1. In an acidic medium, iron (III) ions will react with thiocyanate (SCN^-) ions to create the following complex ion:

$Fe^{3+}(aq) + SCN^-(aq) \leftrightarrow FeSCN^{2+}(aq)$

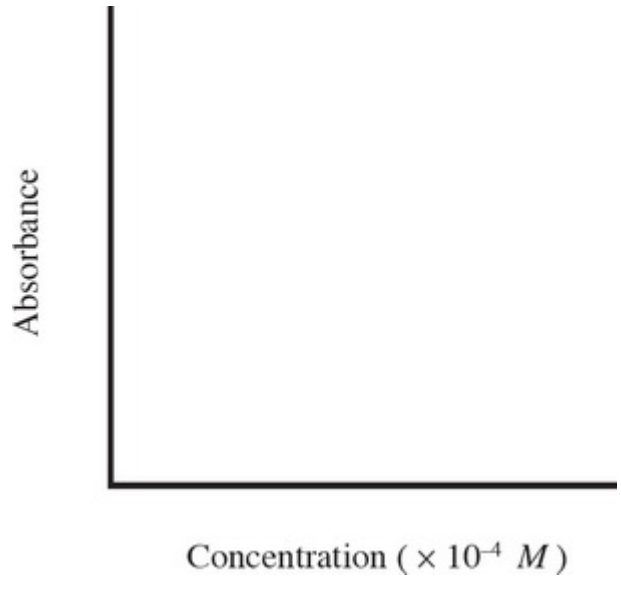
Initially, the solution is a light yellow color due to the presence of the Fe^{3+} ions. As the $FeSCN^{2+}$ forms, the solution will gradually darken to a golden yellow. The reaction is not a fast one, and generally after mixing the ions the maximum concentration of $FeSCN^{2+}$ will occur between 2-4 minutes after mixing the solution.

A student creates four solutions with varying concentration of $FeSCN^{2+}$ and gathers the following data at 298 K using a spectrophotometer calibrated to 460 nm:

$[FeSCN^{2+}]$	Absorbance
$1.1 \times 10^{-4} M$	0.076
$1.6 \times 10^{-4} M$	0.112
$2.2 \times 10^{-4} M$	0.167
$2.5 \times 10^{-4} M$	0.199

(a)

(i) On the axes below, create a Beer's Law calibration plot for $[FeSCN^{2+}]$. Draw a best-fit line through your data points.



(ii) The slope of the best-fit line for the above set of data points is 879 and the *y*-intercept is -0.024. Write out the equation for this line.

To determine the equilibrium constant for the reaction, a solution is made up in which 5.00 mL of 0.0025 *M* $Fe(NO_3)_3$ and 5.00 mL of 0.0025 *M* KSCN are mixed. After 3 minutes, the absorbance of the solution is found to be 0.134.

(b)

(i) Using your Beer's Law best-fit line from (a), calculate $[FeSCN^{2+}]$ once equilibrium has been established.

(ii) Calculate $[Fe^{3+}]$ and $[SCN^-]$ at equilibrium.

(iii) Calculate K_{eq} for the reaction.

After equilibrium is established, the student heats the solution and observes that it becomes noticeably lighter.

(c)

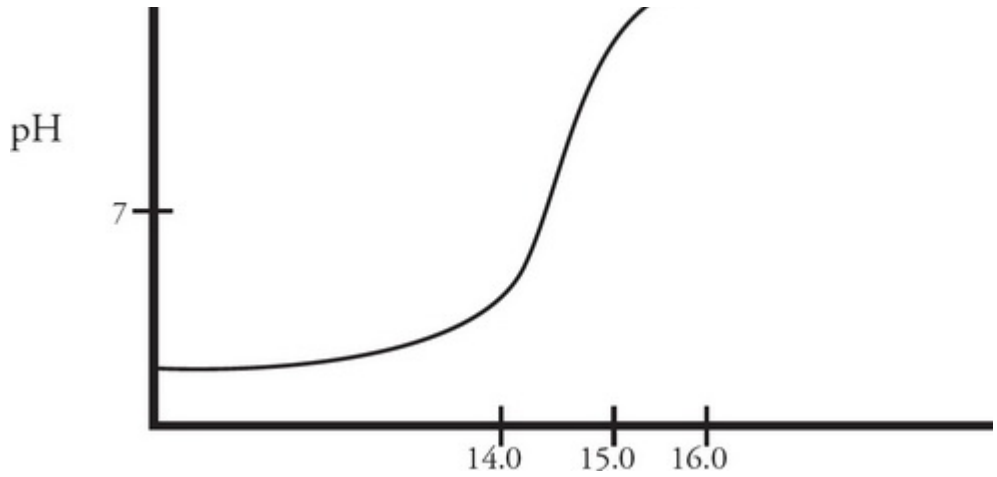
(i) Did heating the mixture increase the equilibrium constant, decrease it, or have no effect on it? Why?

(ii) Is the equilibrium reaction exothermic or endothermic? Justify your answer.

Show Answer

2. $HA + OH \rightleftharpoons A^- + H_2O(l)$

A student titrates a weak acid, HA, with some 1.0 *M* NaOH, yielding the following titration curve:



(A) Which chemical species present in solution dictates the pH of the solution in each of the volume ranges listed below?

(i) 1.0 mL–14.0 mL

(ii) 15.0 mL

(iii) 16.0 mL–30.0 mL

(b) At which volumes is

(i) $[HA] > [A^-]$?

(ii) $[HA] = [A^-]$?

(iii) $[HA] < [A^-]$?

(c) At which point in the titration (if any) would the concentration of the following species be equal to zero? Justify your answers.

(i) HA

(ii) A^-

(d) If the titration were performed again, but this time with 2.0 *M* NaOH, name two things that would change about the titration curve, and explain the reasoning behind your identified changes.

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3. A student performs an experiment to determine the concentration of a solution of hypochlorous acid, HOCl ($K_a = 3.5 \times 10^{-8}$). The student starts with 25.00 mL of the acid in a flask and titrates it against a standardized solution of sodium hydroxide with a concentration of 1.47 *M*. The equivalence point is reached after the addition of 34.23 mL of NaOH.

(a) Write the net ionic equation for the reaction that occurs in the flask.

(b) What is the concentration of the HOCl?

(c) What would the pH of the solution in the flask be after the addition of 28.55 mL of NaOH?

(d) The actual concentration of the HOCl is found to be 2.25 *M*. Quantitatively discuss whether or not each of the following errors could have caused the error in the student's results.

(i) The student added additional NaOH past the equivalence point.

(ii) The student rinsed the buret with distilled water but not with the NaOH solution before filling it with NaOH.

(iii) The student measured the volume of acid incorrectly; instead of adding 25.00 mL of HOCl, only 24.00 mL was present in the flask prior to titration.

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4. A student is tasked with determining the identity of an unknown carbonate compound with a mass of 1.89 g. The compound is first placed in water, where it dissolves completely. The K_{sp} value for several carbonate-containing compounds are given below.

Compound	K_{sp}
Lithium carbonate	8.15×10^{-4}
Nickel (II) carbonate	1.42×10^{-7}

(a) In order to precipitate the maximum amount of the carbonate ions from solution, which of the following should be added to the carbonate solution: $LiNO_3$, $Ni(NO_3)_2$, or $Sr(NO_3)_2$? Justify your answer.

(b) For the carbonate compound that contains the cation chosen in part (a), determine the concentration of each ion of that compound in solution at equilibrium.

(c) When mixing the solution, should the student ensure the carbonate solution or the nitrate solution is in excess? Justify your answer.

(d) After titrating sufficient solution to precipitate out all of the carbonate ions, the student filters the solution before placing it in a crucible and heating it to drive off the water. After several heatings, the final mass of the precipitate remains constant and is determined to be 2.02 g.

(i) Determine the number of moles of precipitate.

(ii) Determine the mass of carbonate present in the precipitate.

(e) Determine the percent, by mass, of carbonate in the original sample.

(f) Is the original compound most likely lithium carbonate, sodium carbonate, or potassium carbonate? Justify your answer.

Show Answer