Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	• Equates right hand sides (1) • Final E_k formula ($\frac{1}{2} m \langle c^2 \rangle = 3/2\ kT$) and k is constant (1)		2

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	• Equate $pV = NkT$ and $pV = \frac{1}{3}Nm\langle c^2 \rangle$ • Suitable algebra		2

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	Any one from: (1) • Point particles • Particles have negligible volume (compared to their container) • Negligible forces between particles (except during a collision) • Range of molecular forces small (in comparison to average separation) • Duration of collisions negligible (in comparison to time between them) • Newtonian mechanics applies • Particles moves with uniform velocity between collisions • Elastic collisions • Particles move with (constant) random motion	Accept molecules for particles	1

(ii)	• States $pV = NkT$ or $pV = 1/3\ Nm\langle c^2\rangle$ (1) • Suitable algebra to show $\frac{1}{2} m\langle c^2\rangle = 3/2\ kT$ (1)		2
(iii)	• Use of a.m.u. to determine particle mass (1) • Use of $\frac{1}{2} m\langle c^2\rangle = 3/2\ kT$ with T in K (1) • rms speed = 590 m s^{-1} (1)	Example of calculation Mass = $28 \times 1.66 \times 10^{-27}$ kg = 4.65×10^{-26} kg $\frac{1}{2} \times 4.65 \times 10^{-26}$ kg $\langle c^2\rangle = 3/2 \times 1.38 \times 10^{-23}$ J $K^{-1} \times 393$ K c = $\sqrt{349900} = 590$ m s^{-1}	3

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $\frac{1}{2} m\langle c^2\rangle = \frac{3}{2} kT$ (1) • mean kinetic energy $= 6.4 \times 10^{-20}$ J (1)	Example of calculation: $\frac{1}{2} m\langle c^2\rangle = \frac{3}{2} kT$ $= \frac{3}{2} \times 1.38 \times 10^{-23}\,\text{J K}^{-1} \times 3100\,\text{K} = 6.42 \times 10^{-20}\,\text{J}$	2

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use total mass / mass of D ion (1) • Use of $pV = NkT$ (1) • $p = 2.8 \times 10^4$ Pa (1)	Example of calculation $N = 5.0 \times 10^{-6}$ kg / 3.3×10^{-27} kg = 1.5×10^{21} $p = 1.5 \times 10^{21} \times 1.38 \times 10^{-23}$ J $K^{-1} \times$ 130 000 000 K / 98 m^3 = 2.77×10^4 Pa	3
(ii)	• Use of $\frac{1}{2} m\langle c^2\rangle = 3/2\ kT$ Or $pV = 1/3\ (Nm\langle c^2\rangle)$ (ecf for N and p from (i)) (1) • $\sqrt{\langle c^2\rangle} = 1.3 \times 10^6$ m s^{-1} (1)	Example of calculation $\frac{1}{2} m\langle c^2\rangle = 3/2\ kT$ $\frac{1}{2} \times (3.3 \times 10^{-27}\ \text{kg}) \times \langle c^2\rangle = 3/2 \times 1.38 \times 10^{-23}$ J $K^{-1} \times 130\,000\,000$ K $\langle c^2\rangle = 1.6 \times 10^{12}$ m^2 s^{-2} $\sqrt{\langle c^2\rangle} = 1.28 \times 10^6$ m s^{-1}	2

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $V = \pi r^2 l$	(1)	Example of calculation:	
	• Use of $pV = NkT$	(1)	$V = \pi \times 0.11^2$ (m)$^2 \times 0.23$(m) $= 8.74 \times 10^{-3}$ m^3	
	• Conversion of °C to K	(1)	T = 21 °C + 273 = 294 K	
	• $N = 4.7 \times 10^{23}$	(1)	2.2×10^5 Pa $\times$ 8.7 $\times 10^{-3}$ m^3 = $N \times 1.38 \times 10^{-23}$ J K^{-1} $\times$ 294 K $N = 4.74 \times 10^{23}$	4
(ii)	• Use of $\frac{1}{2}m < c^2 > = \frac{3}{2}kT$	(1)	Give full credit if a mistake has been made calculating temperature in part (i) e.g if T = 21 °C then r.m.s. speed = 95 m s^{-1} Similarly for V	
	• r.m.s. speed = 360 m s^{-1}	(1)		
	Or		Example of calculation:	
	• Use of $pV = \frac{1}{3}Nm < c^2 >$	(1)	$\frac{1}{2} \times 9.6 \times 10^{-26}$ kg $< c^2 > =$ $\frac{3}{2}$ 1.38 $\times 10^{-23}$ J K^{-1} $\times$ 294 K	
	• r.m.s. speed = 360 m s^{-1} (ecf from (i))	(1)	$< c^2 > = 127000$ m^2 s^{-2} r.m.s. speed = 356 m s^{-1}	2
			Alternative: 2.2×10^5 Pa $\times$ 8.7 $\times 10^{-3}$ m^3 = $\frac{1}{3}4.7 \times 10^{23} \times 9.6 \times 10^{-26}$ kg $< c^2 >$ r.m.s. speed = 360 m s^{-1}	

Q7.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of ½ m $\langle c^2 \rangle$ = 3/2 kT	(1)	Example of calculation ½ m $\langle c^2 \rangle$ = 3/2 kT	
	• with T in Kelvin	(1)	½ $\times$ 5.0 $\times 10^{-26}$ kg $\times$ $\langle c^2 \rangle$ = 3/2 $\times$ 1.38 $\times 10^{-23}$ J K^{-1} $\times$ 298 K	
	• $\sqrt{\langle c^2 \rangle}$ = 497 m s^{-1}	(1)	$\langle c^2 \rangle$ = 247 000 m^2 s^{-2} $\sqrt{\langle c^2 \rangle}$ = 497 m s^{-1}	3

Q8.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of ½ $m \langle c^2 \rangle = 3/2\ kT$ • $\sqrt{\langle c^2 \rangle} = 500\ \text{m s}^{-1}$	(1) (1)	Example of calculation ½ $m \langle c^2 \rangle = 3/2\ kT$ ½ × 4.8 × 10^{-26} kg × $\langle c^2 \rangle$ = 3/2 × 1.38 × 10^{-23} J K^{-1} × 292 K $\langle c^2 \rangle = 2.52 \times 10^5\ \text{m}^2\ \text{s}^{-2}$ $\sqrt{\langle c^2 \rangle} = 502\ \text{m s}^{-1}$	2

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
(ii)(2)	• mass of helium atom = 4u • use of ½ $m \langle c^2 \rangle$ = 3/2 kT • T = 375 K	Example of calculation: Mass of He atom = 4 × 1.66 × 10^{-27} kg = 6.64 × 10^{-27} kg ½ 6.64 × 10^{-27} kg × (1530 m s^{-1})^2 = 3/2 × 1.38 × 10^{-23} J K^{-1} × T T = 375 K	**(3)**

Q10.

Question Number	Answer	Mark
	C	1

Q11.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Calculate no of nuclei • Use of $\ln 2 = t\,½ \times \lambda$ • Use of $A = \lambda N$ • $A = 3.97 \times 10^4$ (Bq)	(1) (1) (1) (1)	Example of calculation $N = (5.18 \times 10^{-5}\text{ g}/230\text{ g}) \times 6.02 \times 10^{23}$ $= 1.36 \times 10^{17}$ $\lambda \times (75\,400 \times 3.15 \times 10^7)\text{ s} = \ln 2$ $\lambda = 2.92 \times 10^{-13}\text{ s}^{-1}$ $A = 2.92 \times 10^{-13}\text{ s}^{-1} \times 1.36 \times 10^{17}$ $A = 3.97 \times 10^4\text{ Bq}$	4
(ii)	• Calculates decays in one year (ecf from (b)(i)) • Use of $pV = NkT$ • uses $T = 295$ K • $V = 5.09 \times 10^{-14}\text{ m}^3$	(1) (1) (1) (1)	Example of calculation ecf λ from (a) decays in one year $= 3.97 \times 10^4\text{ Bq} \times 3.15 \times 10^7\text{ s}$ $= 1.25 \times 10^{12}$ $1.00 \times 10^5\text{ Pa} \times V = 1.25 \times 10^{12} \times 1.38 \times 10^{-23}\text{ J K}^{-1} \times 295\text{ K}$ $V = 5.09 \times 10^{-14}\text{ m}^3$	4
(iii)	• Use of $½\,m\langle c^2\rangle = 3/2\,kT$ **Or** Use of $pV = \frac{1}{3}Nm\langle c^2\rangle$ (allow ecf for N, V from (b)(ii)) • uses $m = 4u$ • $\sqrt{\langle c^2\rangle} = 1360\text{ m s}^{-1}$	(1) (1) (1)	Example of calculation $½\,m\langle c^2\rangle = 3/2\,kT$ $½ \times (4 \times 1.66 \times 10^{-27}\text{ kg}) \times \langle c^2\rangle = 3/2 \times 1.38 \times 10^{-23}\text{ J K}^{-1} \times 295\text{ K}$ $\langle c^2\rangle = 1\,840\,000\text{ m}^2\text{ s}^{-2}$ $\sqrt{\langle c^2\rangle} = 1360\text{ m s}^{-1}$ Accept the use of proton/neutron mass instead of u	3