

CHEMISTRY 102A
Exam III
April 26, 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. The last page of this exam contains some useful equations and constants, plus the periodic table.

On the answer sheet:

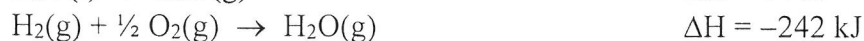
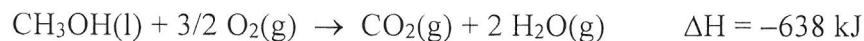
1. **Use #2 pencil. Erase cleanly.**
2. Print your **NAME** in the appropriate designated spaces, then blacken in the letter boxes below each printed letter, last name first, then your first name initial.
3. Fill in your university **ID** number under **STUDENT NUMBER**.
4. Under **SECTION** write the five digit number that corresponds to your section designation, and then blacken in the corresponding number of boxes. **For 102A students**, the numbers are: AQA = 00011, AQB = 00012, AQC = 00013, AQD = 00014, AQE = 00015, AQF = 00016, AQH = 00018, AQJ = 00020, AQK = 00021, AQL = 00022, AQN = 00024, AQO = 00025, AQP = 00026.
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. Given the following data:



calculate the heat of formation, ΔH_f° , for methanol, $\text{CH}_3\text{OH}(\text{l})$.

- a) -84 kJ/mol b) -125 kJ/mol c) $-240. \text{ kJ/mol}$
d) -196 kJ/mol e) -284 kJ/mol
2. Which of the following diatomic molecules is expected to have the largest bond energy?
Hint: draw the Lewis structures.

- a) H_2 b) F_2 c) O_2 d) N_2 e) Cl_2

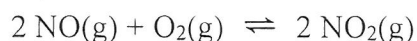
3. Consider the following endothermic reaction at equilibrium:



How many of the following four changes (I-IV) will cause the mass of $\text{SiH}(\text{OH})_3(\text{s})$ to increase?

- I. Increase the volume of the reaction container.
II. Increase the temperature.
III. Add $\text{H}_2\text{O}(\text{l})$.
IV. Remove $\text{HCl}(\text{g})$.

- a) 0 (none) b) 1 c) 2 d) 3
e) 4 [All of these changes (I-IV) will cause the mass of $\text{SiH}(\text{OH})_3$ to increase.]
4. An equilibrium mixture for the reaction:



contains 0.12 mol of NO_2 , 0.080 mol of NO , and 0.64 mol of O_2 in a 4.0 L bulb at a temperature, T. What is the value of K for this reaction at this temperature?

- a) 88 b) 14 c) 9.4 d) 3.5 e) 2.3

5. Excess solid $\text{Ca}_3(\text{PO}_4)_2$ is added to some water. If the equilibrium concentration of $\text{Ca}^{2+}(\text{aq})$ is $4.8 \times 10^{-7} \text{ M}$, what is the molar solubility of $\text{Ca}_3(\text{PO}_4)_2$ in water?
- a) $1.6 \times 10^{-7} \text{ mol/L}$ b) $3.2 \times 10^{-7} \text{ mol/L}$ c) $4.8 \times 10^{-7} \text{ mol/L}$
d) $1.1 \times 10^{-19} \text{ mol/L}$ e) $2.8 \times 10^{-30} \text{ mol/L}$
6. Ethanol ($\text{C}_2\text{H}_5\text{OH}$) has a freezing point of -114°C and a boiling point of 78°C . The specific heat capacity of liquid ethanol is $2.5 \text{ J/g}\cdot^\circ\text{C}$ and the specific heat capacity of gaseous ethanol is $1.5 \text{ J/g}\cdot^\circ\text{C}$. When a 2.00 mol sample of ethanol at 48°C is heated to 108°C , 92 kJ of heat are required for this process. Calculate the enthalpy of vaporization for ethanol ($\Delta H_{\text{vap}} = ?$). The molar mass of ethanol is 46.07 g/mol .
- a) 81 kJ/mol b) 62 kJ/mol c) $40. \text{ kJ/mol}$ d) 15 kJ/mol e) 6600 J/mol
7. Consider the following reaction:
- $$2 \text{ C}_7\text{H}_5\text{N}_3\text{O}_6(\text{s}) \rightarrow 12 \text{ CO}(\text{g}) + 5 \text{ H}_2(\text{g}) + 3 \text{ N}_2(\text{g}) + 2 \text{ C}(\text{s}) \quad \Delta H^\circ = -1899 \text{ kJ}$$
- Calculate ΔE° for the above reaction at 1.00 atm and 25°C .
- a) -1849 kJ b) -1899 kJ c) -1949 kJ d) -1906 kJ e) -1892 kJ
8. You are given 500.0 g of ice at -20.0°C and you heat it until you have water at 40.0°C . Calculate q for the entire process of heating the H_2O from -20.0°C to 40.0°C . Pertinent data: heat capacity of water = $4.184 \text{ J/g}\cdot^\circ\text{C}$, heat capacity of ice = $2.03 \text{ J/g}\cdot^\circ\text{C}$, enthalpy of fusion of ice = 6.02 kJ/mol , molar mass of H_2O = 18.02 g/mol .
- a) 10.4 kJ b) 325 kJ c) 271 kJ d) 167 kJ e) $1.04 \times 10^5 \text{ kJ}$
9. Which of the following statements (a-d) is/are **true**?
- a) The internal energy of a system is equal to the sum of the potential energy and the kinetic energy of the system.
b) A path function is a quantity that is path independent.
c) When a gas expands against the surroundings, the sign associated with the work for this process is positive.
d) An intensive property is a property that depends on the quantity of substance present.
e) In an exothermic process, heat is absorbed by the system.

10. The heat capacity of a bomb calorimeter was determined by combusting 6.31 g of methane in the bomb calorimeter. The temperature changed by 16.3°C . Calculate the heat capacity of the bomb calorimeter. For methane, $\Delta E_{\text{comb}} = -802 \text{ kJ/mol CH}_4$, and the molar mass of methane (CH_4) is 16.04 g/mol .
- a) $311 \text{ kJ/}^{\circ}\text{C}$ b) $0.393 \text{ kJ/}^{\circ}\text{C}$ c) $3.07 \text{ kJ/}^{\circ}\text{C}$ d) $49.2 \text{ kJ/}^{\circ}\text{C}$ e) $19.4 \text{ kJ/}^{\circ}\text{C}$
11. A solution contains 0.10 M SO_4^{2-} , $0.10 \text{ M CrO}_4^{2-}$, 0.10 M IO_3^{-} , and 0.10 M PO_4^{3-} . $\text{AgNO}_3(\text{aq})$ is added dropwise to this solution until a precipitate forms. Which of the following precipitates forms first as $\text{AgNO}_3(\text{aq})$ is added?
- a) $\text{Ag}_2\text{SO}_4(\text{s})$, $K_{\text{sp}} = 1.2 \times 10^{-5}$ b) $\text{Ag}_2\text{CrO}_4(\text{s})$, $K_{\text{sp}} = 9.0 \times 10^{-12}$
c) $\text{AgIO}_3(\text{s})$, $K_{\text{sp}} = 3.1 \times 10^{-8}$ d) $\text{Ag}_3\text{PO}_4(\text{s})$, $K_{\text{sp}} = 1.8 \times 10^{-18}$
12. Which of the statements (a-c) concerning the following reaction is/are **true**?
- $$\text{CO}_2(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \quad K = 1.0 \times 10^{-8}$$
- a) Since $K \ll 1$, at equilibrium the rate of the reverse reaction will be greater than the rate of the forward reaction.
b) Since $K \ll 1$, at equilibrium the reaction system will contain mostly reactants.
c) The value of K at constant temperature depends on the amount of reactants and products that are mixed together initially.
d) Two of the above statements (a-c) are true.
e) All of the above statements (a-c) are true.
13. A solution is prepared by adding 50.0 mL of 2.0 M AgNO_3 with 50.0 mL of $3.0 \text{ M Na}_2\text{CO}_3$. A precipitate of $\text{Ag}_2\text{CO}_3(\text{s})$ forms. Calculate the equilibrium concentration of Ag^+ after precipitation is complete ($[\text{Ag}^+]_{\text{e}} = ?$). K_{sp} for $\text{Ag}_2\text{CO}_3 = 8.1 \times 10^{-12}$.
- a) $2.8 \times 10^{-6} \text{ M}$ b) $2.0 \times 10^{-12} \text{ M}$ c) $1.4 \times 10^{-6} \text{ M}$
d) $4.0 \times 10^{-12} \text{ M}$ e) $9.1 \times 10^{-7} \text{ M}$
14. A solution is prepared by adding 50.0 mL of 2.0 M AgNO_3 with 50.0 mL of $3.0 \text{ M Na}_2\text{CO}_3$. A precipitate of $\text{Ag}_2\text{CO}_3(\text{s})$ forms. Calculate the equilibrium concentration of CO_3^{2-} after precipitation is complete ($[\text{CO}_3^{2-}]_{\text{e}} = ?$). K_{sp} for $\text{Ag}_2\text{CO}_3 = 8.1 \times 10^{-12}$.
- a) 1.5 M b) 3.0 M c) 0.50 M d) 2.0 M e) 1.0 M

15. Consider the following four ionic compounds:

AgCl(s)	$K_{\text{sp}} = 2s$
$\text{PbCl}_2\text{(s)}$	$K_{\text{sp}} = 4s^2$
$\text{Ag}_3\text{PO}_4\text{(s)}$	$K_{\text{sp}} = 9s^3$
$\text{Pb}_3(\text{PO}_4)_2\text{(s)}$	$K_{\text{sp}} = 27s^5$

Next to each compound is a mathematical expression relating molar solubility to the K_{sp} value. These relationships may or may not be correct. How many of the ionic compounds has (have) the correct molar solubility to K_{sp} relationship listed for that compound? Note that s = molar solubility.

- a) 0 (None are correct.) b) 1 c) 2 d) 3 e) 4 (All are correct.)
16. A piston expands against 1.000 atm of pressure from 11.20 L to 29.10 L. In this process, 1038 J of heat are absorbed. Calculate the internal energy change for this process.
- a) -1056 J b) -775 J c) 2851 J d) -2851 e) 1020. J
17. Consider the following reaction at 250°C:

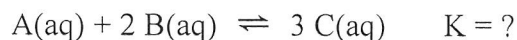


Initially 1.00 mol of N_2 , 1.00 mol of H_2 , and 1.00 mol of NH_3 are placed in a 2.00 L container. Which way will the reaction shift to reach equilibrium and which reagent will have the smallest concentration at equilibrium?

- a) Reaction will shift right; $[\text{NH}_3]$ will be smallest.
b) Reaction will shift left; $[\text{H}_2]$ will be smallest.
c) Reaction will shift left; $[\text{NH}_3]$ will be smallest.
d) Reaction will shift right; $[\text{N}_2]$ will be smallest.
e) Reaction will shift right; $[\text{H}_2]$ will be smallest.
18. $\text{N}_2\text{O}_5(\text{g})$ decomposes into $\text{O}_2(\text{g})$ and $\text{NO}_2(\text{g})$. Which of the following is a **correct** equilibrium constant expression for this decomposition reaction?

- a) $\frac{[\text{O}_2][\text{NO}_2]^2}{[\text{N}_2\text{O}_5]}$ b) $\frac{[\text{N}_2\text{O}_5]}{[\text{O}_2][\text{NO}_2]^2}$ c) $\frac{[\text{O}_2][\text{NO}_2]}{[\text{N}_2\text{O}_5]}$
- d) $\frac{[\text{N}_2\text{O}_5]}{[\text{O}_2][\text{NO}_2]}$ e) $\frac{[\text{O}_2][\text{NO}_2]^4}{[\text{N}_2\text{O}_5]^2}$

19. Consider the following hypothetical reaction at 298 K:



where the initial concentrations are $[\text{A}] = [\text{B}] = [\text{C}] = 1.00 \text{ M}$. The reaction is then allowed to proceed until equilibrium is reached, at which time the concentration of C is observed to be 1.96 M . What is the value of K for the above reaction (at 298 K)?

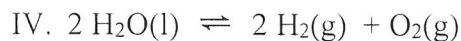
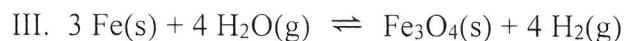
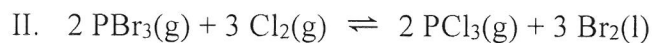
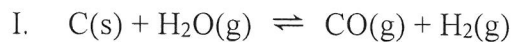
- a) 8.0 b) 16 c) 21 d) 85 e) 116
20. Calculate the molar solubility of solid CaF_2 ($K_{\text{sp}} = 4.0 \times 10^{-11}$) in a 0.25 M KF solution.

- a) $1.6 \times 10^{-9} \text{ mol/L}$ b) $2.2 \times 10^{-4} \text{ mol/L}$ c) $2.2 \times 10^{-6} \text{ mol/L}$
d) $6.4 \times 10^{-10} \text{ mol/L}$ e) 0.25 mol/L

21. A small statue, made of a pure unknown metal, has a mass of 622.5 g. The statue, initially at 26.00°C , is placed in 1.000 kg of water at 100.00°C . The final temperature of the statue and water is 91.33°C . Given that the specific heat capacity of water is $4.184 \text{ J/g}\cdot^\circ\text{C}$, what metal is the statue made of?

- a) Au, $s = 0.127 \text{ J/g}\cdot^\circ\text{C}$ b) Ag, $s = 0.231 \text{ J/g}\cdot^\circ\text{C}$ c) Zn, $s = 0.382 \text{ J/g}\cdot^\circ\text{C}$
d) Fe, $s = 0.448 \text{ J/g}\cdot^\circ\text{C}$ e) Al, $s = 0.892 \text{ J/g}\cdot^\circ\text{C}$

22. Consider the following four reactions:



For how many of these reactions does $K = K_p$?

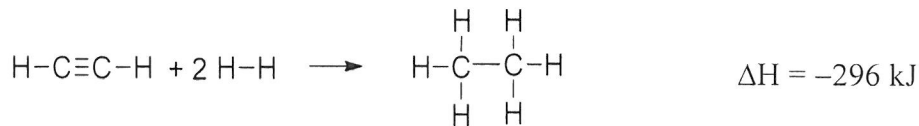
- a) 0 (none) b) 1 c) 2 d) 3
e) 4 (All of these reactions have $K = K_p$.)

23. Consider the following reaction at 35°C:



If 2.0 mol of NOCl are placed in a 1.0 L flask at 35°C, calculate the equilibrium concentration of Cl₂ ([Cl₂]_e = ?).

- a) $5.0 \times 10^{-2} M$ b) $4.0 \times 10^{-3} M$ c) $1.6 \times 10^{-3} M$
d) $8.0 \times 10^{-3} M$ e) $2.5 \times 10^{-2} M$
24. The K_{sp} value for Mg(OH)₂ is 9.0×10^{-12} . When 100.0 mL of $4.0 \times 10^{-4} M$ Mg(NO₃)₂ is added to 100.0 mL of $2.0 \times 10^{-4} M$ NaOH, will a precipitate form?
- a) Yes, because $Q = 2.0 \times 10^{-12}$ and since it is less than K_{sp} , a precipitate will form.
b) No, because $Q = 2.0 \times 10^{-12}$ and since it is less than K_{sp} , no precipitate will form.
c) Yes, because $Q = 1.6 \times 10^{-11}$ and since it is greater than K_{sp} , a precipitate will form.
d) No, because $Q = 1.6 \times 10^{-11}$ and since it is greater than K_{sp} , no precipitate will form.
25. The molar solubility for a compound is $1.0 \times 10^{-15} \text{ mol/L}$. Which of the following could be the compound having this molar solubility?
- a) CuS, $K_{sp} = 8.5 \times 10^{-45}$ b) AgI, $K_{sp} = 1.5 \times 10^{-16}$ c) Ag₂S, $K_{sp} = 1.6 \times 10^{-49}$
d) Bi₂S₃, $K_{sp} = 1.1 \times 10^{-73}$ e) Ag₃PO₄, $K_{sp} = 1.8 \times 10^{-18}$
26. Consider the following reaction and bond energies:



Bond	Bond energy
C-H	413 kJ/mol
H-H	432 kJ/mol
C-C	347 kJ/mol

Calculate the bond energy of a C≡C triple bond given the information above.

- a) 619 kJ/mol b) 839 kJ/mol c) 1040 kJ/mol
d) 562 kJ/mol e) 112 kJ/mol

27. Which of the following statements is **true**?
- a) For a cyclic process, the change in a state function must be zero.
 - b) At constant pressure, $\Delta E = q_p$.
 - c) For $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g})$, $\Delta H = \Delta E$ at constant P and T.
 - d) The internal energy of a system increases when the system does more work on the surroundings than heat is absorbed from the surroundings.
 - e) The energy of the universe is increasing.
28. Consider the following reaction at some constant temperature:
- $$2 \text{HF}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{F}_2(\text{g}) \quad K_p = 4.0$$
- A container is initially filled with 1.0 atm of $\text{H}_2(\text{g})$ and 1.0 atm of $\text{F}_2(\text{g})$. Once equilibrium is reached, calculate the equilibrium partial pressure of $\text{F}_2(\text{g})$.
- a) 0.20 atm b) 0.40 atm c) 0.60 atm d) 0.80 atm e) 1.0 atm
29. Part of the process of the gasification of coal to produce carbon dioxide and methane is shown below:
- $$2 \text{CO}(\text{g}) + 2 \text{H}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{CH}_4(\text{g}) \quad \Delta H^\circ = ?$$
- Given the following standard enthalpies of formation:
- | | ΔH_f° (kJ/mol) |
|-------------------------|-----------------------------|
| $\text{CO}(\text{g})$ | -110.5 |
| $\text{CO}_2(\text{g})$ | -393.5 |
| $\text{CH}_4(\text{g})$ | -74.8 |
- calculate ΔH° for the above reaction.
- a) -247.3 kJ/mol b) -689.3 kJ/mol c) 689.3 kJ/mol
 - d) 247.3 kJ/mol e) 0 kJ/mol
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

$$K = ^\circ\text{C} + 273$$

$$PV = nRT$$

$$R = 0.08206 \text{ L atm/K mol}$$

$$1 \text{ L} = 1000 \text{ mL}$$

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

$$\text{kinetic energy} = (1/2) mv^2$$

$$\frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2}$$

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

$$1 \text{ J} = 1 \text{ kg m}^2/\text{sec}^2$$

$$R = 8.3145 \text{ J/K mol}$$

$$\Delta E = q + w$$

$$101.3 \text{ J} = 1 \text{ L} \cdot \text{atm}$$

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

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

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

$$\Delta H_{\text{rxn}}^{\circ} = \sum \Delta H_{\text{f, products}}^{\circ} - \sum \Delta H_{\text{f, reactants}}^{\circ}$$

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

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											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