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:

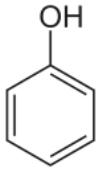
Name:

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, HC_6H_5O, shown here, is an important industrial chemical used in the production of plastics, cosmetics, sunscreens, and pharmaceuticals, aspirin, and antiseptics. Over 7 x 10^9 kg phenol is produced annually. Phenol has a pK_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 pK_b?

cwb:

pK_b =

1c. (9 pts) Which equilibrium expression A, B, C, D, E, F describes each equilibrium below? Fill in the arrows, either ⇌ or → 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.** $K = 1/K_a$

$HC_6H_5O + OH^-$	⇌	$H_2O + C_6H_5O^-$	Circle one: **A B C D E F**
$HC_6H_5O + H_2O$		$H_3O^+ + C_6H_5O^-$	Circle one: **A B C D E F**
$H_3O^+ + OH^-$		$2\ H_2O$	Circle one: **A B C D E F**
$C_6H_5O^- + H_2O$		$OH^- + HC_6H_5O$	Circle one: **A B C D E F**
$C_6H_5O^- + H_3O^+$		$H_2O + HC_6H_5O$	Circle one: **A B C D E F**

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

- ☐ 0.10 mol HC_6H_5O + 0.10 mol $C_6H_5O^-$ in 1 L H_2O
- ☐ 0.10 mol H_3O^+ + 0.10 mol $C_6H_5O^-$ in 500 mL H_2O
- ☐ 0.10 mol HC_6H_5O + 0.040 mol OH^- in 250 mL H_2O
- ☐ 0.10 mol HC_6H_5O + 0.18 mol OH^- in 300 mL H_2O
- ☐ 5.0 g HC_6H_5O + 4.0 g NaC_6H_5O in 400 mL H_2O

1e. (4 pts) What is the pH of a solution prepared by dissolving 0.40 mol HC_6H_5O and 0.35 mol $C_6H_5O^-$ 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, $HC_2H_3O_2$, has a $K_a = 1.8 \times 10^{-5}$. What is the equilibrium constant, K_c for:

$HCO_2H + C_2H_3O_2^- \rightleftharpoons CO_2H^- + HC_2H_3O_2$ K_c = ?

Show work for credit!

Answer: _____

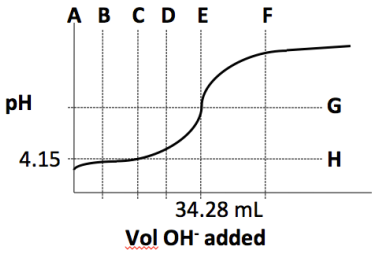
3a. (3 pts) Suppose 40.00 mL 0.1050 M HCl was titrated with NaOH and it took 32.78 mL to reach a phenolphthalein endpoint. What is [NaOH]?

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 CON_2H_4 and a melting point of 134 ^oC. Its solubility in water increases with temperature. Like most organic compounds, urea can be combusted, forming $CO_2(g)$, $H_2O(g)$ and $N_2(g)$. 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_2H_4			
Breaking covalent bonds at 298 K			
Melting of solid urea at 134 ^oC			
Dissolving urea in water			

Score _____

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

6a. (5 pts) Calculate ΔS^o for the reaction: See data sheet.

$$N_2H_4(g) + 2\ N_2O(g) \longrightarrow 3\ N_2(g) + 2\ H_2O(g)$$

Answer with units: _____

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

6b. (5 pts) Calculate ΔG^o for the reaction: See data sheet.

$$N_2H_4(g) + 2\ N_2O(g) \longrightarrow 3\ N_2(g) + 2\ H_2O(g)$$

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^o = +57.0 kJ, ΔS^o = +176 J/K and ΔG^o = +4.6 kJ for the reaction below, calculate ΔG at 298 K when $P_{N_2O_4}$ = 5.0 atm and P_{NO_2} = 0.10 atm.

$$N_2O_4(g) \rightarrow 2\ NO_2(g)$$

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:

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

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

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

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

	ΔH_f^o kJ/mol	ΔG_f^o kJ/mol	S^o J/mol K
$N_2H_4(g)$	95.4	159.3	238.4
$N_2O(g)$	82.0	104.2	219.7
$N_2(g)$	0	0	191.5
$H_2O(g)$	-241.8	-228.6	188.7

Answers

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

1b. Conjugate base $HC_6H_5O^-$ and $pK_b = 4.10$

1c.

$HC_6H_5O + OH^-$	⇌	$H_2O + C_6H_5O^-$	Circle one: **A**
$HC_6H_5O + H_2O$	⇌	$H_3O^+ + C_6H_5O^-$	Circle one: **D**
$H_3O^+ + OH^-$	⇌	$2\ H_2O$	Circle one: **C**
$C_6H_5O^- + H_2O$	⇌	$OH^- + HC_6H_5O$	Circle one: **E**
$C_6H_5O^- + H_3O^+$	⇌	$H_2O + HC_6H_5O$	Circle one: **F**

1d.

X 0.10 mol HC_6H_5O + 0.10 mol $C_6H_5O^-$ in 1 L H_2O

☐ 0.10 mol H_3O^+ + 0.10 mol $C_6H_5O^-$ in 500 mL H_2O

X 0.10 mol HC_6H_5O + 0.040 mol OH^- in 250 mL H_2O

☐ 0.10 mol HC_6H_5O + 0.18 mol OH^- in 300 mL H_2O

X 5.0 g HC_6H_5O + 4.0 g NaC_6H_5O in 400 mL H_2O

1e. 9.84

1f. 9.93

1f. 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. $\Delta S^o = 274.1$ J/mol rxn K; favored

6b. $\Delta G^o = -824.9$ 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. $\Delta G = -10.8$ kJ/mol rxn; Yes, spontaneous

8b $K_p = 0.15$

8c. 324 K