

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: $k_{\text{fp}} = -1.86^\circ\text{C}/m$
 $k_{\text{bp}} = 0.512^\circ\text{C}/m$

$P_1 = X_1 P_1^\circ$

$\Pi = MRTi$

$C_1 V_1 = C_2 V_2$

Quadratic formula:

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

Integrated Rate Laws:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|--------------------------|---------------------------|---------------------------|
| 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 | | | | | | | |

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| 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? |
|--------------------------|-----------------------|-------|-----|---------------------------|
| | 6.19×10^{-6} | | | |
| | | 4.318 | | |

| Conjugate Acid | K_a @ 25°C | Conjugate Base | K_b @ 25°C |
|-------------------------|-----------------------|--|-----------------------|
| H_2SO_3 | | | 5.9×10^{-13} |
| | 1.6×10^{-12} | $\text{C}_6\text{H}_6\text{O}_6^{2-}$ (ascorbate ion) | |

2. A labmate has prepared a sulfate/hydrogen sulfate buffer solution at pH=2.03, but does not write much information down in a lab notebook. You know that the concentration of the buffer is 0.73M and $\text{p}K_b=12.08$ for $\text{SO}_4^{2-}(\text{aq})$. Is the concentration of conjugate acid higher in this buffer or is the concentration of conjugate base in this buffer higher? Over what pH range would sulfate/hydrogen sulfate make an effective buffer? Explain your answers. (12pts)
3. How much 0.164M $\text{HClO}_4(\text{aq})$ must be added to 25.00mL of 0.159M $\text{Ba}(\text{OH})_2(\text{aq})$ to reach the equivalence point? What is the pH of this solution at the equivalence point? Explain. (12pts) {Note: $\text{Ba}(\text{OH})_2$ is a strong base.}

4. You have prepared a buffer solution by combining 0.476mols of nitrous acid (HNO_2 , $K_a = 4.6 \times 10^{-4}$) and 0.397mols of sodium nitrite in enough water to make 500.0mL of solution. What is the pH of this buffer solution? (12pts)
5. What is the expected pH of a 0.914M aqueous solution of ammonium bromide? $\{K_b(\text{NH}_3) = 1.76 \times 10^{-5}\}$ (15pts)
6. What is the K_b of a weak base if 500.0mL of a solution containing 0.241mol of the base and 0.209mol of its conjugate acid has a pH of 8.337? Over what pH range would this conjugate acid/ conjugate base pair make an effective buffer? (15pts)
7. You are going to use a titration to determine the concentration of an unknown phosphorous acid solution (H_3PO_3 , $\text{p}K_a = 1.29$). The base you have chosen to use is 0.796M sodium hydroxide.
- a. Write out the chemical equations for the step-wise deprotonation/neutralization of phosphorous and the overall/net chemical reaction. (7pts)
- b. Someone left your pH probe laying on the bench and it has dried out. After a short search, you have found the following three visual indicators: Thymolphthalein (TP, endpoint pH range = 9.5-10.5); Phenol red (PR, endpoint pH range = 6.8-8.3); Bromophenol Blue (BPB, endpoint pH range = 3.1-4.6). Which of these visual indicators would be useful in your titration? Explain your choice(s). (6pts)

(#7 continued)

- c. Sketch the titration curve you would expect for this titration, labeling all equivalence points and phosphorous acid-based species present in each portion of the curve. (7pts)
- d. As you are about to start your titration, a package arrives with a new pH probe, so you decide to use the pH probe to monitor your titration. You find that 25.00mL of phosphorous acid requires 44.19mL of sodium hydroxide to reach the second equivalence point. What is the concentration of the phosphorous acid solution? (10pts)
- e. How much sodium hydroxide solution would be required to reach the first equivalence point in part “d”? How much sodium hydroxide solution would be required to reach the third equivalence point in part “d”? Explain your answer. (6pts)