Exam 3A
Chem 1142
Spring 2017

Name: KEY

MULTIPLE CHOICE. [3 pts ea.] Record the best response on the scantron sheet. [**45 pts total.**]

Assume all solutions are aqueous and at a temperature of 25 °C, unless stated otherwise.

Q1. Which version of the exam do you have?
a) 3A
b) 3B

Q2. For the chemical equilibrium:

$$HCOOH(aq) + HCO_3^-(aq) \rightleftharpoons H_2CO_3(aq) + HCOO^-(aq)$$

a conjugate acid-base pair would be:
a) $HCOOH$ & H_2CO_3
b) $HCOOH$ & HCO_3^-
c) $HCOOH$ & $HCOO^-$
d) H_2CO_3 & $HCOOH$

Q3. What is the concentration of $[OH^-]$ in a solution which has $[H^+] = 2.5 \times 10^{-10}$ M?
a) 2.5×10^{-10} M
b) 3.0×10^{-5} M
c) 1.6×10^{-5} M
d) 4.0×10^{-5} M

Q4. What is the pH of a solution with $[OH^-] = 1.4 \times 10^{-9}$ M?
a) 8.85
b) 5.15
c) 1.40
d) 9.95

Q5. What is the pOH of 0.30 M $Ba(OH)_2(aq)$?
a) 0.52
b) 1.52
c) 0.22
d) 0.60

Q6. Which of the following acids will have the <u>lowest</u> pH at a concentration of 0.10 M?

HF, $K_a = 7.1 \times 10^{-4}$ **HCO₂H**, $K_a = 1.7 \times 10^{-4}$ **CH₃CO₂H**, $K_a = 1.8 \times 10^{-5}$

a) HF
b) HCO_2H
c) CH_3CO_2H
d) All three acids will have the same pH

Q7. The base dissociation constant (K_b) for CH_3NH_2 is 4.4×10^{-4}. Which of the following is the correct conjugate acid and its K_a?

a) CH_3NH^+ $K_a = 2.3 \times 10^{-4}$
b) CH_3NH^+ $K_a = 2.3 \times 10^{-11}$
c) $CH_3NH_3^+$ $K_a = 2.3 \times 10^{-4}$
d) $CH_3NH_3^+$ $K_a = 2.3 \times 10^{-11}$

Q8. Predict which of the following salts will be acidic:
a) $AlCl_3$
b) KNO_3
c) $Ba(C_2H_3O_2)_2$
d) $LiNO_2$

Q9. A Lewis acid is a(n):
a) H^+ donor
b) electron acceptor
c) OH^- ion producer
d) reducing agent

Q10. Formic acid, HCOOH, can form a buffer when combined with:
a) HCOOLi
b) H_2CO_3
c) NH_3
d) CH_3COONa

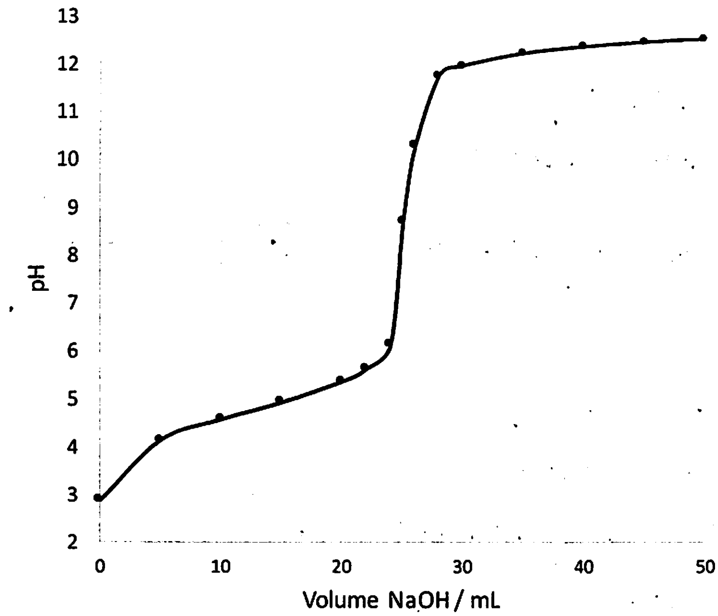
Q11. What pH is required to ensure the ratio of $[NH_3]/[NH_4^+]$ is 100?
Note: K_a $(NH_4^+) = 1.8 \times 10^{-5}$?
a) 3.74
b) 6.74
c) 9.74
d) 10.74

Q12. Which is the correct mathematical expression for K_{sp} $(Mg_3(PO_4)_2)$?
a) $[Mg^{2+}][PO_4^{3-}]$
b) $[Mg_3^{2+}][2PO_4^{3-}]$
c) $[Mg]^2[PO_4]^3$
d) $[Mg^{2+}]^3[PO_4^{3-}]^2$

Q13. The molar solubility of CaF_2 is 2.2×10^{-4} M. What is K_{sp} equal to?
a) 4.3×10^{-11}
b) 4.8×10^{-8}
c) 1.1×10^{-11}
d) 2.2×10^{-4}

Q14. If Q_{sp} for an ionic compound in solution is greater than K_{sp}, what will happen?
a) Nothing—the solution is saturated
b) More solute can dissolve—the solution is un-saturated
c) Solute will precipitate—the solution is super-saturated
d) The solution will cool down until $Q_{sp} = K_{sp}$

Q15. What would be the best pH indicator to use in the titration of CH_3CO_2H vs. NaOH? Its titration curve is given below:



The choice of indicators are:

Indicator	Color: In Acid	Color: In Base	pH Range
Methyl orange	Orange	Yellow	3.1 – 4.4
Methyl red	Red	Yellow	4.2 – 6.3
Cresol red	Yellow	Red	6.2 – 8.8
Alizarin	Yellow	Red	10.1 – 12

a) Methyl orange
b) Methyl red
c) Cresol red
d) Alizarin

Short Response.

Show ALL work to receive credit.

Q16. [10 pts.] (a) Show how to, and then calculate, the pH of 0.040 M $HNO_3(aq)$.

$$HNO_3 \xrightarrow{100\%} H^+ + NO_3^-$$ +1 eq

0.040M ⟶ 0.040M 0.040M

+1 ans

$$pH = -\log_{10}[H^+] = -\log_{10}[0.040] = \boxed{1.40}$$ (2dp) 3

$-\frac{1}{2}$

+1 pH eq

(b) Show how to, and then calculate, the pH of 0.040 M $Ba(OH)_2(aq)$

$$Ba(OH)_2 \xrightarrow{100\%} Ba^{2+} + 2OH^-(aq)$$ eq

0.040M ⟶ 0.040M 0.080M +1

+1 pOH

$$pOH = \cancel{H} -\log_{10}[OH^-] = -\log_{10}[0.080] = 1.10$$ 4

$$pH = 14.00 - pOH = \boxed{12.90}$$ (2dp.)

+1 pH eq +1 ans $-\frac{1}{2}$

(c) Calculate the concentration of OH^- ions in the solution described in part (a).

$$K_w = [H^+][OH^-]$$ +1

+1 +1

$$\Rightarrow [OH^-] = \frac{K_w}{[H^+]} = \frac{1.0\times10^{-14}}{0.040} = \boxed{2.5\times10^{-13}\ M}$$ 3

OR $-\frac{1}{2}$ sf., units.

or ... $pOH = 14.00 - pH = 12.60$ } +1

$$\underbrace{[OH^-] = 10^{-pOH}}_{+1} = 10^{-12.60} = 2.5\times10^{-13} M$$

+1

Q17. [15 pts.] Calculate the pOH and pH of 0.25 M NH_3. K_b (NH_3) = 1.8×10^{-5}. Show all work, including a properly labelled ICE chart, as well as the correct chemical equation for the K_b reaction.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

	$NH_3(aq)$	$H_2O(l)$	$NH_4^+(aq)$	$OH^-(aq)$
I	0.25	—	0	≈ 0
C	$-x$	—	$+x$	$+x$
E	$(0.25-x)$	—	(x)	(x)

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]_{eq}} = 1.8\times10^{-5} = \frac{x^2}{0.25-x} \approx \frac{x^2}{0.25} \text{, if } x \ll 0.25$$

$$\Rightarrow 1.8\times10^{-5} = \frac{x^2}{0.25} \Rightarrow x^2 = 0.25\times1.8\times10^{-5}$$

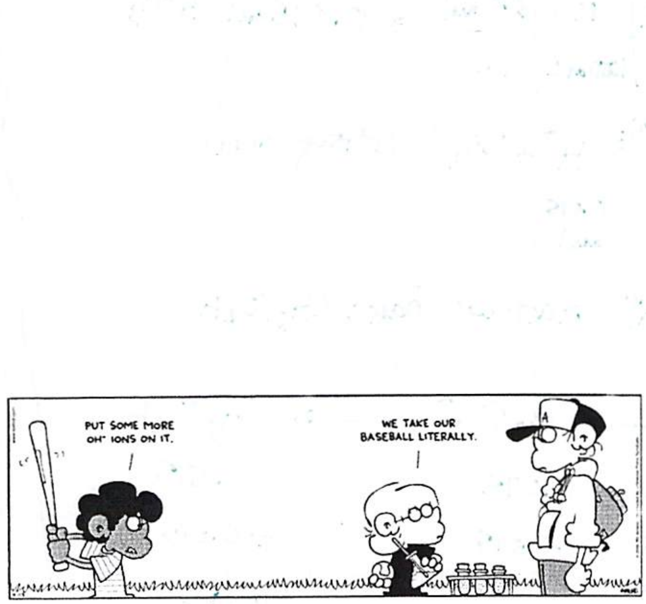
$$\Rightarrow x = \sqrt{0.25\times1.8\times10^{-5}} = 2.\underline{1}2\times10^{-3}$$

($\ll 5\%$, so OK!)

$[OH^-] = x = 2.\underline{1}2\times10^{-3}\,M$ (2s.f.)

$pOH = -\log_{10}[OH^-] = -\log_{10}(x) = 2.67$ (2dp.)

$pH + pOH = 14.00 \Rightarrow pH = 14.00 - pOH = 11.33$



$$\underset{0.30M}{CH_3CO_2Na} \xrightarrow{100\%} \underbrace{\underset{0.30M}{CH_3CO_2^-}}_{\text{conj. base of } CH_3CO_2H} + \underset{0.30M}{Na^+}$$

Q18. [15 pts.] (a) Using the Henderson-Hasselbalch equation, calculate the pH of a solution that is 0.50 M in $CH_3CO_2H(aq)$ as well as 0.30 M in $CH_3CO_2Na(aq)$. Note: K_a (CH_3CO_2H) = 1.8×10^{-5}.

acid — base — acid

$$pH = pK_a + \log \frac{[base]}{[acid]}$$

$$pK_a = -\log_{10}(K_a) = -\log_{10}(1.8 \times 10^{-5}) = 4.74 \text{ (2dp)}$$

$$\Rightarrow pH = 4.74 + \log\left(\frac{0.30M}{0.50M}\right) = 4.52$$

(b) Calculate the new pH of 250-mL of the solution described in part (a) to which 5.0 mL of 3.0 M $HNO_3(aq)$ has been added. Comment on your final result. Be sure to show all relevant chemical equations, and clearly show your work using an ICE chart.

best to work w/ # mol since Vol change!

mol CH_3CO_2H

$$250mL \times \frac{1L}{1000mL} \times \frac{0.50mol}{1L} = 0.125 mol\ CH_3CO_2H$$

mol $CH_3CO_2^-$

$$250mL \times \frac{1L}{1000mL} \times \frac{0.30mol}{1L} = 0.075 mol\ CH_3CO_2H$$

mol HNO_3

$$5.0mL \times \frac{1L}{1000mL} \times \frac{3.0mol}{1L} = 0.015mol\ HNO_3$$

$$\underset{0.015\ mol}{HNO_3} \xrightarrow{100\%} \underset{0.015\ mol}{H^+} + NO_3^- \text{ (strong acid)}$$

H^+ will react w/ base: CH_3CO_2H

	H^+	+ $CH_3CO_2^-$	$\longrightarrow CH_3CO_2H$
I	0.015	0.075	0.125
C	−0.015	−0.015	+0.015
E (final)	0	0.060	0.140

$$[CH_3CO_2^-] = \frac{0.060mol}{0.255L} = 0.235M$$

250mL + 5mL

$$[CH_3CO_2H] = \frac{0.140mol}{0.255L} = 0.549M$$

$$pH = pK_a + \log b/a$$

$$= 4.74 + \log \frac{0.235M}{0.549M}$$

$$= \boxed{4.38}$$

$-\frac{1}{2}$ charges, state symbols, $\rightleftharpoons$

Q19. [15 pts.] (a) Write out the chemical equation for the reaction corresponding to $K_{sp}(Ag_2SO_4)$.

$$Ag_2SO_4(s) \rightleftharpoons 2Ag^+(aq) + SO_4^{2-}(aq) \qquad +3$$

(b) Using an ICE chart, calculate the molar solubility of silver sulfate (Ag_2SO_4) in water, given that $K_{sp} = 1.4 \times 10^{-5}$.

$$Ag_2SO_4(s) \rightleftharpoons 2Ag^+(aq) + SO_4^{2-}(aq)$$

	$Ag_2SO_4(s)$	$2Ag^+(aq)$	$SO_4^{2-}(aq)$	
I	—	0	0	+2
C	"−s"	+2s	+s	
E	—	(2s)	(s)	

$$K_{sp} = [Ag^+]^2[SO_4^{2-}]_{eq} = 1.4 \times 10^{-5} = (2s)^2(s) = 4s^3 \quad +2$$

$$s = \sqrt[3]{\frac{K_{sp}}{4}} = \sqrt[3]{\frac{1.4 \times 10^{-5}}{4}} = 0.015\,M \quad +2$$

$-\frac{1}{2}$ units/sf

(c) Calculate the molar solubility of silver sulfate in 1.35 M $Na_2SO_4(aq)$. Be sure to show all relevant chemical equations, and clearly show your work using an ICE chart. Comment on your final result.

$$\underset{1.35M}{Na_2SO_4} \rightarrow \underset{2.70M}{2Na^+(aq)} + \underset{1.35M}{SO_4^{2-}(aq)}$$

common ion!

Green exam

S = 0.0012M in part (c)

$$Ag_2SO_4(s) \rightleftharpoons 2Ag^+(aq) + SO_4^{2-}(aq)$$

	$Ag_2SO_4(s)$	$2Ag^+(aq)$	$SO_4^{2-}(aq)$	
I	—	0	1.35	+1
C	"−s"	+2s	+s	+1
E	—	(2s)	(1.35+s)	

$$K_{sp} = [Ag^+]^2[SO_4^{2-}]_{eq} = 1.4 \times 10^{-5} = (2s)^2(1.35+s)$$

if $s \ll 1.35$, can write:

$$1.4 \times 10^{-5} \approx 4s^2 \times (1.35) = 5.40s^2 \quad +2$$

$$\Rightarrow \quad s = \sqrt[2]{\frac{1.4 \times 10^{-5}}{5.40}}$$

$$= 0.0016M \quad +1$$

– much less soluble than in pure water! +1

"This is a lovely old song that tells of a young woman who leaves her cottage, and goes off to work. She arrives at her destination, and places some solid NH_4HS in a flask containing 0.50 atm of ammonia, and attempts to determine the pressures of ammonia and hydrogen sulfide when equilibrium is reached."

Useful Information

Periodic Table of the Elements

IA 1	IIA 2	3	4	5	6	7	8	9	10	11	12	IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	VIIIA 18
1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	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** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92160	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
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** 127.60	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba*** 137.3	71 **Lu** 175.0	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** [210]	85 **At** [210]	86 **Rn** [222]
87 **Fr** [223]	88 **Ra**** [226]	103 **Lr** [262]	104 **Rf** [261]	105 **Db** [262]	106 **Sg** [266]	107 **Bh** [264]	108 **Hs** [265]	109 **Mt** [268]	110 [269]	111 [272]	112 [277]	113	114 [285]	115	116 [289]	117	118 [293]

*	57 **La** 138.9	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** 157.3	65 **Tb** 158.9	66 **Dy** 162.50	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0
**	89 **Ac** [227]	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** [237]	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]

$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$

$$R = 8.3145 \frac{\text{J}}{\text{mol} \cdot \text{K}} = 0.08206 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}}$$

$$M_1V_1 = M_2V_2$$

$\text{pH} = -\log_{10}[\text{H}^+]$

$\text{pH} + \text{pOH} = 14.00\ (25\ ^\circ\text{C})$

$K_w = 1.0 \times 10^{-14}\ (25\ ^\circ\text{C})$

$K_a \cdot K_b = K_w$

$$\text{pH} = \text{p}K_a + \log \frac{[\text{Base}]}{[\text{Acid}]}$$

$K_p = K_c(RT)^{\Delta n_g}$

Given: $ax^2 + bx + c = 0$, then $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

+ HCOONa Matata