Al-Mustaqbal University College
Radiological Techniques Department

RADIATION PROTECTION

The Structure of the Atom

Third Stage

First Lecture

By
Assistant lecturer

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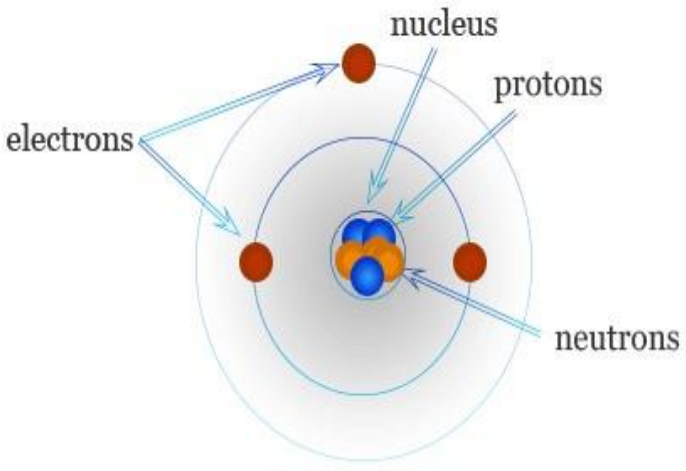
The Structure of the Atom

Introduction

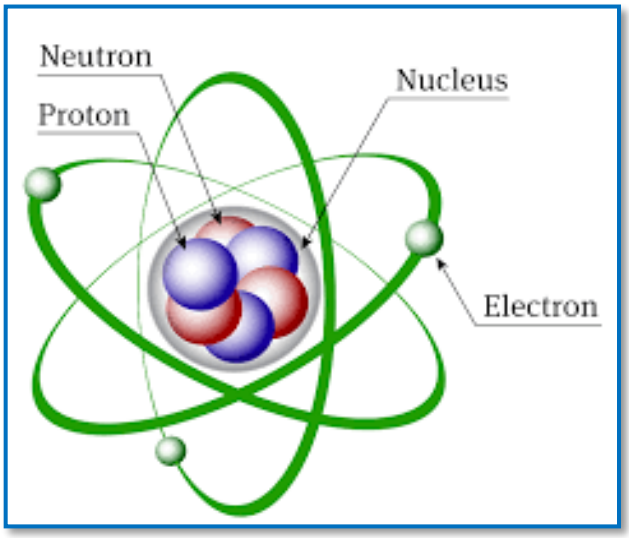
Each atom has a nucleus, which contains more than 99.96% of its mass, and electrons orbiting in spaced-apart orbits around this nucleus.



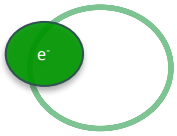
Atom structure

The nucleus of an atom is made up of two types of nuclear particles called nucleons, and the two types are protons and neutrons.

The central core, called the nucleus, contains protons and neutrons. Nuclear forces hold the nucleus together. The shells are formed by electrons which exist in structured orbits around the nucleus.

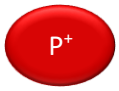


Electrons



Electrons (e-) are negatively charged and travel in specific orbits or energy levels about the nucleus. Each electron has energy which enables it to resist the positive charge of the nucleus. An atom is electrically neutral if the total electron charge equals the total proton charge. Electrons are bound to the positively charged nucleus by electrostatic attraction.

Protons



Protons (p+) are positively charged and located in the nucleus of the atom. The number of protons in the nucleus determines the atom's atomic number and its position in the Periodic Table.

Neutrons

Neutrons (n) are uncharged and located in the nucleus of the atom. Atoms of the same element have the same number of protons, but can have a different number of neutrons.

Atomic Particles

Atoms consist of three basic particles: protons, electrons, and neutrons. The nucleus (center) of the atom contains the protons (positively charged) and the neutrons (no charge). The outermost regions of the atom are called electron shells and contain the electrons (negatively charged). Atoms have different properties based on the arrangement and number of their basic particles.

Volume of Atoms

Accounting for the sizes of protons, neutrons, and electrons, most of the volume of an atom greater than 99 % is in fact empty space. Despite all this empty space, solid objects do not just pass through one another. The electrons that surround all atoms are negatively charged and cause atoms to repel one another, preventing atoms from occupying the same space.

Atomic Mass

Protons and neutrons have approximately the same mass, about 1.67×10^{-24} grams. Scientists define this amount of mass as one atomic mass unit (amu) or one Dalton. Although similar in mass, protons are positively charged, while neutrons have no charge. Therefore, the number of neutrons in an atom contributes significantly to its mass, but not to its charge.

Electrons are much smaller in mass than protons, weighing only 9.11×10^{-28} grams, or about 1/1800 of an atomic mass unit. Therefore, they do not contribute much to an element's overall atomic mass. When considering atomic mass, it is customary to ignore the mass of any electrons and calculate the atom's mass based on the number of protons and neutrons alone.

Electrons contribute greatly to the atom's charge, as each electron has a negative charge equal to the positive charge of a proton. Scientists define these charges as "+1" and "-1. " In an uncharged, neutral atom, the number of electrons orbiting the nucleus is equal to the number of protons inside the nucleus. In these atoms, the positive and negative charges cancel each other out, leading to an atom with no net charge.

Electrons , Protons, neutrons			
Particle	Charge	Mass(amu)	Location
Proton	+1	1	Nucleus
Neutron	0	1	Nucleus
Electron	-1	0	Orbitals

- Neutral atoms of each element contain an equal number of protons and electrons.
- The number of protons determines an element's atomic number and is used to distinguish one element from another.
- The number of neutrons is variable, resulting in isotopes, which are different forms of the same atom that vary only in the number of neutrons they possess.

- Together, the number of protons and the number of neutrons determine an element's mass number.
- Since an element's isotopes have slightly different mass numbers, the atomic mass is calculated by obtaining the mean of the mass numbers for its isotopes.

Atomic Number

The number of protons in the nucleus of an element is called the atomic number (Z). Atomic numbers are all integers. For example a hydrogen atom has one proton in the nucleus. Therefore, the atomic number of hydrogen is 1($_1$H). A helium atom has two protons in the nucleus, which means the atomic number is 2 ($_2$He). Uranium has ninety two protons in the nucleus and, therefore, has an atomic number of 92 ($_{92}$U).

The organization of elements into groups with similar chemical properties in the periodic table is based on atomic numbers.

The mass number

Is the sum of the protons and neutrons in an atom. **A=Z+N**

Although all atoms of an element have the same number of protons, they may have a different number of neutrons. Atoms that have the same number of protons but different numbers of neutrons are called isotopes. For example, deuterium (H) and tritium (^{3}H) are isotopes of hydrogen with mass numbers of two and three respectively.

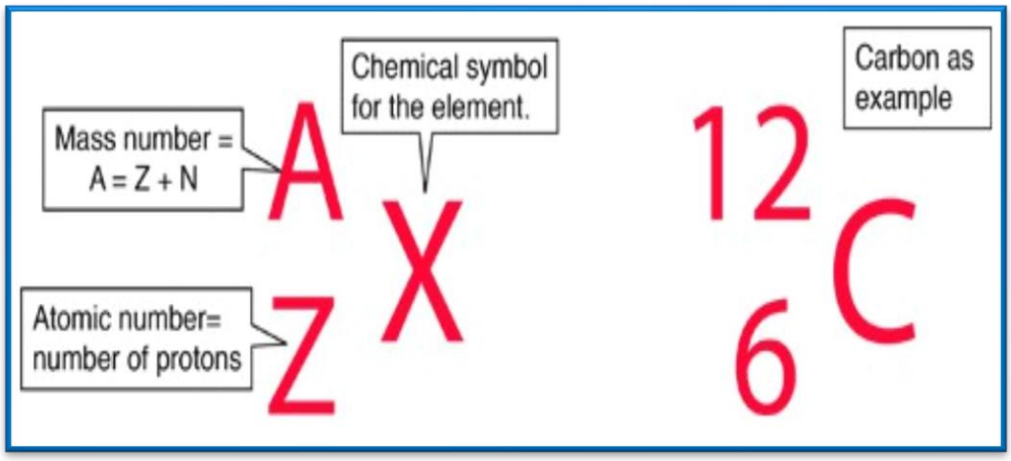
The mass number written as a superscript at the upper left of the symbol:

$$^{A}X$$

Where: **X** = Symbol for element

A = Mass number (number of protons (Z) plus the number of neutrons (N))

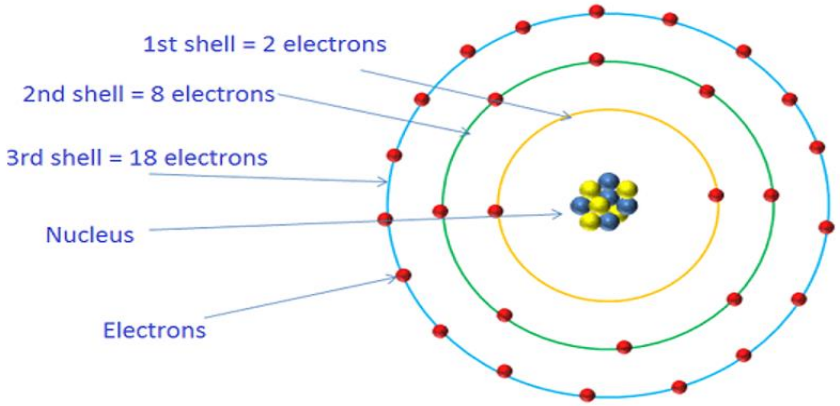
For example, the notation for uranium-238 would be 238U



Neutral atoms of an element contain an equal number of protons and electrons. The number of protons determines an element's atomic number (Z) and distinguishes one element from another.

For example, carbon's atomic number (Z) is 6 because it has 6 protons. The number of neutrons can vary to produce isotopes, which are atoms of the same element that have different numbers of neutrons. The number of electrons can also be different in atoms of the same element, thus producing ions (charged atoms). For instance, iron, Fe, can exist in its neutral state, or in the $^{+}2$ and $^{+}3$ ionic states.

Protons and neutrons both weigh about one atomic mass unit or amu. Isotopes of the same element will have the same atomic number but different mass numbers.



Orbit levels of electrons in an atom

The electrons are revolving around the nucleus in different orbits at a fixed distance from the nucleus. Each orbit or shell contains a fixed number of electrons. Generally, each orbit or shell contains a maximum of $2n^2$ electrons where, n is the number of shell. By just substituting the shell number in ' n ' we can easily calculate number of electrons in each shell. First shell occupy a maximum of two electrons ($2 \times 1^2 = 2$), second shell occupy a maximum of eight electrons ($2 \times 2^2 = 8$), and third shell occupy a maximum of 18 electrons ($2 \times 3^2 = 18$) and so on.

Example -1

The mass number of an oxygen atom (O) is 16 and the atomic number is 8. How many neutrons are there in the nucleus of this oxygen atom?

Solution

A= Mass Number =16

Z = Atomic Number = 8

Since we have :

A= Z + N

Then: Number of Neutrons:

N = A –Z = 16 –8 = 8 Neutrons.

H.W. What is the mass number of Radium (Ra) atom with 88 protons and 138 neutrons?