Structure of the Atom

Case Study Based Questions

Case Study 1

Many scientists contributed in revealing the presence of charged particles in an atom.

It was known by 1900 that the atom was indivisible particle but contained at least one sub-atomic particle - the electron identified by J. J. Thomson. Even before the electron was identified, in 1886 E. Goldstein discovered the presence of new radiations in a gas discharge and called them canal rays. These rays were positively charged radiations which ultimately led to the discovery of another sub-atomic particle. This sub-atomic particle had a charge, equal in magnitude but opposite in sign to that of the electron. Its mass was approximately 2000 times as that of the electron. It was given the name of proton. In general, an electron is represented as 'e^-' and a proton as 'p^+'. The mass of a proton is taken as one unit and its charge as plus one. The mass of an electron is considered to be negligible and its charge is minus one.

It seemed that an atom was composed of protons and electrons, mutually balancing their charges. It also appeared that the protons were in the interior of the atom, for whereas electrons could easily be removed off but not protons.

Read the given passage carefully and give the answer of the following questions:

Q1. Who discovered electron?

a. E. Goldstein

b. Bohr

c. J. J. Thomson

d. J. Chadwick

Q2. Which of the following has a charge of +1 and a mass of 1 amu?

a. A neutron

b. A proton

c. An electron

d. A helium nucleus

Q3. Mass of proton is:

a. equal to the mass of hydrogen atom

b. less than the mass of hydrogen atom

c. negligible

d. more than the mass of hydrogen atom

Q4. Proton was discovered by:

a. Thomson

b. Rutherford

c. Chadwick

d. Goldstein

Q5. Which statement is true?

a. The nucleus of an atom contains only neutrons.

b. The nucleus of an atom contains only protons and electrons.

c. Protons and neutrons are sub-atomic particles.

d. Protons have the same charge as neutrons.

Solutions

1. (c) J. J. Thomson

2. (b) A proton

3. (a) equal to the mass of hydrogen atom

4. (d) E. Goldstein

E. Goldstein discovered the presence of new radiations in a gas discharge and called them canal rays. These rays were positively charged radiations which ultimately led to the discovery of sub-atomic particle-proton.

5. (c) Protons and neutrons are sub-atomic particles.

Protons, neutrons and electrons are known as sub-atomic particles. The nucleus of an atom contains protons and neutrons. A proton has a relative charge of +1. A neutron has a relative charge of 0.

Case Study 2

Rutherford conducted an experiment by bombarding a thin sheet of gold (100 nm thickness) with a-particles and then studied the trajectory of these particles after their interaction with the gold foil.

Read the given passage carefully and give the answer of the following questions:

Q1. Rutherford's a-particles scattering experiment resulted into discovery of:

a. electron

b. proton

c. nucleus in the atom

d. atomic mass

Q2. ..... was known as the 'Father' of nuclear physics. He is famous for his work on radioactivity and the discovery of the nucleus of an atom with the gold foil experiment.

a. J. J. Thomson

b. Neils Bohr

c. E. Rutherford

d. J. Chadwick

Q3. Rutherford concluded from the a-particle scattering experiment that:

(i) most of the space inside the atom is empty because most of the a-particles passed through the gold foil without getting deflected.

(ii) very few particles were deflected from their path, indicating that the negative charge of the atom occupies very little space.

(iii) a very large fraction of a-particles was deflected by 180°, indicating that all the negative charge and mass of the gold atom were concentrated in a very small volume within the atom.

Identify the incorrect statements:

a. (i) and (ii)

b. (ii) and (iii)

c. (i) and (iii)

d. (i), (ii) and (iii)

Q4. Rutherford's a-particle scattering experiment showed that:

(i) electrons have negative charge.

(ii) the mass and positive charge of the atom is concentrated in the nucleus.

(iii) neutron exists in the nucleus.

(iv) most of the space in atom is empty.

Which of the above statements are correct?

a. (i) and (iii)

b. (ii) and (iv)

c. (i) and (iv)

d. (iii) and (iv)

Q5. Select the correct statements.

(i) The radius of the nucleus is about 107 times less than the radius of the atom.

(ii) There is a positively charged centre in an atom called the nucleus. Nearly, all the mass of an atom resides in the nucleus.

(iii) The electrons revolve around the nucleus in circular paths.

(iv) The size of the nucleus is very large as compared to the size of the atom.

a. (i) and (iv)

b. (ii) and (iii)

c. (i), (ii) and (iii)

d. All the statements are correct.

Solutions

1. (c) nucleus in the atom

Rutherford's α-particles scattering experiment resulted into discovery of nucleus in the atom. A large number of particles went straight through the atom while a very small number of particles were deflected back showing the presence of positively charged nucleus.

2. (c) E. Rutherford

3. (b) (ii) and (iii)

Very few particles were deflected from their path, indicating that the positive charge of the atom occupies very little space. A very small fraction of α-particles was deflected by 180°, indicating that all the positive charge and mass of the gold atom were concentrated in a very small volume within the atom.

4. (b) (ii) and (iv)

Two important observations of Rutherford's a-particles scattering experiment were- (i) The mass and positive charge of the atom is concentrated in the nucleus, (ii) Most of the space in the atom is empty.

5. (b) (ii) and (iii)

The radius of the nucleus is about 10^5 times less than the radius of the atom. The size of the nucleus is very small as compared to the size of the atom.

Case Study 3

The following rules are followed for writing the number of electrons in different energy levels or shells:

(i) The maximum number of electrons present in a shell is given by the formula $2n^2$, where 'n' is the orbit number or energy level index, 1, 2, 3, ... Hence, the maximum number of electrons in different shells are as follows:

First orbit or K-shell will be = $2 \times 1^2 = 2$,

Second orbit or L-shell will be = $2 \times 2^2 = 8$,

Third orbit or M-shell will be = $2 \times 3^2 = 18$,

Fourth orbit or N-shell will be = $2 \times 4^2 = 32$,

and so on.

(ii) The maximum number of electrons that can be accommodated in the outermost orbit is 8.

(iii) Electrons are not accommodated in a given shell, unless the inner shells are filled i.e., the shells are filled in a stepwise manner.

Read the given passage carefully and give the answer of the following questions:

Q1. The number of electrons in an element X is 15 and the number of neutrons is 16. Which of the following is the correct representation of the element?

a. ${}^{31}_{15}X$ b. ${}^{31}_{16}X$ c. ${}^{16}_{15}X$ d. ${}^{15}_{16}X$

Q2. How many numbers of protons and electrons are present in Ca^{2+}?

a. 20 protons; 20 electrons

b. 20 protons; 22 electrons

c. 18 protons; 18 electrons

d. 20 protons; 18 electrons

Q3. Maximum number of electrons which can be filled in the third shell of an atom is:

a. 8 b. 18

c. 10 d. 32

Q4. Which pair of molecules has the same number of electrons?

a. N_2 and F_2 b. Cl_2 and CO_2

c. H_2O and H_2S d. O_2 and C_2H4

Q5. Which of the following elements has same number of protons, electrons and neutrons?

a. Al b. Mg

c. P d. Cl

Solutions

1. (a) $^{31}_{15}X$

Number of electrons = 15

Number of neutrons = 16

Hence, atomic number of element *X* is 15 and atomic mass is 31.

Hence, the element is represented as $^{31}_{15}X$.

2. (d) 20 protons; 18 electrons

Atomic number of Ca = 20

Hence, number of protons in Ca^{2+} = 20

and number of electrons in Ca^{2+} = 20 – 2 = 18

3. (b) 18

The maximum number of electrons present in a shell is given by $2n^2$, where n = 1, 2, 3. .....

Maximum number of electrons which can be filled in the third shell of an atom is $2 \times (3)^2 = 18$

4. (d) O_2 and C_2H4

Number of electrons in $0_2 = 2 \times 8 = 16$

Number of electrons in $C_2H_1 = (2 \times 6) + (4 \times 1) = 16$

Number of electrons in N_2 = 2 x7 = 14

Number of electrons in F_2 = 2 x 9=18

Number of electrons in Cl_2 = 2 x 17 = 34

Number of electrons in $CO_2 = 6 + (2 \times 8) = 22$

Number of electrons in $H_2O = (2 \times 1) + 8 = 10$

Number of electrons in H_2S= (2 x 1) +16=18

5. (b) Mg

Mg is represented as $^{24}_{12}Mg$. It has protons, electrons and neutrons equal to 12 (all are same).

Case Study 4

The combining capacity of the atoms of elements, i.e., their tendency to react and form molecules with atoms of the same or different elements, was thus explained as

an attempt to attain a fully-filled outermost shell. An outermost shell, which had eight electrons was said to possess an octet. Atoms would thus react, so as to achieve an octet in the outermost shell. This was done by sharing, gaining or losing electrons. The number of electrons gained, lost or shared, so as to make the octet of electrons in the outermost shell, gives us directly the combining capacity of the element, i.e., the valency. For example, hydrogen/lithium/ sodium atoms contain one electron each in their outermost shell, therefore each one of them can lose one electron. So, they are said to have valency of one. The valency of magnesium and aluminium is two and three, respectively, because magnesium has two electrons in its outermost shell and aluminium has three electrons in its outermost shell.

If the number of electrons in the outermost shell of an atom is close to its full capacity, then valency is determined in a different way. For example, the fluorine atom has 7 electrons in the outermost shell, and its valency could be 7. But it is easier for fluorine to gain one electron instead of losing seven electrons.

Hence, its valency is determined by subtracting seven electrons from the octet and this gives us a valency of one for fluorine.

Read the given passage carefully and give the answer of the following questions:

Q1. Which atom loses two electrons from its valence shell to form an ion?

a. Calcium

b. Carbon

c. Chlorine

d. Oxygen

Q2. The element with the atomic number 3 is likely to have similar chemical properties to the element with the atomic number:

a. 5

b. 11

c. 8

d. 20

Q3. Which of the following has the same number of electrons as an oxide ion (0^{2-})?

a. K^{+}

b. Mg^{2+}

c. Cl^{-}

d. S^{2-}

Q4. What is the atomic structure of X^{2-} ion in which X has an atomic number of 8 and a mass number of 17?

	Electrons	Protons	Neutrons
a.	8	8	9
b.	10	9	8
c.	10	8	9
d.	10	8	8

Q5. The ion of an element has 2 positive charges. Mass number of the atom is 24 and the number of neutrons is 12. What is the number of electrons in the ion?

a. 8 b. 10

c. 12 d. 24

Solutions

1. (a) Calcium

Calcium has 20 electrons.

Electronic configuration = 2, 8, 8, 2

Carbon has 6 electrons.

Electronic configuration = 2, 4

Chlorine has 17 electrons.

Electronic configuration = 2, 8, 7

Oxygen has 8 electrons.

Electronic configuration = 2, 6

2. (b) 11

Electronic configuration of the element with the atomic number 3 = 2, 1.

Electronic configuration of the element with the atomic number 11 = 2, 8, 1.

Both have same number of electrons in the valence shell, hence show similar chemical properties.

3. (b) Mg^{2+}

0^{2-} has 10 electrons.

K^{+} has 18 electrons.

Mg^{2+} has 10 electrons.

Cl^{-} has 18 electrons.

S^{2-} has 18 electrons.

4. (c)

Electron	Proton	Neutrons
10	8	9

X has an atomic number of 8 and a mass number of 17.

So, number of neutrons is 17 – 8 = 9

Number of protons = 8

Number of electrons in X^{2}-ion = (8 + 2) = 10

5. (b) 10

The ion of an element has 2 positive charges.

A = 24, n = 12, p = 24 -12 = 12, e = 12 - 2 = 10

So, the number of electrons in the ion = 10

Case Study 5

Isotopes are elements with the same number of protons but have different number of neutrons. Since, the atomic number is equal to the number of protons and the atomic mass is the sum of protons and neutrons, isotopes are elements with the same atomic number but different mass numbers. For example, hydrogen has three isotopes namely protium, deuterium and tritium. Other such examples are (i) ${}^{12}_{6}C$ and ${}^{14}_{6}C$, (ii) ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$.

Read the given passage carefully and give the answer of the following questions:

Q 1. The average atomic mass of a sample of an element 'X' is 16.2 u. What are the percentage of isotopes $^{16}_{8}X$ and $^{18}_{8}X$ in the sample?

a. $^{16}_{8}X = 80\%,\ ^{18}_{8}X = 20\%$

b. $^{16}_{8}X = 60\%,\ ^{18}_{8}X = 40\%$

c. $^{16}_{8}X = 90\%,\ ^{18}_{8}X = 10\%$

d. $^{16}_{8}X = 45\%,\ ^{18}_{8}X = 55\%$

Q 2. Which isotope of chlorine has larger number of neutrons than protons?

a. $^{35}_{17}Cl$ b. $^{37}_{17}Cl$

c. Both a. and b. d. Neither of the two

Q 3. An atom of ..... contains no neutrons.

a. hydrogen b. tritium

c. deuterium d. None of these

Q 4. Which of the following is a property of isotopes?

a. They have the same numbers of electrons.
b. They have different numbers of protons.
c. They have different chemical properties.
d. They have the same mass number.

Q 5. An element with atomic number equal to 1, exists in three isotopes namely $^{1}_{1}H$, $^{2}_{1}H$ and $^{3}_{1}H$. Which one of these has only one electron in its outermost shell?

a. $^{1}_{1}H$ b. $^{2}_{1}H$ c. $^{3}_{1}H$ d. All of these

Solutions

1. (c) ${}^{16}_{8}X = 90\%,\ {}^{18}_{8}X = 10\%$

Let the % of isotopes ${}^{16}_{8}X$ and ${}^{18}_{8}X$ in the sample be x and $(100-x)$ respectively.
Average atomic mass,

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

$$16.2 = \frac{16x + 1800 - 18x}{100}$$

$$16.2 \times 100 = 16x + 1800 - 18x$$

$$1620 = 1800 - 2x$$

$$2x = 1800 - 1620 = 180$$

$$x = \frac{180}{2} = 90$$

$$(100 - x) \Rightarrow (100 - 90) = 10$$

Thus, % of ${}^{16}_{8}X = 90\%$ and % of ${}^{18}_{8}X = 10\%$

2. (c) Both a. and b.

3. (a) hydrogen

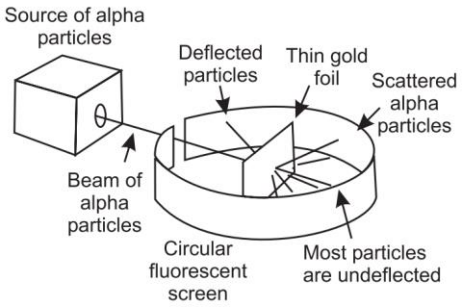
4. (a) They have the same numbers of electrons.

They have the same numbers of protons and electrons. They have different mass numbers.

5. (d) All of these

Case Study 6

A British physicist 'Ernest Rutherford' proposed a model of the atomic structure known as Rutherford's model of an atom. In this experiment, he bombarded fast moving alpha particles (doubly-charged helium ions) on a thin sheet of gold. On the basis of the observations made during the experiment, Rutherford concluded that major space in an atom is empty and the positive charge in an atom is not distributed uniformly and is concentrated in a very small volume. He also concludes that there is a positively charged centre (nucleus) in an atom and the electrons revolve around the nucleus in well defined orbits.



Read the given passage carefully and give the answer of the following questions:

Q1. What is the charge and mass on the particles used by Rutherford in his experiment?

Q2. State any two features of the atom as stated by Rutherford.

Q3. State the observations in α-particle scattering experiment which led Rutherford to make the following conclusions:

(i) Most of the space inside the atom is empty.

(ii) The nucleus of an atom is positively charged.

Q4. What was the drawback of Rutherford's model of the atom?

Q5. Which scientist concluded that size of the nucleus is very small as compared to the size of the atom?

Solutions

1. α-particles are positively charged (+2) and mass is 4u.

2. (i) Atom consist of a positively charged centre called nucleus.

(ii) The electrons revolve around the nucleus in circular paths.

3. (i) Most of the rays passed through the gold sheet without getting deflected.

(ii) Very few rays deflected through larger angles.

4. It could not explain the stability of an atom.

5. Ernest Rutherford.

Case Study 7

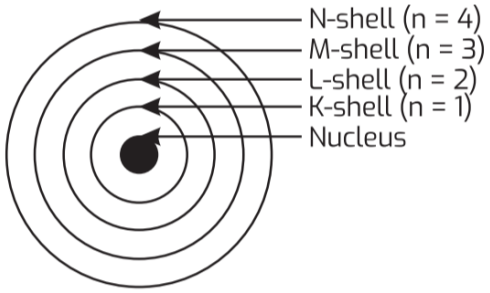
In order to overcome the objections raised against Rutherford's model of the atom, Neils Bohr put forward the following postulates about the model of an atom:

(i) Only certain special orbits known as discrete orbits of electrons, are allowed inside the atom.

(ii) While revolving in discrete orbits the electrons do not radiate energy.

These orbits or shells are called energy levels.

Energy levels in an atom are shown in figure.



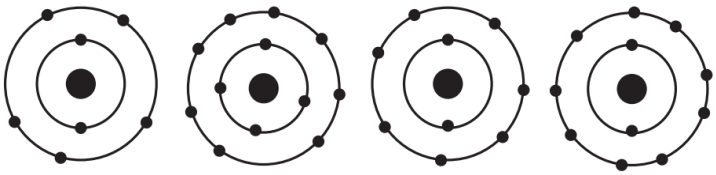
A few energy levels in an atom

These orbits or shells are represented by the letters K, L, M, N, ... or the numbers, n = 1, 2, 3, 4, ...

Read the given passage carefully and give the answer of the following questions:

Q1. A few energy levels in an atom are shown in the above figure. Which model of an atom is represented by the given figure?

Q2. Which of the following figures do not represent Bohr's model of an atom correctly?



(i) (ii) (iii) (iv)

Q3. Write two important postulates of Bohr's model of an atom.

Q4. Which shell of an atom can accommodate a maximum of: (i) 8 electrons (ii) 32 electrons?

Q5. An element has an atomic number of 15 and its mass number is 31. What is the arrangement of electrons in the shells?

Solutions

1. Bohr's model of atom.

2. Fig. (ii) contains 4 electrons in K-shell and fig. (iv) contains 9 electrons in L-shell which are not in accordance with Bohr's model.

3. (i) Only certain special orbits known as discrete orbits of electrons, are allowed inside the atom.

(ii) While revolving in discrete orbits, the electrons do not radiate energy.

4. (i) L-shell, (ii) N-shell

5. Electron distribution K L M

2, 8, 5

Case Study 8

Study the table related to distribution of electrons, neutrons and protons in six atoms/ions (A to F).

Atoms/ Ions	Number of Electrons	Number of Neutrons	Number of Protons
A	4	4	3
B	10	12	11
C	17	18	17
D	17	20	17
E	18	22	18
F	19	21	19

Read the given passage carefully and give the answer of the following questions:

Q1. Find a pair of ions.

Q2. Find an atom of a noble gas.

Q3. Find a pair of isobars.

Q4. Find a pair of isotopes.

Q5. Which atom/ions have valency one?

Solutions

1. A and B are ions as number of protons not equal to the number of electrons.

2. E is a noble gas.

3. E and F are isobars.

4. C and D are isotopes.

5. C, D and F.