TEMPERATURE

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

1 **(a)** **(i)** Given that the mass of an oxygen molecule is **5.3×10^{-26} kg**, show that the root mean square (rms) speed for oxygen molecules in the atmosphere when the temperature is **23 °C** is **480 m s^{-1}**.

[1]

(ii) Explain why the rms speed of argon atoms in the atmosphere at 23 °C will be different from that of the oxygen molecules given in (i)

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.... [1]

(b) The rms speed of hydrogen molecules at **23 °C** is **1920 m s^{-1}**. The escape velocity from the Earth is **11 000 m s^{-1}**.

Explain why almost all the molecules of hydrogen that have ever been in the Earth's atmosphere have escaped into space but many oxygen molecules have remained in the atmosphere.

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.... [2]

(c) Using the Kinetic model of gases, explain how gases exert a pressure on the sides of its container.

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.... [3]

Ans (a)(i)

$$\frac{1}{2}m < c^2 >= \frac{3}{2}kT$$

$$\sqrt{< c^2 >} = \sqrt{\frac{3(1.38x10^{-23})(296)}{(5.3x10^{-26})}}$$

$= 481 \text{ m s}^{-1}$

(ii) According to Kinetic Theory, the **mean KE is the same** since at the **same temperature**. However as **mass is different** they have different rms speed.

(b) Reference made to **distribution of speeds**.
(*ie idea on molecules having speed above and below rms speeds*)
For hydrogen the **probability** of molecules having speed greater than escaped speed is higher than oxygen *as rms speed is higher.*

(c) When molecule collide with the wall, the wall exerts a force on the molecule causing the molecule to experience a **change in momentum,** hence it rebounds.

By N3L, it exerts a force of the same magnitude back on the wall.

As there are **many molecules** moving about **randomly**, colliding with the wall, an **average constant force** and hence **pressure** is exerted on the wall.

2 In a diesel engine, a fixed amount of gas can be considered to undergo a cycle of four stages. The cycle is shown in Fig. 4.1.

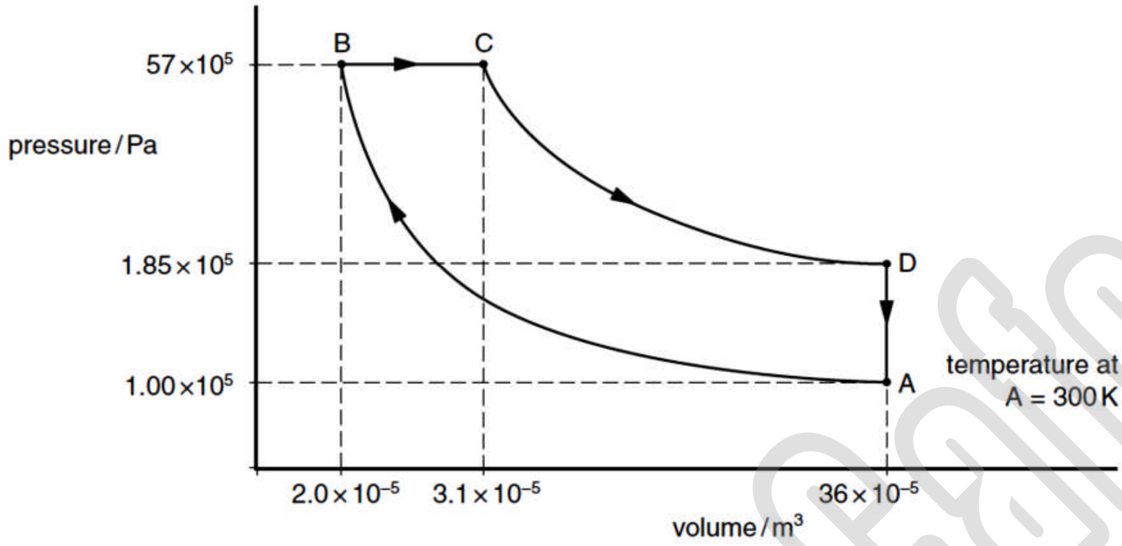

Fig. 4.1 (not to scale)

The four stages are

A → B a compression with a rise in pressure and temperature from an initial temperature of **300 K**,

B → C an expansion at constant pressure while fuel is being burnt,

C → D a further expansion with a drop in both temperature and pressure,

D → A a return to the starting point.

Some numerical values of temperature, pressure and volume are given on Fig. 4.1. The values are for an idealised engine.

(a) Calculate the temperature of the gas at point **B**.

temperature = ... K [2]

(b) Using Fig. 4.1, determine the work done by the gas from **B** to **C**,

work done = ... J [2]

(c) Complete the following table for the four stages of the cycle.

stage of cycle	heat supplied **to the gas** / J	work done **on the gas** / J	**increase** in the internal energy of the **gas**/ J
A $\rightarrow$ B	0	235	
B $\rightarrow$ C	246		
C $\rightarrow$ D	0	-333	
D $\rightarrow$ A			

[3]

(d) Calculate the efficiency of this idealised diesel engine.

efficiency = ... [1]

Ans **(a)** Using equation of states,

$$\frac{P_A V_A}{T_A} = \frac{P_B V_B}{T_B}$$

$$\frac{(1.00\times10^5)(36\times10^{-5})}{300} = \frac{(57\times10^5)(2.0\times10^{-5})}{T_B}$$ [M1]

T_B = 950 K [A1]

(b) Work done by gas
= Area under the P-V graph
= $P_B(V_C - V_B)$
= $(57 \times 10^5)(3.1 - 2.0) \times 10^{-5}$ [M1]
= 62.7 J [A1]

Positive work done by gas as it is expanding.

(c)

stage of cycle	heat supplied **to the gas** / J	work done **on the gas** / J	**increase** in the internal energy of the system/ J
A → B	0	235	235
B → C	246	-62.7	183
C → D	0	-333	-333
D → A	-85	0	-85

$\Delta W_{B\to C}$ = -62.7 J carries no mark as it is given in **(b)**

If $\Delta U_{A\to B}$ = 235 J **and** $\Delta U_{C\to D}$ = -333 J are **both** correct, and

If $\Delta U_{B\to C} = Q_{B\to C} + W_{B\to C}$ (ie -62.7+246=183),

then award (ecf allowed) [B1]

For $W_{D\to A}$ = 0 [C1]

for alluding to sum of overall increase in internal energy at same point is zero) **and**

$\Delta W_{D\to A}$ = 0 J, $\Delta U_{D\to A} = Q_{D\to A}$ then award [C1]

(d) Efficiency

$$= \frac{Net\ Work\ Done\ by\ gas}{Heat\ supplied\ to\ gas}$$

$$= \frac{-(235-62.7-333+0)}{246}$$

$$= \frac{161}{246} = 0.653$$ [A1]

3 Five ideal gas molecules, of the same mass, are trapped in a **8.00 cm³** container.

Their kinetic energies in the container are distributed as shown in Fig. 3.

kinetic energy/ 10^{-21} J	6.31	5.42	7.53	5.64	6.55
no. of molecules	1	1	1	1	1

Fig. 3

The molecules have a root-mean-square speed of **1380 m s⁻¹**.

(a) **(i)** Calculate the mean kinetic energy of an ideal gas molecule.

mean kinetic energy = ... J [1]

(ii) Show that the temperature of the container is 30.7 °C.

[2]

(iii) Calculate the pressure in the container.

pressure = ... Pa [2]

(iv) Calculate the average mass of an ideal gas molecule.

Express your answer in unified atomic mass unit.

mass = ... u [2]

(b) State and explain *qualitatively* the change, if any, to the temperature when the most energetic molecule is removed from the container.

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.... [2]

(c) A student suggests that the identity of the ideal gas molecule is helium.

Comment on the validity of the student's claim based on your answer in **(a)**.

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.... [1]

Ans (a)(i)

mean KE = $\frac{(6.31+5.42+7.53+5.64+6.55) \text{ x } 10^{-21}}{5} = 6.29 \text{ x } 10^{-21} \text{ J}$ [1] – Ans

(a)(ii)

mean KE = $\frac{3}{2}kT$

$6.29 \text{ x } 10^{-21} = \frac{3}{2}\left(1.38 \text{ x } 10^{-23}\right)(T)$ [1] - sub

$T = 303.86 \text{ K}$ [1] - convert

$\theta = 303.86 - 273.15 = 30.7\ ^{\circ}\text{C}$

(a)(iii) $PV = NkT$

$P\left(\frac{8}{100^3}\right) = 5\left(1.38 \text{ x } 10^{-23}\right)(30.7+273.15)$ [1] - sub

$P = 2.62 \text{ x } 10^{-15} \text{ Pa}$ [1] - ans

(a)(iv) $\frac{1}{2}m < c^2 > \ = \ 6.29 \text{ x } 10^{-21} \text{ J}$

$m = \frac{2(6.29 \text{ x } 10^{-21})}{(1380^2)(1.66 \text{ x } 10^{-27})}$ [1] - sub

$m = 3.98 \text{ u}$ [1] - ans

(b) The mean KE of the remaining molecules decreases. Since the thermodynamic temperature depends on the mean KE, the temperature decreases [2] - Ans with correct explanation

(c) From (a)(iv), the molecule has an average mass of ~4 u, thus it can be helium, which has a mass of ~4 u. [1] - ans