

# Solutions to Problem Set 13

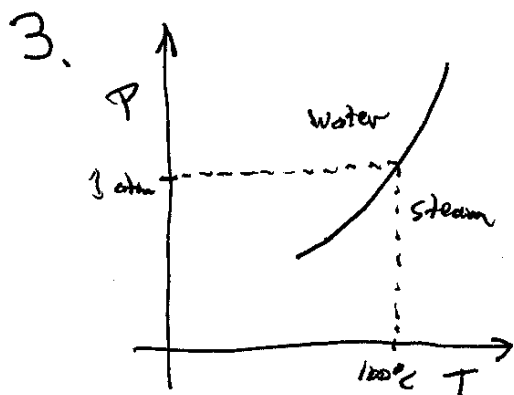
1. Siberia:  $T_f = \frac{9}{5} T_c + 32 = \frac{9}{5} (-71) + 32 = \underline{-96^\circ \text{F}}$ .

$$T_k = T_c + 273 = -71 + 273 = \underline{202 \text{ K}}$$

Death Valley:  $T_c = \frac{5}{9} (T_f - 32) = \frac{5}{9} (134 - 32) = \underline{57^\circ \text{C}}$ .

$$T_k = T_c + 273 = 57 + 273 = \underline{330 \text{ K}}$$

2. There's no "right" answer here, but look for what happens as you cool the system (remove energy) as crystals form and merge. Sometimes they'll have "defects" of various types. Also try the "ball" examples to see how other forms of energy get converted to "thermal" energy.



The positive slope of the liquid-gas phase boundary implies that at lower pressure (higher altitude), water boils at a lower temperature.

Therefore, at high altitude, noodles must cook at a lower temperature, and that takes longer.

4. (a) Molar mass =  $M = \frac{M_{\text{sample}}}{n}$

$$\rightarrow n = \frac{M_{\text{sample}}}{M} = \frac{2.5 \text{ g}}{197 \text{ g/mol}} = \underline{.0127 \text{ mol.}}$$

(b)  $N = n N_A = (.0127 \text{ mol})(6.02 \times 10^{23} \text{ mol}^{-1}) = \underline{7.6 \times 10^{21}}$

5.  $PV = N k_B T \rightarrow N = \frac{PV}{k_B T} = \frac{(10^{-18} \text{ atm}) \left( \frac{10^5 \text{ N/m}^2}{1 \text{ atm}} \right) (1 \text{ cm})^3 \left( \frac{1 \text{ m}}{100 \text{ cm}} \right)^3}{(1.38 \times 10^{-23} \text{ J/K})(293 \text{ K})}$

$$= \underline{25}$$

6. My living room measures about 7m by 4m by 2.5m.

$$\text{So } N = \frac{PV}{k_B T} = \frac{(10^5 \text{ N/m}^2)(70 \text{ m}^3)}{(1.38 \times 10^{-23} \text{ J/K})(300 \text{ K})} = 1.7 \times 10^{27}$$

$$\approx \underline{2 \times 10^{27}}$$

7. Both rooms have the same volume and, because of the open door, have the same pressure — otherwise air would immediately rush from one to the other. But the ideal gas law says

$$PV = N k_B T \rightarrow N = \frac{PV}{k_B} \cdot \frac{1}{T} \propto \frac{1}{T}$$

Same for both

So the cooler room (B) has more molecules.

$$\begin{array}{l}
 \text{8. On the ground, } P_1 V_1 = N k_B T_1 \\
 \text{Up high, } P_2 V_2 = N k_B T_2
 \end{array}
 \left. \vphantom{\begin{array}{l} P_1 V_1 = N k_B T_1 \\ P_2 V_2 = N k_B T_2 \end{array}} \right\} \frac{P_1}{P_2} \frac{V_1}{V_2} = \frac{T_1}{T_2}$$

$$\begin{aligned}
 \text{Solve for } V_2: \quad V_2 &= V_1 \cdot \frac{P_1}{P_2} \cdot \frac{T_2}{T_1} \\
 &= (2.2 \text{ m}^3) \left( \frac{760 \text{ torr}}{380 \text{ torr}} \right) \left( \frac{225 \text{ K}}{293 \text{ K}} \right) \\
 &= \underline{3.4 \text{ m}^3}
 \end{aligned}$$

9. (a) The work done on the gas is

$$\begin{aligned}
 W &= -P \cdot \Delta V = -(10^5 \frac{\text{N}}{\text{m}^2})(2.5 \text{ l} - 1.5 \text{ l}) \left( \frac{1 \text{ m}^3}{1000 \text{ l}} \right) \\
 &= -100 \text{ N}\cdot\text{m} \text{ or } -100 \text{ J.}
 \end{aligned}$$

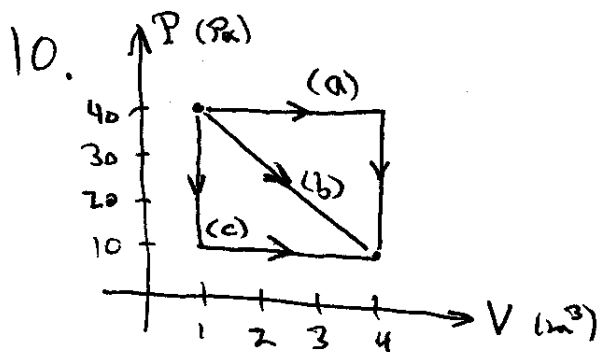
So the work done by the gas is +100 J.

(b) Again,  $W = -P \cdot \Delta V$

$$\begin{aligned}
 &= -(10^5 \text{ N/m}^2)(1.0 \text{ l} - 2.5 \text{ l}) \left( \frac{1 \text{ m}^3}{1000 \text{ l}} \right) \\
 &= +150 \text{ J} = \text{work done on} \\
 &\quad \text{the gas,}
 \end{aligned}$$

So the work done by the gas is -150 J.

(c) To maintain constant pressure you'd need to heat the gas as it expands, or cool it as it is compressed. You could do this with a flame and an ice bath...



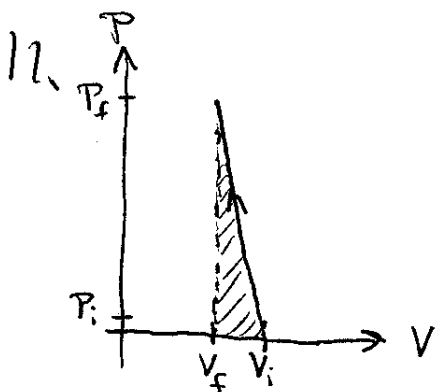
For any process, the work done on the system is  $-(\text{area under graph})$ , so the work done by the system is  $+(\text{area under graph})$ .

(a)  $W_{\text{by system}} = \text{area} = (40 \text{ Pa})(4 \text{ m}^3 - 1 \text{ m}^3) = \underline{120 \text{ J}}$ .

(b) Break the area into 2 pieces:

$$\begin{aligned} \triangle &= \frac{1}{2}(30 \text{ Pa})(3 \text{ m}^3) = 45 \text{ J.} \\ \square &= (10 \text{ Pa})(3 \text{ m}^3) = 30 \text{ J} \end{aligned} \left. \vphantom{\begin{aligned} \triangle \\ \square \end{aligned}} \right\} \underline{75 \text{ J. total.}}$$

(c)  $\text{area} = (10 \text{ Pa})(3 \text{ m}^3) = \underline{30 \text{ J}}$ .



$$\begin{aligned} W &= -(\text{area}) \approx +\frac{1}{2}(\text{base})(\text{height}) \\ &= \frac{1}{2}(V_i - V_f)(P_f) \quad (\text{neglecting } P_i) \\ &= \frac{1}{2}(1 \text{ l} - .99 \text{ l})(200 \text{ atm}) \\ &= \frac{1}{2}(.01 \text{ l})(200 \text{ atm}) \cdot \left(\frac{1 \text{ m}^3}{1000 \text{ l}}\right) \left(\frac{10^5 \text{ Pa}}{1 \text{ atm}}\right) \\ &= \underline{100 \text{ J}} \end{aligned}$$

Given the enormous pressure required, 100 J of work doesn't seem like much...