

University of Windsor
Chemistry & Biochemistry

Chem 59-110

Test 2

13 November, 2000
(50 minutes)

Name (print): [REDACTED]

Student #: [REDACTED]

Lab Day Tuesday ; morn' or eve'? (circle); Name of Lab TA: Nancy Yue

Please attempt all questions on the sheets provided. The first question is multiple choice and requires only the letter corresponding to the appropriate answer in the box provided. The remaining four questions may require some calculations and in all cases you are requested to **indicate the reasoning behind your calculations**. **No reconsideration will be given to questions not written in ink.**

A Periodic Table is attached; the Ideal Gas Law is $PV = nRT$; and the Gas Constant, in case you need it, is: $0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$, or $8.315 \text{ J K}^{-1} \text{ mol}^{-1}$

Question	Marks Available	Marks Obtained	
1	10	4	
2	10	7	
3	10	7	
4	10	10	
5	10	1	
	<u>50</u>	<u>29</u>	= 58%

1. Multiple choice, 10 questions, 1 mark each. Mark the letter corresponding to the correct answer in the box provided.

(a) The Haber Process reaction, $2 \text{NH}_3(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 3 \text{H}_2(\text{g})$, has an equilibrium constant of 10.0 at a certain temperature. What would be the direction of the spontaneous reaction from a 2:1:3 mol mixture of NH_3 , N_2 and H_2 , respectively, at that temperature?

 C

- A. to the right
- B. to the left
- C. neither of the above, the reaction is at equilibrium already

(b) To say that a reaction is *enthalpy-driven* below a certain temperature is to say that:

 C

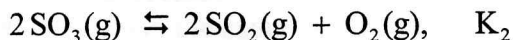
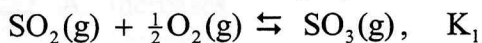
- A. both ΔH° and ΔS° are positive
- B. both ΔH° and ΔS° are negative
- C. ΔH° is negative and ΔS° is positive

(c) The following equilibrium is *endothermic*: $\text{C}(\text{s}) + \text{CO}_2(\text{g}) \rightleftharpoons 2 \text{CO}(\text{g})$. Consider the reaction at equilibrium at a certain temperature and then the temperature is raised. At the new temperature the *position* of the equilibrium

 C

- A. would be unchanged
- B. would shift to favour the reactant
- C. would shift to favour the products

(d) Consider the following equilibria and their constants:



If $K_1 = 0.1$, then K_2 is equal to:

 D

- A. 0.1
- B. 3.16
- C. 100
- D. 0.01
- E. 10

(e) For the reaction, $3 \text{NO}(\text{g}) \rightleftharpoons \text{N}_2\text{O}(\text{g}) + \text{NO}_2(\text{g})$, if K_c is 1000 at 300K, what is ΔG° for the *reverse* reaction?

 A

- A - 172 kJ
- B - 17.2 kJ
- C +17.2 kJ
- D -0.17 kJ

ΔG small $\frac{P}{r}$ spontaneous

1. (cont'd):

(f) If the pOH increases by 3.00 units, the acidity:

B

- A. decreases by 3-fold
- B. decreases by 1000-fold
- C. increases by 3-fold
- D. increases by 1000-fold

(g) The K_b for pyridine, C_5H_5N , is 1×10^{-9} . The pK_a for pyridinium ion, $C_5H_5NH^+$, is

C

- A. 9
- B. 1×10^{-5}
- C. 5

(h) A solution which is 0.10 M in ammonia, NH_3 , ($K_b = 1.8 \times 10^{-5}$) and 0.10 M in ammonium chloride, NH_4Cl , has a pH of

B

- A. 8.25
- B. 9.25
- C. 10.25

(i) What is the effect on the pH of a solution of acetic acid, CH_3CO_2H , ($K_a = 1.8 \times 10^{-5}$) when sodium acetate, CH_3CO_2Na (a strong electrolyte), is added?

A

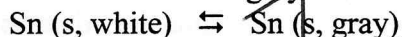
- A. increases
- B. decreases
- C. stays the same

(j) The two pK_a 's for sulfurous acid, H_2SO_3 , are 1.80 and 6.90. For a sodium bisulfite/sodium sulfite ($NaHSO_3/Na_2SO_3$) buffer, the best buffering is around pH:

B

- A. 1.80
- B. 4.35
- C. 6.90

2. (a) Solid tin exists in two forms: white and gray. For the transformation



the enthalpy change is -2.1 kJ and the entropy change is -7.4 J K^{-1} .

- i. Calculate the Gibbs free energy change for the conversion of 1.00 mol of white tin to gray tin at -30°C (3 marks)

$$\Delta G = \Delta H - T\Delta S$$

$$= -2100 \text{ J} - (243)(-7.4)$$

$$\Delta G = 3898 \text{ J}$$

2

- ii. Will white tin convert spontaneously to gray tin at -30°C ? Justify your answer. (2 marks)

Since the entropy is negative, white tin will not spontaneously convert to gray tin.

0

- iii. At what temperature are white and gray tin in equilibrium at 1 atm pressure? (2 marks)

$\Delta G = 0$ at equilibrium

$$\Delta G = \Delta H - T\Delta S = 0$$

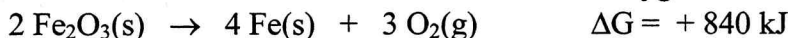
$$T\Delta S = \Delta H$$

$$T(-7.4) = (-2100)$$

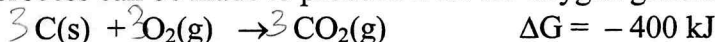
$$T = 283 \text{ K}$$

2

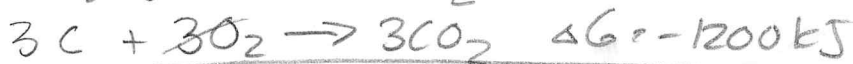
2. (b) At 1200°C , the reduction of iron oxide to elemental iron and oxygen is not spontaneous:



Show how this process can be made to proceed if all the oxygen generated reacts with carbon:



(3 marks; this is the basis for the smelting of iron ore with coke to extract metallic iron)



Now the ΔG is negative and will proceed spontaneously.

3

3. The dehydrogenation of benzyl alcohol to make the flavouring agent benzaldehyde is an equilibrium process described by the equation



At 523 K, the value of its equilibrium constant is $K = 0.558$.

- (a) Suppose 1.20 g of benzyl alcohol is placed in a 2.00-L vessel and heated to 523 K. What is the partial pressure of benzaldehyde when equilibrium is attained? (8 marks)
 (b) What fraction of benzyl alcohol is dissociated into products at equilibrium? (2 marks)

7

$$K = \frac{(P_{\text{H}_2})(P_{\text{C}_6\text{H}_5\text{CHO}})}{P(\text{C}_6\text{H}_5\text{CH}_2\text{OH})} = 0.558$$

$$P = n \frac{RT}{V}$$

$$n = \frac{1.2 \text{ g}}{108 \text{ g/mol}}$$

$$P = 0.011 \frac{(0.0821)(523)}{2}$$

$$n = 0.011 \text{ mol}$$

$$P = 0.238 \text{ atm}$$

$$0.558 = \frac{x^2}{0.238 - x}$$

$$x^2 = 0.133 - 0.558x$$

$$x^2 + 0.558x - 0.132 = 0$$

$$-b \pm \sqrt{b^2 - 4ac}$$

$$-0.558 \pm \frac{\sqrt{0.311 + 0.528}}{2}$$

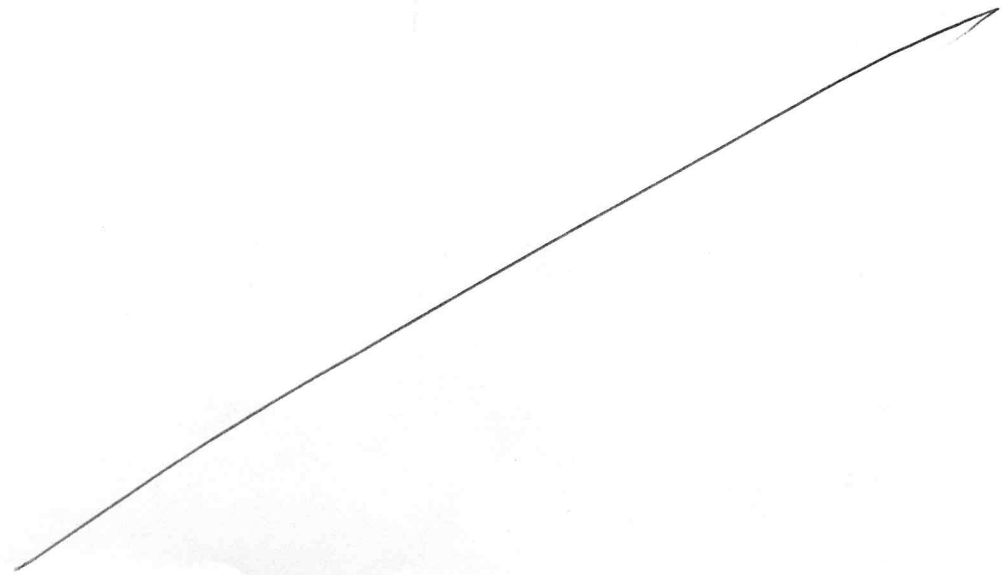
$$\frac{0.558 \pm 0.916}{2}$$

$$x = 0.737, -0.179$$

$$P_{\text{C}_6\text{H}_5\text{CHO}} = 0.737 \text{ atm}$$

$\text{C}_6\text{H}_5\text{CH}_2\text{OH}$	$\text{C}_6\text{H}_5\text{CHO}$	H_2
0.238	0	0
0.238 - x	+x	+x

b)



4. Phenol, C_6H_5OH , is a weak organic acid, $K_a = 1.3 \times 10^{-10}$. Phenol's conjugate base is phenoxide, $C_6H_5O^-$. Although somewhat toxic to humans, it is used as a disinfectant (known as carbolic acid, for use on hospital floors) and in the manufacture of plastics.

(a) What is the pK_b of phenoxide (eg. as the sodium salt, C_6H_5ONa)? (2 marks)

(b) If 9.40 g of phenol is dissolved in water to give 500 mL of solution, what is the equilibrium hydronium ion concentration? (7 marks). What is the pH of the equilibrium solution (1 mark)?

$$a) K_a = 1.3 \times 10^{-10}$$

$$pK_a = 9.88$$

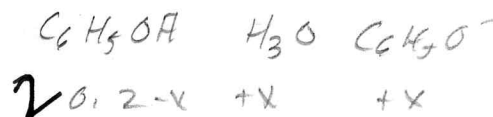
$$pK_a + pK_b = 14$$

$$pK_b = 4.12$$

$$[C_6H_5OH] = \frac{0.1 \text{ mol}}{0.5 \text{ L}} = 0.2 \text{ M}$$



$$K_a = \frac{[H_3O^+][C_6H_5O^-]}{[C_6H_5OH]}$$



$$2 \quad 1.3 \times 10^{-10} = \frac{x^2}{0.2 - x} \quad \text{assume } x \text{ small}$$

$$2.6 \times 10^{-11} = x^2$$

$$x = 5.1 \times 10^{-6}$$

$$2 \quad [H_3O^+] = 5.1 \times 10^{-6}$$

$$pH = 5.3$$

10
10

5. A buffer solution was prepared by adding 0.050 mol of acetic acid ($K_a = 1.8 \times 10^{-5}$) and 0.020 mol of sodium acetate to a flask and making up to 500 mL with water.

(a) Calculate the pH of this buffer (4 marks).

(b) Calculate the pH of this buffer solution after 0.010 mol of NaOH is added without significant volume change (6 marks).



$$K_a = \frac{[H_3O^+][\text{Salt}]}{[A][B]}$$

A	B	Salt
0.1	0.04	—
0.1 - x	0.04 - x	x

(M)