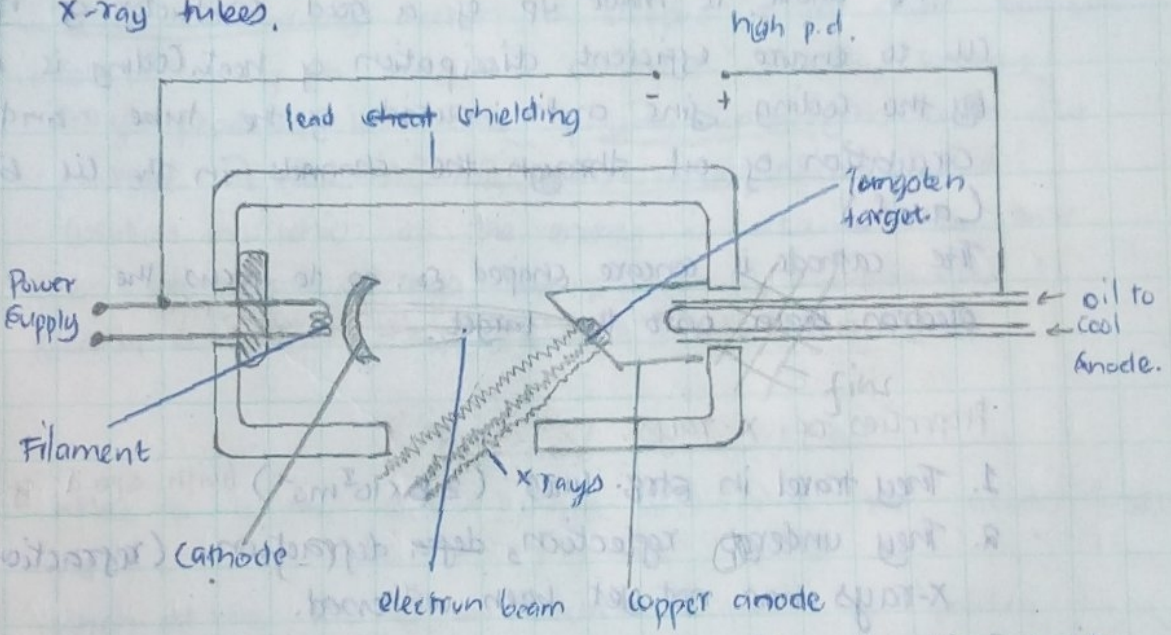
X-Rays

X-rays are members of the electromagnetic spectrum.

Production of X-rays

X-rays are produced when very fast moving electrons hit a target e.g tungsten targets

X-rays are produced by modified discharge tubes called X-ray tubes.



The cathode is in the form of a filament which emits electrons on heating a process known as thermionic emission. Thermionic emission is the process of emission of electrons due to change in heat energy. The electrons are accelerated towards the target (anode by the high p.d). The anode is made up of solid copper ~~or~~ Molybdenum or any other material. A high p.d btwn the cathode and Anode is maintained by an external high voltage source. The filament is made up of tungstern and is coiled to provide high resistance to the passing current. The electrons emitted from the filament experience the p.d and are accelerated towards the anode.

On hitting the anode search electrodes are stopped and they transfer their kinetic energy to the electrons of the anode material giving rise to the X-rays.
The target must therefore be a metal of high melting point. e.g tungsten.

The anode is made up of a good conductor of heat e.g Cu to ensure efficient dissipation of heat. Cooling is enhanced by the cooling fins on the outside of the tube and circulation of oil through the channels in the Cu block (anode)
The cathode is concave shaped so as to focus the electron beam onto the target

Properties of X-rays.

1. They travel in straight lines ($3 \times 10^8 ms^{-1}$) (with speed of light)
2. They undergo reflection, diffraction. (refraction of X-rays has not yet been witnessed.
3. They are not affected by electric or magnetic fields since they are not charged particles.
4. They ionise gases causing them to conduct electricity i.e. They remove electrons from atoms.
5. They cause photoelectric emission.
6. They penetrate matter with the least penetration occuring in materials of high density like lead (Pb).
7. They affect photographic films.
8. They cause flourescence in certain substances e.g zinc sulphide.
9. X-rays are electromagnetic waves of very short wavelength of the order 10^{-10} metres.

experimental results on polarization of x-rays and diffraction of x-rays by crystals have confirmed the nature of x-rays. Through the diffraction experiment the wavelength of x-rays have been determined.

Energy of x-rays.

If a bombarding electron is stopped in a single collision most or all of its energy is converted to x-ray energy. x-rays produced will have varying wavelengths with the shortest λ (lambda) minimum corresponding to a collision in which all the energy is assumed to have been converted to x-rays. The K.E of the bombarding electron is given by $K.E = eV$

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where 'e' is the electron charge and V is the accelerating p.d.

When all the K.E of an electron is used to produce the x-ray energy the frequency of the x-rays will be maximum (f_{max})

~~Where all the~~

Using Plancks theory $E = hf$. h = plancks constant, f = frequency of radiation

thus $eV = hf_{max}$

since $c = f\lambda$ where c is velocity of light

$$f = c/\lambda$$

$$f_{max} = \frac{c}{\lambda_{min}}$$

From the equation

$$eV = hf_{max}$$

$$eV = \frac{hc}{\lambda_{min}} \quad \text{where} \quad f_{max} = \frac{c}{\lambda_{min}}$$

$$\therefore eV = \frac{hc}{\lambda_{max}} = \frac{hc}{\lambda_{max}}$$

Most energetic x-rays have the shortest wavelength.

e.g.

1. Determine the energy possesed by x-rays whose frequency is 40.0×10^{17} Hz. Take $h = 6.63 \times 10^{-34}$ Js.

$$E = hf$$
$$= 6.63 \times 10^{-34} \times 40.0 \times 10^{17}$$
$$= 6.63 \times 10^{-16} \times 4$$
$$= 2.652 \times 10^{-16} \text{ J}.$$

2. An x-ray tube gave x-rays whose wavelength varied from 5.5×10^{-13} m to 4.0×10^{-9} m. What is the range of the frequencies.

$V = 3.0 \times 10^8$

~~$f = \frac{\lambda}{V} = \frac{5.5 \times 10^{-13}}{3.0 \times 10^8} = 1.83 \times 10^{-11}$~~ ~~$\frac{4.0 \times 10^{-9}}{3.0 \times 10^8}$~~

$f = V/\lambda$

$$= \frac{3.0 \times 10^8}{5.5 \times 10^{-13}} \qquad \frac{3.0 \times 10^8}{4.0 \times 10^{-9}}$$
$$= (5.45 \times 10^{20} - 7.5 \times 10^{16}) \text{ Hz}.$$

3. Find the frequency and energy of a type of x-rays whose wavelength is 1.0×10^{-10} m in a vacuum.

$E = hf$

$= 6.63 \times 10^{-34} \times f$

$= 6.63 \times 10^{-34} \times 3.0 \times 10^{8} = 1.99 \times 10^{-25}$ Joules.

$f = V/\lambda = \frac{3.0 \times 10^{8}}{1.0 \times 10^{-10}}$

$= 3.0 \times 10^{18}$ Hz.

4. The frequency of x-rays range from 3.0×10^{17} to 3.0×10^{19} Determine:

(a) range of wavelengths

$V = \lambda f$

$\lambda = V/f$

$= \frac{3.0 \times 10^{8}}{3.0 \times 10^{17}}$ and $\frac{3.0 \times 10^{8}}{3.0 \times 10^{19}}$

$= 1.0 \times 10^{-9}$ m $- 1.0 \times 10^{-11}$ m.

$\therefore$ 1.0×10^{-11} m to 1.0×10^{-9} m.

(b) Find the max. energy of x-rays.

$E = hf_{max}$

$= 6.63 \times 10^{-34} \times 3.0 \times 10^{19}$

$= 2.0 \times 10^{-14}$ J.

5. An X-ray tube has an accelerating p.d of 100 KV
What is the shortest wavelength in its X-ray beam.
Take charge on an electron e^- to be equal to 1.6×10^{-19} C
$= 100000V$ $h = 6.63\times10^{-34}$
$c = 3.0\times10^{8}$ m.

$eV = hf.$
$eV = hf_{max}$
$eV = \frac{hc}{\lambda min.}$

$\lambda min = \frac{hc}{eV}$

$= \frac{6.63\times10^{-34}\times 3.0\times10^{8}}{100000\times 1.6\times10^{-19}}$

$= 1.24\times10^{-11}$ m.

Hard and soft x-rays.

There are two types of x-rays Hard and soft x-rays. Hard x-rays are produced by fast moving electrons as a result of a high accelerating voltage. They have very short wavelength and thus high penetrating power. They can penetrate the flesh but are absorbed by bones.

Soft x-rays are produced by electrons moving at relatively lower velocities than those that produce hard x. They have less energy, longer wavelengths hence less penetrating power compared to hard x-rays. They are u to show malignant growth in tissues, since they only penet soft flesh but are absorbed by such growths.

Dangers of x-rays

Excessive exposure of living tissue to x-rays is dangerous as the radiations can damage or kill cells.

Since the effect of exposure is cumulative it is important that exposure be limited to as short periods as necessary and as few times as possible in one's lifetime.

X-ray machines have a protective lead shield to protect the operators from radiation. The machines ~~have~~ are operated in rooms that have concrete walls to absorb any leaking radiation.

Intensity (quantity) of x-rays.

The intensity is controlled by the heating current. The greater the heating current the greater the number of electron produced, hence the more the x-rays. The strength (quantity) of the x-rays will however remain the same. The strength of the x-rays depends on the speed of electrons, which in turn depends on the accelerating potential difference btwn the cathode and Anode.

Uses of x-rays.

In Medicine (Radiography and radiotherapy)

A broken limb will reveal the nature of the fracture since the x-ray will be absorbed differently.

x-rays are used to administer radiation treatment for tum

N/B x-rays cannot be focused by lenses.

x-rays are also used to detect foreign objects in the bod like pins.

In Industries

X-rays are used to detect flaws in metal castings and welding. The radiation is also used to sterilise surgical equipment before packaging.

In Crystallography.

X-rays are used to study the crystal structure of substances.

An analysis of the diffraction pattern can therefore reveal detailed information on the structure of the crystal.

Security e.g In Airports.

They are used to inspect luggage for any weapons that may be hidden in them.