

Module 5: Chemistry Foundations (CHM 1100)

Introduction

Chemistry is the study of matter and the changes that matter undergoes.

Chemists investigate questions such as:

- What substances are made of
- How atoms combine to form molecules
- How chemical reactions occur
- How much of a substance is produced in a reaction

To answer these questions, chemists must measure quantities of substances very precisely.

However, atoms and molecules are extremely small. A single chemical reaction typically involves enormous numbers of particles.

To handle these quantities, chemists use a special counting unit known as the mole.

Understanding the mole concept is essential for solving many chemistry problems.

The Mole Concept

The mole is a counting unit used to measure the amount of a substance.

One mole contains:

6.022×10^{23} particles

This number is known as Avogadro's number.

The particles counted by a mole can include:

- atoms
- molecules
- ions
- formula units

Why the Mole Is Useful

Because atoms are extremely small, chemists cannot count individual particles directly.

Instead, they measure substances using the mole, which allows chemists to relate:

- number of particles
- mass of substances
- chemical reactions

For example:

1 mole of carbon atoms contains

6.022×10^{23} carbon atoms.

Molar Mass

The molar mass of a substance is the mass of one mole of that substance.

Molar mass is expressed in grams per mole (g/mol).

Example:

The molar mass of carbon is approximately 12 g/mol.

This means:

1 mole of carbon atoms weighs 12 grams.

Example

How many grams are in 1 mole of oxygen atoms?

The atomic mass of oxygen is approximately 16 g/mol.

Therefore:

1 mole of oxygen atoms weighs 16 grams.

Relationship Between Mass and Moles

Chemists frequently convert between mass and moles.

The relationship is:

moles = mass \div molar mass

Worked Example

How many moles are in 32 grams of oxygen (O₂)?

Step 1

Determine molar mass.

O₂ contains two oxygen atoms.

$16 + 16 = 32$ g/mol

Step 2

Use formula.

moles = mass \div molar mass

moles = $32 \div 32$

moles = 1

Answer: 1 mole of O₂

Example

How many moles are in 18 grams of water (H₂O)?

Step 1

Calculate molar mass.

H₂O contains:

2 hydrogen atoms (1 g/mol each)

1 oxygen atom (16 g/mol)

Molar mass = 18 g/mol

Step 2

Calculate moles.

moles = $18 \div 18$

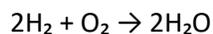
moles = 1

Answer: 1 mole of water

Chemical Reactions

A chemical reaction describes how substances transform into new substances.

For example:



This equation tells us that:

2 molecules of hydrogen react with

1 molecule of oxygen

to produce

2 molecules of water.

Balanced equations describe the ratio of substances involved in a reaction.

Stoichiometry

Stoichiometry is the calculation of quantities in chemical reactions.

Stoichiometry uses the ratios from balanced chemical equations to determine how much product forms from a given amount of reactant.

Stoichiometry Strategy

Students can solve stoichiometry problems using the following steps:

Step 1

Convert the given quantity to moles.

Step 2

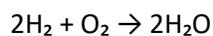
Use the mole ratio from the balanced equation.

Step 3

Convert the result into the desired units.

Worked Example

Given the reaction:



If 4 moles of hydrogen react, how many moles of water form?

Step 1

Identify mole ratio.

2 moles H_2 produce 2 moles H_2O .

Step 2

Apply ratio.

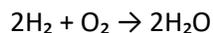
4 moles H_2 produce 4 moles H_2O .

Answer:

4 moles of water form.

Example With Mass

Given the reaction:



How many grams of water form from 4 moles of hydrogen?

Step 1

Determine moles of product.

4 moles $\text{H}_2 \rightarrow 4$ moles H_2O

Step 2

Convert moles to mass.

Molar mass of water = 18 g/mol

mass = moles \times molar mass

mass = 4 \times 18

mass = 72 grams

Answer:

72 grams of water.

Limiting Reactants (Concept Introduction)

In some reactions, one reactant may run out before the others.

The reactant that runs out first is called the limiting reactant.

The limiting reactant determines how much product forms.

Understanding limiting reactants is important in many chemistry calculations.

Practice Problems

1. How many moles are in 44 grams of carbon dioxide (CO₂)?
2. Calculate the molar mass of NaCl.
3. How many grams are in 2 moles of oxygen atoms?
4. If 3 moles of hydrogen react in the reaction
 $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$
how many moles of water form?
5. Convert 36 grams of water to moles.

Challenge Problems

1. How many molecules are in 1 mole of CO₂?
2. How many grams are in 0.5 moles of NaCl?
3. If 6 moles of hydrogen react, how many grams of water are produced?