HW1 (i) When an ideal gas undergoes an isothermal process, $\Delta U = 0$ and $\Delta H = 0$.

$$w = -nRT \ln \frac{P_1}{P_2} = -\left(\overset{1.64}{\cancel{1}}\ \text{mol}\right)\left(8.314\ \text{J K}^{-1}\ \text{mol}^{-1}\right)(300\ \text{K}) \ln \frac{15.0\ \text{atm}}{1.00\ \text{atm}} = -\overset{11.07}{\cancel{6.75}} \times 10^3\ \text{J}$$

$$q = \Delta U - w = -w = 6.75 \times 10^3\ \text{J}$$

**(ii)** $q = 0$ for an adiabatic process.

To determine $\Delta U$ and $\Delta H$, $T_2$ needs to be calculated.

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma} = (300\ \text{K}) \left(\frac{1.00\ \text{atm}}{15.0\ \text{atm}}\right)^{\left(\frac{5}{3}-1\right)/\frac{5}{3}} = 101.6\ \text{K}$$

Now the rest of the quantities can be calculated:

$$\Delta U = C_V \Delta T = \frac{3}{2}\left(\overset{1.64}{\cancel{1}}\ \text{mol}\right)\left(8.314\ \text{J K}^{-1}\ \text{mol}^{-1}\right)(101.6\ \text{K} - 300\ \text{K}) = -\overset{4.05}{\cancel{2.47}} \times 10^3\ \text{J}$$

$$w = \Delta U - q = \Delta U = -2.47 \times 10^3\ \text{J}$$

$$\Delta H = C_P \Delta T = \frac{5}{2}\left(\overset{1.64}{\cancel{1}}\ \text{mol}\right)\left(8.314\ \text{J K}^{-1}\ \text{mol}^{-1}\right)(101.6\ \text{K} - 300\ \text{K}) = -\overset{6.76}{\cancel{4.12}} \times 10^3\ \text{J}$$

**(iii)** When an ideal gas undergoes an isothermal process, $\Delta U = 0$ and $\Delta H = 0$.

$$w = -P_{ex}\left(V_2 - V_1\right)$$

$V_1$ and $V_2$ can be determined using the ideal gas law:

$$V_1 = \frac{nRT}{P_1} = \frac{\left(\overset{1.64}{\cancel{1}}\ \text{mol}\right)\left(0.08206\ \text{L atm K}^{-1}\ \text{mol}^{-1}\right)(300\ \text{K})}{15.0\ \text{atm}} = \overset{2.69}{\cancel{1.641}}\ \text{L}$$

$$V_2 = \frac{nRT}{P_2} = \frac{\left(\overset{1.64}{\cancel{1}}\ \text{mol}\right)\left(0.08206\ \text{L atm K}^{-1}\ \text{mol}^{-1}\right)(300\ \text{K})}{1.00\ \text{atm}} = \overset{40.38}{\cancel{24.62}}\ \text{L}$$

Therefore,

$$w = -(1.00\ \text{atm})\left(\overset{40.38}{\cancel{24.62}}\ \text{L} - \overset{2.69}{\cancel{1.641}}\ \text{L}\right)\left(\frac{101.3\ \text{J}}{1\ \text{L atm}}\right) = -\overset{3.82}{\cancel{2.33}} \times 10^3\ \text{J}$$

and

$$q = \Delta U - w = -w = \overset{3.82}{\cancel{2.33}} \times 10^3\ \text{J}$$

**(iv)** $q = 0$ for an adiabatic process.

To determine $\Delta U$ and $\Delta H$, $T_2$ needs to be calculated. Using the same procedure as **(ii) above**

$$T_2 = \frac{2}{5}\left(\frac{P_{ex}}{P_1} + \frac{3}{2}\right) T_1$$

$$= \frac{2}{5}\left(\frac{1.00 \text{ atm}}{15.0 \text{ atm}} + \frac{3}{2}\right)(300 \text{ K}) = 188 \text{ K}$$

Now the rest of the quantities can be calculated:

$$\Delta U = C_V \Delta T = \frac{3}{2}\left(\overset{1.64}{\cancel{1}} \text{ mol}\right)\left(8.314 \text{ J K}^{-1} \text{ mol}^{-1}\right)(188 \text{ K} - 300 \text{ K}) = -\overset{2.30}{\cancel{1.40}} \times 10^3 \text{ J}$$

$$w = \Delta U - q = \Delta U = -\overset{2.30}{\cancel{1.40}} \times 10^3 \text{ J}$$

$$\Delta H = C_P \Delta T = \frac{5}{2}\left(\overset{1.64}{\cancel{1}} \text{ mol}\right)\left(8.314 \text{ J K}^{-1} \text{ mol}^{-1}\right)(188 \text{ K} - 300 \text{ K}) = -\overset{3.82}{\cancel{2.33}} \times 10^3 \text{ J}$$