

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: _____

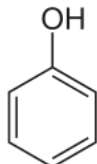
Name: _____

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 carboic 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 7×10^9 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.** $K = 1/K_a$

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

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 H_2O
 0.10 mol H_3O^+ + 0.10 mol $\text{C}_6\text{H}_5\text{O}^-$ in 500 mL H_2O
 0.10 mol $\text{HC}_6\text{H}_5\text{O}$ + 0.040 mol OH^- in 250 mL H_2O
 0.10 mol $\text{HC}_6\text{H}_5\text{O}$ + 0.18 mol OH^- in 300 mL H_2O
 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 H_2O

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?

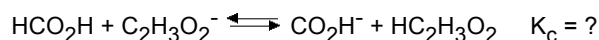
Answer: _____

1f. (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, HCO_2H , 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: _____

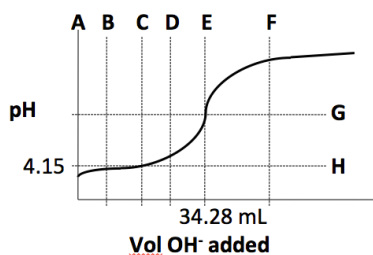
3a. (3 pts) Suppose 40.00 mL 0.1050 M HCl was titrated with NaOH and it took 32.78 mL to reach a phenolphthalein endpoint. What is $[\text{NaOH}]$?

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⁻ 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_a for the weak acid?

4c. (3 pts) Which lines designate volumes of OH⁻ 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: _____

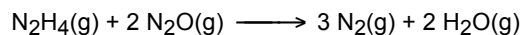
5a. (12 pts) Urea has formula CON₂H₄ and a melting point of 134 °C. Its solubility in water increases with temperature. Like most organic compounds, urea can be combusted, forming CO₂(g), H₂O(g) and N₂(g). Predict the sign for ΔH, ΔS and ΔG for each of the following processes. Write in each box: **+**, **0** or **-**.

Process involving urea:	ΔH	ΔS	ΔG
Combustion of CON ₂ H ₄			
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.](#)



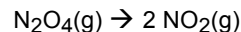
Answer with units: _____

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.	+ -	+ -
only at high temperatures.	+ -	+ -
only at low temperatures.	+ -	+ -
never.	+ -	+ -

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_{N₂O₄} = 5.0 atm and P_{N₂O} = 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:

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

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

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

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

	ΔH_f° kJ/mol	ΔG_f° kJ/mol	S° 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: A
$\text{HC}_6\text{H}_5\text{O} + \text{H}_2\text{O}$	\rightleftharpoons	$\text{H}_3\text{O}^+ + \text{C}_6\text{H}_5\text{O}^-$	Circle one: D
$\text{H}_3\text{O}^+ + \text{OH}^-$	\rightleftharpoons	$2 \text{H}_2\text{O}$	Circle one: C
$\text{C}_6\text{H}_5\text{O}^- + \text{H}_2\text{O}$	\rightleftharpoons	$\text{OH}^- + \text{HC}_6\text{H}_5\text{O}$	Circle one: E
$\text{C}_6\text{H}_5\text{O}^- + \text{H}_3\text{O}^+$	\rightleftharpoons	$\text{H}_2\text{O} + \text{HC}_6\text{H}_5\text{O}$	Circle one: F

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 H_2O
- 0.10 mol H_3O^+ + 0.10 mol $\text{C}_6\text{H}_5\text{O}^-$ in 500 mL H_2O
- 0.10 mol $\text{HC}_6\text{H}_5\text{O}$ + 0.040 mol OH^- in 250 mL H_2O
- 0.10 mol $\text{HC}_6\text{H}_5\text{O}$ + 0.18 mol OH^- in 300 mL H_2O
- 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 H_2O

1e. 9.84

1f. 9.93

1g. stay the same

1g. strong base

2. $K_c = 9.5$

3a. 0.1281 M

3b. 2.29

4a. 3.791×10^{-3}

4b. C and H

4c. Lines B, C, and D

4d. 4.46

4e. 8.40

5a.

Process involving urea:	ΔH	ΔS	ΔG
Combustion of CON_2H_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.

ΔG is spontaneous...	if ΔH is	and ΔS 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