CHEM 202H – 12,13,14 Name_____

EXAM 2, Spring 2016 Signature_____

SCORED GRADE (100 max.)_____

CIRCLE YOUR COURSE SECTION IN THE LIST BELOW

202-12 W 10-12:50 202-13 W 2-2:50 202-14 W 3-3:50

Section 1. Entropy, Enthalpy, and Gibb's Energy under Standard Conditions (16 pts)

1. Identify the compound in each series with the largest *S*°.

A. $Hg_{(l)}$ $Br_{2(l)}$ $CCl_{4(l)}$ $CS_{2(l)}$

_____

B. $CH_3CH_2OH_{(g)}$ $CH_3CH_2OH_{(l)}$ $CH_3CH_2OH_{(s)}$ $CH_3CH_2OH_{(aq)}$

_____

For questions 2 – 3, identify the reaction as: A) Spontaneous at all T; B) Non-spontaneous at all T; C) Spontaneous at low T, but non-spontaneous at high T; or D) Non-spontaneous at low T, but spontaneous at high T.

2. $2\ C_4H_{10(g)} + 13\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 10\ H_2O_{(g)}$ (HINT: This is a combustion reaction)

_____

3. The sublimation of CO_2.

_____

4. Select the thermodynamic value on the left with the appropriate term on the right. (NOTE: not all terms on the right will be used, a term may be used more than once)

	A. endothermic
_____ $\Delta G_{sys} = 0$	B. exothermic
_____ $\Delta S_{univ} < 0$	C. endergonic
_____ $\Delta S_{surr} > 0$	D. exergonic
	E. equilibrium

Section 2. Entropy, Enthalpy, and Gibb's Energy under General Conditions (14 pts)

5. Write a reaction quotient for the following reactions:

A. $2\ NO_{(g)} + 2\ Cl_{2(g)} \rightarrow 2\ Cl_2O_{(g)} + N_{2(g)}$

_____

B. $PbSO_{4(s)} \rightarrow Pb^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$

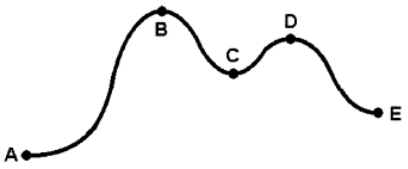
_____

6. Select the thermodynamic condition on the left with the appropriate term on the right. (NOTE: Some terms may be used more than once and some terms may not be used at all.)

_____ Q = K	A. standard conditions
_____ Q/K > 1	B. spontaneous
_____ Q = 1	C. non-spontaneous
_____ Q < K	D. equilibrium

Section 3. Fundamentals of Reaction Mechanisms (12 pts)

7. Use the following Reaction Energy Diagram to the answer the following questions:



What is the spontaneity of this reaction under standard conditions? _____

What point(s) represents the transition state(s)? _____

How many chemical steps are involved in this reaction? _____

What value can be calculated by subtracting the energy at A from that at B? _____

8. For the elementary reaction A + B → products, what two conditions must be met for the reaction to occur?

_____

Section 4. Rates and Rate Laws (10 pts)

9. Consider the following 2 step-reaction:

$$A_{(aq)} + H_2O_{(l)} \rightarrow B_{(aq)} + C_{(aq)}$$

$$B_{(aq)} \rightarrow D_{(aq)}$$

A. Write the overall reaction.

_____

B. Identify any intermediates in the reaction.

_____

C. Write the rate law assuming the first step is the slow step.

_____

D. If the first step is fast and reversible and that the second step is slow, the rate law is:

$$rate = \frac{k_1 k_2 [A]}{k_{-1}[C] + k_2}$$

Under what conditions would this reaction appear first-order overall?

_____

Section 5. General Equilibrium (10 pts)

10. The following reaction is at equilibrium. Indicate if the following changes to the system will:
A) shift reaction towards products; B) shift reaction towards reactants; or C) no shift the equilibrium.

$$HNO_{3(l)} + ClF_{(g)} \rightarrow ClONO_{2(g)} + HF_{(g)}$$

A. Addition of $HF_{(g)}$ _____

B. Addition of $HNO_{3(l)}$ _____

C. Increasing P by addition of $N_{2(g)}$ _____

D. Increasing P by reducing reactor V _____

Section 6. Calculations (30 pts). YOU MUST SHOW YOUR WORK FOR CREDIT.

11. The degradation of SO_2Cl_2 occurs via a single elementary step with a rate constant of $2.2 \times 10^{-5}\ s^{-1}$. If the initial concentration of SO_2Cl_2 is 0.0040 M, what is the concentration of SO_2Cl_2 after 1.00 hour?

$$SO_2Cl_{2(g)} \rightarrow SO_{2(g)} + Cl_{2(g)}$$

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12. The rate constant for 2 A → B is $1.8 \times 10^{-2}\ M^{-1}\ s^{-1}$. Calculate the half-life when the concentration of A is 0.35 *M*.

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13. The standard Gibb's energy ($\Delta G°$) for the following reaction at 298 K is -141.8 kJ/mol.

$$COCl_{2(g)} + H_2O_{(l)} \rightarrow CO_{2(g)} + 2\ HCl_{(g)}$$

What is ΔG for the reaction 298 K when: $P_{COCl2} = 0.3$ atm; $P_{CO2} = 0.6$ atm; and $P_{HCl} = 0.2$ atm.

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14. The equilibrium vapor pressure of H_2O at 20 °C is 2.30×10^{-2} atm. Calculate the standard Gibb's energy ($\Delta G°$) for the vaporization of H_2O at this temperature. (HINT: How is the EVP related to K?)

$$H_2O_{(l)} \rightarrow H_2O_{(g)}$$

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15. At 425 °C, the K_p for the following reaction is 4.18×10^{-9}. At this temperature, if the initial HBr pressure is 1.5 atm, what is the partial pressure of H_2 at equilibrium?

$$2\ HBr_{(g)} \rightarrow H_{2(g)} + Br_{(g)}$$

Section 7. Essay (8 pts). Answer in paragraph form comprised of 4-6 full sentences.

16. The combustion of methane gas is a spontaneous process, but the reaction requires a spark to ignite the gas. Explain this observation in terms of *thermodynamics* and *kinetics.*

THIS PAGE CAN BE REMOVED FROM THE EXAM

USE THE BACK FOR SCRATCH PAPER IF NEEDED

The Periodic Table of the Elements

1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

$S = k \ln W$

$k = 1.381 \times 10^{-23}$ J/K

$R = 8.314$ J/mol K $= 0.08206$ L atm/mol K

$$\Delta G = \Delta G^\circ + RT \ln Q$$

$$K = e^{-\Delta G^\circ / RT}$$

$$\ln \frac{[A]_0}{[A]_t} = akt$$

$$\frac{[A]_0}{[A]_t} = e^{akt}$$

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = akt$$

$$t_{1/2} = \frac{\ln 2}{ak}$$

$$t_{1/2} = \frac{1}{ak\,[A]_0}$$

$$k = A\, e^{-E_a/RT}$$

$$\ln \frac{k_2}{k_1} = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$