CHEMISTRY 104-1
Prof. J.W. Moore
EXAM 2
March 31, 2000

Name ______________________________

T.A. ____________________ **Sec.** __________

FORM A

(Pink)

Instructions

1. This exam consists of 9 pages and a periodic table. If a page is missing, raise your hand and ask a TA to give you a replacement. Print your name in the space at the top of each page; do it now!

2. The periodic table contains constants and conversion factors that may be useful. Some possibly useful formulas are found on the last page of the exam (just before the periodic table). Tables of data are at the end of the exam; these may be useful for answering non-numeric questions as well as for numeric problems.

3. You will have 50 minutes to work on the exam.

4. Many of the questions are multiple-choice; answer multiple-choice questions inside the test and **transfer your answers to the spaces provided below. A penalty of 4 points will be assessed if this is not done.**

5. There is no need to show work on multiple-choice questions. Show your work clearly on open-ended questions so that graders can understand how you arrived at the solution. Round answers to the correct number of significant figures; include appropriate units.

6. Communicating in any way with another student during this exam will be considered to be one form of cheating.

Page	*Score*
2-4	______/ 48
5	______/ 16
6	______/ 6
7	______/ 10
TOTAL	______/ 80

Answers to Multiple-choice Questions

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____
8. ____
9. ____
10. ____
11. ____
12. ____
13. ____
14. ____
15. ____
16. ____

Multiple Choice Questions. There is *one* best response to each question. Read *all* responses, choose the *best* one, circle it on this page, **and write the letter corresponding to that response in the appropriate numbered space on page one of the exam.** Each multiple-choice question is worth three points.

1. Which is not a component of milk?

   A. lipids
   B. proteins
   C. phosphate
   D. carbohydrates
   E. water
   F. All of these are components of milk.

The next three questions (2, 3, and 4) refer to the equilibrium

$$\mathrm{Co(H_2O)_6^{2+}(aq) + 4\ Cl^- \rightleftharpoons CoCl_4^{2-}(aq) + 6\ H_2O(\ell)}$$

2. Which would change the color of the solution from pink to blue?

   A. adding water
   B. adding NaCl(s)
   C. adding concentrated HCl(aq)
   D. adding concentrated HNO_3(aq)
   E. cooling the solution to 0°C

3. The concentration of which substance does not appear in the expression for the equilibrium constant?

   A. Cl^-
   B. $Co(H_2O)_6^{2+}$
   C. $CoCl_4^{2-}$
   D. H_2O

4. Which change in the conditions increases the value of the equilibrium constant?

   A. adding water
   B. adding NaCl(s)
   C. adding concentrated HCl(aq)
   D. adding concentrated HNO_3(aq)
   E. warming the solution from 25°C to 100°C

5. A river has been contaminated with a small quantity of CCl_4, a carcinogen. If the mass fraction of CCl_4 is 0.3 ppb (parts per billion), how much CCl_4 is in 10,000 L of river water?

   A. 3×10^{-3} g
   B. 6×10^{-6} g
   C. 3×10^{-6} g
   D. 6×10^{-3} g
   E. 3×10^{-10} g

6. The osmotic pressure of a 0.32 M solution of NaCl at 20°C is

   A. 15 atm
   B. 7.7 atm
   C. 23 atm
   D. 1.6 atm
   E. None of these is correct.

7. As the concentration of $H_3O^+(aq)$ increases

   A. the pH increases
   B. the $[OH^-]$ increases
   C. the pOH decreases
   D. the pH decreases
   E. the solution becomes less acidic

8. What is the maximum equilibrium concentration of iron(II) ions in a solution whose pH is 8.2? (K_{sp} for $Fe(OH)_2(s)$ is 7.95×10^{-16}.)

   A. 3.4×10^{-3} M
   B. 5.0×10^{-10} M
   C. 6.3×10^{-20} M
   D. 1.8×10^{-23} M
   E. 3.2×10^{-4} M

9. Under which conditions is $N_2(g)$ most soluble in water?

   A. 25°C, 720 mm Hg
   B. 25°C, 760 mm Hg
   C. 40°C, 720 mm Hg
   D. 40°C, 760 mm Hg

10. Which of the following substances is an important cause of acid rain?

    A. N_2
    B. O_3
    C. $CFCl_3$
    D. NH_3
    E. SO_2

11. Which of these is a Bronsted base?

    A. Al^{3+}
    B. NH_4^+
    C. CO_2
    D. HS^-

E. None of these is a Bronsted base.

12. Which of these is not a property of acids?

A. reacts with limestone, generating gas
B. reacts with litmus, turning it red
C. neutralizes bases
D. reacts with metal ions to form a precipitate
E. All of these are properties of acids.

13. Consider the equilibrium

$$Ba(OH)_2(s) \rightleftharpoons Ba^{2+}(aq) + 2\ OH^-(aq) \quad \Delta H° > 0 \text{ (endothermic reaction)}$$

Which is the most effective way to reduce $[Ba^{2+}]$?

A. add $HCl(aq)$
B. add $NaOH(aq)$
C. remove part of the solid $Ba(OH)_2$
D. raise the temperature
E. add a small quantity of $H_2O(\ell)$

14. Which will produce a basic solution when dissolved in water?

A. NH_4Cl
B. $NaHSO_4$
C. KBr
D. CH_3OH
E. $NaOCl$

15. Which is not a colloid?

A. shaving cream
B. clouds in the sky
C. milk of magnesia
D. sea water
E. jelly

16. Which pair of liquids is miscible in all proportions?

A. CH_3OH and nonane
B. CCl_4 and Br_2
C. CCl_4 and water
D. acetic acid and nonane

Open-Ended Questions. Show all work, use correct numbers of significant figures, and write answers in the spaces provided. No credit will be given for solutions to problems where your work is not clearly shown.

17. *(16 pts.)* Consider the equilibrium system

$$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g) \qquad K = 56$$

at a temperature of 698 K.

A. If 1.0 mol H_2, 1.0 mol I_2, and 1.0 mol HI are placed in an empty 2.0−L flask at 698 K, what will be the concentrations of the three substances when equilibrium is reached?

B. After equilibrium has been reached, 0.050 mol H_2 is removed from the flask and 0.050 mol D_2 ($^2H \equiv D$) is introduced. After several hours, the system is analyzed for deuterium. In what substance will most of the deuterium be found? Explain.

C. Suppose that 3.0 mol HI is placed in an empty 2.0−L flask at 698 K. What will be the concentrations of H_2, I_2, and HI when equilibrium is reached?

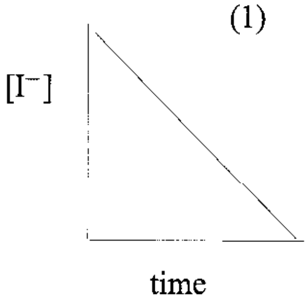
D. At 745 K the equilibrium constant for this reaction is K = 50. Is the reaction endothermic? Explain.

18. *(6 pts.)* Consider the reaction mechanism

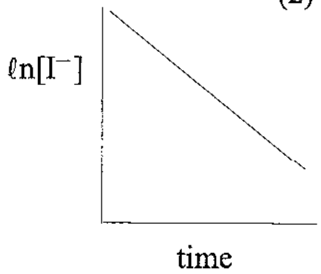
slow $H_2O_2(aq) + I^-(aq) \longrightarrow HOI(aq) + OH^-(aq)$
fast $HOI(aq) + I^-(aq) \longrightarrow I_2(aq) + OH^-(aq)$
fast $2[OH^-(aq) + H_3O^+(aq) \longrightarrow H_2O(\ell)]$

A. Suppose you do a kinetics experiment with initial concentrations of 0.10 M H_2O_2 and 0.0050 M I^-. Which of the graphs below represents the experimental data correctly? Explain.

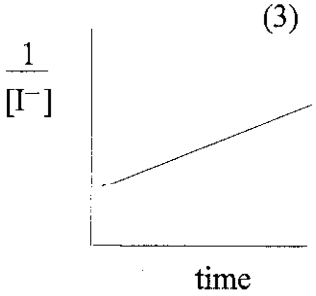
(1)



(2)



(3)



B. On the axes below draw the graph that would represent the experimental data for initial concentrations of 0.050 M H_2O_2 and 0.0050 M I^-. Explain how this graph is related to which ever graph ((1), (2), or (3)) you chose in part A.

19. *(10 pts.)* A buffer solution is made by dissolving 0.50 mol NH_4Cl and 0.50 mol NH_3 in 1.0 L of aqueous solution.

A. What is the pH of this buffer solution?

B. Write a net ionic equation for the reaction that occurs when strong acid is added to this buffer.

C. If 0.10 mol NaOH(s) is added to the 1.0 L of buffer solution, will the pH change significantly? Explain why or why not.

TABLE 17.3 Ionization Constants for Some Acids and Their Conjugate Bases

Acid Name	Acid	K_a	Base	K_b	Base Name
Perchloric acid	$HClO_4$	Large	ClO_4^-	Very small	Perchlorate ion
Sulfuric acid	H_2SO_4	Large	HSO_4^-	Very small	Hydrogen sulfate ion
Hydrochloric acid	HCl	Large	Cl^-	Very small	Chloride ion
Nitric acid	HNO_3	≈ 20	NO_3^-	$\approx 5 \times 10^{-16}$	Nitrate ion
Hydronium ion	H_3O^+	1.0	H_2O	1.0×10^{-14}	Water
Sulfurous acid	H_2SO_3	1.2×10^{-2}	HSO_3^-	8.3×10^{-13}	Hydrogen sulfite ion
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}	SO_4^{2-}	8.3×10^{-13}	Sulfate ion
Phosphoric acid	H_3PO_4	7.5×10^{-3}	$H_2PO_4^-$	1.3×10^{-12}	Dihydrogen phosphate ion
Hexaaquairon(III) ion	$Fe(H_2O)_6^{3+}$	6.3×10^{-3}	$Fe(H_2O)_5OH^{2+}$	1.6×10^{-12}	Pentaaquahydroxoiron(III) ion
Hydrofluoric acid	HF	7.2×10^{-4}	F^-	1.4×10^{-11}	Fluoride ion
Nitrous acid	HNO_2	4.5×10^{-4}	NO_2^-	2.2×10^{-11}	Nitrite ion
Formic acid	HCO_2H	1.8×10^{-4}	HCO_2^-	5.6×10^{-11}	Formate ion
Benzoic acid	$C_6H_5CO_2H$	6.3×10^{-5}	$C_6H_5CO_2^-$	1.6×10^{-10}	Benzoate ion
Acetic acid	CH_3CO_2H	1.8×10^{-5}	$CH_3CO_2^-$	5.6×10^{-10}	Acetate ion
Propanoic acid	$CH_3CH_2CO_2H$	1.4×10^{-5}	$CH_3CH_2CO_2^-$	7.1×10^{-10}	Propanoate ion
Hexaaquaaluminum ion	$Al(H_2O)_6^{3+}$	7.9×10^{-6}	$Al(H_2O)_5OH^{2+}$	1.3×10^{-9}	Pentaaquahydroxoaluminum ion
Carbonic acid	H_2CO_3	4.2×10^{-7}	HCO_3^-	2.4×10^{-8}	Hydrogen carbonate ion
Hexaaquacopper(II) ion	$Cu(H_2O)_6^{2+}$	1.6×10^{-7}	$Cu(H_2O)_5OH^+$	6.25×10^{-8}	Pentaaquahydroxocopper(II) ion
Hydrogen sulfide	H_2S	1×10^{-7}	HS^-	1×10^{-7}	Hydrogen sulfide ion
Dihydrogen phosphate ion	$H_2PO_4^-$	6.2×10^{-8}	HPO_4^{2-}	1.6×10^{-7}	Hydrogen phosphate ion
Hydrogen sulfite ion	HSO_3^-	6.2×10^{-8}	SO_3^{2-}	1.6×10^{-7}	Sulfite ion
Hypochlorous acid	$HClO$	3.5×10^{-8}	ClO^-	2.9×10^{-7}	Hypochlorite ion
Hexaaqualead(II) ion	$Pb(H_2O)_6^{2+}$	1.5×10^{-8}	$Pb(H_2O)_5OH^+$	6.7×10^{-7}	Pentaaquahydroxolead(II) ion
Hexaaquacobalt(II) ion	$Co(H_2O)_6^{2+}$	1.3×10^{-9}	$Co(H_2O)_5OH^+$	7.7×10^{-6}	Pentaaquahydroxocobalt(II) ion
Boric acid	$B(OH)_3(H_2O)$	7.3×10^{-10}	$B(OH)_4^-$	1.4×10^{-5}	Tetrahydroxoborate ion
Ammonium ion	NH_4^+	5.6×10^{-10}	NH_3	1.8×10^{-5}	Ammonia
Hydrocyanic acid	HCN	4.0×10^{-10}	CN^-	2.5×10^{-5}	Cyanide ion
Hexaaquairon(II) ion	$Fe(H_2O)_6^{2+}$	3.2×10^{-10}	$Fe(H_2O)_5OH^+$	3.1×10^{-5}	Pentaaquahydroxoiron(II) ion
Hydrogen carbonate ion	HCO_3^-	4.8×10^{-11}	CO_3^{2-}	2.1×10^{-4}	Carbonate ion
Hexaaquanickel(II) ion	$Ni(H_2O)_6^{2+}$	2.5×10^{-11}	$Ni(H_2O)_5OH^+$	4.0×10^{-4}	Pentaaquahydroxonickel(II) ion
Hydrogen phosphate	HPO_4^{2-}	3.6×10^{-13}	PO_4^{3-}	2.8×10^{-2}	Phosphate ion
Water	H_2O	1.0×10^{-14}	OH^-	1.0	Hydroxide ion
Hydrogen sulfide ion	HS^-	1×10^{-19}	S^{2-}	1×10^5	Sulfide ion
Ethanol	C_2H_5OH	Very small	$C_2H_5O^-$	Large	Ethoxide ion
Ammonia	NH_3	Very small	NH_2^-	Large	Amide ion
Hydrogen	H_2	Very small	H^-	Large	Hydride ion
Methane	CH_4	Very small	CH_3^-	Large	Methide ion

↑ Increasing Acid Strength

↓ Increasing Base Strength

Possibly useful formulas (most constants are on the back of the periodic table):

$T_F = T_C + (9°F/5°C) + 32°F$ $T_K = T_C + 273.15$ $d = m/V$

$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$ % yield = (actual yield/theoretical yield) x 100%

mass % = (mass of element per mole compound)/(mass per mole compound) x 100%

c = molarity = $n_{solute}/V_{solution}$ = amount solute/volume solution

moles solute after dilution = moles solute before dilution M_m = molar mass

$PV = nRT$ $P = F/A$ $P = P_A + P_B + P_C + \ldots$

$P = g\,d\,h$ PV = constant (at const. T, n) mole fraction of A = $n_A/n = P_A/P$

$V = n\,V_m$ V/T = constant (at const. P, n) $P = mRT/VM_m$ $P = dRT/M_m$

$u_{rms} = \dfrac{\sqrt{(3RT)}}{M_m}$ rate of effusion = $\dfrac{1}{\sqrt{M_m}}$ $(P + a\dfrac{n^2}{V^2})(V - bn) = nRT$

energy of emitted photon = $E_i - E_f = h\nu$ $E = h\nu$ $c = \lambda\nu$ $\lambda = h/mv$

$E = mc^2$ $E = hc/\lambda$ $\Delta x \,.\, \Delta(mv) \geq h/4\pi$ $H\psi = E\psi$

$n = 1, 2, 3, \ldots$ $l = 0, 1, 2, \ldots, (n-1)$ $m_l = -l, -l+1, \ldots, 0, \ldots, l-1, l$ $m_s = \pm 1/2$

$E = -2.178 \times 10^{-18}\ J\ (Z^2/n^2)$ $n = 1, 2, 3, 4, \ldots$

$\Delta E = q + w$ $w = -P\Delta V$ $H = E + PV$ $\Delta H = H_{prod} - H_{react}$

$q = C\Delta T = mc\Delta T = nC_m\Delta T$ $\Delta H = \Sigma(a\Delta H_f^o(\text{products})) - \Sigma(b\Delta H_f^o(\text{reactants}))$

$\Delta H = \Sigma(\text{bonds broken}) - \Sigma(\text{bonds formed})$ $\Delta S = \Sigma(aS^o(\text{products})) - \Sigma(bS^o(\text{reactants}))$

$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$ $\Delta S_{surroundings} = -\Delta H_{system}/T$

$\Delta G = \Delta H - T\Delta S$ $\Delta G^o = -RT\ln K_{th} = \Delta H^o - T\Delta S^o$

$j\,A + k\,B \Leftrightarrow l\,C + m\,D$ $K_c = [C]^l[D]^m/[A]^j[B]^k$ $Q = [C]_0^l[D]_0^m/[A]_0^j[B]_0^k$

$E = E^o - (RT/nF)\ln Q = -(0.0592V/n)\log Q$ $pH = pKa + \log([\text{base}]/[\text{conjugate acid}])$

$P = cRT$ $c = P/RT$ $K_p = K_c(RT)^{\Delta n}$

Solubility of gas = $k_H P$ $\Delta T_b = K_b c_m i$ $\Delta T_f = K_f c_m i$ $\Pi V = nRTi$ $\Pi = cRTi$

mass % = (mass solute)/(mass solution) x 100% molality = c_m = (moles solute)/(kg solvent)

mole fraction = (moles solute)/(total moles solution)

For an equation: $ax^2 + bx + c = 0$, *the roots are:* $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\ln(N/N_0) = -kt = -(0.693/t_{1/2})\,t$ $\Delta E = \Delta mc^2$

0th order reaction Rate = $k[A]^0 = k$ $[A] = -kt + [A]_0$

1st order reaction Rate = $k[A]$ $\ln[A] = -kt + \ln[A]_0$

2nd order reaction Rate = $k[A]^2$ $1/[A] = kt + 1/[A]_0$