PHY102

Atomic Structure & Properties

The atom is considered today to be made up of a tiny but massive nucleus at its centre and outside the nucleus is a cloud of electrons which move in wave-like orbits around the nucleus.

The nucleus consists of protons which carry positive charges and neutrons which carry no charge. Both the proton and the neutron make up what is called the nucleon. The fundamental subatomic particles of the atom are the protons, neutrons and electrons.

The proton: has a mass of 1.67×10^{-27} kg it carries a positive charge, $e^{+} = 1.6 \times 10^{-19}$ C.

The neutron: has the same mass as the proton but it carries no charge.

The Electron: has a mass (m_e) of 9.1×10^{-31} kg and it carries negative (electronic) charge $e^{-} = 1.6 \times 10^{-19}$ C

It is the lightest particle of an atom.

From the above, it is seen that the proton is 1835 times heavier than the electron. We can say therefore that virtually all the mass of the atom is concentrated in the central nucleus.

Atoms of the same element contain the same number of protons but atoms of different elements contain different number of protons. In neutral atom, the number of protons equals the number of electrons.

An atom of element X is denoted by $^{A}_{Z}X$ Where A is the mass number or nucleon number and Z is the atomic number or proton number. $^{A}_{Z}X$ is called the nuclide of X.

However, the atomic number or proton number(Z) is the number of protons in the nucleus of an atom. The mass number or nucleon number(A) is the ~~total~~ number of protons and neutrons in the nucleus of an atom.

Given that the number of neutron in the atom of an element is N. then $N = A - Z$ and $A = N + Z$

For instance, the Nitrogen atom is denoted by $^{14}_{7}N$, which implies that Nitrogen has 7 protons, 7 neutrons and a nucleon number of 14. Since there are equal number of protons and electrons in a neutral atom, it means that a neutral atom of Nitrogen has 7 electrons.

The number and arrangement of electrons in the atom of an element determines the chemical properties of that element.

Electrons are arranged in Shell(s) around the nucleus of the atom. The electrons in the outermost Shell of any atom are called valence electrons, and these valence electrons are largely responsible for the Chemical behaviour of the element. Elements having the same number of valence electrons are grouped together in the periodic table and they have similar chemical properties.

We know that Einstein equation is given by,

$E_o=m_oc^2$

Put value of rest mass of an electron and velocity of light in above equation,

We get,

$E_o=9.11\times10^{-31}\times(3\times10^8)^2$

Solve this we get,

$E_o=8.91\times10^{-14}J$——(1)

We can convert joule into eV, as our options are also in eV.

We know that,

$1eV=1.6\times10^{-19}J$

So 1 joule (J) is equal to,

$1J=1eV1.6\times10^{-19}$

Put above value in equation (1)

We get,

$E_o=8.91\times10^{-14}1.6\times10^{-19}eVE_o=0.511\times10^6eVE_o=0.511MeV$

Therefore, rest mass energy is given by $E_o=0.511MeV$.

Answer- (c)

Note: SI unit of energy is joule. There are many conversions of energy in other units i.e. we can express energy in many units. Rest mass in relativity is a little different concept. Rest mass energy is dependent on rest mass and velocity of light in vacuum only. Relativistic mass is the mass which is assigned to the body in motion.

What is the Value of Electrons?

An electron is a subatomic particle commonly represented as e^- or e. It possesses negative polarity. An electron inherits the properties like – Charge, Mass, Spin, etc. The values of electrons imply the value of the charge of an electron, the mass of the electron, and a quantum mechanical property- spin of the electron along with corresponding units.

Charge of Electron

The electric charge by an Electron is the unit elementary negative charge. **The value is:**

$e^- = 1.60217662 \times 10^{-19}$ coulombs

The charge of an electron is responsible for the electric charge.

Mass of Electron

The mass of an electron is 1/1836 of proton mass. **The value of electron mass is:**

$m_e = 9.10938356 \times 10^{-31}$ kilograms

The values of charge and mass of electrons are commonly used in solving problems in physics.

Electron Spin

Spin or angular momentum is an intrinsic quantum mechanical property of subatomic particles. **The spin of an electron is half-integral values:**

$s = ½$

You may also want to check out these topics given below!

- Mu Naught Value
- Epsilon Naught Value
- Relation Between Ev And Joule
- Value Of hc

Summary:

The table given below comprises the Mass, Charge and Spin value of electrons along with units.

	Value of electron	**Unit**
Electron charge	$1.60217662 \times 10^{-19}$	Coulombs
Electron charge in eV	$1.60217662 \times 10^{-19}$	Joule
Electron mass	$9.10938356 \times 10^{-31}$	Kg
Electron mass in amu	0.00054858	Atomic Mass Unit(amu)
Electron Spin	½	

Questions & Answers

- CBSE
- Physics
- Grade 12
- Rest Mass Energy

Answer

Rest mass energy of an electron is:

A. 1.02 MeV
B. 0.511 KeV
C. 0.511 MeV
D. 2.02 MeV

Hint: In physics, rest mass is one of the fundamental constants. Rest mass energy is energy described in the Einstein equation. 'e' trends for electron charge. M tends for mega which is equal to 10^6
. Volt is a unit of energy. The Einstein equation is the most famous equation. It stated that energy and mass are interchangeable and they are different forms of the same thing.

Complete step-by-step answer:
The rest mass of any electron substance is defined by 'Einstein mass energy equivalence relation'.
According to relation of Einstein mass energy,

$E_o = m_o c^2$

Where,

c^2= velocity of light which is $3\times10^8 m/s$

m_o=rest mass of an electron which is $9.11\times10^{-31} kg$

E_o=rest mass energy

Charge & Mass of Electron

The charge is measured directly using a variant of the Millikan oil drop experiment while the mass will be deduced from a measurement of the charge to while the mass will be deduced from a measurement of the charge to mass ratio, e/m, combined with the charge measurement. The two separate measurements can be done in either order with the combined analysis performed at the end of the experiment. However, the table below, gives the values for the mass and charge of the electron for comparison purposes. They are known to much higher accuracy than we can hope to measure in our experiments and therefore, they will be considered to be exact.

Electron, Charge and Mass

Quantity	Symbol	Value	units
Mass Charge	Me E	$9.109X10^{-31}$ $1.602X10^{-19}$	Kg C

1. The charge to mass ratio (e/m) for the Electron,

    In 1897 J.J Thompson discovered the first "elementary particle", the electron, by measuring the ratio for its charge to mass in a manner similar to the experiment that we will perform in due course. Given the mass and charge in the above table, we expects to measure a value that is close to:

$$\frac{e}{m} = \frac{1.602X10^{-19}}{9.109X10^{-13}} = 1.759*10^{11}\frac{c}{kg}$$

ATOMIC STRUCTURE

A lot of what we know about the structure of atom has been developed over a long period of time. This is how scientific knowledge develops, with one person building on the ideas of another.

The idea of atom was invented by the Greek Philosophers; Democritus and Leucippus in the fifth century B.C the Greek word Atomos means indivisible because they believed that atoms could not be broken down into smaller pieces.

In recent times, atoms are known to be made up of a positively charged nucleus surrounded by negatively charge electrons. Before the structure of the atom was properly understand, scientists came up with lots of different models or picture to describe how atom looks like. However the different models that have been proposed by different scientists based on their understanding of the atom. When new truths about an atom are gained through experiments, scientists charge their models of atom to suit the new facts. The atomic models includes:

1. dalton's atomic theory
2. faraday's experiment of electrolysis in 1833
3. thomason's atomic model
4. milikan's oil drop experiment
5. Rutherford model (the planetary atomic model) &
6. The Bolar atomic theory

Haven't said about the above models of the atom, the scope of this course requires or directed us to focus on the Bohr's atomic model. Or the Bohr Theory.

BOHR ATOM

Neil Bohr in 1913, modified Rutherford model of an atom by introducing the quantum idea in the atom. According to Bohr's model, electrons have definite energy which corresponds to certain orbits. As long as an electron is in one of this allowed orbit, it will not radiate energy. Bohr gave two rules or postulates as follows:

1. The orbit at which an electron will move without radiating energy is such that its angular momentum is quantized.
   This means that the electron is not free to move in all orbits:
   only few orbits are allowed. The orbit an electron is permitted to move is given by the equation below.

   $Mvr=\frac{nh}{2\pi}$ where mvr = angular momentum

   M= mass of the electron

   V = speed of the electron round the nucleus

   R = radius of the orbit where the electron is moving

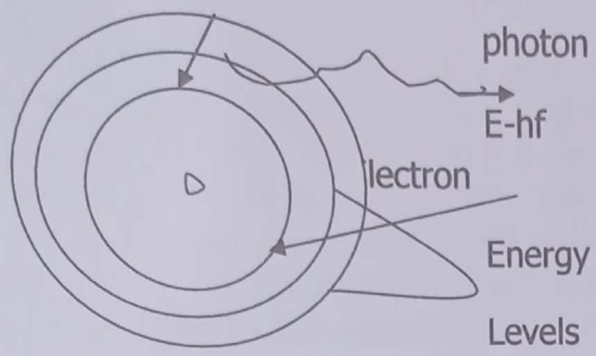
   N = principal quantum number which determines the orbits allowed. (n=1,2,3…)

2. An electron will radiate energy if it jumps from higher orbital or energy to a lower orbital or energy
   The energy radiated is given by:
   $E_i - E_f = hf$

   $E_i - E_f = \Delta E$ = Energy radiated when an electron jumps from initial energy level to a final energy level.

   h = Planck's universal constant, f= frequency.

Bohr's view of the atom is illustrated ind the diagram below



The first allowed orbit, the electron can move in is called the ground state energy level. Electrons in the ground state energy level are stable. When the electron in the ground state energy level absorbs enough energy it moves to higher energy levels.
Electrons in the higher energy levels are said to be excited and unstable. The excited electron loses their excess energy when they jump from the excited energy level to a lower energy level. This is illustrated above.

Bohr model of an atom was very successful in:

1. Calculating the radius of the allowed orbit and the total energy of the electron in each allowed orbit of hydrogen atom.
2. Predicting the bright spectral lines of glowing hydrogen atoms.
3. Explaining the quantized energy state of photon in photo electric effect.

LIMITATIONS OF BOHR ATOMIC MODEL:

Bohr Theory which was based on circular electron orbits, was able to explain successfully a number of experimentally observed facts and has correctly predicted the spectral lines of neutral hydrogen atom and singly ionised helium atom in terms of the principal quantum number N. however, the theory fails to explain the following facts.

1. It could not account the spectra of atoms more complex than hydrogen.
2. It fails to gives any information regarding the distribution and arrangement of electrons in atoms.
3. It does not explain the experimentally observed variations in intensity of the spectral lines of an element.
4. It fails to explain the transitions of electrons from one level to another, the rate at which they occur or the selection rules which apply to them.
5. It fails to accounts the fine structures of spectral lines. Actually, it was found that when spectral lines emitted by an atom are examined, each line is composed of several lines closely packed together. Bohr's theory does not throw any light on it.
6. The theory cannot be used for the quantitative study of chemical bonding.
7. It was found that when electric or magnetic field is applied to the atom, each spectral line is spitted into several lines. The former one is called stark effect while the late as Zeeman effect Bohr's theory fails to explain these effects.

SPECTROPHOTOMETRY

Spectrophotometry is a branch of electromagnetic spectroscopy concerned with the quantitative measurement of the reflection or transmission properties of a material as a function of wavelength . Spectroscopy is the study of the interaction between matter and electromagnetic radiation. Historically, spectroscopy originated through the study of visible light dispersed according to its wavelength, by a prism. Later the concept was expanded greatly to include any interaction as a function of its wavelength or frequency. Spectroscopic data is often represented by an emission spectrum, a plot of the response of interest as a function of wavelength or frequency.

Spectroscopy and spectrograph are terms used to refer to the measurement of radiation intensity as a function of wavelength and are often used to describe experimental spectroscopic methods. Spectral measurement devices are referred to as spectrometers, spectrographs or spectral analyzers.

One of the central concepts in spectroscopy is a resonance and its corresponding resonant frequency. Resonances were first characterized in mechanical systems such as pendulums. Mechanical systems that vibrate or oscillate will experience large amplitude oscillations when they are driven at their resonant frequency. A plot of amplitude Vs. excitation frequency will have a peak cantered at the resonance frequency. This plot is one type of spectrum, with the peak often referred to as a spectral line, and most spectral lines have a similar appearance.

In quantum mechanical systems, the analogous Resonance is a coupling of two quantum mechanical stationary states of one system, such is an atom, via an oscillatory source of energy such as a photon. The coupling of the two states is strongest when the energy of the source matches the energy difference between the two states. The energy (E) of a photon is related to its frequency (v) by $E = h/v$ where h is plank's constant, and so a spectrum of the system response Vs. photon frequency will peak at the resonant frequency or energy particles such as electrons and neutrons have a comparable relationship, de Broglie relations, between their kinetic energy and their wavelength and frequency and therefore can also excite resonant interactions.