Solution

In 100g of water, the weight of hydrogen	=	11.11 g
The weight of oxygen	=	100 – 11.11 = 88.89 g
In 100g of sulphur dioxide, the weight of sulphur	=	50 g
Weight of oxygen	=	100 – 50 = 50 g

The ratio between the weight of oxygen and Hydrogen is 88.89:11.11 i.e. 8:1 (1)

In hydrogen sulphide, the weight of sulphur = 94.11 g

The weight of hydrogen = 100 – 94.11 = 5.89 g

The ratio between the weight of sulphur and hydrogen is 94.11: 5.89 ie. 16: 1 … (2)

The two ratios 1 and 2 are related as 8/1: 16/1 (or) **1 : 2**

These are simple multiples of each other. The ratio between the weight of sulphur (32) and oxygen (16) which combine separately with the weight of Hydrogen (2) supports **the law of reciprocal proportions.**

Activity 3

1 gram of hydrogen combines with 15.88 gram of sulphur. 1 gram of hydrogen combines with 7.92 gram of oxygen. 8 gram of sulphur combines with 7.92 gram of oxygen. Show that these data illustrate the law of reciprocal proportions.

5.2.1 Gay Lussac's law of Combining Volumes

Whenever gases react together, the volumes of the reacting gases as well as the products bear a simple whole number ratio, provided all the volumes are measured under similar conditions of temperature and pressure

Step 1: Hydrogen combines with oxygen to form water (word equation)

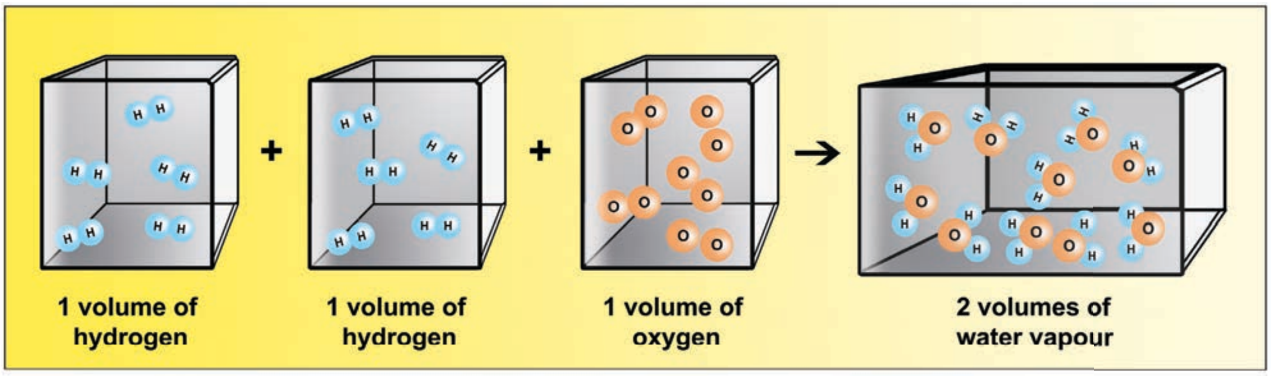
Step2: $H_2 + ½ O_2 \rightarrow H_2O$ (skeletal equation)

Step3: $2H_{2(g)} + O_{2(g)} \rightarrow 2H_20$ (g) (balanced equation)

(2 Volumes) + (1 Volume)→(2 Volumes) **(2:1:2)**

i.e. two volumes of hydrogen react with 1 volume of oxygen to form two volumes of water vapour. i.e. the ratio by volume which gases bears is **2:1:2** which is a simple whole number ratio.

It follows that at a given temperature and pressure the volumes of all gaseous reactants and products bear a simple whole number ratio to each other.



Two volumes of hydrogen react with One volume of oxygen to give Two volumes of water vapour

Let us consider one more example:

Step 1: Hydrogen combines with chlorine to form hydrogen chloride

Step2: $H_2 + Cl_2 \rightarrow 2HCl$

Step 3: $\underset{1\,\text{volume}}{H_{2(g)}} + \underset{1\,\text{volume}}{Cl_{2(g)}} \rightarrow \underset{2\,\text{volumes}}{2HCl_{(g)}}$

[1 : 1 : 2]

i.e. one volume of hydrogen reacts with one volume of chlorine to form two volumes of HCl gas. i.e. the ratio by volume which gases bears is **1:1:2** which is a simple whole number ratio.

Activity 4

Nitrogen combines with hydrogen to form ammonia (NH_3). Illustrate Gay Lussac's law using this example.

Solved Problem

Methane burns in oxygen to form carbon dioxide and water vapour as given by the equation

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)+}\ 2H_2O_{(g)}$$

Calculate: (i) the volume of oxygen needed to burn completely 50 cm^3 of methane and (ii) the volume of carbon dioxide formed in this case.

Solution:

$CH_{4(g)}$	$+2O_{2(g)}$	$\rightarrow CO_{2(g)}$	$+2H_2O_{(g)}$
1 volume	2 volumes	1 volume	2 volumes
1 x 50 cm^3	2 x 50 cm^3	1 x 50 cm^3	2 x 50 cm^3
50 cm^3	100 cm^3	50 cm^3	100 cm^3

Volume of oxygen used = 100 cm^3

Volume of carbondioxide formed = 50 cm^3

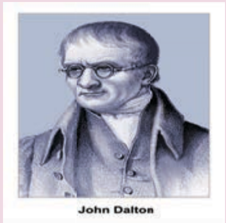
Activity 5

100 cm^3 of propane (C_3H_8) was burnt in excess oxygen to form carbon dioxide and water. Calculate (i) the volume of oxygen used up (ii) the volume of carbon dioxide formed.

[Hint: $C_3H_8(g) + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O(l)$]

More about of structure of atoms

Know your Scientist



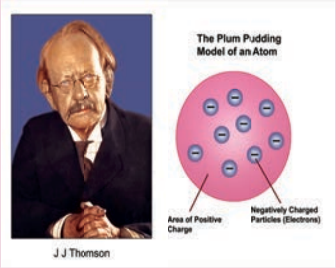
John Dalton

John Dalton FRS was an English chemist, physicist, and meteorologist. He is best known for proposing the modern atomic theory and for his research into colour blindness, sometimes referred to as Daltonism in his honour.

You already have a basic idea of Dalton's atomic theory, J. J. Thomson's Cathode ray experiments, and limitations of Thomson's model of atom.

Let us recall:

According to John Dalton: Matter consists of very small and indivisible particles called atoms. Atoms can neither be created nor be destroyed. The atoms of an element are alike in all respects but they differ from the atoms of other elements. Atoms of an element combine in small whole numbers to form molecules.

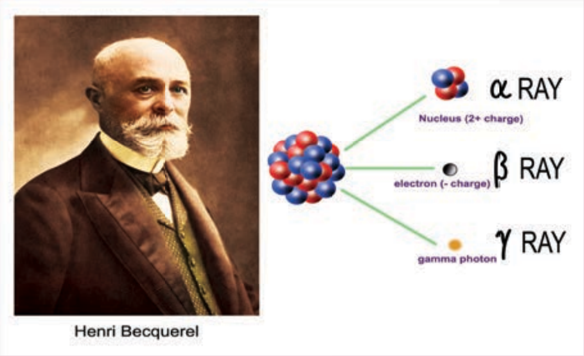


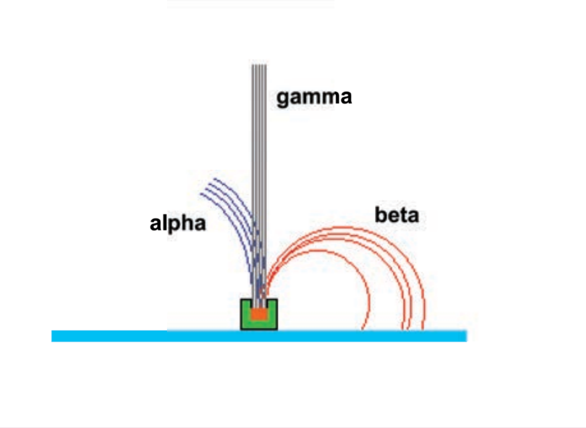
J J Thomson

J J Thomson said that like plums in pudding the negatively charged electrons are dotted here and there in a positively charged sphere. According to this 'plum pudding' model, an atom is considered to be a sphere of uniform positive charge and electrons are embedded into it.

MORE TO KNOW: RADIOACTIVITY

In 1896, Henri Becquerel arranged in his cupboard, a packet of uranium salt beside an unexposed photographic plate. Several days later, he took out the plate and developed it. To his surprise, he noticed that the photographic plate had been exposed without having been exposed to the light. Having repeated this experiment, he concluded that some stream of particles came out from Uranium. Today we call them as alpha particle.

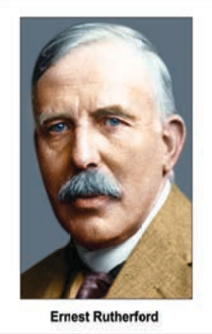




Alpha (α), beta (β) and gamma(γ) rays are emitted during the radioactive decay of an atom. The alpha and beta rays consist of actual matter form, while *gamma rays* are electromagnetic waves. The alpha particles which are the main constituent of the alpha radiation are made up of two protons and two neutrons. An alpha particle is identical with a Helium nucleus. Hence it is positively charged and has mass equal to a Helium atom.(He^{2+}). Beta particle is negatively charged and is identical with electron. Gamma rays have no charge. Rutherford used a stream of alpha particles for his experiment which is discussed below.

5.3 Discovery of Nucleus

Know your Scientist

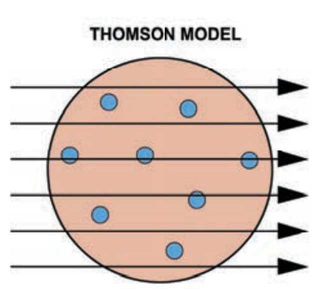


E. Rutherford (1871-1937) was born at Spring Grove on 30th August 1871. He was the 'Father' of nuclear physics. He is famous for his work on radioactivity and the discovery of the nucleus of an atom with the gold foil experiment. He got the Nobel Prize in chemistry in 1908. He was the first to produce Tritium in 1934.

Thomson's model of atoms is a conceptual representation like many other models in science. Scientists test scientific models by doing experiments to find out if they were wrong. The model proposed by Thomson was conceptual. Scientists were eager to test it by doing an experiment. How would you test if the model is correct or wrong? They are so small that even a powerful microscope is useless in peering inside an atom.

In 1905, Ernest Rutherford along with his scholars Hans Geiger and Ernest Marsden came up with an interesting idea to test the Thomson's model. In Thomson's model recall that the charges are symmetrically distributed. Suppose you shoot a highly energetic positively charged particle smaller than an atom, to collide at an atom, what do you expect? As the incoming particle is positive, it should be repelled by the positive atom. This is because you know that "like charges repel each other." If according to plum pudding model, the positive charge of atoms is evenly distributed; it should be very small at each point inside the atom. But as the energy of the incoming particle is higher than the repulsion at the point of contact, the particle should overcome the repulsion and penetrate the atom.

Once it is inside the atom, the positively charged particle is repulsed on all sides with the same force. Assuming that atom is a uniformly positively charged mass with random moving electrons, the particle should come out of the other end of the atom almost undeflected. Some of the electrons inside the atom could attract the positively charged particle and make small change in the path. Therefore it can be predicted that deviation if any, be less than a small fraction of a degree and is negligible.

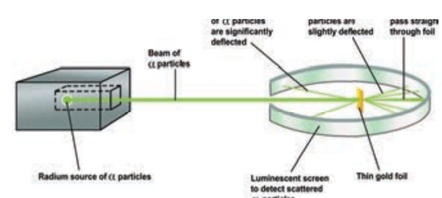


5.3.1 Rutherford's α–ray scattering experiment

Alpha particles are positively charged it possess adequate energy to overcome the repulsive force of positive charge, if the charge is evenly distributed in an atom. As you probably know, according to Coulomb's law, the less concentrated a sphere of electric charge is, the weaker is its electric field at its surface.

Atoms are so small that you cannot pick them one by one to be kept as a target and shoot alpha particles. Gold as you may know is a highly malleable metal and can be made in to a very thin layer.

They arranged an experimental set up. A natural radioactive source that emitted highly energetic alpha particles was chosen. The source was kept inside a lead box with a small hole in it. Alpha particles came out of the source in all directions. Those particles which hit the walls of the box were absorbed by it. Only those alpha particles that were emitted in the direction of the hole could escape. These rays of alpha particles followed a straight line.



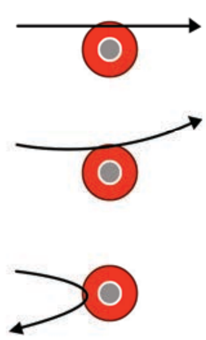
A thin gold foil, about 400 atoms thick, was kept on the path of the alpha particle. They also kept a circular screen coated with zinc sulphide surrounding the foil. When an alpha particle hit the screen, it would produce fluorescence glow in the point where they struck the screen. From the point on the screen, one can infer the path taken by the alpha particle after penetrating the gold foil. The whole set up was kept inside a vacuum glass chamber, to avoid alpha particles from interacting and getting scattered by air molecules.

The experiments were repeated for reproducibility. Each time when the experiment was conducted, they computed and tabulated the angle of the rays of alpha particle after it hits the gold foil. They observed the following.

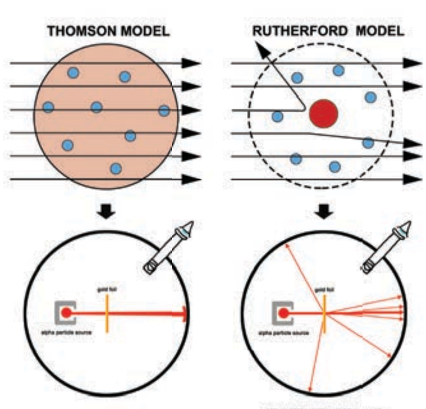
(i) Most of the fast moving α-particles passed straight through the gold foil.

(ii) Some α particles were deflected by small angles and a few by large angles.

(iii) Surprisingly very few α particles completely rebounded.



The experiments showed that most of the alpha particles behaved as expected, but there was a small discrepancy. Out of every 2000 particles that got scattered, just one was deflected by a full 180°. That is, they simply retraced their path after hitting the gold foil. You know that change of direction is possible only if a strong enough force acted against the direction of the motion of the particle.



Based on the plum pudding model of the atom, it was assumed that there was nothing dense or heavy enough inside the gold atoms to deflect the massive alpha particles from their paths. However, what Rutherford actually observed did not match his prediction. These observations indicated that a new model is needed to account for the evidences gathered in the experiment.

Rebound of alpha particle was impossible under the Thomson model. The alpha particle could have been deflected at 180° only if the positive charge was concentrated at a point rather than dispersed throughout the atom. If all the positive charge of the atom was concentrated at a small area inside the atom, only then, the electrostatic repulsion would be strong enough to bounce them back at 180°.

Now two observational evidence were before Rutherford and his team

1) Most of the particles passed are not deviated as there was no obstruction to their path: This should imply that most part of the atom is empty

2) Some alpha particle was deflected right back; implying that the positive charge should be concentrated at the centre of atom.

To be sure that their findings were really correct, the team performed the same type of experiments with many other materials including gases between the period 1908 and 1913.

Based upon these evidences, Rutherford rejected the Thomson's idea and proposed that all the positive charges are concentrated in the central region of the atom called 'nucleus', and electrons orbit the nucleus at a distance. Further he stated that in between the nucleus and electron inside an atom there existed a void. This came to be called as planetary model of atom.

5.3.2 Rutherford's model of an atom- salient features

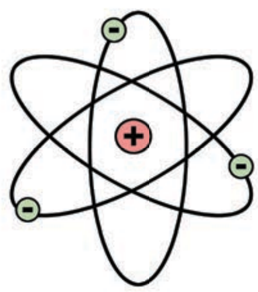
(i) Atom has a very small nucleus at the centre.

(ii) There is large empty space around the nucleus.

(iii) Entire mass of an atom is concentrated in a very small positively charged region which is called the nucleus.

(iv) Electrons are distributed in the vacant space around the nucleus.

(v) The electrons move in circular paths around the nucleus.

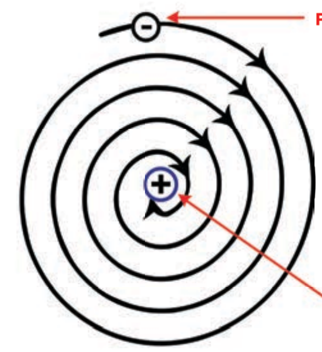


Rutherford Model of the Atom

5.3.3 Limitations in Rutherford's model

Although the model suggested by Rutherford went beyond the one by Thomson and explained the behaviour of alpha particles, it also left a few questions unanswered. Planets can go around the Sun under the gravitational attraction. But negatively charged electron should be attracted by the positively charged nucleus, since opposite charges attract. But it does not happen that way.

It was shown by Clark Maxwell that a charged body moving under the influence of attractive force loses energy continuously in the form of electromagnetic radiation. Thus unlike a planet the electron is a charged body and it emits radiations while revolving around the nucleus. As a result, the electron should lose energy at every turn and move closer and closer to the nucleus following a spiral path consequently the orbit will become smaller and smaller and finally the electron will fall into the nucleus. In other words, the atom should collapse. However, this never happens and atoms are stable.



Thus the stability of the atom could not be explained by Rutherford Model. There were also a few more objections to his model. This led on to more research and evolving better models of atomic structure.

5.3.4 Bohr's model of an atom

Know your Scientist

Niels Bohr

Niels Bohr was born on October 7, 1885 in Copenhagen, Denmark. He was also an outstanding soccer player. He worked with Rutherford at the university of Manchester. Bohr received the Nobel Prize for Physics in 1922.

A new model of atom was needed because Rutherford model could not explain the stability of atom. Neils Bohr developed a successful model of hydrogen atom. In order to justify the stability of an atom Neils Bohr made some improvements on Rutherford's model. The main postulates are:

i. In atoms, electrons revolve around the nucleus in certain special or permissible orbits known as discrete orbits or shells or energy levels

ii. While revolving in these discrete orbits the electrons do not radiate energy.

iii. The circular orbits are numbered as 1, 2, 3, 4,… or designated as K, L, M, N, shells. These numbers are referred to as principal quantum numbers (n).

iv. K shell (n=1) is closest to the nucleus and is associated with lowest energy.
L, M, N, …. etc are the next higher energy levels. As the distance from the nucleus increases the energy of the shells also increases.

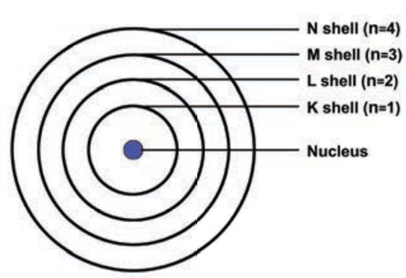
v. The energy of each orbit or shell is a fixed quantity and the energy is quantized.

vi. As the distance from the nucleus increases, the size of the orbits also increases.

vii. Maximum number of electrons that can be accommodated in an energy level is given by $2n^2$ where n is the principal quantum number of the orbit.

viii. When an electron absorbs energy, it jumps from lower energy level to higher energy level.

ix. When an electron returns from higher energy level to lower energy level, it gives off energy.



DO YOU KNOW?

How big are atoms?

Very small! An average atom is 0.000,000,001 metre. (one millionth of 1 mm) across. Blow up a balloon, It seems to contain nothing and weight almost nothing. But it contains about one hundred billion billion atoms which make up the gases in the air.

5.3.5 Limitations of Bohr's model

Many arguments were raised against Bohr's model of an atom. One main limitation was that his model was applicable only to Hydrogen. It could not be extended to multi electron atoms. Hence more research and deeper study of atoms became necessary. A detailed study of these aspects will be done in higher classes.

Orbit or shell:

Orbit is defined as the path by which electrons revolve around the nucleus.

Illustration:

The number of electrons in the first orbit (K)(n = 1);2 x 1^2 = 2

The number of electrons in the second orbit (L) (n = 2); 2 x 2^2 = 8

Activity 6

Calculate the number of electrons present in the third (M) and fourth orbits (N)

5.4 Discovery of Neutrons

In 1932 James Chadwick observed when Beryllium was exposed to alpha particles, particles with about the same mass as protons were emitted.

DO YOU KNOW?

In 1920 Rutherford predicted the presence of another particle in the nucleus as neutral. James Chadwick, the inventor of neutron was student of Rutherford

$_4Be^8 + \alpha \text{ rays} \longrightarrow {_6C^{12}} + \text{Neutron (n)}$
Beryllium + Alpha rays ⟶ carbon + neutron

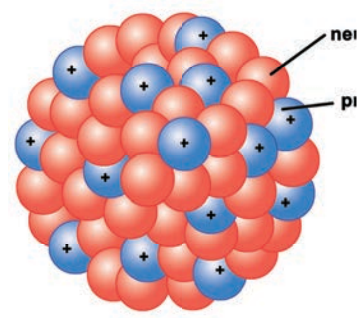
These emitted particles carried no electrical charges. They were called as neutrons. Neutrons present in the nuclei of all the atoms except of hydrogen. The mass of a neutron is almost equal to the mass of proton. Neutron is represented by n.

5.4.1 Composition of nucleus

Electrons have a negligible mass; hence the mass of the atom mainly depends on the mass of the nucleus. Nucleus of an atom consists of two components, they are protons and neutrons.

Protons are positively charged. Protons repel each other because of their like charges. Hence more than one proton cannot be packed in a small volume to form a stable nucleus, unless neutrons are present.

Neutrons reduce the repulsive force between the positively charged protons and contribute to the force that holds the particles in the nucleus together.



DO YOU KNOW? The strong force that binds proton and neutron is more powerful than gravity.

5.4.2 Nucleons

The elementary particles such as protons and neutrons are collectively called as Nucleons. Why are atoms neutral? Because an atom contains the same number of protons and electrons and hence it's neutral.

Characteristics of fundamental particles

The physical and chemical properties of elements and their compounds can be

Particles	Mass	Charge		Location	Mass relative to Hydrogen atom
		Unit	Coulomb		
Electron	9.108×10^{-28}g	–1	-1.602×10^{-19}	Orbit	1/1837
Proton	1.672×10^{-24}g	+1	1.602×10^{-19}	Nucleus	1
Neutron	1.674×10^{-24} g	0	-	Nucleus	1

Activity 7

Complete the following table:

Particles	Mass	Charge	Location	Scientist who discovered
Electron	?	–1	?	J.J. Thomson
Proton	1.672×10^{-24}gm	?	Nucleus	?
Neutron	?	0	?	James Chadwick

explained by the fundamental particles of an atom. The fundamental particles are proton, neutron and electron.

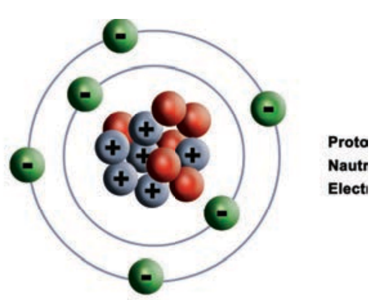
> **DO YOU KNOW?** Besides the fundamental particles like protons, electrons and neutrons some more particles are discovered in the nucleus of an atom. They include mesons, neutrino, antineutrino, positrons etc.

Terminology

Atomic Number (Z)

The figure shown here represents an atom.

Using the colour code given below



	Proton	?
	Neutron	6
	Electron	?

Count the number of protons, electrons and complete the table. Are the number of protons and electrons the same?

An atom of an element has its own characteristic number of protons in its nucleus, which distinguishes it from the atoms of other elements. Hence proton is considered to be the finger print of an atom.

This characteristic number (Number of protons) is called the atomic number of the element. Atomic number is denoted by Z.

What is the Atomic number of the above element?

Since there are 6 protons, the atomic number = 6.

The number of electrons = 6, which is the same as the atomic number.

Atomic number of an atom is therefore equal to the number of protons and it is also equal to the number of electrons present.

> In a neutral atom
>
> Atomic Number = Number of protons = Number of electrons

Illustration:

An atom has 11 protons, 11 electrons and 12 neutrons. What is the atomic number and the name of the element?

Atomic number = Number of protons = Number of electrons

Number of protons = Number of electrons = 11

$\therefore$ Atomic number = 11

Name of the element is Sodium.

> **Test Yourself**
>
> An atom 'A' has 7 protons, 7 neutrons and 7 electrons. Atom 'B' has 9 protons, 9 electrons and 10 neutrons. Identify the Atomic number and names of A and B

Mass Number:(A)

From Rutherford's experiment it was clear that the mass of the atom is concentrated in the nucleus. This means that mass of an atom is practically due to protons and neutrons which are present in the nucleus. Protons and neutrons together are also called nucleons.

Mass number of the element is the total number of protons and neutrons present in the nucleus.

Mass number is denoted by A

Mass number = Number of protons + Number of neutrons

For example if an atom has 3 protons, 3 electrons and 4 neutrons, then its mass number will be equal to 7 (3 protons+ 4 neutrons)

Test Yourself

An atom has 15 protons, 15 electrons and 16 neutrons. What is the mass number?

Symbolic representation of an atom using Atomic Number and Mass Number

An atom can be represented by its symbol with atomic number as subscript and mass number as superscript.

Mass Number		A
	Symbol of element	X
Atomic Number		Z

For example, nitrogen is written as $^{14}_{7}N$

Here **7** is its atomic number and **14** is its mass number.

Activity 8

Symbolically represent the following atoms using atomic number and mass number.

a) Carbon b) Oxygen c) Silicon d) Beryllium

Relationship between Mass Number and Atomic Number:

Mass Number (A) = Atomic Number (z) + Number of Neutrons(n)
Atomic Number (Z) = Number of Protons or Number of Electrons

$$\boxed{A = Z + n}$$

DO YOU KNOW?

Atomic number designated as Z why?
Z stands for Zahl, which means NUMBER in German.
Z can be called Atomzahl or atomic number
A is the symbol recommened in the ACS style guide instead of M (massenzahl in German)

Sample Problem (solved):

Calculate the atomic number of an element whose mass number is 39 and number of neutrons is 20. Also find the name of the element.

Solution:

Mass Number = Atomic Number + Number of neutrons
Atomic Number = Mass Number – Number of neutrons
= 39 – 20
Atomic Number = 19
Element having Atomic Number 19 is Potassium (K)

Complete the following table: Pair work

Elements	Atomic Number	Mass number	No. of protons	No. of electrons	No. of Neutrons
Beryllium	?	9	4	4	?
Oxygen	8	?	?	8	8
Magnesium	12	24	?	?	12
Aluminum	?	27	13	?	?

Do It Yourself

Calculate the atomic number of the element whose mass number 31 number of neutron is 16 and find the name of the element.

DO YOU KNOW?

Chlorine got from natural resources (Sea water) has fractional atomic mass. Why is it so?

This is due to the presence of isotopes.

An atom can have a fractional atomic mass (Relative atomic mass) For example:

Chlorine has fractional atomic mass.

Chlorine – 35 exists by 75% Chlorine – 37 exists by 25%

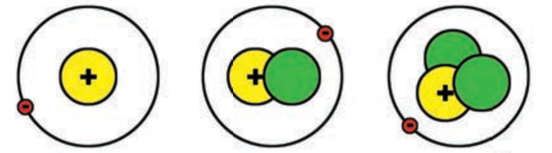
$$35 \times \frac{75}{100} + 37 \times \frac{25}{100} = 35.5 \text{ amu}$$

Fractional atomic mass of Chlorine is [(75/100)x 35] + [(25/100)x37] = 35.5

5.5 Isotopes (Iso – same, topo – place, Isotope – same place

5.5.1 ISOTOPES

Find below three different atoms. Count the different subatomic particles and fill in the table.



More to Know

Thumb rule for isotopes and isobars. Remember **t** for top and **b** for bottom.
Isotope: Top value changes – atomic mass
Isobars: Bottom value changes – atomic number

What do you observe in the above atoms?

Which is same and what is different in them?

All of them have the same number of protons and electrons but different number of neutrons.

What will they have in common?

All the three structures have same atomic number but different mass numbers. They have the same number of electrons also. Such atoms of the same element are called isotopes.

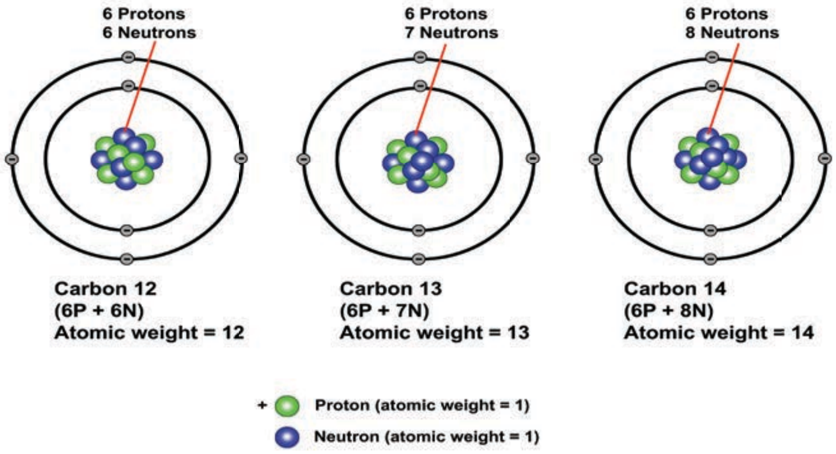
Isotopes are atoms of the same element having same atomic number but different mass numbers.

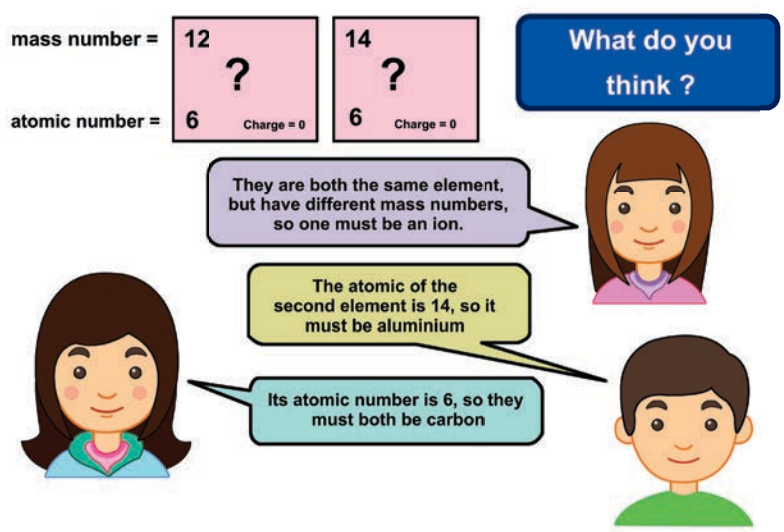
This is due to the difference in the number of neutrons in the nucleus. Isotopes differ in few physical properties such as density, boiling point etc. Physical properties depend upon mass number. Isotopes have different mass numbers. So they differ in physical properties.

DO YOU KNOW?

Lightning can trigger nuclear reaction, creating rare atomic isotopes.

Lightning





Example: Isotopes of carbon

Activity 9

Draw the structures of the isotopes of oxygen O^{16} and O^{18}

Atomic number of oxygen = 8

Why do some isotopes show radioactivity?

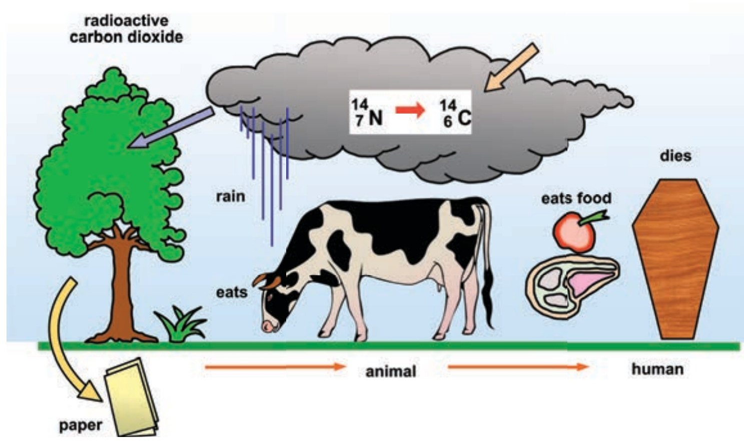
When the number of neutrons exceeds the number of protons in the nucleus of atoms, some nuclei become unstable. These unstable nuclei break up spontaneously emitting certain type of radiations. They are known as radioactive isotopes. Examples: H^3 and C^{14}

Many elements have isotopes of which some of them are radioactive isotopes.

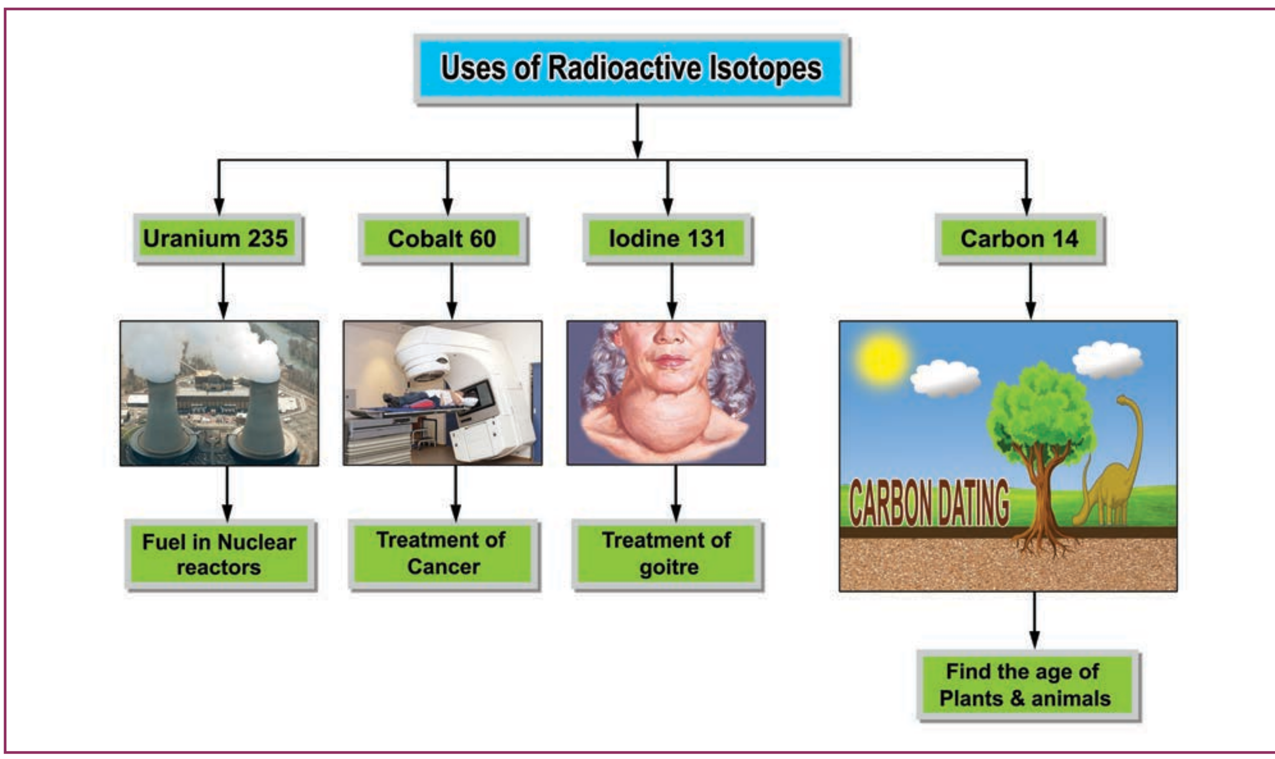
Uses of radioactive isotopes

Radioactivity prevails around us. The food we eat, the air we breathe, the buildings we live in, all contain small amounts of radioactive materials. This radiation will be present always.

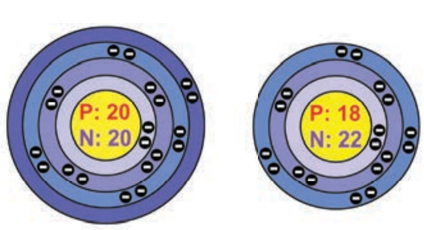
Thus there are a lot of low level natural radioactivity around us. For example, our bodies contain radioisotopes, such as potassium-40, which continuously emit radiation, but the level is so low that this does not harm us.The picture below shows us how radioactive carbon(C^{14}) is all around us.



But the special properties of radioactive isotopes make them useful to us in various fields.



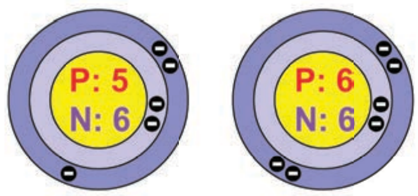
5.5.2 Isobars



What is the difference between these two atoms?

The above two elements calcium and argon have atomic number 20 and atomic number 18 respectively. This means they have different number of protons and electrons. But the mass number of both these elements is 40. It follows that the total number of nucleons in both of them are the same. Atoms of different elements with different atomic numbers, which have the same mass number, are known as isobars.

5.5.3 Isotones



The above pair of elements Boron and Carbon has the same number of neutrons but different number of protons and hence different atomic numbers. Atoms of different elements with different atomic numbers and different mass numbers, but with the same number of neutrons are called isotones.

Activity 10

Draw the model of the following pairs of isotones:

Fluorine & Neon (ii) Sodium & Magnesium (iii) Aluminum and Silicon

How are electrons arranged around the nucleus in an atom?

So far we have been discussing about the nucleus of an atom and the protons and neutrons which constitute the nucleus. We also saw that electrons are extra nuclear particles and they revolve around the nucleus in fixed trajectories or orbits. Let us now see how electrons are arranged in different orbits. The systematic arrangement of electrons in various shells or orbits in an atom is called the electronic configuration.

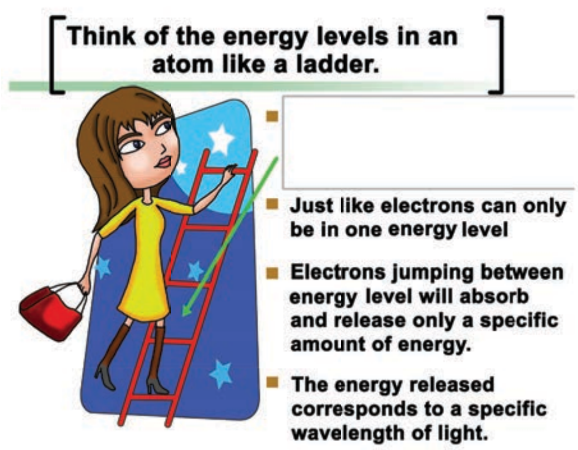
Electronic configuration of atoms:

You already know that electrons occupy different energy levels called orbits or shells.The distribution of electrons in these orbits of an atom is governed by certain rules or conditions. These are known as **Bohr and Bury Rules of electronic configuration.**

Bohr and Bury simultaneously proposed the following rules for the distribution of electrons in different shells.

- **Rule 1:** The maximum number of electrons that can be accommodated in a shell is equal to $2n^2$ where 'n' is the quantum number of the shell (i.e., the serial number of the shell from the nucleus).

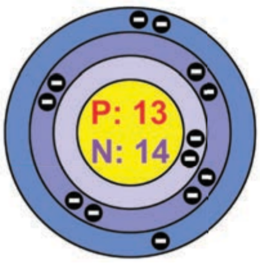
Shell	Value of (n)	Maximum number of electrons ($2n^2$)
K	1	$2 \times 1^2 = 2$
L	2	$2 \times 2^2 = 8$
M	3	$2 \times 3^2 = 18$
N	4	$2 \times 4^2 = 32$



- **Rule 2:** Shells are filled in a **stepwise manner** in the increasing order of energy.
- **Rule 3:** The outermost shell cannot have more than 8 electrons and the next inner, i.e., the penultimate shell cannot have more than 18 electrons.

Illustration:

Structure of Aluminium atom: (13 electrons)
K shell = 2 electron, L shell = 8, M Shell – 3
So its electronic configuration is 2, 8, 3



Atoms are so tiny their mass number cannot be expressed in grams but expressed in amu (atomic mass unit). New unit is U Size of an atom can be measured in nano metre ($1nm=10^{-9m}$)Even though atom is an invisible tiny particle now-a-days atoms can be viewed through SEM that is Scanning Electron Microscope.

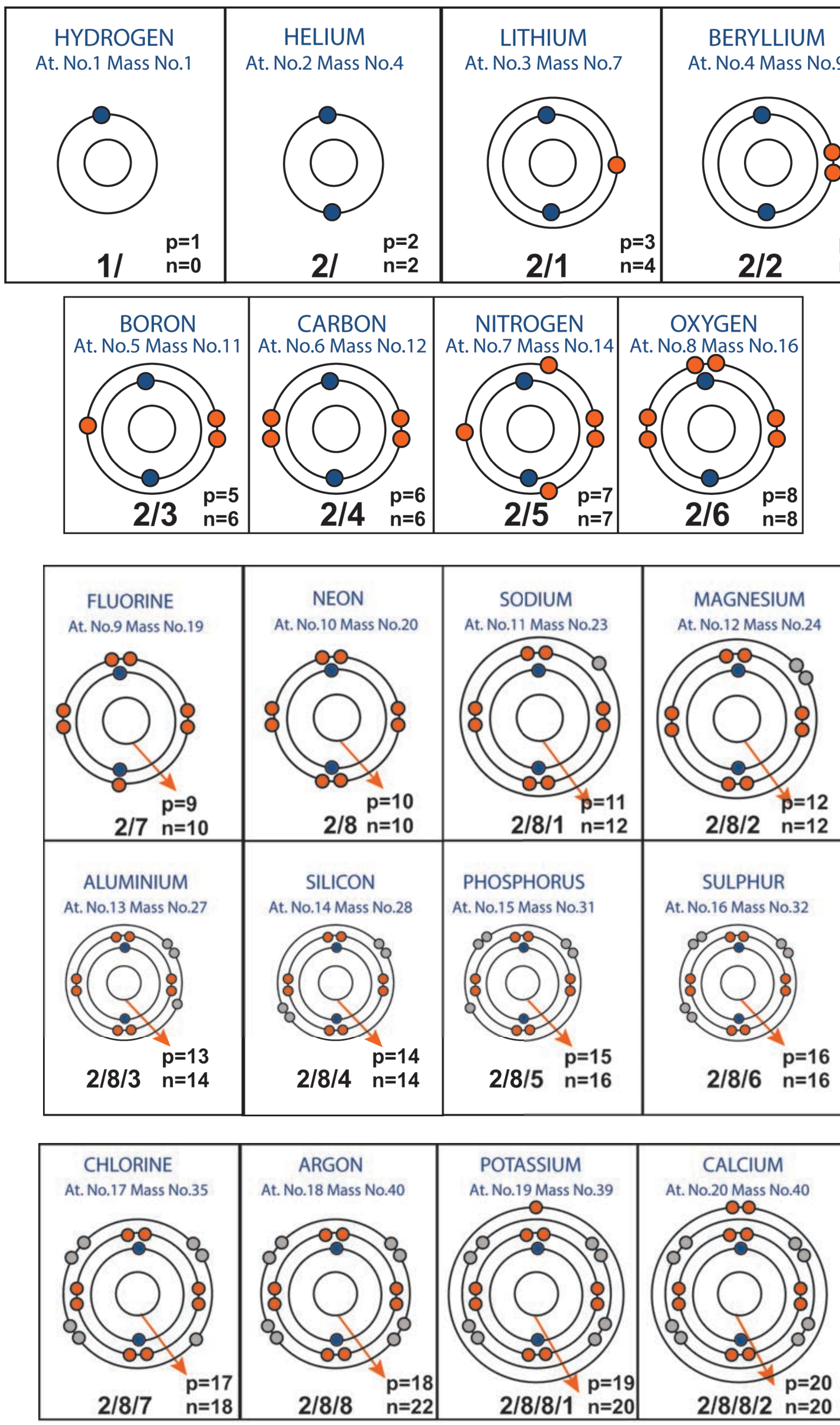
EH95JN

Electronic configuration of first 20 elements

Element	Symbol	Atomic Number	Electronic configuration or Electron distribution			
			K	L	M	N
Hydrogen	H	1	1			
Helium	He	2	2			
Lithium	Li	3	2	1		
Beryllium	Be	4	2	2		
Boron	B	5	2	3		
Carbon	C	6	2	4		
Nitrogen	N	7	2	5		
Fluorine	F	9	2	7		
Neon	Ne	10	2	8		
Sodium	Na	11	2	8	1	
Magnesium	Mg	12	2	8	2	
Aluminium	Al	13	2	8	3	
Silicon	Si	14	2	8	4	
Phosphorus	P	15	2	8	5	
Sulphur	S	16	2	8	6	
Chlorine	Cl	17	2	8	7	
Argon	Ar	18	2	8	8	
Potassium	K	19	2	8	8	1
Calcium	Ca	20	2	8	8	2

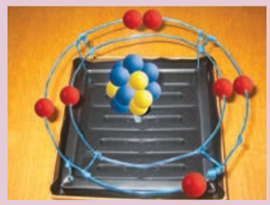
For getting a basic idea about the electron distribution around the nucleus we can draw schematic diagrams as shown below. As you learn more about atomic structure you will come to know that the real picture of electron distribution is entirely different from what we have shown here.

Schematic diagrams for Atomic Structure of Elements (first 20)



Activity 11

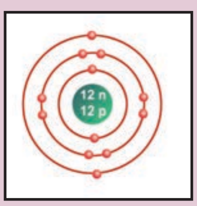
Look at the model given below. Make groups of five. Each group can make models of 4 elements by using available materials like balls, beads, string etc.



Activity 12

Electronic configuration of some elements are given below. Elements follow the sequence of their atomic numbers.

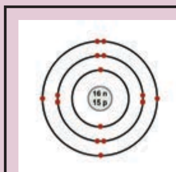
Complete the blank spaces.



?

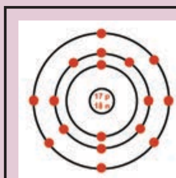
Aluminium

Silicon



?

Sulphur



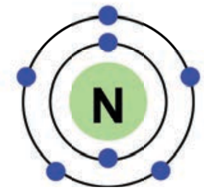
?

Argon

Potassium

5.5.4 Valence electrons

How many electrons are in the outermost shell? 5



The outermost shell of an atom is called its valence shell and the electrons present in the valence shell are known as valence electrons.

Hydrogen atom has only one electron in its valence shell. Hence it has **one** valence electron. Similarly carbon has 4 electrons in the outermost shell and so it has **4 valence electrons.**

The chemical properties of elements are decided by these valence electrons, since they are the ones that take part in chemical reaction.

The elements with same number of electrons in the valence shell show similar properties and those with different number of valence electrons show different chemical properties. Elements, which have valence electrons 1 or 2 or 3 (except Hydrogen) are **metals.**

These elements can lose electrons to form ions which are positively charged and are called **cations**.

Eg: $Na - e^- \rightarrow Na^+$
2, 8, 1 → 2, 8

Elements with 4 to 7 electrons in their valence shells are **non-metals.**

These elements can gain electrons to form ions which are negatively charged and are called **anions**.

Eg: $Cl + e^- \rightarrow Cl^-$ (Chlorine has valence electrons 7)
2, 8, 7 → 2,8,8

5.5.5 Valency

Valency of an element is the combining capacity of the element with other elements and is equal to the number of electrons that take part in a chemical reaction. Valency of the elements having valence electrons 1, 2, 3, 4 is 1, 2, 3, 4 respectively.

While valency of an element with 5, 6 &7 valence electrons is 3, 2 and 1 (8–valence electrons) respectively, where 8 is the number of electrons required by an element to attain stable electronic configuration. Elements having completely filled outermost shell show **Zero valency**.

For example: The electronic configuration of Neon is 2,8 (completely filled). So valency is **0**.

Illustration:

Assign the valency of Magnesium & Sulphur

Electronic configuration of magnesium is 2, 8, 2. So valency is 2.

Electronic configuration of sulphur is 2, 8, 6. So valency is 2 i.e.(8 – 6)

Activity 13

Assign the valency for Phosphorus, Chlorine, Silicon and Argon

Introduction to Quantum Numbers

We have learnt to designate orbits (shells) by K,L,M, N …., and orbitals (sub shells) as s, p, d and f. We have seen that electrons are filled in to these orbitals according to certain rules. Can we now designate an electron in an atom in a manner in which it gets a unique identity? Each electron inside of an atom has its own 'identity' which is given by **four quantum numbers** that communicate a great deal of information about that electron.

The numbers which designate and distinguish various atomic orbitals and electrons present in an atom are called quantum numbers.

How would you describe to someone exactly where you live? I guess you would start with your address. (similar to the identity fo an electron).

When you specify the location of a building, you usually list which country it is in, which state and city it is in that country, then the area and the street and the door number.

Just like no two buildings have the exact same address, no two electrons can have the same set of **quantum numbers**.

A **quantum number** describes a specific aspect of an electron. Just like we have four ways of defining the location of a building (country, state, city, and street address), we have four ways of defining the properties of an electron, i.e.**four quantum numbers.**

These quantum numbers tell us

- how far is the electron from the nucleus,- **(Principal Quantum number)**
- which orbital does it occupy and what is its shape **(Azimuthal Quantum number)**
- how this orbital is oriented in space **(Magnetic Quantum number)**
- what kind of spin the electron has. **(Spin Quantum number)**:

Quantum Number	Symbol	Information conveyed
Principal quantum number	n	Main energy level
Azimuthal quantum number	l	Sub shell/ shape of orbital
Magnetic quantum number	m	Orientation of orbitals
Spin quantum number	s	Spin of the electron

You will learn more details about this in higher classes.

Key words

Atomic number	Isobars	Valency
Mass number	Isotones	Orbit
Nucleons	Electronic configuration	Orbital
Isotopes	Valence electrons	Quantum numbers

Points to Remember

- Rutherford's alpha-particle scattering experiment led to the discovery of the atomic nucleus.
- Rutherford's Planetary model of an atom proposed that nucleus of an atom is in the centre and electrons revolve around this nucleus.
- Neils Bohr's atomic model explained the stability of an atom.
- J.Chadwick discovered presence of neutrons in the nucleus.
- The atomic number of an element is the number of protons or electrons in an atom.
- Mass number of an element is the total number of protons & neutrons.
- Valence electrons are the electrons in the outermost orbit.
- Valency is the combining capacity of an atom.
- Isotopes are atoms of the same element, which have same atomic number but different mass numbers.
- Isobars are the atoms of the different element of same mass number but different atomic number.
- Isotones are the different element having same number of neutron but different atomic number and mass number.
- Simple diagrammatic representation may be used to depict electronic configuration of various elements.
- Quantum numbers designate an electron in an orbital.

A-Z GLOSSARY

1. **Atom** the smallest component of an element, and is also a nucleus with neutrons, protons and electrons.
2. **Atomic mass** the mass of an atom of a chemical element expressed in atomic mass units. It is approximately equivalent to the number of protons and neutrons in the atom (the mass number) or to the average number allowing for the relative abundances of different isotopes.
3. **Atomic number** the number of protons in the nucleus of an atom, which is characteristic of a chemical element and determines its place in the periodic table.
4. **Electron** a stable subatomic particle with a charge of negative electricity, found in all atoms and acting as the primary carrier of electricity in solids.

5. **Isotope** each of two or more forms of the same element that contain equal numbers of protons but different numbers of neutrons in their nuclei, and hence differ in relative atomic mass but not in chemical properties; "some elements have only one stable radioactive isotope".
6. **Isobar** each of two or more isotopes of different elements, with the same atomic weight.
7. **Isotone** one of two or more atoms having an equal number of neutrons but different atomic numbers.
8. **Mass number** the total number of protons and neutrons in a nucleus.
9. **Neutron** a subatomic particle of about the same mass as a proton but without an electric charge, present in all atomic nuclei except those of ordinary hydrogen.
10. **Orbitals** Atomic orbitals are regions of space around the nucleus of an atom where an electron is likely to be found. Atomic orbitals allow atoms to make covalent bonds. The most commonly filled orbitals are s, p, d, and f.
11. **Proton** a stable subatomic particle occurring in all atomic nuclei, with a positive electric charge equal in magnitude to that of an electron.
12. **Quantum number** a number which occurs in the theoretical expression for the value of some quantized property of a subatomic particle, atom, or molecule and can only have certain integral or half-integral values.
13. **Radical** molecule that contains at least one unpaired electron. Most molecules contain even numbers of electrons, and the covalent chemical bonds holding the atoms together within a molecule normally consist of pairs of electrons jointly shared by the atoms.
14. **Valency**: the property of an element that determines the number of other atoms with which an atom of that element can combine.

ICT CORNER

ATOMIC STRUCTURE

Atoms are building blocks. They are made of neutrons, protons and electrons.

This activity help the students to explore more about atoms and its components.

Step 1. Type the following URL in the browser or scan the QR code from your mobile.You can see on the screen. Click that.

Step 2. Select atom. Atomic orbit you can see with multiple options. Select protons, neutrons and electrons to their respective places. According to their numbers name of the elements appear on the periodic table. You can also find out whether the selected element is neutral or charged(ions)

Step 3. click"**symbol**"now. When you arrange electrons, neutrons and protons on the orbits you can see the name of the element, it's atomic number, atomic mass and number of electrons.

Step 4. Third option is games. It's an evaluation one to test your understanding

B121_9_SCI_EM

https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html

EHI1LB

EXERCISE

I. Multiple Choice Questions

1. Among the following the odd pair is
   a) $^{18}_{8}O$, $^{37}_{17}Cl$ b) $^{40}_{18}Ar$, $^{14}_{7}N$
   c) $^{30}_{14}Si$, $^{31}_{15}P$ d) $^{54}_{24}Cr$, $^{39}_{19}K$
2. Change in the number of neutrons in an atom changes it to
   a) an ion. b) an isotope.
   c) an isobar. d) another element.
3. The term nucleons refer to
   a) Protons and electrons
   b) only Neutrons
   c) electrons and neutrons
   d) Protons and neutrons
4. The number of protons, neutrons and electrons present respectively in $^{80}_{35}Br$
   a) 80, 80, 35 b) 35, 55,80
   c) 35, 35, 80 d) 35, 45, 35
5. The correct electronic configuration of potassium is
   a) 2,8,9 b) 2,8,1
   c) 2,8,8,1 d) 2,8,8,3

II. True or false / if false give the correct answer

1. In an atom, electrons revolve around the nucleus in fixed orbits
2. Isotopes of an element have the different atomic numbers
3. Electrons have negligible mass and charge.
4. Smaller the size of the orbit, lower is the energy of the orbit.
5. The maximum number of electron in L Shell is 10

III. Fill in the Blanks:-

1. Calcium and Argon are examples of a pair of ___________________
2. Total Number of electrons that can be accommodated in an orbit is given by _______________
3. ______________ isotope is used in the treatment of goiter
4. The number of neutrons present in $^{7}_{3}Li$ is _____________
5. The valency of Argon is ____________

IV. Match the following

i)

a) Dalton	1. Hydrogen atom model
b) Thomson	2. Planetary model
c) Rutherford	3. First atomic theory
d) Neils Bohr	4. Plum pudding model
	5. Discovery of neutrons

ii)

a) Mass of proton	1) 1.6×10^{-19} C
b) Mass of electron	2) -1.6×10^{-19} C
c) Charge of electron	3) 9.31×10^{-28} g
d) Charge of proton	4) 1.67×10^{-24} g

V. Complete the following table

Atomic Number	Mass Number	Number of Neutrons	Number of Protons	Number of Electrons	Name of the Element
9	-	10	-	-	-
16	-	16	-	-	-
-	24	-	-	12	Magnesium
-	2	-	1	-	-
-	1	0	1	1	-

VI. Arrange the following in the increasing order of atomic number

Calcium, Silicon, Boron, Magnesium, Oxygen, Helium, Neon, Sulphur, Fluorine and Sodium

VII. (a) Cross word puzzle

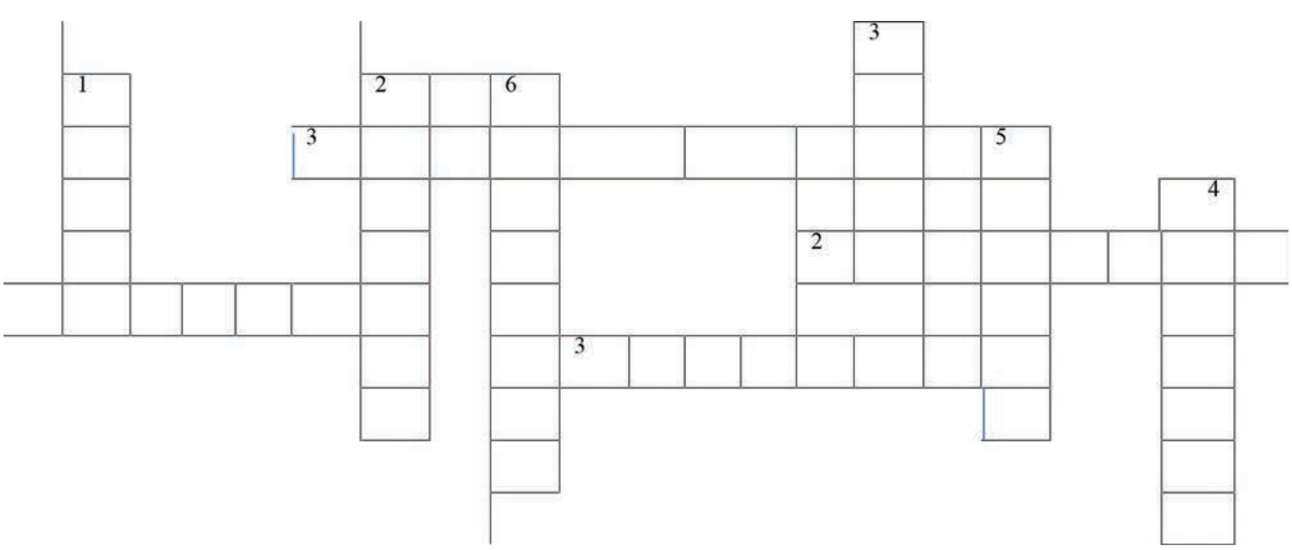
Clues:

Down:

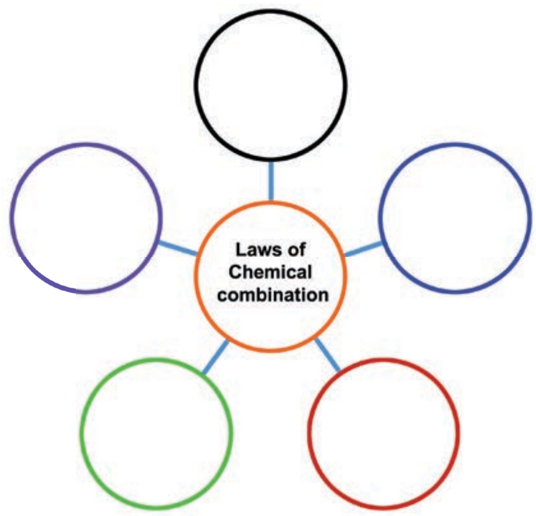
1. Helium Nuclei (Particle)
2. Positive Charge mass at the core of the atom
3. An atom whose valency is zero
4. One or two electrons in the outermost shell of atoms of elements are called as _______________ electrons.
5. $^{14}_{6}C$ is used for carbon dating
6. Discovery of neutron

Across:

1. Electrons present in the outermost shell
2. This pair of atoms $^{40}_{20}Ca$, $^{40}_{18}Ar$ are ____
3. An atom that does not have neutron
4. Scattering of α particles in the gold foil experiment



b) Copy the following and write the names of the laws and their simple definitions in the space provided.



VIII. Very short answer

1. Name an element which has the same number of electrons in its first and second shell.
2. Write the electronic configuration of K^+ and Cl^-
3. Compare the charge and mass of protons and electrons.
4. For an atom 'X', K, L and M shells are completely filled. How many electrons will be present in it?
5. Ca^{2+} has completely filled outer shell. Justify your answer.

IX. Short answer

1. State the law of multiple proportion.
2. List the uses of isotopes?
3. What is isotone? Give an example
4. Draw the structure of oxygen and sulphur atoms.
5. Calculate the number of neutrons, protons and electrons (i) atomic number 3 and mass number 7 (ii)atomic number 92 and mass number238

X. Numerical problem

1. Calculate the volume of oxygen required for the complete combustion of 20 cm^3 of methane[$CH_{4(g)} + 2O_2 \rightarrow CO_{2(g)} + 2H_2O_{(g)}$]
2. A metal combines with oxygen to form two oxides having the following composition

   i) 0.398 gram of metal oxide I contains 0.318 gram of metal

   ii) 0.716 gram of metal oxide II contains 0.636 gram of metal. So that the above data agrees with the law of multiple proportions.
3. Calculate the mass of a proton, given its charge = + 1.60×10^{-19} C

   charge / mass = 9.58×10^7 C kg^{-1}

XI. Long answer

1. What conclusions were made from the observations of Gold foil experiment?
2. Explain the postulates of Bohr's atomic model.

3. State the Gay Lussac's law of combining volumes, explain with an illustration.

XII. Get connected

Health

1. Discuss the uses of radio-active isotopes in Medicine.

Art

1. Make the model of different atoms by using the materials like card boards, colour beads and strings.
2. Draw the time line of history of atomic model

Language

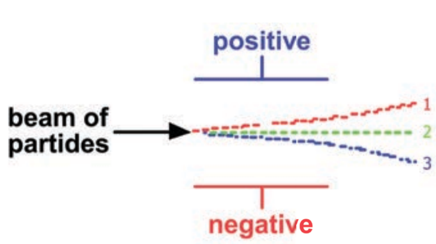
1.Write (in about 200 words) about Homi J Bhabha who was the father of **Indian Nuclear programme**

XIII. Get Together and Do

1. Prepare a science magazine including photos, profiles and contribution of philosophers and scientists related to the history of atom
2. Prepare a display board chart illustrating the electronic configuration and valency of elements with atomic number 1 – 20.

XIV. Unlock

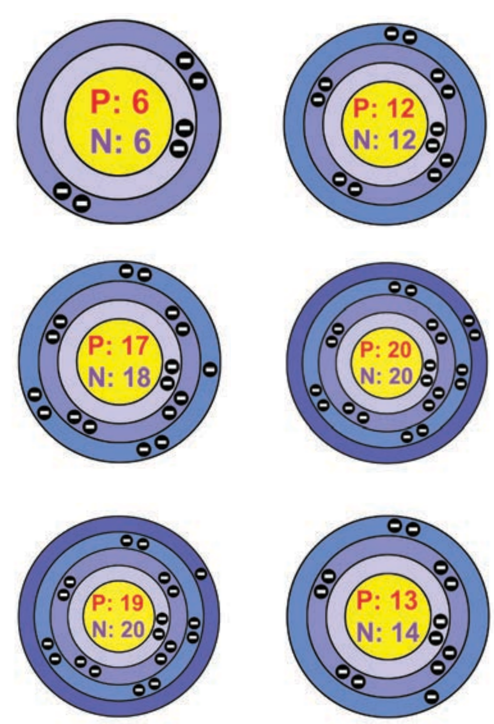
1.



The particles represented above are

	1	2	3
a.	electrons	protons	neutrons.
b.	protons	electrons	neutrons
c.	neutrons.	protons	electrons
d.	electrons	neutrons.	protons

2. From the structures given below, Tabulate the following:
   1. Valence electron
   2. Valency
   3. Atomic Number
   4. Mass number
   5. Electronic configuration



3. The correct numbers of protons and neutrons present in ${}^{23}_{11}Na^{+}$ are

	protons	neutrons
a.	11	23
b.	10	12
c.	11	12
d.	11	22

REFERENCE

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2. Atomic structure and Periodicity Jack Barrett. Royal Society of Chemistry. ISBN 0-85404-657-7.
3. Chemistry for Degree Students (B.Sc. Sem.-I, As per CBCS) R L Madan ISBN: 9789352533039. S. Chand Publishing

INTERNET RESOURCES

Electronic configuration

https://www.youtube.com/watch?v=t4xgvlNFQ3c

https://www.youtube.com/watch?v=P6DMEgE8CK8

https://www.youtube.com/watch?v=YURReI6OJsg

UNIT 1

Heat

Learning Objectives

After completing this chapter, the students will be able to:

- Understand the nature of Heat.
- Identify the effects of heat.
- Differentiate the conducting powers of various substances.
- List out good and bad conductors of heat and their uses.
- Explain conduction using kinetic theory.
- Describe the experiments to show convection in fluids.
- Understand the concept of radiation.
- Define specific heat capacity.
- Define thermal capacity.
- Solve problems on specific heat capacity.
- Describe the concept of change of state.
- Define specific latent heat of fusion and specific latent heat of vaporisation.

BKLGIH

Introduction

All the substances in our surrounding are made up of molecules. These molecules are generally at motion and posses kinetic energy. At the same time each molecule exerts a force of attraction on other molecules and so they posses potential energy. The sum of the kinetic and potential energy is called the internal energy of the molecules. This internal energy, when flows out, is called heat energy. This energy is more in hot substances and less in cold substances and flows from hot substances to cold substances. In this lesson you will study about how this heat transfer takes place. Also you will study about the effect of heat, heat capacity, change of state and latent heat.

1.1 Effects of heat

When a substance is heated, the following things can happen.

Expansion

When heat is added to a substance, the molecules gain energy and vibrate and force other molecules apart. As a result expansion takes place. You would have seen some space being left in railway tracks. It is because, during summer time, more heat causes expansion in tracks. Expansion is greater for liquids than for solids and maximum in case of gases.

Figure 1.1 Gap in railway track

Change in temperature

When heat energy is added to a substance, the kinetic energy of its particles increases and so the particles move at higher speed. This causes rise in temperature. When a substance is cooled, that is, when heat is removed, the molecules lose heat and its temperature falls.

Change in state

When you heat ice cubes, they become water and water on further heating changes into vapour. So, solid becomes liquid and liquid becomes gas, when heat is added. The reverse takes place when heat is removed.

Chemical changes

Since heat is a form of energy it plays a major role in chemical changes. In some cases, chemical reactions need heat to begin and also heat determines the speed at which reactions occur. When we cook food, we light the wood and it catches fire and the food particles become soft because of the heat energy. These are all the chemical changes taking place due to heat.

1.2 Transfer of heat

Heat does not stay where we put it. Hot things get colder and cold things get hotter. Heat is transferred from one place to another till their temperatures become equal. Heat transfer takes place when heat energy flows from the object of higher temperature to an object with lower temperature. It is shown in Fig. 1.2.

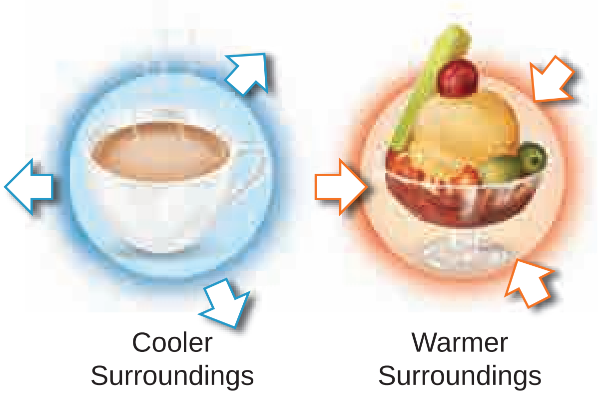


Figure 1.2 Hot and cold surroundings

Activity 1

Aim: To know about transfer of heat.

Take a glass of water and put some ice cubes into it. Observe it for some time. What happens? The ice cubes melt and disappear. Why did it happen? It is because heat energy in the water is transferred to the ice.

DO YOU KNOW?

When a dog keeps out its tongue and breathes hard, the moisture on the tongue turns into water and it evaporates. Heat energy is needed to turn a liquid into a gas, so heat is removed from dog's tongue in the process. This helps to cool the body of the dog.

Heat transfer takes place in three ways:

i. Conduction, ii. Convection, iii. Radiation

1.2.1 Conduction

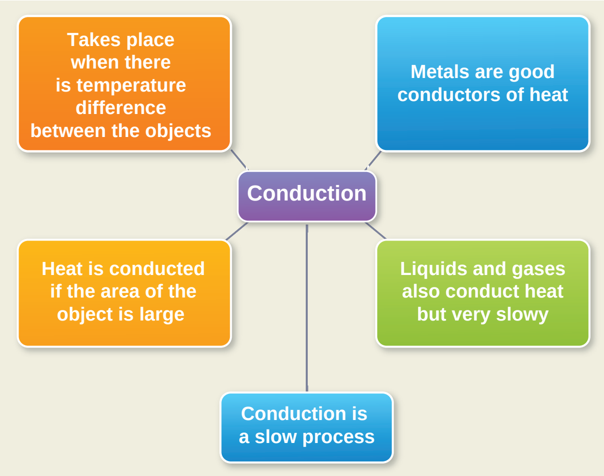
Activity 2

Aim: To know about conduction of heat.

Take a cup of hot water in a glass and leave a silver spoon in it for some time. You can feel that the spoon has become hot. Do you know why it happened? It is because of the transfer of heat from the bottom of the spoon to the top.

In solids, molecules are closely arranged so that they cannot move freely. When one end of the solid is heated, molecules at that end absorb heat energy and vibrate fast at their own positions. These molecules in turn collide with the neighboring molecules and make them vibrate faster and so energy is transferred. This process continues till all the molecules receive the heat energy.

The process of transfer of heat in solids from a region of higher temperature to a region of lower temperature without the actual movement of molecules is called conduction.



Activity 3

Aim: To compare the conducting powers of various metals.

Take metal rods of copper, aluminium, brass and iron. Fix a match stick to one end of each rod using a little melted wax. When the temperature of the far ends reach the melting point of wax, the matches drop off. While conducting the experiment, it is observed that the match stick on the copper rod would fall first, showing copper as the best conductor followed by aluminum, brass and then iron.

Conduction in daily life

i. Metals are good conductors of heat. So, aluminium is used for making utensils to cook food quickly.

ii. Mercury is used in thermometers because it is a good conductor of heat.

iii. We wear woolen clothes is winter to keep ourselves warm. Air, which is a bad conductor, does not allow our body heat to escape.

DO YOU KNOW?

Snow's effective insulating properties enable the inside of the igloo to remain relatively warm. In some cases, a single block of clear ice is inserted to allow light into the igloo. Animal skins are used as door flaps to keep warm air in. Igloos used as winter shelters had beds made of ice and caribou furs. These 'ice beds' are unique to the region and Inuit culture.

1.2.2 Convection

Activity 4

Aim: To know about transfer of heat through convection in liquids.

Drop a few crystals of potassium permanganate down to the bottom of a beaker containing water. When the beaker is heated just below the crystals, by a small flame, purple streaks of water rise upwards and fan outwards.

In the above activity, water molecules at the bottom of the beaker receive heat energy and move upward and replace the molecules at the top. Same thing happens in air also. When air is heated the air molecules gain heat energy allowing them to move further apart. Warm air is less dense than cold air and will rise. Cooler air moves down to replace the air that has risen. It heats up, rises and is again replaced by cooler air, creating a circular flow.

BKVCK5

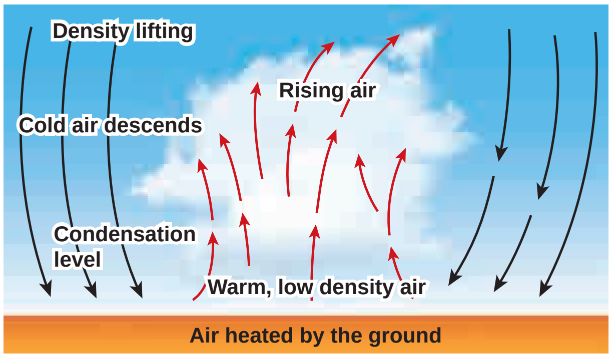


Figure 1.3 Convection in air

Convection is the flow of heat through a fluid from places of higher temperature to places of lower temperature by movement of the fluid itself.

Convection in daily life

Hot air balloons

Air molecules at the bottom of the balloon get heated by a heat source and rise. As the warm air rises, cold air is pushed downward and it is also heated. When the hot air is trapped inside the balloon, it rises.

Figure 1.4 Hot air balloon

Breezes

During day time, the air in contact with the land becomes hot and rises. Now the cool air over the surface of the sea replaces it. It is called sea breeze. During night time, air above the sea is warmer. As the warmer air over the surface of the sea rises, cooler air above the land moves towards the sea. It is called land breeze.

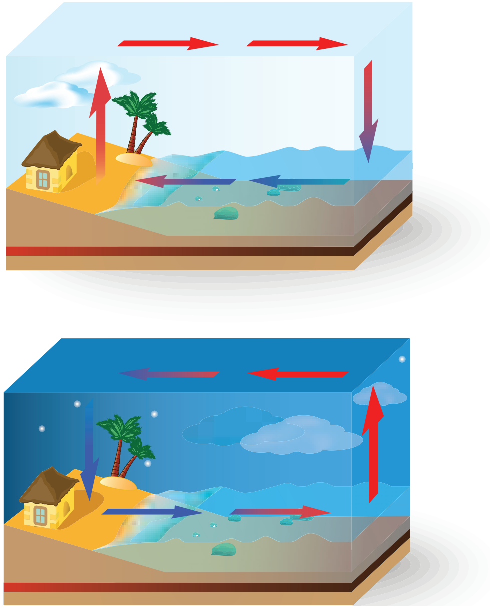


Figure 1.5 Land breeze and sea breeze

Winds

Air flows from area of high pressure to area of low pressure. The warm air molecules over hot surface rise and create low pressure. So, cooler air with high pressure flows towards low pressure area. This causes wind flow.

Chimneys

Tall chimneys are kept in kitchen and industrial furnaces. As the hot gases and smoke are lighter, they rise up in the atmosphere.

DO YOU KNOW?

Black marks often appear on the wall or ceiling above a lamp or fan. They are caused by dust being carried upwards in air convection currents produced by hot lamp or the running fan.

1.2.3 Radiation

Radiation is a method of heat transfer that does not require particles to carry the heat energy. In this method, heat is transferred in the form of waves from hot objects in all direction. Radiation can occur even in vacuum whereas conduction and convection need matter to be present. Radiation consists of electromagnetic waves travelling at the speed of light. Thus, radiation is the flow of heat from one place to another by means of electromagnetic waves.

Transfer of heat energy from the sun reaches us in the form of radiation. Radiation is emitted by all bodies above 0 K. Some objects absorb radiation and some other objects reflect them. This can be shown using the demonstration set up shown in Fig 1.6. In this figure the inside surface of one plate is shiny and of the other is dull black. Coins are stuck on the outside of each plate with candle wax. If the heater is midway between the plates they each receive the same amount of radiation. After few minutes the wax on the black plate melts and the coin falls off. The shiny plate stays cool and the wax on it is un-melted.

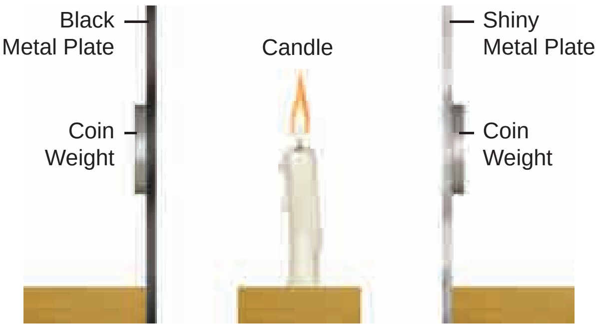


Figure 1.6 Black and shiny metal surface.

Radiation in daily life

i. White or light colored cloths are good reflectors of heat. They keep us cool during summer.
ii. Base of cooking utensils is blackened because black surface absorb more heat from the surrounding.
iii. Surface of airplane is highly polished because it helps to reflect most of the heat radiation from the sun.

DO YOU KNOW?

While firing wood, we can observe all the three ways of heat transfer. Heat in one end of the wood will be transfered to other end due to conduction. The air near the wood will become warm and replace the air above. This is convection. Our hands will be warm because heat reaches us in the form of radiation.

1.3 Concept of temperature

Temperature is the degree of hotness or coolness of a body. The hotter the body is higher is its temperature.

1.3.1 Unit of Temperature

The SI unit of temperature is ***kelvin*** **(K)**. For day to day applications, ***Celsius*** (˚C) is used. Temperature is measured with a thermometer.

1.3.2 Temperature scales

There are three scales of temperature.

i. Fahrenheit scale

ii. Celsius or Centigrade scale

iii. Kelvin or Absolute scale

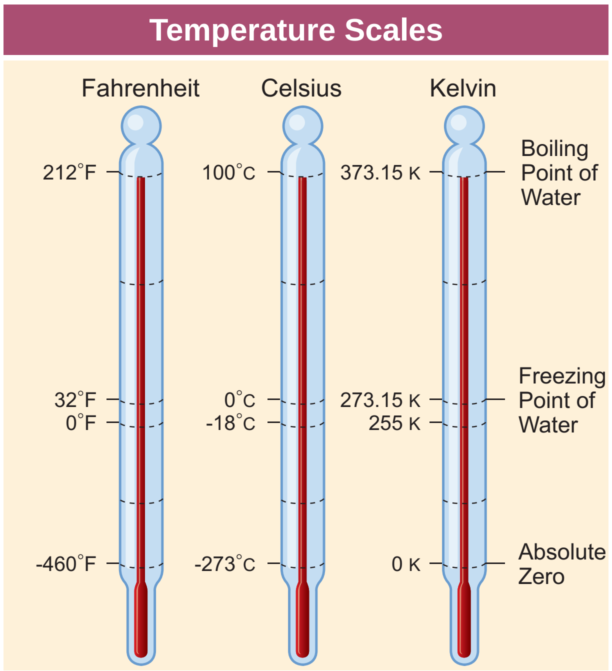


Figure 1.7 Types of temperature scales

Fahrenheit scale

In Fahrenheit scale, 32 ˚F and 212 ˚F are the freezing point and boiling points respectively. Interval has been divided into 180 parts.

Celsius temperature scale

In Celsius scale, also called centigrade scale, 0˚C and 100 ˚C are the freezing point and boiling respectively. Interval has been divided into 100 parts. The formula for converting a Celsius scale to Fahrenheit scale is:

$$F=\frac{9}{5}\,C+32$$

The formula for converting a Fahrenheit scale to Celsius scale is:

$$C=\frac{5}{9}\,(F-32)$$

Kelvin scale (Absolute scale)

Kelvin scale is known as the absolute scale. On the Kelvin scale 0 K represents absolute zero, the temperature at which the molecules of a substance have their lowest possible energy. The solid, liquid, gaseous phases of water can coexist in equilibrium at 273.16 K.

Kelvin is defined as 1/273.16 of the triple point temperature.

The formula for converting a Celsius scale to Kelvin scale is:

$$K = C + 273.15$$

The formula for converting a Kelvin scale to Celsius scale is:

$$C = K - 273.15$$

Absolute zero

The temperature at which the pressure and volume of a gas theoretically reaches zero is called absolute zero. This is shown in Figure 1.8.

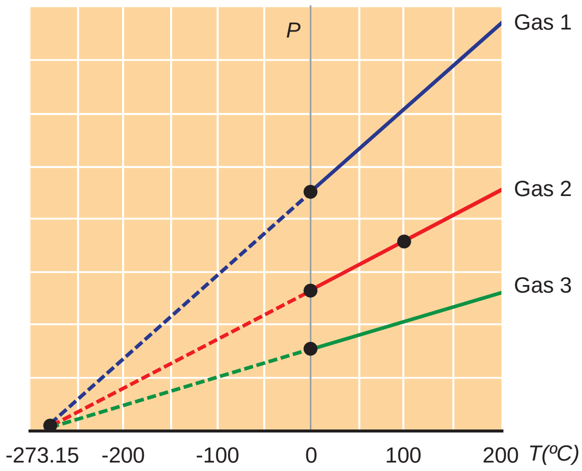


Figure 1.8 Variation of pressure (P) with temperature (T).

For all gases, the pressure extrapolates to zero at the temperature -273.15 ˚C. It is known as absolute zero or 0 K. Some base line temperatures in the three temperature scales are shown in Table 1.1.

Table. 1.1 Some baseline temperatures in the three temperature scales.

Temperature	Kelvins (K)	Degrees Celcius (ºC)	Degrees Fahrenheit (ºF)
Boiling point of water	373.15	100	212
Melting point of ice	273.15	0	32
Absolute zero	0	-273	-460

Exercise 1.1

Convert the following

i. 25 ºC to Kelvin

ii. 200 K to ºC

Solution:

i. $(T_K) = (T_{°C}) + 273.15$

$(T_K) = 25 + 273.15 = 298.15$ K

ii. $(T_{°C}) = (T_K) - 273.15$

$(T_{°C}) = 200 - 273.15 = -73.15$ ºC

Exercise 1. 2

Convert the following

i. 35˚ C to Fahrenheit (°F)

ii. 14˚ F to ˚C

Solution:

i. T(°F) = T(°C) × 1.8 + 32

T(°F) = 25° C × 1.8 + 32 = 77° F

ii. T(°C) = (T(°F) – 32)/ 1.8

T(°C) = (14°F – 32)/ 1.8 = -10° C

1.4 Specific heat capacity

You might have felt that the land is cool in the morning and hot during day time. But, water in a lake will be almost at a particular temperature both in the morning as well as in the afternoon. Both are subjected to same amount of heat energy from the Sun, but they react differently. It is because both of them have different properties. In general the amount of heat energy absorbed or lost by a body is determined by three factors.

1. Mass of the body
2. Change in temperature of the body
3. Nature of the material of the body

We can understand this from the following observations.

Observation:1

Quantity of heat required to raise the temperature of 1 litre of water will be more than the heat required to raise the temperature of 500 ml of water. If Q is the quantity of heat absorbed and m is the mass of the body, then Q α m

Observation: 2

Quantity of heat energy (Q) required to raise the temperature of 250 ml of water to 100^0C is more than the heat energy required to raise the temperature to 50^0C. Here, $Q \alpha \Delta T$, where ΔT is the change in temperature of the body.

Hence, from the above two observations, heat lost or gained by a substance when its temperature changes by ΔT is:

$$Q \alpha m\Delta T$$

$$Q = mC\Delta T \qquad (1.1)$$

From the above equations, the absolute temperature and energy of a system are proportional to each other. The proportionality constant is the specific heat capacity (c) of the substance.

In order to understand the specific heat capacity of the substance, think of heating 500 ml of water and 500 ml of oil. Which will be heated first? Why? It is because heat gained by a body depends upon the nature of the substance. The capacity of a substance to gain heat energy is denoted by the term specific heat capacity. Mathematically it is derived from the equation (1.1) as, $C=Q/m\Delta T$

Thus, specific heat capacity of a substance is defined as the amount of heat required to raise the temperature of 1 kg of the substance by 1^0C or 1 K. The SI unit of specific heat capacity is $Jkg^{-1} K^{-1}$. The most commonly used units of specific heat capacity are J/kg^0C and J/g^0C.

Among all the substances, water has the highest specific heat capacity and its value is $4200\ J/kg^0C$. So, water absorbs a large amount of heat for unit rise in temperature. Thus, water is used as a coolant in car radiators and factories to keep engines and other machinery parts cool. It is because of the same reason the temperature of water in the lake does not change much during day time. Specific heat capacities of some common substances are given in Table 1.2.

DO YOU KNOW?

Water in its various form, has different specific heat capacities.

Water (liquid State) = $4200\ JKg^{-1}\ K^{-1}$

Ice (Solid State) = $2100\ JKg^{-1}\ K^{-1}$

Steam (gaseous State) = $460\ JKg^{-1}\ K^{-1}$

Table 1.2 Specific heat capacity of some common substances

Substance	Specific heat capacity in $JKg^{-1}\ K^{-1}$
Lead	130
Mercury	139
Brass	380
Zinc	391
Copper	399
Iron	483
Glass (flint)	504
Aluminium	882
Kerosene	2100
Ice	2100
Sea Water	3900
Water	4180

Exercise1.3

Calculate the heat energy required to raise the temperature of 2kg of water from 10^oC to 50^oC. Specific heat capacity of water is $4200\ JKg^{-1}\ K^{-1}$.

Solution:

Given m = 2 Kg, ΔT = (50-10) = 40°C

Or in terms of Kelvin (323.15-283.15) = 40K, C= 4200 J Kg^{-1} K^{-1}

$\therefore$ Heat energy required, Q = m × C × ΔT = 2 × 4200 × 40 = 3,36,000 J

Exercise 1.4

Some heat energy is given to 120g of water and its temperature rises by 10K. When the same amount of heat energy is given to 60g of oil, its temperature rises by 40K. The specific heat capacity of water is 4200JKg^{-1} K^{-1}. Calculate:

i) The amount of heat energy in joule given to water.

ii) The specific heat capacity of oil.

Solution:

i. Heat energy given to water = Mass of water × Specific heat capacity of water × rise in temperature.

= 120/1000 kg × 4200 JKg^{-1} K^{-1}× 10 K

= 5040 J.

ii. Since same heat energy is given to oil, heat energy given to oil = 5040 J

Let C in JKg^{-1} K^{-1} be the specific heat capacity of oil,

$$\text{Then } C = \frac{\text{amount of heat energy given to oil}}{\text{mass of oil} \times \text{rise in temperature}}$$

$$= \frac{5040\ J}{\frac{(60)}{(1000)}kg \times 40\ K}$$

= 2100 JKg^{-1} K^{-1}.

1.5 Heat capacity or Thermal capacity

Now, you are familiar with specific heat capacity. It is the heat required to raise the temperature of a unit mass of the body by 1°C. But, heat capacity is the heat required to raise the temperature of a entire mass of the body by 1°C. Thus, heat capacity or thermal capacity is defined as the amount of heat energy required to raise the temperature of a body by 1°C. It is denoted by C'.

$$\text{Heat Capacity} = \frac{\text{Quantity of heat required}}{\text{Rise in temperature}}$$

$$C' = Q/t$$

SI unit of heat capacity is J/K. It is also expressed in cal/°C, kcal/°C or J/°C.

As we saw earlier, if C is the heat required to raise the temperature of unit mass of the body by 1°C then the heat required to raise the temperature of 'm' mass of the substance is m C. So, heat capacity is also given as, C'= m × C.

Note: The symbol of specific heat capacity is C and that of Heat capacity is C'. It should not be confused with the unit of temperature degree Celsius (°C)

Exercise 1.5

An iron ball requires 5000 J heat energy to raise its temperature by 20°C. Calculate the heat capacity of the iron ball.

Solution:

Given, Q = 5000 J, ΔT = 20°C or 20 K

$$\text{Heat Capacity C} = \frac{\text{Heat energy required, Q}}{\text{Rise in temperature, } \Delta T}$$

$$= \frac{5000}{20}$$

$$= 250\ JK^{-1}$$

1.6 Change of state

Any matter around us can be in three forms: solid, liquid and gas. These forms of matter are called states of matter. Depending upon the temperature, pressure and transfer of heat, matter is converted from one state to another. The conversion of matter from one state to another is called change of state in matter. The process of changing of a substance from one physical state to another at a definite temperature is defined as change of state.

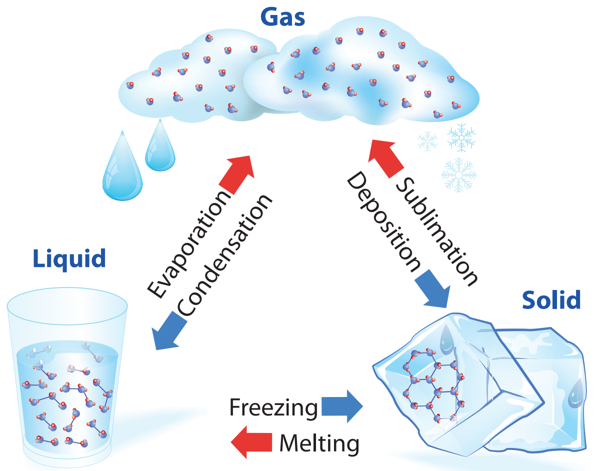


Figure 1.9 Change of state of matter

For example, water molecules are in liquid state at normal temperature. When water is heated to 100^{0}C, it becomes steam which is a gaseous state of matter. On reducing the temperature of the steam it becomes water again. If we reduce the temperature further to 0^{0}C, it becomes ice which is a solid state of water. Ice on heating, becomes water again. Thus, water changes its state when there is a change in temperature. There are different such processes in the change of state in matter. The figure 1.9 shows various processes of change state.

Melting – Freezing

The process in which a solid is converted to liquid by absorbing heat is called melting or fusion. The temperature at which a solid changes its state to liquid is called melting point. The reverse of melting is freezing. The process in which a liquid is converted to solid by releasing heat is called freezing. The temperature at which a liquid changes its state to solid is called freezing point. In the case of water, melting and boiling occur at 0^{0}C.

Boiling-Condensation

The process in which a liquid is converted to vapor by absorbing heat is called boiling or vaporization. The temperature at which a liquid changes its state to gas is called boiling point. The process in which a vapor is converted to liquid by releasing heat is called condensation. The temperature at which a vapour changes its state to liquid is called condensation point. Boiling point as well as condensation point of water is 100^{0}C.

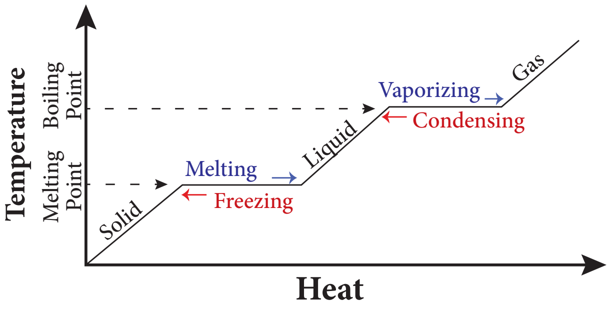


Figure 1.10 Various stages of conversion of state of matter

Sublimation

Some solids like dry ice, iodine, frozen carbon dioxide and naphthalene balls change directly from solid state to gaseous state without becoming liquid. The process in which a solid is converted to gaseous state is called sublimation.

Various stages of conversion of state of matter with heat with the corresponding change in temperature is shown in Figure 1.10

1.7 Latent heat

The word, 'latent' means hidden. So, latent heat means hidden heat or hidden energy. In order to understand latent heat, let us do the activity given below.

Activity 5

Aim:To know about latent heat of water..

Take some crushed ice cubes in a beaker and note down the temperature using thermometer. It will be 0^0C. Now heat the ice in the beaker. You can observe that ice is melting to form water. Record the temperature at regular intervals and it will remain at 0^0C until whole ice is converted to liquid. Now heat the beaker again and record the temperature. You can notice that the temperature will rise up to 100^0C and the temperature will be at 100^0C even after continuous heating until the whole mass of water in the beaker is vaporized..

In the above activity, the temperature is constant at 0^0C until entire ice is converted into liquid and again constant at 100^0C until all the ice is converted into vapor. Why? It is because, when a substance changes from one state to another, a considerable amount of heat energy is absorbed or liberated. This energy is called latent heat. Thus, latent heat is the amount of heat energy absorbed or released by a substance during a change in its physical sates without any change in its temperature.

Heat energy is absorbed by a solid during melting and an equal amount of heat energy is liberated by the liquid during freezing, without any temperature change. It is called latent heat of fusion. In the same manner, heat energy is absorbed by a liquid during vaporization and an equal amount of heat energy is liberated by the vapor during condensation, without any temperature changes. This is called latent heat of vaporization.

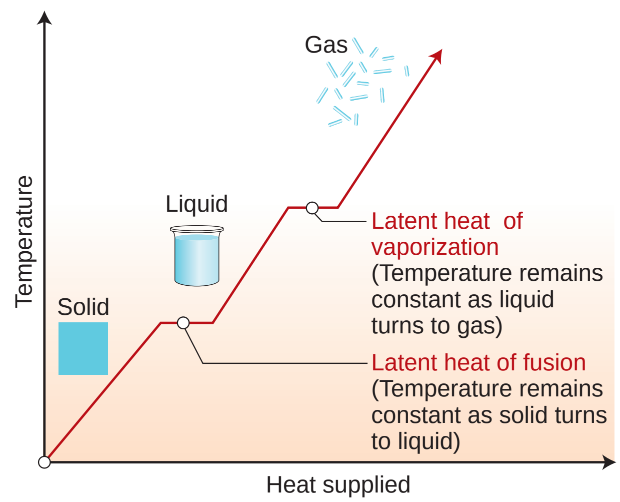


Figure 1.11 Latent heat

DO YOU KNOW?

Steam burn is more damaging than a burn with boiling water at the same temperature?

When steam hits our skin, it condenses to water and then cools down to the temperature of skin. Now, the energy released will be due to latent heat and fall in temperature. Whereas when boiling water hits our skin, there is no phase transition but only fall in temperature and the heat transferred to skin will be only due to cooling. Also, the loss of energy that is released from steam hitting our skin occurs quickly and in a small localized area, therefore causing damage to our cells.

Specific latent heat

Latent heat when expressed per unit mass of a substance, it is called specific latent heat. It is denoted by the symbol L. If Q is the amount of heat energy absorbed or liberated by m mass of a substance during its change of phase at a constant temperature, then specific latent heat is given as L = Q/m.

Thus, specific latent heat is the amount of heat energy absorbed or liberated by unit mass of a substance during change of state without causing any change in temperature. The SI unit of specific latent heat is J/kg.

Exercise 1.6

How much heat energy is required to melt 5 kg of ice? (Specific latent heat of ice = 336 Jg-1)

Solution:

Given, m = 5 Kg = 5000g, L = 336 Jg-1

Heat energy required = m x L

= 5000 x 336

= 1680000J or 1.68 x 10^6 J

Exercise 1.7

How much boiling water at 100°C is needed to melt 2kg of ice so that the mixture which is all water is at 0°C?

[Specific heat capacity of water = 4.2 JKg^{-1} and specific latent heat of ice = 336 Jg^{-1}].

Solution:

Given, Mass of ice = 2 kg = 2000 g.

Let m be the mass of boiling water required.

Heat lost = Heat gained.

m x c x Δt = m x L

m x 4.2 x (100-0) = 2000 x 336

$$m = \frac{2000 \times 336}{4.2 \times 100}$$

= 1600g or 1.6 kg.

Points to remember

- All the molecules have kinetic energy as well as potential energy.
- Expansion, change in temperature and change in state are the effects of heat.
- Heat is transferred from hot region to cold region.
- Heat is transferred in three forms: conduction, convection and radiation.
- Conduction takes place in solids and convection takes place in liquids and gases.
- Radiation takes place in the form of electromagnetic waves.
- The SI unit of temperature is Kelvin (K).
- Kelvin scale is known as the absolute scale.
- There are three scales of temperature: Fahrenheit scale, Celsius or Centigrade scale and Kelvin or Absolute scale.
- Amount of heat energy absorbed or lost by a body is determined by three factors: mass of the body, change in temperature of the body, nature of the material of the body.
- The SI unit of specific heat capacity is Jkg^{-1} K^{-1}.
- Among all the substances, water has the highest specific heat capacity.
- SI unit of heat capacity is J/K.
- The symbol of specific heat capacity is C and that of Heat capacity is C'.
- Depending upon the temperature, pressure and transfer of heat, matter is converted from one state to another.

A-Z GLOSSARY

Conduction	Process of transfer of heat in solids from a region of higher temperature to a region of lower temperature without the actual movement of molecules.
Convection	Flow of heat through a fluid from places of higher temperature to places of lower temperature by movement of the fluid itself.
Radiation	Flow of heat from one place to another by means of electromagnetic waves.
Temperature	It is the degree of hotness or coolness of a body.
Kelvin	It is defined as1/(273.16) of the triple point temperature.
Specific heat capacity	The amount of heat required to raise the temperature of 1 kg of the substance by 10^{0}C or 1 K.
Heat capacity or thermal capacity	The amount of heat energy required to raise the temperature of a body by 1^{0}C.
Melting or fusion	Process in which a solid is converted to liquid by absorbing heat.
Freezing	Process in which a liquid is converted to solid by releasing heat.
Boiling or vaporization	Process in which a liquid is converted to vapour by absorbing heat.
Condensation	Process in which a vapor is converted to liquid by releasing heat.
Latent heat	Amount of heat energy absorbed or released by a substance during a change in its physical sates without any change in its temperature.
Specific latent heat	Amount of heat energy absorbed or liberated by unit mass of substance during change of state without causing any change in temperature.

TEXT BOOK EXERCISES

BL58LS

I. Choose the correct answer:

1. Calorie is the unit of
   - a) heat b) work
   - c) temperature d) food

2. SI unit of temperature is
   - a) fahrenheit b) joule
   - c) celsius d) kelvin

3. The Specific heat capacity of water is
   - a) 4200 $Jkg^{-1}K^{-1}$ b) 420 $Jg^{-1}K^{-1}$
   - c) 0.42 $Jg^{-1}K^{-1}$ d) 4.2 $Jkg^{-1}K^{-1}$

4. Two cylindrical rods of same length have the area of cross section in the ratio 2:1. If

both the rods are made up of same material, which of them conduct heat faster?

a) Both rods b) Rod-2

c) Rod-1 d) None of them

5. Two cylinders of equal height and radius are made of copper and aluminium. Which of them conducts heat faster?

a) Copper rod b) Aluminium rod

c) Both of them d) None of them

6. In which mode of transfer of heat, molecules pass on heat energy to neighbouring molecules without actually moving from their positions?

a) Radiation b) Conduction

c) Convection d) Both B and C

7. A device in which the loss of heat due to conduction, convection and radiation is minimized is

a) Solar cell b) Solar cooker

c) Thermometer d) Thermos flask

II. Fill in the blanks:

1. The fastest mode of heat transfer is ______.
2. During day time, air blows from ____________ to ____________.
3. Liquids and gases are generally ____________ conductors of heat.
4. The fixed temperature at which matter changes state from solid to liquid is called ____________.

III. Assertion and Reason type questions:

Mark the correct choice as:

a. If both assertion and reason are true and reason is the correct explanation of assertion.
b. If both assertion and reason are true but reason is not the correct explanation of assertion.
c. If assertion is true but reason is false.
d. If assertion is false but reason is true.

1. **Assertion:** Food can be cooked faster in copper bottom vessels.

   Reason: Copper is the best conductor of heat.

2. **Assertion:** Maximum sunlight reaches earth's surface during the afternoon time.

   Reason: Heat from the sun reaches earth's surface by radiation.

3. **Assertion:** When water is heated up to $100^{\circ}C$, there is no raise in temperature until all water gets converted into water vapour.

   Reason: Boiling point of water is $10^{\circ}C$.

4. **Assertion:** Aluminium conducts heat faster than copper.

   Reason: Specific heat capacity of aluminium is higher than that of copper.

IV. Short answers questions:

1. Define conduction.
2. Ice is kept in a double-walled container. Why?
3. How does the water kept in an earthen pot remain cool?
4. Differentiate convection and radiation.
5. Why do people prefer wearing white clothes during summer?
6. What is specific heat capacity?
7. Define thermal capacity.
8. Define specific latent heat capacity.

V. Answer in detail:

1. Explain convection in daily life.
2. What are the changes of state in water? Explain.
3. How can you experimentally prove that water is a bad conductor of heat? How is it possible to heat water easily while cooking.

VI. Complete the missing terms in the following table:

Process	Phase I	Phase II
Sublimation	-	Vapour
Solidification	-	Solid
-	Solid	Liquid
Freezing	Liquid	-
Condensation	-	liquid

VII. Identify the answer for the following

O	N	E	L	A	T	E	N	T	S
Y	O	M	N	E	H	E	A	T	O
S	P	E	C	I	F	I	C	S	T
S	J	O	U	L	E	X	B	I	A
C	O	N	V	E	C	T	I	O	N

Clues:

1. A form of energy.
2. Unit for heat energy.
3. Hidden heat
4. If the mass of substance is mentioned, then heat capacity can be replaced with ------- heat capacity.
5. Process taking place in fluids due to heat exchange.

Problems:

1. What is the heat in joules required to raise the temperature of 25 grams of water from 0°C to 100°C? What is the heat in Calories?

   (Specific heat of water = 4.18 J/g°C)

   (Ans. 10450 J)

2. What could be the final temperature of a mixture of 100 g of water at 90°C and 600g of water at 20°C. **(Ans. 30°C)**

3. How much heat energy is required to change 2 kg of ice at 0°C into water at 20°C? (Specific latent heat of fusion of water = 3,34,000J/kg, Specific heat capacity of water = 4200J$Kg^{-1}K^{-1}$). **(Ans. 8,36,000 J)**

4. A piece of aluminium of mass 0.5 kg is heated to 100°C and then placed in 0.4 kg of water at 10°C. If the resulting temperature of the mixture is 30°C, what is the specific heat capacity of aluminium? (SHC of water = 4,200J/Kg°C)

   (Ans. 960J/kg°C)

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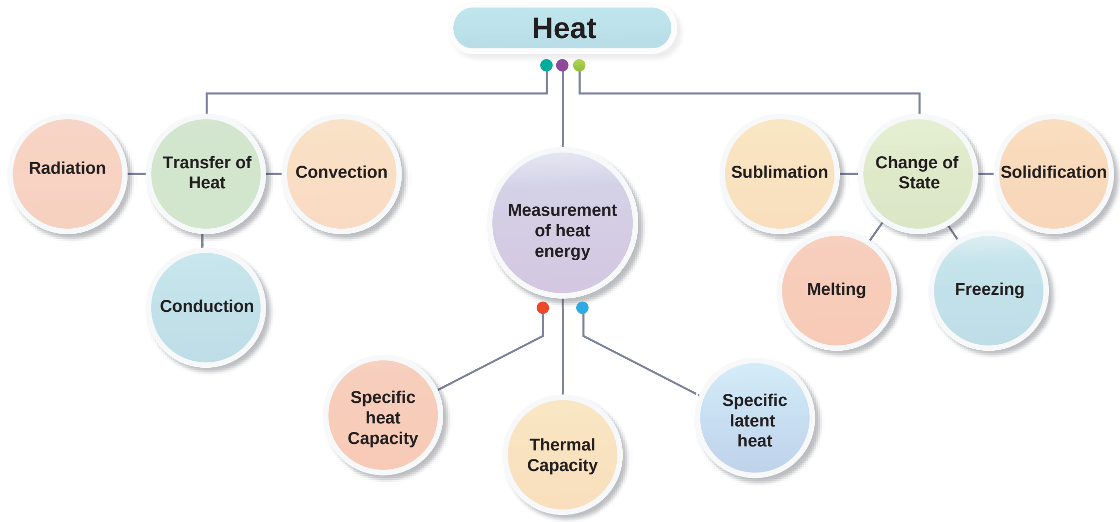
INTERNET RESOURCES

1. https://betterlession.com
2. http://www.britannica.com
3. http://study.com
4. http://www.sciencelearn.org



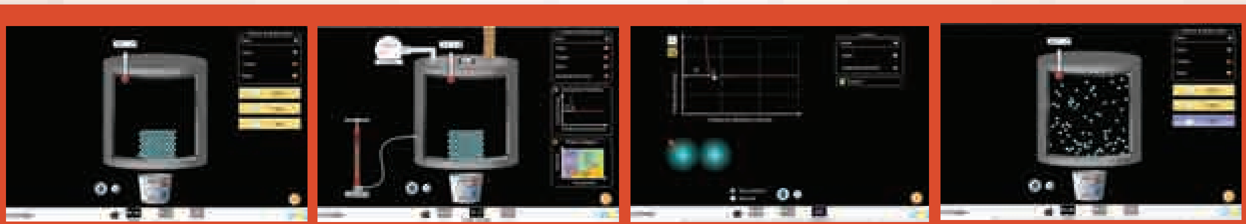
ICT CORNER

States of Matter - Effects of Heat changes

Explore this activity to know about the heat changes in the states of matter.

Steps

- Copy and paste the link given below or type the URL in the browser. Click the option States.
- You can find Atom & Molecules with four options – Neon, Argon, Oxygen and Water. You can also find Solid, Liquid and Gas options.
- Click any one of the Atoms & Molecules to stimulate by holding the Heat or Cool option under the simulation chamber.
- You can also try the simulation by changing the Solid, Liquid and Gas options too.
- The temperature option can be changed to Fahrenheit or Celsius.



Step1 Step2 Step3 Step4

Browse in the link:

URL: https://phet.colorado.edu/sims/html/states-of-matter/latest/states-of-matter_en.html

*Pictures are indicative only

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UNIT 2

Electric charge and electric current

BLE4NF

Learning Objectives

After completing this lesson, students will be able to:

- Understand the electric charge, electric field and Coulomb's law
- Explain concepts of electric current, voltage, resistance and Ohm's law
- Draw electrical circuit diagrams, series and parallel circuits
- Explain effects of electric current like
  heating or thermal effect , chemical effect , magnetic effect
- Understand direct and alternating currents
- Know safety aspects related to electricity

Introduction

Like mass and length, electric charge also is a fundamental property of all matter. We know that matter is made up of atoms and molecules. Atoms have particles like electrons, protons and neutrons. By nature, electrons and protons have negative and positive charges respectively and neutrons do not have charge. An electric current consists of moving electric charges. Electric current is the flow of charges just like water currents are due to the flow of water molecules. Water molecules tend to flow from areas of higher gravitational potential to lower gravitational potential. Similarly, electric current flows from higher electric potential to lower electric potential. Electricity is an important source of energy in the modern times.

2.1 Electric charges

We know that all matter is made up of tiny particles called, atoms. Inside each atom there is a nucleus with positively charged protons and chargeless neutrons and negatively charged electrons orbiting the nucleus. Usually there are as many electrons as there are protons and the atoms themselves are neutral.

As electrons are revolving in the orbits of an atom, they can be easily removed from an atom and also added to it. If an electron is removed from the atom, the atom becomes positively charged. Then it becomes a positive ion. If an electron is added in excess to an atom then the atom is negatively charged. This atom is called negative ion. More than one electron can also be removed from or added to atoms to make them accordingly more positive and more negative (Fig. 2.1).

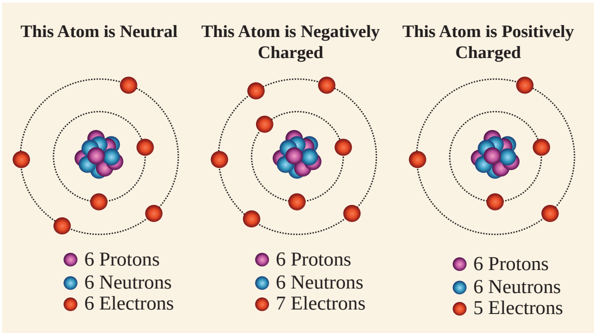


Figure 2.1 Atoms and charges

When you rub a plastic comb on your dry hair, the comb obtains power to attract small pieces of paper, is it not? When you rub the comb vigorously, electrons from your hair leave and accumulate on the edge of the comb. Your hair is now positively charged as it has lost electrons. The comb is negatively charged as it has gained electrons (Fig. 2.2).

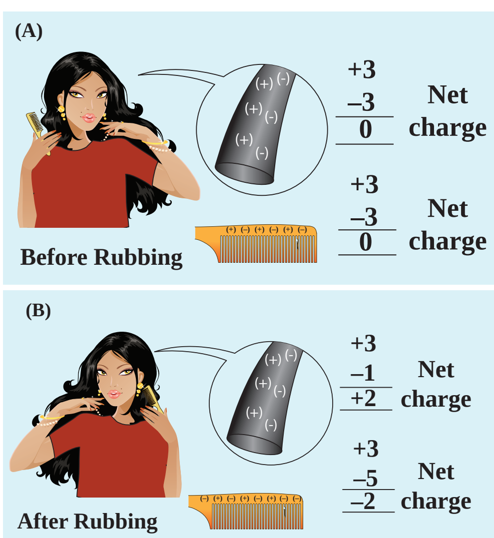
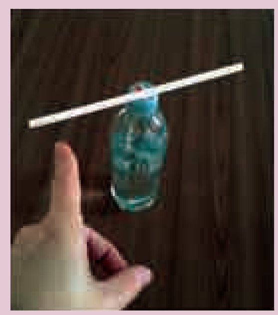
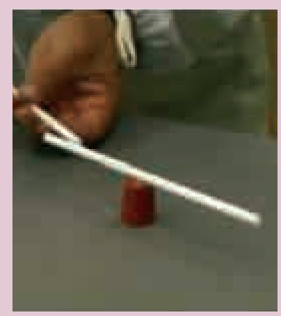


Figure 2.2 Frictional electricity

Activity 1

Take a straw which is used for drinking cool drinks. Cut a piece of it and place it on a plastic cap of a bottle as shown in the figure. Switch off the fan so that the piece does not fly away. Rub your fingers against a muslin or terri-cotton cloth and then bring it near the tip of the piece of straw. Observe what happens to it? It rotates because of deflection, doesn't it? Why does it deflect? Now instead of your finger bring another straw which is rubbed as said. The deflection is in the opposite direction. Can you give the reasons?

2.1.1 Measuring electric charge

Electric charge is measured in coulomb and the symbol for the same is C. The charge of an electron is numerically a very tiny value. The charge of an electron (represented as e) is the fundamental unit with a charge equal to 1.6×10^{-19} C. This indicates that any charge (q) has to be an integral multiple (n) of this fundamental unit of electron charge (e).

$q = ne$

here, n is a whole number.

DO YOU KNOW? There is a wrong understanding that we need protons to get a positive charge. Actually, protons are well seated inside the nucleus of an atom. They cannot be easily removed from or added to the nucleus of an atom. We deal only with electrons for getting a negative as well as positive ions. The excess electrons make an object negative and deficit of electrons make it positive.

Can you guess how many electrons accumulate to make 1 C of electric charge?

Exercise 2.1

How many electrons will be there in one coulomb of charge?

Solution:

Charge on 1 electron, e = 1.6 x 10^{-19} C

q=ne or n=q/e

∴ number of electrons in 1 coulomb

$$= \frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18} \text{ electrons}$$

Practically, we also have μC (micro coulomb) nC (nano coulomb)and pC (pico coulomb) as units of electric charge.

1 μC = 10^{-6} C, 1nC=10^{-9} and 1pC = 10^{-12}C

Electric charge is additive in nature. The total electric charge of a system is the algebraic sum of all the charges located in the system. For example, let us say a system has two charges +5C and –2C. Then the total or net charge on the system is, (+5C) + (–2C) = +3C.

2.1.2 Electric force

Among electric charges there are two types of electric force (F). One is attractive and another is repulsive. The like charges repel and unlike charges attract. **The force existing between the charges is called as 'electric force'.** These forces are non-contact forces, and hence can be experienced even when the charges are not in contact.

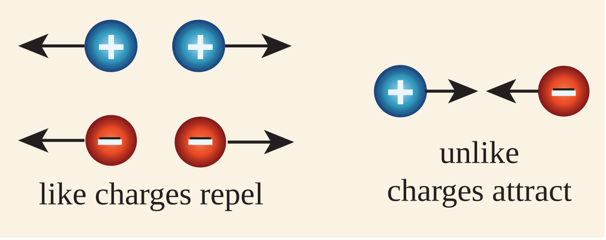


Figure 2.3 Electrostatic forces

The numerical value (magnitude) of electric force between two charges depend on the,

i. value of charges on them,
ii. distance between them and
iii. nature of medium between them.

> **DO YOU KNOW?** Electrostatic forces between two point charges obey Newton's third law. The force on one charge is the action and on the other is reaction and vice versa.

2.1.3 Electric field

The region in which a charge experiences electric force forms the 'electric field' around the charge. Often electric field (E) is represented by lines and arrowheads indicating the direction of the electric filed (Fig. 2.4). The direction of the electric field is the direction of the force that would act on a small positive charge. Therefore the lines representing the electric field are called 'electric lines of force'. **The electric lines of force are straight or curved paths along which a unit positive charge tends to move in the electric field.** Electric lines of force are imaginary lines. The strength of an electric field is represented by how close the field lines are to one another.

For an isolated positive charge the electric lines of force are radially outwards and for an isolated negative charge they are radially inwards.

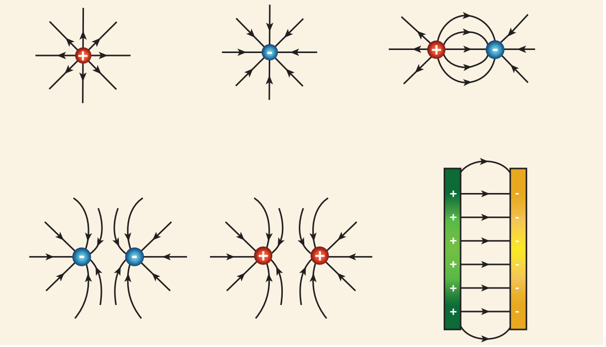


Figure 2.4 Electric lines of force

Electric field at a point is a measure of force acting on a unit positive charge placed at that point. A positive charge will experience force in the direction of electric field and a negative charge will experience in the opposite direction of electric field.

2.1.4. Electric potential

Though there is an electric force (either attractive or repulsive) existing among the charges, they are still kept together, is it not?. We now know that in the region of electric charge there is an electric field. Other charges experience force in this field and vice versa. There is a work done on the charges to keep them together. This results in a quantity called 'electric potential'.

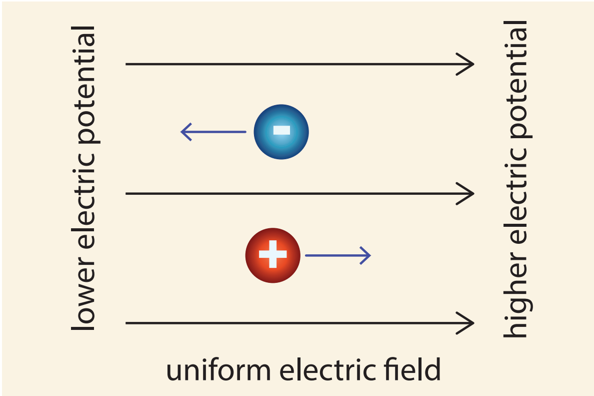


Figure 2.5 Electric potential and Electric field

Electric potential is a measure of the work done on unit positive charge to bring it to that point against all electrical forces. The electric potential (V) near positive charges is positive and near a negative charges is negative. Other positive charges have a tendency to move from higher potential to lower potential and negative charges the other way.

2.2 Electric current

When the charged object is provided with a conducting path, electrons start to flow through the path from higher potential to lower potential region. Normally, the potential difference is produced by a cell or battery. When the electrons move, we say that an electric current is produced. That is, an electric current is formed by moving electrons.

2.2.1 Direction of current

Before the discovery of the electrons, scientists believed that an electric current consisted of moving positive charges. Although we know this is wrong, the idea is still widely held, as the discovery of the flow of electrons did not affect the basic understanding of the electric current. The movement of the positive charge is called as 'conventional current'. The flow of electrons is termed as 'electron current'. This is depicted in Figure 2.6.

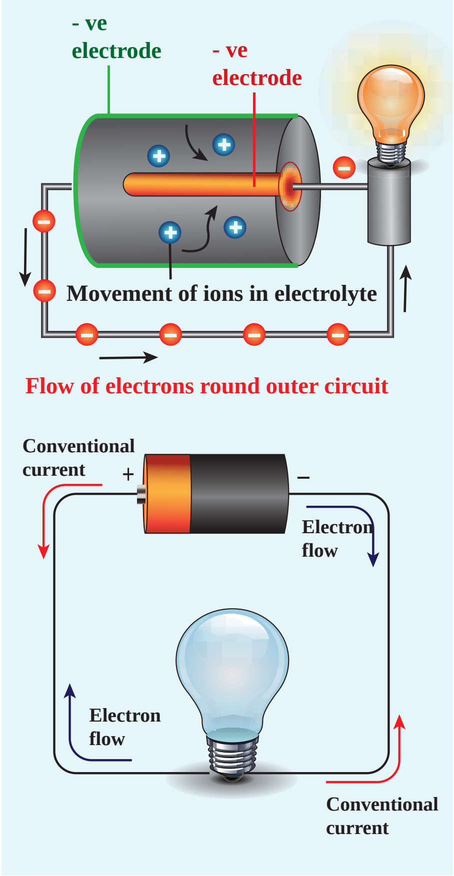


Figure 2.6 Electric current

In a battery, the potential of the positive terminal is maintained positive and the negative terminal is negative. Electrons are removed from the positive terminal and enriched at the negative terminal internally by means of chemical reaction or other processes. When a connection is given externally by a conducting wire, electrons flow from the negative terminal to the positive of the cell. Conventional current or simply the current, behaves as if positive charges cause the current flow. Although in reality it is the electron that moves in one direction, in equivalence, we consider as if it is the positive charges are moving in the opposite direction. This is taken as the direction of 'current'.

In electrical circuits the positive terminal is represented by a long line and negative terminal as a short line. Battery is the combination of more than one cell as shown in the Fig. 2.7.

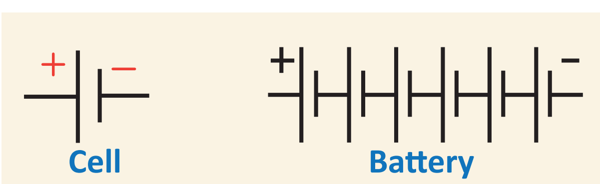


Figure 2.7 Cell and battery

2.2.2 Measurement of electric current

We can measure the value of current and express it numerically. **Current is the rate at which charges flow past a point on a circuit.** That is, if q is the quantity of charge passing through a cross section of a wire in a time t, quantity of current (I) is represented as,

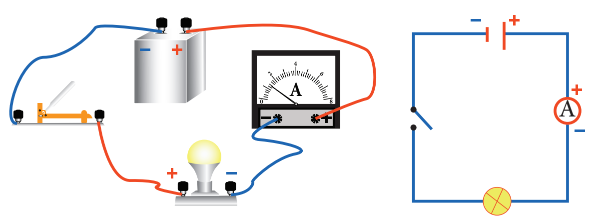
$$I = q/t$$

The standard SI unit for current is ampere with the symbol A. Current of 1 ampere means that there is one coulomb (1C) of charge passing through a cross section of a wire every one second (1 s).

1 ampere = 1 coulomb / 1 second (or)

$1\ A = 1\ C / 1\ s = 1CS^{-1}$

Ammeter is an instrument used to measure the strength of the electric current in an electric circuit.



(a) actual setup (b) Circuit diagram

Figure 2.8 Ammeter in a circuit

The ammeter is connected in series in a circuit where the current is to be found. . The current flows through the positive '+' red terminal of ammeter and leaves from the negative '–' black terminal.

Exercise 2.2

Suppose, 25 C of charge is determined to pass through a wire of any cross section in 50 s, what is the measure of current?

Solution:

I = q / t = (25 C) / (50 s) = 0.5 C/s = 0.5 A

Exercise 2.3

The current flowing through a lamp is 0.2A. If the lamp is switched on for one hour, What is the total electric charge that passes through the lamp?

Solution:

$I = q / t;\ q = I \times t$

Time has to be in second.

$\therefore 1hr = 1 \times 60 \times 60\ s = 3600\ s$

$q = I \times t = 0.2A \times 3600s = 720C$

2.2.3 Electromotive force (e.m.f)

Imagine that two ends of a water pipe filled with water are connected. Although filled with water, the water will not move or circle around the tube on its own. Suppose, you insert a pump in between and the pump pushes the water, then the water will start moving in the tube. Now the moving water can be used to produce some work. We can insert a water wheel in between the flow and make it to rotate and further use that rotation to operate machinery.

BLMZQ3

Likewise if you take a circular copper wire, it is full of free electrons. However, they are not moving in a particular direction. You need some force to push the electrons to move in a direction. The water pump and a battery are compared in Figure 2.9.

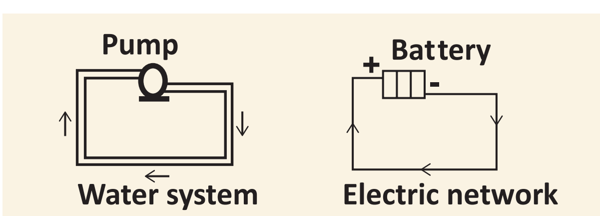


Figure 2.9 Battery is analogues to water pump

Devices like electric cells and other electrical energy sources act like pump, 'pushing' the charges to flow through a wire or conductor. The 'pumping' action of the electrical energy source is made possible by the 'electromotive force' (e.m.f). The electromotive force is represented as (e). The e.m.f of an electrical energy source is the work done (W) by the source in driving a unit charge (q) around the complete circuit.

$$\varepsilon = W/q$$

where, W is the work done or the non-electrical energy converted into electrical energy measured in joules and q is the amount of charge. The SI unit of e.m.f is joules per coulomb (JC^{-1}) or volt (V). In other words **the e.m.f of an electrical energy source is one volt if one joule of work is done by the source to drive one coulomb of charge completely around the circuit.**

Exercise 2.4

The e.m.f of a cell is 1.5V. What is the energy provided by the cell to drive 0.5 C of charge around the circuit?

Solution: $\varepsilon = 1.5V$ and $q = 0.5C$

$\varepsilon = W/q$; $W = \varepsilon \times q$; Therefore $W = 1.5 \times 0.5 = 0.75J$

DO YOU KNOW?

Though the word force is present in electro motive force, it is not a force. Scientists who worked with electricity in earlier days thought that there is force acting on the electrons in moving them through the wire. But, instead of considering the force, considering the potential difference which produces the movement became easy for handling the concepts. But, the name still remains as such but e.m.f is still measured in volt.

2.2.4 Potential difference (p.d)

One does not just let the circuit connect one terminal of a cell to another. Often we connect, say a bulb or a small fan or any other electrical device in an electric circuit and use the electric current to drive them. This is how a certain amount of electrical energy provided by the cell or any other source of electrical energy is converted into other form of energy like light, heat, mechanical and so on. For each coulomb of charge passing through the light bulb (or any appliances) the amount of electrical energy converted to other forms of energy depends on the potential difference across the electrical device or any electrical component in the circuit. The potential difference is represented by the symbol V.

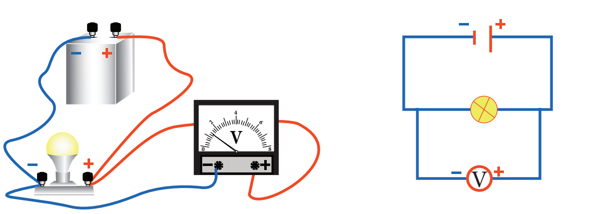
$$V = W/q$$

where, W is the work done, that is the amount of electrical energy converted into other forms of energy measured in joule and q is amount of charge measured in coulomb. The SI unit for both e.m.f and potential difference is the same in volt (V).

Note: Difference between e.m.f and potential difference:

As both e.m.f and potential difference are measured in volt, they may appear the same. But they are not. The e.m.f refers to the voltage developed across the terminals of an electrical source when it does not produce current in the circuit. Potential difference refers to the voltage developed between any two points (even across electrical devices) in an electric circuit when there is current in the circuit.

Voltmeter is an instrument used to measure the potential difference. To measure the potential difference across a component in a circuit, the voltmeter must be connected in parallel to it. Say, you want to measure the potential difference across a light bulb you need to connect the voltmeter as given in Figure 2.10.



(a) actual setup (b) Circuit diagram

Figure 2.10 Connection of voltmeter in a circuit

Note the positive ('+') red terminal of the voltmeter is connected to the positive side of circuit and the negative ('–') black terminal is connected to the negative side of the circuit across a component (light bulb in the above illustration).

Exercise 2.5

A charge of 2×10^4 C flows through an electric heater. The amount of electrical energy converted into thermal energy is 5 MJ. Compute the potential difference across the ends of the heater.

$V = W/q$ that is 5×10^6 J / 2×10^4 C = 250 V

2.2.5 Resistance

The Resistance (R) is the measure of opposition offered by the component to the flow of electric current through it. The opposition to the flow of current is caused in terms of opposition to the flow of electrons by other electrons and the thermal vibrations. Different electrical components offer different electrical resistance.

Even the conducting wires offer resistance to the flow of electric current through it. But, it is very much negligible. Metals like copper, aluminium etc., have very much negligible resistance. That is why they are called good conductors. On the other hand, materials like nicrome, tin oxide etc., offer high resistance to the electric current. We also have a category of materials called insulators; they do not conduct electric current at all (Glass, Polymer, rubber and paper). All these materials are needed in electrical circuits to have usefulness and safety in electrical circuits.

The resistance offered by a material at a particular temperature depends on the,

i. geometry of the material and

ii. nature of the material.

The SI unit of resistance is ohm with the symbol (Ω). **One ohm is the resistance of a component when the potential difference of one volt applied across the component drives a current of one ampere through it.**

We can also control the amount of flow of current in a circuit with the help of resistance. Such components used for providing resistance are called as 'resistors'. The resistors can be fixed or variable.

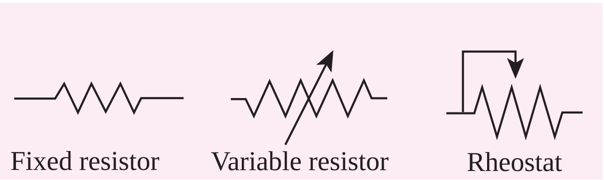


Figure 2.11 Circuit symbol for resistor

Fixed resistors have fixed value of resistance, while the variable resistors like rheostats can be used to obtain desired value of resistance as shown in Figure 2.11.

2.2.6 Ohm's law

Ohm's law states that electric potential difference across two points in an electrical circuit is directly proportional to the current passing through it. That is,

$$V \propto I$$

The proportionality constant is the resistance (R) offered between the two points.

Hence, Ohm's law is written as,

$$V = R\,I \quad \text{(or)} \quad V = I\,R$$

Where V is the potential difference across the component in volt(V), I is the current flowing through the component in ampere(A) and R is the resistance of the component in ohm (Ω).

Any appliance connected to the circuit offers resistance. We can measure it by measuring the current (I) flowing through them and the potential difference (V) across them. Once we measure these two quantities, we can compute R from the formula R=V/I. When we plot a graph by taking current (I) in the x-axis and voltage (V) in the y-axis, we get a straight line as shown in Fig 2.13. The slope of the line gives the value of resistance (R)

RESISTORS

Fixed resistor

A fixed resistor has a resistance of fixed value. Common types of fixed resistors include carbon film resistors and wire-wound resistors.

Some common fixed resistors

Variable resistors

A variable resistor has a resistance that can be varied. It is used to vary the amount of current flowing in a circuit.

A rheostat is a type of variable resistor.

Figure 2.12 Types of resistors

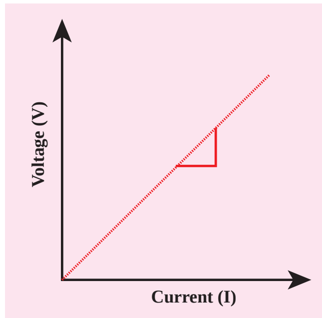


Figure 2.13 Relation between Current and Voltage

Example 2.6

A potential difference of 230 V applied across the heating coil drives a current of 10 A through it. Calculate the resistance of the coil.

V = 230 V; I = 10A

R = V/ I that is 230/10 = 23Ω

Know your Scientist

Georg Simon Ohm, is a well-known German physicist who discovered the relation between potential difference, current and resistance. This relation is named after him, as Ohm's law. The ohm, the physical unit measuring electrical resistance, also was named after him.

He was born in March 16, 1789, at Erlangen, Bavaria in Germany. Ohm became professor of mathematics at the Jesuits' College at Cologne in 1817. His work greatly influenced the theory and applications of current electricity. Georg Ohm resigned his post at Cologne. He accepted a position at the Polytechnic School of Nürnberg in 1833. In 1841 he was awarded the Copley Medal of the Royal Society of London and was made a foreign member a year later. He died on July 6, 1854, in Munich.

2.3 Electric circuit diagram

To represent an electrical wiring or solve problem involving electric circuits, the circuit diagrams are made.

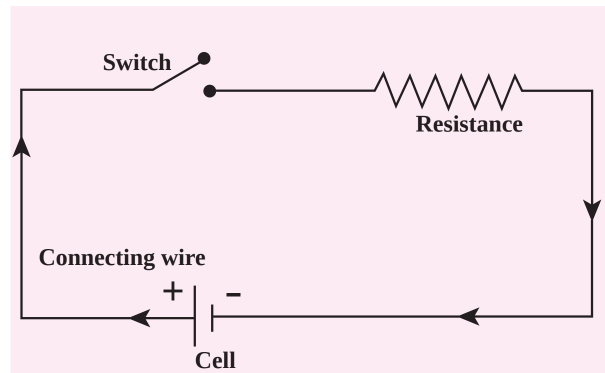


Figure 2.14 Typical electric circuit

The four main components of any circuits namely the, (i) cell, (ii) connecting wire, (iii) switch and (iv) resistor or load are given above. In addition to the above many other electrical components are also used in an actual circuit. A uniform system of symbols has been evolved to describe them. It is like learning a sign language, but useful in understanding circuit diagrams.

Activity 2

Take a condensed electronic circuit board in a TV remote or old mobile phone. Look at the electrical symbols used in the circuit. Find out the meaning of the symbols known to you.

2.3.1 Some common symbols in the electrical circuit

Some of the symbols are shown in Table 1.

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