UNIT

5

Language of Chemistry

Learning Outcomes

Children will be able to:

- *recall the symbols of different elements;*
- *derive the formulae of compounds on the basis of valencies of elements and radicals;*
- *write chemical equation of a reaction;*
- *balance chemical equations by applying the law of conservation of mass.*

Element	Symbol	Element	Symbol
Boron	B	Phosphorus	P
Carbon	C	Sulphur	S
Nitrogen	N	Chlorine	Cl
Oxygen	O	Argon	Ar
Fluorine	F	Potassium	K
Neon	Ne	Calcium	Ca

VALENCY

Valency is the combining capacity of an element:

- It is numerically equal to the number of hydrogen atoms that combine with (or displace) one atom of the element (or radical) forming a compound.

  For example: In ammonia (NH_3), three atoms of hydrogen combine with one atom of nitrogen so the valency of nitrogen is three.

- It is also numerically equal to the number of chlorine atoms that combine with (or displace) one atom of the element forming a compound.

  For example: In hydrogen chloride (HCl), one atom of hydrogen combines with one atom of chlorine, therefore, the valency of hydrogen is one. Similarly in magnesium chloride ($MgCl_2$), the valency of magnesium is two.

- It is also equal to double the number of oxygen atoms with which it combines.

  For example: In calcium oxide (CaO), one atom of oxygen combines with one atom of calcium, so its valency is double of number of oxygen atom that combines. Hence, it is two.

VALENCY OF METALS AND NON-METALS

Valency of a Metal

Valency of a metal is the number of electrons lost by an atom of it during the formation of a compound (*i.e.*, to complete its octet).

For example: Valency of potassium is +1 and that of magnesium is +2.

Valency of a Non-metal

Valency of a non-metal is the number of electrons gained by an atom of it during the formation of a compound (*i.e.*, to complete its octet).

For example: Valency of chlorine is −1 and that of sulphur is −2.

Note: Valency of an element is always a whole number.

INTRODUCTION

Chemical changes in our surroundings may be represented by chemical reactions. Symbols help us to write chemical reactions conveniently. It not only saves time but makes our learning and understanding quick and easy.

SYMBOL OF ELEMENTS

The short form or the abbreviation used to denote and element is called symbol. It represents (i) one atom of an element and (ii) its atomic weight.

REPRESENTATION OF A SYMBOL

1. John Dalton (1807) was the first scientist to use figurative symbols for atoms of various elements.
   For example:

   But this system failed as it was inconvenient.

2. Jakob Berzelius (1814) suggested a simple approach to represent elements (Fig. 1).
   - Some symbols were derived from the first letter of the name of an element they were written in capital letters. For example, the symbol of carbon is C (the first letter of the name). Method was not approved since two elements can have same first letter.
   - Some symbols were derived from the first two letters of the name of an element or another significant letter of the English name of the elements.

     For example: The symbol of neon is Ne, the symbol of chlorine is Cl.

Fig. 1. Berzelius

   - Some symbols were derived from the Latin name of the element.

     For example: The symbol of copper is 'Cu' which is derived from **Cuprum,** the symbol of potassium was taken as 'K' which is derived from the first letter of its name **'Kalium'.**

So the symbol of an element is the first letter or the first and another significant letter of the English name or Latin name of the element.

Table 1: Symbols for Some Elements

Element	Symbol	Element	Symbol
Hydrogen	H	Sodium	Na
Helium	He	Magnesium	Mg
Lithium	Li	Aluminium	Al
Beryllium	Be	Silicon	Si

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Nitrogen	N	Chlorine	Cl
Oxygen	O	Argon	Ar
Fluorine	F	Potassium	K
Neon	Ne	Calcium	Ca

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- It is also equal to double the number of oxygen atoms with which it combines.
  For example: In calcium oxide (CaO), one atom of oxygen combines with one atom of calcium, so its valency is double of number of oxygen atom that combines. Hence, it is two.

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For example: Valency of potassium is +1 and that of magnesium is +2.

Valency of a Non-metal

Valency of a non-metal is the number of electrons gained by an atom of it during the formation of a compound (*i.e.*, to complete its octet).

For example: Valency of chlorine is −1 and that of sulphur is −2.

Note: Valency of an element is always a whole number.

Variable

- Certain elements exhibit more than one valency in different compounds. These elements are said to possess variable valency. It is due to variation in the loss or gain of electrons from the outer shell of an atom of an element during a chemical reaction.
- A suffix 'ous' is added at the end of the name of the metal showing lower valency and 'ic' is added at the end of the name of metal showing higher valency in Table 2.

Table 2: Variable Valencies of Some Elements

S. No.	Element	Symbol	Variable Valency	Symbol and Name of the Ion
1.	Copper	Cu	+1 +2	Cu (I) [Cuprous] Cu (II) [Cupric]
2.	Iron	F	+2 +3	Fe (II) [Ferrous] Fe (III) [Ferric]
3.	Mercury	Hg	+1 +2	Hg (I) [Mercurous] Hg (II) [Mercuric]
4.	Tin	Sn	+2 +4	Sn (II) [Stannous] Sn (IV) [Stannic]
5.	Lead	Pb	+2 +4	Pb (II) [Plumbous] Pb (IV) [Plumbic]

RADICALS

Radical is an atom or group of atoms of different elements that behaves as a single unit with a positive or negative charge. Radicals are of two types:

1. Acid Radicals

The negatively charged radicals are called acid radicals or anions. Non-metallic ions and groups of non-metallic atoms with a negative charge are called acid radicals (See Table 3).

For example: Cl^{-1}, OH^{-1}, NO_3^{-1}, SO_4^{-2} etc.

2. Basic Radicals

The positive charged radicals are called basic radicals or cations. All the metallic cations and some groups of non-metallic atoms with a positive charge (*e.g.*, NH_4^{+1}) are basic radicals (see Table 3).

For example: Na^{+1}, Mg^{+2}, Ca^{+2}, NH_4^{+1} etc.

Table 3: Valency Chart of Radicals

Valency	Positive Valencies (Metals, Hydrogen and Ammonium Radical)			Negative Valencies (Non-metals and Non-metallic Radicals)		
	Element/ *Radical*	Symbol	Ion	Element/ *Radical*	Symbol	Ion
Valency 1	Potassium	K	K^{1+}	Chlorine	Cl	Cl^{1-}(chloride)
	Sodium	Na	Na^{1+}	Bromine	Br	Br^{1-}[bromide]
	Hydrogen	H	H^{1+}	Iodine	I	I^{1-}(iodide)
	Ammonium	NH_4	NH_4^{1+}	*Nitrate*	NO_3	NO_3^{1-}
				Hydroxide	OH	OH^{1-}
				Bicarbonate	HCO_3	HCO_3^{1-}
				Bisulphite	HSO_3	HSO_3^{1-}
				Bisulphate	HSO_4	HSO_4^{1-}
				Aluminate	AlO_2	AlO_2^{1-}
				Permaganate	MnO_4	MnO_4^{1-}
Valency 2	Calcium	Ca	Ca^{2+}	Oxygen	O	O^{2-} (oxide)
	Magnesium	Mg	Mg^{2+}	Sulphur	S	S^{2-} (sulphide)
	Zinc	Zn	Zn^{2+}	*Sulphite*	SO_3	SO_3^{2-}
	Barium	Ba	Ba^{2+}	*Sulphate*	SO_4	SO_4^{2-}
	Nickel	Ni	Ni^{2+}	*Carbonate*	CO_3	CO_3^{2-}
				Dichromate	Cr_2O_7	$Cr_2O_7^{2-}$
				Zincate	ZnO_2	ZnO_2^{2-}
				Plumbite	PbO_2	PbO_2^{2-}
Valency 3	Aluminium	Al	Al^{3+}	*Phosphate*	PO_4	PO_4^{3-}
	Chromium	Cr	Cr^{3+}	Nitrogen	N	N^{3-} (nitride)

CHEMICAL FORMULA

It is the representation of a compound by the symbols of its constituent elements with their number of atoms present in it.

For example:

Substance/Compound	Symbols	No. of Atoms of each Element	Chemical Formula
Calcium chloride	Ca, Cl	1 atom of Ca and 2 atoms of Cl	$CaCl_2$

Writing the Chemical Formula of a Compound

Let us understand the steps involved in writing the chemical formula of a compound

(a) Writing the Formula of Potassium Chloride

Step 1: Write the symbols of the elements

On the left hand side	On the right hand side
Positive ion K	Negative ion Cl

Step 2: Write the valencies of these elements

On the top right corner of positive ion	On the top right corner of negative ion
K^{+1}	Cl^{-1}

Step 3: Now criss-cross or interchange the valencies of these positive and negative ions but ignore their (+) and (−) signs.

$$K^{+1} \quad Cl^{-1}$$
$$1 \qquad 1$$

Step 4: Write the interchanged valency but ignore base number 1.

$$K_1Cl_1 \longrightarrow \underset{\text{Chemical formula}}{KCl}$$

(b) Writing the Chemical Formula of Calcium Oxide

Step 1: Write the symbols.

Ca (Positive ion) O (Negative ion)

Step 2: Write the valency of the ions.

$$Ca^{+2} \quad O^{-2}$$

Step 3: Now interchange the valencies of these ions but ignore their signs.

$$Ca^{+2} \quad O^{-2}$$
$$2 \qquad 2$$

Step 4: Write the interchanged valencies but as the valencies of these elements are same, we write the formula in simplified form.

$$Ca_2O_2 \longrightarrow \underset{\text{Chemical formula}}{CaO}$$

(c) Writing the Chemical Formula of Ammonium Sulphate

Step 1: Write the symbols.

NH_4 (Positive radical) SO_4 (Negative radical)

Step 2: Write the valency of the radicals.

$$NH_4^{+1} \quad SO_4^{2-}$$

Step 3: Now interchange the valencies of these radicals but ignore their signs.

$$NH_4^{+1} \quad SO_4^{-2}$$
$$2 \qquad 1$$

Step 4: There is no common factor between two valencies 2 and 1, then write the chemical formula as follows by ignoring base number 1.

$$(NH_4)_2SO_4$$
Chemical formula

(d) Writing the Chemical Formula of Aluminium Carbonate

Step 1: Write the symbols.

Al	CO_3
(Positive ion)	(Negative ion/radical)

Step 2: Write the valency of ions.

$$Al^{+3} \quad CO_3^{-2}$$

Step 3: Now interchange the valencies of these ions but ignore their signs.

$$Al^{+3} \quad CO_3^{-2}$$
$$2 \qquad 3$$

Step 4: There is no common factor between two valencies 2 and 3, then write the chemical formula as follows.

$$Al_2(CO_3)_3$$
Chemical formula

Note: Put the radical in bracket if the number is 2 or above.

(e) Writing the Chemical Formula of Metals with Variable Valency

(i) Copper (I) Chloride

Step 1: Write the symbols.

Cu	Cl
(Positive ion)	(Negative ion)

Step 2: Write the valency of ions.

$$Cu^{+1} \quad Cl^{-1}$$
$$1 \qquad 1$$

Step 3: Write the interchanged the valencies of these ions but ignore equal base number 1.

$$Cu_1Cl_1 \longrightarrow CuCl$$
Chemical formula

(ii) Copper (II) Chloride

Step 1: Write the symbols.

Cu	Cl
(Positive ion)	(Negative ion)

Step 2: Write the valency of ions.

$$Cu^{+2} \qquad Cl^{-1}$$

Step 3: Now interchange the valencies of these ions but ignore their signs.

$$Cu^{+2} \quad Cl^{-1}$$
$$1 \qquad 2$$

Step 4: There is no common factor between two valencies 1 and 2, then write the chemical formula as follows.

$$CuCl_2$$
Chemical formula

CHEMICAL EQUATION

A chemical equation shows the overall change of reactants to products in a chemical reaction. The starting materials called reactants are listed on the left hand side of the equation. Next comes an arrow ($\longrightarrow$) that indicates the direction of the reaction. The right hand side of the reaction lists the substances that are made, *i.e.*, resulting substance are called products.

Example:

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

Sometimes, state symbols are required to indicate the physical states of the substances in a chemical reaction.

Table 1: Symbols of Physical States

Physical State	State Symbol
Solid	*s*
Liquid	*l*
Gas	*g*
Aqueous solution	*aq*

How to Write the Chemical Equation from the Word Equation?

Word Equation is the representation of chemical equation briefly in words.

Here are some simple covalent formulas that you will find useful to remember		Here are some simple ionic formulas that you will find useful to remember	
Water	H_2O	Sodium chloride	NaCl
Carbon dioxide	CO_2	Calcium chloride	$CaCl_2$
Ammonia	NH_3	Magnesium oxide	MgO
Hydrogen	H_2	Hydrochloric acid	HCl
Oxygen	O_2	Sulphuric acid	H_2SO_4

Nitrogen	N_2	Nitric acid	HNO_3
Sulphur dioxide	SO_2	Sodium hydroxide	$NaOH$
Methane	CH_4	Potassium hydroxide	KOH
Chlorine	Cl_2	Calcium hydroxide	$Ca(OH)_2$
Nitric oxide	NO	Calcium carbonate	$CaCO_3$
Nitrogen dioxide	NO_2	Aluminium oxide	Al_2O_3
Nitrous oxide	N_2O	Iron (III) oxide	Fe_2O_3

Conversion of Word Equation to Chemical Equation

Example 1: In a precipitation reaction, sodium hydroxide solution is mixed with iron(II) chloride solution. Sodium chloride solution and insoluble iron(II) hydroxide are produced. Write a chemical equation including the state symbols.

Solution :

Step 1: Identify reactants and products and place them in a word equation,

sodium hydroxide + iron(II) chloride ⟶ sodium chloride + iron(II) hydroxide

Step 2: Convert the chemical names into chemical formulas. Place them based on the chemical equation and write the state symbols.

Step 3: Write the chemical equation.

$$NaOH(aq) + FeCl_2(aq) \longrightarrow NaCl(aq) + Fe(OH)_2(s)$$

This equation is not a balanced equation, we will further learn how to write a balanced equation.

Example 2: Write a chemical equation for the given word equation:

Sodium(*s*) + Hydrochloric acid(*aq*) ⟶ Sodium chloride(*aq*) + Hydrogen(*g*)

Solution: Convert the chemical names into chemical formulas. Place them based on the chemical equation and write the state symbols.

$$Na(s) + HCl(aq) \longrightarrow NaCl(aq) + H_2(g)$$

How to Write a Balanced Chemical Equation from a Word Equation?

When compounds react, they are chemically changed into new compounds. Every chemical change can be communicated symbolically using a chemical equation. Chemical equations combine formulas with other symbols to show the changes.

Examples:

Aluminium + Iron(III) oxide ⟶ Aluminium oxide + Iron

Oxygen + Hydrogen ⟶ Water

Methane + Oxygen ⟶ Carbon dioxide + Water

Butane + Oxygen ⟶ Carbon dioxide + Water

It takes practice to be able to write balanced equations. There are essentially three steps to the process:

Three Steps for Balancing Chemical Equations

1. Write the Unbalanced Equation

- Chemical formulas of reactants are listed on the left hand side of the equation.
- Products are listed on the right hand side of the equation.
- Reactants and products are separated by putting an arrow ($\longrightarrow$) between them to show the direction of the reaction. '$\longrightarrow$' indicates irreversible reaction.
- Double arrow pointing in opposite sides ($\rightleftharpoons$) indicates reversible reaction.
- Special conditions like sign of heating (Δ), catalyst etc., are shown in the reaction.

2. Balance the Equation

- Apply the law of conservation of mass to get the same number of atoms of every element on each side of the equation.
- Tip: Start by balancing an element that appears in only one reactant and product.
- Once one element is balanced, proceed to balance another, and another, until all elements are balanced.
- Balance chemical formulas by placing coefficients in front of them. Do not add subscripts because this will change the formulae.

3. Indicate the States of Matter of the Reactants and Products

- Use (*g*) for gaseous substances.
- Use (*s*) for solids.
- Use (*l*) for liquids.
- Use (*aq*) for species in solution in water.
- Write the state of matter immediately following the formula of the substance it describes.

Limitations of a Chemical Equation

The chemical equations suffer from a number of limitations and have few drawbacks also.
They do not tell us about:

1. the physical states of the reactants and products.
2. the conditions such as temperature, pressure or catalyst which affect the reaction.
3. the concentration of reactants and products.
4. the speed of the reaction.
5. the heat changes during the reaction.
6. the completion of the reaction.

Balancing of Chemical Equations

A balanced chemical equation is a chemical equation in which the number of atoms of each element in the reactants is equal to that of products. It is done by hit and trial method.

Example 1: Magnesium is burnt in air to form magnesium oxide.

Word equation: Magnesium + Oxygen $\longrightarrow$ Magnesium oxide

Molecular equation: $\underbrace{Mg + O_2}_{\text{Reactants}} \longrightarrow \underbrace{MgO}_{\text{Product}}$

Number of magnesium atom = 1	Number of magnesium atom = 1
Number of oxygen atoms = 2	Number of oxygen atom = 1

Step I: Balance the oxygen atoms by adding a coefficient of 2 before MgO in the product side.

$$Mg + O_2 \longrightarrow 2MgO$$

Number of magnesium atom = 1	Number of magnesium atoms = 2
Number of oxygen atoms = 2	Number of oxygen atoms = 2

Step II: Balance the magnesium atoms by adding a coefficient of 2 before Mg in the reactant side.

$$2Mg + O_2 \longrightarrow 2MgO$$

Number of magnesium atoms = 2	Number of magnesium atoms = 2
Number of oxygen atoms = 2	Number of oxygen atoms = 2

Since above chemical equation has equal number of magnesium and oxygen atoms on the reactants and product side, the balanced equation is written as:

$$\boxed{2Mg + O_2 \longrightarrow 2MgO}$$

Example 2: Reaction of zinc with hydrochloric acid to give zinc chloride and hydrogen gas.

Word equation: Zinc + Hydrochloric acid $\longrightarrow$ Zinc chloride + Hydrogen

Molecular equation: $\underbrace{Zn + HCl}_{\text{Reactants}} \longrightarrow \underbrace{ZnCl_2 + H_2}_{\text{Products}}$

Number of zinc atom = 1	Number of zinc atom = 1
Number of hydrogen and chlorine atom = 1	Number of hydrogen and chlorine atoms = 2

Step I: Balance hydrogen atoms and chlorine atoms by adding a coefficient of 2 before HCl.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

Number of zinc atom = 1	Number of zinc atom = 1
Number of hydrogen and chlorine atoms = 2	Number of hydrogen and chlorine atoms = 2

Step II: Since the number of atoms of elements in the reactants and products are same, the balanced equation is written as:

$$\boxed{Zn + 2HCl \longrightarrow ZnCl_2 + H_2}$$