1 The average mass of an air molecule is 4.8×10^{-26} kg

$KE = \frac{3}{2} KT$

$= 1.55 \times 10^{-20}$

$= \frac{1}{2} m (c_{rms})^2$

What is the mean square speed of an air molecule at 750 K?

- **A** 3.3×10^5 m^2 s^{-2}
- **B** 4.3×10^5 m^2 s^{-2}
- **C** 6.5×10^5 m^2 s^{-2}
- **D** 8.7×10^5 m^2 s^{-2}

so $c_{rms} = 804$ m/s $\therefore$ mss $= 804^2$

(Total 1 mark)

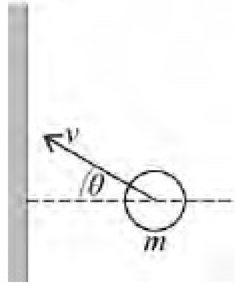
2 A transparent illuminated box contains small smoke particles and air.
The smoke particles are observed to move randomly when viewed through a microscope.

What is the cause of this observation of Brownian motion?

- **A** Smoke particles gaining kinetic energy by the absorption of light.
- **B** Collisions between smoke particles and air molecules.
- **C** Smoke particles moving in convection currents caused by the air being heated by the light.
- **D** The smoke particles moving randomly due to their temperature.

(Total 1 mark)

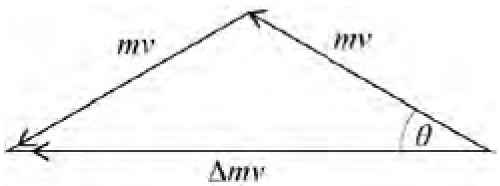
3 The diagram shows a gas particle about to collide elastically with a wall.



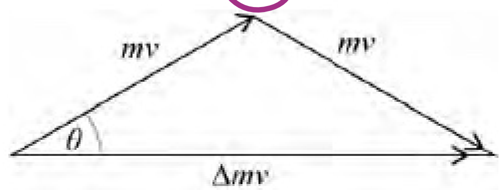
no change in y.

Which diagram shows the correct change in momentum Δ*mv* that occurs during the collision?

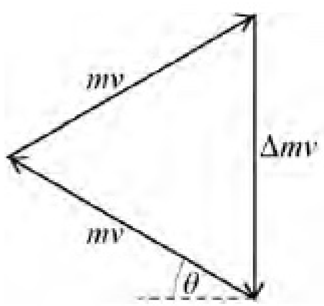
A



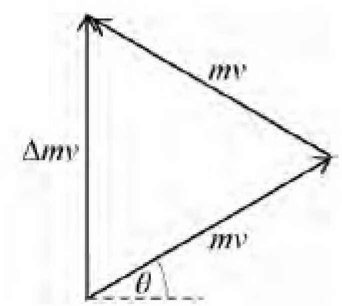
B



C



D



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

4 Specimens **P** and **Q** of the same gas exert the same pressure. **P** is at a temperature of 280 K and contains 10^{20} molecules per unit volume. The temperature of **Q** is 350 K.

What is the number of molecules per unit volume in **Q**?

A	0.09×10^{20}	⬭
B	0.75×10^{20}	⬭
C	0.80×10^{20}	⬭
D	1.25×10^{20}	⬭

(Total 1 mark)

5 The composition of a carbon dioxide (CO_2) molecule is one atom of $^{12}_{6}C$ and two atoms of $^{16}_{8}O$.

What is the number of molecules of CO_2 in 2.2 kg of the gas?

A	1.0×10^{22}	⬭
B	3.0×10^{22}	⬭
C	3.0×10^{25}	⬭
D	4.7×10^{25}	⬭

(Total 1 mark)

6 (a) A number of assumptions are made when explaining the behaviour of a gas using the molecular kinetic theory model.

State **one** assumption about the size of molecules.

____

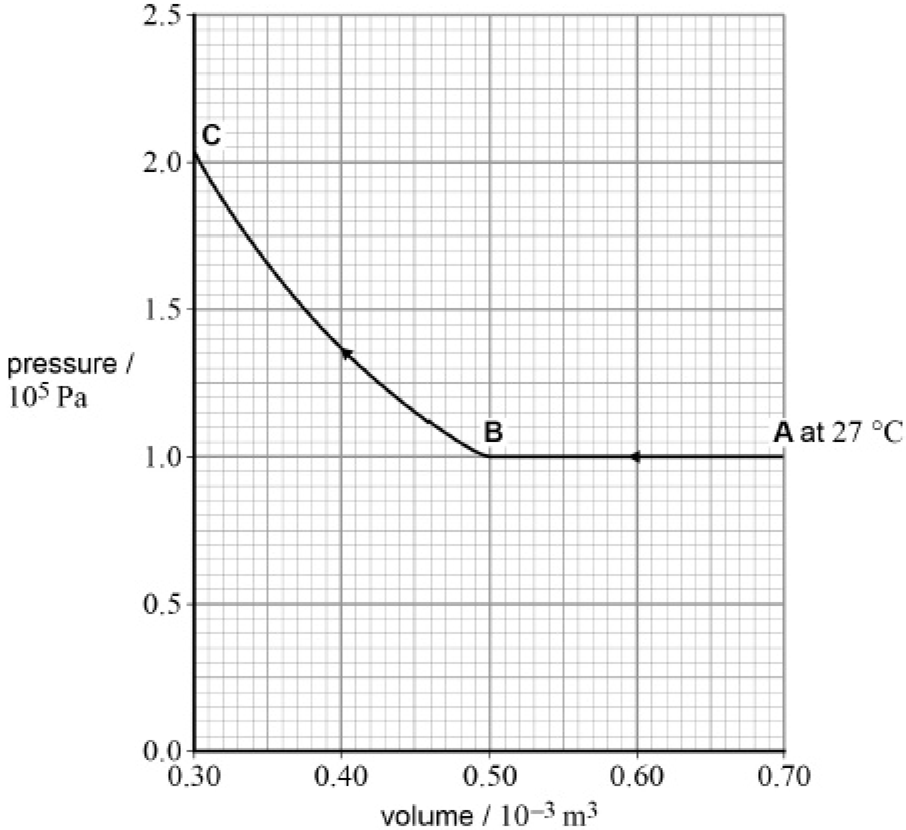
____

____

(1)

The graph shows how the pressure changes with volume for a fixed mass of an ideal gas.

At **A** the temperature of the gas is 27 °C. The gas then undergoes two changes, one from **A** to **B** and then one from **B** to **C**.



(b) Calculate the number of gas molecules trapped in the cylinder using information from the initial situation at **A**.

$pV = NkT \Rightarrow N = \frac{pV}{kT}$

1.7×10^{22}

number of molecules = ______________________

(2)

(c) Calculate, in K, the change in temperature of the gas during the compression that occurs between **A** and **B**.

$\frac{P_A V_A}{T_A} = \frac{P_B V_B}{T} \Rightarrow \frac{T_A P_B V_B}{P_A V_B} = T_2 = 214$

change in temperature = __− 85__ K

(2)

(d) Deduce whether the temperature of the gas changes during the compression from **B** to **C**.

$\frac{P_B V_B}{T_B} = \frac{P_c V_c}{T_c}$ if $T_c = T_B$ then $P_B V_B = P_c V_c$

$0.5 \times 10^{-3} \times 1 \times 10^5 = 50$

$0.3 \times 10^{-3} \times 2 \times 10^5 = 60$

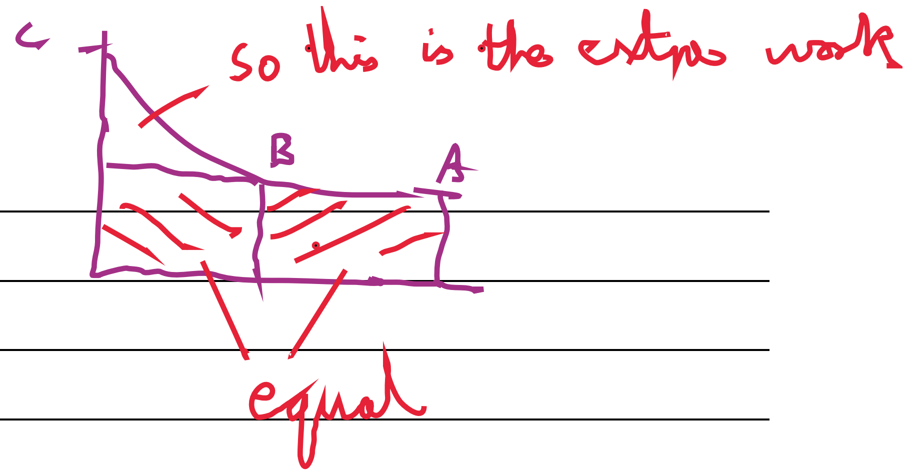
So... $T_C \neq T_B$

(2)

(e) Compare the work done on the gas during the change from **A** to **B** with that from **B** to **C** on the graph.

Area under graph $P \Delta V$

$Nm^{-2} \times m^3 = N \times m$ ie $F \times d$



(3)

(Total 10 marks)

Mark schemes

1 **C** **[1]**

2 **B** **[1]**

3 **B** **[1]**

4 C **[1]**

5 **C** **[1]**

6 (a) The volume / size of the gas molecules is negligible / point mass or point molecule

Or molecules are <u>point</u> masses

Or small <u>compared</u> to the volume / size occupied by of the gas ✓ owtte

No mark for all the same size or spherical.

Without the comparison the word used must suggest extremely small.

Zero volume is wrong.

1

(b) (using $N = PV/kT$)

$N = (1.0 \times 10^5 \times 0.70 \times 10^{-3}/(1.38 \times 10^{-23} \times 300)$ ✓ (first mark is for converting the temperature to kelvin and using it in a valid equation)

$N = 1.7 \times 10^{22}$ molecules ✓ (1.69×10^{22} molecules)

Alternatively (using $n = PV/RT$)

$n = (1.0 \times 10^5 \times 0.70 \times 10^{-3} / 8.31 \times 300) = 0.028$ mol ✓ (first mark is for converting the temperature to kelvin and using it in a valid equation)

N (= $n N_A = 0.028 \times 6.02 \times 10^{23}$) = 1.7×10^{22} molecules ✓ (1.69×10^{22} molecules)

Correct answer scores both marks

Power of 10 issue = AE

Temperature conversion = PE

2

(c) (using $T_B = T_A V_B / V_A$)

$T_B = 300 \times 0.50 / 0.70 = 214$ (K) ✓

Change in temperature (= 214 – 300) = (–) 86 (K)✓

Or

T_B (= PV/Nk) = $1.0 \times 10^5 \times 0.50 \times 10^{-3}/(1.38 \times 10^{-23} \times 1.69 \times 10^{22})$

= 214 (K) ✓

Change in temperature (= 214 – 300) = (–) 86 (K)✓ (± 1 K)

Or

T_B = (PV/nR) = $1.0 \times 10^5 \times 0.50 \times 10^{-3}$ /(0.028 × 8.31)

= 215 (K) ✓

Change in temperature (= 215 – 300) = (–) 85 (K)✓

Correct answer scores both marks

Let the last mark stand alone provided an attempt at calculating T_B is made.

Also allow working in Celsius for this last stand-alone mark.

2

(d) An appropriate calculation might be:

(If the temperature remained constant $P_C = P_B V_B / V_C$)

$P_C = 1.0 \times 10^5 \times 0.50 \times 10^{-3} / 0.30 \times 10^{-3} = 1.7 \times 10^5$ (Pa) ✓

(but the pressure at C is higher than this so) the temperature at C is different / higher / not constant ✓

Or

(If the temperature remained constant $P_C V_C$ would equal $P_B \mathrm{V}_B$)

$P_B \mathrm{V}_B = 1.0 \times 10^5 \times 0.50 \times 10^{-3} = 50$

$P_C V_C = 2.05 \times 10^5 \times 0.30 \times 10^{-3} = 61$ ✓

($P V$ is not equal) the temperature at C is different / higher / not constant ✓

Or a full calculation can be given using $P V / T$ = constant.

$P_B V_B / T_B = 1.0 \times 10^5 \times 0.5 \times 10^{-3} / 214 = (0.234 \text{ J K}^{-1})$

$T_C = P_C V_C$ / constant $= 2.05 \times 10^5 \times 0.30 \times 10^{-3} / 0.234$

$T_C = 263$ K ✓

the temperature at C is different / higher / not constant ✓

On its own higher temperature scores 0. ***Additionally there must be a reference to a correct calculation to obtain the last mark.***

The question only requires the candidate to spot a change. The two marks are for each side of a comparison.

Complete figures are not always required. For example in the last alternative the common factor 10^5 could be missing.

2nd alternative may come from a ratio.

Depending on the sig figs used in the substitution of data the temperature has a range 256 – 270 K

PV = NkT may be used as another alternative.

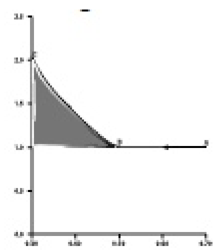
On a few occasions the full paper may be required to view.

2

(e) work done on gas from **A** to **B** (using $W = P\Delta V$ or W = area under the graph $= 1.0 \times (0.70 - 0.50) \times 10^{-3}) = 20$ (J) ✓
giving a reference to the work done being the area under the graph ✓

The third mark can be obtained in the following ways:

calculating the area indicated corresponds to the <u>additional work</u> done on the gas from **B** to **C**



(166 mm^2 where 1 mm^2 = 0.05 J) = 8.3 J √
(allow 8.0 – 10.0 J)

Or

The total work done (566 mm^2 where 1 mm^2 = 0.05 J) = 28.3(J) ✓

(allow 28.0 – 30.0 J)

This second mark can be obtained from an attempt at an area calculation that involves the curved section of the graph.

NB '<u>additional</u> work' must be quoted to give mark for 8 – 10 J.

This 3rd mark is for a correct evaluation and not for details of the process.

3

[10]