

YEAR 2 | MODULE 5 | PACK 04

Kinetic theory and molecular energy

Official past-paper mark scheme

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

Match each extract using its question number and stable TP identifier. Original OCR answers, examiner guidance, alternatives, diagrams and level descriptors are preserved.

The heading gives the maximum marks for the assigned subparts. Alternative methods and "any n from" lists offer routes to those marks; do not add every printed point together.

Click a source reference to open OCR's full official mark scheme. Keep this file closed while attempting the questions.

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

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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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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

Question	Answer	Marks	Guidance
15	A	1	

Q02 | TP10

1 mark

June 2022 | H556/01 | Q8

Question	Answer	Marks	Guidance
8	A	1	

Q03 | TP01

1 mark

June 2017 | H556/01 | Q14

Question	Answer	Marks	Guidance
14	C	1	

Q04 | TP22

2 marks

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

Question			Answer	Marks	Guidance
		(ii)2	$\frac{1}{2}Mv^2 = \frac{3}{2}RT$ and $T = 290$ $v = \sqrt{(3 \times 8.31 \times 290 / 0.029)}$ $v = 5(.0) \times 10^2 \text{ (m s}^{-1}\text{.)}$	C1 A1	or $\frac{1}{2}mv^2 = \frac{3}{2}kT$ so $v^2 = 3 \text{ (k/m)} 290$ N.B. remember to record a mark out of 4 here

The OCR note about recording a mark out of 4 refers to the original combined (a)(ii)1 and (a)(ii)2. Only (a)(ii)2 is assigned here, for 2 marks.

Q05 | TP29

3 marks

November 2020 | H556/03 | Q4(c)

Question			Answer	Marks	Guidance
	(c)		$\frac{1}{2}Mc^2 (\frac{1}{2}N_A mc^2) = \frac{3}{2}RT$ $c^2 = 3 \times 8.31 \times 293 / 2.9 \times 10^{-2} = 2.52 \times 10^5$ $\sqrt{c^2} = 500 \text{ (m s}^{-1}\text{)}$ $(= 7.7 \times 10^3 / 15)$	C1 C1 A1 A0	or $\frac{1}{2}mc^2 = \frac{3}{2}kT$ or $c^2 = 3kT/m$ or $c^2 = 3 \times 1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 293 / 2.9 \times 10^{-2} = 2.52 \times 10^5$ not $(7.7 \times 10^3 / 15) = 510 \text{ (m s}^{-1}\text{)}$

Q06 | TP24D

6 marks

June 2019 | H556/01 | Q21(d)

Question			Answer	Marks	Guidance
	(d)	(i)	$\frac{1}{2} m c_{\text{RMS}}^2 = \frac{3}{2} kT$ $c_{\text{RMS}}^2 = 3 \times 1.38 \times 10^{-23} \times 523 / 4.8 \times 10^{-26}$ (Any subject) root mean square speed = 670 (m s ⁻¹)	C1 C1 A1	Allow this mark even when $T = 250$ is used subsequently Not 250°C Allow $c^2 = 4.5 \times 10^5$ Allow 2 marks for 4.5×10^5 ; mean square speed calculated Allow 1 mark for 464; no conversion to kelvin.
		(ii)	(number of molecules =) $1.3 \times 6.02 \times 10^{23}$ or 7.83×10^{23} mean KE = $\frac{3}{2} \times 1.38 \times 10^{-23} \times 523$ or 1.08×10^{-20} total kinetic energy = 8.5×10^3 (J)	C1 C1 A1	Not 250°C Allow 8.4×10^3 for use of 670 m s ⁻¹ Allow full credit for use of total KE = $1.5nRT$ Allow full credit for use of E_k for one molecule = $\frac{1}{2} m c_{\text{RMS}}^2$ (which may include ECF for their c_{RMS} in (d)(i)) Allow 2 marks for $4.0(5\dots) \times 10^3$ (J) ; no conversion to kelvin.

Q07 | TP33

5 marks

June 2022 | H556/01 | Q21(b)

Question			Answer	Marks	Guidance
	b	i	(diameter =) $6.4 \times 3.1 \times 10^{16}$ or 2.0×10^{17} (m) (volume =) $\frac{4}{3} \pi \times (9.9 \times 10^{16})^3$ (volume =) 4.1×10^{51} (m ³)	C1 C1 A0	Allow (radius =) $3.2 \times 3.1 \times 10^{16}$ or 9.9×10^{16} (m)
		ii	$(E = \frac{3}{2} kT) \frac{3}{2} \times 1.38 \times 10^{-23} \times 250$ or 5.2×10^{-21} (J) ($N =$) $1.0 \times 10^{12} \times 4.1 \times 10^{51}$ or 4.1×10^{63} ($E_k = 4.1 \times 10^{63} \times 5.2 \times 10^{-21}$) $E_k = 2.1 \times 10^{43}$ (J)	C1 C1 A1	

Q08 | TP36

3 marks

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

Question			Answer	Mark	Guidance
	(b)	(i)	Use of $KE_{\text{mean}} = \frac{3}{2} kT = \frac{3}{2} \times k \times 4.0 \times 10^6$ $= \frac{3}{2} \times 1.38 \times 10^{-23} \times 4 \times 10^6$ $= 8.3 \times 10^{-17} \text{ J.}$	C1 A1	Allow k Unrounded answer is $8.28 \dots \times 10^{-17}$

Question			Answer	Mark	Guidance
		(iv)	Reference to Boltzmann distribution / AW OR Some particles will have greater kinetic energies /lower masses	B1	

Q09 | TP21

3 marks

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

Question			Answer	Marks	Guidance
		(iii)	Mercury has a higher escape velocity than Pluto (ORA)	B1	Allow a supporting calculation (speed is about 4.2 km s^{-1})
			Mercury is closer to sun and Mercury is hotter (ORA)	M1	
			Molecules on Mercury (are more likely to) have speed higher than the escape velocity	A1	Allow 'required speed' for 'escape velocity' Allow 'fast enough to escape'

Q10 | TP27B

7 marks

November 2020 | H556/01 | Q21(b)

Question			Answer	Marks	Guidance
	(b)	(i)	$(p =) 6.6 \times 10^{-26} \times 990$ or $6.5(3) \times 10^{-23} \text{ (kg m s}^{-1}\text{)}$ $(\Delta p =) 2 \times 6.6 \times 10^{-26} \times 990$ $\Delta p = 1.3 \times 10^{-22} \text{ (kg m s}^{-1}\text{)}$	C1 A1	Ignore sign of answer
		(ii)1	$990/[2 \times 0.46] (= 1080)$	B1	
		(ii)2	$(F = \Delta p/\Delta t)$ $(F =) 1.3 \times 10^{-22} \times 1000$ $F = 1.3 \times 10^{-19} \text{ N}$	C1 A1	Possible ECF from (b)(i) Note 1080 would give $1.4 \times 10^{-19} \text{ (N)}$
		(iii)	Use of $p = F/A$ or pressure = (total) force/area Idea of multiplying by total number of atoms	B1 B1	Allow particles or molecules for atoms

Q11 | TP31

6 marks

November 2021 | H556/03 | Q4(a)

Question			Answer	Marks	Guidance
4	(a)	*	Level 3 (5 - 6 marks) Clear explanation using kinetic theory ideas and either a clear proof using formulae or a correct calculation <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) A partial explanation using kinetic theory ideas and either a partial proof using formulae or a partial calculation <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) An attempt at either explanation or proof or calculation <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Indicative scientific points may include: Explanation using kinetic theory • pressure = force/area • force is caused by air molecules colliding with oven walls • Newton's 2nd Law states force = rate of momentum change • increased temperature means each molecule has greater KE • hence greater velocity and hence greater momentum • and more collisions with walls per second • hence greater rate of momentum change on hitting walls. • This would lead to greater pressure if N remained constant • so number of molecules in oven must decrease (air escapes) • so fewer but 'harder' collisions at higher temperatures giving constant pressure. • Rms velocity c increases with temperature but number N decreases and so effects balance out to keep total KE ($\frac{1}{2}Nmc^2$) constant Proof using formulae • equate $pV = NkT$ and $E = \frac{3}{2}NkT$ to show $E = \frac{3}{2}pV$ • in an ideal gas, all internal energy E is kinetic energy • so E is independent of temperature Calculation • Internal energy = $\frac{3}{2}pV = 1.5 \times 0.065 \times 1.0 \times 10^5 = 9.8 \text{ kJ}$ • At $T = 293\text{K}$, $N = pV/kT = 1.6 \times 10^{24}$ and $n = 2.7$ moles • At $T = 473\text{K}$, $N = 1.0 \times 10^{24}$ and $n = 1.7$ moles • so we can show that NT (and/or nT) remain constant

Q12 | TP28

6 marks

November 2020 | H556/03 | Q3(b)

Question			Answer	Marks	Guidance
3	(b)	*	Level 3 (5 - 6 marks) Clear expansion of three statements <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear, relevant and substantiated.</i> Level 2 (3 – 4 marks) Clear expansion of two statements or Limited attempt at all three <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Limited attempt at one or two statements <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Indicative scientific points may include: statement 1 • fusion reactions are occurring • which change H into He • and mass is lost which releases energy • energy released = $c^2\Delta m$ • Δm per second = luminosity / c^2 statement 2 • average k.e. of each proton is $\frac{3}{2}kT$ • high T means protons are travelling at high speed • so fast enough to overcome repulsive forces • and get close enough to fuse • p.e. = $e^2/4\pi\epsilon_0 r$ so T must be high enough for $\frac{3}{2}kT > e^2/4\pi\epsilon_0 r$ • r is approximately 3fm statement 3 • k.e. $\propto T$ so average energy at 10^7 K is only one thousandth of the average energy at 10^{10} K when protons might fuse • but M-B distribution applies so at the high energy end there will be a few p with enough energy • quantum tunnelling across potential barrier is possible • small probability of many favourable collisions to boost energy of p • 4 p must fuse to produce He; it is complicated process making probability of fusion much less • number of p in Sun is so huge that, even with such a small probability, 4×10^9 kg of p still interact s^{-1} • a larger probability means lifetime of the Sun would be shorter