

## YEAR 2 | MODULE 5 | PACK 04

# Kinetic theory and molecular energy

Official past-paper questions

2017-2023 | OCR A H556 | 5.1.4(b),(c),(e)-(i)

## 44 marks | 12 question entries

Two sessions: A = 22 marks; B = 22 marks

**Use:** attempt the session after learning its content. Try without notes; record any help used. Mark the session, identify the reason for lost marks, then revisit those questions after a few days.

**Format:** all MCQs appear first with their complete answer boxes. Written extracts retain the original paper's answer space. Only the subparts named in the source reference are assigned.

**Session B:** TP28 also needs nuclear fusion and mass-energy conversion. Defer its 6 marks until taught. If deferred, record Session B out of 16 attempted marks, rather than treating it as a zero.

**Reserved:** all 2024 and 2025 papers are excluded. These files contain official examination questions only; no sample, specimen or practice papers.

Name: \_\_\_\_\_

First attempt: \_\_\_\_\_ Score: \_\_\_\_\_ / 44

[Official data, formulae and relationships booklet](#)

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TP identifiers are stable across the question packs and mark schemes; Q numbers refer to this pack. All MCQs belong to Session A.

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## Q01 | TP06

1 mark

November 2020 | H556/01 | Q15

- 15** The kinetic theory of matter is a model used to describe the behaviour of particles (atoms or molecules) in an ideal gas. There are a number of assumptions made in the kinetic model for an ideal gas.

Which one of the following assumptions is **not** correct?

- A** The collisions of particles with each other and the container walls are perfectly inelastic.
- B** The electrostatic forces between particles are negligible except during collisions.
- C** The particles occupy negligible volume compared to the volume of the gas.
- D** There are a large number of particles in random motion.

Your answer

☐

[1]

## Q02 | TP10

1 mark

June 2022 | H556/01 | Q8

- 8** Which statement(s) below are implied by the assumptions of the kinetic theory model of gases?

- 1 A gas is mostly empty space.
- 2 Gas particles spend more time between collisions than time during collisions.
- 3 There are always forces between the gas particles.

- A** Only 1 and 2
- B** Only 1 and 3
- C** Only 2 and 3
- D** 1, 2 and 3

Your answer

☐

[1]

## Q03 | TP01

1 mark

June 2017 | H556/01 | Q14

- 14** A container has an ideal gas. The mean square speed of the gas molecules in the container is  $3.0 \times 10^5 \text{ m}^2 \text{ s}^{-2}$ .

Over a period of time, a third of the gas molecules escape from the container. The pressure and volume of the gas in the container remain the same.

What is the mean square speed of the molecules left in the container?

- A**  $1.0 \times 10^5 \text{ m}^2 \text{ s}^{-2}$
- B**  $2.0 \times 10^5 \text{ m}^2 \text{ s}^{-2}$
- C**  $4.5 \times 10^5 \text{ m}^2 \text{ s}^{-2}$
- D**  $9.0 \times 10^5 \text{ m}^2 \text{ s}^{-2}$

Your answer

[1]

## Session A - 22 marks

## Q04 | TP22

2 marks

June 2017 | H556/03 | Q5(a)(ii)2

The speed of sound in air at 17 °C is 340 ms<sup>-1</sup>.

(ii) Calculate

- 2 the root mean square speed  $c_{\text{r.m.s.}}$  of the air molecules in the room.  
The molar mass of air is  $2.9 \times 10^{-2} \text{ kg mol}^{-1}$ .

$c_{\text{r.m.s.}} = \dots\dots\dots \text{ms}^{-1}$  [2]

Only (a)(ii)2 is assigned. The original room-temperature statement is retained above it.

## Q05 | TP29

3 marks

November 2020 | H556/03 | Q4(c)

Context from original (b)(ii): the ISS orbital speed is  $7.7 \text{ km s}^{-1}$ .

(c) Use the information in (b)(ii) and the data below to show that the root mean square (r.m.s.) speed of the air molecules inside the ISS is approximately 15 times smaller than the orbital speed of the ISS.

- molar mass of air =  $2.9 \times 10^{-2} \text{ kg mol}^{-1}$
- temperature of air inside the ISS =  $20^\circ\text{C}$

[3]

## Q06 | TP24D

6 marks

June 2019 | H556/01 | Q21(d)

- 21** A substance can exist as a crystalline solid, a liquid or a gas.  
A solid sample of the substance is placed in a sealed container and heated at a constant rate until it changes into a gas.

Fig. 21 shows the variation with time  $t$  of the temperature  $\theta$  for the substance.

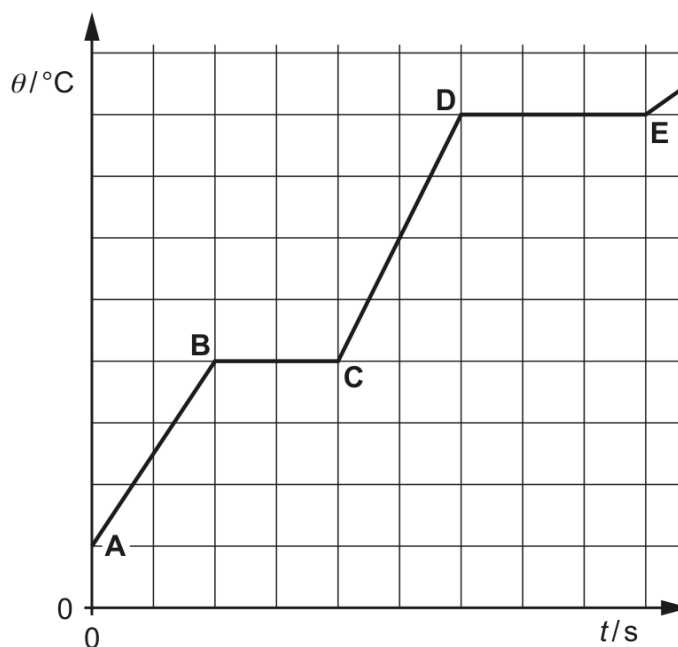


Fig. 21

- (d) Beyond the point **E** in Fig. 21, the substance behaves as an ideal gas.
- (i) The mass of a gas molecule is  $4.8 \times 10^{-26} \text{ kg}$ .  
Calculate the root mean square speed of the gas molecules at a temperature of  $250^\circ\text{C}$ .

root mean square speed = .....  $\text{ms}^{-1}$  [3]

Only (d)(i)-(ii) are assigned. The original heating curve is retained for the reference to point E.

## Q06 | TP24D - continued

6 marks

June 2019 | H556/01 | Q21(d)

- (ii) Calculate the internal energy of 1.3 moles of the gas at 250 °C.

internal energy = ..... J [3]

Only (d)(i)-(ii) are assigned. The original heating curve is retained for the reference to point E.

## Q07 | TP33

5 marks

June 2022 | H556/01 | Q21(b)

(b) A nebula **X** is modelled as a sphere of gas and dust particles of diameter 6.4 pc.

The nebula has  $1.0 \times 10^{12}$  gas and dust particles per  $\text{m}^3$  and a temperature of 250 K. The nebula behaves like an ideal gas.

(i) Show that the volume of the nebula is  $4.1 \times 10^{51} \text{ m}^3$ .

$$1 \text{ pc} = 3.1 \times 10^{16} \text{ m}$$

[2]

(ii) Calculate the **total** kinetic energy  $E_k$  of the gas and dust particles in the nebula.

$$E_k = \dots\dots\dots \text{ J [3]}$$

Only (b) is assigned. The volume calculation is retained because (b)(ii) uses it.

## Q08 | TP36

3 marks

June 2023 | H556/01 | Q23(b)(i), (b)(iv)

For (b)(iv), the omitted part (b)(iii) gives a maximum distance of about  $3.2 \times 10^{10}$  m (OCR mark scheme).

One of the stars studied was Polaris A. Data about this star is in the table below.

|                                           |                                 |
|-------------------------------------------|---------------------------------|
| Parallax angle                            | $7.5 \times 10^{-3}$ arcseconds |
| Radius                                    | $2.1 \times 10^{10}$ m          |
| Mass                                      | $1.1 \times 10^{31}$ kg         |
| Surface temperature                       | 6000 K                          |
| Temperature of the atmosphere of the star | $4.0 \times 10^6$ K             |

- (b) A continuous stream of particles called a solar wind flows from the surface of the star into the surrounding space.

These particles include helium nuclei of mass  $6.6 \times 10^{-27}$  kg.

Assume that the atmosphere is modelled as an ideal gas.

- (i) Show that the typical kinetic energy of a helium nucleus in the atmosphere is about  $10^{-16}$  J.

[2]

- (iv) Explain why the star has a solar wind that reaches a much greater distance from the star than found in (iii).

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..... [1]

Only (b)(i) and (b)(iv) are assigned. Original stellar data are retained above the extracts.

## Session B - 22 marks

## Q09 | TP21

3 marks

June 2017 | H556/01 | Q23(b)(iii)

Context from original (b)(i): the equation below gives the escape speed; its derivation is not assigned.

(b) The table below shows some data for Mercury and Pluto.

|                | Mass / kg              | Radius / m         | Mean distance from Sun / m |
|----------------|------------------------|--------------------|----------------------------|
| <b>Mercury</b> | $3.30 \times 10^{23}$  | $2.44 \times 10^6$ | $57.9 \times 10^9$         |
| <b>Pluto</b>   | $0.131 \times 10^{23}$ | $1.19 \times 10^6$ | $5910 \times 10^9$         |

$$v = \sqrt{\frac{2GM}{r}}$$

where  $M$  is the mass of Pluto and  $r$  is its radius.

(iii) Explain why Mercury has no atmosphere whilst Pluto still has a thin atmosphere. Use data from the table to support your explanation.

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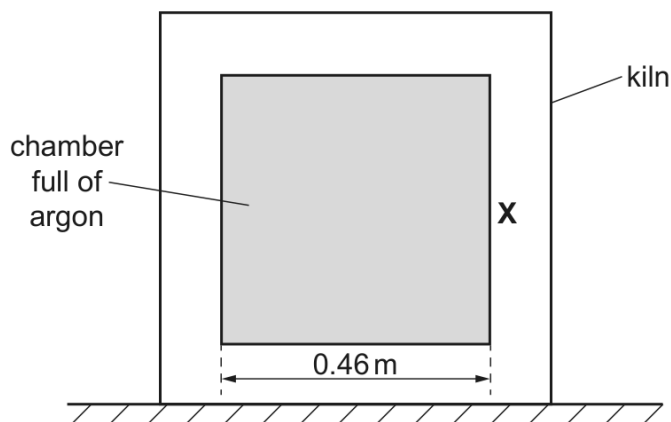
Only (b)(iii) is assigned. The original planet data and escape-speed equation from (b)(i) are retained as context.

## Q10 | TP27B

7 marks

November 2020 | H556/01 | Q21(b)

21 A kiln used to harden ceramics is shown below.



The internal chamber is a cube. Each side of this cube has length 0.46 m.  
The chamber is sealed and full of argon. Argon behaves as an ideal gas.

(b) The temperature of the kiln is 1300 °C.

A single atom of argon is travelling horizontally towards the vertical side **X** of the chamber.  
The initial speed of this atom is 990 m s<sup>-1</sup>. After collision, it rebounds at the same speed.

(i) Calculate the change in momentum  $\Delta p$  of this atom.

- mass of argon atom =  $6.6 \times 10^{-26}$  kg

$$\Delta p = \dots\dots\dots \text{ kg m s}^{-1} \text{ [2]}$$

Only (b)(i)-(iii) are assigned. The original kiln diagram and chamber dimensions are retained.

## Q10 | TP27B - continued

7 marks

November 2020 | H556/01 | Q21(b)

- (ii) Assume that this atom does not collide with any other argon atoms inside the chamber. Instead, it travels horizontally, making repeated collisions with the opposite vertical walls of the chamber.

- 1 Show that the atom makes about 1000 collisions with side **X** in a time interval of 1.0s.

[1]

- 2 Calculate the average force  $F$  on side **X** made by the atom.

 $F = \dots\dots\dots$  N [2]

- (iii) Without calculation, explain how your answer to (ii)2 could be used to estimate the total pressure exerted by the atoms of the argon gas in the kiln.

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..... [2]

Only (b)(i)-(iii) are assigned. The original kiln diagram and chamber dimensions are retained.

## Q11 | TP31

6 marks

November 2021 | H556/03 | Q4(a)

- 4 This question is about an electric cooker, which consists of an oven and an electromagnetic induction hob.

\*(a) The oven is not sealed, so the air inside remains at atmospheric pressure of  $1.0 \times 10^5 \text{ Pa}$ . The volume of the oven is  $0.065 \text{ m}^3$ . The air inside the oven behaves as an ideal gas.

The temperature of the oven increases from room temperature to  $200^\circ\text{C}$ .

Show that the internal energy of the air in the oven is the same at **all** temperatures of the oven. Support your answer with an explanation of the motion of the air molecules in terms of kinetic theory. **[6]**

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The electromagnetic-induction parts (b) are omitted; the original additional response area is retained.

## Q11 | TP31 - continued

6 marks

November 2021 | H556/03 | Q4(a)

Additional answer space if required

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The electromagnetic-induction parts (b) are omitted; the original additional response area is retained.

## Q12 | TP28

6 marks

November 2020 | H556/03 | Q3(b)

**\*(b)** A student attends a lecture about the Sun and makes the following notes.

1. The Sun loses more than  $4 \times 10^9$  kg of its mass every second to maintain its luminosity.
2. Treating hydrogen nuclei (protons) as an ideal gas, a temperature of  $10^{10}$  K provides a kinetic energy of about 1 MeV, which is necessary for fusion.
3. However, the Sun's core temperature is only  $10^7$  K, so the chance of protons fusing on collision is very small. This explains why the Sun has such a long lifetime.

Explain the principles of physics which are involved in each of the three points.  
You should include relevant formulae, but no numbers or calculations are required.

**[6]**

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Later application: this inseparable 6-mark question also needs nuclear fusion and mass-energy conversion. Leave it until that content has been taught; record it as deferred meanwhile.

## Q12 | TP28 - continued

6 marks

November 2020 | H556/03 | Q3(b)

Additional answer space if required.

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Later application: this inseparable 6-mark question also needs nuclear fusion and mass-energy conversion. Leave it until that content has been taught; record it as deferred meanwhile.