

1 Which one of the following is **not** an assumption about the properties of particles in the simple kinetic theory?

- A  $\langle c^2 \rangle$  is the average speed of the particles
- B The forces between the particles are negligible except when particles collide
- C The time spent by particles in collision is negligible compared with the time spent between collisions
- D The volume of the particles is negligible compared to the volume of the container

(Total 1 mark)

2 A fixed mass of gas occupies a volume  $V$ . The temperature of the gas increases so that the root mean square velocity of the gas molecules is doubled.

What will the new volume be if the pressure remains constant?

A  $\frac{V}{2}$

B  $\frac{V}{\sqrt{2}}$

C  $2V$

D  $4V$

(Total 1 mark)

3 Helium is a monatomic gas for which all the internal energy of the molecules may be considered to be translational kinetic energy.

molar mass of helium =  $4.0 \times 10^{-3}$  kg

the Boltzmann constant =  $1.38 \times 10^{-23}$  J K<sup>-1</sup>

the Avogadro constant =  $6.02 \times 10^{23}$  mol<sup>-1</sup>

(a) Calculate the kinetic energy of a tennis ball of mass 60 g travelling at 50 m s<sup>-1</sup>.

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(1)

- (b) Calculate the internal energy of 1.0 g of helium gas at a temperature of 48K.

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(3)

- (c) At what temperature would the internal energy of 1.0 g of helium gas be equal to the kinetic energy of the ball in part (a).

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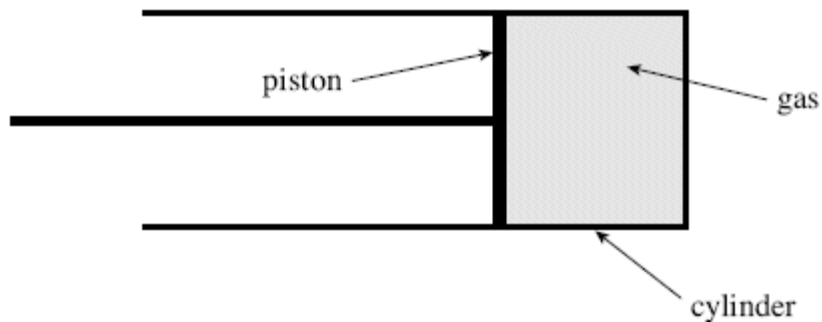
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(1)

(Total 5 marks)

4

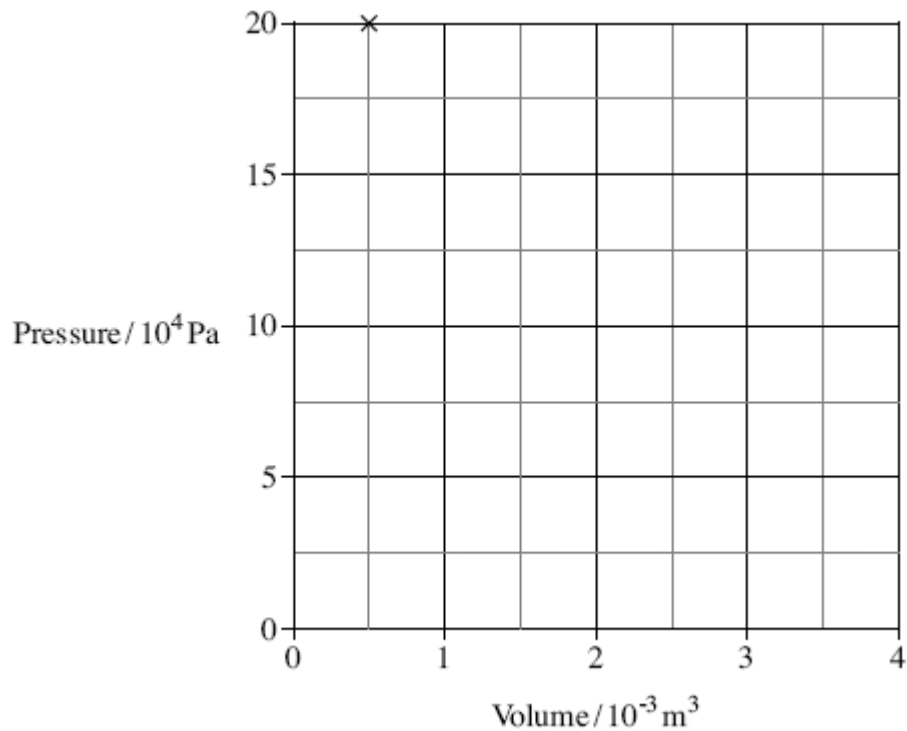
Figure 1



**Figure 1** shows a cylinder, fitted with a gas-tight piston, containing an ideal gas at a constant temperature of 290 K. When the pressure,  $p$ , in the cylinder is  $20 \times 10^4$  Pa the volume,  $V$ , is  $0.5 \times 10^{-3} \text{ m}^3$ .

**Figure 2** shows this data plotted.

**Figure 2**



- (a) By plotting two or three additional points draw a graph, on the axes given in **Figure 2**, to show the relationship between pressure and volume as the piston is slowly pulled out. The temperature of the gas remains constant.

**(3)**

- (b) (i) Calculate the number of gas molecules in the cylinder.

answer = \_\_\_\_\_ molecules

**(2)**

(ii) Calculate the total kinetic energy of the gas molecules.

answer = \_\_\_\_\_ J

(3)

(c) State **four** assumptions made in the molecular kinetic theory model of an ideal gas.

(i) \_\_\_\_\_

\_\_\_\_\_

(ii) \_\_\_\_\_

\_\_\_\_\_

(iii) \_\_\_\_\_

\_\_\_\_\_

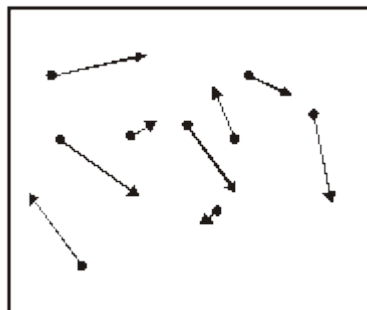
(iv) \_\_\_\_\_

\_\_\_\_\_

(4)

(Total 12 marks)

**5** The diagram below shows a number of smoke particles suspended in air. The arrows indicate the directions in which the particles are moving at a particular time.



(a) (i) Explain why the smoke particles are observed to move.

\_\_\_\_\_

\_\_\_\_\_

(1)

- (ii) Smoke particles are observed to move in a random way. State **two** conclusions about air molecules and their motion resulting from this observation.

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(2)

- (b) A sample of air has a density of  $1.24 \text{ kg m}^{-3}$  at a pressure of  $1.01 \times 10^5 \text{ Pa}$  and a temperature of  $300 \text{ K}$ .

the Boltzmann constant =  $1.38 \times 10^{-23} \text{ J K}^{-1}$

- (i) Calculate the mean kinetic energy of an air molecule under these conditions.

(2)

- (ii) Calculate the mean square speed for the air molecules.

(3)

- (iii) Explain why, when the temperature of the air is increased to  $320 \text{ K}$ , some of the molecules will have speeds much less than that suggested by the value you calculated in part (b)(ii).

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(2)

(Total 10 marks)

**6**

- (a) Write down **four** assumptions about the properties and behaviour of gas molecules which are used in the kinetic theory to derive an expression for the pressure of an ideal gas.

Assumption 1 \_\_\_\_\_

\_\_\_\_\_

Assumption 2 \_\_\_\_\_

\_\_\_\_\_

Assumption 3 \_\_\_\_\_

\_\_\_\_\_

Assumption 4 \_\_\_\_\_

\_\_\_\_\_

**(4)**

- (b) (i) A cylinder, fitted with a pressure gauge, contains an ideal gas and is stored in a cold room. When the cylinder is moved to a warmer room the pressure of the gas is seen to increase. Explain **in terms of the kinetic theory** why this increase in pressure is expected.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

- (ii) After a time, the pressure of the gas stops rising and remains steady at its new value. The air temperature in the warmer room is  $27^{\circ}\text{C}$ . Calculate the mean kinetic energy of a gas molecule in the cylinder.

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\_\_\_\_\_

**(6)**

**(Total 10 marks)**

7

- (a) The molecular theory model of an ideal gas leads to the derivation of the equation

$$pV = \frac{1}{3}Nm\overline{c^2}.$$

Explain what each symbol in the equation represents.

$p$  \_\_\_\_\_

$V$  \_\_\_\_\_

$N$  \_\_\_\_\_

\_\_\_\_\_

$m$  \_\_\_\_\_

$\overline{c^2}$  \_\_\_\_\_

\_\_\_\_\_

(4)

- (b) One assumption used in the derivation of the equation stated in part (a) is that molecules are in state of *random motion*.

- (i) Explain what is meant by random motion.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

- (ii) State **two** more assumptions used in this derivation.

\_\_\_\_\_

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(3)

- (c) Describe how the motion of gas molecules can be used to explain the pressure exerted by a gas on the walls of its container.

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(4)

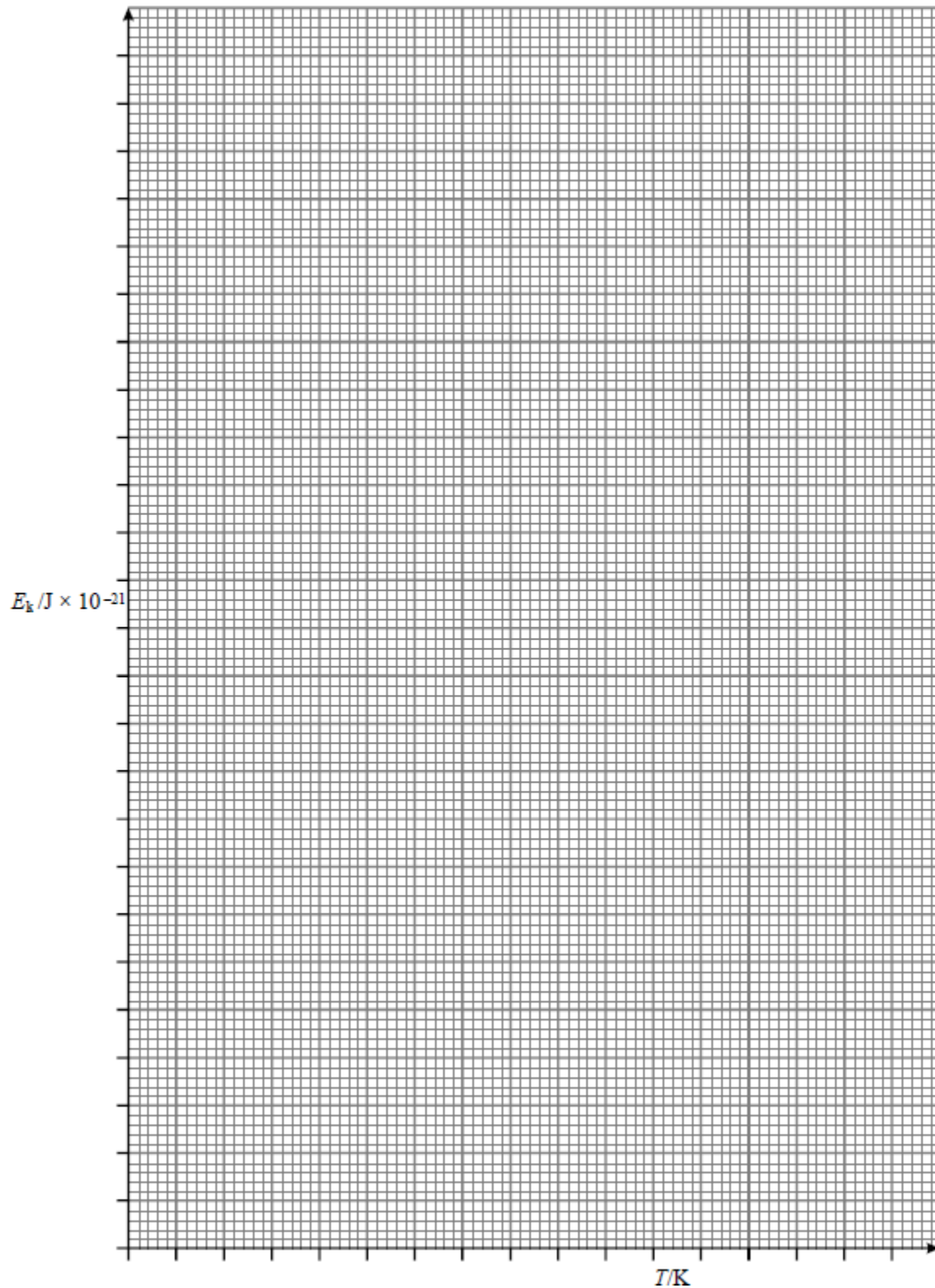
(Total 11 marks)

8

The table gives the average kinetic energy of gas molecules at certain temperatures.

$E_k / \text{J} \times 10^{-21}$	6.21	6.62	7.04	7.45	7.87	8.28
$T / \text{K}$	300	320	340	360	380	400

- (a) On the grid provided below plot a graph of  $E_k$  against  $T$ .



- (i) Use your graph to determine the average kinetic energy of gas molecules at 350K.

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- (ii) Determine the gradient of your graph and hence calculate a value for the Boltzmann constant. Show all your working.

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**(8)**

- (b) One of the assumptions of the kinetic theory is that collisions of gas molecules are elastic.

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

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- (ii) State another assumption of the kinetic theory.

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- (iii) Explain how the data in the table leads to the concept of absolute zero.

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**(4)**

**(Total 12 marks)**