LAST Name: ____

FIRST Name: ____

Student #: ____

CHM2132
Midterm #1
Fall 2013

This is a closed book exam with no notes allowed.
Non-graphing, non-programmable calculators are permitted.
An equation sheet with constants and conversion factors are provided on the last page.
You may rip this page off of the exam and use it for rough work.

You must show all work to receive partial credit.

Remember to include units in all your calculations**.**
Marks will be deducted if units are not shown in your final answer.
Marks will be deducted if an unreasonable number of sig figs is shown in final answer.
If data calculated in previous sections of a multi-part question and used for subsequent calculations is incorrect, no additional mark deductions will be applied.

You have 75 minutes to complete this test.

Q1: __________/8 Q2: __________/13 Q3: __________/14 Q4: __________/10

Total = __________/45

Question 1. The following statements are **FALSE**. **Choose 4 of the 5 statements below** and:

(i) Change the sentence so that it becomes a correct statement.
(ii) In one sentence explain why the statement was incorrect. (8 marks)

NOTE: A wide range of answers was possible for these questions.

a) The entropy of any isothermal process can be experimentally determined by measuring the heat of the process and dividing this number by the temperature.

b) Oil and water undergo spontaneous phase separation because of favorable hydrophobic interactions between oil molecules.

c) If $\Delta S_r^o < 0$ for the isothermal transition of a protein from the unfolded to the folded state then we know that this process will not be spontaneous.

d) For an isothermal chemical reaction run at constant pressure, $\Delta_r U_m$ is always less than $\Delta_r H_m$.

i) For an isothermal chemical reaction run at constant pressure, $\Delta_r U_m$ is sometimes less than $\Delta_r H_m$

ii) $\Delta H_m = \Delta U_m + \Delta(pV) = \Delta U_m + \Delta nRT$ where Dn is the change in the number of moles of gas over the reaction. When Δn is less than zero $\Delta U_m < \Delta H_m$.

e) If a cup of water containing some ice is put into a freezer held at -20°C, the chemical potential of the ice will be constant.

Question 2. Answer the questions below, using the data acquired at 298 K shown in the tables.

	$\Delta H^o_{r,m}$ (kJ/mol)
B_2H_6 (g) +3 O_2 (g) $\rightarrow$ B_2O_3 (s) + 3 H_2O (g)	-2036
2 B (s) + 3/2 O_2 (g) $\rightarrow$ B_2O_3 (s)	-1274
H_2 (g) + ½ O_2 (g) $\rightarrow$ H_2O (g)	-241.8

	S^o_m (J/K/mol)	$C^o_{p,m}$ (J/K/mol)
H_2 (g)	130.7	28.8
O_2 (g)	205.1	29.4
B (s)	5.90	11.1
B_2O_3 (s)	54.0	62.8
B_2H_6 (g)	233.1	56.0

a) Determine $\Delta H^o_{f,m}$ for B_2H_6(g) at 298 K. (3 marks)

The formation reaction is: 2 B (s) + 3H_2 (g) $\rightarrow$ B_2H_6 (g)

So we combine the given data as follows:

	$\Delta H^o_{r,m}$ (kJ/mol)
B_2O_3 (s) + 3 H_2O (g) $\rightarrow$ B_2H_6 (g) +3 O_2 (g)	-2036 x -1
2 B (s) + 3/2 O_2 (g) $\rightarrow$ B_2O_3 (s)	-1274
H_2 (g) + ½ O_2 (g) $\rightarrow$ H_2O (g)	-241.8 x 3
Total $\left(\Delta H^o_{f,m}\right)$	36.6 kJ/mol

b) Based on your answer in a), state whether the formation reaction is exothermic or endothermic. (1 mark)

The formation enthalpy is positive, so the reaction is endothermic (since we put energy in).

c) Determine $\Delta H^o_{f,m}$ for B_2H_6(g) at 310 K. (3 marks)

$$\begin{aligned}
\Delta H^o_{f,m}\left(310\text{ K}\right) &= \Delta H^o_{f,m}\left(298\text{ K}\right) + \Delta C^o_{p,m}\Delta T \\
&= \Delta H^o_{f,m}\left(298\text{ K}\right) + \left(C^o_{p,m}\left(\mathrm{B_2H_6}\right) - 2\times C^o_{p,m}\left(\mathrm{B}\right) - 3\times C^o_{p,m}\left(\mathrm{H_2}\right)\right)\Delta T \\
&= 36.6\text{ kJ mol}^{-1} + \left(56.0 - 2\times 11.1 - 3\times 28.8\right)\text{J K}^{-1}\text{ mol}^{-1}\left(10^{-3}\text{ kJ/J}\right)\left(310\text{ - }298\right)\text{K} \\
&= 36.6\text{ kJ mol}^{-1} + \left(-52.6\right)\text{J K}^{-1}\text{ mol}^{-1}\left(10^{-3}\text{ kJ/J}\right)\left(12\text{K}\right) \\
&= 36.0\text{ kJ mol}^{-1}
\end{aligned}$$

d) Find $\Delta U^o_{f,m}$ for B_2H_6 (g) at 298 K. (3 marks)

$$\Delta U^o_{f,m} = \Delta H^o_{f,m} - \Delta(pV)$$
$$= \Delta H^o_{f,m} - \Delta(\nu RT) = \Delta H^o_{f,m} - \Delta\nu RT$$

There are 3 molar equivalents of gas in the reactants, and 1 molar equivalent of gas in the products so:

$$\Delta U^o_{f,m} = 36.6 \text{ kJ mol}^{-1} - (1-3)(8.314 \text{ J K}^{-1} \text{ mol}^{-1})(298 \text{ K})(10^{-3} \text{ kJ/J})$$
$$= 41.5 \text{ kJ mol}^{-1}$$

e) What is the maximum work that could be done in the formation of 1.00 mol of B_2H_6 at 298 K? (3 marks)

Since this a constant pressure, isothermal process, the Helmholtz energy corresponds to the maximum work that can be done:

Question 3.

A 2.15 mol sample of an ideal gas with $C_{v,m}$ = 3/2 R, for which p = 2.50 atm and T = 465 K is expanded adiabatically against an external pressure of 0.613 atm until the final pressure is 0.613 atm.

a) What is the final temperature of the gas? (4 marks)

$$nC_{V,m}\Delta T = -p_{ext}\Delta V$$
$$n\frac{3R}{2}\Delta T = -p_{ext}\left(\frac{nRT_2}{p_2} - \frac{nRT_1}{p_1}\right)$$
$$\frac{3}{2}(T_2 - T_1) = -T_2 + \frac{p_{ext}T_1}{p_1}$$
$$T_2 = \frac{2}{5}\frac{p_{ext}T_1}{p_1} + \frac{3}{5}T_1$$
$$= \frac{2}{5}\frac{(0.613 \text{ atm})(465 \text{ K})}{2.50 \text{ atm}} + \frac{3}{5}465K$$
$$= 325 \text{ K}$$

b) How much work is done? (3 marks)

Since the process is adiabatic, q=0 and w=ΔU:

$$\begin{aligned}\Delta U &= nC_{V,m}\Delta T\\ &= \left(2.15\text{ mol}\right)\frac{3}{2}\left(8.314\text{ J K}^{-1}\text{ mol}^{-1}\right)\left(325\text{ K - }465\text{ K}\right)\\ &= -3.75\text{ kJ}\end{aligned}$$

c) What is the total entropy change for the gas? (4 marks)

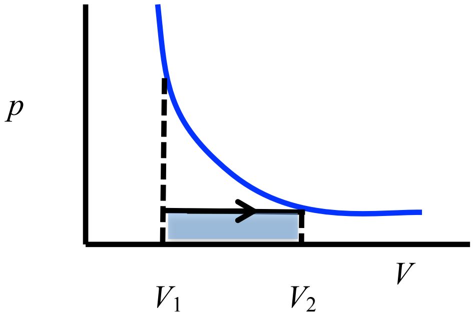
Question 4. Answer the following short questions:

a) Write down the van der Waals equation, and circle the term(s) that account for the attractive interaction between gas molecules. (1 mark)

$$p = \frac{nRT}{V - nb} + \boxed{a\left(\frac{n}{V}\right)^2}$$

b) On a pressure *versus* volume diagram, draw an isothermal expansion against constant pressure, and shade in the portion that corresponds to the work of this process. Be sure to label the initial and final volume on the graph axis. (3 marks)

Since the expansion is against constant pressure this is irreversible.



c) For the process in b), what is doing the work, the system or the surroundings? (1 mark)

The system is doing the work (since work is negative).

d) Given that $\beta = \frac{1}{VT}\left(\frac{\partial V}{\partial T}\right)_p$, find $\frac{V_i}{V_f}$. <u>You must show your work</u> to get marks in this question. (3 marks)

$$\int_{T_1}^{T_2} \beta T \, dT = \int_{V_1}^{V_2} \frac{1}{V} dV$$

$$\tfrac{1}{2}\beta\left(T_2^2 - T_1^2\right) = \ln\left(\frac{V_2}{V_1}\right)$$

$$\frac{V_2}{V_1} = e^{\frac{1}{2}\beta\left(T_2^2 - T_1^2\right)}$$

$$\frac{V_1}{V_2} = e^{-\frac{1}{2}\beta\left(T_2^2 - T_1^2\right)}$$

e) Suppose, two copper bars $\left(C^o_{p,m} = 24.4 \text{ J K}^{-1} \text{ mol}^{-1}\right)$, one initially at 80°C and the other initially at 20°C, are brought into contact with each other in a thermally insulated compartment and then allowed to come to equilibrium. (Assume no volume change.) What is ΔU^o_m and ΔH^o_m for this process? (2 marks)

The heat that is transferred by the warm bar is absorbed by the cool bar, that is: $q_{\text{warm bar}} = -q_{\text{cool bar}}$. Therefore there is no net heat transfer. There is also no volume change, so both ΔU and ΔH equal zero.