Question	Answer	Marks
1	B	1
2	C	1
3 a	kT represents an approximation for the mean particle energy.	1
3 b	E is much larger than kT at room temperature, giving a low chance of particles escaping the surface of the solid aluminium.	1
4 a	$E_k \approx kT = 1.4 \times 10^{-23} \times 10\,000$ $= 1.4 \times 10^{-19} \approx 1.6 \times 10^{-19}$ J	1 1
4 b	(Real gases are not ideal therefore) particles collide and energy is exchanged. So particles will possess a range of energies.	1 1
5 a	$N_2 = e^{-\Delta E/kT}$ where $\Delta E = E_2 - E_1$ $N_2 = N\,e^{\frac{-1.6\times10^{-18}}{1.4\times10^{-23}\times6000}} = 5 \times 10^{-9}N$	1 1
5 b	The energy difference between E_3 and E_2 is different to the energy level between E_2 and E_1. The equation $\frac{N_3}{N_2} = \frac{N_2}{N_1}$ would only work if the difference between energy levels were the same.	1 1
6 a i	Energy required to evaporate 1 molecule = $\frac{\text{energy required to evaporate 1 kg}}{\text{number of molecules in 1 kg}} = \frac{E}{\frac{\text{mass}}{\text{molar mass}} \times N_A}$ $= \frac{8.4\times10^5}{\frac{1000}{46}\times6.02\times10^{23}}$ $= 6.4 \times 10^{-20}$ J (1 s.f.)	 1 1
6 a ii	$E \approx kT = 1.4 \times 10^{-23} \times 310$ $= 4.34 \times 10^{-21}$ J	1 1
6 a iii	$e^{-\Delta E/kT}$ $= e^{-\frac{6.4\times10^{-20}\times310}{1.4\times10^{-23}}}$ $= 3.94 \times 10^{-7} \approx 3 \times 10^{-7}$	1 1 1
6 b	The proportion of ethanol molecules with enough energy to evaporate is greater than for water. Therefore ethanol will evaporate from the skin faster than water and carry away energy at a higher rate.	1 1 1
7 a	$E \approx kT \times 1.4 \times 10^{-23} \times 300 = 4.2 \times 20^{-21}$ J	1
7 b	Potential energy = $mgh = 4.6 \times 10^{-26} \times 3000 \times 9.8 = 1.4 \times 10^{-21}$ J	1
7 c	Boltzmann factor = $e^{-E/kT} = e^{-\frac{1.4\times10^{-21}}{1.4\times10^{-23}\times300}}$ $= 0.71$	1 1
7 d i	Boltzmann factor = $e^{-mgh/kT}$ As h increases above sea level, the probability, according to the Boltzmann probability, that a particle will have the potential energy above ground level energy to occupy that height decreases.	1 1

7 d ii	Any sensible suggestion, e.g.: • Calculate the ratio of density for a number of equally-spaced height intervals above sea level. • If the ratio in each case is roughly the same then… • The decrease is exponential.	1 1 1
7 e	The Boltzmann factor is given by $e^{-E/kT}$. As T increases, the value of $\frac{E}{kT}$ decreases and so the value of the Boltzmann factor increases.	1 1
8 a	As gas molecules collide with the walls of a container they change velocity. There is a corresponding change in momentum that requires an impulse or force. This force acting over an area of the container results in pressure within the container.	1 1 1
8 b	$E \approx kT = 1.4 \times 10^{-23} \times 288$ $= 4.032 \times 10^{-21}$ J $= 4 \times 10^{-21}$ J (1 s.f.)	1 1
8 c	$e^{-E/kT} = e^{-\frac{3.4\times10^{-20}}{1.4\times10^{-23}\times288}}$ $= 2.17 \times 10^{-4}$	1 1
8 d i	As T increases, the Boltzmann factor increases exponentially.	1
8 d ii	Factor of increase = $\frac{\text{Boltzmann factor (360 K)}}{\text{Boltzmann factor (300 K)}} = \frac{12.5}{2.5}$ = 5	1 1