CH 302 Spring 2008 Worksheet 1 Answer Key
A potpourri of thermo questions to get your mind reengaged.

(Questions 1-6) Match the correct term for each question given below. You will only use an answer once, but not all the answers will be used.

Word Bank:

Standard enthalpy change	enthalpy of formation	bond enthalpy
bond order	bond energy	heat capacity
thermochemical standard state		thermodynamics
state functions	equilibrium	empirical state

1. Parameters that define the current state of a chemical system
   state functions
2. ΔH when reactants in standard states are converted to products in standard states.
   standard enthalpy change
3. The study of energy change in chemical systems.
   thermodynamics
4. The energy necessary to break one mole of bonds in a gaseous substance.
   bond energy
5. The most stable state of a substance under standard pressure and temperature.
   thermochemical standard state
6. The amount of heat required to raise the temperature of an object one degree C.
   heat capacity

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

   A. Energy cannot be created nor destroyed.
   B. The entropy in the universe is conserved.
   C. The entropy in a system increases in the phase change from liquid to gas.
   D. The free energy of a system is temperature dependent.

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

8. Explain why the freezing of liquid water (in which the water becomes more ordered) does ***not*** violate the Second Law.

   Answer: Although the entropy of the system decreases, the heat released by the freezing water causes an increase in the entropy the surroundings, resulting in a net positive entropy change for the universe.

9. If you heat 1 kg of water over a Bunsen burner for a few seconds for a few seconds, it might get a little warm. So the same for 1 kg of copper, and it's likely to burn your hand. What physical quantity explains this difference?

   Answer: The heat capacity is a measure of a material's ability to absorb heat. Water absorbs much more heat for a given change in temperature, so it has a higher heat capacity.

10. Provide a simple derivation of the fact that ΔG is negative for a spontaneous process starting with the Second Law, $\Delta S_{universe} > 0$.

Answer: The Second Law states that

$$0 < \Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$$

But $\Delta S_{surroundings} = -\Delta H_{system}/T$, so

$$0 < -\Delta H_{system} + T\Delta S_{system}$$

The right side is $-\Delta G$, so

$$-\Delta G > 0$$

$$\underline{\mathbf{\Delta G < 0}}$$

11. The following reaction is exothermic. For what temperatures is the reaction spontaneous?

$$2\ A(g) + B(g) \rightarrow A_2B(g)$$

Answer: Because there is a decrease in the number of gas molecules, $\Delta S_{rxn} < 0$. Since $\Delta H < 0$ and $\Delta S < 0$, the reaction is spontaneous only at **low temperatures**.

12. Write a single equation expressing the First Law of Thermodynamics for an isolated system.

Answer: **$\Delta E = 0$** for an isolated system.

13. In terms of RT, what is the amount of motional (translational and rotational) internal energy in H_2O? In CO_2?

Answer: **H2O: 3RT**; **CO2: 5/2RT**. Each has 3/2RT translational internal energy, but H2O is non-linear (3/2RT rotational) and CO2 is linear (RT rotational).

14. For the freezing of benzene, $\Delta H = 2.375$ kJ/mol and $\Delta S = 8.523$ J/mol. What is the freezing point of benzene?

Answer:

$$T_f = \Delta H/\Delta S = \frac{2375\ \text{J/mol}}{8.523\ \text{J/mol K}} = 278.66\ \text{K} = \underline{\mathbf{5.51°C}}$$

15. Which of the following molecules will have the largest positional entropy at 0 K?
   A. SF_6
   B. CH_4
   C. CO_2
   D. XeF_5I
   E. $CHCl_3$

Answer: XeF_5I has the largest number of different orientations with 6 ($CHCl_3$ is second with 4, and all the rest have only 1).

16. What is the entropy of 10 molecules of the correct answer to number 15 at 0 K?

Answer:

$$S = k \ln W = (1.38 \times 10^{-23}\ \text{J/K}) \ln 6^{10} = \underline{\mathbf{2.47 \times 10^{-22}\ J/K}}$$

17. Given the following table, which species is the most stable?

	$\Delta G_f°$ (kJ/mol)
CO_2 (g)	-394.4
NO_2 (g)	+51
SO_2 (g)	-300.2
H_2O (g)	-228.60

Answer: The more negative the ΔG_f, the more stable the compound. Thus, CO2 is the most stable.

18. Without using a table, give the free energy of formation for each of the following species: He(g), N_2(g), C(graphite), Hg(l), Fe(s)

Answer: All are zero. Each of these is an element in its standard state.

19. Find $\Delta G_r°$ (at 298 K) for the following reaction, given the thermodynamic data below.

$$2\ C_6H_6(g) + 15\ O_2(g) \rightarrow 12\ CO_2(g) + 6\ H_2O(\ell)$$

	$\Delta H_f°$ (kJ/mol)	S° (J/mol K)
C_6H_6 (g)	+82.931	269.2
O_2 (g)	0	205.14
CO_2 (g)	-393.51	213.74
H_2O (ℓ)	-285.83	69.91

Answer:

$$\Delta G_r = \Delta H_r - T\Delta S_r$$

$$= [12 \bullet (-393.51 \text{ kJ/mol}) + 6 \bullet (-285.83 \text{ kJ/mol}) - 2 \bullet (+82.931 \text{ kJ/mol})] - (298 \text{ K})[12 \bullet (.21374 \text{ kJ/mol}) + 6 \bullet (0.06991 \text{ kJ/mol K}) - 15 \bullet (0.20514 \text{ kJ/mol K}) - 2 \bullet (0.2692 \text{ kJ/mol K})]$$

$$= \mathbf{\underline{-6415 \text{ kJ/mol}}}$$

20. At a certain temperature, the work done on the following reaction is 6.00 kJ. What is this temperature?

$$2\ A(g) + B(g) \rightarrow A_2B(g)$$

Answer:

$$w = -\Delta nRT$$

$$T = -w/(\Delta nR)$$

$$= -(6000 \text{ J})/(-2 \text{ mol} \bullet 8.314 \text{ J/mol K})$$

$$= \mathbf{\underline{361 \text{ K}}}$$