

Unit - 19

Atomic Structure

Students Learning Outcomes (SLOs)

After learning this unit students should be able to

- Describe the structure of an atom in terms of a nucleus and electrons
- Describe the evidence for the nuclear model of the atom
- Describe the composition of the nucleus in terms of protons and neutrons
- Explain that number of protons in a nucleus distinguishes one element from the other.
- Represent various nuclides by using the symbol of proton number Z , nucleon number A and the nuclide notation ${}_Z^AX$
- Use the term isotope

There are over 100 different kinds of atoms.

Among 92 of them occur naturally, while the remainder is manufactured. Atoms are mostly empty spaces. The nucleus of an atom is dense and contains nearly all of the atomic mass. Electrons contribute very little mass to the atom (it takes 1,836 electrons to equal the mass of a proton) and orbit so far away from the nucleus that each atom is 99.9% free space.





Matter composes everything such as bacteria, animals, and plants as well as non-living things such as tables, water, planets, and stars. But the building blocks of matter are atoms. Thus, the composition of everything, living or non-living, atoms.

What the exactly atom is? What is it composed of? Let us study atoms and the structure of atoms in detail in this unit.

19.1 ATOM AND ATOMIC NUCLEUS

The structure of an atom in terms of a nucleus and electrons

Atom is the smallest unit into which matter can be divided without releasing electrically charged particles. This is too small to be seen with any ordinary microscope. However, by shooting tiny atomic particles through atoms, scientists have developed a structure model. The simple Rutherford's atomic model given below; Fig 19.1 is often used to explain the basic structure of an atom.

Every atom is composed of two parts;

- The central hard-core of an atom is the nucleus which is the small, dense region consisting of closely packed protons and neutrons.
- Around the nucleus, electrons revolve at high speed. The number of particles (electrons and protons) depends on the type of atom.

Most of the atom is empty space. The rest comprise a positively charged nucleus surrounded by negatively charged orbiting electrons. The nucleus is tiny and dense compared with the electrons. Electrons are bound by a positively charged nucleus with the electrostatic force.

Nuclear Model of the Atom

Nobody has seen an atom. To visualize the processes in the atom, various models have been proposed. Rutherford put forward one of the earliest model of the nucleus, which he derived from experiments carried out by Geiger and Marsden. Let us discuss this experiment and its results in detail.

Geiger and Marsden α - scattering Experiment

Geiger and Marsden, the two scientists, used a beam of positively charged α - particles to bombard a thin gold

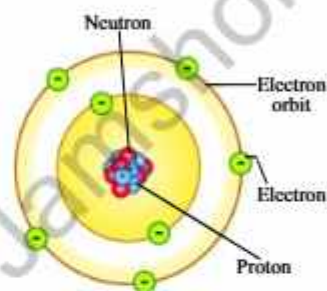


Fig: 19.1
The structure of an atom



Do You Know?

The word "atom" comes from the Greek word "undivided." The name comes from the 5th century BCE Greek philosopher Democritus, who believed matter consisted of particles that could not be divided into smaller particles. For a long time, people believed atoms were the fundamental "undividable" unit of matter.

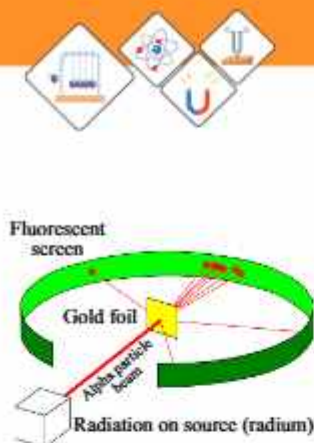


Fig: 19.2
Experimental arrangement of Geiger and Marsden α -scattering

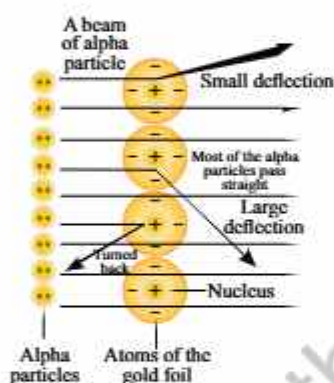


Fig: 19.3.
Scattering of α -particles by a nucleus

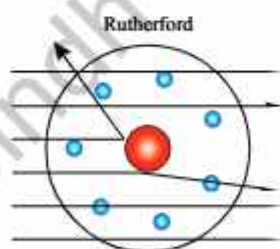


Fig: 19.4
Close up view of scattering of α -particles by a nucleus

foil placed in a vacuum surrounded by a ring-shaped fluorescent screen. After bombarding the foil, the scattered α - particles were detected using a rotating detector. When α - particles hit the screen of light was observed through the detector; Fig 19.2.

Geiger and Marsden found quite unpredicted experimental results that most of the α - particles were not deflected or only a few deflected through small angles. The unexpected result was that a small number of the α - particles were deflected through considerable large angles of more than 90° , and a few of the α - particles were even deflected back through nearly 180° .

To explain these observations, Rutherford postulated an atomic model. The nucleus carries all the positive charge of atom and nearly all its mass, as a large number of α - particles passing through the foil undeflected suggest that there exist large empty spaces in an atom and those positively charged α - particles that deflected through large angles had come very close to the positively charged nucleus. However, a few were repelled so strongly that they bounced back or deflected through large angles, as shown in figures 19.3 and 19.4.

Self-Assessment Questions:

Q1: What the center of an atom is called?

Q2: Where are the electrons found inside an atom?

19.2 PROTONS, NEUTRONS

The composition of the atom

We studied in previous classes that atoms consist of three elemental particles: electrons, protons, and neutrons. The outermost region of the nucleus is called electron shell. It contains electrons. Electrons have a negative (-) charge. The nucleus contains the neutrons and the protons bound tightly together by the nuclear forces (gluons) as shown in figure 19.5. Neutrons carries no charge. The mass of a neutron is slightly larger than that of a proton. Proton have an equal positive (+) charge that of an electron in magnitude. An atom usually has an equal number of protons as electrons, so its net charge is zero. Therefore atom is



considered neutral. Atoms have different properties depending upon the arrangement and number of their elemental particles;



Fig: 19.5

The strong force binds quarks together in clusters to make more-familiar subatomic particles, such as protons and neutrons. It also holds together the atomic nucleus and underlies interactions between all particles containing quarks.

Table 19.1

The relative masses and charges of particles in an atom

Name of Particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	1/1836	-1

The branch of physics concerned with the study and understanding of the atomic nucleus, including its composition and the forces which bind it together, is called nuclear physics.

Self Assessment Questions:

Q1: An atom consists of electrons revolving around the nucleus made of neutrons and protons. State which of these particles have

- An equal and opposite charge
- Almost equal mass.

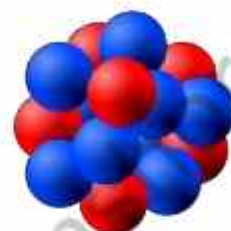


Fig: 19.6
A model of the atomic nucleus showing it as a compact bundle of the two types of particles: protons (red) and neutrons (blue)



Weblinks

Encourage students to visit below link for Atom and its composition
https://www.youtube.com/watch?v=pNroKcV2fgk&ab_channel=FuseSchool-GlobalEducation



Do You Know?

Only electron is fundamental particle



Do You Know?

If the atom is the size of a football ground, the nucleus would be the size of a pea. Although the nucleus is much denser than the rest of the atom.



Weblinks

Encourage students to visit below link for Atomic Number

https://www.youtube.com/watch?v=D3GR6thtApl&ab_channel=Don%27tMemorise

19.3 ELEMENTS

All materials are made from about 100 essential substances known as elements. The smallest part of an element is an atom. How is it possible to find the characteristics that differ between each element and distinguish one element from another? Each element have a unique number of protons.

The number of protons in the nucleus of an atom in an element is called atomic number (Z).

The atomic number distinguishes one element from another. For example, the atomic number (Z) of carbon is six because it has 6 protons, and the atomic number (Z) of nitrogen is seven because it has 7 protons. There are some other examples given in table 19.2. The atomic number also tells you the number of electrons in that atom.

Table 19.2.
Atoms of the first eight elements of the periodic table

Name of Element	Protons $P = Z$	Neutrons $N = A - Z$	Electrons $\bar{e}$	Atomic Number $Z = P^+$	Atomic Mass (A)
Hydrogen	1	0	1	1	1
Helium	2	2	2	2	4
Lithium	3	4	3	3	7
Beryllium	4	5	4	4	9
Boron	5	6	5	5	11
Carbon	6	6	6	6	12
Nitrogen	7	7	7	7	14
Oxygen	8	8	8	8	16

Nuclides

An atom of an element has all the characteristics of that element. The nucleus is at the center of the atom and contains the protons and neutrons, which are collectively called nucleons. The number of protons in an atom of an element is called the atomic number, (Z). The number of neutrons in the nucleus is the neutron number, (N).

The number of protons and neutrons is collectively known as nucleon number (A) or atomic mass (A).



The total number of nucleons is the atomic mass, A . Table 19.2. These numbers are related by the symbol A .

$$A = Z + N$$

A nucleus is represented symbolically by:

$${}_Z\text{X}^A$$

Where X represents the nuclide of a chemical element, A is the nucleon number, and Z is the atomic number.

For example, ${}_6\text{C}^{12}$ represents the carbon nucleus with six protons and twelve nucleons. Thus, the total orbiting electrons are also six, and the neutron number is:

$$A = Z + N$$

$$N = A - Z$$

$$N = 12 - 6$$

$$N = 6$$

Self-Assessment Questions:

Q1: The nuclide notation for the uranium-235 is ${}_{92}\text{U}^{235}$. Determine the proton number, electron number, neutron number, and nucleon number of the uranium.

19.4 ELEMENTS AND ISOTOPES

Isotopes

The atoms of an element are not exactly alike. Some may have more neutrons than others. These different variants of the elements are called isotopes.

Two or more species of atoms of an element with the same atomic number, (Z) have different atomic mass, (A) is called Isotopes.

Most elements have mixture of two or more isotopes. For example, the hydrogen atom (atomic number 1) has three isotopes with atomic masses 1, 2, and 3. You can see how to represent an atom of Hydrogen using symbols and numbers in the table 19.3 given below.

Table 19.3. Isotopes of the Hydrogen atom

Name of Isotope	Proton number, Z	Neutron Number, N	Atomic Mass, A	Symbol
Protium	1	0	1	${}_1\text{H}^1$
Deuterium	1	1	2	${}_1\text{H}^2$
Tritium	1	2	3	${}_1\text{H}^3$

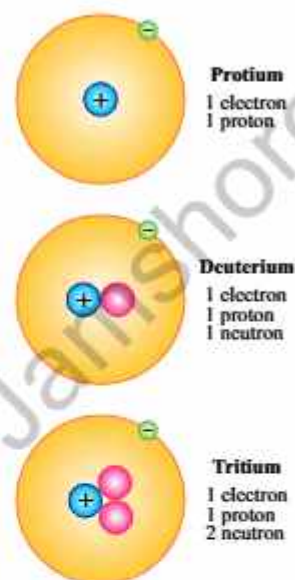


Fig: 19.7.
Isotopes of hydrogen

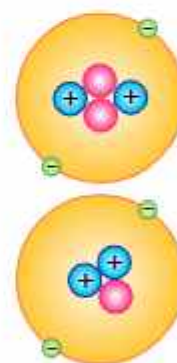


Fig: 19.8.
Isotopes of helium



Do You Know?

The elements with the most isotopes are Cesium and Xenon with 36 known isotopes.



Do You Know!

The term isotope is formed from the Greek roots isos "equal" and topos "place", meaning "the same place"; thus, the meaning behind the name is that different isotopes of a single element occupy the same position on the periodic table.

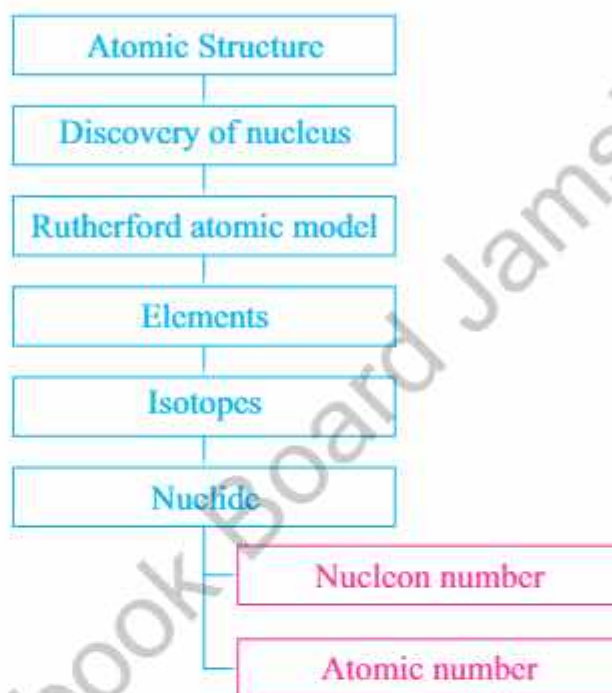
Every element has a specific position in the periodic table and nearly identical chemical behavior or properties with the same number of electrons.

Many other essential properties of an isotope depend on its mass. The total number of neutrons and protons in the nucleus of mass number (symbol A) gives it different physical properties, i.e. mass, surface area, volume, and density.

Isotopes are two or more species of atoms of an element with identical chemical properties that have different physical properties.



CONCEPT MAP





SUMMARY

- Everything around us is made up of atoms.
- Atom is the smallest unit of matter.
- Every atom is composed of two parts; the nucleus and the shell.
- The nucleus is a central small and dense part of the atom that contains protons and neutrons.
- The shell part of the atom contains electrons that orbit at high speed around the nucleus.
- Most of the atom is an empty space.
- In an atom, electric forces bind the electrons to the nucleus.
- An atom consists of three elemental particles: electrons, protons, and neutrons.
- Each element, however, does have a unique number of protons in its nucleus.
- The number of protons in an atom of an element is called the atomic number.
- The number of protons and neutrons in an atom is known as nucleons.
- The total number of nucleons in an atom is called the mass number.
- Isotope has the same atomic number but a different mass number.

Section (A) Multiple Choice Questions (MCQs)

Choose the correct answer from the following choices:

1. ${}^2_1\text{H}$ and ${}^3_1\text{H}$ are:
a) Isotopes b) Isobars
c) Isotones d) Isochores
2. The neutral atoms of all of the isotopes of the same element have
a) different numbers of protons.
b) exact numbers of neutrons.
c) An exact number of protons.
d) An exact number of nucleons.
3. Consider the species ${}_{17}\text{Cl}^{35}$, and ${}_{17}\text{Cl}^{37}$. These species have:
a) the exact number of nucleons
b) the exact number of protons
c) the exact number of neutrons.
d) the exact mass number.
4. Atomic mass of an element is equal to
a) Mass of protons and neutrons
b) Mass of protons and electrons
c) Mass of electrons and neutrons
d) Mass of protons only



5. The maximum mass of an atom is concentrated in:
a) nucleus b) neutrons
c) protons d) electrons
6. Consider isotope ${}_{92}\text{U}^{237}$ of uranium. The number of neutrons in it is:
a) 92 b) 237
c) 145 d) 329
7. The symbol denotes the proton number is:
a) P b) A
c) N d) Z
8. The number of neutron(s) in Protium is:
a) no b) one
c) two d) three
9. In an atom, the nucleus when compared to the extra-nuclear part, is
a) More significant in volume and heavier in mass
b) smaller in volume but heavier in mass
c) More significant in volume but lighter in mass
d) Smaller in volume and lighter in mass
10. If an element B has five protons and six neutrons what will be the symbol of element B
a) ${}_{11}^6\text{B}$ b) ${}_{11}\text{B}$
c) ${}_{11}^5\text{B}$ d) ${}_{11}^5\text{B}$

Section (B) Structured Questions

1. (a) Which particles are found in the nucleus of an atom?
(b) Describe the structure of an atom.
(c) How does the number of protons in a nucleus distinguish one element from the other?
2. (a) Cite the Geiger Marsden experiment with the help of a diagram.
(b) Give the Rutherford model of an atom.
(c) Why it was proposed that most atoms possess an empty space.
3. (a) Define Atomic number (Z)
(b) Explain the symbolic representation of an atom of an element. Give an example.
4. (a) What is the isotope?
(b) Explain the isotope with an example.
(c) Why are the chemical properties of an element's different isotopes identical?
(d) List the physical properties of different isotopes of an element that are different.

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