

15.1 The mole

Name: _____ Class: _____ Date: _____

Total: 21 marks

KEY WORDS mole 摩尔 • amount of substance 物质的量 • avogadro constant 阿伏伽德罗常量
 • molecule 分子 • molar mass 摩尔质量

Objective

Build the skills to answer exam questions on **the mole** and the Avogadro constant.

You must be able to:

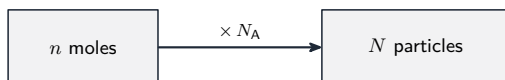
- use the **mole** as the SI unit of amount of substance
- use $N = nN_A$ and find masses of moles and single particles

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ The mole

Amount of substance is an SI base quantity; its unit is the **mole** (mol). One mole contains N_A particles:



$$N = nN_A, \quad N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

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The **molar mass** M_m is the mass of one mole; one particle has mass $m_0 = M_m/N_A$. Always say **what** you are counting (atoms or molecules).

2 Practice

Now apply the methods above.

2.1 State the SI **unit** of amount of substance. [1]

2.2 State the value of the **Avogadro constant**. [1]

2.3 How many molecules are there in 2.0 mol of a gas? [2]

3 Exam-style questions

3.1 One mole of oxygen gas (O_2) contains: [1]

- **A** 6.02×10^{23} atoms
- **B** 6.02×10^{23} molecules
- **C** 32 molecules
- **D** 16 molecules

3.2 A gas sample contains 3.0×10^{24} molecules. Find the number of **moles**. [2]

3.3 The molar mass of water is 18 g mol^{-1} . Calculate the mass of **one** water molecule. [2]

3.4 A sealed cylinder holds an ideal gas. The Avogadro constant is $6.02 \times 10^{23} \text{ mol}^{-1}$, the molar gas constant is $8.31 \text{ J mol}^{-1} \text{ K}^{-1}$ and the Boltzmann constant is $1.38 \times 10^{-23} \text{ J K}^{-1}$.

(a) **State** what is meant by the **Avogadro constant**. [1]

(b) **State** the relationship between the Avogadro constant N_A , the molar gas constant R and the Boltzmann constant k . [1]

(c) The cylinder holds 0.32 mol of the gas. **Determine** the number of molecules in it.[2]

(d) A second, identical cylinder holds **twice** as many molecules of the same gas at the same temperature T . **Complete** the table, giving each entry in terms of some or all of N , m , T , V , k and N_A , where sample X contains N molecules each of mass m in volume V . [4]

quantity	sample X	sample Y
pressure	_____	_____
amount of substance	_____	_____
mean kinetic energy per molecule	_____	_____
internal energy	_____	_____

(e) **Explain** why the mean kinetic energy per molecule is the same in both samples, while the internal energies differ. [2]

(f) The temperature of sample X is now varied. In the space below, **sketch** how the root-mean-square speed of its molecules varies with thermodynamic temperature. **Label** both axes. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- the **mole** (mol)

2.2

- $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$

2.3

- $N = nN_A$

$$N = (2.0 \text{ mol})(6.02 \times 10^{23} \text{ mol}^{-1}) = \mathbf{1.2 \times 10^{24}}$$

3.1 B

- one mole contains 6.02×10^{23} molecules
- A** is $N_A/10$; **C** is $2N_A$; **D** is a mass, not a number

3.2

- $n = N/N_A$

$$n = \frac{3.0 \times 10^{24}}{6.02 \times 10^{23} \text{ mol}^{-1}} = \mathbf{5.0 \text{ mol}}$$

3.3

- $m_0 = M_m/N_A$

$$m_0 = \frac{0.018 \text{ kg mol}^{-1}}{6.02 \times 10^{23} \text{ mol}^{-1}} = \mathbf{3.0 \times 10^{-26} \text{ kg}}$$

3.4

(a) the number of particles per unit amount of substance — the number of particles in one mole

(b) $N_A = R/k$

(c) $N = nN_A$

$$N = (0.32 \text{ mol})(6.02 \times 10^{23} \text{ mol}^{-1}) = \mathbf{1.9 \times 10^{23}}$$

molecules

(d) sample Y has $2N$ molecules in the same volume at the same temperature

quantity	sample X	sample Y
pressure	NkT/V	$2NkT/V$
amount of substance	N/N_A	$2N/N_A$
mean kinetic energy per molecule	$\frac{3}{2}kT$	$\frac{3}{2}kT$
internal energy	$\frac{3}{2}NkT$	$3NkT$

- pressures; amounts; both mean kinetic energies the same; internal energies

(e) the mean kinetic energy of a molecule is $\frac{3}{2}kT$, which depends **only on the temperature** — and both samples are at T

- internal energy is the **total** for all the molecules, so twice as many molecules at the same energy each gives twice the internal energy

(f) axes labelled *root-mean-square speed* and *thermodynamic temperature / K*

- a curve from the **origin** rising with a **decreasing** gradient, since $c_{\text{r.m.s.}} \propto \sqrt{T}$ — quadrupling T only doubles the speed