

CCo1 — Atoms, Molecules & Chemical Arithmetic

📖 CCo1 · CDS General Science — Chemistry

★ High Priority

This chapter forms the quantitative backbone of all chemistry. Every reaction and compound you study in later chapters connects back to atoms, molecules, and the mole concept. CDS expects you to know Avogadro's number, mole relationships, basic laws of combination, and how to balance simple equations.

✦ **CDS Focus:** Avogadro's number (6.022×10^{23}), gram atomic/molecular mass as the mole bridge, Law of Conservation of Mass and Law of Constant Proportion, balancing equations by inspection, and percentage composition. Expect 1–2 direct factual questions.

PART 1 — BASIC DEFINITIONS

1. Atom, Molecule & Atomic Mass

An **atom** is the smallest particle of an element that retains its chemical identity. A **molecule** is the smallest particle of a compound (or some elements) that can exist independently.

FIG. 1 — ATOMS, MOLECULES AND THE MOLE: HOW THEY CONNECT

ATOMS → MOLECULES → MOLE → MASS: The Mole Bridge



ATOM

Smallest unit of an element that retains its identity.
Atomic mass measured in atomic mass units (amu).

H = 1 amu, C = 12 amu, O = 16 amu, Na =



MOLECULE

Two or more atoms bonded. Molecular mass = sum of atomic masses.

H₂O = 2(1)+16 = **18 amu** | CO₂ = 12+2(16) = **44 amu** | NaCl = 23+35.5 = **58.5 amu**



MOLE

1 mole = **6.022 × 10²³** particles (Avogadro's Number N_a).

Gram molecular mass of H₂O = 18 g/mol. At STP, 1 mol gas = 22.4 L.

THE MOLE BRIDGE (most important formula)

Moles = Mass (g) / Molar Mass (g/mol) = Particles / 6.022×10²³ = Volume (L) / 22.4 (at STP)

Key Formulae — Mole Concept:

- Moles = mass (g) / molar mass (g/mol)
- Number of particles = moles × 6.022 × 10²³
- Volume at STP (gas) = moles × 22.4 L
- Molar mass numerically equals molecular mass in g/mol
- Gram atomic mass: mass of 1 mole of atoms = atomic mass in grams

PART 2 — LAWS OF CHEMICAL COMBINATION

2. Laws of Chemical Combination

FIG. 2 — FIVE LAWS OF CHEMICAL COMBINATION WITH EXAMPLES

FIVE LAWS OF CHEMICAL COMBINATION

Law & Scientist	Statement	Example
1. Conservation of Mass Lavoisier, 1789	Mass is neither created nor destroyed in any reaction. Reactant mass = Product mass.	$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ $4 + 32 = 36 \text{ g both sides}$
2. Constant Proportion Proust, 1808	A compound always contains elements in the same mass ratio, regardless of source.	H ₂ O always has H:O = 1:8 by mass
3. Multiple Proportions Dalton, 1803	When two elements form more than one compound, masses of one are in a simple ratio.	CO and CO ₂ : oxygen = 16 and 32 (ratio 1:2)
4. Reciprocal Proportions Richter, 1792	Masses combining with a fixed mass of a third element are simple multiples of each other.	H ₂ S, H ₂ O and SO ₂ : related S and O ratios
5. Combining Volumes Gay-Lussac	Gases react in simple whole-number ratios by volume at same T and P.	$\text{H}_2 + \text{Cl}_2 \rightarrow 2 \text{HCl}$ $1 \text{ vol} + 1 \text{ vol} \rightarrow 2 \text{ vol}$

PART 3 – CHEMICAL EQUATIONS

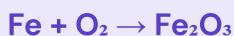
3. Balancing Chemical Equations

A balanced equation has equal numbers of each type of atom on both sides (Law of Conservation of Mass). Use the trial-and-balance (inspection) method for CDS level.

FIG. 3 – HOW TO BALANCE A CHEMICAL EQUATION STEP BY STEP

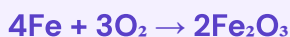
BALANCING: $\text{Fe} + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3$ — Step by Step

STEP 1 — Write the unbalanced equation



Count: Fe = 1 left, 2 right; O = 2 left, 3 right → NOT balanced

STEP 2 — Balance by adjusting coefficients (never subscripts)



LCM method: need 4 Fe and 6 O atoms on both sides ($3 \times \text{O}_2 = 6 \text{ O}$)

STEP 3 — Verify: count atoms on both sides

LHS: Fe = 4, O = 6 RHS: Fe = 4, O = 6 ✓ BALANCED

RULES: Change coefficients only (never subscripts). Balance metals first, then non-metals, then H and O last.
 Verify atom count on both sides after each step. Coefficients must be whole numbers.

4. Percentage Composition & Empirical Formula

Percentage Composition:

% of element = (mass of element in 1 mole of compound / molar mass of compound) × 100

Example – H₂O: % H = (2/18) × 100 = 11.1% % O = (16/18) × 100 = 88.9%

Empirical Formula: Simplest whole-number ratio of atoms. Molecular formula = n × Empirical formula.

Example: Glucose C₆H₁₂O₆ → Empirical formula CH₂O (n = 6)

✎ Worked Example – Mole Concept

How many molecules are there in 36 g of water (H₂O)? Molar mass of H₂O = 18 g/mol.

Moles of H₂O = 36/18 = **2 moles**

Number of molecules = 2 × 6.022 × 10²³ = **1.204 × 10²⁴ molecules**

✓ **1.204 × 10²⁴ molecules**

CDS PYQs – Atoms, Molecules & Chemical Arithmetic

Q1. Avogadro's number is: CDS PYQ

(a) 6.022 × 10²¹ (b) 6.022 × 10²² (c) 6.022 × 10²³ (d) 6.022 × 10²⁴

✓ **Answer: (c) 6.022 × 10²³**

Avogadro's number (N_a) = **6.022 × 10²³** — this is the number of atoms, molecules, or ions present in one mole of any substance. It was determined by Amedeo Avogadro's hypothesis that equal volumes of gases at the same T and P contain equal numbers of

molecules. This is one of the most fundamental constants in chemistry and is directly tested in CDS.

Q2. Which law states that matter is neither created nor destroyed in a chemical reaction? CDS PYQ

- (a) Law of Constant Proportion (b) Law of Multiple Proportions
(c) Law of Conservation of Mass (d) Avogadro's Law

✓ Answer: (c) Law of Conservation of Mass

The **Law of Conservation of Mass** (Lavoisier, 1789) states that the total mass of reactants equals the total mass of products in a chemical reaction. This is why chemical equations must be balanced. Example: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ — $4\text{g} + 32\text{g} = 36\text{g}$ on both sides. This is the most fundamental law of chemistry.

Q3. The molecular mass of CO_2 is: CDS PYQ

- (a) 28 g/mol (b) 40 g/mol (c) 44 g/mol (d) 48 g/mol

✓ Answer: (c) 44 g/mol

$\text{CO}_2 = 1 \text{ carbon} + 2 \text{ oxygens} = 12 + 2(16) = 12 + 32 = \mathbf{44 \text{ g/mol}}$. Note: CO (carbon monoxide) = $12 + 16 = 28 \text{ g/mol}$ (common CDS confusion). CO_2 is the gas exhaled during respiration and is a greenhouse gas. Its molecular mass of 44 is a frequently tested fact.

Q4. Which law explains why CO and CO_2 are different compounds?

⚡ Tricky

- (a) Law of Conservation of Mass (b) Law of Constant Proportion
(c) Law of Multiple Proportions (d) Avogadro's Law

✓ Answer: (c) Law of Multiple Proportions

CO and CO_2 are two compounds formed by the same two elements (C and O). In CO, oxygen = 16g per 12g carbon; in CO_2 , oxygen = 32g per 12g carbon. The ratio of oxygen in both = $16:32 = 1:2$ (a simple whole-number ratio). This is exactly what **Dalton's Law of Multiple Proportions** states: when two elements form more than one compound, the masses of one element relative to a fixed mass of the other are in a simple ratio.

Q5. How many grams is 1 mole of NaCl? (Na = 23, Cl = 35.5) CDS PYQ

- (a) 23 g (b) 35.5 g (c) 58.5 g (d) 47 g

✓ Answer: (c) 58.5 g

Molar mass of NaCl = 23 + 35.5 = **58.5 g/mol**. One mole of any substance has a mass equal to its molar mass in grams. So 1 mole of NaCl weighs 58.5 g and contains 6.022×10^{23} formula units (Na^+ and Cl^- ion pairs).

Quick Memory Chart — CCo1

Mole Facts

- ◆ 1 mole = 6.022×10^{23} particles
- ◆ 1 mole gas at STP = **22.4 L**
- ◆ Moles = mass/molar mass
- ◆ Molar mass numerically = molecular mass
- ◆ $\text{H}_2\text{O} = 18 \text{ g/mol}$; $\text{CO}_2 = 44 \text{ g/mol}$

5 Laws

- ◆ Conservation: mass neither created nor destroyed
- ◆ Constant Proportion: same ratio by mass
- ◆ Multiple Prop: simple whole-number ratios
- ◆ Gay-Lussac: gases combine in simple volume ratios
- ◆ Avogadro: equal volumes \rightarrow equal molecules

Key Values

- ◆ H = 1; C = 12; N = 14; O = 16
- ◆ Na = 23; Mg = 24; Al = 27; S = 32
- ◆ Cl = 35.5; Ca = 40; Fe = 56; Cu = 64
- ◆ NaCl = 58.5; $\text{H}_2\text{SO}_4 = 98$; $\text{CaCO}_3 = 100$
- ◆ $N_A = 6.022 \times 10^{23}$



Practice Exercise — Attempt Before Checking

E1. How many moles are there in 44 g of CO_2 ? (Molar mass = 44 g/mol)

- (a) 0.5 mol (b) 1 mol (c) 2 mol (d) 44 mol

E2. A compound always has the same elements in the same mass ratio. This is:

- (a) Law of Conservation of Mass (b) Law of Constant Proportion
(c) Law of Multiple Proportions (d) Dalton's Atomic Theory

E3. The percentage of oxygen in H_2O is approximately:

- (a) 11.1% (b) 66.7% (c) 88.9% (d) 50%

E4. 1 mole of oxygen gas (O_2) at STP occupies:

- (a) 11.2 L (b) 22.4 L (c) 32 L (d) 44.8 L

Answers:

E1 → (b) 1 mol [$44/44 = 1$ mol] | E2 → (b) Law of Constant Proportion (Proust's Law) | E3
→ (c) 88.9% [$16/18 \times 100$] | E4 → (b) 22.4 L [any gas at STP occupies 22.4 L per mole]

 **Mock Tests**

 **Subject Quizzes**

 **Telegram**

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