Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1	a		$\lambda = \frac{v}{f}$ $(= \frac{340}{262})$ $\lambda = 2L$ $(L =)\ \frac{1.30}{2} = 0.65$ (m)	B1 B1 B1	Formula may be implied by substitution **Allow** *c* for *v* Relationship may be inferred from a correct diagram of fundamental drawn in a tube open at both ends,or from a statement such as 'half a wavelength fits inside the tube' Some working leading to correct answer must be shown; don't accept a bald answer **Allow** *L* = 0.649 (0.64885) as evidence of working Do not allow working backwards from the answer **Examiner's Comments** This is a 'show that' question and so every step of the calculation needs to be made clear. It is not enough to point out that 340 / (2 × 262) = 0.65: the examiner needs to know why the data is being combined in this particular way. The step that was most often omitted was saying that, for the fundamental (lowest) frequency, half a wavelength fits inside the flute. This could be demonstrated using a diagram, showing an open tube containing half a wavelength with antinodes at both ends. However, a written statement (length is half of a wavelength) or a mathematical statement ($L = \lambda/2$) are just as good.
	b	i	Any **two** from • particles occupy negligible volume (compared to volume of container/gas) • collisions are (perfectly) elastic • time of collisions is negligible (compared to the time between collisions)	B1 × 2	Mark as for Short Answer Questions (requiring only a list by way of a response) and contradictory responses see page 3. **Allow** zero / no / none for negligible throughout **Ignore** particles occupy negligible space

			• negligible <u>forces</u> exist between particles (except during collisions)		**Ignore** particles are very small **Allow** <u>kinetic</u> energy is conserved (during collisions) **Allow** the particles move at constant velocity (in between collisions) **Ignore** type of force if specified **<u>Examiner's Comments</u>** Most candidates confidently wrote two correct assumptions. Errors most often came about through careless wording, such as 'the time between collisions is negligible' (rather than the time of collisions) or 'the particles take up negligible space' (rather than volume).
		ii	$M = 4.00 \times 10^{-3}$ (kg mol^{-1}) $T = 263$ (K) $v^2 = \frac{1.67 \times 8.31 \times 263}{4.00 \times 10^{-3}}$ $v = 955$ (m s^{-1}) $f = (\frac{v}{\lambda} =) \frac{955}{1.30} = 730$ (Hz) **Alternative method using ratios** $\frac{f_1}{f_2} = \left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2}$ or $\frac{v_1}{v_2} = \left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2}$ $T = 263$ (K) $\left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2} = \left(\frac{1.67 \times 263 \times 29}{1.4 \times 293 \times 4}\right)^{1/2}$ $= 2.786$ $f\ (= 2.786 \times 262) = 730$ (Hz)	C1 C1 C1 A1 C1 C1 C1 A1	This C1 mark is for converting *M* into kg mol^{-1} **Allow ECF** for an incorrect POT in *M* *T* = -10 (K) is **XP** onwards (first C1 mark can still be scored) but **allow ECF** for incorrect conversion of *T*. This C1 mark is for correct substitution into the given formula; v^2 does not need to be calculated for the mark but seeing *v* = 955 implies the mark **Allow** *M* given to 1sf **Allow** 8.3 or *R* for 8.31 If a value for γ or *M* is taken from the wrong row of the table, this is a TE (*M* must be in kg/mol). If both wrong values are used, count this as a single TE. **ECF** candidate's value of λ or (λ = 2L) from 1a **Allow** *f* = 740 (Hz) For reference, POT error in *M* gives *v* = 30.2 (ms^{-1}) and *f* = 23 (Hz) *T* = −10 (K) is **XP** onwards (first C1 mark can still be scored) but **allow ECF** for incorrect conversion of *T*

					This C1 mark is for substitution and the ratio 2.786 does not need to be calculated for the mark The values for *M* may be given in kg/mol or left in g/mol as long as there is consistency **Allow** *M* = 4 to 1sf **Allow** *f* = 740 (Hz) If using $\frac{v_1}{v_2}$ then v = 2.786 × 340 = 947 giving *f* (= *v* /*λ* = 947 / 1.3) = 730 (Hz) but **ECF** candidate's own value of *λ* or *L* (*λ* = 2L) from 1a **Examiner's Comments** **Common problems in 1 (b) (ii)** • failing to convert the molar mass *M* into units of kg mol^{-1} • substituting the length of the flute (0.65m) instead of 1.30m for the wavelength.
•			**Total**	**9**	
2	a	i	Internal energy (of an ideal gas) is the sum of the (randomly distributed) kinetic energies of the particles	B1	Allow use of KE or E_k and atoms/molecules for particles. Ignore reference to PE (of particles) **Examiner's Comments** This definition did not trouble the vast majority of candidates, although some did forget to mention about particles. References to potential energy were ignored.
		ii	evidence of $NkT = \frac{1}{3}Nmc^2$ Manipulation to insert ½ to give ½*mc*^{2} = *3/2 kT*	M1 A1	**Examiner's Comments** Almost all candidates that responded successfully equated the two expressions here. Many then went on to successfully manipulate the equation to give the familiar relationship given in the Mark Scheme and in the formula sheet.
	b	i	(r.m.s. speed =) $\sqrt{\frac{310^2+370^2+440^2+550^2}{4}}$ r.m.s. speed evaluated as 427 (m s^{-1})	M1 A1	Not arithmetic mean 418. Treat as XP. Allow 729100 as evidence of summation of squares Allow mean squared speed = 182275

					(m^2s^{-2}) Allow any candidate evaluation that rounds to or is 427 i.e. 426.93… **<u>Examiner's Comments</u>** Most candidates completed this item successfully by squaring each number, adding those four results, dividing that by four and square rooting as shown in the Mark Scheme. Those that did not either made a numerical slip or calculated the simple mean of the four numbers.
		ii	$\frac{1}{2}mc^2 = 3/2\ kT$ $\frac{1}{2}m \times 430^2 = 3/2 \times 1.38 \times 10^{-23} \times 290$ (molar mass = $6.02 \times 10^{23} \times 6.49 \times 10^{-26}$) molar mass = 0.039 (kg mol^{-1})	C1 C1 A1	allow $\frac{1}{2}Mc^2 = 3/2\ RT$ allow any valid rearrangement allow $\frac{1}{2}M \times 430^2 = 3/2 \times 8.31 \times 290$ allow m = $6.5… \times 10^{-26}$ (kg) or m = 6.7×10^{-26} (kg) Using 427 m s^{-1} gives 0.0396 i.e. 0.040 **<u>Examiner's Comments</u>** This question proved rather more challenging than the 20(a)(ii), even though the formula was included in the formula booklet. The most common error was omitting the 'square' on the mean-squared-speed. The conversion from the mass of a single particle to the molar mass proved challenging. **Examination Tip** Quantities and units in Physics can be of either or mixed case. In this question, n, N, m and M are all valid quantities and can be muddled easily. Also, as a check, the mass of a mole of a substance in grams is equal to the relative formula mass, i.e. one mole of iodine-128 has a mass of 128 g or 0.128 kg.
	c	i	Energy transferred from electrical (energy) to internal (energy) or thermal (energy) of filament	B1 B1 B1	Allow power supply doing electrical work on filament Allow heating of gas by conduction

			Energy transferred from filament to internal energy of gas (because) the (rate of) energy lost to the surroundings = the (rate of) energy transfer gained (by filament)		Allow description of Newton's Law of Cooling Allow heating of gas by radiation Allow reference to thermal equilibrium of any part or whole of lamp structure **Examiner's Comments** Again, the language required to suitably communicate the correct Physics was challenging here. Respones which described gas law physics had missed the point. The principal reasons why the temperature of the filament does not increase above any given temperature is that the energy in = energy out in a given time period. Further marks were for describing the energy process for supplying energy to the filament and the transfer of energy away from the filament. **Examination Tip** Quantities in Physics remain unchanged often because an idea of equilibrium or balancing two sides of an equation (see questions 16(a)(iii) or 16(b) for earlier examples). Explaining the physics of either side of that equation is often creditworthy.
		ii	(P/T = constant) $\frac{120}{2400} = \frac{p}{290}$ pressure = 14.5 (kPa)	C1 A1	Allow 15 Allow 14 **Examiner's Comments** Most candidates used the directly proportional relationship of pressure to absolute temperature successfully here.
			Total	**13**	
3			**D**	1	**Examiner's Comments** Option C can be eliminated here because N m is equivalent to the joule, which is not equivalent to kW, the unit of power. Option A cannot be correct as it has a negative absolute temperature.

					Option B cannot be correct - the units are equivalent however 1 kg m s^{-1} and 1 N s are equivalent.
			Total	**1**	
4		i	**Either** (thermal/heat) energy required per unit mass to change solid to liquid <u>at constant temperature</u> **or** (thermal/heat) energy released per unit mass when liquid changes to solid <u>at constant temperature</u>	B1 (B1)	**Ignore** $L = E/m$ unless letters are defined **Allow** energy per kg /energy of 1kg for energy per unit mass **Allow** energy required to melt unit mass at constant temperature **Allow** energy released when unit mass solidifies at constant temperature **<u>Examiner's Comments</u>** There were several reasons why responses to this question did not gain credit: • constant temperature was not mentioned • per unit mass (or per kg) was omitted • the phase change was not stated, or was incorrect • it was stated that energy was required to turn a liquid into a solid.
	•	ii	(Energy =) $Pt = mL$ $m = \frac{40 \times 60}{9.4 \times 10^4} =$ **2.6 × 10^{-2}** (kg)	C1 A1	**Allow** $E = Pt$ **and** $E = mL$ seen separately Formulae may be implied from subsequent calculation Correct to at least 2sf 2.553 ×10^{-2} to 4sf so annotate 2.5 ×10^{-2} as AE **<u>Examiner's Comments</u>** This question was well answered by most candidates. However, some tried to use $E = mc\Delta\theta$ with $\Delta\theta$ = 160°C and a few gave their answer to only 1 sf.
		iii	Any two from • not all the heat / energy is used to melt the PLA **or** some	B1 × 2	For environment, **allow** printer or any named part of printer (e.g. nozzle, print head, print bed, build plate, hot-end, cables)

			heat / energy is 'lost' (to environment / surroundings) • some heat / energy / time is used to raise temperature of PLA up to **or** above its melting point / 160°C • (PLA not all applied to same spot so) PLA needs (time) to move from one place to another • PLA needs (time) to solidify		**Allow** energy transfer is not 100% efficient **Not** energy is lost through sound or light **Not** PLA needs time to melt **Examiner's Comments** The most common correct response related to energy dissipated to the surroundings. A smaller number of correct responses mentioned that energy was needed to raise the temperature to melting point. Some candidates incorrectly referred to energy used for other parts of the system (e.g. motors to drive the mechanism) which was not relevant to the question.
		iv	a single line (or curve) starting at **A** which gradually and continuously rises to 160°C followed by an initial flat section at 160°C after a flat section at 160°, the line (or curve) rises and then falls back to 160°C a second flat section at 160°C followed by a single line (or curve) which gradually and continuously falls, ending at **B**	B1 B1 B1	Note: this flat-topped shape gains the first and third marks  **Examiner's Comments** Most responses gained 2 marks for a line from point A followed by a flat section at 160°C and then a line down to point B. A small minority of candidates also gained the 3rd mark for a 'blip' within the flat section, rising above 160°C. Responses that went from A to B without a flat section at 160°C gained no credit.
			Total	**8**	
5		i	Use of KE_{mean}= 3/2 kT = 3/2 x *k* x 4.0 x 10^6 $= \frac{3}{2}\times 1.38\times 10^{-23}\times 4\times 10^{6}$ $=8.3\times10^{-17}$ J.	C1 A1	Allow k Unrounded answer is 8.28… x 10^{-17} **Examiner's Comments** Candidates answered Question 23 (b) (i) well, provided that they used the correct temperature i.e. that of the stellar atmosphere and not the surface temperature.

		ii	$= -2.3\times10^{-16} + 8.3\times10^{-17}$ $= -1.5\times10^{-16}$ J.	B1	Allow use of 10^{-16} J from stem to give -1.3×10^{-16} J Reject response without negative sign **<u>Examiner's Comments</u>** The helium nucleus in parts (b) (ii) and (b) (iii) has a KE of 10^{-16} J and a GPE of -2.3×10^{-16} J. This helium nucleus cannot therefore escape and so the GPE at the further possible point of the helium nucleus must be negative. The GPE at this furthest possible point is where the KE is zero and there has been a gain of 10^{-16} J of GPE, giving the GPE = -1.3×10^{-16} J, using the values in the question. Of course, we used the exact value calculated in part (b) (i) instead of 10^{-16} J, giving $U = -1.5 \times 10^{-16}$ J as the 'correct' answer.
		iii	selection of GMm/r Substitution of values for M,m and energy and rearrangement 3.2×10^{10}m e.g. $(-)\frac{GMm}{r} = (-)1.5\times10^{-16}$ $r = \frac{6.67\times10^{-11}\times1.1\times10^{31}\times6.6\times10^{-27}}{1.5\times10^{-16}}$ $= 3.2 \times10^{10}$m	C1 C1 A1	Allow ECF from (b)(ii) NB Use of values in stem gives 3.7 $\times10^{10}$ **<u>Examiner's Comments</u>** The helium nucleus in parts (b) (ii) and (b) (iii) has a KE of 10^{-16} J and a GPE of -2.3×10^{-16} J. This helium nucleus cannot therefore escape and so the GPE at the further possible point of the helium nucleus must be negative. The GPE at this furthest possible point is where the KE is zero and there has been a gain of 10^{-16} J of GPE, giving the GPE = -1.3×10^{-16} J, using the values in the question. Of course, we used the exact value calculated in part (b) (i) instead of 10^{-16} J, giving $U = -1.5 \times 10^{-16}$ J as the 'correct' answer.
		iv	Reference to Boltzmann distribution / AW OR Some particles will have greater kinetic energies /lower masses	B1	**<u>Examiner's Comments</u>** Question 23 (b) (iv) has several acceptable responses yet the predominant correct candidate answers were that the solar wind particles might be lighter (i.e.

					hydrogen) or that the Maxwell-Boltzmann distribution of KE values in a gas of particles would mean that some particles would have greater than average KE. **Assessment for learning** Usually in physics calculations, we use the calculator value all the way through the calculation. Any rounding should take place at the very end of the calculation.
			Total	**7**	
6	a		pV=nRT mass (or m) = nM Substitution into $\rho = \frac{m}{V}$ for m and V and cancelling n to give $\rho = \frac{pM}{RT}$	M1 M1 M1 A0	Not n=1 Not n=1 **<u>Examiner's Comments</u>** Successful candidates correctly identified the starting point for this question as the ideal gas equation, *pV = nRT.* Many candidates took the approach that *n* = 1 which was not sufficient. A more sufficient proof used the idea that the total mass of the gas was *n* × *M,* allowing cancelling of the *n* in the ideal gas equation.
	b	i	$\rho = \frac{100\,000 \times 0.029}{8.31 \times 293}$ $=1.19$ kg m^{-3}	M1 A0	Accept R for 8.31, T = 293.1(5) Reject 20 for T. **<u>Examiner's Comments</u>** The vast majority of candidates correctly substituted values into the given formula, also remembering to convert the temperature from celsius into kelvin. Good practice for "show that" questions is to calculate the quantity required to at least one more significant figure in the question. In this example, that would mean evaluating the density to 1.19 kg m^{-3}.

		ii	Mass of air = 1.19 × 12,000 = 14 300 kg Weight of air = mg = 140 000 N	C1 A1	Accept all answers that round to 140 000 N, eg 140210, 141264 **Examiner's Comments** In part (b) (ii), finding the weight was a matter of finding the mass and then finding the weight, all by using data in the question.
		iii	Upthrust = weight of fluid or air displaced Airship in equilibrium/resultant force is 0 (so upthrust = weight of the airship)	B1 B1	Do not accept unqualified “Archimedes' principle” Not water for fluid **Examiner's Comments** Part (b) (iii) required understanding of Archimedes' principle, rather than merely referring to it. Most candidates successfully related the principle to this context, writing about the upthrust being equal to the weight of fluid or air displaced by the gasbag. This is *always* true, regardless of the other forces that may be in play. References to displacement of water at this point were rejected. Fewer candidates completed the explanation by mentioning that the upthrust must be equal to the weight of the gas bag because we know that the gas bag is in equilibrium.
		iv	**Two** from • (Greater pressure) would increase the density/mass/weight of the helium • (increased pressure but) no change in volume therefore no more upthrust. • If the volume goes up then the upthrust will increase / ORA • Pressure only needs to be large enough to inflate the gasbag • (increased pressure difference or volume) may cause structural failure • (higher pressure means) more collisions of helium atoms with	B1 x 2	**Examiner's Comments** Most candidates scored a mark in part (b) (iv) because they referred to some sort of structural failure if the pressure increased. Others delved a bit deeper, correctly stating that an increase in mass without an increase in volume (and hence upthrust) would cause the gas bag to sink. **Misconception** Some candidates confused the ideas of mass and weight. Remember that weight = mass × gravitational field strength.

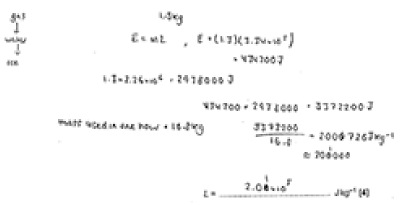
			walls so more leakage of helium		**Misconception** Some candidates suggested that an increase in pressure alone would cause a change in temperature in this question, using the ideal gas equation as supporting evidence. Here, the pressure change has been caused by an increase in the number of moles of gas. As previously mentioned, candidates should take care to think about what is constant in such relationships and what is not.
	c		F = ([delta mass ÷ delta time] x speed =) 7.8 x 45 = 350N	C1 A1	reject 'F=ma = 7.8 x 45' score zero annotate XP **Examiner's Comments** Question 20 parts (c) and (d) group well here. Part (c) is similar in nature to previous questions about rate of change of momentum. We rejected the use of the idea *F=ma* as it is wrong physics, even though the numerical value is the same.
	d		Density or mass per unit time is less so the (rate of) momentum change from the engines is reduced. There is less drag/resistive force on the airship.	B1 B1	**Examiner's Comments** The idea of rate of momentum transfer carries on in part (d). Most candidates correctly assumed that the density of air at high altitudes is much lower than at low altitudes. Many candidates implied that this meant a reduction in drag, which is correct. Far fewer correctly described the reduction of rate of change of momentum, causing less thrust. **Assessment for learning** Candidates should take care to use technical language. In this question, responses that included ideas of 'less air to push' or 'less mass moved per second' are insufficient at A2 Level.
			Total	**14**	
7			D	1	
			Total	**1**	

8			C	1	
			Total	**1**	
9		i	$\lambda_{max} \propto 1/T$ (T has decreased over time so in the past) the <u>peak</u> was at a shorter wavelength / further to the left on the graph	B1 B1	**Not** $\lambda_{max} = 1/T$ May be inferred from candidate's diagram **Ignore** overall shape of spectrum **<u>Examiner's Comments</u>** The mention of Wien's displacement law gave a clue that it would be useful in answering the question. A mark was given for stating the law. Note that the law is $\lambda_{MAX} \propto 1/T$ rather than $\lambda \propto 1/T$ or $\lambda_{MAX} = 1/T$. Candidates who did not draw on the diagram to illustrate their response sometimes missed the second B1 mark because they said that the wavelength (rather than the <u>peak</u> wavelength) would have been smaller. If an examiner says, 'You may draw on the diagram', it is generally a beneficial approach.
		ii	$E\left(=\frac{hc}{\lambda}\right)=\frac{6.63\times10^{-34}\times3\times10^{8}}{1.1\times10^{-3}}$ $E = 1.8 \times 10^{-22}$(J)	C1 A1	Full substitution needed if judging explicitly **<u>Examiner's Comments</u>** This was a straightforward question and most candidates correctly chose and applied the formula $E=\frac{hc}{\lambda}$ **Common problems in 4(b)(ii)** • not converting mm to m • trying to convert the answer to or from MeV
•		iii	**EITHER** $\frac{3\times10^{-6}}{1.8\times10^{-22}}$ **or** 1.66×10^{16} (photons m^{-2} s^{-1}) **OR** $3 \times 10^{-6} \times (150 \times 10^{-4})$ **or** 4.5×10^{-8} (W) number of photons per second $\left(=\frac{3\times10^{-6}\times150\times10^{-4}}{1.8\times10^{-22}}\right)$	C1 A1	**Allow** 2×10^{14} (s^{-1}) or 3×10^{14} (s^{-1}) Expect to see $1.66 \times 10^{16} \times 150 \times 10^{-4}$ **or** $\frac{4.5\times10^{-8}}{1.8\times10^{-22}}$ **<u>Examiner's Comments</u>** This is a complex, multi-stage calculation. A good approach was to use:

			= 2.5 × 10^{14} (s^{-1})		number of photons per second × energy of each photon = amount of energy per second = power = intensity × area The total intensity of the microwave background radiation was given at the start of the question as 3 × 10^{-6} Wm^{-2}. Converting cm^2 into m^2 proved difficult for many.
		iv	*E* = *Pt* = *IAt* and *V* = *Ah* where *A* is CSA of cylindrical tank and *h* is height of tank $\Delta\theta = \frac{E}{mc} = \frac{IAt}{\rho Ahc} = \frac{It}{\rho hc}$ and so $\frac{\Delta\theta}{t} = \frac{I}{\rho hc}$ $E = mc\theta$ **and** $m = \pi\rho V$ max temp rise s^{-1} $(= \frac{\Delta\theta}{t}) = \frac{3 \times 10^{-6}}{1000 \times 5 \times 4200}$ max temp rise s^{-1} = 1 × 10^{-13} (°C s^{-1})	C1 C1 A1	**Allow** nonstandard letters as long as meaning is clear **Allow** 1000 (kg m^{-3}) for *ρ* **Allow** $\pi r^2 h$ or $5\pi r^2$ for *V* **Allow** answer to more than 1s.f. (1.43 × 10^{-13} (°C s^{-1})) **Examiner's Comments** This too was a complex, multi-stage calculation. Most candidates correctly found their way into the question by writing down the formula $E = mc\Delta\theta$ and realising that they needed to use the formula $\rho = m/V$ in order to calculate the mass. The volume *V* of the cylindrical tank could be found using *V* = depth × cross-sectional area. However, although the depth was specified in the question, the cross-sectional area was not. Successful candidates realised that, if the cross-sectional area was not given, then it must cancel out later in the calculation. Some used algebra and called the cross-sectional area *A*. Others simply made up a value for *A* (*A* = 1 m^2 is the easiest).
			Total	**9**	
10	a	i	(diameter =) 6.4 × 3.1 × 10^{16} **or** 2.0 × 10^{17} (m)	C1	**Allow** (radius =) 3.2 × 3.1 × 10^{16} **or** 9.9 × 10^{16} (m) **Examiner's Comments**

			(volume =) 4/3 π × $(9.9 \times 10^{16})^3$ (volume =) 4.1×10^{51} (m^3)	C1 A0	Candidates successfully converted the radius from parsecs into metres and from there the volume of the nebula.
		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	<u>**Examiner's Comments**</u> This brief yet multi-stage question proved relatively challenging. The correct approach here was to find the average kinetic energy of a single particle (using Ek = 3/2 kT) and then multiplying this by the number of particles in the nebula. The number of particles in the nebula was found by multiplying the number density by the volume of the nebula.
	b	i	Mass is proportional to volume **or** diameter^3 **or** radius^3 or $(\frac{6.4}{3})^3$ or $(\frac{3.2}{1.5})^3$ ratio = 9.7	C1 A1	**Allow** attempt at calculating volume of second nebula and comparing volumes directly **Allow** 9.76 (if volume divided by volume of Sun's nebula) <u>**Examiner's Comments**</u> Candidates used several different approaches here. By assuming a similar density, the mass is directly proportional to the volume. Some candidates calculated the volume of the Sun's nebula. Others correctly assumed that the volume and hence mass of each nebula was directly proportional to the diameter^3 (or radius^3).
		ii	Fuel (hydrogen) runs out Super red giant star (Mass of core > Chandrasekhar limit /1.4 therefore) supernova neutron star or black hole (formed)	B1 B1 × 3	**Note: incorrect order is CON** **Allow** alternative route: Red giant formed (mass of star< 10 solar masses, therefore) planetary nebula (and) white dwarf formed <u>**Examiner's Comments**</u> Some candidates used the ratio from the previous part of the question to assume that the star from nebula X would eventually become a white

					dwarf, as suggested in one of the endorsed textbooks. Others used the information in the question, i.e. that the mass of nebula X was far greater than that of the Sun. This meant they were justified in assuming that this particular star would become a supernova. Both approaches were acceptable, provided the candidate chose one route and described it correctly.
			Total	**11**	
11	a		Kinetic energy of particles is constant **and** the potential energy increases. internal energy has increased (as the internal energy = KE + PE)	B1 B1	**Allow** internal energy of a gas is the kinetic energy of the particles **Allow** potential energy of particles in a liquid is negative/the potential energy has increased to zero **<u>Examiner's Comments</u>** Most candidates got at least one of the marking points here. A significant fraction correctly linked the increase in PE and the constant KE to an increase in total internal energy.
	b	i	$pV = nRT$ **and** $T = 296$ (K) $100 \times 10^3 \times 15 = n \times 8.31 \times 296$ $n = 610$ (mol)	C1 C1 A1	**Note** answer is 609.81559… **Allow** 1 mark for 7850; 23 used instead of 300 K **<u>Examiner's Comments</u>** Almost all candidates could show this well, by using the ideal gas equation carefully. Those that scored less than full marks often did so because they forgot to convert the temperature from Celsius to kelvin.
		ii	(mass = 610 × 0.028) = 17 (kg)	B1	**Allow** ecf from (b)(i) Expect n=600,610,609(.8…) **<u>Examiner's Comments</u>** Candidates consistently used their answer from the previous part of the question to calculate the mass of nitrogen gas.

		iii	Reduce the pressure or increase the temperature (at which it is added)	B1	**Examiner's Comments** This question asks the candidate to rearrange the ideal gas equation and think how to reduce the value for *n*. If *V* is constant, the only two ways of reducing the expression *pV*/*T* is to either reduce the pressure or increase the temperature.
		iv	The energy is transferred from the water vapour is equal to the energy gained by the liquid nitrogen $L_v = \frac{m_{H_2O} \times (L_{fusion\,H_2O} + L_{evaporation\,H_2O})}{m_{N_2}}$ $L_v = \frac{1.3 \times (334000+2260000)}{17}$ Lv = 2.0 × 10^5 (J kg^{-1})	C1 C1 C1 A1	**Allow** use of only one of the specific latent heats of water at this stage e.g. $m_{N_2} \times L_{N_2} = m_{H_2O} \times L\ vaporisation_{H_2O}$ **NOTE**: this can be awarded across whole response Evidence of addition of **both** latent heats (of water) is required **Note** answer is 1.97 × 10^5 to 3 SF **Note: 1 mark only for**: answer using only fusion = 2.5 or 2.6 × 10^4 (J kg^{-1}) answer using only vaporisation = 1.7 × 10^5 (J kg^{-1}) **Examiner's Comments** Most candidates calculated the energy loss for either the vapour to liquid change or the liquid to ice change for the water. A minority realised that the correct approach was to add these two energy changes before dividing by the mass of the nitrogen.  This candidate has set out the calculation very carefully, with a diagram in the top left to help their thinking. They have calculated the energy loss required to condense the

					vapour to liquid water and also the energy loss required to freeze the water to ice. These calculations are done on separate lines yet one after the other. This total energy loss must be equal to the total energy gained by the nitrogen when turning from liquid to gas.
			Total	**11**	
12			**D**	1	**<u>Examiner's Comments</u>** By thinking about the formula for specific heat capacity ($\Delta E = m\ c\ \Delta\theta$) and dividing both sides by Δt, the equation becomes $P = m\ c\ \Delta\theta\ /\ \Delta t$. $\Delta\theta\ /\Delta t$ is the equivalent to the gradient, G. Rearranging this will give the correct answer.
			Total	**1**	
13			**A**	1	**<u>Examiner's Comments</u>** Three-quarters of all candidates could recall that statement three is not true, leaving only the first two statements to be implied by the assumption of the kinetic theory of gases.
			Total	**1**	
14			**C**	1	**<u>Examiner's Comments</u>** A sensible approach here is to use the equation $p = 1/3\ \rho$ $p = 1/3\ \rho \overline{c^2}$ and $\rho = M\ /V$ where M is the total mass of the gas. Given that there is 1.0 mole of gas, the total mass of gas is Avagadro's number multiplied by the mass of each gas particle. By suitable rearrangement, the volume can be found.
			Total	**1**	