CHEMISTRY 102C/102D
Exam III
April 27, 2022
T. Hummel

NAME _____

SIGNATURE _____

SECTION _____

FORM "A"

This exam is made up of an answer sheet, this cover sheet, 6 numbered pages, a constants/equation/periodic table page, and 2 pieces of scratch paper. Below are instructions for coding the answer sheet, and at the bottom are solubility rules. At the end of the exam is a page that contains some useful equations and constants, plus the periodic table, along with some scratch paper.

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 **UIN** 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 102C students,** the numbers are: CQ1 = 00011, CQ2 = 00012, CQ3 = 00013, CQ4 = 00014, CQ5 = 00015, CQ6 = 00016, CQ7 = 00017, CQ8 = 00018, CQ9 = 00019, CQA = 00021, CQB = 00022, CQE = 00025, CQF = 00026, CQG = 00027, CQH = 00028. **For 102D students**, the numbers are DQ1 = 00031, DQ2 = 00032, DQ3 = 00033, DQ4 = 00034, DQ5 = 00035, DQ6 = 00036.
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. If your answer differs from one given in the last proper significant figure, mark that answer as correct and not the response "none of these". 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. Consider 50.0 g of $H_2O(l)$ at an initial temperature of 25.0°C. What quantity of energy is necessary to convert the water from 25.0°C to 125.0°C? For water, the enthalpy of vaporization is 40.7 kJ/mol, the heat capacity of $H_2O(g)$ is 2.02 J/g•°C, and the heat capacity of $H_2O(l)$ is 4.184 J/g•°C.

a) 18.2 kJ b) 131 kJ c) 95.6 kJ d) 202 kJ e) 20.9 kJ

2. Consider the reaction at constant pressure and temperature:

$$2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$$

Which of the following relationships between ΔH and ΔE is **correct** for this reaction?

a) $\Delta H = \Delta E$ b) $\Delta H = \Delta E - RT$ c) $\Delta H = \Delta E + RT$

d) $\Delta H = \Delta E - 3RT$ e) $\Delta H = \Delta E + 4RT$

3. A sample of $S_8(g)$ is placed in an otherwise empty container at 1325 K and at an initial pressure of 1.00 atm, where it decomposes to $S_2(g)$ by the reaction:

$$S_8(g) \rightleftharpoons 4\ S_2(g) \qquad K_p = ?$$

At equilibrium, the partial pressure of S_8 is 0.25 atm. Calculate K_p for the above reaction at 1325 K.

a) 3.0 b) 12 c) 320 d) 48 e) 0.040

4. Consider the following **exothermic** reaction at equilibrium in a closed container:

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$$

Which of the following statements is **false**?

a) Addition of PCl_3 to the container will shift the equilibrium toward formation of more PCl_5.
b) An increase in temperature will shift the equilibrium toward formation of more PCl_3.
c) Addition of a catalyst will have no effect on the equilibrium position.
d) Removal of Cl_2 from the container will shift the equilibrium toward the formation of more PCl_3.
e) An increase in the volume of the container will shift the equilibrium toward formation of more PCl_5.

5. How many of the following five ionic compounds are more soluble in acidic solution than in pure water?

I. $Al(OH)_3$ II. Ag_2CO_3 III. CaF_2 IV. PbI_2 V. NiS

a) 1 b) 2 c) 3 d) 4

e) 5 (All are more soluble in acidic solution than in pure water.)

6. Which of the following statements is **false**?

a) If only products are present initially, equilibrium cannot be reached.

b) At constant temperature, the value of K is constant regardless of the amounts of reactants and products that are mixed together initially.

c) At equilibrium the rate of the forward reaction equals the rate of the reverse reaction.

d) At equilibrium, the concentration of reactants and products are constant.

e) Reactions that strongly favor product formation have large K values (K >> 1).

7. Self-contained breathing apparatuses sometimes use the following reaction to produce oxygen gas:

$$4\ KO_2(s) + 2\ CO_2(g) \rightleftharpoons 2\ K_2CO_3(s) + 3\ O_2(g) \quad K = ?$$

At a particular temperature, an equilibrium mixture of this reaction contains 2 mol of $KO_2(s)$, 4×10^{-10} mol $CO_2(g)$, 1 mol $K_2CO_3(s)$ and 0.4 mol of $O_2(g)$ all in a 4.0 L container. Calculate the value for the equilibrium constant, K, for this reaction.

a) 4×10^{17} b) 1×10^{9} c) 1×10^{17} d) 4×10^{9} e) 6.4×10^{18}

8. Consider the reaction:

$$2\ SO_3(g) \rightleftharpoons 2\ SO_2(g) + O_2(g) \quad K = 4.0 \times 10^{-24}$$

Initially, 4.0 mol of $SO_3(g)$ and 4.0 mol of O_2 are placed in a 1.0 L container. The reaction then proceeds to reach equilibrium according to the above reaction. At equilibrium, what is the concentration of $SO_2(g)$?

a) $4.0 \times 10^{-12}\ M$ b) $4.0 \times 10^{-24}\ M$ c) $2.0 \times 10^{-12}\ M$

d) $1.0 \times 10^{-12}\ M$ e) $1.0 \times 10^{-8}\ M$

9. A coffee-cup calorimeter contains 100.0 g of water at 24.3°C. A 10.0 g sample of NaCl is added to the water in the calorimeter. After the solid has dissolved, the temperature of the solution is 23.1°C. Calculate the enthalpy change for the dissolution of sodium chloride in kJ per mol NaCl. Assume the heat capacity of the solution is 4.18 J/g•°C.

a) 550 J/mol b) −3.2 kJ/mol c) 3.2 kJ/mol d) −550 J/mol

10. Calculate the molar solubility of $Ca_3(PO_4)_2(s)$ in a 1.0×10^{-2} *M* $Ca(NO_3)_2$ solution. K_{sp} for $Ca_3(PO_4)_2 = 1.3 \times 10^{-32}$.

a) 5.7×10^{-14} mol/L b) 1.6×10^{-7} mol/L c) 1.1×10^{-10} mol/L

d) 1.6×10^{-14} mol/L e) 3.2×10^{-13} mol/L

11. The heat capacity of ice is 2.03 J/g•°C, the enthalpy of fusion of ice is 6.02 kJ/mol, and the heat capacity of liquid water is 4.184 J/g•°C. Consider some ice cubes at −5°C, with each ice cube containing one mole of H_2O. What is the smallest number of ice cubes at −5°C necessary to cool 500.0 g of liquid water from 23°C to 2°C.

a) 1 ice cube b) 7 ice cubes c) 14 ice cubes

d) 15 ice cubes e) 126 ice cubes

12. Consider the following reaction at 25°C and 1.00 atm:

$$2\ H(g) \rightarrow H_2(g)$$

What are the algebraic signs of q and w for this reaction?

a) Both q and w are negative.
b) Both q and w are positive.
c) q is positive and w is negative.
d) q is negative and w is positive.

13. Which of the following salts has the smallest molar solubility in water?

a) Ag_2S ($K_{sp} = 1.6 \times 10^{-49}$) b) Bi_2S_3 ($K_{sp} = 1.0 \times 10^{-72}$)

c) CuS ($K_{sp} = 8.5 \times 10^{-45}$) d) CoS ($K_{sp} = 5.0 \times 10^{-22}$)

e) MnS ($K_{sp} = 2.3 \times 10^{-13}$)

14. Consider a theoretical insoluble ionic compound having the formula M_2Y_5. Which of the following mathematical statements correctly relates K_{sp} to the molar solubility for this ionic compound formed from M^{5+} and Y^{2-} ions? Note: s = molar solubility.

a) $K_{sp} = 7s^{10}$ b) $K_{sp} = 256s^5$ c) $K_{sp} = 9775s^{10}$

d) $K_{sp} = 3125s^7$ e) $K_{sp} = 12{,}500s^7$

15. Given the bond energies below (in kJ/mol), estimate the enthalpy change for the reaction:

$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g) \qquad \Delta H = ?$$

C–H	413	C=O	799	O–O	146	C–C	347
C–O	358	O–H	467	O=O	495		

a) –118 kJ b) 118 kJ c) –1303 kJ d) 1303 kJ e) –824 kJ

16. The $[IO_3^-]$ in a solution in equilibrium with $Ce(IO_3)_3(s)$ is 5.7×10^{-3} *M*. Calculate the K_{sp} value for $Ce(IO_3)_3$.

a) 3.2×10^{-5} b) 3.6×10^{-6} c) 2.7×10^{-8}

d) 7.4×10^{-7} e) 3.5×10^{-10}

17. When ethanol [$C_2H_5OH(l)$] is combusted (reacted with oxygen gas), $H_2O(l)$ and $CO_2(g)$ are produced. If the standard enthalpy of combustion of ethanol (ΔH°_{comb}) is –1367 kJ/mol, and the ΔH_f° values for $H_2O(l)$ and $CO_2(g)$ are –286 kJ/mol and –393 kJ/mol respectively, what is the value of ΔH_f° for ethanol?

a) –277 kJ/mol b) –185 kJ/mol c) –110 kJ/mol

d) 185 kJ/mol e) 110 kJ/mol

18. A solution is prepared by mixing 100.0 mL of 0.20 *M* $Pb(NO_3)_2$ and 100.0 mL of 2.00 *M* KCl. After precipitation of $PbCl_2(s)$, calculate the equilibrium Pb^{2+} concentration ($[Pb^{2+}]_e = ?$). K_{sp} for $PbCl_2 = 1.6 \times 10^{-5}$.

a) 3.2×10^{-4} *M* b) 2.5×10^{-5} *M* c) 1.6×10^{-5} *M*

d) 0.80 *M* e) 0.10 *M*

19. Consider the following generic reaction:

$$A(g) + B(g) \rightleftharpoons 2\ C(g) \qquad K_p = 4.0$$

where the initial partial pressures are $P_A = P_B = P_C = 0.100$ atm. Once equilibrium has been reached, calculate the equilibrium partial pressure of C(g).

a) 0.075 atm b) 0.100 atm c) 0.125 atm d) 0.150 atm e) 0.200 atm

20. Given the following two reactions at 298 K and 1 atm, which of the statements (a-d) is **true**?

A. $N_2(g) + O_2(g) \rightarrow 2\ NO(g)$ ΔH_A

B. $NO(g) + 1/2\ O_2(g) \rightarrow NO_2(g)$ ΔH_B

a) $\Delta H°_f$ for $NO_2(g) = \Delta H_B$
b) $\Delta H°_f$ for $NO(g) = -\Delta H_A$
c) $\Delta H_A = \Delta H_B$
d) $\Delta H°_f$ for $NO_2(g) = \Delta H_B + 1/2\ \Delta H_A$
e) None of the above statements (a-d) are true.

21. Consider when 1.0 mole of A(g) and 1.0 mole of B(g) are added to a 2.0 L container and the following balanced reaction occurs:

$$A(g) + 2\ B(g) \rightleftharpoons 2\ C(g) + 3\ D(g)$$

Which of the following statements **must** be **true** regarding this reaction once equilibrium has been reached?

a) The value of the equilibrium constant for this reaction must be greater than 1 ($K > 1$).
b) The value of the equilibrium constant for this reaction must be less than 1 ($K < 1$).
c) The value of the equilibrium constant for this reaction must be equal to 1 ($K = 1$).
d) At equilibrium, the concentration of B(g) must be equal to the concentration of C(g) ($[B]_e = [C]_e$).
e) At equilibrium, the concentration of B(g) must be smaller than the concentration of A(g) ($[B]_e < [A]_e$).

22. A gas in a piston performs work of 21 kJ on the surroundings while the volume increases from 10.0 L to 25.0 L. At the same time, 4.5 kJ of heat is transferred from the surroundings to the system. Calculate the external pressure that the expansion occurred against.

a) 0.64 atm b) 1.4 atm c) 4.7 atm d) 14 atm e) 1400 atm

23. Given the following data:

$I_2(s) + Cl_2(g) \rightarrow 2\ ICl(g)$ $\Delta H = 34$ kJ

$Cl_2(g) \rightarrow 2\ Cl(g)$ $\Delta H = 242$ kJ

$I_2(g) \rightarrow 2\ I(g)$ $\Delta H = 151$ kJ

$I_2(g) \rightarrow I_2(s)$ $\Delta H = -63$ kJ

calculate the I–Cl bond energy in ICl.

a) 211 kJ/mol b) 490 kJ/mol c) 439 kJ/mol d) 262 kJ/mol e) 243 kJ/mol

24. A solution contains a mixture of 0.010 *M* $AgNO_3$ and 0.010 *M* $Sc(NO_3)_3$. A dilute solution of KOH is added dropwise until a precipitate forms. Which precipitate will form first and at what concentration of OH^- will it form? K_{sp} for AgOH(s) = 1×10^{-8} and K_{sp} for $Sc(OH)_3(s) = 1 \times 10^{-14}$. Assume no volume change on addition of KOH.

a) $Sc(OH)_3(s)$ forms first when $[OH^-] > 1 \times 10^{-4}$ *M*.

b) AgOH(s) forms first when $[OH^-] > 1 \times 10^{-6}$ *M*.

c) AgOH(s) forms first when $[OH^-] > 1 \times 10^{-8}$ *M*.

d) $Sc(OH)_3(s)$ forms first when $[OH^-] > 1 \times 10^{-12}$ *M*.

e) $Sc(OH)_3(s)$ forms first when $[OH^-] > 1 \times 10^{-14}$ *M*.

25. My answers for this Chem 102 exam should be graded 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)

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

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

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