①

$$v_{avg} = \frac{1}{N} \sum n_i v_i = \frac{1}{22} \left[2 \times 1.0 + 4 \times 2.0 \times 6 \times 3.0 \times 8 \times 4.0 + 2 \times 5.0 \right]$$

$$= 3.2 \text{ m/s}$$

$$(v^2)_{avg} = \frac{1}{N} \sum n_i (v_i)^2 = \frac{1}{22} \left[2 \times (1.0)^2 + 4 \times (2.0)^2 + 6 \times (3.0)^2 + 8 \times (4.0)^2 + 2 \times (5.0)^2 \right]$$

$$= 11.36 \text{ m}^2/\text{s}^2$$

$$v_{rms} = \sqrt{(v^2)_{avg}} = 3.4 \text{ m/s}$$

② (a) Translational motion : energy per molecule $= 3 \times \frac{1}{2} kT = \frac{3}{2} kT$

Rotational : $2 \times \frac{1}{2} kT = kT$

Trans. + Rot : $E = \frac{3}{2} kT + kT = \frac{5}{2} kT$

$$\Delta E = \frac{5}{2} k \Delta T = \frac{5}{2} (1.38 \times 10^{-23} \text{ J/k})(65.2 \text{K}) = 2.25 \times 10^{-21} \text{ J}$$

for $N = 1.43 \times 10^{24}$ molecules : $\Delta E = 3.22 \times 10^{3} \text{ J}$

(b) Vibrational : $E = 2 \times \frac{1}{2} kT = kT$

Trans + Rot + Vib $E = \frac{3}{2} kT + kT + kT = \frac{7}{2} kT$

$$\Delta E = \frac{7}{2} kT = 3.15 \times 10^{-21} \text{ J} \quad \text{per molecule}$$

N molecules : $\Delta E = 4.50 \times 10^{3} \text{ J}$

(c) Trans. $= \frac{3}{2} kT \implies \Delta E = 1.93 \times 10^{3} \text{ J}$
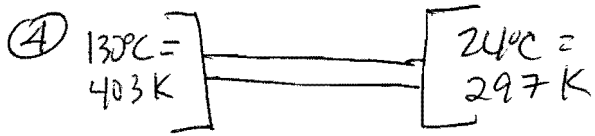
③

$$P(v) = 4\pi \left(\frac{M}{2\pi kT} \right)^{3/2} v^2 e^{-\frac{1}{2}Mv^2/kT}$$

$$M = (0.028 \text{ kg/mole})(6.02 \times 10^{23} \text{ molecule/mol})$$
$$= 4.65 \times 10^{-26} \text{ kg}$$

With $v = 643.1 \text{ m/s}$ and $dv = v_2 - v_1 = 655.8 \frac{m}{s} - 643.1 \frac{m}{s} = 12.7 \frac{m}{s}$

$$P(v)\,dv = (4\pi)\left(\frac{4.65 \times 10^{-26}\ kg}{2\pi(1.38 \times 10^{-23}\ J/k)(280K)}\right)^{3/2}(643.1\ m/s)^2 e^{-\frac{\frac{1}{2}(4.65 \times 10^{-26}\ kg)(643.1\ m/s)^2}{(1.38 \times 10^{-23}\ J/K)(280K)}}(12.7\ \frac{m}{s})$$

$$= 0.0145$$

④

130°C = 403 K   24°C = 297 K

For constant temperature process, $\Delta S = \dfrac{Q}{T}$

High-temp reservoir $\Delta S = -\dfrac{1200J}{403+} = -2.98\ J/K$

Low-temp reservoir $\Delta S = +\dfrac{1200J}{297k} = +4.04\ J/K$

Rod $\Delta S = 0$ (no net heat enters or leaves the rod: $dQ = 0$)

Surroundings $\Delta S = 0$ (because system is insulated)

$$\Delta S_{universe} = +4.04\ J/K - 2.98\ J/K = +1.06\ J/K.$$

⑤   Ice at 0°C → water at 0°C   333 J/g.

$102\,lg - 262\,g = 759\,g$ of ice melted $\Rightarrow Q = 2.53 \times 10^5 J$

$$\Delta S = \frac{Q}{T} = \frac{2.53 \times 10^5 J}{273k} = 926\ J/K$$