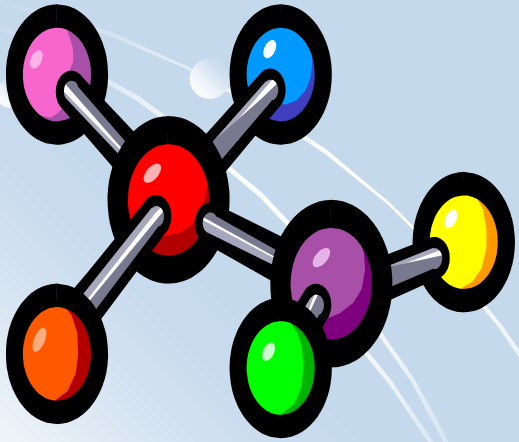
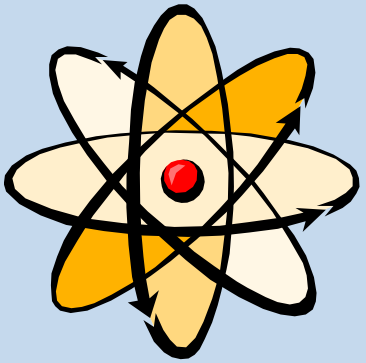
Chapter 1 : MATTER

1.1 Atoms and Molecules

1.2 Mole Concept

1.1 Atoms and Molecules





Learning Outcome

At the end of this topic, students should be able :

(a) Identify and describe proton, electron and neutron as subatomic particle.

(b) Define proton number, Z, nucleon number, A and isotope. Write isotope notation.

Introduction

- Matter

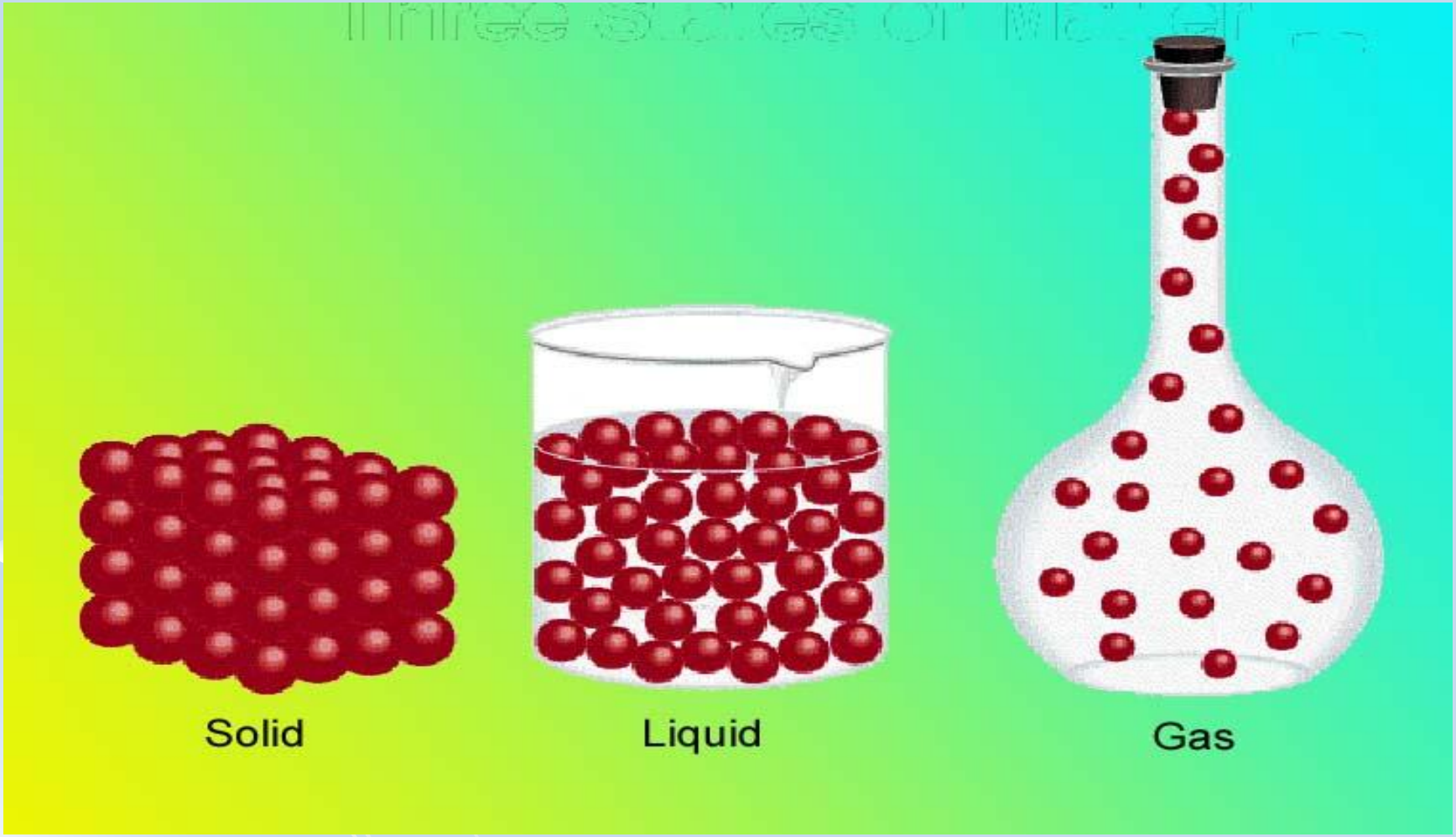
  Anything that occupies space and has mass.

  e.g

  air, water, animals, trees, atoms, …..

- Matter may consists of atoms, molecules or ions.

Three States of Matter



1.1 Atoms and Molecules

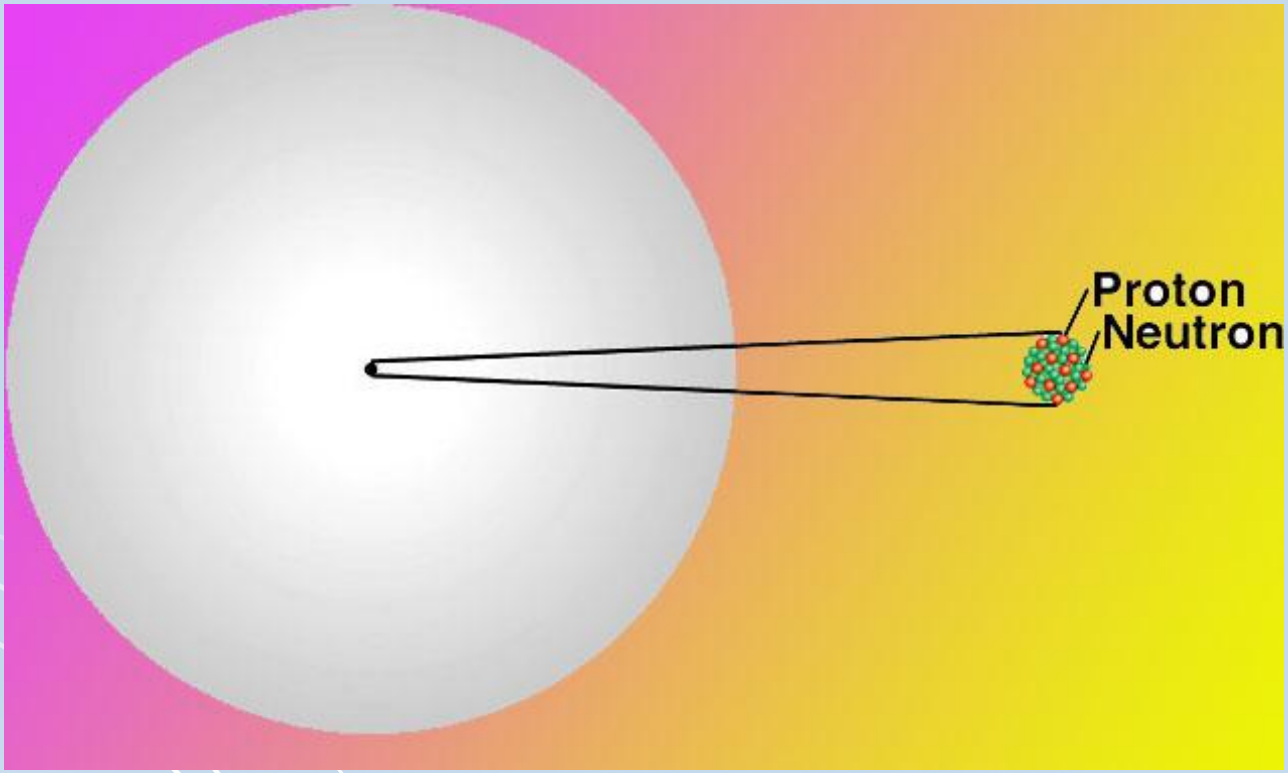
1.1.1 Atoms

- An atom is the smallest unit of a chemical element/compound.
- In an atom, there are three subatomic particles:
  - Proton (p)
  - Neutron (n)

  } Packed in a small nucleus

  - Electron (e) } Move rapidly around the nucleus of an atom

Modern Model of the Atom



- Electrons move around the region of the atom.

Subatomic Particles

Particle	Mass (gram)	Charge (Coulomb)	Charge (units)
Electron (e)	9.1×10^{-28}	-1.6×10^{-19}	-1
Proton (p)	1.67×10^{-24}	$+1.6 \times 10^{-19}$	+1
Neutron (n)	1.67×10^{-24}	0	0

Elements

- A substance that cannot be separated into simpler substances by chemical reactions.

- An element is composed of atoms of only one kind.

Isotope

- Isotopes are two or more atoms of the same element that have the same number of protons in their nucleus but different number of neutrons.
- Examples:

$^{1}_{1}H$	$^{2}_{1}H$ (D)	$^{3}_{1}H$ (T)
$^{235}_{92}U$	$^{238}_{92}U$	

Isotope Notation

- An atom can be represented by an isotope notation

  (atomic symbol)

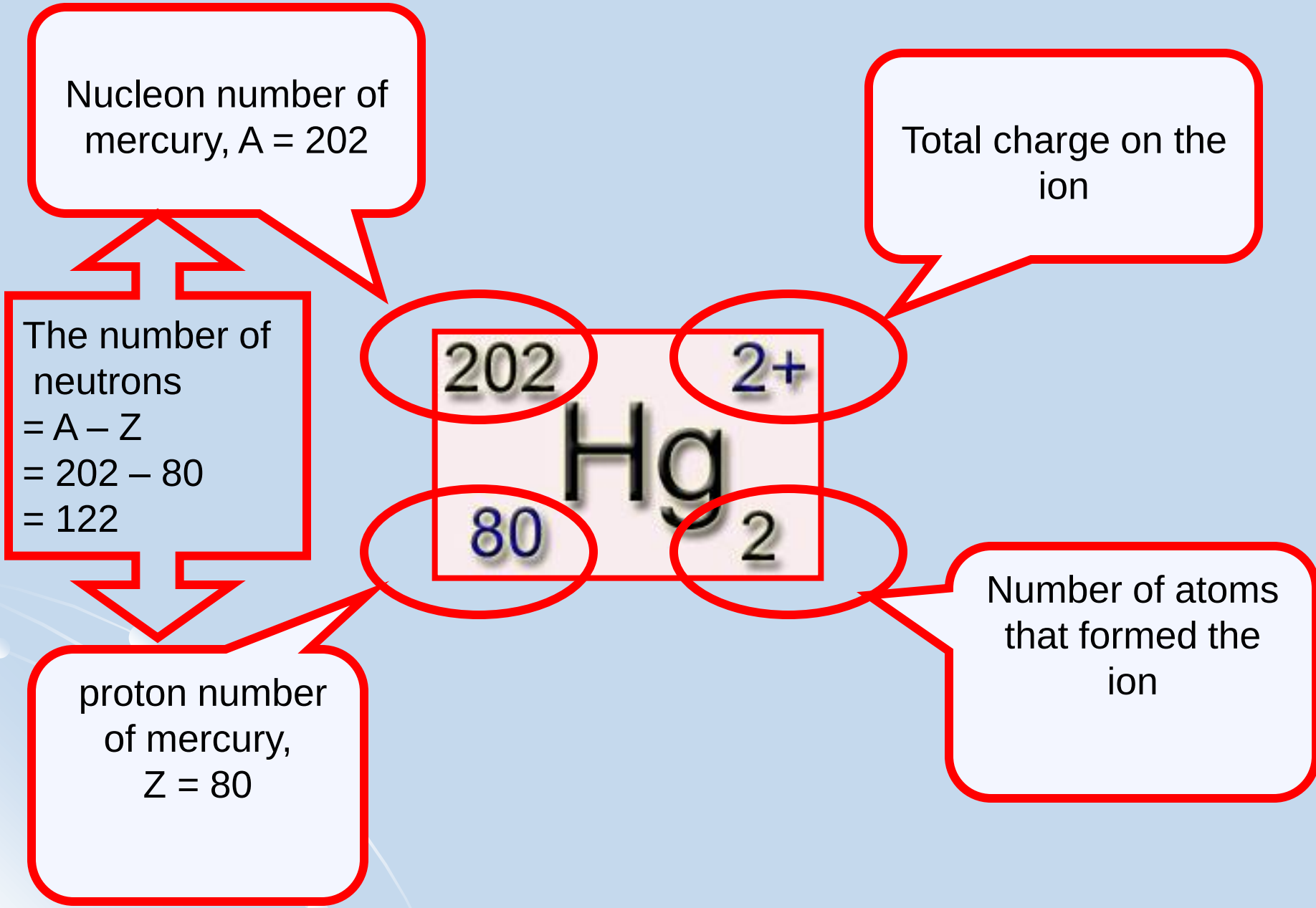
X = element symbol

Z = Proton Number of X

= p

A = Nucleon Number of X

= Z + n


Nucleon number of mercury, A = 202
Total charge on the ion
The number of neutrons
= A – Z
= 202 – 80
= 122
202
2+
Hg
80
2
proton number of mercury, Z = 80
Number of atoms that formed the ion

Exercise 1

- Give the number of protons, neutrons,electrons and charge in each of the following species:

Symbol	Number of :			Charge
	Proton	Neutron	Electr0n	
$^{200}_{80}Hg$				
$^{63}_{29}Cu$				
$^{17}_{8}O^{2-}$				
$^{59}_{27}Co^{3+}$				

Exercise 2

- Write the appropriate notation for each of the following nuclide :

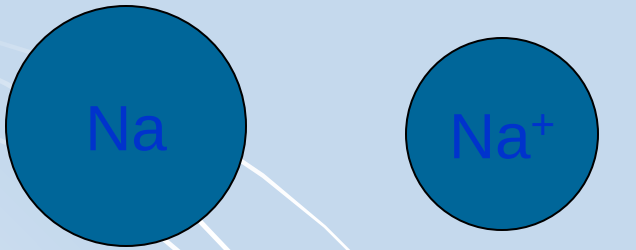
Species	Number of :			Notation for nuclide
	Proton	Neutron	Electron	
A	2	2	2	
B	1	2	0	
C	1	1	1	
D	7	7	10	

1.1.5 Ion

- Two types of ions : a) cation b) anion

Cation

a positive charge ion formed when a neutral atom loses an electron(s).

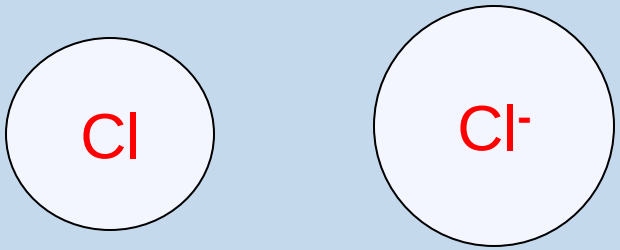


11 protons
11 electrons

11 protons
10 electrons

Anion

a negative charge ion formed when a neutral atom gains an electron(s).

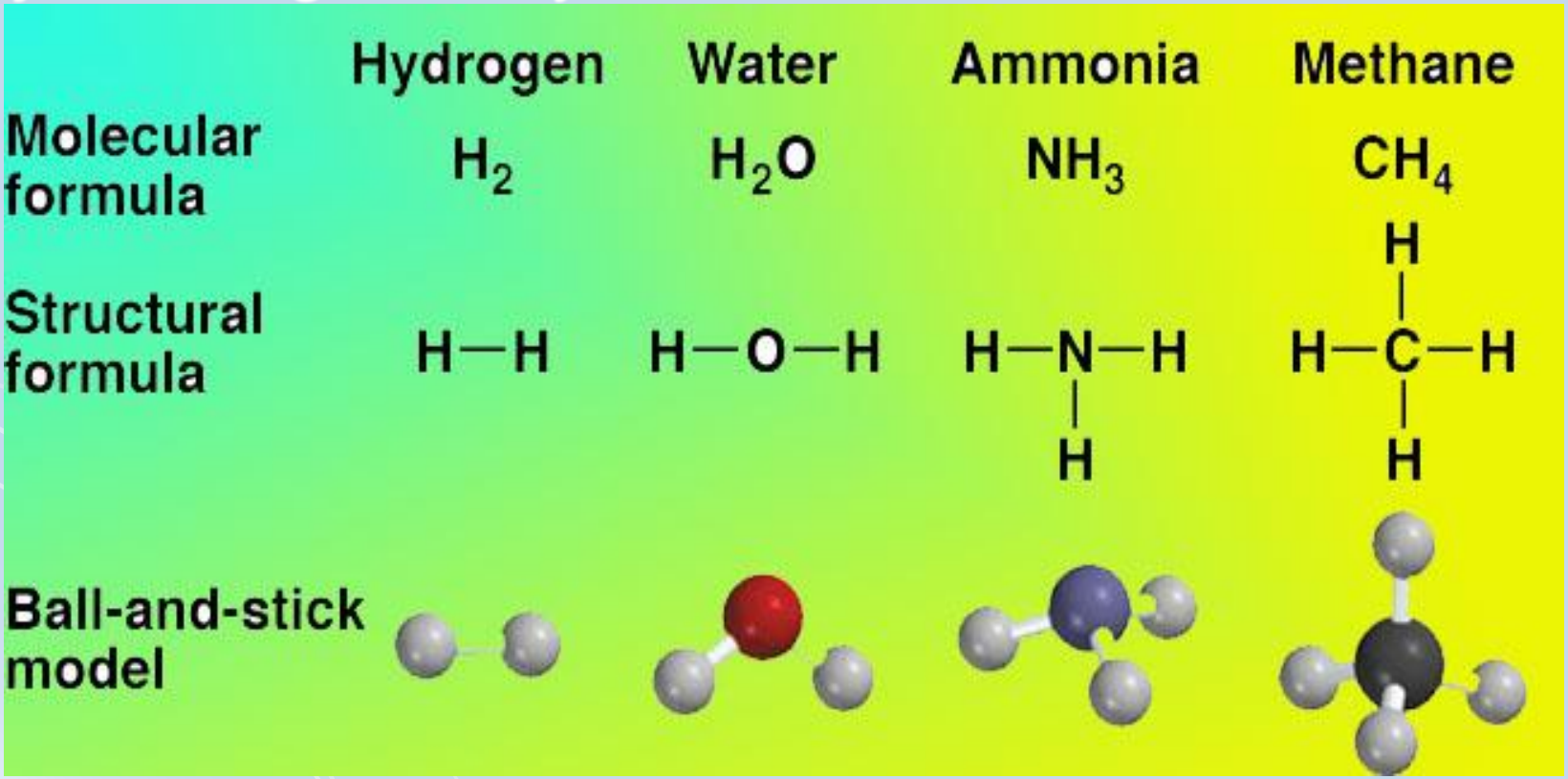


17 protons
17 electrons

17 protons
18 electrons

Molecule

- A molecule consists of a small number of atoms joined together by bonds.



A diatomic molecule

- Contains only two atoms
- Example :

  H_2, N_2, O_2, Br_2, HCl, CO

A polyatomic molecule

- Contains more than two atoms
- Example :

  O_3, H_2O, NH_3, CH_4

Relative Mass

i. **Relative Atomic Mass, Ar**

A mass of one atom of an element compared to 1/12 mass of one atom of ^{12}C with the mass 12.000

$$\text{Relative atomic mass, Ar} = \frac{\text{Mass of one atom of element}}{\frac{1}{12} \text{ X Mass of one atom of } {}^{12}C}$$

Example 1

- Determine the relative atomic mass of an element Y if the ratio of the atomic mass of Y to carbon-12 atom is 0.45

ANSWER:

$$\text{Ar (Y)} = \frac{\text{Mass of one atom of Y}}{\text{1/12 x Mass of one atom of C-12}}$$

$$= 0.45 \times 12$$

$$= 5.4$$

ii) Relative Molecular Mass, Mr

- A mass of one molecule of a compound compared to 1/12 mass of one atom of ^{12}C with the mass 12.000

$$\text{Relative molecular mass, Mr} = \frac{\text{Mass of one molecule of a compound}}{\frac{1}{12} \text{ X Mass of one atom of } {}^{12}C}$$

- The relative molecular mass of a compound is the summation of the relative atomic masses of all atoms in a molecular formula.

Example 2

- **Calculate the relative molecular mass of C_5H_5N,**

  Ar C = 12.01

  Ar H = 1.01

  Ar N = 14.01

ANSWER:

Mr = 5(Ar of C) + 5(Ar of H) + Ar of N

= 5(12.01) + 5(1.01) + 14.01

= 60.05 + 5.05 + 14.01

= 79.11

Mass Spectrometer

- **A mass spectrometer is used to determine:**

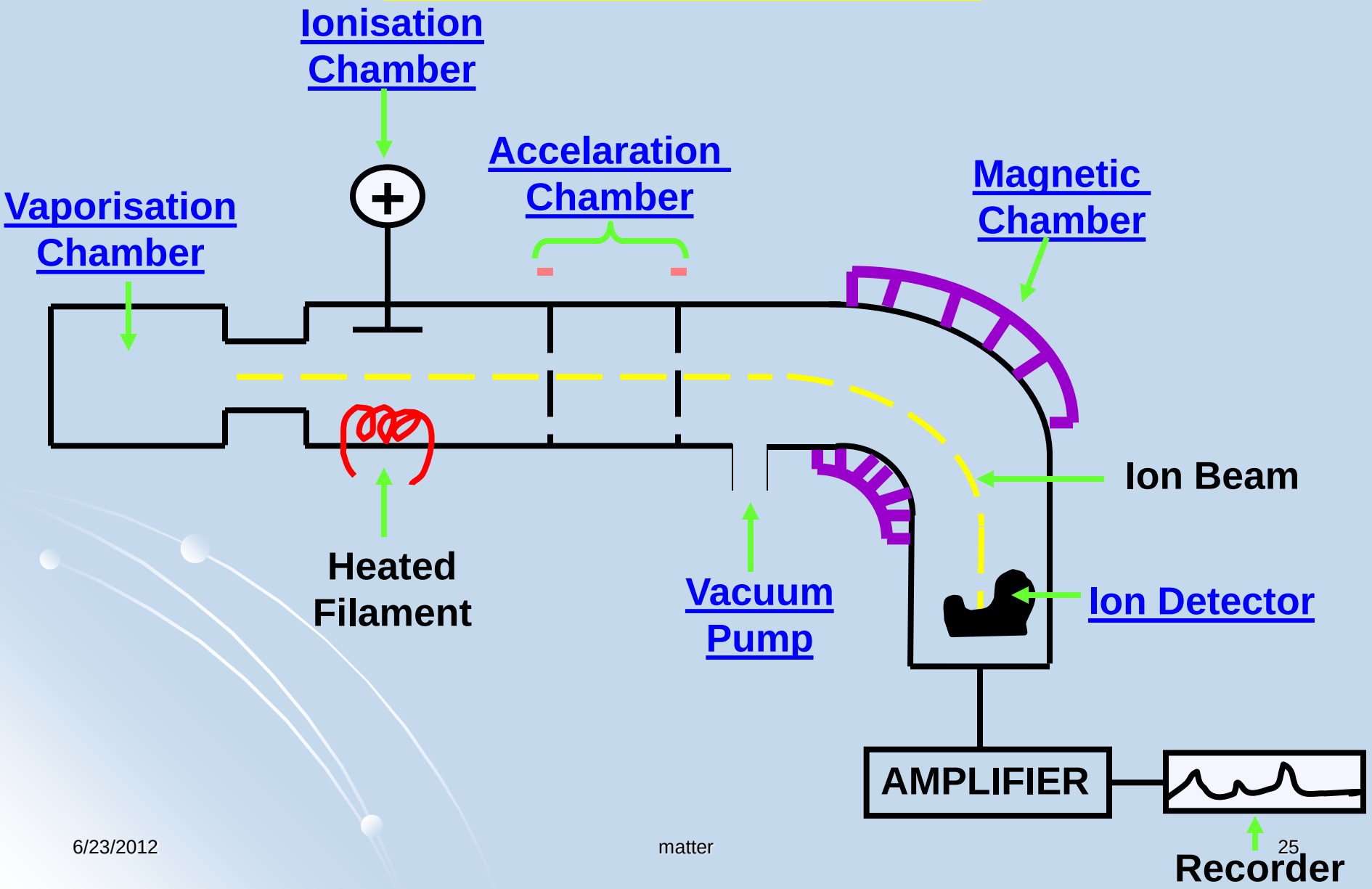
  i. Relative atomic mass of an element

  ii. Relative molecular mass of a compound

  iii. Types of isotopes, the abundance and its relative isotopic mass

  iv. Recognize the structure of the compound in an unknown sample

A Mass Spectrometer



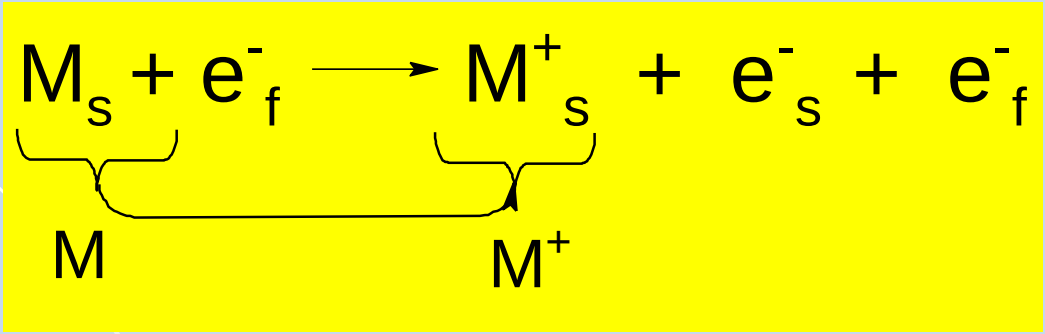
Vaporisation Chamber

- sample of the element is vaporised into gaseous atom

Ionisation Chamber

- A gaseous sample is bombarded by a stream of high-energy electrons that are emitted from a hot filament.

- Collisions between the electrons and the gaseous sample produce positive ions



Vacuum Pump

- A pump maintains a vacuum inside the mass spectrometer to avoid any small particle that would block the movement.

Acceleration Chamber

- the positive ions are accelerated by an electric field towards the two oppositely charge plates

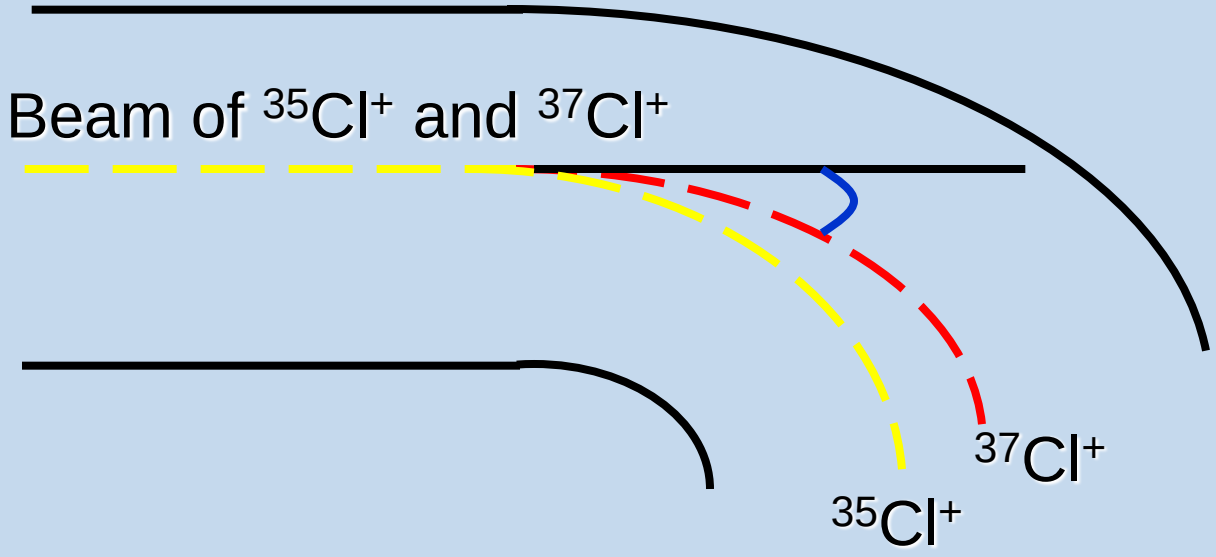
- the electric field is produced by a high voltage between the two plates

- the emerging ions are of high and constant velocity.

Magnetic Field

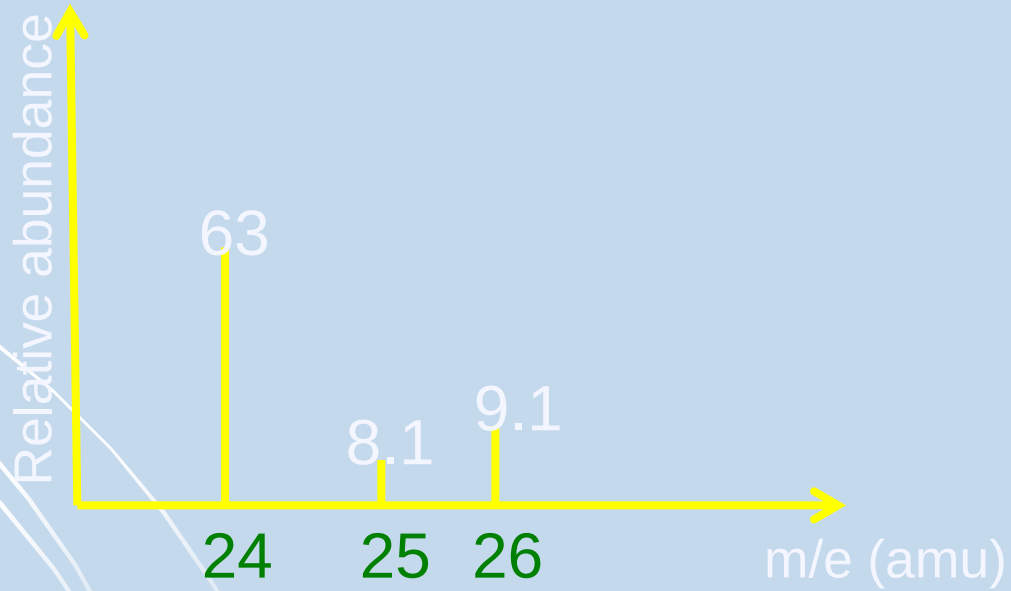
- The positive ions are separated and deflected into a circular path by a magnet according to its mass / charge (m/e) ratio.

- Positive ions with **small m/e ratio** are deflected **most** Ions with **large m/e ratio** are deflected **least.**

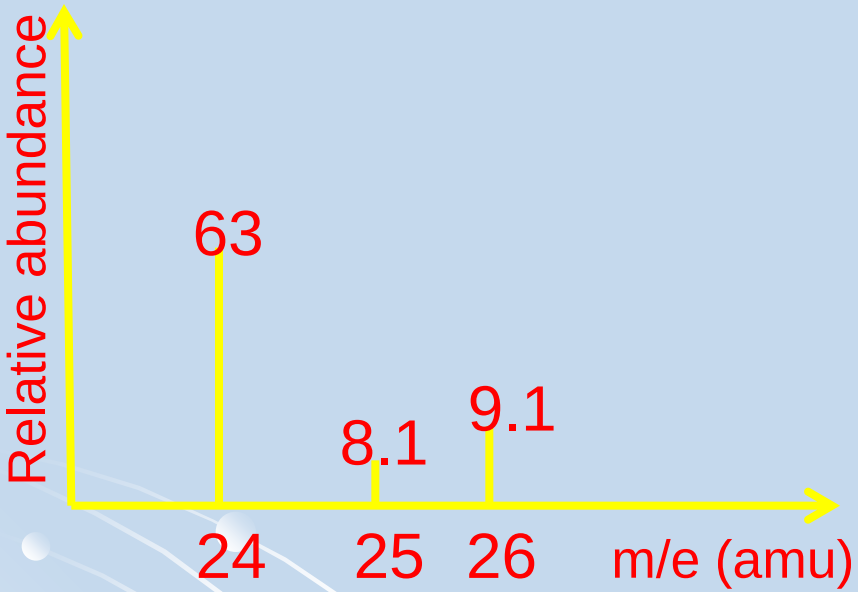

Beam of $^{35}Cl^{+}$ and $^{37}Cl^{+}$
$^{37}Cl^{+}$
$^{35}Cl^{+}$

Ion Detector

- The numbers of ions and types of isotopes are recorded as a mass spectrum.
- Example : A mass spectrum of Mg



Mass Spectrum of Magnesium



- The mass spectrum of Mg shows that Mg consists of **three isotopes**: **^{24}Mg, ^{25}Mg and ^{26}Mg.**
- The **height of each line** is propartional to the **abundance of each isotope.**
- **^{24}Mg** is the most abundant of the three isotopes

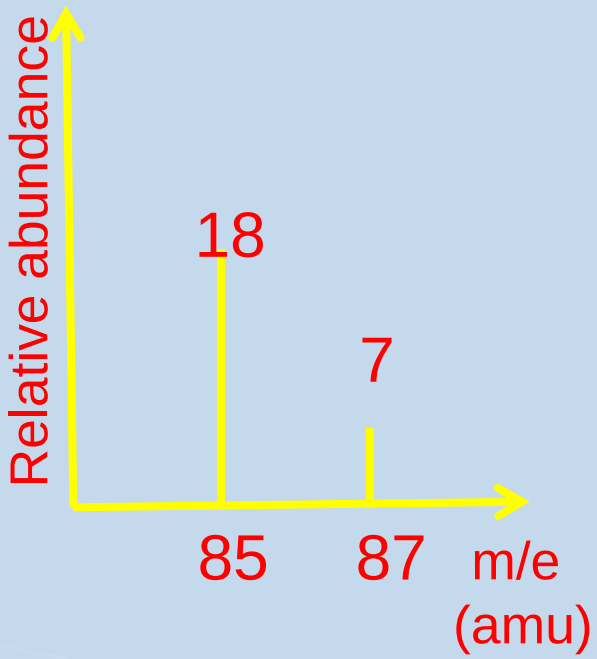
How to calculate the relative atomic mass from mass spectrum?

$$Ar = \frac{\Sigma Q_i M_i}{\Sigma Q_i}$$

Q = **the relative abundance / percentage abundance of an isotope of the element**

M = **the relative isotopic mass of the element**

Example 1



1. **Fig 1.1 shows the mass spectrum of the element rubidium, Rb;**

   a. **What isotopes are present in Rb?**

   ^{85}Rb and ^{87}Rb

   b. **What is the percentage abundance of each isotope?**

% abundance ^{85}Rb

$$= \frac{18}{25} \times 100$$

$$= 72\ \%$$

% abundance ^{87}Rb

$$= \frac{7}{25} \times 100$$

$$= 28\ \%$$

Example 1 (cont…)

c. Calculate the relative atomic mass of Rb.

$$\text{Average mass of Rb} = \frac{\Sigma QiMi}{\Sigma \text{Qi}}$$

$$= \frac{(18\text{x}85) + (7\text{x}87)}{25}$$

$$= 85.56 \text{ amu}$$

$$\text{A}_\text{r} \text{ of Rb} = \frac{85.56 \text{ amu}}{\frac{1}{12}\text{x}12.00 \text{ amu}}$$

$$= 85.56$$

Example 2

The relative atomic mass of $^{6}_{3}Li$ and $^{7}_{3}Li$ are 6.01 and 7.02. What is the percentage abundance of each isotope if the relative atomic mass of Li is 6.94?

Assume that,

% abundance of ^{6}Li = X %

% abundance of ^{7}Li = (100 - x) %

$$\text{Ar Li} = \frac{\sum QiMi}{\sum Qi}$$

$$6.94 = \frac{X\,(6.01) + (100 - X)\,7.02}{X + 100 - X}$$

$$6.94 = \frac{6.01\,X + 702 - 7.02\,X}{100}$$

$$694 - 702 = -1.01\,X$$

$$+8 = +1.01\,X$$

$$X = 7.92\ \%$$

So, % abundance of ^{6}Li = 7.92 %

And % abundance of ^{7}Li = 92.08 %

Exercise 1

The ratio of relative abundance of naturally occuring of chlorine isotopes is as follow:

$$\frac{^{35}Cl}{^{37}Cl} = 3.127$$

Based on the carbon-12 scale, the relative atomic mass of $^{35}Cl = 34.9689$ and $^{37}Cl = 36.9659$. Calculate the Ar of chlorine.

(Ans: 35.45)

Exercise 2

Naturally occuring iridium, Ir is composed of 2 isotopes ^{191}Ir and ^{193}Ir in the ratio of 5 : 8 . The relative mass of ^{191}Ir and ^{193}Ir are 191.021 and 193.025 respectively. Calculate the relative atomic mass of iridium.

(Ans : 192.254)

IUPAC Nomenclature of Ions

A) Cations

i) For the metals of group 1, 2 and 13 :

Name the metals followed by the word ‘ ions ‘

e.g : Na^+ : sodium ion, Al^{3+} : aluminium ion

ii) For the metal with more oxidation states, Roman numerals are used to indicate the oxidation state.

e.g : Cu^{2+} : copper(II) ion, Fe^{3+} : iron(III) ion

B. Anions

- Monoatomic ions have names that ended with ‘ide’

  e.g : F^{-} : fluoride ion, O^{2-} : oxide ion

- Other polyatomic anions have their own names

  e.g : CO_3 : carbonate ion, SO_4^{2-} : sulphate ion,

  $Cr_2O_7^{2-}$: dichromate ion

- When a metal combines with a nonmetal element, the metal is named before the nonmetal

Example : $Fe_2(SO_4)_3$ - Iron(III) sulphate

$FeCl_3$ - Iron(III) chloride

$CuCl_2$ - copper(II) chloride