was discovered later on by Chadwick in 1932. It was called **neutron.**

Protons and neutrons present in the nucleus are collectively called **nucleons.**

(iv) The nucleus is surrounded by negatively charged electrons which balance the positive charge on the nucleus. Thus, the atom is electrically neutral.

(v) The electrons are not stationary but are revolving around the nucleus at very high speeds like planets revolving around the sun. As a result, the electrons are also called *planetary electrons.**

Thus, the Rutherford's model of atom resembles the solar system in which the nucleus plays the role of the sun and revolving electrons play the role of planets.

(vi) The electrons and the nucleus are held together by electrostatic forces of attraction.

(vii) Most of the space in an atom between the nucleus and the revolving electrons is empty.

CONCEPT OF ATOMIC NUMBER, MASS NUMBER AND DISCOVERY OF NEUTRON

In 1913, Moseley determined the magnitude of the positive charge on the nucleus of an atom by studying the nature of X-rays emitted by different elements. *The number of unit positive charges carried by the nucleus of an atom is termed as* **the atomic number.** Since the positive charge on the nucleus is due to the presence of protons in it and each proton carries one unit positive charge, therefore, the atomic number is numerically equal to the *number of protons present* in the nucleus of an atom. For example, the number of protons in the hydrogen nucleus is 1 and therefore, atomic number of hydrogen is 1. Similarly, the atomic number of carbon is 6.

Moreover, the number of protons in an atom is equal to the number of electrons since atom on the whole is electrically neutral. Thus, atomic number of an element is equal to the number of protons present in the nucleus or the number of electrons present outside the nucleus. For example, number of electrons in hydrogen atom and carbon atoms are 1 and 6 respectively.It is generally denoted by the letter Z. Thus,

Atomic number (Z) = Nuclear charge or number of protons (p) = Number of electrons (e)

Discovery of Neutrons

The whole of the mass of an atom is due to the nucleus containing protons because the electrons revolving outside are of negligible mass. This means that the nucleus must contain protons equal to the mass of the atom (atomic mass). But, the number of protons is equal to atomic number. This means that atomic mass should be equal to the atomic number. However, it has been found that *for all atoms except hydrogen, atomic mass is more than the atomic number.* For example, the atomic number of carbon is 6 and thus, it should have 6 protons in the nucleus and six extra nuclear electrons. This means that carbon atom should be six times heavier than the hydrogen atom. However, its mass has been found to be twelve times heavier than that of the hydrogen atom (at. mass = 12 a.m.u.). To solve this problem, it was thought that the *balance of the mass has to be provided by some neutral particles as the positive charge is already balanced by electrons.* The neutral particle, called neutron, was discovered by Chadwick.

Chadwick, in 1932 bombarded a thin sheet of beryllium element with α-particles and observed highly penetrating rays which consist of streams of neutral particles. The neutral particles were found to have mass of 1.675×10^{-27} kg which is *nearly the same as that of hydrogen atom* and have no charge. These were named **neutrons.**

$$^{9}_{4}Be + \underset{\alpha\text{-particle}}{^{4}_{2}He} \longrightarrow {}^{12}_{6}C + \underset{\text{Neutron}}{^{1}_{0}n}$$

Thus, *a* ***neutron is a sub-atomic particle having mass (1.675×10^{-27} kg) equal to that of hydrogen atom and carrying no electrical charge.***

Thus, an atom consists of three fundamental particles; electron, proton and neutron. Their mass and charge are summarized below in Table 1.

This means that the nucleus consists of protons and neutrons and these are collectively known as **nucleons.** Since the electrons are of negligible mass, the entire mass of the atom is due to the

Table 1. Mass and charge of sub-atomic particles.

Particle	Mass (kg)	Relative mass (u)	Approximate mass (u)	Charge	Relative charge
Electron (e)	9.10939×10^{-31}	5.4858×10^{-4}	0	-1.6022×10^{-19} C	−1
Proton (p)	1.67262×10^{-27}	1.00737	1	$+1.6022 \times 10^{-19}$ C	+1
Neutron (n)	1.67493×10^{-27}	1.00867	1	0	0

REMEMBER

One unit charge = 4.80298×10^{-10} esu or = 1.60210×10^{-19} Coulombs

One u = $\frac{1}{12}$th the mass of C–12 or = 1.66056×10^{-27} kg

* It was misnomer to call the electrons as planetary electrons because electrons are extremely small particles and are negatively charged whereas planets are massive and neutral.

...cleus *i.e.*, nucleons. *The sum of the neutrons and protons is known as* **mass number.**

Mass number =

No. of protons + No. of neutrons

Mass number is generally represented by the letter A.

Therefore, from the knowledge of atomic number and mass number of an element, the number of electrons, protons and neutrons can be easily predicted. We know

Atomic number, Z = No. of protons (p)
= No. of electrons (e)

Mass number, A = No. of protons (p) + No. of neutrons (n)

Therefore, for an atom with mass number A and atomic number Z :

Number of electrons = Z, Number of protons = Z

Number of neutrons = A – Z

For example, lithium has an atomic number (Z) = 3 and mass number (A) = 7. Therefore,

Number of electrons = Atomic number = 3

Number of protons = Atomic number = 3

Number of neutrons = A – Z = 7 – 3 = 4

Generally, an atom is represented by its symbol for the element. Atomic number is written on the lower side of the symbol and the mass number is written on the upper side. For example, lithium with atomic number equal to 3 and mass number equal to 7 may be represented as $^{7}_{3}Li$.

Mass number → $^{A}_{Z}X$ ← Symbol of the element

Atomic number

NOTE

While using the notation $^{A}_{Z}X$, it is essential to know whether the species is neutral atom, a cation or an anion. If it is neutral, then number of protons = number of electrons = atomic number. If the species is an ion, determine whether the number of protons are larger (for cations) or smaller (for anions) than the number of electrons. Number of neutrons is always given by A – Z whether the species is neutral or ion.

ISOTOPES, ISOBARS AND ISOTONES

Isotopes

Atoms of the same element which have the same atomic number but different mass numbers are called ***isotopes.***

Since the atomic number of different isotopes of the same element is same, it means that **they have same number of electrons and protons.** The difference in their mass numbers is due to different number of neutrons present in their nuclei.

Hydrogen is the common example which has three isotopes. These are commonly known as *hydrogen, deuterium* and *tritium*. These three isotopes have the same atomic number, one, but different mass numbers 1, 2 and 3 respectively as given below:

Isotope	Atomic number	Mass number	No. of electrons	No. of protons	No. of neutrons
Hydrogen $^{1}_{1}H$ (or protium)	1	1	1	1	0
Deuterium $^{2}_{1}H$(or D)	1	2	1	1	1
Tritium $^{3}_{1}H$(or T)	1	3	1	1	2

The term hydrogen is used only for first isotope. All these isotopes have only one electron.

Similarly, chlorine has two isotopes having same atomic number, Z = 17 whereas, their mass numbers are 35 and 37.

Isotope	Atomic number	Mass number	No. of electrons	No. of protons	No. of neutrons
$^{35}_{17}Cl$	17	35	17	17	18
$^{37}_{17}Cl$	17	37	17	17	20

Isotopes of some other elements are

Element	Isotopes
Carbon	$^{12}_{6}C$, $^{13}_{6}C$, $^{14}_{6}C$
Oxygen	$^{16}_{8}O$, $^{17}_{8}O$, $^{18}_{8}O$
Nitrogen	$^{14}_{7}N$, $^{15}_{7}N$
Sulphur	$^{32}_{16}S$, $^{33}_{16}S$, $^{34}_{16}S$, $^{36}_{16}S$
Uranium	$^{235}_{92}U$, $^{238}_{92}U$, $^{239}_{92}U$

It may be noted that the chemical properties of atoms are mainly controlled by electrons, which are determined by the number of protons in the nucleus. Therefore, ***all the isotopes of a given element will show almost same chemical properties.***

Isobars

Atoms of different elements having the same mass number but different atomic numbers are called ***isobars.***

Since isobars have same mass number, therefore, **the sum of protons and neutrons in the nucleus of each atom is the same.** These atoms differ in their atomic number and therefore, they have different number of protons (or electrons) and also different number of neutrons.

For example, $^{40}_{18}Ar$, $^{40}_{19}K$ and $^{40}_{20}Ca$ are isobars.

The characteristics of these isobars are:

Isobar	Atomic number	Mass number	No. of electrons	No. of protons	No. of neutrons
$^{40}_{18}Ar$	18	40	18	18	22
$^{40}_{19}K$	19	40	19	19	21
$^{40}_{20}Ca$	20	40	20	20	20

Isobars are atoms of different elements and hence they have different properties.

Isotones

Atoms having same number of neutrons but different mass numbers are called ***isotones.***

Thus, **isotones have same number of neutrons.** These atoms differ in mass number as well as atomic number. For example, $^{30}_{14}Si$ (14 protons, 16 neutrons), $^{31}_{15}P$ (15 protons, 16 neutrons) and $^{32}_{16}S$ (16 protons, 16 neutrons) are isotones because all have 16 neutrons. Similarly, $^{14}_{6}C$ (6 protons, 8 neutrons), $^{15}_{7}N$ (7 protons, 8 neutrons) and $^{16}_{8}O$ (8 protons, 8 neutrons) are isotones because all have 8 neutrons.

Isoelectronic atoms and ions

The species (atoms or ions) containing same number of electrons are called isoelectronic. For example O^{2-}, F^-, Na^+, Mg^{2+}, Al^{3+} and Ne are isoelectronic because each of these contain 10 electrons.

REMEMBER

- **Isotopes** have same number of protons but different number of neutrons.
- **Isobars** have different number of protons as well as neutrons but same sum of protons and neutrons.
- **Isotones** have same number of neutrons but different number of protons.
- In all neutral atoms, no. of electrons = no. of protons.

SOLVED EXAMPLES

Example 1.

How many protons, electrons and neutrons are there in the following nuclei ?

(i) $^{17}_{8}O$ *(ii)* $^{25}_{12}Mg$ *(iii)* $^{80}_{35}Br$

Solution: *(i)* $^{17}_{8}O$

Atomic number, Z = 8, Mass number, A = 17

No. of protons = No. of electrons = Z = 8

No. of neutrons + No. of protons = A

No. of neutrons + 8 = 17

or No. of neutrons = 17 – 8 = 9

(ii) $^{25}_{12}Mg$

Atomic number, Z = 12, Mass number, A = 25

No. of protons = No. of electrons = Z = 12

No. of neutrons = A – No. of protons

= 25 – 12 = 13.

(iii) $^{80}_{35}Br$

Atomic number, Z = 35, Mass number, A = 80

No. of protons = No. of electrons = Z = 35

No. of neutrons = A – No. of protons

= 80 – 35 = 45.

Example 2.

The number of electrons, protons and neutrons in a species are equal to 18, 16 and 16 respectively. Assign proper symbol to the species. **N.C.E.R.T.**

Solution: Atomic number is equal to number of protons = 16

So, the element is sulphur (S)

Mass number = No. of protons + No of neutrons

= 16 + 16 = 32

Species is not neutral because the number of protons is not equal to number of electrons. It is anion with charge equal to excess electrons = 18 – 16 = 2

∴ Symbol is $^{32}_{16}S^{2-}$

Example 3.

Complete the following table :

Particle	*Mass Number*	*Atomic Number*	*Protons*	*Neutrons*	*Electrons*
O		8		8	
Al	27				13
Cl^-	35		17		
Mg^{2+}				12	10

Solution: *First row :* Mass number = $n + p$

But p = At. No. = 8

n = 8

∴ Mass number = 8 + 8 = 16

Now $e = p = 8$

Second row : Atomic number

$= p = e = 13$

Protons = 13

$n + p$ = Mass number

= 27

n = 27 – 13 = 14

Third row : Atomic No. = p = 17

$n + p$ = Mass number

∴ = 35

n = 35 – 17 = 18

Now electrons in Cl atom = p = 17

∴ Electrons in Cl^- ion = 17 + 1 = 18

Fourth row : Mass number = $n + p$

But $p = e$ in Mg-atom

Electrons in Mg^{2+} = 10

∴ Electrons in Mg = 10 + 2 = 12

p = 12

Mass number = 12 + 12 = 24

Atomic No. = p = 12

Thus, the complete table is given below :

Particle	*Mass Number*	*Atomic Number*	*Protons*	*Neutrons*	*Electrons*
O	16	8	8	8	8
Al	27	13	13	14	13
Cl^-	35	17	17	18	18
Mg^{2+}	24	12	12	12	10

Example 4

Write the complete symbol for the atom with the given atomic number Z and atomic mass (A) :

(i) $Z = 17$, $A = 35$

(ii) $Z = 92$, $A = 233$

(iii) $Z = 4$, $A = 9$ **N.C.E.R.T.**

Solution: (i) $^{35}_{17}Cl$ (ii) $^{233}_{92}U$ (iii) $^{9}_{4}Be$

Example 5

Calculate the mass and charge of one mole of electrons. **N.C.E.R.T.**

Solution: Mass of one electron $= 9.11 \times 10^{-31}$ kg

Mass of 1 mol of electrons $= 9.11 \times 10^{-31} \times 6.022 \times 10^{23}$

$= 5.486 \times 10^{-7}$ kg.

Charge on one electron

$= 1.602 \times 10^{-19}$ C

Charge of 1 mol of electrons

$= 1.602 \times 10^{-19} \times 6.022 \times 10^{23}$ Coulombs

$= 9.647 \times 10^{4}$ C

Example 6

Calculate the number of electrons which will together weigh one gram. **N.C.E.R.T.**

Solution: Mass of one electron $= 9.11 \times 10^{-31}$ kg

$\therefore$ 9.11×10^{-31} kg $= 1$ electron

$$1 \text{ g or } 10^{-3} \text{ kg} = \frac{1}{9.11 \times 10^{-31}} \times 10^{-3} \text{ electrons}$$

$= 1.098 \times 10^{27}$ electrons

Example 7

Calculate (a) the total number and (b) the total mass of neutrons in 7 mg of ^{14}C (assume the mass of a neutron $= 1.675 \times 10^{-27}$ kg). **N.C.E.R.T.**

Solution: In ^{14}C

No. of neutrons + No. of Protons = 14

No. of protons = 6

$\therefore$ No. of neutrons + 6 = 14

$\therefore$ No. of neutrons = 14 − 6 = 8

Now 1 mol of ^{14}C = 14 g C

or $= 6.022 \times 10^{23}$ atoms of ^{14}C

$= 6.022 \times 10^{23} \times 8$ neutrons

$= 4.8176 \times 10^{24}$ neutrons

(a) 14 g of ^{14}C contain $= 4.8176 \times 10^{24}$ neutrons

7mg (7×10^{-3} g) of ^{14}C contain

$$= \frac{4.8176 \times 10^{24}}{14} \times 7 \times 10^{-3} \text{ neutrons}$$

$= 2.4068 \times 10^{21}$ neutrons

(b) Mass of 1 neutron $= 1.675 \times 10^{-27}$ kg

$\therefore$ Mass of 2.4068×10^{21} neutrons

$= 1.675 \times 10^{-27} \times 2.4068 \times 10^{21}$ kg

4.035×10^{-6} kg.

Example 8

An element with mass number 81 contains 31.7% more neutrons as compared to protons. Assign the atomic symbol. **N.C.E.R.T.**

Solution: We know

Mass number = No. of protons + No. of neutrons = 81

i.e., $p + n = 81$

Let number of protons $= x$

$$\text{Number of neutrons} = x + \frac{x \times 31.7}{100}$$

$$= 1.317\,x$$

$$\therefore \quad x + 1.317x = 81$$

$$x = \frac{81}{2.317} = 34.96 = 35$$

Symbol = $^{81}_{35}Br$

Example 9

An ion with mass number 56 contains 3 units of positive charge and 30.4% more neutrons than electrons. Assign the symbol for the ion. **N.C.E.R.T.**

Solution: Since the ion carries 3 units of positive charge, it will have 3 electrons less than the number of protons.

Let number of electrons $= x$

No. of protons $= x + 3$

$$\text{No. of neutrons} = x + \frac{x \times 30.4}{100}$$

$$= x + 0.304\,x = 1.304\,x$$

Now, No. of protons + No. of neutrons = 56

$$x + 3 + 1.304\,x = 56$$

$$2.304\,x = 53$$

$$x = \frac{53}{2.304} = 23$$

No. of electrons = 23, No of protons = 23 + 3 = 26

No. of neutrons = 56 − 26 = 30

Symbol = $^{56}_{26}Fe^{3+}$

Practice Problems

1. How many protons and neutrons are present in the following nuclei ?

(i) $^{12}_{6}C$ (ii) $^{56}_{26}Fe$

(iii) $^{88}_{38}Sr$ (iv) $^{238}_{92}U$.

2. An atom having atomic mass number 13 has 7 neutrons. What is the atomic number of the atom ? *(NCERT Exemplar Problem)*

3. Are neutrons present in all atoms ?

4. Fill in the blanks :

(a) If an electron has a charge -1.6×10^{-19} C, the charge on the nucleus of an atom of carbon is .....C.

(b) The size of the nucleus is of the order of ..... m.

(c) An atom of mercury contains 120 neutrons in its nucleus and 80 electrons around it. It contains ..... protons in its nucleus, its atomic number is ..... and mass number is .....