

Please follow the instructions for each section of the exam. Show your work on all mathematical problems. Provide answers with the correct units and significant figures. Be concise in your answers to discussion questions.

**Part 0: Complete all of problems 1-5**

1. You have prepared a buffer solution at  $\text{pH} = 4.00$ . If you take 100 mL of this solution and dilute it to 200 mL with distilled water, what will be the pH of the new solution? (4 points)

- a. Greater than 4.00                      c. 4.00                                      Answer \_\_\_\_\_  
b. Less than 4.00                        d. Thursday

2. The conjugate acid of  $\text{HPO}_4^{2-}$  is \_\_\_\_\_. (4 points)

- a.  $\text{H}_3\text{PO}_4$                                       c.  $\text{PO}_4^{3-}$                                       Answer \_\_\_\_\_  
b.  $\text{H}_2\text{PO}_4^-$                                     d.  $\text{H}_3\text{O}^+$

3. The effect of adding 0.001 mol KOH to 1.00 L of a solution that is 0.10 M  $\text{NH}_3$  and 0.10 M  $\text{NH}_4\text{Cl}$  is to (4 points)

- a. Raise the pH very slightly  
b. Lower the pH very slightly  
c. Raise the pH by several units                                      Answer \_\_\_\_\_  
d. Lower the pH by several units

4. Write one **charge balance** and one **mass balance** expression for a solution that is 0.10 M NaOH, 0.14 M KOH, 0.10 M NaCl and 0.12 M  $\text{Ba}(\text{OH})_2$ . All of the solutes are strong electrolytes. (8 points)

Charge Balance:

Mass Balance:

5. Define **three (3)** of the following in one or two sentences each. (6 points)

- a. amphiprotic  
  
b. van't Hoff factor  
  
c. molality  
  
d. diprotic acid

**Part I: Complete four (4) of problems 6-10. 10 points each.**

6. What is the pH of a solution that contains the strong electrolytes 0.100 M NaOH, 0.140 M KOH, 0.100 M NaCl and 0.115 M Ba(OH)<sub>2</sub>?

Sapling 16-6, Quiz 7-1

7. Vitamin B<sub>2</sub>, riboflavin, is soluble in water. If 0.833 g of riboflavin is dissolved in 18.1 g H<sub>2</sub>O, the resulting solution has a freezing point of -0.227°C. What is the molar mass of riboflavin?

Sapling 13-16

8. 50.00 mL of 0.0188 M HCl(aq) is mixed with 75.00 mL of 0.0112 M NaOH(aq). What is the pH of the final solution?

Sapling 16-6

9. In the lab you need to prepare at least 100.0 mL of the following solutions. **Select one of the solutions below** and explain how you would prepare the solution, giving amounts (masses and volumes) of material needed.
- 25% NaOH by mass in CH<sub>3</sub>OH (density = 0.79 g/mL)
  - 0.10 mole fraction of C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> (molar mass 180.16 g/mol) in water.
  - 200.0 ppm K<sup>+</sup> in water, using KCl as your source of K<sup>+</sup> (density = 1.00 g/mL)

Sapling 13-1 to 13-5

10. A buffer solution is prepared by dissolving 0.150 moles of hydrofluoric acid ( $K_a = 6.30 \times 10^{-4}$ ) and 0.200 moles of sodium fluoride in 0.500 L of solution.
- What is the pH of this buffer? (4 points)

Sapling 17-3, 17-5

Answer \_\_\_\_\_

- What will be the new pH after 25.00 mL of 2.087 M NaOH is added to this buffer solution? (6 points)

Sapling 17-3, 17-5

Answer \_\_\_\_\_

**Part II. Answer three (3) of problems 9-13. Clearly mark the problems you do not want graded. 12 points each.**

11. Some ethylene glycol ( $C_2H_6O_2$ , molar mass 62.07 g/mol) is added to your car's cooling system along with 5.0 kg of water.
- If the freezing point of this water-glycol solution is  $-15.0^\circ C$ , how many grams of ethylene glycol must have been added?

Sapling 13-17 to 13-17

Answer \_\_\_\_\_

- What is the boiling point of the solution?

Sapling 13-17 to 13-17

Answer \_\_\_\_\_

12. I've given you the task of preparing a pH 4.75 buffer. You've sought the help of a few of your classmates and have narrowed your choices down to the following list. *Each of these combinations should produce a buffer with pH=4.75.* **Which student's suggestion would provide the best choice to make the highest capacity buffer?** Justify your reasoning by identifying benefits of the "best" choice and the shortcomings of the two unfavorable choices.

<b>Student</b>	<b>Buffer Composition</b>	<b>K<sub>a</sub> of weak acid</b>
Annie Yun	0.200M salicylic acid and 0.0032 M sodium salicylate	$1.1 \times 10^{-3}$
Ty Trate	0.010 M acetic acid and 0.010 M sodium acetate	$1.8 \times 10^{-5}$
Chris Talls	0.200 M acetic acid and 0.200 M sodium acetate	$1.8 \times 10^{-5}$

Sapling 17-2 to 17-5

13. Sodium benzoate, used as a preservative in foods, is the conjugate base of benzoic acid. **Calculate the pH of a solution prepared by dissolving 8.24 grams of sodium benzoate in 500.0 mL water.** (The molar mass of sodium benzoate is 144.11 g/mol. The  $K_a$  for benzoic acid is  $6.3 \times 10^{-5}$ )

Sapling 16-14, 16-20

Answer \_\_\_\_\_

14. A solution is prepared by mixing the following materials and diluting to a total volume of 2.00 liters: 15.6 grams of sodium sulfide (molar mass 78.05 g/mol), 150.0 mL of 0.500 M sodium hydroxide (molar mass 40.00 g/mol) and 20.00 g of 38.4% by mass sodium chloride (molar mass 58.44 g/mol). **What is the molarity of sodium ion in the resulting solution?** You may assume all of the solutes are strong electrolytes.

Sapling 13-1 to 13-5

Answer \_\_\_\_\_

## Possibly Useful Information

$R = 8.31441 \text{ J mol}^{-1} \text{ K}^{-1}$	$^{\circ}\text{C} = \text{K} - 273.15$	$R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$
$\Delta t_{\text{fp}} = k_{\text{fp}}m$	$\Delta t_{\text{bp}} = k_{\text{bp}}m$	$\Pi = MRT = iMRT$
$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ} = -RT\ln K$	$\Delta G = \Delta G^{\circ} - RT\ln Q$	$P_{\text{soln}} = X_{\text{solvent}}P^{\circ}_{\text{solvent}}$
$\text{pH} = \text{pK}_a + \log\left(\frac{[\text{conjugatebase}]}{[\text{weak acid}]}\right)$	$\text{pH} + \text{pOH} = 14$	$K_a K_b = K_w = 1.00 \times 10^{-14}$
$1 \text{ atm} = 760 \text{ mm Hg}$	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	

## Selected Constants

Solvent	Normal Boiling Point ( $^{\circ}\text{C}$ )	$k_{\text{bp}}$ ( $^{\circ}\text{C kg/mol}$ )	Normal Freezing Point ( $^{\circ}\text{C}$ )	$k_{\text{fp}}$ ( $^{\circ}\text{C kg/mol}$ )
Water	100.0	0.51	0	1.86
Benzene	80.1	2.53	5.5	5.12
Ethyl Ether	34.5	2.02	-116.2	1.79
Chloroform	61.2	3.63	-63.5	4.70
cyclohexane	80.7	2.92	6.59	20.8
ethanol	78.4	1.22	-117.3	1.99

**Periodic Table of the Elements**

1 <b>H</b> Hydrogen 1.008	2 <b>He</b> Helium 4.003																
3 <b>Li</b> Lithium 6.941	4 <b>Be</b> Beryllium 9.012											5 <b>B</b> Boron 10.811	6 <b>C</b> Carbon 12.011	7 <b>N</b> Nitrogen 14.007	8 <b>O</b> Oxygen 15.999	9 <b>F</b> Fluorine 18.998	10 <b>Ne</b> Neon 20.180
11 <b>Na</b> Sodium 22.990	12 <b>Mg</b> Magnesium 24.305											13 <b>Al</b> Aluminum 26.982	14 <b>Si</b> Silicon 28.086	15 <b>P</b> Phosphorus 30.974	16 <b>S</b> Sulfur 32.066	17 <b>Cl</b> Chlorine 35.453	18 <b>Ar</b> Argon 39.948
19 <b>K</b> Potassium 39.098	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.956	22 <b>Ti</b> Titanium 47.867	23 <b>V</b> Vanadium 50.942	24 <b>Cr</b> Chromium 51.996	25 <b>Mn</b> Manganese 54.938	26 <b>Fe</b> Iron 55.845	27 <b>Co</b> Cobalt 58.933	28 <b>Ni</b> Nickel 58.693	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.38	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.631	33 <b>As</b> Arsenic 74.922	34 <b>Se</b> Selenium 78.971	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.798
37 <b>Rb</b> Rubidium 85.468	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.906	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.906	42 <b>Mo</b> Molybdenum 95.95	43 <b>Tc</b> Technetium 98.907	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.906	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.868	48 <b>Cd</b> Cadmium 112.414	49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.711	51 <b>Sb</b> Antimony 121.760	52 <b>Te</b> Tellurium 127.6	53 <b>I</b> Iodine 126.904	54 <b>Xe</b> Xenon 131.294
55 <b>Cs</b> Cesium 132.905	56 <b>Ba</b> Barium 137.328	57-71 Lanthanide Series	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.948	74 <b>W</b> Tungsten 183.84	75 <b>Re</b> Rhenium 186.207	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.217	78 <b>Pt</b> Platinum 195.085	79 <b>Au</b> Gold 196.967	80 <b>Hg</b> Mercury 200.592	81 <b>Tl</b> Thallium 204.383	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.980	84 <b>Po</b> Polonium [208.982]	85 <b>At</b> Astatine 209.987	86 <b>Rn</b> Radon 222.018
87 <b>Fr</b> Francium 223.020	88 <b>Ra</b> Radium 226.025	89-103 Actinide Series	104 <b>Rf</b> Rutherfordium [261]	105 <b>Db</b> Dubnium [262]	106 <b>Sg</b> Seaborgium [266]	107 <b>Bh</b> Bohrium [264]	108 <b>Hs</b> Hassium [269]	109 <b>Mt</b> Meitnerium [278]	110 <b>Ds</b> Darmstadtium [281]	111 <b>Rg</b> Roentgenium [280]	112 <b>Cn</b> Copernicium [285]	113 <b>Nh</b> Nihonium [286]	114 <b>Fl</b> Flerovium [289]	115 <b>Mc</b> Moscovium [289]	116 <b>Lv</b> Livermorium [293]	117 <b>Ts</b> Tennessine [294]	118 <b>Og</b> Oganesson [294]
		57 <b>La</b> Lanthanum 138.905	58 <b>Ce</b> Cerium 140.116	59 <b>Pr</b> Praseodymium 140.908	60 <b>Nd</b> Neodymium 144.243	61 <b>Pm</b> Promethium 144.913	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.964	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.925	66 <b>Dy</b> Dysprosium 162.500	67 <b>Ho</b> Holmium 164.930	68 <b>Er</b> Erbium 167.259	69 <b>Tm</b> Thulium 168.934	70 <b>Yb</b> Ytterbium 173.055	71 <b>Lu</b> Lutetium 174.967	
		89 <b>Ac</b> Actinium 227.028	90 <b>Th</b> Thorium 232.038	91 <b>Pa</b> Protactinium 231.036	92 <b>U</b> Uranium 238.029	93 <b>Np</b> Neptunium 237.048	94 <b>Pu</b> Plutonium 244.064	95 <b>Am</b> Americium 243.061	96 <b>Cm</b> Curium 247.070	97 <b>Bk</b> Berkelium 247.070	98 <b>Cf</b> Californium 251.080	99 <b>Es</b> Einsteinium [254]	100 <b>Fm</b> Fermium 257.095	101 <b>Md</b> Mendelevium 258.1	102 <b>No</b> Nobelium 259.101	103 <b>Lr</b> Lawrencium [262]	

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