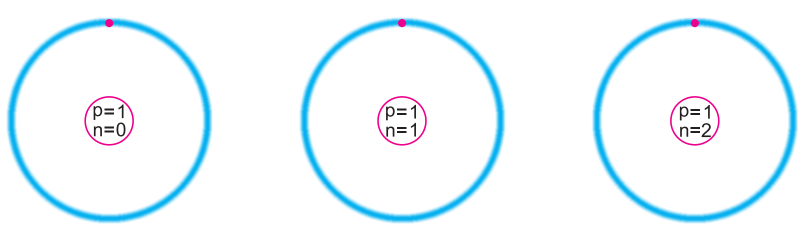
Isotopes *are defined as the atoms of an element that have same atomic number but different mass numbers.* They have same electronic configuration and number of protons but they differ in the number of neutrons. Isotopes have similar chemical properties because these depend upon electronic configuration. But they have different physical properties because these depend upon mass numbers. Most of the elements have isotopes. Here we will discuss the isotopes of hydrogen, carbon, chlorine and uranium only.

2.3.2 Examples

i) Isotopes of Hydrogen

The naturally occurring hydrogen is combination of its three isotopes, present in different abundances. The three isotopes of hydrogen are named as **protium,** ($^{1}_{1}H$) **deuterium**($^{2}_{1}H$, or D) and **tritium**($^{3}_{1}H$ or T). Each one of them has 1 proton and 1 electron, but number of neutrons are different as shown in Table 2.2

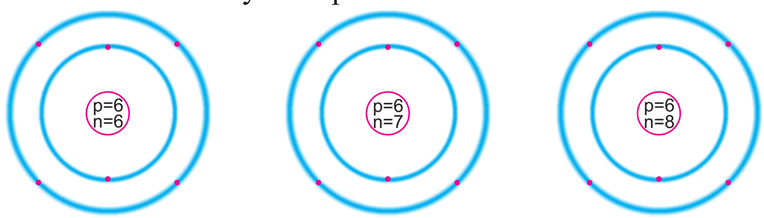
The isotopes are represented as:



protium ($^{1}_{1}H$) deuterium ($^{2}_{1}H$) tritium ($^{3}_{1}H$)

ii) Isotopes of Carbon

There are two stable isotopes of carbon ^{12}C and ^{13}C and one radioactive isotope ^{14}C. The isotope ^{12}C is present in abundance of 98.9 %, while ^{13}C and ^{14}C are both present only 1.1 % in nature. All of them have the same number of protons and electrons but differ in number of neutrons. They are represented as follows:



carbon ($^{12}_{6}C$) carbon ($^{13}_{6}C$) carbon ($^{14}_{6}C$)

iii) Isotopes of Chlorine

There are two isotopes of chlorine, $^{35}_{17}Cl$ and $^{37}_{17}Cl$

iv) Isotopes of Uranium

There are three isotopes of uranium i.e. $^{234}_{92}U$, $^{235}_{92}U$ and $^{238}_{92}U$. The $^{238}_{92}U$ is found in nature nearly 99%.

The difference in their number of electrons, protons and neutrons is shown below:

Table 2.2 Atomic Number, Mass Number, Number of Protons and Neutrons of H, C, CI and U

Symbol	Atomic Number	Mass Number	No. of Proton	No. of Neutron
^{1}H	1	1	1	0
^{2}H	1	2	1	1
^{3}H	1	3	1	2
^{12}C	6	12	6	6
^{13}C	6	13	6	7
^{14}C	6	14	6	8
^{35}Cl	17	35	17	18
^{37}Cl	17	37	17	20
^{234}U	92	234	92	142
^{235}U	92	235	92	143
^{238}U	92	238	92	146

SCIENCE TECHNOLOGY SOCIETY

APPLICATION OF ISOTOPES

In science and many different technological fields isotopes have vast applications. The biggest application is in the field of medicine. They are applied in diagnosis, radiotherapy and treatment of many diseases like cancer.

2.3.3 Uses

With the advancement of the scientific knowledge, the isotopes have found many applications in our lives. Following are the major fields in which isotopes have vast applications:

i. Radiotherapy (Treatment of Cancer)

For the treatment of skin cancer, isotopes like P-32 and Sr-90 are used because they emit less penetrating beta radiations. For cancer, Co-60, affecting within the body, is used because it emits strongly penetrating gamma rays.

ii. Tracer for Diagnosis and Medicine

The radioactive isotopes are used as tracers in medicine to diagnose the presence of tumor in the human body. Isotopes of Iodine-131 are used for diagnosis of goiter in thyroid gland. Similarly technetium is used to monitor the bone growth.

iii. Archaeological and Geological Uses

The radioactive isotopes are used to estimate the age of fossils like dead plants and animals and stones, etc. The age determination of very old objects based on the half-lives of the radioactive isotope is called radioactive-isotope dating. An important method of *age determination of old carbon containing objects (fossils) by measuring the radioactivity of C-14 in them is called radio-carbon dating or simply* ***carbon dating***.

iv. Chemical Reaction and Structure Determination

The radioisotopes are used in a chemical reaction to follow a radioactive element during the reaction and ultimately to determine the structure. For example: C-14 is used to label CO_2. As CO_2 is used by the plants for photosynthesis to form glucose, its movement is detected through the various intermediate steps up to glucose.

v. Applications in Power Generation

Radioactive isotopes are used to generate electricity by carrying out controlled nuclear fission reactions in nuclear reactors. For example, when U-235 is bombarded with slow moving neutrons, the uranium nucleus breaks up to produce Barium-139 and Krypton-94 and three neutrons.

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

A large amount of energy is released which is used to convert water into steam in boilers. The steam then drives the turbines to generate electricity. This is the peaceful use of atomic energy for development of a nation.

Test yourself 2.4

i. Why do the isotopes of an element have different atomic masses?
ii. How many neutrons are present in C-12 and C-13?
iii. Which of the isotopes of hydrogen contains greater number of neutrons?
iv. Give one example each of the use of radioactive isotope in medicine and radiotherapy.
v. How is the goiter in thyroid gland detected?
vi. Define nuclear fission reaction.
vii. When U-235 breaks up, it produces a large amount of energy. How is this energy used?
viii. How many neutrons are produced in the fission reaction of U-235?
ix. U-235fission produces two atoms of which elements?

SOCIETY TECHNOLOGY SCIENCE

TESTING PREVAILING THEORIES BRINGS ABOUT CHANGE IN THEM

Science is a process for producing knowledge. The process depends both on making careful observations of phenomenae and inventing theories for making sense out of those observations. Change in knowledge is inevitable because new observations may challenge prevailing theories. No matter how well one theory explains a set of observations, it is possible that another theory may fit just as well or better, or may fit a still wider range of observations. In science, the testing and improving and occasional discarding of theories, whether new or old, go on all the time. Scientists assume that even if there is no way to secure complete and absolute truth, increasingly accurate approximations can be made to account for the world and how it works.

Key Points

- Cathode rays were discovered in last decade of nineteen century. The properties of cathode rays were determined and they led to the discovery of electron.
- Canal rays were discovered in 1886 by Goldstein . The properties of canal rays resulted in the discovery of proton in the atom.
- Neutron in the atom was discovered in 1932 by Chadwick.
- First of all structure of an atom was presented by Rutherford in 1911. He proposed that an atom contains nucleus at the center and electrons revolve around this nucleus.
- Bohr presented an improved model of an atom in 1913 based upon four postulates. He introduced the concept of circular orbit, in which electrons revolve. As long as electron remains in a particular orbit, it does not radiate energy. Release and gain of energy is because of change of orbit.
- The concept of shells and subshells is explained.
- A shell consists of subshells.
- Isotopes are defined as the atoms of elements that have the same atomic number but different atomic mass.
- Hydrogen, carbon and uranium have three isotopes each, whereas chlorine has two isotopes.

EXERCISE

Multiple Choice Questions

Put a (✓) on the correct answer

1. **Which one of the following results in the discovery of proton**
   (a) cathode rays (b) canal rays (c) X-rays (d) alpha rays.
2. **Which one of the following is the most penetrating.**
   (a) protons (b) electrons (c) neutrons (d) alpha particles
3. **The concept of orbit was used by**
   (a) J. J. Thomson (b) Rutherford (c) Bohr (d) Planck
4. **Which one of the following shell consists of three subshells.**
   (a) O shell (b) N shell (c) L shell (d) M shell
5. **Which radioisotope is used for the diagnosis of tumor in the body?**
   (a) cobalt-60 (b) iodine-131 (c) strontium-90 (d) phosphorus-30
6. **When U-235 breaks up, it produces:**
   (a) electrons (b) neutrons (c) protons (d) nothing
7. **The p subshell has:**
   (a) one orbital (b) two orbitals (c) three orbitals (d) four orbitals
8. **Deuterium is used to make:**
   (a) light water (b) heavy water (c) soft water (d) hard water
9. **The isotope C-12 is present in abundance of:**
   (a) 96.9 % (b) 97.6 % (c) 99.7 % (d) none of these
10. **Who discovered the proton:**
    (a) Goldstein (b) J. J. Thomson (c) Neil Bohr (d) Rutherford Short

Short answer questions.

1. What is the nature of charge on cathode rays?
2. Give five characteristics of cathode rays.
3. The atomic symbol of a phosphorus ion is given as ^P3~
   (a) How many protons, electrons and neutrons are there in the ion?
   (b) What is name of the ion?
   (c) Draw the electronic configuration of the ion.
   (d) Name the noble gas which has the same electronic configuration as the phosphorus ion has.
4. Differentiate between shell and subshell with examples of each.
5. An element has an atomic number 17. How many electrons are present in K, L and M shells of the atom?

6. Write down the electronic configuration of Al^{3+}. How many electrons are present in its outermost shell?
7. Magnesium has electronic configuration 2, 8, 2,
   (a) How many electrons are in the outermost shell?
   (b) In which subshell of the outermost shell electrons are present?
   (c) Why magnesium tends to lose electrons?
8. What will be the nature of charge on an atom when it loses an electron or when it gains an electron?
9. For what purpose U-235 is used?
10. A patient has goiter. How will it be detected?
11. Give three properties of positive rays.
12. What are the defects of Rutherford's atomic model?
13. As long as electron remains in an orbit, it does not emit or absorb energy. When does it emit or absorb energy?

Long Answer Questions.

1. How are cathode rays produced? What are its five major characteristics?
2. How was it proved that electrons are fundamental particles of an atom?
3. Draw a labeled diagram to show the presence of protons in the discharge tube and explain how canal rays were produced.
4. How Rutherford discovered that atom has a nucleus located at the centre of the atom?
5. One of the postulates of Bohr's atomic model is that angular momentum of a moving electron is quantized. Explain its meaning and calculate the angular momentum of third orbit (i.e. n=3)
6. How did Bohr prove that an atom must exist?
7. What do you mean by electronic configuration? What are basic requirements while writing electronic configuration of an element (atom)?
8. Describe the electronic configuration of Na^{+}, Mg^{2+} and Al^{3+} ions. Do they have the same number of electrons in the outermost shell?
9. Give the applications of isotopes in the field of radiotherapy and medicines.
10. What is an isotope? Describe the isotopes of hydrogen with diagrams.