1)

Question			Expected Answers	Marks	Additional guidance
	a		(n) number of **moles** (T) **absolute** temperature OR thermodynamic temp OR temp measured in **Kelvin**	B1 B1	 Accept **K** for Kelvin
	b	i	(When gas is heated) molecules gain KE/move faster this would cause more collisions/sec (with the walls) collisions exert more force/greater change in momentum per collision For constant pressure fewer collisions/sec are required Constant pressure is achieved by the increase in volume OR with a bigger volume there are fewer collisions/sec	B1 B1 B1 B1 B1 *max 4*	If no reference to rate of collisions, max of 3 marks This must be explained fully but can be done with reference to $P = (1/3)\rho <c^2>$
		ii	correct substitution in pV/T = constant: OR V/T = constant e.g. 1.2×10^{-4} /**293** = V/**363** V= (363/293)x1.2x10^{-4} = **1.49 x10^{-4}** m^3.	 C1 A1	 Both temps must be in Kelvin. Allow 1.5 x 10^{-4} m^3
	c		Use of $1/2m<c^2> = 3/2\ kT$ Correct substitution: $\sqrt{<c^2>} = \sqrt{(3kT/m)} = \sqrt{(3\times1.38\times10^{-23}\times363/4.7\times10^{-26})}$ $\sqrt{<c^2>}$ = **565** ms^{-1}	C1 C1 A1	If 90^0 C is used $\sqrt{<c^2>}$ = 282 ms^{-1} and scores 2 marks Allow 570 ms^{-1} If they do not square root, they get 319225 ms^{-1} and score 2 marks
			Total	**11**	

2)

Question	Expected answers	Mark	Additional guidance
(a)(i)	smoke particles move in random/haphazard/zig-zag/jiggling/jerky manner	B1	random/haphazard/zig-zag/ jiggling/jerky must be spelled correctly
(a)(ii)	ANY 3 of the following: B1 + B1 +B1 movement of smoke particles caused by (being hit by) **randomly moving air molecules** smoke particles are continuously moving because the **air molecules** are **continuously moving** smoke particles are visible but air molecules are not hence **air molecules must be (very) small**. small movement of smoke particles is due to the large numbers of **air molecules hitting from all sides**	 (B1) (B1) (B1) (B1) B3	 An observation must be **linked** to an appropriate conclusion Condone reference to "water molecules" in place of air molecules. Condone air atoms/particles. Max 3
(b)	(absolute) temp $\propto$ mean KINETIC ENERGY $½ m_o (v_o)^2 = ½ m_h (v_h)^2$ OR mv^2 is constant OR $v^2 \propto 1/m$ OR mean KE of oxygen = mean KE of hydrogen $v_o = \sqrt{(m_h/m_o)}$x1800 = $\sqrt{\{(.002/.032) \times 1800\}}$ = **450** m s^{-1}.	C1 C1 A1	Allow $(½)m<c^2> = (3/2)kT$
	Total	**7**	

3)

Question	Expected answer	Mark	Additional guidance
(a)(i)	pressure is inversely proportional to volume (WTTE) for a fixed mass of gas at constant temperature (WTTE)	B1 B1	Accept P $\propto$ 1/V or PV = constant
(a)(ii) 1	hyperbolic (i.e.Boyles law) curve shape looks asymptotic to both axes i.e does not touch axes	B1 B1	
(a)(ii) 2	straight line through origin OR would extrapolate back to the origin	B1	
(b)(i)	correct sub^n in pV = nRT ⇒ 5 x 10^5 x 0.040 = nx8.31x288 OR sub^n into pV = NkT ⇒ 5 x 10^5 x 0.040 = Nx1.38x10^{-23}x288 (hence) n = 5 x 10^5 x 0.040 / (8.31 x 288) = **8.4 (8.36)** mol (hence) N = 5.03 x 10^{24} molecules ⇒ **8.36 moles**	C1 A1	Any incorrect Kelvin temp (eg 188) correctly used treat as an AE. Allow 8.35 **Use of 15^0C scores ZERO**
(b)(ii)	from pV = nRT new n = 7.52 mol moles lost is 8.36 – 7.52 = 0.84 mol = **2.3 (2.34) x 10^{-2}** kg (0.023)	C1 C1 A1	Allow ecf from b(i) OR Pressure has dropped by 1/10 number of moles lost = 0.836 mol; Mass lost = 0.836 x 0.028 = 2.3 x 10^{-2} kg
	Total	**10**	

4)

Question			Answer	Marks	Guidance
	(a)	(i)	Collision in which <u>kinetic</u> energy is conserved	B1	**Allow**: no ke lost (wtte)
		(ii)	Any **four** from • <u>Many</u> molecules collide with the walls • A change in momentum occurs when molecule(s) collide with (and rebound from) the walls of container • Force is rate of change of momentum • The force exerted by the molecule(s) on wall is equal to force exerted by the wall on the molecule(s) (by Newton's third law) • pressure (on wall) = (total) force (on wall) / area (of wall)	B1 x 4	Symbols must be defined in formulae
		(iii)	Any **two** from • Molecules move faster/have greater <u>kinetic</u> energy (at higher temperature) • There is an increased <u>rate</u> of collision / more collisions occur <u>per second</u> / collisions occur <u>more often</u> • Each collision involves a greater change in momentum	B1 x 2	**Not**: greater force **Not**: harder collisions
	(b)	(i)	$P_1V_1/ T_1 = P_2V_2/T_2$ with T stated in Kelvin or clearly shown in subsequent working $P_2 = 105 \times 5 \times 10^3 \times (273 - 30)/ (273 + 20) \times 1.2 \times 10^4$ $P_2 = 36$ (kPa)	C1 C1 A1	Temperatures must be in kelvin to score this mark. **Allow** : consistent working in pascal
		(ii)	Risk that balloon will burst (with further increase in volume)	B1	**Allow**: pop / explode
			Total	**11**	

5)

Question			Answer	Marks	Guidance
	(a)		Mass of one hydrogen molecule $= 2.02 \times 10^{-3} / 6.02 \times 10^{23}$ Mass $= 3.4 \times 10^{-27}$ (kg)	C1 A1	
	(b)		Mean k.e $= 3kT/2$ Mean ke $= 3/2 \times 1.38 \times 10^{-23} \times 1100$ Mean ke $= 2.3 \times 10^{-20}$ (J) Mean ke $\approx 2 \times 10^{-20}$ (J)	B1 B1 A0	
	(c)		$E_k = ½ mv^2$ $2.3 \times 10^{-20} = ½ \times 6.6 \times 10^{-27} v^2$ $v^2 = (2 \times 2.3 \times 10^{-20} / 6.6 \times 10^{-27})$ $v = (2 \times 2.3 \times 10^{-20} / 6.6 \times 10^{-27})^{1/2}$ $v = 2.6 \times 10^3$ (m s^{-1})	M1 A1	**Note**: Full credit to be given for the use of 2×10^{-20} (J) from (b) giving $v = 2.5 \times 10^3$ (ms^{-1}) **Note:** If 3.36×10^{-27} is used from (a) (hydrogen molecules) then speed $= 3.68 \times 10^3$ m s^{-1} and scores max 1 mark
	(d)		Helium atoms have a range of speeds / kinetic energies Hence some atoms have a velocity greater than 11 km s^{-1} / escape velocity	M1 A1	Accept equivalent wording or suitable diagram .
			Total	**8**	

6)

Question			Answer	Marks	Guidance
5	(a)	(i)	*n* = number of moles (in sample) **AND** *N* = number of atoms / molecules (in sample)	B1	**Note: both** definitions are required **Not:** particles / Avogadro's constant
		(ii)	*n* or *N* **AND** T is constant (and R and k are constants) for a fixed mass (of gas), *pV* = constant / $p \propto 1/V$	M1 A1	*nRT* or *NkT* is constant is **not** sufficient
		(iii)	Shows that $Nm^{-2} \times m^3 = Nm$	B1	**Allow:** Use of base units for **both** *pV* **and** work done
	(b)	(i)	Calculates $p \times (1/V)^{-1}$ at **two** points on the graph values are the same *pV* = constant / $p \propto 1/V$ / nRT = constant	M1 A1	Expected values for *pV* are 7500 (Nm) or 0.075 ($\times 10^{-5}$)for most points **Allow:** Correct calculation of gradient (M1) Calculates intercept = 0 hence graph is through the origin and *pV* = constant / $p \propto 1/V$ (A1)
		(ii)	Number of moles in 0.050 kg = 0.05/0.016 (= 3.125) $T = \frac{pV}{nR} = \frac{7500}{3.125 \times 8.31}$ $= 289$ (K) $T = 16$ (°C)	C1 C1 A1	**Allow:** possible ecf from (b)(i) or error in *n* but apply POT error for use of *pV* = 0.075 leading to $T = 2.9 \times 10^{-3}$ K **Note:** Mark is for correct conversion of their *T* (K) value **Note**: Allow full range of marks for other sensible alternative approaches e.g. use of a molecular mass of 0.032 kg/mol giving a temperature of 305°C
			Total	**9**	

7)

Question	Expected Answers	Marks	Additional guidance
(a) (i)	**Brownian** (motion) (QWC mark)	B1	QWC Brownian spelled correctly
(a) (ii)	ANY two from the following three: air molecules are moving in different directions/randomly with different speeds mass/size of air molecules is smaller than smoke particles	B1 B1	Answers that refer to smoke particles only cannot score the marks.
(b) (i)	vol = (4/3) $\pi r^3 = 5.58 \times 10^{-3}$ correct sub into pV = nRT i.e. with T as 290K n = $(2.6\times10^5 \times 5.58\times10^{-3})/8.31\times290$ = 0.602 moles mass = n x 0.028 = **0.0169** kg (0.016856)	C1 C1 A1 A1	Allow ecf for wrong volume Allow use of pV = NkT and n = N/N_A Allow ecf for cand's value for n If 17° C used allow maximum of 2 marks for n = 10.3 moles and m = 0.29 kg
(b) (ii) 1	no net heat flow between objects (WTTE)	B1	Allow "they are at the same temp."
(b) (ii) 2	correct use of P/T = constant: e.g. P = (273/290) x 2.6×10^5 P = $\mathbf{2.45 \times 10^5}$ (or 2.4×10^5 or 2.5×10^5)Pa	C1 A1	Allow correct use of pV=nRT
	Total	10	

8)

	Expected answers	Mark	Additional guidance
(a)(i)	A collision with no change / loss of kinetic energy.	B1	**Allow** coeff't of restitution = 1
(a)(ii)	Any 3 from Volume of particles negligible compared to volume of vessel OR molecules much smaller than distance between them No intermolecular forces acting (other than during collisions) OR molecules only have kinetic energy (and no PE) Particles travel in straight lines/at uniform velocity between collisions OR force of gravity on molecules is negligible time of collisions much smaller than time between collisions gas consists of a large number of molecules moving randomly (both needed for the mark)	B1 B1 B1	do not allow a bare "negligible volume of molecules " Do not allow "collisions between molecules are elastic" because this is given in the question. do not allow a bare "negligible time of collisions" Do not allow a bare "rapid random motion"
(b)(i)	$\Delta p = mv - mu$ $= 4.8 \times 10^{-26}$ [500 - (-500)] $= 4.8 \times 10^{-23}$ kg m s^{-1}	C1 A1	 2.4×10^{-23} scores zero
(b)(ii)	(time between collisions = 0.4 /500 s) . Number of collisions/sec. = 500/0.4 = 1250	A1	Correct answer only
(b)(iii)	(Mean) force = $\Delta p/t$ OR Force = rate of change of momentum OR Impulse = change in momentum Force = 1250 x 4.8×10^{-23} /1 = 6.0×10^{-20} N	C1 A1	**Allow** ecf from (b)(i) and (b)(ii) e.g. if 2500 is used from (b)(ii) F = 2500x4.8×10^{-23} = 1.2×10^{-19} N and this scores 2 marks
(b)(iv)	Same value as candidate's (b)(iii) due to Newton's third law OR this force acts in opposite direction	B1	 OR –ve sign shown
(c)(i)	3 x 6×10^{23} = 1.8×10^{24}	B1	1.806×10^{24} if 6.02 is used
(c)(ii)	(very) large number of particles that are moving randomly means that at any instant the number of collisions on each face will be the same (WTTE)	B1	Allow no gravitational forces and hence uniform density
(c)(iii)	(mean) KE/speed of molecules increases Increased rate of collisions with wall OR 'harder' collisions with wall	B1 B1	Also **allow** greater change of momentum per collision (WTTE) Not just "more collisions".
	Total	**14**	

9)

Q6	Expected answers	Mark	Additional guidance
(a)(i)	Straight line (judged by eye)with positive slope AND passing through the origin	B1	correct answer only
(a)(ii)	8.31 (J mol^{-1} K^{-1})	B1	Allow *R* and molar gas constant, but do not allow *pV/T* OR *nR*
(b)(i)	-40 °C = 233 K, AND 250 °C = 523 K Use of $V_1/T_1 = V_2/T_2$ 2.4×10^{-2} / 233 = V_2 / 523 V_2 = 0.053(8) (m^3)	M1 C1 A1	No marks scored if 40° C and/or 250°C are used Accept other correct versions.
(b)(ii)	Use of $p = nRT/ V$ = 1.5 x 8.31 x 233 / 2.4×10^{-2} = 1.21×10^5 (Pa)	C1 A1	Allow *T*= 523 and *V*= 0.053 hence $p = 1.2 \times 10^5$ Allow ecf from (b)(i)
	Total	**7**	

10)

Question			Answer	Marks	Guidance
	(a)		Gas molecules move in **random / erratic / haphazard** motion (AW) :	B1	**Use tick or cross on Scoris** ✎ **random / erratic / haphazard** must be spelled correctly to score the mark.
	(b)	(i)	constant temperature	B1	
		(ii)	$P_1V_1 = P_2V_2$ $350 \times 120 \times (A) = P_2 \times 55 \times (A)$ $P_2 = \frac{350 \times 120}{55}$ = 760 (kPa)	C1 A1	**Note:** Answer to 3 sf is 764 (kPa) **Note:** 7.6 x 10^5 (kPa) scores 1 mark
		(iii)	When a molecule collides with the (moving) piston it rebounds with higher speed / ke / momentum (Mean) kinetic energy of molecules is <u>proportional / ∝</u> to (Kelvin) temperature	B1 B1	Must refer to collisions with piston or rebounds from piston not collisions within gas molecules. Allow: E_k = 3kT/2 without definition of terms.
			Total	**6**	