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 $= 6.022 \times 10^{23}$ $^{units}/_{mol}$

$R = 8.314$ $^{J}/_{mol \cdot K}$

$32.00^{o}F = 0.000^{o}C = 273.15K$

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

Integrated Rate Laws:

$[A]_t = -kt + [A]_o$

$ln[A]_t = -kt + ln[A]_o$

$^1/_{[A]_t} = kt + {}^1/_{[A]_o}$

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

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

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)

Multiple Choice (5pts each)

1. For a system at equilibrium:
    a. [reactants]/[products] is the equilibrium constant
    b. The forward rate constant ($k_{forward}$) is equal to the reverse rate constant ($k_{reverse}$)
    c. The concentration of products is equal to the concentration of reactants
    d. The forward rate is equal to the reverse rate
    e. The reaction stops

2. The reaction A(cis) $\leftrightarrows$ B(trans) is allowed to come to equilibrium, and the values of the forward and reverse rate constants are measured, $k_{for} = 7.39 \times 10^{-6}$ s^{-1} and $k_{rev} = 2.88 \times 10^{-2}$ s^{-1}. Which of the following graphs is correct for this reaction?
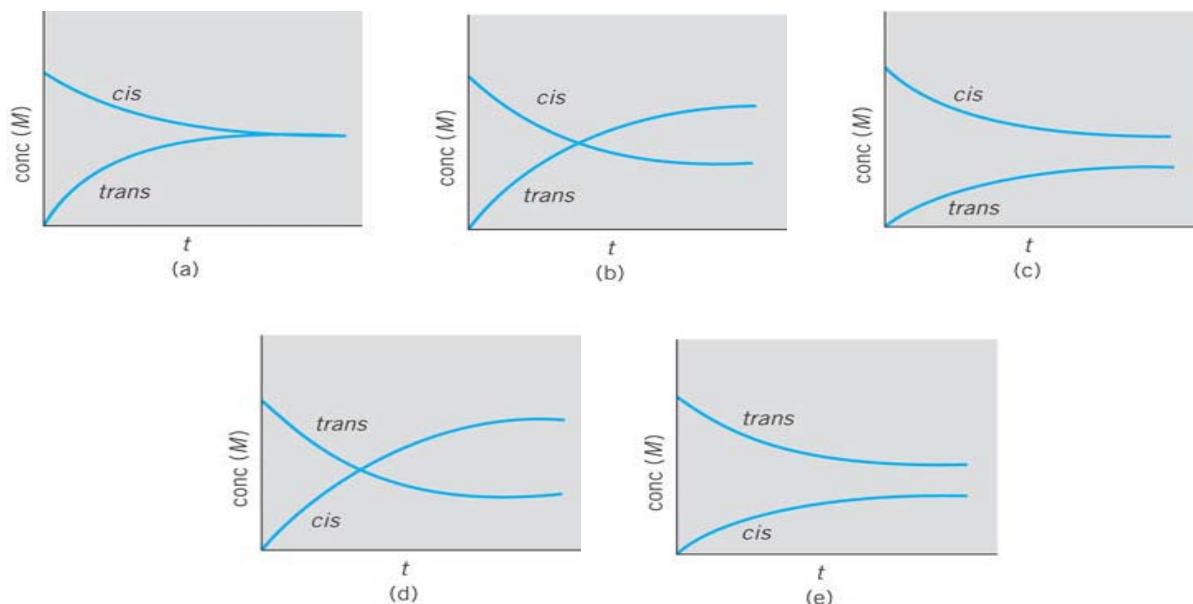
3. For a system at equilibrium:
    a. The forward rate constant ($k_{forward}$) is equal to the reverse rate constant ($k_{reverse}$)
    b. [reactants]/[products] is the equilibrium constant
    c. The reaction stops
    d. The forward rate is equal to the reverse rate
    e. The concentration of products is equal to the concentration of reactants

4. Which of the following is the correct equilibrium constant for the reaction?
$$2C_2H_6(g) + 7\ O_2(g) \leftrightarrows 4CO_2(g) + 6H_2O(g)$$
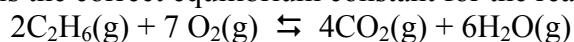
a. $K_c = \dfrac{[CO_2]^4 + [H_2O]^6}{[C_2H_6]^2 + [O_2]^7}$

d. $K_c = \dfrac{[C_2H_6]^2[O_2]^7}{[CO_2]^4[H_2O]^6}$

b. $K_c = \dfrac{4[CO_2] + 6[H_2O]}{2[C_2H_6] + 7[O_2]}$

e. $K_c = \dfrac{(4[CO_2])(6[H_2O])}{(2[C_2H_6])(7[O_2])}$

c. $K_c = \dfrac{[CO_2]^4[H_2O]^6}{[C_2H_6]^2[O_2]^7}$

5. If the value of the equilibrium constant, K_c, is:
    a. Extremely large, no reaction occurs
    b. Equal to 1, the reaction has stopped
    c. Negative, the reaction is spontaneous
    d. Less than 1, the products and reactants are at the same concentration
    e. Greater than 1, the equilibrium favors the products

6. For the equilibrium reaction:
    $$CO(g) + 3 H_2(g) \leftrightarrows CH_4(g) + H_2O(g) \qquad \Delta H = -206.2 \ ^{kJ}/_{mol}$$
    Which of the following is *false*?
    a. Increasing the pressure will shift this equilibrium to the right
    b. Increasing the temperature will shift this equilibrium to the left
    c. Adding extra hydrogen {$H_2(g)$} will shift this equilibrium to the right
    d. Removing carbon monoxide {$CO(g)$} will shift this equilibrium to the right
    e. The reaction is exothermic

7. The reaction quotient for a reaction:
    a. Tells you how fast the reaction happens
    b. Is a constant
    c. Is usually a negative number
    d. Tells you what direction the reaction must shift to reach equilibrium
    e. Is the concentration of reactants divided by the concentration of products

8. Which of the following is *true* about perturbing a system at equilibrium?
    a. If there is more than 1 reactant, all of the reactants must be added to shift the reaction toward products
    b. If more products or reactants are added and all other conditions remain the same, the equilibrium constant will change
    c. If more reactant is added, the reaction will shift toward products
    d. Removing products from the reaction will cause the reaction to shift toward reactants
    e. If one (or more) of the products is a solid (precipitate), the equilibrium constant will be exactly the same as if everything was in solution

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

10. Which of the following is *false* regarding the solubility product constant, K_{sp}?
    a. A large value for K_{sp} means that the substance is very soluble
    b. K_{sp} is just an equilibrium constant that applies to a specific system
    c. If K_{sp} is very small, the substance is insoluble
    d. The concentration of solids never appears in K_{sp}
    e. For substances that are extremely insoluble, the value of K_{sp} can be negative
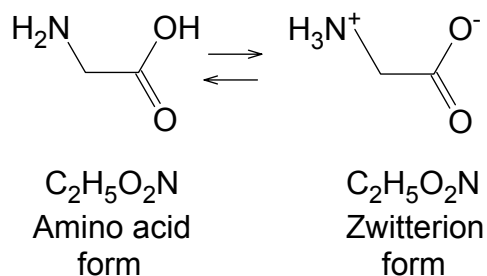
11. For the reaction:

$$CH_4(g) + H_2O(g) \rightleftarrows CO(g) + 3 H_2(g) \qquad \Delta H = 206.2 \; ^{kJ}/_{mol}$$
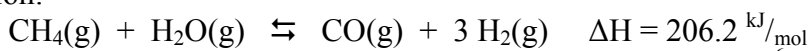
The equilibrium concentrations have been found to be $[CH_4]_{eq} = 5.34 \times 10^{-6}$ M, $[H_2O]_{eq} = 1.16 \times 10^{-8}$ M, $[CO]_{eq} = 3.35 \times 10^{-5}$ M, $[H_2]_{eq} = 8.81 \times 10^{-4}$ M.

a. What is the equilibrium constant *expression* for this reaction? (10pts)

b. What is the *value* of the equilibrium constant for this reaction? (10pts)

c. If the pressure on this system is changed and it is allowed to re-establish equilibrium, the "new" $[CO]_{eq}$ is 3.47×10^{-5} M. What are the new equilibrium concentrations of all species? (15pts)

d. Was the pressure on the system increased or decreased in part c? Explain. (10pts)

12. Amino acids are the building blocks of proteins and can exist as either the "amino acid" form or the "zwitterion" form in aqueous solution. The simplest amino acid is glycine:

$$H_2N \quad\quad OH \quad\longrightarrow\quad H_3N^+ \quad\quad O^-$$

$$\text{(structures)}$$

$C_2H_5O_2N$	$C_2H_5O_2N$
Amino acid	Zwitterion
form	form

After taking some careful measurements, it is found that the equilibrium constant for this reaction, K_c, is equal to 2.24×10^7.

a. What is the equilibrium constant expression for this reaction? (Use the abbreviation "gly(aa)" for the amino acid form and "gly(z)" for the zwitterions form.) (7pts)

b. If 62.357g of gly(aa) is dissolved in water to make 500.0mL of solution and allowed to reach equilibrium, what are the equilibrium concentrations of products and reactants, $[gly(z)]_{eq}$ and $[gly(aa)]_{eq}$? (14pts)

c. After the flask reaches equilibrium, as additional 16.113g of gly(aa) is added. When the system again reaches equilibrium, what are $[gly(aa)]_{eq}$ and $[gly(z)]_{eq}$? (Assume the total volume of the solution remains at 500.0mL.) (14pts)

Name: _____

13. Strontium phosphate has $K_{sp}=3.67\times10^{-43}$. What are the concentrations of strontium and phosphate ions in a saturated solution of strontium phosphate? (10pts)

14. You have set up two separate experiments:
Experiment #1: To a saturated solution of silver acetate ($AgC_2H_3O_2$, $K_{sp}=4.4\times10^{-3}$) you have added 0.10 M sodium sulfide $\{Na_2S(aq)\}$.
Experiment #2: To a saturated solution of silver sulfide (Ag_2S, $K_{sp}=6.3\times10^{-50}$) you have added 0.10 M sodium acetate $\{NaC_2H_3O_2(aq)\}$.
Will a precipitate form in either, neither or both experiments? Explain. (10pts)

Bonus: Alanine is another amino acid, similar to the glycine shown in problem 12. If the equilibrium constant for ala(aa)$\leftrightharpoons$ala(z) is 5.13×10^{5}, what *percentage* of alanine is in the amino acid form in a solution that is at equilibrium? (10pts)