



Dr. Bbosa Science

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## S4 New Curriculum Physics

**Theme: Modern physics**

**Chapter 5 – Atomic model**

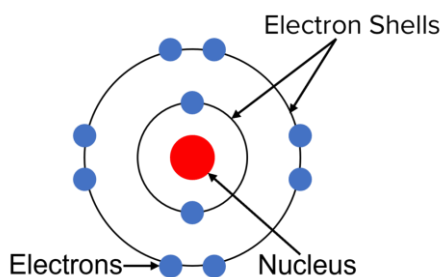
### An atom

It is the smallest invisible, electrically neutral particle of an element that can take part in a chemical reaction.

An atom is composed of electrons, protons and neutrons the properties of which are given in the table below:

components	symbol	charge	mass
Proton	p	+1	1
Neutron	n	0	1
Electron	e	-1	$\frac{1}{1840}$

The **protons** and **neutrons** are situated in the **nucleus** whereas the **electrons** rotate around the nucleus in definite **shells** around the nucleus.



Basic Atomic Structure

### Definitions

**Atomic number (A)** is the number of protons present in the nucleus of an atom. The number of protons are usually equal to the number of electrons.

**Atomic mass (Z)** is the sum of protons and neutron in an atom

For any element X the atomic number, A, and atomic mass, Z, are represented as follows



All atoms of the same element contain the **same number of protons**.

### Trial 1

Fill in the relevant information of the first 20 elements in the table below:

Hint: you may consult a Periodic Table

Name	Symbol	Atomic number	Atomic mass	Number of electrons	Number of neutrons	Formula of atom
Hydrogen	H	1				${}^1_1\text{H}$
Helium		2				
Lithium						
Beryllium						
Boron		5				
Carbon		6				
Nitrogen	N	7				
Oxygen						
Fluorine						
Neon						
Sodium		11				
Magnesium	Mg		24			
Aluminium			27			
Silicon			28			
Phosphorus			31			
Sulphur		16	32			
Chlorine	Cl		35			
Argon			40			
Potassium	K	39	39			
Calcium			40			

## Ions

The electronic configuration of noble gases is very stable. This is why noble gases do not take part in any chemical reactions. Atoms combine to attain the noble gas configuration.

Elements attain this noble configuration by either losing or acquiring electrons.

An atom, which has either acquired or lost electron(s) is called an **ion**

**Positively charged ions** are produced by loss of electrons while negatively charged ions are produced by acquiring electrons

### Trial 2

Fill in the missing information in the table below

Element	Ion	Atomic number	Number of electrons in an atom	Number of electrons in an ion
Mg	$\text{Mg}^{2+}$			10
Cl	$\text{Cl}^-$	17		
Na	$\text{Na}^+$		11	
O	$\text{O}^{2-}$	8		

## Isotopes

**Isotopes** are atoms of the same element having the same atomic number but different number of neutron and thus different atomic mass. Examples of isotopes of hydrogen are indicated in the table below

Isotopes of hydrogen	Number of protons	Number of neutrons	Atomic mass	symbol
Hydrpgen-1 (Hydrogen)	1	0	1	${}^1_1\text{H}$
Hydrogen-2 (Deuterium)	1	1	2	${}^2_1\text{H}$
Hydrogen-3 (Tritium)	1	2	3	${}^3_1\text{H}$

### Trial 3

Fill in the following table for the isotopes of carbon and oxygen

(a) Isotopes of carbon

Isotopes of carbon	Number of protons	Number of neutrons	Atomic mass	symbol
Carbon – 12	6			
Carbon – 13				
Carbon - 14				${}^{14}_6\text{C}$

(b) Isotopes of oxygen

Isotopes of Oxygen	Number of protons	Number of neutrons	Atomic mass	symbol
Oxygen – 16				${}^{16}_8\text{O}$
Oxygen – 17	8			
Oxygen - 18				

## Uses of isotopes

### 1. Medical Applications

- **Diagnosis:** Isotopes like *Technetium-99m* are used in imaging organs (like the heart or bones) through nuclear medicine scans.
- **Treatment:** *Iodine-131* treats thyroid disorders, while *Cobalt-60* is used in radiotherapy to target cancer cells.

### 2. Archaeology and Geology

- **Radiocarbon Dating:** *Carbon-14* helps determine the age of ancient organic materials—like fossils or artifacts—up to about 50,000 years old.
- **Geological Tracing:** *Argon-39* and other isotopes help date rocks and understand Earth's history.

### 3. Energy Production

- **Nuclear Fuel:** *Uranium-235* and *Plutonium-239* are key fuels in nuclear reactors, releasing energy through fission.

### 4. Industrial Uses

- **Thickness Gauging:** *Cesium-137* and *Cobalt-60* help measure the thickness of materials like paper, plastic, or metal sheets during manufacturing.
- **Leak Detection:** Tracer isotopes are used to detect leaks in pipelines or underground systems.

## 5. Agriculture

- **Soil and Fertilizer Studies:** *Nitrogen-15* helps track how plants absorb nutrients, improving fertilizer use.
- **Pest Control:** Sterile insect techniques use radiation from isotopes to control pest populations without chemicals.

## 6. Environmental Science

- Isotopes help trace pollution sources, study water cycles, and monitor climate change through ice cores and sediment analysis.

### Trial 4

- (a) What is meant by atomic number of an element
- (b) One isotope of neon is denoted by  ${}^{20}_{10}\text{Ne}$ . How many neutrons does the isotope have?

### Nuclide

A nuclide is a nucleus of an atom of specific isotope. It is characterised by the number of positively charged protons (Z), Neutrons (N) and the energy of the nucleus. Examples are given in the table below

Nuclide	Number of protons	Number of neutrons
Chlorine - 37	17	20
Chlorine - 35	17	18
Sodium – 23	11	12

### Electron emission

Electrons may be emitted from metal surfaces when supplied with energy. This can be done by either exposure of the metal surface to light or heat.

#### Definitions

**Photoelectric emission** is the liberation of electrons from a metal surface by use of light or electromagnetic radiations of suitable frequency. That is, the light (radiation) supplies the electrons with an amount of energy equal or exceeding the energy that binds them to the surface.

Note: Photo-electric emission take place only if the frequency of incident radiation is above certain minimum value called the threshold frequency, ( $f_0$ ).

**Thermionic emission** is the liberation of electrons from a metal surface by application of heat.

**Photoelectrons** are electrons liberated by light striking a metal surface.

**Photo emissive surfaces** are metal surfaces that emit electrons when struck by light.

**Work function** is the minimum amount of energy required by an electron to escape from the metal surface

### Trial 5

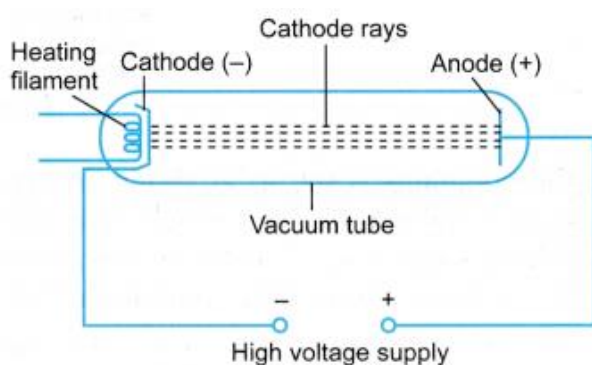
- (a) What is meant by
- Thermionic emission
  - Photoelectric effect
- (b) State the conditions necessary for photoelectric effect to take place

### Cathode rays

These are streams of fast moving electrons that travel from the cathode to the anode.

#### Production of cathode rays

Cathode rays are produced in a discharge tube by thermionic emission as shown in the diagram below



**Figure** Vacuum tube

- Electrons are released from the hot filament or cathode by thermionic emission.
- High voltage is applied between the cathode and the anode accelerates a stream of electrons at high speed towards the anode. This stream of electrons which is moving at high speed is called cathode rays.
- The **vacuum tube** is an evacuated glass tube where streams of electrons can move without any obstruction by air molecules.

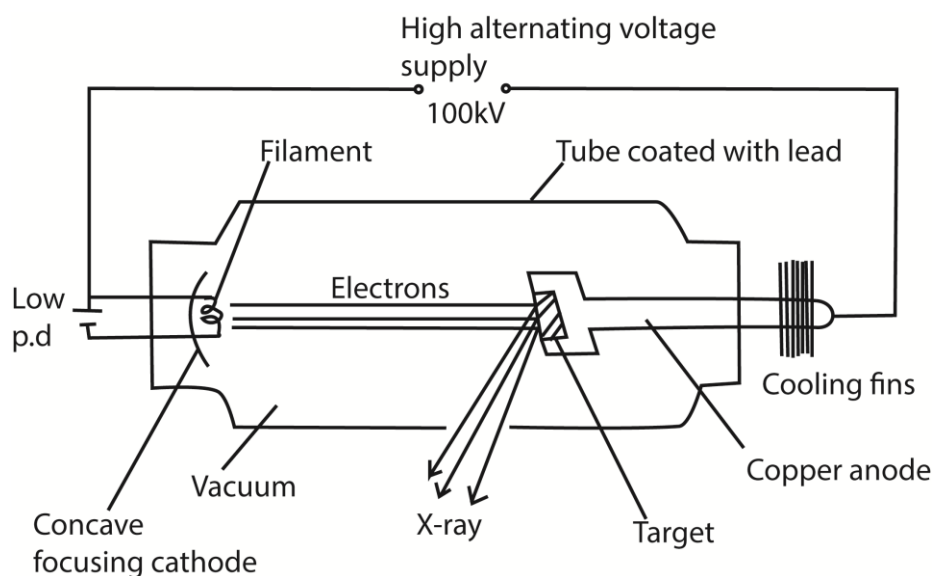
#### Properties of cathode rays

- They travel in straight lines.
- They are negatively charged.
- They are deflected by both electric and magnetic fields.
- They cause fluorescence in some metals e.g. Zinc metal.
- They ionize gaseous atoms.
- They affect photographic plates.
- They produce X – rays when stopped by a metal target.
- They possess momentum therefore they have mass.

## X-Rays

X- Rays are electromagnetic radiations of short wavelength produced when fast moving electrons are stopped by heavy metal target.

### Production of X – Rays



### Mode of operation

- The filament is heated by a low voltage supply and the electrons are emitted by thermionic emission.
- The concave focusing cathode focuses the electrons from the filament onto the target.
- These electrons are accelerated towards the anode by the high voltage between the filament and the Anode.
- When the electrons (cathode rays) strike the metal target, about only 1% their kinetic energy is converted to X-rays and the 99% of their kinetic energy is converted to heat, which is conducted away by the cooling fins.

### Properties of X –rays

- (i) They travel in a straight line at a speed of light in vacuum
- (ii) They are not deflected by both magnetic and electric fields. This indicates that they carry no charge.
- (iii) They penetrate all matter to some extent. Penetration is least in materials with high density and atomic number e.g. lead.
- (iv) They ionize gases through which they pass.
- (v) They affect photographic plates.
- (vi) They cause fluorescence in some materials.
- (vii) They cause photoelectric emission
- (viii) They are diffracted by crystals leading to an interference pattern.

## Uses of X-rays

1. Structural analysis, stresses, fractures in solids, castings and welded joints can be analysed by examining X-ray photograph.
2. Crystallography; Orientation and identification of minerals by analysis of diffraction patterns using Bragg's law.
3. Medical uses;
  - i) Analytical uses. These include location of fractures, cancer and tumor/defective tissue absorbs x-rays differently from normal tissue.
  - ii) Therapeutics use for destroying cancerous cells and tumors.
4. Detection of fire arms at international airports

## Health hazards caused by x-rays:

- Destroy living cells in our bodies especially hard X-rays.
- Cause Gene mutation (genetic changes in our bodies).
- Cause damage of our eye sight and blood. ☑ Produce deep skin burns.

NOTE: It's highly important to remember that each time you are exposed to X-rays, your health is also at risk yet we cannot live without them

## Safety precautions:

- Avoid unnecessary exposure to X-rays.
- When exposure is necessary, keep it as short as possible.
- X-ray beams should ONLY be restricted to the body part being investigated.
- A worker should wear a shielding jacket with a layer of Lead.
- Exposure should be avoided for unborn babies and very young children.

## Differences between cathode rays and X-rays

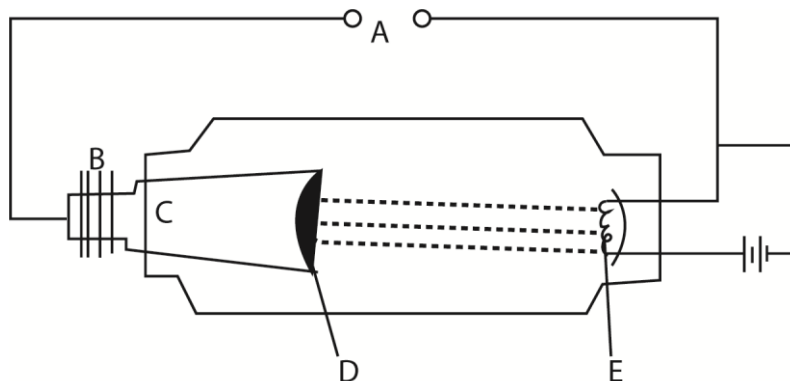
Cathode rays and X-rays are both types of radiation, but they're quite different in nature, origin, and behavior. Here's a quick breakdown of their key differences:

Property	Cathode Rays	X-rays
<b>Nature</b>	Streams of <b>electrons</b> (particles with mass and charge)	<b>Electromagnetic waves</b> (no mass, no charge)
<b>Production</b>	Produced in a <b>discharge tube</b> when high voltage is applied between electrodes	Produced when high-energy electrons <b>strike a metal target</b> (e.g., in X-ray tubes)
<b>Charge</b>	<b>Negative</b> charge (since they are electrons)	<b>Neutral</b> , since they're electromagnetic radiation
<b>Path Behavior</b>	Deflected by electric and magnetic fields	Not deflected by electric or magnetic fields
<b>Penetration Power</b>	Relatively <b>low</b> —stopped by thin metal or glass	<b>High</b> —can pass through body tissues and many materials
<b>Effect on Photographic Plates</b>	Can darken photographic plates	Also darken photographic plates—used in medical imaging

<b>Speed</b>	Slower—depends on accelerating voltage	Speed of <b>light</b> in a vacuum
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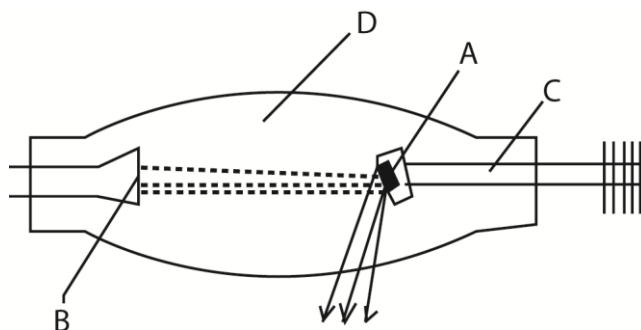
### Trial 6

1. The diagram below shows essential parts of an X-ray tube



- name the parts A, B, C, D, E and F
- State one function of each parts in (i).
- Describe how X-ray are produced
- Give the safety precautions taken by people working with in X-ray environment.

2. The figure below shows the main parts of an X-ray tube



- Name parts labelled A, B, C and D.
- List the order the energy changes which occur in x-ray tube
- Describe one industrial use of X-rays.
- what is meant by half-life of radioactive material
  - the activity of radioactive source decreases from 4000 counts per minutes to 250 counts per minute in 40 minutes. What is the half-life of the source?

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Thanks

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