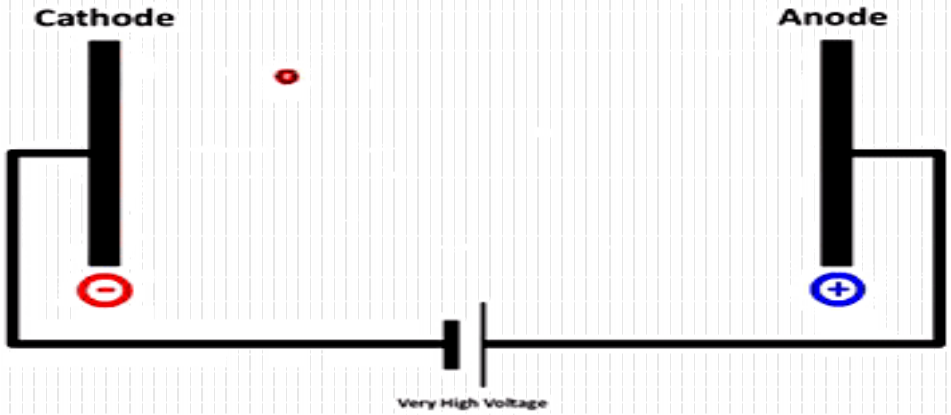
Session 2

X- Ray Production

Medical Imaging Physics



By

Dr. Ahmad Mokhtar Abodahab

WHAT IS OCCUR IN EACH X RAY FILM ?

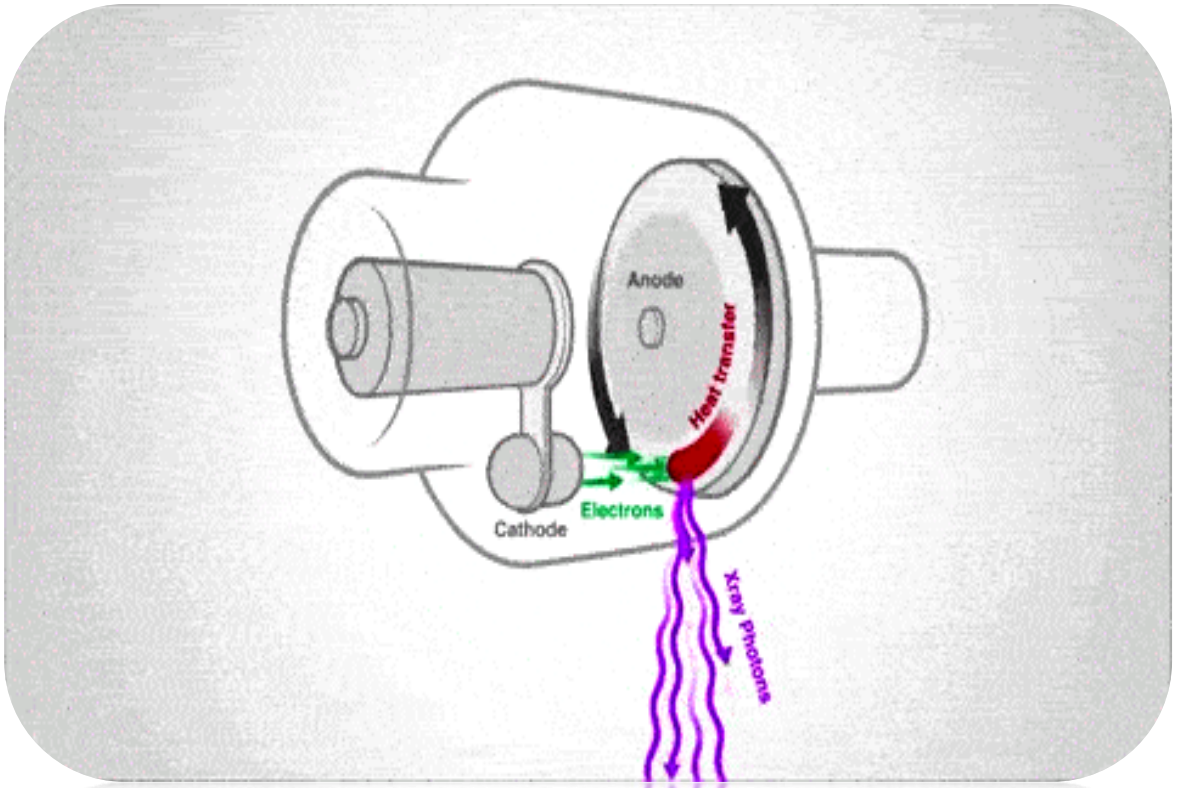

Adjust
Position & Collimation

Adjust
kV – mA - & Time mAs

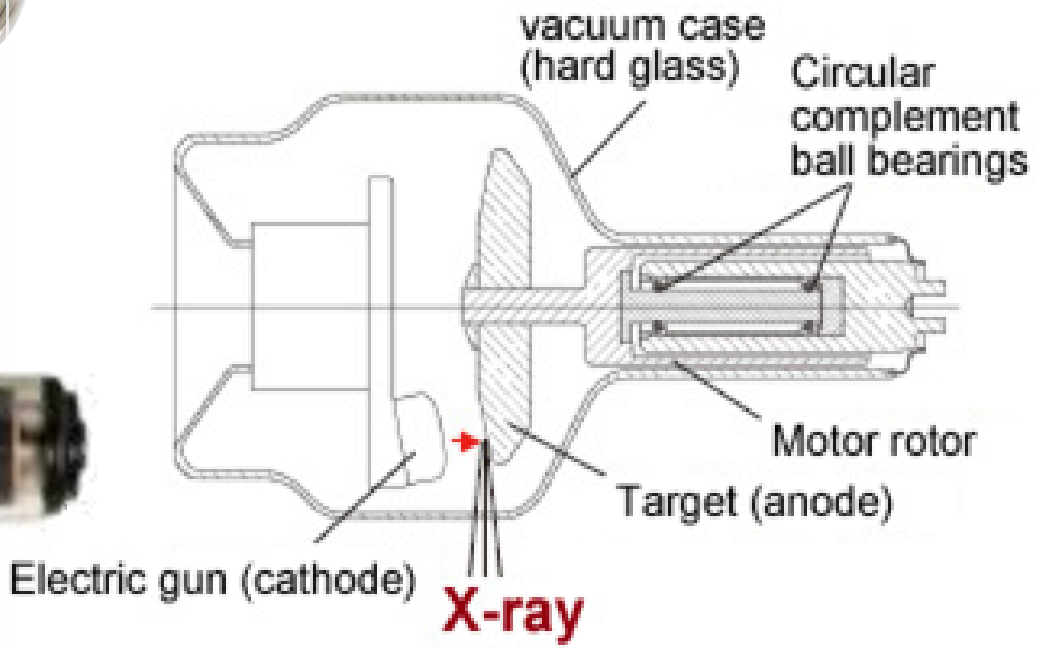
& ….On

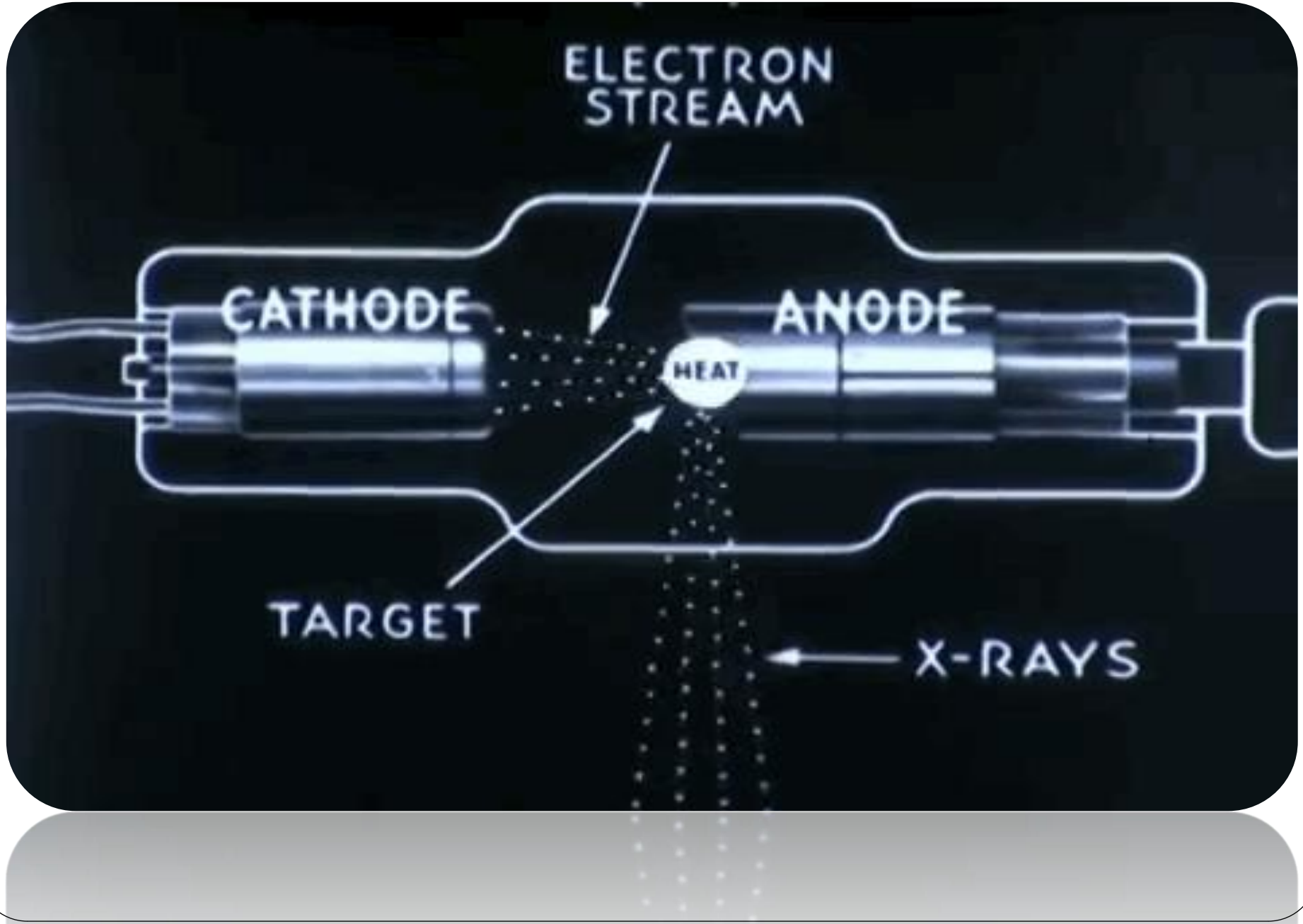
(of 2 Clicks !!)


WeissOrtho.com



X RAY PRODUCTION


vacuum case
(hard glass)
Circular
complement
ball bearings
Motor rotor
Target (anode)
Electric gun (cathode)
X-ray


ELECTRON
STREAM
CATHODE
ANODE
HEAT
TARGET
X-RAYS

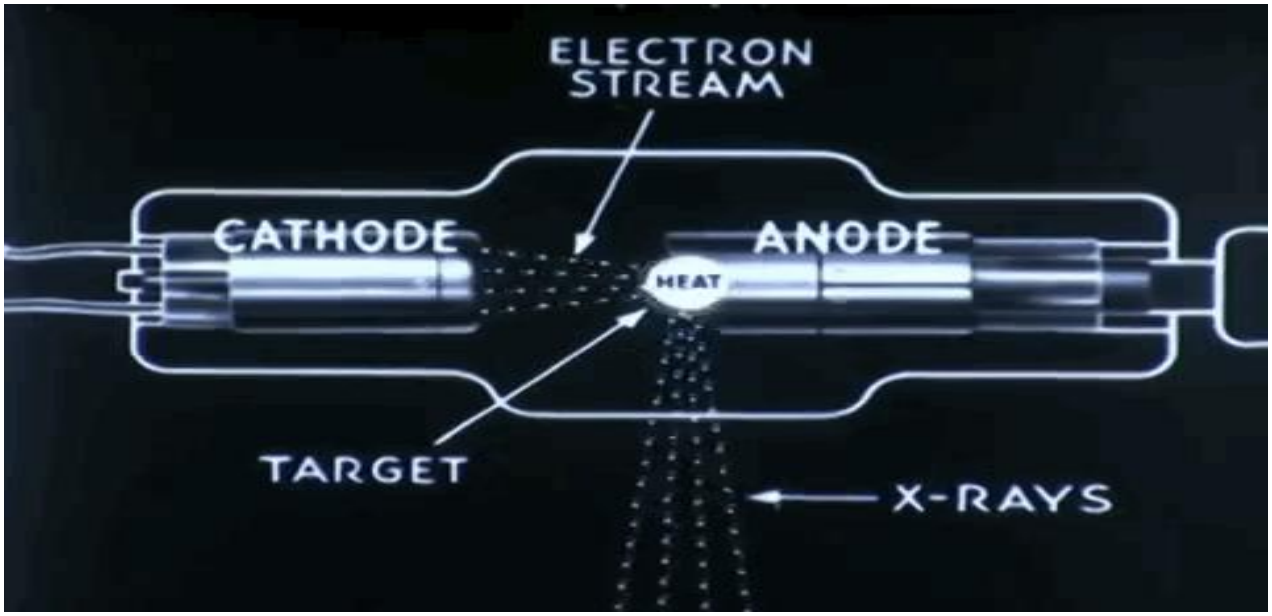
X-RAY TUBE

- X-rays are produced when :

fast-moving electrons are → suddenly stopped by impact on a metal target.

- **kinetic energy** of the electrons is → converted into **X-rays**

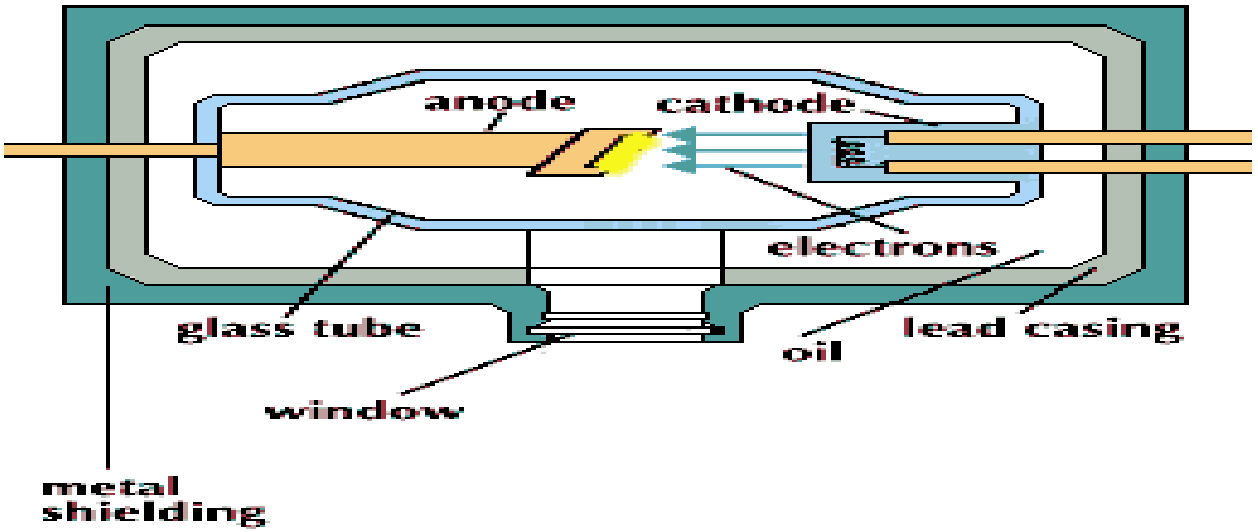
(no more than **1%)** and into **heat (99%).**

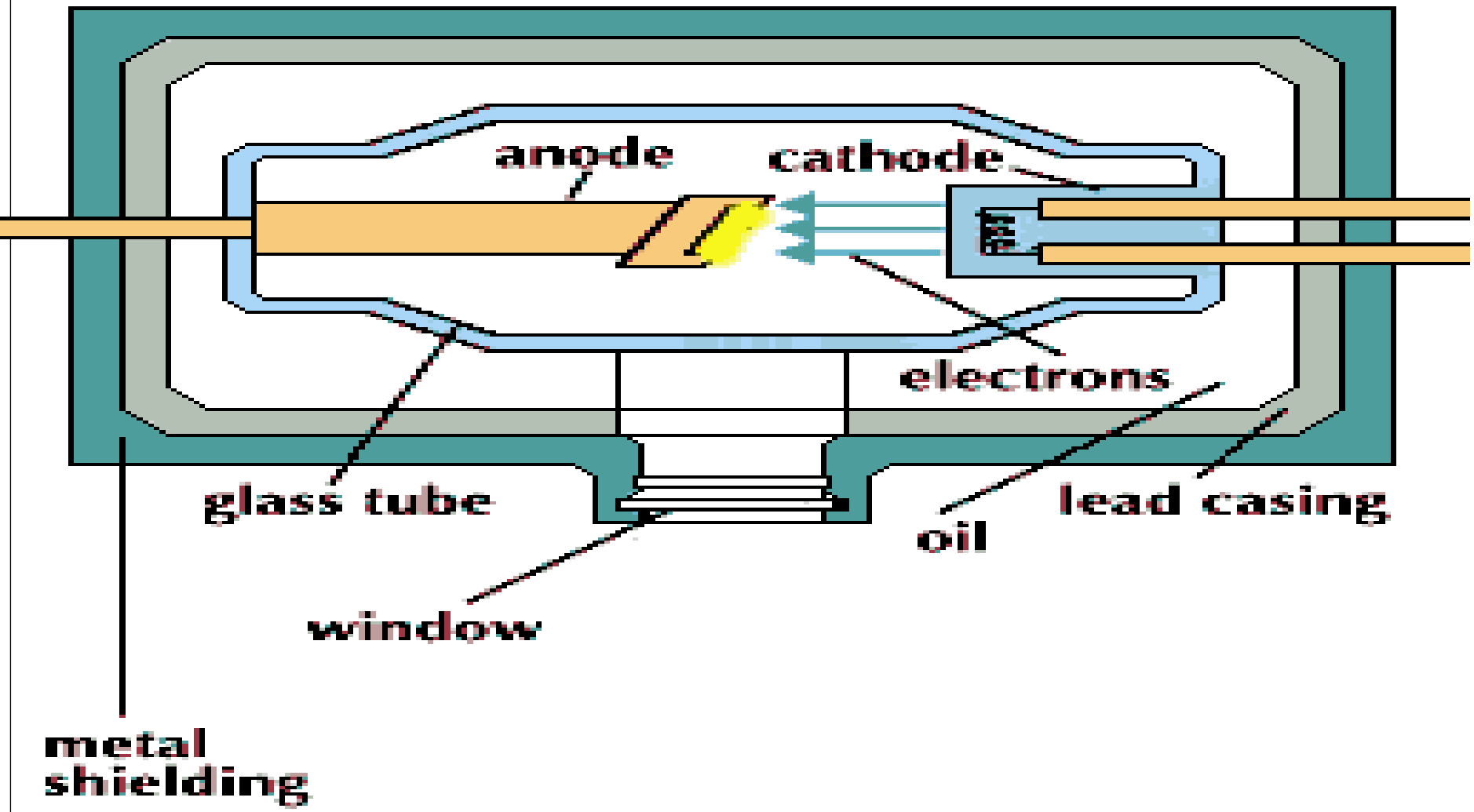


- **X-ray tube** consists of :
  - Evacuated glass envelope
  - two electrodes sealed into an :
    - (**cathode**) negative electrode

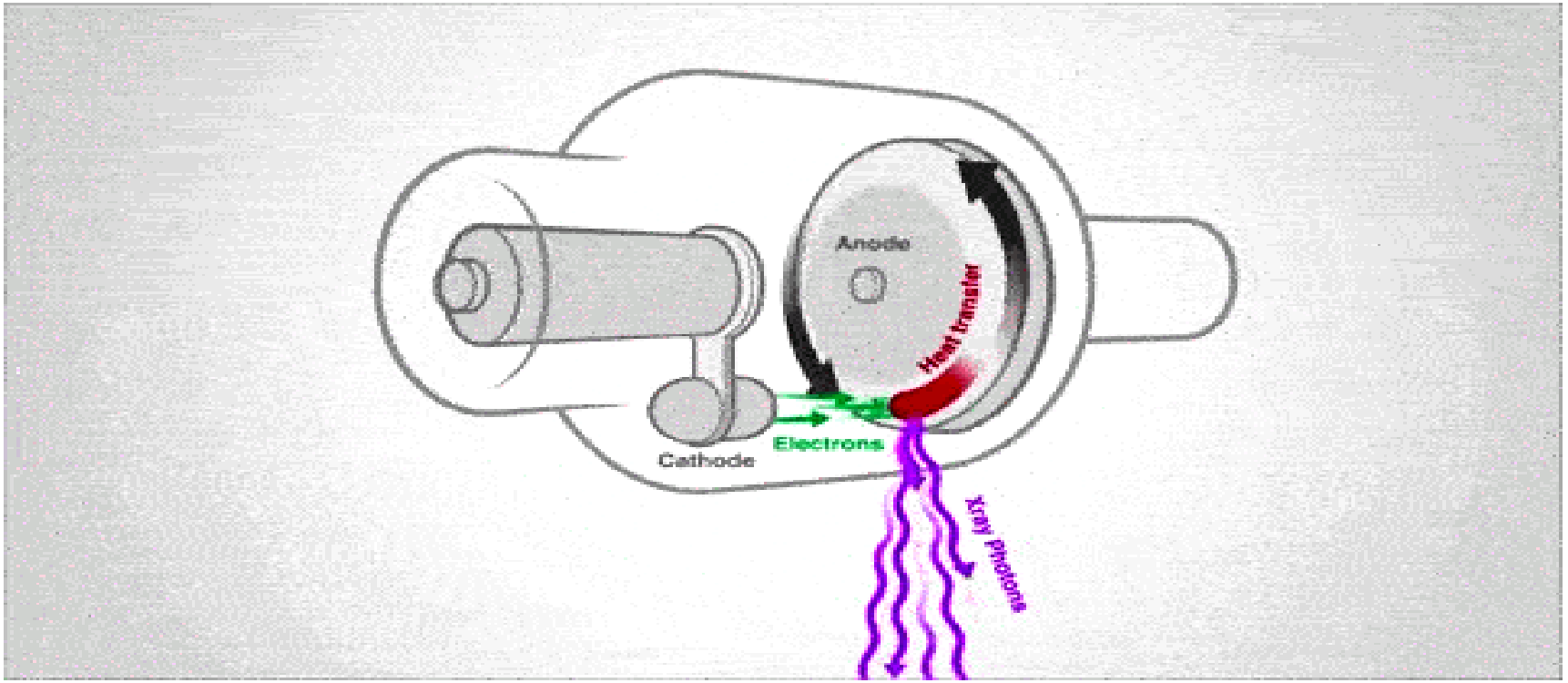
      fine **tungsten coil** or **filament**
    - **(anode)** a positive electrode

      smooth flat metal target, usually of **tungsten**.

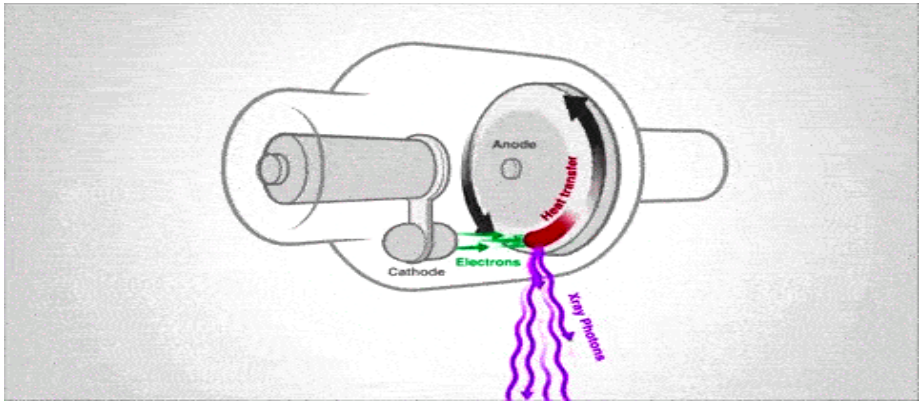



anode
cathode
electrons
glass tube
oil
lead casing
window
metal
shielding

- The filament **(Cathode / -Ve)** is **heated** by → passing an electrical current through it to a temperature at which it is white hot → emits **electrons** by the process of **(thermionic emission)**.



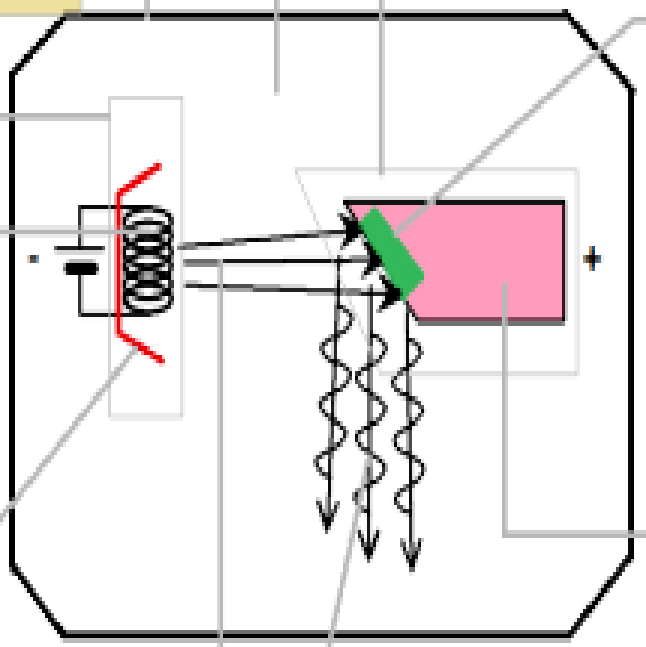
- At such high temperatures (~2200°C), → fraction of the free electrons → leave the surface despite the net attractive pull of the lattice of positive ions.
- The electrons are then repelled by the **negative**
- **cathode** → attracted by the **positive anode**.
- **vacuum**, → Electrons not hindered in any way and → bombard the target with a velocity around **<u>half the speed of light</u>**.



Cathode Filament is strongly Heated …..

Electrons hit the rotating +ve Anode

شرح توضيحي عن كيفية إنتاج الأشعة



الأنود أو المصعد

هذا هو الجزء الذي ينتج الأشعة السينية
ويتكون من جزأين رئيسيين هما

1. التنجستن Tungsten

وظيفة التنجستن هو تحويل الإلكترونات القادمة بسرعة عالية جداً من الكاثود إلى أشعة سينية. ولكن كيف يتم ذلك؟ الإلكترونات القادمة من الكاثود تتوجه نحو التنجستن بسرعة عالية وهذه طاقة حركية Kinetic Energy

عندما تصطدم الإلكترونات بالتنجستن يحدث توقف مفاجئ للإلكترونات وتتحول الطاقة الحركية إلى نوعين أخرين من الطاقة هما أشعة سينية وطاقة حرارية

2. القاعدة النحاسية Copper Base

لديها القدرة على إمتصاص الطاقة الحرارية من التنجستن

%98 من الطاقة الحركية تتحول إلى طاقة حرارية وحوالي 2% فقط هي أشعة سينية.

وهذا تطبيق لقانون حفظ الطاقة الذي درسناه في الثانوية: "الطاقة لاتفنى ولاتستحدث من العدم ولكن تتحول من شكل إلى آخر

أنبوب زجاجي مفرغ من الهواء
Vaccum Glass

فراغ Vaccum

توجد بداخله جميع أجزاء أنبوبة الأشعة الداخلية الأخرى ويمنع من وجود أي هواء داخل أنبوبة الأشعة فهذا سيؤثر على إنتاج الأشعة السينية

الكاثود أو المهبط

وظيفته هو إنتاج الإلكترونات التي سيتحول جزء منها لاحقاً إلى أشعة سينية. الكاثود هو سالب الشحنة.

يتكون الكاثود من جزئين رئيسيين

1. الفتيلة Filament

عندما يتعرض الكاثود إلى فرق جهد تسخن الفتيلة وتولد الإلكترونات وتنطلق بسرعة عالية نحو الأنود. وفرق الجهد هو الطاقة الازمة لجعل الإلكترونات تتحرك من القطب السالب إلى القطب الموجب. عادة يكون فرق الجهد في الأشعة التشخيصية مابين 20 إلى 150 كيلوفولت وكلما زاد فرق الجهد زادت كمية الإلكترونات المنبعثة من الفتيلة.

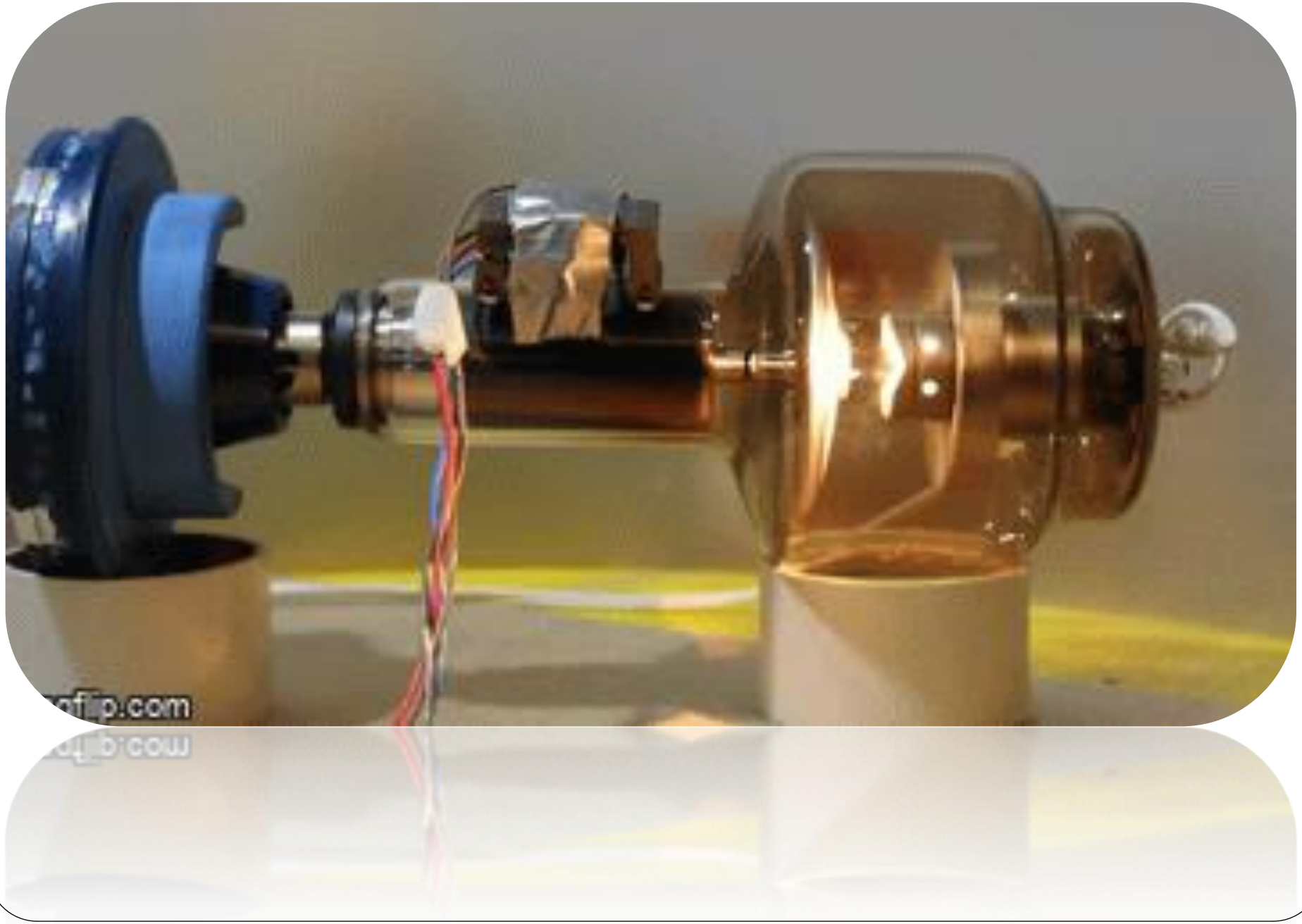
2. الموجه Focusing Cup

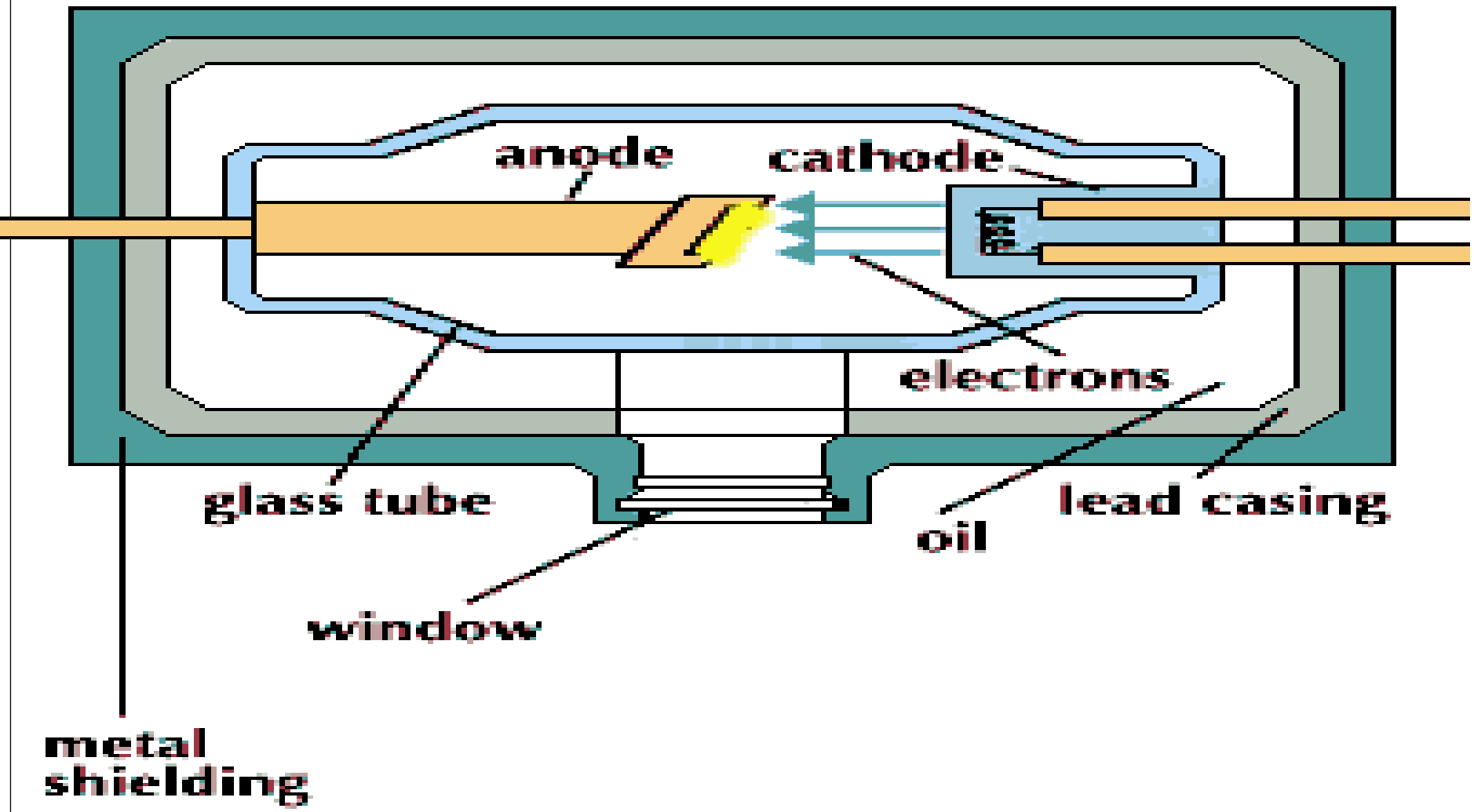
وذوره فقط توجيه الإلكترونات نحو الأنود

إلكترونات منبعثه من الكاثود ومتجهه نحو الأنود بسرعة عالية جداً

أشعة سينية

RADCLASS.NET




anode
cathode
electrons
glass tube
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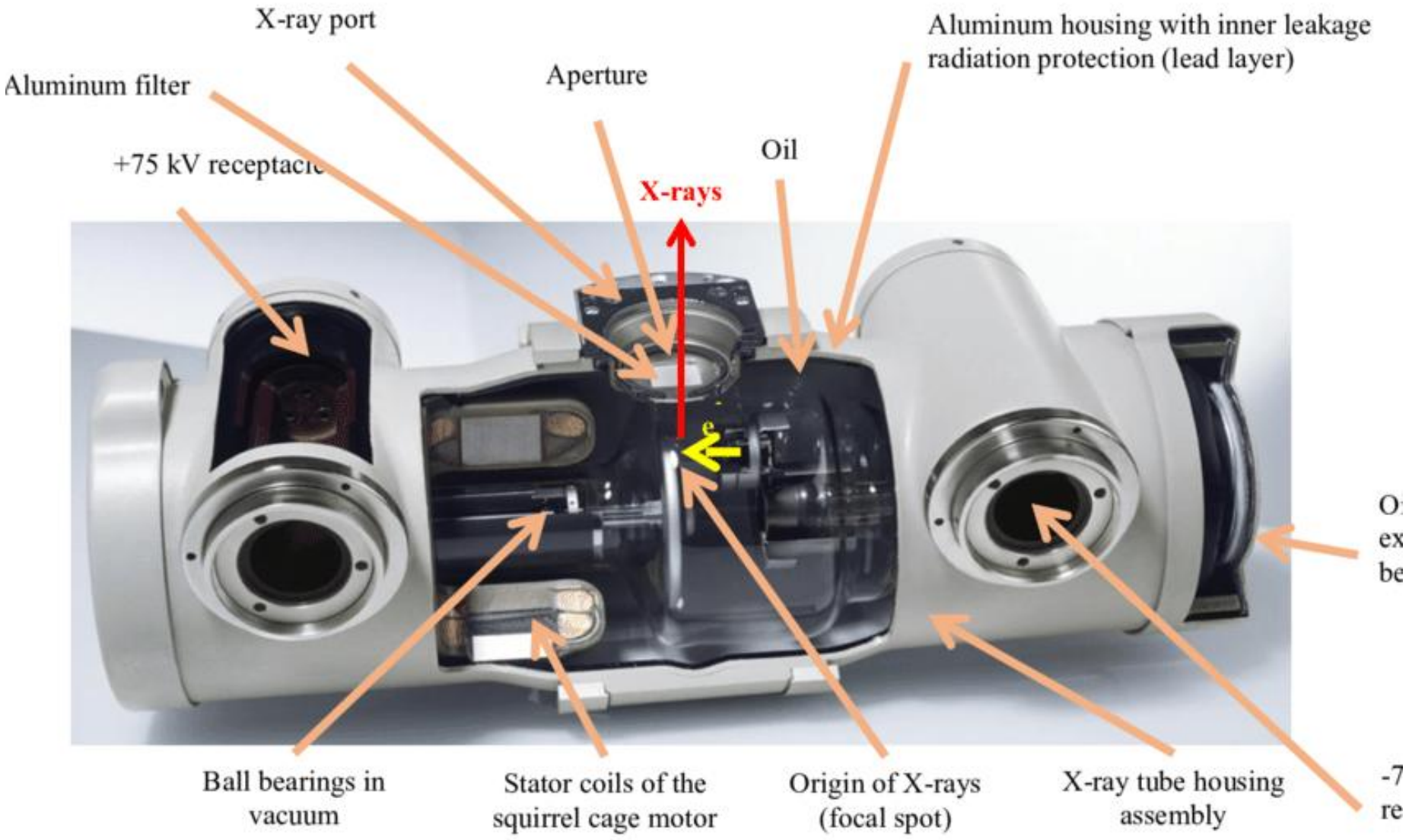

X-ray port
Aluminum filter
Aperture
Aluminum housing with inner leakage radiation protection (lead layer)
+75 kV receptacle
Oil
X-rays
Ball bearings in vacuum
Stator coils of the squirrel cage motor
Origin of X-rays (focal spot)
X-ray tube housing assembly

Structure & Why ?

Why vacuum ?	No O2 , avoid more heat & oxidation of cathode
Why Pyrex glass envelop ?	To resist over heat
Why lead envelop ?	to avoid X ray scattering in all direction
Why Oil around ?	For good cooling
Why Steel envelop ?	For good protection
Why Aluminum filter ?	For Filtering of low energy rays

X ray Properties :

- ✓Electromagnetic waves
- ✓Non visible , Non charged
- ✓ Light velocity
- ✓ pass straight
- ✓ Highly penetrating
- ✓ Blacking radiographic film

خواص الأشعة السينية:

- هي موجات كهرومغناطيسية تتكون من فوتونات photons.
- لها نفس سرعة الضوء.
- تسير في إتجاه مستقيم.
- لايمكن رؤيتها.
- لديها القدرة على إختراق الأشياء highly penetrating.
- تحول لون فلم الأشعة عند ملامستها له إلى اللون الأسود.

KV AND MA

For X ray production , :

- Two sources of electrical energy are required from the alternating current (AC) :

- **Filament heating voltage** (about **10 V**) and current (about **10 A**)

- **Accelerating voltage** (typically **30–150** kV)

✓ **Tube potential**, high voltage, kilovoltage or kV);

this drives the current of electrons &

✓ **Tube current**, (typically **0.5–1000** mA) flowing between the anode and cathode


sri
source-ray, inc.
SR-130
KVP
80
MAS
120.0
TIME
4.00
mA
High Frequency
Made in the USA

kV is controlling **X ray penetration**

mA is controlling **X ray amount**

عوامل التعرض Exposure Factors:

هي العوامل التي يمكن من خلالها التحكم بالأشعة الخارجة من إنبوبة الأشعة وهي ثلاث عوامل:

1. الكيلو فولت KV: هو فرق الجهد بين الكاثود والأنود خلال إنتاج الأشعة. وهو يتحكم بطاقة الأشعة السينية فكلما زاد الكيلوفولت زادت طاقة الأشعة. وكلما زادت طاقة الأشعة السينية زادت قدرتها على إختراق الأجسام.
2. الميلي أمبير mA: كلما زاد الميلي أمبير زادت الإلكترونات المنبعثة من الكاثود إلى الأنود مما يؤدي إلى زيادة كمية الأشعة السينية.
3. مدة إنتاج الأشعة: فكلما زادت مدة إنتاج الأشعة زادت معها كمية الأشعة وهي تقاس بالثانية.

➢PROCESSES OCCURRING IN THE TARGET (ANODE)

- Electron arrives surface of anode with a kinetic energy (expressed in units of **kiloelectronvolts**, keV) equivalent to the **kV**
- The electrons **penetrate** several micrometres into the target → lose their energy by a combination of processes:

- 99% of electrons → **unwanted heat**
- 1% producing X-rays, by interaction with either the inner shells of the atoms

- **X ray production Interaction may be of (3 Types)**
  - interaction with K shell → **Line spectrum** characteristic X ray
  - Interaction with nucleus →**Continuous spectrum,** ***Bremsstrahlung***,
  - Electron immediately & completely stopped.

INTERACTION WITH THE K-SHELL: LINE SPECTRUM, CHARACTERISTIC RADIATION

- Cathode filament → an **electron (a)** →

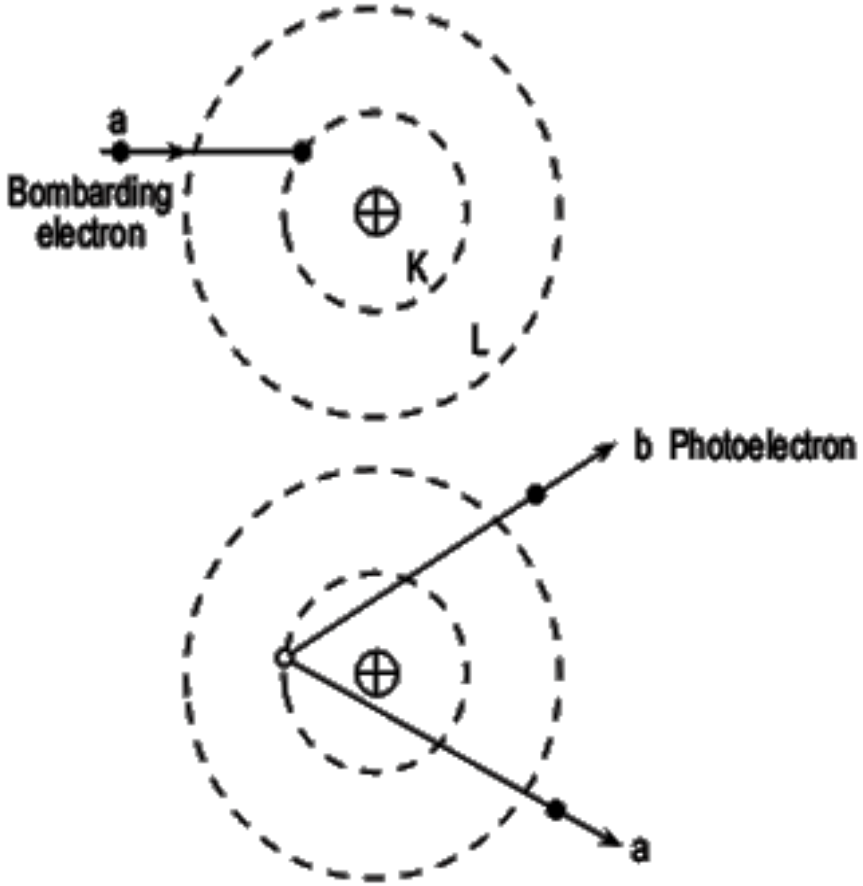
  Bombard an electron (b) in the K-shell,

→ electron **b ejected**

- As Energy of bombarding electron >

  binding energy of the shell.

→ **vacancy** or **hole** created in **K-shell** :



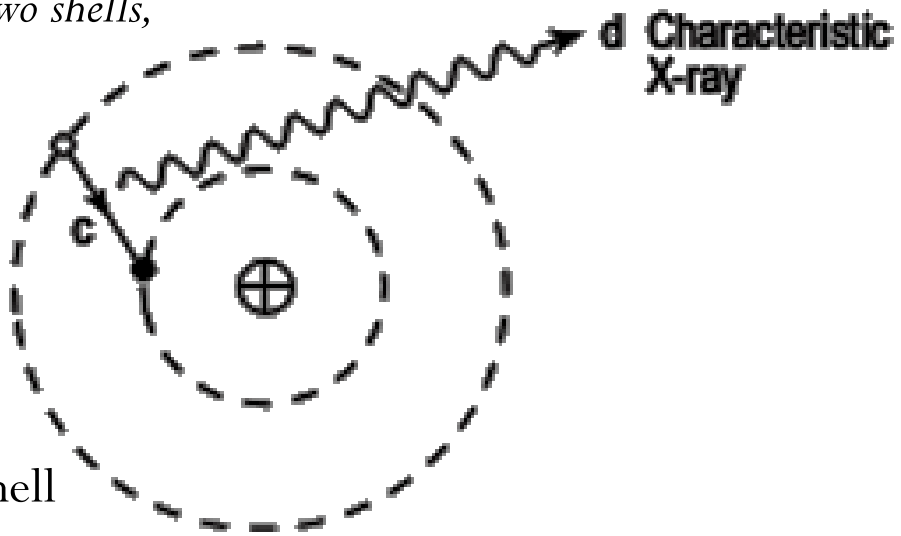
- **Most likely**

- Filled by an **electron (c)** falling down from the L-shell

- with the emission of a **single X-ray photon (d)**

of energy = *difference in binding energies of the two shells,*

EK - EL = Kα radiation.



- Alternatively, but less likely,

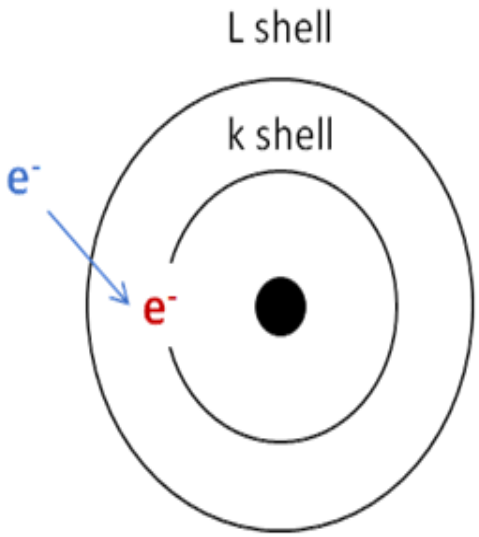
- Filled by an electron falling in from the M-shell

-with the emission of a single X-ray photon

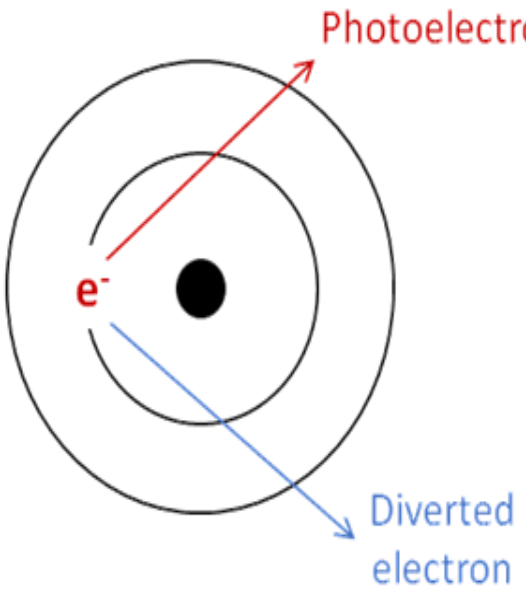
of energy,

EK - EM, = **Kβ radiation**.

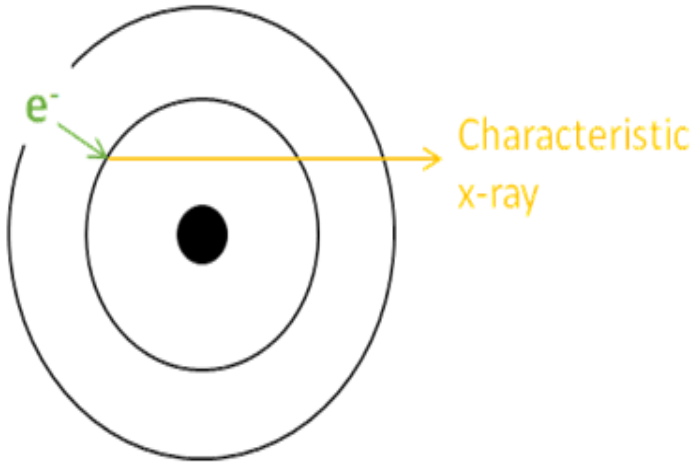
Characteristic x-ray production



1. Bombarding electron strikes k shell (or other shell) electron



2. Bombarding electron diverted. Electron that's hit ejected as a photoelectron and absorbed



3. Outer shell electron moves down to fill the ejected electron's space. The energy from this is released as a characteristic energy photon

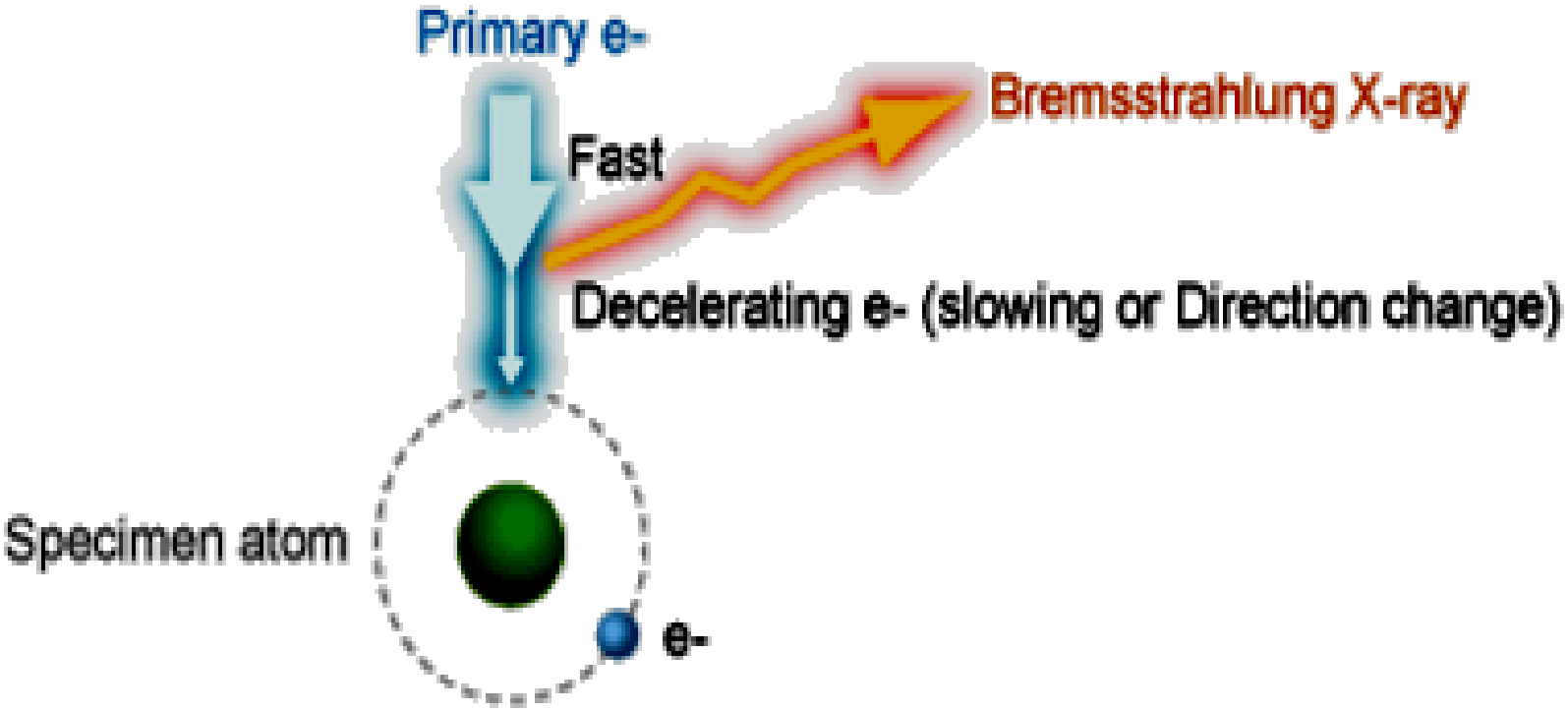
INTERACTION WITH THE NUCLEUS: BREMSSTRAHLUNG, CONTINUOUS SPECTRUM

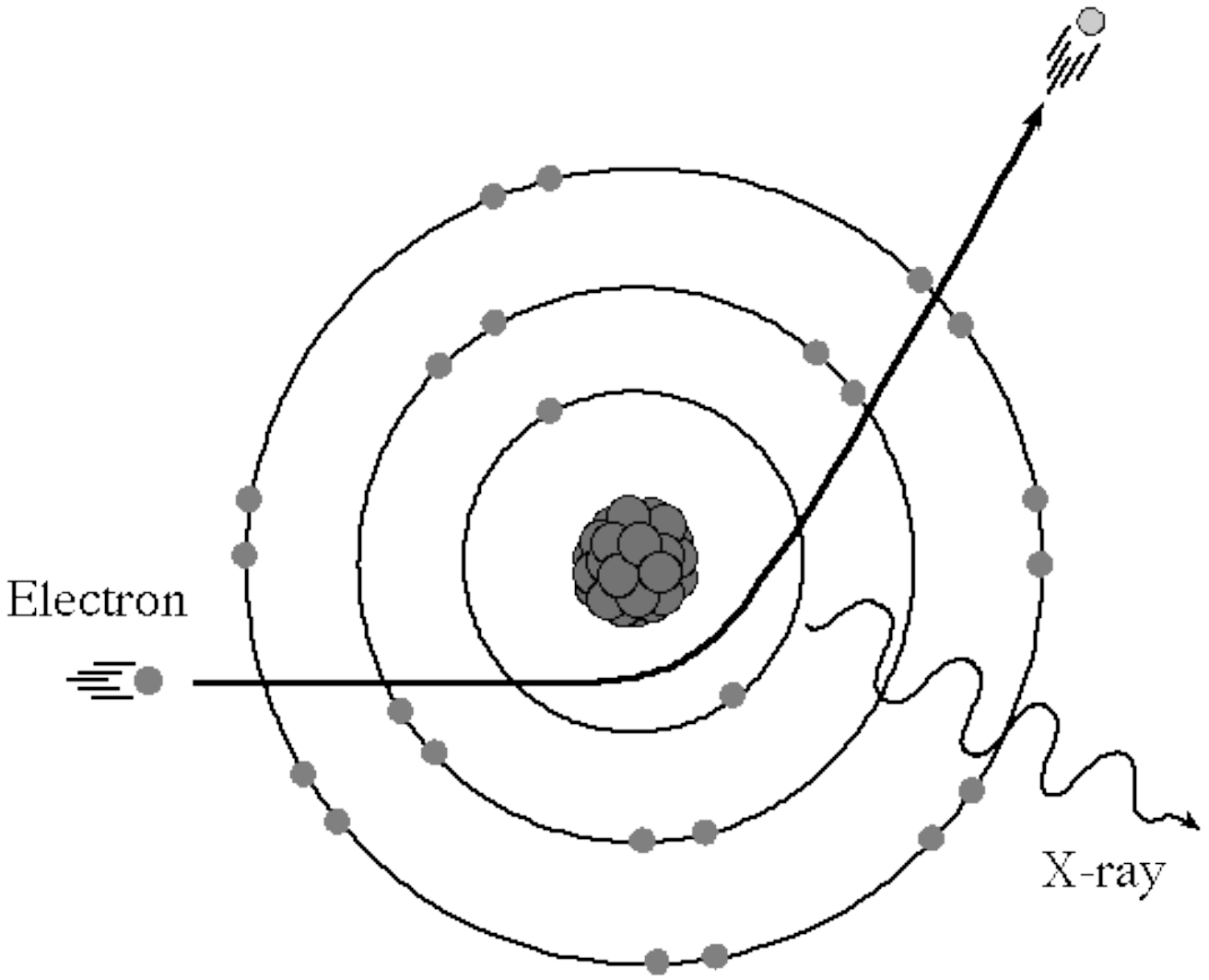
- Bombarding electron → penetrates K-shell & approaches close to the nucleus.
- It approaches fast and leaves less quickly, → losing some or all of its energy.
- **The lost energy** is carried away as a single photon of X-rays or

Bremsstrahlung (i.e., '**braking radiation**').

- **Except in mammography**,: 80% or more of the X-rays emitted by a diagnostic X-ray tube are bremsstrahlung.

Bremsstrahlung X-ray production




Electron
X-ray

- *Very rarely*,

an electron bombarding anode , **immediately and completely stopped** → produces a single photon of energy equivalent to the applied **kV**.

- This is the **largest photon energy** can be produced at this kV.

- It is more likely that **bombarding electron :**

✓ first loses some of its energy as **heat**

✓ then, when it interacts with the nucleus, it loses only part of its remaining energy, with the emission of **bremsstrahlung** of lower photon energy.

- The X-rays may be emitted in any direction (although mainly sideways to the electron beam) and with any energy up to the maximum.
- the relative number of photons having each photon energy (keV). The bremsstrahlung forms a continuous spectrum(A).
- The **maximum photon energy** (in keV) is numerically equal to the **kV**.

CONTROLLING THE X-RAY SPECTRUM

To summarize, there are **factors** that affect the X-ray spectrum.

- **Increasing the kV**
  - ✓ It increases the **maximum** and **effective energies** and the **total number of X-ray photons**.
  - ✓ Below a certain kV (70 kV for a **tungsten** target), the characteristic K-radiation is not produced.

- **Increasing the mA** does not affect the shape of the spectrum but increases the output of both bremsstrahlung and characteristic radiation proportionately.

- **Changing anode to one of lower atomic number**

→ reduces the output of **bremsstrahlung** but does not otherwise affect its spectrum, unless the filtration is also changed.

✓ The photon energy of the characteristic lines will also be less.

INTERACTION OF X- & GAMMA RAYS WITH MATTER

- **Three possible fates** of photons when a beam of X- or gamma rays travels through matter.

✓ ● **Transmitted**: pass unaffected, as **primary** or **direct radiation.**

✓ ● **Absorbed:** transferring to the matter all of their energy (photon *disappearing completely*).

✓ ● **Scattered:** diverted in a new direction,

with or with-out loss of energy transferring to the matter, and so may leave the material → as **scattered** or **secondary radiation**.

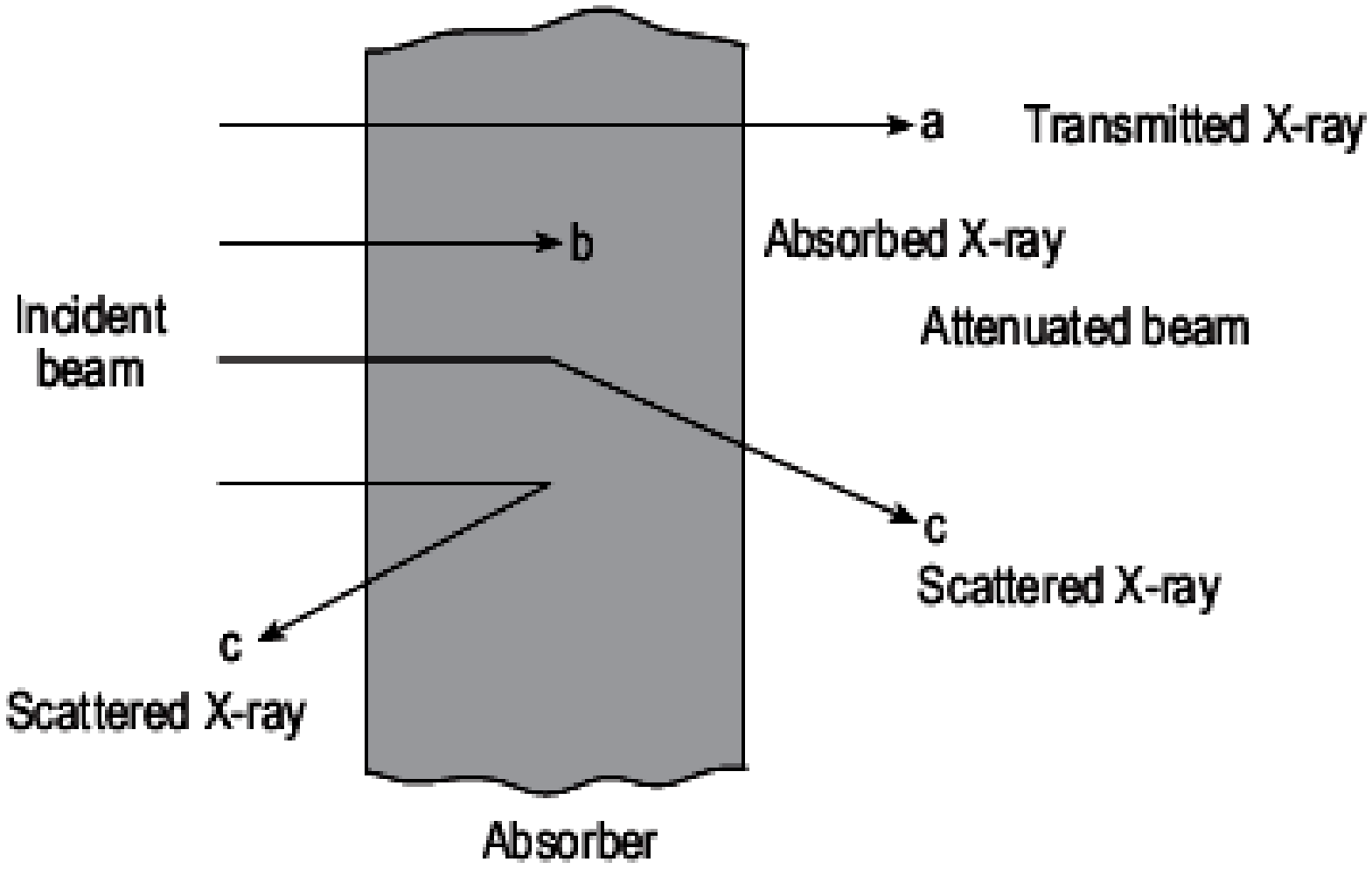
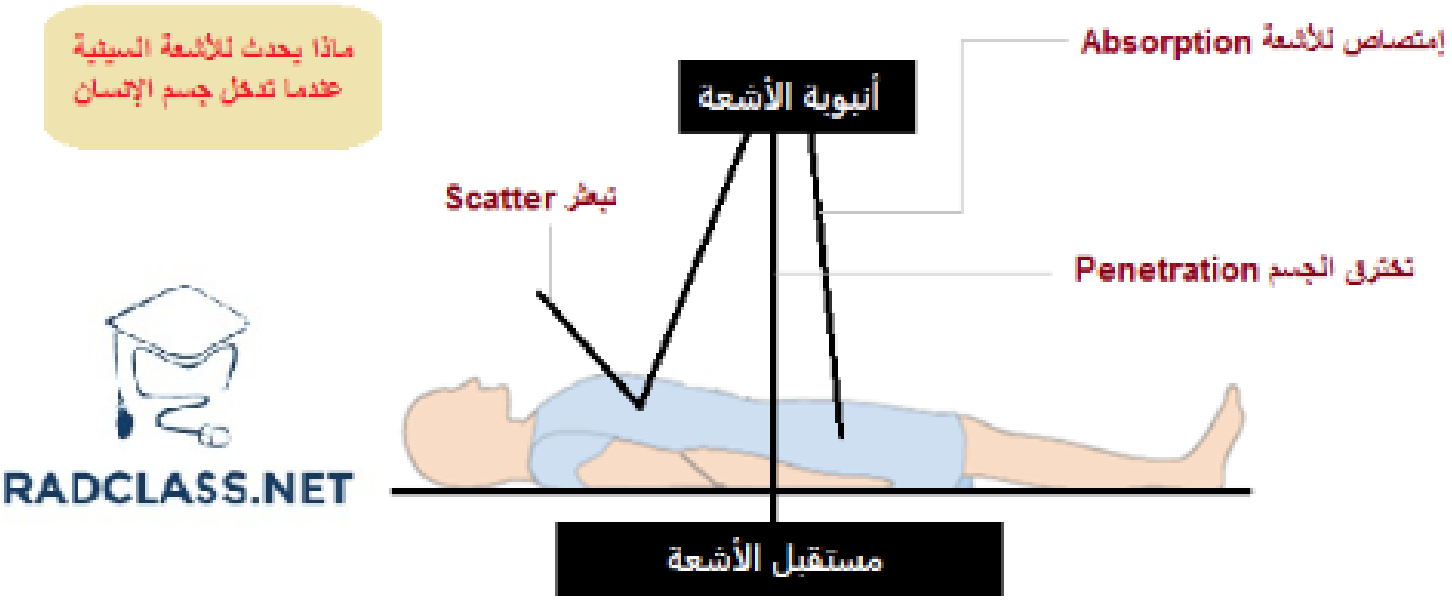


Figure 1.10 Interaction of X- or gamma rays with matter.



يعتمد تفاعل الأشعة السينية مع جسم الإنسان على عدة عوامل منها:

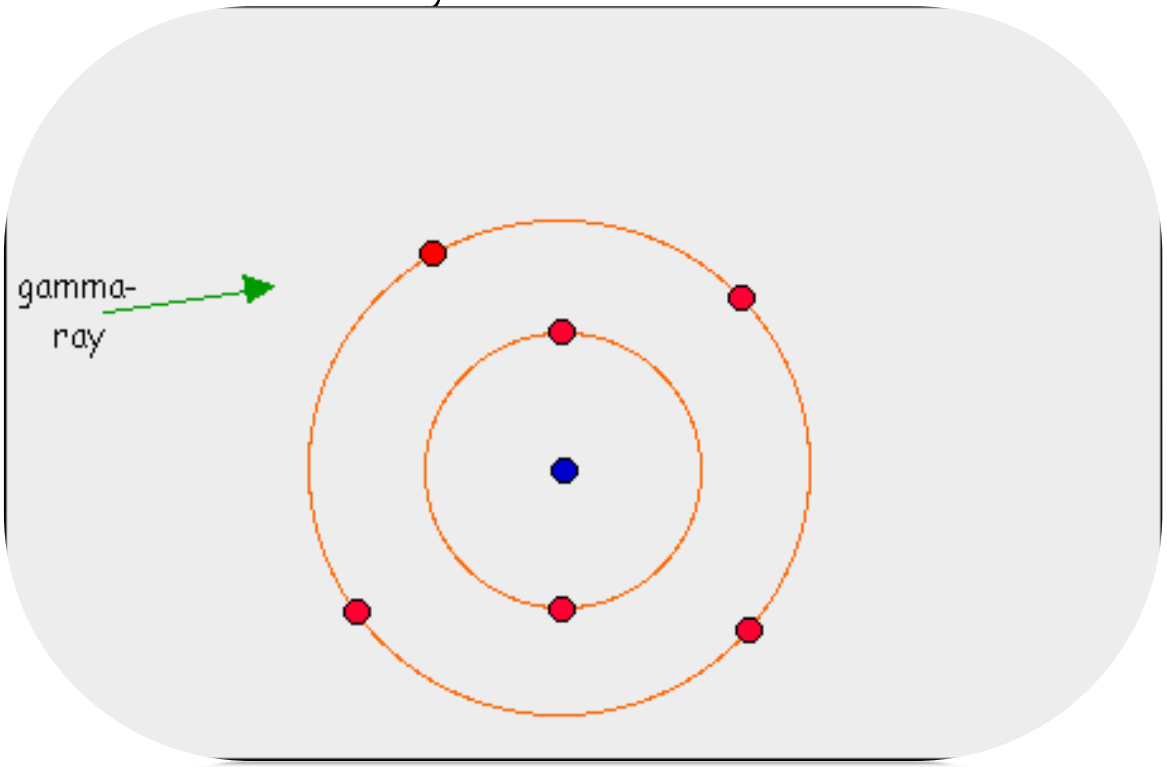
طاقة الأشعة السينية – السماكة – العدد الذري – الكتلة.

SOURCES & FURTHER READING :

- https://www.youtube.com/watch?v=T1WwHh4b__M
- https://sites.google.com/site/frcrphysicsnotes/production-of-x-rays
- Farr's , Physics of Medical Imaging
-

- Next ……

X ray interactions




Thank you
A.M. Abodahab
Oct 2020