CBSE Class 12 Physics Notes Chapter 12: In "Atoms," Chapter 12 of CBSE Class 12 Physics, the structure of atoms and the development of atomic models are examined. The early atomic hypotheses, such as Dalton's model, are covered in the first section of the chapter before J.J.

Thomson's discovery of the electron. The gold foil experiment by Rutherford, which produced the nuclear model of the atom and highlighted the nucleus and orbiting electrons, is then covered. Along with a brief overview of X-rays and the dual nature of matter, the chapter also covers energy levels, spectral lines, and the Bohr model of the hydrogen atom.

CBSE Class 12 Physics Notes Chapter 12 Overview

CBSE Class 12 Physics Notes Chapter 12 Atoms, explores the concept of atomic structure by following the evolution of atomic models across time. Early theories, like Dalton's atomic theory, which defined atoms as indivisible particles, was where it all started. The discovery of the electron by J.J. Thomson and his "plum pudding" concept, in which electrons were lodged in a positively charged sphere, come next.

The gold foil experiment by Rutherford, which refuted Thomson's theory and gave rise to the nuclear model of the atom, is the subject of the next section of the chapter. According to Rutherford's hypothesis, an atom is made up of a compact, positively charged nucleus that is encircled by electrons in a vacuum. The Bohr model was developed as a result of this concept's inability to explain why atoms are stable.

The stability of atoms and the discrete spectral lines seen in atomic spectra were explained by Niels Bohr's model, which linked quantised electron orbits with Rutherford's nuclear structure. The chapter also discusses the duality of matter and light, including a brief overview of wave-particle duality and de Broglie's theory.

CBSE Class 12 Physics Notes Chapter 12 Atoms

Here we have provided CBSE Class 12 Physics Notes Chapter 12 Atoms -

Nucleus

The nucleus is the small, dense central core of an atom, containing most of the atom's mass. It is composed of protons, which carry a positive charge, and neutrons, which are electrically neutral. Together, these particles are known as nucleons.

1.1 Isotopes:

The atoms of an element, which constitute the same atomic number but different mass numbers are termed isotopes. Some examples are:

I. $_8O^{16}, _8O^{17}, _8O^{18}$

II. $_{17}O^{35}, _{17}Cl^{37}$

III. $_{82}Pb^{206}, _{82}Pb^{207}, _{82}Pb^{208}$.

1.2 Isotones:

The atoms whose nuclei constitute the same number of neutrons are termed isotones.

1.3 Isobars:

The atoms which constitute the same mass numbers but different atomic numbers are termed isobars. Some examples are:

I. $_1H^3$ and $_1He^3$

II. $_2Li^7$ and $_4Be^7$

III. $_{28}Ar^{40}$ and $_{29}Ca^{40}$

IV. Ge^{76} and $_{34}Se^{76}$

Atomic Mass Unit

The atomic mass unit (amu), also known as the unified atomic mass unit (u) or Dalton (Da), is a standard unit of mass that quantifies mass on an atomic or molecular scale. It is defined as one-twelfth of the mass of an unbound carbon-12 atom, which is in its ground state and at rest.

It is defined as $1/12^{th}$ the mass of one $_6C^{12}$ atom.

With respect to Avogadro's hypothesis, number of atoms in 12 g of $_6C^{12}$ is taken equivalent to the Avogadro number i.e., 6.023×10^{23}.

Thus, the mass of one carbon atom $(_6C^{12})$ is given by $\frac{12}{6.023\times10^{23}} = 1.992678 \times 10^{-26} kg$

Further,

$$1\ amu = \frac{1}{12} \times 1.992678 \times 10^{-26} kg$$

$$\Rightarrow 1\ amu = 1.660565 \times 10^{27} kg$$

Energy Equivalent of Atomic Mass Unit

With respect to Einstein's mass-energy equivalence formula, the energy equivalent of mass m is expressed as $E = mc^2$, where c is the speed of light.

If it is supposed that $m = 1\ amu = 1.660565 \times 10^{-27} kg$; and as $c = 2.998 \times 10^8 ms^{-1}$; the energy equivalent of $1\ amu$ is given by

$$1\ amu = \left(1.660565 \times 10^{-27} kg\right) \times \left(2.998 \times 10^8 ms^1\right)^2 = 1.4925 \times 10^{-10} J$$

Now, it is known that $1\ \mathrm{MeV} = 1.602 \times 10^{-13}\mathrm{J}$;

Thus,

$$\Rightarrow 1\ amu = \frac{1.4925 \times 10^{-10}}{1.602 \times 10^{-13}} eV = 931.5\ MeV$$

1.6 Nuclear Size:

The volume of a nucleus is in direct proportion to the number of nucleons (mass number) involved in the nucleus. When R is the radius of the nucleus having mass number A, then,

$$\frac{4}{3}\pi R^3 \propto A \Rightarrow R \propto A^{\frac{1}{3}} \Rightarrow R = R_0 A^{\frac{1}{3}}$$

Nuclear Density

Mass of the nucleus of the atom of mass number A is given by $A = A\ amu = A \times 1.660565 \times 10^{27} kg$

When $R$is radius of the nucleus, then,

Volume of nucleus$= \dfrac{4}{3}R^3 = \dfrac{4}{3}\pi\left(R_0 A^{1/3}\right)^3 = \dfrac{4}{3}R^3{}_0 A$

Taking $R_0 = 1.1 \times 10^{15} m$;

Density of the nucleus is given by

$$\rho = \frac{\text{mass of nucleus}}{volume \text{ of nucleus}} = \frac{A \times 1.66065 \times 10^{-27}}{4/3\pi\left(1.1 \times 10^{-15}\right)^3 \times A} = 2.97 \times 10^{17} kgm^{-3}$$

Clearly, density is independent of A.

Mass Defect

The difference between the sum of the masses of the nucleons forming a nucleus and the rest mass of the nucleus is termed mass defect. It is represented by Δm.

Let us evaluate the mass defect for the nucleus of an atom ${}_{Z}X^{A}$.

The nucleus of the atom consists of Z protons and $(A - Z)$neutrons.

Thus, if $\mathrm{m_N}$ is the mass of the nucleus of the atom ${}_{Z}X^{A}$,then the mass defect is expressed as

$$m = \left[Zm_p + (A - Z)\, m_n m_N({}_{Z}X^{A})\right]$$

The binding energy of a nucleus refers to the energy equivalent to the mass defect of the nucleus. It may be computed as the work required to be done to separate the nucleon to an infinite distance apart in order to make them no longer in contact with each other.

If Δm refers to mass defect of a nucleus, then according to Einstein's mass-energy relation, the binding energy of the nucleus is given by Δmc^2 (in joules).

Here, mass defect Δm has to be taken in kilograms. On the other hand, if the mass defect is taken in amu, then,

Binding energy of the nucleus $= \Delta m \times 931.5\,(in\ MeV)$

$\Rightarrow$Binding energy $= \left[Zm_p + (A - Z)\, m_n - m_N({}_{Z}X^{A})\right] \times 931.5$

Binding Energy Per Nucleon

The binding energy per nucleon refers to the average energy required to extract a single nucleon from the nucleus. Clearly,

binding energy per nucleon $= \frac{\text{binding energy}}{A}$.

1.10 Packing Fraction:

Mathematically, packing fraction $= \frac{mass\ defect}{A}$.

Natural Radioactivity

Natural radioactivity refers to the spontaneous emission of particles or electromagnetic radiation from the unstable nuclei of certain naturally occurring elements. This process is a form of nuclear decay, where the unstable atomic nuclei transform into more stable configurations by emitting radiation.

Laws of Radioactivity Decay

The laws of radioactive decay describe how unstable atomic nuclei lose energy by emitting radiation. These laws are fundamental to understanding the behavior of radioactive materials over time.

Rutherford and Soddy learnt the phenomenon of radioactivity in detail and put forward the following laws, known as the laws of radioactive decay:

a. Radioactivity is a sudden phenomenon and one cannot predict when a particular atom in a given radioactive sample would undergo disintegration.

b. When a radioactive atom disintegrates, either an α-particle (nucleus of helium) or a β-particle (electron) gets emitted.

c. The emission of an α-particle by radioactive-atom results in a daughter atom, whose atomic number is 2 units less than that of the parent atom.

$${}_{Z}X^{A} \xrightarrow{\alpha-decay} {}_{Z-2}Y^{A-4}$$

d. The emission of a β-particle by a radioactive atom results in a daughter atom, whose atomic number is 1 unit more than that of the parent atom. However, the mass number remains the same as that of the parent atom.

$${}_{Z}X^{A} \xrightarrow{\beta-decay} {}_{Z+1}Y^{A}$$

e. The number of atoms disintegrating per second of a radioactive sample at any time is in direct proportion to the number of atoms present at that time. The rate of disintegration of the sample cannot be changed by altering the external factors such as pressure, temperature, etc. This is known as radioactive decay law.

With respect to radioactive decay law, the rate of disintegration at any time t is in direct proportion to the number of atoms present at time. Mathematically, $\frac{dN}{dt} \propto N \Rightarrow \frac{dN}{dt} = -\lambda N$

In this case, the radioactive sample's decay constant is denoted by the constant of proportionality λ . It is also known as the transformation constant or the disintegration constant. The radioactive sample's nature determines its value. Furthermore, the expression's negative sign indicates that the sample's atomic count decreases over time.

Simplifying the expression further by integrating,

$\Rightarrow \int \frac{dN}{N} = -\int \lambda dt$

$\Rightarrow \log_e \frac{N}{N_0} = -\lambda t$

$\Rightarrow \frac{N}{N_0} = e^{-\lambda t}$

$\Rightarrow N = N_0 e^{-\lambda t} \Rightarrow N = N_0 e^{t}$

1.11.2 Radioactive Decay Constant

From radioactive decay law,

$\frac{dN}{dt} = -\lambda N$

$\Rightarrow \lambda = \frac{-dN/dt}{N}$

Thus, radioactive decay constant of a substance (radioactive) refers to the ratio of its instantaneous rate of disintegration to the number of atoms present at that time.

Also do we have $N = N_0 e^{t}$.

Now, if $t = 1/\lambda$; then,

$N = N_0 e^{-\lambda I/\lambda} = 1/e\ N_0 = N_0/\left(2.718\right) = 0.368\ N_0$

Clearly, radioactive decay constant of a substance may also refer to the reciprocal of the time, after which the number of atoms of a radioactive substance reduces to 0.368 or 36.8% of their number present initially.

Half Life

Let a radioactive sample contain N_0 atoms at time $t = 0$.

The number of atoms left behind after time t is represented as $N = N_0 e^{t}$.

Using the definition of half life, it follows that when $t = t_{1/2}; N = N_0/2$.

Considering the above condition, it follows that

$\Rightarrow \frac{N_0}{2} = N_0 e^{-\lambda t_{1/2}} = 2$

$\Rightarrow e^{-\lambda t_{1/2}} = \frac{1}{2} \Rightarrow e^{-\lambda t_{1/2}} = 2$

$\Rightarrow \lambda T = \log_e 2 = 2.303 \log_{10} 2 = 2.303 \times 0.3010 = 0.693$

$\Rightarrow t_{1/2} = \frac{0.693}{\lambda}$

Clearly, half life of a radioactive substance is inversely proportional to its decay constant and can be considered as a characteristic property of its nucleus. It cannot be changed by any known method.

Mean Life or Average Life

The average life of a radioactive substance refers to the average time for which the nuclei of the atoms of the radioactive substance exist. It is mathematically given by

$$t_{avg} = \frac{1}{\lambda}$$

1.11.5 Activity of Radioactive Substance

The activity of a radioactive substance refers to the rate at which the nuclei of its atoms in the sample disintegrate. When a radioactive sample consists of N atoms at any time t, then its activity at time t is given by

$$A = -\frac{dN}{dt}$$

The negative sign mentions that with the passage of time, the activity of the radioactive substance reduces.

Involving radioactive decay law, $\frac{dN}{dt} = -\lambda N$ and $N = N_0 e^{-\lambda t}$ here,

$$\Rightarrow A = \lambda N$$

$$\Rightarrow A = \lambda N_0 e^{-\lambda t}$$

$$\Rightarrow A = A_0 e^{-\lambda t}$$

Here, $\lambda N_0 = A_0$ is known as the activity of the radioactive sample at time $t = 0$.

Units of Activity

The activity of a radioactive sample can be expressed as the number of disintegrations per second. The practical unit of activity of a radioactive sample is curie (Ci).

The activity of a radioactive sample is known to be one curie when it undergoes 3.7×10^{10} disintegrations per second.

Clearly, $1\, curie(Ci) = 3.7 \times 10^{10} di \sin tegrations/s$

There is also another unit of radioactivity termed Rutherford (Rd). The activity of a radioactive sample is known to be one rutherford when it undergoes 10^6 disintegrations per second.

Clearly, $1 \text{rutherford}\ (Rd)\ = 10^6 \text{disintegrations}/s$

1.12 Nuclear Fission

The process of splitting a heavy nucleus into two nuclei of nearly comparable masses with liberation of energy is termed nuclear fission. For example,

$${}_{92}U^{235} + {}_0n^1 \rightarrow \left[{}_{92}U^{236}\right] \rightarrow {}_{56}Ba^{141} + {}_{30}Kr^{92} + 3_0n^1 + Q$$

Neutron reproduction factor refers to the ratio of the rate of production of neutrons to the rate of loss of neutrons. Mathematically, it is given by,

$$k = \frac{rate\ of\ production\ of\ neutrons}{rate\ of\ loss\ of\ neutrons}$$

When $k = 1$, the fission reaction would be steady;

When $k > 1$, the fission reaction would accelerate;

When $k < 1$, the fission reaction would decelerate.

Nuclear Reactor

A nuclear reactor is a device used to initiate and control a sustained nuclear chain reaction, primarily for generating electricity, producing isotopes for medical and industrial use, or for research purposes. It operates on the principle of nuclear fission, where the nucleus of a heavy atom, such as uranium-235 or plutonium-239, splits into smaller nuclei when struck by a neutron, releasing a large amount of energy.

Key Components of a Nuclear Reactor:

Fuel:

The primary fuel used in a nuclear reactor is enriched uranium or plutonium, which undergoes fission to release energy.

Moderator:

The moderator slows down the neutrons produced during fission, increasing the likelihood of further fission events. Common moderators include water, heavy water, and graphite.

Control Rods:

Control rods are made of materials like boron, cadmium, or hafnium, which absorb neutrons. They are inserted or withdrawn from the reactor core to control the rate of the nuclear reaction.

Coolant:

The coolant transfers heat from the reactor core to a steam generator or directly to a turbine. Common coolants include water, heavy water, gas, or liquid metal.

Reactor Core:

The reactor core contains the fuel assemblies, moderator, and control rods, where the fission reaction takes place.

Containment Structure:

A robust structure that encloses the reactor core to prevent the release of radioactive materials in case of an accident.

Free Electrons in Metals

One could think of electrons as the building blocks of an atom. Electrons in a metal are free to roam freely and arbitrarily through the atomic gaps. On the other hand, the metal's surface produces an equal positive charge as soon as an electron leaves the metal.

The electron is subsequently drawn back into the metal and stays within it as a result. It is noted that the pull on the electrons at the surface depends on the properties of the metal surface and is represented by a property of the metal known as the work function.

Work Function

The phrase "work function" refers to the minimal amount of energy required for an electron to simply exit a metal surface.

Electron emission is the term for this process, which can be accomplished in the following ways:

Thermionic emission: Heat is produced as a result of the additional energy. We refer to the released electrons as thermo-electrons.

Photoelectric emission: In this case, electromagnetic radiation provides the additional energy. We refer to the released electrons as photoelectrons.

Secondary emission: In this instance, the rapidly travelling electrons release secondary electrons when they collide with the metal surface.

Field emission: In this case, electrostatic fields are used to help release electrons.

Thomson’s Atom Model

According to this idea, electrons are contained within the sphere of positive charges, which are uniformly distributed throughout the sphere, much like plums or seeds in custard or watermelons. For this reason, the plum-pudding model is another name for Thomson's atom model.

Every atom is electrically neutral because the total positive charge within it equals the total negative charge carried by its electrons.
When an atom is slightly perturbed, its electrons fluctuate around their equilibrium positions, which causes radiation of specific frequencies to be ejected in the form of ultraviolet, visible, or infrared light.

Failure of Thomson’s Atom Model

It was necessary to abandon this model for the following reasons:

It was unable to convey the spectral lines' origin in a series, as was the case with hydrogen atoms.

The experiment was unable to accurately depict the dispersion of α particles at large angles, unlike Rutherford's α scattering experiment.

Rutherford’s Atomic Model

Carrying forward the Gieger-Marsden experiment was Rutherford. According to this idea, the atom is composed of a small, dense, positively charged core known as the nucleus, where almost all of the mass is concentrated. Similar to how planets orbit the Sun, the light-weight component, or electrons, revolves around it.

Impact Parameter

When the alpha particle (Helium) is far from the atom's nucleus, the impact parameter (b) is the initial velocity vector's perpendicular distance from the nucleus's central line. It uses this formula:

$$b = \frac{1}{4\pi\epsilon_0} \frac{ze^2 cot\frac{\theta}{2}}{E}$$

The Distance of Closest Approach (r_o)

To find the size of the nucleus, we have a formula, i.e.,

$$r_o = \frac{ze(2e)}{4\pi\epsilon_0(\frac{1}{2}mv^2)}$$

Here, Z_e = charge on the nucleus

2e = charge on alpha particle

r_o = radius of the nucleus

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \ Nm^2C^{-2}$$

Bohr's Model

1. The radii of Bohr's stationary orbit is:

$$r = \frac{n^2h^2}{4\pi^2 mKe^2}$$

2. The frequency of electron in Bohr's stationary orbit is:

$$f = \frac{KZe^2}{nhr}$$

Benefits of CBSE Class 12 Physics Notes Chapter 12

The benefits of studying Chapter 12 "Atoms" in CBSE Class 12 Physics notes are numerous, offering a strong foundation in understanding atomic structure and related concepts. Here are some key benefits:

Conceptual Clarity: The notes provide a clear explanation of complex concepts such as atomic models, the discovery of the electron, and the nucleus, helping students grasp the fundamental ideas of atomic physics.

Historical Perspective: The chapter traces the evolution of atomic theory, giving students a deeper appreciation of how scientific models are developed and refined over time.

Exam Preparation: Well-organized notes help in efficient revision, making it easier to recall key concepts and theories during exams, thus enhancing performance.

Application of Concepts: Understanding the atomic structure is crucial for advanced topics in physics, chemistry, and even biology. The chapter lays the groundwork for further studies in quantum mechanics and nuclear physics.

Problem-Solving Skills: The chapter includes numerical problems related to atomic models and spectra, helping students develop problem-solving techniques that are essential for scoring well in exams.