Chem 205 sec 222
Answers to problem set thermo-1, Jan 2004

Question 1:

A system is being used to convert heat to work. During this process q J of heat are transferred to the system which does w J of work on the surroundings (by lifting a weight for example).What is the change in internal energy of the system during this process?

Since system absorbs the heat by sign convention q>0 and since work is done by the system w<0 so according to the first law of thermodynamics change in internal energy will be:

$$\Delta E = q + w$$
$$if \qquad q = 2290J \qquad and \qquad w = -682J$$
$$\Delta E = 2290J - 682J = 1662J$$

Question 2:

Calculate the work, w,(in Joules) when V_i litre of an ideal gas at an initial pressure of P_i atm is expanded ISOTHERMALLY to a final pressure P_f atm against constant external pressure of P_{ext} atm.

$$w = -\int_{Vi}^{Vf} P_{ext}dV = -P_{ext}\int_{Vi}^{Vf} dV = -P_{ext}(V_f - V_i) = -P_{ext}\Delta V$$

In order to calculate work we have to find out Δ V,or V_f using the ideal gas law:

$$P_f V_f = nRT = P_i V_i$$
$$\Rightarrow V_f = \frac{P_i V_i}{P_f}$$
$$R = 8.314 J / Kmol$$
$$1 atmL = 101.325J$$

Question 3:

Calculate the work w when V_i litre of an ideal gas at an initial pressure of P_i atm is expanded or compressed ISOTHERMALLY to a final volume of V_f litre into a VACUUM.

Starting from the definition of work:

$$w = -\int_{Vi}^{Vf} P_{ext}dV$$

and definition of vacuum where $P_{vacuum}=P_{ext}=0$

$$w = 0$$

Question 4:

Calculate the heat when V_i litre of an ideal gas at an initial pressure of P_i atm is expanded or compressed ISOTHERMALLY to a final volume of V_f litre into a VACUUM.
First law of thermodynamics says that

$$\Delta E = q + w$$

For an ideal gas internal energy is a function of temperature only, so for an isothermal process (T=const.) there is no change in internal energy of an ideal gas, $\Delta E = 0$ .Since $w = 0$ => $q = 0$.

Question 5:

Calculate the heat when V_i litre of an ideal gas at an initial pressure of P_i atm is expanded or compressed ISOTHERMALLY to a final volume of V_f litre against a constant external pressure P_{ext} atm.
Starting from the definition of work :

$$w = -\int_{Vi}^{Vf} P_{ext} dV$$

when P_{ext}=const

$$w = -P_{ext}\int_{Vi}^{Vf} dV = -P_{ext}(V_f - V_i) = -P_{ext}\Delta V$$

Since for isothermal process $\Delta E = 0$, q=-w=$P_{ext}\Delta V$

Question 6:

Calculate the work when V_i litre of an ideal gas at an initial pressure of P_i atm is expanded or compressed ISOTHERMALLY to a final volume of V_f litre reversibly.

For a reversible process using the fact that $P_{gas}=P_{ext}=P=\frac{nRT}{V}$ work can be expressed as:

$$w = -\int_{Vi}^{Vf} P_{ext} dV = -\int_{Vi}^{Vf} P_{gas} dV = -\int_{Vi}^{Vf}\frac{nRT}{V}dV = -nRT\ln\frac{V_f}{V_i} \quad \text{where}$$

$$P_f V_f = nRT = P_i V_i$$

Question 7:

Calculate the change in internal energy , ΔE, when V_i litre of an ideal gas at an initial pressure of P_i atm is expanded or compressed ISOTHERMALLY to a final volume of V_f litre reversibly.

For an ideal gas internal energy is a function of temperature only, E=E(T), so for an isothermal process(T=const.) there is no change in internal energy of an ideal gas, $\Delta E = 0$.

Question 8:

V_i litre of an ideal monoatomic gas (C_v=3R/2) initially at T_i degrees C and P_i atm pressure undergo an expansion against a constant external pressure of P_{ext} atm and do work of w (w<0)J. The final pressure of the gas is P_f atm. Calculate the change in enthalpy, delta H.

$$\Delta H = \Delta E + \Delta(PV) = nC_v\Delta T + nR\Delta T = n(C_v + R)\Delta T = nC_p\Delta T = \frac{5}{2}nR\Delta T$$

From the ideal gas law applied to an initial state $T_i = \frac{P_i V_i}{nR}$ number of moles, n can be calculated. From the work equation

$$w = -P_{ext}\int_{Vi}^{Vf} dV = -P_{ext}(V_f - V_i) = -P_{ext}\Delta V$$

V_f can be determined.

Only missing data is T_f that can be calculated from the ideal gas law applied to the final state $T_f = \frac{P_f V_f}{nR}$.