CH302 Worksheet 1b Answers and Solution Key: ElementaryThermodynamics Questions

(These 8 questions are very similar in content and format to the kind of questions you will see on quizzes 5 and 6 and on exam 3. Don't simply memorize them, but learning how to work this kind of problem and similar problems that you make up yourself will be a great aid as you work the quiz.)

1. Which of the following is a correct statement concerning the Second Law of Thermodynamics?

1. The free energy of a system is temperature dependent.
2. Entropy of a system increases in the phase change from a liquid to a gas. Correct
3. Energy cannot be created nor destroyed.
4. The entropy in the universe is conserved.

Answer: The second law says that the overall entropy (disorder) of the universe is always increasing. However it is possible for a local (system) entropy to go up or down in a physical or chemical change.

For the question above, in the case of a phase change from liquid to gas, the system gets more disordered because gas molecules are less ordered than liquids in which intermolecular forces exist.

2. 75 g of a potato chips are burned in a calorimeter that contains 2 liters of water initially at 297K. After the combustion, the temperature rises 12^{o}C. How much heat is evolved per gram of potato chip burned? The heat capacity of the calorimeter is 200 J/^{o}C? The density of water is 1.0 g/ml. The specific heat of water is 4.18 J/g^{o}C.

1. 7.1 kJ/g
2. 100.3 kJ/g
3. 102.7 kJ/g
4. 1.37 kJ/g correct

Solution: The problem was set up in class. Here you need to calculate the mCΔT of the water and the bomb calorimeter. The mCΔT of water = (2000 grams)(4.18 J/g^{o}C)(12^{o}C)= 100,320 J and the mCΔT of the calorimeter is (200 J/^{o}C)(12 ^{o}C)= 2400J. The total for both reactions is 102,720J = 102.7kJ per 75g potato chips. But the answer needs to be per gram of potato chip so divide by 75 g.
102.7 kJ/75g = 1.37kJ/g.

- Some things to note: the heat capacity of the calorimeter has units of J/^{o}C so the mass is included in the heat capacity term. The specific heat of water has different units because the mass of water can vary.
- You need to get 2 liters of water into 2000 ml water and then into 2000 g of water using density.
- Hint for quiz: sometimes you are told the ΔH of the calorimeter doesn't mater and

to just calculate ΔH for the water.

- Hint for quiz. You need to make sure you put your final answer in the units requested. In this case you divide by 75 g to get the answer into a per gram basis.

3. What is the change of enthalpy associated with the combustion of one mole of ethylene?

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

1. 0 kJ
2. -1323 kJ correct
3. +1323 kJ
4. -3230 kJ
5. +3230 kJ

Solution: From the heats of formation (all In kJ/mole) in Appendix 2 of the text (around page A11-17 in the back)

ΔH_f = 52.26 for C_2H_4, ΔH_f = 0 for O_2, ΔH_f = -393kJ for CO_2, ΔH_f = -242 for H_2O
So accounting for the stoichiometry,

ΔHreaction = [2(-393) + 2(-241)] - [52 + 3(0)] = -1323 kJ

Note the reaction is large negative meaning a lot of heat is given off as expected for a combustion reaction.

4. For the combustion reaction of acetaldehyde (C_2H_4O)

$$2C_2H_4O + 5O_2 \rightarrow 4CO_2 + 4H_2O$$

assume all reactants and products are gases and calculate the ΔH^0_{rxn} using the following bond energy values:

There are some errors in the listed bond energies so they need to be fixed to get the right answer. Use the corrected bond energies below:

C-C BE = 348 kJ/mol (corrected)
C-H BE = 413 kJ/mol
O=O BE = 498 kJ/mol
C=O BE = 799 kJ/mol in CO2 and 743 in organic molecules (corrected)
H-O BE = 463 kJ/mol

1. -1080 kJ/mol correct
2. +1080 kJ/mol
3. 0 kJ/mol
4. -2303 kJ/mol
5. +2303 kJ/mol

Solution: Note that C_2H_4O has 4 C-H bonds, 1 C-C bond and C=O bond. CO_2 has 2

C=O bonds, H_2O has 2 O-H bonds, and O_2 has 1 O=O bond per molecule. Also remember to take into account the stoichiometry. There are $2C_2H_4O$, $5O_2$, $4CO_2$ and $4H_2O$

So
$BE_{reaction} = \Sigma BE_{reactants} - \Sigma BE_{products}$ = [8(813) + 2(348) + 2(743) + 5(498)] - [8(799) + 8(463)] = -1080 kJ

Note the reaction is a large negative number which makes sense for a combustion reaction.

5. For the reaction

$$3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$$

find the approximate value for the work done at 300 K.

1. -5.0 kJ
2. -2:5 kJ
3. 2.5 kJ
4. 5.0 kJ correct

Solution. First calculate Δn_{gas}. All the molecules are gas so $\Delta n = 2 - 4 = -2$. So $w = -\Delta nRT = -(-2)(8.3 \text{ J/mole K})(300) = +5000 \text{ J} = +5 \text{ kJ}$. Note that the value is positive because the volume is decreasing as work is done on the system, in effect, arming the bomb.

6. Heat flow is considered negative when heat flows (into, out of) a system; work is considered positive when work is done (by, on) a system.

1. out of; by
2. into; by
3. out of; on **correct**
4. into; on

Solution: Be the system. When something leaves, like heat, it is negative. When something is added, like work, it is positive.

7. Which of the following processes results in an increase in the system entropy?

1. cleaning up from the party while your parents are out of town
2. getting dressed in the morning
3. making ice cubes
4. pouring salt on an icy bridge correct
5. memorizing the eight question types on the first quiz

Solution: All of the answers result in increased organization (decreased entropy) except pouring salt on ice which converts ice to liquid water, an increase in entropy.

8. For the exothermic combustion of a hydrogen balloon:

$$2H_2 + O_2 \text{-->}\ 2\,H_2O_{(g)}$$

what can you say about the spontaneity?

1. Always spontaneous because ΔS in formation $H_2O_{(g)}$ is negative.
2. Always spontaneous because ΔS in formation $H_2O_{(g)}$ is positive.
3. Spontaneous at higher temperature because ΔS in formation $H_2O_{(g)}$ is negative
4. Spontaneous at lower temperature because ΔS in formation $H_2O_{(g)}$ is negative. correct
5. Spontaneous at higher temperature because ΔS in formation $H_2O_{(g)}$ is positive.
6. Spontaneous at lower temperature because ΔS in formation $H_2O_{(g)}$ is positive.

Solution: This exploding balloon clearly gives off heat so it is exothermic (ΔH is negative.) However there are fewer molecules produced so ΔS is also negative. To ensure that the $T\Delta S$ term doesn't dominate and make the reaction non-spontaneous, it is necessary to mke the T as small as possible. In other words, this reaction will happen here on earth, but not next to the sun.