Identity and Concentration of AB-4

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2014-04-23

The objective of this experiment is to determine the identity and concentration of a given unknown solution from among these species: carbonic acid, citric acid, formic acid, oxalic acid, phosphoric acid, succinic acid, or their associated salts. Solution AB-4 was selected for experimental study. The pH of AB-4 was about 2.5, indicating the acidic form of the unknown.

Preparation of Standard Titrant

A Sodium Hydroxide (NaOH) standardized solution was prepared using Potassium Hydrogen Phthalate (KHP). The concentration of the standardized NAOH used in this experiment was $0.09623 \pm 0.00004\, M (\pm 0.04_5\, \%)\, (n = 5)$.

pH Titration

A pH titration of AB-4 was conducted using the standardized NaOH. A total of 568 pH data points were collected over a domain of 0 to 50 mL (the size of the Buret in use). The reported pH range spanned 2.2 to 12.3. The curve is located in Addendum 1.

The well-defined equivelance point is ph 8.8 at 30.25 mL. This curve represents a monoprotic (single euivelance point), a diprotic (equivelance points at 15.13 mL and 30.25 mL), or a triprotic acid (equivelance points at 10.08 mL, 20.17 mL, and 30.25 mL). Inspection of the curve at maximum resulotion did not yield any apparent change of slopes at the proposed equivelance points for diprotic and triprotic acids. Therefore, identification of diprotic and triprotic pKa values were determined wholly by calculation. The pKa values derived from the titration curve are represented in the following table. Graphs of pKa regions for the triprotic type are found in Addendums 3-5.

Type	pKa_1	pKa_2	pKa_3
Monoprotic	4.355 @ 15.13 mL	–	–
Diprotic	3.263 @ 7.56 mL	5.421 @ 22.69 mL	–
Triprotic	2.917 @ 5.04 mL	4.355 @ 15.13 mL	5.788 @ 25.21 mL

Identification

The following table shows the list of pKa's for the given species (possible identities of AB-4 solution) at ionic strength of 0.1 M (based on molarity of the standardized base), placed in order from monoprotic to triprotic:

Species	pKa_1	pKa_2	pKa_3
formic	3.57	–	–
carbonic	6.13	9.91	–
oxalic	(1.2)	3.80	–
succinic	3.99	5.44	–
citric	2.90	4.351	5.70
phosphoric	1.92	6.71	11.52

Source: Harris, Quantitative Chemical Analysis, 8th ed.

Carbonic, oxalic, and phosphoric acids were ruled out due to extreme pKa values. AB-4 was odorless; however, formic acid has a pungent odor. Formic and succinic values were not very close. Citric acid is the best fit for the possible pKa values reported for the AB-4 unknown solution. The relative differences of AB-4 triprotic pKa values to citric acid pKa values are less than 2%. According to one website, the buffering affect between the three pKa's of citric acid cause the extended ramp without any distinctive equivelance points.[1] The curve for citric acid from this same website (Addendum 2) is identically shaped to the curve of AB-4.

Concentration

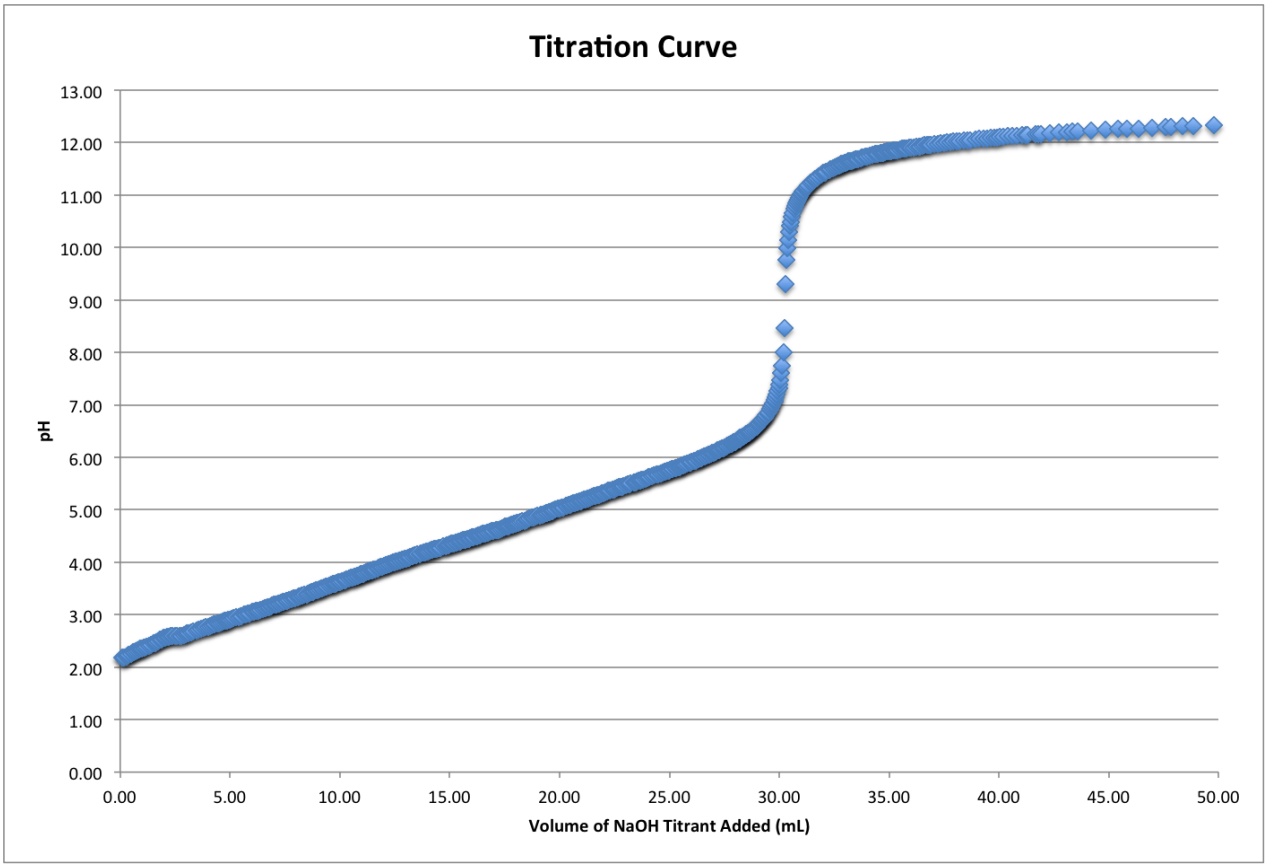
The equation of the chemical reaction for determining concentration of citric acid with standardized NaOH is:

$$\mathrm{C_6H_8O_7 + 3\,NaOH \rightleftharpoons Na_3C_6H_5O_7 + 3\,H_2O} \tag{1}$$

Titrations were performed using phenolphthalein indicator (pH range 8.0-9.6) targeting the final equivelance point. The end point was signaled by a change in color from clear to very slight pink. The results were shifted slightly by a slight corrective factor determined by titrating a prepared 0.1 M citric acid solution. The concentration of citric acid in AB-4 was calculated as $0.03888 \pm 0.00002\,M(\pm 0.05_{56}\,\%)\,(n = 10)$.

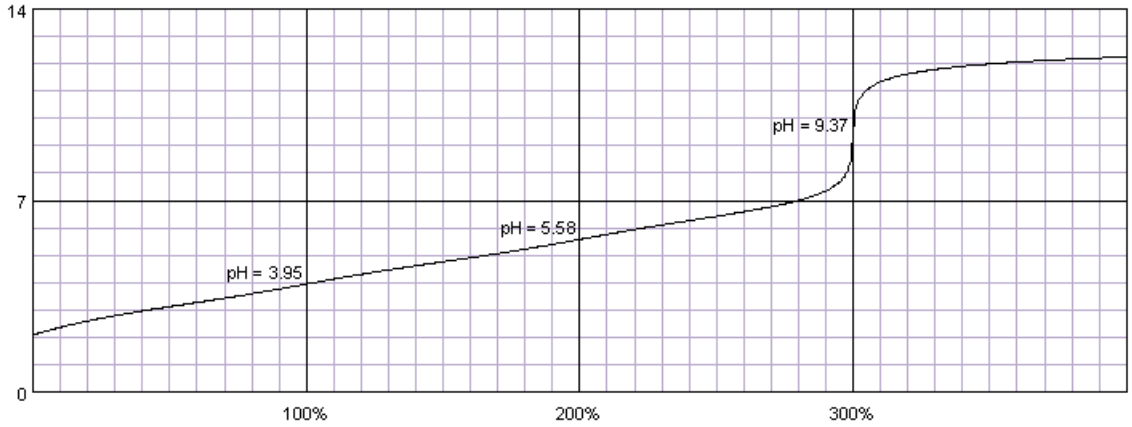
[1] http://www.titrations.info/acid-base-titration-polyprotics-and-mixtures

Addendum 1: AB-4 pH Titration Curve

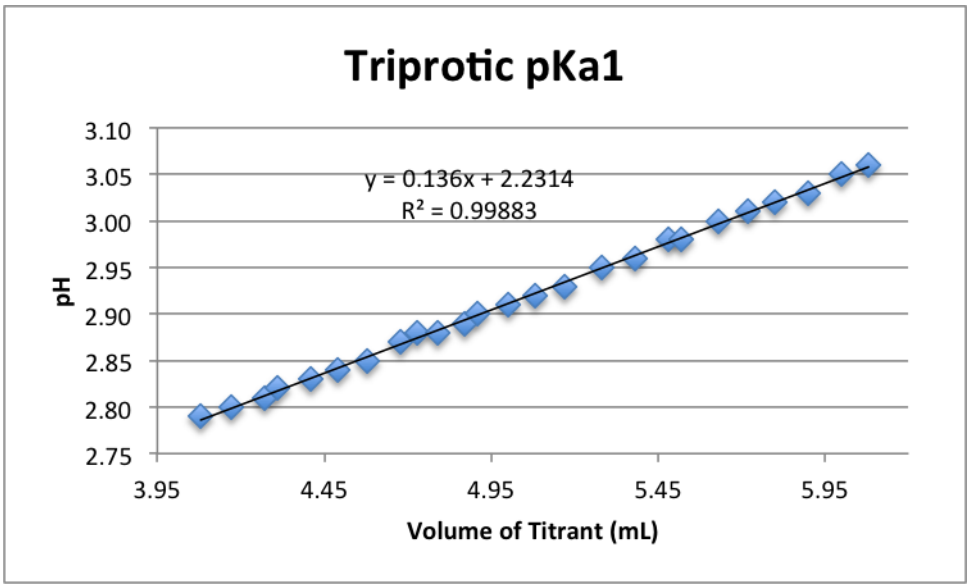


Addendum 2: Citric Acid pH Curve

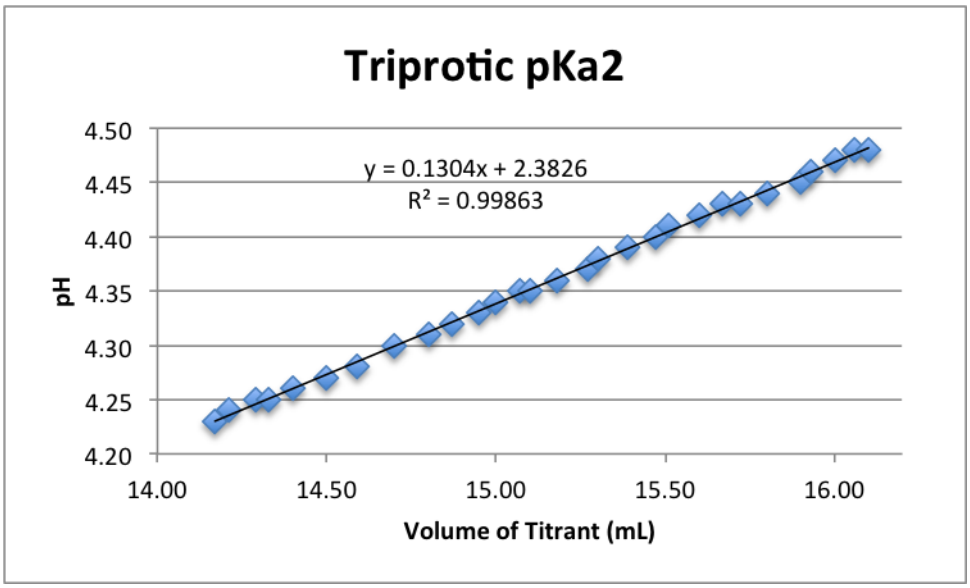
Source: http://www.titrations.info/acid-base-titration-polyprotics-and-mixtures



Addendum 3: AB-4 Triprotic pKa_1 Region
(pH2.917 @ 5.04 mL)



Addendum 4: AB-4 Triprotic pKa_2 Region
(pH 4.355 @ 15.13 mL)



Addendum 5: AB-4 Triprotic pKa_3 Region
(pH 5.788 @ 25.21 mL)