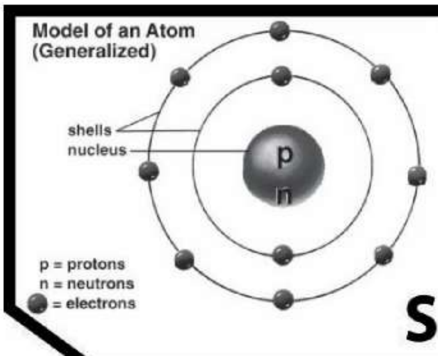


CHAPTER 2

STRUCTURE OF ATOMS

SUBJECTIVE PART

LONG QUESTION ANSWERS

Introduction

Idea of Greeks about matter:

Ancient Greek philosopher Democritus suggested that matter is composed of tiny indivisible particles called atoms.

Derivation of word Atom:

The name atom was derived from the Latin word 'Atomos' meaning indivisible.

Historical background of Atom:

- In the beginning of 19th 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 19th century it was considered that atom cannot he subdivided.
- In the beginning of 20th 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.

Theories and experiments related to structure of atom

Q.1 What is the Dalton's atomic theory and Plum pudding theory?

Ans: Dalton's atomic theory

In the beginning of 19th century John Dalton put forward Atomic Theory. According to it 'all matter is made up of very small indivisible particles called atoms'.

i. All matter is composed of atoms.
ii. An atom is an indivisible, hard, dense sphere.
iii. Atoms of the same element are alike.
iv. They combine in different ways to form compounds.

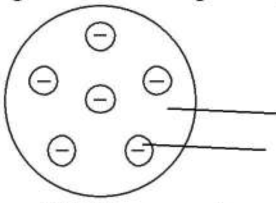
J.J Thomson (1856-1940) was a British physicist. He was awarded the 1906 Noble Prize in Physics for the discovery of electron and for his work on the conduction of electricity in gases.

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 observed new sub-atomic particles.

Plum pudding theory

In the late 1800, J.J Thomson proposed a model of an atom based on coulomb's law. 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."



Q.2 How the cathode rays were discovered? What are its major properties? (Ex. Q.2)

Ans: Cathode rays and discovery of electron: (Ex. Q.1)

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

Introduction

In 1879 Sir William Crooks performed experiments by passing electric current through gases in a discharge tube at very low pressure.

Experiment:

He took a glass tube fitted with two metallic electrodes, 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 surface move towards the anode as shown in figure 2.1.

Name Reasons:

These rays were given the name of 'cathode rays' as these were originated from the cathode.

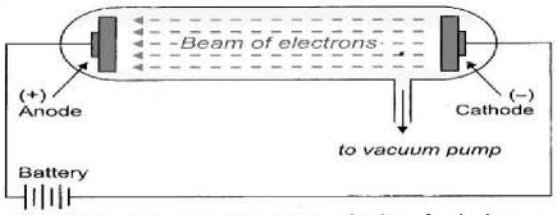


Fig 2.1 Discharge tube used for the production of cathode rays.

Properties of cathode rays:

The major characteristics of cathode rays are given below:

i. **Travelling in straight line:** These rays travel in a straight line perpendicular to the cathode surface.

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

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

iv. **Rise in temperature:** They raise temperature of the body on which they fall.

v. **e/m ratio:** J.J. Thomson discovered their charge/mass (e / m) 'ratio:

vi. **Production of light:** Light is produced when these rays hit the sides of the discharge tube.

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

Conclusions:

i. All these properties suggested that the nature of cathode rays was 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.

ii. Since all the materials produce same type of particles, it means all the materials contain electrons.

iii. As we know materials are composed of atoms, hence the electrons are fundamental particles of atoms.

Q.3 How the protons were discovered? Write down its properties. (Ex. Q.3)

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 proton

Introduction:

Protons were discovered by Goldstein in 1886.

Experiment:

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 wall. He called these rays as "canal rays".

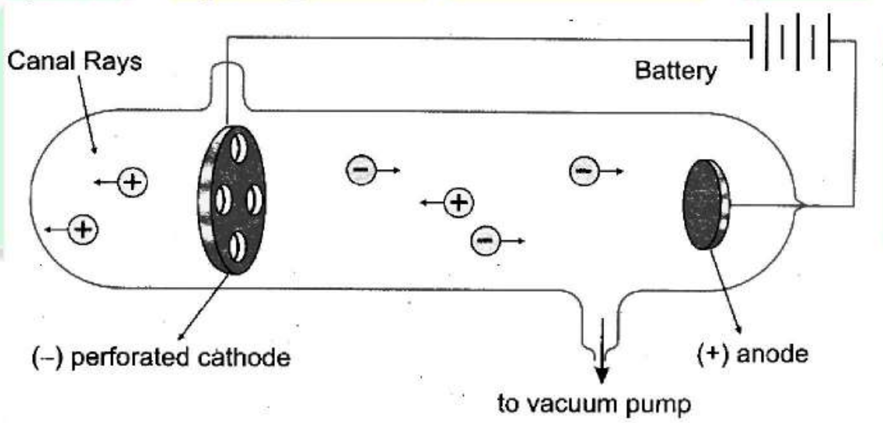


Fig 2.2 Discharge tube used for the production of canal rays.

Properties of positive rays or canal rays:

i. **Travelling in straight line:** These rays travel in a straight line in a direction opposite to cathode rays.

ii. **Deflection in electric field:** Their deflection in electric and magnetic field proved that these were positively charged.

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

iv. **Origin:** 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 molecule present in the discharge tube and ionize them.

v. **Mass of positive rays:** 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.

Results:

i. These rays are made up of positively charged particles.

ii. 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.

iii. Positive particles produced by a gas will be of the same type i.e. positive rays produced by the lightest gas hydrogen contain protons.

Q.4 How were neutrons discovered? Write down their properties.

Ans: Discovery of Neutron

Historical Backgrounds:

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.

Experiment:

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

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

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

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

Q.5 How Rutherford discovered that atom has a nucleus located at the centre of the atom? (Ex. Q.4)

OR

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

Ans: Rutherford's Experiment

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

Introduction:

This experiment was performed by Lord Rutherford and his co-worker in 1911. For his work he was awarded |Nobel prize for chemistry in 1908.

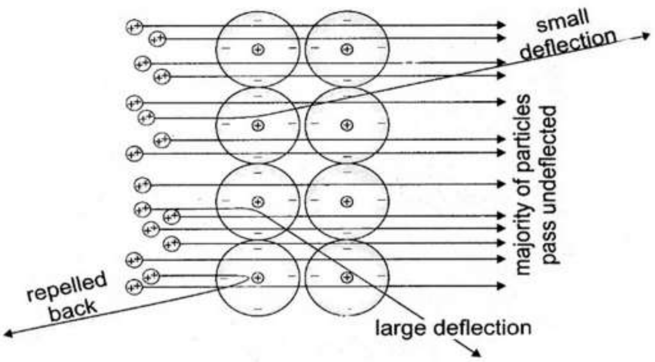
Objectives:

Rutherford performed 'Gold Foil' experiment to understand how negative and positive charges could coexist in an atom.

Experiment:

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 a-particles on a photographic plate or a screen coated with zinc sulphide He proved that the 'plum-pudding' model of the atom was not correct.



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.

Scattering of alpha particles by the atoms of gold foil

Observations:

The observation 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 (Postulates of Rutherford's Atomic Model:

Rutherford proposed planetary model for an atom and concluded following results:

i. Empty part: since most of the particles passed through the foil un-deflected, therefore most of the volume occupied by an atom is empty.

ii. Center of positive charges: 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. Dense and hard nucleus: The complete rebounce of a few particles show that the nucleus is very dense and hard.

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

v. Revolving of electron: The electrons revolve around the nucleus.

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

vii. Nucleon number: Except electrons, all other fundamental particles that lie within a nucleus are known as nucleons.

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

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

Despite of objections on the Rutherford's atomic model, yet it cultivated thought provoking ideas among them.

Q.6 Write down the postulates of Bohr's atomic theory.

OR

How Bohr prove that an atom must exist?

Ans: Bohr's atomic theory:

Introduction

Neil 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.

Energy of an electron:

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.

Niels 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.

Postulates of Bohr's atomic theory:

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

ii. **Energy of orbit:** Each orbit has a fixed energy that is quantized.

iii. **Emission or absorption of energy:** 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. **Change in energy:** When an electron jumps from lower orbit to higher orbit it absorbs energy and when it jumps back from higher orbit to lower orbit it radiates energy. This change in energy, ΔE is given by following Planck's equation

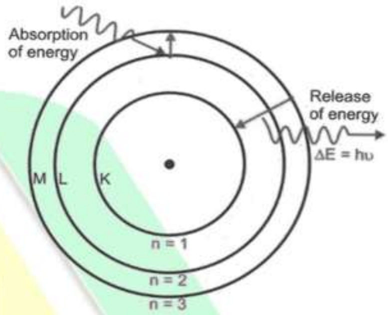


Fig 2.4 Bohr's atomic model showing orbits.

$$\Delta E = E_2 - E_1 = h\upsilon$$

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

v. **Angular momentum:** 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.

Q.7 What are differences between Rutherford's Atomic theory and Bohr's Atomic theory?

Ans: Differences between "Rutherford's and Bohr's Atomic Theories"

	Rutherford's Atomic Theory	Bohr's Atomic Theory
i.	It was based on 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.

Q.8 Write a note on shells and subshells.

Ans: a. Shell

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

Examples: K, L, M, N etc.

Properties of a shell:

i. Shells are the main energy levels that electrons occupy.

ii. Shells are represented by circles around the nucleus.
iii. The number of electron that a shell can accommodate is given by $2n^2$, where 'n' is the shell number.
iv. Different energy levels or shells are counted from the centre to outwards.
v. A shell also consists of subshells or orbitals.
vi. Each subshell or orbital is designated by a small alphabetical letter s, p, d etc.
vii. Energy levels are represented by on' values 1, 2, 3 and so on.
viii. Shells are designated by the alphabets or shells K, L, M and so on.
ix. A shell closer to the nucleus is of minimum energy.
x. Since K shell is closest to the nucleus, the energy of shells increases from K shell and onwards.

Shells and their energies:

1^{st} energy level is K shell; it has the lowest energy.
2^{nd} energy level is L shell; it has more energy than K shell.
3^{rd} energy level is M shell; it has more energy than K and L shell.
4^{th} energy level is N shell; it has more energy than K, L and M shell

Maximum capacity of shells to accommodate electrons:

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

K shell: $2n^2 = 2(1)^2 = 2\times1 = 2$
L shell: $2n^2 = 2(2)^2 = 2\times4 = 8$
M shell: $2n^2 = 2(3)^2 = 2\times9 = 18$
N shell: $2n^2 = 2(4)^2 = 2\times16 = 32$

Figure showing different energy levels or shells counted from the centre outwards.

b. Sub-shell:

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

Properties of subshells:

i. First energy level or K shell has only one subshell called s subshell.
ii. Second energy level L, shell has two subshells s and p.
iii. Third energy level M shell has three subshells s, p and d.
iv. Fourth energy level or N shell has four subshells 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

Q.9 What do you mean by electronic configuration? What are basic requirements while writing electronic configuration of an element.

OR

Explain electronic configuration and give the rules for electronic configuration.

Ans: Electronic Configuration:

"The distribution of electrons around the nucleus in various shells and subshells according to their increasing energy is called electronic configuration."

Principle:

The electronic configuration of an atom can be written by using the Aufbau principle.
"In filling the subshells, electrons always enter in lower energy subshell first."
The increasing order in which the electrons will enter into subshell is:
$1s^2$, $2s^2$, sp^6, $3s^2$, $3p^6$, $4s^2$, $3d^{10}$, $4p^6$, $5s^2$ etc.

Where,

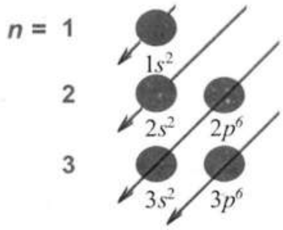
i. 'n' represents the shell number

ii. Letters (s and p) represent subshells

iii. Subscript shows the number of electrons in a subshell.

The sum of subscripts number is the total number of electrons in an atom i,e. atomic number of an element. as following:

$1s^2$, $2S^2$, $2p^6$, $3s^2$, $2p^6$…………..



Rules for electronic configuration

i. The most stable or ground state electronic configuration of an atom is the one in which electrons are present in the lowest possible energy level.

ii. The electrons fill the shells in order of their increasing energy, i.e. lower energy level is occupied first then the higher energy level and so on as indicated earlier.

The maximum capacity of sub shells to accommodate electrons:

's' orbital can accommodate 2 electrons.
'p' orbital can accommodate 6 electrons.
'd' orbital can accommodate 10 electrons.
'f' orbital can accommodate 14 electrons.

The maximum capacity of shells to accommodate electrons:

The maximum capacity of shells to accommodate electrons is as follows:

K shell: $2n^2 = 2(1)^2 = 2\times1 = 2$
L shell: $2n^2 = 2(2)^2 = 2\times4 = 8$
M shell: $2n^2 = 2(3)^2 = 2\times9 = 18$
N shell: $2n^2 = 2(4)^2 = 2\times16 = 32$

As we know there is a slight difference between the energies of the sub shells or orbital within a shell, therefore, filling of electrons in sub shells of a shell is such as that's' sub shell is filled first and then its p sub shell and then other sub shells are filled.

Basic requirements for writing electronic configuration:

While writing the electronic configuration of the elements and their ions, we should know three things.

i. The number of electrons in an atom or ion.

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 sub shells.

Q.10 Draw electronic configuration of first 18 elements.

Ans: The electronic configuration of first 18 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	$1s^2, 2s^2, 2p^6, 3p^1$
Silicon	Si	14	$1s^2, 2s^2, 2p^6, 3p^2$
Phosphorus	P	15	$1s^2, 2s^2, 2p^6, 3p^3$
Sulphur	S	16	$1s^2, 2s^2, 2p^6, 3p^4$
Chlorine	Cl	17	$1s^2, 2s^2, 2p^6, 3p^5$
Argon	Ar	18	$1s^2, 2s^2, 2p^6, 3p^6$

Q.11 Define isotopes. Explain the isotopes of hydrogen.

OR

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

Ans: Isotopes

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

Properties of isotopes:

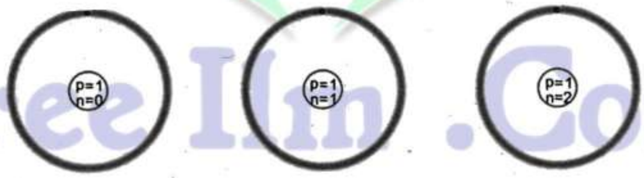
- **i.** They have same electronic configuration and number of protons
- **ii.** They differ in the number of neutrons.
- **iii.** Isotopes have similar chemical properties because they depend upon electronic configuration.
- **iv.** They have different physical properties because these depend upon atomic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

Example:

Isotopes of Hydrogen:

The naturally occurring hydrogen is combination of its three isotopes, present in different abundances. The isotopes of hydrogen are as follows:

The isotopes are represented as:



protium (^1_1H) deuterium (^2_1H) tritium (^3_1H)

	Isotopes	Natural Abundance	At No	Mass No	No of proton	No of Electron	No of Neutron
(i)	Protium (^1_1H or P)	99.985%	1	1	1	1	0
(ii)	Deutrium (^2_1H or D)	0.015%	1	2	1	1	1
(iii)	Tritium (^3_1H or T)	In trace amount	1	3	1	1	2

For more Information

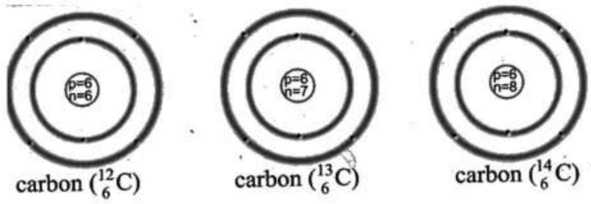
- The word isotope is derived from two Greek words i.e. iso means same, Greek topes means place.
- Isotopes were first discovered by the English Chemist Friedrick Soddy in 1913.

Q.12 Explain isotopes of carbon, chlorine and uranium.

Ans:

a. Isotopes of Carbon:

There are two stable isotopes of carbon ^{12}C and ^{13}C and one radioactive isotope ^{14}C. Natural abundance of isotopes. 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. The isotopes are represented as:



b. Isotopes of Chlorine:

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

Natural abundance:

The isotope Cl-35 is present in abundance of 75% while Cl-37 is present in abundance of 25%. All of them have same number of protons and electrons but differ in number of neutrons.

c. Isotopes of Uranium

There are 3 isotopes of uranium i.e. $^{234}_{92}U$, $^{235}_{92}U$ and $^{238}_{92}U$

The $^{234}_{92}U$ is found in nature nearly 99%.

All of them have same number of protons and electrons but different number of neutrons.

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, Cl and U

Symbol	Atomic Number	Mass Number	No. of Proton	No. of Neutron
$_1H$	1	1	1	0
$_2H$	1	2	1	1
$_3H$	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
$2_{34}U$	92	234	92	142
$_{235}U$	92	235	92	143
$_{238}U$	92	238	92	146

Q.13 Give the applications of isotopes in the field of radiotherapy, medicines, archaeology, structure determination and power generation.

Ans: Uses or Applications of isotopes:

The major fields in which isotopes have vast applications are the following:

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, affecting inside the body** Co-60, is used because it emits strongly penetrating gamma rays and beta 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.

Examples:

i. Isotopes of Iodine-131 are used for diagnosis of goiter in thyroid gland.

ii. 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."

"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. This is an important method of age determination of old objects"

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.

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.

When U-235 is bombarded with slow moving neutrons, the uranium nucleus breaks up to produce Barium-139 and Krypton 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.

For more information

Testing Prevailing Theories Brings About Change in Them

Science is a process for producing knowledge. The process depends both on making careful observations of phenomena 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.