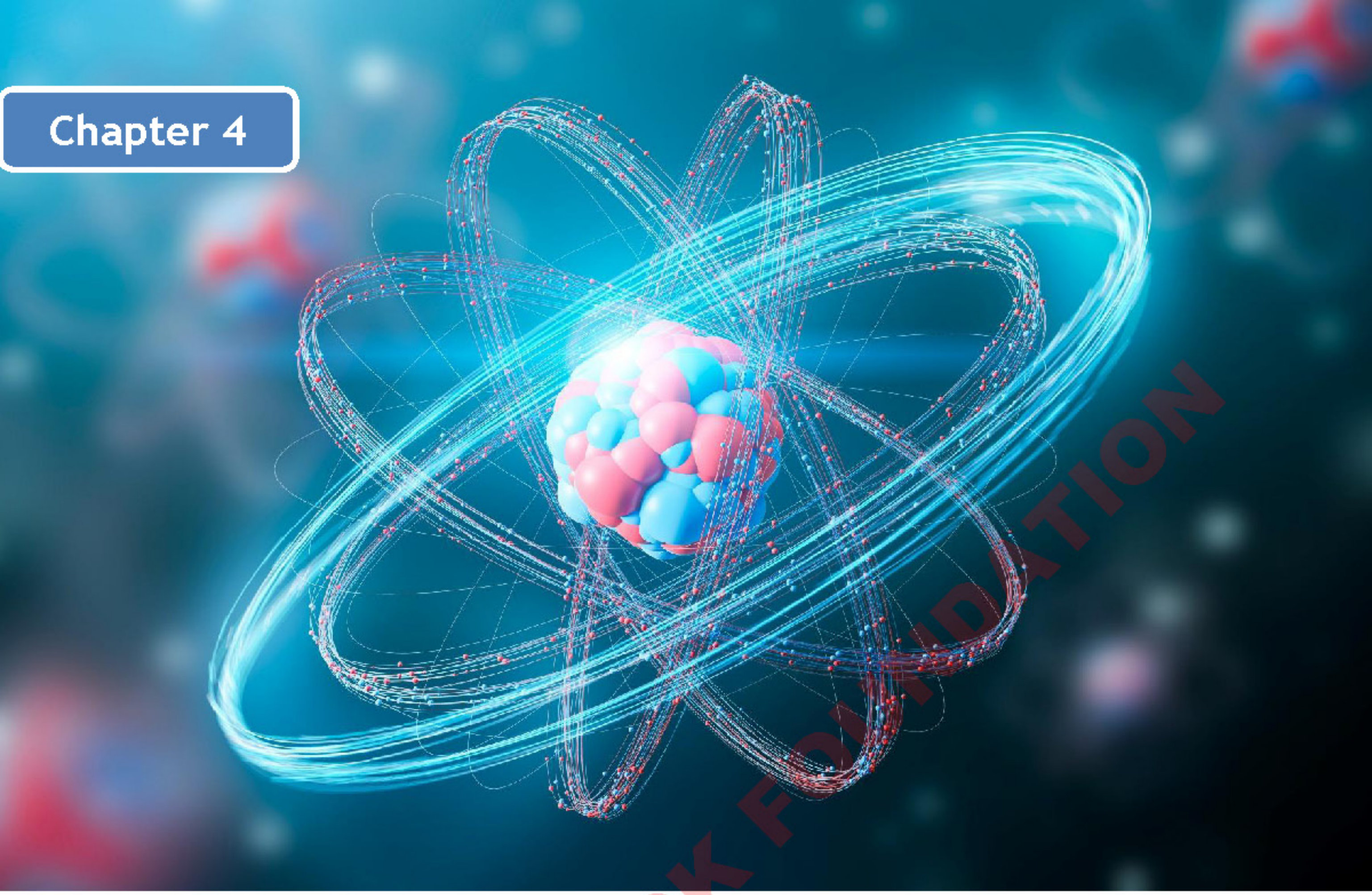
Chapter 4



STRUCTURE OF ATOM

SLOs: After completing this lesson, the student will be able to:

1. describe the structure of an atom including the location on electric charges of proton, electron and neutron.
2. Draw atomic structure of the first twenty elements of the periodic table.
3. Determine the number of protons, neutrons, and electrons in different isotopes of hydrogen carbon oxygen chlorine and uranium.
4. Describe Rutherford’s experiment leading to the discovery of atomic nucleus.
5. Describe the defects of Rutherford’s atomic model.
6. List the main postulates of Bohr’s atomic model.

4.1 ATOM

Everything in the world is made of tiny things called atoms. An atom is like a building block of stuff. The word 'atom' comes from Greek and means 'indivisible' because atoms are the smallest bits of stuff and can't be broken into smaller pieces.

Atoms are made of even smaller parts called protons, neutrons, and electrons.

Each element has its own atoms, and they all have the same number of protons and electrons, which makes them neutral.

The center of the atom is called the nucleus. It has the protons, which are positive, and the neutrons, which have no charge.(Table 4.1) Around the nucleus, there are regions called electronic shells, where the electrons, which are negative.

Atoms have different characteristics depending on how their parts are arranged and how many of each part they have.

DO YOU KNOW

Empty Space: Despite appearances, atoms are mostly empty space. If you removed all the empty space from the atoms in the human body, the entire world population could fit into an apple.

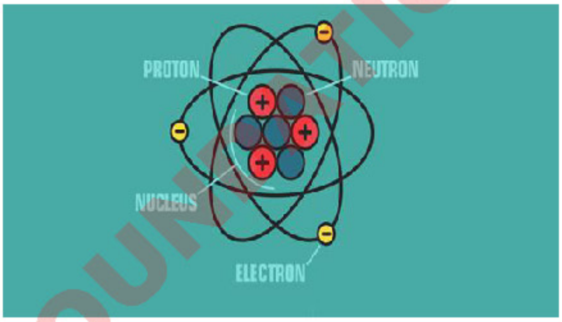


Fig. 4.1 Structure of an atom

Table4.1Protons, Neutrons, and Electrons			
	Charge	Mass (amu)	Location
Proton	+1	1	Nucleus
Neutron	0	1	Nucleus
Electron	-1	0	Orbitals

4.2. ARRANGEMENT OF FIRST 20 ELEMENTS IN THE PERIODIC TABLE

The periodic table is like a list of all the elements, organized by their number of protons. The number of protons in an atom is also called the atomic number. For example, hydrogen (H) is the first element on the list.

Atomic structure is like a picture that shows where electrons are inside an atom. Electrons move around in different layers called shells, named with letters like K, L, M, and so on.

The atomic number and symbols are important in chemistry. Symbol is a one- or two-letter abbreviation of the name of the

For your Information:

Tiny Yet Massive: If an atom were magnified to the size of a football field, the nucleus would be about the size of a pea, but the pea would contain 99.9% of the atom's mass.

Interesting Information

Electron Dance: Electron move so quickly and unpredictably that their precise location can only be described as a probability cloud, leading to the concept of the electron dance the nucleus element. While writing long chemical equations, we need to write a short form of the compounds and elements that time these symbols are very useful. The atomic number of elements gives an idea about the atomic structure of elements, such as how many electrons and protons that particular element has. The first 20 elements of the periodic table are given in the figure below.

Fun Facts:

Lithium - Lithium is one of the lightest metals on the periodic table. ...

Beryllium - Beryllium has a high melting point and an amazing ability to dissipate heat. ...

Sodium - The production of paper uses sodium hydroxide to separate fibers. ...

Magnesium - Magnesium is light weight metal.

Each shell can hold a certain number of electrons. You can find out how many electrons a shell can hold by using a simple formula: $2n^2$, where 'n' is the number of the shell. (Table 4.2)

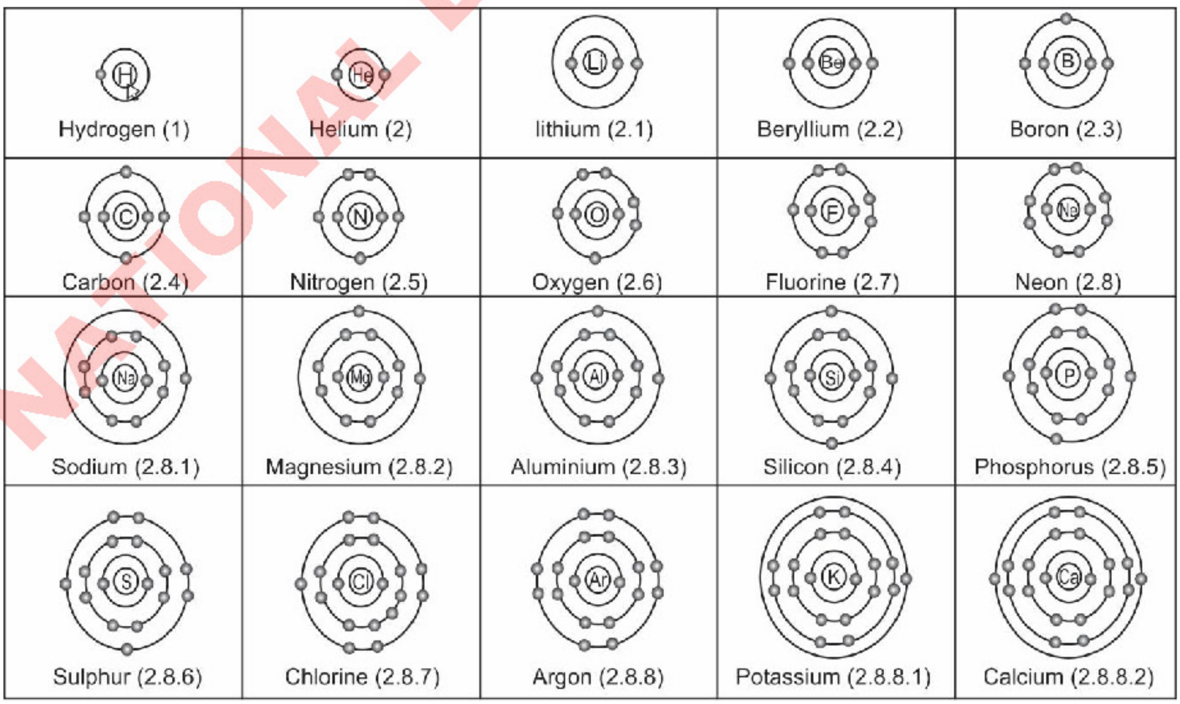
Do you know?

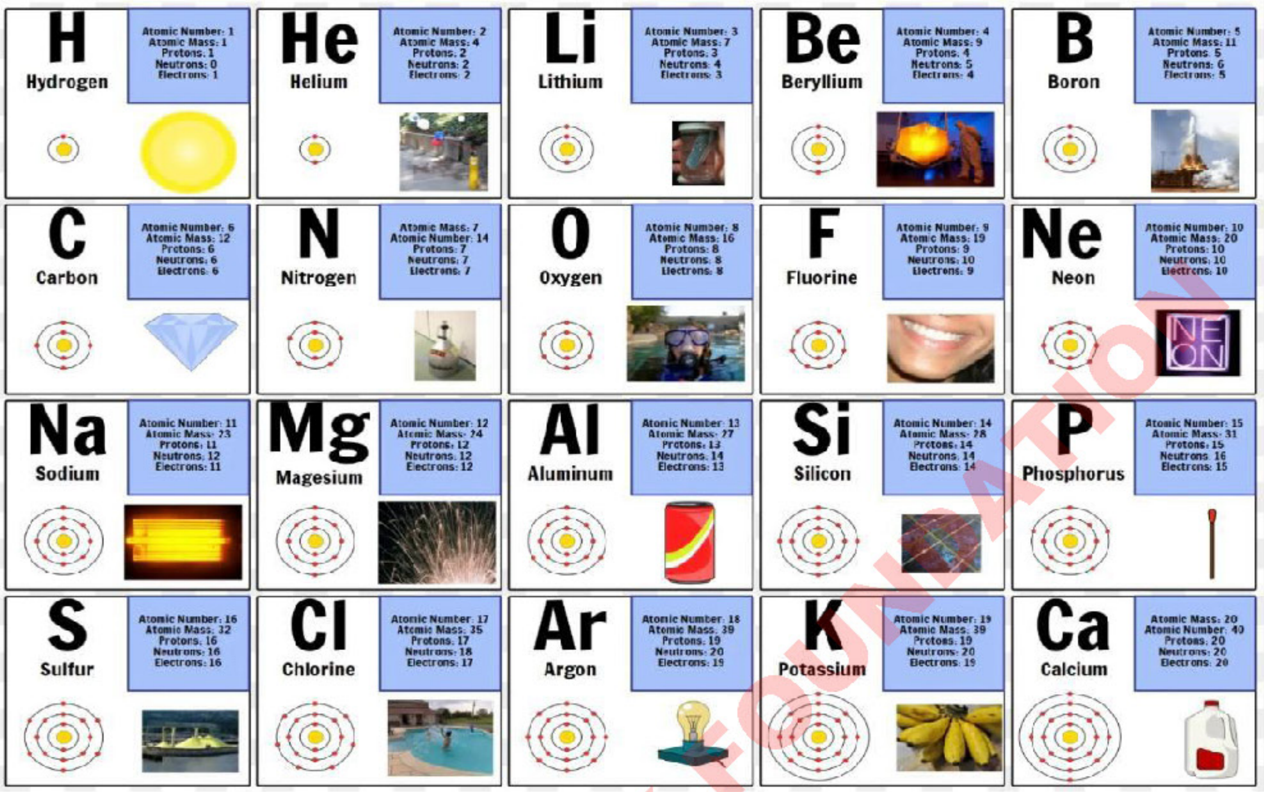
What special about first twenty elements

The first 20 elements provide a great overview of the various element groups. They can also be found in more common chemical processes.

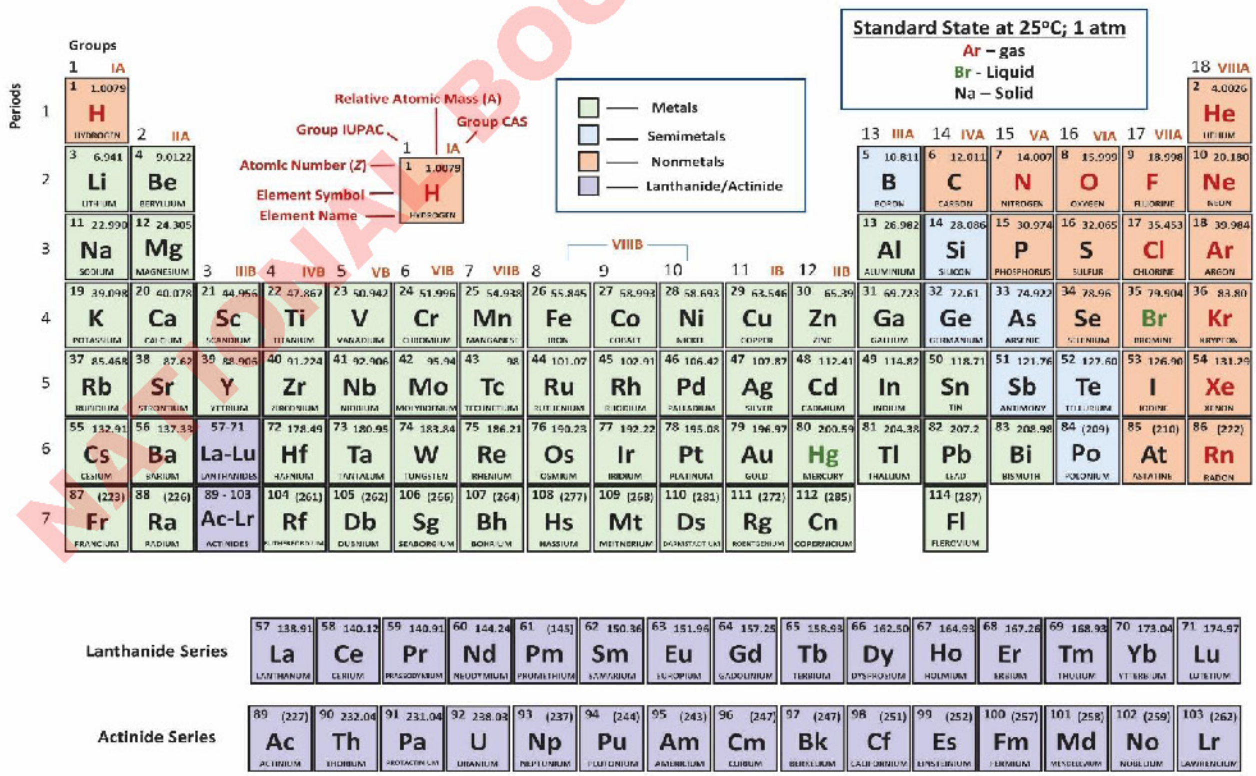
knowing about the first twenty elements of the periodic table is the basic step in order to gain knowledge about all the elements. The atomic number of an element tells us how many protons are in its nucleus and how many electrons orbit around it. For instance, sodium has an atomic number of 11, meaning its nucleus holds 11 protons and it's orbited by 11 electrons. Because an atom's atomic number equals its electron count, we can figure out its electron arrangement simply by knowing its atomic number.

Table4.2 Electron arrangements of the first 20 elements in the Periodic Table





Periodic Table of the Elements



4.3. ISOTOPE

Every atom of an element has the same number of protons and electrons, which makes it balanced and gives it a neutral charge. The number of protons in an atom is called its atomic number, like its ID card that tells us where it belongs in the periodic table.

Atoms can have different numbers of neutrons. When this happens, we get isotopes, which are just different versions of the same atom. Isotopes might have the same number of protons, but they have different numbers of neutrons.

Do You Know

Like a person has a skeleton, muscles, and skin, an atom has its construction. If you look at the illustrations of its structure, you will see:
centre or nucleus;
so-called cloud that surrounds the centre.

The total number of protons and neutrons in an atom adds up to its mass number. And since isotopes can have slightly different mass numbers, scientists calculate the atomic mass by finding the average mass number of all the isotopes of an element.

Fact about Isotopes:

All elements have isotopes. There are two main types of isotopes: stable and unstable (radioactive). There are 254 known stable isotopes. All artificial (lab-made) isotopes are unstable and therefore radioactive; scientists call them radioisotopes.

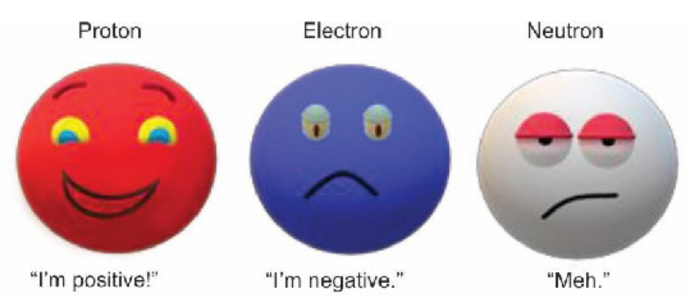
Atomic Number

Every atom of an element has the same number of protons and electrons, which makes it balanced and gives it a neutral charge. The number of protons in an atom is called its atomic number, like its ID card that tells us where it belongs in the periodic table.

Atoms can have different numbers of neutrons. When this happens, we get isotopes, which are just different versions of the same atom. Isotopes might have the same number of protons, but they have different numbers of neutrons.

Mass Number

An element's mass number (A) is the total of its protons and neutrons. To calculate number of neutron of an element can be done by subtracting the number of protons from its mass number. Protons and neutrons both weigh about the same, which is one atomic mass unit (amu).



Isotopes of the same element have the same number of protons but different numbers of neutrons. Isotopes are different types of atoms of the same element. So, they have the same atomic number but different mass numbers. For example, elements like hydrogen, oxygen, carbon and uranium have different types of isotopes as given in table 4.3

For example, carbon has two common isotopes: carbon-12 and carbon-14.

Table 4.3 Mass of some Isotopes				
Element	Isotope	Protons	Neutrons	Mass Number (Amu)
Carbon	Carbon-12	6	6	12
Carbon	Carbon-12	6	8	14

Element	Isotope	Atomic Mass (Amu)	Isotopic Mass (Amu)	Isotope Mass Number	Percent Abundance (%)
Hydrogen	Hydrogen 1	1.007825	1.007825	1	99.985
Hydrogen	Deuterium	2.014102	2.014102	2	0.015
Boron	Bron-10	10.012937	10.012937	10	19.9
Boron	Boron-11	11.009305	11.009305	11	80.1
Carbon	Carbon-12	12.000000	12.000000	12	98.89
Carbon	Carbon-13	13.003355	13.003355	13	1.11
Oxygen	Oxygen-16	15.994915	15.994915	16	99.76
Oxygen	Oxygen-18	17.999160	17.999160	18	0.04
Chlorine	Chlorine-37	36.965903	36.965903	37	24.23
Iron	Iron-56	55.934939	55.934939	56	91.72
Iron	Iron-57	55.935939	55.935939	57	2.2
Iron	Iron-58	57.933273	57.933273	58	0.28
Uranium	Uranium 238	238.050786	238.050786	238	99.2745
Uranium	Uranium 235	235.043929	235.043929	235	0.7200
Uranium	Uranium 234	234.040948	234.040948	234	0.0055

The **chemical properties** of an element tell us how it will behave when it reacts with other elements. These properties are determined by the number of electrons in the atom, which is the same as the atomic number. That means isotopes of the same element have the same chemical properties. However, even though isotopes have the same chemical properties, they can have different numbers of neutrons whereas **physical properties**, like boiling and freezing points ,densities depend on nucleon number. So, isotopes of the same element might have different physical properties.

Examples of Isotopes

Carbon: Carbon-12: 6 protons, 6 neutrons, 6 electrons
Carbon-13: 6 protons, 7 neutrons, 6 electrons
Carbon-14: 6 protons, 8 neutrons, 6 electrons

Oxygen: Oxygen-16: 8 protons, 8 neutrons, 8 electrons
Oxygen-17: 8 protons, 9 neutrons, 8 electrons
Oxygen-18: 8 protons, 10 neutrons, 8 electrons

Fluorine: Fluorine-17: 9 protons, 8 neutrons, 9 electrons
Fluorine-18: 9 protons, 9 neutrons, 9 electrons
Fluorine-19: 9 protons, 10 neutrons, 9 electrons

Chlorine: Chlorine-35: 17 protons, 18 neutrons, 17 electrons
Chlorine-37: 17 protons, 20 neutrons, 17 electrons

Uranium: Uranium-235: 92 protons, 143 neutrons, 92 electrons
Uranium-238: 92 protons, 146 neutrons, 92 electrons

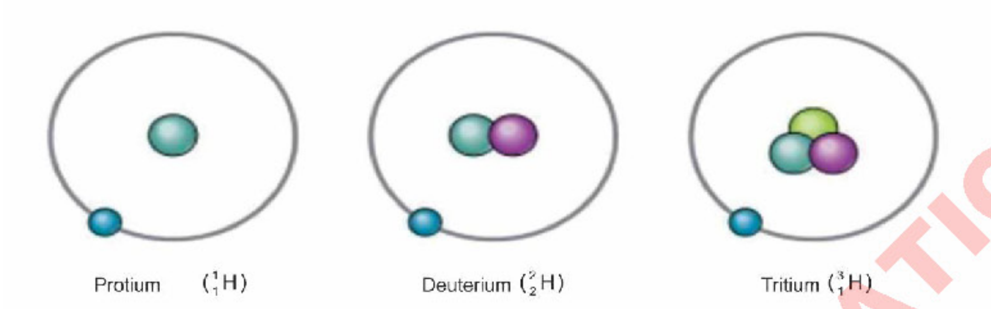


Fig 4.2. Isotopes of Hydrogen

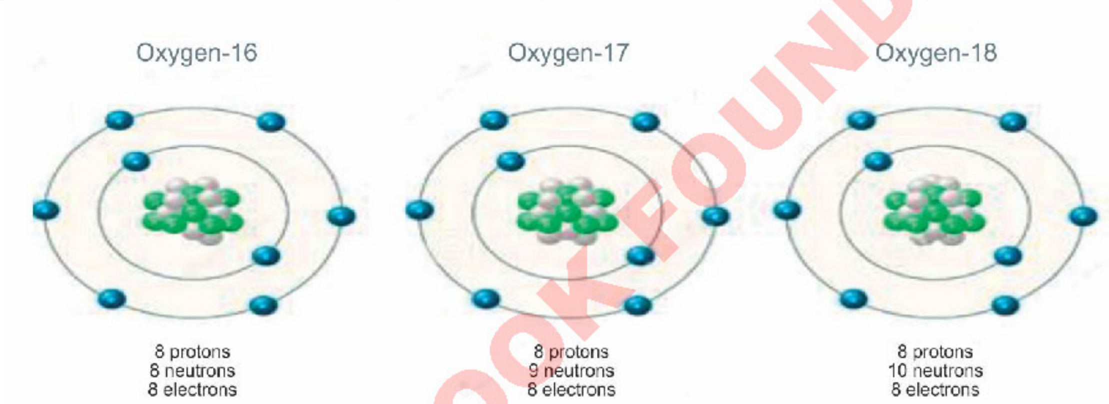


Fig 4.3. Isotopes of Oxygen

Uses of Isotopes

1. Carbon-14: This is a special kind of carbon that is found in the air. Scientists use it to learn about fossils
2. Uranium isotopes (like U-235): These are important for making something called nuclear energy.
3. Arsenic-74: It helps to find tumors in our bodies.
4. Sodium-24: It helps to find blood clots.
5. Cobalt-60: This is another kind of isotope. It's used to help treat cancer.

4.4. RUTHERFORD'S EXPERIMENT

Ernest Rutherford was a scientist from Britain who did an important experiment with tiny particles called alpha particles. He shot these particles at a very thin piece of gold and watched what happened. Some of the particles bounced back, which surprised him.

Rutherford thought about this and came up with a new idea about atoms. He said atoms have a middle part called the nucleus, which is heavy and has a positive charge. Around the nucleus, there are small, light particles called electrons, which move around like planets around the sun. This idea is called Rutherford's Atomic Model. In his experiment, Rutherford found that most alpha particles passed straight through the gold foil. This discovery showed that atoms are mostly empty space. He realized that the centre of the atom, called the nucleus, is very tiny but heavy. Around this nucleus, tiny electrons move in orbits, kind of like planets around the sun.

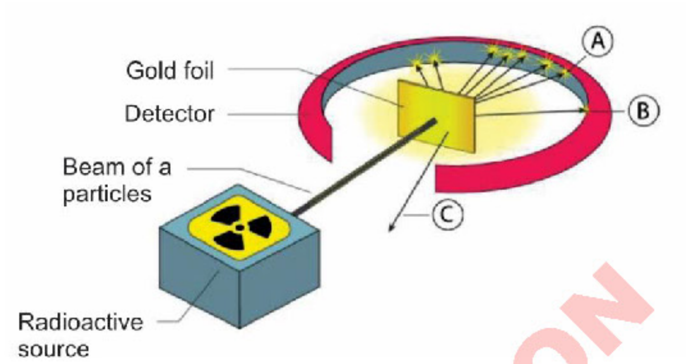


Fig. 4.4: Rutherford's Experiments

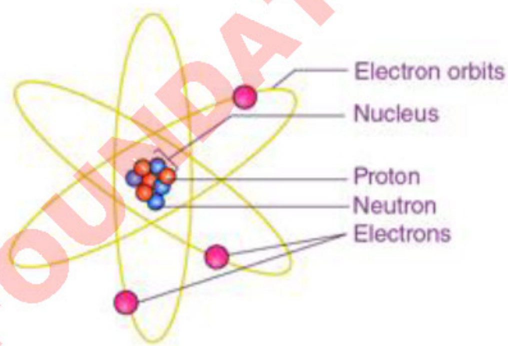


Fig. 4.5: Fig. 9.4 Rutherford Atomic Model

The observations made by Rutherford

Rutherford made some important discoveries about atoms:

1.Most of an atom is empty space: He found that many tiny particles called alpha particles could pass through a gold sheet without changing direction much. This showed that most of an atom is like empty space.

2.Positive charge isn't spread out: Some alpha particles were deflected slightly, showing that the positive charge in an atom isn't spread out evenly. Instead, it's concentrated in a small area.

3.Atom's positively charged part is tiny: Only a few alpha particles bounced straight back. This meant that the space taken up by the positively charged part of an atom is very small compared to the whole size of the atom.

So, Rutherford's experiments helped us understand that atoms have mostly empty space, their positive charge is concentrated in a small area, and their positively charged part is very tiny.

Postulates of Rutherford's model of an atom:

RutherFord had following ideas about atom

1. **Nucleus**: Most of the atom's mass is in a small, dense part called the nucleus.

2. **Positive Nucleus**: The nucleus has a positive charge, while the rest of the atom is mostly empty space.

3. **Electrons Orbit**: Tiny, negatively charged particles called electrons move around the nucleus in fixed paths called orbits or energy levels.

4. **Electron Movement**: Electrons can move between these orbits, but they can only exist in certain allowed energy levels.

5. **Outer Orbit:** The number of electrons in the outer orbit of an atom decides its chemical behavior and how it connects with other atoms.

6. **Electron Space**: Even though electrons are much smaller than the nucleus, they take up a lot of space around the nucleus, which gives the atom its size.

So, Rutherford's model told us about the nucleus in the center, electrons moving around it, and how atoms interact with each other.

4.5 LIMITATIONS OF RUTHERFORD MODEL OF THE ATOM

Rutherford's model of the atom had some limitations:

1. **Stability Issue**: Rutherford's model couldn't explain why atoms stay together without collapsing.

2. **Electron Movement**: It didn't say exactly how electrons move in their circular paths around the nucleus. According to Rutherford, electrons move quickly around the nucleus in circles, but this model didn't explain why moving electrons don't lose energy and fall into the nucleus.

3. **Energy Emission**: Any particle moving in circles should give off energy, but Rutherford's model didn't talk about this.

4. **Arrangement of Electrons**: Rutherford's model didn't describe how electrons are arranged in these circular orbits, leaving some important details out. Later, a scientist named Niels Bohr suggested a better way of arranging electrons in atoms.

So, while Rutherford's model was a big step forward, it still had some unanswered questions. Later scientists, like Niels Bohr, helped to fill in these gaps and improve our understanding of atoms.

4.6. BOHR'S ATOMIC MODEL

According to the Bohr Atomic model, a compact nucleus with a positive charge is encircled by orbiting electrons carrying negative charges in fixed paths. Bohr deduced that electrons possess greater energy when situated farther from the nucleus, while their energy decreases when they are closer to it.

Bohr improved upon Rutherford's model of the atom. In Rutherford's model, the nucleus is positively charged and surrounded by negatively charged electrons. According to Bohr, electrons move in fixed paths called orbits and reside in specific energy levels within these orbits. While Rutherford focused on the nucleus, Bohr expanded the model by detailing the behavior of electrons and their distinct energy levels.

Postulates of Bohr Atomic Model

1. **Nucleus:** Atoms have a tiny center called the nucleus, where all the atom's mass is found.

2. **Electron Movement**: Electrons move around the nucleus in circular paths called orbits or shells. These paths are also called energy levels and are named with letters like K, L, M, N, or numbers like 1, 2, 3, 4, and so on.

3. **Stationary Orbits**: These paths, called "stationary orbits," are like set pathways where electrons stay without gaining or losing energy. Each orbit has a specific amount of energy.

4. Energy Levels: Different orbits have different amounts of energy, which are marked by numbers called quantum numbers, like n=1, 2, 3, and so on. The lower energy levels are named K, L, M, and N. The lowest energy level is called the ground state.

5. Energy Changes: When an electron moves between these orbits, its energy changes. It gains energy when it moves to a higher orbit and loses energy when it moves to a lower one.

So, atoms have a small nucleus in the center, and electrons move around it in specific paths called orbits, with each orbit having its own energy level.

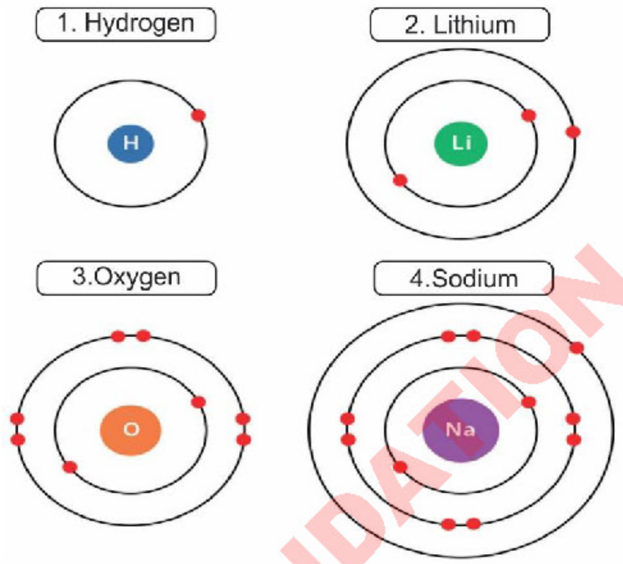


Fig. 4.6. Examples of Bohr's Atomic Model

Therefore,

1st orbit (energy level) is represented as K shell and it can hold up to 2 electrons.

2nd orbit (energy level) is represented as L shell and it can hold up to 8 electrons.

3rd orbit (energy level) is represented as M shell and it can contain up to 18 electrons.

4th orbit (energy level) is represented as N Shell and it can contain maximum 32 electrons.

The orbits continue to increase in a similar manner.

SUMMARY

1. The atomic number is the number of protons in an element, while the mass number is the number of protons plus the number of neutrons.
2. The number of neutrons is variable, resulting in isotopes, which are different forms of the same atom that vary only in the number of neutrons they possess.
3. Together, the number of protons and the number of neutrons determine an element's mass number.
4. Since an element's isotopes have slightly different mass numbers, the atomic mass is calculated by obtaining the mean of the mass numbers for its isotopes.
5. Isotopes are atoms of the same element that contain an identical number of protons, but a different number of neutrons.
6. Despite having different numbers of neutrons, isotopes of the same element have very similar physical properties.
7. Rutherford conducted an experiment by bombarding a thin sheet of gold with α-particles and then studied the trajectory of these particles after their interaction with the gold foil.

   Rutherford described the atom as having a tiny, dense, and positively charged core called the nucleus.
8. Rutherford established that the mass of the atom is concentrated in its nucleus.

9. The light, negatively charged, electrons circulated around this nucleus, much like planets revolving around the Sun.
10. Main Points of the Bohr Model
    a) Electrons revolve around the nucleus in a fixed circular path termed “orbits” or “shells” or “energy level.”The orbits are termed as “stationary orbit.”
    b) Every circular orbit will have a certain amount of fixed energy
    c) The different energy levels are denoted by integers such as n=1 or n=2 or n=3 and so on. These are called quantum numbers.
    d) The different energy levels or orbits are represented in two ways such as 1, 2, 3, 4... or K, L, M, N..... shells. The lowest energy level of the electron is called the ground state.
    e) The change in energy occurs when the electrons jump from one energy level to other. In an atom, the electrons move from lower to higher energy level by acquiring the required energy. However, when an electron loses energy it moves from higher to lower energy level.

EXERCISE

Section I: Multiple Choice Questions

Select the correct answer:

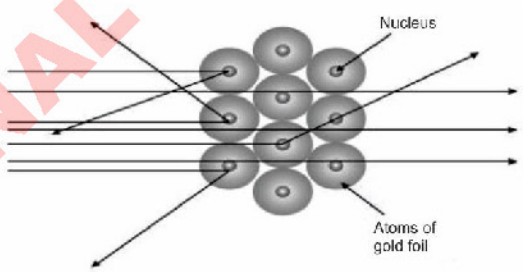
1- An atom becomes negatively charged by.

A) Gaining an electron
B) Losing an electron
C) Losing a proton
D) Gaining a neutron

2- How many neutrons does an atom of hydrogen contain?

A) 3
B) 1
C) 0
D) 2

3- The diagram represents Rutherford's Gold Foil experiment. Which statement is a conclusion that came from this experiment?



A) Electrons orbit the nucleus in rings at set distances.
B) The nucleus of an atom is made of protons and neutrons.
C) The probable location of electrons can be predicted using a cloud model.
D) Most of an atom is empty space and its mass is concentrated in its center.

4- The space surrounding the nucleus is called the

A) Electron cloud
B) Ionic field
C) Nucleus field
D) Proton cloud

5- What does atomic number of an element indicate indicates?

A) Neutron plus number of protons in the nucleus
B) Electron in the nucleus
C) Neutron in the nucleus
D) Proton in the nucleus

6- How many neutrons are there in an atom of potassium

A) 19 B) 20 C) 39 D) 58

7- The neutral atoms of all of the isotopes of the same element have

A) Different numbers of protons
B) Equal numbers of neutrons
C) The same number of electrons
D) The same mass numbers

8- Which of the following determines the atomic number of an atom?

A) Number of electrons.
B) Number of protons.
C) Number of electrons and protons.
D) Number of protons and neutrons.

9. Rutherford carried out experiments in which a beam of alpha particles was directed at a thin piece of metal foil. From these experiments he concluded that:

A) Electrons are massive particles.
B) The positively charged parts of atoms are moving about with a velocity approaching the speed of light.
C) The positively charged parts of atoms are extremely small and extremely heavy particles.
D) The diameter of an electron is approximately equal to that of the nucleus.

10. Which of the following statements you think is wrong regarding α particle scattering effect?

A) A particles mostly move through the gold foil having zero deflection
B) A small fraction are deflected
C) One in Twenty Thousand turns 180°
D) The thickness of the gold foil is about 100μm

Section II: Short Answer Questions

1. What are subatomic particles?
2. Why is the atomic nucleus important?
3. How do the atomic structures of isotopes vary?
4. What is inside an atomic nucleus?
5. What are the shortcomings of Rutherford's atomic model?
6. How can the total number of neutrons in the nucleus of a given isotope be determined?
7. What is structure of an Atom?
8. Draw structure of carbon atom?
9. Name three subatomic particles?
10. How big is an atom?

Section III: Extensive Answer Questions

1. Write features of Bohr's atomic theory?
2. What is the brief review of the atomic structure of an atom?
3. What is the basic concept of atomic structure?
4. Why did Rutherford use alpha particles?
5. Why was Rutherford's model rejected?
6. Why did Rutherford use gold foil?
7. Draw electronic structure of Sodium, Chlorine and Nitrogen?
8. How many atoms of nitrogen are in the formula NH_4OH?
9. How many atoms of oxygen are in Sn(SO4)2?
10. Differentiate between Rutherford Model and Bohr Atomic model?

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