

15.3 Kinetic theory of gases

Name: _____ Class: _____ Date: _____

Total: 14 marks

Objective

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

You must be able to:

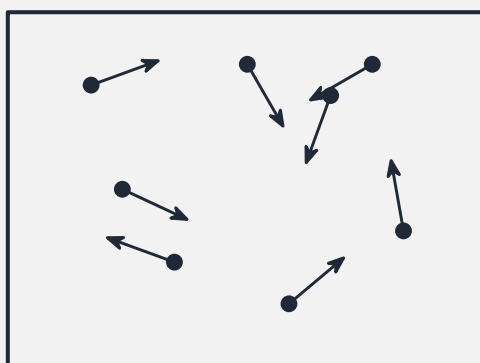
- state the **assumptions** of the kinetic theory and explain gas pressure
- use $pV = \frac{1}{3}Nm\langle c^2 \rangle$ and the **r.m.s. speed**
- use mean translational KE $= \frac{3}{2}kT$

1 Worked examples

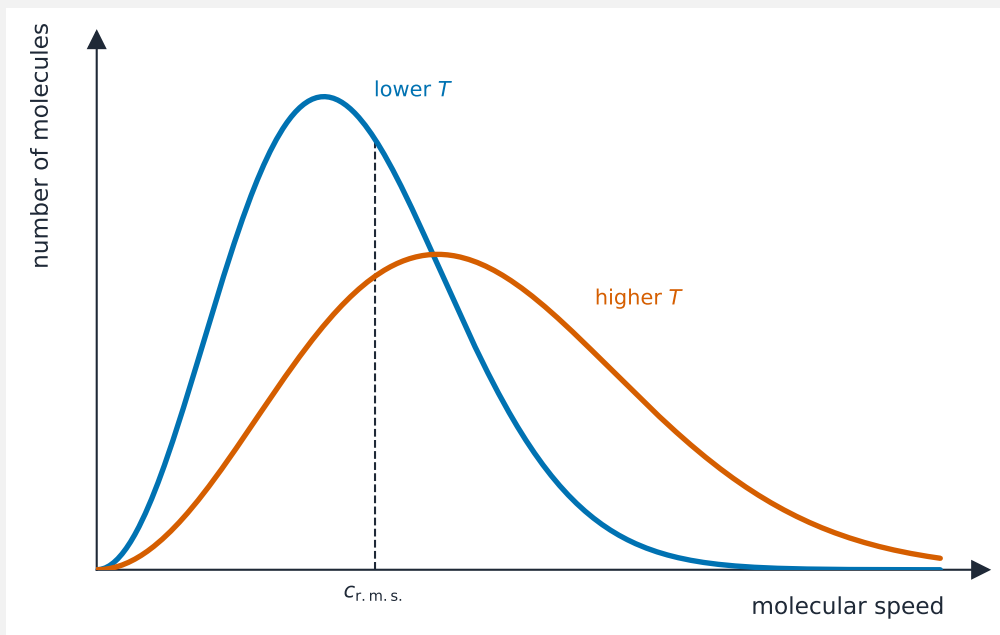
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ 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



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]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **15.3 Kinetic theory of gases** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/41 J25 —Q4 (kinetic theory)
- 9702/43 J25 —Q4 (r.m.s. speed)
- 9702/41 N25 —Q4 (molecular KE)
- 9702/44 J25 —Q3 (kinetic model)
- 9702/42 J25 —Q4 (kinetic theory)

Solutions

2.1 Any two: many identical molecules in **random motion**; molecular **volume negligible**; **no forces** except during collisions; collisions are **elastic**; collision time negligible.

2.2 Molecules collide with the walls and **change momentum** (rebound); this exerts a **force** on the wall; force over the wall area is the **pressure**.

2.3 The **square root of the mean of the squared speeds** of the molecules ($\sqrt{\langle c^2 \rangle}$).

2.4 The product of pressure and volume equals **one third** of (the number of molecules $\times$ molecular mass $\times$ mean-square speed).

3.1 B $-\frac{3}{2}kT$.

3.2 $E = \frac{3}{2}kT = 1.5 \times (1.38 \times 10^{-23}) \times 300 = 6.2 \times 10^{-21} \text{ J}$.

3.3 $\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT \Rightarrow \langle c^2 \rangle = \frac{3kT}{m}$; $c_{\text{r.m.s.}} = \sqrt{\frac{3(1.38 \times 10^{-23})(300)}{5.3 \times 10^{-26}}} = 4.8 \times 10^2 \text{ m s}^{-1}$.

3.4 Heating raises the **mean KE / mean speed** of the molecules; they hit the walls **harder and more often**, so the pressure rises (volume fixed).