PHYSICS OF RADIOLOGY

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FUNDEMANTAL OF MEDICAL PHYSICS

spring semester

Week 2

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Outline

Fundamental particles

Nuclear binding energy

Nuclear stability

Auger electrons

Radioactive decay

Radioactive materials

Activity

Half-life

Objectives of 2nd week lecture

The student should be able to do the followings;

Explain the following: Fundamental particles, Nuclear binding energy, Nuclear stability

Auger electrons, Radioactive decay, Radioactive materials, Activity, and Half-life

Give examples on Fundamental particles

Calculate the binding energy for electrons

The fundamental particles

- The fundamental particles of an atom are

1- the electron

2- the proton

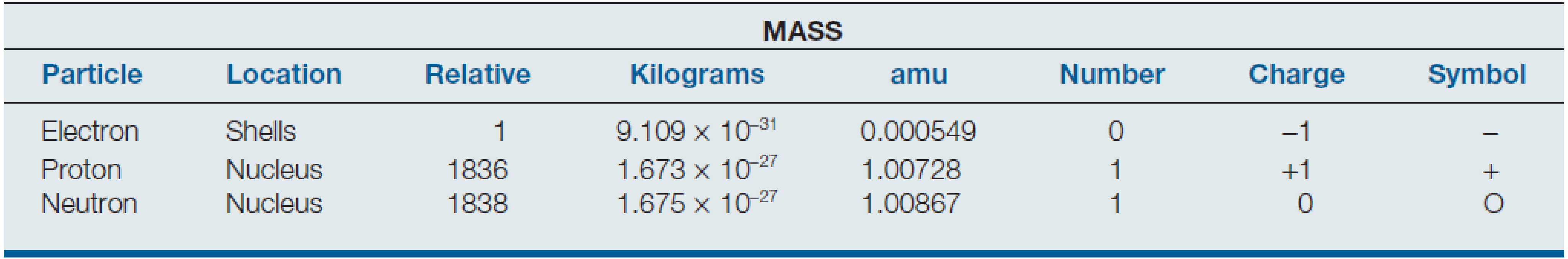
3- the neutron.

- Electrons are very small particles that carry one unit of negative electric charge.

Their mass is only 9.1×10^{-31} kg. They can be pictured as revolving about the nucleus in precisely fixed orbits, just as the planets in our solar system revolve around the sun.

The fundamental particles

- The nucleus contains particles called **nucleons**, of which there are two types: protons and neutrons.
- Both have nearly 2000 times the mass of an electron.
- The mass of a proton is 1.673×10^{-27} kg;
- the neutron is just slightly heavier at 1.675×10^{-27} kg.
- The atomic mass number of each is one.
- The primary difference between a proton and a neutron is electric charge.
- The proton carries one unit of positive electric charge. The neutron carries no charge; it is electrically neutral.

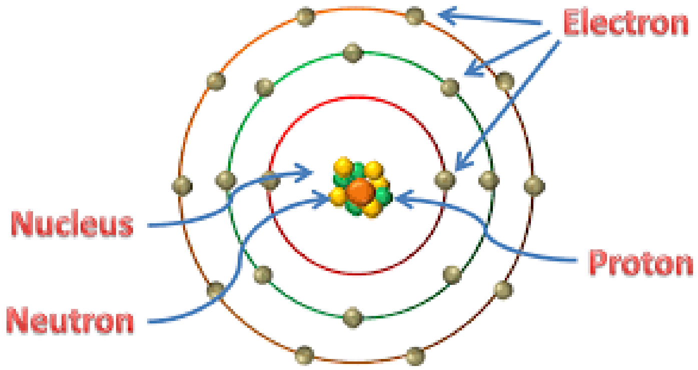


		MASS					
Particle	**Location**	**Relative**	**Kilograms**	**amu**	**Number**	**Charge**	**Symbol**
Electron	Shells	1	9.109×10^{-31}	0.000549	0	–1	–
Proton	Nucleus	1836	1.673×10^{-27}	1.00728	1	+1	+
Neutron	Nucleus	1838	1.675×10^{-27}	1.00867	1	0	O

Binding Energy

- Binding energy is the amount of energy required to separate a particle from a system of particles or to disperse all the particles of the system
- The strength of attachment of an electron to the nucleus is called the *electron binding energy*, designated E_b. The closer an electron is to the nucleus, the more tightly it is bound.
- Electronic Binding Energy (Ionization Energy): Energy required to remove the electron from the nucleus. For hydrogen, this is 13.6 eV
- For Hydrogen atom, the binding energy for electrons in orbit (n):

$$E_b = \frac{-13.6\ eV}{n^2}$$



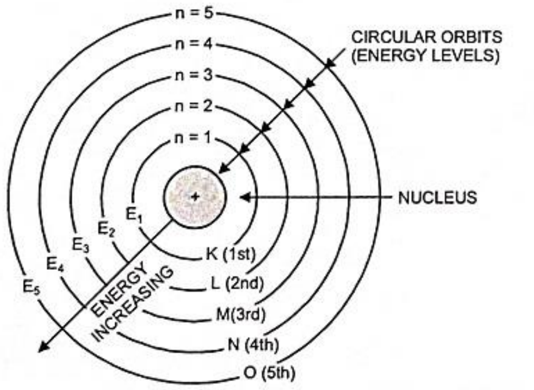


Fig. 4.1 *Orbit-Like Representation of Various Energy Levels*

Nuclear Stability

- Many factors affect nuclear stability. Perhaps the most important is the number of neutrons.
- When a nucleus contains too few or too many neutrons, the atom can disintegrate radioactively, bringing the number of neutrons and protons into a stable and proper ratio.

Auger electrons

- Auger electrons are secondary electrons emitted from an atom when an inner-shell vacancy is filled by an outer-shell electron, releasing energy that ejects another electron. This is radiationless process.
- Emission Process: An inner shell electron (e.g., or K-shell) is removed, leaving a vacancy. An electron from a higher energy level (e.g., L-shell) drops down to fill it. Instead of emitting an X-ray photon, the released energy ejects a second electron from a higher shell.

Radioactivity

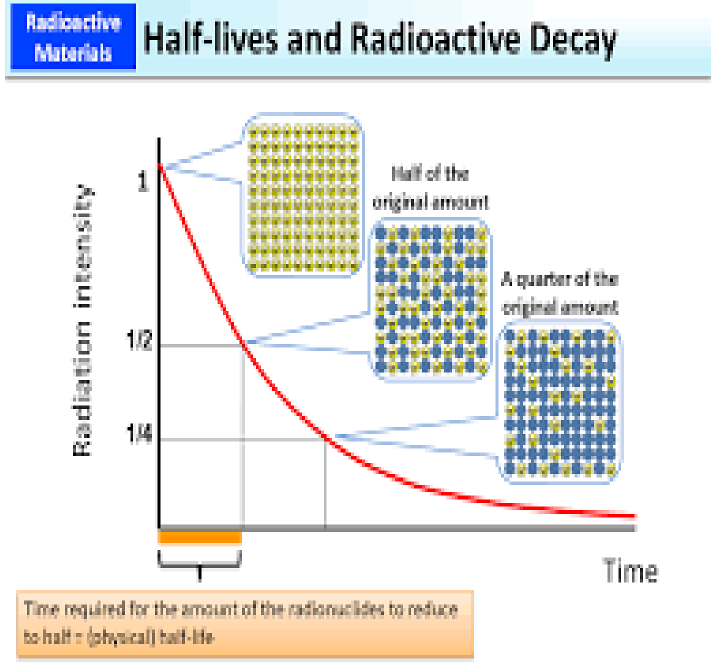
- Radioactivity is the spontaneous emission of particles and energy to become stable.
- Some atoms exist in an abnormally excited state characterized by an unstable nucleus. To reach stability, the nucleus spontaneously emits particles and energy and transforms itself into another atom. This process is called **radioactive disintegration** or **radioactive decay.**
- The atoms involved are **radionuclides.** Any nuclear arrangement is called a **nuclide**; only nuclei that undergo radioactive decay are radionuclides.
- **Isotopes** are atoms of the same element with the same number of protons but different numbers of neutrons, resulting in different atomic masses

$$^{127}\mathrm{Ba},\ ^{128}\mathrm{Ba},\ ^{129}\mathrm{Ba},\ ^{130}\mathrm{Ba},\ ^{131}\mathrm{Ba},\ ^{132}\mathrm{Ba},\ ^{133}\mathrm{Ba},$$

$$^{134}\mathrm{Ba},\ ^{135}\mathrm{Ba},\ ^{136}\mathrm{Ba},\ ^{137}\mathrm{Ba},\ ^{138}\mathrm{Ba},\ ^{139}\mathrm{Ba},\ ^{140}\mathrm{Ba}$$

Half Life

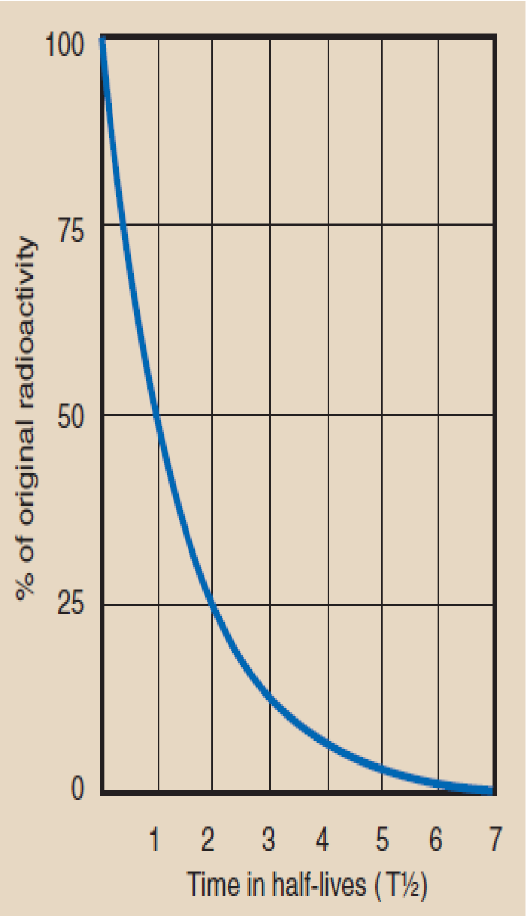
- The half-life of a radioisotope is the time required for a quantity of radioactivity to be reduced to one-half its original value.
- The half-life of ^{131}I is 8 days
- If 10 MBq of ^{131}I was present on January 1 at noon, then at noon on January 9, only 5 MBq would remain. On January 17, 2.5 MBq would remain, and on January 25, 1.25 MBq would remain. A plot of the radioactive decay of 131I allows one to determine the amount of radioactivity remaining after any given length of time



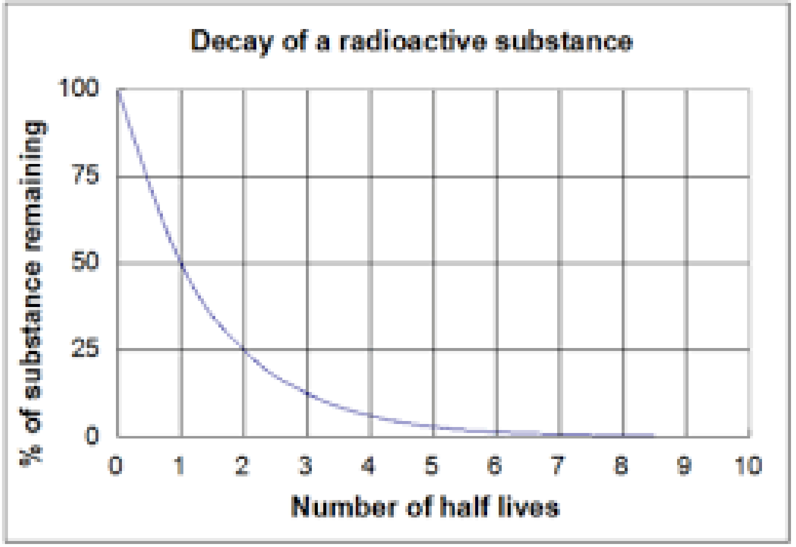
Radioactive Materials

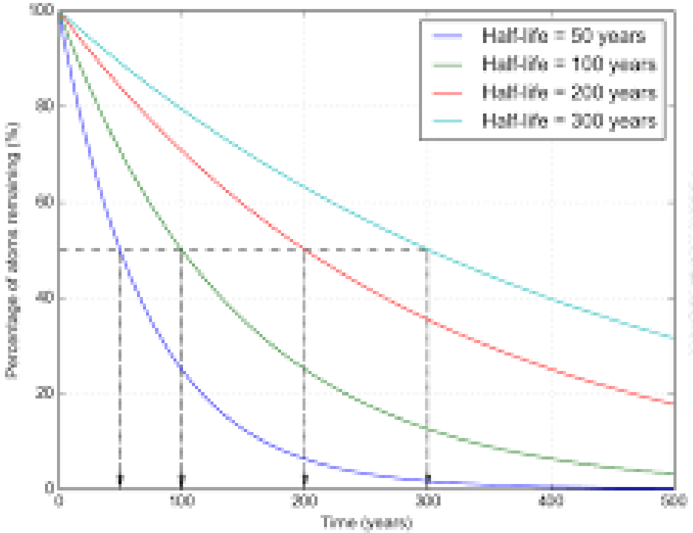
Half-lives and Radioactive Decay

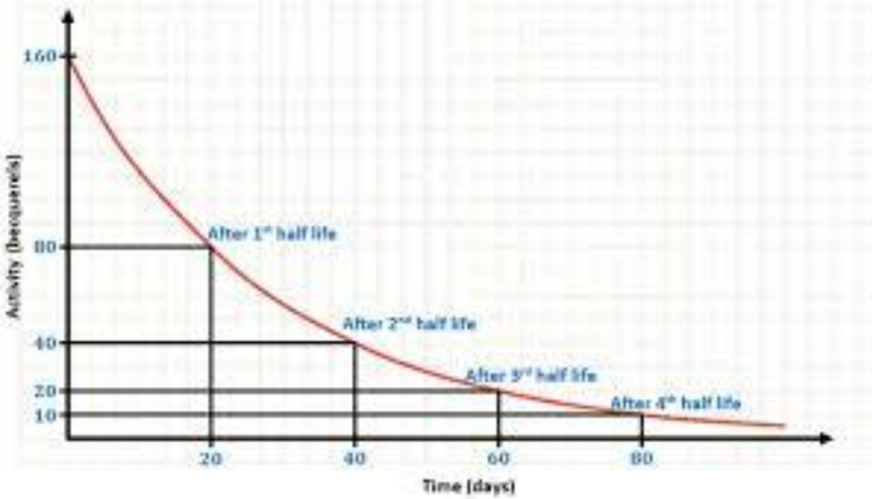
Time required for the amount of the radionuclides to reduce to half = (physical) half-life

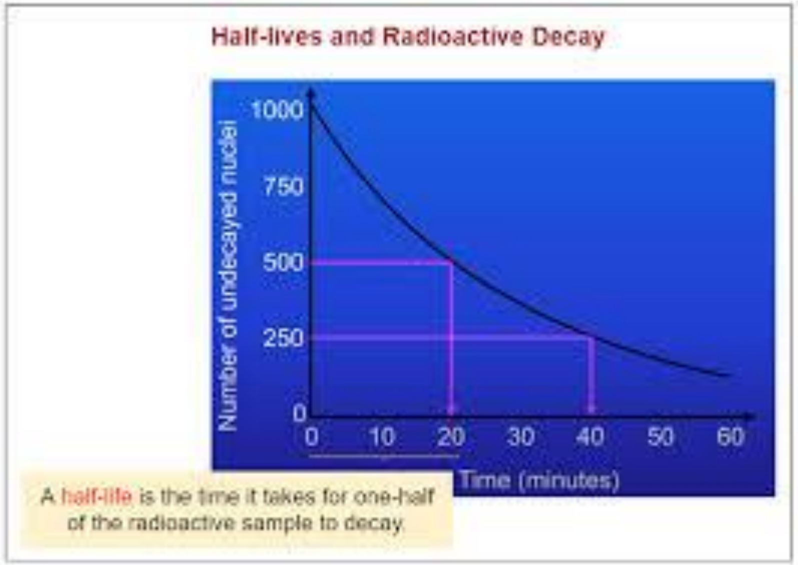


Half Life Example: what are the $t_{1/2}$ for each atom

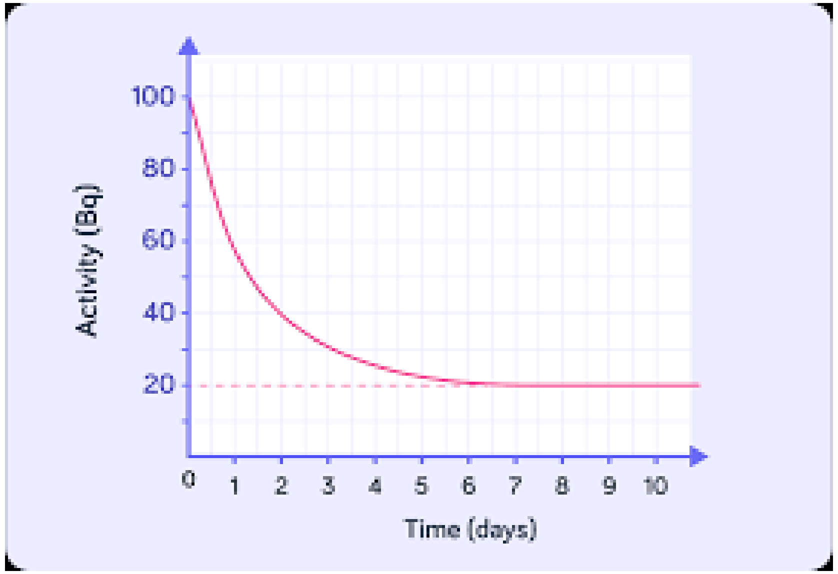


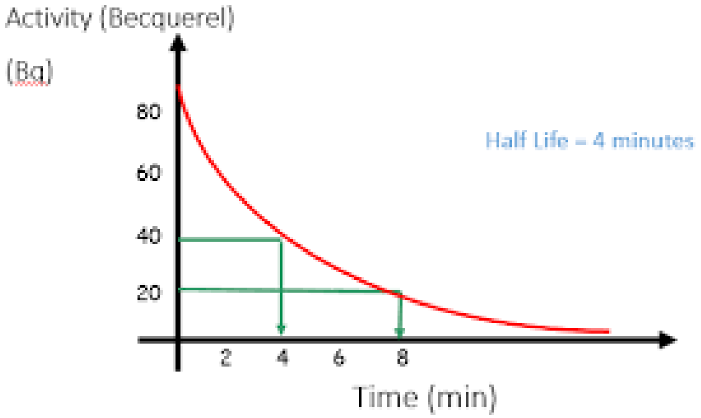






A half-life is the time it takes for one-half of the radioactive sample to decay.





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