Ideal Gases

Question paper 5

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Ideal Gases
Sub Topic	
Paper Type	Theory
Booklet	Question paper 5

Time Allowed: **63 minutes**

Score: **/52**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 The pressure p of an ideal gas is given by the expression

$$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle .$$

(a) Explain the meaning of the symbol $\langle c^2 \rangle$.

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..... [2]

(b) The ideal gas has a density of $2.4\,\text{kg}\,\text{m}^{-3}$ at a pressure of 2.0×10^5 Pa and a temperature of 300 K.

(i) Determine the root-mean-square (r.m.s.) speed of the gas atoms at 300 K.

r.m.s. speed = ... $\text{m}\,\text{s}^{-1}$ [3]

(ii) Calculate the temperature of the gas for the atoms to have an r.m.s. speed that is twice that calculated in **(i)**.

temperature = ... K [3]

2 **(a)** State what is meant by *internal energy*.

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..... [2]

(b) The variation with volume V of the pressure p of an ideal gas as it undergoes a cycle ABCA of changes is shown in Fig. 2.1.

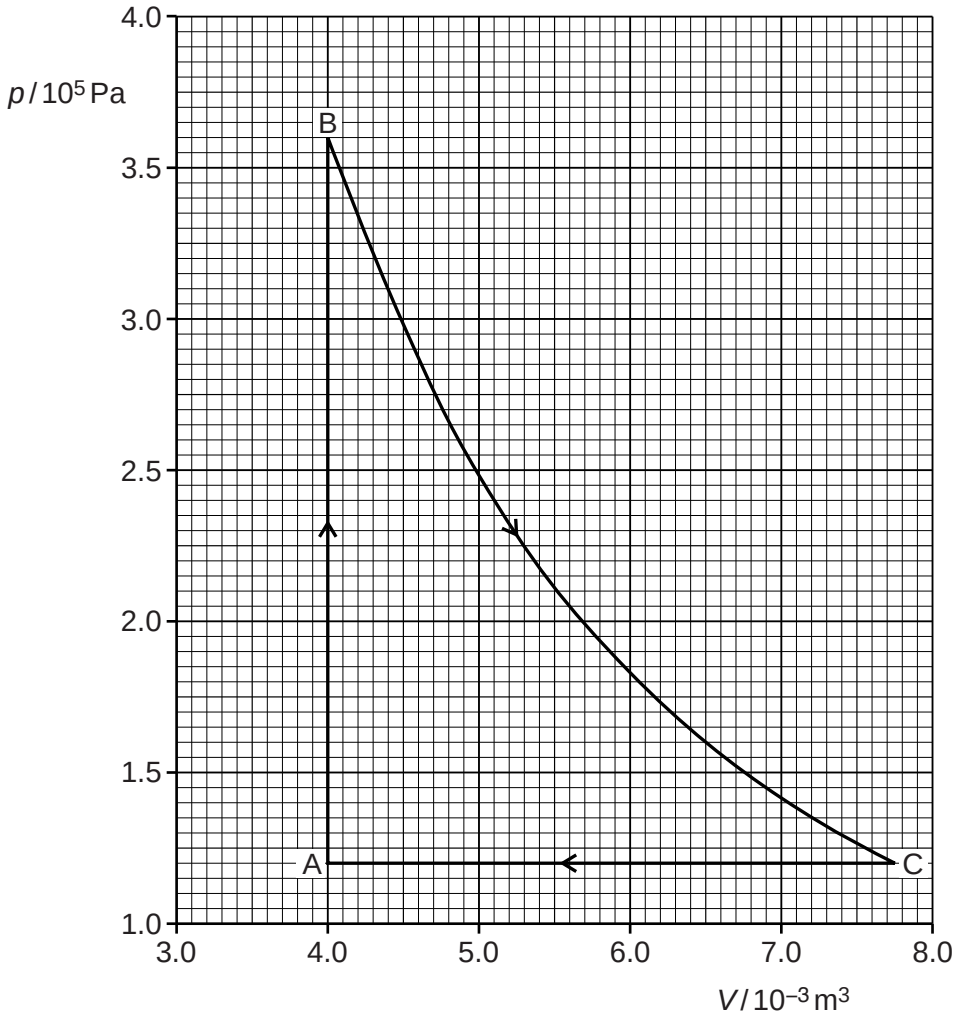

Fig. 2.1

The temperature of the gas at A is 290 K. The temperature at B is 870 K.

Determine

(i) the amount, in mol, of gas,

amount = ... mol [2]

(ii) the temperature of the gas at C.

temperature = ... K [2]

(c) Explain why the change from C to A involves external work and a change in internal energy.

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3 The planet Mars may be considered to be an isolated sphere of diameter 6.79×10^6 m with its mass of 6.42×10^{23} kg concentrated at its centre.
A rock of mass 1.40 kg rests on the surface of Mars.

For this rock,

(a) **(i)** determine its weight,

weight = ... N [3]

(ii) show that its gravitational potential energy is -1.77×10^7 J.

[2]

(b) Use the information in **(a)(ii)** to determine the speed at which the rock must leave the surface of Mars so that it will escape the gravitational attraction of the planet.

speed = ... $m\,s^{-1}$ [3]

(c) The mean translational kinetic energy $\langle E_K \rangle$ of a molecule of an ideal gas is given by the expression

$$\langle E_K \rangle = \frac{3}{2}kT$$

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

(i) Determine the temperature at which the root-mean-square (r.m.s.) speed of hydrogen molecules is equal to the speed calculated in **(b)**.
Hydrogen may be assumed to be an ideal gas.
A molecule of hydrogen has a mass of 2 u.

temperature = ... K [2]

(ii) State and explain one reason why hydrogen molecules may escape from Mars at temperatures below that calculated in **(i)**.

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..... [2]

4 **(a)** Some gas, initially at a temperature of 27.2 °C, is heated so that its temperature rises to 38.8 °C.
Calculate, in kelvin, to an appropriate number of decimal places,

(i) the initial temperature of the gas,

initial temperature = ... K [2]

(ii) the rise in temperature.

rise in temperature = ... K [1]

(b) The pressure p of an ideal gas is given by the expression

$$p = \frac{1}{3}\rho\langle c^2\rangle$$

where ρ is the density of the gas.

(i) State the meaning of the symbol $\langle c^2\rangle$.

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.....[1]

(ii) Use the expression to show that the mean kinetic energy $\langle E_K\rangle$ of the atoms of an ideal gas is given by the expression

$$\langle E_K\rangle = \frac{3}{2}kT.$$

Explain any symbols that you use.

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..... [4]

(c) Helium-4 may be assumed to behave as an ideal gas.
A cylinder has a constant volume of $7.8 \times 10^3\,\text{cm}^3$ and contains helium-4 gas at a pressure of $2.1 \times 10^7\,\text{Pa}$ and at a temperature of 290 K.

Calculate, for the helium gas,

(i) the amount of gas,

amount = ... mol [2]

(ii) the mean kinetic energy of the atoms,

mean kinetic energy = ... J [2]

(iii) the total internal energy.

internal energy = ... J [3]

5 The volume of some air, assumed to be an ideal gas, in the cylinder of a car engine is $540\,cm^3$ at a pressure of $1.1 \times 10^5\,Pa$ and a temperature of 27 °C. The air is suddenly compressed, so that no thermal energy enters or leaves the gas, to a volume of $30\,cm^3$. The pressure rises to $6.5 \times 10^6\,Pa$.

(a) Determine the temperature of the gas after the compression.

temperature = …… K [3]

(b) **(i)** State and explain the first law of thermodynamics.

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(ii) Use the law to explain why the temperature of the air changed during the compression.

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