CHEM 130 **Name** _____

Quiz 8 – Due at the start of class Monday, November 5, 2018

Complete the following problems. Write your final answers in the blanks provided. You must show your work to receive full credit. Show your answers to the correct number of significant figures with the correct units.

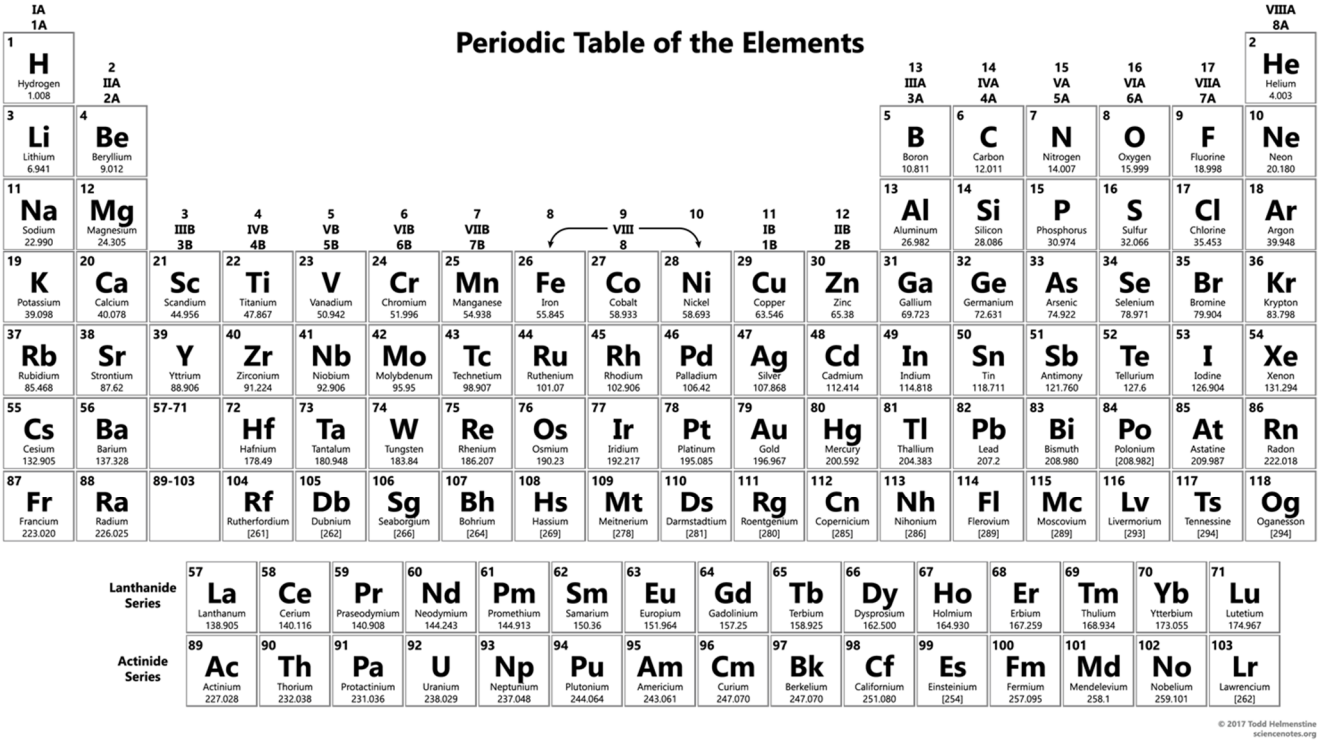
Rules for this take-home quiz.

DO NOT OPEN THE QUIZ UNTIL YOU ARE READY TO TAKE IT!

- You may allocate a maximum of **50 continuous minutes** for this quiz, split in to two 25-minute segments.
- For the first 25-minute segment, you will take the quiz using only the materials on these pages, a calculator and a **pencil**. Treat this time as though you were taking the quiz in the classroom. You may not use your book, notes, electronic sources or anyone else to help. Record the start and end of the first 25 minutes below.
- For the second 25 minutes, you may use your book, notes or electronic resources to make any corrections to your work. **Make these corrections in blue or red pen.** You **MAY NOT** ask anyone else for help. Record the end of the second 25 minute block below.
- Once you have completed the quiz, sign below to affirm that the quiz was taken following the rules above. This signature is your pledge that the quiz was completed in an ethical manner!

Start time: _____ End of 1st 25 minutes: _____ End of 2nd 25 minutes: _____

Signature_____Date_____



Possibly Useful Information

$K = {}^{o}C + 273.15$	$q=mc\Delta T$	$q=n_{LR}\Delta H_{rxn}$	$q=m\Delta H$
$\Delta S_{universe} = \Delta S_{system} - \Delta S_{surr}$		$\Delta G = \Delta H - T\Delta S$	$\Delta S_{surr} = -\Delta H_{sys}/T$

1. From the information in the table below, combine the reactions as necessary to determine the ΔG^o for the following reaction. (8 pts)

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

Reaction	ΔG^o
$N_2(g) + O_2(g) \rightarrow 2NO(g)$	+173.1 kJ
$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$	-1010.5 kJ
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	-33.0 kJ
$2N_2(g) + O_2(g) \rightarrow 2N_2O(g)$	+208.4 kJ

First combine reactions to get appropriate compounds as reactants and products, cancelling out redundant species.

$2[2NO(g) \rightarrow N_2(g) + O_2(g)]$	-2(+173.1 kJ)
$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$	-1010.5 kJ
$2[N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)]$	2(-33.0kJ)
~~$4NO$~~ + ~~$4NH_3$~~ + $5O_2$ + ~~$2N_2$~~ + $6H_2$ → ~~$2N_2$~~ + ~~2~~ O_2 + ~~$4NO$~~ + $6H_2O$ + ~~$4NH_3$~~	(-346.2 kJ) +(-1010.5 kJ) +(-66.0 kJ) = -1422.7 kJ
$3O_2 + 6H_2 \rightarrow 6H_2O$	

Now adjust to get the appropriate coefficients for all the reactants and products

$1/3(3O_2 + 6H_2 \rightarrow 6H_2O)$	1/3(-1422.7 kJ)
$O_2 + 2H_2 \rightarrow 2H_2O$	**-474.3 kJ**

Answer____-474.3 kJ _____

2. For each of the reactions below, select which of the following describes the reaction and justify your assertion in a sentence or two. (a) spontaneous at all temperatures, (b) nonspontaneous at all temperatures, (c) spontaneous at high temperatures, (d) spontaneous at low temperatures, (e) unable to tell. (8 pts)

   a. $PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$ $\Delta H^o = -87.9$ kJ

   $\Delta H^o < 0$ and $\Delta S^o < 0$ (since there are fewer moles of gas on the products side compared to the reactants side) for this reaction. Thus, this reaction is spontaneous at low temperatures and non-spontaneous at high temperatures.

   b. $H_2O_2(g) \rightarrow 2H_2O(g) + O_2(g)$ $\Delta H^o = -211$ kJ

   $\Delta H^o < 0$ and $\Delta S^o > 0$ (since there are more moles of gas on the products side compared to the reactants side) for this reaction. Thus, this reaction is spontaneous at all temperatures since $\Delta G^o = \Delta H^o - T\Delta S^o$ and (-) – (+)(-) = (-).

3. A possible reaction for converting methanol to ethanol is

$$CO(g) + 2H_2(g) + CH_3OH(g) \rightarrow C_2H_5OH(g) + H_2O(g)$$

This reaction is not spontaneous at all temperatures. Use the information below to calculate ΔG^o for the reaction and determine the temperature where the sign of ΔG^o changes. (9 pts)

Compound	ΔH^o_f, kJ mol^{-1}	ΔG^o_f, kJ mol^{-1}	S^o_f, J mol^{-1} K^{-1}
$CO(g)$	-110.5	-137.2	+197.7
$H_2(g)$	0	0	+130.7
$CH_3OH(g)$	-200.7	-162.0	+239.8
$C_2H_5OH(g)$	-235.1	-168.5	+282.7
$H_2O(g)$	-241.8	-228.6	+188.8

$$\Delta H^o = [\Delta H^o_f(C_2H_5OH(g)) + \Delta H^o_f(H_2O(g))] - [\Delta H^o_f(CO(g)) + 2\Delta H^o_f(H_2(g)) + \Delta H^o_f(CH_3OH(g))]$$
$$\Delta H^o = [-235.1 \text{ kJ} + (-241.8 \text{ kJ})] - [(-110.5 \text{ kJ}) + 2(0 \text{ kJ}) + (-200.7 \text{ kJ})]$$
$$\Delta H^o = -165.7 \text{ kJ}$$

$$\Delta S^o = [S^o_f(C_2H_5OH(g)) + S^o_f(H_2O(g))] - [S^o_f(CO(g)) + 2S^o_f(H_2(g)) + S^o_f(CH_3OH(g))]$$
$$\Delta S^o = [282.7 \text{ J/K} + (188.8 \text{ J/K})] - [(197.7 \text{ J/K}) + 2(130.7 \text{ J/K}) + (239.8 \text{ J/K})]$$
$$\Delta S^o = -227.4 \text{ J/K}$$

$\Delta G^o = \Delta H^o - T\Delta S^o = -165.7 \text{ kJ} - (298 \text{ K})(-0.2274 \text{ kJ/K}) = -97.9 \text{ kJ}$

Since ΔS^o and ΔH^o have the same sign, there must be a temperature that causes the sign of ΔG^o to change. You can calculate that temperature as shown below but you did not have to.

$$0 = \Delta H^o - T\Delta S^o$$
$$T = \Delta H^o/\Delta S^o = -165.7 \text{ kJ}/(0.2274 \text{ kJ/K}) = 729 \text{ K}$$

You could also have calculated ΔG^o from the ΔG^o_f values as shown below:

$$\Delta G^o = [\Delta G^o_f(C_2H_5OH(g)) + \Delta G^o_f(H_2O(g))] - [\Delta G^o_f(CO(g)) + 2\Delta G^o_f(H_2(g)) + \Delta G^o_f(CH_3OH(g))]$$
$$\Delta G^o = [-168.5 \text{ kJ} + (-228.6 \text{ kJ})] - [(-137.2 \text{ kJ}) + 2(0 \text{ kJ}) + (-162.0 \text{ kJ})]$$
$$\Delta G^o = -97.9 \text{ kJ}$$

NOTE: You could make the judgment on whether ΔG^o changes sign without actually calculating ΔH^o and ΔS^o. Looking at the reaction, there are 5 moles of gas on the reactant side and two moles of gas on the product side, indicating the ΔS^o will be negative. Since $\Delta G^o = \Delta H^o - T\Delta S^o$, if ΔS^o is negative, the only way ΔG^o could be negative as well is if ΔH^o is also negative. If ΔS^o and ΔH^o both have the same sign, there must be a temperature where the sign of ΔG^o changes.

$\Delta G^o = -97.9$ kJ

Answer____ T = 729 K (456°C)_____