PapaCambridge

Cambridge International AS & A Level

PHYSICS

Paper 4

Topical Past Paper Questions
+ Answer Scheme

2016 - 2021

PapaCambridge

Chapter 3

Ideal gases

40. 9702_w19_qp_41 Q: 2

(a) The kinetic theory of gases is based on a number of assumptions about the molecules of a gas.

State the assumption that is related to the volume of the molecules of the gas.

....

....

.... [2]

(b) An ideal gas occupies a volume of $2.40 \times 10^{-2}\,m^3$ at a pressure of $4.60 \times 10^5\,Pa$ and a temperature of 23 °C.

(i) Calculate the number of molecules in the gas.

number = ... [3]

(ii) Each molecule has a diameter of approximately $3 \times 10^{-10}\,m$.

Estimate the total volume of the gas molecules.

volume = ... m^3 [3]

(c) By reference to your answer in **(b)(ii)**, suggest why the assumption in **(a)** is justified.

....

.... [1]

[Total: 9]

41. 9702_w16_qp_42 Q: 2

(a) The equation of state for an ideal gas of volume V at pressure p is

$$pV = nRT$$

where R is the molar gas constant.

State what is meant by

(i) the symbol n,

....

....[1]

(ii) the symbol T.

....

....[1]

(b) An ideal gas is held in a container of volume $2.4 \times 10^3\,cm^3$ at pressure $4.9 \times 10^5\,Pa$.
The temperature of the gas is 100 °C.

Show that the number of molecules of the gas in the container is 2.3×10^{23}.

[3]

(c) Use data from **(b)** to estimate the mean distance between molecules in the gas.

mean distance = ... cm [3]

[Total: 8]

42. 9702_m21_qp_42 Q: 2

A fixed mass of an ideal gas is at a temperature of 21 °C. The pressure of the gas is 2.3×10^5 Pa and its volume is 3.5×10^{-3} m^3.

(a) **(i)** Calculate the number *N* of molecules in the gas.

N = ... [2]

(ii) The mass of one molecule of the gas is 40 u.

Determine the root-mean-square (r.m.s.) speed of the gas molecules.

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

(b) The temperature of the gas is increased by 84 °C.

Calculate the value of the ratio

$$\frac{\text{new r.m.s. speed of molecules}}{\text{original r.m.s. speed of molecules}}.$$

ratio = ... [2]

[Total: 6]

43. 9702_s20_qp_42 Q: 2

(a) A square box of volume V contains N molecules of an ideal gas. Each molecule has mass m.

Using the kinetic theory of ideal gases, it can be shown that, if all the molecules are moving with speed v at right angles to one face of the box, the pressure p exerted on the face of the box is given by the expression

$$pV = Nmv^2. \qquad \text{(equation 1)}$$

This expression leads to the formula

$$p = \frac{1}{3}\rho\langle c^2\rangle \qquad \text{(equation 2)}$$

for the pressure p of an ideal gas, where ρ is the density of the gas and $\langle c^2\rangle$ is the mean-square speed of the molecules.

Explain how each of the following terms in equation 2 is derived from equation 1:

ρ: ....

....

$\frac{1}{3}$: ....

....

$\langle c^2\rangle$: ....

....
[4]

(b) An ideal gas has volume, pressure and temperature as shown in Fig. 2.1.

volume $6.0 \times 10^{-3}\,m^3$
pressure $3.0 \times 10^5\,Pa$
temperature 17 °C

Fig. 2.1

The mass of the gas is 20.7 g.

Calculate the mass of one molecule of the gas.

mass = ... g [4]

[Total: 8]

44. 9702_m19_qp_42 Q: 2

The pressure p of an ideal gas having density ρ is given by the expression

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

(a) State what is meant by:

(i) an ideal gas

....

....

.... [2]

(ii) the symbol $\langle c^2\rangle$.

....

.... [1]

(b) A cylinder contains a fixed mass of a gas at a temperature of 120 °C. The gas has a volume of $6.8 \times 10^{-3}\,m^3$ at a pressure 2.4×10^5 Pa.

(i) Assuming the gas acts like an ideal gas, show that the number of atoms of gas in the cylinder is 3.0×10^{23}.

[3]

(ii) Each atom of the gas, assumed to be a sphere, has a radius of 3.2×10^{-11} m.

Use the answer in **(i)** to estimate the actual volume occupied by the gas atoms.

volume = ... m^3 [2]

(iii) One of the assumptions of the kinetic theory of gases is related to the volume of the atoms.
State this assumption. Explain whether your answer in **(ii)** is consistent with this assumption.

....

....

....

.... [2]

[Total: 10]

45. 9702_w19_qp_43 Q: 2

(a) The kinetic theory of gases is based on a number of assumptions about the molecules of a gas.

State the assumption that is related to the volume of the molecules of the gas.

....

....

.... [2]

(b) An ideal gas occupies a volume of $2.40 \times 10^{-2}\,\text{m}^3$ at a pressure of $4.60 \times 10^5\,\text{Pa}$ and a temperature of 23 °C.

(i) Calculate the number of molecules in the gas.

number = ... [3]

(ii) Each molecule has a diameter of approximately $3 \times 10^{-10}\,\text{m}$.

Estimate the total volume of the gas molecules.

volume = ... m^3 [3]

(c) By reference to your answer in **(b)(ii)**, suggest why the assumption in **(a)** is justified.

....

.... [1]

[Total: 9]

46. 9702_w18_qp_42 Q: 2

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

....

....

....[2]

(b) An ideal gas comprised of single atoms is contained in a cylinder and has a volume of $1.84 \times 10^{-2}\,m^3$ at a pressure of $2.12 \times 10^7\,Pa$.
The mass of gas in the cylinder is 3.20 kg.

(i) Determine, to three significant figures, the root-mean-square (r.m.s.) speed of the atoms of the gas.

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

(ii) The temperature of the gas in the cylinder is 22 °C.

Determine, to three significant figures,

1. the amount, in mol, of the gas,

amount = ... mol [2]

2. the mass of one atom of the gas.

mass = ... kg [2]

(c) Use your answer in **(b)(ii) part 2** to determine the nucleon number *A* of an atom of the gas.

A = ... [1]

[Total: 10]

47. 9702_s17_qp_43 Q: 4

(a) Describe the motion of molecules in a gas, according to the kinetic theory of gases.

....

....

....[2]

(b) Describe what is observed when viewing Brownian motion that provides evidence for your answer in **(a)**.

....

....

....[2]

(c) At a pressure of 1.05×10^5 Pa and a temperature of 27 °C, 1.00 mol of helium gas has a volume of $0.0240\,m^3$.
The mass of 1.00 mol of helium gas, assumed to be an ideal gas, is 4.00 g.

(i) Calculate the root-mean-square (r.m.s.) speed of an atom of helium gas for a temperature of 27 °C.

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

(ii) Using your answer in **(i)**, calculate the r.m.s. speed of the atoms at 177 °C.

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

[Total: 10]

48. 9702_w21_qp_42 Q: 3

(a) One of the assumptions of the kinetic theory of gases is that all collisions involving molecules of the gas are elastic.

(i) State what is meant by an *elastic* collision.

....

.... [1]

(ii) State **two** other assumptions of the kinetic theory of gases.

1. ....

....

2. ....

....
[2]

(b) A molecule of an ideal gas has mass m and is contained in a cubic box of side length L. The molecule is moving with velocity u towards the face of the box that is shaded in Fig. 3.1.

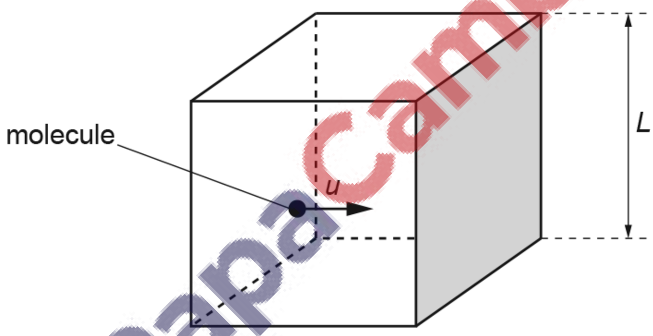

Fig. 3.1

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

Deduce expressions, in terms of 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 molecule on the shaded face

force = ... [1]

(iv) the pressure on the shaded face if the force in **(iii)** is exerted over the whole area of the face.

pressure = ... [1]

(c) When the model described in **(b)** is extended to three dimensions, and to a gas containing N molecules, each of mass m, travelling with mean-square speed $\langle c^2 \rangle$, it can be shown that

$$pV = \frac{1}{3}Nm\langle c^2 \rangle$$

where p is the pressure exerted by the gas and V is the volume of the gas.

Use this expression, together with the equation of state of an ideal gas, 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]

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

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

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

[Total: 11]

49. 9702_s18_qp_42 Q: 2

(a) Use one of the assumptions of the kinetic theory of gases to explain why the potential energy of the molecules of an ideal gas is zero.

....

....[1]

(b) The average translational kinetic energy E_K of a molecule of an ideal gas is given by the expression

$$E_K = \frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$$

where m is the mass of a molecule and k is the Boltzmann constant.

State the meaning of the symbol

(i) $\langle c^2\rangle$,

....[1]

(ii) T.

....[1]

(c) A cylinder of constant volume $4.7 \times 10^4\,\text{cm}^3$ contains an ideal gas at pressure $2.6 \times 10^5\,\text{Pa}$ and temperature 173 °C.

The gas is heated. The thermal energy transferred to the gas is 2900 J. The final temperature and pressure of the gas are T and p, as illustrated in Fig. 2.1.

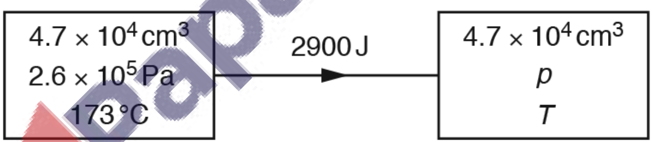

Fig. 2.1

(i) Calculate

1. the number N of molecules in the cylinder,

N = ...[3]

2. the increase in average kinetic energy of a molecule during the heating process.

increase = ... J [1]

(ii) Use your answer in **(i) part 2** to determine the final temperature *T*, in kelvin, of the gas in the cylinder.

T = ... K [3]

[Total: 10]

50. 9702_s17_qp_41 Q: 4

(a) Describe the motion of molecules in a gas, according to the kinetic theory of gases.

....

....

....[2]

(b) Describe what is observed when viewing Brownian motion that provides evidence for your answer in **(a)**.

....

....

....[2]

(c) At a pressure of 1.05×10^5 Pa and a temperature of 27 °C, 1.00 mol of helium gas has a volume of 0.0240 m^3.
The mass of 1.00 mol of helium gas, assumed to be an ideal gas, is 4.00 g.

(i) Calculate the root-mean-square (r.m.s.) speed of an atom of helium gas for a temperature of 27 °C.

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

(ii) Using your answer in **(i)**, calculate the r.m.s. speed of the atoms at 177 °C.

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

[Total: 10]