Question			Answer	Marks	Guidance
1	(a)		$E = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{1.1\times10^{-6}}$ $E = 1.8\times10^{-19}$ (J)	M1 A0	Values must be substituted Answer to 3sf is 1.81 x 10^{-19} (J)
	(b)		$m = \rho V = 8.1\times10^{-12}\times4.5\times10^{3} = (3.645\times10^{-8})$ Thermalenergygained= $(mc\,\Delta\theta) = 3.645\times10^{-8}\times520\times[1700-20]$ $(= 0.0318)$ $1.81\times10^{-19}\times6.3\times10^{19}\times t = 0.0318$ $t = 2.8\times10^{-3}$ (s)	C1 C1 A1	**Allow**: ecf from (a) and mass of titanium
	(c)		Thermal energy is conducted / transferred to the rest of titanium/metal Photons are reflected / scattered from / not absorbed the titanium surface	B1 B1	**Not:** heat lost to surroundings
	(d)		(Photon) energy is converted into potential energy (rather than kinetic energy) OR Energy is used to change solid to liquid / phase (rather than increase kinetic energy) OR Energy provides (specific) latent heat of fusion (rather than increase kinetic energy)	B1	**Allow:** energy is used to overcome the forces between atoms / breakdown the crystal structure of titanium (rather than increase kinetic energy)
			Total	**7**	

Question			Answer	Marks	Guidance
2	(a)		Idea of extrapolating graph back (to negative temperatures) Volume is zero at absolute zero / negative volumes are impossible	B1 B1	Can be shown on diagram Allow 'negligible volume' rather than zero and use of -273 ºC / 0 K
	(b)	(i)	(Internal energy of a system) is the sum of the random (distribution of) kinetic and potential energies of (all) **atoms/molecules** (in the system)	B1	**Allow :**particles
		(ii)	Any **two** from Comparison of kinetic energies in gas and liquid phases linked to temperature Potential energy of gas phase is greater than PE of liquid phase / energy must be supplied to change liquid into gas phase..	 B1 B1	 **Allow**: potential energy of gas phase is ('close' to) zero
	(c)	(i)	$p = \frac{nRT}{V} = \frac{45 \times 8.31 \times 293}{1.2 \times 10^{-2}}$ $p = 9.1 \times 10^{6}$ (Pa)	C1 A1	**No credit** If temperature is not converted to kelvin
		(ii)	$n_{He} = \frac{5.0 \times 10^{7} \times 2.0 \times 10^{-3}}{8.31 \times 293} = 41$ $p_{trimix} = \frac{[45 + 41] \times 8.31 \times 293}{[1.2 \times 10^{-2} + 2.0 \times 10^{-3}]}$ $p_{trimix} = 1.5 \times 10^{7}$ (Pa)	C1 C1 A1	**Allow:** ECF if temperature is used in ºC only if penalised in (i) Otherwise max mark allowed is 1 out of 3 for *n* = 602 mol **Allow:** use of partial pressures
		(iii)	Internal / kinetic energy of molecules decreases (as temperature falls) Hence pressure would decrease	M1 A0	**Allow:** $p \propto T$ if (n and) *V* constant
			Total	**11**	

Question			Answer	Marks	Guidance
3			**Diagram showing** • Oil in (insulated) container • Electrical heater <u>fully immersed in oil</u> • <u>Thermometer / Temperature sensor</u>	B1	**Not:** oven or hotplate **Allow:** 'Fully immersed' seen in the body of text **Thermometer /Temperature sensor** must be spelled correctly on diagram
			Electrical circuit • Ammeter in series , voltmeter in parallel with heater / joulemeter in parallel with heater • Power supply /+ & - signs marked on wires	B1	All elements should be shown to score these diagram marks. Ignore appropriate additional items Connections to heater should be clear.
			Measurements • Measure mass of oil /use known mass of oil, • Measure change in temperature / initial and final temperatures • Measure current, pd and (fixed) time / energy	B1	Must have all elements. **Allow:** Use of symbols **Allow:** Take energy reading from joulemeter **Not:** use given power rating of heater
			Calculation $\text{Input Energy} = E = Pt = VIt \quad \text{and} \quad c = \frac{E}{m\Delta\vartheta}$	B1	Input energy must be consistent with equipment used. c must be the subject of the equation and temperature **rise** ($\Delta\vartheta$ or $\vartheta_2 - \vartheta_1$) must be clear. **Allow**: Draw graph of temperature against time $c = VI$ / [gradient x mass]
			Uncertainties Any **two** together with minimising action. • Heat losses (make $\Delta\vartheta$ uncertain) - minimise by using initial ϑ below and final ϑ <u>same amount</u> above, room temperature • Temperature varies throughout oil - minimise by stirring before taking temperature readings • Some energy is required to raise temperature of the container / heater (etc) - allow by including in calculation. • Temperature will continue to rise after heater is turned off – find max temperature.	2 x B1	These points may be scored in the description of method. No credit for other uncertainties including heat lost to surroundings
			Total	6	

Question			Answer	Marks	Guidance
4	(a)	(i)	Molecules (of the liquid) are in random / haphazard motion (AW) Molecules (of liquid) are smaller than pollen grains	B1 B1	Not zig-zag must compare to pollen grains **Ignore** mass is smaller
		(ii)	Increase the temperature (of the liquid)	B1	**Allow:** Heating the liquid
	(b)	(i)	Any **three** from: • Collisions with the walls/container/sides are elastic • force between molecules is negligible / zero except during collisions • Volume of the molecules is negligible compared to the volume of the container (AW) • Time within a collision is negligible compared to time between collisions **Max 3**	(B1) (B1) (B1) (B1) B3	**Collision/collides** must be spelled correctly to score the mark Ignore collisions between gas molecules Must refer to comparison to score either of the last two points. Ignore references to incomplete assumptions and assumption not given in expected answer.
		(ii)	Momentum of the molecule changes when it collides with the wall (AW) Force on the molecule is rate of change of momentum (by N 2nd Law) (By N 3rd Law) Force on wall is equal to and opposite to the force on the molecule pressure = $\frac{\textbf{sum}\text{ of forces (due to all molecules)}}{\text{Area of wall}}$	B1 B1 B1 B1	**Allow:** There is an impulse on molecule when it collides with wall.

Question			Answer	Marks	Guidance
	(c)		$\rho = \frac{m}{V}$ (any subject) $n = \frac{m}{M}$ (any subject) $pV = nRT$ $p\left(\frac{m}{\rho}\right) = \left(\frac{m}{M}\right)RT$ $p = \frac{\rho RT}{M}$	M1 M1 A1 A0	**Allow:** $\rho = \frac{m}{V}$ (M1) A clear statement of "n = 1 then m = M" (M1) **Note:** <u>Both</u> M marks must be scored and the method **must be clear** to score the A1 mark. $pV = nRT$ $p\left(\frac{M}{\rho}\right) = RT$ (A1) $p = \frac{\rho RT}{M}$ (A0)
	(d)	(i)	Use of $p \propto \rho T$ or $\frac{p_T}{p_B} = \frac{\rho_T T_T}{\rho_B T_B}$ $0.35 = \frac{\rho_T \times 240}{1.3 \times 293}$ $\rho_T = \frac{0.35 \times 1.3 \times 293}{240}$ $\rho_T = 0.56$ (kg m^{-3})	C1 C1 A1	**Allow:** any subject **Allow:** any subject **Allow:** Max 1 mark if temperatures are not converted to kelvin. Expect density to be – 0.276 kg m^{-3} Answer to 3 sf is 0.555 (kg m^{-3})
		(ii)	**Correct** use of $N \propto \frac{p}{T}$ or $\frac{N_T}{N_B} = \frac{p_T T_B}{p_B T_T}$ $\frac{N_T}{N_B} = \frac{0.35 \times 293}{240}$ $\frac{N_T}{N_B} = 0.43$	C1 A1	Do not penalise use of ºC if already penalised in (i) **Allow:** Alternative approach using $\frac{N_T}{N_B} = \frac{\rho_T}{\rho_B}$ with possible ecf from (i) Answer to 3 sf is 0.427
			Total	18	

Question			Answer	Marks	Guidance
5	**(a)**		Mass of air = 4.5 x 4 x 2.4 x 1.3 (= 56.2)	B1	
			$Q = mc\Delta\theta$ = 56.2 x 990 x (21 – 12) Q = 5.0 x 10^5 (J)	C1 A1	**Allow:** follow through (FT) for mass of air **Note:** Max 1 mark out of 3 if temperature **rise** is given as 282 K.
	(b)	**(i)**	$t = \frac{Q}{P} = \frac{5.0 \times 10^5}{2300}$ $t = 220 \quad (s)$	C1 A1	Possible **ecf** from **(a)** Answer is 217 (s) or 218 (s) to 3 sf depending on accuracy of Q used from (a)
		(ii)	$\text{Volume of gas}, V = \frac{5.0 \times 10^5}{39 \times 10^6}$ (= 0.0128 (m^3)) $\text{Mass of gas} = V\rho = 0.0128 \times 0.72$ $\text{Mass} = 9.2 \times 10^{-3} \quad (kg)$	C1 A1	Possible **ecf** from **(a)**
	(c)		Any **two** from the following : • thermal energy/heat is lost through or to walls / ceiling / floor/windows /door of room (AW) • other objects within the room (AW) • warm air may escape from room / cold air or draughts may enter the room	B1 B1	**Not:** Bald 'Heat lost to surrounding' **Ignore** any references to heater
			Total	**9**	