Group I

I-1

41-8 $L_0 = 300.00$ cm $\alpha = 1.20 \times 10^{-5}/°C$ at 20°C

What is the temperature if the rod's length is 299.71 cm?

$$\Delta L = L - L_0 = -0.29\,cm = \alpha L_0 \Delta T$$

$$\Delta T = -0.29\,\cancel{cm} / (1.20 \times 10^{-5}/°C)(300.00\,\cancel{cm})$$

$$= -(2.9 \times 10^4/360)°C = -80.55°C$$

So $T_F = T_0 + \Delta T = 20°C - 80.55°C = -60.55°C$

I-2

41-12 $m_c = 0.600$ kg $m_W = 1.00$ kg $T_0 = 15°C$ $m_{cu} = 1.12$ kg at 100°C is dropped in. Energy lost by the warm body is transferred to the colder body. That's why the temperature of the cold body rises to 22.5°C. What is S_{cu}?

energy lost by the warm body: $m_{cu} S_{cu} (100°C - 22.5°C)$

energy gained by the cold body: $(m_{cu} S_{cu} + m_W S_W) \times (22.5°C - 15°C)$

So

$$1.12\,kg \times 77.5°C\, S_{cu} = (0.600\,kg\, S_{cu} + 1.00\,kg \times 4186\,J/kg°C) \times 7.5°C$$

$$(1.12\,kg \times 77.5°C - 0.600\,kg \times 7.5°C) S_{cu} = 7.5 \times 4186\,J$$

$$S_{cu} = 31395\,J / (86.8 - 4.5)\,kg°C$$

$$= \frac{31395}{82.3}\,J/(kg°C) = 381\,J/(kg°C)$$

II - 3

41-24 Here, energy gained by the cold body must be the energy lost by the warm body. 2 kg of steam at 100 °C is the warm body. 10 kg of water at 20 °C is the cold body.

$$\text{energy gained} = (10.0\,\text{kg})(4186\ \text{J/kg}\,^\circ\text{C})(T_F - 20\,^\circ\text{C})$$
$$\text{energy lost} = (2.0\,\text{kg})(\text{latent heat of vaporization}) + (2.0\,\text{kg})(4186\ \text{J/kg}\,^\circ\text{C})(100\,^\circ\text{C} - T_F)$$

So

$$\text{energy lost} = (2.0\,\text{kg})(2256\,000\ \text{J/kg}) + (2.0\,\text{kg})(4186\ \text{J/kg}\,^\circ\text{C})(100\,^\circ\text{C}) - (2.0\,\text{kg})(4186\ \text{J/kg}\,^\circ\text{C})T_F$$

$$\text{energy gained} = (10.0\,\text{kg})(4186\ \text{J/kg}\,^\circ\text{C})T_F - (10.0\,\text{kg})(4186\ \text{J/kg}\,^\circ\text{C})(20\,^\circ\text{C})$$

So

$$4512\,000\ \text{J} + 669\,760\ \text{J} - (8372\ \text{J}/^\circ\text{C})T_F = (41860\ \text{J}/^\circ\text{C})T_F - 837200\ \text{J}$$

or

$$(125\,580\ \text{J}/^\circ\text{C})T_F = 6018960\ \text{J}$$

$$T_F = \frac{6018960\ \text{J}}{125\,580\ \text{J}/^\circ\text{C}} \approx 47.9\,^\circ\text{C}$$

J-4

41-27 We will use the ideal gas-law.

$p_0 = 4.00 \times 10^7$ Pa, $V_0 = 2.25\ m^3$, $T_0 = 680$ K.

a. The ideal gas law says pV/T = constant $= N k_B$

Hence

$$N = \frac{pV}{k_B T} = \frac{(4.00 \times 10^7 \text{Pa})(2.25\, m^3)}{(1.38 \times 10^{-23} \text{J/K})(680\text{K})} = 9.59 \times 10^{27}$$

b. In an adiabatic expansion pV^γ = constant, where $\gamma = c_p/c_v$. For a diatomic gas $c_p = \frac{7}{2}R$ and $c_v = \frac{5}{2}R$, so $\gamma = 7/5 = 1.4$. Thus

$$p_0 V_0^{1.4} = p_F V_F^{1.4} \quad \text{and} \quad V_F = 2V_0$$

so

$$p_F = p_0/2^{1.4} = p_0/2.64$$

Thus

$$p_0 V_0/T_0 = p_F V_F/T_F \Rightarrow \frac{p_0 V_0}{T_0} = \frac{(p_0/2.64)(2V_0)}{T_F}$$

so

$$T_F = T_0 \frac{2}{2.64} = 0.758\, T_0 = 515 \text{ K}$$

c. $$\Delta W = \int_{V_0}^{2V_0} p\, dV = N k_B T \int_{V_0}^{2V_0} \frac{dV}{V} = N k_B T \ln \frac{2V_0}{V_0} = N k_B T \ln$$

$$= p_0 V_0 \ln 2 = 9 \times 10^7 \text{ J} \ln 2$$
$$= 6.24 \times 10^7 \text{ J}$$

42-19 What is the temperature at the surface of Uranus? First, how far away from the sun is Uranus?

$$R_{US} = 2869 \times 10^8 \text{ km}$$

The solar constant 1.4 kW/m² at ~~Earth~~, will be

$$1.4 \frac{kW}{m^2} \times \left(\frac{R_{ES}}{R_{US}}\right)^2 =$$

$$1.4 \frac{kW}{m^2} \times \left(\frac{149.6}{2869}\right)^2 = 3.81 \text{ W/m}^2$$

Then this solar constant times the effective area of Uranus, πR_U^2, gives total energy input from the sun:

$$(3.81 \text{ W/m}^2)(\pi)(25{,}000 \text{ km})^2$$
$$= 7.474 \times 10^{15} \text{ W}$$

Now, Uranus must radiate away as much energy as it absorbs. If it's a blackbody, then

$$4\pi(25{,}000 \text{ km})^2 \sigma T^4 = \text{energy radiated away}$$

So

$$T^4 = \frac{3.81 \text{ W/m}^2}{4\sigma} = \frac{3.81 \text{ W/m}^2}{4(5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4)}$$

$$= 1.68 \times 10^7 \text{ K}^4$$

$$T = (1.68 \times 10^7 \text{ K}^4)^{1/4} = 64.0 \text{ K}$$

If there is an albedo, it will mean less energy absorbed, so a lower ambient temperature.

I-6

42-24 Why are the planet and star not at thermal equilibrium – at the same temperature?

They are at a dynamic equilibrium – the star emits energy supplied by its nuclear furnace. The planet is at equilibrium because its energy input (from the star) is equal to its energy output (radiation to space).

I-7

42-42 Laser light is 100 W/m². It hits a metal plate on one side. What is the equilibrium temperature of the plate if emissivity is 0.3?

The metal plate has a surface area of about 2A – the two sides, each of area A. The thin edge contributes very little area.

So

$$\cancel{A}\, 0.3\,(100\ \mathrm{W/m^2}) = 2\cancel{A}\,\sigma T^4$$

$$T^4 = \frac{30\ \mathrm{W/m^2}}{2(5.67\times10^{-8}\ \mathrm{W/(m^2K^4)})}$$

$$= 2.65\times10^{8}\,\mathrm{K}^4$$

so $$T = (2.65\times10^{8}\,\mathrm{K}^4)^{1/4}$$

$$= 127.5\ \mathrm{K}$$

7-8

43-2 N molecules of average energy $4k_B T$

a. Each degree of freedom represents a mean energy of $\frac{1}{2}k_B T$. Therefore there must be 8 degrees of freedom.

b. $U = N\frac{1}{2}m\langle v^2\rangle = 4Nk_B T = 4nRT$

c. To find c_p, we first find c_v, since

$$dU = nc_v dT$$
$$= 4nRdT$$
$$\Rightarrow c_v = 4R$$
$$\Rightarrow c_p = c_v + R = 5R$$

d. $$\frac{1}{2}m\langle v^2\rangle = 4k_B T$$

$$\langle v^2\rangle = \frac{2\cdot 4 k_B T}{m}$$, where m is the molecular mass

Now mN_A = molecular mass, so

$$\langle v^2\rangle = \frac{8k_B N_A T}{M} = \frac{8RT}{M}$$
$$= \frac{8(8.314\ J/\cancel{(mol\ K)})(400\ \cancel{K})}{46.5\ g/\cancel{mol}}$$
$$= 5.72\times10^5\ J/kg = 5.72\times10^5\ m^2/s^2$$

$$\langle v^2\rangle = v_{rms} = 756.4\ m/s$$

2-9

43-10 We wish to use $f(v)$ to find out what propotion of the molecules are within ± 1 m/s of $v_{most\ likely}$.

$$\frac{N_{ml}}{V} = \frac{4\pi N}{V}\left(\frac{m}{2\pi k_B T}\right)^{3/2}\int_{v_{most\ likely}-1\,m/s}^{v_{most\ likely}+1\,m/s} v^2 e^{-mv^2/2k_BT}\,dv$$

The propotion is this

$$\frac{N_{ml}}{N} = 4\pi\left(\frac{m}{2\pi k_B T}\right)^{3/2} v^2 e^{-mv^2/2k_BT}\Big|_{v_{most\ likely}} \Delta v$$

$$= 4\pi\left(\frac{m}{2\pi k_B T}\right)^{3/2} \frac{2k_BT}{m} e^{-1}(2\,m/s)$$

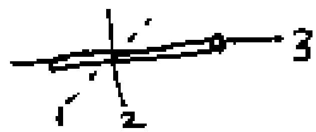
$$= 4\pi \frac{1}{\pi^{3/2}}\left(\frac{m}{2k_BT}\right)^{1/2} e^{-1}(2\,m/s)$$

$$= 4\pi^{-1/2}\left(\frac{m}{2k_BT}\right)^{1/2} e^{-1}(2\,m/s)$$

$$= 4.26\times 10^{-3}$$

I-10

43-17 A long thin rod floats in a gas, at temperature T. There are 3 moments of inertia for a cylinder



$I_1 = I_2 = \frac{1}{12} m l^2$ and $I_3 = \frac{1}{2} m r^2$, where l is the rod length and r is the rod radius, $r \ll l$. Given equipartition of energy, we'd expect

$$\frac{L_1^2}{2I_1} = \frac{L_2^2}{2I_2} = \frac{L_3^2}{2I_3}$$

Since we expect $I_3 < I_1 = I_2$, L_3 must be greater than $L_1 = L_2$. Hence the angular momentum vector should be greatest around axis 3.