Chapter 2

Structure of Atoms

Q1. Describe the contribution that Rutherford made to the development of the atomic theory.

OR

How did Rutherford's model of an atom first of all proved the existence of nucleus in an atom?

OR

What are the conclusions drawn by Rutherford from the following observations on the scattering experiment of a particles?

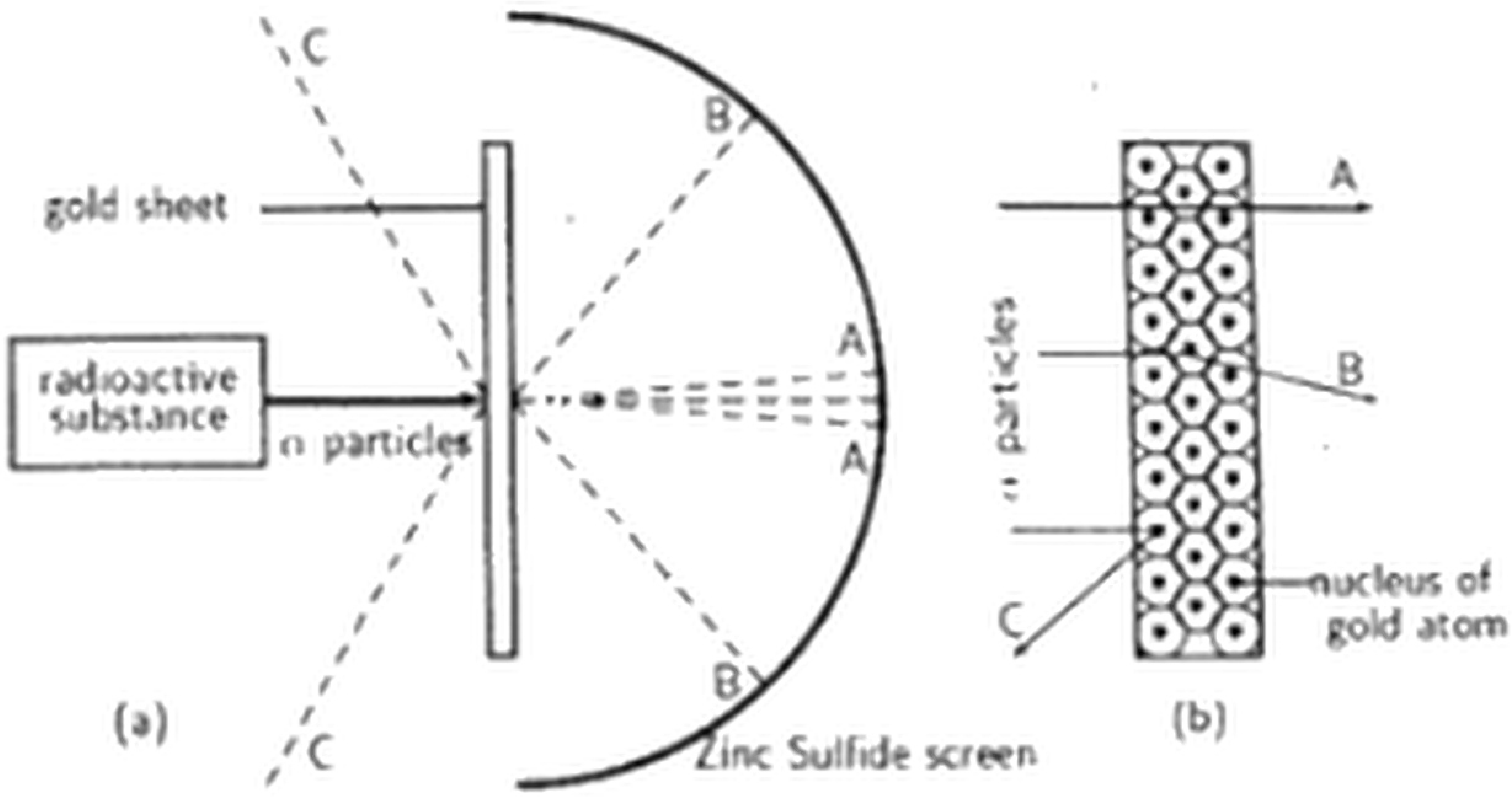
Ans: Rutherford's atomic model:

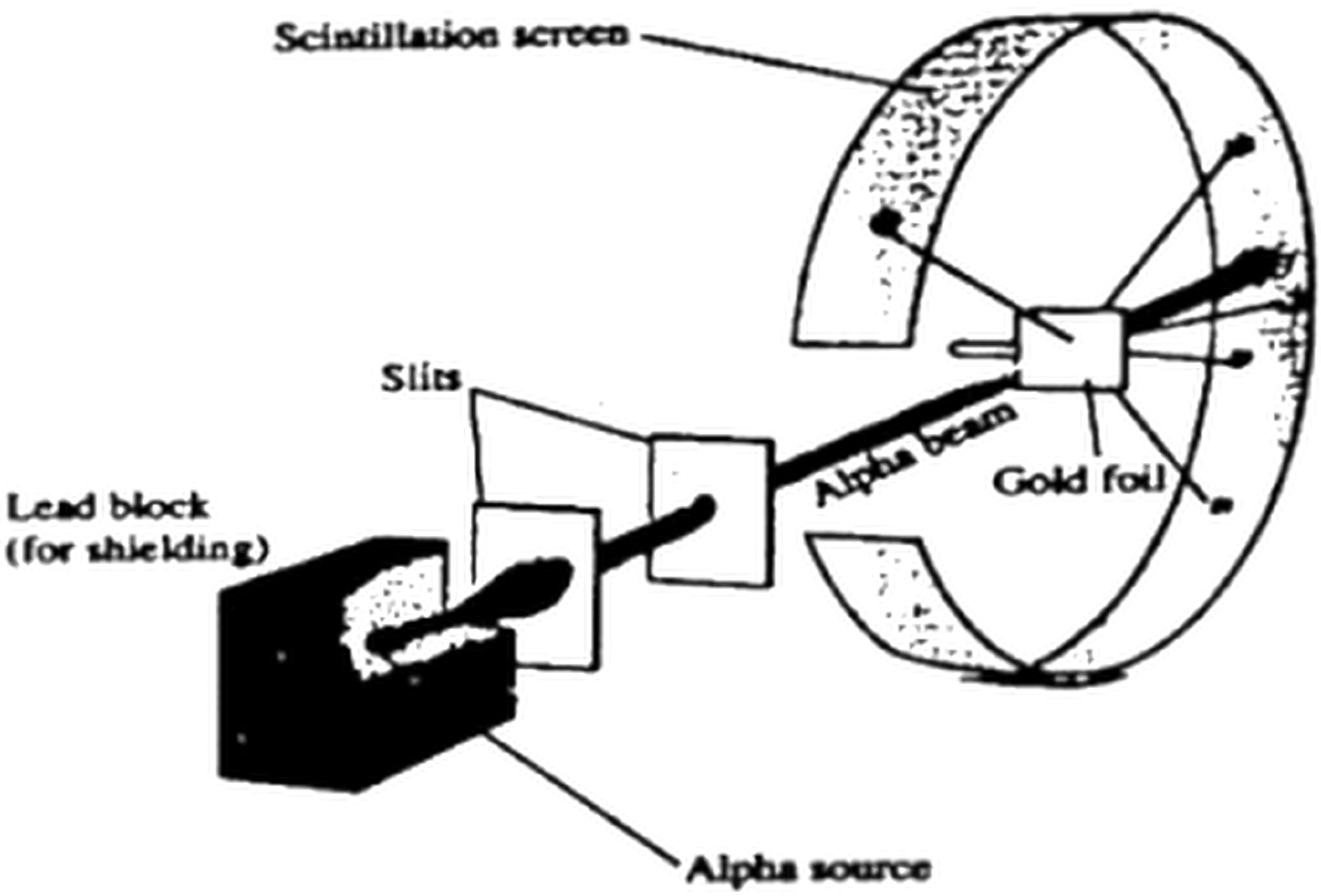
In 1911 Rutherford performed an experiment in order to know the arrangement of electrons and protons in atoms.

Rutherford's experiment:

Rutherford bombarded a very thin gold foil about 0.0004cm thickness with α-particles. He used α-particles obtained from the disintegration of polonium. α-particles are helium nuclei that are doubly positively charged (He^{++}).

Most of these particles passed straight through the foil. Only few particles were slightly deflected. But one in 1 million was deflected through an angle greater than 90° from their straight paths. Rutherford performed a series of experiments using thin foils of other elements. He observed similar results from these experiments.





Rutherford's Experiment

Rutherford draw following conclusions:

1. Since majority of the α-particles passed through the foil undeflected, most of the space occupied by an atom must be empty 2.
2. The deflection of a few α-particles through angles greater than 90° shows that these particles are deflected by electrostatic repulsion between the positively charged α-particles and the positively charged part of atom.
3. Massive α particle is not deflected by electrons.

Discovery of nucleolus:

Rutherford proposed a planetary model (similar to the solar system) for an atom. An atom is neutral particle. The mass of an atom is concentrated in a very small dense positively charged region. He named this region as nucleus.

A positively charged region is present at the centre of an atom and the electrons are revolving around the nucleus in circles. These circles are called orbits

Note:

The centripetal force due to the revolution of electrons balances the electrostatic force of attraction between the nucleus and electron.

Q2. What are the defects of Rutherford's model of atom?

Ans: Defects in Rutherford's atomic model:

Rutherford's model of an atom resembles our solar system. It has following defects

1. Classical physics suggests that electron being charged particle will emit energy continuously while revolving around the nucleus. Thus, the orbit of the revolving electron becomes smaller and smaller until it would fall into

2. If revolving electron emits energy continuously it should form a continuous spectrum for an atom but a line spectrum is obtained Bohr formulated new explanation and a new theory to remove defects from the Rutherford's atomic model.

Q3. How did Bohr's atomic theory modify Rutherford's model of atom with the help of Quantum theory?

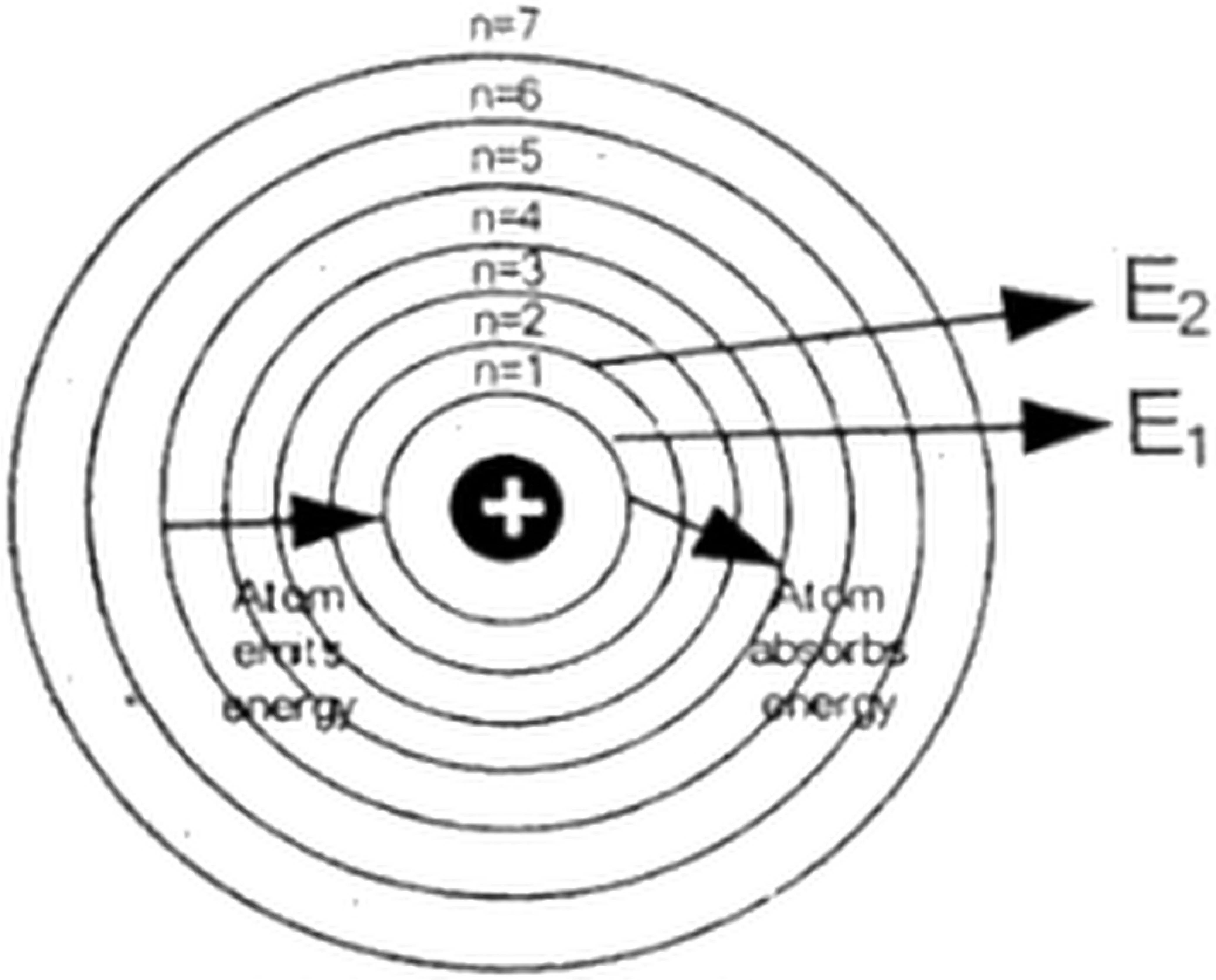
OR

Explain the postulates of Bohr's atomic theory?

Ans: Bohr's atomic theory:

1. In 1913 Neil Bohr, proposed a model for an atom that was consistent with Rutherford's model. But it also explains the observed line spectrum of the hydrogen atom. Main postulates of Bohr's atomic theory are as follows:
2. The electron in an atom revolves around the nucleus in one of the circular orbits. Each orbit has a fixed energy. So, each orbit is also called energy level.
3. The energy of the electron in an orbit is proportional to its distance from the nucleus. The farther the electron is from the nucleus, the more energy it has.
4. The electron revolves only in those orbits for which the angular momentum of the electron is an integral multiple of $\frac{h}{2\pi}$ where his Plank's constant (its value is 6.626×10^{-34} J.s).
5. Light is absorbed when an electron jumps to a higher energy orbit and emitted when an electron falls into a lower energy orbit. Electron present in a particular orbit does not radiate energy.
6. The energy of the light emitted is exactly equal to the difference between

Where ΔE is the energy difference between any two orbits with energies E_2 and E_1.



Bohr's model of the atom

Society, Technology and Science

Rutherford was the first scientist who proposed first atomic model of an atom He suggested that all of the positive change and most of the mass of the atom is concentrated in the nucleus. The remaining volume of the atom is occupied by electrons that revolve around the nucleus in circles called orbits. These suggestions remained unchallenged. But his model could not explain the stability of an atom and line spectrum for an atom. Bohr leaped over difficulty by using Quantum Theory of Radiation that was proposed by Max Plank. Bohr proposed that an electron moves around the nucleus in well-defined circular paths called orbits. An orbit has fixed energy. Electron present in an orbit does not emit energy. Bohr atomic atom gives line spectrum. Development of Bohr's atomic model explains how interpretations of experimental results of other scientists help chemists to formulate new explanations and new theories.

SELF ASSESSMENT EXERCISE 2.1

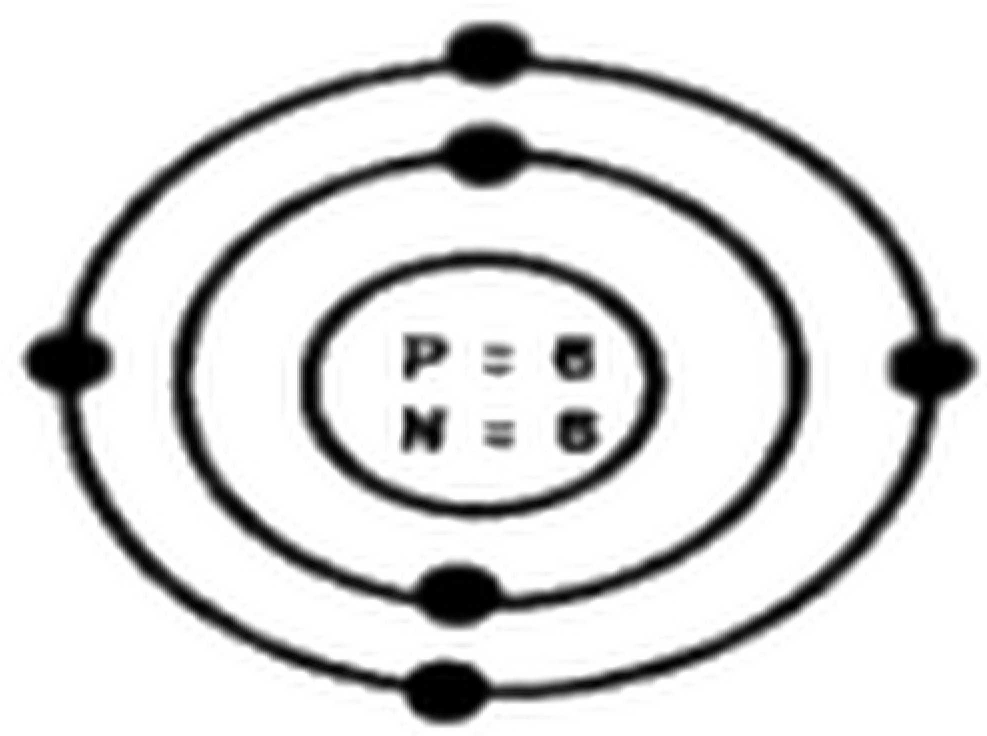
Draw Bohr's Model for the following atoms indicating the location for electrons, protons and neutrons,

a. Carbon (Atomic Number = 6, Mass Number = 12)

b. Chlorine (Atomic No. 17, Mass No. 35)

a. Carbon (Atomic Number 6, Mass Number = 12)

Solution:



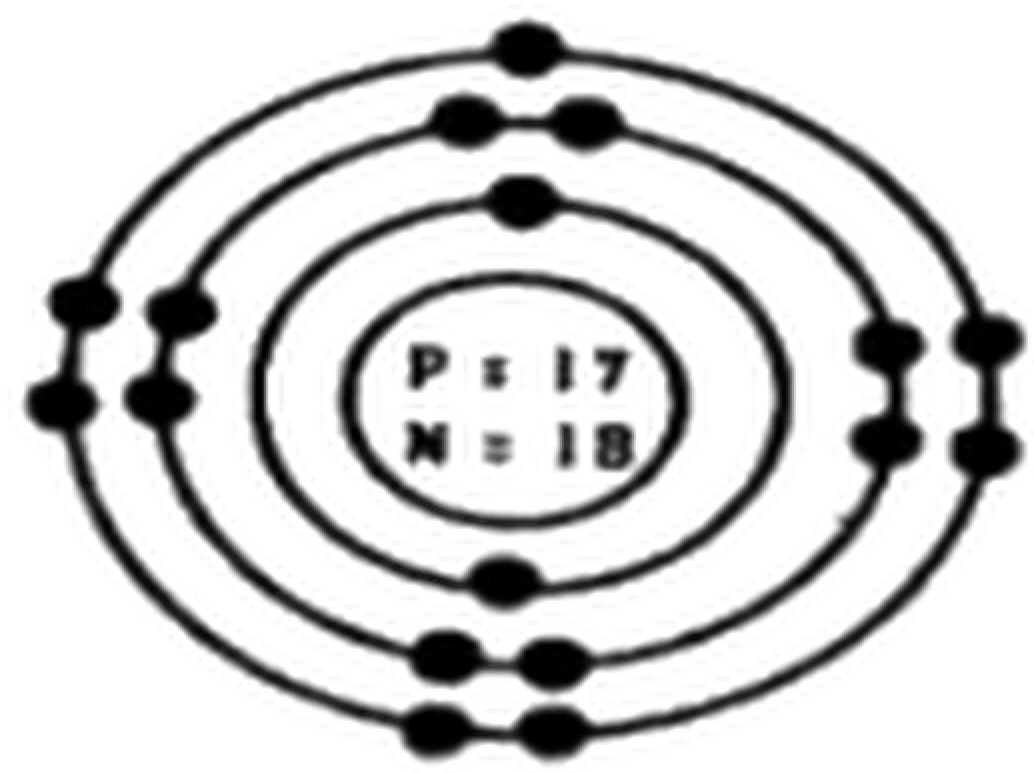
Number of electrons = 6

Number of protons = 6

Number of neutrons = A – Z = 12 – 6 = 6

b. Chlorine (Atomic No. 17, Mass No. 35)

Solution:



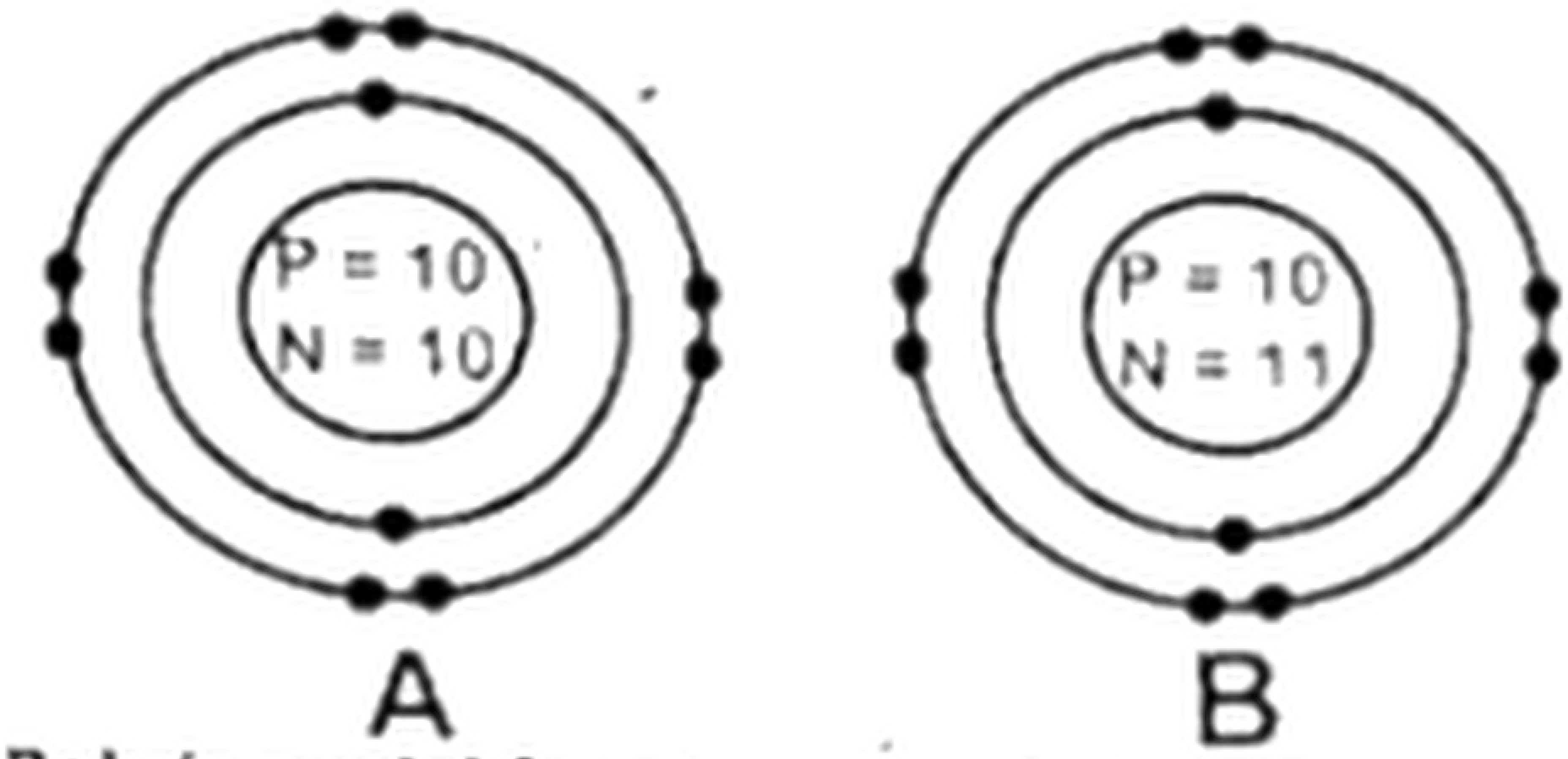
Number of electrons = 17

Number of protons = 17

Number of neutrons = A – Z = 35 – 17 = 18

Q4. Can you identify three similarities and two differences in these atoms?

Figure 23 shows Bohr Model for two atoms A and B



Bohr's model for atom A and atom B

Solution:

Similarities:

You will find

(a) Both the atoms have same number of protons.

(b) Both the atoms have same number of electrons.

(c) Both have same atomic number.

Dissimilarities:

(d) Both have different number of neurons

(e) Both differ in total number of protons and neutron. This means they have different mass numbers

Note:

Since both the atoms have same atomic number, they must be the atoms of same element and are called isotopes.

Q5. What are isotopes? Give two examples.

The word isotope was first used by Seddy. It is a Greek word "isos" means same and "tope" means place.

Isotopes are atoms of an element whose nuclei have the same atomic number but different mass number. This is because atoms of an element can differ in the number of neutrons. Isotopes are chemically like and after in the physical properties.

Q6. How does the discovery of isotopes contradict Dalton's atomic theory?

Ans. According to Dalton's atomic theory

"All atoms of the same element have the same mass".

Whereas isotopes are atoms of an element whose nuclei have the same atomic number but different mass number.

This is because atoms of an element can differ in the number of neurons. Thus, the discovery of isotopes contradicted Dalton's atomic theory.

Society, Technology and Science

Dalton's atomic theory explained data from many experiments so was widely accepted Discovery of sub-atomic particles and isotopes proved that some of the Dalton's ideas about atoms we not correct Scientists did not discard his theory Instead; they revised the theory to take into account new discoveries. This shows how testing prevailing theories bring about changes in them.

Q7. Give names and symbols of isotope of hydrogen. Write their properties and applications in daily life. Draw diagrammatic sketches of isotopes of hydrogen.

Hydrogen has three isotopes.

i. **Hydrogen-1 (Protium):**

Hydrogen-1 Protium has no neutron. Almost all the hydrogen is Hydrogen-1. The symbol of protium is ^1H. Naturally occurring hydrogen contains 99.99% protium:

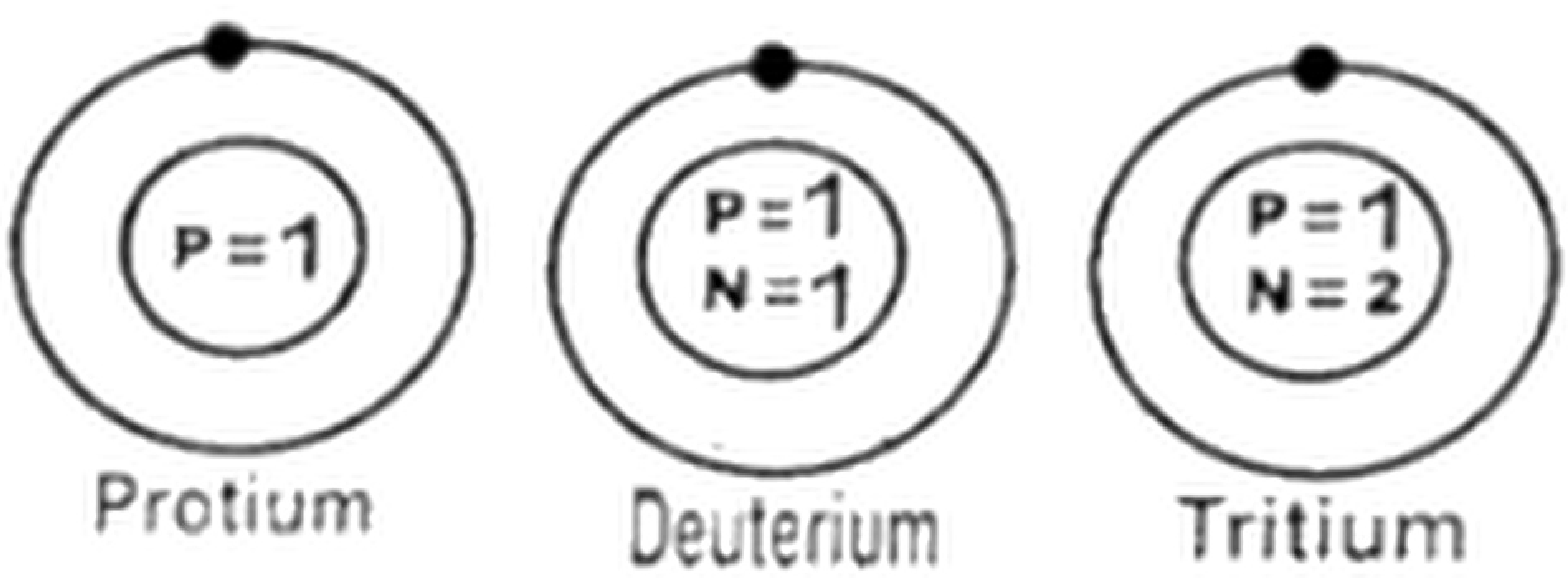
Hydrogen-1 also known as protium has only one proton, adding a neutron doubles it mass. Protium / Hydrogen is a colorless Odorless and tasteless gas. It is insoluble in water and is highly inflammable gas

ii. **Hydrogen-2 (deuterium):**

Hydrogen-2 (deuterium) has one neutron. The symbol of deuterium is ^2H. Water that contain hydrogen-2 atoms in place of hydrogen-1 is called heavy water. Naturally occurring hydrogen contains 0.0015% deuterium.

iii. **Hydrogen-3 (Tritium):**

Hydrogen-3 (Tritium) has two neutrons. The symbol of tritium is ^3H. Tritium is not found in naturally occurring hydrogen because its nucleus is unstable.



Isotopes of hydrogen

Q8. Define heavy water?

Water that contain hydrogen-2 atoms in place of hydrogen-1 called heavy water.

Q9. Give Comparison of ordinary water and heavy water?

OR

Write the physical properties of water and heavy water?

Ans: Comparison of ordinary water and heavy water:

Property	**Ordinary water (H_2O)**	**Heavy water (D_2O)**
Melting Point	0.00°C	3.81°C
Boiling point	100°C	101.2°C
Density at 25°C	0.99701 g/cm^3	1.1044 g/cm^3

Q10. At what temperature would a sample of heavy water freeze?

Ans: Freezing point of heavy water is 3.82°C.

Q11. Give names and symbols of isotope of carbon. Write their properties and applications in daily life. Draw diagrammatic sketches of isotopes of carbon.

Ans: Isotopes of carbon:

Carbon has three isotopes Carbon-12, carbon-13 and carbon –14.

Carbon-12:

Almost all the carbon is carbon-12. Its symbol is ^{12}C. It has six neutrons and six protons.

Carbon-13 has symbol ^{13}C. It has seven neutrons and six protons.

Carbon-14:

Carbon-14 has eight neutrons and six protons. Its symbol is ^{14}C.

Properties of Isotopes of carbon:

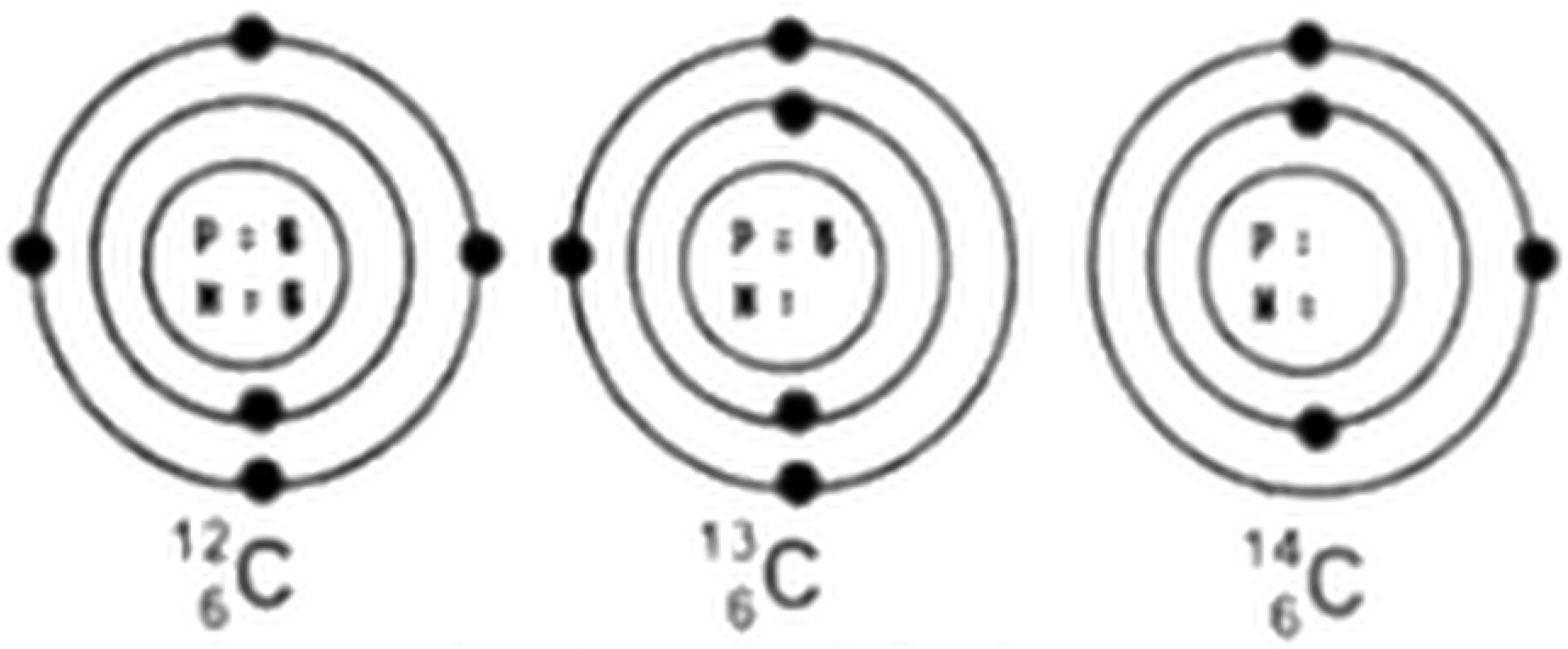
Different forms of carbon are black or grayish black solids except diamond. They are odorless and tasteless. They have high melting and boiling points and are insoluble in water.

Natural abundance of isotopes of carbon is as follows:

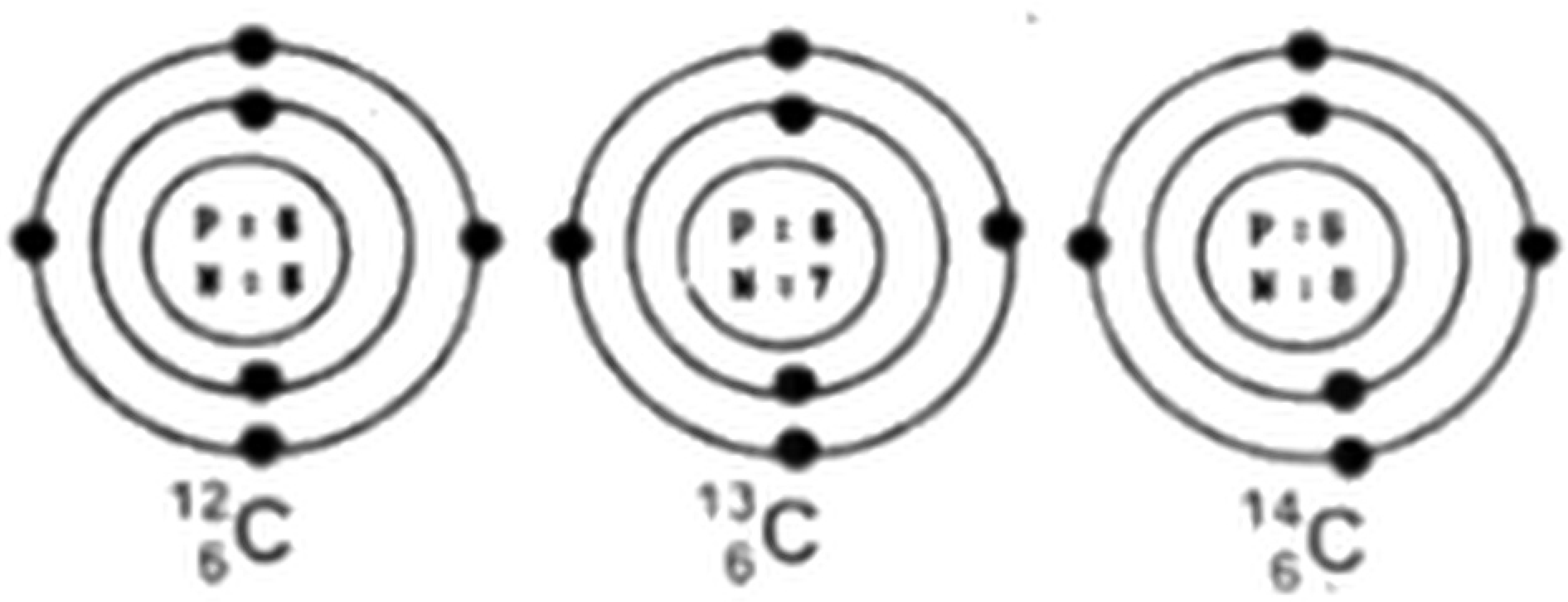
^{12}C = 98.8% ^{13}C = 1.1% ^{14}C -0.009%

ACTIVITY 2.1

Carbon has three isotopes ^{12}C, ^{13}C, ^{14}C Figure 2.6 shows incomplete structure of isotopes of carbon. Can you complete it?



Isotopes of Carbon



Q12. Give names and symbols of isotope of chlorine. Write their properties and applications in daily life. Draw diagrammatic sketches of isotopes of chlorine.

Ans: Isotopes of chlorine:

There are two natural isotopes of chlorine, chlorine-35 and chlorine-37.

Chlorine-35:

An atom of chlorine-35 has 17 protons and 18 neutrons. Chlorine-35 occurs in nature about 75%.

Chlorine-37:

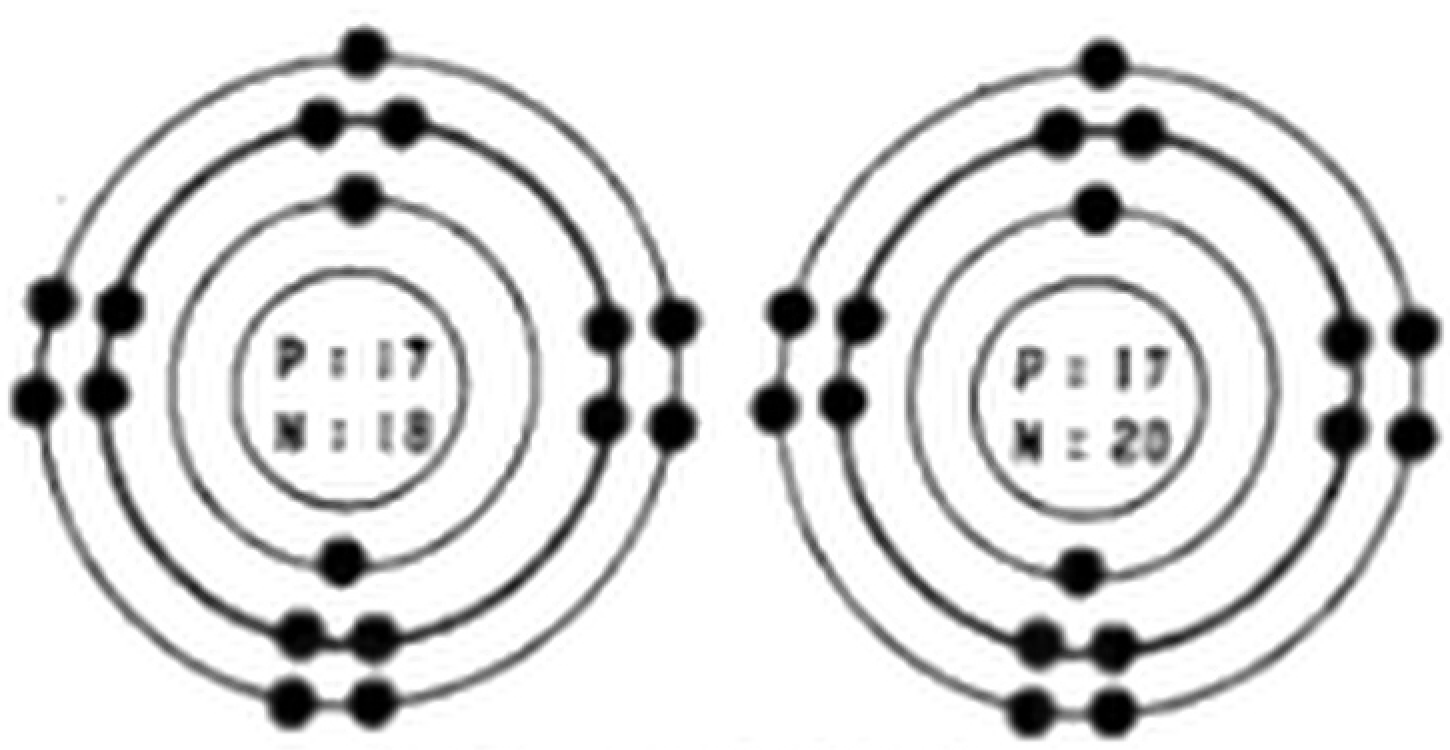
An atom of chlorine-37 has 17 protons and 20 neutrons Chlorine-37 occurs in nature about 25%.

Properties of isotopes of chlorine:

Chlorine is a grayish yellow gas with sharp pungent irritating smell. It is fairly soluble in water.

ACTIVITY 2.2

Chlorine has two isotopes. Figure 2.7 shows the structure of isotopes of chlorine. Can you write isotope symbol for each?



Isotopes of chlorine

75.77% 24.23%

Solution:

Isotope symbols:

Natural abundance

Q13. Give names and symbols of isotope of uranium. Write their properties and applications in daily life. Draw diagrammatic sketches of isotopes of uranium.

Ans: Isotopes of uranium

Uranium has three isotopes with mass number 234, 235 and 238 respectively.

$$^{234}U, \quad ^{234}U, \quad ^{234}U$$

^{235}U **isotope:**

The ^{235}U isotope is used in nuclear reactors and atomic bombs.

The fission of uranium-235 yields smaller nuclei neutron and energy. The nuclear energy released by the fission of one kilogram of uranium-235 is equivalent to chemical energy produced by burning more than 17000 kg of coal.

^{238}U **isotope:**

The ^{238}U isotope lacks the properties necessary for these applications.

When uranium-238 decays into thorium-234, it emits alpha particle. An alpha particle is doubly positively charged helium nucleus.

$$^{238}U \rightarrow {}^{234}Th + {}^{4}He$$

^{234}U **isotope:** ^{234}U is rare.

Note: Natural abundance of Uranium isotopes is as follows:

$^{234}U = 0.006\%$, $^{234}U = 0.72\%$, $^{234}U = 99.27\%$

Q14. Why Isotopes of an element have similar chemical properties.

Ans: Chemical properties of an element depend upon the number of protons and electrons Neutrons do not take part ordinary chemical reactions Therefore, isotopes of an element have similar chemical properties.

ACTIVITY 2.3

Fill in the blanks?

1. ^{234}U has ____ protons, _____ electrons and _____ neutrons
2. ^{235}U has ____ protons, _____ electrons and _____ neutrons
3. ^{238}U has ____ protons, _____ electrons and _____ neutrons

Solution:

1. ^{234}U has _92_ protons, _92_ electrons and _142_ neutrons
2. ^{235}U has _92_ protons, _92_ electrons and _143_ neutrons
3. ^{238}U has _92_ protons, _92_ electrons and _146_ neutrons

Note:

Atomic number = Z = Number of protons = Number of electrons

Atomic mass = A = Number of protons = Number of neutrons

Number of neutrons = Atomic mass - Atomic Number = A - Z

Important information

Carbon-14 is used to estimate the age of carbon-containing substances.

much faster than they decay. As a rest the concentration of C-14 in all living things keep on increasing. After death organisms no longer pick up C-14. By comparing the activity of a sample of skull or jaw bones, with the activity of living tissues. We can estimate how long it has been since the organism died. This process is called dating.

Q15. State the importance and uses of isotopes in various fields of life.

Ans: Uses of isotopes:

Stable and radioactive isotopes have many applications in science and medicines. Some of these are as follows

- **i.** Radioactive iodine - 131 used as a tracer in diagnosing thyroid problem.
- **ii.** Na- 24 used to trace the flow of blood and detect possible constructions or obstructions in the circulatory System.
- **iii.** Iodine-123 is used to image the brain.
- **iv.** Cobalt-60 is commonly used to irradiate cancer cells in the hope of killing or shrinking the tumors
- **v.** Carbon-14 is used to trace the path of carbon in photosynthesis.
- **vi.** Radioactive isotopes are used to determine the molecular structure eg. Sulphur-35 has been used in the structure determination of thiosulphate,
    - a. $S_2O_3^{-2}$ ion.
- **vii.** Radioactive isotopes are also used to study the mechanism of chemical reactions.
- **viii.** Radioactive isotopes are used to date rocks, soils, archaeological objects and mummies.

Q16. What do you mean by shells/orbits and energy level?

According to Bohr's atomic theory the electron in an atom revolves around the nucleus in one of the circular paths called shells or orbits

Each shell is described by an n value n can have values 1, 2, 3, ...

When,

n = 1, it is K shell

n = 2, it is L shell

n = 3, it is M shell etc.

As the value of increases distance of electron from the nucleus and energy of the shell increases.

Energy level:

Each shell has a fixed energy. So, each she is also called energy level

Q17. Describe the presence of sub-shells in a shell?

Ans: Sub-shells:

A shell or energy level is subdivided into sub-shells or sub-energy levels value of a shell is placed before the symbol for a sub-shell.

For instance:

i. **For K shell:**

n =1, for K shell it has only one sub-shell which as represented by 1s

ii. **For L shell:**

N = 2, L shell has two sub-shells these are designated as 2s and 2p.

iii. **For M shell:**

n = 3, So M shell has 3 sub-shells called 3s, 3p and 3d

iv. **For N shell:**

N shell has 4s, 4p, 4d and 4f sub-shell

Note:

s sub-shell can accommodate maximum 2 electrons.

p sub-shell can accommodate maximum 6 electrons.

d sub shell can accommodate maximum 10 electrons.

f sub-shell can accommodate maximum 14 electrons.

The increasing order of energy of the sub-shells belonging to different shells is

Q18. Define Auf Bau principle.

Ans: Auf Bau principle:

We can fill the electrons present in various elements by using Auf Bau Principle.

According to this principle, electrons the lowest energy sub-shell that is available first. This means electron will fill first 1s, then 2s, then 2p and so on

$$1s < 2s < 2p < 3s < 3p < 4s < 3d$$

Q19. What do you mean by electronic configuration? Explain by taking specific examples?

Ans: Electronic configuration:

Electronic configuration is the distribution arrangement of electrons among the different sub-shells of an atom.

Examples:

Electronic configuration of hydrogen:

Hydrogen has atomic number 1. So, it has only one electron that will copy lowest energy sub-shell 1s. The electronic configuration of H is $1s^1$..

Electronic configuration of helium:

Helium has atomic number 2 so it has two electrons. Since s sub-shell can accommodate two electrons so electronic configuration of. He is $1s^2$.

Electronic configuration of lithium:

Lithium has atomic number 3, so it has three electrons, two will fills sub-shell and one 2s sub-shell. So electronic configuration of Li is $1s^2\ 2s^1$.

Electronic configuration of Beryllium:

Beryllium has atomic number 4, so it has four electrons. Two of these electrons go into1s sub-shell and two will go to 2s sub-shell. Thus, electronic

$_5B = 1s^2\ 2s^2\ sp^1$

$_6C = 1s^2\ 2s^2\ 2p^2$

$_7N = 1s^2\ 2s^2\ 2p^3$

$_8O = 1s^2\ 2s^2\ 2p^4$

$_9F = 1s^2\ 2s^2\ 2p^5$

$_{10}Ne = 1s^2\ 2s^2\ 2p^6$

$_{11}Na = 1s^2\ 2s^2\ 2p^6\ 3s^1$

$_{12}Mg = 1s^2\ 2s^2\ 2p^6\ 3s^2$

SELF ASSESSMENT EXERCISE 2.3

Write the complete electronic configuration for the following elements;

1. **Al (atomic number 13)**
2. **Si (atomic number 14)**
3. **P (atomic number 15)**
4. **S (atomic number 16)**
5. **Cl (atomic number 17)**
6. **Ar (atomic number 18)**

Solution:

1. Al (atomic number 13): $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$
2. Si (atomic number 14): $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$
3. P (atomic number 15): $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$
4. S (atomic number 16): $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
5. Cl (atomic number 17): $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

Describe the electronic configuration in the sub-shell last occupied for the first eighteen elements.

Ans: Valence shell configuration of first 18 elements:

Table shows the electronic configuration in the sub-shell last occupied for the first eighteen elements.

H $1s^1$							He $1s^2$
Li $2s^1$	Be $2s^2$	B $2s^22p^1$	C $2s^22p^2$	N $2s^22p^3$	O $2s^22p^4$	F $2s^22p^5$	Ne $2s^22p^6$
Na $3s^1$	Mg $3s^2$	Al $3s^23p^1$	Si $3s^23p^2$	P $3s^23p^3$	S $3s^23p^4$	Cl $3s^23p^5$	Ar $3s^23p^6$

SELF ASSESSMENT EXERCISE 2.4

Write the electronic configuration for the following isotopes.

(a) $^{14}_{6}C$ **(b)** $^{35}_{17}C$ **(c)** $^{37}_{17}C$

Solution:

(a) $^{14}_{6}C$

$1s^2\ 2s^2\ 2p^2$

(b) $^{35}_{17}C$

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

(c) $^{37}_{17}C$

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

KEY POINTS

Rutherford's Atomic Model:

• Rutherford proposed a planetary model for an atom. The nucleus of an atom is composed of protons. The electrons Surround the nucleus and occupy most of the volume of the atom.

Bohr's atomic model:

• According to Bohr's atomic model the electron in an atom revolves around the nucleus in fixed circular orbits called shells Energy absorbed when an electron jumps to a higher energy and ended when an electron falls into a lower energy orbit.

Isotopes:

• Isotopes are atoms of an element that her in the number of neutrons.

^{235}U isotope:

• ^{235}U isotope: is used in nuclear reactors and atomic bombs.

Radioactive isotopes:

• Radioactive isotopes have many applications in science and medicines such as killing cancer cells, diagnosing thyroid problem to image the brain to detect obstruction in the circulatory system, to date rocks, soils, mummies etc.

Sub-shells:

• A shell or energy level is divided into subshells.

Electronic configuration:

• The arrangement of electrons in sub-shells called as the electronic configuration.

- According to the Auf Bau Principle electrons fill the lowest energy levels