Chemistry 456A (10:30AM Bagley 154)

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Problem Set 3A (due 9PM Tuesday, 1/17/12)

Q1) 1-mol sample of an ideal gas for which $C_{V,m} = \frac{3}{2}R$ undergoes the following two step process:

a) From an initial state of the gas described by $T = 28°C \text{ and } P = 2.0 \cdot 10^4 \, Pa$, the gas undergoes an isothermal expansion against a constant external pressure of $1.0 \cdot 10^4 \, Pa$ until the volume has doubled. Calculate $q, \quad w, \text{and } \Delta U$ for this step of the process.

b) Subsequently, the gas is cooled at constant volume (isochoric). The temperature falls to $-40.5°C$. Calculate $q, \quad w, \text{and } \Delta U$ for this step of the overall process.

c) Calculate $q, \quad w, \text{and } \Delta U$ for the overall process.

Q2) Energy can be put into a gas by heating. The increase in temperature is related to the increase in internal energy according to the heat capacity.

a) If one mole of an ideal monoatomic gas is raised from $25°C$ to $125°C$ how much does the internal energy of the gas increase?
b) If the gas of part a is a diatomic molecule how much does the internal energy increase for the same temperature change.
c) Explain why the change is different for the two different types of gas.
d) The heat capacity of a material is often somewhat temperature dependent. Use the temperature dependence of the heat capacity of chlorine gas (a diatomic molecule) to estimate the change in its internal energy when the temperature of one mole of chlorine gas is raised from $25°C$ to $125°C$.

$$C = a + bT + cT^2$$

$$a = 25.635 \, J/mol-K, \quad b = 10.144 \cdot 10^{-3} \, J/mol-K^2, c = -40.38 \cdot 10^{-7} \, J/mol-K^3$$

Compare your result to part b. [Hint, again we use the principle $\Delta U = \int dU$]

Q3) Consider the gas in question 1, part a for which we found $q, \quad w, \text{and } \Delta U$. For the same gas, and a similar process compute the $q, \quad w, \text{and } \Delta U$. For (the same gas and same final and ending T and P as question 1a) one mole of a monoatomic gas that goes isothermally from an initial state described by $T = 28°C \text{ and } P = 2.0 \cdot 10^4 \, Pa$, to a state where the pressure of the gas is $1.0 \cdot 10^4 \, Pa$. The process by which the change occurs is reversible: that is, the pressure is very slowly reduced so that the reversible path may be used.

a) Compare the work done by the system for this process with the work done in question 1a. Which is “larger” and why?
b) Compare the heat transferred for this process and that in question 1a.

c) Compare the energy change for the system for this process and that in question 1a.
d) Comment on which parameters are different and which are the same and why.

Q4) Now consider one mole of an ideal gas for which $C_{V,m} = \frac{3}{2}R$ From an initial state of the gas described by $T = 28°C \text{ and } P = 2.0 \cdot 10^4 Pa$, the gas undergoes an adiabatic expansion against a constant external pressure of $1.0 \cdot 10^4 Pa$ until internal pressure equals the external pressure. In an adiabatic expansion $q = 0$ because no heat is transferred either in or out of the system.

a) Write down the equation of state, the general equations for Law 1A (the first law) and Law 1B (the relation of the energy to the thermodynamic parameters), and the work. This represents your starting point.

EoS:
Law 1A:
Law 1B:
Work:

b) Develop a general expression that relates the temperature change ($\Delta T = T_2 - T_1$) and the pressure change, which can include the start and end pressures and temperatures (and the heat capacity) but not the volumes. [You have enough expressions to equate the work and the internal energy change and using the EoS remove the volume dependence.] This gives you an equation for the temperature drop, and you should know everything else.
c) Determine the final temperature and comment on why you expect the temperature to go up or down.
d) Determine the new volume. Compare the volume change to the result in question 1a in which the volume doubled. Did you expect the final volume to be larger or smaller than that in 1a?
e) Compare the amount of work done in this (adiabatic) process with that in 1a (the isothermal process). [As a hint: The ratio of these two works is 5/3, not specifying which is which.]