Marking Scheme

#1

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*		The specific heat capacity is the heat required to increase the temperature of 1 kg [or unit mass] of a material by 1 °C (1 degree K – or one degree/ unit temperature rise). [Alternative: equation with all terms fully defined.]	1			1		
	(b)	(i)	Idea: heat lost by boiling water=heat gained by other water (1) $1.6[\times 10^{-3}](100.0-\theta_f)=0.6[\times 10^{-3}](\theta_f-19.5)$ (1) θ_f = 78.0 °C (1) **Alternative (for second mark)** If $\Delta\theta$ is temperature rise of water in flask $1.6[\times 10^{-3}](80.5-\Delta\theta)=0.6[\times 10^{-3}]\Delta\theta$ (✓)			3	3	2	
		(ii)	Mass of water = $1.6\times 10^{-3}\times 1000 = 1.6$ [kg] (1) Application of $m=\rho V$ [even if 0.6×10^{-3} m^3 used → 0.6 kg] [Can be credited from *(b)*(i) Heat lost = 1.6(100.0 − 78.0 ecf) × 4200 (1) = 1.48×10^5 J (1) 148 J → 1 mark		3		3	3	
		(iii)	[Work done is negligible as] negligible / no change in volume.			1	1		
			Question 3 total	**1**	**3**	**4**	**8**	**5**	**0**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*		[Induced] emf (or pd or voltage) equal to (or proportional to) the rate of change (or cutting) of flux [linkage] (1) The emf [tends to] oppose the <u>change</u> [to which it is due] (1)	2			2		
	(b)		**Indicative content:** Flux in pipe(s) changes or flux cut by pipe(s) Emf induced in pipe(s) Pipe P current cannot flow / incomplete circuit Pipe Q current flows [Current] opposes motion (change) …. …..(since) magnetic field set up due to (induced) current Uniform acceleration - no opposing force or gravity only **Additional useful points –** Terminal velocity - magnetic force equal (and opposite) to weight Slow velocity - due to strong magnet or small resistance or large current GPE converted to internal energy or electrical energy or electromagnetic energy Copper is not magnetic **5-6 marks** Comprehensive list of observations made. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Some reasonable observations made. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Limited observations made. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*		6		6		
	(c)		mgh or $mc\Delta\theta$ used or implied (i.e. E_p = 2.35 J) (1) Use of $V = Ah$ (1) Use of $m = \rho V$ (1) (i.e. m = 0.056 kg) Answer = 0.109 [K] (1)		4		4	4	
			Question 5 total	**2**	**10**	**0**	**12**	**4**	**0**

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	(a)	(i)	Mass of a molecule [accept: atom or particle] [of the gas]	1					
		(ii)	Mean [accept: average] square velocity / speed [of a molecule of the gas]	1			2		
	(b)		N_A, [Avogadro's number is] the number of molecules per mole [or in a mole] [of gas] (1) There are n moles [of the gas] (1) So the total number of molecules [in the gas] = nN_A (1)	3			3		
	(c)		Realising that KE = $N_{(A)}\frac{1}{2}m\overline{c^2}$ (1) Substitution of $pV = nRT$ (1) Convincing algebra, e.g handling $\frac{2}{3}\frac{1}{3}\frac{3}{2}$(1) Explanation that n = 1 [NB. if M used need to see molar mass when n = 1] (1) **Alternative:** $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ (1) Multiplication by $N \rightarrow \frac{1}{2}Nm\overline{c^2} = \frac{3}{2}NkT$ (1) Justification that $R = kN_A$ (1) with justification (1)	4			4	2	
	(d)		$n = \frac{pV}{RT} = \frac{115\times10^3\times2.2\times10^{-3}}{8.31\times294}$ = 0.104 [mol] (1) Final temperature, $T = \frac{pV}{nR} = \frac{115\times10^3\times2.6\times10^{-3}}{0.104\times8.31}$ = 346.0 K (1) [value depends upon rounding of n. No rounding $\rightarrow$ 347.5 K] $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}\times0.104\times8.31(346-294)$ = 67.4 J (1) Allow ecf on 1 mol for the last two marks. **Alternative:** $\Delta U = \frac{3}{2}(p_1V_1 - p_2V_2)$ or $\Delta U = \frac{3}{2}p\Delta V$ (for constant pressure) (1) $= \frac{3}{2}115\times10^3(2.60-2.20)\times10^{-3}$ (1) = 69 J (1)		3		3	3	
			Question 2 total	**9**	**3**	**0**	**12**	**5**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		**Increase in temperature - kinetic theory effects** Molecules move randomly Collisions become more frequent [when heat supplied] [No change in volume so heat flowing in] causes increase in U / kinetic energy No work done [as constant volume] T increases with U as temperature proportional to U, or equivalent **Newton's laws of motion** Momentum of molecules increase Force on molecules = rate of change of momentum (during collision with wall) Force on wall is equal and opposite to force on molecules Greater forces during the collisions **Increase in pressure** Molecules collide with walls exerting force on walls and / or pressure Pressure increases with temperature Pressure = force on walls per unit area Mean pressure due to many collisions [and many molecules] **5-6 marks** Comprehensive account including reference to increase in temperature, Newton's laws of motion and increase in pressure. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Comprehensive account including reference to 2 out of 3 of increase in temperature, Newton's laws of motion and increase in pressure or brief account of all 3 areas. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Comprehensive account including reference to one of increase in temperature, Newton's laws of motion and increase in pressure or limited account of 2 areas. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*	6			6		
	(b)	(i)	rms $= \sqrt{\frac{400^2+425^2+450^2+550^2+625^2}{5}}$ (1) = 497 [m s^{-1}] (1)		2		2	2	
		(ii)	The expected rms is explained by: $PV = nRT$ so $P = \frac{nRT}{V}$ $\rho = \text{mass}/V = \frac{n\,(M_r \times 10^{-3})}{V}$ use of **both** equations by substitution (1) substitute these into: $P = \frac{1}{3}\rho\overline{c^2}$; $\sqrt{\overline{c^2}} = \sqrt{\frac{3P}{\rho}}$; $\sqrt{\overline{c^2}} = \sqrt{3\frac{nRT}{V}\frac{V}{n(M_r \times 10^{-3})}} = \sqrt{\frac{3RT}{(M_r \times 10^{-3})}}$ $\sqrt{\overline{c^2}} = \sqrt{\frac{3(8.31)(293)}{(32 \times 10^{-3})}} = 478$ [m s^{-1}] (1) Valid conclusion with data i.e. yes, the rms speed of the five molecules is slightly higher [about 4% above the expected rms of the gas] (1) **ecf** **Alternative solution**: Use $m\overline{c^2} = 3kT$ $\sqrt{\overline{c^2}} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.38 \times 10^{-23})(293)}{(32)(1.66 \times 10^{-27})}}$ with sensible substitution (1)= 478 [m s^{-1}] (1)		1	1 1	3	3	
		(iii)	Density does not change **and** Pressure increases from the original pressure p to $1.2p$ (1) i.e. an increase of 20%. so $\left(\sqrt{\overline{c^2}}\right)_{\text{new}} = \sqrt{\frac{3(1.2p)}{\rho}}$ $\left(\sqrt{\overline{c^2}}\right)_{\text{new}} = \sqrt{1.2}\sqrt{\frac{3p}{\rho}} = \sqrt{1.2}\,(478) = 524$ m s^{-1} (1)		2		2	2	

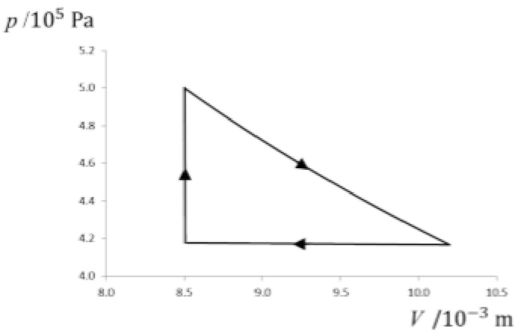
<table>
<tr><td></td><td></td><td></td><td>$(\sqrt{c^2})_{new} = \sqrt{1.2}\sqrt{\frac{p}{\rho}} = \sqrt{1.2}\,(478) = 524\ \text{m s}^{-1}$ (1)</td><td></td><td>2</td><td></td><td>2</td><td>2</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Question total</td><td>6</td><td>5</td><td>2</td><td>13</td><td>7</td><td>0</td></tr>
</table>

#5

<table>
<tr><th colspan="3" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="4">Marks available</th><th></th><th></th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td></td><td>(a)</td><td></td><td>ΔU increase (or change) in internal energy of a system (1)
Q heat flowing into the system (1)
W work done by the system (1)
Reference to system at least once otherwise award a maximum of 2 marks</td><td>3</td><td></td><td></td><td>3</td><td></td><td></td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td><table>
<tr><th>Process</th><th>Description of process</th><th>Work done on/by gas (if any)</th></tr>
<tr><td>A → B</td><td>Increase in pressure at constant volume</td><td>No work done (1) – AO2</td></tr>
<tr><td>B → C</td><td>Decrease in volume at constant pressure (1) – AO1</td><td>Work done on gas (1) – AO2</td></tr>
<tr><td>C → A</td><td>[Linear] decrease in pressure with increasing volume (1) – AO1</td><td>Work done by gas (1) – AO2</td></tr>
</table></td><td>2</td><td>3</td><td></td><td>5</td><td></td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Work done on the gas is given by the "area" enclosed
$= \frac{1}{2}(8-4)10^{-3}(2-1)10^{5}$ (1)
$= \frac{1}{2}(4)(1)10^{2} = 200$ [J] (1)</td><td></td><td>2</td><td></td><td>2</td><td>2</td><td></td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td>Use of $PV = nRT$ and note T constant (1)
At A $PV = (1\times10^{5})(8\times10^{-3}) = 800$ [J]
(or at C $PV = (2\times10^{5})(4\times10^{-3}) = 800$ [J]) (1)
Check any point on curve e.g.<table>
<tr><th>If V (m^3)</th><th>P (Pa)</th></tr>
<tr><td>5.0×10^{-3}</td><td>1.60×10^{5}</td></tr>
<tr><td>6.0×10^{-3}</td><td>1.33×10^{5}</td></tr>
<tr><td>7.0×10^{-3}</td><td>1.14×10^{5}</td></tr>
</table>(1)</td><td>1</td><td>1

1</td><td></td><td>3</td><td>3</td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Attempt at calculation of area – [accept small square count of between 170 and 280 i.e. 225 $\pm$ ~25%] (1)
If 225 i.e. 2.25 large squares, work difference =
$2\,\Delta V\,\Delta p$ (ΔV and Δp for large square)
$= 2.25\,(1\times10^{-3})(0.2\times10^{5}) = 45$ J with uncertainty of 25%, accept a value between 34 and 56 J provided method correct (1)</td><td></td><td></td><td>2</td><td>2</td><td>2</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Question total</td><td>6</td><td>7</td><td>2</td><td>15</td><td>7</td><td>0</td></tr>
</table>

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*	(i)	Substitution $n = \frac{pV}{RT} = \frac{(5\times10^5)(8.5\times10^{-3})}{(8.31)(285)}$ (1) $= 1.79$ [mol] (1)	1	1		2	2	
		(ii)	$N = N_A n = (6.02 \times 10^{23}) \times 1.79$ **ecf** $= 1.08 \times 10^{24}$		1		1	1	
		(iii)	Substitution of p and V **or** k and T (1) Correct use of Nm **or** m in either: $p = \frac{1}{3}\rho \overline{c^2}$ or $pV = \frac{1}{3}Nm\overline{c^2}$ **ecf** (1) $c_{rms} = 471$ [m s^{-1}] (1)	1	1 1		3	2	
		(iv)	Force $= pA = (5.0 \times 10^5) \times 0.04 = 20\,000$ [N]		1		1	1	
	(b)	(i)	Substitution e.g. $p = \frac{5.0\times10^5 \times 8.5\times10^{-3}}{10.2\times10^{-3}}$ (1) **ecf** on n if $pV = nRT$ used $p = 420$ k[Pa] (1)	1	1		2	2	
		(ii)	$\Delta U = 0$ (1) So by using the first law of thermodynamics $\Delta U = Q - W$ hence $Q = W = 773$ [J] (1)	1	1		2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(iii)	Work done = [–]710 [J] **or** area of triangle attempted (1) Total work done by the gas around cycle = 773 – 710 + 0 = 63 [J] **and** $Q = W = 63$ [J] (1) Axes labelled with units (1) Correct closed triangle as shown (1) Treat arrows as neutral  			4	4	3	
			Question 5 total	**4**	**7**	**4**	**15**	**13**	**0**

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
1	*(a)*		Award 1 mark for ± 0.1 [cm] **or** measure to resolution of ruler Award 2 marks for ± 0.2 [cm]	1	1		2	1	2
	(b)	(i)	$V=\pi\left(\frac{d}{2}\right)^2 l=\pi\left(\frac{1.5\times10^{-3}}{2}\right)^2\times11.5\times10^{-2}$ (subst and convincing change of units for l and d) (1) = 2.03×10^{-7} m^3 **or** 0.2 cm^3 **or** 203mm^3 (1) **unit mark**	1	1		2	2	2
		(ii)	$p_V=2p_d+p_l=2\frac{0.1}{1.5}(1)+\frac{0.2}{11.5}(1)$ (or by impl.) = 0.133 + 0.017 = 0.150 (1) allow **ecf** for this mark, on the use of 0.1 instead of 0.2 only Hence p_V = 15 % (**Alternative:** use percentages throughout)	1	1 1		3	3	3
	(c)	(i)	From intercepts with x-axis, mean = – 270 [°C] (1) Uncertainty = 20 [°C] (1) Award 1 mark only if 270 used		2		2	1	2
		(ii)	**Any 4 ×(1) from:** -Straight line -Intercept is consistent i.e. −273 °C / line would go through the origin if temp plotted in K -Passes through all error bars -Volume linked to length -$V \propto T$ **or** $l \propto T$			4	4	1	4
	(d)		Kinetic or internal energy (or velocity) approaches minimum / zero. Accept very little KE / stopped moving / molecules stop / stops vibrating Don't accept KE decreases greatly / superconduct or superfluid	1			1		

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
	(e)		**Any 2 ×(1) from:** -Meniscus or equivalent linked to liquid pellet -Moving readings -Expansion of glass -Gas not ideal -Variation in atmospheric pressure -Gas and liquid at different temperatures -Friction / viscosity of liquid pellet -Parallax / looking at eye level -Ruler not parallel to tube don't accept just ruler vertical Accept inaccuracy of thermometer Don't accept resolution of thermometer			2	2		2
			Question 1 total	**4**	**6**	**6**	**16**	**8**	**15**

#8

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	Kinetic energy and [gravitational] potential energy referred to (1) $\frac{1}{2}mv^2 - \frac{GMm}{r}$ = total [initial] energy or ΔKE = [−]ΔPE (1) Final and initial energy are zero and equal [accept final KE = 0 or final PE = 0] (1)	3			3		
		(ii)	Rearrangement / simplification i.e. $v^2 = \frac{2GM}{r}$ (1) [accept *m* = 1 inserted] Substitution e.g. $v^2 = \frac{2 \times 6.67 \times 10^{-11} \times 1.99 \times 10^{30}}{6.96 \times 10^8}$ (1) Answer = 618 [or 620] km s^{-1} (1) c.a.o. [accept ~600 km s^{-1}b.o.d.]	1	1 1		3	3	
	(b)	(i)	Applying KE of molecule/atom/particle = $\frac{3}{2}kT$ (or deriving) (1) Rearrangement e.g. accept $v^2 = \frac{3kT}{m}$ (1) Substitution e.g. $v^2 = \frac{3 \times 1.38 \times 10^{-23} \times 5780}{9.11 \times 10^{-31}}$ (1) Answer = 513 km/s (1) [accept just ~500 km s^{-1} only with correct substitution]	1	1 1 1		4	3	
		(ii)	Many electrons have enough KE to escape (ecf) or just 'some electrons escape' (1) Because (b)(i) close to (a)(ii) / some electrons have higher velocity / [Boltzmann] distribution / collisions] (ecf) (1) Or protons don't escape		2		2		
		(iii)	Valid method employed e.g. electrostatic force & gravitational forces calculated/equated or other (1) Valid calculation carried out correctly e.g. F_E = 2.4 × 10^{-28} N and F_g =2.5 × 10^{-28} N or charge = 0.084 C (1) [Or using *GMm* = *kQq* → 1.2 × 10^{-10} [N m^2] and 1.15 × 10^{-10} [N m^2]] Valid conclusion (not independent) e.g. she's quite close (1) ecf from calculation of forces [not fields] or alternative above. [Accept: *E* force bigger / *G* force smaller]			3	3	2	
		(iv)	Sun electrons ≈ $\frac{1.99 \times 10^{30}}{1.66 \times 10^{-27}}$ ≈ 1.2 × 10^{57} (assumption dependent, allow Sun composed of deuterium) (1) [Accept M_S / 1 u] $\frac{0.08}{e}$ = 5 × 10^{17} electrons lost or charge on Sun's electrons = 1.92 × 10^{38} [C] (1) % lost ≈ 10^{-38} (1)		3		3	3	
			Question 2 total	**5**	**10**	**3**	**18**	**11**	**0**