Based on the latest CBSE syllabus

10

LIVING SCIENCE
CHEMISTRY

Arun Syamal

Ratna Sagar

Based on the latest syllabus and guidelines issued
by the Central Board of Secondary Education (CBSE)

LIVING SCIENCE
CHEMISTRY

10

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Dr Syamal has published about 350 scientific research papers, some of which are in the field of improvement of science education at the high school level. He has received awards from American Chemical Society for his contribution towards the development of science and technology in the last four decades. He has also received two awards from Indian Chemical Society for his researches in Chemistry. He was a Research Associate at Texas State University, Denton, Texas, USA and Emory University, Atlanta, Georgia, USA from 1968 to 1973.

Chemistry creates its objects, and this creative faculty is similar to that of art itself, (and) essentially distinguishes it from the natural and historical sciences.

— Marcelin Berthelot

This book is dedicated to my late parents.

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Preface

It has been a real pleasure to note the response with which the first revised edition has been received. It gives me immense pleasure in presenting Living Science Chemistry for Class X written strictly in accordance with the latest NCERT syllabus woven with the latest CBSE guidelines aimed at the holistic assessment of the learners.

Salient Features of the Book

- This book contains Let Us Revise, Check Your Progress, Activities, Chapter-end Exercises, etc. in each chapter to develop cognitive, psychomotor and affective domains of learning and lays emphasis on scientific thought process.
- **Practice Questions:** Each chapter has Practice Questions at the end. It measures or 'sums-up' how much a student has learnt from the chapter. It is a graded assignment consisting of the questions based on knowledge, understanding, application, analysis, synthesis and evaluation type of questions. The following types of questions have been included in practice questions:
  - Very Short Answer Type (VSA) questions (one-mark each)
  - Short Answer Type-I (SA-I) questions (two-marks each)
  - Short Answer Type-II (SA-II) questions (three-marks each)
  - Long Answer Type (LA) questions (five-marks each)

  Due weightage has been given to
  - Questions asked in CBSE Board Examinations
  - Higher Order Thinking Skills (HOTS) questions
  - Value-Based Questions
  - Passage-Based Questions
  - Questions Based on Practical Skills in Science

Constructive criticisms and suggestions from teachers and students for the improvement of this book are most welcome. Lastly, I hope you will enjoy reading this book as much I have enjoyed writing it. Do email your feedback.

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Arun Syamal

Remodeled Assessment Structure

(Based on CBSE Circular No.: Acad-05/2017 dated 31/01/2017)

1. SCHOLASTIC AREA

<table>
<tr><td rowspan="3">Subjects</td><td colspan="4">Total 100 marks
(Syllabus for assessment will be only Class-X)</td></tr>
<tr><td rowspan="2">80 Marks
(Board Examination)
Student has to secure 33% marks out of 80 marks in each subject</td><td colspan="3">20 Marks
(Internal Assessment)
Students has to secure 33% marks out of overall 20 marks earmarked in each subject</td></tr>
<tr><td>Periodic Test
(10 Marks)</td><td>Notebook Submission
(5 Marks)</td><td>Subject Enrichment Activity
(5 Marks)</td></tr>
<tr><td></td><td>(i)</td><td>(ii)</td><td>(iii)</td></tr>
<tr><td>Language 1</td><td rowspan="5">Board will conduct Class-X Examination for 80 marks in each subject covering 100% syllabus of the subject of Class-X only.
Marks and Grades both will be awarded for individual subjects.
9-point grading will be same as followed by the Board in Class XII.</td><td rowspan="5">Periodic written Test, restricted to three in each subject in an Academic Year.
Average of the best two tests to be taken for final marks submission.</td><td rowspan="5">This will cover:
❖ Regularity
❖ Assignment Completion
❖ Neatness & upkeep of notebook</td><td>Speaking and listening skills</td></tr>
<tr><td>Language 2</td><td>Speaking and listening skills</td></tr>
<tr><td>Science</td><td>Practical Lab work</td></tr>
<tr><td>Mathematics</td><td>Maths Lab Practical</td></tr>
<tr><td>Social Science</td><td>Map Work and Project Work</td></tr>
</table>

(i) Periodic Test (10 marks)

The school should conduct three periodic written tests in the entire academic year and the average of the best two will be taken. The schools have the autonomy to make its own schedule. However, for the purpose of gradient learning, three tests may be held as one being the mid-term test and other the two being pre-mid and post mid-term with portion of syllabus cumulatively covered. The gradually increasing portion of contents would prepare students acquire confidence for appearing in the Board examination with 100% syllabus. The school will take the average of the best two tests for final marks submission.

(ii) Notebook Submission (5 marks)

Notebook submission as a part of internal assessment is aimed at enhancing seriousness of students towards preparing notes for the topics being taught in the classroom as well as assignments. This also addresses the critical aspect of regularity, punctuality, neatness and notebook upkeep.

(iii) Subject Enrichment Activities (5 marks)

These are subject specific application activities aimed at enrichment of the understanding and skill development. These activities are to be recorded internally by respective subject teachers.

For Languages: Activities conducted for subject enrichment in languages should aim at equipping the learner to develop effective speaking and listening skills.

For Mathematics: The listed laboratory activities and projects as given in the prescribed publication of CBSE/NCERT may be followed.

For Science: The listed practical works/activities may be carried out as prescribed by the CBSE in the curriculum.

For Social Science: Map and project work may be undertaken as prescribed by the CBSE in the curriculum.

2. CO-SCHOLASTIC ACTIVITIES

Schools should promote co-curricular activities for the holistic development of the student. These activities will be graded on a 5-point grading scale (A to E) and will have no descriptive indicators. No upscaling of grades will be done.

Activity	To be graded on a 5-point scale (A–E) in school	Areas and Objectives (as prescribed in the Scheme of Studies for Subjects of Internal Assessment)
Work Education or Pre-Vocational Education	By the concerned Teacher	Work education is a distinct curricular area for students for participation in social, economic and welfare activities. Student gets a sense of community service and develops self-reliance. (for Pre-Vocational Education as per Scheme of Studies)
Art Education	By the VA/PA or the concerned teacher	Art Education constitutes an important area of curricular activity for development of wholesome personality of the students. Students will select one or more forms of creative arts.
Health & Physical Education (Sports/ Martial Arts/Yoga/ NCC, etc.)	By the PE Teacher	Health & Physical Activity preferably sports must be given a regular period. Students should be provided opportunities to get professionally trained in the area of their interest. Indigenous sports, yoga and NCC must be encouraged in the schools creating a sense of physical fitness, discipline, sportsmanship, patriotism, self-sacrifice and health care.

3. DISCIPLINE (Attendance, Sincerity, Behaviour, Values)

Discipline significantly impacts career shaping and it helps build character. Sincerity, good behaviour and values develop strength and foster unity and cooperation. Therefore, the element of discipline has been introduced. Class teacher will be responsible for grading the students on a Five-point scale (A to E).

The internal assessment comprising 20 marks (10 + 5 + 5) entails objectivity and a structured approach. For a holistic assessment, the teachers are expected to make it an effective tool.

B. DOCUMENTATION

Records pertaining to the internal assessment of the students done by the schools will be maintained for a period of three months from the date of declaration of result for verification at the discretion of the Board. Subjudiced cases, if any or those involving RTI/Grievances may however be reatined beyond three months.

C. ASSESSMENT SCHEME FOR CLASS VI TO IX IN THE CBSE AFFILIATED SCHOOLS

The CBSE affiliated schools, for the purpose of uniformity in classes VI to IX may, replicate the same assessment model as described above for Class X.

The above scheme must be implemented in letter and spirit.

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"Chemistry is the study of redox reactions — where there is oxidation there is always reduction."

— MARIE CURIE

CHAPTER 1

Chemical Reactions

Learning Objectives

- Types of chemical reactions—combination, decomposition, displacement, double displacement, precipitation, neutralisation
- Oxidation and reduction in terms of gain and loss of oxygen and hydrogen.

The process which transforms one or more substances into new substances with new properties is called a **chemical reaction. The substances which take part in a chemical reaction are called reactants and the substances which are formed due to a chemical reaction are called products.** For example, in the reaction of metallic zinc with dilute sulphuric acid to give zinc(II) sulphate and hydrogen gas, zinc and sulphuric acid are reactants, and zinc(II) sulphate and hydrogen gas are products.

$$\underbrace{\underset{\text{Zinc}}{Zn} + \underset{\text{Sulphuric acid}}{H_2SO_4}}_{\text{Reactants}} \longrightarrow \underbrace{\underset{\text{Zinc(II) sulphate}}{ZnSO_4} + \underset{\text{Hydrogen}}{H_2}}_{\text{Products}}$$

In our daily life, we not only observe various materials around us, but also come across various chemical changes. For example, rusting of iron on exposure to moist air, burning of wood to give gases and ash, curdling of milk when left at room temperature during summer, ripening of fruits, cooking of food, digestion of food in our stomach, bursting of a cracker, etc.

In the above chemical changes, the nature and identity of the substances undergo some change. A permanent change in which the original substance gives rise to one or more new substances with different properties, is called a **chemical change**. A chemical change occurs when there is a chemical reaction between the substances. In order to understand what is meant by a chemical reaction, let us conduct the following three experiments.

Activity 1

Showing the changes taking place when a magnesium ribbon is burnt in air

Take a strip of magnesium ribbon and clean it by rubbing with sandpaper. Hold the strip of magnesium ribbon with the help of tongs over a watch glass. Burn the magnesium ribbon with the non-luminous flame of a Bunsen burner. Magnesium ribbon burns with a dazzling flame and white powder is collected on a watch glass kept below the flame. The white powder is

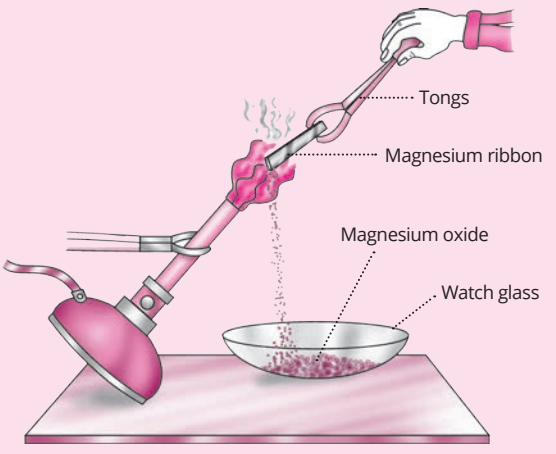

Fig. 1.1 Burning of magnesium ribbon in air

magnesium oxide formed by the reaction of magnesium and oxygen gas present in air.

$$\underset{\text{Magnesium}}{2Mg(s)} + \underset{\text{Oxygen (from air)}}{O_2(g)} \longrightarrow \underset{\text{Magnesium oxide (white powder)}}{2MgO(s)}$$

Activity 2

Showing the changes taking place when granulated zinc is added to dilute sulphuric acid

Take 20 mL of dil. H_2SO_4 in a conical flask fitted with a cork and a delivery tube having a fine jet. Clamp the conical flask to the clamp stand (Fig. 1.2). Add some pieces of granulated zinc to the conical flask and stopper the flask with a cork fitted with delivery tube having fine jet. There occurs formation of tiny bubbles with the evolution of a colourless and odourless gas. Touch the conical flask with your fingers and you will find that there is an increase in temperature and the conical flask has become warm. Bring a burning matchstick close to the mouth of the fine jet. You will observe that the lighted matchstick extinguishes and the gas burns with a popping sound indicating that there is evolution of hydrogen gas. Hydrogen gas is formed due to the reaction of zinc with dil. H_2SO_4. After some time the granulated zinc becomes soluble in dilute sulphuric acid.

$$\underset{\text{Zinc}}{Zn(s)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq)} \rightarrow \underset{\text{Zinc sulphate}}{ZnSO_4(aq)} + \underset{\text{Hydrogen}}{H_2(g)} + \text{Heat}$$

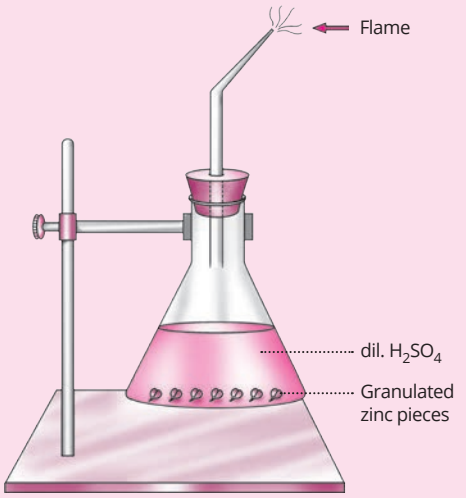

Fig. 1.2 Evolution of hydrogen gas by the reaction of zinc and dil. H_2SO_4

Activity 3

Showing the changes taking place when potassium iodide solution is added to lead(II) nitrate solution

Take 5 mL of colourless lead(II) nitrate solution in a test tube. Add to this 2 mL of colourless potassium iodide solution and shake the test tube. You will observe that a yellow precipitate is formed. The yellow precipitate is lead(II) iodide formed due to the reaction of lead(II) nitrate with potassium iodide.

By performing the Activities 1, 2 and 3, we find that there occurs one or more of the following changes:

1. Change in colour
2. Change in temperature
3. Evolution of a gas
4. Formation of a precipitate
5. Change of state.

These changes indicate that chemical reactions have occurred. In our daily life, we find that there occurs a large variety of chemical reactions within our body and in our surroundings.

CHEMICAL EQUATION

A chemical reaction is represented by a chemical equation. A chemical equation involves the formulae of reactants and products as well as the reaction conditions.

A chemical equation can be written in the form of word equation as well as equation involving the chemical formulae of reactants and products. The latter system is being preferred than the former due to brevity and simplicity.

Rules for writing word equation

1. Write the names of the reactants on the left hand side (LHS) with plus sign (+) between them.
2. Write the names of the products on the right hand side (RHS) with plus sign (+) between them.
3. Put an arrow between the reactants and the products in order to show the direction of the reaction. The direction of the arrowhead should point towards the products.

Let us write the word equation for the chemical reaction involved in the Activity 1. In this reaction, magnesium reacts with oxygen to form magnesium oxide. The word equation for this reaction is written as follows:

Magnesium + Oxygen ⟶ Magnesium oxide

Magnesium and oxygen are the reactants and magnesium oxide (new substance) is the product.

The word equations for the Activities 2 and 3 are written as follows:

Activity 2: Zinc + Sulphuric acid $\longrightarrow$ Zinc(II) sulphate + Hydrogen

Activity 3: Lead(II) nitrate + Potassium iodide $\longrightarrow$ Lead(II) iodide + Potassium nitrate

Writing a skeletal chemical equation using the chemical formulae of the reactants and the products

A chemical equation is a symbolic notation which uses the chemical formulae of the reactants and the products instead of words to represent a chemical reaction. The use of chemical formula instead of words makes a chemical equation more concise, simple and useful. The chemical equation for the chemical reaction involved in the Activity 1 is written as follows:

$$Mg + O_2 \longrightarrow MgO$$

The above chemical equation is a skeletal chemical equation for the chemical reaction involved in the Activity 1 and is an unbalanced equation. By unbalanced equation, we mean that the number of atoms of each element on the left and right hand side of the arrow is not equal. There are two atoms of oxygen on the left hand side of the above chemical equation, but one atom of oxygen on the right hand side. It appears that one atom of oxygen has disappeared during the chemical reaction. We know according to Dalton's atomic theory that atoms can neither be created nor be destroyed during a chemical reaction. An unbalanced chemical equation indicates that total mass of all atoms is not same on both sides of the chemical equation. The law of conservation of mass requires that the total mass of all the reactants of a chemical reaction must be equal to the total mass of all the products. Hence, the chemical equation, as written above, is inaccurate.

Writing balanced chemical equations

In a chemical equation, we must have the equal number of atoms of each element in the reactants and the products. This is known as **balancing a chemical equation**. If in a chemical equation the number of atoms of each element in the reactants is equal to the number of atoms of each element in the products, the chemical equation is called a **balanced chemical equation**. The following rules are followed while balancing a chemical equation:

1. While balancing a chemical equation, one should not alter the formulae of the reactants and products. The formulae of the reactants and products must be written in the molecular form and not in the atomic form.
2. Appropriate numbers should be written before the formulae of the reactants and products just as we write coefficients in an algebraic equation.
3. A chemical equation is balanced with the smallest possible numbers as coefficients of reactants and products.

In order to balance the equation, $H_2 + O_2 \rightarrow H_2O$, we must make number of atoms of each element equal on both sides of the equation. This is done by putting the coefficient 2 before the formula of H_2 as well as of H_2O. Hence, this is now a balanced chemical equation. This equation not only balances the number of atoms of the reactants and products but balances their mass also. The masses of the reactants are written in terms of unified mass (u) as follows:

$$\underset{2 \times 2 \times 1\ u = 4\ u}{2H_2} + \underset{2 \times 16\ u = 32\ u}{O_2} \longrightarrow \underset{2 \times (2 \times 1 + 16)\ u = 36\ u}{2H_2O}$$

Thus, the masses of the reactants are properly balanced. This method of balancing a chemical equation is called **hit-and-trial method,** since we keep on balancing the equation using the smallest whole number of coefficient only.

Information conveyed by a chemical equation

In the chemical equation representing the reaction of hydrogen and oxygen to give water, i.e.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

We get the following information:

1. Hydrogen combines with oxygen to give water.
2. Two molecules of hydrogen combine with one molecule of oxygen to give two molecules of water.
3. Four parts by weight of hydrogen react with thirty two parts by weight of oxygen to produce thirty six parts by weight of water.
4. Two moles of hydrogen combine with one mole of oxygen to produce two moles of water.

5. The masses of the reactants and products can be calculated. The relative masses of the elements involved are: H = 1, O = 16. The calculation of masses of the reactants and products is illustrated below:

$2H_2$	+	O_2	⟶	$2H_2O$
2 molecules		1 molecule		2 molecules
2 moles		1 mole		2 moles
2 × 2 g		2 × 16 g		2 × 18 g
= 4 g		= 32 g		= 36 g

6. If a chemical reaction involves gases, the volume of the reactants and products is predictable.

$2H_2$	+	O_2	⟶	$2H_2O$
2 vol		1 vol		2 vol

In this reaction, three volumes of reactants produce two volumes of product and there occurs a decrease in volume from the reactants to the product.

Example 1 Write and balance the reaction between calcium carbonate and phosphoric acid.

Solution

Step 1: Write the formulae of the reactants.

$$CaCO_3 + H_3PO_4$$

Step 2: When a carbonate is treated with an acid, a salt, water and carbon dioxide are formed. In this case, the salt formed is calcium phosphate. Write the skeletal equation containing the reactants and the products.

$$CaCO_3 + H_3PO_4 \rightarrow Ca_3(PO_4)_2 + H_2O + CO_2$$

Step 3: Balance the calcium atoms on both sides of the equation.

$$3CaCO_3 + H_3PO_4 \rightarrow Ca_3(PO_4)_2 + H_2O + CO_2$$

Step 4: Balance the phosphate radical.

$$3CaCO_3 + 2H_3PO_4 \rightarrow Ca_3(PO_4)_2 + H_2O + CO_2$$

Step 5: Balance the carbon atoms.

$$3CaCO_3 + 2H_3PO_4 \rightarrow Ca_3(PO_4)_2 + H_2O + 3CO_2$$

Step 6: Balance the hydrogen atoms.

$$3CaCO_3 + 2H_3PO_4 \rightarrow Ca_3(PO_4)_2 + 3H_2O + 3CO_2$$

The equation is balanced.

Using the above method, balance the following reactions:

i. Sodium carbonate + Sulphuric acid ⟶ Sodium sulphate + Water + Carbon dioxide

ii. Magnesium carbonate + Hydrochloric acid ⟶ Magnesium chloride + Water + Carbon dioxide

iii. Aluminium carbonate + Nitric acid ⟶ Aluminium nitrate + Water + Carbon dioxide

iv. Potassium carbonate + Phosphoric acid ⟶ Potassium phosphate + Water + Carbon dioxide

Example 2 Write the equation for the reaction between ethane and oxygen and balance the equation.

Solution

Step 1: Write the skeletal equation indicating the formulae of the reactants and the products.

$$C_2H_6 + O_2 \longrightarrow H_2O + CO_2$$

Step 2: Balance the carbon atoms.

$$C_2H_6 + O_2 \longrightarrow H_2O + 2CO_2$$

Step 3: Balance the hydrogen atoms.

$$C_2H_6 + O_2 \longrightarrow 3H_2O + 2CO_2$$

Step 4: Balance the oxygen atoms. The number of oxygen atoms in the products is 7. In order to make the number of oxygen atoms in the reactant 7, write it as 7[O].

$$C_2H_6 + 7[O] \longrightarrow 3H_2O + 2CO_2$$

Step 5: Since it is customary to write the formulae of the reactants and products in molecular forms, [O] must be changed to O_2. Hence, every term of the equation is multiplied by 2.

$$2C_2H_6 + 7O_2 \longrightarrow 6H_2O + 4CO_2$$

The equation is balanced.

Using the above method, balance the following equations:

i. $C_2H_2 + O_2 \longrightarrow H_2O + CO_2$

ii. $C_3H_8 + O_2 \longrightarrow H_2O + CO_2$

iii. $C_4H_{10} + O_2 \longrightarrow H_2O + CO_2$

iv. $C_5H_{12} + O_2 \longrightarrow H_2O + CO_2$

Example 3 Write the equation for the reaction between iron(III) hydroxide and sulphuric acid and balance the reaction.

Solution

Step 1: Write the formulae of the reactants.

$$Fe(OH)_3 + H_2SO_4$$

Step 2: When an acid is treated with a base, a salt and water are formed. In this case, the salt formed is iron(III) sulphate. Write the skeletal equation containing the reactants and the products.

$$Fe(OH)_3 + H_2SO_4 \longrightarrow Fe_2(SO_4)_3 + H_2O$$

Step 3: Balance the number of iron atoms.

$$2Fe(OH)_3 + H_2SO_4 \longrightarrow Fe_2(SO_4)_3 + H_2O$$

Step 4: Balance the number of sulphate radicals.

$$2Fe(OH)_3 + 3H_2SO_4 \longrightarrow Fe_2(SO_4)_3 + H_2O$$

Step 5: Balance the number of hydrogen atoms.

$$2Fe(OH)_3 + 3H_2SO_4 \longrightarrow Fe_2(SO_4)_3 + 6H_2O$$

The equation is balanced.

Using the above method, balance the following reactions:

i. Aluminium hydroxide + Sulphuric acid ⟶ Aluminium sulphate + Water

ii. Ammonium hydroxide + Sulphuric acid ⟶ Ammonium sulphate + Water

iii. Iron(III) hydroxide + Nitric acid ⟶ Iron(III) nitrate + Water

iv. Magnesium hydroxide + Hydrochloric acid ⟶ Magnesium chloride + Water

Example 4 Write the balanced equations for the following chemical reactions:

a. Hydrogen + Chlorine ⟶ Hydrogen chloride

b. Magnesium oxide + Carbon ⟶ Magnesium + Carbon monoxide

c. Sodium + Water ⟶ Sodium hydroxide + Hydrogen

(Textbook Question)

Solution

a. Step 1: Write the skeletal equation indicating the formulae of the reactants and the product.

$$H_2 + Cl_2 \longrightarrow HCl$$

Step 2: Balance the hydrogen atoms.

$$H_2 + Cl_2 \longrightarrow 2HCl$$

The equation is balanced.

b. Write the skeletal equation indicating the formulae of the reactants and the products.

$$MgO + C \longrightarrow Mg + CO$$

The equation is balanced.

c. Step 1: Write the skeletal equation indicating the formulae of the reactants and the products.

$$Na + H_2O \longrightarrow NaOH + H_2$$

Step 2: Balance the hydrogen atoms.

$$Na + 2H_2O \longrightarrow 2NaOH + H_2$$

Step 3: Balance the sodium atoms.

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$

The equation is balanced.

Example 5 Write the balanced chemical equations with state symbols for the following reactions:

a. Iron filings react with steam to produce solid iron(III) oxide and hydrogen gas.

b. Sodium hydroxide solution (in water) reacts with hydrochloric acid solution in water to produce sodium chloride and water. **(Textbook Question)**

Solution

a. Step 1: Write the skeletal equation indicating the formulae of the reactants and the products.

$$Fe + H_2O \longrightarrow Fe_2O_3 + H_2$$

Step 2: Balance the oxygen atoms.

$$Fe + 3H_2O \longrightarrow Fe_2O_3 + H_2$$

Step 3: Balance the iron atoms.

$$2Fe + 3H_2O \longrightarrow Fe_2O_3 + H_2$$

Step 4: Balance the hydrogen atoms.

$$2Fe + 3H_2O \longrightarrow Fe_2O_3 + 3H_2$$

Step 5: Write the state symbols at the right hand side of the formulae.

$$2Fe(s) + 3H_2O(g) \longrightarrow Fe_2O_3(s) + 3H_2(g)$$

The equation is balanced.

b. Step 1: Write the skeletal equation indicating the formulae of the reactants and the products.

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

Step 2: Write the state symbols at the right hand side of the formulae.

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

The equation is balanced.

Study Tip

The gaseous, liquid, aqueous and solid states of reactants and products are represented by the notations (*g*), (*l*) and (*s*).

Example 6 Balance the following chemical equations:

a. $HNO_3 + Ca(OH)_2 \longrightarrow Ca(NO_3)_2 + H_2O$

b. $NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O$

c. $NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$

d. $BaCl_2 + H_2SO_4 \longrightarrow BaSO_4 + HCl$

(Textbook Question)

Solution

a. Step 1: Write the skeletal equation.

$$HNO_3 + Ca(OH)_2 \longrightarrow Ca(NO_3)_2 + H_2O$$

Step 2: Balance the calcium atoms. Already balanced (1 on each side). Balance the nitrogen atoms. Nitrogen atoms on LHS = 1, nitrogen atoms on RHS = 2. In order to balance nitrogen atoms, we multiply HNO_3 on LHS by 2.

$$2HNO_3 + Ca(OH)_2 \longrightarrow Ca(NO_3)_2 + H_2O$$

Balance the hydrogen atoms. Hydrogen atoms on LHS = 2 + 2 = 4, hydrogen atoms on RHS = 2. In order to balance hydrogen atoms, we multiply H_2O on RHS by 2.

$$2HNO_3 + Ca(OH)_2 \longrightarrow Ca(NO_3)_2 + 2H_2O$$

Balance the oxygen atoms. Oxygen atoms on LHS = $2 \times 3 + 2 \times 1 = 8$, oxygen atoms on RHS = $3 \times 2 + 2 \times 1 = 8$. Hence, oxygen atoms are already balanced.

Step 3: Checking the correctness of the balanced equation:

Element	*No. of atoms on LHS*	*No. of atoms on RHS*
H	4	4
N	2	2
O	8	8
Ca	1	1

Hence, the balanced equation is

$$2HNO_3 + Ca(OH)_2 \longrightarrow Ca(NO_3)_2 + 2H_2O$$

b. Step 1: Write the skeletal equation.

$$NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O$$

Step 2: Balance the sodium atoms. Sodium atoms on LHS = 1, sodium atoms on RHS = 2. In order to balance sodium atoms, we multiply NaOH on LHS by 2.

$$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O$$

Balance the sulphur atoms. Already balanced (1 on each side).

Balance the hydrogen atoms. Hydrogen atoms on LHS = 4. Hydrogen atoms on RHS = 2. In order to balance hydrogen atoms, we multiply H_2O on RHS by 2.

$$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$$

Balance the oxygen atoms. Oxygen atoms on LHS = 6. Oxygen atoms on RHS = 6. Hence, oxygen atoms are already balanced.

Step 3: Checking the correctness of the balanced equation:

Element	*No. of atoms on LHS*	*No. of atoms on RHS*
Na	2	2
O	6	6
H	4	4
S	1	1

Hence, the balanced equation is

$$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$$

c. Step 1: Write the skeletal equation.

$$NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$$

Step 2: Checking the number of different elements on both sides.

Element	*No. of atoms on LHS*	*No. of atoms on RHS*
Na	1	1
Cl	1	1
Ag	1	1
N	1	1
O	3	3

Hence, the given equation is a balanced equation.

d. Step 1: Write the skeletal equation.

$$BaCl_2 + H_2SO_4 \longrightarrow BaSO_4 + HCl$$

Step 2: Balance the barium atoms. Already balanced (1 on each side). Balance chlorine atoms. Chlorine atoms on LHS = 2. Chlorine atoms on RHS = 1. In order to balance chlorine atoms, we multiply HCl on RHS by 2.

$$BaCl_2 + H_2SO_4 \longrightarrow BaSO_4 + 2HCl$$

Balance the sulphur atoms. Already balanced (1 on each side). Balance the hydrogen atoms. Already balanced (2 on each side).

Step 3: Checking the number of different elements on both sides.

Element	*No. of atoms on LHS*	*No. of atoms on RHS*
Ba	1	1
Cl	2	2
H	2	2
S	1	1
O	4	4

Hence, the balanced equation is

$$BaCl_2 + H_2SO_4 \longrightarrow BaSO_4 + 2HCl$$

Example 7 Write balanced chemical equations for the following reactions:

a. Hydrogen + Chlorine ⟶ Hydrogen chloride

b. Barium chloride + Aluminium sulphate ⟶ Barium sulphate + Aluminium chloride

Solution

a. Step 1: Write the skeletal equation.

$$H_2 + Cl_2 \longrightarrow HCl$$

Step 2: Balancing of different elements. In order to balance hydrogen atoms on both sides, multiply HCl on RHS by 2.

$$H_2 + Cl_2 \longrightarrow 2HCl$$

Chlorine atoms are automatically balanced. Hence, the above equation is a balanced equation.

b. Step 1: Write the skeletal equation.

$$BaCl_2 + Al_2(SO_4)_3 \longrightarrow BaSO_4 + AlCl_3$$

Step 2: Select the biggest formula and balance its different elements.

Aluminium atoms on LHS = 2. Aluminium atoms on RHS = 1. In order to balance aluminium atoms, multiply $AlCl_3$ on RHS by 2.

$$BaCl_2 + Al_2(SO_4)_3 \longrightarrow BaSO_4 + 2AlCl_3$$

Sulphur atoms on LHS = 3. Sulphur atoms on RHS = 1. In order to balance S atoms, multiply $BaSO_4$ on RHS by 3.

$$BaCl_2 + Al_2(SO_4)_3 \longrightarrow 3BaSO_4 + 2AlCl_3$$

Oxygen atoms are automatically balanced. Barium atoms on LHS = 1. Barium atoms on RHS = 3. In order to balance barium atoms, multiply $BaCl_2$ on LHS by 3.

$$3BaCl_2 + Al_2(SO_4)_3 \longrightarrow 3BaSO_4 + 2AlCl_3$$

Chlorine atoms are automatically balanced.

Step 4: Checking the number of different elements on both sides.

Element	*No. of atoms on LHS*	*No. of atoms on RHS*
Ba	3	3
Cl	6	6
Al	2	2
S	3	3
O	12	12

Hence, the above equation is a balanced chemical equation.

Example 8 Write a balanced chemical equation with state symbols for the following reaction:

Solutions of barium chloride and sodium sulphate in water react to give insoluble barium sulphate and the solution of sodium chloride.

Solution

Step 1: Write the word equation.

Barium chloride (solution) + Sodium sulphate (solution) ⟶ Barium sulphate (insoluble solid) + Sodium chloride (solution)

Step 2: Write the skeletal chemical equation.

$$BaCl_2(aq) + Na_2SO_4(aq) \longrightarrow BaSO_4(s) + NaCl(aq)$$

Step 3: Balance the barium atoms. Already balanced. Balance the chlorine atoms. Chlorine atoms on LHS = 2. Chlorine atoms on RHS = 1. In order to balance chlorine atoms, multiply NaCl on RHS by 2.

$$BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaCl$$

Sodium atoms are automatically balanced. Sulphur and oxygen atoms are automatically balanced.

Step 4: Checking the number of elements on both sides.

Element	*No. of atoms on LHS*	*No. of atoms on RHS*
Ba	1	1
Cl	2	2
Na	2	2
S	1	1

Hence, the above equation is a balanced chemical equation.

Example 9 Write balanced chemical equations for the following reactions:

a. Calcium hydroxide + Carbon dioxide ⟶ Calcium carbonate + Water

b. Zinc + Silver nitrate ⟶ Zinc nitrate + Silver

c. Lead + Copper(II) chloride ⟶ Lead(II) chloride + Copper

d. Barium chloride + Sodium sulphate ⟶ Barium sulphate + Sodium chloride

(Textbook Question)

Solution

a. $Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$

b. $Zn + 2AgNO_3 \longrightarrow Zn(NO_3)_2 + 2Ag$

c. $Pb + CuCl_2 \longrightarrow PbCl_2 + Cu$

d. $BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaCl$

Example 10 Why should magnesium ribbon be cleaned before burning in air? **(Textbook Question)**

Solution Magnesium is a reactive metal. It combines with oxygen present in air to form a layer of magnesium oxide on magnesium ribbon. The layer of magnesium oxide should be removed by rubbing with a sandpaper so that we can perform the reaction with pure magnesium. Since magnesium oxide is a thermal insulator, the burning of magnesium ribbon does not occur smoothly in the presence of a film of magnesium oxide on its surface. Therefore, magnesium ribbon should be cleaned before burning in air.

Limitations of a chemical equation

The chemical equations presented above have several limitations. The following are some important limitations of a chemical equation:

1. A chemical equation does not indicate the physical states of the reactants and the products.
2. A chemical equation does not indicate whether the reaction occurs with the evolution of a gas or separation of a precipitate.

We can make a chemical equation more informative if the above informations are provided in the chemical equation itself.

Improvement of chemical equations

The chemical equations can be made more informative by the use of the following symbols and signs.

1. **Physical states of reactants and products:** The physical states of the reactants and products, by the use of the following small letters in *italics face*, are enclosed in first brackets and placed immediately after the formulae in the reactants and products without leaving any gap between the formula and the first bracket enclosing the small letters; *g*, *l* and *s* are used to denote gaseous, liquid and solid substance, respectively. The symbol *aq* is used to denote the presence of a substance in aqueous medium. For example,

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$$

2. **Precipitation of a solid during a chemical reaction:** The precipitation of a solid during a chemical reaction is indicated by placing a downward arrow ↓ or the letter *s* enclosed in first brackets immediately after the formula of the precipitated product without leaving any gap. For example,

$$NaCl(aq) + AgNO_3(aq) \longrightarrow AgCl(\downarrow) + NaNO_3(aq)$$

3. **Evolution of a gas during a chemical reaction:** The evolution of a gas during a chemical reaction is indicated by placing an upward arrow ↑ or the letter *g* enclosed in first brackets immediately after the formula of the gaseous product without leaving any gap. For example,

$$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O(l) + CO_2(\uparrow)$$

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- The substances which take part in a chemical reaction are called **reactants** and the substances which are formed due to a chemical reaction are called **products**.
- A permanent change in which the original substance gives rise to one or more new substances with different properties, is called a **chemical change**.
- A chemical equation is a symbolic notation which uses the chemical formulae of the reactants and products instead of words to represent a chemical reaction.
- An unbalanced chemical equation violates the law that matter can neither be created nor be destroyed during a chemical change and hence chemical equations must always be balanced.
- A chemical equation in which the number of atoms of each element on both the sides of the equation is equal, is called a **balanced chemical equation**.
- A chemical equation is made more informative by the use of the symbols of physical states of the reactants and products along with the chemical formulae. The symbol (↑) is used to represent the evolution of a gas, and the symbol (↓) is used to represent the formation of a precipitate.

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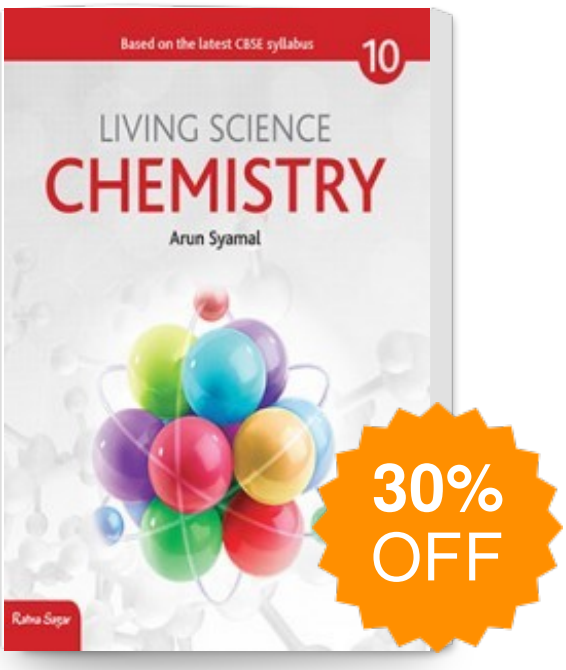

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