Cambridge Assessment International Education

Cambridge International AS & A Level

8: Thermodynamics – Topic questions

The questions in this document have been compiled from a number of past papers, as indicated in the table below.

Use these questions to formatively assess your learners' understanding of this topic.

Question	Year	Series	Paper number
4	2017	June	41
2	2017	March	42
2	2016	March	42

The mark scheme for each question is provided at the end of the document.

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]

2 **(a)** The first law of thermodynamics can be represented by the expression

$$\Delta U = q + w.$$

State what is meant by the symbols in the expression.

$+\Delta U$ ....

$+q$ ....

$+w$ ....

[2]

(b) A fixed mass of an ideal gas undergoes a cycle ABCA of changes, as shown in Fig. 2.1.

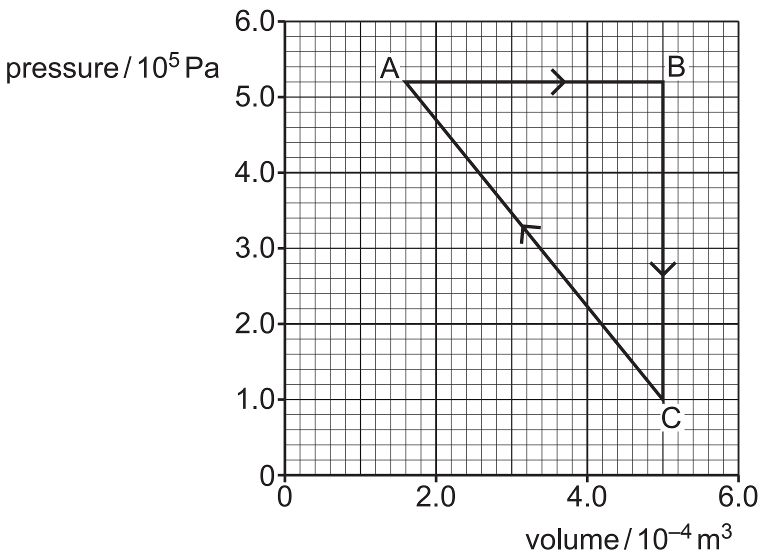

Fig. 2.1

(i) During the change from A to B, the energy supplied to the gas by heating is 442 J.

Use the first law of thermodynamics to show that the internal energy of the gas increases by 265 J.

[2]

(ii) During the change from B to C, the internal energy of the gas decreases by 313 J.

By considering molecular energy, state and explain qualitatively the change, if any, in the temperature of the gas.

....

....

....

....

....[3]

(iii) For the change from C to A, use the data in **(b)(i)** and **(b)(ii)** to calculate the change in internal energy.

change in internal energy = ... J [1]

(iv) The temperature of the gas at point A is 227 °C. Calculate the number of molecules in the fixed mass of the gas.

number = ...[2]

[Total: 10]

2 **(a)** State

(i) what is meant by *internal energy*,

....

....

....[2]

(ii) the basic assumption of the kinetic theory of gases that leads to the conclusion that there is zero potential energy between the molecules of an ideal gas.

....

....[1]

(b) The pressure p and volume V of an ideal gas are related by

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

where N is the number of molecules, m is the mass of a molecule and $\langle c^2 \rangle$ is the mean-square speed of the molecules.

Use this equation to show that the mean kinetic energy $\langle E_K \rangle$ of a molecule is given by

$$\langle E_K \rangle = \frac{3}{2} kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

[3]

(c) A cylinder contains 17 g of oxygen gas at a temperature of 12 °C. The mass of 1.0 mol of oxygen gas is 32 g. It may be assumed that the oxygen behaves as an ideal gas.

Calculate, for the oxygen gas in the cylinder,

(i) the mean kinetic energy of a molecule,

mean kinetic energy = ...J [2]

(ii) the number of molecules,

number = ...[2]

(iii) the total internal energy.

internal energy = ...J [1]

[Total: 11]

Question	Answer	Marks
4 (a)	random/haphazard	**1**
	constant velocity **or** speed in a straight line between collisions **or** distribution of speeds/different directions	**1**
4 (b)	(small) specks of light/bright specks/pollen grains/dust particles/smoke particles	**1**
	moving haphazardly/randomly/jerky/in a zigzag fashion	**1**
4 (c) (i)	$pV = \frac{1}{3} Nm\langle c^2\rangle$ $1.05 \times 10^5 \times 0.0240 = \frac{1}{3} \times 4.00 \times 10^{-3} \times \langle c^2\rangle$	**1**
	$\langle c2\rangle = 1.89 \times 10^6$	**1**
	or	
	$\frac{1}{2} m\langle c^2\rangle = (3 / 2)\ kT$ $0.5 \times (4.00 \times 10^{-3} / 6.02 \times 10^{23}) \times \langle c^2\rangle = 1.5 \times 1.38 \times 10^{-23} \times 300$	**(1)**
	$\langle c^2\rangle = 1.87 \times 10^6$	**(1)**
	or	
	$nRT = \frac{1}{3} Nm\langle c^2\rangle$ $1.00 \times 8.31 \times 300 = \frac{1}{3} \times 4.00 \times 10^{-3} \times \langle c^2\rangle$	**(1)**
	$\langle c^2\rangle = 1.87 \times 10^6$	**(1)**
	$c_{\text{r.m.s.}} = 1.37 \times 10^3$ m s–1	**1**
4 (c) (ii)	$\langle c^2\rangle \propto T$	**1**
	$\langle c^2\rangle$ at 177 °C = $1.89 \times 10^6 \times (450 / 300)$	**1**
	$c_{\text{r.m.s.}}$ at 177 °C = 1.68×10^3 m s–1	**1**
		Total: 10
2 (a)	$+\Delta U$ increase in internal energy $+q$ heat (energy) transferred to the system / heating of system $+w$ work done on system	**1**
2 (b) (i)	$W = p\Delta V$ $= 5.2 \times 10^5 \times (5.0 – 1.6) \times 10^{-4}$ (=177 J)	**1**
	$\Delta U = q + w$ = 442 – 177 = 265 J	**1**
2 (b) (ii)	no (molecular) potential energy	**1**
	internal energy decreases so (total molecular) kinetic energy decreases	**1**
	(mean molecular) kinetic energy decreases so temperature decreases	**1**
2 (b) (iii)	ΔU + 265 – 313 = 0 ΔU = 48 J	**1**

Question	Answer	Marks
2 (b) (iv)	*pV* = *NkT* or *pV* = *nRT* and $N = nN_A$	**1**
	$5.2 \times 10^5 \times 1.6 \times 10^{-4} = N \times 1.38 \times 10^{-23} \times (273 + 227)$ *or* $5.2 \times 10^5 \times 1.6 \times 10^{-4} = n \times 8.31 \times (273 + 227)$ and $n = N / 6.02 \times 10^{23}$ $N = 1.2 \times 10^{22}$	**1**
		Total: 9
2 (a) (i)	sum of kinetic and potential energy of atoms/molecules	**1**
	reference to random (distribution)	**1**
2 (a) (ii)	no forces (of attraction or repulsion) between molecules	**1**
2 (b)	pV = NkT or pV = nRT and $R = kN_A$, $n = N / N_A$	**1**
	$\frac{1}{3}$ Nm $\langle c^2 \rangle$ = NkT or $\frac{1}{3}$ Nm $\langle c^2 \rangle$ = kT	**1**
	$\langle E_K \rangle = \frac{1}{2} m \langle c^2 \rangle$ so $\langle E_K \rangle$ = 3/2 kT	**1**
2 (c) (i)	$\langle E_K \rangle = 3/2 \times 1.38 \times 10^{-23} \times (273 + 12)$	**1**
	$= 5.9\ (5.90) \times 10^{-21}$ J	**1**
	(use of T = 12 K not T = 285 K scores 0 / 2)	
2 (c) (ii)	number = $(17 / 32) \times 6.02 \times 10^{23}$	**1**
	$= 3.2\ (3.20) \times 10^{23}$	**1**
2 (c) (iii)	internal energy = $5.9 \times 10^{-21} \times 3.2 \times 10^{23}$ = 1900 (1890) J	**1**
		Total: 11

Notes about the mark scheme are available separately.