Question			Answer	Marks	Guidance
1	(a)		Mass of one hydrogen molecule = $2.02 \times 10^{-3} / 6.02 \times 10^{23}$	C1	
			Mass = 3.4×10^{-27} (kg)	A1	
	(b)		Mean k.e = $3kT/2$		
			Mean ke = $3/2 \times 1.38 \times 10^{-23} \times 1100$	B1	
			Mean ke = 2.3×10^{-20} (J)	B1	
			Mean ke ≈ 2×10^{-20} (J)	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 = 3.68×10^3 m s^{-1} and scores max 1 mark
	(d)		Helium atoms have a range of speeds / kinetic energies	M1	Accept equivalent wording or suitable diagram
			Hence some atoms have a velocity greater than 11 km s^{-1} / escape velocity	A1	.
			Total	**8**	

Question	Expected Answers	Marks	Additional guidance
2(a)(i)	(1 kWh is) the **<u>energy</u>** used/provided by a 1 kW device in 1 hour	B1	Allow 1 kWh = 60x60x1000 = 3.6×10^6 J
(a)(ii)	Energy used in kWh = (70/1000) x (7 x 24) = 11.8 kWh Cost = 11.8 x 0.12 = **£1.41 (or £1.4)**	C1 A1	Any arithmetic error loses one mark
(b)(i)	use of E = mc Δθ e.g. E = 2 x 3800 x (18-3) = **1.14×10^5 J**	C1 A1	
(b)(ii)	Rate of energy loss = 1.14×10^5 /100x60 = **19** W	B1	Allow ecf for cand's (b)(i) value
(c)	1. ^oC to 0 ^oC negative gradient line 2. horizontal line on time a 3. ^oC to -18 ^oC line of **steeper –ve gradient** (judged by eye) than in 1	B1 B1 B1	
	Total	**9**	

Question	Expected answers	Mark	Additional guidance
3(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 <u>KINETIC ENERGY</u> $\frac{1}{2} m_o (v_o)^2 = \frac{1}{2} m_h (v_h)^2$ OR mv^2 is constant OR $v^2 \propto 1/m$ OR mean KE of oxygen = mean KE of hydrogen $v_o = \sqrt{(m_h / m_o)} \times 1800 = \sqrt{\{(.002/.032) \times 1800\}} =$ **450** m s^{-1}.	C1 C1 A1	Allow $(\frac{1}{2})m\langle c^2\rangle = (3/2)kT$
	Total	**7**	

Question	Expected answer	Mark	Additional guidance
4(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 $pV = nRT \Rightarrow 5 \times 10^5 \times 0.040 = n \times 8.31 \times 288$ OR sub^{n} into $pV = NkT \Rightarrow 5 \times 10^5 \times 0.040 = N \times 1.38 \times 10^{-23} \times 288$ (hence) $n = 5 \times 10^5 \times 0.040 / (8.31 \times 288)$ = **8.4 (8.36)** mol (hence) $N = 5.03 \times 10^{24}$ molecules $\Rightarrow$ **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 = $0.836 \times 0.028 = 2.3 \times 10^{-2}$ kg
	Total	**10**	

Question			Expected Answers	Marks	Additional guidance
5	a	i	correct substitution in E = mc$\Delta\theta$: eg E = 0.08x4180x40 ratio = 0.08x4180x40/5 x 10^{-5} x2460x40 = **2.7(2) x 10^{3}**	C1 A1	Allow 80x4180/0.05x2460 (13376/4.92) for this C1 mark. 1: 2700 does not score the second mark.
		ii	*Any valid advantage: eg* car cooling systems because it absorbs large amounts of heat for a small rise in temp OR ideal fluid for central heating systems because it releases large amounts of heat for a small drop in temp. OR helps to maintain constant body temperature since body is mainly water which absorbs lots of heat for small temp rise	 B1 B1	First mark for valid situation Second mark for correct explanation of why the high value of the shc is helpful.
	b		***labelled diagram (2 marks)*:** liquid in vessel with electrical heater (submerged) and thermometer ammeter connected in series between supply and heater AND voltmeter connected across heater. ***list of measurements (3 marks):*** mass of liquid, initial and final temperature/change of temp (of the liquid) I, V and t values OR energy meter readings OR power and time ***explanation (1 mark):*** E = mc$\Delta\theta$ rearranged to c = E/m$\Delta\theta$ ***uncertainties (2 marks) each stated with explanation of remedy:*** e.g. - heat losses (makes E or $\Delta\theta$ uncertain) *(solved by)* insulating beaker/use lid - false temp reading *(solved by)* stir the liquid - temp continues to rise after heater switched off measure highest value - thermal capacity of vessel (*solved by*) take this into account in calculation	 B1 B1 B1 B1 B1 B1 B1 B1 max 2	 Allow use of joule meter if convincingly connected to heater and power supply i.e. 2 wires from power supply two wires to heater Allow such things as “find mass”, “known mass”, “10K temp rise”, “time for 2 minutes” “known power”, etc. Allow ItV/m$\Delta\theta$. Do not allow “repeat the experiment”. Give credit for valid suggestions if mentioned anywhere in the description of the experiment.
			Total	**12**	