Name: ____

Chemistry 210 Exam 2

Be sure to put your name on each page. This page can be removed from your exam so that you will have a Periodic Table handy throughout the exam, it does not need to be turned in. Show all your work for problems which require any sort of calculation, no credit will be given for answers without work shown. If you have shown a significant amount of work or multiple drawings for a problem, draw a box around what you consider your final answer.

Avogadro's Number = 6.022×10^{23} $^{\text{units}}/_{\text{mol}}$
$32.00^{o}F = 0.000^{o}C = 273.15K$
Density of Water = $1.000\,^{g}/_{mL}$
$R = 0.08206\ ^{L\bullet atm}/_{mol\bullet K} = 8.314\ ^{J}/_{mol\bullet K}$
$PV=nRT$
$\Delta T_{fp/bp} = k_{fp/bp}\bullet m\bullet i$
For water, $k_{fp} = -1.86\,^{^oC}/_{m}$; $k_{bp} = 0.52\,^{^oC}/_{m}$
$P_1 = X_1P_1^{o}$
$P = cRTi$
$C_1V_1 = C_2V_2$
Quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Integrated Rate Laws:

$\ln[A]_t = -kt + \ln[A]_o$
$1/[A]_t = kt + 1/[A]_o$
$[A]_t = -kt + [A]_o$

$k = Ae^{-Ea/RT}$

$$\ln(k) = \left(\frac{-E_a}{R}\right)\left(\frac{1}{T}\right) + \ln(A)$$

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

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.88	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.03	89 **Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 (269)	111 (272)	112 (277)		114		116		

58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.94	70 **Yb** 173.04	71 **Lu** 174.97
90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (258)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Score

Multiple Choice: Circle the letter of the most correct response. (5pts. per question)

1. All of the following affect the value of the equilibrium constant, K_c, except:
   a. The temperature of the system
   b. The concentration of products
   c. The concentration of reactants
   d. The presence of a catalyst
   e. The pressure of the system

2. For the generic equation:

$$aA + bB \rightarrow cC + dD$$

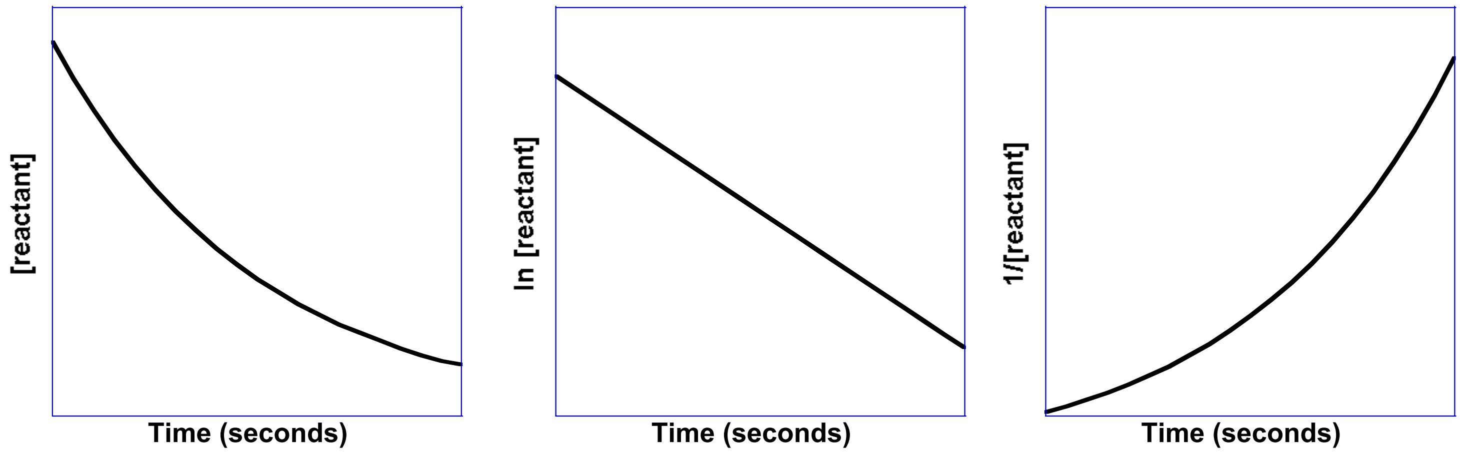
   Which of the following is a correct expression of the rate of the reaction:
   a. $^{1}/_{a}\ ^{\Delta[A]}/_{\Delta t}$
   b. $^{-1}/_{b}\ ^{\Delta[B]}/_{\Delta t}$
   c. $k[A]^{a}[B]^{b}$
   d. $^{-1}/_{d}\ ^{\Delta[D]}/_{\Delta t}$
   e. $k[C]^{c}[D]^{d}$

3. For an elementary reaction:
   a. The rate must be measured, it cannot be derived
   b. There can be no more than 2 products
   c. The rate law is always first order
   d. There can be no more than 2 reactants
   e. The rate is always fast

4. If the rate of a reaction increases by a factor if 16 when the initial concentration of reactant "A" is increased by a factor of 4, the reaction must be:
   a. 2nd order overall
   b. 4th order with respect to [A]o
   c. 1st order with respect to[A]o
   d. 2nd order with respect to [A]o
   e. The order of the reaction depends on the balanced chemical equation

5. For a second order reaction:
   a. The slope of the integrated rate law plot is equal to k
   b. The intercept of the integrated rate law plot is equal to the initial concentration
   c. The slope of the integrated rate law plot is equal to ($-E_a/R$)
   d. The intercept of the integrated rate law is equal to the *ln* of the initial concentration
   e. The slope of the integrated rate law is equal to the frequency factor, A.

Score



6. The reaction represented by the plots above:
   a. Is zero order
   b. Is first order
   c. Is second order
   d. Is third order
   e. The order can't be determined by these graphs

7. Which of the following is ***true*** regarding catalysts and catalyzed reactions?
   a. The presence of a catalyst changes the energy of the products and reactants in a reaction
   b. The presence of a catalyst changes the equilibrium constant for a reaction
   c. The presence of a catalyst does not change the mechanism of a reaction
   d. The concentration of a catalyst cannot appear in the rate law for a reaction
   e. The presence of a catalyst changes the activation energy for a reaction

8. Which of the following is ***false*** regarding equilibrium?
   a. The concentrations of products and reactants does not change once the reaction has reached equilibrium
   b. Equilibrium can be shifted by changing pressure or temperature
   c. The rates of the forward and reverse reactions are equal
   d. Equilibrium concentrations do not depend upon whether you approach equilibrium from the left or the right
   e. The forward and reverse reactions stop when a system reaches equilibrium

9. Which of the following is ***false*** regarding reaction mechanisms?
   a. A mechanism must be composed of elementary reactions
   b. The observed rate law must agree with the rate law of the slowest step
   c. The steps of the mechanism can contain chemical species that do not appear in the overall correctly balanced chemical equation
   d. The observed rate law is equal to the sum of the rate laws from all steps
   e. Catalysts can appear in the steps of a mechanism

Score

10. For an elementary reaction:
    a. The activation energy is very small
    b. ΔH must be exothermic
    c. The rate law is always first order
    d. There can be no more than 2 reactants
    e. The rate is always fast

11. Which of the following does ***not*** affect the rate of a reaction?
    a. The orientation of colliding particles
    b. The energy of collisions between reacting particles
    c. The frequency of collisions between reacting particles
    d. The coefficients of the reactants in the balanced equation
    e. The temperature of the system

12. For the generic equation

$$aA(g) + bB(g) \leftrightarrows cC(g) + dD(g)$$

    The value of the equilibrium constant, K_c:
    a. Must be measured, it cannot be derived from the balanced equation
    b. Is equal to $k[A]^a[B]^b$
    c. Is equal to $([A]^a[B]^b)/([C]^c[D]^d)$
    d. Is not affected by temperature
    e. Is equal to $([C]^c[D]^d)/([A]^a[B]^b)$

13. Which of the following statements is ***false*** regarding the reaction quotient, *Q*?
    a. It has the same mathematical form as the equilibrium constant
    b. If $Q>K_c$, the system needs to shift toward the products to reach equilibrium
    c. If $Q<K_c$, the system needs to shift toward the products to reach equilibrium
    d. If $Q=K_c$, the system is at equilibrium
    e. It tells the direction that the reaction must shift to reach equilibrium

Score

Multiple Choice Calculations: (10pts each)

14. A reaction is found to be first order with respect to reactant A and zero order with respect to reactant B. If $[A]_o$ = 1.26M, $[B]_o$ = 1.94M and k = 3.84×10^3 $hour^{-1}$, what is the initial rate of the reaction?
    a. 1.98×10^3 $^M/_{hour}$
    b. 4.84×10^3 $^M/_{hour}$
    c. 9.39×10^3 $^M/_{hour}$
    d. 7.45×10^3 $^M/_{hour}$
    e. 3.05×10^3 $^M/_{hour}$

15. For the reaction:

$$CH_4(g) + H_2O(g) \leftrightarrows CO(g) + 3\,H_2(g) \qquad \Delta H = 206.2\ ^{kJ}/_{mol}$$

    The equilibrium concentrations have been found to be $[CO]_{eq}$ = 1.94M, $[H_2]_{eq}$ = 2.15M, $[CH_4]_{eq}$ = 6.49×10^{-2} M, $[H_2O]_{eq}$ = 9.29×10^{-3} M. What is the equilibrium constant?
    a. 6.92×10^3
    b. 1.45×10^{-4}
    c. 3.13×10^{-5}
    d. 3.20×10^4
    e. 9.38×10^3

16. A reaction is found to be second order with respect to ammonium ion, a reactant. If $[NH_4^+]_o$ = 1.64M and k = 2.53×10^{-4} $M^{-1}sec^{-1}$, what will the concentration be after 45 minutes have passed?
    a. 1.05 M
    b. 0.773 M
    c. 1.29 M
    d. 0.828 M
    e. 0.957 M

17. You have found the following value in a table of equilibrium constants at 25ºC:

$$PbBr_2(s) \leftrightarrows Pb^{+2}(aq) + 2\,Br^-(aq) \qquad K_c = 6.29\times10^{-6}$$

    What is the equilibrium constant for the reaction:

$$\tfrac{1}{2}\,Pb^{+2}(aq) + Br^-(aq) \leftrightarrows \tfrac{1}{2}\,PbBr_2(s)$$

    a. 2.53×10^{10}
    b. 1.59×10^5
    c. 7.95×10^4
    d. 399
    e. 3.18×10^5

Score

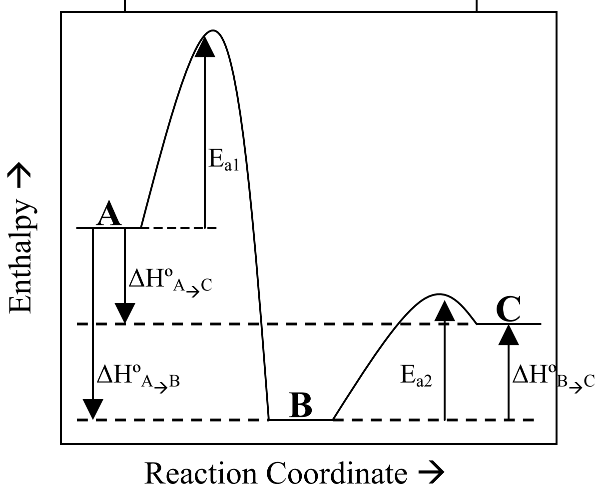
Problems: Select 3 of the following 4 problems. Clearly indicate which problem you do **not** want graded by placing an "X" through that problem. If no problem is crossed out, you will receive the score for the **lowest 3** problems. (15pts each)

18. You have been studying the reaction series:

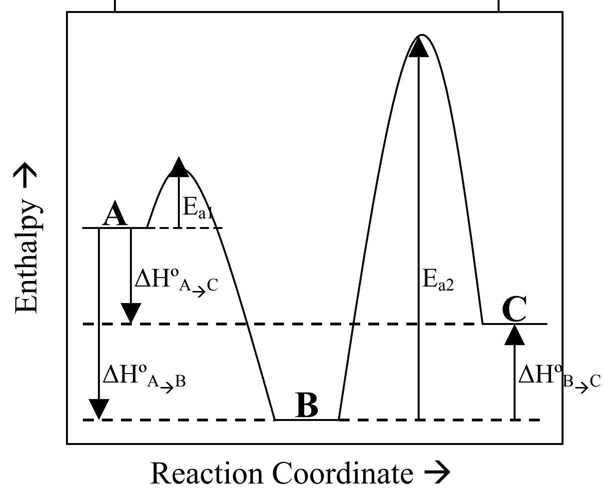
A → B → C

The first step (A → B) is exothermic, the second step (B → C) is endothermic, and the overall reaction (A → C) is exothermic. Draw qualitatively correct Reaction Coordinate/Energy diagrams for this series of reactions if: a) the first step is slow; b) the second step is slow. Label all axes and any other features of importance on the graphs. **(Your answer will include 2 separate graphs.)**

a) the first step is slow
$E_{a1} > E_{a2}$



b) the second step is slow
$E_{a1} < E_{a2}$



21. You have combined 50.00mL of 1.267M calcium nitrate solution and 50.00mL of 0.936M potassium phosphate solution. After you filter and dry the resulting precipitate, you find that you have recovered 4.982g of solid. What is the percent yield?

$3\ Ca(NO_3)_2(aq) + 2\ K_3PO_4(aq) \rightarrow Ca_3(PO_4)_2(s) + 6\ KNO_3(aq)$

Calculating the possible product formed from each reactant:

$$\left(1.267\frac{\text{mol } Ca(NO_3)_2}{\text{L } Ca(NO_3)_2(aq)}\right)\left(0.05000\text{ L } Ca(NO_3)_2(aq)\right)\left(\frac{1\text{ mol } Ca_3(PO_4)_2}{3\text{ mol } Ca(NO_3)_2}\right)\left(310.174\frac{\text{g } Ca_3(PO_4)_2}{\text{mol } Ca_3(PO_4)_2}\right) = 6.550\text{ g } Ca_3(PO_4)_2$$

$$\left(0.936\frac{\text{mol } K_3PO_4}{\text{L } K_3PO_4(aq)}\right)\left(0.05000\text{ L } K_3PO_4(aq)\right)\left(\frac{1\text{ mol } Ca_3(PO_4)_2}{2\text{ mol } K_3PO_4}\right)\left(310.174\frac{\text{g } Ca_3(PO_4)_2}{\text{mol } Ca_3(PO_4)_2}\right) = 7.26\text{ g } Ca_3(PO_4)_2$$

Since $Ca(NO_3)_2(aq)$ can produce less product, it is the limiting reagent. Percent yield is:

(4.982g / 6.550g) * 100% = 76.06% yield

Score

19. For the reaction:

$$Cu^{2+}(aq) + 4\ NH_3(aq) \rightarrow [Cu(NH_3)_4]^{2+}(s)$$

You have collected the following data at 32.85ºC:

Experiment	$[Cu^{2+}]_o$	$[NH_3]_o$	$Rate_{observed}$
1	0.527 M	3.152 M	$6.94x10^{-2}\ ^{M}/_{sec}$
2	0.527 M	1.576 M	$3.47x10^{-2}\ ^{M}/_{sec}$
3	1.054 M	1.576 M	$6.94x10^{-2}\ ^{M}/_{sec}$

What are the rate law and the value of the rate law constant, k, for this reaction?
If you redo Experiment 2 at 8.35ºC, the rate slows to $7.53x10^{-3}\ ^{M}/_{sec}$. What is the activation energy for this reaction?

Comparing runs #1 and #2, $[NH_3]_o$ is halved, $Rate_{obs}$ is halved, the rxn is 1st order w.r.t. $[NH_3]_o$
Comparing runs #2 and #3, $[Cu^{2+}]_o$ is doubled, $Rate_{obs}$ is doubled, the rxn is 1st order w.r.t. $[Cu^{2+}]_o$
The rate law expression is:

$$Rate_o = k[NH_3]_o[Cu^{2+}]_o$$

Plugging in the values for any of the above runs and solving for "k", $k = 0.0418\ M^{-1}sec^{-1}$

Plugging in run 2 values at the lower temperature, $k = 9.07x10^{-3}\ M^{-1}sec^{-1}$

Plugging in to the comparative form of the Arrhenius equation:

$$\ln\left(\frac{0.0418\ M^{-1}sec^{-1}}{0.00907\ M^{-1}sec^{-1}}\right) = \frac{E_a}{8.314\ ^{J}/_{mol\bullet K}}\left(\frac{1}{281.50} - \frac{1}{306.00}\right)$$

$$E_a = 4.47x10^{4}\ ^{J}/_{mol}$$

20. When 6.548g of nitrogen dioxide $\{NO_2(g)\}$ and 3.992g of water are sealed together in a 5.000L vessel, they reach equilibrium with ammonia $\{NH_3(g)\}$ and oxygen $\{O_2(g)\}$. If the equilibrium concentration of water is found to be $1.686x10^{-3}$ M:
   a. What are the equilibrium concentrations of all products and reactants?
   b. What is the value of K_c?
   c. Is the reaction Product-favored or reactant-favored?

	$4\ NO_2(g)$ +	$6\ H_2O(g)$ ⇆	$4\ NH_3(g)$ +	$7\ O_2(g)$
Initial	$\frac{\frac{6.548\ g\ NO_2}{46.005\ ^{g}/_{mol}}}{5.000L} =$ 0.02847 M	$\frac{\frac{3.992\ g\ H_2O}{18.015\ ^{g}/_{mol}}}{5.000L} =$ 0.04432 M	0 M	0 M
Change	-4x	-6x	+4x	+7x
Equilibrium	(0.02847 – 4x) M = $4.733x10^{-5}$ M	(0.04432 – 6x) M = $1.686x10^{-3}$ M so x = $7.106x10^{-3}$	4x M 0.02842 M	7x M 0.04974 M

$$K_c = \{(0.02842)^4(0.04974)^7\} / \{(4.733x10^{-5})^4(1.686x10^{-3})^6\} = 4.263x10^{18}$$

K_c is much greater than 1, therefore the reaction is product favored.

Score