Chemistry 2740 Spring 2016 Test 2

Time: 50 minutes
Marks: 30
Aids allowed: calculator, 8.5×11-inch formula sheet
Useful data is given on the reverse of this page.
Instructions: You can answer the questions in any order, but make sure that you clearly label each of your answers with the question number in your exam booklet(s).

1. The absolute standard entropy of liquid octane (C_8H_{18}) is $361.2\,\mathrm{J\,K^{-1}mol^{-1}}$. Octane boils at $398.7\,\mathrm{K}$, with an enthalpy of vaporization of $34.41\,\mathrm{kJ\,mol^{-1}}$. The molar heat capacity of liquid octane is $254.7\,\mathrm{J\,K^{-1}mol^{-1}}$. Estimate the absolute entropy of octane vapor at the boiling point. [6 marks]

2. In chloroform solution, C_{70} reacts with 8-(4-methoxy-3-methylphenyl)-7,9,10-triphenylfluoranthene (pictured in figure 1, hereafter abbreviated L) to form a complex:[1]

$$C_{70(\mathrm{sol})} + L_{(\mathrm{sol})} \longrightarrow C_{70} \cdot L_{(\mathrm{sol})}$$

For this reaction at $298\,\mathrm{K}$, $\Delta_r H_m^\circ = -7.42\,\mathrm{kJ\,mol^{-1}}$, and $\Delta_r S_m^\circ = 41.56\,\mathrm{J\,K^{-1}mol^{-1}}$.

(a) $\Delta_r G_m^\circ$ for this reaction will be negative at any temperature. Explain how we know this. [3 marks]

(b) Suppose that we isolate the complex, then redissolve it in chloroform at $40\,^\circ\mathrm{C}$ at a concentration of $4.3 \times 10^{-2}\,\mathrm{mol\,L^{-1}}$ along with $1.8 \times 10^{-4}\,\mathrm{mol\,L^{-1}}$ C_{70} and $5.2 \times 10^{-5}\,\mathrm{mol\,L^{-1}}$ of L. Would the reaction proceed in the forward direction to form more complex, or in the reverse direction, dissociating the complex back into C_{70} and L? [8 marks]

[1] S. Bhattacharya *et al.*, *Spectrochim. Acta A* **64**, 47 (2006).

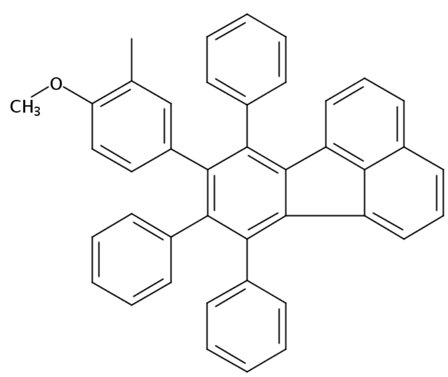

Figure 1: 8-(4-methoxy-3-methylphenyl)-7,9,10-triphenylfluoranthene

Bonus: The positive entropy change for this reaction may be a surprise to you. (It was to me when I first saw it.) Can you provide a plausible physical explanation for this positive entropy change?

3. As discussed in class, statistical entropy is a very broad concept. It is not unusual for this concept to be applied to DNA sequences. Some of the applications are relatively sophisticated. Here, we're going to take a very simple (perhaps even simplistic) view.

   DNA is, as you likely know, a polymer made of the four nucleotides adenine (A), thymine (T), guanine (G) and cytosine (C). For our purposes, it doesn't matter that DNA is usually found as a duplex, the famous double helix. We just need to consider the coding strand. During translation, the synthesis of proteins encoded in the DNA, the nucleotides are read (from mRNA, but that's not important to us right now) in triplets called codons, so for example TAG and CTG are two possible codons.

   (a) How many different codons are there? [2 marks]

   (b) A typical bacterial gene might have 999 nucleotides, or 333 codons. If we want those 333 codons to encode a protein, then this sequence can't contain a stop codon. (There has to be a stop codon at the end of the sequence. Here, we're just considering the part of the sequence that encodes the protein.) There are three different stop codons, TAA, TAG and TGA. How many possible protein-coding sequences of 333 codons are there? Don't evaluate your answer, i.e. leave your answer as an algebraic expression. [4 marks]

   (c) What would be the entropy of a protein-coding sequence generated by stringing together 333 random amino-acid codons? Leave your answer in symbolic form, i.e. don't evaluate any logarithms, and don't substitute any constants into your expression. [2 marks]

   (d) Most codons code for more than one amino acid. The codons encode just 20 amino acids. If instead of a sequence of random codons, we designed a random protein by stringing together 333 randomly selected amino acids, what would the entropy of the protein be? How does this compare to the entropy of the DNA sequence calculated in part (c)? Does this make sense? Comment briefly. [5 marks]

Useful data

$R = 8.314\,472\,\mathrm{J\,K^{-1}mol^{-1}}$
To convert degrees Celsius to Kelvin, add 273.15.