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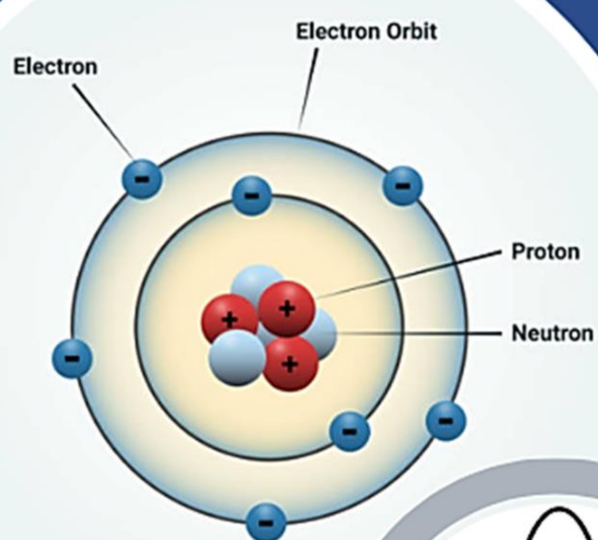

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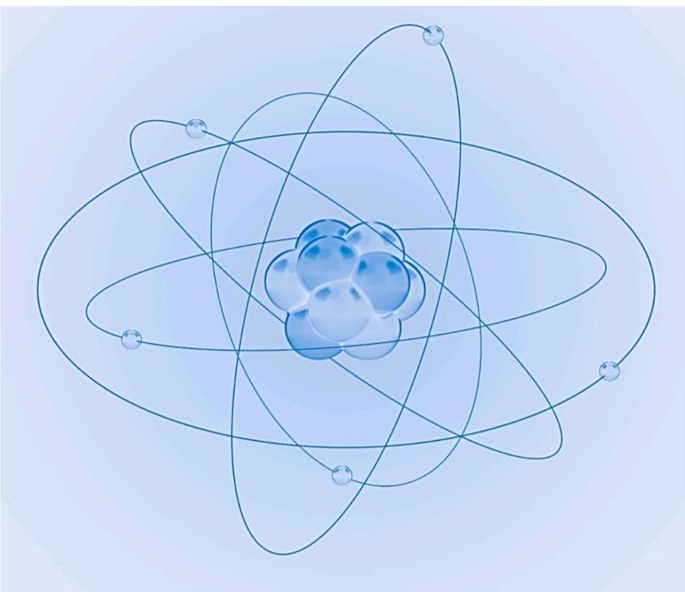
STRUCTURE OF ATOMS



Remember

Before beginning this chapter, you should be able to:

- understand basic concept of matter and atom.
- identify presence of subatomic particles.

Key Ideas

After completing this chapter, you should be able to:

- understand the concept of divisibility of atom and the characteristics of subatomic particles.
- study the stability of nucleus and nuclear reactions.
- conceptuliaze the model of atom based on the discovery of electrons.
- learn the planetary model of atom based on the concept of nucleus.
- study the concept of stationary orbits based on quantisation of energy and approach towards the modern atomic model.

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INTRODUCTION

The concept that atoms are the fundamental building blocks of matter dates back to very ancient times. However, the ideas regarding atoms of those times had no experimental evidence and remained as mere speculation. Therefore, these ideas had to lay dormant for a long period until John Dalton proposed his atomic theory on the basis of certain observations and experimental results. The basic principle of his theory was that it regarded an atom as the ultimate particle of matter.

Dalton's atomic theory has been successful in giving a convincing explanation for the various laws of chemical combination, such as, the law of conservation of mass, the law of definite proportions and the law of multiple proportions. However, Dalton's idea that the atom is an indivisible particle of matter has been disproved by later discovery of radioactivity. Several series of experiments on radioactivity which were carried out later proved the presence of various subatomic particles in an atom. Atoms are found to be mainly composed of three types of fundamental particles, namely, positively-charged protons, neutral particles known as neutrons and negatively-charged electrons. The discovery of these fundamental particles paved the way for further research on the internal structure of an atom which obviously explains the enormous diversity of chemistry involved in a wide range of chemical reactions.

DISCOVERY OF FUNDAMENTAL PARTICLES

The electron was the first fundamental particle that was discovered. The credit for the discovery of the electron goes to J.J. Thomson based on his experiments carried out in a discharge tube.

Sir William Crookes was the first scientist who designed the discharge tube which was called Crooke's discharge tube or cathode ray tube. It is a long glass tube having two metal plates connected to the oppositely charged poles of a battery. The pressure inside the discharge tube can be adjusted by means of an exhaust pump.

This discharge tube was later slightly modified by J.J. Thomson. When high voltage (HV) was applied between the cathode and the anode with a small hole at the centre of a partially evacuated tube at a pressure of 0.01 mm of Hg, a bright spot of light was formed on the zinc sulphide screen kept at the opposite end of the discharge tube. This was caused by the rays which originated from the cathode called cathode rays.

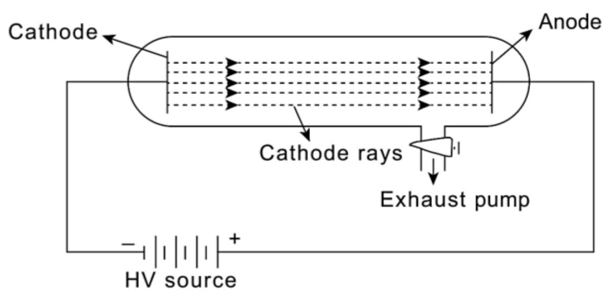


FIGURE 2.1 Cathode ray tube

J. J. Thomson conducted some experiments with a discharge tube for studying the properties of cathode rays.

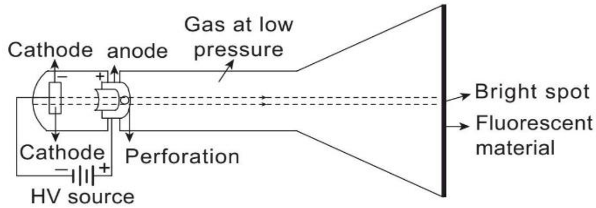
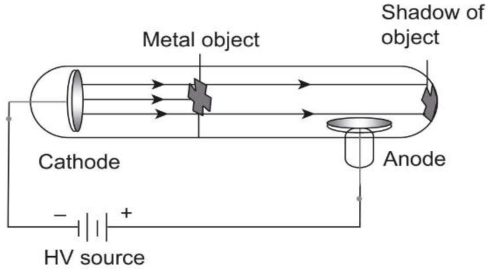
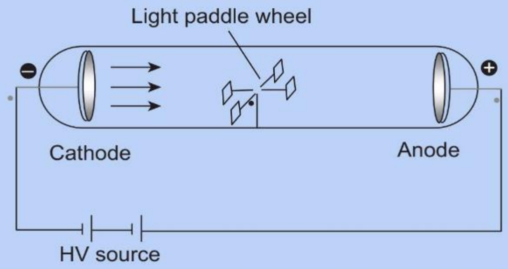
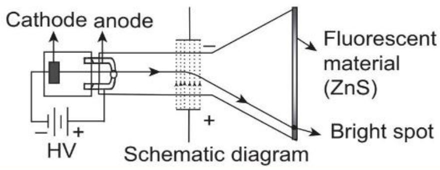
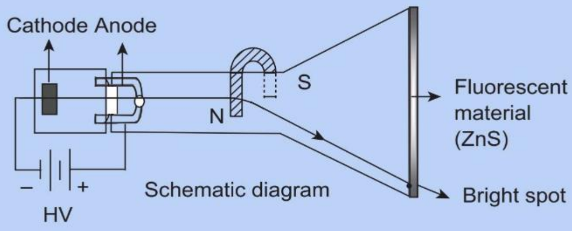


FIGURE 2.2 J.J. Thomson's cathode ray tube

TABLE 2.1 Experiments involved in discovery of fundamental particles

Experiments	Properties based on observation
Placing a small object in between the cathode and anode 	Formation of a shadow of the object on the opposite side of the cathode Cathode rays travel in straight lines
Placing a light paddle wheel between cathode and anode 	Rotation of light paddle wheel. Small particles having mass and kinetic energy
Passing through electric field 	Bending of rays towards the positive plate Negatively-charged particles
Passing through magnetic field applied perpendicular to the path of the cathode rays 	Deflection perpendicular to the applied magnetic field
The above experiments were carried out with different gases in the discharge tube.	No change in properties The properties do not depend on the nature of gas taken in the discharge tube. Specific charge (e/m value) remains the same.

The discovery of negatively-charged electron was later followed by the experiment conducted by Robert Millikan in 1909 to determine the quantity of charge on an electron.

Millikan's Oil Drop Experiment

Some fine oil droplets were allowed to be sprayed into the chamber by an atomiser. The air in the chamber was subjected to ionisation by X-rays. The electrons produced by the ionisation of air attached themselves to the oil drops. When sufficient amount of electric field is applied which can balance the gravitational force acting on an oil drop, the drop remains suspended in the air.

From this experiment, Millikan observed that the smallest charge found on them was approximately 1.59×10^{-19} coulombs and the charge on each drop was always an integral multiple of that value.

On the basis of this observation, he concluded that 1.59×10^{-19} coulombs is the smallest possible charge and considered that value as the charge of the electron.

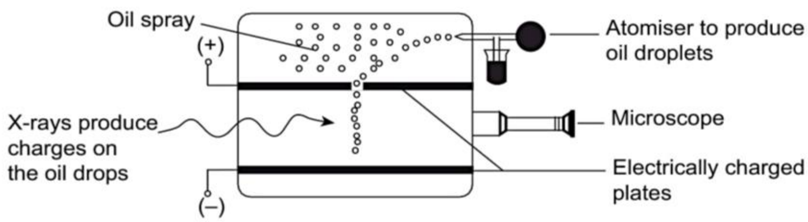


FIGURE 2.3 A schematic representation of the apparatus used by Millikan to determine the charge of an electron

DISCOVERY OF PROTONS

The presence of positively-charged particles in an atom has been predicted by Goldstein based on the electrical neutrality of an atom. The discovery of proton by Goldstein was done on the basis of the cathode ray experiment conducted by using a perforated cathode.

Just like the cathode rays, some rays were found to emanate from an anode. These are called anode rays or canal rays.

Anode rays were found as a stream of positively-charged particles in contrast to the cathode rays. When hydrogen gas is taken in a discharge tube, these positively-charged particles were found to be protons.

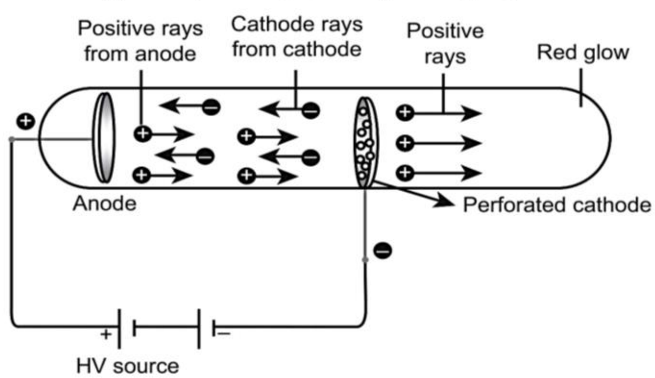


FIGURE 2.4 Discovery of Protons

Properties of Anode Rays

1. Anode rays travel in straight lines.
2. Anode rays possess positive charge since they were found to deflect towards negatively-charged electrodes.

3. The properties of anode rays depend upon the nature of the gas taken in the discharge tube.
4. The mass of the particles was same as the atomic mass of the gas inside the discharge tube.

The discovery of electrons and protons as subatomic particles inside the atom lead to the conception of atomic models which depict the arrangement of fundamental particles in an atom.

Various atomic models have been proposed by different scientists, like, J.J. Thomson, Rutherford, Bohr and Sommerfeld.

Thomson's Atomic Model

J.J. Thomson proposed his atomic model soon after his discovery of electrons as listed hereunder.

1. An atom contains negatively-charged particles called electrons embedded uniformly throughout a thinly spread positively-charged mass.
2. Since the atom is electrically neutral, the total negative charge of electrons is balanced by the total positive charge.

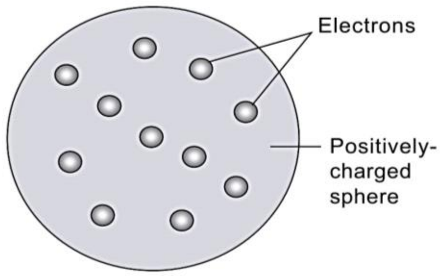


FIGURE 2.5 Thomson's atomic model

Thomson's model of an atom is popularly known as 'plum pudding model' or 'apple pie model' or 'watermelon model'.

Validity of Thomson's Model

Thomson's model could successfully explain the electrical neutrality of atom. However, it failed to explain how the positively-charged particles are shielded from the negatively-charged electrons without getting neutralised.

EXAMPLE

Write different isotopes of oxygen, carbon and chlorine.

SOLUTION

The isotopes of oxygen are: ${}_8O^{16}$, ${}_8O^{17}$, ${}_8O^{18}$.

The isotopes of chlorine are: ${}_{17}Cl^{35}$, ${}_{17}Cl^{37}$.

The isotopes of carbon are: ${}_6C^{12}$, ${}_6C^{13}$, ${}_6C^{14}$.

EXAMPLE

What was the basis for the proposal of Dalton's atomic theory?

SOLUTION

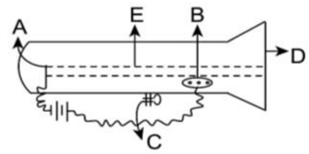
Laws of chemical combination, such as, the law of conservation of mass, the law of definite proportions and the law of multiple proportions, were the basis for the proposal of Dalton's atomic theory.

EXAMPLE

(i) What are A, B, C, D, and E in the given figure?

(ii) What is the purpose of C?

(iii) Explain the role of D in the phenomenon taking place in the discharge tube.



SOLUTION

(i) A is cathode, B is perforated anode, C is suction pump, D is zinc sulphide screen and E is cathode ray.

(ii) C is suction pump which can help in reducing the pressure in the discharge tube.

(iii) D is zinc sulphide screen. Zinc sulphide is a fluorescent material. When cathode rays strike the zinc sulphide screen, bright spots are formed on the screen.

EXAMPLE

An atom of an element is represented as $_ZX^A$. After the emission of a β-particle, another element Y is formed. Represent Y with atomic number and mass number.

SOLUTION

$_zX^A \rightarrow {}_{z+1}Y^A + \beta$ particle.

EXAMPLE

Calculate the specific charges (e/m) of the following particles and then arrange the particles in the ascending order of their specific charges.

(a) Electron **(b)** Proton **(c)** α-particle

SOLUTION

$$\text{Specific charge of an electron} = \frac{1.6\times10^{-19}}{9.1\times10^{-31}} \text{ coulomb/kg}$$

$$= 0.176 \times 10^{12} = 17.6 \times 10^{10} \text{ coulomb/kg}$$

$$\text{Specific charge of a proton} = \frac{1.6\times10^{-19}}{1.67\times10^{-27}} \text{ coulomb/kg} = 0.96 \times 10^{8} \text{ coulomb/kg}$$

$$\text{Specific charge of } \alpha\text{ - particle} = \frac{2\times1.6\times10^{-19}}{2\times10^{-27}(1.67+1.72)} = \frac{1.6\times10^{8}}{3.39} = 0.472 \times 10^{8} \text{ coulomb/kg}$$

Hence, ascending order of specific charges of electron, proton and α-particles is

α-particle < proton < electron.

EXAMPLE

Calculate the mass of a charged particle in CGS units if its charge is x coulomb and specific charge is y coulomb/g.

SOLUTION

The mass of the particle in CGS units is $\dfrac{e}{\frac{e}{m}}\,g = \dfrac{x}{y}\,g$.

EXAMPLE

The isotopes of an element have mass numbers: A, A + 1, A + 2. The ratio of abundance of these isotopes is 3 : 2 : 4. Calculate the average atomic mass of the element.

SOLUTION

Average atomic mass $= \dfrac{A \times 3 + (A+1)2 + (A+2)4}{9} = \dfrac{3A + 2A + 2 + 4A + 8}{9} = A + \dfrac{10}{9}$

Rutherford's α-ray Scattering Experiments

In order to test the validity of Thomson's atomic model, Rutherford conducted α-ray scattering experiment.

In this experiment, α-particles were allowed to pass through a pair of positively-charged parallel plates and the resultant narrow beam of α-particles was allowed to strike the gold foil which was surrounded by zinc sulphide screen.

The observations or results of this experiment completely disproved Thomson's model.

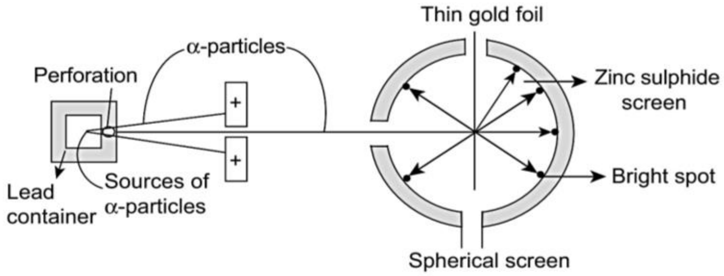


FIGURE 2.6 α-ray Scattering Experiment

TABLE 2.2 Observations and conclusions of α-ray scattering experiment

Observations	Conclusions
Most of the particles passed straight through the gold foil without any deflection	Presence of large empty space in an atom
Very few α-particles completely rebounded and few α-particles showed large deflection	Presence of a central, positively-charged core known as nucleus

Rutherford's Atomic Model

The atom is mostly composed of empty space. The entire positive charge and mass of the atom is concentrated in the small, central part known as the nucleus. The size of the nucleus is so small that its diameter is 10^5 times less than that of the atom. The diameter of the nucleus has been estimated by

Rutherford as 10^{-13} cm in contrast to that of the atom to be 10^{-8} cm. The electrons present outside the nucleus revolve round the nucleus with high velocities.

The electrons revolve round the nucleus with high velocities to counterbalance the electrostatic forces of attraction between protons and electrons. Rutherford's atomic model resembles the planetary motion in solar system. Therefore, Rutherford's model of an atom is also called planetary model.

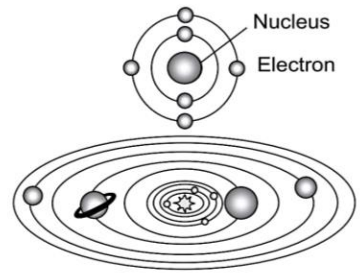


FIGURE 2.7 The solar system

Validity of Rutherford's Atomic Model

Rutherford's atomic model could very well explain the presence of positively-charged nucleus and presence of electrons outside the nucleus in the atom. However, the failure of Rutherford's theory stemmed from two major objections.

1. This model is in contradiction to the principle of classical electrodynamics. According to this, any charged particle in a circular motion radiates energy continuously. The electron being a charged particle in the circular motion loses energy. This should ultimately result in its spiral path towards nucleus and the atom should then collapse.
2. The second major objection to Rutherford's model came from the pattern of atomic spectra.

When light passes through a prism, it gets split up into its components of different wave lengths, like, visible, ultraviolet, infrared light, etc. The arrangement of component light energies according to their wavelengths is called spectrum and spectroscope is the instrument designed to observe the spectra.

Since white light is composed of lights of different wavelengths, a continuous band of different wave lengths is obtained which is called continuous spectrum. Light from the sun or incandescent bulb gives such type of spectra.

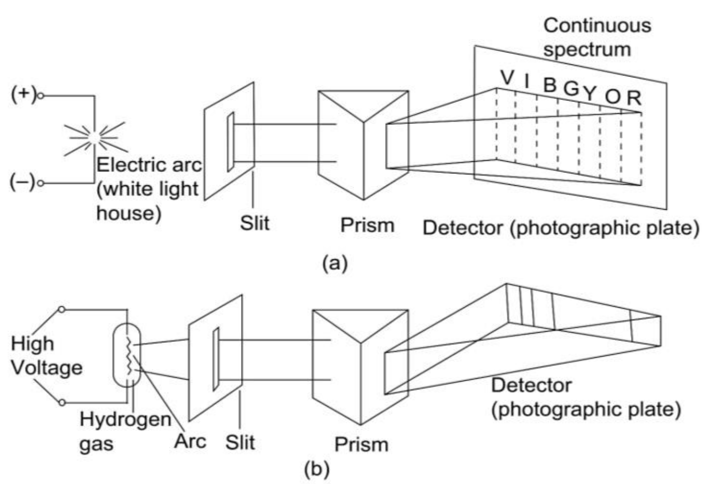


FIGURE 2.8 (a) Spectrum produced by the white light
(b) Atomic spectra of hydrogen

But when the spectrum is taken for the atoms of the gas present in the discharge tube, it is found to consist of discrete lines of different colours. This is called line spectrum, which is a discontinuous spectrum. Figure 2.8 (b) shows the atomic spectra of hydrogen gas.

According to Rutherford's atomic model, electrons revolving around the nucleus should lose energy continuously. Hence, the spectra of the atom should be a continuous spectrum, whereas the observed atomic spectrum was a line spectrum.

In 1913, Danish scientist, Neils Bohr could overcome the limitation of Rutherford's atomic model successfully based on the quantum theory of radiation proposed by Max Planck.

Quantum Theory of Radiation

At the end of the 19th century, physicists had an idea that matter and energy are distinctly different. Matter consists of particles which have mass and have specific positions in space.

Energy is the form of electromagnetic radiation which has no mass and does not have any specific position in space. Matter can absorb or emit any quantity of energy.

But in the beginning of the 20th century, these ideas were proved to be incorrect on the basis of some experimental results.

German physicist, Max Planck, in 1901 carried out the first important experiment by studying the radiation emitted by solid bodies heated to incandescence.

He concluded from his experimental observation that energy can be absorbed or radiated by a body in the form of small packets of energy called quanta which are whole number multiples of the quantity $h\nu$ where

h = Planck's constant = 6.625×10^{-34} J.s

ν = frequency of the radiation

EXAMPLE

Following conclusions are drawn by observing α-ray scattering experiment. Write the respective observations based on which these conclusions are drawn.

(i) Non-uniform distribution of positive charge.

(ii) Presence of positively-charged core or nucleus.

(iii) Presence of large empty space in an atom.

SOLUTION

	Observations	Conclusions
(i)	Non-uniform distribution of positive charge	The angle of deflections of various α-particles were different
(ii)	Presence of positively-charged core or nucleus	Very few α-particles completely rebounded and few α-particles showed large deflection
(iii)	Presence of large empty space in an atom	Most of the α-particles passed through the gold foil without any deflection

EXAMPLE

Compare Thomson's atomic model with Rutherford's atomic model.

SOLUTION

	Thomson's atomic model	Rutherford's atomic model
(a)	In Thomson's model positively-charged particles are thinly spread throughout the atom.	In Rutherford's model, positively-charged particles are concentrated in a small central part called nucleus.
(b)	Electrons are embedded in the thin positively-charged mass.	Electrons revolve around the nucleus with a high velocity.

EXAMPLE

The wavelength of particular radiation is 700 nm (1 nm = 10^{-9} m). Find its frequency (ν).

SOLUTION

λ = 700 nm = 700 × 10^{-9} m = 7 × 10^{-7}m. Also, c = velocity of light = 3 × 10^8 m/s

So, $\nu = \dfrac{c}{\lambda} = \dfrac{3\times10^8}{7\times10^{-7}} = 0.42 \times 10^{15}$/s

This theory proves the particle nature of energy.

On the basis of this theory, Bohr proposed his atom model.

Bohr's Model of an Atom

1. Electrons revolve around the nucleus in specified circular paths called orbits or shells.
2. Each orbit or shell is associated with a definite amount of energy. Hence, these are also called energy levels and are designated K, L, M and N, respectively.
3. The energy associated with a certain energy level increases with the increase of its distance from the nucleus. Hence, if the energy associated with the K, L, M and N shells are E_1, E_2, E_3……… respectively, then $E_1 < E_2 < E_3$ ………., etc.
4. As long as the electron revolves in a particular orbit, the electron does not lose its energy. Therefore, these orbits are called stationary orbits and the electrons are said to be in stationary energy states.
5. An electron jumps from a lower-energy level to a higher-energy level, by absorbing energy, but when it jumps from a higher- to lower-energy level, the energy is emitted in the form of electromagnetic radiation. The energy emitted or absorbed (ΔE) is an integral multiple of 'hν.'
6. The electron can revolve only in the orbit in which the angular momentum of the electron (mvr) is quantised, i.e., mvr is a whole number multiple of h/2π. This is known as the principle of quantisation of angular momentum.

   The angular momentum is written as

   $$mvr = \frac{nh}{2\pi},$$

   where, n is an integer (n = 1,2,3,4,…….) and is called principal quantum number.
   m = mass of the electron
   v = velocity of an electron in its orbit
   r = distance of the electron from the nucleus

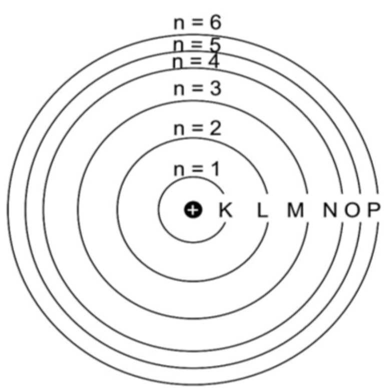


FIGURE 2.9 Stationary orbits of an atom

By applying the concept of quantisation of energy, Bohr calculated the radius and energy of the n^{th} orbit of hydrogen atom.

$$r_n = \frac{n^2h^2}{4\pi^2me^2}, E_n = \frac{-2\pi^2me^4}{n^2h^2}$$

With the help of these expressions, Bohr gave a satisfactory explanation for the spectra of hydrogen and hydrogen-like species (ions having one electron, e.g., He^+, Li^{+2}, Be^{+3}).

Limitations of Bohr's Atomic Model

The following are the limitations of Bohr's atomic model:

1. Bohr could not explain the spectral series for the multi-electron atoms.
2. Bohr's model could not give a satisfactory justification for the assumption that electrons can revolve in those orbits where their angular momentum (*mvr*) is a whole number multiple of $nh/2\pi$, i.e., he could not justify quantisation of angular momentum.
3. According to Heisenberg's uncertainty principle, it is impossible to determine simultaneously with certainty the exact position and the momentum of the particle. Bohr assumed that an electron of an atom is located at a definite distance from the nucleus and revolves around the nucleus with a definite velocity, i.e., the momentum of the electron is fixed which is against Heisenberg's uncertainty principle.
3. The atomic spectral lines split into a number of closely packed lines in the presence of a magnetic field and an electric field. These effects are called **Zeeman effect** and **Stark effect**, respectively. Bohr failed to explain these effects.
4. When the hydrogen spectrum was observed with the spectroscope of high resolving power, it was found that the individual lines in the spectrum consisted of several fine lines lying close to each other. This is called fine spectrum and he failed to explain the fine structure of the spectrum.

DISCOVERY OF NEUTRONS

The electrons being particles having negligible mass and massive protons concentrated inside the nucleus, it could be predicted that the mass of an atom has to be equal to the mass of the total number of protons present in the atom. However, this was found to be true only in case of a hydrogen atom.

The difference in the predicted mass and actual mass of the atom has been found to be equal to the mass of the proton or multiples of the mass of a proton. These particles are supposed to have neutral charge since the atom is electrically neutral. They were called neutrons and they were discovered by James Chadwick by an experiment involving the bombardment of beryllium nucleus with α-particles.

The discovery of fundamental particles has ultimately resulted in the establishment of a basic atomic model. The basic model of an atom comprises small positively-charged nucleus at the centre of the atom and the electrons revolving round the nucleus in orbits.

TABLE 2.3 Characteristics of fundamental particles

S. No.	Fundamental Particles	Charges	Masses	Relative Charges
1.	Electron (*e*)	-1.6×10^{-19}C -4.8×10^{-10} esu	9.1×10^{-31} kg (or) 0. 00055 amu	–1
2.	Proton (*p*)	+ 1.6×10^{-19} C + 4.8×10^{-10} esu	1.67×10^{-27} kg (or) 1.0078 amu	+1
3.	Neutron (*n*)	0	1.72×10^{-27} kg (or) 1.0083 amu	0

TABLE 2.4 Atomic number and mass number

Representations		Definitions	Examples
Atomic number	Z	The number of protons in an atom	Cl atom has 17 protons in its atom, Z = 17
Mass number	A	The total number of nucleons, i.e., number of protons and neutrons in an atom	Cl atom has 17 protons and 18 neutrons in its nucleus. $\therefore$ A = 17 + 18 = 35

An element when represented along with its atomic number and mass number is represented as $_ZX^A$. Elements are found to exist in their isotopic forms. Isotopes are the atoms of the same element having different mass number. Based on their percentage abundance of each isotopic form, average atomic mass of an element is calculated.

Examples: $_1H^1$, $_1H^2$, $_1H^3$, etc.

It is also found that atoms of different elements have same mass number. These are called isobars.

Examples: $_{18}Ar^{40}$, $_{20}Ca^{40}$, etc.

Electronic Configuration

The systematic arrangement of electrons in the various shells or orbits in an atom is called electronic configuration.

The electrons are arranged in an atom in the various shells around the nucleus. The last shell or the outermost shell from the nucleus with electrons is called valence shell. The shell inner to this is called penultimate shell and the one inner to the penultimate shell is called anti-penultimate shell.

Shell	$2n^2$
K	2
L	8
M	18
M	32
O	50

The filling of electrons in various shells can be done according to Bohr–Bury scheme. According to this, the maximum number of electrons that can be accommodated in any shell is given by $2n^2$, where *n* represents the number of the shell.

The maximum number of electrons that can be filled in the valence shell is 8, that in the penultimate shell is 18 and the anti-penultimate shell has a maximum capacity of 32 electrons. The filling of electrons till atomic number 30 follows the following pattern:

K	L	M	N
2			
2	8		
2	8	8	
2	8	8	2
2	8	18	2

EXAMPLE

An element has protons whose mass is equal to 23,881 times that of an electron. Identify the element and write its electronic configuration.

SOLUTION

Mass of a proton is 1837-times than that of an electron.

Number of protons $= \dfrac{23{,}881}{1837} = 13$

Atomic number of the element is 13.

So, the element is aluminium and its electronic configuration is 2, 8, 3.

EXAMPLE

Write the electronic configuration and the atomic number of the atom which becomes stable by gaining 3 electrons in fifth shell.

SOLUTION

The electronic configuration of the stable species is 2, 8, 18, 18, 8

Hence, the electronic configuration of the atom which becomes stable after gaining 3 electrons in the fifth shell is 2, 8, 18, 18, 5 and the atomic number is 51.

EXAMPLE

What is the ratio of the amount of energy required to remove an electron from hydrogen and He^+ ion?

SOLUTION

Energy of electron (single electron species) $E_n = -\dfrac{13.6 \times Z^2}{n^2}\,\text{eV}$;

For hydrogen $\Rightarrow -13.6 \times \dfrac{1^2}{1^2} = -13.6\,\text{eV}$; Energy required to remove this electron = +13.6 eV

For He^+ $\Rightarrow -13.6 \times \dfrac{2^2}{1^2} = -54.4\,\text{eV}$; Energy required to remove this electron = +54.4 eV

Ratio of energy required $= \dfrac{13.6}{54.4} = \dfrac{1}{4} = 1 : 4$.

EXAMPLE

Complete the following table:

Valence shells in atom	Charges on stable ions	Electronic configurations of element	Number of electrons in penultimate shell	Number of core electrons
M	+3			
	+1		8	18
N	+2			18
		2, 8, 6		

Note: Core electrons are inner electrons which exclude valence electrons.

SOLUTION

Valence shells in atom	Charges on stable ion	Electronic configurations of element	Number of electrons in penultimate shell	Number of core electrons
M	+3	2, 8, 3	8	10
N	+1	2, 8, 8, 1	8	18
N	+2	2, 8, 8, 2	8	18
M	−2	2, 8, 6	8	10

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TEST YOUR CONCEPTS

Very Short Answer Type Questions

1. Which postulate of Dalton's atomic theory is considered to be correct even today?
2. Like atoms are identical in all respects. This statement of Dalton's atomic theory is contradicted. Which discovery contradicts this?
3. The value of the Planck's constant '*h*' in erg-s is ______.
4. Why was a gas at low pressure taken by Thomson while conducting the experiment?
5. Why is Rutherford's model called nuclear model?
6. Mass of the electron is calculated from ____ and ____ values of electron.
7. Give the mass and charge of fundamental particles of an atom.
8. What is an atomic model?
9. The equation for the calculation of energy of nth orbit of hydrogen atom derived by Bohr is ______.
10. Who discovered protons? Based on what experiment was he able to discover these protons?
11. What was the mathematical equation given by Max Planck?
12. Who discovered neutrons? How was the discovery made?
13. Neutrons were discovered by bombarding beryllium with _____ particles.
14. What name did Max Planck give to energy packets?
15. What is Heisenberg's uncertainty principle?
16. According to _______, the charges in an atom are arranged like the pulp and seeds of a watermelon.
17. Which theory supported the particle nature of an electron?
18. Give the value of Planck's constant in
    (1) erg-s
    (2) joule-s
19. Give equations to calculate the following:
    (a) the radius of the nth orbit of hydrogen atom
    (b) energy of the nth orbit of hydrogen atom
20. What happens when an electron jumps from a lower energy level to a higher energy level?
21. What is Zeeman effect?
22. What is Stark effect?
23. With the increase in the radius of the orbit, the energy of an electron ____________.
24. What is an α-particle?
25. What is a continuous spectrum?
26. The circular paths in which electrons revolve are called ______.
27. Why are light rays known as electromagnetic waves?
28. The ______ consists of well-defined lines of definite frequencies.
29. In the formula $E = h\nu$, E is ______ and ν is ______.

Short Answer Type Questions

30. 'Electrons jump from one orbit to another orbit.' Justify this statement on the basis of Bohr's theory.
31. On what basis did Bohr propose his atomic model?
32. What are orbits and why are they called stationary orbits?
33. Mention the properties of anode rays.
34. What is the amount of energy needed to remove an electron from a hydrogen atom to produce an H+ ion? Explain.
35. If Rutherford's atomic model is correct, then the atom should collapse. Why?
36. Describe Millikan's oil drop experiment in brief.
37. According to Rutherford's atomic model, where are the protons and electrons located in an atom?

38. Why was the presence of neutrons in an atom predicted? How were neutrons discovered?

39. Describe J.J. Thomson's atomic model.

40. Define angular momentum. In the relation $mvr = \frac{nh}{2\pi}$, what do m, v, r and h denote?

41. On what basis did Bohr assume the concept of stationary orbits for an electron?

42. The wavelength of a particular radiation is 700 nm (1 nm = 10^{-9} m). Find its frequency (ν).

43. Distinguish between continuous spectrum and discontinuous spectrum. Give some examples of sources for these spectra.

44. An electron revolving round in an orbit has angular momentum equal to $\frac{h}{2\pi}$. Can it lose energy?

Essay Type Questions

45. Explain Bohr's atomic model.

46. What are the observations and conclusions drawn by J.J. Thomson while conducting experiments with a discharge tube for studying the properties of cathode rays?

47. What are the drawbacks of Rutherford's atomic model?

48. Describe Rutherford's atomic model.

49. State the limitations of Bohr's model.

CONCEPT APPLICATION

Level 1

Direction for questions from 1 to 7:
State whether the following statements are true or false.

1. According to Thomson's atomic model, electrons revolve round the nucleus.

2. In a discharge tube, anode rays originate when electrons collide with gas molecules.

3. ${}_8O^{16}$ and ${}_8O^{18}$ are isotopes while ${}_{20}Ca^{40}$ and ${}_{18}Ar^{40}$ are isobars.

4. Energy is absorbed when the electron jumps from K to L energy shells.

5. α-ray scattering experiment proved that the positive particles are present in the extra nuclear part of an atom.

6. Characteristic spectra of atoms are line spectra.

7. An electron in the excited state of an atom is highly unstable.

Direction for questions from 8 to 14:
Fill in the blanks.

8. Anode rays are deflected towards the negative plate in the presence of an electric field because they consist of _____ particles.

9. Some of the α-rays deflect in acute and obtuse angles due to the presence of the _______ in the centre of the atom.

10. According to classical electrodynamics, if an electrically charged particle revolves in a circular path, it continuously ______ energy.

11. The energy of an electron present in the first orbit of an atom is ________ than the energy of electron in the other orbits.

12. Splitting of spectral lines in the presence of magnetic field is known as _____ effect.

13. The kinetic energy of an electron present in the first orbit of an atom is ________ than that of the electron in the last orbit.

14. The spectra produced by the deexcitation of an electron is called ________________.

PRACTICE QUESTIONS

Direction for question 15:

Match the entries given in Column A with appropriate ones from Column B.

15.

Column A	Column B
A. $\frac{e}{m}$ value varies with the nature of gas	( ) a. *hv*
B. Plum pudding model	( ) b. Rutherford's atomic model
C. Mass of the atom is concentrated at the centre of atom	( ) c. Sun rays
D. Continuous spectrum	( ) d. Bohr's stationary orbit
E. $mvr = \frac{nh}{2\pi}$	( ) e. Thomson's atomic model
D. Quantum	( ) f. Anode rays

Direction for questions from 16 to 45:

For each of the questions, four choices have been provided. Select the correct alternative.

16. Which of the following concepts was not considered in Rutherford's atomic model?

(a) the electrical neutrality of atom

(b) the quantisation of energy

(c) electrons revolve around nucleus at very high speeds

(d) existence of nuclear forces of attraction on the electrons

17. When alpha particles are sent through a thin metal foil, only one out of ten thousand of them rebounded. This observation led to the conclusion that

(a) positively-charged particles are concentrated at the centre of the atom

(b) more number of electrons is revolving around the nucleus of the atom

(c) unit positive charge is only present in an atom

(d) a massive sphere with more negative charge and unit positive charge is present at the centre of the atom

18. Canal ray experiment lead to the discovery of ______.

(a) protons (b) neutrons

(c) electrons (d) nucleus

19. In which of the following pairs of shells, energy difference between two adjacent orbits is minimum?

(a) K, L (b) L, M

(c) M, N (d) N, O

20. **Assertion A:** An electron in the inner orbit is more tightly bound to the nucleus.

Reason B: The greater the absolute value of energy of an electron the more tightly the electron is bound to the nucleus.

(a) Both A and B are true but B is not the appropriate reason for A.

(b) Both A and B are individually correct and B is the correct reason for A.

(c) A is correct but B is not correct.

(d) Both A and B are not correct.

21. The electron revolves only in the orbits in which

(a) $mvr > \frac{nh}{2\pi}$ (b) $mvr \geq \frac{nh}{2\pi}$

(c) $mvr = \frac{nh}{2\pi}$ (d) $mvr < \frac{nh}{2\pi}$

22. Which among the following pairs are having different number of valence electrons?

(a) Na^+, Al^{+3} (b) P^{-3}, Ar

(c) Mg^{+2}, Ar (d) O^{-2}, $\bar{F}$

23. If two naturally occurring isotopes of an element are 7^{X15}, 7^{X11}; what will be the percentage composition of each isotope of X occurring, respectively, if the average atomic weight accounts to 14?

(a) 95, 5 (b) 80, 20

(c) 75, 25 (d) 65, 35

24. According to quantum theory of radiation, which is false?

(a) radiations are associated with energy

(b) radiation is neither emitted nor absorbed discontinuously

(c) the magnitude of energy associated with a quantum is dependent on frequency

(d) photons are quanta of radiation

25. Select True/False among the following statements:

(i) Bohr's theory successfully explained stability of the atom.

(ii) Atoms give line spectra.

(iii) Velocity of electromagnetic waves depends on the frequency.

(iv) Bohr introduced the concept of orbital.

(a) (i) T, (ii) T, (iii) F, (iv) F

(b) (i) T, (ii) F, (iii) T, (iv) T

(c) (i) F, (ii) T, (iii) F, (iv) F

(d) (i) F, (ii) F, (iii) T, (iv) T

26. Which of the following particles do not produce electronic spectra?

(a) Li^{+2} (b) He^{+2}

(c) Be^{+2} (d) Na^{+}

27. An element has two isotopes with mass numbers 16 and 18. The average atomic weight is 16.5. The percentage abundance of these isotopes is ______ and ______, respectively.

(a) 75, 25 (b) 25, 75

(c) 50, 50 (d) 33.33, 66.67

28. Which among the following are isobars?

(a) ${}_{b}X^{a}$ and ${}_{b}Y^{a+1}$ (b) ${}_{b}X^{a}$ and ${}_{c}Y^{b}$

(c) ${}_{b}X^{a}$ and ${}_{b+1}Y^{a}$ (d) ${}_{b}X^{a}$ and ${}_{b-1}Y^{a-1}$

29. Some of the elements have fractional atomic masses. The reason for this could be

(a) the existence of isobars

(b) the existence of isotopes

(c) the nuclear reactions

(d) the presence of neutrons in the nucleus

30. Which of these pairs has almost similar masses?

(a) proton–electron (b) neutron–electron

(c) electron–${}_{1}H^{1}$ (d) neutron–${}_{1}H^{1}$

31. The energy of an electron revolving in the 3rd orbit of Be^{+3} ion is _________ ev

(a) −10.2 (b) −13.6

(c) −24.2 (d) −18.1

32. Which of the following concepts, was not considered in Rutherford's atomic model?

(a) the electrical neutrality of atom

(b) the quantisation of energy

(c) electrons revolve around the nucleus at very high speeds

(d) existence of nuclear forces of attraction on the electrons

33. ${}_{7}X^{15}$, ${}_{7}X^{11}$ are two naturally occurring isotopes of an element X. What is the percentage of each isotope of X if the average atomic mass is 14?

(a) 95, 5 (b) 80, 20

(c) 75, 25 (d) 65, 35

34. A trinegative ion of an element has 8 electrons in its M shell. The atomic number of the element is

(a) 15 (b) 18

(c) 20 (d) 16

35. Arrange the following statements given by various scientists in chronological order:

(1) calculation of energy and radius of orbit

(2) atoms of the same elements are identical in all respects

(3) calculation of diameter of the nucleus and the atom

(4) assumption of thinly spread positively-charged mass

(a) 4 3 1 2 (b) 4 2 3 1

(c) 2 4 3 1 (d) 3 4 2 1

36. What is the ratio of radii of the first successive odd orbits of hydrogen atom?

(a) 9 : 1 (b) 1 : 9

(c) 1 : 3 (d) 3 : 1

37. An electron revolves round the nucleus in the 3rd orbit and jumped to a higher orbit X showing a difference in angular momentum equal to $\frac{h}{\pi}$. The value of 'X' could be

(a) 4 (b) 6

(c) 5 (d) 7

38. Rutherford's α-particle scattering experiment eventually led to the conclusion that

(a) mass and energy are related

(b) the point of impact with matter can be precisely determined

(c) neutrons are buried deep in the nucleus

(d) electrons are distributed in a large space around the nucleus

39. Arrange the following steps which are carried out in μ-ray experiment in the correct sequence:

(1) Passage of μ-particles through a slit

(2) bombardment of μ-particles with a gold foil

(3) deflection of μ-particles
(4) production of μ-particles
(a) 4 1 2 3 (b) 4 1 3 2
(c) 1 4 3 2 (d) 1 4 2 3

40. Which among the following pairs are having different number of total electrons?
(a) Na^+ and Al^{+3} (b) P^{-3} and Ar
(c) Mg^{+2} and Ar (d) O^{-2} and F^-

41. The postulates of Bohr's atomic model are given below. Arrange them in the correct sequence:
(1) As long as the electron revolves in a particular orbit, the electron does not lose its energy. Therefore, these orbits are called stationary orbits and the electrons are said to be in stationary energy states.
(2) Electrons revolve round the nucleus in specified circular paths called orbits or shells.
(3) The energy associated with a certain energy level increases with the increase of its distance from the nucleus.
(4) An electron jumps from a lower energy level to a higher energy level by absorbing energy. But when it jumps from a higher to lower energy level, energy is emitted in the form of electromagnetic radiation.
(5) Each orbit or shell is associated with a definite amount of energy. Hence, these are also called energy levels and are designated as K, L, M and N, respectively.
(a) 1 3 4 5 2 (b) 2 3 5 1 4
(c) 2 5 3 1 4 (d) 2 1 4 3 5

42. The ratio of atomic numbers of two elements A and B is 1 : 2. The number of electrons present in the valence shell (3rd) of A is equal to the difference in the number of electrons present in the other two shells. Steps involved for the calculation of ratio of number of electrons present in a penultimate shell to anti-penultimate shell of B are given below. Arrange them in the correct sequence:
(1) calculation of atomic number of B
(2) calculation of valence electrons present in A
(3) calculation of atomic number of A
(4) calculation of number of electrons present in the penultimate and anti-penultimate shells of B
(5) writing electronic configuration of B
(a) 2 3 4 1 5 (b) 2 3 1 5 4
(c) 4 5 2 3 1 (d) 4 2 1 3 5

43. The equation given by Bohr to calculate radius of n^{th} orbit of hydrogen atom is
(a) $r_n = \frac{n^2h^2}{4\pi^2 me}$ (b) $r_n = \frac{n^2h^2}{4\pi^2 me}$
(c) $r_n = \frac{nh^2}{4\pi^2 me}$ (d) $r_n = \frac{n^2h^2}{4\pi^2 m^2 e}$

44. The number of electrons present in the valence shell of an atom with atomic number 38 is
(a) 2 (b) 10
(c) 1 (d) 8

45. The mass number of an atom whose unipositive ion has 10 electrons and 12 neutrons is
(a) 22 (b) 23
(c) 21 (d) 20

Level 2

1. When the same isotopic gas is taken in two discharge tubes, the angle of deflection is found to be different though the strength of the external electric field applied is the same. Explain.

2. In a canal ray experiment, different gases were found to produce canal rays with the same specific charge. Explain.

3. When canal rays experiment is conducted with hydrogen gas, scientists were found to give particles with different $\frac{e}{m}$ values. Justify.

4. Energy of the electron in the atom is negative. Explain.
[Hint: Energy of a free electron is taken as zero.]

5. If the energy released when an electron jumped from the 4th orbit to the 3rd orbit of hydrogen is '*x*,' then what would be the energy difference when it jumps from the 3rd orbit to the 2nd orbit?

6. Electronic spectra can distinguish isobars but not isotopes. Justify.

7. If the energy difference between the orbits when an electron in H atom gets excited to higher energy orbit from its ground state is 12.1 eV/atom, calculate the frequency of radiation emitted (1 eV = 1.602×10^{-19}J) when electron comes back to second energy level.

PRACTICE QUESTIONS

8. Is the energy difference between successive orbits the same for all orbits? Justify your answer.

9. Though there is only one electron in a hydrogen atom, the spectrum of hydrogen contains a number of lines. How do you explain this?

10. What is the ratio of the radius of the 1st orbit to 2nd orbit, if the velocity of the electron in the 1st orbit is twice that of the 2nd orbit.

11. A particular atom has the 4th shell as its valence shell. If the difference between the number of electrons between K and N shells and L and M shells is zero, find the atomic number of the element and electronic configuration of its stable ion.

12. A stable unipositive ion of an element contains three fully filled orbits. What is the atomic number of the element?

13. Explain why a blackened platinum strip when placed at the radius of curvature turns red hot, only when the cathode taken has concave shape.

14. The average atomic mass of two isotopes with mass numbers A and A + 2 is A + 0.25. Calculate the percentage abundance of the isotopes.

15. Spectral line given by an atom is a kind of signature of the respective atom. Comment on this statement.

    [**Hint:** The nuclear charges of different atoms are different.]

Directions for questions from 16 to 25:
Application-Based Questions

16. Why was a spherical sulphide screen used in α-ray scattering experiment?

17. Why is the source of α-particles kept inside the lead block?

18. If Thomson's model is considered to be correct, what would be the observation of Rutherford's α-ray scattering experiment?

19. The ratio of the atomic numbers of two elements A and B is 2 : 3. A is an inert gas with the first 3 orbits completely filled. Identify A and B and write their electronic configurations.

20. A stable dipositive ion and a dinegative ion are isoelectronic with an octet configuration in the second shell of their atoms. Identify the preceding and succeeding elements and write their electronic configurations.

21. Predict the possible atomic number(s) of an atom in which the third shell is incompletely filled and maximum 3 more electrons can be added in that shell.

22. The radius of nth orbit of a single electron species is 0.132 n^2 A°. Identify the element.

23. What is the frequency of light emitted when an electron in a hydrogen atom jumps from the 3rd orbit to the 2nd orbit?

24. An electron having an angular momentum of 1.05×10^{-34} joules jumps to another orbit such that it has an angular momentum of 4.20×10^{-34} joules. Explain the possible transitions.

25. The mass number of a particular element which has equal number of protons and neutrons is 32. What is the electronic configuration of the atom and its stable ion?

Level 3

1. In Millikan's oil drop experiment, the distance between the metal plates, A and B to which an electric potential is applied such that A is positive and B is negative is 5 mm. An oil drop is found to be suspended at a distance of 2 mm from B. Predict the change in the position of the oil drop when there is a sudden drop or rise in potential. Justify.

2. Different gases in the discharge tube produce different colours under suitable conditions of pressure and voltage. Explain.

   [**Hint:** Each element has its own characteristic atomic spectrum.]

3. Is the velocity of an electron in all orbits the same for an atom of a particular element? How does it vary for different single electron species? Give reasons in support of your answer.

4. What is the ratio of distance between successive orbits of 1 and 2 to 2 and 3 of hydrogen atom?

   [**Hint:** radius of nth orbit in hydrogen is 0.529 × n^2 A°]

5. If ${}^{y}_{x}A^{+1}$ or ${}^{y-2}_{x-1}B^{+1}$ were to be used instead of α-particles in Rutherford's experiment, which would be better and why?

Directions for questions from 6 to 10:
Application-Based Questions

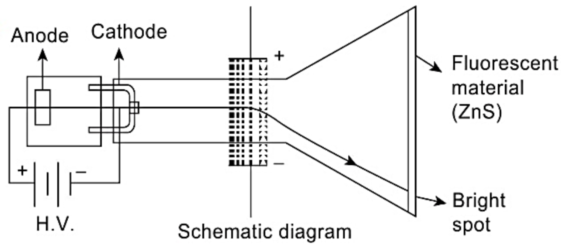
6. Draw a comparison between the potential energy and kinetic energy of electrons in the 1^{st} orbits of hydrogen and He^+ ion. Also comment on the total energy of the electrons in the above cases.

7. Though the kinetic energy of electrons decreases with an increase in the distance from the nucleus, the potential energy of the electron increases. How do you account for this?

8. Why is high voltage and low pressure maintained in the discharge tube?

9. If canal ray experiments are conducted with different isotopes of hydrogen gas, do the canal rays produced show the same deflection under the external electric field? Give reasons to support your answer.

10.



If the given schematic diagram represents Thomson's experiment and the corresponding observation, what would be his atomic model?

HINTS AND EXPLANATION

CONCEPT APPLICATION

Level 1

True or false

1. False **2.** True **3.** True **4.** True
5. False **6.** True **7.** True

Fill in the blanks

8. positively-charged **10.** loses **12.** Zeeman **14.** emission spectrum
9. positive charge **11.** less **13.** more

Match the following

15. A : f B : e C : b
D : E : d F : a

Multiple choice questions

16. b **20.** a **24.** b **28.** c
17. a **21.** c **25.** a **29.** b
18. a **22.** c **26.** b **30.** d
19. d **23.** c **27.** a

31. Energy, $E_n = \dfrac{-13.6Z^2}{n^2}$ eV 13 6

$$E_3 = \frac{-13.6\times 16}{9}\text{eV} = -24.2\,\text{eV}$$

32. According to Rutherford's theory, an atom is electrically neutral and electrons revolve around the nucleus. Nuclear forces of attraction exist between the nucleus and electrons. The only assumption that Rutherford did not consider is quantisation of energy.

33. Let the percentage of ${}_7X^{15}$ is x.

$\therefore$ The percentage composition of ${}_7X^{11}$ is $100 - x$

$$\text{Average atomic weight} = 14 = \frac{x(15) \;+(100-x)11x}{100}$$

$\Rightarrow 1400 = 15x + 1100 - 11x$

$\Rightarrow 1400 = 4x + 1100 \Rightarrow 4x = 300$

$$x = \frac{300}{4} = 75$$

$\therefore$ The percentage of ${}_7X^{11} = 100 - x$

$= 100 - 75 = 25$ and that of ${}_7X^{15}$ is 75

34. Since electronic configuration of the trinegative ion is 2, 8, 8 the electronic configuration of the neutral atom is 2, 8, 5 and its atomic number is 15.

35. (i) Atoms of the same elements are identical in all respects.

(ii) Assumption of thinly spread positively-charged mass

(iii) Calculation of the diameters of the nucleus and the atom

(iv) Calculation of energy and radius of orbit

36. $r_n = 0.529 \times n^2$ A°

Successive first odd orbits are 1 and 3

$$\frac{r_1}{r_3} = \frac{0.529 \times 1^2}{0.529 \times 3^2} = \frac{1}{9} = 1:9$$

37. Angular momentum in third orbit is given by

$$mvr = \frac{3h}{2\pi} \quad \Rightarrow$$

Angular momentum in X orbit is given by

$$mvr = \frac{Xh}{2\pi} \rightarrow (2)$$

$$\frac{Xh}{2\pi} - \frac{3h}{2\pi} = \frac{h}{\pi}$$

$$(X-3)\frac{h}{2\pi} = \frac{h}{\pi} \Rightarrow X=5$$

38. The α-ray scattering experiment led to the discovery of nucleus which in turn helped him conclude that electrons revolve around the nucleus to overcome the strong electrostatic force of attraction.

39. (i) production of α-particles

(ii) production of a narrow beam of α-particles

(iii) bombardment of α-particles with gold foil

(iv) deflection of α-particles

40. The electronic configuration of Mg^{+2} is 2, 8

∴ Total no. of electrons = 10

The electronic configuration of Ar is 2, 8, 8

∴ Total no. of electrons = 18.

Hence, Mg^{+2} and Ar are having different number of total electrons.

41. (i) Electrons revolve around the nucleus in specified circular paths called orbits or shells.

(ii) Each orbit or shell is associated with a definite amount of energy. Hence, these are also called energy levels and are designated as K, L, M and N, respectively.

(iii) The energy associated with a certain energy level increases with the increase of its distance from the nucleus.

(iv) As long as the electron revolves in a particular orbit, the electron does not lose its energy. Therefore, these orbits are called stationary orbits and the electrons are said to be in stationary energy states.

(v) An electron jumps from a lower energy level to a higher energy level by absorbing energy. But when it jumps from a higher to lower energy level, energy is emitted in the form of electromagnetic radiation.

42. (i) calculation of valence electrons present in A

(ii) calculation of atomic number of A

(iii) calculation of atomic number of B

(iv) writing electronic configuration of B

(v) calculation of number of electrons present in the penultimate and anti-penultimate shells of B

43. The equation given by Bohr to calculate radii of n^{th} orbit of hydrogen atom is

$$r_n = \frac{n^2h^2}{4\pi^2me^2}$$

44. $Z = 38$, electronic configuration = 2, 8, 18, 8, 2

∴ Two valence electrons

45. Mass number = 11 + 12 = 23

Level 2

1. (i) factors which affect angle of deflection in an electric field

(ii) conditions for changing the factors which affect the angle of deflection

2. (i) factors affecting specific charge

(ii) conditions where different gases can have the same specific charge

3. (i) e/m depends on number of protons and neutrons

(ii) existence of isotopes

(iii) variation in e/m for isotopes

4. (i) comparing energy of free electron and energy of electron in an atom

(ii) change in energy when an electron is brought closer to the atom

(iii) reason for the change in the energy of an electron

6. (i) fundamental particle responsible for the spectra
(ii) relation between fundamental particle and structure of spectra
(iii) difference in number of the above particles between isobars and isotopes
(iv) effect of this on structure of spectra

7. (i) relation between energy and n
(ii) calculation of n_2 value from the difference in energy
(iii) calculation of frequency from energy
(iv) calculation of energy difference based on n values
(v) calculation of frequency
(vi) $\nu = 0.456 \times 10^{15}\ s^{-1}$

8. (i) factors affecting deflection
(ii) the effect of atomic number on deflection
(iii) the effect of kinetic energy on deflection

9. (i) Bohr's model of atom
(ii) relation between energy absorbed and excitation
(iii) relation between the path of electron during deexcitation and energy emitted
(iv) relation between energy emitted and spectrum

10. (i) comparing the angular momentum of electron in the orbits
(ii) comparison of radius
(iii) $r_1 : r_2 = 1 : 4$

11. (i) number of electrons in K and L shells when N shell is the valence shell
(ii) calculation of number of electrons in K, L, M and N shells
(iii) calculation of atomic number
(iv) number of electrons to be lost to form stable ion
(v) atomic number = 20

12. (i) maximum number of electrons present in an orbit (Bohr–Bury scheme).
(ii) electronic configuration of neutral atom
(iii) 37

13. (i) factors responsible for the strip to turn red hot
(ii) The path in which the electrons travel from concave cathode.

14. (i) $(n_1 \times A) + (n_2 \times (A + 2)) = (n_1 + n_2)$ (A + 0.25) form
(ii) 87.5% and 12.5%

15. (i) calculation of energy of electrons in He^+ and Li^{+2} ions
(ii) 4 : 9

16. to observe scintillations even if the α-rays get deflected at large angles

17. α-particles cannot penetrate lead, but β- and γ-rays can. In order to screen α-particles from β- and γ-rays, lead block was used.

18. If Thomson's model is correct, all the α-particles would have penetrated the gold foil and their angle of deflection would be insignificant.

19. A → electronic configuration – 2, 8, 18, 8. Thus, the atomic number = 36.

A : B = 2 : 3

$$\therefore B = \frac{36 \times 3}{2} = 54$$

The electronic configuration of

B = 2, 8, 18, 18, 8.

20. Let the dipositive ion be X^{+2} and dinegative ion is Y^{-2}.

The octet in the second shell → 2, 8

The number of electrons in X = 10 + 2 = 12.

The number of electrons in Y = 10 – 2 = 8.

X is magnesium with an electronic configuration 2, 8, 2. Y is oxygen with a configuration 2, 6.

The element preceding magnesium is sodium and the succeeding one is aluminium. They have electronic configurations 2, 8, 1 and 2, 8, 3, respectively. The elements preceding and succeeding for oxygen are nitrogen and fluorine which have electronic configurations 2, 5 and 2, 7, respectively.

21. Electronic configuration of the atom which can accommodate three more electrons in the 3rd shell could be 2, 8, 5 and 2, 8, 15, 2. Hence, the probable atomic numbers are 15 and 27.

22. $r_n = \dfrac{Kn^2}{Z}$

$\therefore 0.132n^2 = \dfrac{0.529 \times n^2}{Z}$

$\therefore Z = \dfrac{0.529}{0.132} = 4$

Since the atomic number is 4, the element is beryllium.

23. $E_3 - E_2 = -21.72 \times 10^{-19}\left(\dfrac{1}{9} - \dfrac{1}{4}\right)$

$= 21.72 \times 10^{-19} \times \dfrac{5}{36}$

$\therefore$ Difference in energy, $E_3 - E_2 = 3.01 \times 10^{-19}$ J

According to Planck's equation, $\Delta E = h\nu$

$3.01 \times 10^{-19} = 6.625 \times 10^{-34}\ \nu$

Frequency, $(\nu) = \dfrac{3.01 \times 13^{-19}}{6.625 \times 10^{-34}} = 4.5 \times 10^{14}\,s^{-1}$

24. Angular momentum of an orbit

$mvr = \dfrac{nh}{2\pi}$

Initial angular momentum = 1.05×10^{-34} joules

$1.05 \times 10^{-34} = \dfrac{n \times 6.625 \times 10^{-34}}{2 \times 3.14}, n = 1$

The electron is present in the 1st orbit originally.

When the electron gets excited, the angular momentum = 4.20×10^{-34} joules.

$4.20 \times 10^{-34} = \dfrac{n \times 6.625 \times 10^{-34}}{2 \times 3.14}, n = 4$

An electron can lose energy when it is present in the 4th orbit and not from the 1st orbit.

The possible transitions are $4 \to 3$, $4 \to 2$, $4 \to 1$, $3 \to 2$, $3 \to 1$ and $2 \to 1$.

25. Mass number = 32

No. of protons = No. of neutrons = 16

$\therefore$ Electronic configuration = 2, 8, 6

Element is sulphur and stable ion is S^{-2}

Electronic configuration of S^{-2} is 2, 8, 8

Level 3

1. (i) charge acquired by oil drop
(ii) different forces acting on the charged oil drop when it is at a distance of 2 mm from B.
(iii) relation between position of oil drop and different forces
(iv) effect of a particular force on the position of oil drop
(v) change in position of oil drop with change in potential

2. (i) energy of electron

Excitation and deexcitation

(ii) factors affecting the energy of electron
(iii) comparison of the energy emitted during the deexcitation of electron in different atoms

3. (i) forces acting on moving electron
(ii) position of the electron in the orbit
(iii) relationship between position, forces and velocity
(iv) comparison of nuclear charge in different single electron species

4. (i) effects of high voltage and low pressure on the gas molecules in the discharge tube
(ii) the effect of velocity of electrons on ionisation
(iii) relation between the voltage and the velocity of electrons
(iv) relation between the pressure and the number of gas molecules
(v) the effect of the number of gas molecules on the impact of collision

5. (i) the factors affecting angle of deflection
(ii) the characteristics in which the two particles differ

6. The electrons revolve round the nucleus with high velocities to counter balance the nuclear force of attraction. As nuclear force of attraction in the 1st orbit of He^+ is more than that in H atom.

Kinetic energy of electron in He^+ is more (due to greater velocity) than in H atom. When an electron approaches towards an atom, it loses potential energy because it works towards the force of attraction. The greater the force of attraction, the more is the loss of potential energy. Hence, the electron in He^+ has lesser potential energy than the electron in H atom. But the loss of PE is more significant than the change in KE. Hence, total energy of helium is less than that of hydrogen.

7. The kinetic energy of an electron is proportional to its velocity. With the increase in distance from the nucleus, the velocity of the electron decreases as the electron has to overcome a lesser nuclear force of attraction. An electron loses its potential energy when it approaches towards an atom that is a nucleus because it works towards the force of attraction during this process. Hence, the potential energy of the electron decreases with decrease in distance between the nucleus and the electron and increases with increase in distance between the nucleus and electron.

8. Low pressure means that less number of gas molecules is present in the discharge tube. If the number of molecules is very less, the collisions between the electrons which move towards the anode with a high velocity and the gas molecules become effective. These collisions lead to the dislodgement of electrons from gaseous molecules and formation of cathode rays takes place. Moreover, high voltage increases the kinetic energy of the electrons which in turn increases the probability of removal of electrons from the gaseous molecules.

9. Protium ($_1H^1$), deuterium ($_1H^2$) and tritium ($_1H^3$) are naturally occurring isotopes of hydrogen. Unipositive ions of protium, deuterium and tritium differ in their mass.

Thus, their e/m ratio is different. Therefore, they deflect at different angles in an external electric field.

10. Since in the given experiments, it is observed that positively-charged particles are detached from the molecules under low pressure and high voltage, Thomson's model would be the other way round, i.e., positively-charged particles would be embedded in a thinly spread negatively-charged mass.