

### 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.

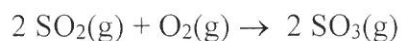
### Solubility rules:

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  $\text{Ag}^+$ ,  $\text{Pb}^{2+}$ , and  $\text{Hg}_2^{2+}$  ions are insoluble.
4. Most sulfate salts are soluble.  
Exceptions: sulfates containing  $\text{Ca}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Pb}^{2+}$ , and  $\text{Hg}_2^{2+}$  ions are insoluble.
5. Most hydroxide salts are insoluble.  
Exceptions: hydroxides containing alkali metals,  $\text{Ba}^{2+}$ ,  $\text{Sr}^{2+}$ , and  $\text{Ca}^{2+}$  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  $\text{H}_2\text{O}(\text{l})$  at an initial temperature of  $25.0^\circ\text{C}$ . What quantity of energy is necessary to convert the water from  $25.0^\circ\text{C}$  to  $125.0^\circ\text{C}$ ? For water, the enthalpy of vaporization is  $40.7 \text{ kJ/mol}$ , the heat capacity of  $\text{H}_2\text{O}(\text{g})$  is  $2.02 \text{ J/g}\cdot^\circ\text{C}$ , and the heat capacity of  $\text{H}_2\text{O}(\text{l})$  is  $4.184 \text{ J/g}\cdot^\circ\text{C}$ .

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:



Which of the following relationships between  $\Delta H$  and  $\Delta E$  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)  $\Delta H = \Delta E + 4RT$

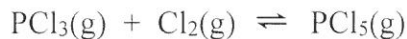
3. A sample of  $\text{S}_8(\text{g})$  is placed in an otherwise empty container at 1325 K and at an initial pressure of 1.00 atm, where it decomposes to  $\text{S}_2(\text{g})$  by the reaction:



At equilibrium, the partial pressure of  $\text{S}_8$  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:



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

- a) Addition of  $\text{PCl}_3$  to the container will shift the equilibrium toward formation of more  $\text{PCl}_5$ .  
b) An increase in temperature will shift the equilibrium toward formation of more  $\text{PCl}_3$ .  
c) Addition of a catalyst will have no effect on the equilibrium position.  
d) Removal of  $\text{Cl}_2$  from the container will shift the equilibrium toward the formation of more  $\text{PCl}_3$ .  
e) An increase in the volume of the container will shift the equilibrium toward formation of more  $\text{PCl}_5$ .

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

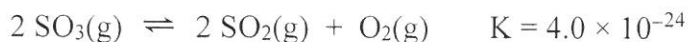
I.  $\text{Al}(\text{OH})_3$       II.  $\text{Ag}_2\text{CO}_3$       III.  $\text{CaF}_2$       IV.  $\text{PbI}_2$       V.  $\text{NiS}$

- 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 ( $K \gg 1$ ).
7. Self-contained breathing apparatuses sometimes use the following reaction to produce oxygen gas:



At a particular temperature, an equilibrium mixture of this reaction contains 2 mol of  $\text{KO}_2(\text{s})$ ,  $4 \times 10^{-10}$  mol  $\text{CO}_2(\text{g})$ , 1 mol  $\text{K}_2\text{CO}_3(\text{s})$  and 0.4 mol of  $\text{O}_2(\text{g})$  all in a 4.0 L container. Calculate the value for the equilibrium constant,  $K$ , for this reaction.

- a)  $4 \times 10^{17}$       b)  $1 \times 10^9$       c)  $1 \times 10^{17}$       d)  $4 \times 10^9$       e)  $6.4 \times 10^{18}$
8. Consider the reaction:



Initially, 4.0 mol of  $\text{SO}_3(\text{g})$  and 4.0 mol of  $\text{O}_2$  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  $\text{SO}_2(\text{g})$ ?

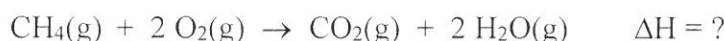
- a)  $4.0 \times 10^{-12} M$       b)  $4.0 \times 10^{-24} M$       c)  $2.0 \times 10^{-12} M$   
d)  $1.0 \times 10^{-12} M$       e)  $1.0 \times 10^{-8} M$

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  $\text{Ca}_3(\text{PO}_4)_2(\text{s})$  in a  $1.0 \times 10^{-2} \text{ M}$   $\text{Ca}(\text{NO}_3)_2$  solution.  $K_{\text{sp}}$  for  $\text{Ca}_3(\text{PO}_4)_2 = 1.3 \times 10^{-32}$ .
- a)  $5.7 \times 10^{-14} \text{ mol/L}$       b)  $1.6 \times 10^{-7} \text{ mol/L}$       c)  $1.1 \times 10^{-10} \text{ mol/L}$   
d)  $1.6 \times 10^{-14} \text{ mol/L}$       e)  $3.2 \times 10^{-13} \text{ mol/L}$
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  $\text{H}_2\text{O}$ . 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:
- $$2 \text{H}(\text{g}) \rightarrow \text{H}_2(\text{g})$$
- 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)  $\text{Ag}_2\text{S}$  ( $K_{\text{sp}} = 1.6 \times 10^{-49}$ )      b)  $\text{Bi}_2\text{S}_3$  ( $K_{\text{sp}} = 1.0 \times 10^{-72}$ )  
c)  $\text{CuS}$  ( $K_{\text{sp}} = 8.5 \times 10^{-45}$ )      d)  $\text{CoS}$  ( $K_{\text{sp}} = 5.0 \times 10^{-22}$ )  
e)  $\text{MnS}$  ( $K_{\text{sp}} = 2.3 \times 10^{-13}$ )

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:



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  $5.7 \times 10^{-3} M$ . Calculate the  $K_{sp}$  value for  $Ce(IO_3)_3$ .
- a)  $3.2 \times 10^{-5}$                       b)  $3.6 \times 10^{-6}$                       c)  $2.7 \times 10^{-8}$   
d)  $7.4 \times 10^{-7}$                       e)  $3.5 \times 10^{-10}$
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 ( $\Delta H_{comb}^\circ$ ) is -1367 kJ/mol, and the  $\Delta H_f^\circ$  values for  $H_2O(l)$  and  $CO_2(g)$  are -286 kJ/mol and -393 kJ/mol respectively, what is the value of  $\Delta H_f^\circ$  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)  $3.2 \times 10^{-4} M$                       b)  $2.5 \times 10^{-5} M$                       c)  $1.6 \times 10^{-5} M$   
d) 0.80 M                      e) 0.10 M

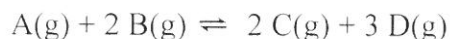
19. Consider the following generic reaction:



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.  $N_2(g) + O_2(g) \rightarrow 2 NO(g) \quad \Delta H_A$
- B.  $NO(g) + 1/2 O_2(g) \rightarrow NO_2(g) \quad \Delta H_B$
- a)  $\Delta H^\circ_f$  for  $NO_2(g) = \Delta H_B$
- b)  $\Delta H^\circ_f$  for  $NO(g) = -\Delta H_A$
- c)  $\Delta H_A = \Delta H_B$
- d)  $\Delta H^\circ_f$  for  $NO_2(g) = \Delta H_B + 1/2 \Delta H_A$
- e) None of the above statements (a-d) are true.

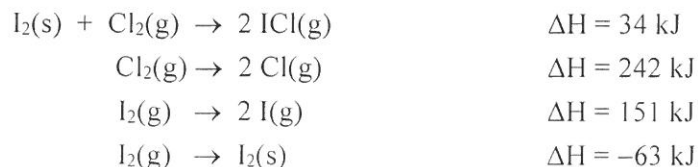
21. Consider when 1.0 mole of  $A(g)$  and 1.0 mole of  $B(g)$  are added to a 2.0 L container and the following balanced reaction occurs:



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:



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<sub>3</sub> and 0.010 *M* Sc(NO<sub>3</sub>)<sub>3</sub>. A dilute solution of KOH is added dropwise until a precipitate forms. Which precipitate will form first and at what concentration of OH<sup>−</sup> will it form? *K*<sub>sp</sub> for AgOH(s) = 1 × 10<sup>−8</sup> and *K*<sub>sp</sub> for Sc(OH)<sub>3</sub>(s) = 1 × 10<sup>−14</sup>. Assume no volume change on addition of KOH.
- a) Sc(OH)<sub>3</sub>(s) forms first when [OH<sup>−</sup>] > 1 × 10<sup>−4</sup> *M*.  
b) AgOH(s) forms first when [OH<sup>−</sup>] > 1 × 10<sup>−6</sup> *M*.  
c) AgOH(s) forms first when [OH<sup>−</sup>] > 1 × 10<sup>−8</sup> *M*.  
d) Sc(OH)<sub>3</sub>(s) forms first when [OH<sup>−</sup>] > 1 × 10<sup>−12</sup> *M*.  
e) Sc(OH)<sub>3</sub>(s) forms first when [OH<sup>−</sup>] > 1 × 10<sup>−14</sup> *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

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