Chapter 15 Homework

1, 3, 8, 9, 11, 15, 22, 31, 34, 35, 36

P1. An ideal gas expands isothermally, performing $3.40 \times 10^3$ J of work in the process. Calculate (a) the change in internal energy of the gas, and (b) the heat absorbed during this expansion.

Solution:
(a) $T = \text{const.} \rightarrow \Delta U = 0$
(b) $\Delta U = Q - W \rightarrow Q = 0 + 3.4 \times 10^3 \text{J} = 3.4 \times 10^3 \text{J}$

P3. One liter of air is cooled at constant pressure until its volume is halved, and then it is allowed to expand isothermally back to its original volume. Draw the process on a PV diagram.

Solution:

P8. An ideal gas expands at a constant total pressure of 3.0 atm from 400 mL to 660 mL. Heat then flows out of the gas at constant volume, and the pressure and temperature are allowed to drop until the temperature reaches its original value. Calculate (a) the total work done by the gas in the process, and (b) the total heat flow into the gas.

Solution:
3 atm = (3.0 atm)$\left(\frac{1.013 \times 10^5 \text{Pa}}{1 \text{ atm}}\right)$ = 3.039 $\times 10^5$ Pa

$V_1 = 400 \text{ mL} = 400 \times 10^{-6} \text{ m}^3 = 4.00 \times 10^{-4} \text{ m}^3$

$V_2 = 660 \text{ mL} = 660 \times 10^{-6} \text{ m}^3 = 6.60 \times 10^{-4} \text{ m}^3$

(a) $W = P \Delta V = (3.039 \times 10^5 \text{Pa})(6.60 \times 10^{-4} \text{m}^3 - 4.00 \times 10^{-4} \text{m}^3) = 79 \text{ J}$

(b) $\Delta U = Q - W \rightarrow \Delta U = 0 \rightarrow Q = W = 79 \text{ J}$

P9. One and a half moles of an ideal monatomic gas expand adiabatically, performing 7500 J of work in the process. What is the change in temperature of the gas during this expansion?

Solution:

$Q = 0$

$\Delta U = Q - W \rightarrow \frac{3}{2} nR \Delta T = -W \rightarrow \Delta T = \frac{-7500 \text{ J}}{\frac{3}{2}\cdot(1.5)(8.315)} = -4.0 \times 10^2 \text{ K}$

P11. The PV diagram in Fig. 15-23 shows two possible states of a system containing 1.35 moles of a monatomic ideal gas. ($P_1 = P_2 = 455 \frac{\text{N}}{\text{m}^2}$, $V_1 = 2.00 \text{ m}^3$, $V_2 = 8.00 \text{ m}^3$)

(a) Draw the process which depicts an isobaric expansion from state 1 to state 2, and label this process A
(b) Find the work done by the gas and the change in internal energy of the gas in process A.
(c) Draw the two-step process which depicts an isothermal expansion from state 1 to the volume \( V_2 \), followed by an isovolumetric increase in temperature to state 2, and label this process B.
(d) Find the change in internal energy of the gas for the two-step process B.

**Solution:**

\((b)\)  
\[ W = P \Delta V = \left( 455 \text{ N/m}^2 \right) (8.00 \text{ m}^3 - 2.00 \text{ m}^3) = 2.73 \times 10^3 \text{ J} \]
\[ \Delta U = \frac{3}{2} n R \Delta T = \frac{3}{2} (nRT_2) - \frac{3}{2} (nRT_1) = \frac{3}{2} (P_2V_2 - P_1V_1) \]
\[ \Delta U = \frac{3}{2} P \Delta V = \frac{3}{2} W = 4.10 \times 10^3 \text{ J} \]

\((d)\)  
\( \Delta U \) depends only on the initial and final state, which are the same for process A and B:
\[ \Delta U_B = \Delta U_A = 4.10 \times 10^3 \text{ J} \]

**P22.** It is not necessary that a heat engine's hot environment be hotter than ambient temperature. Liquid nitrogen (77 K) is about as cheap as bottled water. What would be the efficiency of an engine that made use of heat transferred from air at room temperature (293 K) to the liquid nitrogen "fuel"?

**Solution:**

\[ e = 1 - \frac{T_h}{T_i} = 1 - \frac{77 \text{ K}}{293 \text{ K}} = 0.7372 \approx 74\% \]

**Problems 15, 31, 34, 35, 36 are canceled.**