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 _____/10 Problem 2 _____/16 Problem 3 _____/14 Problem 4 _____/12

Problem 5 _____/12 Problem 6 _____/12 Problem 7 _____/12 Problem 8 _____/12

Total_____

A few constants and thermodynamics values are given here:

$d_{H_2O} = 1.00$ g/mL $\qquad S_{H_2O} = 4.184$ J/g·°C

$R = 8.314$ J/mol$_{rxn}$·K $\qquad F = 96{,}485$ J/V·mol e$^-$

species	ΔH^o_f (kJ/mol$_{rxn}$)	ΔG^o_f (kJ/mol$_{rxn}$)	S^o (J/mol$_{rxn}$·K)
C*(s, graphite)*	0	0	5.74
CO_2*(g)*	-393.5	-394.4	213.7
C_6H_6*(l)*	49.028	124.50	172.8
C_8H_{18}*(l)*	-208.45	16.40	466.73
H_2*(g)*	0	0	130.684
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)* + $2e^-$ → Fe*(s)*	-0.409
Fe^{3+}*(aq)* + $3e^-$ → Fe*(s)*	-0.036
Fe^{3+}*(aq)* + e^- → Fe^{2+}*(aq)*	0.770

Problem 1. A student is asked to determine the concentration of aspirin in tablets of St. Joseph's aspirin, obtaining values of 79.3 mg, 81.8 mg, 78.4 mg, 81.3 mg and 80.1 mg. The tablets are known to contain 80.0 mg of aspirin. Does the student's data show evidence of indeterminate and/or determinate errors? As part of you answer be sure to define each type of error and to state your evidence for that error's presence or absence.

Problem 2. Imagine you are caught in a rainstorm and that your clothes absorb 1.00 L of water, H_2O. The temperature is 20^oC and remains constant during the time it takes the water to evaporate. Knowing that ΔH^o for the evaporation of water is +44 kJ/mol_{rxn}, how much heat is needed to effect the evaporation of this water?

Suppose you are a cold-blooded animal and cannot regulate your body's temperature by producing heat from metabolism. Assuming a body weight of 60.0 kg and assuming that the specific heat of the body is that of water, what will be the change in your body's temperature upon evaporating this water? If you don't have an answer for the first part of this problem, then assume the answer is X.

Problem 3. There is a growing interest in using H_2 as a fuel for automobiles. In a H_2-powered vehicle, energy comes from the following combustion reaction

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

while in a traditional automobile the energy comes from the combustion of *n*-octane

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$$

Which automobile can supply the greatest amount of energy per gram of fuel and what is its value?

Problem 4. You work for a biotech company that uses a lot of benzene and you have been given the job of finding the cheapest way of obtaining benzene for your company. A salesperson at another company offers you a great deal on a machine that she says will speed up the reaction of carbon and hydrogen to make benzene at a temperature of 500 K and under standard state conditions

$$6C(s, graphite) + 3H_2(g) \rightarrow C_6H_6(l)$$

In two or three sentences, and supported with some thermodynamic information, explain to your bosses why you should or should not purchase the machine.

Problem 5. The table below gives atom combination enthalpies for several simple gas-phase hydrocarbons.

compound	ΔH^{o}_{ac} (kJ/mol$_{rxn}$)
CH_4	-1662
$HC{\equiv}CH$	-1642
$H_2C{=}CH_2$	-2252
$H_3C\text{-}CH_3$	-2824

Using this data present a convincing argument showing that a carbon-carbon triple bond is stronger than a carbon-carbon double bond, which is stronger than a carbon-carbon single bond. The best answers to this question will provide estimates for the bond energies for each type of carbon-carbon bond.

Problem 6. Nicotinamide adenine dinucleotide, abbreviated NAD^+, is an oxidizing agent and one of the central agents for electron transfer in biological systems. The E^o value for the reduction of NAD^+ to NADH

$$NAD^+ + 2e^- + H_3O^+ \rightarrow NADH + H_2O$$

is -0.320 V. Is NAD^+ capable of oxidizing Fe^{2+} to Fe^{3+} under standard state conditions? Justify your answer with an appropriate calculation and a one sentence explanation.

Problem 7. The atom combination enthalpy for $CH_4(g)$ is -1662 kJ/mol_{rxn} and the heat of formation for $CH_4(g)$ is -74.8 kJ/mol_{rxn}. In two or three sentences, explain why the ΔH^o_f value for $CH_4(g)$ is smaller than its value for ΔH^o_{ac}.

Problem 8. Dissolving pentane in hexane creates a mixture, or solution, of the two liquids. To a physical chemist, an "ideal solution" has very specific thermodynamic properties. The enthalpy involved in dissolving pentane in hexane can be envisioned as occurring by the following hypothetical pathway. First, thermal energy is added to convert the pentane from a liquid into fully separated molecules; this is ΔH^o_1. Second, thermal energy is added to convert the hexane from a liquid into fully separated molecules; this is ΔH^o_2. Finally, when the fully separated molecules of hexane and pentane are allowed to come together, producing the ideal solution of pentane dissolved in hexane, energy is released; this is ΔH^o_3. For an ideal solution the following is true

$$\Delta H^o_1 + \Delta H^o_2 = -\Delta H^o_3$$

Based on this information, predict the signs for ΔG^o, ΔH^o and ΔS^o for the reaction

$$\text{pentane}(l) + \text{hexane}(l) \rightarrow \text{ideal solution of pentane in hexane}$$

For each parameter, clearly state if the value is greater than zero, less than zero, equal to zero or that it cannot be determined, and provide a one-sentence explanation for your choice.