CHEM 1515 Sections 20511 and 20516
Exam III
John III. Gelder
April 7, 2021

Name ________________________

TA's Name ________________________

Section (CRN): ________________________

INSTRUCTIONS:

1. This examination consists of a total of 9 different pages. The last two pages include a periodic table, some useful relationships, a table of equilibrium values and a Solubility Table. All work should be done in this booklet.

2. PRINT your name, TA's name and circle your lab CRN number <u>now</u> in the space at the top of this sheet. <u>DO NOT SEPARATE THESE PAGES</u>.

3. Answer all questions that you can and whenever called for show your work clearly. Your method of solving problems should pattern the approach used in lecture. You do not have to show your work for the multiple choice or short answer questions.

4. No credit will be awarded if your work is not shown in Questions 2b, 3, 4 and 5.

5. Point values are shown next to the problem number.

6. Budget your time for each of the questions. Some problems may have a low point value yet be very challenging. If you do not recognize the solution to a question quickly, skip it, and return to the question after completing the easier problems.

7. Look through the exam before beginning; plan your work; then begin.

8. Relax and do well.

	Page 2	Page 3	Page 4	Page 5	Page 6	Page 7	TOTAL
SCORES	____	____	____	____	____	____	____
	(18)	(10)	(24)	(18)	(16)	(17)	(103)

(6) 1. Write the chemical formula(s) of the product(s) and balance the following reactions. Identify all products phases as either (g)as, (l)iquid, (s)olid or (aq)ueous. Soluble ionic compounds should be written in the form of their component ions.

a) $\mathbf{2}\ HBr(aq) + Mg(OH)_2(aq) \rightarrow \mathbf{Mg^{2+}(aq) + 2\ Br^{-}(aq) + 2\ H_2O(l)}$

b) $HC_7H_5O_2(aq) + NH_3(aq) \rightarrow \mathbf{NH_4^{+}(aq) + C_7H_5O_2^{-}(aq)}$

(12) 2a. Write the ionic and net ionic chemical equation for 1a). (4)

Ionic equation

Net Ionic equation

2b) Based on the net ionic equation determine the value of K for the reactions in Question 1. (8)

i) 1a

ii) 1b

$$HC_7H_5O_2(aq) \rightarrow H^+(aq) + C_7H_5O_2^-(aq) \qquad K_a = 1.8 \times 10^{-5}$$

$$NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq) \qquad K_b = 1.8 \times 10^{-5}$$

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l) \qquad K_w = \frac{1}{1.0 \times 10^{-14}}$$

$$HC_7H_5O_2(aq) + NH_3(aq) \rightarrow NH_4^+(aq) + C_7H_5O_2^-(aq) \qquad K = K_a \cdot K_b \cdot \frac{1}{1.0 \times 10^{-14}}$$

$$K = 3.2 \times 10^4$$

(For Questions 3, 4 and 5 you must show a reasonable amount of work including your chemical equation(s); equilibrium expression(s) where appropriate; and problem set-up(s) for full credit.)

(10) 3. Calculate the pH of a 0.500 M $HC_3H_5O_2$ (propionic acid) solution.

	$HC_3H_5O_2(aq)$ ⇌	$C_3H_5O_2^-(aq)$ +	$H^+(aq)$
I	**0.500 M**	**0**	**0**
C	**–x**	**+x**	**+x**
E	**0.500 – x**	**0 + x**	**0 + x**

$$K_a = 1.3 \times 10^{-5} = \frac{[C_3H_5O_2^-][H^+]}{[HC_3H_5O_2]}$$

$$1.3 \times 10^{-5} = \frac{[x][x]}{[0.500 - x]} \quad x <<< 0.500$$

$$2.55 \times 10^{-3} = x = [H^+]$$

$$pH = -\log [H^+] = -\log [2.55 \times 10^{-3}] = 2.59$$

(24)4. a) Calculate the pH of a 250. mL sample of a buffer solution that is 0.550 M NH_3 and 0.450 M NH_4Cl. (10)

	$NH_3(aq)$	+ $H_2O(l)$ ⇌	$NH_4^+(aq)$	+ $OH^-(aq)$	
I	**0.550 M**	**-**	**0.450 M**	**~1 x 10^{-7}**	
C	**-x**	**-**	**+x**	**+x**	**x=$[NH_3]_{reacting}$**
E	**0.550 - x**	**-**	**0.450 + x**	**+x**	

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

$$1.8 \times 10^{-5} = \frac{(0.450 + x)(+x)}{0.500 - x} \qquad x < 0.450$$

$$1.8 \times 10^{-5} = \frac{(0.450)(x)}{0.500}$$

$$2.0 \times 10^{-5} = x = [OH^-]$$

pOH = - log [OH⁻] = - log [2.0 x 10^{-5}] = 4.70 **pH = 14 – pOH = 14 – 4.70 = 9.30**

b) Calculate the pH of the buffer solution above after the addition of 0.015 mol of NaOH*(s)*. Assume no change in volume. (14)

$$\text{moles } NH_4^+(aq) = \frac{0.450 \text{ mol}}{L}(0.250 \text{ L}) = 0.1125 \text{ mol}$$

$$\text{moles } NH_3(aq) = \frac{0.550 \text{ mol}}{L}(0.250 \text{ L}) = 0.1375 \text{ mol}$$

	$NH_4^+(aq)$ +	$OH^-(aq)$ ⇌	NH_3 +	$H_2O(l)$
I	**0. 1125 mol**	**0.015 mol**	**01375**	**-**
C	**–0.015**	**–0.015**	**+0.015**	
F	**0.0975 mol**	**0**	**0.1525 mol**	**-**

$$[NH_4^+] = \frac{0.0975 \text{ mol}}{0.250 \text{ L}} = 0.39 \text{ M} \qquad [NH_3] = \frac{0.1525 \text{ mol}}{0.250 \text{ L}} = 0.61 \text{ M}$$

	$NH_3(aq)$	+ $H_2O(l)$ ⇌	$NH_4^+(aq)$	+ $OH^-(aq)$	
I	**0.61 M**	**-**	**0.39 M**	**~1 x 10^{-7}**	
C	**-x**	**-**	**+x**	**+x**	**x=$[NH_3]_{reacting}$**
E	**0.61 - x**	**-**	**0.39 + x**	**+x**	

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

$$1.8 \times 10^{-5} = \frac{(0.39 + x)(+x)}{0.61 - x} \qquad x < 0.39$$

$$1.8 \times 10^{-5} = \frac{(0.39)(x)}{0.61}$$

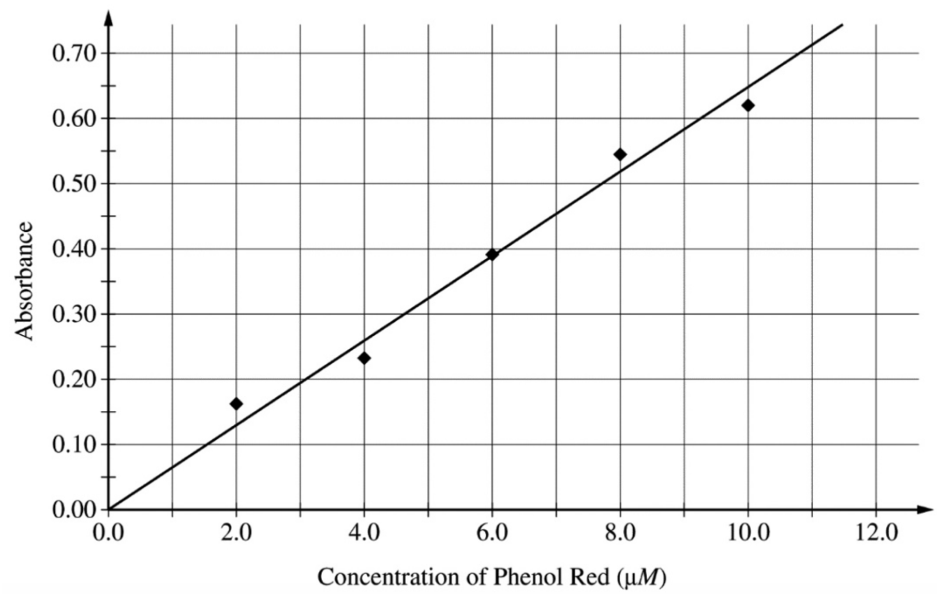
$$2.8 \times 10^{-5} = x = [OH^-]$$

pOH = - log [OH⁻] = - log [2.8 x 10^{-5}] = 4.55
pH = 14 – pOH = 14 – 4.55 = 9.45

(18)5.a) Calculate the pH at the equivalence point for a titration when 0.120 M NaOH was used to neutralize 10.00 mL of 0.130 M solution of butanoic acid, $HC_4H_7O_2$.

(16) 6. Phenol red is an acid-base indicator that can be used to identify the approximate equivalence point of a titration. In a basic solution the indicator is pink. A student analyzes a sample solution using a spectrophotometer set at a wavelength of 560 nm, a wavelength where phenol red has a maximum absorbance. The student records the absorbance of 0.325 for the sample solution.

a) Based on the standard curve shown below, what is the concentration of the sample solution in micromoles per liter (μM)? (4)



b) If 10 mL of the sample solution is mixed with 10 mL of distilled water, would the absorbance of the diluted solution be less than, greater than or equal to the absorbance of the original undiluted sample solution? Justify your answer. (6)

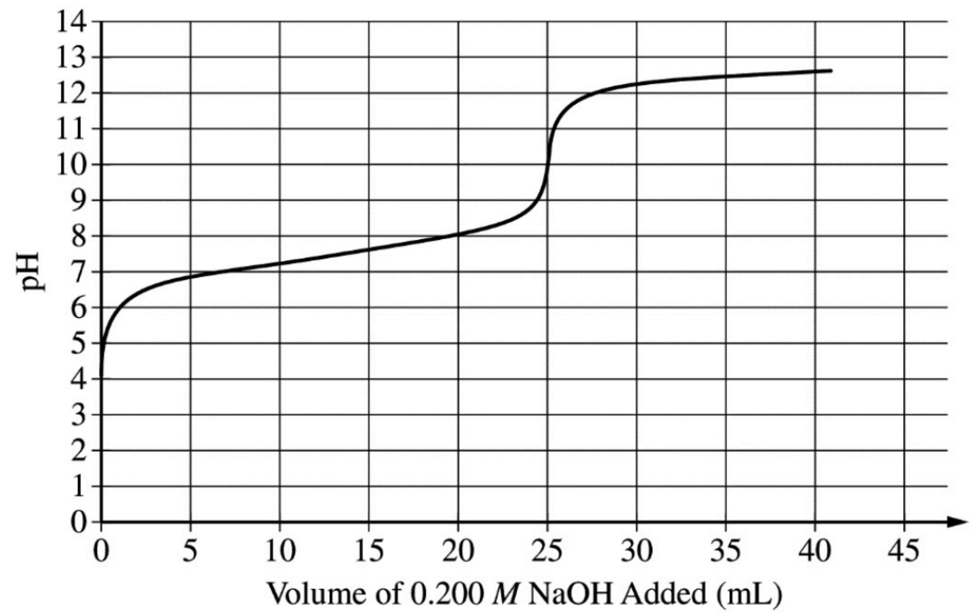
c) If the absorbance of the original sample solution is measured using the same spectrometer, but at a wavelength of 650 nm, would the absorbance be less than, greater than, or equal to the absorbance of the solution measured at 560 nm? Justify your answer. (6)

$$HClO(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + ClO^-(aq)$$

(17) 7. The reaction between hypochlorous acid and water is represented above.

(a) Identify one of the conjugate acid-base pairs in the reaction. (4)

(b) Shown in the graph below is the titration curve that results when 25.0 mL of 0.200 M HClO is titrated with 0.200 M NaOH. Carefully draw a second curve on the graph that would result from the titration of 25.0 mL of 0.200 M $HClO_4$ with 0.200 M NaOH. (7)



(c) A student proposes creating a buffer by dissolving 0.010 mol of $NaClO_4(s)$ in 100. mL of 0.100 M $HClO_4$. Explain why the resulting solution would not be a buffer. (6)

Periodic Table of the Elements

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1 **H** 1.008																	2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** 226.0	89 **Ac** 227.0	104 (261)	105 (262)	106 (263)												

Lanthanides	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.2	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
Actinides	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Useful Information

$pH = -\log[H^+]$ $pOH = -\log[OH^-]$ $pH + pOH = 14$ $K_w = 1.00 \times 10^{-14}$

$A = \varepsilon \cdot l \cdot c$

Name	Formula	K_{a1}	K_{a2}	K_{a3}
Acetic	$HC_2H_3O_2$	1.8×10^{-5}		
Benzoic	$HC_7H_5O_2$	6.5×10^{-5}		
Butanoic acid	$HC_4H_7O_2$	1.5×10^{-5}		
Carbonic	H_2CO_3	4.3×10^{-7}	5.6×10^{-11}	
Citric	$H_3C_6H_5O_2$	7.4×10^{-4}	1.7×10^{-5}	4.0×10^{-7}
Hydrocyanic	HCN	4.9×10^{-10}		
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}		
Hypochlorous	$HClO$	3.0×10^{-8}		
Nitrous	HNO_2	4.5×10^{-4}		
Phosphoric	H_3PO_4	7.5×10^{-3}	6.2×10^{-8}	4.2×10^{-13}
Propionic	$HC_3H_5O_2$	1.3×10^{-5}		
Sulfuric	H_2SO_4	strong acid	1.2×10^{-2}	

E.2 DISSOCIATION CONSTANTS FOR BASES AT 25˚C

Name	Formula	K_b	Name	Formula	K_b
Ammonia	NH_3	1.8×10^{-5}			
Aniline	$C_6H_5NH_2$	4.3×10^{-10}	Methylamine	CH_3NH_2	4.4×10^{-4}
Dimethylamine	$(CH_3)_2NH$	5.4×10^{-4}	Trimethylamine	$(CH_3)_3N$	6.4×10^{-5}
Ethylamine	$C_2H_5NH_2$	6.4×10^{-4}			

Solubility Table

Ion	Solubility	Exceptions
NO_3^-	soluble	none
ClO_4^-	soluble	none
Cl^-	soluble	except Ag^+, Hg_2^{2+}, *Pb^{2+}
I^-	soluble	except Ag^+, Hg_2^{2+}, Pb^{2+}
SO_4^{2-}	soluble	except Ca^{2+}, Ba^{2+}, Sr^{2+}, Hg^{2+}, Pb^{2+}, Ag^+
CO_3^{2-}	insoluble	except Group IA and NH_4^+
PO_4^{3-}	insoluble	except Group IA and NH_4^+
^-OH	insoluble	except Group IA, *Ca^{2+}, Ba^{2+}, Sr^{2+}
S^{2-}	insoluble	except Group IA, IIA and NH_4^+
Na^+	soluble	none
NH_4^+	soluble	none
K^+	soluble	none

*slightly soluble