EXPERIMENTAL METHODS FOR STUDYING CHEMICAL EQUILIBRIA in AQUEOUS SOLUTIONS

Potentiometry, conductometry, spectrophotometry

1. The acid-base titration of weak monoprotic acids (potassium hydrogen phthalate, acetic acid): *potentiometric and conductometric titration experiments*

Materials

Potassium hydrogen phthalate (KHP), 0.1 M hydrochloric acid (HCl), 0.1 M acetic acid (CH_3COOH), 0.1 M sodium hydroxide (NaOH), standard buffer solutions (pH 4, 7, 9)

Instruments

The Cerko Lab System microtitration unit fitted with a 5-mL Hamilton's syringe and the thermostated measuring cell with a magnetic stirrer. A pH combined electrode (potentiometric measurements). A conductometric electrode.

Software

MS Excel, Origin, the Hyss program (for details see: http://www.hyperquad.co.uk/hyss.htm)

LITERATURE

a) L. S. Lanka K. Fernando, L. Hasini R. Perera, *Graphical Application to Assist Students Understand the Basic Concepts in Acid−Base Titrations*, J. Chem. Educ., 2022, 99, 1547−1552

b) P. Gans, B. O'Sullivan, *GLEE, a new computer program for glass electrode calibration*, *Talanta*, 2000, 51, 33–37 [Download the installation file: Install_GLEE.EXE: http://www.hyperquad.co.uk/glee.htm]

c) L. Alderighi, P. Gans, A. Ienco, D. Peters, A. Sabatini, A. Vacca, *Hyperquad simulation and speciation (HySS): a utility program for the investigation of equilibria involving soluble and partially soluble species*, Coord. Chem. Rev., 1999, 184, 311-318 [Download the installation: Install HySS2009.EXE: http://www.hyperquad.co.uk/hyss.htm]

d) K. C. Smith, E. Edionwe, B. Michel, *Conductimetric Titrations: A Predict-Observe-Explain Activity for General Chemistry*, J. Chem. Educ., 2010, 87, 1217−1221

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2. The acid-base titration of a polyprotic acid (*citric acid*): *potentiometric titration experiments*

Materials

Citric acid (H_3Cit), 0.1 M hydrochloric acid (HCl), 0.1 M sodium hydroxide (NaOH), standard buffer solutions (pH 4, 7, 9)

Instruments

The Cerko Lab System microtitration unit fitted with a 5-mL Hamilton's syringe and the thermostated measuring cell with a magnetic stirrer. A pH combined electrode (potentiometric measurements).

Software

MS Excel, Origin, the Hyss program (for details see: http://www.hyperquad.co.uk/hyss.htm)

LITERATURE

a) A. Kraft, *The Determination of the pKa of Multiprotic, Weak Acids by Analyzing Potentiometric Acid–Base Titration Data with Difference Plots*, J. Chem. Educ. 2003, 80, 554−559

b) B. Sarac, S. Hadzi, *Analysis of Protonation Equilibria of Amino Acids in Aqueous Solutions Using Microsoft Excel*, J. Chem. Educ. 2021, 98, 1001−1007

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3. The equilibrium constant for *bromothymol blue*: *spectrophotometric measurements (Vis)*

Materials

Bromothymol blue, 0.1 M hydrochloric acid (HCl), 0.1 M sodium hydroxide (NaOH), standard buffer solutions (pH 4, 7, 9)

Instruments

The Perkin-Elmer Lambda 650 spectrophotometer equipped with the temperature control system.

Software

MS Excel, Origin, the Hyss program (for details see: http://www.hyperquad.co.uk/hyss.htm)

LITERATURE

a) E. Klotz, R. Doyle, E. Gross, B. Mattson, *The Equilibrium Constant for Bromothymol Blue: A General Chemistry Laboratory Experiment Using Spectroscopy*, J. Chem. Educ. 2011, 88, 637–639

b) G. S. Patterson, *A Simplified Method for Finding the pKa of an Acid–Base Indicator by Spectrophotometry*, J. Chem. Educ., 1999, 76, 395–398

c) A. S. Kooser, J. L. Jenkins, L. E. Welch, *Acid–Base Indicators: A New Look at an Old Topic*, J. Chem. Educ., 2001, 78, 1504–1506

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4. Critical micelle concentration (colloid chemistry: cetyltrimethylammonium bromide, CTAB; sodium dodecyl sulfate, SDS)**:**
conductometric and spectrophotometric (1-phenyl-1,3-butadione, BZA) measurements

Materials
Cetyltrimethylammonium bromide, CTAB; sodium dodecyl sulfate, SDS; 1-phenyl-1,3-butadione, BZA

Instruments
The Cerko Lab System microtitration unit fitted with a 5-mL Hamilton's syringe and the thermostated measuring cell with a magnetic stirrer. A pH combined electrode (potentiometric measurements). A conductometric electrode. The Perkin-Elmer Lambda 650 spectrophotometer equipped with the temperature control system

Software
MS Excel, Origin, Advanced models – see: W. Al-Soufi, L. Piñeiro, M. Novo, J. Colloid Interface Sci. 2012, 370, 102-110

LITERATURE
a) A. Domínguez, A. Fernández, N. González, E. Iglesias, L. Montenegro, *Determination of Critical Micelle Concentration of Some Surfactants by Three Techniques*, J. Chem. Educ. 1997, 74, 1277−1231

b) J. Goronja, N. Pejic, A. Janosevic Lezaic, D. Stanisavljev, A. Malenović, *Using a Combination of Experimental and Mathematical Method To Explore Critical Micelle Concentration of a Cationic Surfactant*, J. Chem. Educ. 2016, 93, 1277−1281

c) M. M. Mabrouk, N. A. Hamed, F. R. Mansour, *Simple Spectrophotometric Method to Measure Surfactant CMC by Employing the Optical Properties of Curcumin's Tautomers*, J. Chem. Educ., 2021, 98, 2603−2609

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