Ideal Gases

Question paper 4

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Ideal Gases
Sub Topic	
Paper Type	Theory
Booklet	Question paper 4

Time Allowed: **71 minutes**

Score: **/59**

Percentage: **/100**

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

1 **(a)** State the basic assumptions of the kinetic theory of gases.

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.... [4]

(b) Use equations for the pressure of an ideal gas to deduce that the average translational kinetic energy $\langle E_K \rangle$ of a molecule of an ideal gas is given by the expression

$$\langle E_K \rangle = \frac{3}{2}\frac{R}{N_A}T$$

where R is the molar gas constant, N_A is the Avogadro constant and T is the thermodynamic temperature of the gas.

[3]

(c) A deuterium nucleus $^{2}_{1}\mathrm{H}$ and a proton collide. A nuclear reaction occurs, represented by the equation

$$^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{p} \longrightarrow {}^{3}_{2}\mathrm{He} + \gamma.$$

(i) State and explain whether the reaction represents nuclear fission or nuclear fusion.

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....

.... [2]

(ii) For the reaction to occur, the minimum total kinetic energy of the deuterium nucleus and the proton is 2.4×10^{-14} J.
Assuming that a sample of a mixture of deuterium nuclei and protons behaves as an ideal gas, calculate the temperature of the sample for this reaction to occur.

temperature = ... K [3]

(iii) Suggest why the assumption made in **(ii)** may not be valid.

....

.... [1]

2 An ideal gas occupies a container of volume $4.5 \times 10^3\,\text{cm}^3$ at a pressure of $2.5 \times 10^5\,\text{Pa}$ and a temperature of 290 K.

(a) Show that the number of atoms of gas in the container is 2.8×10^{23}.

[2]

(b) Atoms of a real gas each have a diameter of $1.2 \times 10^{-10}\,\text{m}$.

(i) Estimate the volume occupied by 2.8×10^{23} atoms of this gas.

volume = ... m^3 [2]

(ii) By reference to your answer in **(i)**, suggest whether the real gas does approximate to an ideal gas.

....

....

.... [2]

3 Sources of α-particles are frequently found to contain traces of helium gas.

A radioactive source emits α-particles at a constant rate of $3.5 \times 10^6\,s^{-1}$. The α-particles are collected for a period of 40 days. Each α-particle becomes one helium atom.

(a) By reference to the half-life of the source, suggest why it may be assumed that the rate of emission of α-particles is constant.

....

.... [1]

(b) The helium gas may be assumed to be an ideal gas. Calculate the volume of gas that is collected at a pressure of 1.5×10^5 Pa and at a temperature of 17 °C.

volume = ... m^3 [3]

4 **(a)** Explain qualitatively how molecular movement causes the pressure exerted by a gas.

....

....

....

....[3]

(b) The density of neon gas at a temperature of 273 K and a pressure of 1.02×10^5 Pa is $0.900\,kg\,m^{-3}$. Neon may be assumed to be an ideal gas.

Calculate the root-mean-square (r.m.s.) speed of neon atoms at

(i) 273 K,

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

(ii) 546 K.

speed = ... $m\,s^{-1}$ [2]

(c) The calculations in **(b)** are based on the density for neon being 0.900 kg m^{-3}.
Suggest the effect, if any, on the root-mean-square speed of changing the density at constant temperature.

....

....

.... [2]

5 **(a)** An amount of 1.00 mol of Helium-4 gas is contained in a cylinder at a pressure of 1.02×10^5 Pa and a temperature of 27 °C.

(i) Calculate the volume of gas in the cylinder.

volume = ... m^3 [2]

(ii) Hence show that the average separation of gas atoms in the cylinder is approximately 3.4×10^{-9} m.

[2]

(b) Calculate

(i) the gravitational force between two Helium-4 atoms that are separated by a distance of 3.4×10^{-9} m,

force = ... N [3]

(ii) the ratio

$$\frac{\text{weight of a Helium-4 atom}}{\text{gravitational force between two Helium-4 atoms with separation } 3.4 \times 10^{-9}\,\text{m}}.$$

ratio = ...[2]

(c) Comment on your answer to **(b)(ii)** with reference to one of the assumptions of the kinetic theory of gases.

....

....

....[2]

6 The air in a car tyre has a constant volume of $3.1 \times 10^{-2}\,m^3$. The pressure of this air is 2.9×10^5 Pa at a temperature of 17 °C. The air may be considered to be an ideal gas.

(a) State what is meant by an *ideal* gas.

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....

.... [2]

(b) Calculate the amount of air, in mol, in the tyre.

amount = ... mol [2]

(c) The pressure in the tyre is to be increased using a pump. On each stroke of the pump, 0.012 mol of air is forced into the tyre.
Calculate the number of strokes of the pump required to increase the pressure to 3.4×10^5 Pa at a temperature of 27 °C.

number = ... [3]

7 **(a)** State what is meant by an *ideal* gas.

....

....

....[2]

(b) The product of pressure p and volume V of an ideal gas of density ρ at temperature T is given by the expressions

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

and

$$pV = NkT,$$

where N is the number of molecules and k is the Boltzmann constant.

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

....[1]

(ii) Deduce that the mean kinetic energy E_K of the molecules of an ideal gas is given by the expression

$$E_K = \tfrac{3}{2}kT.$$

[2]

(c) In order for an atom to escape completely from the Earth's gravitational field, it must have a speed of approximately $1.1 \times 10^4\,\mathrm{m\,s^{-1}}$ at the top of the Earth's atmosphere.

(i) Estimate the temperature at the top of the atmosphere such that helium, assumed to be an ideal gas, could escape from the Earth. The mass of a helium atom is 6.6×10^{-27} kg.

temperature = ... K [2]

(ii) Suggest why some helium atoms will escape at temperatures below that calculated in **(i)**.

....

....[1]