
بسم الله الرحمن الرحيم

MEDICAL IMAGING PHYSICS

The Atom

Session 1

FOR 1ST MSC RADIOLOGY

BY

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- **Diagnostic imaging** employs radiations :

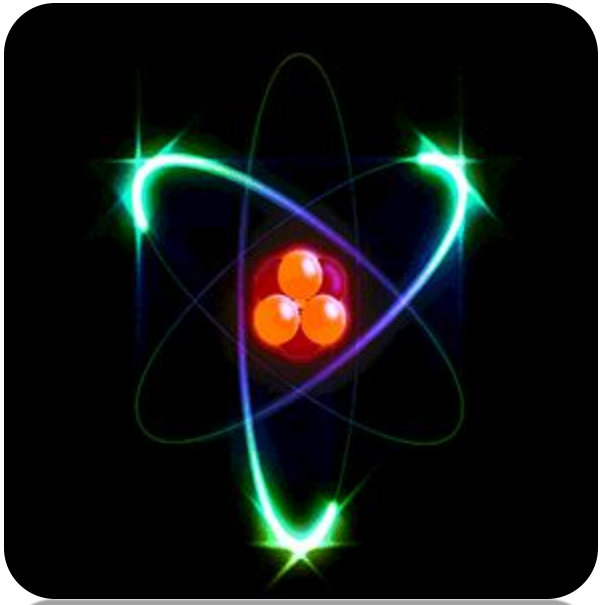
  X, gamma, radiofrequency and sound

- It has special properties of a number of elements & compounds.

- **Ionizing radiations** (**X-rays** and **gamma rays**)

need to understand the structure of atom and the production of X-rays.

STRUCTURE OF ATOM



- **Atom** consists mainly of **nucleus** & **shells**.
- Its mass is concentrated in a **central nucleus**
- **Nucleus** contains (protons "+ve" and neutrons), = **Mass number**
- **Protons,** number = **Atomic number**
- Atom of **Neutral** charge , **Protons** equal to **electron**

Key1 :

Proton is **P**ositive

Neutron is **N**eutral

Neutron

no charge

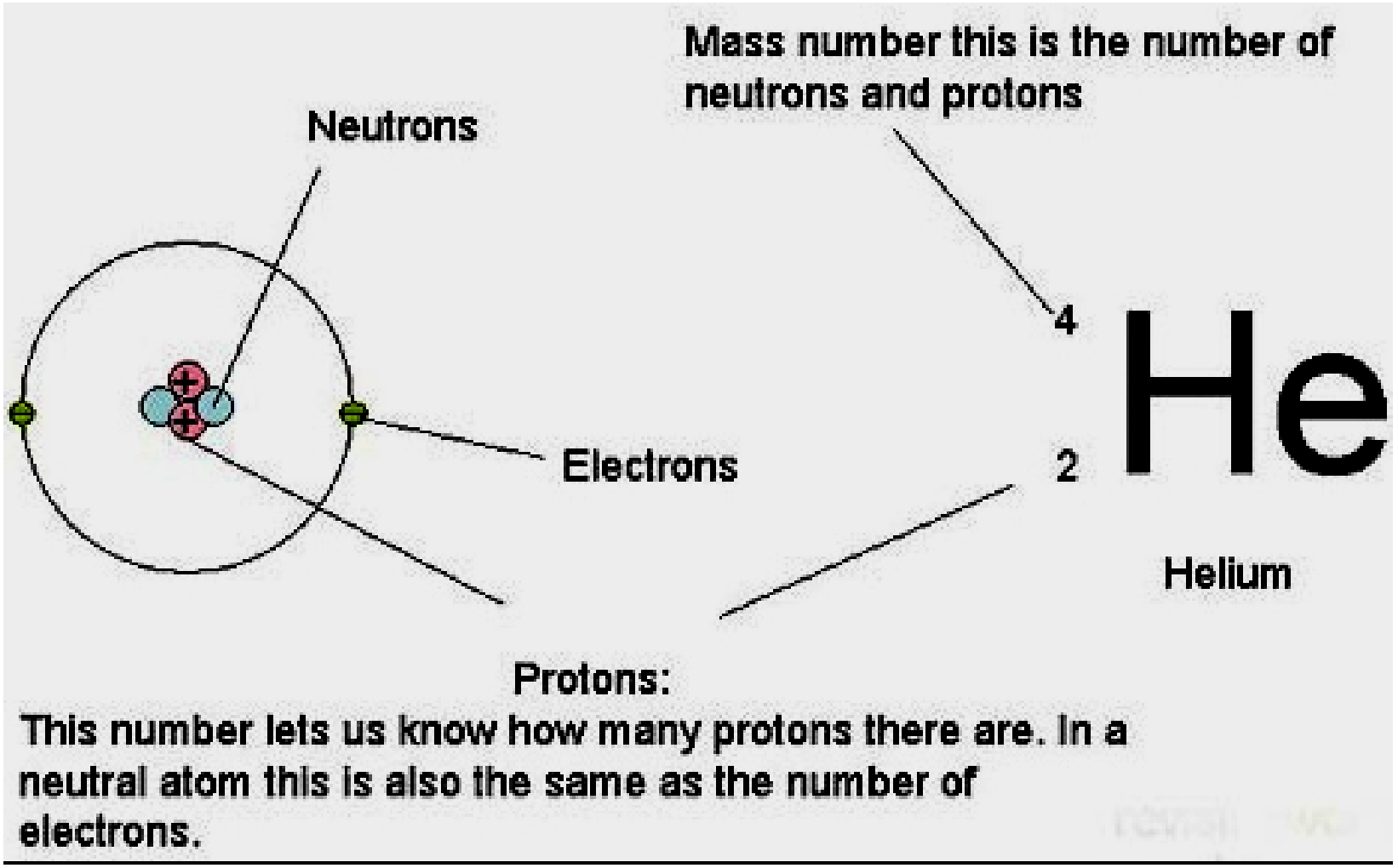
Proton

+

Electron

-

كتلة البروتون
تبلغ حوالي **١٨٣٦** مرة ضعف
كتلة الإلكترون


Mass number this is the number of neutrons and protons
Neutrons
4
He
Electrons
2
Helium
Protons:
This number lets us know how many protons there are. In a neutral atom this is also the same as the number of electrons.

Mass number
Number of protons and neutrons in atom

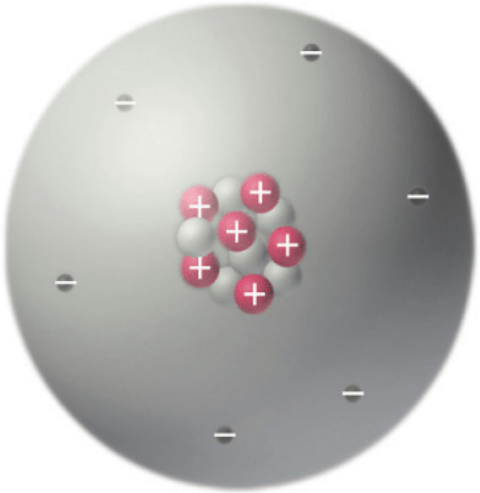
$^{A}_{Z}X$

Atomic symbol
Abbreviation used to represent atom in chemical formulas

Atomic number
Number of protons in atom

$^{12}_{6}C$

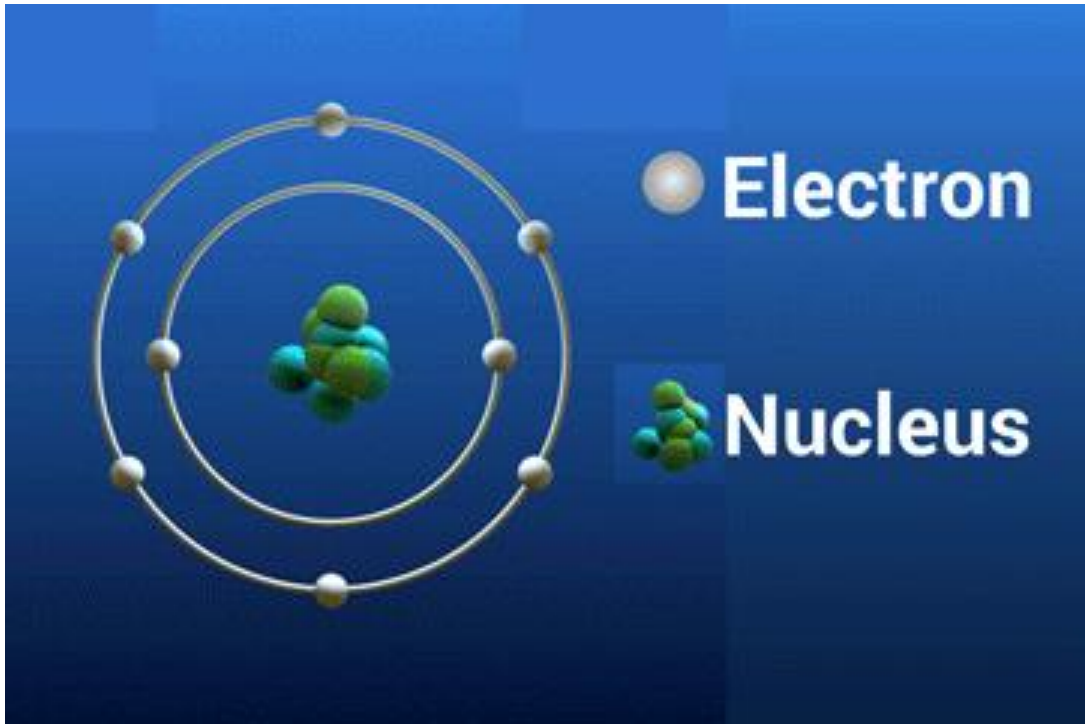
6 protons
6 neutrons
6 electrons



➔ Electron Shells :

- Orbits Around nucleus
- Electrons Rotating in it
- Maximal number of orbits are **7**
- Named **K, L, M, N, O, P, Q**,
- Each orbit has certain number of electrons (2 in K shell, 8 in L ….etc

Shell	Max. No. of Electrons
K	2
L	8
M	18
N	32
O	50
P	72
Q	98

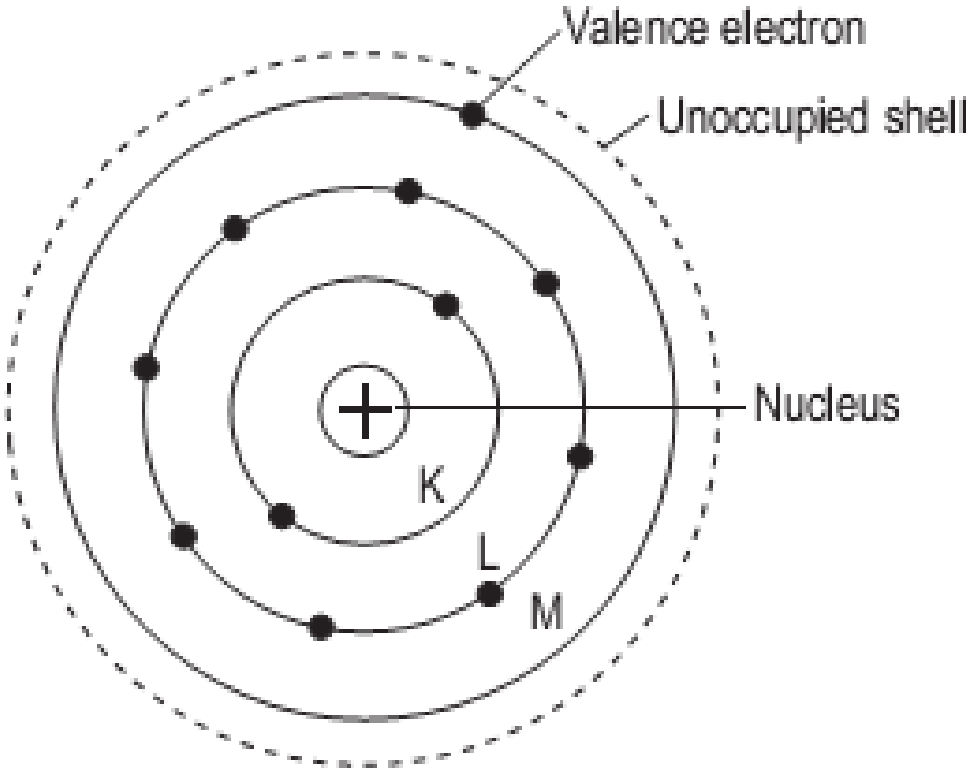


In each atom,

- **Outermost** shell = **valence shell** is :
  - concerned with the chemical, thermal, optical and electrical properties of the element.
  - have **not > 8 electrons**.

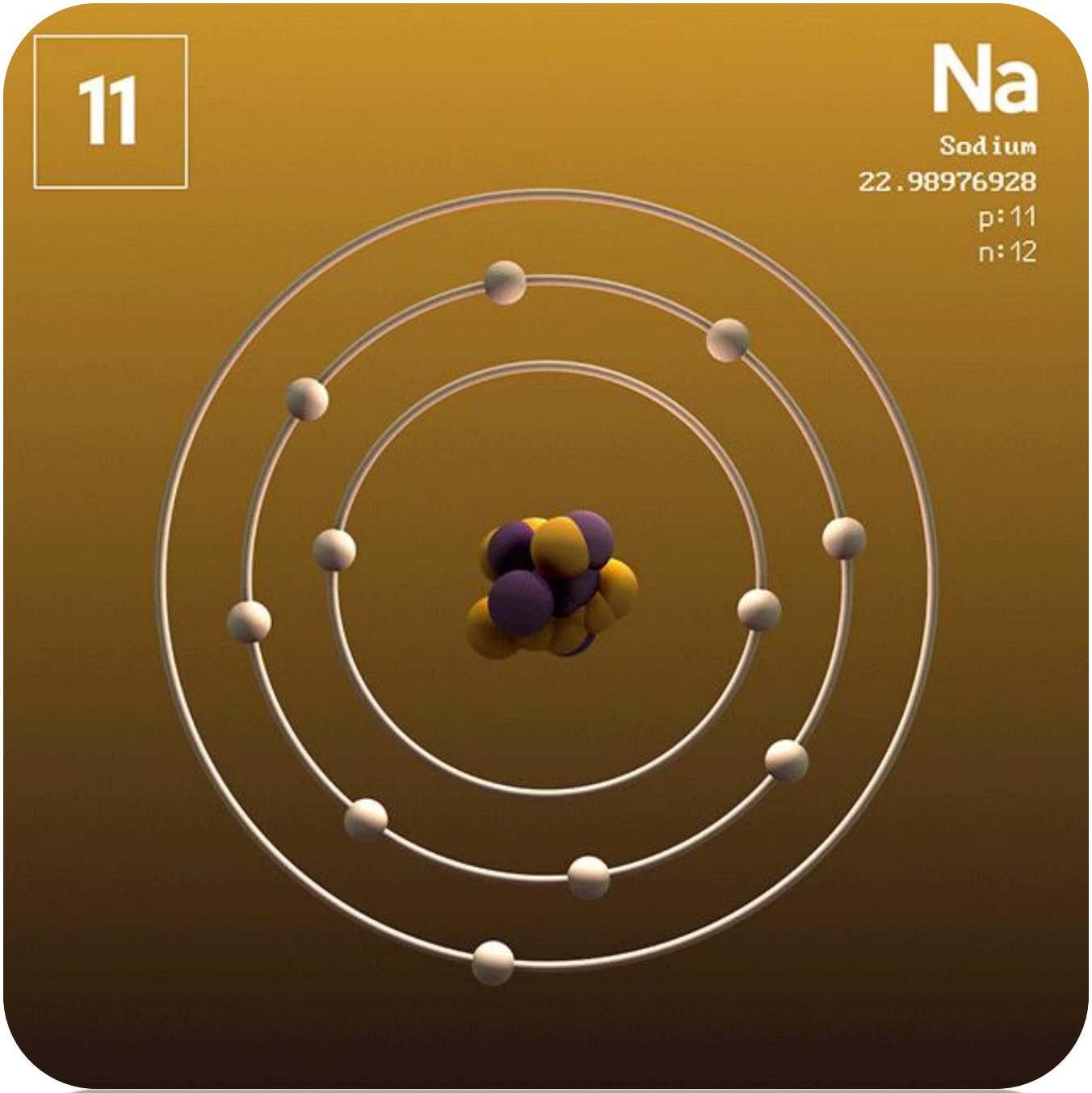
Valence = تكافؤ

- 2 electrons in the K-shell,
- 8 in the L-shell and
- 1 in the outermost M-shell.



Electron shells in a sodium atom

- **The properties of X-rays** and their interaction with materials concern the orbiting electrons, particularly those in the inner shell.
- **Metals** have up to *3 electrons* in valence shell ,
- **One of which** is easily detached from the atom and being free.
- This cause good conduction of heat and electricity.


11
Na
Sodium
22.98976928
p:11
n:12

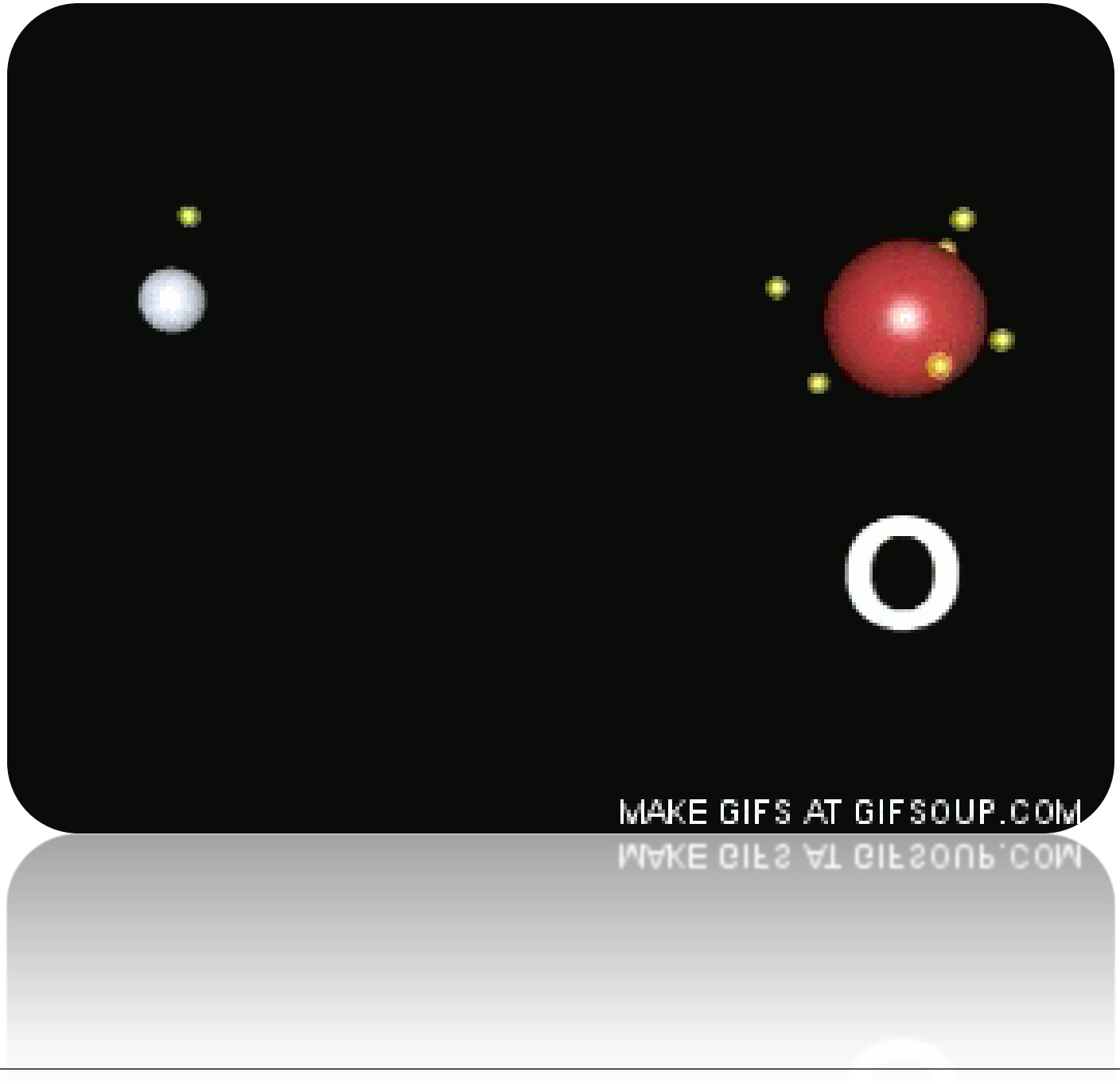
مستوى الطاقة الرئيسي	١	٢	٣	٤
عدد المستويات الفرعية	١	٢	٣	٤
عدد الأفلاك	١	٤	٩	١٦
نوع و عدد الأفلاك في كل مستوى فرعي	s 1	p s 3 1	d p s 5 3 1	f d p s 7 5 3 1
عدد الإلكترونات الأقصى في كل مستوى فرعي	٢	٦ ٢	١٠ ٦ ٢	١٤ ١٠ ٦ ٢
عدد الإلكترونات الأقصى في كل مستوى رئيسي	٢	٨	١٨	٣٢

Binding energy

- **Ionized atom** = one of its electrons completely removed.
- Detached electron is a negative ion & the remnant atom a positive ion.

➔ **Binding energy (E)**

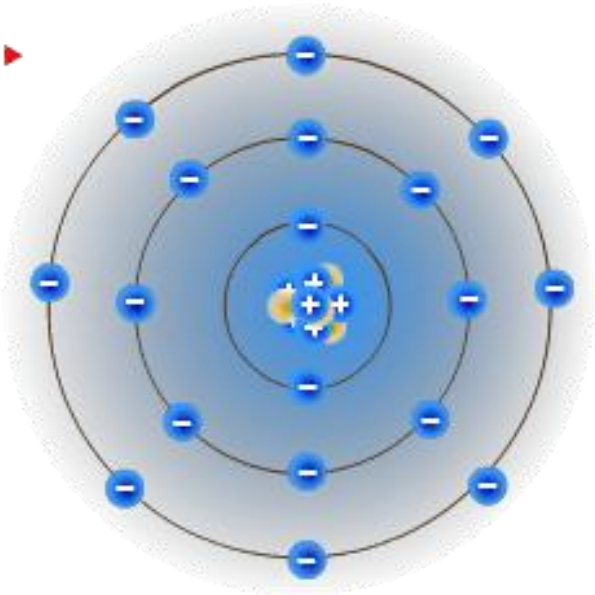
is the energy For removing electron from atom against the **attractive** force of positive nucleus.

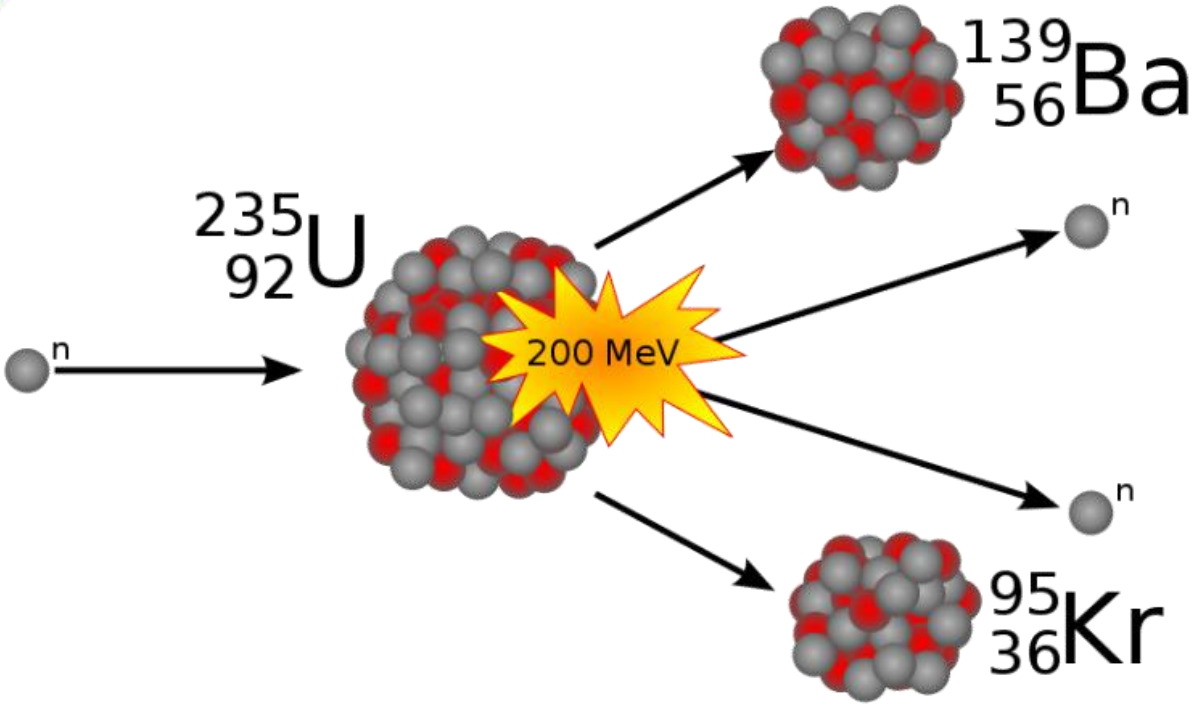

O
MAKE GIFS AT GIFSOUP.COM

- This energy is expressed in **electronvolts (eV),**
- It depends on the shell (E**K** E**L** E**M**…) and on the element,
- It increasing as the atomic number increases.

Table 1.2 Atomic number (Z) and K-shell binding energy (E_k) of various elements

Element	Z	E_k (keV)
Aluminium	13	1.6
Calcium	20	4
Molybdenum	42	20
Iodine	53	33
Barium	56	37
Gadolinium	64	50
Tungsten	74	70
Lead	82	88

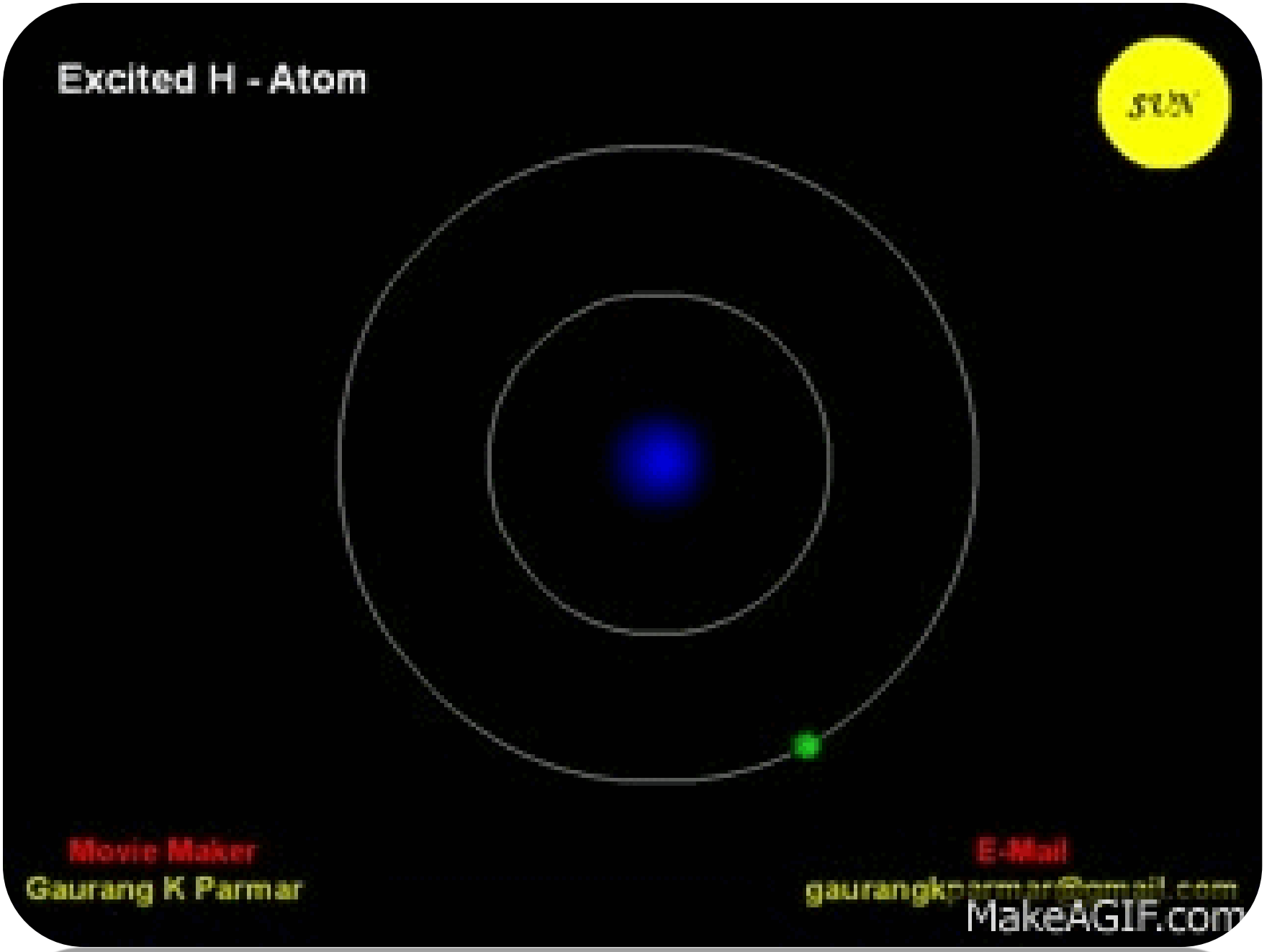


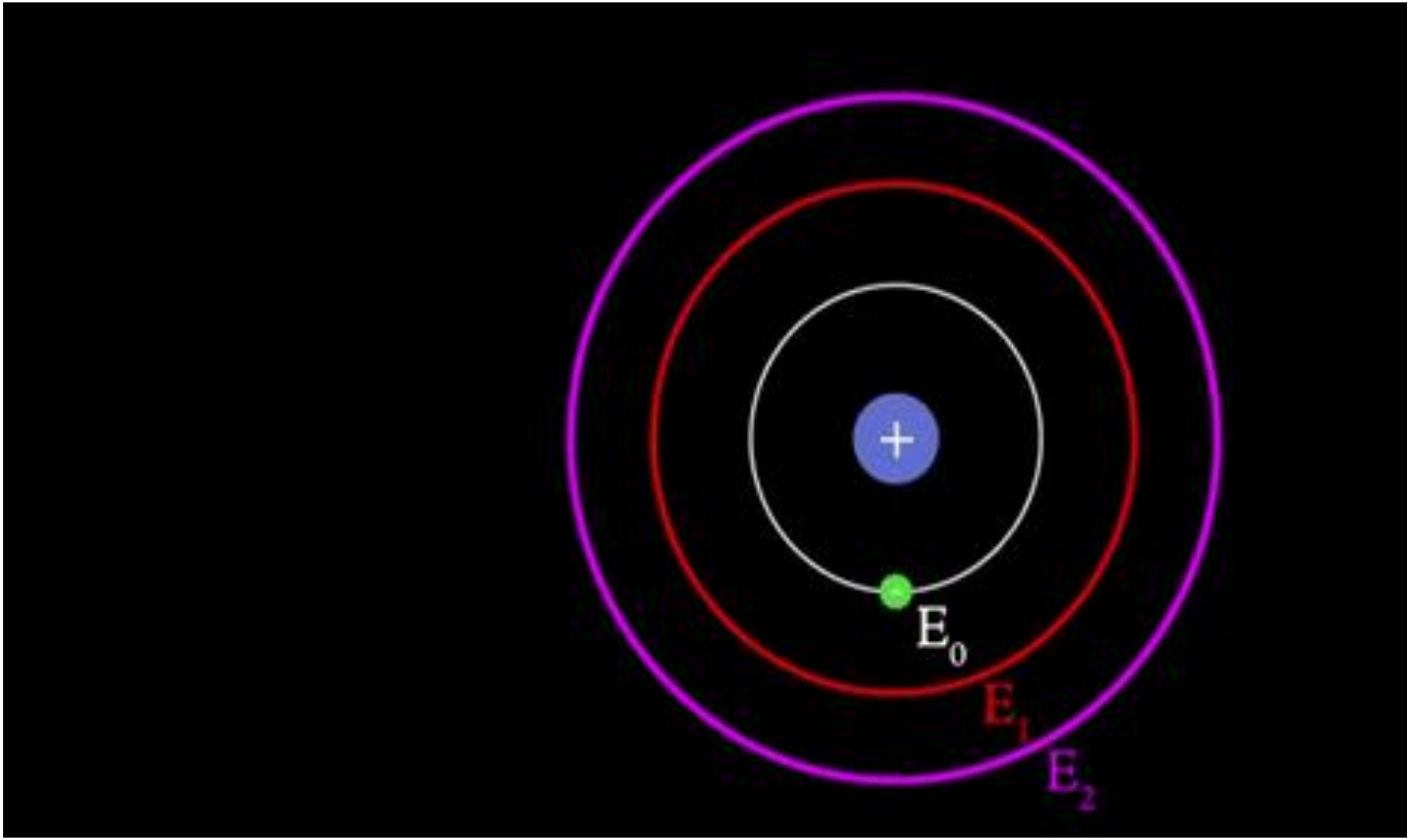

$^{139}_{56}Ba$
$^{235}_{92}U$
n
200 MeV
n
n
$^{95}_{36}Kr$

يعطي **جرام واحد من اليورانيوم** U_{235}
عند انشطاره
الطاقة الناتجة من احتراق **٢,٥ طن من الفحم**

EXCITED ATOM

- **Excited atom** = when an electron is raised from one shell to another further out.
- the atom as a whole has more energy than normal → so is said to be **excited.**
- When electron is falls back, → energy is re-emitted as a single 'packet' of energy or **photon** of light (visible or ultraviolet).


Excited H - Atom
sun
Movie Maker
Gaurang K Parmar
E-Mail
gaurangkparmar@email.com
MakeAGIF.com


E0
E1
E2

ELECTROMAGNETIC RADIATION

ELECTROMAGNETIC RADIATION

- energy travelling across empty space.
- All forms travel with the **same velocity (c) as light** : $3 \times 10^8 ms^{-1}$

or 300.000.000 m i.e. 300.000 Km/sec

- Named according to how **produced** and its **special properties**.
  - **X-rays** (emitted by *X-ray tubes*)
  - **Gamma rays** (emit-ted by *radioactive nuclei*)

They have the same properties and differ only in their origin.

Wave length & Frequency

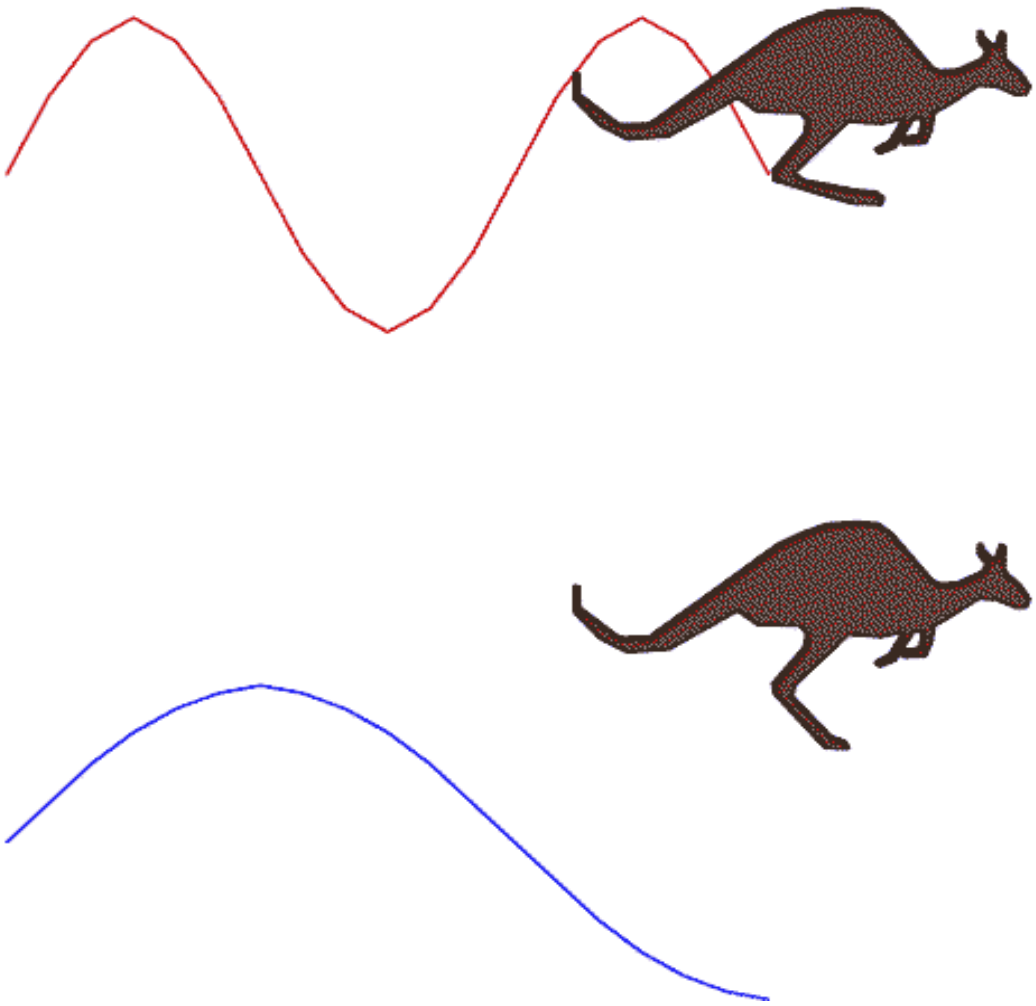
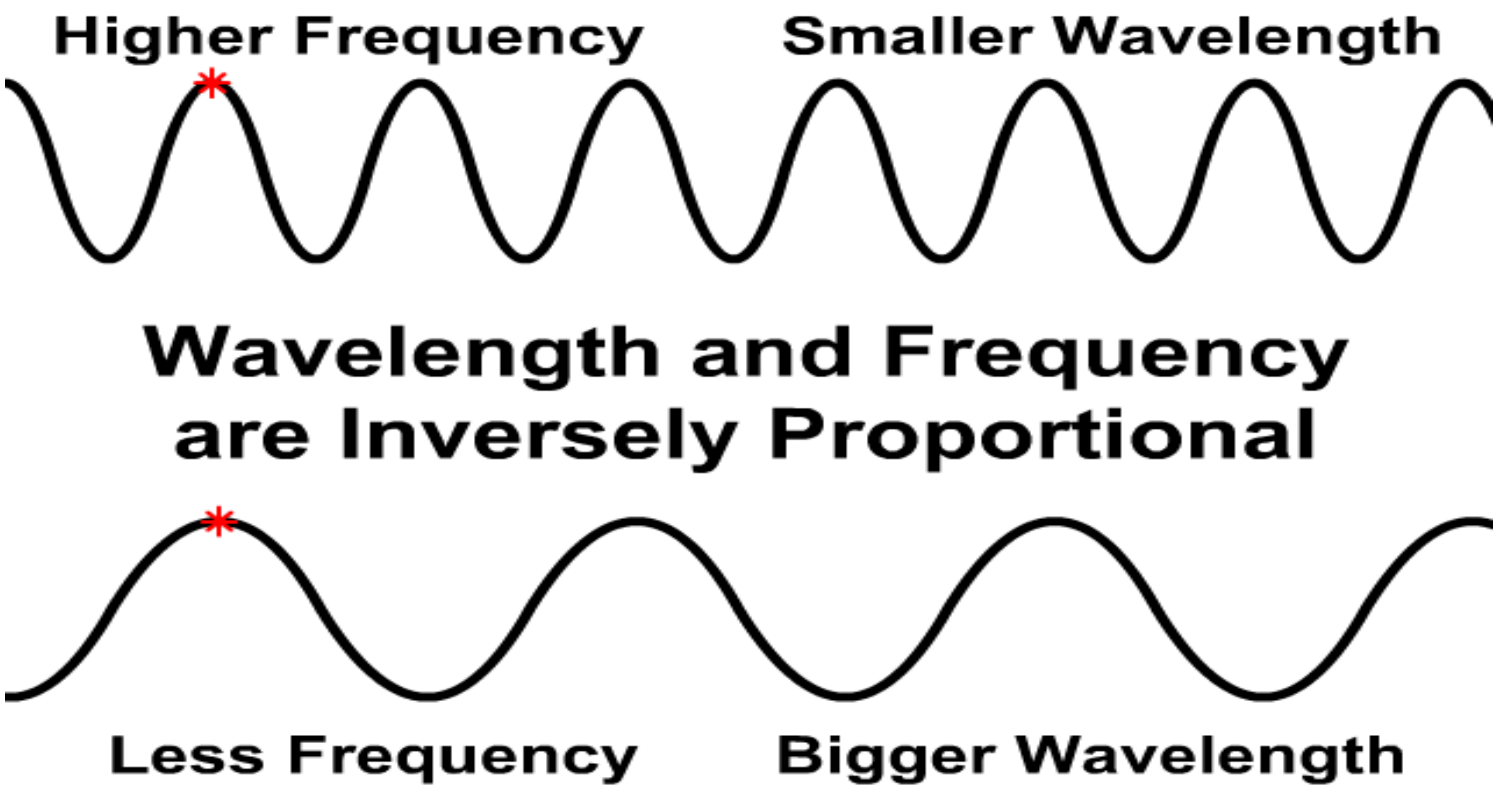
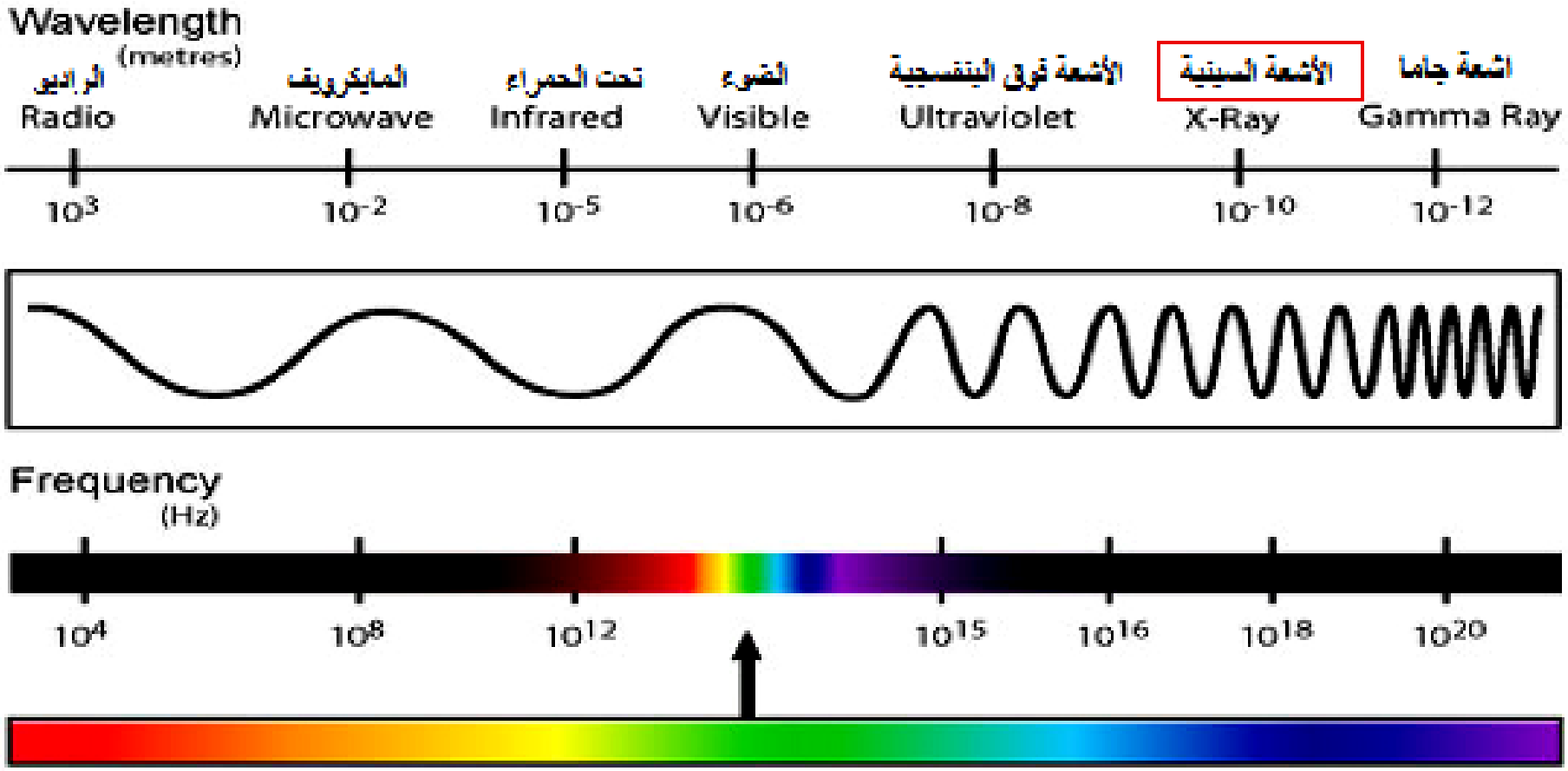


Table 1.3 Electromagnetic spectrum

Radiation	Wavelength	Frequency	Energy
Radiowaves	1000–0.1 m	**0.3–3000 MHz**	0.001–10 μeV
Microwaves	100–1 mm	**3–300 GHz**	10–1000 μeV
Infrared	**100–1 μm**	3–300 THz	10–1000 meV
Visible light	**700–400 nm**	430–750 THz	1.8–3 eV
Ultraviolet	**400–10 nm**	750–30 000 THz	1.8–100 eV
X- and gamma rays	1 nm–0.1 pm	$3 \times 10^5 - 3 \times 10^9$ THz	**1 keV–10 MeV**

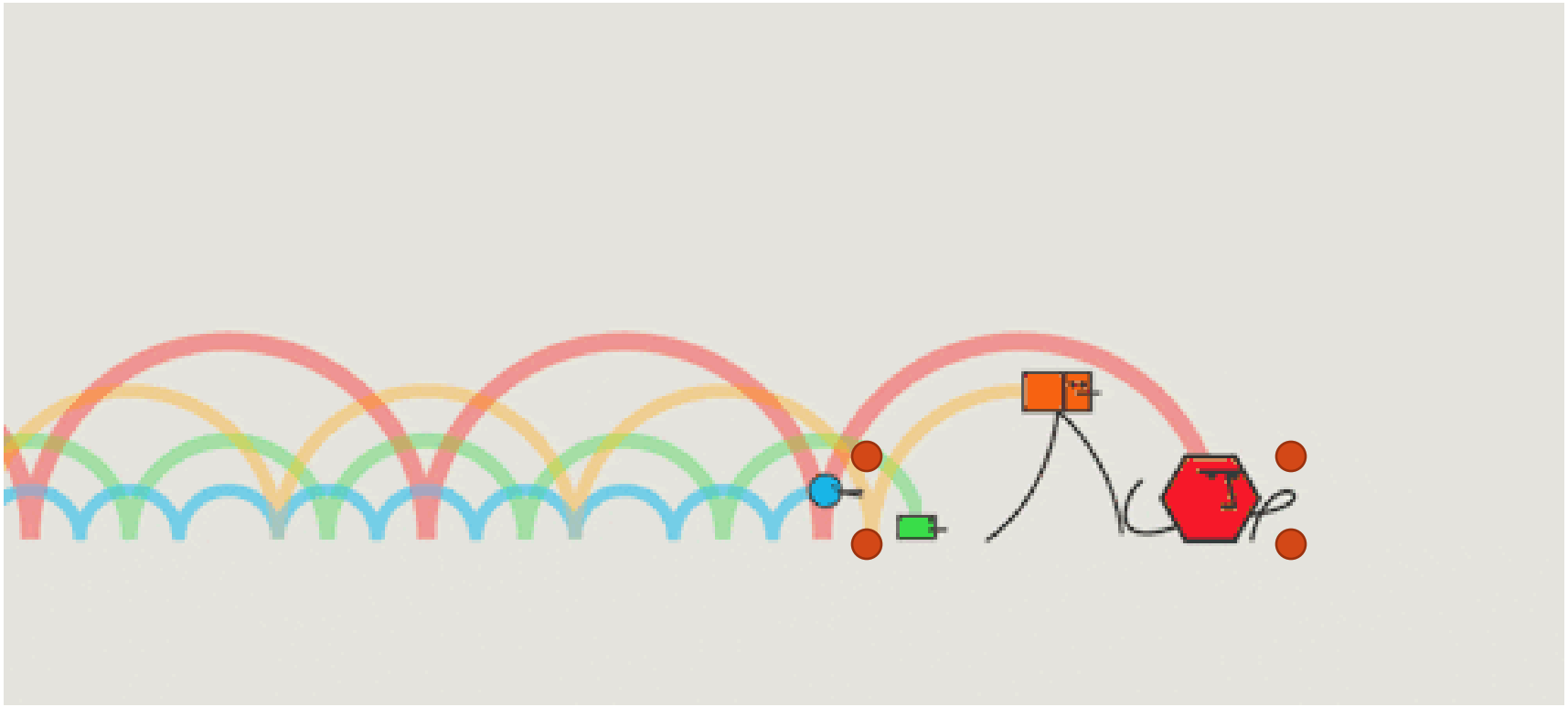



Wavelength
(metres)
الراديو
Radio
المايكروويف
Microwave
تحت الحمراء
Infrared
الضوء
Visible
الأشعة فوق البنفسجية
Ultraviolet
الأشعة السينية
X-Ray
اشعة جاما
Gamma Ray
10^3
10^-2
10^-5
10^-6
10^-8
10^-10
10^-12
Frequency
(Hz)
10^4
10^8
10^12
10^15
10^16
10^18
10^20

- **Photon energy (E)** is proportional to the **frequency (f)**.
- The constant of proportionality is called **Planck's constant (h).**
- Thus E = hf.

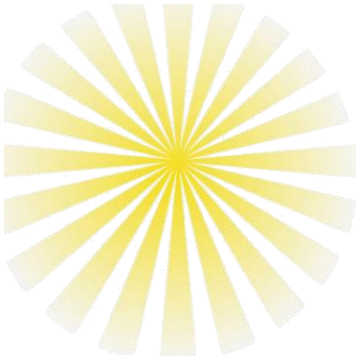
For example:

Blue light	$\lambda = 400\,\text{nm}$	$E \approx 3\,\text{eV}$
Typical X- and gamma rays	$E = 140\,\text{keV}$	$\lambda \approx 0.1\,\text{nm}$.

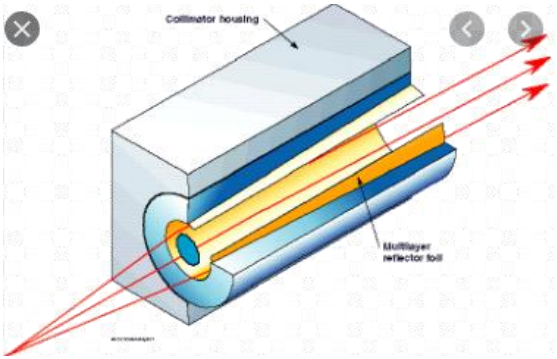


- **Key:**
  <u>Smaller</u> Wave length = <u>More Penetration</u> ability

- Radiation travels in straight lines called → Rays



- It radiate in all directions from a point source.
- **Beam**: A collimated set of rays .
- A beam may contain photons of *Different energies*



- **Energies** of all the individual photons → gives the **total amount of energy / unit area**

passing through the cross section in the time, =

Energy fluence at the point

BEAM INTENSITY

- The **total amount of energy** per **unit area** passing through the cross-section per **unit time** is called the energy **fluence rate at the point**, and is also referred to as the **beam intensity.**

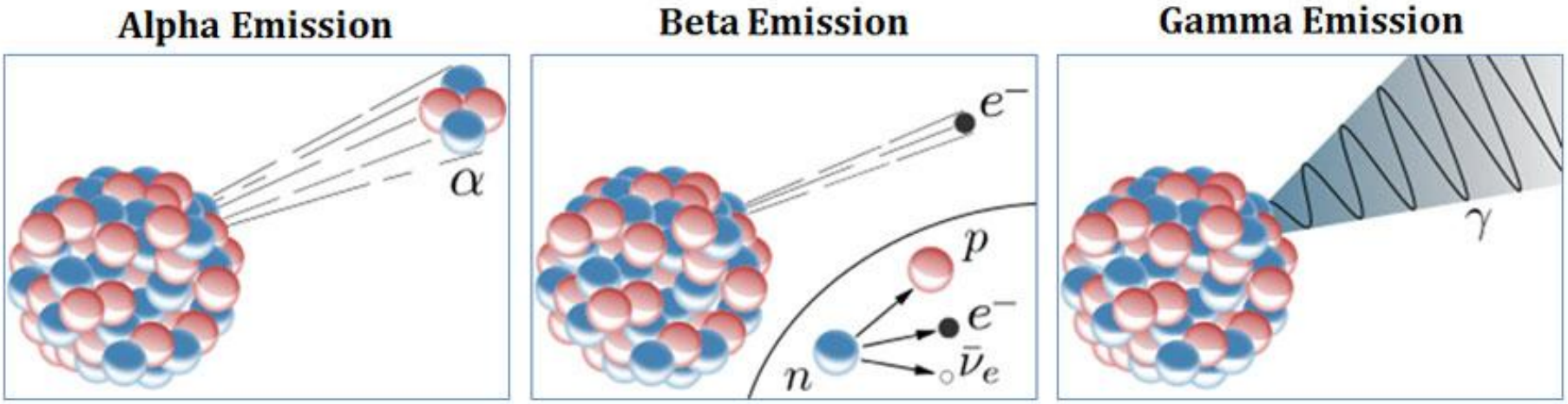
- **Energy fluence** and **intensity** are not easy to measure directly.

X ray :

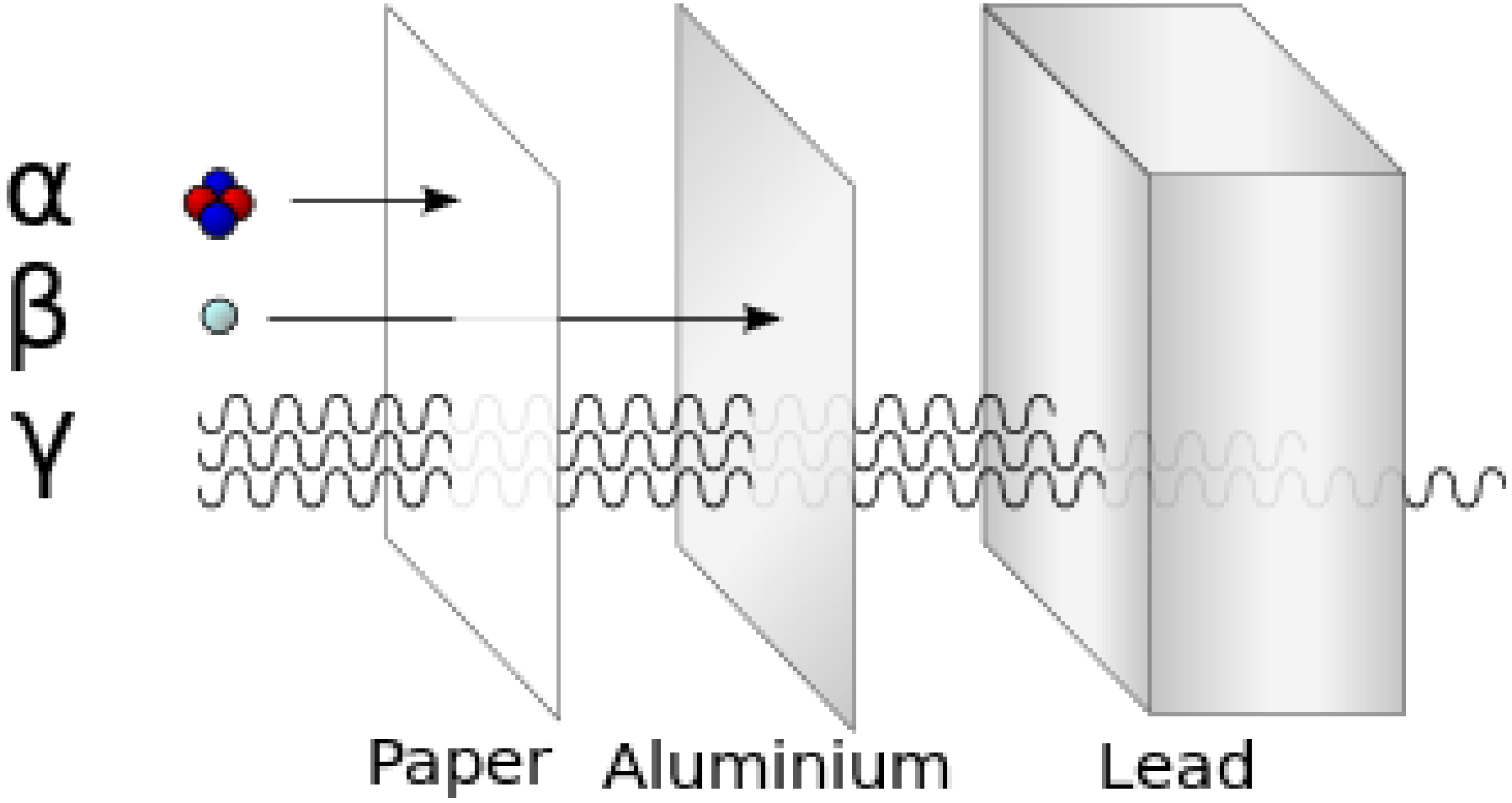
- **Name** : X i.e. Unknown
- **Type** : Electromagnetic wave
- **Wavelength** : 0.01 : 10 nanometer
- High penetration ability
- Radiographic characters.

Key :
1 mm = 1 Million nano

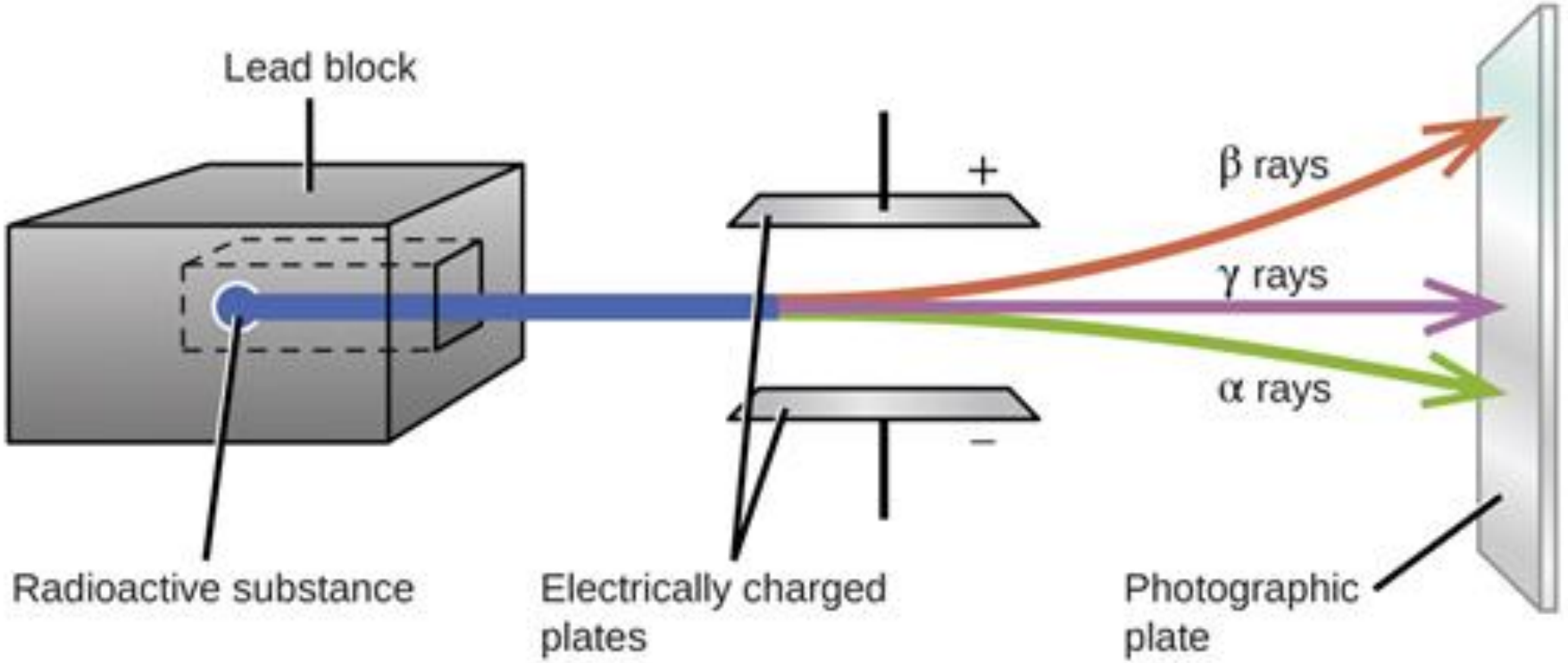
Types of Radiations



- **Alpha** : He nucleus , +ve – Large particle → low penetration
- **Beta** : Rapid electron , -ve , small particle → more penetration
- **Gama** : electromagnetic waves , no charge, high Penetration

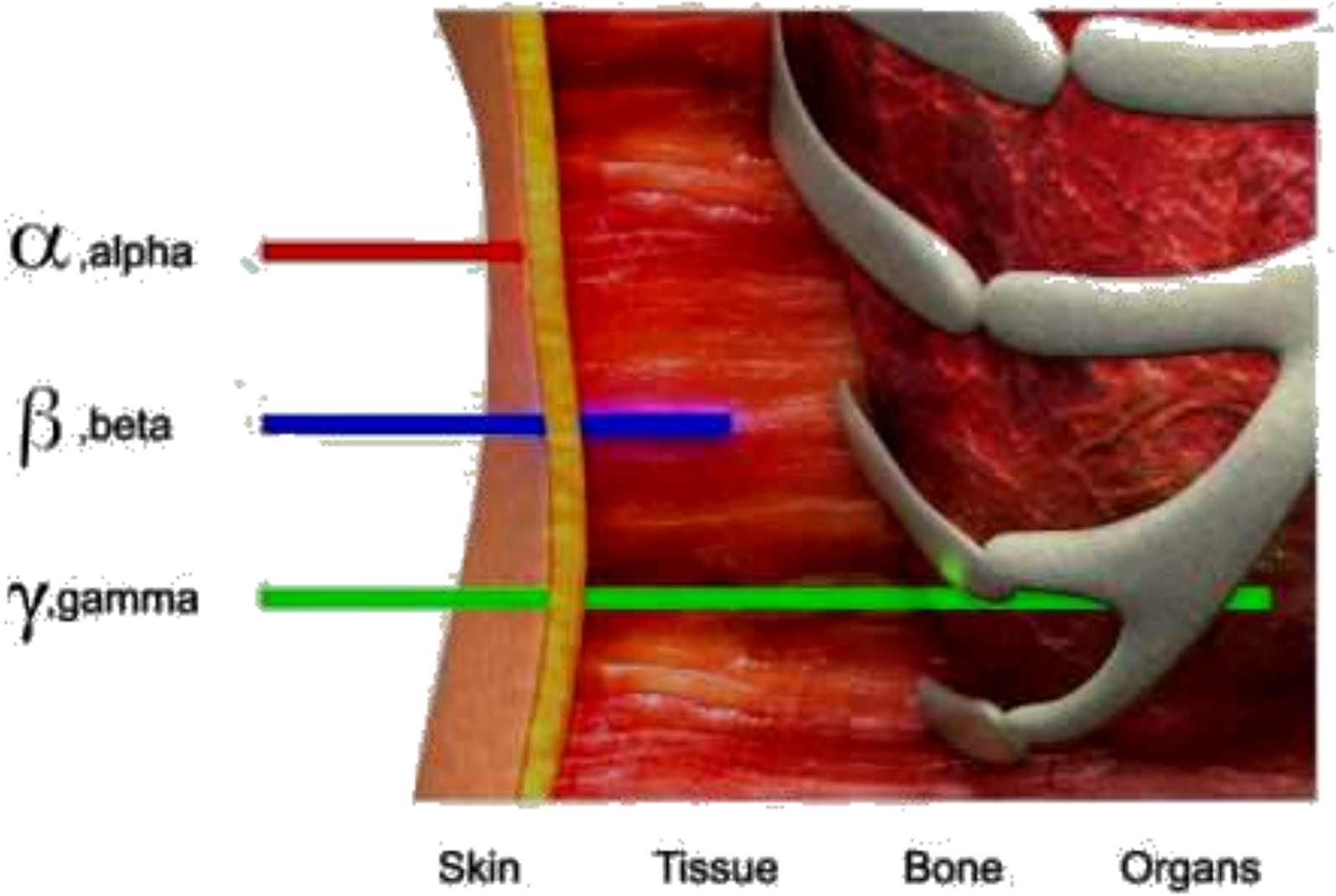


Gamma Rays has High penetration ability

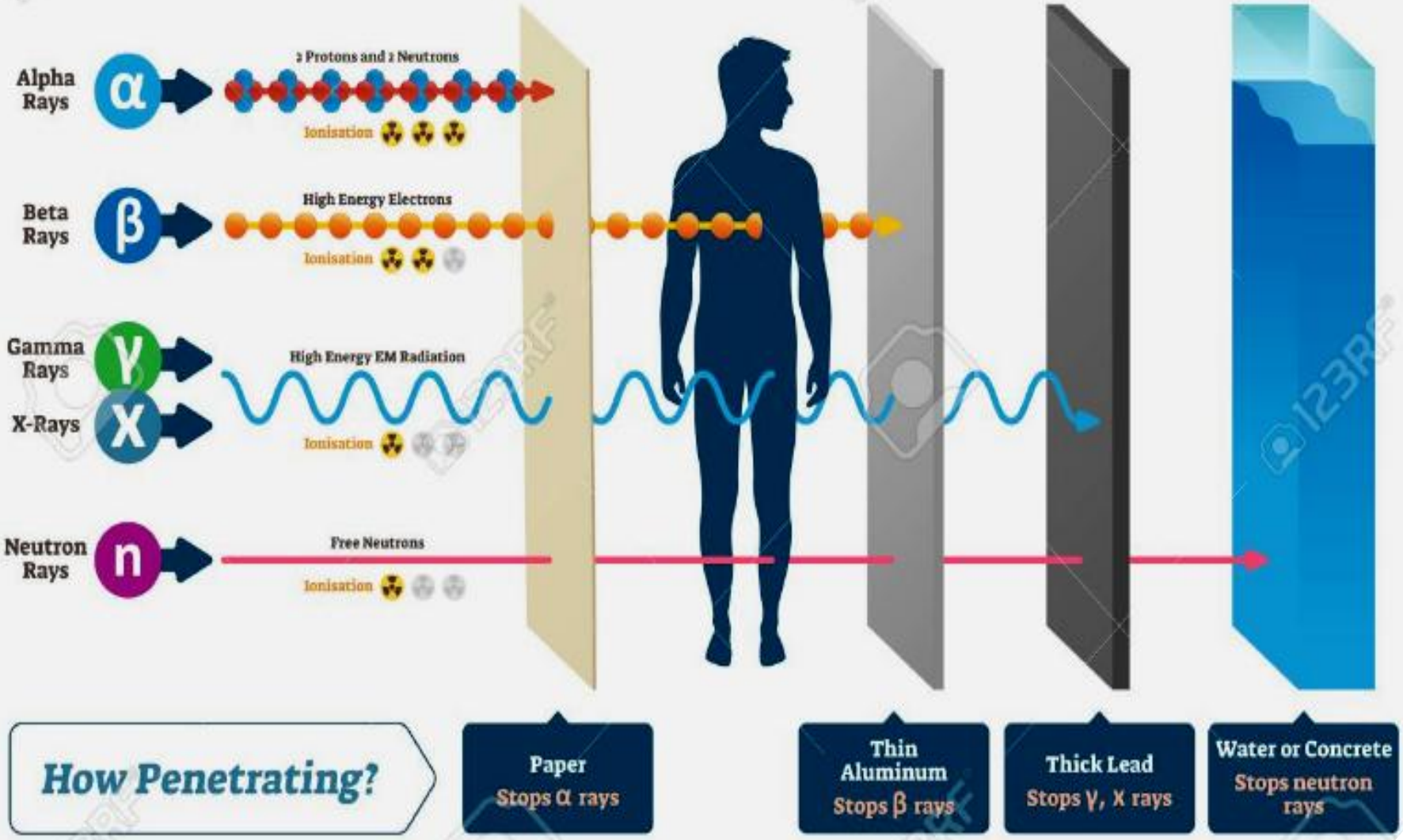


Gamma Rays Not affected by magnetic Field

Radiation Rays



TYPES OF RADIATION



SOURCES & FURTHER READING

- Farr's Physics of Medical Imaging
- https://ar.wikipedia.org/wiki/%D8%A3%D8%B4%D8%B9%D8%A9_%D8%B3%D9%8A%D9%86%D9%8A%D8%A9
- https://radclass.net/
- https://radiopaedia.org/articles/linear-attenuation-coefficient

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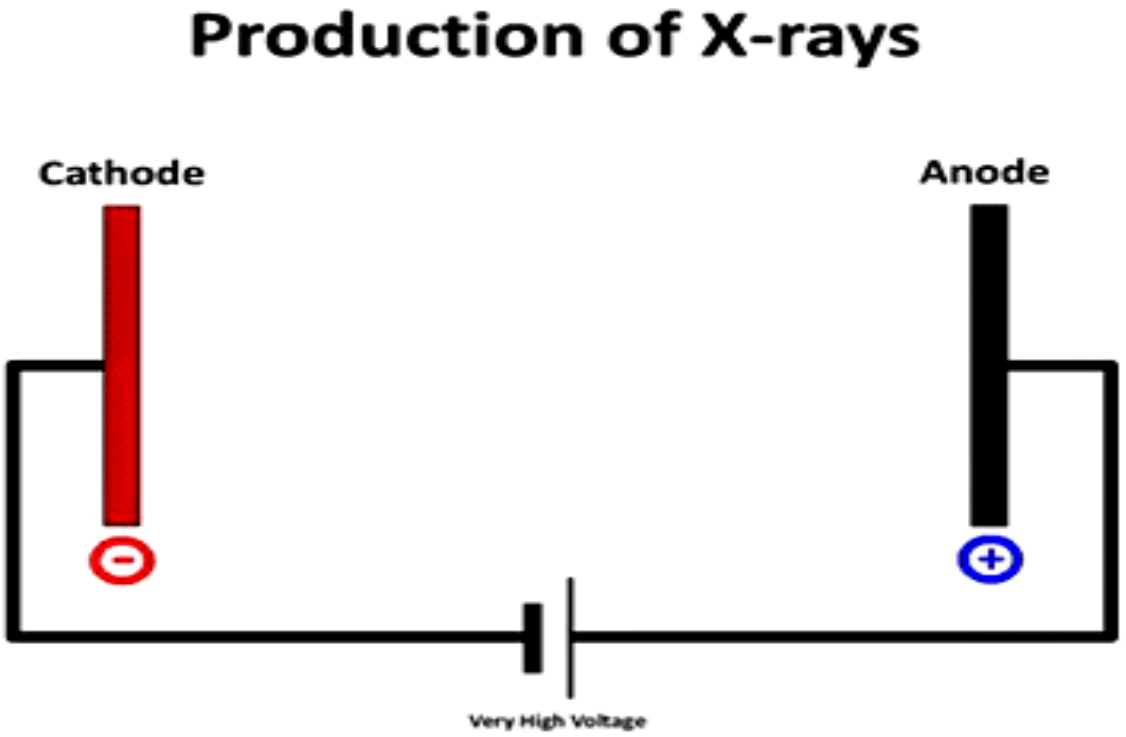

THANK YOU

A.M.Abodahab

6 Oct 2020