Chemistry 2720 Fall 2001 Test 1

Write all your answers in the booklets provided. Don't hand in the question sheet.

Formulas and data are given at the end of this paper.

Aids allowed: calculator. Periodic tables and other printed aids are strictly forbidden.

Questions: 4. Total marks: 52. Time: 75 min.

1. The gas phase reaction
$$BrF_{3(g)} + F_{2(g)} \rightarrow BrF_{5(g)}$$
is carried out in an adiabatic container at constant pressure. Assuming that the reaction goes to completion, that the container initially holds a stoichiometric mixture of the reactants, and that the initial temperature of the reactants is 25°C, estimate the final temperature of the product. [9 marks]

2. Suppose that an industrial process generates heat by burning methane in a constant-volume chamber at 1200 K.
   (a) Calculate the enthalpy of combustion of methane at 1200 K. [9 marks]
   (b) Were there any doubtful approximations made in the above calculation? Explain briefly. [2 marks]
   (c) Calculate the heat released per mole by the combustion of methane at 1200 K under constant-volume conditions. [6 marks]

3. The standard entropy of liquid methanol at 298.15 K is 126.8 $\mathrm{J\,K^{-1}mol^{-1}}$ and its heat capacity is 81.6 $\mathrm{J\,K^{-1}mol^{-1}}$. Methanol boils at 337.22 K with an enthalpy of vaporization at that temperature of 35.270 kJ/mol. The heat capacity of the vapor is 43.9 $\mathrm{J\,K^{-1}mol^{-1}}$. Calculate the entropy of methanol vapor at 800 K. [9 marks]

4. Cogeneration is a process in which a heat engine (typically a steam turbine) is used to drive an electrical generator and the waste heat is used either to heat some buildings or to provide hot water.
   (a) TransAlta is currently building a natural gas cogeneration plant which will generate 440 MW of electrical power in Sarnia, Ontario. This plant will provide power and steam to factories owned by Dow Chemical Canada Inc. and NOVA Chemicals. Suppose that this plant has a steam inlet temperature of 500°C and an outlet temperature of 120°C. Calculate the amount of natural gas which must be burned per day to sustain the electrical output of this cogeneration plant. The specific heat of combustion of natural gas is 37.0 $\mathrm{kJ/m^3}$.[1] [8 marks]

[1] The amount of natural gas is normally measured by volume corrected to 15°C and 1 atm.

(b) At what minimum rate is heat ejected by the generator? [2 marks]

(c) Suppose that the heat ejected is used to replace heat which would have been generated by burning natural gas. How much natural gas is saved per day? [3 marks]

(d) A real steam turbine will function at a somewhat lower efficiency than that calculated in question 4a. Is this as serious a problem for a cogeneration plant as it is for a heat engine which makes no use of the waste heat? Explain briefly. [4 marks]

Formulas and data

$PV = nRT$

$R = 8.314472\,\mathrm{J\,K^{-1}mol^{-1}}$

$\Delta E = q + w$

$H = E + PV$

$C_P = \left.\frac{dq}{dT}\right|_P$

$dS = dq_{\mathrm{rev}}/T$

$\eta = 1 - \frac{T_{\mathrm{low}}}{T_{\mathrm{high}}} = -\frac{w}{q_{\mathrm{in}}}$

$1\,\mathrm{W} = 1\,\mathrm{J/s}$

To convert degrees Celsius to Kelvin, add 273.15.

Standard Thermodynamic Properties at 298 K and 1 bar		
Species	$\Delta\overline{H}_f^\circ$ (kJ/mol)	$\overline{C}_P$ ($\mathrm{J\,K^{-1}mol^{-1}}$)
$BrF_{3(g)}$	−255.60	66.61
$BrF_{5(g)}$	−428.8	99.62
$CH_{4(g)}$	−74.81	35.31
$CO_{2(g)}$	−393.51	37.1
$F_{2(g)}$	0	31.30
$H_2O_{(g)}$	−241.826	33.58
$O_{2(g)}$	0	29.35