# CHAPTER SEVEN

## ATOM, PHOTOELECTRIC EFFECT AND THERMIONIC EMISSION

### Introduction:

The atom is the smallest particle of an element, and atomic physics is the physics of the atom. The atom is round in shape and its central part is occupied by the nucleus. Surrounding the nucleus are the orbitals or shells, within which can be found the negatively charged electrons. Inside the nucleus can be found the protons and the neutrons. The protons are positively charged, while the neutrons are neutral. The electrons, protons and the neutrons are referred to as the sub-atomic particles, and some of these sub-atomic particles can further be divided into elementary particles i.e. quarks and leptons, which are referred to as the fundamental or elementary particles. The atom can be positively or negatively charged. If the number of negative charges (electrons) within an atom is more than that of positive charges (protons), then the atom will be negatively charged and if the number of positive charges is more than that of the negative charges, then the atom will be positively charged. On the other hand if the number of positive charges is equal to that of the negative charges, then the atom will be neutral.

**The atomic number:** This is the number of protons or electrons within a neutral atom. It is represented by the symbol Z.

### The mass number:

- This refers to the number of protons and neutrons within an atom.

- If an element has 2 protons and 5 neutrons, then its mass number will be 7.

-In the symbol $X^a_b$,

X = the element,

a = the mass number

b = the atomic number.

- For example, in the symbol $O^{16}_{8}$, the element is oxygen, its mass number is 16 and its atomic number is 8.

## Isotopes:

These are two atoms of the same element, which have the same atomic number but different mass numbers.

- Examples are $Cl^{37}_{17}$ and $Cl^{37}_{18}$.

## Isotones:

- These are two atoms which have the same number of neutrons, and examples are $Cl^{37}_{17}$ and $Cl^{39}_{19}$.

- The number of neutrons within the first atom = 37 -17 =20, and that within the second atom = 39 - 19 = 20.

## Nuclide:

Even though isotopes are two different types of the same element, each specific kind of atom with a specific mass umber is called a nuclide e.g. $^{1}_{1}H$ and $^{2}_{1}H$.

## The atomic weight scale:

- Where more exact masses must be used, a comparative mass scale for the atom is used and this is called the atomic mass scale.

- On this scale, the mass of a particular atom is chosen arbitrary as standard, to which the masses of all the other atoms are compared.

- The current standard is carbon 12, having the mass of 12 atomic mass units.

- Therefore an atomic mass unit is $\frac{1}{12}$ the mass of carbon.

- The atomic weight is therefore the weight of an atom, compared with the weight of an atom of carbon -12, where the weight of carbon -12 is set at 12 atomic mass units, which is the unit of atomic weight.

- An element usually has several Isotopes, each with a different atomic weight and the atomic weight of an element is the average of the weights of these isotopes, in the proportion in which they occur in nature.

- For example, the atomic weight of chlorine is 35.453 a.m.u, and this is the average for the two isotopes $Cl^{35}$ (atomic mass 34.969), and $Cl^{37}$ (atomic mass 36.966) in the proportions in which they occur in nature.

## The relative atomic mass:

-This is ratio of the mass of one atom of an element to $\frac{1}{12}$ the mass of carbon twelve ($C^{12}$) Isotope.

=> R.A.M = $\frac{\text{Mass of an atom of the element}}{\frac{1}{12}\ Mass\ of\ C^{12}\ isotopes}$.

**The ground state:** When an atom is in its lowest energy level, it is said to be in the ground state.

**The excited state:** When the electrons within the atom are in higher energy level, then the atom is said to be in the excited state.

**Ionization energy:** This is the energy required to remove an electron completely from an atom which is in its ground state.

## Photons (light):

- The electrons within an atom are confined to their various orbitals, each of which is associated with a specific energy level.

- An electron within its orbital is stable and will not radiate or gain energy.

- If however an electron gains excess energy through means such as heating, the electron will become unstable and as such move into another orbital or shell, associated with a higher energy level.

- Under such a condition, the atom is said to be in the excited state.

- The electron will finally return to its original or previous orbital and in doing so, it loses the excess energy which appears in the form of light or photon.

- Photon which is a quantum of electromagnetic radiation, is a particle of no mass and no charge.

## Electromagnetic wave and spectrum:

- Photons of light are surrounded by an electric and a magnetic field, and for this reason, light is referred to as an electromagnetic wave or radiation.

- These electric and magnetic fields are at right angle to each other, and to the direction in which the wave is moving.

- Apart from light, there are other kinds of electromagnetic waves, which differ from light in frequencies and wavelengths.

-Some electromagnetic waves such as microwaves and radio waves, have lower frequencies and longer wavelengths than light.

- Others including gamma rays and x-rays, have higher frequencies and shorter wavelengths.

- A chart of all the electromagnetic waves arranged according to their frequencies and wavelengths, is called the electromagnetic spectrum.

- All the types of electromagnetic waves have the properties of light.

## Uses of electromagnetic waves:

- Gamma rays is used by doctors to treat cancer and other diseases.

- X-rays is used to treat cancer and to diagnose internal disorders.

- Infrared rays carry heat and is used to dry paint.

- Ultraviolet rays is used to disinfect objects.

## The visible spectrum:

This consists of all the electromagnetic waves that the eyes can see. It appears as a band of colours, because the eyes see the different wavelengths of light as different colours. Sunlight consists of all the wavelengths of light, and for this reason when sunlight passes through a prism, these wavelengths spread out to form the visible spectrum. This spectrum is called the continuous spectrum because it has no gaps or missing colours. Light from some sources does not contain all the wavelengths of the continuous spectrum, and a spectrum from such a source has dark gaps. By studying the spectrum from such a source, scientists can learn about the source

itself and this study is called spectrum analysis. This study is done by means of a spectrometer.

## Dalton`s atomic theory:

-Dalton was the first to give clear and precise scientific suggestions, on the physical and the chemical properties of the atom.

- Dalton formulated that:

(1) Matter is made up of tiny indivisible particles called atoms.
(2) Atoms can neither be created nor destroyed.
(3) Atoms of the same element are identical and have the same mass and size.
(4) Atoms of different elements have different masses and sizes.
(5) Atoms combine to form compounds and they do so in small whole numbers.

- According to Dalton's model of the atom, the atom is a small hard ball which is indivisible and cannot be destroyed.

## J.J Thompson`s model of the atom:

- According to this model which is also known as the "plum pudding" model, the electrons are distributed throughout the atom, like jelly-beans in a ball of cotton.

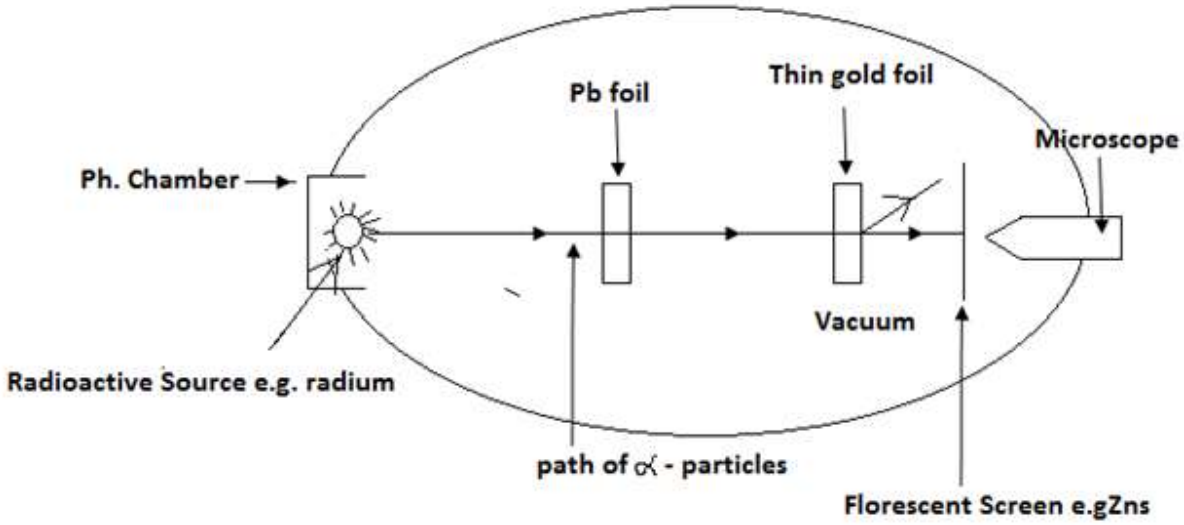
- This implies that the electrons which are negatively charged, are located within a continuous distribution of positive charge.

- The charge distribution is assumed to be spherical in shape.

- In short, what this model implies is that the mass and the positive charges are uniformly distributed throughout the atom, which is spherical in shape.

**Limitation of the Thompson`s model:** It could not account for Rutherford`s alpha particle experiment.

## Rutherford`s model of the atom: Experiment description:




- He studied ∝ - particles from a radioactive source, such as radium through a thin foil e.g. gold.

-These rays were collimated and oriented at an angle of $180^0$, before being allowed to impinge on the screen.

-The deflected rays were then studied by means of a microscope.

-The space between the gold field and the screen must be highly evacuated, to prevent any impurity from retarding the speed of the rays.

### Results/ observations:

(1) Most of the particles went through the foil undiviated, i.e. without any change in path.

(2) A few particles were deflected through small angles.

(3) Very few were deflected backwards or in the backward or opposite direction.

### Deductions:

(1) The deflections were caused by the ∝ - particles which are positively charged, approaching very close to a concentrated form of positive charges.

(2) The fact that most of the ∝ - particles went through undeviated, implies that this concentrated form of positive charges (the nucleus), only forms a small part of the atom.

(3) The fact that a few were deviated though large acute angles, implies that they came close to the concentrated positive charges.

(4) The fact that a minute were deflected backwards or in the opposition direction, implies that they had a head on collision with the nucleus or the positive charge concentration.

**Conclusions:**

The conclusions made by Rutherford are:

(1) The entire mass of the atom as well as the entire positive charges, are concentrated in the centre of the atom (nucleus).

(2) Moving within the orbitals around the nucleus are negatively charged electrons, which are spread out in an almost empty volume.

## Problems with Rutherford`s model:

- According to Rutherford`s model of the atom, electrons move round the central nucleus in orbits and from the study of waves, charged particles undergoing acceleration emit radiations.

- As a result of this emission of radiation, they will gradually be losing energy and correspondingly the orbital radius of each will be decreasing, so that the elections will gradually spiral towards the nucleus.

- For this reason, the atomic structure will collapse but this not the case.

- Also according to Rutherford`s model, as the electrons emit radiations continuously, their frequencies of radiation will keep on changing leading to a mixture of frequencies.

- However, the study of the spectra of atoms reveals that atoms possess definite energy levels, and radiate energy at a definite frequency only.