Section 1 - Kuwata Chemistry 112 FYC Fall 2004

General Chemistry II
Problem Set 7
Due Monday, November 8

1. (3 points) Atkins and Jones Exercise 6.10

2. (3 points) Atkins and Jones Exercise 6.15

3. (3 points) Atkins and Jones Exercise 6.35
   What fraction (percentage) of the required energy goes into actually melting the ice?

4. (2 points) Atkins and Jones Exercise 6.52

5. (3 points)
   Derive an expression for the standard enthalpy change (ΔH°) of the following reaction:

   $2\ XNO_{(s)} + CO_{2(g)} \rightarrow X_2O_{3(s)} + CO_{(g)} + N_{2(g)}$ ΔH°

   Please use the following thermochemical data:

   $X_{(s)} + CO_{2(g)} + \_\ N_{2(g)} \rightarrow XNO_{(s)} + CO_{(g)}$ ΔH^o_1 (Reaction 1)

   $CO_{(g)} + \_\ O_{2(g)} \rightarrow CO_{2(g)}$ ΔH^o_2 (Reaction 2)

   $2\ X_{(s)} + /\ O_{2(g)} \rightarrow X_2O_{3(s)}$ ΔH^o_3 (Reaction 3)

   and express your answer in terms of ΔH^o_1, ΔH^o_2, and ΔH^o_3.

   Hint: Your answer will look like , where α, β, and γ are numbers you need to figure out. They
   can be fractions, and they can be either positive or negative.

6. (4 points)
   Boron and hydrogen combine to form a large number of compounds called boranes (more about boranes on pp. 553-4 of Atkins and Jones), one of which is pentaboron nonahydride (B_5H_9), a volatile liquid at room temperature. B_5H_9 vapor ignites spontaneously in air with a green flash to produce B_2O_3 (a white solid) and $H_2O_{(\lambda)}$. The standard molar heat of combustion of $B_5H_{9(g)}$ has been reported to be 4540 kJ·mol^{-1} at 25 °C. This is the molar enthalpy change (ΔH^o_{rxn}) for the reaction

   $B_5H_{9(g)} + 6\ O_{2(g)} \rightarrow 2.5\ B_2O_{3(s)} + 4.5\ H_2O_{(\lambda)}$ $\Delta H^o_{reaction} = -4540$ kJ·mol^{-1} @ 25ºC

   a. Write the correctly balanced chemical reaction for which the molar enthalpy change is $\Delta H^o_f\ [B_5H_{9(g)}]$.
   b. Based on the molar heat of combustion given above and the data in Appendix 2A of Jones & Atkins, calculate $\Delta H^o_f[B_5H_{9(g)}]$ in kJ·mol^{-1}. (Hint: If you like, you may check your answer by looking up the accepted value in a good physical chemistry reference book, like the CRC Handbook of Chemistry and Physics!)

      Note: $\Delta H^o_f[B_{(s)}] = 0$. This tells you something about the standard state of boron!

7. (7 points)
Ima Bingedrinker, tired of paying what she considers to be draconian alcohol taxes to the state, has decided to ferment her own liquor. Having a breadth of interests with regard to the impurities present in her alcohol, she decides to set up two different stills. In each still, the same fermentation reaction takes place:

$$C_6H_{12}O_{6(aq)} \rightarrow 2C_2H_5OH_{(aq)} + 2CO_{2(g)} \qquad \Delta H^o_{rxn} = -67\ kJ\cdot mol^{-1}$$

The standard enthalpy change associated with this reaction (ΔH^o_{rxn}) is -67 kJ per mole of glucose ($C_6H_{12}O_6$) that ferments at a constant temperature and pressure of 25ºC and 1.0 atm. Ima doesn't really know what she is doing, but she's determined. The first thing on Ima's wish list of inebriants is bourbon whiskey. The still she's trying to use for this (let's call it "Still A") is essentially a huge (30 gallon) garbage bag with 5 gallons of malted corn mash in it, "burped" before sealing so that all the air is removed and only the liquid remains inside. As the corn ferments, the CO_2 produced causes the bag to expand, but never to the point where the bag is actually full. Thus the reaction takes place at constant pressure, expanding against the atmosphere's pressure of 1.0 atm. [Ima doesn't realize that whiskey is a distilled liquor…] Ima hopes to make beer in her other still ("Still B"), and so she's designed it to keep the CO_2 produced in the above reaction under high pressure. Still B is actually a stolen commercial (5 gallon) pony keg which Ima has filled to the brim with yeasty barley extract and tightly sealed. The fermentation reaction will take place in this fixed volume, and all the CO_2 released in the reaction will be forced to remain in the fermenting liquid, because it has nowhere else to go. By the time Ima's beer is ready the pressure should be very high. Ima hopes this will allow her to tap into Still B just like it was a store-bought keg. (Ima doesn't know how kegs work, either…)

a. Is the fermentation reaction shown above exothermic or endothermic?
b. Suppose the corn mash in Still A initially contains 200. g of glucose. How much heat will be released into or extracted from Ima's basement by this glucose fermenting according to the reaction above? Be sure to clearly specify whether heat energy *enters or leaves* the system!
c. How much work will Still A do against the atmosphere as it expands? (Assume a temperature of 25ºC in Ima's basement, and a constant atmospheric pressure of 1.0 atm.)
d. Say Still B also initially contains 200. g of glucose. Suppose (as isn't unlikely) the pressure in Still B rises to a point where the keg explodes. "Beer" goes flying everywhere. When all is said and done all that's left behind is a pool of flat alcoholic liquid of effectively the same volume and composition as what is sitting in Still A. Once this liquid reaches room temperature, the internal energy change associated with the entire process will be the same as that experienced by Still A. Is the total heat released into Ima's basement as a net result of the events in Still B more than, less than, or the same as the amount of heat released as a result of the process that took place in Still A? Why?

Units: $R = 0.08206\ \lambda\cdot atm\cdot mol^{-1}\cdot K^{-1}$ $\quad MW_{C_6H_{12}O_6} = 180.156\ g\cdot mol^{-1}$ $\quad$ 1 mol of ideal gas occupies 24.45 λ at 25ºC and 1 atm

$1\ m^3 = 1000\ \lambda$ $\quad$ 1.000 atmosphere (atm) = 760.00 torr = 101325 Pascals (Pa) $\quad 1\ Pa \equiv 1\ kg\cdot m^{-1}\cdot s^{-2}$ $\quad 1\ J \equiv 1\ kg\cdot m^2\cdot s^{-2}$

Hints: Fermentation doesn't give off light or any other form of radiation, so it is safe to assume that the only work done in these scenarios is PV work. Assume that the reaction vessels stay in thermal equilibrium with Ima's 25ºC basement during the entire fermentation process, if you think that is important at any point along the way. You smarties who know about heat capacities should assume they are the same for the contents of the two stills. After all, the mashes are both mostly water.
I fear Ima's going to be disappointed. Among other things, she's going to get some methanol (CH_3OH) as a side product of her fermentations, which will cause her to go blind: at least temporarily. Temporary or even permanent loss of eyesight is a price commonly paid by those who try to make their own booze without asking enough questions or reading enough books.

8. (3 points)
Calculate the molar standard enthalpy of combustion, $\Delta \tilde{H}^o_c$, of methane (CH_4) using

a) Standard Enthalpies of Formation (Appendix 2A, except CH_4, which is in Appendix 2B!)
b) Mean Bond Enthalpies (Table 6.8)

Explain the reason for any differences between your answers and the value given in Table 6.4 (In one case there will be a difference, even if you do everything right, and there is *at least* one good reason for it!)