

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 _____

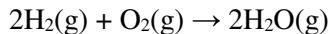
Periodic Table of the Elements																			
IA 1A		VIIA 8A																	
H Hydrogen 1.008		Be Beryllium 9.012														He Helium 4.003			
Li Lithium 6.941	Na Sodium 22.990	Mg Magnesium 24.305	Ca Calcium 40.078	Sc Scandium 44.956	Ti Titanium 47.867	V Vanadium 50.942	Cr Chromium 54.938	Mn Manganese 55.845	Fe Iron 56.933	Co Cobalt 58.933	Ni Nickel 58.693	Cu Copper 63.546	Zn Zinc 65.38	Ga Gallium 69.723	Ge Germanium 72.631	As Arsenic 74.922	Se Selenium 78.971	Br Bromine 79.904	Kr Krypton 83.798
3 3B	4 4B	5 5B	6 6B	7 7B	8	9	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 Neon 20.180				
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 54.938	25 Mn Manganese 55.845	26 Fe Iron 56.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798		
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 131.294	54 Xe Xenon 131.294		
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.548	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018		
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [293]	116 Lv Livermorium [294]	117 Ts Tennessee [294]	118 Og Oganesson [294]		
Lanthanide Series		57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967			
Actinide Series		89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]			

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Possibly Useful Information

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

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



Reaction	ΔG°
$\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$	+173.1 kJ
$4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g})$	-1010.5 kJ
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$	-33.0 kJ
$2\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{N}_2\text{O}(\text{g})$	+208.4 kJ

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

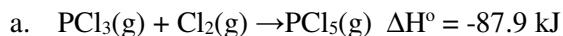
$2[2\text{NO}(\text{g}) \rightarrow \text{N}_2(\text{g}) + \text{O}_2(\text{g})]$	-2(+173.1 kJ)
$4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g})$	-1010.5 kJ
$2[\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})]$	2(-33.0 kJ)
$4\text{NO} + 4\text{NH}_3 + 5\text{O}_2 + 2\text{N}_2 + 6\text{H}_2 \rightarrow 2\text{N}_2 + 2\text{O}_2 + 4\text{NO} + 6\text{H}_2\text{O} + 4\text{NH}_3$	$(-346.2 \text{ kJ}) + (-1010.5 \text{ kJ}) + (-66.0 \text{ kJ}) = -1422.7 \text{ kJ}$
$3\text{O}_2 + 6\text{H}_2 \rightarrow 6\text{H}_2\text{O}$	

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

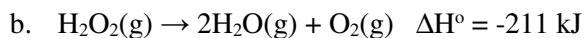
$1/3(3\text{O}_2 + 6\text{H}_2 \rightarrow 6\text{H}_2\text{O})$	1/3(-1422.7 kJ)
$\text{O}_2 + 2\text{H}_2 \rightarrow 2\text{H}_2\text{O}$	-474.3 kJ

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)

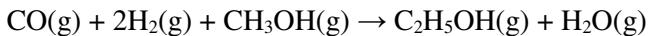


$\Delta H^\circ < 0$ and $\Delta S^\circ < 0$ (since there are fewer moles of gas on the products side compared to the reactants side) for this reaction. Thus, this reaction is spontaneous at low temperatures and non-spontaneous at high temperatures.



$\Delta H^\circ < 0$ and $\Delta S^\circ > 0$ (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 $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ and $(-) - (+)(-) = (-)$.

3. A possible reaction for converting methanol to ethanol is



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

Compound	$\Delta H_f^\circ, \text{kJ mol}^{-1}$	$\Delta G_f^\circ, \text{kJ mol}^{-1}$	$S_f^\circ, \text{J mol}^{-1} \text{K}^{-1}$
CO(g)	-110.5	-137.2	+197.7
H ₂ (g)	0	0	+130.7
CH ₃ OH(g)	-200.7	-162.0	+239.8
C ₂ H ₅ OH(g)	-235.1	-168.5	+282.7
H ₂ O(g)	-241.8	-228.6	+188.8

$$\Delta H^\circ = [\Delta H_f^\circ(\text{C}_2\text{H}_5\text{OH(g)}) + \Delta H_f^\circ(\text{H}_2\text{O(g)})] - [\Delta H_f^\circ(\text{CO(g)}) + 2\Delta H_f^\circ(\text{H}_2\text{(g)}) + \Delta H_f^\circ(\text{CH}_3\text{OH(g)})]$$

$$\Delta H^\circ = [-235.1 \text{ kJ} + (-241.8 \text{ kJ})] - [(-110.5 \text{ kJ}) + 2(0 \text{ kJ}) + (-200.7 \text{ kJ})]$$

$$\Delta H^\circ = -165.7 \text{ kJ}$$

$$\Delta S^\circ = [S_f^\circ(\text{C}_2\text{H}_5\text{OH(g)}) + S_f^\circ(\text{H}_2\text{O(g)})] - [S_f^\circ(\text{CO(g)}) + 2S_f^\circ(\text{H}_2\text{(g)}) + S_f^\circ(\text{CH}_3\text{OH(g)})]$$

$$\Delta S^\circ = [282.7 \text{ J/K} + (188.8 \text{ J/K})] - [(197.7 \text{ J/K}) + 2(130.7 \text{ J/K}) + (239.8 \text{ J/K})]$$

$$\Delta S^\circ = -227.4 \text{ J/K}$$

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

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

$$0 = \Delta H^\circ - T\Delta S^\circ$$

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

You could also have calculated ΔG° from the ΔG_f° values as shown below:

$$\Delta G^\circ = [\Delta G_f^\circ(\text{C}_2\text{H}_5\text{OH(g)}) + \Delta G_f^\circ(\text{H}_2\text{O(g)})] - [\Delta G_f^\circ(\text{CO(g)}) + 2\Delta G_f^\circ(\text{H}_2\text{(g)}) + \Delta G_f^\circ(\text{CH}_3\text{OH(g)})]$$

$$\Delta G^\circ = [-168.5 \text{ kJ} + (-228.6 \text{ kJ})] - [(-137.2 \text{ kJ}) + 2(0 \text{ kJ}) + (-162.0 \text{ kJ})]$$

$$\Delta G^\circ = -97.9 \text{ kJ}$$

NOTE: You could make the judgment on whether ΔG° changes sign without actually calculating ΔH° and ΔS° . 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° will be negative. Since $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$, if ΔS° is negative, the only way ΔG° could be negative as well is if ΔH° is also negative. If ΔS° and ΔH° both have the same sign, there must be a temperature where the sign of ΔG° changes.

$\Delta G^\circ = -97.9 \text{ kJ}$
Answer T = 729 K (456°C)