

## Exam 3 Chm 205 (Dr Mattson) 6 April 2016

**Academic Integrity Pledge:** In keeping with Creighton University's ideals and with the Academic Integrity Code, I pledge that this work is my own and that I have neither given nor received inappropriate assistance in preparing it.

Signature: \_\_\_\_\_

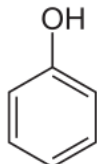
Name: \_\_\_\_\_

Chemistry Student Number: \_\_\_\_\_

**Instructions:** Show all work whenever a calculation box is provided! Write legibly. Include units whenever appropriate. You will receive credit for **how** you worked each problem as well as for the correct answer. If you need more space, you may use the back of the data sheet provided — Write: "See data sheet" in the answer box — then write your name on the data sheet. On your desk you are allowed only pencils (but no pencil pouch), an eraser, and a non-programmable calculator without a slipcover. Backpacks, bags, and purse-like items must be stored in the rear section of the room. Cell phones must be silent and placed in your backpack/bag/purse — not in your pocket.

**Note:** All of these questions refer to aqueous solutions.

1. Phenol or carbolic acid,  $\text{HC}_6\text{H}_5\text{O}$ , shown here, is an important industrial chemical used in the production of plastics, cosmetics, sunscreens, and pharmaceuticals, aspirin, and antiseptics. Over  $7 \times 10^9$  kg phenol is produced annually. Phenol has a  $\text{p}K_a = 9.90$ .



1a. (2 pts) What is the numerical value of  $K_a$ ? **Sig fig problem**

$K_a =$  \_\_\_\_\_

1b. (3 pts) What is the formula of the conjugate base of phenol and what is the numerical value of  $\text{p}K_b$ ?

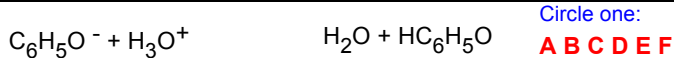
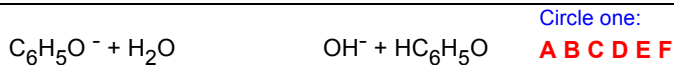
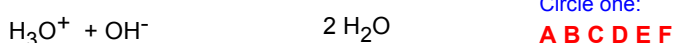
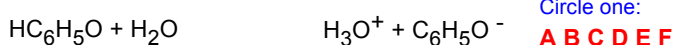
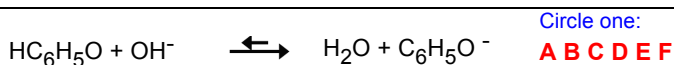
cwb: \_\_\_\_\_

$\text{p}K_b =$  \_\_\_\_\_

1c. (9 pts) Which equilibrium expression **A, B, C, D, E, F** describes each equilibrium below? **Fill in the arrows, either  $\rightleftharpoons$  or  $\rightleftharpoons$  for each. Circle A B C D E or F.**

**A.**  $K = K_a/K_w$     **B.**  $K = K_w$     **C.**  $K = 1/K_w$

**D.**  $K = K_a$     **E.**  $K = K_w/K_a$     **F.**  $K = 1/K_a$



1d. (5 pts) Which would form a buffer? **More than one!**

- 0.10 mol  $\text{HC}_6\text{H}_5\text{O}$  + 0.10 mol  $\text{C}_6\text{H}_5\text{O}^-$  in 1 L  $\text{H}_2\text{O}$
- 0.10 mol  $\text{H}_3\text{O}^+$  + 0.10 mol  $\text{C}_6\text{H}_5\text{O}^-$  in 500 mL  $\text{H}_2\text{O}$
- 0.10 mol  $\text{HC}_6\text{H}_5\text{O}$  + 0.040 mol  $\text{OH}^-$  in 250 mL  $\text{H}_2\text{O}$
- 0.10 mol  $\text{HC}_6\text{H}_5\text{O}$  + 0.18 mol  $\text{OH}^-$  in 300 mL  $\text{H}_2\text{O}$
- 5.0 g  $\text{HC}_6\text{H}_5\text{O}$  + 4.0 g  $\text{NaC}_6\text{H}_5\text{O}$  in 400 mL  $\text{H}_2\text{O}$

1e. (4 pts) What is the pH of a solution prepared by dissolving 0.40 mol  $\text{HC}_6\text{H}_5\text{O}$  and 0.35 mol  $\text{C}_6\text{H}_5\text{O}^-$  in 250 mL water?

Answer: \_\_\_\_\_

1f. (4 pts) What is the pH of the solution in Question 1e if 0.040 mol potassium hydroxide were added?

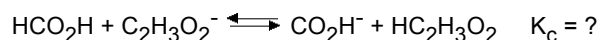
Answer: \_\_\_\_\_

1g. (1 pt) What will happen to the pH if another 50 mL water is added to the solution in the previous problem? It will:  Increase  Decrease  Stay the same

1g. (1 pt) The solution in Question 1e has a larger buffer capacity towards the addition of...

Circle one:  Strong acid  Strong base  Both

2. (4 pts) Methanoic acid,  $\text{HCO}_2\text{H}$ , has a  $K_a = 1.7 \times 10^{-4}$  and ethanoic acid,  $\text{HC}_2\text{H}_3\text{O}_2$ , has a  $K_a = 1.8 \times 10^{-5}$ . What is the equilibrium constant,  $K_c$  for:



Show work for credit!

Answer: \_\_\_\_\_

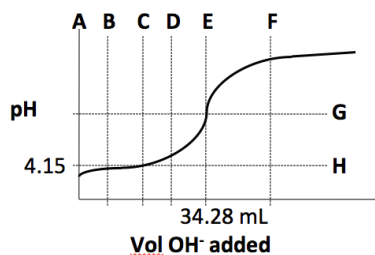
3a. (3 pts) Suppose 40.00 mL 0.1050 M HCl was titrated with NaOH and it took 32.78 mL to reach a phenolphthalein endpoint. What is  $[\text{NaOH}]$ ?

Answer: \_\_\_\_\_

3b. (4 pts) What is the pH of the solution after 30.00 mL NaOH(aq) has been added? **Sig fig problem.**

Answer: \_\_\_\_\_

4. An unknown weak acid, HA, was dissolved in 50.00 mL water and titrated with 0.1106 M NaOH as shown in the figure.



4a (3 pts) How many moles of OH<sup>-</sup> did it take to reach the equivalence point? **Sig fig problem.**

Answer with units: \_\_\_\_\_

4b. (2 pts) The intersection of what **two lines** (for example: B & G) would you use in order to determine the pK<sub>a</sub> for the weak acid?

\_\_\_\_\_

4c. (3 pts) Which lines designate volumes of OH<sup>-</sup> added where we have a buffer solution? **Circle all that apply.**

**Line A   Line B   Line C   Line D   Line E**

4d. (4 pts) Suppose Line D represented a volume of 23.00 mL. What is the pH of the solution at this point?

Answer: \_\_\_\_\_

4e. (4 pts) What is the pH at the equivalence point?

Answer: \_\_\_\_\_

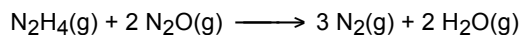
5a. (12 pts) Urea has formula CON<sub>2</sub>H<sub>4</sub> and a melting point of 134 °C. Its solubility in water increases with temperature. Like most organic compounds, urea can be combusted, forming CO<sub>2</sub>(g), H<sub>2</sub>O(g) and N<sub>2</sub>(g). Predict the sign for ΔH, ΔS and ΔG for each of the following processes. Write in each box: **+**, **0** or **-**.

Process involving urea:	ΔH	ΔS	ΔG
Combustion of CON <sub>2</sub> H <sub>4</sub>			
Breaking covalent bonds at 298 K			
Melting of solid urea at 134 °C			
Dissolving urea in water			

Score \_\_\_\_\_

**A ≥ 90; B+ ≥ 85; B ≥ 80; C+ ≥ 75; C ≥ 70; D ≥ 60**

6a. (5 pts) Calculate ΔS° for the reaction: [See data sheet.](#)



Answer with units: \_\_\_\_\_

Is this reaction entropy favored? **Yes No**

6b. (5 pts) Calculate ΔG° for the reaction: [See data sheet.](#)



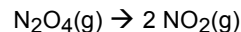
Answer with units: \_\_\_\_\_

Is this reaction spontaneous? **Yes No**

7. (8 pts) Circle **+** or **-** for each of these

ΔG is spontaneous...	if ΔH is	and ΔS is
at all temperatures.	<b>+</b> <b>-</b>	<b>+</b> <b>-</b>
only at high temperatures.	<b>+</b> <b>-</b>	<b>+</b> <b>-</b>
only at low temperatures.	<b>+</b> <b>-</b>	<b>+</b> <b>-</b>
never.	<b>+</b> <b>-</b>	<b>+</b> <b>-</b>

8a. (5 pts) Given that ΔH° = +57.0 kJ, ΔS° = +176 J/K and ΔG° = +4.6 kJ for the reaction below, calculate ΔG at 298 K when P<sub>N<sub>2</sub>O<sub>4</sub></sub> = 5.0 atm and P<sub>N<sub>2</sub>O</sub> = 0.10 atm.



Answer with units: \_\_\_\_\_

Is the forward reaction spontaneous? **Yes No**

8b (5 pts) Calculate the equilibrium constant at 298 K for the reaction.

Answer: \_\_\_\_\_

8c. (4 pts) Calculate the crossover temperature (when ΔG = 0 kJ) for this reaction.

Answer: \_\_\_\_\_

## Data sheet

### Useful Formulas:

$$\Delta G = \Delta G^\circ + R T \ln Q$$

$$\Delta G^\circ = -R T \ln K$$

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$$

	$\Delta H_f^\circ$ kJ/mol	$\Delta G_f^\circ$ kJ/mol	$S^\circ$ J/mol K
$\text{N}_2\text{H}_4(\text{g})$	95.4	159.3	238.4
$\text{N}_2\text{O}(\text{g})$	82.0	104.2	219.7
$\text{N}_2(\text{g})$	0	0	191.5
$\text{H}_2\text{O}(\text{g})$	-241.8	-228.6	188.7

## Answers

1a.  $K_a = 1.3 \times 10^{-10}$

1b. Conjugate base  $\text{HC}_6\text{H}_5\text{O}^-$  and  $\text{p}K_b = 4.10$

1c.

$\text{HC}_6\text{H}_5\text{O} + \text{OH}^-$	$\rightleftharpoons$	$\text{H}_2\text{O} + \text{C}_6\text{H}_5\text{O}^-$	Circle one: <b>A</b>
$\text{HC}_6\text{H}_5\text{O} + \text{H}_2\text{O}$	$\rightleftharpoons$	$\text{H}_3\text{O}^+ + \text{C}_6\text{H}_5\text{O}^-$	Circle one: <b>D</b>
$\text{H}_3\text{O}^+ + \text{OH}^-$	$\rightleftharpoons$	$2 \text{H}_2\text{O}$	Circle one: <b>C</b>
$\text{C}_6\text{H}_5\text{O}^- + \text{H}_2\text{O}$	$\rightleftharpoons$	$\text{OH}^- + \text{HC}_6\text{H}_5\text{O}$	Circle one: <b>E</b>
$\text{C}_6\text{H}_5\text{O}^- + \text{H}_3\text{O}^+$	$\rightleftharpoons$	$\text{H}_2\text{O} + \text{HC}_6\text{H}_5\text{O}$	Circle one: <b>F</b>

1d.

- 0.10 mol  $\text{HC}_6\text{H}_5\text{O}$  + 0.10 mol  $\text{C}_6\text{H}_5\text{O}^-$  in 1 L  $\text{H}_2\text{O}$
- 0.10 mol  $\text{H}_3\text{O}^+$  + 0.10 mol  $\text{C}_6\text{H}_5\text{O}^-$  in 500 mL  $\text{H}_2\text{O}$
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1e. 9.84

1f. 9.93

1g. strong base

1g. strong base

2.  $K_c = 9.5$

3a. 0.1281 M

3b. 2.29

4a.  $3.791 \times 10^{-3}$

4b. C and H

4c. Lines B, C, and D

4d. 4.46

4e. 8.40

5a.

Process involving urea:	$\Delta H$	$\Delta S$	$\Delta G$
Combustion of $\text{CON}_2\text{H}_4$	-	+	-
Breaking covalent bonds at 298 K	+	+	+
Melting of solid urea at 134 °C	+	+	0
Dissolving urea in water	+	+	-

6a.  $\Delta S^\circ = 274.1 \text{ J/mol rxn K}$ ; favored

6b.  $\Delta G^\circ = -824.9 \text{ kJ/mol rxn}$ ; spontaneous

7.

$\Delta G$ is spontaneous...	if $\Delta H$ is	and $\Delta S$ is
at all temperatures.	-	+
only at high temperatures.	+	+
only at low temperatures.	-	-
never.	+	-

8a.  $\Delta G = -10.8 \text{ kJ/mol rxn}$ ; Yes, spontaneous

8b.  $K_p = 0.15$

8c. 324 K