201 DRD
X-ray Physics

Lecture 1,2: Introduction to Radiation Physics

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شرح جديد

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لا أحل النشر والتصوير

Atomic Structure

- In a physical analysis, all things *visible* and *invisible* can be classified as *matter* or *energy*.
- **Matter** is anything, such as a solid, liquid or gas, that has weight (mass) and occupies space. For anything to occupy space, it must have volume.

أي شيء له كتلة ويشغل حيزاً من الفراغ

- A matter is composed of fundamental building blocks called ***atoms***.
- Atoms can attach to one or more other atoms by *chemical bonds* to form *chemical compounds* such as *molecules*.

atom + atom $\xrightarrow[\text{bond}]{\text{by ch.}}$ ch. comp. (Molecule)

Atomic Structure Cont.

- Matter is usually classified into three classical states, with plasma sometimes added as a fourth state.

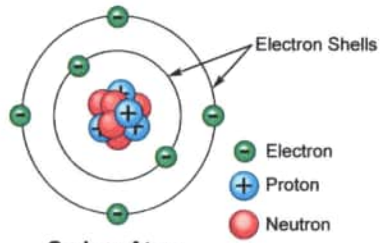
- Matter can be transformed from one shape to another, so energy can be transformed from type to another.
- In radiology, for example, electrical energy in the X- ray machine is used to produce electromagnetic energy (the X-radiation), which then is converted to chemical energy in the radiographic film.

electrical energy → EM Energy (x-ray) → chemical energy in (radiographic film)

Atomic Structure Cont.

The Atom

The atom meaning indivisible (By Greeks).



Carbon Atom

Atomic Structure Cont.

The Atom

- An atom is the *smallest* particle of matter that has the properties of an element
- Although the word 'atom' comes from the Greek for indivisible, we now know that atoms are not the smallest particles of matter. Atoms are made from smaller *subatomic particles*.
- Every solid, liquid, gas, and plasma is composed of *neutral* or *ionized* atoms.
- Atoms are extremely small; typical sizes are around 100 picometers (a ten-billionth of a meter).

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الذرة هي أصغر جزء من المادة لها خواص المادة

Atomic Structure Cont.

The Atom

- Every atom is composed of a *nucleus* and one or more *electrons* bound to the nucleus.
- The *nucleus* is made of one or more *protons*. *Protons* and *neutrons* are called *nucleons*.
- More than 99% of an atom's mass is in the nucleus.
- The *protons* have a *positive electric charge*, the *electrons* have a *negative electric charge*, and the *neutrons* are *neutral*.

(P, N are called nucleons)

atom → nucleus (99 %) → P (+ve), N (neutral)

atom → e⁻ (−ve)

Atomic Structure Cont.

The Atom

- If the number of protons and electrons are *equal*, that atom is electrically *neutral*. So the atoms are electrically neutral; the electric charge on the atom is zero. This means *atoms have no overall electrical charge*.
- If an atom has more or fewer electrons than protons, then it has an overall *negative* or *positive* charge, respectively, and it is called an *ion*. So the atom is unstable.

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if P = e → neutral (charge = 0)

" P < e → −ve charged

" P > e → +ve charged

Atomic Structure Cont.

The Atom

- The electrons of an atom are attracted to the protons in an atomic nucleus by an *electromagnetic force*.
- The protons and neutrons in the nucleus are attracted to each other by a different force, the nuclear force, which is usually stronger than the electromagnetic force repelling the positively charged protons from one another.
- Under certain circumstances, the repelling electromagnetic force becomes stronger than the nuclear force, and nucleons can be ejected from the nucleus, leaving behind a different element: *nuclear decay* resulting in *nuclear transmutation*.

NTM

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علي كلام ص 20

b/w e and p → EMF (weaker)

b/w p and n → NF (stronger)

b/w p and p → EMF (repelling +vely charged protons) from each other

في حالات خاصة

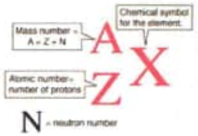
NF < Repelling EMF → الكود بالبني → ejection of nucleons → diff. element (NTM)

Atomic Structure Cont.

The Atom

عدد البروتونات هي هوية العنصر
(Z)

- The number of protons in the nucleus defines to what chemical element the atom belongs.
- The number of protons in an atom is called its *atomic number.*
- Atoms are arranged in the periodic table in order of increasing atomic number.
- *The mass number* also called *atomic mass number* or *nucleon number,* is the total number of *protons* and *neutrons* in an atomic nucleus. It determines the atomic mass of atoms.



العناصر ترتيب حسب الزيادة في العدد الذري

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P+n = Mass no.
(determines atomic mass)

Atomic Structure Cont.

The Atom

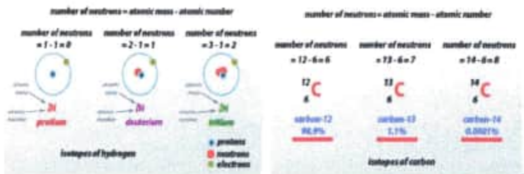
- *Isotopes* are atoms of the same element having the same numbers of *protons* (atomic number), but different numbers of *neutrons*. They have same chemical properties due to the same electronic configuration but different physical properties.

← مهم

نفس عدد البروتونات
ولكن الـ n مختلف

- same chemical prop.
- diff. physical =

Examples of isotopes



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	(e)	(P)	(N)	mass no.
protium $^{1}_{1}H$	1	1	0	1
deuterium $^{2}_{1}H$	1	1	1	2
tritium $^{3}_{1}H$	1	1	2	3

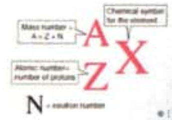
Atomic Structure Cont.

Determining the number of protons and neutrons

- Li has a mass number of 7 and an atomic number of 3
  - Protons = 3 (same as atomic #)
  - Neutrons= 7-3 = 4 (mass # - atomic #)
- Ne has a mass number of 20 and an atomic number of 10
  - Protons = 10
  - Neutrons = 20 - 10= 10

$^{20}_{10}Ne$

$^{7}_{3}Li$



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Atomic Structure Cont.

Determining the number of protons and neutrons

- Cl has a mass # of 35 and an atomic # of 17
  - $p^+ = 17$, $n^o = 18$, $e^- = 17$
- K has a mass # of 39 and an atomic # of 19
  - $P^+ = 19$, $n^o = 20$, $e^- = 19$

$^{35}_{17}Cl$

$^{39}_{19}K$

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	(e)	(P)	(N)	mass no.	
C-12 $^{12}_{6}C$	6	6	6	12	
C-13 $^{13}_{6}C$	6	6	7	13	
C-14 $^{14}_{6}C$	6	6	8	14	(radioactive)

History of atom

TimeLine of Atomic Model

Scientist have done experiments and learn more and more about atoms. They changed the way they think about atoms. So, in this part of lecture we are going to look at the timeline of a different ways that scientist have pictured or imagined atoms over the time.

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History of atom

Timeline: 400 BC
Scientist: Democritus (Greek Philosopher)

Democritus was a Greek philosopher who was the first person to use the term **atom** (*atomos: meaning indivisible*).

He thought that if you take a piece of matter and divide it and continue to divide it you will eventually come to a point where you could not divide it any more. This **fundamental** or **basic** unit was what Democritus called an atom.

He called this the **theory of the universe**:

- All matter consists of atoms, which are bits of matter too small to be seen.
- There is an empty space between atoms
- Atoms are completely solid
- Atoms have no internal structure
- Each atom (of a different substance) is different in size, weight and shape.

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400 BC
العالم demoritus
1st who use the term atom.
قال لو معاك Matter
وصرت تقطع فيها
وضلك تقطع لين
توصل atom
where. you can't
divide it more!

History of atom Cont.

Timeline: 1800's
Scientist: John Dalton

John Dalton was the first to adapt Democritus theory into the first modern atomi model.

1. Matter consists of indivisible atoms
2. Atoms arrange indifferent combination to made different components

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History of atom Cont.

Timeline: 1890's
Scientist: J.J Thomson

Discovered the Electrons

J.J Thomson was a physicist who is credited for discovering the **electron**. He used his research on **cathode ray tube** technology in this discovery.

اكتشف الالكترون

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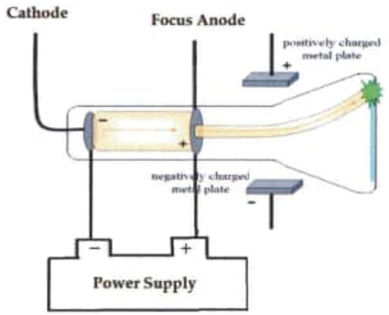
History of atom Cont.

Timeline: 1890's
Scientist: J.J Thomson



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تابع

Thompson

History of atom Cont.

Timeline: 1890's
Scientist: J.J Thomson

1. Nearly Empty tube (Air has been sucked out)
2. An electric charge is passed through the tube. Travels from cathode to anode
3. The charge is invisible, so to see where it traveled a fluorescent screen is placed at back of tube. Where the beam hits, a dot will appear on the screen. You could also use a fluorescent gas and the whole tube will light up.
4. This beam will always travel straight if not interfered with.
5. The deflection coils each have a specific charge. One is positive and the other is negative.
6. Thomson showed (as in the diagram above) that the charge would deflect away from the negative coil. He then stated that this charge was thus a negative charge.

•18

الاستنتاج there is +ve center of foil.
He called this center
(nucleus)

ثومبسون

History of atom Cont.

He then found out that this charge was 2000 times lighter that a hydrogen atom. He made a bold statement saying that this **negative charge** must be inside an **atom**. This negative charge (he called ***corpuscles***) later became known as the **electron**.

THOMSON'S ATOMIC MODEL

Using what he had discovered, Thomson predicted what an atom should look like. These are the key points to Thomson's Atomic Model:

1. Because of its design this model is known as the plum pudding model
2. Each atom is a sphere filled with positively charged 'fluid'. This resembles the sticky jam part of a pudding.

He did not predict the movement of these electrons

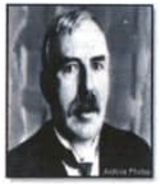
•19

نموذج
بودنغ
البرقوق

لم يتنبأ بحركة الـ e

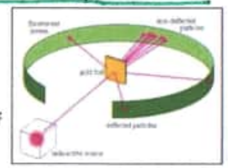
History of atom Cont.

Timeline: 1910's
Scientist: Ernest Rutherford



Ernest Rutherford was not convinced about the model of the atom proposed by Thomson. He thus set up his now famous Gold Foil Experiment.

1. He fired alpha particles (positively charged) at a gold foil.
2. He measured the deflection as the particles came out the other side.
3. Most of the particles did not deflect at all. Every now and then a particle would deflect all the way back.
4. He said that there must be a positive centre of the foil. He called this centre the nucleus.



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اسّيش عمل fired α particles (+vely charged) at Gold foil.

التوقع على حسب نظرية بودنغ البرقوق

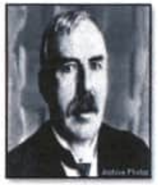
α particles will pass with minimal deflection.
(+ve charge will spread out in pudding)

المفاجأة
most α particles pass, but significant no. deflected at larger angles, some bounced back completely!

History of atom Cont.

Timeline: 1910's
Scientist: Ernest Rutherford

مكرر



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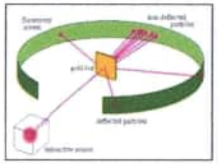

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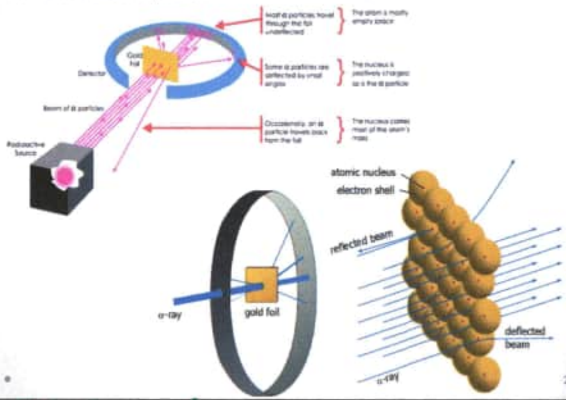
History of atom Cont.

Rutherford's Gold Foil Experiment



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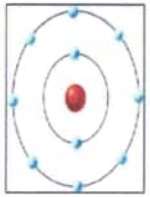
المشاهدة	التفسير
Most α travel trough foil undeflexed	The atom is mostly empty space.
some defected by small angles	nucleus is +vely charged as α particle
occasionally, α bounce back	nucleus carries most of atoms mass

وتابع إرنست

History of atom Cont.

RUTHERFORD'S ATOMIC MODEL (AKA THE PLANETARY MODEL)



1. The nucleus of the atom is a dense mass of positively charged particles.
2. The electrons orbit the nucleus

شكل المجموعة الشمسية

Rutherford stated that the atom was like a mini solar system and that the electrons orbited the nucleus in a wide orbit. That is why it is known as the planetary model.

نموذج كوكبي

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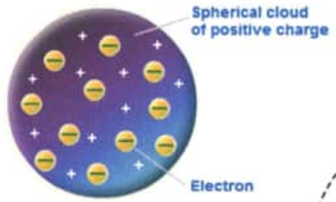
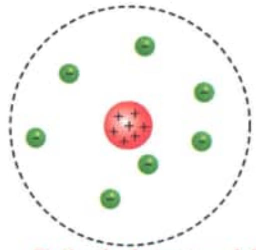
History of atom Cont.



Thomson's Plum pudding model



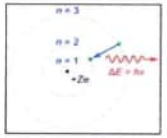
Rutherford atom model

بوهر

History of atom Cont.

Timeline: 1910's
Scientist: Niels Bohr

Niels Bohr agreed with the planetary model of the atom, but also knew that it had a few flows. Using his knowledge of energy and quantum physics he was able to perfect Rutherford's model. He was able to answer why the electrons did not collapse into the nucleus.

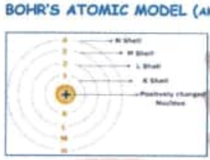


-agreed with planetary model of Ernest.

- عرفته بالطاقة وعلم الكم استطاع أن يكمل نظرية ارنست

He was able to answer why e- didn't collapse into nucleus.

BOHR'S ATOMIC MODEL (AKA THE RUTHERFORD-BOHR MODEL)



1. Electrons orbit the nucleus in orbits that have a set size and energy.
2. The lower the energy of the electron, the lower the orbit.
3. This means that as electrons fill up the orbitals, they will fill the lower energy level first.
4. If that energy level is fill (or at capacity), a new energy level will begin.
5. Radiation is when an electron moves from one level to another.

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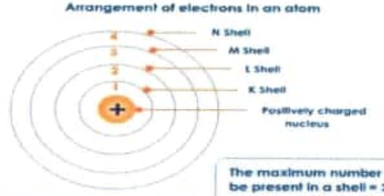
ستمتلئ المستويات الأقل طاقة في الأولى طبقة.

الاشعاع يكون عندما يتحرك الـe من مستوى لآخر.

Electron shells and the Bohr model

Arrangement of electrons in an atom



1st Shell	$2n^2 = 2 \times 1^2 = 2 \times 1 = 2$
2nd Shell	$2n^2 = 2 \times 2^2 = 2 \times 4 = 8$
3rd Shell	$2n^2 = 2 \times 3^2 = 2 \times 9 = 18$
4th Shell	$2n^2 = 2 \times 4^2 = 2 \times 16 = 32$

The maximum number of electrons that can be present in a shell = $2n^2$
n = the number of the shell

Shell label	K	L	M	N
Shell Number	1	2	3	4
Electrons	2	8	18	32

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المدار الأول 2
الثاني // $2\,2^2 = 8$
الثالث // $2\,3^2 = 18$
الرابع // $2\,4^2 = 32$

Electron shells and the Bohr model Cont.

- In atomic physics, an electron shell, or a principal energy level, may be thought of as an orbit followed by electrons around an atom's nucleus.
- The closest shell to the nucleus is called the "1 shell" (also called "K shell"), followed by the "2 shell" (or "L shell"), then the "3 shell" (or "M shell"), and so on farther and farther from the nucleus.
- The shells correspond with the principle quantum numbers (n = 1, 2, 3, 4 ...) or are labeled alphabetically with letters used in the X-ray notation (K, L, M, …).

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Electron shells and the Bohr model Cont.

- Each shell can contain only a fixed number of electrons, the first shell can hold up to two electrons, the second shell can hold up to eight (2 + 6) electrons, the third shell can hold up to 18 (2 + 6 + 10) and so on.
- The general formula is that the n^{th} shell can in principle hold up to $2(n^2)$ electrons.
- the electron shells of an atom are populated from the inside out, with electrons filling up the low-energy shells closer to the nucleus before they move into the higher-energy shells further out.

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Electron shells and the Bohr model Cont.

- Since electrons are electrically attracted to the nucleus, an atom's electrons will generally occupy outer shells only if the more inner shells have already been completely filled by other electrons.
- The electrons in the outermost occupied shell (or shells) determine the chemical properties of the atom; it is called the *valence shell* and the electrons found in it are called valence electrons.
- In general, atoms are most stable, least reactive, when their outermost electron shell is full.

\#

\#

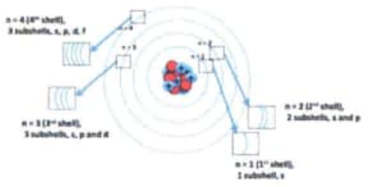
full لو المدار الخارجي

الذرة بتكون

stable

Electron shells and the Bohr model Cont.

- Each shell consists of one or more subshells, and each subshell consists of one or more atomic orbitals.



Shells and Subshells

Except for K shell, all shells contain sub shells.

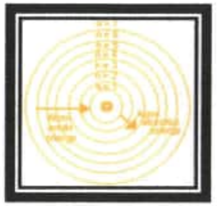
→ جدول التحضيري

Electron shells and the Bohr model Cont.

Shell	Subshell	Max electrons in subshell	Max electrons in shell
K	1s	2	2
L	2s	2	2 + 6 = 8
	2p	6	
M	3s	2	2 + 6 + 10 = 18
	3p	6	
	3d	10	
N	4s	2	2 + 6 + 10 + 14 = 32
	4p	6	
	4d	10	
	4f	14	

Electron shells and the Bohr model Cont.

- *In order to move between shells*, an electron must absorb or release an amount of energy corresponding exactly to the difference in energy between the shells.
- For instance, if an electron *absorbs* energy from a photon, it may become *excited* and move to a *higher-energy* shell.
- Conversely, when an excited electron *drops back down* to a lower-energy shell, it will *release* energy, often in the form of heat. ($h\nu = E_i - E_f$)

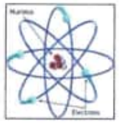


if e → absorb energy → excited → go to higher E

→ drop back down to lower shell → release energy $h\nu = E_i - E_f$

Summary of Atom

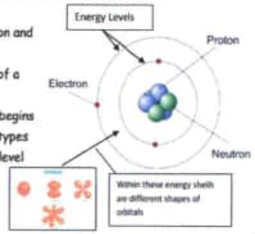
SUMMARY OF ATOM



- The smallest part of an element is called an atom
- Each atom (of an element) is different in structure from other atoms (of other elements)
- An atom can be divided in smaller subatomic particles: Protons, Electrons and Neutrons

كلام مكرر

- The nucleus is the centre of an atom. It contains protons and neutrons.
- Electrons orbit the nucleus
- As we go up the periodic table, an electron and proton is added.
- Electrons occupy a certain energy level (of a certain size)
- Once the energy level is full, a new level begins
- Within each of these levels are specials types of orbitals. These depend on the energy level
- Each orbital can contain two electrons



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Atomic Mass and Energy

- Atomic masses may be given either in grams or in relative numbers called **(atomic mass unit)**
- The atomic mass unit (u or amu) is one unit for measuring the atomic mass of particles. It is defined as **one-twelfth (1/12) of the mass of an unbonded Carbon-12.**

تعريف amu

- 1 amu= 1.66×10^{-24} gm
- The mass of neutral atom in amu is calculated as:

Mass= 12 × (actual mass of the atom\actual mass of ^{12}C atom)

- **Example: What is the mass of proton and neutron in mass unit?**

Proton mass in amu= 1.672649×10^{-24} gm (1\$1.66\times 10^{-24}$ gm)= 1.008 amu

Neutron mass in amu= 1.674954×10^{-24} gm (1\$1.66\times 10^{-24}$ gm)= 1.008 amu

Electron mass in amu= 9.1091×10^{-28} gm (1\$1.66\times 10^{-24}$ gm)= 0.00055 amu

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Atomic Mass and Energy Cont.

- The mass energy conversion is given by the Einstein equation:

$E= mc^2$

Where m= the mass in Kg, c= is the speed of light (3×10^8 m\s)

حساب الطاقة المنطلقة من المادة

- **Example: if one gram of a material is converted into energy, how much is the energy released?**

$E= mc^2$

$= (1\times 10^{3}\ \text{kg})(3\times 10^{8}\ \text{m\s})^2$

$= 9\times 10^{13}$ Joule

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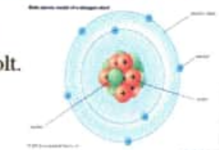
Electron Binding Energy

3 تعريفات متطابقة (الطاقة الارتباط)

- **The binding energy** is the strength of attachment of an electron to the nucleus (attraction between the negatively charged electrons and the positively charged protons in the nucleus) **or** the energy required to overcome the attachment and remove an orbital electron from an atom.
- Usually designated E_b
- Electron binding energy is typically measured **in electron volts (eV)**
- **Electron volt** is a unit of energy commonly used in atomic and nuclear physics, equal to the energy gained by an electron when the electrical potential at the electron increases by one volt.



eV = الطاقة التي يحصل عليها الـ e عندما تزيد الجهد الكهربائي بمقدار 1 volt

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Electron Binding Energy Cont.

- The closer an electron is to the nucleus, the more tightly it is bound.
- The electron in the k-shell is the **most tightly bound** and therefore the binding energy is the **greatest**.
- K shell has **highest binding energy** than L shell and L more than M and so on.
- Higher atomic materials (higher Z) result in **more binding energy**.(More positive charge in nucleus).
- **Not all K-shell** electrons of all atoms are bound with the same binding energy.
- Since electrons of large atoms are more tightly bound to the nucleus than those of small atoms, it takes more energy to be ionize

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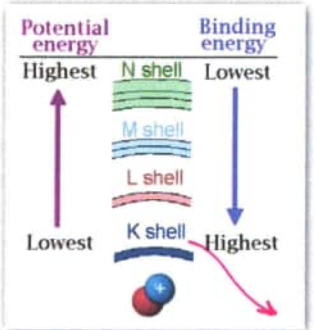
higher Z → more the charge in nucleus → more binding Energy

Electron Binding Energy Cont.



highest BE (Most lightly bound)

تختلف من ذرة لأخرى
(مستوى البني)

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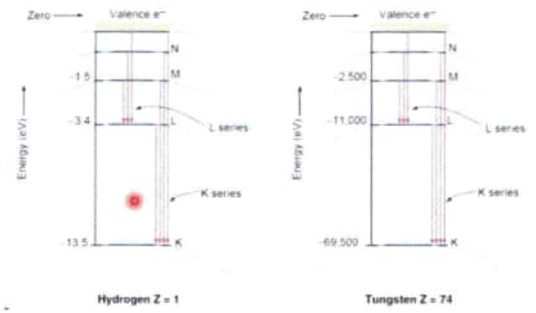
Electron Binding Energy Cont.



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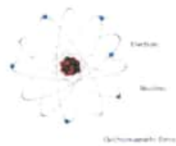
Electromagnetic force and Nuclear force

The electromagnetic force:

- binds negatively charged electrons to positively charged atomic nuclei and gives rise to the bonding between atoms to form matter in bulk.
- The electromagnetic force has an infinite range



- **The Nuclear force:**
  - bind protons and neutrons (together called nucleons) into the atomic nuclei.
  - is a short-range force and causes the stability of the nucleus.

Electromagnetic force binds atoms

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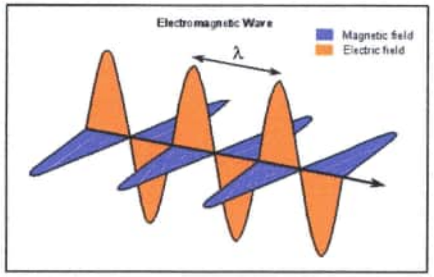
Electromagnetic Spectrum

represented as **a bundle of energy** consisting of varying **electric and magnetic fields traveling at the speed of light.**



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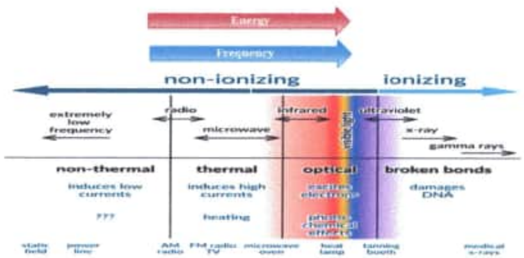
Electromagnetic Spectrum Cont.



- **The only difference among photons of these various portions of the electromagnetic spectrum is** in frequency and wavelength.

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طاقة أعلى
تردد أعلى
طول موجي أقل

Electromagnetic Spectrum Cont.

Examples of Electromagnetic Radiation

- Radio Waves.
- TV waves.
- Radar waves.
- Heat (infrared radiation)
- Visible Light
- Ultraviolet Light.
- X-rays.
- Short waves.
- Microwaves, like in a microwave oven
- Gamma Rays.

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Electromagnetic Spectrum Cont.

- Electromagnetic radiation is **quantized**, meaning that it exists in discrete quantities called **photons**.
- Photons may behave as **waves or particles** but have **no mass.**
- Photon energy (E) is **directly proportional** to frequency.
- Photon energy is **inversely proportional** to wavelength.
- Photon energy is $\mathbf{E = h\ f = h\ (c/\lambda)}$, where h is Plank's constant (6.626176×10^{-34} joule-seconds.) .
- A10 keV photon has a wavelength of 0.1 nm, A 100 keV photon has a wavelength of 0.01 nm.
- **Radio waves** have **low frequencies** (low photon energies) and **gamma waves** have **high frequencies** (high photon energies).
- High energy photons are called **X-rays** if produced by electron interactions but **gamma rays** if produced in a nuclear process.

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$$E = hf = h\frac{c}{\lambda}$$

$\uparrow E \rightarrow \uparrow f$

$\uparrow E$ is x ray if produced by e^- interactions.
is γ rays = = = nuclear process.

PLANK'S QUANTUM EQUATION

•Mathematically , the relationship between energy and frequency is expressed as:

Where;

E is the photon energy,

h is Plank's constant (6.63×10^{-34} Js).

Or (4.15X10-15 eV-s)

and f is the photon frequency in hertz

energy of the light

frequency of the light

$E = h\nu$

Planck's constant

E= hc\ λ

مكرر

▶ In other words, photon energy is inversely proportional to photon wavelength, the longer the wavelength of radiation, the lower the energy of each photon.

PLANK'S QUANTUM EQUATION Cont.

Example: What is the frequency of a 70 keV x-ray photon?

$E = h\nu$

$= \left(\frac{70000 \text{ eV}}{4.15\text{X}10\text{-}15 \text{ eV-s}}\right)$

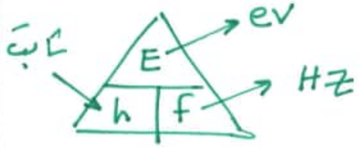
$= 1.69\text{X}10^{19}$ Hz

$f = ?$

$E = 70$ kev

$E = hf$

$f = \frac{E}{h} = \frac{70000}{4.15 * 10^{-15}} = 1.69 * 10^{19}$ Hz



PLANK'S QUANTUM EQUATION Cont.

• **EXAMPLE:** What is the energy contained in one photon of radiation from radio Station WIMP, which has a broadcast frequency of 960 kHz?

• **answer:** $E = hf$

$= (4.15 \times 10^{-15}$ eV.S)$.(9.6 \times 10^{5}/\text{s})$

$= 3.98 \times 10^{-9}$ eV

$E = hf = 4.15 * 10^{-15} * 960 * 10^{3}$

PLANK'S QUANTUM EQUATION Cont.

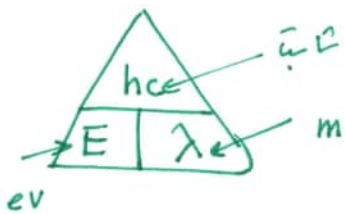
• **EXAMPLE:** What is the energy in (ev) one photon of green light whose wavelength is 550 nm?

• **Answhr:** E= hc/λ

$E = h\frac{c}{\lambda}$

• $= \frac{(4.15 \times 10^{-15} \text{ eV-s})(3 \text{ X } 10^{8} \text{ m/s})}{550 \times 10^{-9} \text{ m}}$

$= 2.26$ eV



Radiation

Radiation is the emission or transmission of energy in the form of electromagnetic waves or charged particles through space or through a material medium.

Types of Radiation (by effect)

Ionizing Radiation

- A radiation that has sufficient energy to remove electrons from atoms or molecules as it passes through matter.
- Examples. Gamma-rays, x-rays, UV radiation, Beta-radiation, Alpha radiation, Proton, neutron and other particles.

Non-ionizing Radiation

- A radiation that is not as energetic as ionizing radiation and cannot remove electrons from atoms or molecules.
- Examples. light, lasers, heat, microwaves and radar.

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MW
radar
laser

directly — indirectly

مشحونة
- e⁻, Proton | α, X, UV, neutrons
- α
- B

Radiation Cont.

تعريف 1
- **Ionization**, is the process by which an atom or a molecule acquires a negative or positive charge by gaining or losing electrons to form ions, often in conjunction with other chemical changes.

تعريف 2
OR is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become charged or ionized.

تعريف 3
OR is radiation that carries enough energy to liberate electrons from atoms or molecules, thereby ionizing them.

- Ionization can result from the loss of an electron after collisions with subatomic particles, collisions with other atoms, molecules and ions, or through the interaction with electromagnetic radiation.

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أسباب التأين - loss of e⁻ after collision with — subatomic particles; atoms, molecules, ions

- = = = interaction with EMR

Radiation Cont.

Types of Ionizing Radiations

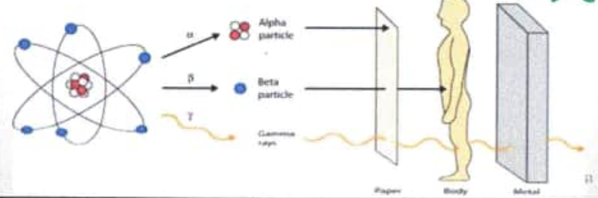
Directly

- When absorbed in material, they directly cause ionization leading to damage. eg., Electrons, α-particles, β-particles (Charged particles).

Indirectly

- When absorbed in material, they give up their energy to produce fast moving charged particles which produce the damage. eg., Electromagnetic radiation, neutrons.

↳ γ, X



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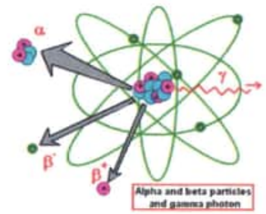
Radioactivity



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