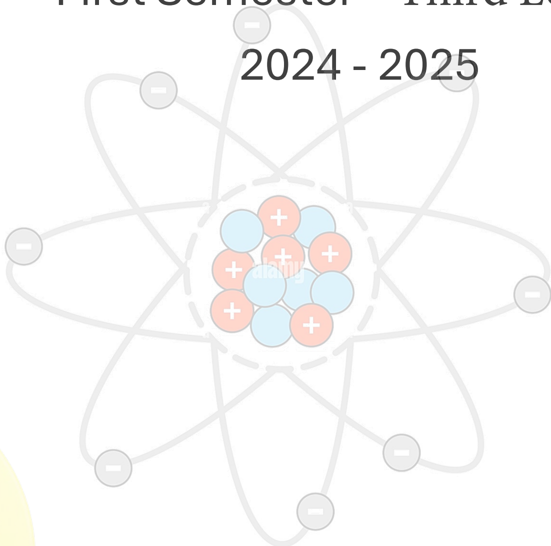
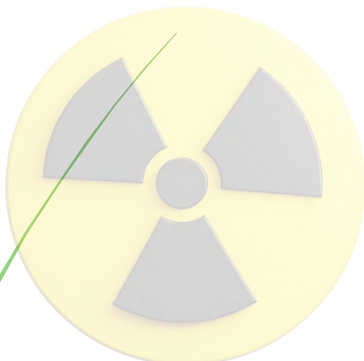
Radiation Protection

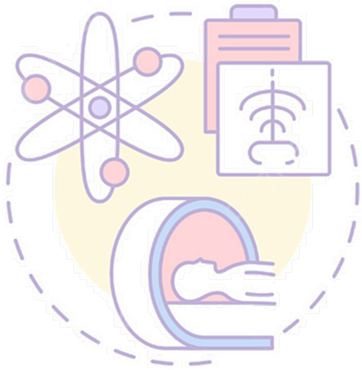
The Second Stage

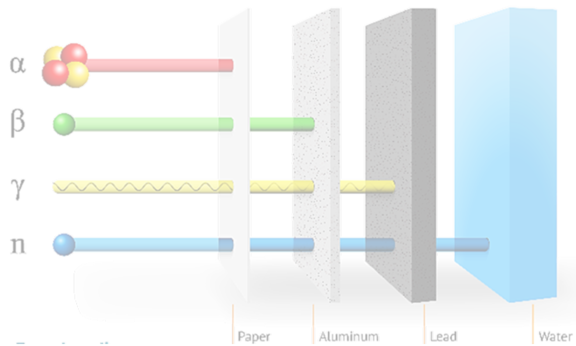
First Semester – Third Lecture

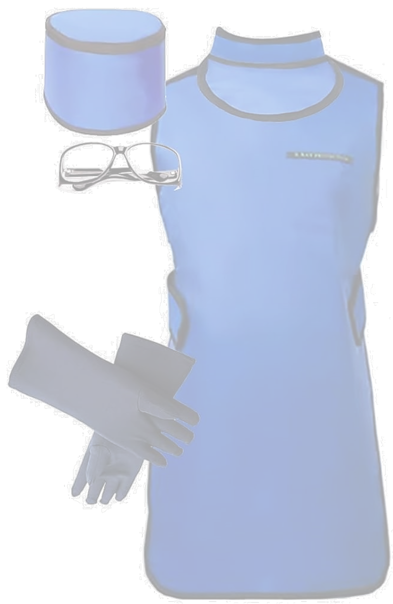
2024 - 2025











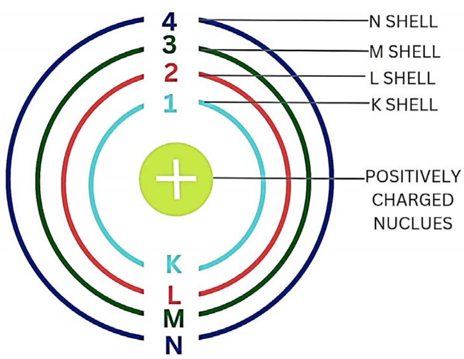
Asses. Prof.: Mahmoud Abdelhafez Kenawy

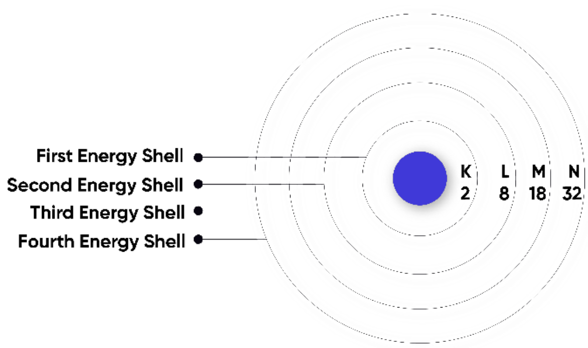
Bohr's Atomic Theory (Bohr's model):

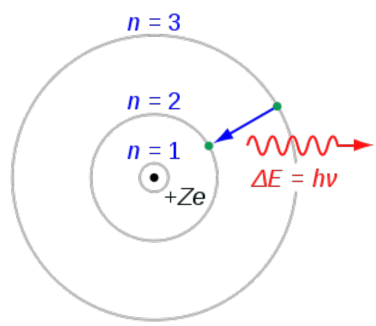
Bohr's model consists of a small nucleus (positively charged) surrounded by negative electrons moving around the nucleus in orbits. Bohr found that an electron located away from the nucleus has more energy, and the electron which is closer to nucleus has less energy.

Postulates of Bohr's Model of an Atom

- The atom looks like a vacuum and its mass concentrated in the nucleus.
- In an atom, electrons (negatively charged) revolve around the positively charged nucleus in a definite circular path called orbits or shells.
- Each orbit or shell has a fixed energy and these circular orbits are known as orbital shells.
- The energy levels are represented by an integer (n=1, 2, 3…) known as the quantum number. This range of quantum numbers starts from nucleus side with n=1 having the lowest energy level. The orbits n=1, 2, 3, 4… are assigned as K, L, M, N…. shells and when an electron attains the lowest energy level, it is said to be in the ground state.
- The electrons in an atom move from a lower energy level to a higher energy level by gaining the required energy and an electron moves from a higher energy level to lower energy level by losing energy.







Atomic gram – atom: is the number of grams of atomic compound that contains exactly one Avogadro's number of atoms.

Molecular gram – mole: is the number of grams of molecular compound that contains exactly one Avogadro's number of molecules.

For example:

- 1 mole of water is (16+2*1=18 grams) of water.
- 1 mole of carbon dioxide is (12+2*16= 44 grams) of CO_2.

Remark:

Number of atoms of an element: $N = \frac{m\,(gram) \times N_A}{A}$

Problem 2:

How much 0.1gram of pure Co-60 of atoms?.

Solution: $N= 0.1 \times 6.022 \times 10^{23}/60= 0.1 \times 10^{23}$ atoms

Why does an electron not fall in the nucleus; and not run away from the atom?

By simply:

- The electron does not fall into the nucleus because it is moving in orbit at high speed. So, the force of attraction due to the nucleus is just strong enough to give it the necessary centripetal force and keep it in the circular orbit.
- The electrons revolve around the nucleus at a fixed energy level. These electrons cannot cross this energy level until extra energy is supplied even if the energy is supplied to the system.
- Also, every revolving charged particle radiates energy and should fall into the nucleus.
- But as Niel's Bohr stated, only certain special orbits known as discrete orbits of electrons are allowed inside the atom and while revolving in discrete orbits, the electrons do not radiate energy. Hence do not fall into the nucleus.

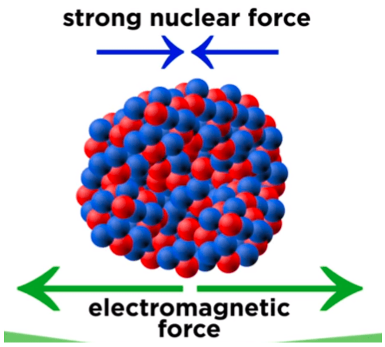
Nuclear forces:

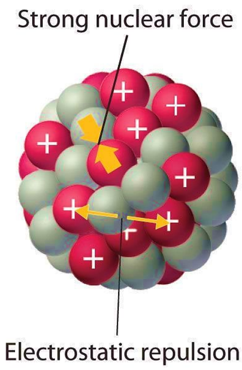
Protons and ***neutrons*** in nucleus are known as ***nucleons***.

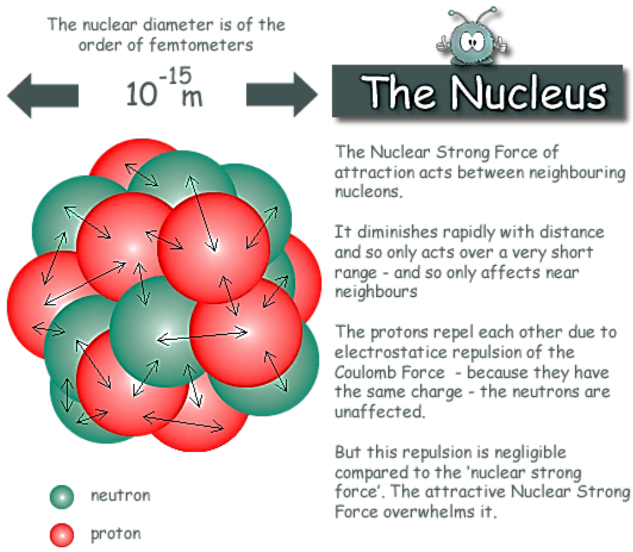
There is a force that holds nucleons together in a nucleus. For the force that holds quarks together in a nucleon that is also called the strong nuclear force, which is not to be confused with weak nuclear force.

Since protons have charge +1 e, they experience an electric force that tends to push them apart, but at short range the attractive nuclear force is strong enough to overcome the electrostatic force. The nuclear force binds nucleons into atomic nuclei.

The nuclear force has an essential role in storing energy that is used in nuclear power and nuclear weapons. Work (energy) is required to bring charged protons together against their electric repulsion. This energy is stored when the protons and neutrons are bound together by the nuclear force to form a nucleus. The mass of a nucleus is less than the sum total of the individual masses of the protons and neutrons. The difference in masses is known as the mass defect, which can be expressed as an energy equivalent.







The nucleus keeps its stability in spite of huge ***electric repulsive force*** (قوة التنافر) (named coulomb electric force) between the positive protons compared to the small attractive force between the nucleons, due to the presence of other forces working on combining these nucleons called the ***strong nuclear forces***. *These forces are named by strong nuclear force, because they have a great effect on the nucleons inside the small nucleus.*

In summary: **the electrons** of an atom are attracted to the protons in an atomic nucleus by **electromagnetic force**. Therefore, to bind a nucleus together there must be a strong attractive force of a different kind. It must be strong enough to overcome the repulsion between the (positively charged) protons and to bind both protons and neutrons (**nucleons**), the protons and neutrons in the nucleus are attracted to each other by the **nuclear force**.

Properties of strong nuclear forces:

They have great power.

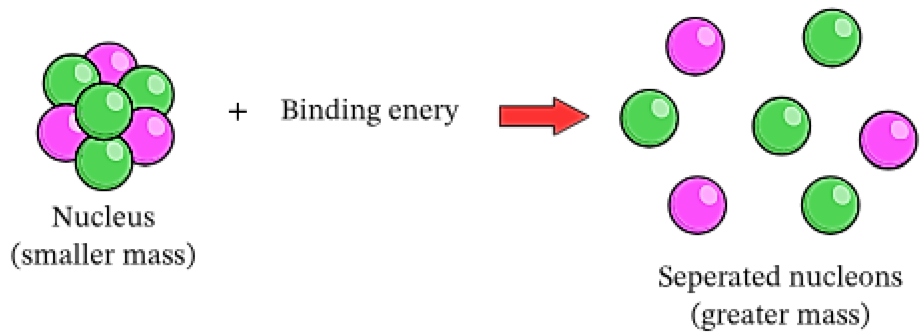
They do not depend on the type of charge of nucleons, but it may be between them (proton – proton; neutron – neutron; proton - neutron).

They are short-range forces (work only when space between nucleons is very small).

Definition:

1- Binding Energy: The binding energy of an electron of a given type in any state of a neutral or ionized atom *defined as* that required energy to remove the electron along successive terms of a spectral series to its limit.

2- Nuclear binding energy “nucleons” is the minimum energy that is required to disassemble “تفكيك” the nucleus of an atom into its constituent protons and neutrons, known collectively as nucleons.

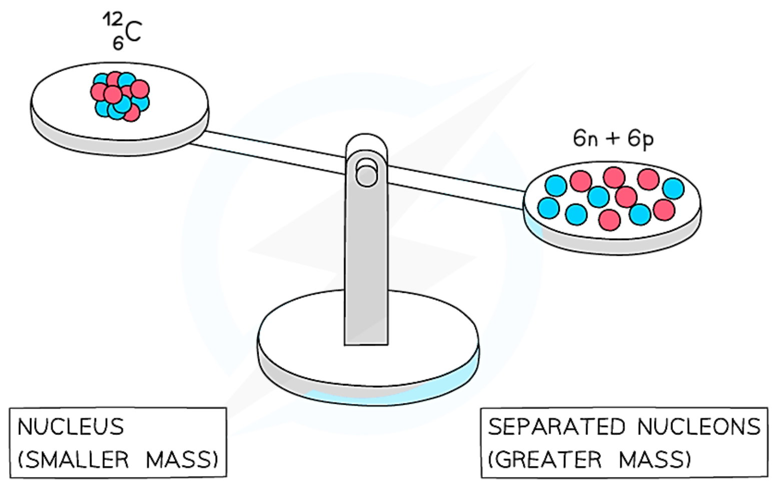


Nucleons are attracted to each other by the strong nuclear force. In theoretical nuclear physics.

- The binding energy for stable nuclei is always a positive number, as the nucleus must gain energy for the nucleons to move apart from each other.
- Nuclear binding energy is considered a negative number. In this context it represents the energy of the nucleus relative to the energy of the constituent nucleons when they are infinitely far apart.

Remark: The nuclear binding energies and forces are on the order of a million times greater than the electron binding energies. (This is because of the relative sizes of the atomic nucleus and the atom (10^{-15} and 10^{-10}m)).

3- The Mass defect: The total mass of the nucleus(m_{nuc}) is less than the sum of individual masses of neutrons and protons which in fact constitutes it.



Mass defect = Theoretical mass – Actual mass

This difference in the mass is called mass defect given by equation:

$$\Delta m = Zm_p + (A - Z)m_n - m_{nuc}$$

$$were\ Zm_p\ is\ total\ mass\ of\ protons$$

$$were\ (A - Z)m_n\ is\ total\ mass\ of\ neutrons$$

How to calculate binding energy?

Once the mass defect is known as **mass defect** (m_{nuc}), you can calculate Δm

Then calculate binding energy from the equation:

$$E_b = (\Delta m)c^2 \ldots\ldots\ldots\ldots were\ c\ is\ speed\ of\ light.$$

$$or \qquad E_b = mass\ defect\ \times 931.494\ MeV$$

So we can define the binding energy as: *its amount of energy that is equivalent to decrease (loss) in the mass of nucleus constituents.*

"كمية الطاقة التي تعادل الانخفاض في كتلة مكونات النواة"

and binding energy per nucleon = $\frac{Total\ binding\ energy\ for\ all\ nucleons}{atomic\ mass} = \frac{E_b}{A}$

Problem 3: Calculate binding energy of ($^{12}_{6}C$); consider carbon atom mass is (5.486 × 10^{-4}).

In this example, Carbon contains 6 protons and 6 neutrons so A = 12.

Because carbon atom have12u (by definition of the atomic mass unit, u);

So; m_{nuc} of carbon equal to:

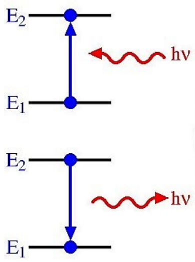
$$12 - (5.486 \times 10^{-4}) = 11.996\ u.$$

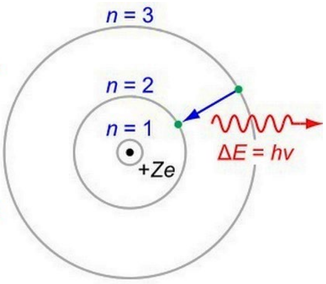
Now: Δm = 6 × 1.0007276 (*mass of proton*) + 6 × 1.008665 (*mass of neutron*) -11.9967 (*mass of ^{12}C nucleus*) = 0.0989 u

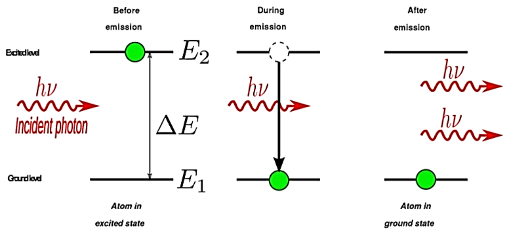
$$E_b = (\Delta m)c^2 = 0.0989\ \times 931.494\ MeV/c^2\ = 92.2\ MeV$$

Energy Level Transitions

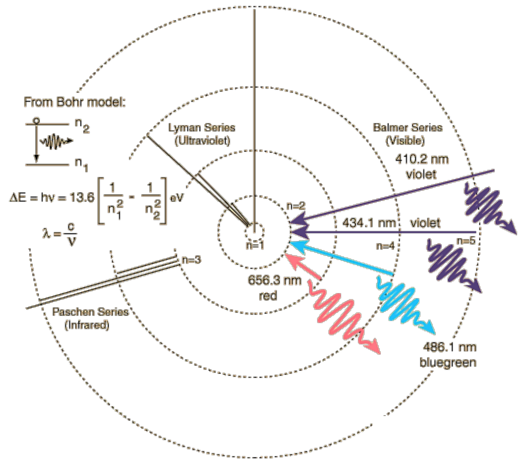
In the process known as absorption, a particle absorbs a photon which provides it the extra energy needed to increase to a higher energy level. Since the energy levels are quantized, the energy of the photon has to be exactly equals to the energy difference, ΔE , between two levels.







$$E_2 - E_1 = \Delta E = h\nu$$

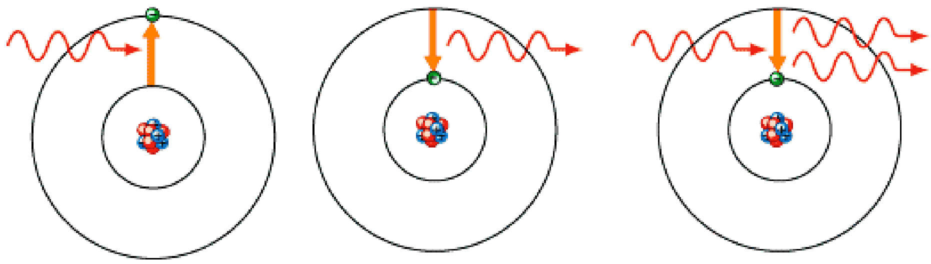


$$\Delta E = hv = \frac{hc}{\lambda}\ eV.nm$$

When a particle drops from a higher to a lower energy level, that change in energy is conserved by the creation of a photon due to the transition. This is known as photon emission. This process is depicted above for a particle dropping from a higher energy level, E_2, to a lower energy level, E_1, and as a result emitting a photon whose energy must equal exactly the energy difference between the two levels, $E_2 - E_1 = E_{photon}$.

Definition:

<u>Spontaneous emission</u>: is an energy conversion process in which an excited electron or molecule decays to an available lower energy level and in the process gives off a photon.



When all electrons of an atom are at the lowest possible energy levels and thus the atom possesses the lowest energy it has, we say that it is at the ground state.

Fig. 1 shows the electronic configuration of a carbon atom at the ground state.

When one or more electrons are at a higher energy level, we say that the atom is at an exciting state. It was mentioned earlier that electrons transit between energy levels by absorbing or emitting light. These transitions are divided into three types:

- Spontaneous absorption - an electron transit from a lower energy level to a higher one by absorbing a photon (Fig. a)
- Spontaneous emission - an electron spontaneously emits a photon to transit from a higher energy level to a lower one (Fig. b)
- Stimulated emission - photons incident into the matter to stimulate the electrons to transit from a higher energy level to a lower one and to emit a photon. The incident photon and their emitted counterparts have the same wavelength and phase; this wavelength corresponds to the energy difference between the two energy levels. A photon stimulates an atom to emit another photon, and hence two identical photons resulted (Fig. c).