

Chemistry 210

Exam 3

Be sure to put your name on each page. This page can be removed from your exam so that you will have a Periodic Table handy throughout the exam, it does not need to be turned in. Show all your work for problems which require any sort of calculation, no credit will be given for answers without work shown. If you have shown a significant amount of work or multiple drawings for a problem, draw a box around what you consider your final answer.

Avogadro's Number = 6.022×10^{23} units/mol

$32.00^\circ\text{F} = 0.000^\circ\text{C} = 273.15\text{K}$

Density of Water = $1.000^{\text{g}}/\text{mL}$

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

$PV = nRT$

$\Delta T_{\text{fp/bp}} = k_{\text{fp/bp}} \cdot m \cdot i$

For water, $k_{\text{fp}} = -1.86^\circ\text{C}/m$; $k_{\text{bp}} = 0.52^\circ\text{C}/m$

$P_1 = X_1 P_1^\circ$

$P = cRTi$

$C_1 V_1 = C_2 V_2$

Quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Integrated Rate Laws:

0th order $[A]_t = -kt + [A]_0$

1st order $\ln[A]_t = -kt + \ln[A]_0$

2nd order $1/[A]_t = kt + 1/[A]_0$

$k = Ae^{-E_a/RT}$

$$\ln(k) = \left(\frac{-E_a}{R} \right) \left(\frac{1}{T} \right) + \ln(A)$$

$$\ln\left(\frac{k_1}{k_2} \right) = \frac{E_a}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

$$\text{pH} = \text{p}K_a + \log\left(\frac{[\text{conjugate base}]}{[\text{conjugate acid}]} \right)$$

$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{RT}{nF} \ln Q$

$E^\circ_{\text{cell}} = \frac{RT}{nF} \ln K^\circ$

$K^\circ = e^{(nF/RT) E^\circ_{\text{cell}}}$

$F = 96485 \text{ J}/\text{V}\cdot\text{mol of electrons}$

$\Delta G^\circ = \Delta H^\circ_{\text{system}} - T\Delta S^\circ_{\text{system}}$

$\Delta G^\circ = -nFE^\circ_{\text{cell}} = -RT \ln K^\circ$

$\Delta G = \Delta G^\circ + RT \ln Q$

$F = 96485 \text{ C}/\text{mol electrons}$

$1A = 1 \text{ C} / \text{sec}$

1 H 1.0079																2 He 4.0026	
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	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	57 La 138.91	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 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.03	89 Ac 227.03	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114		116		

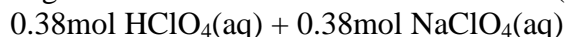
58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.94	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (258)	101 Md (258)	102 No (259)	103 Lr (260)

1. Complete each **row** of the following tables for aqueous solutions at 25°C (4pts per box):

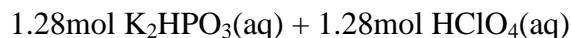
$[\text{H}_3\text{O}^+]$	$[\text{OH}^-]$	pH	pOH	Acidic, Basic or Neutral?
5.37×10^{-6}	1.86×10^{-9}	5.270	8.730	Acidic
1.52×10^{-10}	6.56×10^{-5}	9.817	4.183	Basic

Conjugate Acid	K_a @ 25°C	Conjugate Base	K_b @ 25°C
H_2PO_3^-	1.95×10^{-7}	HPO_3^{2-}	5.13×10^{-8}
HTe^-	1.58×10^{-11}	Te^{2-}	6.33×10^{-4}

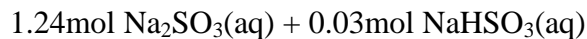
2. Explain why each of the following *does not* result in an effective buffer? (15pts)



This is a combination of a strong acid with its conjugate base. Strong acid/conjugate base and strong base/conjugate acid mixtures do not make effective pH buffers.



The result of mixing these will be a solution of $\text{H}_2\text{PO}_3^-(\text{aq})$, not an effective buffer on its own. This *could* be an effective buffer if only 0.64mols of perchloric acid were used; the result in that case would be 0.64mols $\text{HPO}_3^{2-}(\text{aq})$ and 0.64mols $\text{H}_2\text{PO}_3^-(\text{aq})$, an equimolar mixture of a weak conjugate base and its weak conjugate acid.



The ratio of conjugate acid to conjugate base is not between 0.1 and 10, so this would not make an effective buffer. If more HSO_3^- were used, this would make an effective buffer.

3. How much 1.183M KOH(aq) must be added to 25.00mL of 1.262M HCl(aq) to reach the equivalence point? (14pts)

$$\text{KOH(aq)} + \text{HCl(aq)} \rightleftharpoons \text{H}_2\text{O(l)} + \text{KCl(aq)}$$

$$\left(\frac{1.262\text{mols HCl}}{1\text{L HCl(aq)}}\right)(25.00\text{mL HCl(aq)})\left(\frac{1\text{L}}{1000\text{mL}}\right)\left(\frac{1\text{mol KOH}}{1\text{mol HCl}}\right)\left(\frac{1\text{L KOH(aq)}}{1.183\text{mol KOH}}\right)\left(\frac{1000\text{mL}}{1\text{L}}\right) = 26.67\text{mL KOH(aq)}$$

This could also have been reported as 0.02667L KOH(aq)

4. You have dissolved 11.338g of sodium fluoride in enough water to make 300.0mL of solution. What is the expected pH of this solution? { $K_b(\text{F}^-) = 1.52 \times 10^{-11}$ } (15pts)

	$\text{F}^-(\text{aq}) +$	$\text{H}_2\text{O(l)} \rightleftharpoons$	$\text{OH}^-(\text{aq}) +$	HF(aq)
Initial	$\left(\frac{11.338\text{g}}{41.988\text{g/mol}}\right) / 0.3000\text{L} = 0.900\text{M}$	--	10^{-7}	0
Δ	-x	--	+x	+x
@Equilibrium	$(0.900-x)\text{M}$	--	$(10^{-7}+x)\text{M}$	x M

Plugging in and solving...

$$K_b = \frac{[\text{OH}^-]_{\text{eq}} [\text{HF}]_{\text{eq}}}{[\text{F}^-]_{\text{eq}}} = \frac{(10^{-7} + x)(x)}{(0.900 - x)} \approx \frac{(x)(x)}{(0.900)} \approx 1.52 \times 10^{-11}$$

$$x = 3.70 \times 10^{-6} = [\text{OH}^-]_{\text{eq}}$$

NOTE: 10^{-7} is less than 3% of 3.70×10^{-6} , so our assumption is OK

$$\text{pOH} = -\log(3.70 \times 10^{-6}) = 5.432$$

$$\text{pH} = 14 - \text{pOH} = 14 - 5.432 = 8.568$$

5. What is the expected pH of a buffer prepared by dissolving 13.537g of selenous acid and 14.661g of sodium hydrogen selenite in enough water to make 150.00mL of solution? { $K_a(\text{H}_2\text{SeO}_3) = 2.43 \times 10^{-8}$ } (18pts)

$$\text{p}K_a(\text{H}_2\text{SeO}_3) = -\log(K_a(\text{H}_2\text{SeO}_3)) = -\log(2.43 \times 10^{-8}) = 7.614$$

$$\text{pH} = \text{p}K_a + \log \frac{[\text{HSeO}_3^-]}{[\text{H}_2\text{SeO}_3]} = 7.614 + \log \frac{\left(\frac{14.661\text{g NaHSeO}_3}{150.955\text{g/mol}}\right) / 0.15000\text{L}}{\left(\frac{13.537\text{g H}_2\text{SeO}_3}{128.973\text{g/mol}}\right) / 0.15000\text{L}} = 7.580$$

6. What is the K_a of an acid if 250.0mL of a solution containing 0.318 mol of the acid and 0.393 mol of its conjugate base has a pH of 9.357? Over what pH range would this conjugate acid/ conjugate base pair make an effective buffer? (20pts)

$$pK_a(\text{H}_2\text{SeO}_3) = -\log(K_a(\text{H}_2\text{SeO}_3)) = -\log(2.43 \times 10^{-8}) = 7.614$$

$$pH = pK_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

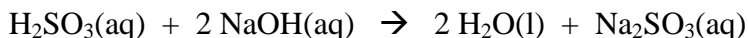
$$9.357 = pK_a + \log \frac{\left(\frac{0.393 \text{ mols A}^-}{0.25000 \text{ L}}\right)}{\left(\frac{0.318 \text{ mols HA}}{0.25000 \text{ L}}\right)}$$

$$pK_a = 9.265$$

$$K_a = 10^{-9.265} = 5.43 \times 10^{-10}$$

This conjugate acid/conjugate base pair will make an effective buffer over the pH range ($pK_a - 1$) to ($pK_a + 1$), so 8.265 to 10.265

7. You have titrated 25.00mL of 0.773M sulfurous acid solution with an unknown sodium hydroxide solution. You reach the second equivalence point when 44.17mL of base is added. What is the concentration of the original stock sodium hydroxide solution? What is the expected pH of the sulfurous acid solution before the titration begins? ($K_{a1}(\text{H}_2\text{SO}_3) = 1.68 \times 10^{-2}$, $K_{a2}(\text{H}_2\text{SO}_3) = 6.42 \times 10^{-8}$) (20pts)



$$\left(\frac{0.773 \text{ mols H}_2\text{SO}_3}{1 \text{ L H}_2\text{SO}_3(\text{aq})}\right) (0.02500 \text{ L H}_2\text{SO}_3(\text{aq})) \left(\frac{2 \text{ mol NaOH}}{1 \text{ mol H}_2\text{SO}_3}\right) \left(\frac{1}{0.04417 \text{ L NaOH}(\text{aq})}\right) = 0.875 \text{ M NaOH}(\text{aq})$$

	$\text{H}_2\text{SO}_3(\text{aq}) +$	$\text{H}_2\text{O}(\text{l}) \rightleftharpoons$	$\text{H}_3\text{O}^+(\text{aq}) +$	$\text{HSO}_3^-(\text{aq})$
Initial	0.773	--	10^{-7}	0
Δ	-x	--	+x	+x
@Equilibrium	$(0.773-x)\text{M}$	--	$(10^{-7}+x)\text{M}$	x M

Plugging in and solving...

$$K_a = \frac{[\text{H}_3\text{O}^+]_{\text{eq}} [\text{HSO}_3^-]_{\text{eq}}}{[\text{H}_2\text{SO}_3]_{\text{eq}}} = \frac{(10^{-7} + x)(x)}{(0.773 - x)} \approx \frac{(x)(x)}{(0.773)} \approx 1.68 \times 10^{-2}$$

$x = 0.114$ This is NOT small compared to 0.773 (almost 15%), so we cannot make that assumption. 0.114 is much larger than 10^{-7} , so that assumption is OK. Re-solving to a quadratic...

$$K_a = \frac{[\text{H}_3\text{O}^+]_{\text{eq}} [\text{HSO}_3^-]_{\text{eq}}}{[\text{H}_2\text{SO}_3]_{\text{eq}}} = \frac{(10^{-7} + x)(x)}{(0.773 - x)} \approx \frac{(x)(x)}{(0.773 - x)} \approx 1.68 \times 10^{-2}$$

$$x^2 + (1.68 \times 10^{-2})x + (-0.0129864) = 0$$

Plugging in to the quadratic formula, $x = 0.106 = [\text{H}_3\text{O}^+]$

$$pH = -\log(0.106) = 0.975$$

NOTE: 0.106 isn't too far away from 0.114, so the assumption would probably be fine for an approximate pH, but it's far enough off to alter the results just a little bit.