CHEMISTRY 102B/C
Exam III
November 29, 2023
T. Hummel

NAME _____

SIGNATURE _____

SECTION _____

FORM "A"

This exam is made up of an answer sheet, two cover sheets and 7 numbered pages. Below are instructions for coding the answer sheet. At the bottom of this page are solubility rules. One of the last pages of this exam contains some useful equations and constants, plus the periodic table. Scratch paper is also attached to the end of the exam.

On the answer sheet:

1. **Use #2 pencil. Erase cleanly**.
2. Print your **NAME** in the appropriate designated spaces, then blacken in the letter boxes below each printed letter, last name first, then your first name initial.
3. Fill in your university **ID** number under **STUDENT NUMBER**.
4. Under **SECTION** write the five-digit number that corresponds to your section designation, and then blacken in the corresponding number of boxes. **For 102B students,** the numbers are: BQ2 = 00012, BQ3 = 00013, BQ4 = 00014, BQ6 = 00016, BQ7 = 00017, BQ8 = 00018, BQA = 00021, BQB = 00022, BQC = 00023, BQD = 00024, BQG = 00027, BQH = 00028, BQI = 00029. **For 102C students**, the numbers are: CQ1 = 00031, CQ2 = 00032, CQ3 = 00033, CQ4 = 00034, CQ5 = 00035, CQ6 = 00036, CQ8 = 00038, CQA = 00041, CQB = 00042, CQC = 00043, CQD = 00044, CQE = 00045, CQF = 00046.
5. Under **NETWORK ID** print your University Network ID beginning on the left-hand side with box #1, and then blacken in the corresponding letters, numbers and/or dashes under each character. Do not fill in a character for any unused boxes.
6. Under **TEST FORM** blacken the letter corresponding to the form designated on the upper left hand corner of the exam booklet.
7. Your TA's name should be printed for **INSTRUCTOR** and write your section number for **SECTION** in the lines provided.
8. **Sign** your name (do not print) on the line provided. Print your name underneath it.
9. **Mark** only one answer per question and do not use the answer sheet for scratch paper or make any stray marks on it. Erase cleanly if you wish to change an answer. The exam itself can be used for scratch paper.

Work carefully and efficiently. All questions are worth the same.

Solubility rules:

1. Most nitrate salts are soluble.
2. Most salts of alkali metals and ammonium cations are soluble.
3. Most chloride, bromide, and iodide salts are soluble.
   Exceptions: salts containing Ag^+, Pb^{2+}, and Hg_2^{2+} ions are insoluble.
4. Most sulfate salts are soluble.
   Exceptions: sulfates containing Ca^{2+}, Ba^{2+}, Pb^{2+}, and Hg_2^{2+} ions are insoluble.
5. Most hydroxide salts are insoluble.
   Exceptions: hydroxides containing alkali metals, Ba^{2+}, Sr^{2+}, and Ca^{2+} ions are soluble.
6. Most sulfide, carbonate, chromate, and phosphate salts are insoluble.
   Exceptions: salts of alkali metals and ammonium cations are soluble.

1. At some temperature, the gas arsine (AsH_3) decomposes by the following reaction:

$$2\ AsH_3(g) \rightleftharpoons 2\ As(s) + 3\ H_2(g) \qquad K = 3.0 \times 10^{-6}$$

If 3.0 mol of AsH_3 are initially placed in a 1.0 L container, calculate the equilibrium H_2 concentration ($[H_2]_{equilibrium} = ?$).

a) $1.4 \times 10^{-2}\ M$ b) $0.14\ M$ c) $2.8 \times 10^{-3}\ M$

d) $1.7 \times 10^{-3}\ M$ e) $3.0 \times 10^{-2}\ M$

2. Consider the following generic reaction:

$$2\ A_2(g) + B(g) \rightleftharpoons BA_4(g)$$

At a specific set of conditions, it is determined that the rate of the forward reaction is greater (faster) than the rate of the reverse reaction. Which of the following statements is **false** regarding what happens as this reaction proceeds to equilibrium?

a) The rate of the forward reaction **must** decrease as the reaction proceeds to equilibrium.

b) When this reaction reaches equilibrium, the value of K_p will **not** equal the value of K for this reaction ($K_p \neq K$).

c) The concentration of $BA_4(g)$ **must** increase as the reaction proceeds to equilibrium.

d) The value of the equilibrium constant for this reaction **must** be greater than one ($K > 1$).

3. Consider the following exothermic reaction:

$$CH_4(g) + 2\ O_2(g) \rightleftharpoons CO_2(g) + 2\ H_2O(l) \qquad \Delta H = -891\ kJ$$

How many of the following five statements (I-V) are **true**?

I. If CH_4 is added at some constant temperature, the reaction shifts right and K decreases.

II. If CO_2 is added at some constant temperature, the reaction shifts left and K decreases.

III. If the temperature is increased, the reaction shifts left and K decreases.

IV. If the pressure is decreased by increasing the volume at some constant temperature, the reaction shifts left.

V. If, in a rigid container at constant temperature, the pressure is increased by adding argon gas, the reaction shifts right.

a) 1 b) 2 c) 3 d) 4 e) 5 (All statements are true.)

4. Consider the following reaction at some temperature:

$$SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g) \qquad K = 4.0$$

If 2.00 mol of $SO_2(g)$ and 2.00 mol of $NO_2(g)$ are reacted in a 2.00 L rigid container, calculate the equilibrium concentration of $NO_2(g)$.

a) 0.33 *M* b) 1.41 *M* c) 1.00 *M* d) 0.50 *M* e) 0.67 *M*

5. Consider the following reaction which takes place in a 4.0 L rigid container at 800. K:

$$N_2(g) + 3\ F_2(g) \rightleftharpoons 2\ NF_3(g) \qquad K_p = ?$$

An equilibrium mixture contains the following partial pressures: $P_{N_2} = 0.021$ atm, $P_{F_2} = 0.063$ atm, $P_{NF_3} = 0.48$ atm. Calculate K_p for this reaction at 800. K.

a) 1.9×10^5 b) 280 c) 4.4×10^4 d) 170 e) 360

6. How many of the following four statements (I-IV) is/are **true**?

I. In general, when the bond strengths of the products are stronger than the bond strengths of the reactants, an exothermic reaction results.

II. In general, bond energies give a good estimate of ΔH for a reaction when all reactants and products are in the gas phase.

III. In an endothermic reaction, the products have a higher potential energy than the reactants.

IV. When determining ΔH for a reaction using bond energies, the strengths of the intermolecular forces are not taken into consideration.

a) 0 (none) b) 1 c) 2 d) 3 e) 4 (All statements are true.)

7. Consider the following data:

$P_4(s) + 6\ Cl_2(g) \rightarrow 4\ PCl_3(g)$ $\Delta H° = -1226$ kJ

$P_4(s) + 5\ O_2(g) \rightarrow P_4O_{10}(s)$ $\Delta H° = -2967$ kJ

$PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$ $\Delta H° = -84$ kJ

$PCl_3(g) + 1/2\ O_2(g) \rightarrow Cl_3PO(g)$ $\Delta H° = -286$ kJ

Calculate $\Delta H°$ for the reaction:

$$P_4O_{10}(s) + 6\ PCl_5(g) \rightarrow 10\ Cl_3PO(g) \qquad \Delta H° = ?$$

a) −111 kJ b) −615 kJ c) −2680 kJ d) −7555 kJ e) 111 kJ

8. Suppose you add 45 J of heat to a system and let it do 10 J of expansion work, then return the system to its initial state by cooling and compression. Which of the following statements **must** be **true** for the overall process?

a) $\Delta H < \Delta E$
b) The quantity of work done in the compression step must exactly equal the quantity of work done by the system in the expansion step.
c) $\Delta H = 70.$ J
d) In the compression step, $q = -45$ J.
e) The change in the internal energy for this overall process is zero.

9. The standard enthalpy of combustion of propane, $C_3H_8(g)$, is –2222 kJ/mol. The ΔH_f^o values for $CO_2(g)$ and $H_2O(l)$ are –394 kJ/mol and –286 kJ/mol, respectively. Calculate ΔH_f^o for propane.

a) 2326 kJ/mol b) 76 kJ/mol c) –104 kJ/mol
d) –76 kJ/mol e) –2326 kJ/mol

10. Calculate the molar solubility of solid $Pb_3(PO_4)_2$ in a 0.10 *M* $Pb(NO_3)_2$ solution. K_{sp} for $Pb_3(PO_4)_2 = 1.0 \times 10^{-54}$.

a) 6.2×10^{-17} mol/L b) 6.2×10^{-12} mol/L c) 2.5×10^{-52} mol/L
d) 1.6×10^{-27} mol/L e) 1.6×10^{-26} mol/L

11. Consider the following information:

N_2 bond energy = 941 kJ/mol

F_2 bond energy = 154 kJ/mol

$N_2(g) + 3\ F_2(g) \rightarrow 2\ NF_3(g)$ $\Delta H = -206$ kJ

Use this information to calculate the N–F bond energy.

a) 233 kJ/mol b) 268 kJ/mol c) 317 kJ/mol
d) 66 kJ/mol e) 434 kJ/mol

12. Calcium chloride ($CaCl_2$) is a common de-icing agent used in the winters to prevent ice formation on roads. The solubility of $CaCl_2$ is 74.5 g of $CaCl_2$ per 200.0 mL of solution. Calculate the K_{sp} value for solid calcium chloride. The molar mass of calcium chloride is 110.98 g/mol.

a) 151 b) 2.06×10^8 c) 3.36 d) 451 e) 45.1

13. A 1.00 L flask was initially filled with 3.00 mol N_2 and 3.00 mol Br_2, which then reacts by the following reaction at some constant temperature:

$$N_2(g) + 3\ Br_2(g) \rightleftharpoons 2\ NBr_3(g) \qquad K = ?$$

At equilibrium, 2.75 mol of N_2 remains. Calculate the value of K for the above reaction.

a) 0.43 b) 2.6×10^{-2} c) 8.0×10^{-3} d) 1.8×10^{-5} e) 6.5×10^{-2}

14. Consider the following reaction at some constant temperature:

$$2\ TeO_2(g) + O_2(g) \rightleftharpoons 2\ TeO_3(g) \qquad K = 4.0$$

Some TeO_3 is added to an otherwise empty 4.0 L container. After equilibrium is reached, 16.0 mol of TeO_3 and 8.0 mol of TeO_2 are present. How many **moles** of O_2 are present at equilibrium?

a) 8.0 mol b) 2.0 mol c) 1.0 mol d) 4.0 mol e) 16.0 mol

15. Consider the following four (I-IV) solutions:

I. 50.0 mL of 2×10^{-5} *M* $Cd(NO_3)_2$ is added to 50.0 mL of 2×10^{-5} *M* KOH; K_{sp} for $Cd(OH)_2(s) = 1 \times 10^{-14}$

II. 50.0 mL of 2×10^{-5} *M* $Mn(NO_3)_2$ is added to 50.0 mL of 2×10^{-5} *M* KOH: K_{sp} for $Mn(OH)_2(s) = 1 \times 10^{-13}$

III. 50.0 mL of 2×10^{-5} *M* $Mg(NO_3)_2$ is added to 50.0 mL of 2×10^{-5} *M* KOH; K_{sp} for $Mg(OH)_2(s) = 1 \times 10^{-9}$

IV. 50.0 mL of 2×10^{-5} *M* $Zn(NO_3)_2$ is added to 50.0 mL of 2×10^{-5} *M* KOH; K_{sp} for $Zn(OH)_2(s) = 1 \times 10^{-16}$

In how many of the above four solutions (I-IV) will a precipitate form?

a) 0 (none) b) 1 c) 2 d) 3

e) 4 (A precipitate will form in all four of the solutions.)

16. Two metals of equal mass with different heat capacities are subjected to the same amount of heat. Which metal undergoes the **smallest** change in temperature?

a) The metal with the larger heat capacity.

b) The metal with the smaller heat capacity.

c) Because they have the same mass, both undergo the same change in temperature.

d) We need to know the initial temperature of the metals.

e) The identity of the metals must be known.

17. Consider a theoretical ionic compound formed from M^{4+} and Y^{3-} ions. Which of the following mathematical statements correctly relates K_{sp} to the molar solubility for the ionic compound formed from M^{4+} and Y^{3-} ions? Note: s = molar solubility.

a) $K_{sp} = 7s^{12}$ b) $K_{sp} = 256s^5$ c) $K_{sp} = 6912s^7$

d) $K_{sp} = 9775s^{12}$ e) $K_{sp} = 12s^7$

18. Which of the following statements correctly describes the signs of q and w for the following process at P = 1 atm and T = 298 K?

$$H_2O(g) \rightarrow H_2O(l)$$

a) q and w are negative.
b) q is positive, w is negative.
c) q is negative, w is positive.
d) q and w are both positive.
e) q and w are both zero.

19. An ideal gas absorbs 100 J of heat and is simultaneously compressed by a constant external pressure of 2.00 atm from an initial volume of 10.0 L to 6.00 L. What is the change in internal energy?

a) –910 J b) –710 J c) 710 J

d) 810 J e) 910 J

20. Solid calcium carbonate, $CaCO_3$, decomposes to form solid calcium oxide, CaO, and gaseous carbon dioxide, CO_2. What is the correct equilibrium expression for this reaction?

a) $K = \dfrac{[CO_2][CaO]}{[CaCO_3]}$ b) $K = \dfrac{1}{[CO_2]}$ c) $K = \dfrac{[CaCO_3]}{[CO_2][CaO]}$

d) $K = [CO_2][CaO]$ e) $K = [CO_2]$

21. An initial solution contains 0.10 *M* Pb^{2+}, 0.10 *M* Cu^+, 0.10 *M* Ag^+, and 0.10 *M* La^{3+}. Into the initial solution, KCl(aq) is added dropwise until a precipitate forms. Which of the following precipitates forms first as KCl(aq) is added dropwise?

a) $PbCl_2(s)$, $K_{sp} = 1 \times 10^{-5}$ b) $CuCl(s)$, $K_{sp} = 1 \times 10^{-7}$

c) $AgCl(s)$, $K_{sp} = 1 \times 10^{-10}$ d) $LaCl_3(s)$, $K_{sp} = 1 \times 10^{-22}$

22. Which expression correctly gives the value for the standard enthalpy of formation for liquid carbon disulfide (CS_2) using the following data:

$C(graphite) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H^\circ_{rxn} = -394$ kJ

$S(s) + O_2(g) \rightarrow SO_2(g)$ $\quad \Delta H^\circ_{rxn} = -296$ kJ

$CS_2(l) + 3\ O_2(g) \rightarrow CO_2(g) + 2\ SO_2(g)$ $\quad \Delta H^\circ_{rxn} = -1072$ kJ

$\Delta H^\circ_{f,\ CS_2} = ?$

a) [−1072 + 394 + 296] kJ
b) [1072 − 394 − 2(296)] kJ
c) [2(1072) − 394 − 296] kJ
d) [−1072 + 394 + 2(296)] kJ
e) [1072 − 394 − 296] kJ

23. The concentration of I^- in a solution saturated with $BiI_3(s)$ is 3.9×10^{-5} mol/L. Calculate the K_{sp} value for $BiI_3(s)$.

a) 6.2×10^{-17} b) 5.1×10^{-10} c) 2.3×10^{-18} d) 7.7×10^{-19} e) 5.9×10^{-14}

24. Consider the reaction $2\ N_2O_5(g) \rightarrow 4\ NO_2(g) + O_2(g)$ and the following data:

Substance	ΔH°_f
$N_2O_5(g)$	11.3 kJ/mol
$NO_2(g)$	33.2 kJ/mol
$O_2(g)$	?

Calculate $\Delta E°$, the internal energy change, for this reaction at 1 atm and 25°C.

a) 102.8 kJ b) −7.4 kJ c) 117.6 kJ d) 7.4 kJ e) 110.2 kJ

25. A coffee-cup calorimeter contains 60.00 g of water at 22.0°C. A 4.25 g sample of NH_4NO_3 is added to the water in the calorimeter. After the NH_4NO_3 has dissolved, the temperature of the water is 16.9°C. Calculate the enthalpy change for the dissolution of ammonium nitrate in units of kJ/mol. Assume no heat loss to the calorimeter and assume the solution has a heat capacity of 4.18 J/°C•g. The molar mass of H_2O is 18.02 g/mol and the molar mass of NH_4NO_3 is 80.05 g/mol.

a) 26 kJ/mol b) 1.4×10^3 kJ/mol c) 150 kJ/mol
d) -1.4×10^3 kJ/mol e) −24 kJ/mol

Consider the following H_2O data for the next two questions:

Specific heat capacity of ice = 2.03 J/°C•g; ΔH_{fusion} = 6.02 kJ/mol;

Specific heat capacity of water = 4.18 J/°C•g; $\Delta H_{vaporization}$ = 40.7 kJ/mol;

Specific heat capacity of steam = 2.02 J/°C•g

26. Consider the process of heating 18.0 g of ice from −100.0°C to steam at 200.0°C. Which part of this heating process requires the **largest** amount of energy?

a) Heating 18.0 g of ice at −100.0°C to ice at 0.0°C.
b) Converting 18.0 g of ice at 0.0°C to water at 0.0°C.
c) Heating 18.0 g of water at 0.0°C to water at 100.0°C.
d) Converting 18.0 g of water at 100.0°C to steam at 100.0°C.
e) Heating 18.0 g of steam at 100.0°C to steam at 200.0°C.

27. A coffee cup calorimeter is filled with 36.0 g of water initially at 95.0°C. A 36.0 g-sample of ice at −5.0°C is then added to the calorimeter contents. Calculate the final temperature of the mixture assuming no heat loss to the surroundings or to the calorimeter.

a) 50.0°C b) 2.3°C c) 92.7°C d) 6.3°C e) 0.0°C

28. When 1.00 L of 2.40 *M* $AgNO_3$ is added to 1.00 L of 2.00 *M* K_3PO_4, a precipitate of Ag_3PO_4 forms (K_{sp} for $Ag_3PO_4 = 1.8 \times 10^{-18}$). Calculate the equilibrium Ag^+ concentration in the resulting solution ($[Ag^+]_e$ = ?).

a) 4.8×10^{-7} *M* b) 1.0×10^{-18} *M* c) 6.0×10^{-17} *M*

d) 1.4×10^{-6} *M* e) 1.20 *M*

29. When 1.00 L of 2.40 *M* $AgNO_3$ is added to 1.00 L of 2.00 *M* K_3PO_4, a precipitate of Ag_3PO_4 forms (K_{sp} for $Ag_3PO_4 = 1.8 \times 10^{-18}$). Calculate the equilibrium PO_4^{3-} concentration in the resulting solution ($[PO_4^{3-}]_e$ = ?).

a) 0.60 *M* b) 0.80 *M* c) 1.00 *M*

d) 0.40 *M* e) 1.20 *M*

30. My answers for this Chemistry 102 exam should be graded with the answer sheet associated with:

a) Form A b) Form B c) Form C d) Form D e) Form E

USEFUL CONSTANTS/EQUATIONS

$K = °C + 273$

$PV = nRT$

$R = 0.08206$ L atm/K mol

1 L = 1000 mL

Avogadro's number, $N = 6.022 \times 10^{23}$

kinetic energy $= (1/2)\, mv^2$

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

$K_p = K(RT)^{\Delta n}$

1 J = 1 kg m^2/sec^2

$R = 8.3145$ J/K mol

$\Delta E = q + w$

101.3 J = 1 L • atm

$\Delta H = \Delta E + \Delta(PV)$

$w = -P\Delta V = -RT\Delta n$ (at constant P and T)

$\Delta E_{univ} = \Delta E_{surr} + \Delta E_{sys}$

$$\Delta H^{o}_{rxn} = \Sigma \Delta H^{o}_{f,\,products} - \Sigma \Delta H^{o}_{f,\,reactants}$$

$q = s \times \text{mass} \times \Delta T$, s = specific heat capacity

PERIODIC TABLE OF THE ELEMENTS

1 1A																	18 8A
1 H 1.008	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	2 He 4.003
3 Li 6.941	4 Be 9.012					26 Fe 55.85	←Atomic number ←Atomic mass					5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po 209	85 At 210	86 Rn 222
87 Fr 223	88 Ra 226	89 Ac† 227	104 Rf 261	105 Db 262	106 Sg 266	107 Bh 262	108 Hs 265	109 Mt 266	110 Ds 271	111	112						

*Lanthanides	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm 145	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
†Actinides	90 Th 232.0	91 Pa 231	92 U 238	93 Np 244	94 Pu 242	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 260