CHEM 331
Physical Chemistry
Fall 2010

Problem Set 5

Problems

1. Use the First Law to determine whether each of the quantities Q, W and ΔU is positive, negative or zero for the following processes. Make reasonable assumptions.

   a) A rubber band is stretched rapidly. In the process, its temperature rises several degrees.
   b) 10g of solid $NaNO_3$ is added to Water at 25°C in a Dewar flask. As the salt dissolves, the temperature drops to 22°C.
   c) 10 g of solid $NaNO_3$ is added to Water at 25°C in an Erlenmeyer flask immersed in a thermostat at 25°C. After the salt dissolves, thermal equilibrium with the bath is restored.
   d) A flashlight is switched on, then off. The light bulb momentarily becomes warm then cools off to ambient temperature. Take the light bulb as the system.

2. One mole of an Ideal Gas is isothermally expanded from an initial pressure of 2 MPa to a final pressure of 1MPa at 300K. What are the values of ΔU, ΔH, Q and W for the expansion:

   a) if the expansion is carried out reversibly.
   b) if the expansion is carried out irreversibly against a constant pressure of 1 MPa.

3. A sample consisting of 1.00 mole of an Ideal Gas with a heat capacity $C_v = 3/2\ R$ is initially at 1.00 atm and 300K. This sample is heated reversibly to 400K at constant volume. Calculate the final pressure and ΔU, Q and W.

4. At 25°C the Coefficient of Thermal Expansion for Water is $\alpha = 2.07 \times 10^{-4}\ K^{-1}$ ant the density is 0.9970 g/cm^3. Additionally, $C_p = 75.30$ J/K mol. If the temperature of 200g of Water is raised from 25°C to 50°C under a constant pressure of 101 kPa, calculate Q, ΔU and ΔH. (W for this process was calculated in Problem Set 4, Problem 6.)

5. Calculate, generally, Π_T for a van der Waals gas. Interpret the result. Use this result to calculate ΔU for a van der Waals gas that expands Isothermally from a volume equal to *b*, the liquid volume, to a volume of 20.0L. Take $a = 0.136\ m^6Pa/mol^2$ and $b = 0.0391\ dm^3/mol$.
   [Ans. 3.47 kJ/mol]

6. For the reaction:

$$H_2(g) + \tfrac{1}{2} O_2(g) \longrightarrow H_2O(l) \qquad (101.3\ kPa, 298K)$$

285.45 kJ of heat are evolved per mole of Water formed if the reaction is carried out at constant pressure. How much heat would be evolved if the reaction were carried out at constant volume?
[Ans. 282.1 kJ]

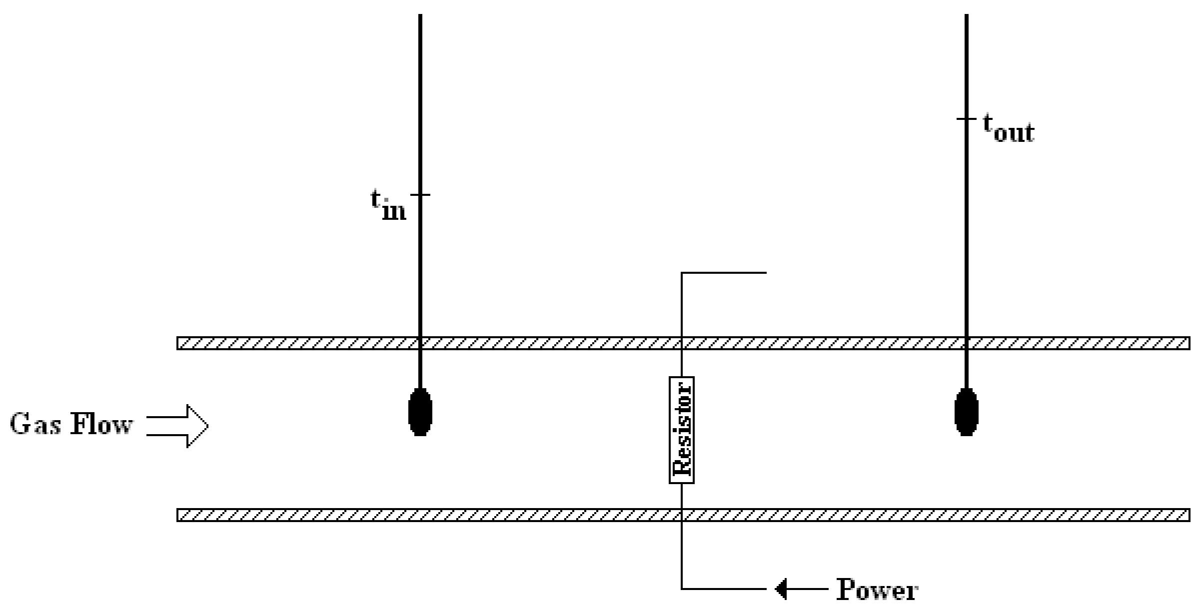
7. When 3.0 mole O_2 is heated at constant pressure of 3.25 atm, its temperature increases from 260K to 285K. Given that C_p = 29.4 J/K mol for O_2, calculate Q, ΔH, and ΔU.

8. The Heat Capacity of solid Lead Oxide, PbO, is given by:

$$\bar{C}_p \text{ [J/K mol]} = 44.35 + (1.67 \times 10^{-3})\,T$$

Calculate ΔH if PbO is cooled at constant pressure for 500K to 300K.
[Ans. -9004 J/mol]

9. In an adiabatic flow calorimeter system fitted with an electric heater:



the following data were obtained for Water vapor:

Pressure	=	20.0 kPa
Inlet Temp	=	110.0°C
Flow Rate	=	0.8462 mmole/sec
Temp Rise	=	1.039°C
Elec Power	=	0.03187 Watts

a) Calculate the molar Heat Capacity C_p.
[Ans. 36.25 J/K mol]

b) With the heater is removed and a throttle installed, the following results were obtained for Water vapor:

Flow Rate	=	0.5603 mmole/sec
Inlet Press	=	33.00 kPa
Exit Press	=	2.95 kPa
Inlet Temp	=	110.0°C
Temp Rise	=	1.605°C

Calculate the mean value of the Joule-Thomson Coefficient μ_{JT} for this pressure interval.
[Ans. – 5.34 x 10^{-5} K/Pa]

c) Calculate the derivative:

$$\left(\frac{\partial H}{\partial P}\right)_T$$

for Water vapor at this temperature for this pressure range. Express the result in J/atm mol.
[Ans. 196 J/atm mol]

10. The Joule-Thomson Coefficient μ_{JT} for a van der Waals Gas is given by:

$$\mu_{JT} = [(2a/RT)- b]/\bar{C}_p$$

Calculate the value of ΔH for the isothermal (300K) compression of 1 mole of Nitrogen gas from 1 atm to 500 atm. [van der Waals constants are given in a previous handout.]

11. The restoring force F on a stretched elastic substance is a function of length *l* and temperature T; F(*l*,T). If U is also a function of *l* and T, U(*l*,T), show that the heat capacity at constant F is:

$$C_F = \left(\frac{\partial U}{\partial T}\right)_l + \left[\left(\frac{\partial U}{\partial l}\right)_T - F\right]\left(\frac{\partial l}{\partial T}\right)_F$$