CHEMISTRY 102C/102D
Exam III
April 24, 2024
T. Hummel

NAME _____

SIGNATURE _____

SECTION _____

FORM "A"

This exam is made up of an answer sheet, two cover sheets and 8 numbered pages. Below are instructions for coding the answer sheet. The last page of this exam contains some useful equations and constants, plus the periodic table.

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 102C students,** the numbers are: CQ1 = 00011, CQ2 = 00012, CQ3 = 00013, CQ4 = 00014, CQ5 = 00015, CQ6 = 00016, CQ7 = 00017, CQ9 = 00019, CQA = 00021, CQB = 00022, CQF = 00026, CQG = 00027, CQH = 00028, CQI = 00029. **For 102D students,** the numbers are: DQ1 = 00031, DQ2 = 00032, DQ3 = 00033, DQ4 = 00034, DQ5 = 00035, DQ6 = 00036, DQ7 = 00037, DQ8 = 00038, DQA = 00041, DQB = 00042.
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 the following reaction:

$$4\ NO_2(g) + O_2(g) \rightleftharpoons 2\ N_2O_5(g) \qquad K = 6.2 \times 10^{-6}$$

If 4.0 moles of NO_2 and 4.0 mol of O_2 are placed in a 2.0 L container, what is the equilibrium concentration of N_2O_5?

a) $1.4 \times 10^{-2}\ M$ b) $4.0 \times 10^{-2}\ M$ c) $8.0 \times 10^{-2}\ M$

d) $7.0 \times 10^{-3}\ M$ e) $2.5 \times 10^{-3}\ M$

Consider the following data for the next two questions:

Specific heat capacity of ice = 2.03 J/°C•g
Specific heat capacity of water = 4.18 J/°C•g
Specific heat capacity of steam = 2.02 J/°C•g
ΔH_{fusion} = 6.02 kJ/mol
$\Delta H_{vaporization}$ = 40.7 kJ/mol

2. Consider a 1.00 mole sample of ice at –30.0°C, which is heated to steam at 140.0°C. Calculate q for the entire process.

a) 123 kJ b) 1070 kJ c) 6.75 kJ d) 234 kJ e) 56.8 kJ

3. A 500.0 g sample of an element at 195°C is dropped into an ice-water mixture. 109.5 g of ice melts and an ice-water mixture remains. Calculate the specific heat capacity of the element.

a) 2.67 J/°C•g b) 0.375 J/°C•g c) 0.789 J/°C•g d) 1.62 J/°C•g

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4. Which of the following mathematical relationships is **false**?

a) $\Delta E_{system} = -\Delta E_{surroundings}$

b) At constant pressure, $q = \Delta E + P\Delta V$.

c) $\Delta H_{system} - \Delta H_{universe} = \Delta H_{surroundings}$

d) At constant volume, $\Delta E = q$.

e) For an overall cyclic process, $w_{overall} = -q_{overall}$.

5. Consider the following reaction:

$$2\ NO_2(g) \rightleftharpoons 2\ NO(g) + O_2(g) \qquad K = ?$$

4.0 moles of NO_2 are placed in a 1.0 L container and are allowed to react to reach equilibrium. At equilibrium the concentration of NO(g) is 1.0 *M*. Calculate the value of the equilibrium constant, K, for this reaction.

a) 0.056 b) 0.11 c) 0.17 d) 25 e) 590

6. The K_{sp} value for BaF_2 is 5.0×10^{-7}. When 10.0 mL of 0.010 *M* NaF is mixed with 10.0 mL of 0.010 *M* $Ba(NO_3)_2$, will a precipitate form?

a) No, because $Q = 1.0 \times 10^{-6}$ and since it is greater than K_{sp}, no precipitate will form.
b) Yes, because $Q = 1.0 \times 10^{-6}$ and since it is greater than K_{sp}, a precipitate will form.
c) No, because $Q = 1.3 \times 10^{-7}$ and since it is less than K_{sp}, no precipitate will form.
d) Yes, because $Q = 1.3 \times 10^{-7}$ and since it is less than K_{sp}, a precipitate will form.

7. The reaction for the formation of the complex ion $Cu(NH_3)_4^{2+}$ is:

$$Cu^{2+}(aq) + 4\ NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$$

Which of the following is the correct expression for the equilibrium constant, K, for this reaction?

a) $K = \dfrac{[Cu(NH_3)_4^{2+}]}{[Cu^{2+}][NH_3]}$ b) $K = \dfrac{[Cu(NH_3)_4^{2+}]^4}{[Cu^{2+}][NH_3]^4}$ c) $K = \dfrac{1}{[Cu^{2+}][NH_3]}$

d) $K = \dfrac{1}{[Cu^{2+}][NH_3]^4}$ e) $K = \dfrac{[Cu(NH_3)_4^{2+}]}{[Cu^{2+}][NH_3]^4}$

8. The heat capacity of a bomb calorimeter was determined by combusting 6.79 g of CH_4 (energy of combustion of CH_4 = – 802 kJ/mol CH_4); the temperature of the bomb calorimeter increased by 10.8°C. In a second experiment with the same bomb calorimeter, combustion of a 12.6 g sample of ethyne, C_2H_2, produced a temperature increase of 16.9°C. Calculate the energy of combustion of C_2H_2 in kJ/mol. The molar mass of CH_4 is 16.04 g/mol and the molar mass of C_2H_2 is 26.04 g/mol.

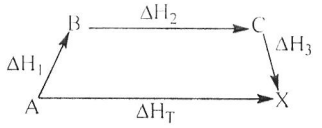
a) –31.4 kJ/mol b) -1.10×10^3 kJ/mol c) 1.47×10^3 kJ/mol

d) –532 kJ/mol e) 340. kJ/mol

9. Consider the following reaction which has an enthalpy change of ΔH_T:

$$A \rightarrow X \qquad \Delta H = \Delta H_T$$

This reaction can be broken down into a series of steps as shown in the following diagram:



Which of the following relationships **must** be **true** for this reaction?

a) $\Delta H_T - \Delta H_1 - \Delta H_2 - \Delta H_3 = 0$

b) $\Delta H_2 - (\Delta H_3 + \Delta H_1) = \Delta H_T$

c) $\Delta H_1 + \Delta H_1 + \Delta H_2 + \Delta H_3 = 0$

d) $\Delta H_T + \Delta H_2 = \Delta H_1 + \Delta H_3$

e) $\Delta H_3 - (\Delta H_1 + \Delta H_2) = 0$

10. Consider the following reaction at some temperature:

$$Cl_2(g) + F_2(g) \rightleftharpoons 2\ ClF(g) \qquad K_p = 16$$

If initially 3.00 atm of F_2 and 3.00 atm of Cl_2 are reacted in a rigid container, calculate the equilibrium partial pressure of $Cl_2(g)$.

a) 0.25 atm

b) 0.50 atm

c) 1.0 atm

d) 1.5 atm

e) 2.0 atm

11. A 50.0 mL sample of 0.200 *M* $Ca(NO_3)_2$ is mixed with 50.00 mL of 0.200 *M* NaF. When the system has come to equilibrium, what are the equilibrium concentrations of Ca^{2+} and F^-? K_{sp} for $CaF_2 = 4.0 \times 10^{-11}$.

	$[Ca^{2+}]_e$	$[F^-]_e$
a)	$5.0 \times 10^{-2}\ M$	$1.4 \times 10^{-5}\ M$
b)	$1.0 \times 10^{-1}\ M$	$1.0 \times 10^{-5}\ M$
c)	$2.2 \times 10^{-4}\ M$	$4.3 \times 10^{-4}\ M$
d)	$1.0 \times 10^{-1}\ M$	$2.0 \times 10^{-5}\ M$
e)	$5.0 \times 10^{-2}\ M$	$2.8 \times 10^{-5}\ M$

12. Aluminum fluoride has a solubility of 6.66×10^{-2} mol/L. Calculate the K_{sp} value for $AlF_3(s)$.

a) 4.44×10^{-3}

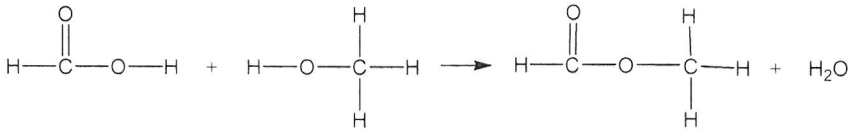
b) 1.97×10^{-5}

c) 5.90×10^{-5}

d) 5.31×10^{-4}

e) 5.90×10^{-6}

13. Using the bond energies below, estimate the enthalpy change in kJ for the reaction:



Bond Energy (kJ/mol)

C–H	413
C–O	358
C=O	745
O–H	467
C–C	347
H–H	432

a) $\Delta H = -2654$ kJ b) $\Delta H = -567$ kJ c) $\Delta H = 567$

d) $\Delta H = 0$ kJ e) $\Delta H = 1258$ kJ

14. An equilibrium mixture for the reaction:

$$2\ NH_3(g) \rightleftharpoons N_2(g) + 3\ H_2(g) \qquad K = ?$$

contains 9.0 mol N_2, 6.0 mol H_2, and 6.0 mol NH_3, all in a 3.0 L container at a certain temperature. Calculate the value of K for this reaction at this temperature.

a) 2.0 b) 4.0 c) 6.0

d) 9.0 e) 12

15. Calculate the molar solubility of $Ag_2CO_3(s)$ in an aqueous solution that is 0.50 *M* in K_2CO_3. K_{sp} for $Ag_2CO_3 = 8.2 \times 10^{-12}$

a) 2.0×10^{-6} mol/L b) 2.6×10^{-4} mol/L c) 1.3×10^{-4} mol/L

d) 2.8×10^{-6} mol/L e) 3.4×10^{-3} mol/L

16. Given the following set of gas phase reactions:

$$H_2 + Cl_2 \rightarrow 2\ HCl \qquad \Delta H° = -184\ kJ$$
$$H_2 \rightarrow 2\ H \qquad \Delta H° = 432\ kJ$$
$$Cl_2 \rightarrow 2\ Cl \qquad \Delta H° = 240\ kJ$$

calculate the bond energy of the H–Cl bond.

a) 248 kJ b) 428 kJ c) 864 kJ

d) 92 kJ e) 184 kJ

17. Determine ΔE for a system which undergoes both of the following two processes:

I. 15 J of work is done on the system, while 30 J of heat is absorbed by it; then:

II. 20 J of heat is given off by the system, while 25 J of work is done by the system.

a) 30 J b) –30 J c) 40 J

d) 45 J e) 0

18. Consider the reaction:

$$NH_4NO_3(s) \rightleftharpoons N_2O(g) + 2\ H_2O(g) \qquad K = 4.85$$

200. g of $NH_4NO_3(s)$ are placed in a reaction vessel containing $H_2O(g)$ at a concentration of 2.0 *M* and $N_2O(g)$ at a concentration of 2.0 *M*. After equilibrium is reached, will the mass of $NH_4NO_3(s)$ increase, decrease or remain unchanged?

a) The mass of $NH_4NO_3(s)$ will decrease (< 200. g).

b) The mass of $NH_4NO_3(s)$ will increase (> 200. g).

c) The mass of $NH_4NO_3(s)$ will remain unchanged (= 200. g).

19. Consider the following endothermic reaction at equilibrium:

$$SiHCl_3(g) + 3\ H_2O(g) \rightleftharpoons SiH(OH)_3(s) + 3\ HCl(g)$$

Which of the following would cause the reaction to shift toward reactants (shift left) to reestablish equilibrium?

a) Adding $H_2O(g)$.
b) Increasing the temperature.
c) Adding Ar(g) (assume a constant volume container).
d) Increasing the volume of the reaction container.
e) Adding $SiH(OH)_3(s)$.

20. How many of the following five quantities is/are state functions?

I. work II. enthalpy III. highway distance from Peoria to Champaign
IV. pressure V. temperature

a) 1 b) 2 c) 3 d) 4 e) 5 (All are state functions.)

21. Consider the reaction:

$$Ca_3P_2(s) + 6\ H_2O(l) \rightarrow 3\ Ca(OH)_2(s) + 2\ PH_3(g) \qquad \Delta H = -721.70\ kJ$$

If this reaction were carried out at 298 K in a beaker open to a constant-pressure atmosphere, which of the following would be **false**?

a) $\Delta E = -716.74$ kJ b) $w = -4.96$ kJ c) $q_p = -721.70$ kJ

d) The reaction is exothermic. e) Heat is released.

22. The following reaction was studied in a coffee cup calorimeter:

$$2\ HCl(aq) + Ba(OH)_2(aq) \rightarrow BaCl_2(aq) + 2\ H_2O(l) \qquad \Delta H = -118\ kJ$$

In the coffee cup calorimeter, 100.00 mL of 0.500 *M* HCl was mixed with 300.0 mL of 0.500 *M* $Ba(OH)_2$. Assuming a solution density of 1.00 g/mL, a solution heat capacity of 4.18 J/°C•g, an initial solution temperature of 25.00°C, and no heat loss to the coffee cups, calculate the final temperature of the reaction mixture.

a) 23.24°C b) 25.92°C c) 2.89°C d) 27.89°C e) 26.76°C

23. When ethene gas, C_2H_4, is combusted at 298 K, $CO_2(g)$ and $H_2O(l)$ are produced. The enthalpy of combustion of ethene at 298 K is −1411.1 kJ/mol ethene. Given the following standard enthalpies of formation, calculate the standard enthalpy of formation for ethene.

	$\Delta H_f°$
$CO_2(g)$	−393.5 kJ/mol
$H_2O(l)$	−285.9 kJ/mol

a) 52.3 kJ/mol b) 731.7 kJ/mol c) −2769.9 kJ/mol

d) −126.2 kJ/mol e) −296.0 kJ/mol

24. The solubility of $La(IO_3)_3$ in a 0.10 *M* KIO_3 solution is 1.0×10^{-7} mol/L. Calculate the K_{sp} value for $La(IO_3)_3$.

a) 1.0×10^{-8} b) 2.7×10^{-9} c) 1.0×10^{-10}

d) 2.7×10^{-27} e) 6.2×10^{-8}

25. Consider the following five reactions:

I. $P_4(s) + 6\ Cl_2(g) \rightarrow 4\ PCl_3(g)$

II. $P_4(s) + 5\ O_2(g) \rightarrow P_4O_{10}(g)$

III. $PCl_3(g) + \frac{1}{2}\ O_2(g) \rightarrow Cl_3PO(l)$

IV. $PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$

V. $P_4O_{10}(s) + 6\ PCl_5(g) \rightarrow 10\ Cl_3PO(l)$

For which reaction should bond energies give the best estimation for $\Delta H_{reaction}$?

a) I b) II c) III d) IV e) V

26. Which of the following compounds has the smallest molar solubility (mol/L) in water?

a) $Al(OH)_3$ $K_{sp} = 2 \times 10^{-32}$

b) CdS $K_{sp} = 1 \times 10^{-28}$

c) $PbSO_4$ $K_{sp} = 1 \times 10^{-8}$

d) $Sn(OH)_2$ $K_{sp} = 3 \times 10^{-27}$

e) $MgCO_3$ $K_{sp} = 7 \times 10^{-6}$

27. The standard enthalpy of formation for liquid water is –286 kJ/mol. For which of the following reactions does $\Delta H_{reaction} = -286$ kJ?

a) $H_2O(l) \rightarrow 2\ H(g) + O(g)$

b) $2\ H(g) + O(g) \rightarrow H_2O(l)$

c) $H_2O(l) \rightarrow H_2(g) + \frac{1}{2}\ O_2(g)$

d) $H_2(g) + \frac{1}{2}\ O_2(g) \rightarrow H_2O(l)$

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

28. 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 greater than 1 ($K < 1$).

c) At equilibrium, the rate of the reverse reaction must be greater than the rate of the forward reaction.

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) ($[B]_e < [A]_e$).

29. My 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

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

$w = -P\Delta V$ (at constant P)

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

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

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

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

$\Delta H_{rxn} = \Delta H_{break} + \Delta H_{form}$

PERIODIC TABLE OF THE ELEMENTS

1 1A																	18 8A
1 H 1.008	2 2A					26 Fe 55.85	←Atomic number ←Atomic mass					13 3A	14 4A	15 5A	16 6A	17 7A	2 He 4.003
3 Li 6.941	4 Be 9.012											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