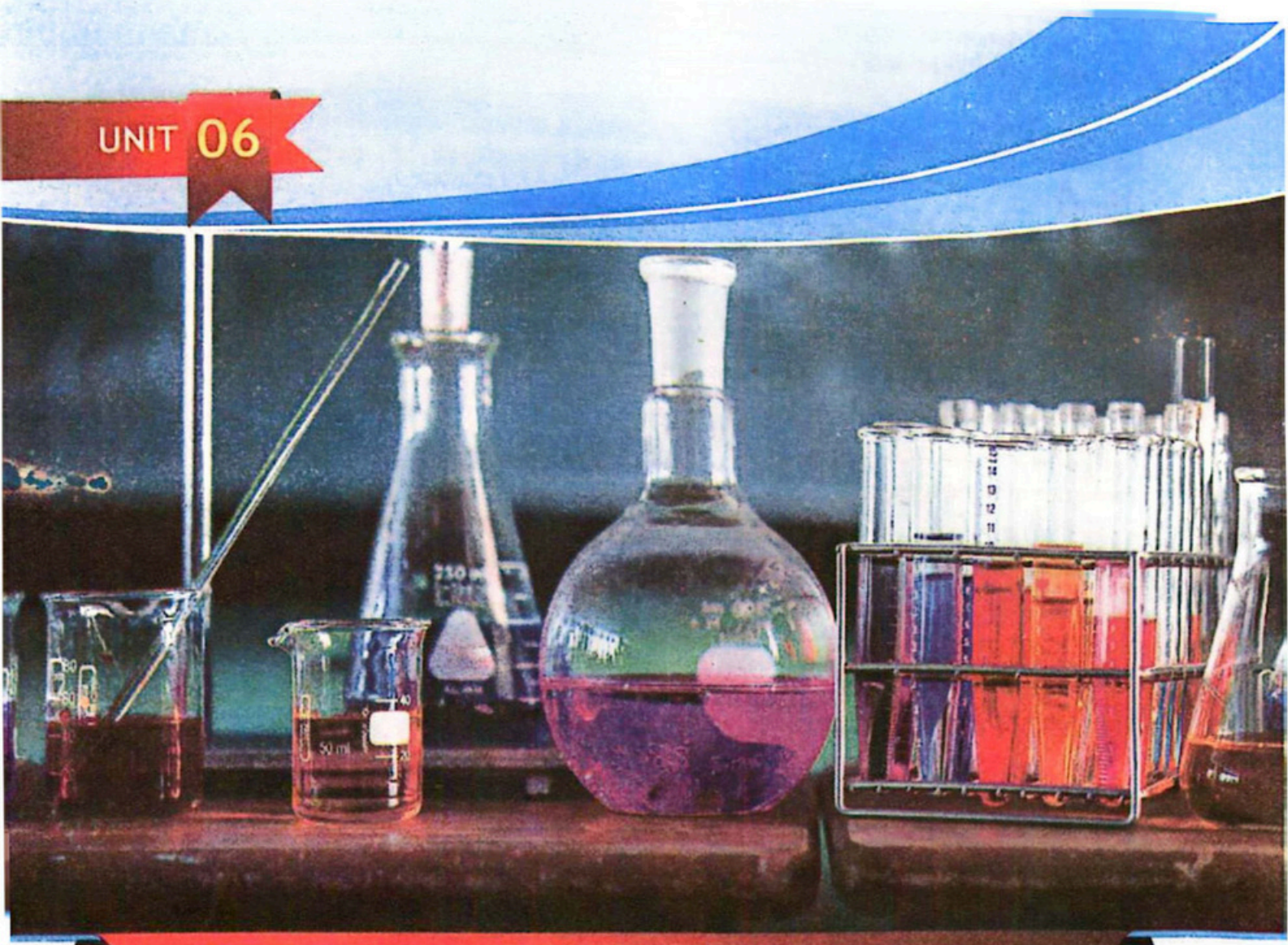
UNIT 06



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Student Learning Outcomes (SLOs)

After completing this lesson, the student will be able to:

- State the formulae of common elements and compounds.
- Define molecular formula of a compound as the number and type of different atoms in one molecule.
- Define empirical formula of a compound as the simplest whole number ratio of different atoms in a molecule.
- Deduce the formula and name of a binary compound from ions given relevant information.
- Deduce the formula of a molecular substance from a given structure of molecules.
- Use the relationship amount of substance = mass/molar mass to calculate number of moles, mass, molar mass, relative mass (atomic/molecular/formula) and number of particles.
- Define mole as amount of substance containing Avogadro`s number (6.022×10^{23}) of particles.
- Explain the relationship between a mole and Avogadro`s constant.
- Construct chemical equations and ionic equations to show reactants forming products, including state symbols.
- Deduce the symbol equation with state symbols for a chemical reaction given relevant information.

INTRODUCTION

What are the simplest components of wood, rocks and living organisms? This is an age-old question. Ancient Greek Philosophers believed that everything was made of an elemental substance. Some believed that substance to be water, other thought it was air. Some other believed that there were four elemental substances.

As 19th century began, John Dalton proposed an atomic theory. This theory led to rapid progress in chemistry. By the end of the century however, further observations exposed the need for a different atomic theory. 20th century led to a picture of an atom with a complex internal structure.

A major goal of this chapter is to acquaint you with the fundamental concepts about matter. In this chapter you will learn some basic definitions to understand matter. This knowledge will help you in grade XI.

6.1 EMPIRICAL FORMULA AND MOLECULAR FORMULA

Remember that the chemical formula of a compound tells you which elements it contains and the whole number ratio of those atoms. In a chemical formula, the elemental symbol and numerical subscripts indicate the type and number of each atom in the compound. The compound has several chemical formulas. Learn about the two types of chemical formulas.

6.1.1 Empirical Formula

The empirical formula of a compound is the chemical formula that gives the simplest integer ratio of the atoms of each element. For example, the compound hydrogen peroxide has one H atom for every O atom. Therefore, the simplest ratio of hydrogen to oxygen is 1:1. The empirical formula for hydrogen peroxide is therefore written as HO.

The simplest ratio between C, H and O atoms in glucose is 1 : 2 : 1. What is the empirical formula of glucose?

6.1.2 Molecular Formula

A molecular formula is an expression that specifies the number of atoms of each element in one molecule of a compound. This shows the actual number of atoms in each molecule. For example, the molecular formula of hydrogen peroxide is H_2O_2. It shows that each molecule of hydrogen peroxide is made up of two hydrogen atoms and two atoms of oxygen. Similarly $C_6H_{12}O_6$ is molecular formula of glucose. It shows that every molecule of glucose has 6 carbon atoms, 12 hydrogen atoms and 6 oxygen atoms. The molecular formula of a compound shows the simplest ratio between different atoms present in the compound.

Benzene is a compound of carbon and hydrogen. It contains one C atom for every H atom. Each benzene molecule actually has six carbon atoms and six hydrogen atoms. Identify the empirical and molecular formulas of benzene from the following formulas.

C_6H_6 , CH

Molecular formulas for water and carbon dioxide are H_2O and CO_2 respectively. What are empirical

formulas for these compounds?

For many compounds, empirical and molecular formulas are same. For example water (H_2O), carbon dioxide (CO_2) ammonia (NH_3), methane (CH_4), sulphur dioxide (SO_2) etc. Can you show it why?

Table 6.1 Formulae of some common elements and compounds

Element	Formula	Compound	Formula
Hydrogen	H_2	Water	H_2O
Oxygen	O_2	Carbon dioxide	CO_2
Nitrogen	N_2	Hydrochloric acid	HCl
Fluorine	F_2	Sodium hydroxide	NaOH
Chlorine	Cl_2	Copper (II) sulphate	$CuSO_4$
Bromine	Br_2	Glucose	$C_6H_{12}O_6$

CONCEPT ASSESSMENT EXERCISE 6.1

Write the empirical formulas for the compound containing carbon to hydrogen in the following ratios:

(a) 1:4 (b) 2:6 (c) 2:2 (d) 6:6

CONCEPT ASSESSMENT EXERCISE 6.2

1. Aspirin is used as a mild pain killer. There are nine carbon atoms, eight hydrogen atoms and four oxygen atoms, in this compound. Write its empirical and molecular formulas.
2. Vinegar is 5% acetic acid. It contains 2 carbon atoms, four hydrogen atoms and 2 oxygen atoms. Write its empirical and molecular formulas.
3. Caffeine ($C_8H_{10}N_4O_2$) is found in tea and coffee. Write the empirical formula for caffeine.

6.2 MOLECULAR MASS AND FORMULA MASS

Molecular mass is the sum of the atomic masses of all the atoms present in the molecule. All you have to do is to add up the atomic masses of all the atoms in the compound. For example,

Molecular mass of water H_2O = 2(atomic mass of H) + atomic mass of oxygen

= 2(1.008) + 16.00

= 2.016 + 16.00

= 18.016amu

Example 6.1: Determining molecular mass

1. Determine the molecular mass of glucose $C_6H_{12}O_6$ which is also known as blood sugar.
2. Determine the molecular mass of naphthalene $C_{10}H_8$, which is used in mothballs.

Problem solving strategy:

Multiply atomic masses of carbon, hydrogen and oxygen by their subscripts and add.

Solution:

1. Molecular mass of $C_6H_{12}O_6$ = 6(12.00) + 12(1.008) + 6(16.00)
   =180.096 amu
2. Molecular mass of $C_{10}H_8$ = 12 x 10 + 1 x 8
   = 120 + 8 = 128 amu

The term molecular mass is used for molecular compounds. Whereas, the term formula mass is used for ionic compounds. Ionic compounds consist of arrays of oppositely charged ions rather than separate molecules. So we represent an ionic compound by its formula unit. A formula unit indicates the simplest ratio between cations and anions in an ionic compound. For example, the common salt consists of Na^+ and Cl^- ions. It has one Na^+ ion for every Cl^- ion. So formula unit for common salt is NaCl.

The sum of the atomic masses of all the atoms in the formula unit of a substance is called formula mass.

Example 6.2: Determining formula mass

1. Sodium Chloride, also called as table salt is used to flavour food, preserve meat, and in the preparation of large number of compounds. Determine its formula mass.
2. Milk of magnesia which contains $Mg(OH)_2$, is used to treat acidity. Determine its formula mass.

Problem solving strategy:

Add the atomic masses of all the atoms in the formula unit.

Solution:

1. Formula mass of NaCl = 1 x Atomic mass of Na + 1 x Atomic mass of Cl
   = 1 x 23+ 1 x 35.5
   = 58.5amu
2. Formula mass of $Mg(OH)_2$ = 24 + 16x2 + 1x2
   = 24 + 32 + 2
   = 58 amu

CONCEPT ASSESSMENT EXERCISE 6.3

1. Potassium Chlorate ($KClO_3$) is used commonly for the laboratory preparation of oxygen gas. Calculate its formula mass.
2. When baking soda, $NaHCO_3$ is heated carbon dioxide is released, which is responsible for the rising of cookies and bread. Determine the formula masses of baking soda and carbon dioxide.
3. Following compounds are used as fertilizers. Determine their formula masses.
   (i) Urea, $(NH_2)_2CO$ (ii) Ammonium nitrate, NH_4NO_3

6.3 CHEMICAL FORMULA AND NAME OF BINARY IONIC COMPOUNDS

A binary ionic compound is composed of mono-atomic metal cations and mono-atomic non-metal anions. To write the name of an ionic compound, the cation is named first followed by the name of anion. How do you name cations and anions? The name of the cation is the same as the name of the metal, but in the name of mono-atomic anion, the suffix ide is added to the root name of the element. For example, sodium chloride, magnesium oxide, aluminium nitride, etc.

The following steps are used to write the chemical formula of a binary ionic compound.

Step 1. Write the symbols for the cation first and then the symbols for the anion and their charges

Step 2. Balance the charges on the cations and anions using the smallest coefficient. The total charge on the cation must equal the total charge on the anion because an ionic compound is nutral

Step 3. Write coefficient as subscripts for each ion.

Step 4. Write the formula of ionic compound. For this leave out all the charges subscript which are 1.

For example, the chemical formula of sodium chloride is written as follows;

$$Na^{+1}Cl^{-1}$$

$$1(+1) = (-1)1$$

$$Na_1Cl_1 = NaCl$$

Example 2, the chemical formula of aluminium oxide is written as follows;

$$Al^{+3}O^{-2}$$

$$2(+3) = (-2)3$$

$$+6 = -6$$

$$Al_2O_3$$

Table indicating names and symbols for cations and anions

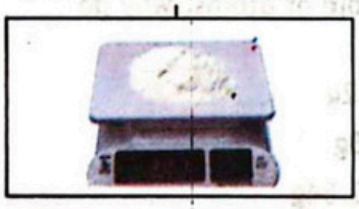
Cations		Anions	
Lithium	Li^+	Fluoride	F^-
Sodium	Na^+	Chloride	Cl^-
Ammonium	NH_4^+	Nitrite	NO_2^-
Potassium	K^+	Bromide	Br^-
Magnesium	Mg^{2+}	Nitrate	NO_3^-
Calcium	Ca^{2+}	Phosphate	PO_4^{3-}
Copper	Cu(II)	Sulfate	SO_4^{2-}

6.4 AVOGADRO'S NUMBER AND MOLE

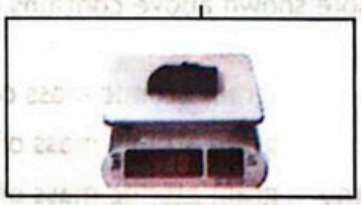
How do you count your shoes? Since the shoes come in pairs, you'll probably count them in pairs rather than individually. Likewise, eggs, oranges, etc. are counted in the dozens, but paper with the ream. So the unit of counting depends on what you are counting. Chemists also use a practical unit for counting atoms, molecules and ions. They use a counting unit called mole to measure the amount of a substance.

A mole is an amount of a substance that contains 6.022×10^{23} particles of that substance. This experimentally determined number is known as Avogadro's number. It is represented by N_A. Just as a dozen eggs represent twelve eggs, a ream of paper represent 500 papers, a mole of a substance represents 6.022×10^{23} representative particles of a substance.. For example a mole of carbon is 6.022×10^{23} atoms. A mole of sulphur is 6.022×10^{23} atoms. A mole of water is 6.022×10^{23} molecules.

A mole of S-atoms (6.022×10^{23} S-atoms)



A mole of C-atoms (6.022×10^{23} C-atoms)



A pair of Shoes & a dozen eggs

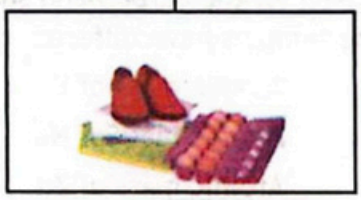


Figure 6.1 A mole of S-atoms, a mole of C-atoms & pair of Shoes & a dozen eggs

What is the mass of one mole C-atoms?

How many atoms are there in 32.1 g of S-atoms?

Does a dozen eggs have the same mass as a dozen bananas? Does a mole of carbon atoms have a different mass than a mole of sulphur atoms?

The mass of one mole of substance is called as molar mass. What are the molar masses of carbon and sulphur? The term representative particles in a substance are atoms, molecules, formula units or ions. For instance

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Size of the Mole

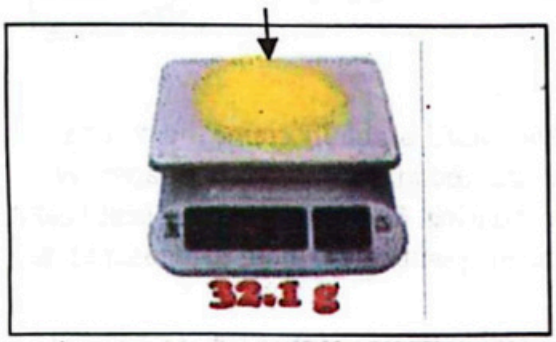
Entire population cannot count 1 mole of coins in a year. They need about one million year to count them. So, when counting a pile of coins, it would not be convenient to count them one by one. The concept of mole has given a very simple method to count large number of items. Mole is not only a number but also represents definite amount of a substance. Just as 6.02×10^{23} carbon atoms weigh 12 g, 6.02×10^{23} coins will also have a definite mass. So an easy way is to weigh them. If you know the mass of one coin, you can count them by weighing.

water exists as molecules, therefore, one mole of water contains 6.022×10^{23} molecules of water. Hydrogen exists as H_2 molecules, so one mole of hydrogen contain 6.022×10^{23} molecules. Carbon exists as atoms so 1 mole of carbon contains 6.022×10^{23} atoms.

6.4.1 Gram Atomic Mass, Gram Molecular Mass and Gram Formula Mass

A mole of S-atoms

(6.022×10^{23} S-atoms)

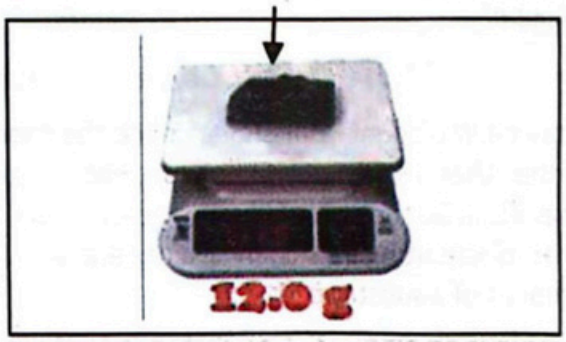


What is the mass of 6.022×10^{23} S-atoms?

Is this mass of S-atoms equal to its atomic mass?

A mole of C- atoms

(6.022×10^{23} C-atoms)



What is the mass of one mole of C-atoms?

Is this mass of C-atoms equal to its atomic mass?

Atomic mass of an element expressed in grams is called gram atomic mass.

Is the gram atomic mass of C- atoms 12 g?

What is the gram atomic mass of S-atoms?

If each of the carbon and sulphur sample shown above contains one mole of atoms, why do the samples have different masses?

Atomic mass of C	= 12amu	\gram atomic mass of C = 12g
Atomic mass of Na	= 23amu	gram atomic mass of C = 23g
Atomic mass of Zn	= 63.54amu	gram atomic mass of C = 63.54g

Gram atomic mass of an element contains 1 mole of atoms.

Therefore,

Mass of 1 mole of C-atoms = 12g

Mass of 1 mole of Na-atoms = 23g

Mass of 1 mole of Zn-atoms = 63.54g

A mole of H_2O-molecules

(6.022×10^{23} H_2O-molecules)

A mole of $C_6H_{12}O_6$-molecules

(6.022×10^{23} $C_6H_{12}O_6$-molecules)

What is the mass of one mole of water molecules? Is this mass of water molecules equal to molecular mass of water?

what is the mass of 6.022×10^{23} molecules of glucose? is this mass of glucose molecules equal to molecular mass of glucose?

Molecular mass of a substance expressed in grams is called gram molecular mass.

Molecular mass of H_2O $= 2 \times 1.008 + 16$
$= 18.016$amu

So, gram molecular mass of H_2O $= 18.016$g

Molecular mass of $C_6H_{12}O_6$ $= 6 \times 12 + 12 \times 1.008 + 16 \times 6$
$= 180.096$amu

So, gram molecular mass of $C_6H_{12}O_6$ $= 180.096$g

Formula mass of a substance expressed in gram is called gram formula mass.

An ionic compound is represented by the formula unit that represents the simplest ratio between the ions of a compound. For example NaCl, KCl, $CuSO_4$ etc.

Formula mass of NaCl $= 23 + 35.5$
$= 58.5$amu

Therefore, gram formula mass of NaCl $= 58.5$

Formula mass of KCl $= 39 + 35.5$
$= 74.5$amu

So, gram formula mass of KCl $= 74.5$g

6.4.2 Difference between the Terms Gram Atomic Mass, Gram Molecular Mass And Gram Formula Mass

1. Gram atomic mass represents one mole of atoms of an element, gram molecular mass represents one mole of molecules of a compound or an element that exists in molecular state whereas gram formula mass represents one mole of ionic formula units of a compound.
2. Gram atomic mass contains 6.022×10^{23} atoms, gram molecular mass contains 6.022×10^{23} molecules whereas gram formula mass contain 6.022×10^{23} formula units.
3. All of these quantities represent molar mass. Mass of one mole of a substance expressed in grams is called molar mass. "Therefore, mole can be defined as atomic mass, molecular mass or formula mass expressed in grams".

6.5 CHEMICAL CALCULATIONS

In this section, you will learn about the chemical calculations based on the concept of mole and Avogadro's number.

6.5.1 Mole-Mass Calculations

Example 6.3: Calculating mass of one mole of a substance

Calculate the molar masses of (a) Na (b) Nitrogen (c) Sucrose $C_{12}H_{22}O_{11}$

Problem solving strategy:

If an element is a metal then its molar mass is its atomic mass expressed in grams (gram atomic mass). If an element exists as a molecule, its molar mass is its molecular mass expressed in grams (gram molecular mass).

Solution:

a) 1 mole of Na = 23g

b) Nitrogen occurs as a diatomic molecules.

Molecular mass of N_2 = 14 x 2

= 28amu

Therefore, mass of 1 mole of N_2 = 28 g

c) Molecular mass of $C_{12}H_{22}O_{11}$ = 12x12 + 1x22 + 16x11

= 144 + 22 + 176

Therefore, mass of 1mole of sucrose = 342g

CONCEPT ASSESSMENT EXERCISE 6.4

1. Calculate the mass of one mole of
   (a) Copper (b) Iodine (c) Potassium (d) Oxygen
2. Differentiate between gram formula mass and gram molecular mass.

Example 6.4: Calculating the mass of a given number of moles of a substance

Oxygen is converted to ozone (O_3) during thunder storms. Calculate the mass of ozone if 9.05 moles of ozone is formed in a storm?

Problem solving strategy:

Ozone is a molecular substance. Determine its molar mass and use it to convert moles to mass in grams.

9.05 moles of O_3 ⟶ ? g of

Solution:

1 mole of O_3 = 16 x 3

= 48 g

1 mole of O_3 = 48 g

So, 9.05 moles of O_3 = 48 g x9.05

= 434.4g of O_3

Example 6.5: When natural gas burns CO_2 is formed. If 0.25 moles of CO_2 is formed, what mass of CO_2 is produced?

Problem solving strategy:

Carbon dioxide is a molecular substance. Determine its molar mass and use it to convert moles to mass in grams

0.25 moles of CO_2 ⟶ ? g of CO_2

Solution:

Molar mass of CO_2 = 12 + 16 x 2

= 44g

1 mole of CO_2 =44g of CO_2

So, 0.25 moles of CO_2 = 44 x 0.25

= 11g of CO_2

Example 6.6: Converting grams to moles

How many moles of each of the following substance are present?

(a) A balloon filled with 5g of hydrogen.

(b) A block of ice that weighs 100g.

Problem solving strategy:

Hydrogen and ice both are molecular substances. Determine their molar masses. Use the molar mass of each to convert the masses in grams to moles.

mass ⟶ ? moles

Solution:

a) Molar mass of H_2 = 1.008 x 2

= 2.016g

1 mole of H_2 = 2.016g

So, 2.016g of H_2 = 1 mole of H_2

1g of H_2 = $\frac{1}{2.016}$ moles of H_2

5g of H_2 = $\frac{1}{2.016}$ x5 moles of H_2

= 2.48 moles of H_2O

b) 1 mole of H_2O = 2 x 1.008 + 16

= 2.016 + 16

= 18.016g

1 mole of H_2O = 18.016g

So, 18.016g of H_2O = 1 mole

1g of H_2O = $\frac{1}{18.016}$ moles

100g of H_2O $= \frac{1}{18.016} \times 100$ moles
$= 5.55$ moles of H_2O

CONCEPT ASSESSMENT EXERCISE 6.5

1. The molecular formula of a compound used for bleaching hair is H_2O_2. Calculate (a) Mass of this compound that would contain 2.5 moles. (b) No. of moles of this compound that would exactly weigh 30g.
2. A spoon of table salt, NaCl contains 12.5grams of this salt. Calculate the number of moles it contains.
3. Before the digestive systems X-rayed, people are required to swallow suspensions of barium sulphate $BaSO_4$ Calculate mass of one mole of $BaSO_4$.

6.5.2 Mole-Particles Calculations

Example 6.7: Calculating the number of atoms in given moles

1. Zn is a silvery metal which is used to galvanize steel to prevent corrosion. How many atoms are there in 1.25 moles of Zn.
2. A thin foil of aluminium (Al) is used as wrapper in food industries. How many atoms are present in a foil that contains 0.2 moles of aluminium?

Problem solving strategy:

Remember that symbols Zn and Al stand for one mole of Zn and Al atoms respectively.

Solution:

1. 1 mole of Zn contains $= 6.022 \times 10^{23}$ atoms
   1.25 moles of Zn contain $= 6.022 \times 10^{23} \times 1.25$
   $= 7.53 \times 10^{23}$ Zn atoms
2. 1 mole of Al contains $= 6.022 \times 10^{23}$ atoms
   So 0.2 moles of Al will contain $= 6.022 \times 10^{23} \times 0.2$
   $= 1.2044 \times 10^{23}$ atoms

Example 6.8: Calculating the number of molecules in given moles of a substance

1. Methane (CH_4) is the major component of natural gas. How many molecules are present in 0.5 moles of a pure sample of methane?
2. At high temperature hydrogen sulphide (H_2S) gas given off by a volcano is oxidized by air to sulphur dioxide (SO_2). Sulphur dioxide reacts with water to form acid rain. How many molecules are there in 0.25 moles of SO_2

Problem solving strategy:

Remember that CH_4 is a molecular compound, thus 1 mole of methane will have 6.022×10^{23}

molecules. Similarly, SO_2 is a molecular compound, its one mole will also have 6.022×10^{23} molecules.

Solution:

1. 1 mole of CH_4 contains = 6.022×10^{23} molecules
   So, 0.5 moles of CH_4 will contain = $6.022 \times 10^{23} \times 0.5$
   = 3.011×10^{23} molecules
2. 1 mole of SO_2 contains = 6.022×10^{23} molecules
   So, 0.25 moles of SO_2 will contain = $6.022 \times 10^{23} \times 0.25$
   = 1.5055×10^{23} molecules

Example 6.9: Calculating the number of moles in the given number of atoms

Titanium is corrosion resistant metal that is used in rockets, aircrafts and jet engines. Calculate the number of moles of this metal in a sample containing 3.011×10^{23} Ti-atoms.

Problem solving strategy:

Remember that 1 mole of an element contains 6.022×10^{23} atoms.

Thus,

6.022×10^{23} atoms = 1 mole

3.011×10^{23} atoms $\longrightarrow$? moles

Solution:

6.022×10^{23} Ti atoms = 1 mole of Ti

1 Ti atom = $\frac{1}{6.022 \times 10^{23}}$ moles of Ti

3.011×1023 Ti atoms = $\frac{1}{6.022 \times 10^{23}} \times 3.011 \times 10^{23}$ moles of Ti

= 0.5 moles of Ti

Example 6.10: Calculating number of moles in the given number of molecules

Formaldehyde is used to preserve dead animals. Its molecular formula is CH_2O Calculate the number of moles that would contain 3.011×10^{22} molecules of this compound.

Problem Solving Strategy:

Remember that 1 mole of any compound contains 6.022×10^{23} molecules.

Thus,

6.022×10^{23} molecules = 1 mole of compound

3.011×10^{22} molecules $\longrightarrow$? moles

Solution:

6.022×10^{23} molecules = 1 mole of formaldehyde

1 molecule = $\frac{1}{6.022 \times 10^{23}}$ moles of formaldehyde

3.011×10^{22} molecules $= \frac{1}{6.022 \times 10^{23}} \times 3.011 \times 10^{22}$ moles of formaldehyde

$= 0.05$ moles of formaldehyde

CONCEPT ASSESSMENT EXERCISE 6.5

1. Aspirin is a compound that contains carbon, hydrogen and oxygen. It is used as a painkiller. An aspirin tablet contains 1.25×10^{30} molecules. How many moles of this compound are present in the tablet?
2. A method used to prevent rusting in ships and underground pipelines involves connecting the iron to a block of a more active metal such as magnesium. This method is called cathodic protection. How many moles of magnesium are present in 1 billion (1×10^9) atoms of magnesium.

6.6 CHEMICAL EQUATION AND BALANCING

The symbolic representation of a chemical reaction is called chemical equation. The reactants in a chemical equation are the substances that initiate the chemical reaction, and the products are the substances that are formed during the chemical reaction. Reactants are always written on the left of the equation and products on the right, an arrow between them is used to show the direction of the chemical change.

For writing a chemical equation, follow the following steps.

Step 1. Identify reactants and products and write word equation for the reaction. Represent chemical equation is as follows:

Reactants → Products

Step 2. Write the symbols and formulae of reactants and products. Indicate their physical states in parenthesis. Use s for solid, l for liquid, g for a gas and aq for aqueous.

Example 6.11: burning of coal is represented as follows.

Coal + Oxygen → Carbon dioxide

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

CONCEPT ASSESSMENT EXERCISE 6.6

Represent the following chemical reactions by chemical equations.

1. Burning of hydrogen(H_2) to produce water.
2. Burning of magnesium(Mg) to produce magnesium oxide(MgO).

6.6.1 Balancing a chemical equation

A chemical reaction only changes the arrangements of atons.The number of atons remains the same. Count the number of atoms of atoms of each type in the following equation:

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

Reactants	Products
1 C-atom	1 C-atom

2 O-atoms 2 O-atoms

Note that the number of atoms of each type are the same on the reactant side adn the product side. Such a chemical equation is called a balanced chemical equation.How can you balance a chemical reaction, it is unbalanced?

Consider the following reaction;

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

Reactants	Products
1 C-atom	1 C- atom
4 H-atoms	2 H-atoms
2 O-atoms	3 O-atoms

C-atoms are balanced, but H and O- atoms are unbalanced.

Balance one element at a time. To balance the chemical equation use co-efficients. Always start with the lowest co-efficient. Remember that you should not chamge **subscripts in a chemical formula.**

Step 1

Put a co-efficient 2 before H_2O to balance H- atoms.

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

Step 2

Now balance O-atoms. There are 2O-atoms on the left side and O-atoms on the right side. Put 2 before O_2

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

Step 3

Now check the equation again, it is balanced.

6.6.2 Exploring ionic equation

A chemical equation in which substances dissolved in water are written as individual ions is called an ionic equation. For example,

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

Write the substances that are soluble in water in their dissociated form.

$H^{+1}(aq) + Cl^{-1}(aq) + Na^{+1}(aq) + OH^{-1}(aq) \rightarrow Na^{+1}(aq) + Cl^{-1}(aq) + H_2O(l)$

Remove common ions from both sides. These ions do not actually take part in the chemical reaction and are called spectator ions. Write net ionic equation.

$H^{+1}(aq) + OH^{-1}(aq) \rightarrow H_2O(l)$

Example 6.12: Transform the following chemical equations into ionic equations.

$Mg_{(s)} + H_2SO_{4(aq)} \rightarrow MgSO_4 + H_{2(g)}$

$Mg_{(s)} + 2H^{1+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + H_{2(g)}$

$Mg_{(s)} + 2H^{1+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + H_{2(g)}$

CONCEPT ASSESSMENT EXERCISE 6.7

Transform the following chemical equations into ionic equations.

1. $AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$
2. $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$

6.7 MOLECULAR AND STRUCTURAL FORMULA

A structural formula of a compound shows the arrangement of atoms present in it. Whereas a molecular formula shows the number of atoms of each element. For example,

Structural formula of n-Butane is $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3$ and its molecular formula is C_4H_{10}.

How can you write the molecular formula of a compound from its structural formula?

Follow the following steps:

1. Identify different types of elements present in the structural formula.
2. Write symbols of these elements side by side in a line.
3. Count the number of atoms of each element from the structural formula.
4. Show this number of atoms as subscripts of symbol of corrosponding element.

Example 6.13: Writing the molecular formula of the following compound.

$CH_3\text{-}CH_2\text{-}CH_2\text{-}OH$

Solution: C_3H_8O

CONCEPT ASSESSMENT EXERCISE 6.8

Write the molicular formulae of the following compounds,

1. $CH_3\text{-}CH_2\text{-}OH$
2. $CH_3\text{-}CH\text{-}_2\text{-}NH_2$
3. $CH_3\text{-}CO\text{-}CH_3$

KEY POINTS

- Chemistry is the science of materials of the universe.
- The branch of Chemistry that deals with laws and theories to understand the structure and changes of matter is called Physical Chemistry.
- An element is a substance all the atoms of which have the same atoı ic number.
- A compound consists of two or more elements held together in fixed proportions by chemical bonds.
- Chemical formula of a compound that gives the simplest whole-number ratio between atoms is called empirical formula.

- Molecular formula of a compound gives the exact number of atoms present in a molecule.
- Molecular mass is the sum of atomic masses of all the atoms present in the molecule.
- The number of representative particles in one mole of the substance is known as Avogadro's number.
- The amount of matter that contains as many atoms, ions or molecules as the number of atoms in exactly 12g of C-12 is called mole. Mole can also be defined as atomic mass, molecular mass or formula mass expressed in grams.
- Atomic mass of an element expressed in grams is called gram atomic mass.
- Molecular mass of an element or a compound expressed in grams is its gram molecular mass.
- Gram formula mass is the formula mass of a substance in grams.

References for additional information

- Zumdahl, Introductory Chemistry.
- Raymond Chang, Essential Chemistry.

REVIEW QUESTIONS

1. Encircle the correct answer.

(i) What is the formula mass of $CuSO_4.5H_2O$. (Atomic masses: Cu=63.5, S=32, O=16, H=1)

(a) 159.5 (b) 185.5

© 249.5 (d) 149.5

(ii) A compound with chemical formula Na_2CX_3 has formula mass 106amu. Atomic mass of the element X is

(a) 106 (b) 23

(c) 12 (d) 16

(iii) How many moles of molecules are there in 16g oxygen.

(a) 1 (b) 0.5

© 0.1 (d) 0.05

(iv) What is the mass of 4 moles of hydrogen gas.

(a) 8.064g (b) 4.032g

(c) 1g (d) 1.008g

(v) What is the mass of carbon present in 44g of carbon dioxide.

(a) 12g (b) 6g

(c) 24g (d) 44g

(vi) Which term is the same for one mole of oxygen and one mole of water?

(a) volume (b)

(c) mass (d) atoms

(e) molecules

(vii) If one mole of carbon contains x atoms, what is the number of atoms contained in 12g of Mg.

(a) x (b) $0.5x$

(c) $2x$ (d) $1.5x$

2. Give short answer.

(i) What is mole?

(ii) Differentiate between empirical formula and molecular formula.

(iii) What is the number of molecules in 9.0 g of steam?

(iv) What are the molar masses of uranium -238 and uranium -235?

(v) Why one mole of hydrogen molecules and one mole of H-atoms have different masses?

3. Define ion, molecular ion, formula unit, free radical, atomic number, mass number, atomic mass unit.

4. Describe how Avogadro's number is related to a mole of any substance.

5. Calculate the number of moles of each substance in samples with the following masses:

(a) 2.4 g of He (b) 250mg of carbon

(c) 15g of sodium chloride (d) 40g of sulphur

(e) 1.5kg of MgO

6. Calculate the mass in grams of each of the following samples:

(a) 1.2 moles of K (b) 75moles of H_2

(c)0.25 moles of steam (d) 1.05 moles of $CuSO_4.5H_2O$

(e) 0.15moles of H_2SO_4

7. Calculate the number of molecules present in each of the following samples:

(a) 2.5 moles of carbon dioxide (b) 3.4 moles of ammonia, Nh_3

© 1.09 moles of benzene, C_6H_6 (d)0.01 moles of acetic acid, CH_3COOH

8. Decide whether or not each of the following is an example of empirical formula:

(a) Al_2Cl_6 (b) Hg_2Cl_2

(c)NaCl (d) C_2H_6O

9. TNT or trinitrotoluene is an explosive compound used in bombs. It contains 7 C-atoms, 5 H-atoms,3-Natoms and 6 O-atoms. Write its empirical formula.

10. A molecule contains four phosphorus atoms and ten oxygen atoms. Write the empirical formula of this compound. Also determine the molar mass of this molecule.

11. Indigo ($C_{16}H_{10}N_2O_2$), the dye used to colour blue jeans is derived from a compound

known as indoxyl (C_8H_7ON). Calculate the molar masses of these compounds. Also write their empirical formulas.

12. Identify the substance that has formula mass of 133.5amu.

(a) $MgCl_2$ (b) S_2Cl_2

(c) BCl_3 (d) $AlCl_3$

13. Calculate the number of atoms in each of the following samples:

(a) 3.4 moles of nitrogen atoms (b) 23g of Na

(c) 5g of H atoms

14. Calculate the mass of the following:

(a) 3.24×10^{18} atoms of iron (b) 2×10^{10} molecules of nitrogen gas

(c) 1×10^{25} molecules of water (d) 3×10^{6} atoms of Al

15. Balance the following chemical equations

(a) $Na_{(s)} + H_2O_{(l)} \rightarrow NaOH_{(aq)} + H_{2(g)}$

(b) $NH_{3(g)} \rightarrow N_{2(g)} + H_{2(g)}$

16. Potassium is Group 1 element. It is silvery white metal. It burns in air and forms both potassium oxide and potassium nitride. The nitride ion is N^{3-}.

(a) Predict the formula of potassium oxide and potassium nitride.

(b) A 0.5g sample of K was added in $100cm^3$ of water.

$K_{(s)} + H_2O_{(l)} \rightarrow KOH_{(aq)} + H_{2(g)}$

Show that 1.28×10^{-2} mole of K were added to the water.

(c) Balance above chemical equation.

(d) Transform above chemical equation into ionic equation.

(e) Calculate the number of atoms present in the sample of K.

(f) Predict period number of potassium in the periodic table.