X-Ray Machine

Chapter 1/ white & pharoah
Dr yazdanpanah
OMFR

X-Ray Machine

- X-ray machines produce x rays that pass through a patient's tissues and strike a digital receptor or film to make a radiographic image.

- primary components of an x-ray machine :

1. x-ray tube
2. power supply

- The x-ray tube is positioned within the tube head

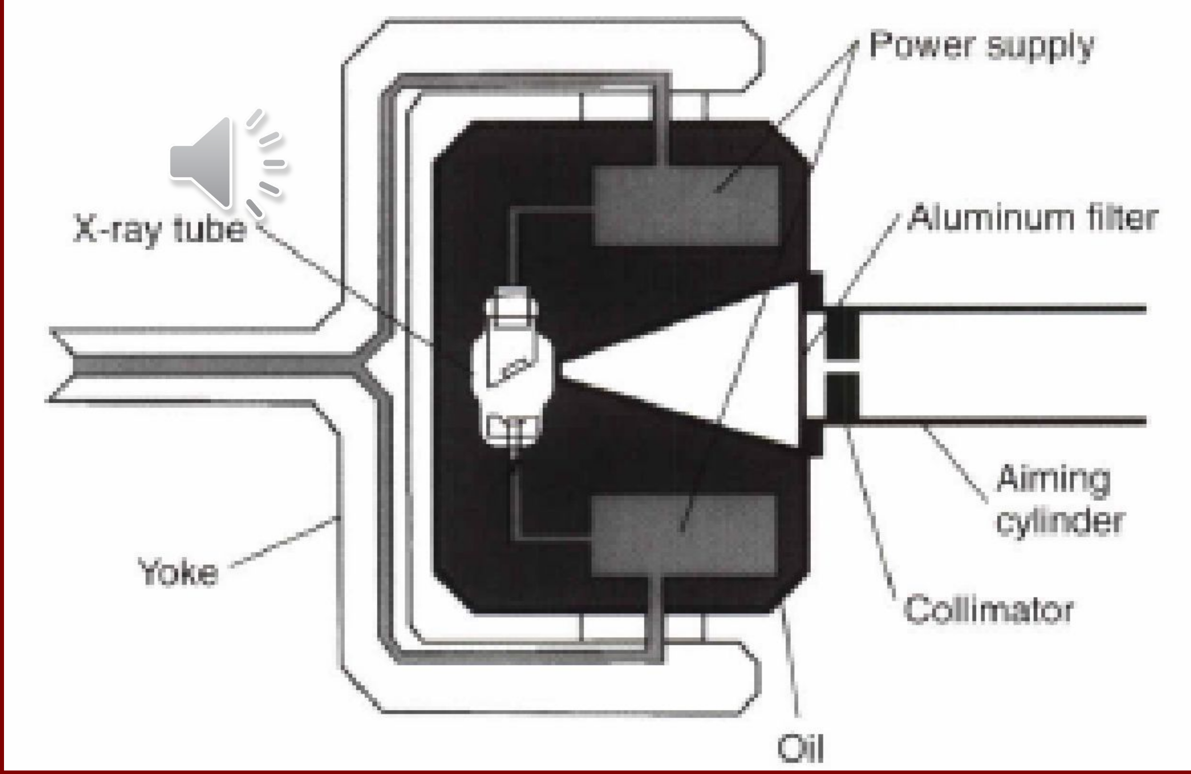
- An electrical insulating material, usually oil, surrounds the tube and transformers.
- Often, the tube is recessed within the tube head to improve the quality of the radiographic image

X-Ray Machine

- Tube head
- Arm
- Control Panel

Tube Head

- X-Ray Tube
- Power Supply

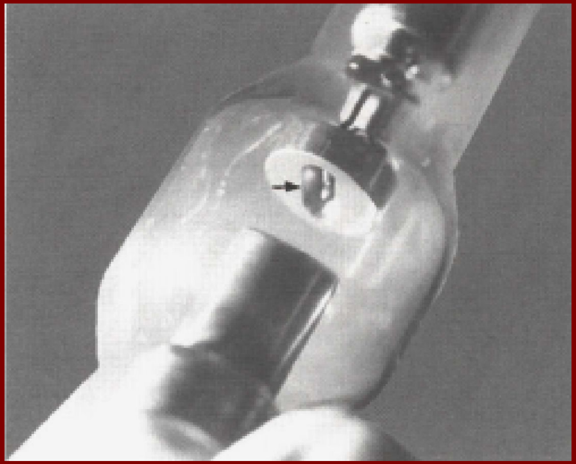


Power supply

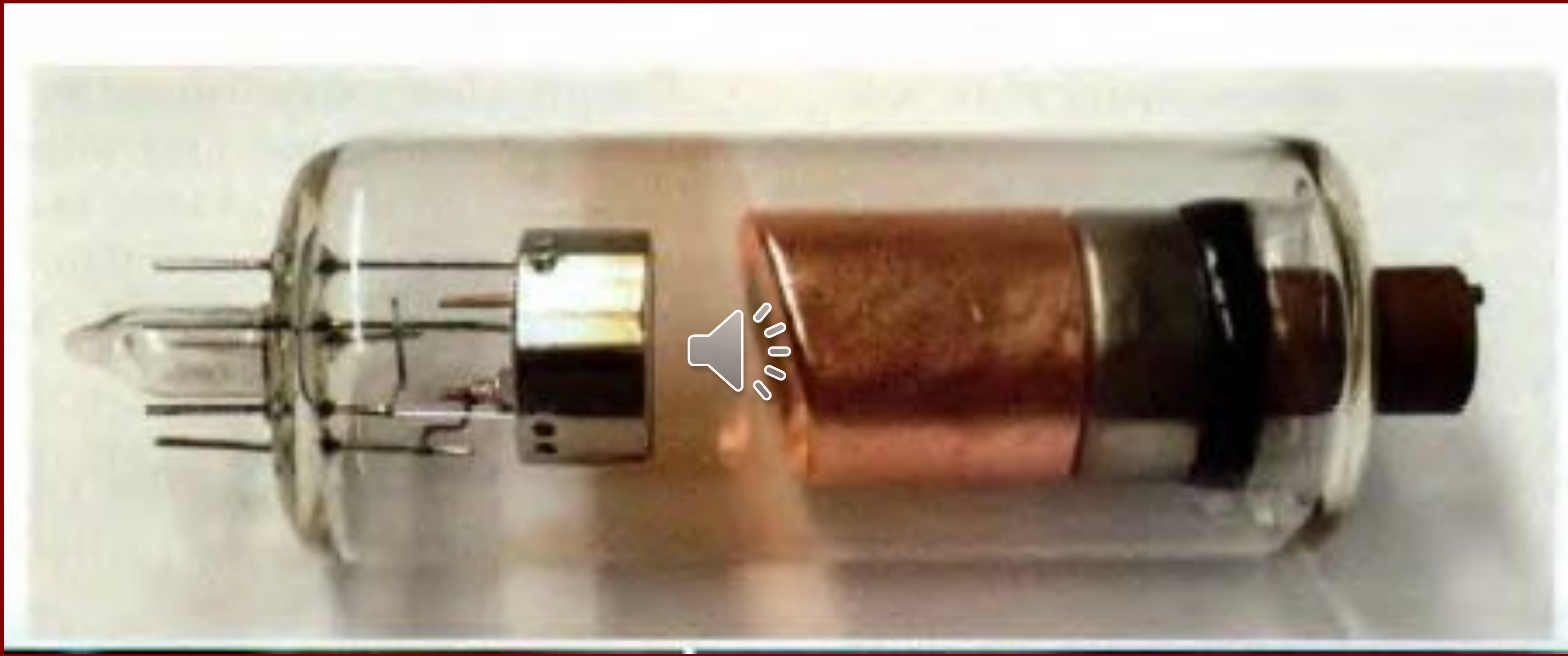
- Heat the cathode filament to generate electrons.
- High potential difference accelerate electrons from cathode to the focal spot on the anode.

Cathode

- Filament:
  - tungsten + 1% thorium
- Focusing cup
  - molybdenum

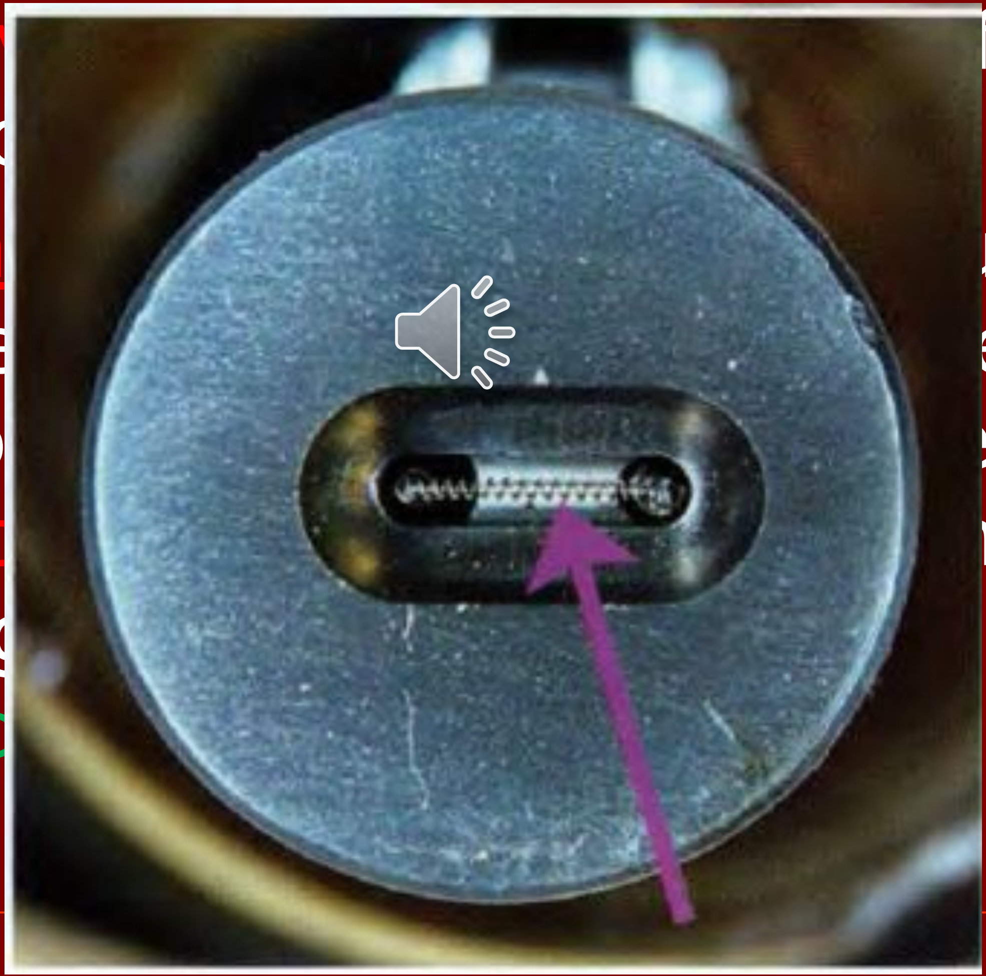


Filament



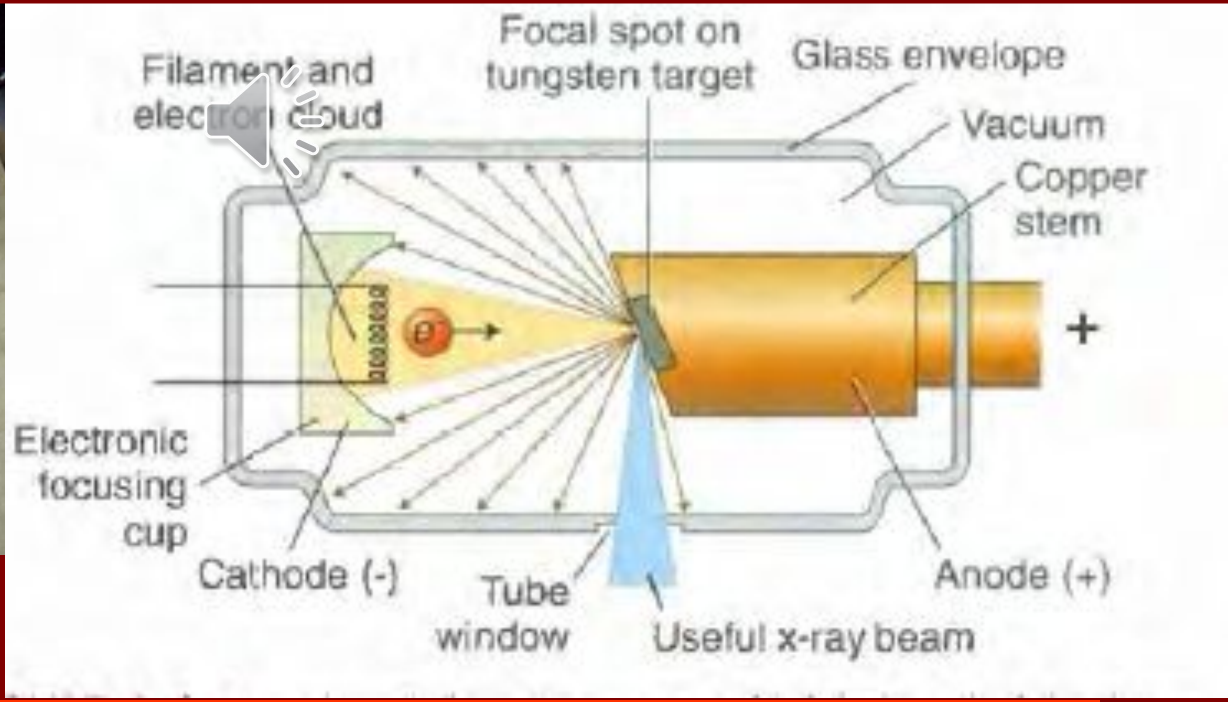
Focusing cup

- Negati... flector made ...
- The pa... ...using cup ele... ...e electro... ...ent into a narro... ...mall rectang... called the foc...



X-Ray Tube

- Glass envelope



X-Ray Tube

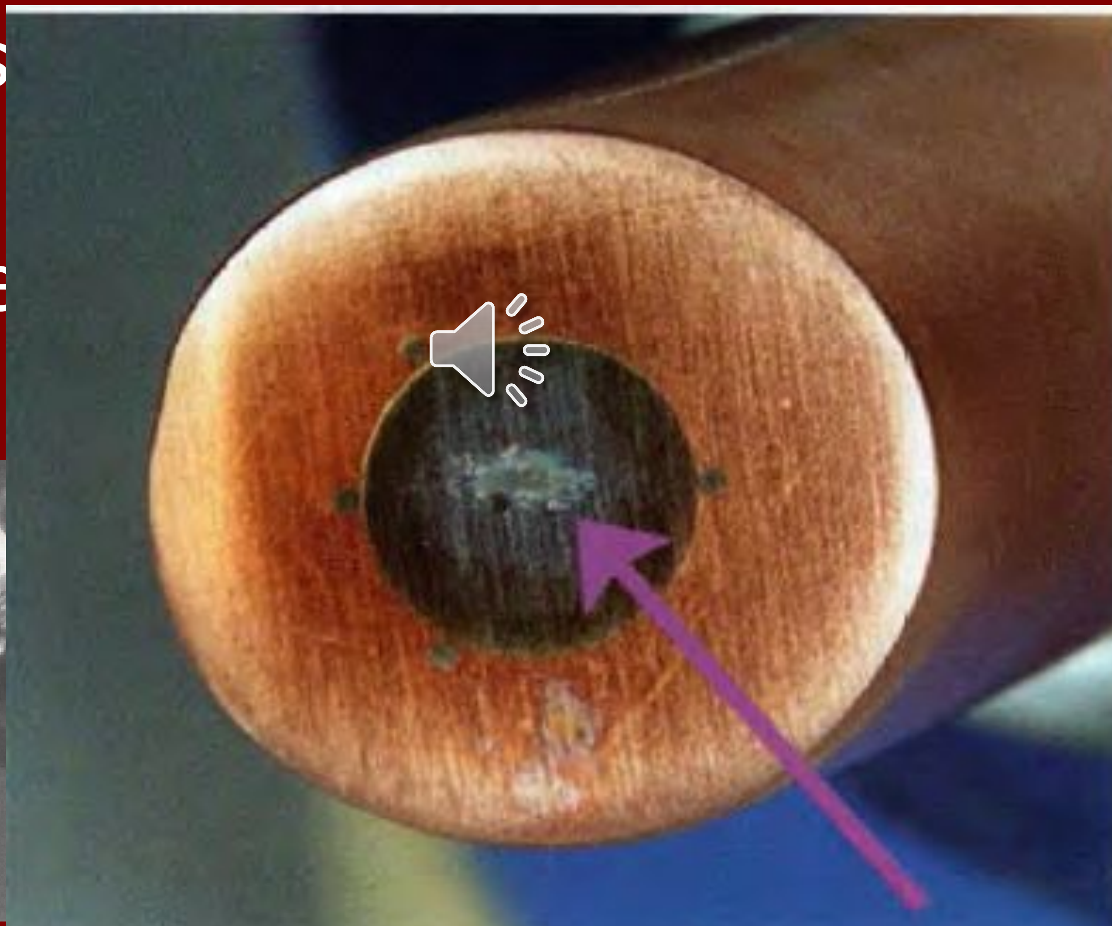
- Glass envelope

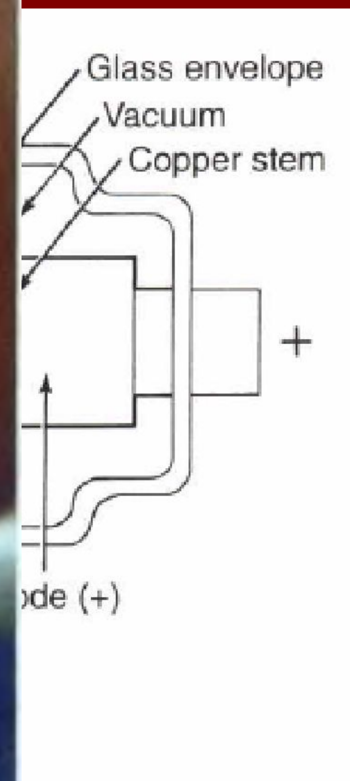
Evacuated to prevent collision of the fast-moving electrons with gas molecules, which would significantly reduce their speed.

The vacuum also prevents oxidation, or "burnout," of the filament.

Anode

- Tungs
- Coppe





Anode

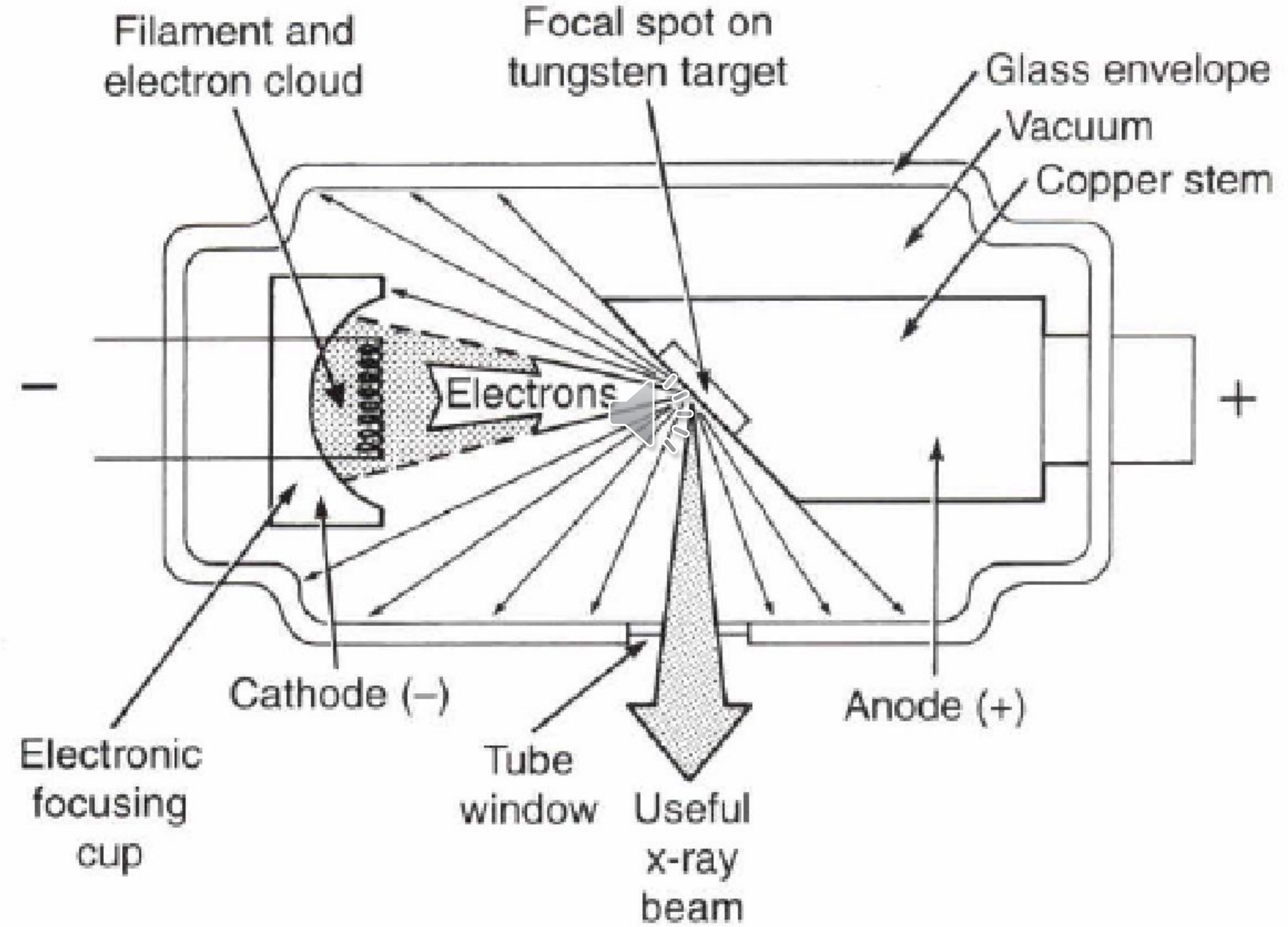
- Purpose of target:
- Conversion of energy to X-ray is inefficient

Ideal Target

- High atomic number(74)
- High melting point(3422 °C)
- High thermal conductivity(173 W, m^{-1},K^{-1})
- Low vapor pressure

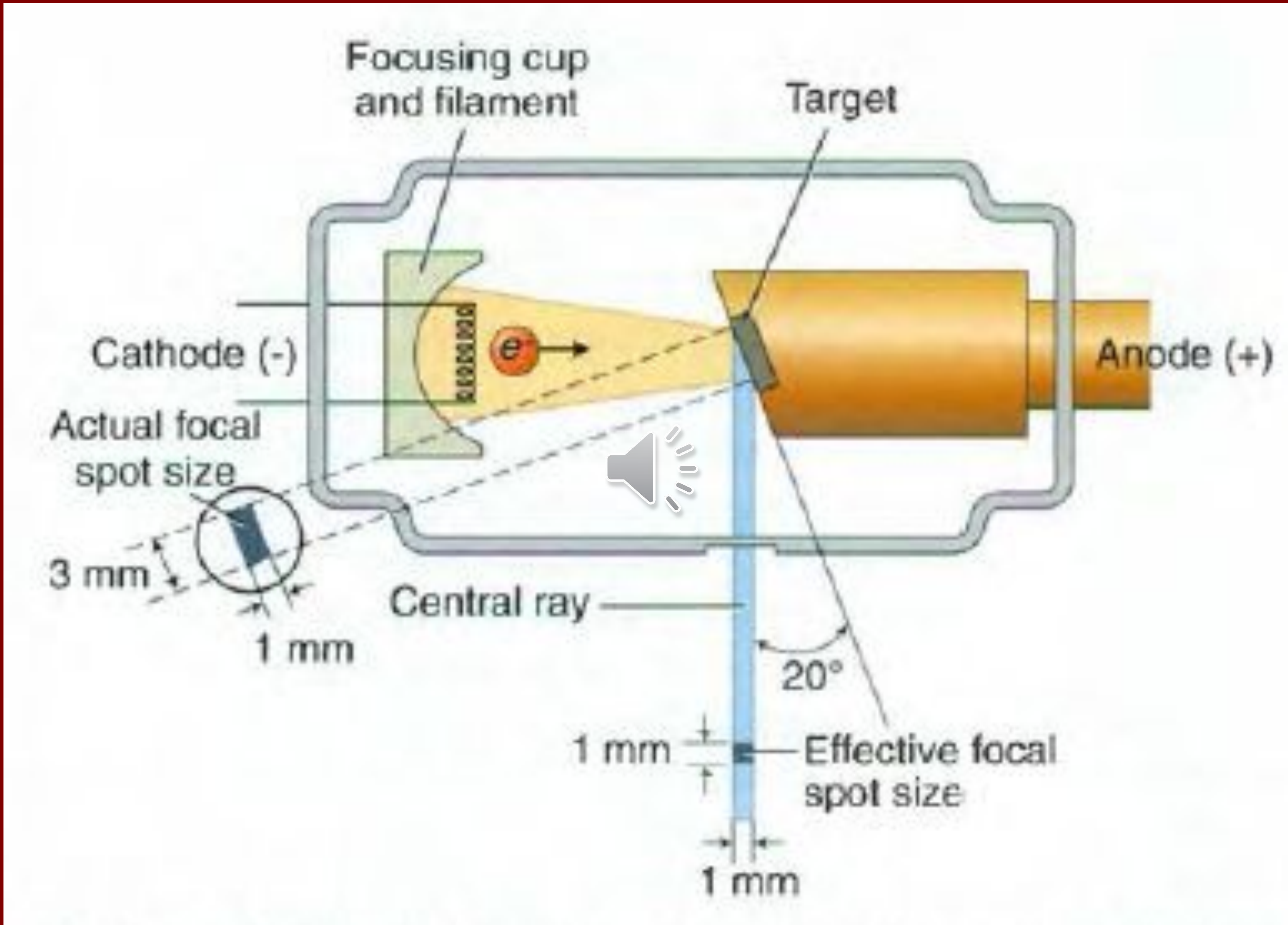
Focal Spot

- The area on the target to which the focusing cup directs the electrons and from which x rays are produced


Filament and electron cloud
Focal spot on tungsten target
Glass envelope
Vacuum
Copper stem
−
Electrons
+
Cathode (−)
Anode (+)
Electronic focusing cup
Tube window
Useful x-ray beam

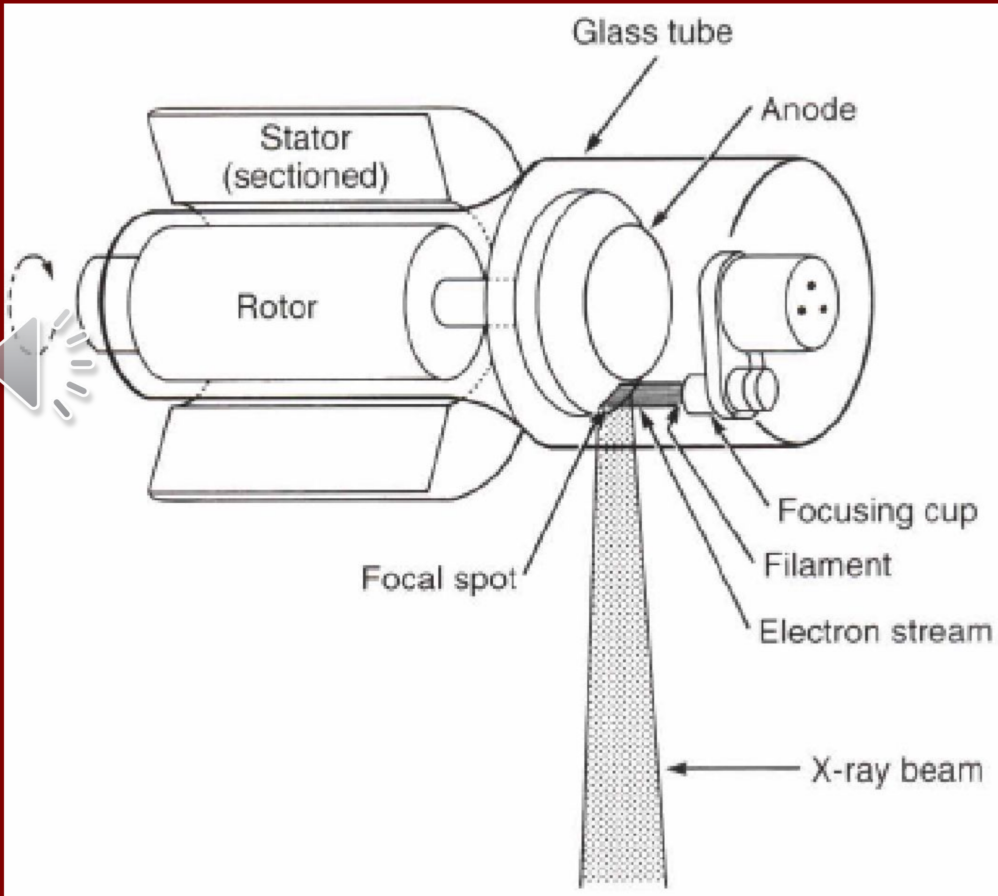
Focal Spot

- Size : is important to image quality
  - sharpness
  - heat:1.stationary anode 2.rotating anode
- Angle of target:target is inclined 20 degrees to the central ray
  - effective focal spot : 1 x 1 mm
  - actual focal spot: 1 x 3 mm


Focusing cup
and filament
Target
Cathode (-)
Anode (+)
Actual focal
spot size
3 mm
1 mm
Central ray
20°
1 mm
Effective focal
spot size
1 mm

Methods of dissipating the heat : from focal spot

- Anode
- Angle of target
- Copper stem
- Insulating oil
- Rotating anode:
  - focal track
  - CT
  - cephalometic & cone-beam machine

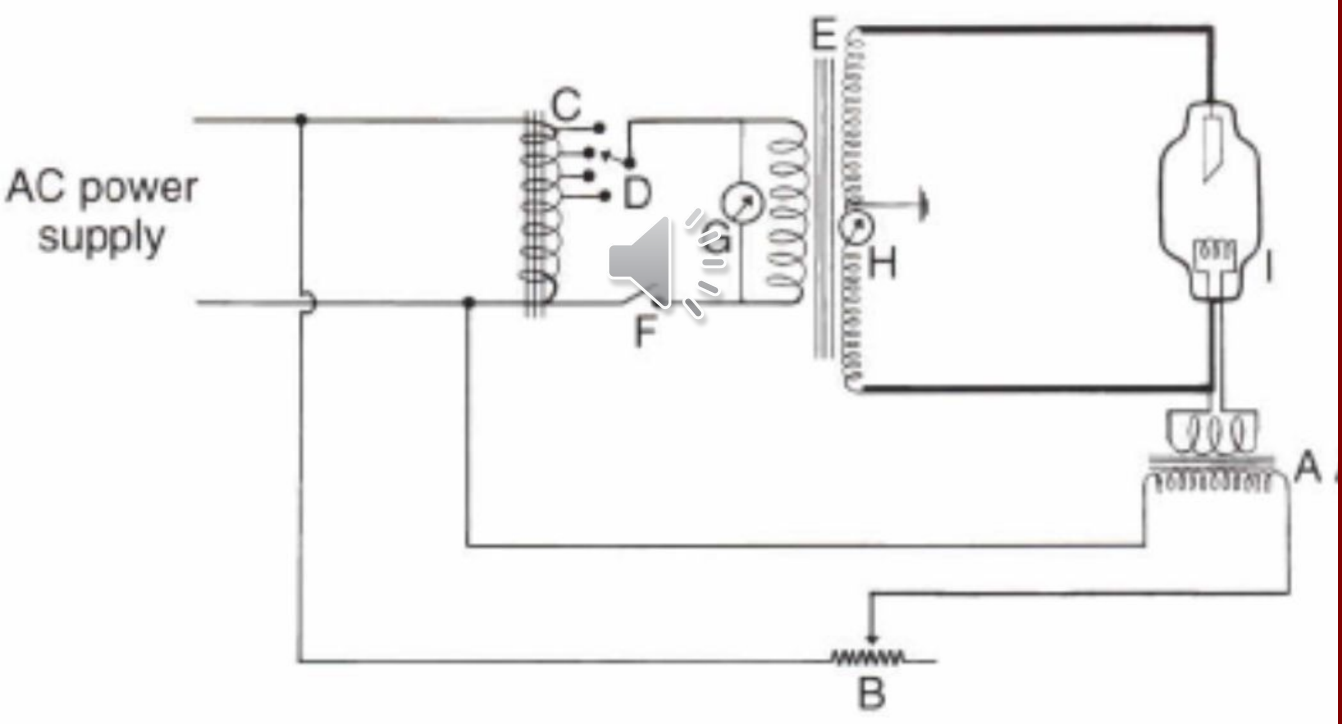


Power supply

- Primary functions:

1. Low voltage: emit electrons
2. High voltage: accelerate electrons

- Head of x-ray machine:
  - x-ray tube
  - 2 transformers
  - insulating oil


AC power supply
C
D
G
E
H
I
F
A
B

Tube Current

- Filament step-down transformer (filament transformer)(10v)

- mA selector or filament current control:
  - actually tube current

- When the hot filament releases electrons, it creates a cloud of electrons around the filament, a negative space charge.
- This negative space charge imbedes the further release of electrons. The higher the voltage, the greater the removal of the electrons from the space charge, and the greater the tube current.

Tube voltage

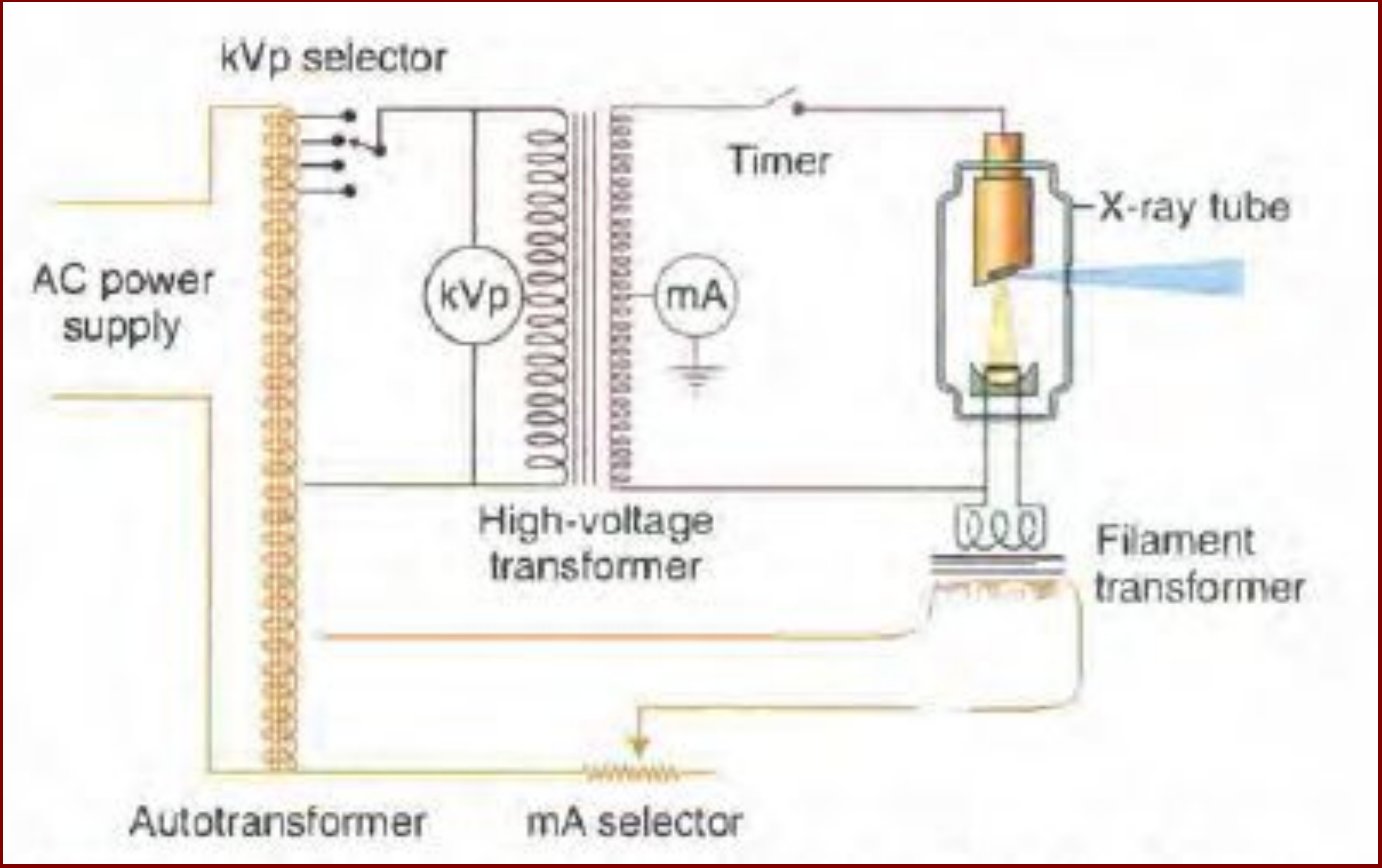
- Why High voltage?

- Autotransformer:

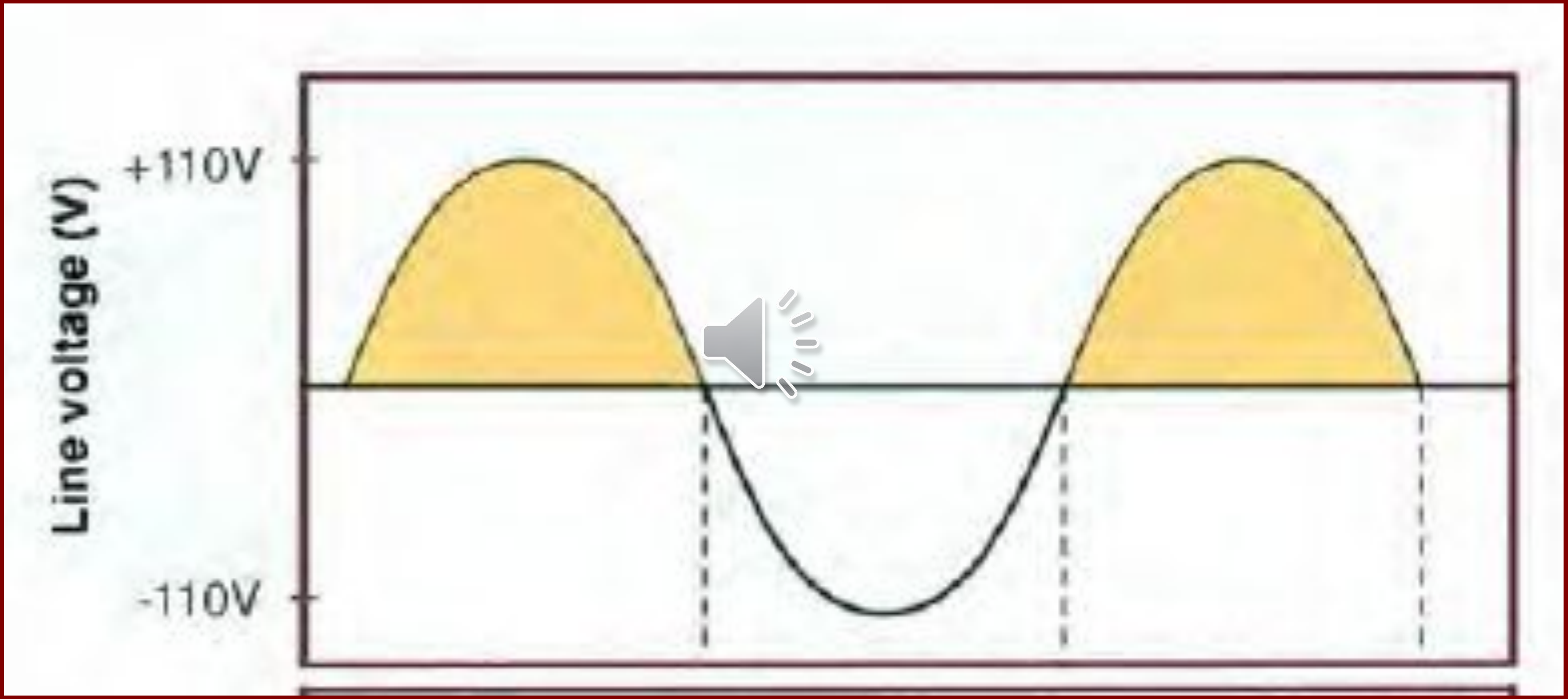
The actual voltage used on an x-ray machine is adjusted with the autotransformer

- kVp selector (peak operating voltage)

primary voltage (110v)→ secondary voltage

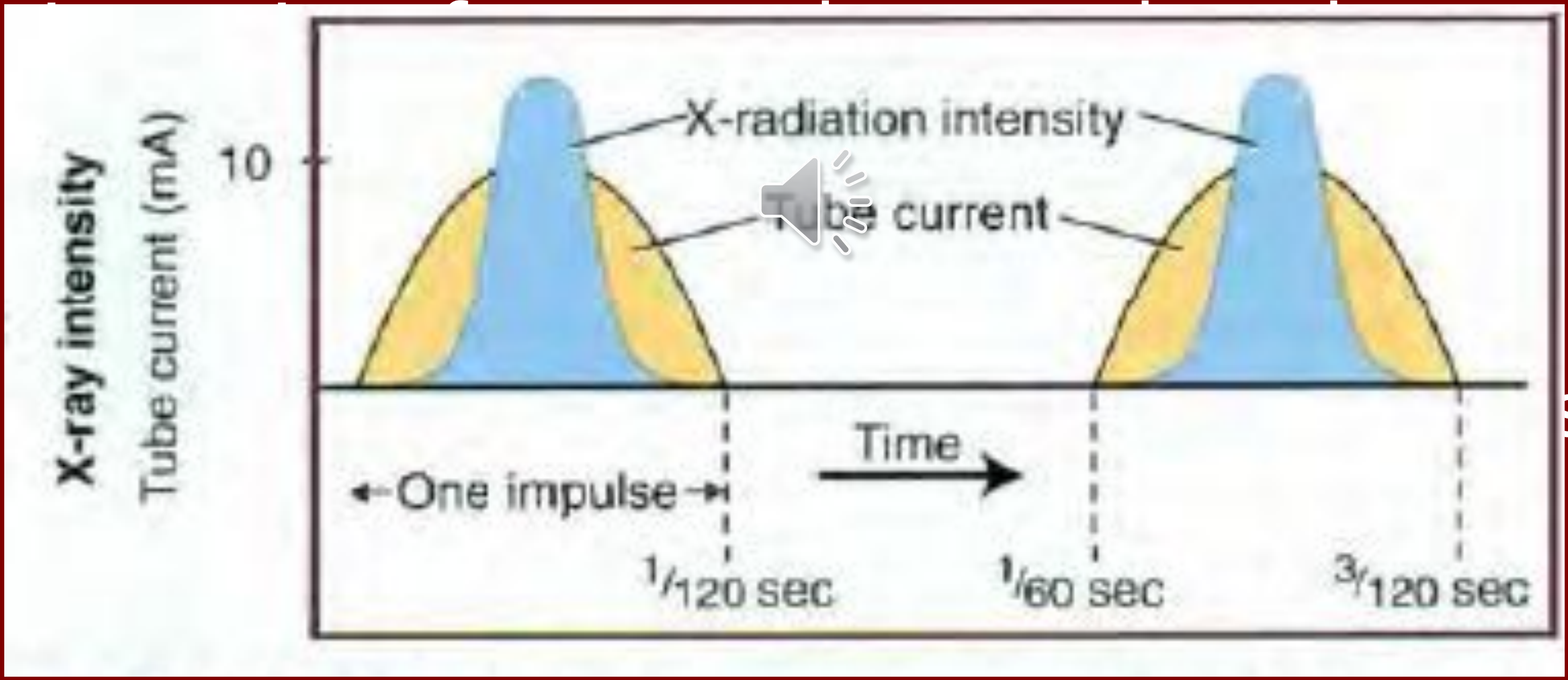

kVp selector
Timer
X-ray tube
AC power supply
kVp
mA
High-voltage transformer
Filament transformer
Autotransformer
mA selector

Tube voltage



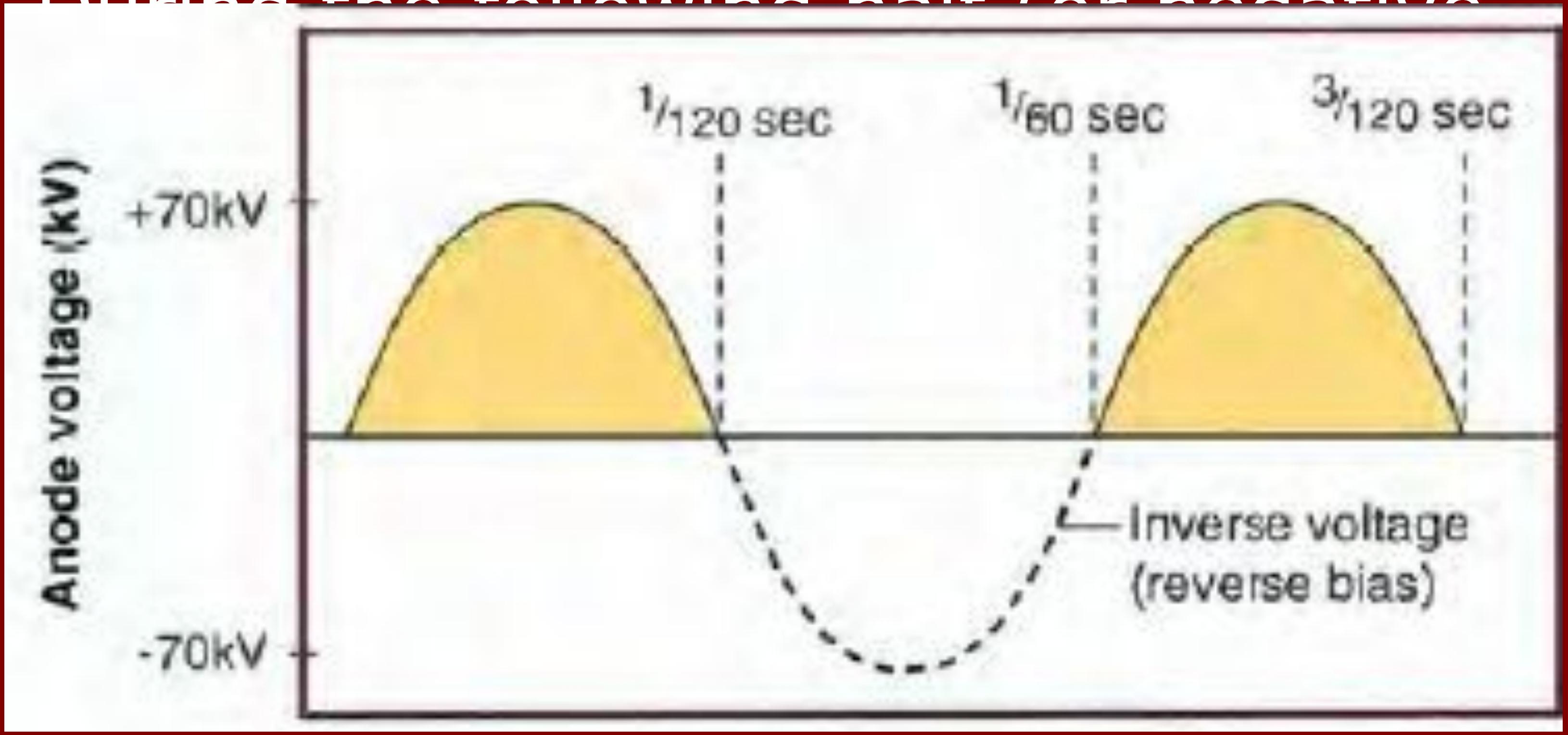
Tube voltage

- Voltage ↑ speed of electron ↑



Tube voltage

- During the following half (or negative



Tube voltage

- Self-rectified or Half-wave rectified:

The alternating high voltage is applied directly across the x-ray tube, limits x-ray production to half the AC cycle

- Conventional dental x-ray machines are self-rectified

Tube voltage

- Replace the conventional 60-cycle AC, half-wave rectified power supply with a full-wave rectified, high-frequency power supply
- Higher mean energy
- images have a longer contrast scale
- The patient receives a lower dose

Tube voltage

- Intraoral,Panoramic, and Cephalometric machines operate between 50 and 90 kVp, whereas cone-beam computed tomographic machines operate at 90 to 120 kVp

Timer

- Duration of x-ray exposure/ into the high-voltage circuit
- Length of high-voltage
- To minimize filament damage

- Tube Rating : longest exposure time

HU = (kVp x mA) x seconds

The heat storage capacity for anodes of dental diagnostic tubes is approximately 20 kHU

- Duty Cycle : frequency of exposures
-   - anode size
-   - cooling methods

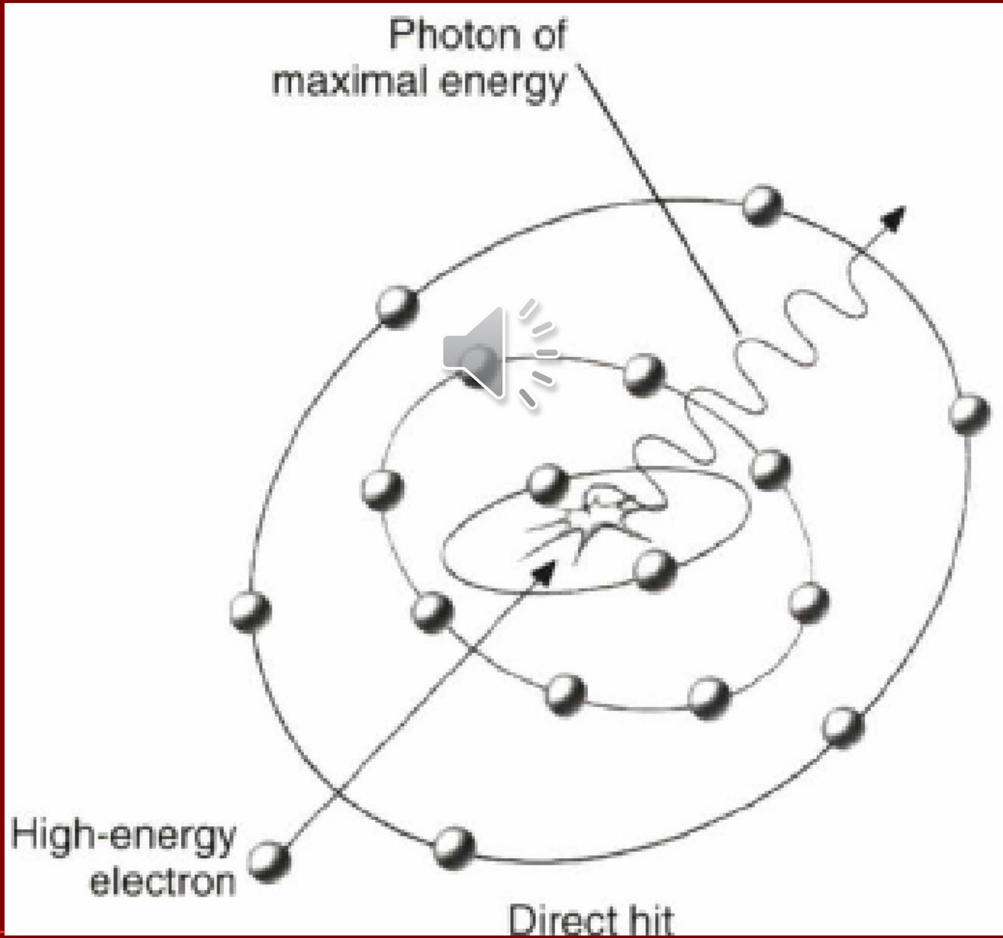
Production of X-Rays

Most energy : Heat

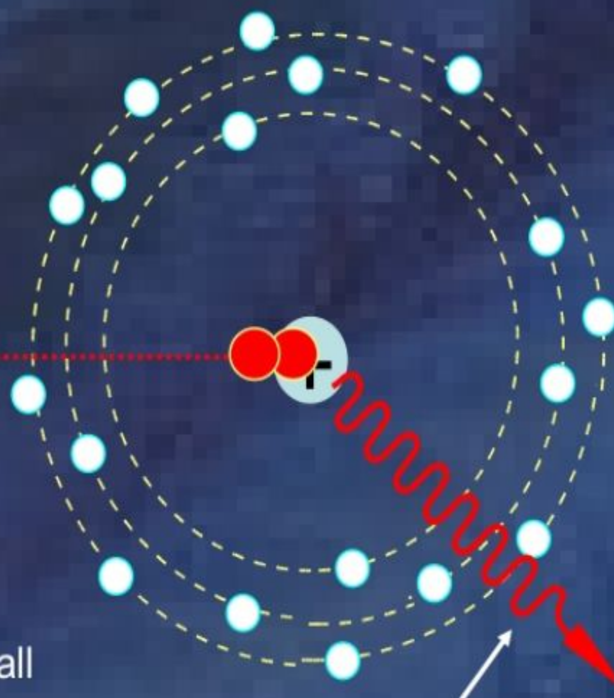
Bremsstrahlung Radiation (برم اشترالانگ)

- The sudden stopping or slowing of high-speed electrons by tungsten nuclei
- “breaking radiation”
- Primary source

Electrons from the filament directly hit the nucleus of a target atom



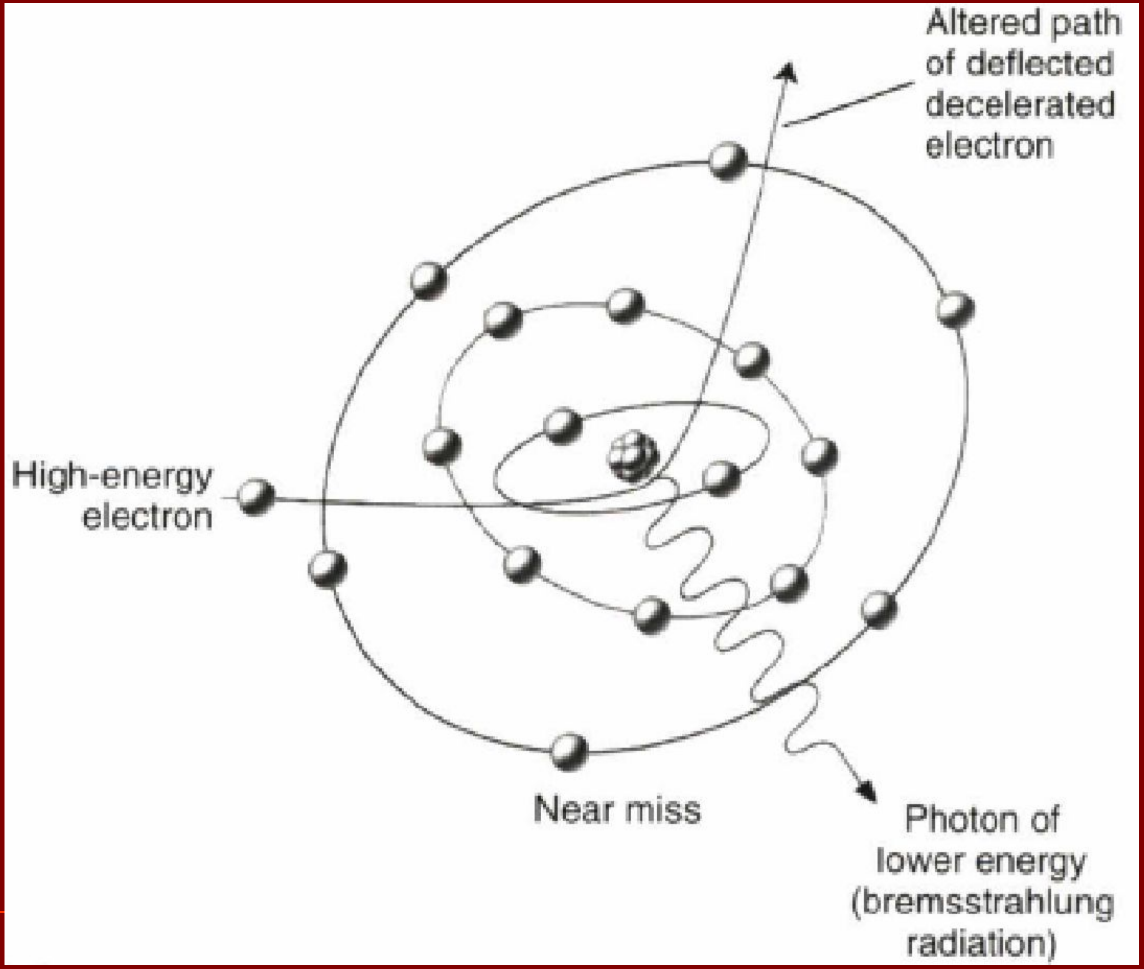
Bremsstrahlung X-ray Production
Maximum energy



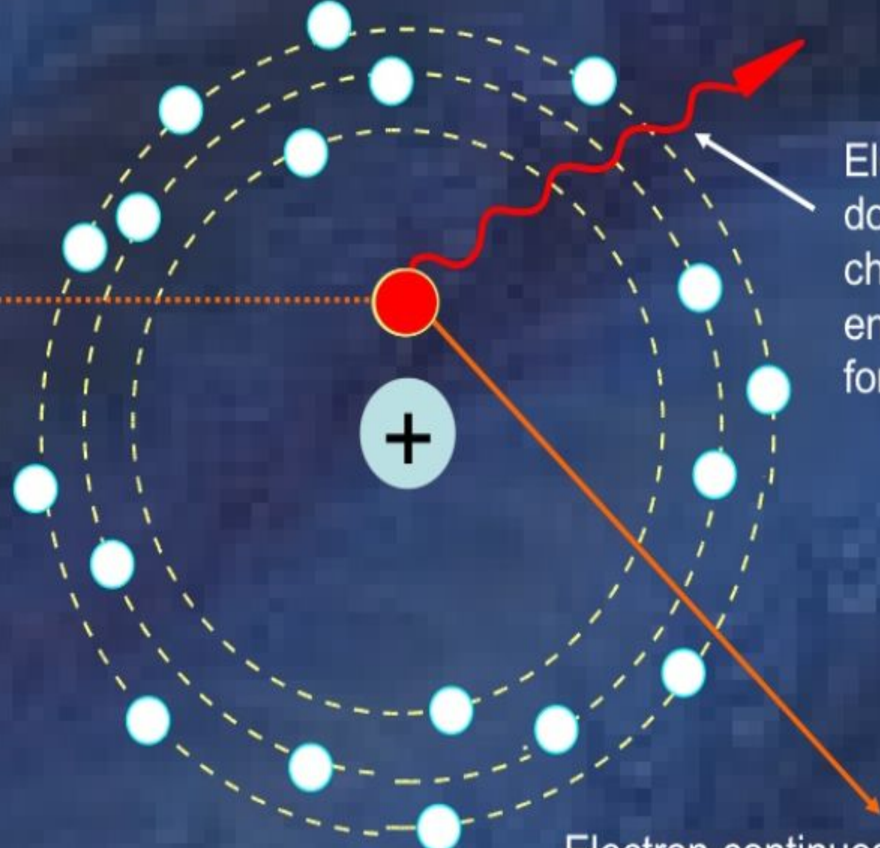
High-speed electron from filament enters tungsten atom and strikes target, losing all its energy and disappearing

The x-ray produced has energy equal to the energy of the high-speed electron; this is the maximum energy possible

High-speed electrons pass by tungsten nuclei with near or wide misses(proportional to the square of the atomic number of the target)



Bremsstrahlung X-ray Production

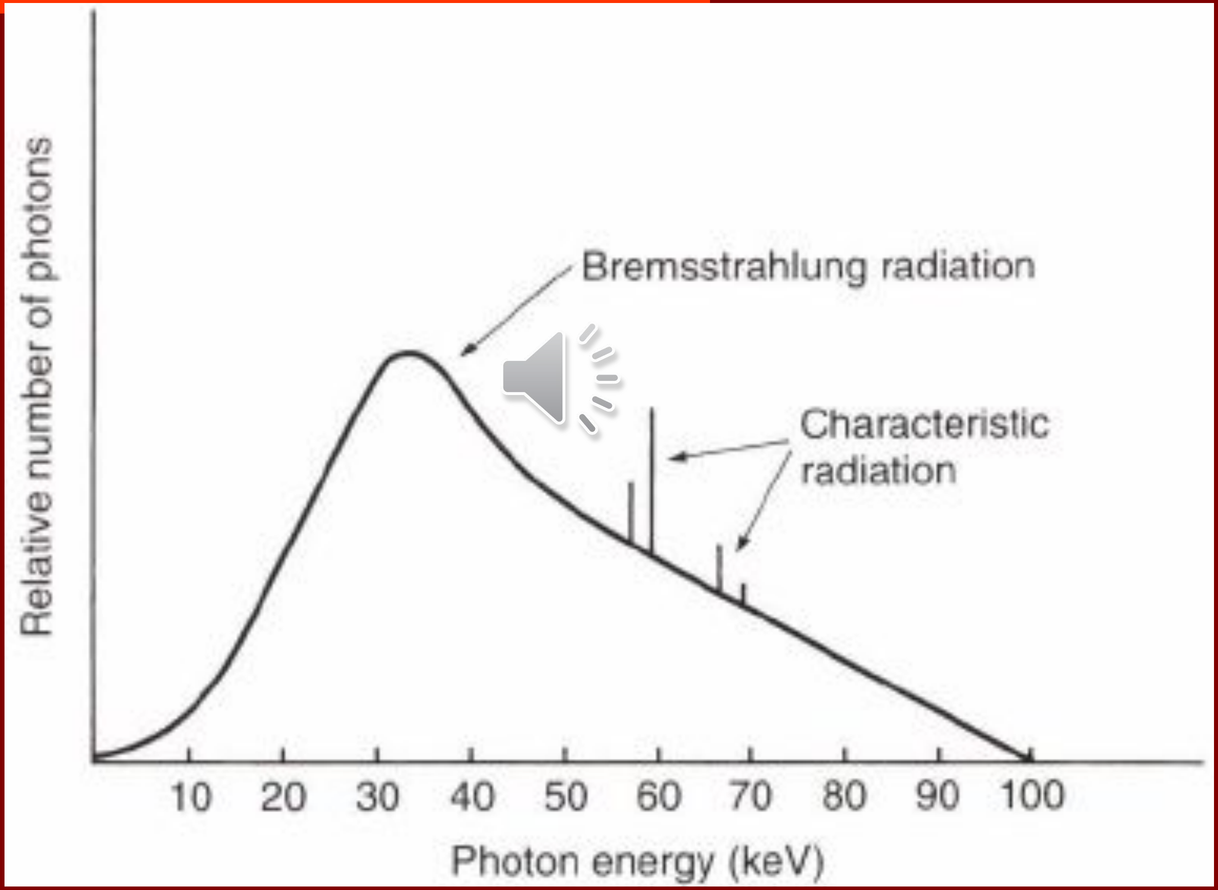


High-speed electron from filament enters tungsten atom

Electron slowed down by positive charge of nucelus; energy released in form of x-ray

Electron continues on in different direction to interact with other atoms until all of its energy is lost

Continuous spectrum of energy



Bremsstrahlung Radiation

- The continuously varying voltage difference between the target and filament causes the electrons striking the target to have varying levels of kinetic energy.

Bremsstrahlung Radiation

- The bombarding electrons pass at varying distances around tungsten nuclei and are thus deflected to varying extents. As a result, they give up varying amounts of energy in the form of bremsstrahlung photons.

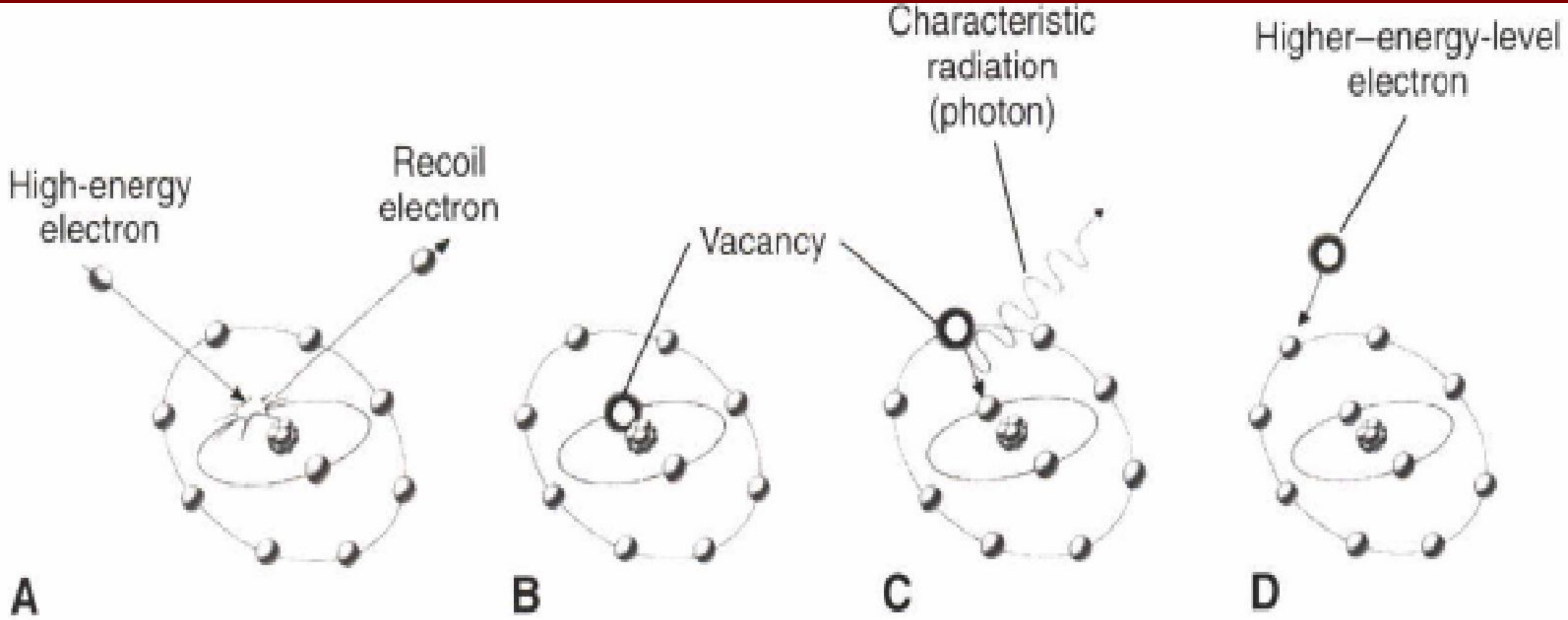
Bremsstrahlung Radiation

- Most electrons participate in the target before losing all their kinetic energy. As a consequence, an electron carries differing amounts of energy after successive interactions with tungsten nuclei

Characteristic Radiation

- Characteristic radiation contributes only a small fraction of the photons in an x-ray beam
- An incident electron ejects an inner electron from the tungsten target
- When the outer orbital electron replaces the displaced electron, a photon is emitted

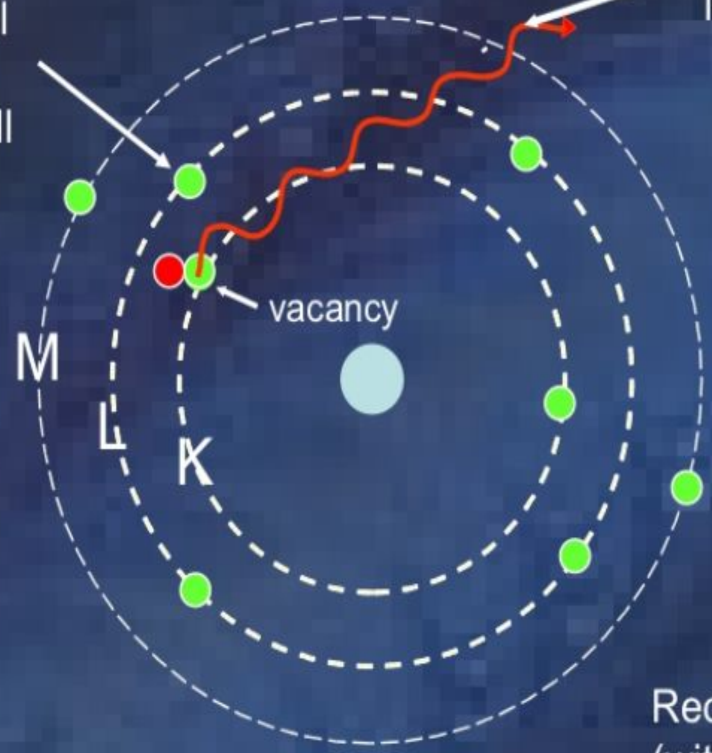
Characteristic Radiation



Characteristic X-ray Production

Electron in L-shell drops down to fill vacancy in K-shell

Ejected electron leaves atom

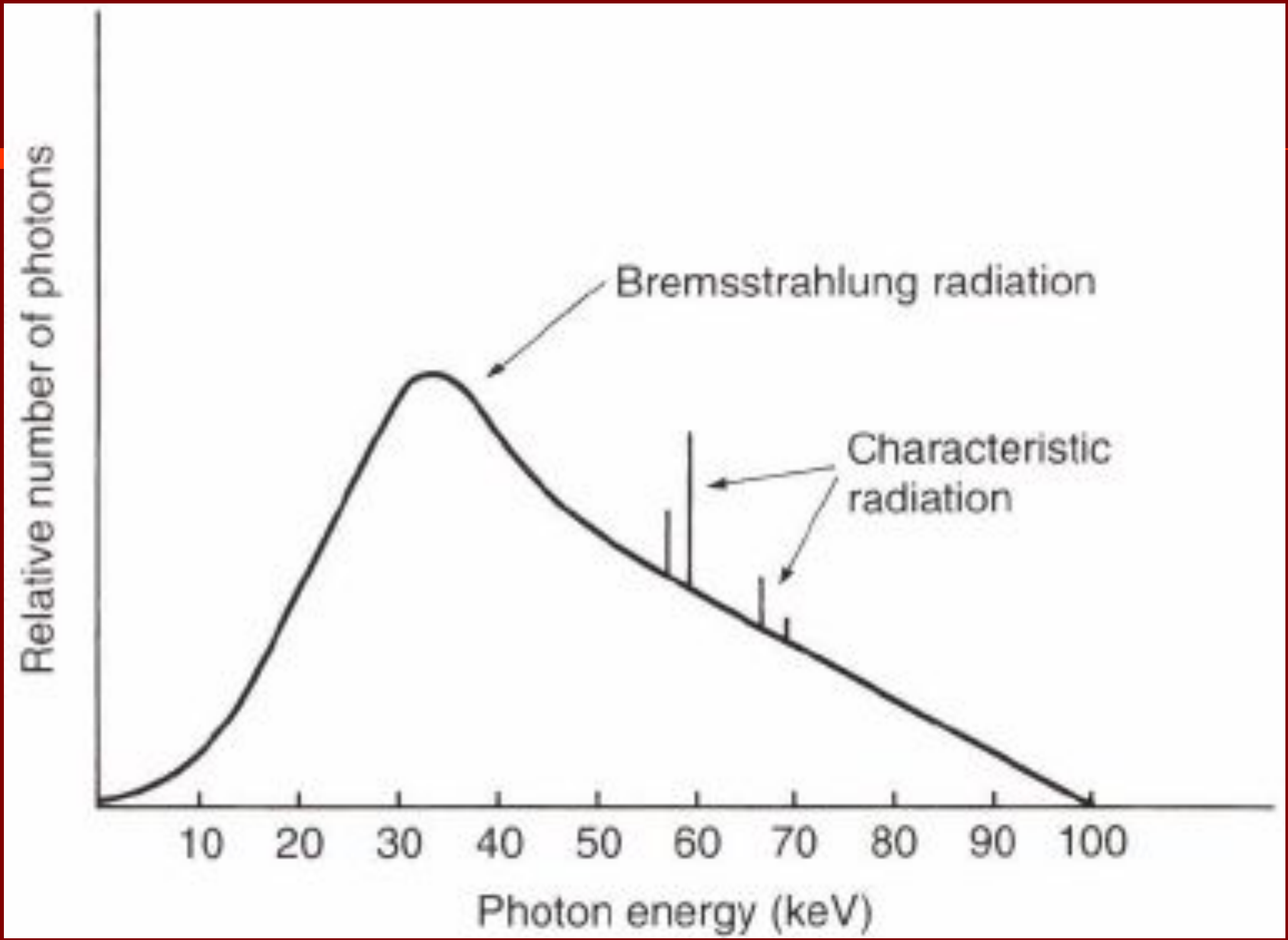


X-ray with 59 keV of energy produced. 70 (binding energy of K-shell electron) minus 11 (binding energy of L-shell electron) = 59.

High-speed electron with at least 70 keV of energy (must be more than the binding energy of k-shell Tungsten atom) strikes electron in the K shell, knocking it out of its orbit

Recoil electron (with very little energy) exits atom

- Small fraction
- Discrete spectrum
- Difference of energy levels of electron orbitals
- Characteristic of target atoms


Relative number of photons
Bremsstrahlung radiation
Characteristic
radiation
10
20
30
40
50
60
70
80
90
100
Photon energy (keV)

The Orinoco River near the Esmeralda (Amazon Rain Forest), Amazonas region, Venezuela (N 3°10'-W 65°33')
http://www.yannarthusbertrand.org