

15.3 Kinetic theory of gases

Name: _____ Class: _____ Date: _____

Total: 23 marks

KEY WORDS root-mean-square 均方根 • kinetic theory 分子动理论 • kinetic energy 动能
• translational kinetic energy 平动动能 • mean-square speed 均方速率

Objective

Build the skills to answer exam questions on the **kinetic theory of gases**.

You must be able to:

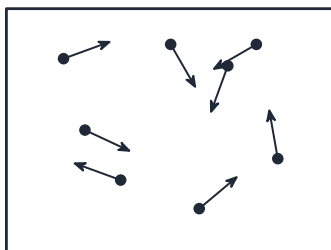
- state the **assumptions** of the kinetic theory and explain gas pressure
- use $pV = \frac{1}{3}Nm\langle c^2 \rangle$ and the **r.m.s. speed**
- use mean translational KE $= \frac{3}{2}kT$

1 Worked examples

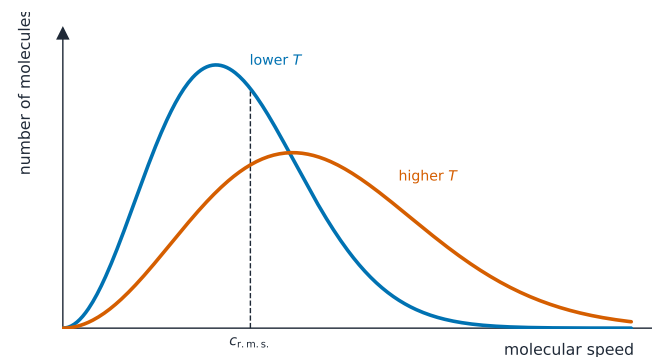
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Kinetic model

A gas is many identical molecules in **continuous random motion**; their collisions with the walls cause **pressure**:



random motion — wall collisions cause pressure



higher T : peak $\rightarrow$ higher speeds, flatter curve

The Maxwell-Boltzmann speed distribution

Assumptions: many molecules, random motion; their volume is negligible; collision time is negligible; no forces except in collisions; collisions are **elastic**; Newton's laws hold.

■ Key results

$$pV = \frac{1}{3}Nm\langle c^2 \rangle, \quad c_{\text{r.m.s.}} = \sqrt{\langle c^2 \rangle}.$$

Comparing with $pV = NkT$ gives the **mean translational KE** of a molecule:

$$\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT.$$

So molecular KE depends only on **temperature**.

2 Practice

Now apply the methods above.

2.1 State **two** assumptions of the kinetic theory of gases.

[2]

2.2 Explain how gas molecules cause **pressure** on the walls of a container. [2]

2.3 State what is meant by the **root-mean-square (r.m.s.) speed**. [1]

2.4 Write the relationship $pV = \frac{1}{3}Nm\langle c^2 \rangle$ in words. [1]

3 Exam-style questions

3.1 The **mean translational kinetic energy** of a gas molecule is: [1]

- | | |
|---|------------------------|
| A | kT |
| B | $\frac{3}{2}kT$ |
| C | $\frac{1}{2}mv^2$ only |
| D | RT |

3.2 Calculate the mean translational kinetic energy of a gas molecule at 300 K. ($k = 1.38 \times 10^{-23}$.) [2]

3.3 A gas at 300 K has molecules of mass 5.3×10^{-26} kg. Calculate the **r.m.s. speed**. ($k = 1.38 \times 10^{-23}$.) [3]

3.4 Explain, using the kinetic theory, why the pressure of a fixed mass of gas **increases** when it is heated at **constant volume**. [2]

3.5 A fixed sample of an ideal gas at thermodynamic temperature T has internal energy U .

(a) **State** what is meant by the **internal energy** of a system. [2]

(b) **Explain** why the internal energy of an **ideal** gas is directly proportional to its thermodynamic temperature. [2]

(c) The gas is first **compressed**, which raises its temperature to $3T$; work W is done on it during this compression. It is then **cooled at constant volume** back to $2T$. **Complete** the table, giving each entry in terms of some or all of W and U . [4]

process	work done on the gas	thermal energy supplied to the gas	increase in internal energy
compression to $3T$	W	_____	_____
cooling to $2T$	_____	_____	_____

(d) **Explain** why the work done on the gas during the second process is what it is. [1]
