Chem 260 – First Exam

On the following pages are seven problems covering material in thermodynamics. Read each problem carefully and think about how best to approach the problem before you begin work. If you aren't sure how to begin a problem, then move on; working on a new problem may stimulate an idea that helps you solve the more troublesome one. For problems requiring a written response, be sure that your answer directly and clearly answers the question. No brain dumps allowed! Generous partial credit is available, but only if you include sufficient work for evaluation.

Problem 1 _____/12   Problem 2 _____/18   Problem 3 _____/12

Problem 4 _____/14   Problem 5 _____/15   Problem 6 _____/14   Problem 7 _____/15

Total_________

A few constants and thermodynamics values are given here:

d_{H_2O} = 1.00 g/mL S_{H_2O} = 4.184 J/g·^oC

R = 8.314 J/mol_{rxn}·K   F = 96,485 J/V·mol e^-

species	ΔH^o_f (kJ/mol_{rxn})	ΔG^o_f (kJ/mol_{rxn})	S^o (J/mol_{rxn}·K)
$CO_2(g)$	-393.5	-394.4	213.7
C_4H_8(*g, 1-butene*)	-20.5	-0.63	215.6
$C_6H_{12}O_6(s)$	-1273.0	-910.4	212.1
$O_2(g)$	0	0	205.0
$H_2O(g)$	-241.8	-228.6	188.2
$H_2O(l)$	-285.8	-237.1	69.9

Reduction Reaction	E^o (V)
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	-0.409
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$	-0.036
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	0.770
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	-0.8272
$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$	-0.401
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	1.229

Problem 1. Imagine you are holding a large, unstretched rubber band in your hands. With a quick movement you stretch the rubber band and touch it to your forehead, noting that the rubber band is warm. Based on this information, predict the signs for ΔG, ΔH and ΔS for the stretching of the rubber band, which we can represent as:

$$\text{unstretched rubber band} \rightarrow \text{stretched rubber band}$$

In each case indicate if the thermodynamic parameter is positive, negative or unknown and, for each, briefly explain your reasoning in one sentence.

Problem 2. Suppose you placed a six-pack of your favorite beverage in an insulated cooler. Each can is made from 38.5 g of aluminum and contains 354.8 mL of your favorite beverage. Assume that the specific heat of your favorite beverage is equal to that of water, but that its density is 0.993 g/mL. The specific heat of Al is 0.902 $J/g{\cdot}^oC$ To cool the drinks from 22.8^{o}C to 0^{o}C, what is the minimum amount of ice, in grams, that you need to add to the cooler? The ΔH^o for melting ice is 6.00 kJ/mol_{rxn}.

Problem 3. Isomers are molecules with the same elemental composition but with a different arrangements of the atoms. Three of the six isomers of C_4H_8 are *cis*-butene, *trans*-butene and 1-butene. Each isomer undergoes the same combustion reaction

$$C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$$

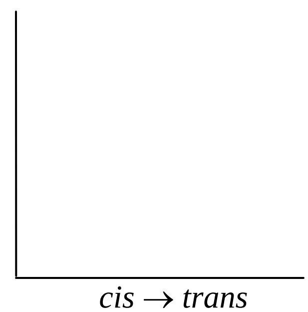
but the standard state enthalpy changes for combustion, as shown below, are different.

cis-butene	-2687.5 kJ/mol_{rxn}
trans-butene	-2684.2 kJ/mol_{rxn}
1-butene	-2696.7 kJ/mol_{rxn}

Draw an energy diagram, using the axes shown to the right, for the reaction

$$\textit{cis}\text{-butene} \rightarrow \textit{trans}\text{-butene}$$

Clearly show on your diagram the transition that is equivalent to the reaction's change in enthalpy and state its value below.



Knowing that the ΔH_f^o for 1-butene is -20.5 kJ/mol_{rxn}, what is the standard state heat of formation for *trans*-butene?

Problem 4. The conversion of inorganic carbon, in the form of CO_2, to organic carbon in the form of glucose, $C_6H_{12}O_6$, is important in many biological systems. The net reaction is:

$$CO_2(g) + H_2O(l) \rightarrow \frac{1}{6}C_6H_{12}O_6(s) + O_2(g)$$

Under standard state conditions and at 298 K this reaction is unfavorable. Is there a temperature at which this reaction becomes favorable under standard state conditions, and, if so, what is that temperature? Clearly justify your response with appropriate calculation(s) and a one sentence explanation.

Problem 5. The reaction quotient for the reaction in problem 4 is

$$Q = P_{O_2}/P_{CO_2}$$

where P_{O_2} and P_{CO_2} are the partial pressures of O_2 and CO_2. At a temperature of 298 K, what is the largest or smallest possible value for the reaction quotient if the conversion of CO_2 to $C_6H_{12}O_6$ is to be favorable? Report your answer as "Q must be greater than…" or "Q must be less than…"

Problem 6. The autotrophic bacterium *Ferrobacillus ferrooxidans* uses the oxidation of Fe^{2+} to Fe^{3+} by oxygen

$$4Fe^{2+}(aq) + O_2(g) + 4H^+(aq) \rightarrow 4Fe^{3+}(aq) + 2H_2O(l)$$

as a source of free energy. What is ΔG^o for this reaction at 298 K?

Problem 7. The bacterium *Ferrobacillus ferrooxidans* uses the free energy from the reaction in Problem 6 to drive the synthesis of glucose under standard state conditions, as shown by the reaction in problem 4. How many moles of Fe^{2+} are needed to synthesize 1.0 mole of glucose? Assume a temperature of 298 K.