**IGCSE/GCE O-LEVEL**

# Radioactivity

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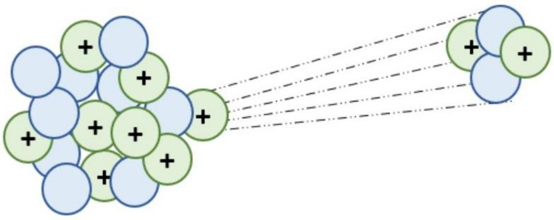
## Radioactive Decay

A process in which an unstable element emits radiations to become stable is called radioactive decay.



- Element which emits radiations is called radioactive element.
- Emitted radiations are called radioactive radiations.

## Properties

There are two properties of radioactive decay.

- Random Process
- Spontaneous Process

## Random Process

Rate of decay of radioactive atoms does not remain constant.

or

Number of atoms decayed after every second does not remain constant.

## Spontaneous Process

Rate of decay is not affected by the change in physical conditions.

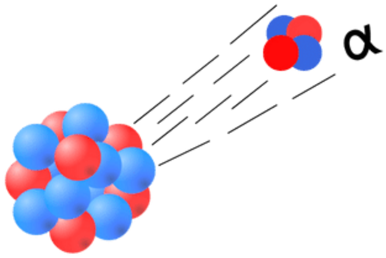
- It means that charge in physical conditions such as change in temperature and process will not change no. of atoms which are decaying.

## Radioactive Radiations

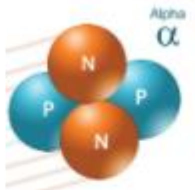
There are three types of radioactive radiations.

- Alpha radiation
- Beta radiations
- Gamma radiations

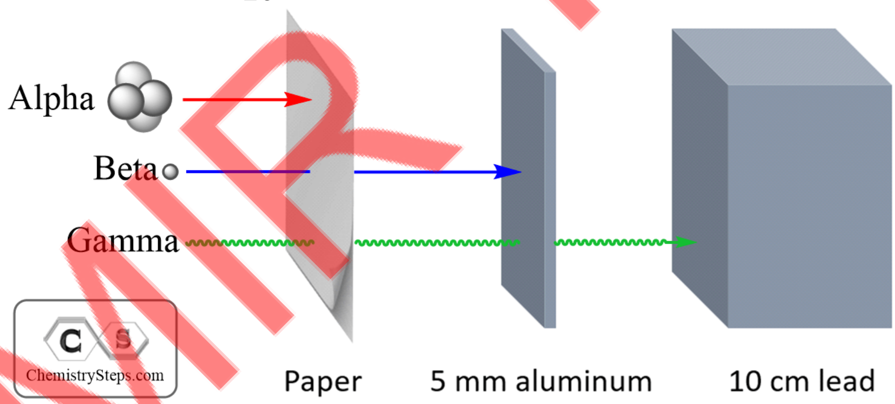
## Alpha radiations



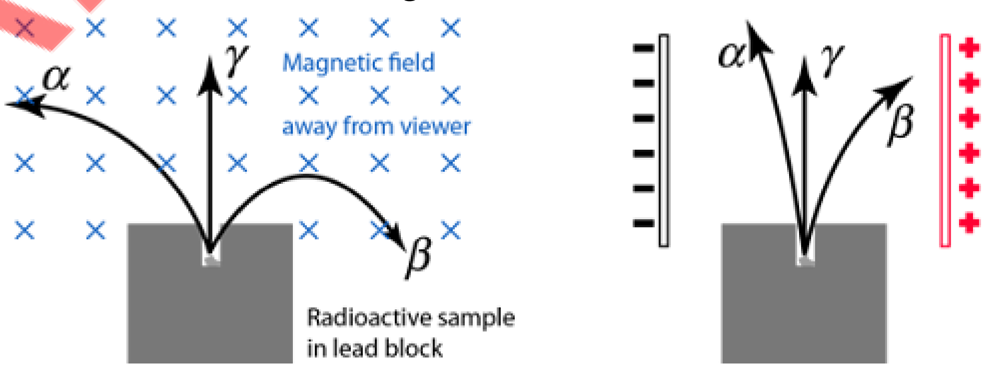

1. They consists of particles which are called Alpha particles.
2. Alpha particle consists of two protons and two neutrons.




3. Alpha particle is represented by the Symbol $^{4}_{2}\alpha$ , $^{4}_{2}He$
4. It is also called Helium Nucleus.
5. It carries Positive charge which is equal to 2 times charge of proton.
6. Its mass is equal to 4 times mass of proton.
7. Its speed in air is equal to $\frac{1}{10}$ of speed of light.

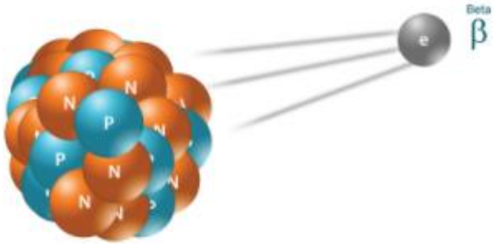



8. Its range in air is 5cm and it can be stopped of a paper sheet.
9. It is deflected in both electric and magnetic fields.

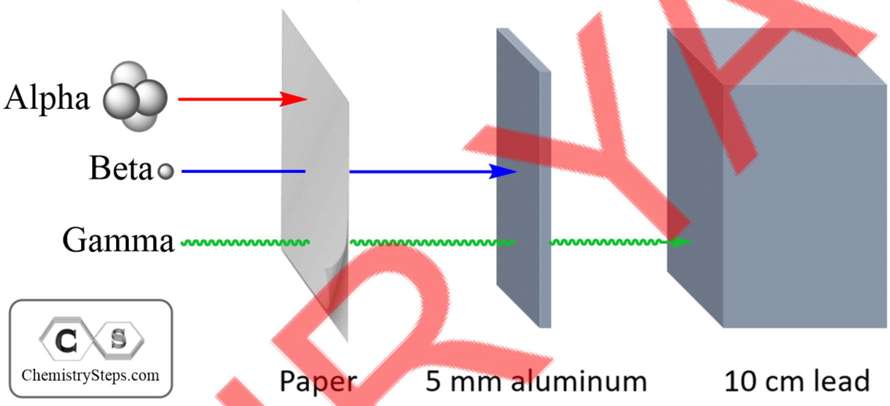



10. It produces ionizations is gases and its ionizing power is very high.

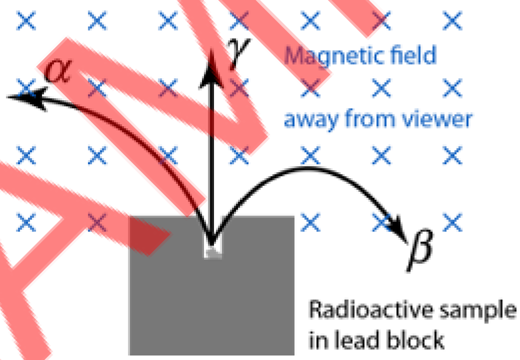
## Beta Radiations

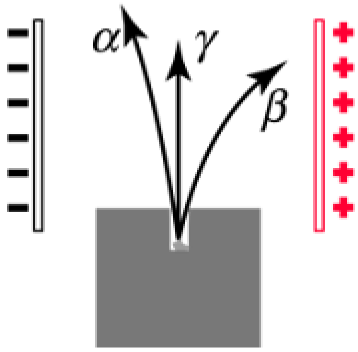



1. Beta radiations consists of particles which are called beta particle.
2. Beta particle consists of an electron.
3. Beta particles is represented by the symbol $^{0}_{-1}\beta$ or $^{0}_{-1}e$
4. It carries negative charge which is equal to charge on electron.
5. Its mass is equal to $\frac{1}{1840}$ time mass of proton.
6. Its speed in air is equal to $\frac{9}{10}$ times speed of light.



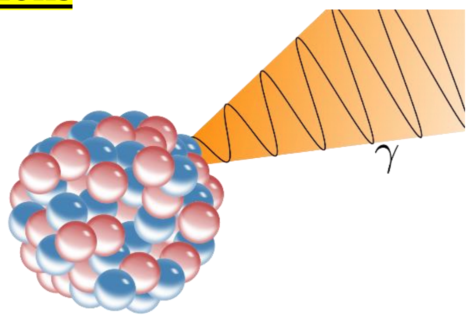

7. Its range in air is 50 cm and it can be stopped by a 5mm thick sheet of aluminum.
8. It is deflected in both electric and magnetic fields.



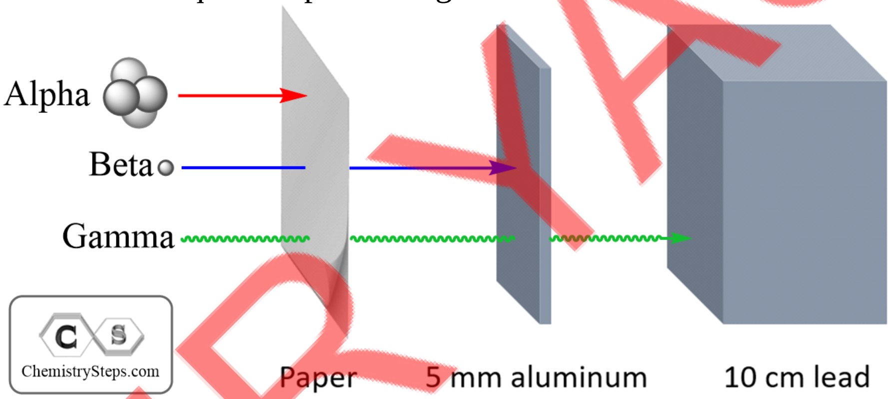




9. It produces ionization in gases but its ionizing power is less than of Alpha radiaitons.

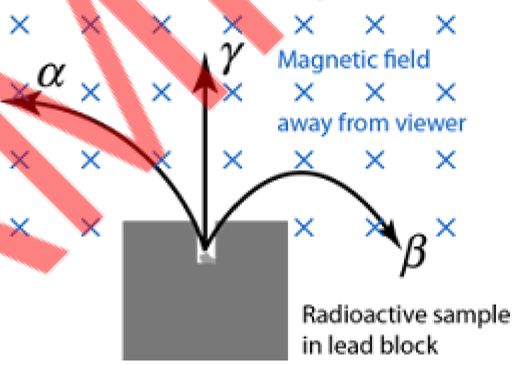
## Gamma Radiations

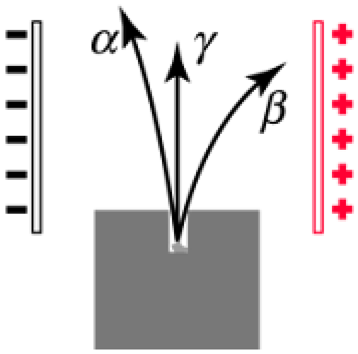



1. Gamma radiations are electromagnetic waves.
2. They carry energy.
3. They are represented by symbol .
4. They are charge less.
5. They are mass less.
6. Their speed in air is equal to speed of light.




7. Their range in air is infinite and they are stopped by lead block of 5cm thickness.
8. They are not deflected by electric or magnetic fields.




9. They also produce ionization in gases but their ionizing power is very low.

## Alpha Decay

When element emits Alpha particle then its mass number decreases by four units and atomic number decreases by two units.

$$ {}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha $$

**Example**

$$ {}^{208}_{48}P_o\text{(polonium)} \longrightarrow {}^{204}_{82}P_o\text{ (lead) } + {}^{4}_{2}\alpha + \text{Energy} $$

In this reaction, energy is in the form of Kinetic Energy of alpha particle and daughter nucleus.

## Beta Decay

When element emits beta particle then mass number remains the same but atomic number increases by one unit.

$$ {}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}X' + {}^{0}_{-1}\beta $$

**Example**

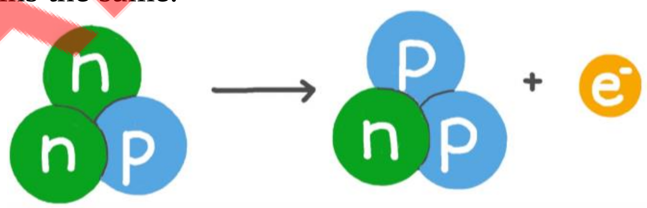
$$ {}^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta + \text{Energy} $$

Energy is in the form of Kinetic Energy of beta particle and daughter nucleus.

## NOTE

When nucleus emits beta particle then one neutron splits into a proton and an electron. Electron comes out of nucleus as beta particle.

Since one proton is increased therefore atomic number increases by one unit and mass number remains the same.



## Gamma Decay

When element emits gamma radiations then its mass number and atomic number remains unchanged.

$${}^{A}_{Z}X^{*} \longrightarrow {}^{A}_{Z}X + \gamma$$

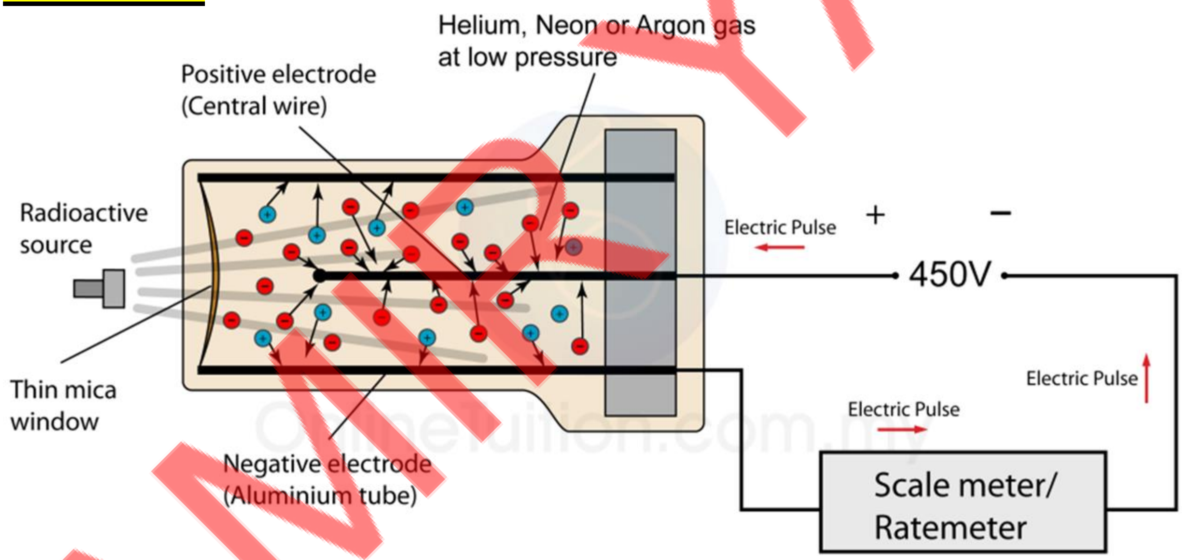
## Example

$${}^{29}_{14}Si \longrightarrow {}^{29}_{14}Si + \gamma$$

## NOTE

Gamma radiation is emitted by the source after the emission of alpha or beta radiations. The gamma radiation is emitted at the same time as alpha or beta or it may be emitted some time later.

## Geiger-Muller Tube
## GM Tube




- GM tube can be used to detect the presence of radioactive radiations.
- When GM tube is placed in front of radioactive source, radiations entre into tube through the window and produce ionization in the gas present in the tube.
- Positive ions are attracted towards the can and Negative ions are attracted towards the rod.
- Negative ions then pass through the rate meter and neutralize positive ions.
- For each Negative ions passing through the rate meter, it shows a count on the screen and a click / beep sound is produced.
- More the count rate shown on the screen of rate meter more the intensity of radioactive radiations.

## Background Radiations

Radioactive radiations which are already present in air is called background radiations. If we place GM tube in air without placing radioactive source in front of tube then rate meter will still show some count.
It is due to background radiation and is called background count.

## Sources of Background radiations

**1.** Natural Source
**2.** Artificial Source

## Natural Source

- Radioactive radiations are present in air due to radon gas which comes from uranium rocks which are present below the ground.
- Radioactive radiations comes from some radioactive material we use in our houses for example granite.
- Radioactive radiations reach to us from space inform cosmic rays some of these rays come from sun and form further out from space.
  Most of cosmic rays are stopped by the atmosphere of Earth.
- If you live up a mountain, you will be exposed to more radiations from this source.

## Artificial Source

- Radioactive radiations are present in air due to medical sources for example X-rays and gamma radiation used for destroying cell.
- Radioactive radiations are also present in air due to nuclear reactors and their waste and testing of nuclear weapons.
- Since background radiations are present in air therefore firstly we measure background count and then we subtract it from the count-rate due to radioactive source to get actual count-rate to radioactive source only.

## Half Life

Average time in which half of atoms of a radioactive source decay is called half life of radioactive element.

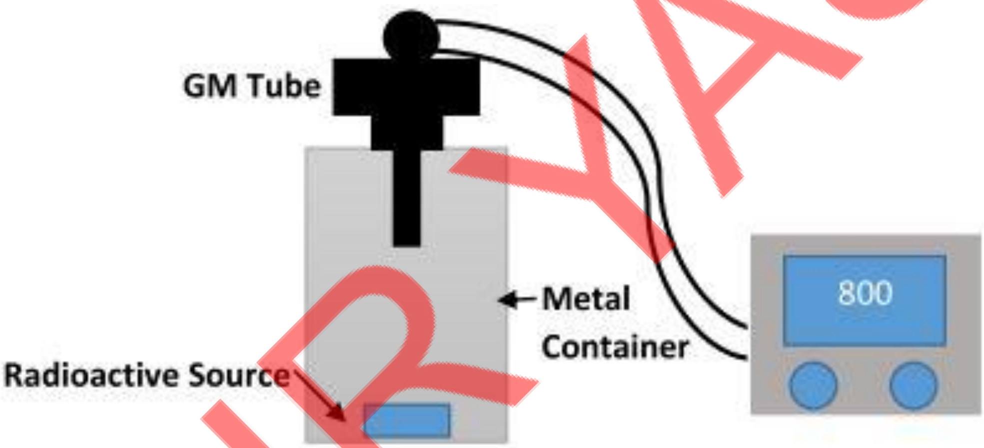
## Example

Let's say initially there are 800 atoms in a radioactive element.
Its half-life is 5 min. then after 5min, 400 atoms will be left in radioactive element after further 5min, 200 atoms will be left and then after further 5 min 100 atoms will be left and so on.

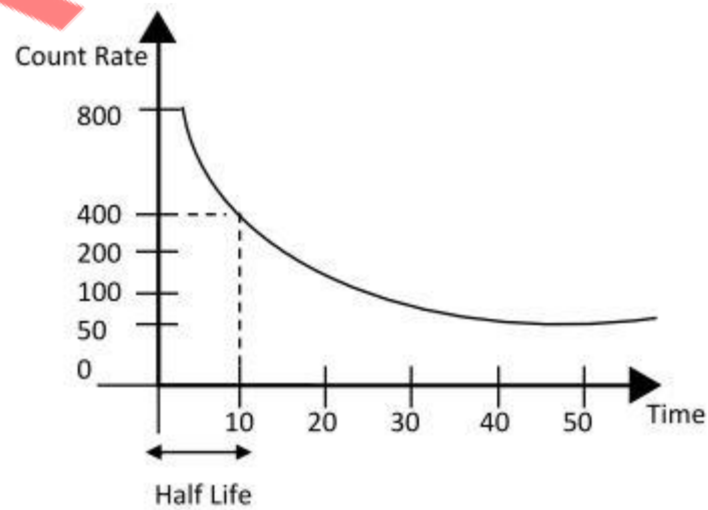
## NOTE

Different radioactive elements have different half-lives but for a certain radioactive element half-life remains fixed.

## Determination of Half life




- Place a radioactive source in metal container then place GM-tube in the container and seal the container connect the G-M tube with the rate meter.
- Now note the count rate shown by the rate meter after a fixed internal of time, let's say after every 10s then plot a graph of count rate (y-axis) and time (x-axis).
- This graph is called decay curve.
- Find the time from graph for count rate to decrease to half of its initial value.
- This time will represent half-life of radioactive element.



# Dangers / Hazards of Radioactive Radiation

## Contamination

If radioactive substance gets inside our body then we say that we have been contaminated.

## Irradiation

If radiations produced by radioactive source hit our bodies then we say that we have irradiated.

There are three ways in which radiations can damage living cells.

**1.** When cell is exposed to radiation then ionization is produced in cell which destroys the cell. This is also called burning of cell.

**2.** If DNA of cell is damaged due to radiations then cell may be divided uncontrollably and tumor is formed this is how radiation causes cancer.

**3.** If affected cell is a gamete (a sperm or egg cell), the damaged DNA of its genes may be passed on to future generations. This is how radiation produced future mutations. i.e babies are born with genetic disorder.

## Safe Handling of Radioactive source

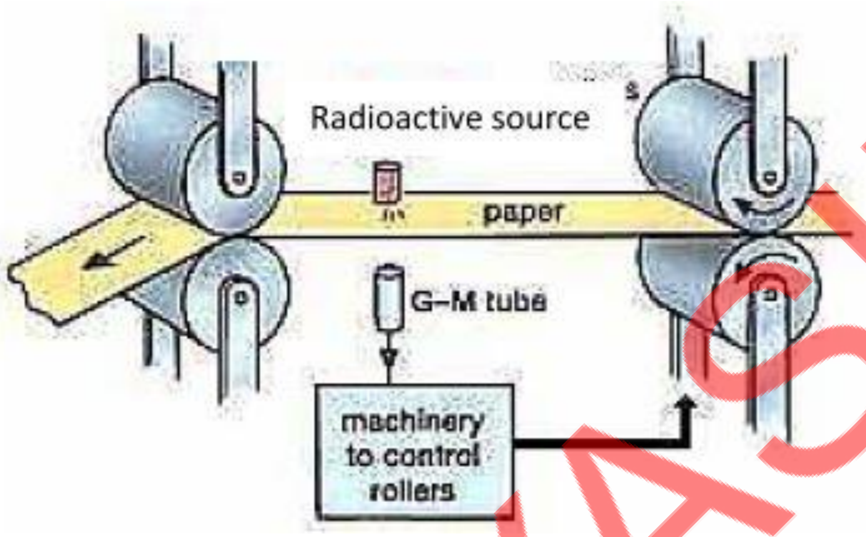
**1.** Radioactive source should be placed in a lead box.

**2.** Tongs can be used to handle the radioactive source to avoid direct contract with the source.

**3.** A safe distance is kept from the radioactive source daring the experiment.

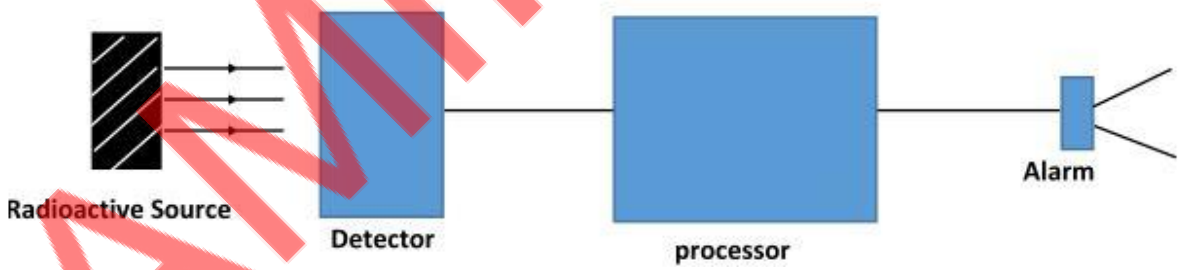
# Uses of Radioactive Radiations

## 1. Thickness Measurement

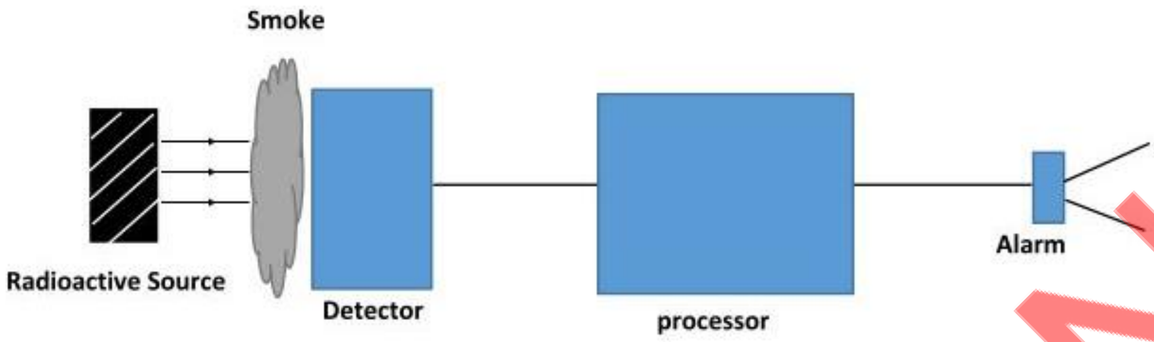



- Manufacture of paper / plastic sheet monitor the thickness of paper sheet using radioactive radiations.
- Radioactive source is placed to one side and detector is placed to other side of the sheet. If count rate remains stable then its means that thickness is uniform but if count rate fluctuates then it means thickness is not uniform.
- If thickness changes it can be re-adjusted from the paper making plant.
- Beta radiations are used for thickness measurements.

## 2. Smoke Detector




- When radiations fall on detector it produces its own current which cancels out the current already present in processor therefore net current in processor is zero and hence alarm is silent.




- When smoke enters the gap between radioactive source and detector then it absorbs the radiations.
- Current is not produced by the detector.
- Current which is already present in processor turns on the alarm.

## 3. Medical Diagnosis

- The diagnosis of some disease may be carried out using a source of gamma radiation.
- The patient is injected with a radioactive chemical that targets the problem area (It may accumulate in bone).
- Then camera detects the radiations coming from the chemical and gives the image of tissue under investigation.

## 4. Radiation Therapy

- Tumors can be destroyed using gamma rays.
- Gamma rays are directed towards tumor that is to be destroyed.

## 5. Food Irradiator

- Microbes often decay food.
- Microbes can be destroyed using gamma rays.
- This method of preserving food is called food irradiation.

## 6. Sterilization

- Medical instruments are sealed in plastic bag and then exposed to gamma rays which kill the microbes.
- This method is called sterilization.

## 7. Fault Detection

- A metal pipe is wrapped with photographic film and then radioactive source is placed inside pipe X-ray picture and photographic film will indicate any fault in welding.

## Carbon Dating

Carbon has three isotopes i.e

$^{12}_{6}C$ , $^{13}_{6}C$ and $^{14}_{6}C$

$^{12}_{6}C$ and $^{13}_{6}C$ are stable isotopes but $^{14}_{6}C$ is unstable i.e it is radioactive with half life equal to 5400 years. Every living object in text carbon both $^{13}_{6}C$ and $^{14}_{6}C$. When any object plant or animal dies then it stops taking further carbon $^{12}_{6}C$ remains unchanged i.e its mass remains unchanged because it is not radioactive but $^{14}_{6}C$ decays and its mass inside the dead plant or animal decreases.

Now by comparing mass of $^{12}_{6}C$ and $^{14}_{6}C$ of dead plant or animal we can find that when this plant or animal died.

For example if mass of $^{14}_{6}C$ is half of $^{12}_{6}C$ then it means that plant or animal died 5400 years ago mass of $^{14}_{6}C$ is ¼ of mass of $^{12}_{6}C$ then it died 10800 years ago and so on.