3 The kinetic theory of gases deals with how molecular movement causes pressure to be exerted by a gas. The pressure of a gas is due to the elastic collision of the gas molecules with the walls of a container.

A single molecule of mass m is travelling with speed u directly towards a wall of a cubical box of sides L is as shown in Fig 3.1.

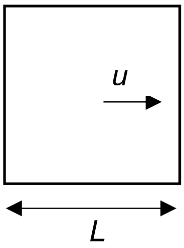

Fig 3.1

(a) Express the following in terms of L, m and u.

Momentum to the right before collision with wall = mu

Momentum immediately after an elastic collision = ...

Time between collisions with the same wall = ...

Number of collisions with this wall per unit time = ...

Rate of change of momentum of the molecule = ...

Average force on the wall due to the molecule = ... [5]

(b) The pressure p of an ideal gas which contains N molecules with different speeds in a container of volume V is given by

$$pV = \frac{1}{3} Nm < c^2 >$$

where $<c^2>$ is the mean square speed of the molecules.

(i) State the assumption regarding the type of collision between gas molecules. [1]

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(ii) The deduction of the relationship stated in **(a)** does not involve collisions between the gas molecules. In practice, gas molecules will collide with one another.

Using your answer in **(b)(i)**, explain why the collision among the molecules do not have an impact on the pressure. [2]

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(c) Using the expression in **(b)** and the ideal gas equation, show that the average kinetic energy of an ideal gas molecule is proportional to the thermodynamic temperature T. [2]

(d) The first law of thermodynamics when applied to an ideal gas can be expressed as

$$\Delta U = Q + W$$

where ΔU is the increase in internal energy, Q is the heat supplied to the gas and W is work done on the gas.

(i) The gas undergoes a process from state A to state B in such a way that ΔU is 0 as shown in Fig 3.2.

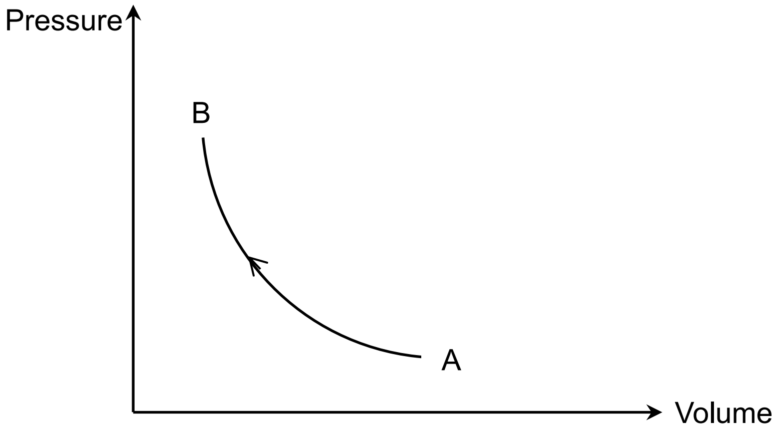

Fig 3.2

1. Shade in Fig 3.2 the area that numerically represents the heat exchange between the gas and its surroundings. [1]

2. State and explain the difference in the product of pressure and volume of the gas at both state A and state B. [2]

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(ii) The change in volume in **(d)(i)** takes place slowly. State and explain the changes to the mean square speed of the gas molecules if the change in volume takes place very quickly instead. [3]

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