Chem 1142—Exam 3A

Spring 2011 **Name:** KEY

Multiple Choice. [5 pts. Each]
Circle the best response.

Q1. A Brønsted acid is:
a) a proton acceptor
b) a proton donor
c) an electron-pair donor
d) an electron-pair acceptor
e) a substance that ionizes to produce H_3O^+ ions.

Q2. The pH of 0.20 M $Sr(OH)_2(aq)$ is: Don't forget to account for the fact that it forms 2 × OH^- ions for every 1 × $Sr(OH)_2$!

$$\underset{0.20M}{Sr(OH)_2(aq)} \longrightarrow \underset{0.20M}{Sr^{2+}(aq)} + \underset{0.40M}{2OH^-(aq)}$$

a) 0.70
b) 0.40
c) 1.00
d) 13.30
e) 13.60

Q3. A weak acid:
a) Has a high pH
b) Has a low pH
c) Has a pH close to 7.00
d) Partially ionizes in water
e) Is chemically unreactive

Q4. Which of the following has the **greatest** molar solubility?
a) PbF_2 ; K_{sp} = 4.1 x 10^{-8}
b) CaF_2 ; K_{sp} = 4.0 x 10^{-11}
c) BaF_2 ; K_{sp} = 1.7 x 10^{-6}
d) Ag_2SO_4 ; K_{sp} = 1.4 x 10^{-5}

Q5. An aqueous solution of NH_4Br is:
a) Acidic
b) Basic
c) Neutral
d) Not enough information to give an answer

Q6. K_{sp} for $PbCl_2$ is 2.4 x 10^{-4}. What is the molar solubility of $PbCl_2$?
a) 6.2 x 10^{-2} M
b) 3.9 x 10^{-2} M
c) 2.4 x 10^{-4} M
d) 7.7 x 10^{-3}
e) 6.0 x 10^{-5} M

Short Response Questions. Show ALL work to receive credit.

Q7. [10 pts.] Calculate the pH of a 0.10 M aqueous solution of NaF(aq), given K_a (HF) = 7.1 x 10^{-4}.

$$\underset{0.10M}{NaF(aq)} \longrightarrow \underset{\substack{0.10M \\ (neutral)}}{Na^+(aq)} + \underset{\substack{0.10M \\ (basic)}}{F^-(aq)}$$

$$F^-(aq) + H_2O(l) \xrightarrow{H^+} HF(aq) + OH^-(aq)$$

	$F^-(aq)$	$H_2O(l)$	$HF(aq)$	$OH^-(aq)$
I	0.10M	—	0	≈0
C	−x	—	+x	+x
E	(0.10−x)	—	(x)	(x)

$$K_b = \frac{[HF][OH^-]}{[F^-]_{eq}}$$

$$\underset{HF}{K_a} \cdot \underset{F^-}{K_b} = K_w \Rightarrow K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{7.1\times10^{-4}} = 1.41\times10^{-11}$$

(conj. pair)

$$\Rightarrow 1.41\times10^{-11} = \frac{(x)(x)}{0.10-x} \approx \frac{x^2}{0.10} \quad (\text{assuming } x \ll 0.10)$$

$$\Rightarrow \sqrt{x^2} = \sqrt{0.10 \times 1.41\times10^{-11}}$$

$$\Rightarrow x = 1.19\times10^{-6}$$

% ionization = $\frac{x}{0.10}\times100$ (<5%) ✓

$$pOH = -\log[OH^-] = -\log(\underset{\substack{\uparrow \\ 2sf}}{x}) = \underset{\substack{\uparrow \\ 2d.p.}}{5.926}$$

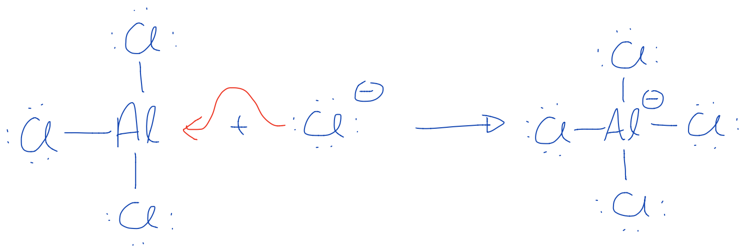
$$pH + pOH = 14.00$$
$$\Rightarrow pH = 14.00 - pOH = 8.07 \quad (2d.p.)$$

<u>Comment?</u> Basic (pH >7) 2nd comment: assumption that init conc of OH^- ≈0 <u>may</u> be poor. Should use 1.0×10^{-7}M.

Q8. [10 pts.] Identify (and explain how you identified) the Lewis acid and base in the following reaction:

$AlCl_3 + Cl^- \rightarrow AlCl_4^-$

Be sure to write valid Lewis structures as part of your answer.



$AlCl_3$ = Lewis acid (it accepted e^- pair)

Cl^- = Lewis base (it donated e^- pair)

(Al is e^- deficient, like B)

Q9. [6 pts.] The pK_as of two monoprotic acids, HA and HB, are 5.9 and 8.1 respectively. Which of the two is the stronger acid?

stronger acid!

$$pK_a = -\log(K_a)$$

$$\Rightarrow K_a = 10^{-pK_a}$$

$\Rightarrow$ lower pK_a = higher K_a = stronger acid.

Q10. [10 pts.] Write formulas for the following compounds:

a) lithium phosphate Li^+ PO_4^{3-} = $\boxed{Li_3PO_4}$

b) ammonium bicarbonate NH_4^+ HCO_3^- = $\boxed{NH_4HCO_3}$

c) sulfuric acid $\boxed{H_2SO_4}$

d) calcium sulfate dihydrate Ca^{2+} SO_4^{2-} $\cdot 2H_2O$ = $\boxed{CaSO_4 \cdot 2H_2O}$

e) trisulfur heptabromide tri=3 hepta=7 $\Rightarrow$ $\boxed{S_3Br_7}$

Q11. [15 pts.] Calculate the pH of a buffer with an acetic acid concentration of 0.900 M, and a sodium acetate concentration of 0.500 M. What will the pH of the buffer change to if 5.00 mL of 12.0 M HCl is added to 125 mL of this buffer? K_a ($HC_2H_3O_2$) = 1.8 x 10^{-5}.

H-H eqn! $pH = pK_a + \log \frac{[base]}{[acid]} = -\log(1.8\times10^{-5}) + \log \frac{0.500M}{0.900M} = 4.49$

#mol HCl $\frac{5.00mL}{} \left| \frac{1L}{1000mL} \right| \frac{12.0 mol HCl}{1L} = 0.0600 mol HCl$

$HCl \longrightarrow H^+ + Cl^-$ (strong acid!)

$\Rightarrow \boxed{0.0600 mol H^+}$

#mol CH_3CO_2H $\frac{125mL}{} \left| \frac{1L}{1000mL} \right| \frac{0.900 mol CH_3CO_2H}{1L} = 0.1125 mol CH_3CO_2H$

#mol $CH_3CO_2^-$ $\frac{125mL}{} \left| \frac{1L}{1000mL} \right| \frac{0.500 mol CH_3CO_2^-}{1L} = 0.0625 mol CH_3CO_2^-$

HCl/H^+ will react w/ base in buffer!

	$H^+(aq)$ +	$CH_3CO_2^-(aq)$ →	$CH_3CO_2H(aq)$
I(mol)	0.0600	0.0625	0.1125
C	−0.0600	−0.0600	+0.0600
E	0	0.0025	0.1725

New volume = 130. mL = 0.130 L

$[CH_3CO_2^-] = \frac{0.0025 mol}{0.130 L} = 0.0192 M$

$[CH_3CO_2H] = \frac{0.1725 mol}{0.130 L} = 1.327 M$

$pH = pK_a + \log \frac{[base]}{[acid]} = -\log(1.8\times10^{-5}) + \log \frac{0.0192M}{1.327M}$

$= \boxed{2.91}$

Comment: HCl almost neutralized all the base in our buffer! Since ratio of base:acid is almost 1:100, H-H eq is @ limit of usefulness!

Q12. [10 pts.] 15.4 g of $H_2(g)$ is reacted with 18.3 g of $N_2(g)$ and forms 10.9 g of $NH_3(g)$. Calculate the percent yield of this reaction.

Balanced eq: $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

XS

$15.4g H_2 \times \frac{1 mol H_2}{2.02g H_2} \times \frac{2 mol NH_3}{3 mol H_2} \times \frac{17.04g NH_3}{1 mol NH_3} = 86.6g NH_3$

LR

$18.3g N_2 \times \frac{1 mol N_2}{28.02g N_2} \times \frac{2 mol NH_3}{1 mol N_2} \times \frac{17.04g NH_3}{1 mol NH_3} = 22.3g NH_3$ *

$\% yield = \frac{actual}{theoretical} \times 100 = \frac{10.9g}{22.3g} \times 100 = 48.9\%$ (3 s.f.)

Q13. [10 pts.] How many grams of $CaCO_3$ will dissolve in 300. mL of 0.050 M $Ca(NO_3)_2$(aq)?
K_{sp} ($CaCO_3$) = 8.7 x 10^{-9}.

common ion

$Ca(NO_3)_2(aq) \longrightarrow Ca^{2+}(aq) + 2NO_3^-(aq)$ [Remember solubility rules from Gen Chem I!]

0.050M 0.050M 0.10M

Ksp rxn:

	$CaCO_3(s)$ $\rightleftharpoons$	$Ca^{2+}(aq)$ +	$CO_3^{2-}(aq)$
I	——	0.050M	0
C	"−s"	+s	+s
E	——	(0.050+s)	(s)

$K_{sp} = [Ca^{2+}][CO_3^{2-}]_{eq}$ assume s<<0.050

$\Rightarrow 8.7\times10^{-9} = (0.050+s)(s) \cong (0.050)(s)$

$\Rightarrow s = \dfrac{8.7\times10^{-9}}{0.050} = 1.7\times10^{-7} M$ assumption was valid!

$300.\,mL \times \dfrac{1\,L}{1000\,mL} \times \dfrac{1.7\times10^{-7}\,mol\ CaCO_3}{1\,L} \times \dfrac{100.09\,g\ CaCO_3}{1\,mol\ CaCO_3} = 5.1\times10^{-6}\,g\ CaCO_3$.

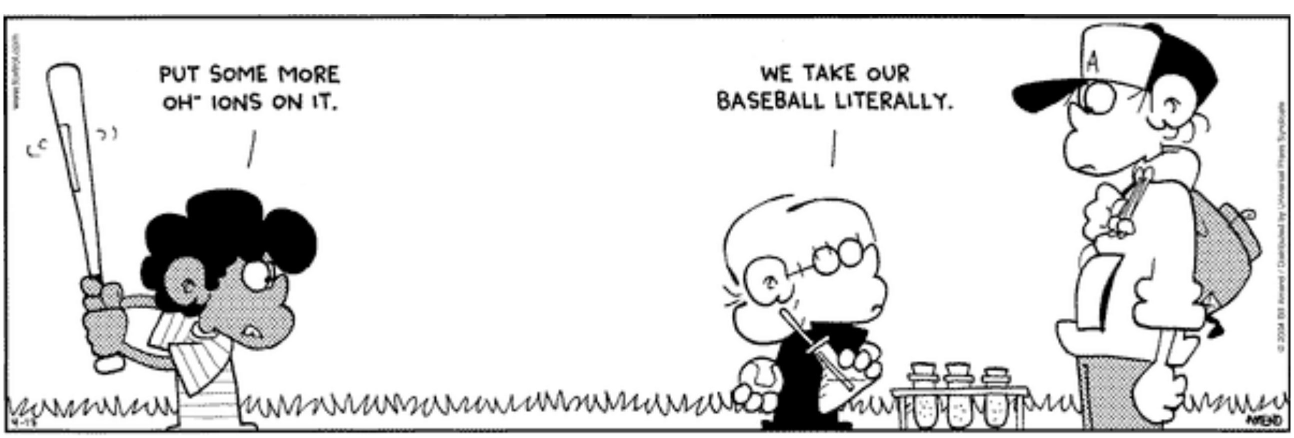
BONUS QUESTION.

H_3PO_4 is a triprotic acid. Write out the chemical reactions corresponding to K_{a1}, K_{a2}, and K_{a3}.

K_{a1}: $H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + H_2PO_4^-(aq)$

K_{a2}: $H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HPO_4^{2-}(aq)$

K_{a3}: $HPO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + PO_4^{3-}(aq)$



Useful Information

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

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

$K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14}$ at 25 °C.

$pH = -\log[H_3O^+]$

$pH + pOH = 14.00$ (at 25 °C)

$K_aK_b = K_w$

$R = 8.314\ \text{J/mol·K} = 0.08206\ \text{L·atm/mol·K}$

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

$M_1V_1 = M_2V_2$

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** 1.01																	2 **He** 4.00
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
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** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba*** 137.33	71 **Lu** 174.97	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.20	83 **Bi** 208.98	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** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** [145]	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04
**	89 **Ac** [227]	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	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]