## S17 Exam4

Tuesday, April 18, 2017 10:46 AM

Chem 105 Exam 4

Name \_\_\_\_\_

This exam is schedule for 75 minutes and I anticipate it to take the full time allotted. You are free to leave if you finish. In multiple part problems, points awarded will not be penalized for incorrect answer on previous parts, so simply **move on if you get stuck on one part**. If you need to, make up an answer for the previous part. Always neatly show work for partial credit.

 Define the first and second laws of thermodynamics and explain what impact they have on the important concepts of thermodynamics that we have discussed in class.
 First Law - heat must be conserved. This is the origin of enthalpy during our discussion (ΔH)

Second Law - The universe tends toward disorder. This was our introduction to entropy and it allows us to understand how entropy relates to spontaneity and  $\Delta G$ .

2. Coal power plants are not 100% efficient; that is, not all of the energy produced from the combustion reaction results in usable energy.

a. The combustion of coal is shown below. Is this reaction endothermic or exothermic? Explain your choice.

 $C(s) + O_2(g) \rightleftharpoons CO_2(g)$ 

Exothermic. Two bonds are being made and only one broken. Making bonds is exothermic.

b. V	What happen	s to the rest	of the energy?
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It is transferred to the surroundings as heat.

c. Clearly explain how this is related to thermodynamics.

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\Delta U = q + w
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The work done by the system is the usable energy. The heat lost is shown as q. The total energy exchange is  $\Delta U$ 

- 3.  $\Delta S_{vaporization} > \Delta S_{fusion}$ ; Explain why this statement is true. Liquid --> gas creates much more disorder
- Which direction does a reaction "shift" when Q > K. You must clearly explain your choice to receive full credit.

  Reactants
  Products

reducturits	
If Q > K, this means th	at there are more products and less reactants than are needed at equilibrium.

What is the sign of  $\Delta G$  when Q < K ?

negative

5. Explain why each of the following statements are false.

a. A spontaneous reaction occurs when energy is consumed by a system. Spontaneous reactions do not require energy.

positive

- b. Liquid water has a formation enthalpy of zero ( $\Delta H_f^0 = 0$ ). Only elements in their most stable form have values of zero.
- c. Br<sub>2</sub> (*I*) has a standard molar entropy of zero ( $S^0 = 0$ ) This violates the 3rd law of thermodynamics
- d. Endothermic reactions are never spontaneous. They can be if there is a strong entropic favorability
- e. Equilibrium occurs when the concentration of products and reactants are equal. Equilibrium occurs when the rate of the forward are reverse reactions are equal, not when the concentrations are equal.
- Consider the following reactions. Which is most likely to have a negative ∆S? You must clearly explain your answer to receive credit.

 $CO_2$  (g) + H<sub>2</sub>O (i)  $\Rightarrow$  H<sub>2</sub>CO<sub>3</sub> (aq) 2 C<sub>8</sub>H<sub>18</sub> (i) + 25 O<sub>2</sub> (g)  $\Rightarrow$  16 CO<sub>2</sub> (g) + 18 H<sub>2</sub>O (g)

The other reaction is creating more gas molecules. The highlighted reaction is consuming a gas, producing an aqueous compound, AND it is making one molecule from two. All of these things suggest it will be unfavorable.

7. The synthesis of NO occurs according to the following reaction where  $Kc = 7.5 \times 10^{-9} M^{-1}$  at 1000 K.

 $N_2(g) + 2 O_2(g) \rightleftharpoons 2 NO_2(g)$ 

- a. If 1 M of each gas is mixed together at 1000 K, would the synthesis of NO<sub>2</sub> be spontaneous?
  - NO K<1
- b. Determine Kc for this related reaction:  $2 \text{ NO}_2(g) \Rightarrow N_2(g) + 2 \text{ O}_2(g)$

c. Calculate Kp at 1000 K. Include the correct units.

$$\Delta n = -1$$
  $K_{p} = K_{c} (RT)^{\Delta n} 3^{cs}$ 

- 8. Consider the following reaction:
  - 6 HCl (g) + 2 As (s)  $\rightleftharpoons$  2 AsCl<sub>3</sub> (l) + 3 H<sub>2</sub> (g)
    - a. For each of the following, determine if the equilibrium will shift. If so, determine if products or reactants will be formed.
      - i. Magnesium is added NO Change ii. HCl is added. products
      - iii. The volume of the flask is decreased. more ges as reacted ... more impact
    - b. Using the information available at the back of the exam, calculate  $\Delta G^{\circ}$  and  $\Delta H^{\circ}$ .

d. Calculate  $\Delta S^{\circ}$ 

e. Calculate ∆G if 0.4 atm of CO, 2.5 atm of CO<sub>2</sub>, 14 g of S, and 0.98 atm of CS<sub>2</sub> are added to a reaction flask at 25 °C.

$$\Delta G = 305200 + 8.314(251.11) \ln Q$$

9. Consider the following reaction.

 $3 F_2(g) + N_2(g) \rightleftharpoons 2 NF_3(g)$ 

a. 2 atm of F2 and 1 atm of N2 are combined in a sealed reaction flask at 100 °C. Once equilibrium has been reached, the pressure is the flask is 1.706 atm. Determine the equilibrium constant at this temperature.

$$3F_{2} + N_{1} = 2NF_{3}$$

$$2 - 3X + 1 - X + 7X = 1.706$$

$$T = 2 - 1$$

$$C - 3X - X = 2($$

$$X = 0.647$$

$$F_{2} - 3X - X = 1.294$$

$$F_{N}F_{3} = 1.294$$

$$F_{1} = 0.553$$

$$F_{1} = 0.055$$

$$K = 2.31K10^{4}$$

b. When the temperature is raised to 200 °C, the pressure of F2 decreases to 0.01 atm.





- e. Which reaction might have  $\Delta H > 0$  and  $\Delta S < 0$ ?
- 11. Complete one of the problems on this page. You can answer more for extra credit. Please use the next page to show your work if you need more space.
- a. Determine the total pressure at equilibrium if 14 grams of carbon, 1.82 atm of H<sub>2</sub>, and 2.33 atm of CH<sub>4</sub> are ( 3.2 6 5 / ~ added to a reaction flask at 500 °C. 8910.4 - 195322++ 10760x2 = 2.32++
  - $C(s) + 2 H_2(g) \rightleftharpoons CH_4(g) \qquad Kp = 2690 \text{ atm}^{-1} \text{ at } 500 \text{ °C}$   $H L 2.77 \qquad a = 0.7 \qquad Lu(b) = \frac{2.33+4}{(111-24)^2}$ 10760 x2 - 19584.2X + 8908.07 -7
- b. Using the information in the table below, determine the heat capacity of solid CS<sub>2</sub> if 2.34 kJ of heat is released when 10 grams of liquid CS<sub>2</sub> is cooled from 46.3 °C to -150 °C.  $\Delta H = 73.75(-116.1 46.3) \times 75(-116.1 -$ 
  - $\Lambda C = \lambda = \Lambda H = T \Lambda$ .....

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Thermodynamic values for CS <sub>2</sub>	ΔH	-Taj		τī = -	F6.57	- 211.	, i v
Т <sub>ь</sub> (°С)	T <sub>m</sub> (°C)	∆H <sub>fusion</sub> (kJ/mol)	∆H <sub>vaporization</sub> (kJ/mol)	C (solid) J / (mol K)	C (liquid) J / (mol K)	C (gas). J / (mol K)	41
	-110.8	4.39	27.65		78.99	46.55	_7

d. 1368 kJ of heat is required to decompose 112.04 grams of CO (g). Noting that the bond enthalpy of a CO triple bond is 1072 kJ mol<sup>-1</sup>, calculate the bond enthalpy of a CO double bond.

 $2 \text{ CO} (g) \rightleftharpoons \text{C}(s) + \text{CO}_2 (g)$ 

e. Incomplete combustion of natural gas produces carbon monoxide and water vapor (see unbalanced reaction below).

 $CH_4(g) + O_2(g) \rightleftharpoons CO(g) + H_2O(g)$ Determine  $\Delta H^{\circ}$  for this reaction from the data below:

 $CH_4$  (g) + 2  $O_2$  (g)  $\Rightarrow$   $CO_2$  (g) + 2  $H_2O$  (g) ∆H° = -802 kJ mol<sup>-1</sup>

ΔH° = -566 kJ mol<sup>-1</sup> en byon Set  $2 \text{ CO} (g) + O_2 (g) \rightleftharpoons 2 \text{ CO}_2 (g)$ 

mitch

f. Using the information at the back of the exam, determine the temperature that is needed to make this reaction spontaneous.

$$6 \text{ HCl } (g) + 2 \text{ As } (s) \rightleftharpoons 2 \text{ AsCl}_3 (s) + 3 \text{ H}_2 (g)$$

$$\begin{aligned} \Delta H_{1} + \Delta H_{2} &= -2.2 \text{ KT} \\ -2.34 + 7.2 &= -0.139 = \Delta H_{3} \\ \Delta H_{3} &= 0.131 (C) (-150 - 110.8) \\ \hline C &= 27.05 \text{ J}_{MN} \text{ K} \end{aligned}$$

All2 - - 4.39(.131) Ally = -0.575

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								0.7	(222)		1 2	Francium	0.7	132.91	Cs	55	Cesium	0.8	85.47	RB	37	0.8	39.10	7	5	Potassium	0.9	22.99	Na	11	1.0	6.94	5	ω	Lithium	2.1	2	Hydrogen	-	•
	9	**			IGIIU	*loot		6.0	(022)	Ka	8	Radium	0.9	137.33	Ba	56	Barium	1.0	87.62	Ş	38	1.0	40.08	Ca	8	Calcium	1.2	24.31	Ma	nagnesum 12	1.5	9.01	Be	4	Beryllum	2			-	
	ALL LICES	tinidae			Idilluco	anidoo					89-102					57-70															-									
	(227)	89	Actinium	130.91	La	57	1 anthanim	1	(202)	<u>ک</u>	100	Lawrencium	11	174.97	Ε	71	Lutetium	12	88.91	~	39	1.3	44.96	Sc	22	Scandium	ω				signific	quantiti	be treat	Allaver	decima	are rou	Average			
4	232.04	9	Thorium	140.12	Ce	58	Carlism	1	(102)	A	Į	Rutherfordium	1.3	178.49	Ŧ	72	Hafnium	14	91.22	Ľ	40	1.5	47.88	=	12	Titanium	4				ant tigure	es, and su	ed as mea	age mass	places.	ided to tw	relative r			
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	(237)	93	Noptunium	(140)	Pm	61	Promobilin		(204)	ğ		Bohrium	1.9	186.21	Re	75	Rhenium	1.9	(98)	7	43	1.5	54.94	Mn	25	Manganese	7			ctronega				Syn	,		Nar	Eleme	00	erio
4	(244)	g	Plutonium	100.30	Sm	62	Samarian		(202)	SH	IUO	Hassium	2.2	190.23	ŝ	76	Osmium	22	101.07	R	44	1.8	55.85	Fe	1 26	Iron				uvity -				100			me	ž		tic T
	(243)	95	Americium	191.97	E	8	Furnham	1	(200)	MI	00	Meitnerium	2.2	192.22	=	77	Indium	22	102.91	Ŗ	45	1.8	58.93	00	27	Cobalt	9					200		¥		æ	INICIO	Merc		able
	(247)	98 8	Curium	C7.7C1	Ga	2	Gadoliniam		(112)	SO	2	Darmstadtiur	2	195.08	₽	78	Platinum	2	106.42	Pd	46	Dollardon 1.8	58.69	Z	28	Nickel	10			1.9	5	59 4	C	2		1				of the
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	(251) (251)	8	Californium	00.701	Dy	8	Dysprosium		(277)	ŝ		Copernicium	1.9	200.59	Hg	80	Mercury	17	112.41	ß	48	1.6	65.39	Zn	w ا	Zinc	12					9c	2		1	4				ment
	(252)	1 ფ	Einsteinium	104.93	н	67	n Holmium		(204)			Ununtrium	1.8	204.38	=	81	Thallium	17	114.82	5	49	1.6	69.72	Ga	<u>ب</u>	Gallium	1.5	26.98	₽	13	2.0	10.81		1 01	Boron	13			10	S
	(257)	10	Fermium	107.70	Ē	68	Erhium		(607)	ž	1	Flerovium	1.8	207.20	PB	82	Lead	1.8	118.71	S	5	1.8	72.61	Ge	32	Germanium	1.8	28.09	s	14	2.5	12.01	C	6	Carbon	14				
	(258)	101	Mendelaviu	00.93	Tm	69	Thulum	1	(200)	quo	110	Ununpentiur	1.9	208.98	<u>0</u>	83	Bismuth	1	121.76	SP	51	2.0	74.92	As	33	Arsenic	2	30.97	•	15	3.0	14.01	z	7	Nitrogen	15				
	(259)	102	n Nobelium	1/3.04	Υb	70	Viterhium		(CEZ)			n Livermoriu	2.0	(209)	Po	84	Polonium	2.	127.60	5	52	2	78.96	Se	34	Selenium	22	32.07	s	16	3.	16.00	C	00	Oxygen	16				
~			1-				_		(294)	Sno		n Ununseptiu	2	(210)	₽	85	Astatine	2	126.90	_	53	2	79.90	<b>9</b>	35	Bromine	3	35.45	Ω	17	4	19.00	-	9	Fluorine	17				
									(294)	Ouo	110	m Ununoctiun	2 2.4	(222)	Rn	86	Radon	5 26	131.29	Xe	24	8 3.0	83.80	5	36	Krypton	1	39.95	Ą	18		20.18	Ne	10	Neon		4 00	22	81	
													- 18 M																											

	$\Delta H_f^0$ kJ mol <sup>-1</sup>	$\Delta G_f^0$ kJ mol <sup>-1</sup>
AsCl <sub>3</sub> (I)	-305.2	-259.0
HCI (g)	-110.5	-137.2

## Equations

$$\begin{split} \Delta G &= \Delta H - T\Delta S \qquad \Delta G^0 = -RTlnK \qquad \Delta G = \Delta G^o + RTlnQ \\ \Delta U &= q + w \qquad w = -p\Delta V \qquad \Delta G = -T\Delta S_{universe} \\ \Delta H &= C_p\Delta T \qquad ln\frac{K_2}{K_1} = \frac{\Delta H}{R} \Big(\frac{1}{T_1} - \frac{1}{T_2}\Big) \quad \text{R} = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1} \qquad \text{R} = 8.314 \text{ J mol}^{-1} \text{ K}^{-1} \\ \text{Kp} &= \text{Kc} (\text{RT})^{\Delta \text{ngas}} \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \end{split}$$