ATOMIC STRUCTURE

Atomic structure deals with the study of the composition of an atom.

Atom is the smallest particle of an element that can take part in a chemical reaction. An atom has all properties of a given element.

Atoms can combine together to form a **molecule.**

A molecule is a particle that consists of two or more atoms which are chemically combined together.

Generally, molecules can be categorized into:

- a molecule of an element
- a molecule of a compound.

A molecule of an element is made up of only one type of atom; for example, oxygen molecule (O_2), is made up of two atoms of oxygen.

A molecule of a compound must contain more than one type of atom; for example, a molecule of water (H_2O) is made up of two atoms of hydrogen element and one atom of oxygen.

Both molecule and atom are neutral, that is, they have no charges.

Molecules usually exist on their own. *Atoms* may or may not exist on their own.

Atomic Theory

Dalton's Atomic Theory of Matter

1. Matter is made up of tiny indivisible particles called atoms.
2. Atoms can neither be created nor destroyed.
3. Atoms of same element are identical and have the same mass and properties and they differ from those of other elements.
4. Compounds are formed by a combination of two or more different atoms in simple whole number ratios.

The Weakness of Dalton's Atomic theory

1. It did not explain why atoms combine with each other.
2. Discovery of isotopes indicated that all atoms of the same element are not perfectly identical.
3. With the discovery of sub-atomic particles, atom is no longer considered as indivisible.
4. With the existence of complex compounds and polymers atoms are no longer combine in small number ratios.

Modern Atomic Theory of Matter

1. An atom is made up of smaller sub-atomic particles called protons, neutrons and electrons.
2. Atoms can be created or destroyed through nuclear reactions.
3. Atoms of the same element can have different masses. Such atoms are called **isotopes**.
4. Atoms of different elements may combine in many different ratios to form complex compounds.

Subatomic Particles

Atoms are made up of tiny particles called **sub-atomic particles.**
→An atom contains three types of subatomic particles:

- Protons
- Neutrons
- Electrons

Electron

This is a negatively charged particle.
→It has a very small mass about $\frac{1}{1840}$ that of the proton.

→Its symbol is e^-
→The electron moves around the nucleus at a very high speed.
The path of electrons around the nucleus is called **shell** or **energy level.**

Proton

This is a positively charged particle.
→It has a relative mass of 1.
→It is found in the nucleus of an atom
→Its symbol is p.
→The number of protons in the nucleus determines the element's identity (atomic number).

Neutron

This particle has no charge at all; therefore, it is a neutral particle.
→It has mass approximately equal to that of proton, that is 1.
→It is found in the nucleus of an atom
→Its symbol n.

Properties of sub-atomic particles

Subatomic	**symbol**	**Location**	**Charge**	**Real mass(g)**	**Relative mass**
Proton	p	In the nucleus	+1	1.6726×10^{-24}	1
Neutron	n	In the nucleus	0	1.6750×10^{-24}	1
Electron	e^-	Outside the nucleus	-1	9.109×10^{-24}	$\frac{1}{1840}$

The collective name for neutrons and protons is known as **nucleons.**

Atom has a nucleus which is positively charged and shells or energy levels.

An atom is **neutral** because the number of electrons equals to the number of protons in an atom.

Arrangement of Electrons in an Atom

- Always the electrons move around the nucleus of an atom in the special path which is known as **shell or energy level**

- Each shell can hold only a certain number of electrons.
- The number of electrons each shell can hold is determined by the formula $2n^2$ where n = the position of a shell from the nucleus.
- The first shells are represented by K, L, M and N respectively

Shell number from the nucleus	**$2n^2$**	**Number of electrons**
1	2×1^2	2
2	2×2^2	8
3	2×3^2	18
4	2×4^2	32

It is, however, important to note that for the first 20 elements, the third shell or energy level can only hold a maximum of 8 electrons.

The arrangement of electrons in different shells of an atom is known as **electronic configuration.**

The electronic configuration of an element can be represented simply by numbers separated by commas (,) or dots (.) or ratio symbol sign **(:)**.

Electrons fill up shells from the inner shell to the outer shell. This is because the innermost shell is of lowest energy.

Element	**Number of electrons**	**No of shells**	**Electronic configuration**
Hydrogen	1	1	1
Helium	2	1	2

Lithium	3	2	2:1
Calcium	20	4	2:8:8:2

Draw and write the electronic configurations of the atoms of the following elements:

(a) Magnesium
(b) Aluminium
(c) Sulphur
(d) neon

ATOMIC NUMBER, MASS NUMBER AND ISOTOPES

a. Atomic number (Z)

This is the number of protons in the nucleus of an atom.
→It is also the number of electrons in a neutral atom.
→The official symbol for atomic number is Z.
→It is written as a subscript in front of the symbol for the atom.
For example an atom of Calcium which has atomic number of 20, it can be written as $_{20}$Ca.

b. Mass number (A)

This is the sum of the numbers of protons and neutrons in the nucleus of an atom.
→Its official symbol is A.
→It is written as superscript in front of the symbol for the atom.
For example, calcium has a mass number of 40, therefore it can be written as ^{40}Ca.
→The combination of atomic number and mass number for a particular atom can be written as $^{A}_{Z}X$. This way of writing is known as **NUCLIDE NOTATION.**
→Therefore the nuclide notation of calcium *is* $^{40}_{20}Ca$.

The relationships among atomic number, mass number and sub-atomic particles.

- **Atomic number (Z) = Number of protons(p) = Number of electrons in a neutral atom.**
- **Mass number (A) = Number of protons (p) + Number of neutrons (N).**
- **Number of neutrons (N) = Mass numbers (A) - Atomic number (Z).**

  N = A-Z.

Examples

1. Atom Q has a mass number of 49 and an atomic number of 24. What is its number of neutrons? What is the number of electrons in atom Q?

   Solution

   Mass number = 49

   Atomic number = 24

   (a) Neutron number = mass number – atomic number = 49 – 24 = 25

   (b) Number of electrons = number of protons = atomic number =24

2. Potassium atom has 19 electrons and the mass number of 39.

   (c) Workout the:

   (i) Atomic number and

   (ii) Number of neutrons

   (d) The symbol for potassium is K. Give the nuclide notation.

   (e) Show the representation of the nucleus of the potassium atom.

   (f) Draw the electronic configuration of potassium.

Solution

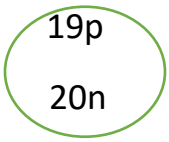
(a)(i) atomic number = number of protons = number of electrons = 19

(ii) Number of neutrons = mass number – number of protons

= 39 – 19

= 20

(b) $^{39}_{19}\mathrm{K}$

© 

(d) draw

3. An element has a symbol of $^{16}_{8}\mathrm{Y}$. Write down its

   a. atomic number
   b. mass number
   c. number of electrons
   d. number of protons
   e. number of neutrons

4. Copy the table and fill all the blank spaces in the table

Element	symbol	Number of protons	Number of neutrons	Number of electrons	Mass number	Atomic number
Lithium	Li			3	7	3
Beryllium	Be		5			4
Oxygen	O				16	8
Hydrogen	H	1	0		1	1
Nitrogen	N				14	7

5. How many protons, electrons and neutrons are in:
   (a) $^{27}_{13}\mathrm{Al}$
   (b) $^{24}_{12}\mathrm{Mg}$
   © $^{12}_{6}\mathrm{C}$.

<u>Discuss the electronic configurations of ions</u>

When an atom loses or gains electron(s) it becomes **an ion.**

There are two types of ions:

Cations are positively charged ions. They are formed when an atom loses electrons eg. Ca^{2+}=calcium ion, K^{+} = potassium ion

Anions are negatively charged ions. They are formed when an atom gains electrons eg. . O^{2-} oxide ion, Cl^{-} chloride ion

Write the electronic configuration of:

(a) Al^{3+} = 2:8
(b) Ca^{2+} = 2:8:8
(c) O^{2-} = 2:8

c. Isotopes

Isotopes are atoms of the same element with the same number of protons but different number of neutrons.
OR
Isotopes are atoms of the same element with the same atomic numbers but different mass numbers.

Isotopy is the existence of atoms of the same element having the same atomic number but different mass numbers.
Isotopes have:

i. the same number of protons, electrons and atomic number.
ii. the same chemical properties but may have slightly different physical properties.
iii. different mass numbers and neutron numbers.

Why isotopes have the same chemical properties?
Because they have the same arrangement and number of electrons.

Examples of elements with isotopes are:

1. **Hydrogen has three isotopes**

Protium $^{1}_{1}H$ or hydrogen-1
Deuterium $^{2}_{1}H$ or hydrogen-2
Tritium $^{3}_{1}H$ or hydrogen-3.

2. **Chlorine has two isotopes**

Chlorine-35
Chlorine -37

3. **Carbon has three isotopes**

Carbon-12
Carbon-13
Carbon -14

Refer students book page 98

Question

An isotope of carbon has a mass number of 13 and atomic number of 6.

a. **Write its nuclide notation.**
b. **How many neutrons does it have?**
c. **How many electrons does it have?**

Relative Atomic mass (R.A.M or Ar)

Relative atomic mass is the average mass of one atom of the element relative to $\frac{1}{12\text{th}}$ the mass of one atom of carbon -12.

Relative Atomic Mass(R.A.M) = The sum of isotopic mass x Percentage abundance

Example.

In a sample of chlorine gas, the relative abundance of chlorine -35 atoms is 75% and that of chlorine -37 is 25%. Calculate the relative atomic mass of chlorine.
Soln.

Relative Atomic Mass(R.A.M) = The sum of (isotopic mass x Percentage abundance)

$$= \frac{(75\times35)+(25\times37)}{100}$$

$$= 35.5$$

Therefore,

the relative atomic mass of chlorine is 35.5

The relative atomic mass is always a decimal number between the mass numbers of the isotopes.

The isotope with the higher abundance has a greater influence on the relative atomic mass.

Example 2: If the relative atomic mass of magnesium is 24.3 and the relative atomic mass of Mg-24 is 24, what is the abundance of Mg-25?
Answer: 11.1%.
Example 4:A sample of carbon contains 98.9% C-12 (relative atomic mass = 12), 1.1% C-13 (relative atomic mass = 13), and a trace amount of C-14 (relative atomic mass = 14). What is the relative atomic mass of the sample?
Answer: 12.01

Example 5: Given the following information about the isotopes of copper:
Cu-63 has an abundance of W in a sample.
Cu-65 has an abundance of 30.83% in a sample.
The relative atomic mass of copper is 63.546.
Calculate the value of W.
Answer: 69.05%.

1. Multiple Choice Questions

(i)The smallest part of an element that can take part in a chemical reaction is called:

A. Molecule

B. Atom

C. Compound

D. Mixture

(ii)Which of these particles has a positive charge?

A. Electron

B. Neutron

C. Proton

D. All of the above

(iii)The part of an atom where protons and neutrons are found is called:

A. Electron shell

B. Nucleus

C. Orbit

D. Energy level

(iv)Which particle in an atom has almost no mass?

A. Proton

B. Neutron

C. Electron

D. All have equal mass

(v)Atoms of the same element with different numbers of neutrons are called:

A. Isotopes

B. Ions

C. Molecules

D. Compounds

(vi)Electrons are found:

A. In the nucleus

B. Orbiting the nucleus

C. Between protons and neutrons

D. Nowhere in an atom

(vii)The atomic number of an element tells you the number of:

A. Protons

B. Neutrons

C. Electrons

D. All of the above

(viii)Which of these is NOT a part of an atom?

A. Proton

B. Neutron

C. Electron

D. Molecule

(ix)The mass of an atom mostly comes from:

A. Protons and neutrons

B. Electrons

C. The empty space in the atom

D. The number of electrons

(x)Atoms combine to form:

A. Elements

B. molecules

C. Mixtures

D. Isotopes

Answers

B. Atom

C. Proton

B. Nucleus

C. Electron

A. Isotopes

B. Orbiting the nucleus

A. Protons

D. Molecule

A. Protons and neutrons

B. Molecules

2. Fill in the Blanks:

(i)An atom is the smallest unit of an _____ that retains its chemical properties.

(ii)The center of an atom is called the _____.

(iii)The nucleus contains _____ and _____.

(iv) Particles with a negative charge that orbit the nucleus are called _____.

(v) The arrangement of _____ in shells determines an atom's chemical properties.

Relative molecular mass of a compound (Mr or RMM)

RMM is the mass of a molecule compared to $\frac{1}{12th}$ the mass of a carbon-12 atom.

It is calculated by summing the relative atomic masses of all atoms in the molecule.

It is also known as relative formular mass or molecular weight.

Example:

The chemical formula of ethanol is C_2H_5OH. Calculate its relative molecular mass.

Given that the relative atomic mass of each element: C=12, O=16 H= 1

Solution

Relative molecular mass of C_2H_5OH.

= (12 x 2) + (1 x 5) + 16 + 1

= 46

Percentage composition of elements

The percentage by mass of each element in a compound.

% percentage composition of element = $\frac{Number\ of\ aloms\ of\ element\ x\ Relative\ atomic\ mass}{Relative\ molecular\ mass}$

1. **Calculate percentage composition of hydrogen and oxygen in H_2O**
2. **Calculate the percentage composition of Carbon in CO_2**

6: PERIODIC CLASSIFICATION OF ELEMENTS

This is the systematic arrangement of elements in order of their increasing atomic number in the Periodic Table.

Dmitri Mendeleev, a Russian chemist was the first person to formulate the periodic table. He noticed that, when elements were arranged in order of increasing atomic mass, certain properties recurred periodically.

He used this observation to create a table with elements grouped by their shared properties.

Mendeleev's contributions include:

1. He arranged the known elements in increasing order of their atomic masses and observed patterns in their properties.
2. He grouped elements with similar properties into horizontal rows called periods.
3. He left the gaps in the table for undiscovered elements and predicted their properties based on their positions.
4. He proposed the periodic law "**the properties of elements are a periodic function of their atomic masses**."

Weaknesses of Mendeleev's Periodic Table:

i. It was based on atomic masses, which led to some inconsistencies.
ii. Isotopes could not be accommodated in his periodic table.

iii. Noble gases were unknown at the time, so he did not include in the original table.

The Modern Periodic Table

In the modern periodic table, elements are arranged in increasing order of atomic number, which reflects the number of protons in the nucleus.
It provides a more accurate representation of the relationships between elements and their chemical properties.
The modern periodic law states that "**the chemical properties of elements are a periodic function of their atomic numbers**".

Periodic table is a table in which elements are arranged in order of increasing of atomic number and recurring chemical properties**.**

Periodicity is the periodic recurrence of similar properties when elements are arranged according to their atomic numbers.

GROUPS

Groups are the vertical columns of elements in the periodic table.
They are usually written by Roman numerals.
There are eight (8) groups in the modern periodic table.

Some characteristics of elements in the same group:

i. Elements in the same group have the same number of electrons in their outermost shell (valence shell)
ii. Elements in the same group have similar chemical properties because they have the same valence electrons.

PERIODS

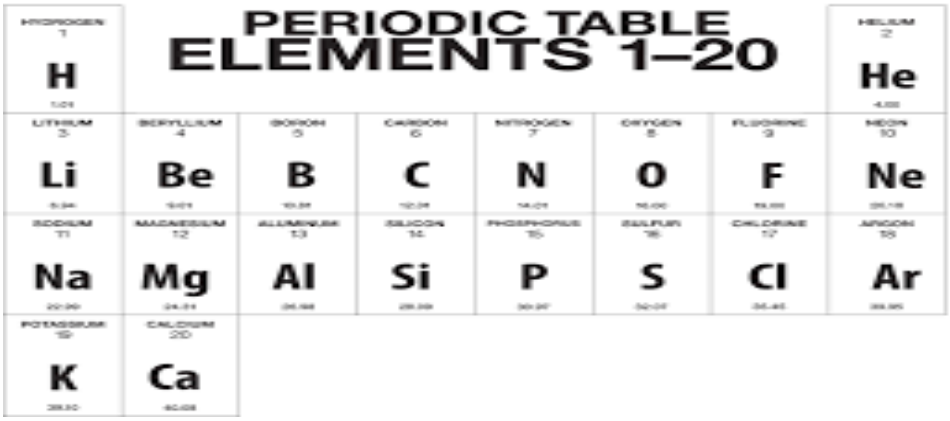
Periods are the horizontal rows of elements in the periodic table.

They are indicated by English numerals.

There are 7 periods of elements in the modern periodic table.

Some characteristics of elements in the same period:

i. Elements within the same period have the same number of shells occupied by electrons.
ii. Each period ends with a noble gas.



The part of the Periodic Table showing the first 20 elements.

Some groups have special names and so their elements.

- Group I elements are called **Alkali metals.**
- Group II elements are called **Alkaline Earth metals.**
- Group VII elements are called **Halogens** *(in Greek=salt formers).*
- Group VIII /0 are called **Noble gases (or inert elements).**
  Generally, Groups I-III are metals while Groups V-VIII are non-metals.
- Elements which have both metallic and non-metallic characteristics are called **metalloids.** They include boron (B), silicon (Si), germanium (Ge), arsenic (As), Antimony (Sb) and tellurium (Te).
- The elements in the block between Group II and Group III are **transition metals.**
  Transitional metals have the following characteristics
  - ✓ They have high densities and melting points.
  - ✓ They form coloured compounds.
  - ✓ Act as catalysts whether in compounds or elements
  - ✓ Most exhibit variable oxidation states.

ATOMIC STRUCTURE AND PERIODIC TABLE.

(a) Group number

- ***Group number of elements is the same as number of electrons in their outermost shells.***
- Therefore, elements in the same group have the same number of electrons in their outer shell.

For example,

Group I

K 2:8:8:1 group I

Na 2:8:1 group 1

Group II

They have 2 electrons in their outer shell. They are in group II.

Ca 2:8:8:2.

Mg 2:8:2

(b) Period number

- ***The number of shells an element has represents the Period in which that element occurs in the periodic table.***

Element	Electronic configuration	Period
Li	2:1	Period 2
K	2:8:8:1	Period 4
Na	2:8:1	Period 3

GENERAL PERIODIC TRENDS

- **Atomic size**

The size of an atom usually is measured by using its radius.

Atomic radius is the distance from the nucleus of an atom to the outermost shell.

→Atomic size or radius decreases from left to right of the period.

→On moving down a group in the periodic Table, the atomic size increases.

- **Ionization energy**

Ionization energy is the minimum amount of energy required to remove completely electron from an atom.

→The ionization energy increases from left to right across the periods.

→The ionization energy decreases from top to the bottom of the periodic table**.**

- **Metallic character (Electropositivity).**

This is the tendency of an atom to lose electrons and form positive ions in a chemical reaction.

It is a measure how easily an atom can donate its valence electrons to other atoms.

Metal atoms have this tendency of donating electrons.

→Metallic character/electropositivity decreases from left to right in the periods.

→On moving down the group the metallic character/ electropositivity increases.

- **Electronegativity (non-metallic character)**

This is the tendency of an atom to attract the electrons towards itself in a chemical bond.

→Moving from left to right across a period, the electronegativity of the elements generally increases.

→The electronegativity decreases down the group.

The element with highest electronegativity is **Fluorine**.

- **Electron affinity**

E.A is the amount of energy released or spent when an electron is added to the atom to form a negative ion.

It is a measure of the attraction an atom has for an additional electron**.**

→The electron affinity increases from left to right across the period in the Periodic Table.

→Electron affinity decreases down the group.

- **<u>Melting point and boiling points</u>**

Generally, melting and boiling points are varied and do not form the distinguishable trend across the periodic table.

→MP and BP decrease down the group as the elements become more metallic in nature.

Note that the MP& BP are varied due to molecular complexity, crystal structure and presence of specific bonds.

SPECIFIC TRENDS IN THE GROUPS

1. Group I – Alkali metals

Physical properties

- They are called alkali metals because they produce hydroxide which are soluble in water.
- They are very soft and can be easily cut with a knife.
- They have low density.
- They are good conductors of heat and electricity.
- They have low melting and boiling points compared to other metals.

Chemical properties

They are the most reactive metals and usually stored under the oil to prevent them coming into contact with water or vapour. Some of chemical properties are:

- React with oxygen or air with a characteristic flame colour forming white solid oxide

  Metal + oxygen → metal oxide

These metal oxides dissolve in water to form alkaline solutions

Metal oxide + water → metal hydroxide.

- React vigorously with water to give the alkaline solution and hydrogen gas

  Metal + water →metal hydroxide + hydrogen

- Reacts vigorously with halogens to form metal halides.

Eg. Sodium + chlorine →sodium chloride.

2. Group II-Alkaline Earth Metals

They are called alkaline earth metals because they are the only metals found beneath the earth which are alkaline.

Physical properties

- They are harder than those in group I
- They are silvery grey in colour pure and clean. They tarnish quickly when exposed to air.
- They are good conductors of heat and electricity.

Chemical properties

Alkaline earth metals react similar to alkali metals except that they are less reactive than group I or alkali metals. Most alkaline earth metals are commonly used in the school chemistry laboratories example magnesium.

- React with oxygen to form solid white metal oxide.

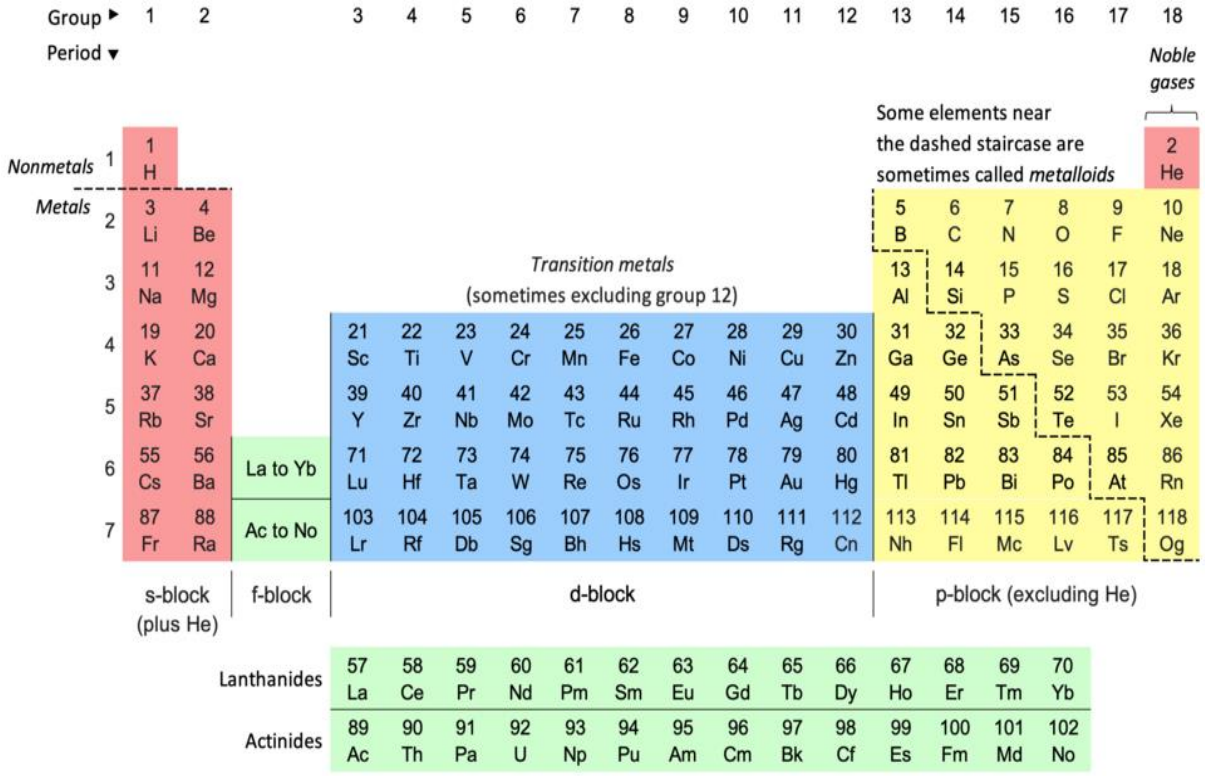
Metal + oxygen → metal oxide

- React with water to give metal hydroxide and hydrogen gas.

Flame colours of some metals

Element	Flame colour
Sodium	Golden yellow
potassium	Lilac
Calcium	Brick red
Lithium	Crimson

The Modern Periodic Table



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