Thermodynamics - Mark Scheme

Q1.

Question Number	Answer	Mark
	The only correct answer is D *A is not correct because deep space is a few degrees above absolute zero* *B is not correct because nitrogen liquefies at a much higher temperature* *C is not correct because we have not yet attained absolute zero in an experiment*	**1**

Q2.

Question Number	Answer		Mark
(a)	Use of $pV = NkT$	(1)	
	Conversion of temperature to kelvin	(1)	
	$N = 3.1 \times 10^{23}$	(1)	**3**
	<u>Example of calculation</u> $N = \frac{pV}{kT} = \frac{1.55 \times 10^{5}\,\mathrm{N\,m^{-2}} \times 8.18 \times 10^{-3}\,\mathrm{m^{3}}}{1.38 \times 10^{-23}\,\mathrm{m^{2}kgs^{-2}K^{-1}} \times (273 + 20)\mathrm{K}} = 3.14 \times 10^{23}$		

Question Number	Answer		Mark
(b)(i)	Use of energy conservation [$\Delta E_{grav} = \Delta E_k$]	(1)	
	Use of $\Delta E_{grav} = mg\Delta h$	(1)	
	$\Delta E_k = 2.43$ (J)	(1)	3
	<u>Example of calculation</u> $\Delta E_{grav} = 0.62\text{kg} \times 9.81\text{m s}^{-2} \times (1.8\text{m} - 1.4\text{m}) = 2.43\text{ J}$		
(b)(ii)	**EITHER**	(1)	
	Use of $\Delta E = mc\Delta\theta$ to find energy for temperature rise of 0.5°C		
	Use of number of drops = $\dfrac{\Delta E}{\Delta E_k}$	(1)	
	For a rebound to 1.40 m, number of times ball must be dropped = 149 [Accept 150] [Use of 'show that' value gives 151] **Or** For a rebound to 1.60 m, number of times ball must be dropped = 297 [accept 298]	(1)	
	OR		
	Use of $\Delta E = mc\Delta\theta$ to find $\Delta\theta$ for one drop	(1)	
	Use of number of drops = $\dfrac{0.5}{\Delta\theta}$	(1)	
	For a rebound to 1.40 m, number of times ball must be dropped = 149 [Accept 150] [Use of 'show that' value gives 151] **Or** For a rebound to 1.60 m, number of times ball must be dropped = 297 [accept 298] (ecf candidate's value of ΔE_k from (i) used to find minimum number of drops)	(1)	3
	<u>Example of calculation</u> $\Delta E = 0.62\text{kg} \times 1170\text{J kg}^{-1}\text{K}^{-1} \times 0.5\text{K} = 363\text{J}$ Number of bounces = $\dfrac{363\text{J}}{2.43\text{J}} = 149$		

Question Number	Answer		Mark
b(iii)	No energy transfer to the surroundings [Accept Ball rebounds to 140 m every time Ball rebounds to 160 m every time Ball rebounds to same height every time No energy lost to surroundings No energy is dissipated] [Accept heat for energy] [Do not accept No heat/energy lost Volume/mass of ball is constant Air behaves as an ideal gas Room temperature is constant No air leaks from the ball]	(1)	1
	Total for question		**10**

Q3.

Question Number	Answer		Mark
(a)	Evidence of calculation of average temperature [52.5 °C] Use of $\Delta E = mc\Delta\theta$ ΔE = 2920 (J) Example of calculation $\Delta E = mc\Delta\theta$ $\therefore \Delta E = 22.5\times10^{-3}\,\text{kg}\times4190\,\text{J kg}^{-1}\,\text{K}\times(52.5-21.5) = 2920\,\text{J}$	**(1)** **(1)** **(1)**	**3**
(b)	Precaution Corresponding reason [dependent mark] Example of answers: Water should be stirred So water is all at the same temperature No draughts So that all the energy from the crisp is transferred to the test tube Light crisp close to test tube So that all the energy from the crisp is transferred to the test tube Keep crisp close to test tube To reduce the heat dissipated to surroundings Small thermometer bulb To reduce energy transfer to the bulb Use test tube of low specific heat capacity To reduce energy transferred to the test tube Read thermometer at eye level To avoid parallax error leading to incorrect temperature	**(1)** **(1)**	**2**
(c)	The energy value calculated (from the experimental data) is much less (than the value stated on the crisp packet) [accept a ratio e.g. 13%] not all the energy (from the crisp) is transferred to the water **Or** not all of the energy content of the crisps is released by burning [do not accept a bald statement "energy transferred to surroundings"]	**(1)** **(1)**	**2**
	Total for question		**7**

Q4.

Question Number	Answer	Mark
	C is correct because $E_k \propto T$	**1**

Q5.

	Answer		Mark
(a)	Use of $\Delta E = mc\Delta T$ $\Delta E = 1.7 \times 10^7$ J <u>Example of calculation</u> $\Delta E = mc\Delta T = 275\,\text{kg} \times 3.59 \times 10^3\,\text{J kg}^{-1}\,\text{K}^{-1} \times (18.5 - 1.5)\text{K}$ $\Delta E = 1.68 \times 10^7\,\text{J}$	(1) (1)	2
(b)	Use of $P = \frac{\Delta W}{\Delta t}$ Valid attempt at calculation of ΔT **Or** Valid attempt at calculation of "safe" time [t =3430 s if $\Delta\theta = 4\,^{\circ}$C] Conclusion that θ > 4 (°C) (so meat may be unsafe to eat) **Or** "Safe" time less than 3600 s (so meat may be unsafe to eat) <u>Example of calculation</u> $\Delta W = Pt = 720\,\text{W} \times 3600\,\text{s} = 2.59 \times 10^6\,\text{J}$ $\Delta\theta = \frac{\Delta W}{mc} = \frac{2.59 \times 10^6\,\text{J}}{275\,\text{kg} \times 3.59 \times 10^3\,\text{Jkg}^{-1}\text{K}^{-1}} = 2.6\,\text{K}$	(1) (1) (1)	3
	Total for Question		**5**

Q6.

Question Number	Answer		Mark
(a)	Use of $pV = NkT$	(1)	
	p = 1.1 × 10^5 (Pa)	(1)	
	<u>Example of calculation</u> $p = \frac{NkT}{V} = \frac{2.2 \times 10^{23} \times 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}} \times 293\,\mathrm{K}}{8.2 \times 10^{-3}\,\mathrm{m^3}} = 1.08 \times 10^5\,\mathrm{Pa}$		2
(b)	Correct use of a factor of 50	(1)	
	V = 0.019 m^3 [0.018 m^3 if 'show that' value used]	(1)	
	[Ratio method, $p_1V_1 = p_2V_2$ can score both marks, for this method apply ecf from ai]		
	For candidates who take the number of molecules that remain in the canister into account: • Use of $V_{helium} = (50 \times V_{balloon} + V_{canister})$ • V = 0.0203 m^3	(1) (1)	
	<u>Example of calculation</u> $V = \frac{NkT}{p} = \frac{50 \times 2.2 \times 10^{23} \times 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}} \times 293}{2.3 \times 10^6\,\mathrm{Pa}} = 0.0193\,\mathrm{m^3}$		2
(c)	There are fewer atoms (in the canister), so the collision rate with the walls decreases [accept molecules but not particles]	(1)	
	Hence the (overall) rate of change of momentum is less	(1)	
	Therefore there is a smaller force (on the container walls) [dependent upon mp2]	(1)	3
	Total for Question		**7**

Q7.

	Answer	Mark
	A	**1**

Q8.

Question Number	Answer		Mark
(a)(i)	$V_{in} = 5.9 \times 10^{-3}\ m^3$ and $V_{out} = 1.3 \times 10^{-3}\ m^3$ **Or** $\Delta V = 4.6 \times 10^{-3}\ m^3$ Use of $pV = NkT$ $N = 1.1 \times 10^{23}$ Example of calculation: $N = \frac{pV}{kT} = \frac{1.02\times10^5\ Pa \times (5.9-1.3)\times10^{-3}\ m^3}{1.38\times10^{-23}\ J\ K^{-1}\ (273+37)K} = 1.10\times10^{23}$	(1) (1) (1)	3
(a)(ii)	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ $E_{k,\ tot} = 710\ J$ [apply ecf for responses that use a value of N that would round to the 'show that' value] Example of calculation: $E_{k,tot} = N\times\frac{3}{2}kT = 1.1\times10^{23}\times1.5\times1.38\times10^{-23}\ JK^{-1}\times(273+37)K = 706\ J$	(1) (1)	2
(a)(iii)	Internal energy is the sum of kinetic and potential energy of the (molecules/atoms in the) air The molecules/atoms (in an ideal gas) have no potential energy	(1) (1)	2
(b)(i)	Oxygen molecules (are more massive than nitrogen molecules and) have a lower mean square speed than the nitrogen molecules. Because $\frac{1}{2}m\langle c^2\rangle$ is the same for each type of molecule **Or** average/mean kinetic energy is the same for each type of molecule	(1) (1)	2
*(b)(ii)	QWC – Work must be clear and organised in a logical manner using technical wording where appropriate Both gases occupy the same volume V and are at the same temperature T As pressure $p = \frac{NkT}{V}$ then $p \propto N$ the number of molecules The contribution to pressure exerted by each gas is determined by the number of molecules (of that gas) [accept statement that 80% of the molecules in the gas are nitrogen molecules and so nitrogen accounts for 80% of the pressure for mp3]	(1) (1) (1)	3
	Total for question		**12**

Q9.

Question Number	Answer		Mark
(a)	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ **Or** $\frac{1}{2}m\langle c^2\rangle = \text{constant}$	(1)	
	$\langle c^2\rangle_X = 5.6\times10^4\,(\text{m}^2\text{s}^{-2})$	(1)	2
	[If a reasonable Kelvin temperature is estimated and used in the equation, can score MP1 only]		
	Example of calculation $\frac{\langle c^2\rangle_X}{\langle c^2\rangle_K} = \frac{m_K}{m_X}$ $\langle c^2\rangle_X = \frac{(1.39\times10^{-25}\text{ kg})}{(2.18\times10^{-25}\text{ kg})}\times 8.72\times10^4\text{ m}^2\text{s}^{-2} = 5.56\times10^4\text{ m}^2\text{s}^{-2}$		
* (b)	(QWC Spelling of technical terms must be correct and the answer must be organised in a logical sequence.)		
	The molecules/atoms move faster **Or** the (average) kinetic energy of molecules/atoms is greater	(1)	
	Collision rate of molecules/atoms with the glass bulb is larger **Or** there are more frequent collisions between the molecules/atoms and the glass bulb	(1)	
	There is more momentum change in each collision **Or** the rate of change of momentum is greater	(1)	4
	Therefore there is a larger force on the glass bulb (dependent upon mp2 or mp3)	(1)	
	[No credit for attempt to justify increase in pressure by using $pV = NkT$.] [Accept container/walls for glass bulb.]		
	Total for question		**6**

Q10.

Question Number	Answer		Mark
(a)	Use of $\Delta E = mc\Delta\theta$	(1)	
	Use of $P = \frac{\Delta W}{\Delta t}$	(1)	
	$t = 250$ s	(1)	3
	<u>Example of calculation:</u> $44 \times 85 \text{ W} = 110 \text{ kg} \times 720 \text{ J kg}^{-1}\text{K}^{-1} \times \frac{(28-16) \text{ K}}{\Delta t}$ $\Delta t = \frac{110 \text{ kg} \times 720 \text{ J kg}^{-1}\text{K}^{-1} \times 12 \text{ K}}{44 \times 85 \text{ W}} = 254 \text{ s}$		
(b)	Conduction through the walls and windows of the carriage **Or** Heating the materials of the carriage. **Or** Warm air escaping from the carriage (and replaced by cooler air) **Or** Not all the energy from the people is used to raise the temperature of the air	(1)	1
			4

Q11.

Question Number	Answer	Mark
	The only correct answer is B A is not correct because at the same temperature, the average kinetic energy is the same all molecules C is not correct because mass of H_2 molecule < mass of He molecule D is not correct because mass of H_2 molecule < mass of He molecule	1

Q12.

Question Number	Answer	Mark
	C is the correct answer as the gas obeys Boyle's law, $p \propto \frac{1}{V}$	1