PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 9: THERMODYNAMICS

THERMAL ENERGY TRANSFER AND TEMPERATURE

SCORE	PERCENTAGE
/150	%

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Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\Delta E = mc\Delta\theta$ (1) • Use of $\Delta E = L\Delta m$ (1) • Apply 5% to calculate energy saved (1) • Use of $P = VI$ or Use of $Q = It$ (1) • Use of $P = \frac{W}{t}$ or Use of $E = QV$ (1) • 2.69×10^5 J compared with 1.93×10^5 J for energy saved, and concludes claim invalid. (1) **Or** a phone could run for 5 days compared to 7 days and conclusion claim invalid **Or** a phone could run for 433 900 s compared to 604 800 s and conclusion claim invalid	Example of calculation: For aluminium when being heated up to m.pt.: $\Delta E = 14 \times 10^{-3}\ \text{kg} \times 902\ \text{J kg}^{-1}\text{K}^{-1} \times (660 - 293)\text{K}$ $\Delta E = 4.63 \times 10^3\ \text{J}$ For aluminium when melting: $\Delta E = 14 \times 10^{-3}\ \text{kg} \times 396 \times 10^3\ \text{J kg}^{-1} = 5.54 \times 10^3\ \text{J}$ Energy saved $= \frac{0.95}{0.05} \times (4630 + 5540)\text{J}$ Energy saved $= 1.93 \times 10^5\ \text{J}$ $P = 3.7\ \text{V} \times 120 \times 10^{-3}\ \text{A} = 0.444\ \text{W}$ $\Delta E = 0.444\ \text{W} \times 7 \times 24 \times (60 \times 60)\text{s} = 2.69 \times 10^5\ \text{J}$	6

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use ofincrease in thermal energy of milk = latent heat energy released by steam + decrease in thermal energy of condensed steam (1) • Use of $\Delta Q = mc\Delta\theta$ (1) • Use of $\Delta Q = L\Delta m$ (1) • $m = 0.15$ kg (150 g) (1)	Example of calculation $(mc\Delta\theta)_{\text{milk}} = (mc\Delta\theta)_{\text{water}} + L\Delta m_{steam}$ $m \times 3900\ \text{J kg}^{-1}\ \text{K}^{-1} \times (65.0\ °\text{C} - 4.00\ °\text{C})$ $= (0.015\ \text{kg} \times 4200\ \text{J kg}^{-1}\ \text{K}^{-1} \times (100\ °\text{C} - 65.0\ °\text{C})) + (2.3 \times 10^6\ \text{J kg}^{-1} \times 0.015\ \text{kg})$ $m = 0.15$ kg	4

Q3.

Question Number	Answer	Mark
	B – 545 ÷ 838 000	**1**
	Incorrect Answers: Correct method: mass = energy transfer ÷ latent heat of vaporisation A – uses energy transfer ÷ latent heat of fusion C – uses latent heat of fusion ÷ energy transfer D – uses latent heat of vaporisation ÷ energy transfer	

Q4.

Question Number	Answer		Mark
(a)	(When the air is heated) the density (of air in) the balloon decreases	**(1)**	
	So the upthrust is greater than the weight of the balloon (plus occupants)	**(1)**	**2**
(b)	Use of $\rho = \frac{m}{V}$	**(1)**	
	Use of $\Delta E = mc\Delta\theta$ [$\Delta\theta$ must be a temperature difference]	**(1)**	
	$\Delta E = 1.3(5) \times 10^9$ J	**(1)**	**3**
	Example of calculation: $m = \rho V = 1.20\,\text{kg m}^{-3} \times 7.4\times10^4\,\text{m}^3 = 8.88\times10^4\,\text{kg}$ $\Delta E = mc\Delta\theta = 8.88\times10^4\,\text{kg} \times 1010\,\text{J kg}^{-1}\,\text{K}^{-1}(35-20)\text{K} = 1.345\times10^9\,\text{J}$		
(c)(i)	Use of $pV = NkT$ [temperature in either K or °C]	**(1)**	
	$p = 9.24 \times 10^4$ Pa	**(1)**	**2**
	Example of calculation: $\frac{p_2}{p_1} = \frac{T_2}{T_1}$ $p_2 = (1.01\times10^5)\text{Pa} \times \frac{(273-5)\text{K}}{(273+20)\text{K}} = 9.238\times10^4$ Pa		
(c)(ii)	**Max 2** Hydrogen/gas behaves as an ideal gas	**(1)**	
	Mass of hydrogen/gas in balloon stays constant [Accept amount of hydrogen/gas]	**(1)**	
	Or number of molecules/atoms/particles of hydrogen/gas in balloon stays constant	**(1)**	**2**
	Temperature of hydrogen/gas is the same as the temperature of the surroundings		
(c)(iii)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)		
	The average/mean kinetic energy of the molecules decreases	**(1)**	
	Molecules travel slower (on average) **Or** rate of collisions with walls is less	**(1)**	
	So rate of change of momentum (during collisions) with walls is less	**(1)**	**3**
	Total for question		**12**

Q5.

Question Number	Answer		Mark
(a)	Use of electrical power equation e.g. $P = \frac{V^2}{R}$ R = 8.8 Ω [Use of V=IR and P=VI gains mp1] Example of calculation $R = \frac{(230V)^2}{6000W} = 8.82\Omega$	(1) (1)	**2**
(b)	See 30 K [30 °C] **Or** 6000 J s^{-1} Use of $\Delta E = mc\Delta\theta$ [Do not penalise wrong temperature conversions, but $\Delta\theta$ must be a temperature difference] $\frac{\Delta m}{\Delta t} = 0.048\,kg\,s^{-1}$ [accept 0.048 litre s^{-1} and other volume flow rates with correct units] Example of calculation $\Delta\theta = (37.5 - 7.5)\,°C = 30\,°C$ $\frac{\Delta m}{\Delta t} = \frac{6000\,W}{4200\,J\,kg^{-1}\,K^{-1} \times 30\,K} = 0.0476\,kg\,s^{-1}$	(1) (1) (1)	**3**
	Total for question		**5**

Q6.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Use of $E_K = \frac{1}{2}mv^2$	**(1)**	Example of calculation $E_K = \frac{1}{2} \times 1.75\ \text{kg} \times (6.25\ \text{m s}^{-1})^2 = 34.2\ \text{J}$	**5**
	• Use of $\Delta E = mc\Delta\theta$	**(1)**	$\Delta E = 0.65 \times 8000 \times 34.2\ \text{J} = 1.78 \times 10^5\ \text{J}$	
	• Use of 8000 **Or** use of (energy required) / (energy per slap)	**(1)**	$\Delta E = 0.875\ \text{kg} \times 1770\ \text{J kg}^{-1}\text{K}^{-1} \times (165 - 23)\text{K}$ $\therefore \Delta E = 2.20 \times 10^5\ \text{J}$	
	• Use of 65% with input energy • Energy from 8000 slaps would be 1.78×10^5 J which is less than the energy required to raise the temperature to 165 °C (2.20×10^5 J) **Or** final temperature would be 138 °C, so not enough **Or** 9900 slaps would be needed, so not enough **Or** temperature rise from 8000 slaps is 115 K which is less than required temperature rise of 142 K	**(1)** **(1)**	$E_K = \frac{1}{2} \times 1.75\ \text{kg} \times (6.25\ \text{m s}^{-1})^2 = 34.2\ \text{J}$ $\Delta E = 0.65 \times 34.2\ \text{J} = 22.2\ \text{J}$ $\Delta E = 0.875\ \text{kg} \times 1770\ \text{J kg}^{-1}\text{K}^{-1} \times (165 - 23)\text{K}$ $\therefore \Delta E = 2.20 \times 10^5\ \text{J}$ $\text{Number of slaps} = \frac{2.20 \times 10^5\ \text{J}}{22.2\ \text{J}} = 9910$ $E_K = \frac{1}{2} \times 1.75\ \text{kg} \times (6.25\ \text{m s}^{-1})^2 = 34.2\ \text{J}$ $\Delta E = 0.65 \times 8000 \times 34.2\ \text{J} = 1.78 \times 10^5\ \text{J}$ $1.78 \times 10^5\text{J} = 0.875\ \text{kg} \times 1770\ \text{J kg}^{-1}\text{K}^{-1} \times (T_f - 296)\text{K}$ $\therefore T_f = \frac{1.78 \times 10^5\ \text{J}}{1.55 \times 10^3\ \text{J K}^{-1}} + 296\ \text{K} = 411\ \text{K}$ $\therefore \theta_f = (411 - 273)\ \text{K} = 138\ ^\circ\text{C}$ MP5: must see a correct value as part of the conclusion	

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• use of $\Delta E = mc\Delta\theta$ **(1)** • use of $P = E/t$ **(1)** • Correct calculation of an appropriate quantity **and** comment consistent with their value. **(1)**	**MP2** Candidates need to calculate either a time, a final temperature, an energy or a power Examples: Yes, because $t = 30$ s, which is less than one minute **Or** Yes, because it could reach temperature of 408 °C in one minute **Or** Yes, because it would transfer 156 000 J in one minute **Or** Yes, because the power required is 1.3 kW <u>Example of calculation</u> $\Delta E = 0.89\ \text{kg} \times 450\ \text{J kg}^{-1}\ \text{K}^{-1} \times (215\ °\text{C} - 18\ °\text{C})$ $= 78\ 900\ \text{J}$ $t = 78\ 900\ \text{J} \div 2600\ \text{W} = 30\ \text{s}$	**3**

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\Delta Q = mc\Delta\theta$ **(1)** • … for correct temperature differences **(1)** • Final temperature is 61.4 °C which is above range **(1)**	<u>Example of calculation</u> $0.180\ \text{kg} \times 4200\ \text{J kg}^{-1}\ \text{K}^{-1} \times (82\ °\text{C} - \theta_f)$ $= 0.068\ \text{kg} \times 3900\ \text{J kg}^{-1}\ \text{K}^{-1} \times (\theta_f - 2.7\ °\text{C})$ $\theta_f = 61.4\ °\text{C}$ Answers making comparisons based on equivalent Physics may be awarded MP3 e.g. 16 600 J must be transferred from coffee to reach 60°C but required energy transfer to milk is only 15 200 J	**3**

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• Use of $P = VI$ (1) • $P = 1900$ W (1.9 kW) (1)	Example of calculation $P = 230\text{ V} \times 8.20\text{ A} = 1890\text{ W}$	2
(a)(ii)	• Use of $\Delta E = mc\Delta\vartheta$ • Use of $P = \frac{\Delta E}{\Delta t}$ (1) • $\Delta t = 112$ s or 113 s [106 s or 107 s if show that value used] (1) ECF from (a)(i) (1)	Example of calculation $\Delta E = 0.655\text{ kg} \times 4190\text{ J kg}^{-1}\text{K}^{-1} \times (100 - 22.5)\text{K}$ $\Delta E = 2.13 \times 10^5\text{ J}$ $\Delta t = \frac{2.13 \times 10^5\text{J}}{1890\text{ W}} = 112.5\text{ s}$	3

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• After a short time of boiling in the flask, all the apparatus would be at 100 °C. **Or** so energy is not being used to heat up the flask **Or** so steam won't condense in the flask (1)		1
(b)(ii)	• Use of $\Delta E = mL$ (1) • Use of $P = \frac{\Delta E}{\Delta t}$ (1) • 1720 W (1.72 kW) (1)	Example of calculation $\frac{\Delta m}{\Delta t} = \frac{95 \times 10^{-3}\text{ kg}}{125\text{ s}}$ $= 7.6 \times 10^{-4}\text{ kg s}^{-1}$ $\frac{\Delta E}{\Delta t} = 7.6 \times 10^{-4}\text{ kg s}^{-1} \times 2.26 \times 10^6\text{J kg}^{-1}$ $P = 1720\text{ J s}^{-1}$	3
(b)(iii)	• Comparison of answer to (a)(i) with answer to (b)(ii) (1) • Not all of the energy from the heater is used to turn water from liquid state into vapour (1) **Or** energy is being used to heat the heat exchanger (1) **Or** not all the steam condenses in the heat exchanger • Some energy is transferred to the surroundings	e.g. rate at which thermal energy is supplied to the water in the flask is greater than rate at which thermal energy is removed from the water in the heat exchanger. If answer for (b)(ii) is bigger than 2 kW,1 mark for correct comparison can be scored.	3

Q10.

Question Number	Answer		Mark
(a)	Idea that internal energy is the sum of (Total) kinetic energy and potential energy of molecules/atoms	(1) (1)	2
(b)(i)	Use of $\Delta E = mc\Delta\theta$ $\Delta E = 8100$ (J) Example of calculation: $\Delta E = mc\Delta\theta = 175\times10^{-3}\ \text{kg}\times4200\,\text{J kg}^{-1}\,\text{K}^{-1}\times(85-74)\text{K} = 8090\,\text{J}$	(1) (1)	2
(b)(ii)	Use of ΔE value from (i) in $\Delta E = mc\Delta\theta$ $m = 0.030$ kg No energy transferred to surroundings **Or** all energy transferred from tea used to heat milk Example of calculation: $\Delta E = mc\Delta\theta$ $8100\,\text{J} = m\times3900\,\text{J kg}^{-1}\,\text{K}^{-1}\times(74-4.5)\text{K}$ $\therefore \text{m} = \dfrac{8100\,\text{J}}{3900\,\text{J kg}^{-1}\,\text{K}^{-1}\times69.5\,\text{K}} = 0.0299\,\text{kg}$	(1) (1) (1)	3
	Total for question		7

Q11.

Question Number	Answer		Mark
(a)(i)	$N + \alpha \rightarrow {}^{17}_{8}O + {}_{1}p$ All values correct	(1)	1
(a)(ii)	In nuclear fission a chain reaction can be set up **Or** in a chain reaction the (total) energy released can be very large **Or** heavier/larger nuclei release much more energy **Or** a very high reaction rate releases much more energy	(1)	1
(b)	Attempt at mass deficit calculation Use of $\Delta E = c^2 \Delta m$ (Allow use of 1 u = 1.66 x 10^{-27} kg) Use of 1 MeV = 1.6 × 10^{-13} J (Allow use of 1u = 931.5 MeV/c^2) ΔE = 174 MeV Example of calculation $\Delta m = (390.29989 - 233.99404 - 152.64708 - (2 \times 1.67493)) \times 10^{-27}\,\text{kg}$ $\Delta m = 3.0891 \times 10^{-28}\,\text{kg}$ $\Delta E = (3.00 \times 10^{8}\,\text{m s}^{-1})^2 \times 3.0891 \times 10^{-28}\,\text{kg} = 2.780 \times 10^{-11}\,\text{J}$ $\Delta E = \frac{2.780 \times 10^{-11}\,\text{J}}{1.60 \times 10^{-13}\,\text{J MeV}^{-1}} = 173.8\,\text{MeV}$	(1) (1) (1) (1)	4
(c)(i)	Same number of protons [do not accept atomic/proton number], Different numbers of neutrons [do not accept mass/nucleon/neutron number]	(1) (1)	2
(c)(ii)	Correct calculation for ω [see 6283 or 2000π or $\frac{60\,000 \times 2\pi}{60}$] a = (-) 5.9 × 10^{6} m s^{-2} Example of calculation $a = -\left(\frac{60000 \times 2\pi}{60\,\text{s}}\right)^2 \times 15 \times 10^{-2}\,\text{m} = 5.92 \times 10^{6}\,\text{m s}^{-2}$	(1) (1)	2
(c)(iii)	**Max 2** Stiff/stiffness Strong/strength Low density	(1) (1) (1)	2
(d)	Use of ΔE = mcΔθ Rate at which energy is removed = 3.1 × 10^{9} (W) Use of the efficiency equation [must have 2.2 × 10^{9} (W) on top line] Efficiency = 42% [accept 0.42] Example of calculation $\Delta E = 70000\,\text{kg} \times 3990\,\text{J kg}^{-1}\,\text{K}^{-1} \times 11\,\text{K} = 3.07 \times 10^{9}\,\text{J}$ $\%\,\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}} \times 100 = \frac{2.2 \times 10^{9}\,\text{W}}{(2.2 + 3.1) \times 10^{9}\,\text{W}} \times 100 = 41.5\%$	(1) (1) (1) (1)	4

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of $W = VIt$ (1) • use of $\Delta E = mc\Delta\theta$ (1) • use of efficiency = useful power output / total power input • efficiency = 0.90 Or 90% (1)	Example of calculation: W = 247 V × 11.8 A × 172 s = 501 000 J ΔE = 1.20 kg × 4180 J kg^{-1} K^{-1} × (101 - 11) K = 451 000 J Efficiency = 451 000 / 501 000 = 0.90	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• calculates area of sphere of radius 30 cm = 1.13 m^2 (1) • use of $I = P/A$ (1) • use of $W = Pt$ (1) • W = 2.0 J (1)	Example of calculation: Area = 4π × (0.3 m)^2 = 1.13 m^2 P = 10.5 × 10^{-3} W m^{-2} × 1.13 m^2 = 1.19 × 10^{-2} W W = 1.19 × 10^{-2} W × 172 s = 2.0 J	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	An explanation that makes reference to the following: • the quiet boil electric kettle is more efficient, but only by 3% which isn't 'much' (1) • the energy transferred by sound is very small, so it is not the reason for the difference (1)	Allow 1 mark if the student gives a comment that the uncertainties are too high to draw a valid conclusion without reference to the data in the question, the candidate's calculations may be awarded one mark	**(2)**

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following: • To bring tubing up to temperature (of steam) (1) • So steam only condenses in the cup (1) **Or** steam doesn't condense in the tubing		2
(ii)	• Thermal energy will be transferred from the steam/tubing to the surroundings (1) • Lagging/insulating/shortening the tubing (1)	Accept: • Thermal energy is transferred to the cup/ probe • These should have a small a heat capacity	2

Q14.

Question Number	Answer	Mark
(a)	The water molecules will have a greater average K.E. **Or** the water will be hotter **Or** less energy transferred to teapot (1)	1
(b)(i)	Use of $\Delta E = mc\Delta\theta$ (1) $\Delta E = 15\,000$ J (1) Example of calculation: $\Delta E = mc\Delta\theta = 0.26\text{ kg} \times 4200\text{ J kg}^{-1}\text{ K}^{-1} \times (95 - 81)\text{ K} = 15\,300\text{ J}$	2
(b)(ii)	Assumption: no heat is lost to the surroundings **Or** all energy goes to the teapot (1) Use of ΔE value from (i) in $\Delta E = mc\Delta\theta$ (1) c = 600 (J kg^{-1} K^{-1}) (1) Example of calculation: $c = \frac{\Delta E}{m\Delta\theta} = \frac{15300\text{ J}}{0.43\text{ kg} \times (81 - 22)\text{ K}} = 603\text{ J kg}^{-1}\text{ K}^{-1}$	3
(b)(iii)	(The calculated value for the specific heat capacity has been overestimated) because energy is transferred to the surroundings (by heating) (1) so the energy gained by the teapot has been overestimated (1)	2
	Total for question	8

Q15.

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Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Change in temperature and corresponding time (1) • Use of $P = \Delta E/\Delta t$ and $\Delta E = mc\Delta\theta$ (1) • $c = 950\ \text{J kg}^{-1}\ \text{K}^{-1}$ (1)	Example of calculation: $\frac{\Delta\theta}{\Delta t} = \frac{(36 - 16)\ \text{K}}{(500 - 0)\ \text{s}} = 0.04\ \text{K s}^{-1}$ $37.5\ \text{W} = 0.986\ \text{kg} \times c \times 0.04\ \text{K s}^{-1}$ $c = 951\ \text{J kg}^{-1}\ \text{K}^{-1}$	3
(ii)	An explanation that makes reference to the following points: • In 240 s the temperature of the block rose by only 9.6 °C **Or** It took 250 s for the temperature of the block to rise by 10 °C. (1) • Hence there must have been energy transfer to the surroundings (by heating) (1)	For MP1 accept 9.5 °C Accept it took 10 s longer For MP2 accept energy dissipated to the surroundings	2

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	An answer that makes reference to the following: • because the helium atoms are moving, there is a change in frequency/ wavelength of the emitted light (1) • for particles moving away from the observer there will be an decrease in frequency and for particles moving towards the observer there will be an increase in frequency OR for particles moving away from the observer there will be an increase in wavelength and for particles moving towards the observer there will be an decrease in wavelength (1)		**(2)**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)(1)	• use of $v/c = \Delta\lambda/\lambda$ • $v = 1530\ \text{m s}^{-1}$	Example of calculation: $v / 3 \times 10^{8}\ \text{m s}^{-1} = 3 \times 10^{-3}\ \text{nm} / 587\ \text{nm}$ $v = 1530\ \text{m s}^{-1}$	**(2)**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)(2)	• mass of helium atom = 4u • use of $\frac{1}{2} m \langle c^2 \rangle = 3/2\ kT$ • $T = 375\ \text{K}$	Example of calculation: Mass of He atom = $4 \times 1.66 \times 10^{-27}\ \text{kg} = 6.64 \times 10^{-27}\ \text{kg}$ $\frac{1}{2}\ 6.64 \times 10^{-27}\ \text{kg} \times (1530\ \text{m s}^{-1})^2 = 3/2 \times 1.38 \times 10^{-23}\ \text{J K}^{-1} \times T$ $T = 375\ \text{K}$	**(3)**

Q2.

Question Number	Answer	Mark
	B	**1**

Q3.

Question Number	Answer		Mark
(a)	Idea that internal energy is the sum of (Total) kinetic energy and potential energy of molecules/atoms	**(1)** **(1)**	**2**
(b)(i)	Use of $\Delta E = mc\Delta\theta$ $\Delta E = 8100$ (J) Example of calculation: $\Delta E = mc\Delta\theta = 175\times10^{-3}\,\text{kg}\times4200\,\text{J kg}^{-1}\,\text{K}^{-1}\times(85-74)\text{K} = 8090\,\text{J}$	**(1)** **(1)**	**2**
(b)(ii)	Use of ΔE value from (i) in $\Delta E = mc\Delta\theta$ $m = 0.030$ kg No energy transferred to surroundings **Or** all energy transferred from tea used to heat milk Example of calculation: $\Delta E = mc\Delta\theta$ $8100\,\text{J} = m\times3900\,\text{J kg}^{-1}\,\text{K}^{-1}\times(74-4.5)\text{K}$ $\therefore \text{m} = \dfrac{8100\,\text{J}}{3900\,\text{J kg}^{-1}\,\text{K}^{-1}\times69.5\,\text{K}} = 0.0299\,\text{kg}$	**(1)** **(1)** **(1)**	**3**
	Total for question		7

Q4.

Question Number	Answer	Mark
	D	**1**

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $V = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3$ (1) • Use of $pV = NkT$ (1) • Conversion of temperature to kelvin (1) • $N = 6.5 \times 10^{17}$ (1)	Example of calculation: $V = \frac{4}{3}\pi(0.080\ \text{m})^3 = 2.14 \times 10^{-3}\ \text{m}^3$ $N = \frac{1.25\ \text{Pa} \times 2.14 \times 10^{-3}\ \text{m}^3}{1.38 \times 10^{-23}\ \text{N m K}^{-1} \times (273+25)\text{K}}$ $= 6.50 \times 10^{17}$	4

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • The intercept represents the temperature of the air at which the volume occupied would be zero (1) • This is the absolute zero (of temperature) (1) • Absolute zero is the lowest attainable temperature **Or** absolute zero is the temperature at which the atoms/molecules of the gas have zero kinetic energy (1)	For MP3 accept atoms/molecules stop moving	3
(ii)	**MAX 4** **Resolution:** • It is correct that uncertainties would be reduced by using high resolution instruments (1) • But the instruments are not high resolution (1) • There could be a systematic error (in the measurements) (1) **Graph:** • The points do not lie on a perfect straight line **Or** the true relationship may not linear (1) • Temperature intercept may not be accurate **Or** there may be extrapolation errors (1) • More points are needed **Or** a wider range is needed (1)		4

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	An answer that makes reference to the following: • because the helium atoms are moving, there is a change in frequency/ wavelength of the emitted light (1) • for particles moving away from the observer there will be an decrease in frequency and for particles moving towards the observer there will be an increase in frequency (1) OR for particles moving away from the observer there will be an increase in wavelength and for particles moving towards the observer there will be an decrease in wavelength (1)		**(2)**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)(1)	• use of $v/c = \Delta\lambda/\lambda$ • $v = 1530$ m s^{-1}	Example of calculation: v / 3×10^{8} m s^{-1} = 3×10^{-3} nm / 587 nm $v = 1530$ m s^{-1}	**(2)**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)(2)	• mass of helium atom = 4u • use of ½ $m \langle c^2 \rangle = 3/2\ kT$ • $T = 375$ K	Example of calculation: Mass of He atom = $4 \times 1.66 \times 10^{-27}$ kg = 6.64×10^{-27} kg ½ 6.64×10^{-27} kg × (1530 m s^{-1})^2 = $3/2 \times 1.38 \times 10^{-23}$ J K^{-1} × T $T = 375$ K	**(3)**

Q4.

Question Number	Answer	Mark
	B	**1**

Q5.

Question Number	Answer		Mark
(a)	Pressure (of gas)	**(1)**	
	Amount of gas **Or** mass of gas **Or** number of moles / molecules / atoms	**(1)**	**2**
(b)	Extending/extrapolating the line backwards	**(1)**	
	The volume occupied by a gas will be zero at a particular temperature	**(1)**	
	Or		
	The graphs for different gases	**(1)**	
	All cut the x axis at the same temp	**(1)**	**2**

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Calculate no of nuclei • Use of $\ln 2 = t\,½ \times \lambda$ • Use of $A = \lambda N$ • $A = 3.97 \times 10^4$ (Bq)	(1) (1) (1) (1)	Example of calculation $N = (5.18 \times 10^{-5}\text{ g}/230\text{ g}) \times 6.02 \times 10^{23}$ $= 1.36 \times 10^{17}$ $\lambda \times (75\,400 \times 3.15 \times 10^7)\text{ s} = \ln 2$ $\lambda = 2.92 \times 10^{-13}\text{ s}^{-1}$ $A = 2.92 \times 10^{-13}\text{ s}^{-1} \times 1.36 \times 10^{17}$ $A = 3.97 \times 10^4\text{ Bq}$	4
(ii)	• Calculates decays in one year (ecf from (b)(i)) • Use of $pV = NkT$ • uses $T = 295$ K • $V = 5.09 \times 10^{-14}\text{ m}^3$	(1) (1) (1) (1)	Example of calculation ecf λ from (a) decays in one year = $3.97 \times 10^4\text{ Bq} \times 3.15 \times 10^7\text{ s}$ $= 1.25 \times 10^{12}$ $1.00 \times 10^5\text{ Pa} \times V = 1.25 \times 10^{12} \times 1.38 \times 10^{-23}\text{ J K}^{-1} \times 295\text{ K}$ $V = 5.09 \times 10^{-14}\text{ m}^3$	4
(iii)	• Use of $½\,m\langle c^2\rangle = 3/2\,kT$ **Or** Use of $pV = \frac{1}{3}Nm\langle c^2\rangle$ (allow ecf for N, V from (b)(ii)) • uses $m = 4u$ • $\sqrt{\langle c^2\rangle} = 1360\text{ m s}^{-1}$	(1) (1) (1)	Example of calculation $½\,m\langle c^2\rangle = 3/2\,kT$ $½ \times (4 \times 1.66 \times 10^{-27}\text{ kg}) \times \langle c^2\rangle = 3/2 \times 1.38 \times 10^{-23}\text{ J K}^{-1} \times 295\text{ K}$ $\langle c^2\rangle = 1\,840\,000\text{ m}^2\text{ s}^{-2}$ $\sqrt{\langle c^2\rangle} = 1360\text{ m s}^{-1}$ Accept the use of proton/neutron mass instead of u	3

Q7.

Question Number	Answer	Mark
	B	1