

FOR CLASS 8 AND 9 · THE FOUNDATION FOR CBSE · NEET · JEE

ROOTS

of

CHEMISTRY

VOLUME 2

A book every student must read

The Mole · Gases · Formulae · Calculations from Equations · Solutions ·
Titrations · Electrolysis



S K SHUKLA

Mentoring IIT-JEE Aspirants Since 1994

Roots of Chemistry Vol 2

The Mole Concept for Class 8 and 9: Counting Atoms, Gases, Formulae, Equations and Solutions

S K Shukla

Mentoring IIT-JEE Aspirants Since 1994

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Every answer in this book has been checked by computer. Every number is worked out again from the data in the question, and every chemical equation is checked so that its atoms and charges are the same on both sides. The book is not printed if any answer fails this check. If you still find a mistake, please write to the author.

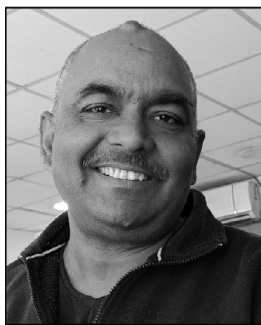
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S K Shukla has taught chemistry to IIT-JEE students since 1994. In more than thirty years of teaching he has seen one thing again and again: a student who understands the mole finds chemistry calculations easy, and a student who does not finds every numerical question hard.

He is the founder of Master Testing Agency, Roorkee, which writes practice tests for CBSE, NEET, JEE Main and JEE Advanced, sold at www.mastertestingagency.com. He is also the author of *Octacurv of Inorganic Chemistry*, *Octacurv of Organic Chemistry* and *Octacurv of Organic Reactions*, and of *Roots of Chemistry Vol 1*, the volume before this one.

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Preface

Atoms are far too small to see or to count one by one. Yet a chemist must know how many atoms react. How? By weighing. A fixed, very large number of particles is called a **mole**. If we know the mass of one mole, we can count atoms simply by weighing them.

This idea — the **mole concept** — is the key to every calculation in chemistry. Volume 1 taught the language of chemistry: symbols, formulae and equations. This Volume 2 teaches how to use that language to work out amounts: how many moles, how many grams, how many litres of gas, how strong a solution is.

The book is written for students of Class 8 and 9, in the simplest words I could find. Every chapter has the same plan:

- **The lesson**, in short and simple sentences;
- **Solved examples**, worked out step by step;
- **Remember** boxes with the common mistakes;
- **Test your understanding** — fill in the blanks, with the key;
- **Exercises** — with all the answers at the end of the chapter.

The last chapter, **Test Yourself**, has mixed questions of the kind asked in school and entrance examinations.

In every question, first change the given amount into moles. Then think in moles. Change back to grams or litres only at the end. This one habit solves almost every problem in this book.

I wish every reader success.

S K Shukla

How to use this book

- Read each lesson slowly. Work out each solved example yourself in your notebook.
- Do the exercises yourself first. Then check with the answers at the end of the chapter.
- Always write the unit (g, mol, L) with every number.

Values used in this book

Avogadro number, N_A	6.022×10^{23} per mole
Volume of 1 mole of any gas at STP (0 °C, 1 atm)	22.4 L
Gas constant, R	0.0821 L atm per mol per K
Faraday (charge of 1 mole of electrons)	96 500 C
Temperature	$K = ^\circ C + 273$

Atomic masses used in this book

H 1, He 4, C 12, N 14, O 16, Na 23, Mg 24, Al 27, P 31, S 32, Cl 35.5, K 39, Ca 40, Fe 56, Cu 63.5, Zn 65, Ag 108, I 127, Ba 137.

Chapter 1 · The Mole: Counting by Weighing

1.1 Why we need the mole

Atoms and molecules are far too small to see. Even a drop of water has more molecules than you could count in your whole life. So how does a chemist know how many atoms react?

Think of a shopkeeper selling rice. He does not count the grains. He **weighs** the rice, because he knows that a fixed weight always has about the same number of grains. Chemists do the same thing with atoms. They weigh, and from the weight they know the number. The tool that makes this possible is the **mole**.

1.2 What is a mole?

We use words for fixed numbers every day: a **pair** is 2, a **dozen** is 12, a **gross** is 144. In the same way:

One mole is 6.022×10^{23} particles.

This number is called the **Avogadro number**, N_A . Written in full it is 602 200 000 000 000 000 000 000. It is huge because atoms are tiny.

The particles can be anything: atoms, molecules, ions or electrons. So we must always say what we are counting.

- 1 mole of carbon atoms = 6.022×10^{23} carbon atoms.
- 1 mole of water molecules = 6.022×10^{23} water molecules.
- 1 mole of O_2 molecules has 2 moles of O atoms (each molecule has two atoms).

1.3 Molar mass: the weight of one mole

Why was this strange number chosen? Because it makes weighing easy:

The mass of 1 mole of a substance, in grams, is the same number as its atomic or molecular mass.

Substance	Atomic or molecular mass	Mass of 1 mole (molar mass)
Carbon, C	12 u	12 g
Oxygen gas, O_2	32 u	32 g
Water, H_2O	18 u	18 g
Common salt, NaCl	58.5 u	58.5 g

The mass of one mole is called the **molar mass**. Its unit is g/mol (grams per mole).

So 12 g of carbon, 18 g of water and 58.5 g of salt all contain the same number of particles: one mole each.

1.4 The three-way bridge

Every mole problem moves between three things: **mass**, **moles** and **number of particles**.

THE MOLE BRIDGE

- Moles = mass $\div$ molar mass ($n = m \div M$)
- Mass = moles $\times$ molar mass ($m = n \times M$)
- Number of particles = moles $\times 6.022 \times 10^{23}$
- Moles = number of particles $\div 6.022 \times 10^{23}$

1.5 Where the atomic masses come from

Atomic masses are not counted; they are compared. Scientists chose one atom as the standard. Today the standard is the **carbon-12 atom**, and its mass is fixed at exactly 12 u. Every other atom is compared with it. A magnesium atom is twice as heavy, so its atomic mass is 24 u.

(In the past, hydrogen = 1 and later oxygen = 16 were used as standards. The values changed only very slightly when carbon-12 was chosen in 1961.)

REMEMBER

- Always say what particle you mean. "1 mole of oxygen" could mean 32 g of O₂ molecules or 16 g of O atoms.
- Moles are found from grams, never from the number of atoms in the formula alone.

1.6 Solved examples**Solved Example 1.1: Grams to moles**

How many moles are there in 88 g of carbon dioxide, CO₂?

Solution. Molar mass of CO₂ = 12 + 2 $\times$ 16 = 44 g/mol. Moles = 88 $\div$ 44 = **2 mol**.

Solved Example 1.2: Moles to grams

What is the mass of 0.25 mol of calcium carbonate, CaCO₃?

Solution. Molar mass = 40 + 12 + 3 $\times$ 16 = 100 g/mol. Mass = 0.25 $\times$ 100 = **25 g**.

Solved Example 1.3: Counting molecules

How many molecules are there in 9 g of water?

Solution. Moles = 9 $\div$ 18 = 0.5 mol. Molecules = 0.5 $\times$ 6.022 $\times$ 10²³ = **3.011 $\times$ 10²³**.

Solved Example 1.4: Counting atoms

How many hydrogen atoms are there in 0.1 mol of methane, CH₄?

Solution. Each CH₄ molecule has 4 H atoms. So 0.1 mol CH₄ has 0.4 mol H atoms = 0.4 $\times$ 6.022 $\times$ 10²³ = **2.41 $\times$ 10²³** H atoms.

Solved Example 1.5: The mass of one atom

What is the mass of one atom of sodium?

Solution. 1 mole of Na (6.022×10^{23} atoms) weighs 23 g. One atom weighs $23 \div 6.022 \times 10^{23} = 3.82 \times 10^{-23}$ g.

Test your understanding

Fill in the blanks.

1. One mole is particles.
2. This number is called the number.
3. The mass of one mole of a substance in grams is called its
4. The molar mass of water is g/mol.
5. Moles = mass $\div$
6. Today atomic masses are compared with the atom, whose mass is exactly 12 u.

Key. 1. 6.022×10^{23} . 2. Avogadro. 3. molar mass. 4. 18. 5. molar mass. 6. carbon-12.

Exercises**I. Grams and moles.**

- (1) How many moles are there in 36 g of water?
- (2) How many moles are there in 11 g of CO_2 ?
- (3) How many moles are there in 4.6 g of sodium?
- (4) How many moles are there in 117 g of NaCl?
- (5) What is the mass of 3 mol of oxygen gas, O_2 ?
- (6) What is the mass of 0.5 mol of sulphuric acid, H_2SO_4 ?
- (7) What is the mass of 0.1 mol of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$?
- (8) What is the mass of 2.5 mol of NaOH?

II. Counting particles.

- (1) How many atoms are there in 2 mol of iron?
- (2) How many molecules are there in 16 g of oxygen gas?
- (3) How many atoms in all are there in 16 g of oxygen gas?
- (4) How many moles are there in 1.2044×10^{23} atoms of copper?
- (5) How many oxygen atoms are there in 0.5 mol of CO_2 ?
- (6) How many ions in all are there in 58.5 g of NaCl (Na^+ and Cl^- together)?
- (7) What is the mass of one molecule of water?
- (8) What is the mass of 6.022×10^{22} atoms of calcium?

III. Which is more?

- (1) Which has more atoms: 1 g of hydrogen gas (H_2) or 1 g of helium (He)? Give the number of moles of atoms in each.
- (2) Which has more molecules: 10 g of CO_2 or 10 g of H_2O ? Give the moles of each.

Answers

I.

- | | |
|--------------|-----------|
| (1) 2 mol | (5) 96 g |
| (2) 0.25 mol | (6) 49 g |
| (3) 0.2 mol | (7) 18 g |
| (4) 2 mol | (8) 100 g |

II.

- | | |
|--------------------------------------|----------------------------------|
| (1) 1.2044×10^{24} atoms | (5) 6.022×10^{23} atoms |
| (2) 3.011×10^{23} molecules | (6) 1.2044×10^{24} ions |
| (3) 6.022×10^{23} atoms | (7) 2.99×10^{-23} g |
| (4) 0.2 mol | (8) 4 g |

III.

- | | |
|--|---|
| (1) Hydrogen: 1 mol of H atoms against 0.25 mol of He atoms. | (2) Water: 0.556 mol of H ₂ O against 0.227 mol of CO ₂ . |
|--|---|