Section B

Answer **one** question from this section in the spaces provided.

8 **(a)** A cube of length L contains N molecules of an ideal gas. A molecule of mass m moves with velocity u towards the face of the box that is shaded in Fig. 8.1.

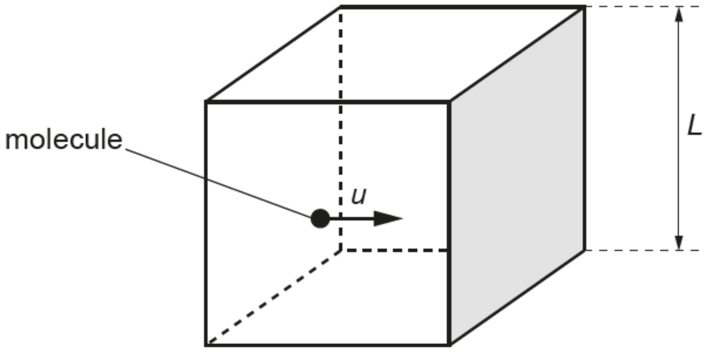

Fig. 8.1

The molecule collides elastically with the shaded face and the face opposite to it alternately.

Deduce expressions, in terms of N, m, u and L, for:

(i) the magnitude of the change in momentum of the molecule on colliding with a face,

change in momentum = ... [1]

(ii) the time between consecutive collisions of the molecule with the shaded face,

time = ... [1]

(iii) the average force exerted by the molecules on the shaded face,

force = ... [1]

(iv) the pressure on the shaded face.

pressure = ... [1]

(b) **(i)** When the model described in **(a)** is extended to three dimensions, it can be shown that

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

where p is the pressure exerted by the gas, V is the volume of the gas and $<c^2>$ is the mean square speed of the molecules,

Explain how your answer in **(a)(iv)** leads to the above equation.

[3]

(ii) Use this expression to show that the average translational kinetic energy E_K of a molecule of an ideal gas is given by

$$E_k = \frac{3}{2} kT$$

where T is the thermodynamic temperature of the gas and k is the Boltzmann constant.

[2]

(c) The mass of a hydrogen molecule is 3.34×10^{-27} kg.

Use the expression for E_K in **(b) (ii)** to determine the root-mean-square (r.m.s.) speed of the molecules of hydrogen gas at 25 °C.

r.m.s. speed = ... m s^{-1} [2]

(d) Explain why the internal energy of the gas is equal to the total kinetic energy of the molecules.

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……………………………………………………………………………………………….…. [2]

(e) The gas in **(a)** is supplied with thermal energy Q.

(i) Explain, with reference to the first law of thermodynamics, why the increase in internal energy of the gas is Q.

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…..……………………………………………………………………………………… [2]

(ii) Define *specific heat capacity.*

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…..……………………………………………………………………………………… [1]

(iii) Use the expression in **(b) (ii)** and the information in **(e) (i)** to show that the specific heat capacity c of the gas is given by

$$c = \frac{3k}{2m}$$

[2]

(f) The container in **(a)** is now replaced with one that does not have a fixed volume. Instead, the gas is able to expand, so that the pressure of the gas remains constant as thermal energy is supplied.

Suggest, with a reason, how the specific heat capacity of the gas would now compare with the value in **(e)(iii)**.

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[Total: 20]