Flinn*PREP*™ for Practice Exam 1
Untimed Free Response

1. Benzoic acid is a monoprotic carboxylic acid with the formula $C_7H_6O_2$. Its heat of combustion is 26.4 kJ/g and its dissociation constant is equal to 6.46×10^{-5}.

  a. The structure of benzoic acid is shown above.

      i. Draw an additional resonance structure for benzoic acid. (1)

      ii. Identify the acidic, or ionizable, H atom on the benzoic acid molecule. (1)

  b. In order to confirm experimentally the heat of combustion of benzoic acid, a student burns 2.00 g of the solid in a porcelain crucible directly beneath an aluminum can that holds 50.0 mL of 25.3 °C water. The student performs several trials keeping these parameters relatively constant.

      i. The student consistently finds the experimental heat of combustion is lower than the theoretical value. Explain. (1)

      ii. Combustion reactions like the burning of benzoic acid in air are generally exothermic. Is the spontaneous combustion of benzoic acid, once ignited, enthalpy- or entropy-driven, or both? Justify your answer. (2)

  c. In order to confirm experimentally the K_a of benzoic acid, the student prepares a 0.01 M solution of the acid by dissolving 0.0305 g in water in a 25.0 mL volumetric flask filled to the mark.

      i. The student uses a dilute solution of benzoic acid owing to its very limited solubility in water. Describe two steps the student might take to increase the acid's solubility. (2)

      ii. Because the initial concentration of the acid is very small the amount of dissociated H^+ is significant relative to this initial concentration value. The student does not consider this when calculating the theoretical pH value of the solution. With this in mind, explain why the student consistently measures a pH value that is higher than the theoretical value in lab. (1)

  d. In a separate experiment, the student sets out to determine the buffering capacity of a benzoic acid/sodium benzoate buffer solution. The student prepares a buffer solution whose pH is equal to the pK_a of benzoic acid.

      i. How much solid sodium benzoate, in grams, does the student add to 25.0 mL of 0.01 M benzoic acid solution? (1)

      ii. Which of the indicators or combination of indicators from the table below should be used if the student wants to determine the buffering capacity to within about +/- 1 pH unit? Explain. (1)

		Color Transition Range (pH)		
	pK_a	1 2 3 4 5 6 7 8 9 10 11 12 13		
Methyl orange	3.40	Red	Yellow	
Methyl red	4.95	Red	Yellow	
Phenolphthalein	9.4	Colorless		Red
Bromthymol blue	7.1	Yellow		Blue

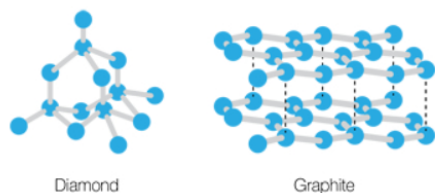| Thymolphthalein	10.0	Colorless	Blue

2.

Diamond   Graphite

Carbon atoms are the basic building units of both graphite and diamond, shown above. In diamond, each carbon atom is bound to four other carbon atoms to form a near infinite network of connections. In graphite, each carbon atom is bound to three other carbon atoms to form layers.

    a. Provide a justification for the fact that graphite is softer than diamond, based on structural differences between the two solids. (1)

    b. Circle the number on the scale below that most closely approximates the bond angles in diamond and draw a square around the number that most closely approximates the bond angles in graphite. Justify your selections. (1)

       60   70   80   90   100   110   120   130   140   150   160   170   180

    c. The conversion of diamond to graphite is thermodynamically favorable yet does not occur. Draw a qualitative reaction diagram (one that lacks specific numbers) to justify this observation. (1)

    d. Graphite can be converted to diamond under very high pressures. What does this indicate about the relative densities of the two substances? Explain. (1)

3. The K_{sp} of $Al(OH)_3$ is equal to 2.0×10^{-32}.

    a. Calculate the molar solubility of $Al(OH)_3$ in 0.2 M $Al(NO_3)_3$. (1)

    b. Consider the addition of HCl to an aqueous solution of $Al(OH)_3$ in which a small amount of the solid has been dissolved. Will addition of the HCl increase or decrease the concentration of Al^{3+} ions? Justify your answer. (1)

For each of the following statements, determine whether the statement is true or false. In each case, explain the reasoning that supports your answer.

    i. Solid hydroxides with small K_{sp} values must always be weak bases. (1)

    ii. A particulate-level drawing of a solution of a 0.001 M solution of $Al(OH)_3$ would have to include undissolved $Al(OH)_3$ formula units and dissociated Al^{3+} and OH^- ions in the following ratio: 10:1:3, respectively. (1)

4.

$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons FeSCN^{2+}(aq)$ $K_{eq} = 150$

Yellow   Colorless   Red-orange

The equilibrium constant for the reaction between Fe^{3+} and SCN^- ions, represented above, can be determined by setting a spectrophotometer at a wavelength of 450 nm and comparing the absorbance values of reaction mixtures with unknown $FeSCN^{2+}$ concentrations to the absorbance values of reference solutions with known $FeSCN^{2+}$ concentrations.

    a. The reference solutions with known $FeSCN^{2+}$ concentrations are prepared by mixing a large excess of Fe^{3+} ions with known amounts of SCN^- ions. Explain why this is possible in terms of LeChâtelier's principle. (1)

    b. If a student wishes to study directly the concentration of Fe^{3+} ions in the reaction mixtures, what modifications to the experiment are necessary? (1)

    c. When the equilibrium mixture is heated, the color turns a dark red. Is the equilibrium exothermic or endothermic? Justify your answer. (1)

    d. Complete a particle representation diagram that includes eight water molecules, four oriented around a Fe^{3+} ion and four oriented around a SCN^- ion. Represent water molecules as (1)

5. A student is given the task of building an electrochemical cell from the following electrodes: Zn(s), Cu(s), and Sn(s), Ni(s) and 1 M solutions of their sulfate salts. Redox half-reactions and standard cell potentials, E° are given below.

$Zn^{2+}(aq) \rightarrow Zn(s)$ $E° = -0.76$ V
$Cu^{2+}(aq) \rightarrow Cu(s)$ $E° = 0.34$ V
$Sn^{2+}(aq) \rightarrow Sn(s)$ $E° = -0.14$ V
$Ni^{2+}(aq) \rightarrow Ni(s)$ $E° = -0.25$ V
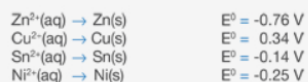
   a. Which two metals should the student select to construct a galvanic cell that will produce the highest voltage? Justify your answer by drawing and labeling the electrodes and identifying the aqueous solutions present in each beaker in the representation below. (2)
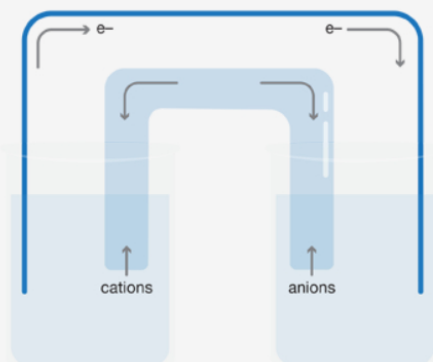
   b. When the reaction is run to completion, the electrodes are removed from the solutions. Identify which of the electrodes below is the anode and which is the cathode. Justify your answer. (1)
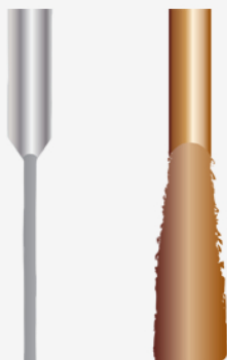
   c. Determine the mass of Cu(s) that will form on the cathode in an electrolytic cell if 9 amps of current are passed through a 1 M Cu^{2+} solution for 25 minutes. (1)

6. Excess barium nitrate solution was added to 120.0 mL of a sodium sulfate solution. The precipitate was then collected, rinsed and dried. The original concentration of the sodium sulfate solution is unknown.

Filter Paper	0.970 g
Filter Paper & Precipitate (dried)	4.050 g

   a. Write the balanced, net ionic equation below. (1)

   b. Why is a net ionic equation the best way to represent the reaction above? (1)

   c. Before the barium nitrate solution was added, what was the initial number of moles of the sodium ions in solution? (1)

   d. What was the unknown initial concentration of sodium sulfate? (1)

   e. To prepare the 120.0 mL of sodium sulfate solution, how many grams of sodium sulfate were added to the distilled water? (1)

   f. If the filter paper was still wet when it was weighed, how would the concentration of sodium sulfate be affected? (1)

      i. How can the student ensure the mass of precipitate dried is correct? (1)

g. The student making the solution used a sodium sulfate bottle that had been contaminated with sodium nitrate. The original mass used to make the sodium sulfate solution was 3.41 g.
   i. What concentration of the sodium sulfate solution was the student trying to make? (1)
   ii. What was the percent mass of sodium sulfate in the mass used to make the solution? (1)
   iii. Assuming the contaminated bottle is homogeneously mixed, how many grams more of the sodium sulfate/sodium nitrate mixture will the student need to add to make the sulfate concentration that was initially desired? (1)

7.

$$H_3C-\overset{\overset{O}{\|}}{C}-CH_3(aq) + H^+(aq) + I_2(aq) \rightarrow H_3C-\overset{\overset{O}{\|}}{C}-CH_2I + H^+(aq) + I^-(aq)$$
acetone
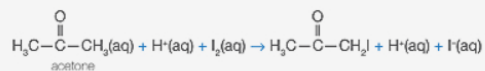
The rate law for the reaction between iodine and acetone in the presence of an acid catalyst can be determined by measuring the time it takes for reaction mixtures of varying composition to change from yellow to colorless.

a. Explain why the rate of the reaction may be reported as $[I_2°]/\Delta t$ if iodine is the limiting reactant and the other reactants are present in large excesses. (2)

b. If each experimental observation of a yellow to colorless transition is considered a "run," what is the fewest number of runs necessary to determine the reaction orders of H^+ and acetone, assuming the iodine concentration is held constant? (1)

c. The transition from yellow to colorless occurs on a time scale that is slow enough to measure with a stopwatch.

   i. What does this imply about the magnitude of the reaction's activation energy? Is it extremely large? Justify your answer. (1)

   ii. A student is tasked with experimentally determining the activation energy of the reaction. What experimental parameter must the student vary and what experimental parameter must the student control to accomplish this task? (1)

d. Fill in the table below based on the following information: rate = k[acetone][H^+]. (2)

Run	[Acetone], M	[HCl], M	[I₂], M	Reaction rate (M/min)
1	1	0.25	0.00125	4.17×10^{-4}
2	2	0.25	0.00125	8.93×10^{-4}
3	1		0.00125	8.34×10^{-4}
4	1	0.25	0.0025	

e. For each of the following statements, determine whether the statement is true or false. In each case, explain the reasoning that supports your answer.

   i. The iodination of acetone proceeds via a single, elementary step in which two molecules of $I_2(aq)$ combine with one molecule of aqueous acetone. (1)

   ii. The iodination of acetone is thermodynamically unfavorable. (1)

   iii. Diluting the reaction mixtures described in the table above by adding 100 mL of water to each changes the experimentally-determined rate law but does not change the rates of the reactions. (1)

Finished