4

Structure of the Atom

In the Chapter

- Credit for the discovery of proton and electron goes to E.Goldstein, and J.J. Thomson respectively.
- J.J. Thomson told that electrons are embedded in a positive sphere.
- Rutherford's alpha-particle scattering experiment led to the discovery of the atomic nucleus.
- Rutherford's model of the atom proposed that a very tiny nucleus is present inside the atom and electrons revolve around this nucleus. The stability of the atom could not be explained by this model.
- Neils Bohr's model of the atom was more successful. He proposed that electrons are distributed in different shells with discrete energy around the nucleus. If the atomic shells are complete then the atom will be stable and less reactive.
- J. Chadwick discovered presence of neutrons in the nucleus of an atom. So, the three sub-atomic particles of an atom are: (i) electrons, (ii) protons and (iii) neutrons. Electrons are negatively charged, protons are positively charged and neutrons have no charges. The mass of an electron is about 1/2000 times the mass of an hydrogen atom. The mass of a proton and a neutron is considered as one unit each.
- Shells of an atom are marked as K,L,M,N,....
- Valency is the combining capacity of an atom.
- The atomic number of an element is similar to the number of protons in the nucleus of its atom.
- The mass number of an atom is similar to the number of nucleons in its nucleus.
- Isotopes are atoms of the same element, which have different mass numbers.
- Isobars are atoms which have the same mass number but different atomic numbers.
- Elements are defined by the number of protons they possess.

Intext Exercises

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1. What are canal rays?

Ans. Canal rays are positively charged radiations discovered by E. Goldstein in a discharge tube. These rays led to the discovery of proton. These rays are called canal rays because these rays passed through the holes or canals in the cathode.

2. If an atom contains one electron and one proton, will it carry any charge or not?

Ans. No, it will not carry any charge. The charge will cancel each other.

Page No. 49

1. On the basis of Thomson's model of an atom, explain how the atom is neutral as a whole.

Ans. In 1899, Thomson proposed that :

(i) An atom consists of a positively charged sphere and the electrons are embedded in it.

(ii) The negative and positive charges balance each other and so the atom as a whole is neutral.

2. On the basis of Rutherford's model of an atom, which subatomic particle is present in the nucleus of an atom?

Ans. No, the basis of Rutherford's model of an atom proton is present in the nucleus of an atom.

3. Draw a sketch of Bohr's model of an atom with three shells.

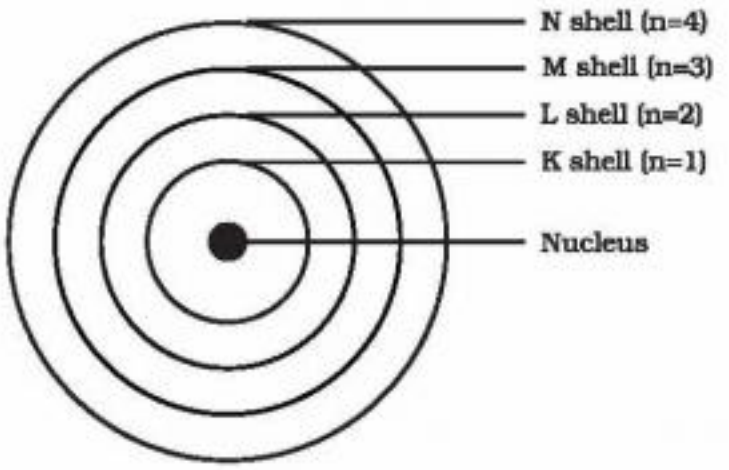

Fig. 4.11: A few energy levels in an atom

4. What do you think would be the observation if the α-particle scattering experiment is carried out using a foil of a metal other than gold?

Ans. Gold is the most malleable metal and hence it increases the probability of the a-particle hitting the atom in the first plane. Also, gold is the least reactive metal. If any other metal is used other than gold, the metal may react with the α-particles or the α-particles may not be able to hit the atom if the metal is thick and less malleable.

Page No. 49

1. Name the three sub-atomic particles of an atom.

Ans. The three sub-atomic particles of an atom are electrons, protons and neutrons.

2. Helium atom has an atomic mass of 4 u and two protons in its nucleus. How many neutrons does it have?

Ans. Atomic mass of Helium atom = 4u

Number of protons = 2

Number of neutrons = 2 (4 – 2 = 2)

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1. Write the distribution of electrons in carbon and sodium atoms.

Ans. (i) Atomic number of carbon = 6
Distribution of electrons = K - 2 and I = 4.
(ii) Atomic number of sodium = H
Distribution of electrons = K - 2, L - 5 and M - 1

2. If K and L shells of an atom are full, then what would be the total number of electrons in the atom?

Ans. If K and L shells of an atom are full, then the total number of electrons in the atom would be 10. (K shell can have maxmium 2 electrons and L shell can have maximum 8 electrons.)

Page No. 52

1. How will you find the valency of chlorine, sulphur and magnesium?

Ans.

Name of element	Atomic number	Electronic configuration K	L	M	Valence electrons	Valency
Chlorine	17	2	8	7	7	8 – 7 = 1
Sulphur	16	2	8	6	6	8 – 6 = 2
Magnesium	12	2	8	2	2	2

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1. If number of electrons in an atom is 8 and number of protons is also 8, then (i) what is the atomic number of the atom? and (ii) what is the charge on the atom?

Ans. (i) Atomic number – Number of protons = 8
(ii) Electronic configuration = K - 2, L - 6.
Charge on the atom will be 2+.

2. With the help of Table 4.1, find out the mass number of oxygen and sulphur atom.

Ans. Mass number - No. of protons + No. of neutrons
Mass number of oxygen = 8 + 8 = 16
Mass number of sulphur = 16 + 16 = 32

Page No. 53

1. For the symbol H, D and T tabulate three sub-atomic particles found in each of them.

Ans. There are three isotopes of hydrogen.

Isolope	Formula	Mass	No. of	No. of	No. of
Protium	1/1 H (H)	1	1	0	1
Deuterium	8/1 H(D)	2	1	1	1
Tritium	3/1 H(T)	3	1	2	1

2. Write the electronic configuration of any one pair of isotopes and isobars.

Ans. (i) Isobars : 40/20 Ca and 40/18 Ar
Electronic configuration of Ca 2, 8, 8, 2
Electronic configuration of Ar = 2, 8, 8
(ii) Isotopes : 12/9 C and 13/6 C.
Electronic configuration of C = 2, 4.

Exercise

1. Compare the properties of electrons, protons and neutrons.

Ans.

Particle	*Symbol*	*Mass*	*Charge*	*Location*
Electrons	${}^{0}_{-1}e$	9.108×10^{-31} kg	1 unit negative charge (–1.602 109^{-19} C)	Extra nuclear part i.e., outside nucleus.
Protons	${}^{1}_{+1}p$	1.676×10^{-27} kg	1 unit postive charge (+1.602 109^{-19} C)	Nucleus
Neutrons	${}^{1}_{0}p$	1.676×10^{-27} kg	Neutral (No charge)	Nucleus

2. What are the limitations of J.J. Thomson's model of the atom?

Ans. Although Thomson's model explained well that atoms are electrically neutral, but the results of experiments done by other scientists could not be explained by this model.

3. What are the limitations of Rutherford's model of the atom?

Ans. The major drawback of Rutherford's model of an atom is that it does not explain the stability of an atom.

When charged bodies move in circular orbits, they emit radiation. This emission of radiation would cause a reduction in the energy of the electrons. The electrons should come closer and closer to the nucleus, as they lose energy and finally fall into the nucleus. Rutherford could not explain why this did not seem to be happening.

4. Describe Bohr's model of the atom.

Ans. A Danish physicist, Neils Bohr proposed an atomic model in 1913. This model of atom is called Bohr's model of atom.

Basic postulates of the Bohr's atomic model are:

(i) In an atom, the electrons revolve around the nucleus in certain definite circular orbits. These circular orbits are also called energy shells, or energy levels.

(ii) An electron revolving in a particular orbit has a fixed energy.

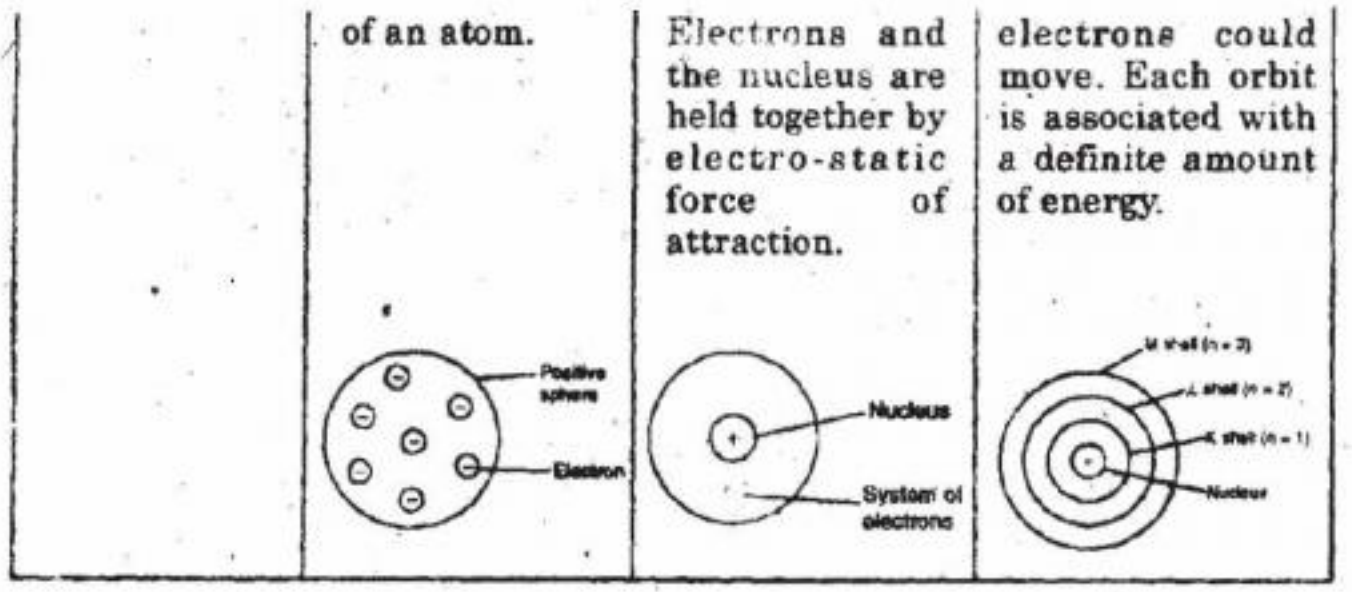
(iii) The orbits, or the energy shells are numbered as n = 1, 2, 3, 4... etc., or K, L, M, N.:. etc.., shells starting from the nucleus. These integers 1, 2, 3, 1 4, ... etc. are known as quantum numbers of the orbits.

(iv) An electron can lose or gain only certain definite energies.

5. Compare all the proposed models of an atom given in this chapter.

Ans.

	Thomson's model of an atom	*Rutherford's model of an atom*	*Bohr's model of an atom*
(*a*) Positive charge (Proton)	An atom consists of a positively charged sphere.	The positive charge is concentrated at the core of the atom. This heavy, positively charged core is called nucleus.	The positive charge is present in the core of the atom, called nucleus.
(*b*) Negative charge (electrons)	The electrons are embedded in the positively charged sphere	The nucleus is surrounded by a system of electrons.	For the first time Bohr introduced the concept of orbits in which



6. Summarise the rules for writing of distribution of electrons in various shells for the first eighteen elements.

Ans. Bahr and Bury scheme for the distribution of electrons in an atom is based on the following rules :

(i) The maximum number of electrons which a shell can have is $2n^2$ where n is the quantum number of that energy shell. So, the maximum number of electrons in various shells are :

1st (K) shell $2 \times 12 = 2$
2nd (L) shell $2 \times 22 = 8$
3rd (M) shell $2 \times 32 = 18$
4th (N) shell $2 \times 42 = 32$

(ii) The outermost shell (also called valence shell) can have a maximum of 8 electrons. Next to the outermost shell (called penultimate shell) can accommodate a maximum of 18 electrons, if permitted by rule (i).

(iii) Electrons are not accommodated in a given shell unless the inner shells are fulled. That is the shells are filled in a step wise manner.

7. Define valency by taking examples of silicon and oxygen.

Ans. The combining capacity of an atom of an element is known as its valency. The number of electrons gained, lost or shared so as to make the octet of electrons in the outermost shell of an atom of an element gives us directly the combining capacity of the element.

Valency of oxygen is 2 because it can complete the octet by gaining 2 electrons. Valency of silicon is 4 because it can loose, gain or share 4 electrons to complete its octet.

8. Explain with examples (i) Atomic number, (ii) Mass number, (iii) Isotopes and iv) Isobars. Give any two uses of isotopes.

Ans. (a) (i) The number of protons present in the nucleus of an atom of an element is called its atoms number.

For hydrogen Z = 1 because in hydrogen atom only one proton is present in the nucleus.
For carbon , Z = 6 because in carbon atom six protons are present in the nucleus.

(ii) The sum of the total number of protons and neutrons present in the nucleus of an atom of an element is called mass number. For example,

Mass of carbon is 12 because it has 6 protons and 6 neutrons (6 + 6 = 12). Similarly mass number of aluminium is 27 (13 p + 14 n).

(iii) Atoms of the same element, having the same atomic number, but different mass numbers are called isotopes of that element.

(vi) Iostopes may also be defined as follows:

"The atoms of an element having the same number of protons, but different number of neutrons are called isotopes of that element."

(b) Some applications of isotopes are:

(i) An isotope of Uranium is used as a fuel in a nuclear reactor.

(ii) An isotope of Cobalt is used in the treatment of cancer.

(iii) An isotope of Iodine is used in the treatment of goitre.

9. Na+ has completely filled K and L shells. Explain.

Ans. The atomic number of sodium is 11.

Distribution of electrons K - 2, L - 8, M - 1.

A positively charged ion is formed by loosing electrons. The sodium atom loose one electron and forms sodium ion (Na+).

The distribution of electrons in sodium ion is K-2, L - 8. Thus, Na+ has completely filled K and L shells and since the maximum capacity of K shell is 2 and the maximum capacity of L shell is 8.

10. If bromine atom is available in the form of, say, two isotopes 79 35 Br (49.7%) and 81 35 Br (50.3%), calculate the average atomic mass of bromine atom.

Ans. The atomic mass of bromine atom

$= 79 \times 49.7/100 + 81 \times 50.3/100$

$= 79 \times 0.497 + 81 \times 0.503$

$= 39.263 + 40.743$

$= 80.006$ u

11. The average atomic mass of a sample of an element X is 16.2 u. What are the percentages of isotopes 16/8 X and 18/8 X in the sample?

Ans. Let the percentage of 18 / 8 X in the sample be x. Then the percentage of 18 / 8 X in the sample is $(100 - x)$.

$$\text{Atomic mass of X} = 16x\left(\frac{x}{100}\right) + 18x\left(\frac{100-x}{100}\right)$$

$$16.2 = \frac{16x}{100} + \frac{18 \times 100}{100} - \frac{18x}{100}$$

$$1620 = 16x - 18x + 1800$$

or $2x = (1800 - 1620) = 180$

Thus, $x = 180/2 = 90$

Percentage of 18/8 X in the sample = 90

Percentage of 18/8 X in the sample = 10.

12. If Z = 3, what would be the valency of the element? Also, name the element.

Ans. Atomic number, Z = 3

Distribution of electrons = K - 2, L - 1.

Valency = 1

The element of Lithium.

13. Composition of the nuclei of two atomic species X and Y are given as under.

	X	Y
Protons =	**6**	**6**
Neutrons =	**6**	**8**

Give the mass numbers of X and Y. What is the relation between the two species?

Ans. Mass number = Number of protons + Number of neutrons

Mass number of X = 6 + 6 = 12

Mass number of Y = 6 + 8 = 14

Atomic number = Number of protons.

Atomic number of X = 6
Atomic number of Y = 6.
Since X and Y have the same atomic number but different mass number they are isotopes.

14. For the following statements, write T for True and F for False.
(a) J.J. Thomson proposed that the nucleus of an atom contains only nucleons.
(b) A neutron is formed by an electron and a proton combining together. Therefore, it is neutral.
(c) The mass of an electron is about 1/2000 times that of proton.
(d) An isotope of iodine is used for making tincture iodine, which is used as a medicine. Put tick (✓) against correct choice and cross (✗) against wrong choice in questions 15, 16 and 17.

Ans. a, b , c, d, = False
e = True.

15. Rutherford's alpha-particle scattering experiment was responsible for the discovery of
(a) Atomic Nucleus **(b) Electron**
(c) Proton **(d) Neutron**

Ans. (a) Atomic Nucleus

16. Isotopes of an element have
(a) the same physical properties
(b) different chemical properties
(c) different number of neutrons
(d) different atomic numbers.

Ans. (c) different number of neutrons

17. Number of valence electrons in Cl– ion are:
(a) 16 (b) 8 (c) 17 (d) 18

Ans. (b) 8

18. Which one of the following is a correct electronic configuration of sodium?
(a) 2,8 (b) 8,2,1 (c) 2,1,8 (d) 2,8,1
(d) 2,8,1.

19. Complete the following table.

Ans.

Atomic Number	Mass Number	Number of Neutrons	Number of Protons	Number of Electrons	Name of the Atomic Species
9	-	10	-	-	-
16	32	-	-	-	Sulphur
-	24	-	12	-	-
-	2	-	1	-	-
-	1	0	1	0	-

Atomic Number	Mass Number	Number of Neutrons	Number of Protons	Number of Electrons	Name of the Atomic Species
9	10	10	9	9	Fluorine
16	32	10	16	16	Sulphur
12	24	10	12	12	Magnesium
1	2		1	1	Hydrogen
10	1	0	1	0	Neon

Additional Questions

1. Atomic number of an element is 16. What is its valency ?

Ans. Atomic number = 16
Electronic configuration = 2, 8, 6
Valency = 6 - 8 = - 2.

2. The atomic number of neon is 10. Write its electronic configuration.

Ans. Electronic configuration = 2, 8

3. Which subatomic particles of an atom are responsible for atomic mass?

Ans. Neutrons and protons are the sub atomic particles responsible for atomic mass.

4. There are 15 protons and 16 neutrons in the nucleus of an element. Calculate its atomic number and mass number.

Ans. Atomic number = Number of protons = 15
Mass number = No. of neutrons + No. of protons = 16 + 15 = 31

5. State two properties of alpha particles.

Ans. (i) Alpha particles are positively charged particles.
(ii) They are doubly charged helium ions having a mass of 44. (Consists of 2 protons and 2 neutrons).

6. How many electrons are present in the outermost orbit of a noble gas other than helium.

Ans. Eight electrons are present in the outermost orbit of a noble gas other than helium.

7. The atom of an element has 9 protons, 10 neutrons and 9 electrons. Mention its atomic number and mass number.

Ans. Atomic number = Number of protons =9
Mass number = Number of protons + Number of neutrons
= 9 + 10 = 19

8. What is the charge and mass of a neutron?

Ans. Charge of neutron is zero and its mass is 1.67×10^{-24}g

9. What happens to an element 'Z' if its atom gains three electrons.

Ans. Element Z becomes Z3-ion, if its atom gains three electrons.

10. There are 11 protons and 12 neutrons in the nucleus of an element. Calculate its atomic number and mass number.

Ans. Atomic number = No. of protons = 11
Atomic mass = No. of protons + No. of electrons = 11 + 12 = 23

11. What is the atomic number of the element X, which has 2 shells, K and L having 2 and 6 electrons, respectively ?

Ans. Atomic number of element X
= Number of protons = Number of electrons =2+6=8

12. Atomic number of element is 12. What is its valency ?

Ans. Atomic number = 12
Its electronic configuration = 2, 8, 2
So, its valency = 2 (number of electrons in the outermost shell).

13. How is an α-particle different from a helium atom?

Ans. α-particle is doubly ionised helium atom He++ Helium atom is electrically neutral.

14. Who discovered the neutrons ?

Ans. Chadwick discovered the neutron.

15. Why is an atom neutral inspite of the presence of charged particles in it ?

Ans. An atom is neutral because it has equal number of protons and electrons.

16. What are canal rays?

Ans. Canal rays are a stream of positively charged particles shot out from the anode of a discharge tube when a current is passed through a gas at very low pressure.

17. An atom has mass number 40 and atomic number 20.
(i) How many electrons are revolving around the nucleus?
(ii) How many electron shells are there in the atoms?

Ans. (i) 20 electrons are revolving around the nucleus.
(ii) The electronic configuration of the element is 2(K), S(L), 8(M) and 2(N). So, there are 4 electron shells in the atom for the element.

18. Write down the electron distribution of chlorine atom. How many electrons are there in the L shell? (Atomic number of chlorine is 17).

Ans. K, L, M, $_{17}Cl = 2, 8, 7$. The L shell has eight electrons.

19. One electron is present in the outermost shell of the atom of an element X. What would be the nature and value of charge on the ion formed if this electron is removed from the outermost shell?

Ans. +1.

20. In the atom of an element X, 6 electrons are present in the outer most shell. If it acquires noble gas configuration by accepting requistic number of electrons, then what would be the charge on the ion so formed?

Ans. –1.

21. The atomic numbers of calcium and argon are 20 and 18, respectively, but the mass number of both these elements is 40. What is the name given to such a pair of elements?

Ans. Isobars.

22. In response to a question, a student stated that in an atom, the number of protons is greater than the number of neutrons, which in turn is greater than the number of electrons. Do you agree with the statement? Justify your answer.

Ans. No, the statement is incorrect. In an atom the number of protons and electrons is always equal and here it is given that the number of electron is less than the number of proton, which can only be in case of an ion.

23. Helium atom has 2 electrons in its valence shell but its valency is not 2. Explain.

Ans. Helium atom has 2 electrons in its outermost shell and its duplet is complete. Hence the valency is zero.

24. An element X has a mass number 4 and atomic number 2. Write the valency of this element?

Ans. Valency is zero as K shell is completely filled.

25. Why do helium, neon and argon have a zero valency?

Ans. Helium has two electrons in its only energy shell, while argon and neon have 8 electrons in their valence shells. As these have maximum number of electrons in their valence shells, they do not have any tendency to combine with other elements. Hence, they have a valency equal to zero.

26. In what way is the Rutherford's atomic model different from that of Thomson's atomic mode?

Ans. Rutherford proposed a model in which electrons revolve around the nucleus in well defined orbits. There is a positively charged centre in an atom called the nucleus. He also proposed that the size of the nucleus is very small as compared to the size of the atom and nearly all the mass of an atom is centred in the nucleus. Whereas, Thomson proposed the model of an atom to be similar to a Christmas pudding. The electrons are studded like curents in a positively charged sphere like Christmas pudding and the mass of the atom was supposed to be uniformly distributed.

Multiple Choice Questions

1. Rutherford's 'Alpha (α) particles scattering experiment' resulted into discovery of:

(a) Electron (b) Proton
(c) Atomic mass (d) Nucleus in the atom

Ans. (d)

2. Which of the following correctly represents the electronic distribution in the Mg atom?

(a) 3, 8, 1 (b) 2, 8, 2
(c) 1, 8, 3 (d) 8, 2, 2

Ans. (b)

3. The ion of an element has 3 positive charges. Mass number of the atom is 27 and the number of neutrons is 15. What is the number of electrons in the ion?

(a) 13 (b)14
(c) 10 (d) 16

Ans. (c)

4. The atom which does not contain any neutron in the nucleus is:

(a) protium (b) deuterium
(c) tritium (d) helium

Ans. (a)

5. The alpha particles are the same as:

(a) protons (b) helium atoms
(c) helium nuclei (d) lithium nuclei

Ans. (c)

6. Which of the following elements contains only two electrons in the outermost shell?

(a) Helium (b) Beryllium
(c) Magnesium (d) All the above

Ans. (d)

7. Mass of neutron is

(a) equal to that of electron
(b) equal to that of proton
(c) less than that of proton
(d) slightly more than that of proton

Ans. (d)

8. The mass of an electron is

(a) 1.6×10^{-30}kg (b) 6.1×10^{-27}kg
(c) 9.1×10^{-31} kg (d) 9.1×10^{-27}kg

Ans. (c)

9. Maximum number of electrons which can be filled in the third shell of an atom is

(a) 8 (b) 18
(c) 10 (d) 32

Ans. (b)

10. The mass number A, atomic number Z and number of neutrons n are related as

(a) $n=A-Z$ (b) $n=A\times Z$
(c) $n=A+Z$ (d) None of these

Ans. (a) $n=A-Z$

11. Which of the following elements has same number of protons, electrons and neutrons?

(a) Al (b) p
(c) Mg (d) Cl

Ans. (c)

12. Protons, neutrons and electrons are present in chlorine atom in the sequence:

(a) 17, 17, 18 (b) 17, 18, 17
(c) 18,17,17 (d) 17,17,17

Ans. (b)

13. Rutherford's alpha (α) particles scattering experiment resulted into discovery of

(a) Electron (b) Proton
(c) Nucleus in the atom
(d) Nucleus as well as extra nuclear portion in an atom.

Ans. (d)