Student Experiments for *Quantitative Chemical Analysis*

This list of experiments, mainly taken from the *Journal of Chemical Education*, is keyed to chapters in Daniel C. Harris, *Quantitative Chemical Analysis*, 9th edition (New York: W. H. Freeman & Co., 2010).

Chapter 1 Chemical Measurements

W. B. Guenther, "Supertitrations: High-Precision Methods," *J. Chem. Ed.* **1988**, *65*, 1097.

E. A. Butler and E. H. Swift, "Gravimetric Titrimetry: A Neglected Technique," *J. Chem. Ed.* **1972**, *49*, 425.

Chapter 2 Tools of the Trade

V. Tsionsky, "The Quartz-Crystal Microbalance in an Undergraduate Laboratory Experiment," *J. Chem. Ed.* **2007**, *84*, 1334, 1337, 1340. Covers instrumentation, measuring viscosity, and measuring mass.

Chapters 3 and 4 Experimental Error and Statistics

S. L. Garvey, G. Shahmohammadi, D. R. McLain, and M. L. Dietz, "Determination of Calcium in Dietary Supplements: Statistical Comparison of Methods in the Analytical Laboratory," *J. Chem. Ed.* **2015**, *92*, 167.

A. D. Jordan, "Which Method is Most Precise: Which is Most Accurate?," *J. Chem. Ed.* **2007**, *84*, 1459.

J. Bularzik, "The Penny Experiment Revisited: An Illustration of Significant Figures, Accuracy, Precision, and Data Analysis," *J. Chem. Ed.* **2007**, *84*, 1456.

J. Burnett and W. A. Burns, "Using a Spreadsheet to Fit Experimental pH Titration Data to a Theoretical Expression: Estimation of Analyte Concentration and K_a," *J. Chem. Ed*. **2006**, *83*, 1190.

M. J. Samide, "Statistical Comparison of Data in the Analytical Laboratory," *J. Chem. Ed.* **2004**, *81*, 1641.

D. Harvey, "Two Experiments Illustrating the Importance of Sampling in Quantitative Chemical Analysis," *J. Chem. Ed*. **2002**, *79*, 360. Analysis of variance.

P. L. Edmiston and T. R. Williams, "Laboratory Experiment in Error Analysis: Repeated Determination of Glucose Using Commercial Glucometers," *J. Chem. Ed.* **2000**, *77*, 377.

F. A. Settle and M. Pleva, "The Weakest Link Exercise," *Anal. Chem.* **1999**, *71*, 538A.

R. S. Herrick, L. P. Nestor, and D. A Benedetto, "Using Data Pooling to Measure the Density of Sodas," *J. Chem. Ed.* **1999**, *76*, 1411.

R. J. Stolzberg, "Do New Pennies Lose Their Shells? Hypothesis Testing in the Sophomore Analytical Chemistry Laboratory," *J. Chem. Ed.* **1998**, *75*, 1453.

K. Thomasson, S. Lofthus-Merschman, M. Humbert, and N. Kulevsky, "Applying Statistics in Experiments with Food Dyes," *J. Chem. Ed.* **1998**, *75*, 231.

M. F. Vitha and P. W. Carr, "A Laboratory Exercise in Statistical Analysis of Data," *J. Chem. Ed.* **1997**, *74*, 998.

J. C. Salzsieder, "Statistical Analysis Experiment for Freshman Chemistry Lab," *J. Chem. Ed*. **1995**, *72*, 623.

J. Marcos, A. Ríos and M. Valcárcel, "Practicing Quality Control in a Bioanalytical Experiment," *J. Chem. Ed.* **1995**, *72*, 947.

Chapter 5 Quality Assurance and Calibration Methods

T. Krawczyk, R. Slupska, and S. Baj, "Applications of Chemiluminescence in the Teaching of Experimental Design," *J. Chem. Ed.* **2015**, *92*, 317.

J. C. Chan and P. T. Palmer, "Determination of Calcium Ion in Powdered Milk Via X-Ray Fluorescence Using External Standard and Standard Addition Based Methods," *J. Chem. Ed.* **2013**, *90*, 1218.

R. R. de Oliveira, L. S. das Neves, and K. M. G. de Lima, "Experimental Design, Near-Infrared Spectroscopy, and Multivariate Calibration," *J. Chem. Ed*. **2012**, *89*, 1566.

B. Schazmann, F. Regan, M. Ross, D. Diamond, and B. Paull, "Introducing Quality Control in the Chemistry Teaching Laboratory Using Control Charts," *J. Chem. Ed*. **2009**, *86*, 1085. (Spectrophotometry and liquid chromatography)

J. E. T. Andersen, "Exercise in Quality Assurance: A Laboratory Exercise," *J. Chem. Ed*.

2009, *86*, 733. (Statistics of calibration curves from spectrophotometry conducted by batch procedures or flow injection.)

M. J. Goldcamp, M. N. Underwood, J. L. Cloud, S. Harshman, and K. Ashley, "An Environmentally Friendly, Cost-Effective Determination of Lead in Environmental Samples Using Anodic Stripping Voltammetry," *J. Chem. Ed*. **2008**, *85*, 976. (standard addition)

R. Wanke and J. Stauffer, "An Advanced Undergraduate Chemistry Laboratory Experiment Exploring NIR Spectroscopy and Chemometrics," *J. Chem. Ed.* **2007**, *84*, 1171. Multicomponent calibration procedure.

R. D. Barrows, "Quantitative Comparison of Three Standardization Methods Using a One-Way ANOVA for Multiple Mean Comparisons," *J. Chem. Ed*. **2007**, *84*, 839. Gas chromatography experiment compares the results of calibration curve, internal standard, and standard addition.

J. M. Gozálvez and J. C. García-Díaz, "Mixture Design Experiments Applied to the Formulation of Colorant Solutions," *J. Chem. Ed.* **2006**, *83*, 647. Design of experiments.

L. Puignou and M. Llauradó, "Experimental Introduction to Interlaboratory Exercises in Analytical Chemistry," *J. Chem. Ed.* **2005**, *82*, 1079.

M. M. Warnke, A. E. Erickson, and E. T. Smith, "Simplex Optimization of Headspace-Enrichment Conditions of Residual Petroleum Distillates Used by Arsonists," *J. Chem. Ed.* **2005**, *82*, 1082.

J. C. Penteado, L. Angnes, J. C. Massini, and P. C. C. Oliveira, "FIA-Spectrophotometric Method for Determination of Nitrite in Mean Products," *J. Chem. Ed.* **2005**, *82*, 1074. (Experimental design)

M. J. Santos-Delgado and L. Larrea-Tarruella, "A Didactic Experience of Statistical Analysis for the Determination of Glycine in a Nonaqueous Medium Using ANOVA and a Computer Program," *J. Chem. Ed.* **2004**, *81*, 97.

R. A. Cazar, "An Exercise in Chemometrics for a Quantitative Analysis Course," *J. Chem. Ed.* **2003**, *80*, 1026.

S. E. Quintar, J. P. Santagata, O. I. Villegas, and V. A. Cortinez, "Detection of Method Effects on Quality of Analytical Data," *J. Chem. Ed.* **2003**, *80*, 326.

D. Harvey, "External Standards or Standard Additions? Selecting and Validating a Method

of Standardization," *J. Chem. Ed.* **2002**, *79*, 613.

P. de B. Harrington, E. Kolbrich, and J. Cline, "Experimental Design and Multiplexed Modeling Using Titrimetry and Spreadsheets," *J. Chem. Ed.* **2002**, *79*, 863.

C. A. Heimbuck and N. W. Bower, "Teaching Experimental Design Using a GC-MS Analysis of Cocaine on Money," *J. Chem. Ed.* **2002**, *79*, 1254.

D. A. Cancilla, "Integration of Environmental Analytical Chemistry with Environmental Law: Development of a Problem-Based Laboratory," *J. Chem. Ed.* **2001**, *78*, 1652.

F. A. Settle and M. Pleva, "The Weakest Link Exercise," *Anal. Chem.* **1999**, *71*, 538A. Analysis of variance.

S. Pandey, M. E. R. McHale, K. S. Coym, and W. E. Acree, Jr., "Bilinear Regression Analysis As a Means to Reduce Matrix Effects in Simultaneous Spectrophotometric Determination of Cr^{III} and Co^{II}," *J. Chem. Ed.* **1998**, *75*, 878.

P. J. Oles, "Fractional Factorial Experimental Design as a Teaching Tool for Quantitative Analysis," *J. Chem. Ed.* **1998**, *75*, 357.

R. Stolzberg, "Screening and Sequential Experimentation: Simulations and Flame Atomic Absorption Spectrometry Experiments," *J. Chem. Ed.* **1997**, *74*, 216.

J. Marcos, A. Ríos and M. Valcárcel, "Practicing Quality Control in a Bioanalytical Experiment," *J. Chem. Ed.* **1995**, *72*, 947.

J. A. Palasota and S. N. Deming, "Central Composite Experimental Designs," *J. Chem. Ed.* **1992**, *69*, 560.

J. Van Ryswyk and G. R. Van Hecke, "Attaining Optimum Conditions," *J. Chem. Ed.* **1991**, *68*, 878.

S. Sangsila, G. Labinaz, J. S. Poland, and G. W. vanLoon, "Sequential Simplex Optimization of an Atomic Absorption Analysis Procedure," *J. Chem. Ed.* **1989**, *66*, 351

Chapter **6 Chemical Equilibrium**

E. Keszei, M. G. Takács, and B. Vizkeleti, "A Straightforward Method to Determine Equilibrium Constants from Spectrophotometric Data," *J. Chem. Ed.* **2000**, *77*, 927.

E. Junquera and E. Aicart, "An Easy and Fast Experiment for the Determination of the Equilibrium Constants of an Acid–Base Pair, Free and Complexed with a Molecular

Receptor," *J. Chem. Ed.* **2000**, *77*, 1215.

G. A. Ibañez, A. C. Olivieri, and G. M. Escandar, "Determination of Equilibrium Constants of Metal Complexes from Spectrophotometric Measurements," *J. Chem. Ed.* **1999**, *76*, 1277.

B. Ungerer, R. Jurio, and R. J. Manuele, "Potentiometric Determination of the 'Operational' K_{sp} of $Ag(CN)_2Ag$," *J. Chem. Ed.* **1972**, *49*, 434. An advanced titration of CN^- and I^- with Ag^+.

R. W. Ramette, "Formation of Monothiocyanatoiron (III): A Photometric Equilibrium Study," *J. Chem. Ed.* **1963**, *40*, 71.

Chapter 7 Titrations

K. M. Blyth, L. R. Mullings, D. N. Phillips, D. Pritchard, and W. van Bronswijk, "Preparation, Analysis, and Characterization of Some Transition Metal Complexes," *J. Chem. Ed.* **2005**, *82*, 1667. Kjeldahl analysis and halide titration.

G. Lisensky and K. Reynolds, "Chloride in Natural Waters," *J. Chem. Ed.* **1991**, *68*, 334.

B. Ungerer, R. Jurio, and R. J. Manuele, "Potentiometric Determination of the 'Operational' K_{sp} of $Ag(CN)_2Ag$," *J. Chem. Ed.* **1972**, *49*, 434. An advanced titration of CN^- and I^- with Ag^+.

Chapter 8 Activity and the Systematic Treatment of Equilibrium

J. D. Willey, "The Effect of Ionic Strength on the Solubility of an Electrolyte," ($CaSO_4$) *J. Chem. Ed.* **2004**, *81*, 1644.

J. M. Bonicamp, A. Loflin, and W. R. Clark, "Measurement of Activity Coefficients in Concentrated Electrolyte Solutions," *J. Chem. Ed.* **2001**, *78*, 1541.

C. L. Cobb and G. A. Love, "Iron (III) Thiocyanate Revisited: A Physical Chemistry Equilibrium Lab Incorporating Ionic Strength Effects," *J. Chem. Ed.* **1998**, *75*, 90.

D. B. Green, G. Rechsteiner, and A. Honodel, "Determination of the Thermodynamic Solubility Product, K_{sp}^{o}, of PbI_2 Assuming Nonideal Behavior," *J. Chem. Ed.* **1996**, *73*, 789.

R. W. Ramette, "Formation of Monothiocyanatoiron (III): A Photometric Equilibrium Study," *J. Chem. Ed.* **1963**, *40*, 71.

R. W. Ramette, "The Dissociation Quotient of Bromocresol Green," *J. Chem. Ed*. **1963**, *40*, 252.

R. W. Ramette, "Solubility and Equilibria of Silver Chloride," *J. Chem. Ed.* **1960**, *37*, 348.

W. R. Carmody, "Variation of the Solubility Product Constant with Ionic Strength," ($Cd(IO_3)_2$) *J. Chem. Ed.* **1959**, *36*, 125.

R. W. Ramette, "Meaningful Solubility Studies in Elementary Quantitative Analysis," ($CaSO_4$ and $PbSO_4$) *J. Chem. Ed.* **1956**, *33*, 610.

Chapter 11 Acid-Base Titrations

G. Cruz, "Boric Acid in Kjeldahl Analysis," *J. Chem. Ed.* **2013**, *90*, 1645.

T. Michalowski, A. G. Asuero, and S. Wybraniec, "The Titration in the Kjeldahl Method of Nitrogen Determination: Base or Acid as Titrant?" *J. Chem. Ed.* **2013**, *90*, 191.

M. C. C. Azevedo and A. M. V. Cavaleiro, "The Acid-Base Titration of a Very Weak Acid: Boric Acid," *J. Chem. Ed.* **2012**, *89*, 767.

S. Farris, L. Mora, G. Capretti, and L. Piergiovanni, "Charge Density Quantification of Polyelectrolyte Polysaccharides by Conductometric Titration," *J. Chem. Ed.* **2012**, *89*, 121.

N. Koga, T. Kimura, and K. Shigedomi, "Laboratory Inquiry for Determining the Chemical Composition of a Component in Daily Use Detergent: Sodium Sesquicarbonate," *J. Chem. Ed.* **2011**, *88*, 1309.

Acid rain chemistry: F. S. Lopes, L. H. G. Coelho, and I. G. R. Gutz, "Unravelin the Role of Sulfur Compounds in Acid Rain Formation: Experiments on a Wetted Glass pH Electrode," *J. Chem. Ed*. **2010**, *87*, 157.

R. A. Scherrer and S. F. Donovan, "Automated Potentiometric Titrations in KCl/Water-Saturated Octanol: Method for Quantifying Factors Influencing Ion-Pair Partitioning," *Anal. Chem.* **2009**, *81*, 2768.

T. Michalowski, M. Toporek, and M. Rymanowski, "pH-Static Titration: A Quasistatic Approach," *J. Chem. Ed*. **2007**, *84*, 142.

H. Drossman, "Chemical Speciation Analysis of Sports Drinks by Acid-Base Titrimetry and Ion Chromatography: A Challenging Beverage Formulation Project," *J. Chem. Ed*. **2007**, *84*, 124.

J. Burnett and W. A. Burns, "Using a Spreadsheet to Fit Experimental pH Titration Data to a Theoretical Expression: Estimation of Analyte Concentration and K_a," *J. Chem. Ed*. **2006**, *83*, 1190.

K. M. Blyth, L. R. Mullings, D. N. Phillips, D. Pritchard, and W. van Bronswijk, "Preparation, Analysis, and Characterization of Some Transition Metal Complexes," *J. Chem. Ed.* **2005**, *82*, 1667. Kjeldahl analysis and halide titration.

N. E. Meagher, D. B. Bowens, and B. S. Clark, "A Quantitative Examination of Multiple Methods for Standardizing Dilute Hydrochloric Acid," *J. Chem. Ed*. **2005**, *82*, 428.

M. J. Santos-Delgado and L. Larrea-Tarruella, "A Didactic Experience of Statistical Analysis for the Determination of Glycine in a Nonaqueous Medium Using ANOVA and a Computer Program," *J. Chem. Ed.* **2004**, *81*, 97. (acid-base titration of glycine)

A. Kraft, "Determination of the pK_a of Multiprotic, Weak Acids by Analyzing Potentiometric Acid-Base Titration Data with Difference Plots," *J. Chem. Ed*. **2003**, *80*, 554.

P. Charlesworth, M. J. Seguin, and D. J. Chesney, "Comparing the Titrations of Mixed-Acid Solutions Using Dropwise and Constant-flow Techniques," *J. Chem. Ed.* **2003**, *80*, 1311.

C. M. Davis and M. C. Mauck, "Titrimetric Determination of Carbon Dioxide in a Heterogeneous Sample ('Pop Rocks')," *J. Chem. Ed.* **2003**, *80*, 552.

M. Davranche, S. Lacour, F. Bordas, and J.-C. Bollinger, "An Easy Determination of the Surface Chemical Properties of Simple and Natural Solids," *J. Chem. Ed.* **2003**, *80*, 76.

P. de B. Harrington, E. Kolbrich, and J. Cline, "Experimental Design and Multiplexed Modeling Using Titrimetry and Spreadsheets," *J. Chem. Ed.* **2002**, *79*, 863.

E. B. Flint, C. L. Kortz, and M. A. Taylor, "Microscale pH Titrations Using an Automatic Pipet," *J. Chem. Ed.* **2002**, *79*, 705.

M. Inoue and Q. Fernando, "Effect of Dissolved CO_2 on Gran Plots," *J. Chem. Ed.* **2001**, *78*, 1132.

K. R. Williams and L. H. Tennant, "Micelles in the Physical/Analytical Chemistry Laboratory: Acid Dissociation of Neutral Red Indicator," *J. Chem. Ed.* **2001**, *78*, 349.

K. L. Headrick, T. K. Davies, and A. N. Haegele, "A Simple Laboratory-Constructed

Automatic Titrator," *J. Chem. Ed.* **2000**, *77*, 389.

E. Junquera and E. Aicart, "An Easy and Fast Experiment for the Determination of the Equilibrium Constants of an Acid-Base Pair, Free and Complexed with a Molecular Receptor," *J. Chem. Ed.* **2000**, *77*, 1215.

S. S. Clareen, S. R. Marshall, K. E. Price, M. B. Royall, C. H. Yoder, and R. W. Schaeffer, "The Synthesis and Analysis of Ammine Complexes of Copper and Silver Sulfate," *J. Chem. Ed.* **2000**, *77*, 904.

S. Kocmur, E. Cortón, L. Haim, G. Locascio, and L. Galagosky, "CO_2 – Potentiometric Determination and Electrode Construction, a Hands-on Approach," *J. Chem. Ed.* **1999**, *76*, 1253.

G. S. Patterson, "A Simplified Method for Finding the pK_a of an Acid-Base Indicator by Spectrophotometry," *J. Chem. Ed.* **1999**, *76*, 395.

R. García-Doménech, J. V. de Julián-Ortiz, G. M. Antón-Fos, and J. Galvez Alvarez, "Determination of the Dissociation Constant for Monoprotic Acid by Simple pH Measurements," *J. Chem. Ed*. **1996**, *73*, 792.

S. K. Crossno, L. H. Kalbus, and G. E. Kalbus, "Determinations of Carbon Dioxide by Titration," *J. Chem. Ed*. **1996**, *73*, 175.

R. W. Clark, G. D. White, J. M. Bonicamp, and E. D. Watts, "From Titration Data to Buffer Capacities: A Computer Experiment for the Chemistry Lab or Lecture," *J. Chem. Ed*. **1995**, *72*, 746.

S. A. Tucker and W. E. Acree, Jr., "A Student-Designed Analytical Laboratory Method: Titrations and Indicator Ranges in Mixed Aqueous-Organic Solvents," *J. Chem. Ed.* **1994**, *71*, 71.

A. Vesala, "Estimation of Carbonate Content of Base by Gran's Method," *J. Chem. Ed.* **1992**, *69*, 577.

M. E. Lake, D. A. Grunow, and M.-C. Su, "Graphical Presentation of Acid-Base Reactions Using a Computer-Interfaced Autotitrator," *J. Chem. Ed.* **1992**, *69*, 299.

L. H. Kalbus, R. H. Petrucci, J. E. Forman, and G. E. Kalbus, "Titration of Chromate-Dichromate Mixtures," *J. Chem. Ed.* **1991**, *68*, 677.

F. T. Chau, H. K. Tse, and F. L. Cheng, "Modified Gran Plots of Very Weak Acids on a Spreadsheet," *J. Chem. Ed.* **1990**, *67*, A8.

J. A. Lynch and J. D. Narramore, "The Mariotte Bottle and Automation of a Potentiometric Titration," *J. Chem. Ed.* **1990**, *67*, 533.

C. A. Castillo S. and A. Jaramillo A., "An Alternative Procedure for Titration Curves of a Mixture of Acids of Different Strengths," *J. Chem. Ed.* **1989**, *66*, 341.

V. T. Lieu and G. E. Kalbus, "Potentiometric Titration of Acidic and Basic Compounds in Household Cleaners," *J. Chem. Ed.* **1988**, *65*, 184.

Chapter 12 EDTA Titrations

R. Stoodley, J. R. Rodriguez Nuñez, and T. Bartz, "Field and In-Lab Determination of Ca^{2+} in Seawater," *J. Chem. Ed.* **2014**, *91*, 1954.

P.-L. Fabre and O. Reynes, "Determination of Copper and Zinc in Brass," *J. Chem. Ed.* **2010**, *87*, 836.

M. Romero, V. Guidi, A. Ibarrolazza, and C. Castells, "Complexometric Determination of Mercury Based on a Selective Masking Reaction," *J. Chem. Ed.* **2009**, *86*, 1091.

S.-P. Yang and C.-C. Li, "Using Student-Developed, Inquiry-Based Experiments to Investigate the Contributions of Ca and Mg to Water Hardness," *J. Chem. Ed.* **2009**, *86*, 906.

D. Belle-Oudry, "Quantitative Analysis of Sulfate in Water by Indirect EDTA Titration," *J. Chem. Ed.* **2008**, *85* 1269.

E. Garribba and G. Micera, "Complexation of Copper(II) Ion with Tetraglycine as Followed by Electronic Absorption Spectroscopy," *J. Chem. Ed.* **2007**, *84*, 832. Measuring metal-ligand equilibria.

S.-P. Yang and R.-Y. Tsai, "Complexometric Titration of Aluminum and Magnesium Ions in Commercial Antacids," *J. Chem. Ed.* **2006**, *83*, 906.

S. F. Novick, "Complexometric Titration of Zinc," *J. Chem. Ed.* **1997**, *74*, 1463.

D. M. Mossman, R. G. Kooser, and L. E. Welch, "The Complexometric Determination of Calcium and Magnesium in Limestone Using a Laser Photometer for Endpoint Identification," *J. Chem. Ed.* **1996**, *73*, 82.

Chapter 13 Advanced Topics in Equilibrium

M. A. Curtin, L. R. Ingalls, An Campbell, and M. James-Pederson, "Hydroloysis Studies and Quantitative Determination of Aluminum Ions Using ^{27}Al NMR," *J. Chem. Ed.* **2008**, *85*, 291.

Chapter 14 Fundamentals of Electrochemistry

J. L. Brosmer and D. G. Peters, "Galvanic Cells and the Determination of Equilibrium Constants," *J. Chem. Ed.* **2012**, *89*, 763.

J. G. Ibanez, A. Finck-Pastrana, A. Mugica-Barrera, P. Balderas-Hernandez, M. E. Ibarguengoitia-Cervantes, E. Garcia-Pintor, J. M. Hartasanchez-Frenk, C. E. Bonilla-Juarez, C. Maldonado-Cordero, A. Struck-Garza, and F. Suberbie-Rocha, "The One Penny Photovoltaic Cell," *J. Chem. Ed.* **2011**, *88*, 1287.

J. Ge, R. Schirhagl, and R. N. Zare, "Glucose-Driven Fuel Cell Constructed from Enzymes and Filter Paper," *J. Chem. Ed.* **2011**, *88*, 1283.

Chapter 15 Electrodes and Potentiometry

R. Barlag, F. Nyasulu, R. Starr, J. Silverman, P. Arthasery, and L. McMills, "A Student-Made Slilver-Silver Chloride Reference for the General Chemistry Laboratory," *J. Chem. Ed*. **2014**, *91*, 766.

F. C. Sauls, "A Simple Determination of the Ag_2O Solubility Product by Potentiometric Determination of Both Ag+ and OH^-," *J. Chem. Ed*. **2013**, *90*, 1212.

M.. Berger, "Potentiometric Determination of Chloride in Natural Waters," *J. Chem. Ed*. **2012**, *89*, 812.

M. J. Goldcamp, A. Conklin, K. Nelson, J. Marchetti, R. Brashear, and E. Epure, "Inexpensive and Disposble pH Electrodes," *J. Chem. Ed*. **2010**, *87*, 1262.

S. N. Inamadar, M. A. Bhat, and S. K. Haram, "Construction of Ag/AgCl Reference Electrode from Used Felt-Tipped Pen Barrel," *J. Chem. Ed*. **2009**, *86*, 355.

P.-O. Eggen, "A Simple Hydrogen Electrode," *J. Chem. Ed*. **2009**, *86*, 352.

H. Moresco, P. Sansón, and G. Seoane, "Simple Potentiometric Determination of Reducing

Sugars," *J. Chem. Ed*. **2008**, *85*, 1091.

H. M. Marafie, A. F. Shoukry, and L. A. Alshatti, "Plastic Membrane Sensor From a Disposed Combined Glass Electrode," *J. Chem. Ed*. **2007**, *84*, 793. Ion-selective electrode for hydrazalium ion, a vasodilator drug.

H. Van Ryswyk, E. W. Hall, S. J. Petesch, and A. E. Wiedeman, "Extending the marine Microcosm Laboratory," *J. Chem. Ed*. **2007**, *84*, 306. Standard addition with ion-selective electrode.

D. L. Van Engelen, S. W. Suljak, J. P. Hall, and B. E. Holmes, "Undergraduate Introductory Quantitative Chemistry Laboratory Course: Interdisciplinary Group Projects in Phytoremediation," *J. Chem. Ed.* **2007**, *84*, 128. A semester-long course employing multiple analytical methods in the context of group research projects.

D. B. Craig and E. R. Nichols, "Spectroscopic Measurement of the Redox Potential of Cytochrome c for the Undergraduate Biochemistry Laboratory," *J. Chem. Ed.* **2006**, *83*, 1325.

F. Scholz, T. Steinhardt, H. Kahlert, J. R. Pörksen, and J. Behnert, "Teaching pH Measurements with a Student-Assembled Combination Quinhydrone Electrode," *J. Chem. Ed.* **2005**, *82*, 782.

T. A. Bendikov and T. C. Harmon, "A Sensitive Nitrate Ion-Selective Electrode from a Pencil Lead," *J. Chem. Ed.* **2005**, *82*, 439.

J. Liu, "Investigation of Cu(II) Binding to Bovine Serum Albumin by Potentiometry with an Ion Selective Electrode," *J. Chem. Ed.* **2004**, *81*, 395.

J. I. Selco, J. L. Roberts, Jr., and D. B. Wacks, "The Analysis of Seawater: A Laboratory-Centered Learning Project in General Chemistry," *J. Chem. Ed.* **2003**, *80*, 54.

E. Cortón, L. Haim, S. Kocmur, G. J. Visbeek, and L. Galagovsky, "A Nonradioactive Simulation of the Viking Mission Labeled-Release Experiment: A Search for Evidence of Life," *J. Chem. Ed.* **2002**, *79*, 1105. Uses CO_2 electrode.

G. Rum, W.-Y. Lee, and J. Gardea-Torresdey, "Fluoride Determination in an Environmental Chemistry Laboratory," *J. Chem. Ed.* **2000**, *77*, 1604.

G. Li, B. J. Polk, L. A. Meazell, and D. W. Hatchett, "ISE Analysis of Hydrogen Sulfide in Cigarette Smoke," *J. Chem. Ed.* **2000**, *77*, 1049.

S. Kocmur, E. Cortón, L. Haim, G. Locascio, and L. Galagosky, "CO_2–Potentiometric

Determination and Electrode Construction," *J. Chem. Ed.* **1999**, *76*, 1253.

J.K. Christensen, B. Høyer, L. Kryger, N. Pind, and L. S. Kong, "The Determination of Hydrogen Sulfide and Acid-Soluble Metallic Sulfides in Sea-Floor Sediment," *J. Chem. Ed.* **1998**, *75*, 1605.

K. R. Williams, "Automatic Titrators in the Analytical and Physical Chemistry Laboratories," *J. Chem. Ed.* **1998**, *75*, 1133.

P. Riyazuddin and D. Devika, "Potentiometric Acid-Base Titrations with Activated Graphite Electrodes," *J. Chem. Ed*. **1997**, 74, 1198.

S. E. Creager, K. D. Lawrence, and C. R. Tibbets "An Easily Constructed Salicylate-Ion-Selective Electrode for Use in the Instructional Laboratory," *J. Chem. Ed.* **1995**, *72*, 274.

R. T. da Rocha, I. G. R. Gutz, and C. L. do Lago, "From Christmas Ornament to Glass Electrode," *J. Chem. Ed*. **1995**, *72*, 1135. Make your own glass pH electrode.

N. Radić and J. Komijenović, "Potentiometric Determination of an Overall Formation Constant Using an Ion-Selective Membrane Electrode, *J. Chem. Ed*. **1993**, *70*, 509.

W. S. Selig, "Quaternary Ammonium Halides: Versatile Reagents for Precipitation Titrations," *J. Chem. Ed*. **1987**, *64*, 141.

W. H. Chan, M. S. Wong, and C. W. Yip, "Ion-Selective Electrode in Organic Analysis: A Salicylate Electrode," *J. Chem. Ed*. **1986**, *63*, 915.

A. Palanivel and P. Riyazuddin, "Fabrication of an Inexpensive Ion-Selective Electrode," *J. Chem. Ed*. **1984**, *61*, 920.

T. L. Riechel, "A Gas-Sensor-Based Urea Enzyme Electrode," *J. Chem. Ed*. **1984**, *61*, 640.

T. E. Mifflin, K. M. Andriano, and W. B. Robbins, "Determination of Penicllin Using an Immobilized Enzyme Electrode," *J. Chem. Ed*. **1984,** *61*, 638.

W. S. Selig, "Potentiometric Titrations Using Pencil and Graphite Sensors," *J. Chem. Ed*. **1984**, *61*, 80.

Build your own pH meter: E. Vitz and T. A. Betts, "LIMSport (V): pH Data Acquisition: An Inexpensive Probe and Calibration Software," *J. Chem. Ed.* **1994**, *71*, 412; D. L. Harris and D. C. Harris, "A Low-Cost pH Meter for the Classroom," *J. Chem. Ed.* **1992**, *69*, 563; M. R. Paris, D. J. Aymes, R. Poupon, and R. Gavasso, "Development of a New Design for Multipurpose Meter: 'Calo-pH Meter'," *J. Chem. Ed.* **1990**, *67*, 507; M. S. Caceci, "An Inexpensive, Very High Impedance Digital Voltmeter for Selective

Electrodes," *J. Chem. Ed.* **1984**, *61*, 935; and B. D. Warner, G. Boehme, and K. H. Pool, "The Construction of Inexpensive Digital pH Meters," *J. Chem. Ed.* **1982**, *59*, 65.

Chapter 16 Redox Titrations

W. B. Guenther, "Supertitrations: High Precision Methods," *J. Chem. Ed*. **1988**, *65*, 1097. (An extremely precise mass titration that stresses careful laboratory technique.)

C. F. Polomar-Ramírez, J. A. Bazán-Maretínez, M. E. Palomar-Pardavé, M. A. Romero-Romo, and M. T. Ramírez -Silva, "Taking Advantage of a Corrosion Problem to Solve a Pollution Problem," *J. Chem. Ed.* **2011**, *88*, 1109.

M. A. Rizvi, R. M. Syed, and B. Khan, "Complexation Effect on Redox Potential of Iron(III)-Iron(II) Couple," *J. Chem. Ed*. **2011**, *88*, 220.

A. R. Pinhas, "A Redox Titration for a General-Organic-Biochemistry Course using Povidone Iodine," *J. Chem. Ed*. **2010**, *87*, 985.

T. H. Huang, G. Salter, S. L. Kahn, and Y. M. Gindt, "Redox Titration of Ferricyanide to Ferrocyanide with Ascorbic Acid: Illustrating the Nernst Equation and the Beer-Lambert Law," *J. Chem. Ed*. **2007**, *84*, 1180.

S. Sowa and A. E. Kondo, "Sailing on the 'C': A Vitamin Titration with a Twist," *J. Chem. Ed*. **2003**, *80*, 550.

J. N. Richardson, M. T. Stauffer, and J. L. Henry, "Microscale Quantitative Analysis of Hard Water Samples Using an Indirect Potassium Permanganate Redox Titration," *J. Chem. Ed*. **2003**, *80*, 65.

D. N. Phillips, "Teaching Analytical Chemistry Through Mineral Analysis," *Anal. Chem*. **2002**, *74*, 427A.

M. H. F. B. Soares, L. A. Ramos, and E. T. G. Cavalhiero, "Spectrophotometric Determination of Total Sulfite in White Wine Samples Using Crude Extracts from Flowers," *J. Chem. Ed*. **2002**, *79*, 1111. Compares iodimetric and spectrophotometric determinations.

G. A. East and E. C. Nascimento, "Microscale Determination of Vitamin C by Weight Titrimetry," *J. Chem. Ed*. **2002**, *79*, 100.

M. d. C. S. Barreto, L. d. L. Medeiros, and P. C. d. H. Furtado, "Indirect Potentiometric

Titration of Fe(III) with Ce(IV) by Gran's Method," *J. Chem. Ed*. **2001**, *78*, 91.

O.-W. Lau, S.-F. Luk, N. L. N. Cheng, and H.-Y. Woo, "Determination of Free Lime in Clinker and Cement by Iodometry," *J. Chem. Ed*. **2001**, *78*, 1671.

S. Murov and B. Stedjee, "Analysis of Zinc Tablets, An Extension to a Stoichiometry Experiment," *J. Chem. Ed*. **2001**, *78*, 1389.

B. A. Balko and P. G. Tratnyek, "A Discovery-Based Experiment Illustrating How Iron Metal is Used to Remediate Contaminate Groundwater," *J. Chem. Ed*. **2001**, *78*, 1661.

J. R. Powell, S. A. Tucker, W. E. Acree, Jr., J. A. Sees, and L. H. Hall, "A Student-Designed Potentiometric Titration: Quantitative Determination of Iron(II) by Caro's Acid Titration," *J. Chem. Ed*. **1996**, *73*, 984.

V. Kumar, P. Courie, and S. Haley, "Quantitative Microscale Determination of Vitamin C," *J. Chem. Ed.* **1992**, *69*, A213.

R. L. Helser, "Improving a Microscale Vitamin C Laboratory," *J. Chem. Ed*. **1995**, *72*, A10.

M. Bader, "Environmentally Acceptable Determination of Iron," *J. Chem. Ed*. **1995**, *72*, 860.

S. Kaufman and H. DeVoe, "Iron Analysis by Redox Titration," *J. Chem. Ed*. **1988**, *65*, 183.

Chapter 17 Electroanalytical Techniques

S. J. Messersmith, "Cyclic Voltammetry Simulations with DigiSim Software: An Upper Level Undergraduate Experiment," *J. Chem. Ed.* **2014**, *91*, 1498.

J. R. Mott, P. J. Munson, R. A. Kreuter, B. S. Chohan, and D. G. Sykes, "Design, Development, and Characterization of an Inexpensive Portable Cyclic Voltameter" *J. Chem. Ed*. **2014**, *91*, 1028.

C. Scanlon, Z. Gebeyehu, K. Griffin, and R. B. Dabke, "Volumetric Titrations Using Electrolytically Generated Reagents for the Determination of Ascorbic Acid and Iron in Dietary Supplement Tablets" *J. Chem. Ed*. **2014**, *91*, 898.

D. E. Goodney and T. P. Silverstein, "Using the Tyrosinase-Based Biosensor to Determine the Concentration of Phenolics in Wine" *J. Chem. Ed*. **2013**, *90*, 1710.

J. M. Hobbs, N. N. Patel, D. W. Kim, J. K. Rugutt, and A. K. Wanekaya, "Glucose Determination in Beverages Using Carbon Nanotube Modified Biosensor," *J. Chem. Ed*. **2013**, *90*, 1226.

P. Heinzerling, F. Schrader, and S. Schanze, "Measurement of Enzyme Kinetics by Use of a Blood Glucometer: Hydrolysis of Sucrose and Lactose," *J. Chem. Ed*. **2012**, *89*, 1582.

A. Izadyar, Y. Kim, M. M. Ward, and S. Amemiya, "Double-Polymer-Modified Pencil Lead for Stripping Voltammetry of Perchlorate in Drinking Water," *J. Chem. Ed*. **2012**, *89*, 1323.

M. Riehl, "Determination of Biochemical Oxygen Demand of Area Waters: A Bioassay Procedure for Environmental Monitoring," *J. Chem. Ed*. **2012**, *89*, 807.

U. K. Sur, A. Dhason, and V. Lakshminarayanan, "A Simple and Low-Cost Ultramicroelectrode Fabrication and Characterization Method for Undergraduate Students," *J. Chem. Ed*. **2012**, *89*, 168.

R. B. Dabke, Z. Gebeyehu and R. Thor, "Coulometric Analysis Experiment for the Undergraduate Chemistry Laboratory," *J. Chem. Ed*. **2011**, *88*, 1707.

T. S. Kuntzleman, J. B. Kenney, S. Hasbrouck, M. J. Collins, and J. R. Amend, "Simple and Automated Coulometric Titration of Acid Using Nonisolated Electrodes," *J. Chem. Ed*. **2011**, *88*, 1565.

R. H. Parker, "An Inexpensive Electrodeposition Device and its Use in a Quantitative Analysis Laboratory Exercise," *J. Chem. Ed*. **2011**, *88*, 1428. (electrogravimetric nickel determination)

A. H. Elsayed-Ali, T. Abdel-Fattah, and H. E. Elsayed-Ali, "Laboratory Experiment on Electrochemical Remediation of Soil," *J. Chem. Ed*. **2011**, *88*, 1126.

J. G Ibanez, P. Balderas-Hernandez, E. Garcia-Pintor, S. N. Barba-Gonzalez, M. del Carmen Doria-Serrano, L. Hernaiz-Arce, A. Diaz-Perez, and A. Lozano-Cusi, "Laboratory Experiments on the Electrochemical Remediation of the Environment. Part 9: Microscale Recovery of a Soil Metal Pollutant and its Extractant," *J. Chem. Ed*. **2011**, *88*, 1123.

K. R. Williams, V. Y. Young, and B. Killian, "Coulometric Titration of EDTA with Spectrophotometric End Point Detection," *J. Chem. Ed.* **2011**, *88*, 315.

V. C. Dominguez, C. R. McDonald, M; Johnson, D. Schunk, R. Kreuter, D. Sykes, ,B. T. Wigton, and B. S. Chohan, "The Characterization of a Custom-Built Coulometric Karl Fischer Titration Apparatus," *J. Chem. Ed*. **2010**, *87*, 987.

D. J. Schmidt, E. M. Pridgen, P. T. Hammond, and J. C. Love, "Layer-by-Layer Assembly of

a pH-Responsive and Electrochromic Thin Film," *J. Chem. Ed*. **2010**, *87*, 208.

H. Sariçayir, M. Uce, and A. Koca, "In Situ Techniques for Monitoring Electrochromism," *J. Chem. Ed*. **2010**, *87*, 205.

G. Stewart, T. S. Kuntzleman, J. R. Amend, and M. J. Collins, "Affordable Cyclic Voltammetry," *J. Chem. Ed*. **2009**, *86*, 1080.

T. Ito, D. M. Neluni, T. Perera, and S. Nagasaka, "Gold Electrodes Modified with Self-Assembled Monolayers for Measuring L-Ascorbic Acid," *J. Chem. Ed*. **2008**, *85*, 1112. (cyclic voltammetry)

M. J. Goldcamp, M. N. Underwood, J. L. Cloud, S. Harshman, and K. Ashley, "An Environmentally Friendly, Cost-Effective Determination of Lead in Environmental Samples Using Anodic Stripping Voltammetry," *J. Chem. Ed*. **2008**, *85*, 976. (standard addition)

C. E. Perles and P. L. O. Volpe, "A Simple Laboratory Experiment to Determine the Kinetics of Mutarotation of D-Glucose Using a Blood Glucose Meter," *J. Chem. Ed*. **2008**, *85*, 686.

S. K. Lunsford, N. Speelman, J. Stinson, A. Yeary, H. Choi, J. Widera, and D. D. Dionysiou, "Electroanalytical and Spectroscopic Studies of Poly(2,2'-bithiophene)-Modified Platinum Electrode to Detect Catechol in the Presence of Ascorbic Acid," *J. Chem. Ed*. **2008**, *85*, 128.

M. Hepel, "Electrochromic WO_3 Films: Nanotechnology Experiments in Instrumental Analysis and Physical Chemistry Laboratories," *J. Chem. Ed*. **2008**, *85*, 125.

T. Shtoyko, O. D. Stuart, and H. N. Gray, "Spectroelectrochemical Sensing of Aqueous Iron," *J. Chem. Ed*. **2007**, *84*, 1467.

E. Igartúa-Nieves, Y. Ocasio-Delgado, J. Rivera-Pagán, and J. E. Cortés-Figueroa, "Electrochemistry of (Dihapto-Buckminster-Fullerene)Pentacarbonyl Tungsten(0)," *J. Chem. Ed*. **2007**, *84*, 1464.

J. Njagi, J. Warner, and S. Andreescu, "A Bioanalytical Chemistry Experiment for Undergraduate Students: Biosensors Based on Metal Nanoparticles," *J. Chem. Ed*. **2007**, *84*, 1180.

N. Nunes, A. Martins, And R. E. Leitão, "Study of Metal-NH_3 Interfaces (Metal = Cu, Ni, Ag) Using Potentiostatic Curves," *J. Chem. Ed*. **2007**, *84*, 1017.

Q. Xie, Z. Li, C. Deng, M. Liu, Y. Zhang, M. Ma, S. Xia, X. Xiao, D. Yin, and S. Yao, "Electrochemical Quartz Crystal Microbalance Monitoring of the Cyclic Voltammetric Deposition of Polyaniline," *J. Chem. Ed*. **2007**, *84*, 681.

M. C. Blanco-López, M. J. Lobo-Castañón, and A. J. Miranda-Ordieres, "Homemade Bienzymatic-Amperometric Biosensor for Beverages Analysis," *J. Chem. Ed*. **2007**, *84*, 677.

M. Kamata and M. Paku, "Exploring Faraday's Law of Electrolysis Using Zinc-Air Batteries with Current Regulative Diodes," *J. Chem. Ed*. **2007**, *84*, 674.

C. D. Ceballos, M. A. Zón, and H. Fernández, "Using Square Wave Voltammetry on Ultramicroelectrodes to Determine Synthetic Antioxidants in Vegetable Oil," *J. Chem. Ed*. **2006**, *83*, 1349.

T. Aiyejorun, J. Kowalik, J. Janata, and M. Josowicz, "Label-Free Detection of DNA Hybridization by Cyclic Voltammetry," *J. Chem. Ed*. **2006**, *83*, 1208.

R. A. Verdini and C. M. Lagier, "Studying Current-Potential Curves Using a Bipotentiometric Iodometric Back-Titration for the Determination of Ascorbic Acid in Fruits and Vegetables," *J. Chem. Ed.* **2004**, *81*, 1482.

L. Ma and M. M. F. Choi, "Application of a Data Logger in Biosensing: A Reagentless Hydrogen Peroxide Biosensor," *J. Chem. Ed.* **2004**, *81*, 862.

C. M. Sánchez-Sánchez, E. Expósito, A. Frías-Ferrer, J. González--García, V. Montiel, and A. Aldaz, "Chlor-Alkali Industry: A Laboratory Scale Approach," *J. Chem. Ed.* **2004**, *81*, 698.

M. T. S. R. Gomes, M. M. O. Oliveira, M. A. Fonseca, and J. A. B. P. Oliveira, "An Expeditious Experiment to Determine the Faraday Constant," *J. Chem. Ed.* **2004**, *81*, 116.

C. M. Sánchez-Sánchez, E. Expósito, J. Solla-Gullón, V. García-García, V. Montiel, and A. Aldaz, "Calculation of the Characteristic Performance Indicators in an Electrochemical Process," *J. Chem. Ed.* **2003**, *80*, 529. Efficiency of an electrochemical synthesis.

M. M. F. Choi and P. S. Wong, "Application of a Data Logger in Biosensing: A Glucose Biosensor," *J. Chem. Ed.* **2002**, *79*, 982.

M. M. F. Choi, P. S. Wong, and T. P. Yiu, "Application of a Data Logger in Observing Photosynthesis," *J. Chem. Ed.* **2002**, *79*, 980. Uses oxygen electrode.

D. Martel, N. Sojic, and A. Kuhn, "A Simple Student Experiment for Teaching Surface Electrochemistry: Adsorption of Polyoxometalate on Graphite Electrodes," *J. Chem. Ed.* **2002**, *79*, 349.

M. B. Jensen, "Integrating HPLC and Electrochemistry: A LabVIEW-Based Pulsed Amperometric Detection System," *J. Chem. Ed.* **2002**, *79*, 345.

D. Lowinsohn and M. Bertotti, "Coulometric Titrations in Wine Samples: Determination of S(IV) and the Formation of Adducts," *J. Chem. Ed.* **2002**, *79*, 103.

G. A. East and E. C. Nascimento, "Microscale Determination of Vitamin C by Weight Titrimetry," *J. Chem. Ed.* **2002**, *79*, 100. Bipotentiometric end point detection.

T. J. Melton, "Modification of a Lactase Experiment by Use of Commercial Test Strips," *J. Chem. Ed.* **2001**, *78*, 1243.

P. A. Mabrouk and K. Castriotta, "Moisture Analysis in Lotion by Karl Fischer Coulometry," *J. Chem. Ed.* **2001**, *78*, 1385.

J. J. Gooding, W. Yang, and M. Situmorang, "Bioanalytical Experiments for the Undergraduate Laboratory: Monitoring Glucose in Sports Drinks," *J. Chem. Ed*. **2001**, *78*, 788.

J. M. D. Rodríguez, J. A. H. Melián, and J. P. Peña, "Determination of the Real Surface Area of Pt Electrodes by Hydrogen Adsorption Using Cyclic Voltammetry," *J. Chem. Ed.* **2000**, *77*, 1195.

H. E. Toma, K. Araki, and S. Dovidauskas, "A Cyclic Voltammetry Experiment Illustrating Redox Potentials, Equilibrium Constants, and Substitution Reactions in Coordination Chemistry," *J. Chem. Ed.* **2000**, *77*, 1351.

E. Howard and J. Cassidy, "Analysis with Microelectrodes Using Microsoft Excel Solver," *J. Chem. Ed.* **2000**, *77*, 409.

P. L. Edmiston and T. R. Williams, "An Analytical Laboratory Experiment in Error Analysis: Repeated Determination of Glucose Using Commercial Glucometers," *J. Chem. Ed.* **2000**, *77*, 377.

T. Schober and J. Friedrich, "Laboratory Application and Demonstration of Automotive Oxygen Sensors," *J. Chem. Ed*. **1999**, *76*, 1697.

R. John and D. Lord, "Determination of Anionic Surfactants Using Atomic Absorption Spectrometry and Anodic Stripping Voltammetry," *J. Chem. Ed.* **1999**, *76*, 1256.

O. A. Sadik, S. Brenda, P. Joasil, and J. Lord, "Electropolymerized Conducting Polymers as Glucose Sensors," *J. Chem. Ed.* **1999**, *76*, 967.

M. Situmorang, M. T. B. Lee, K. Witzeman, and W. R. Heineman, "Liquid Chromatography with Electrochemical Detection (LC–EC): An Experiment Using 4-Aminophenol," *J. Chem. Ed.* **1998**, *75*, 1035.

A. Lötz, "A Variety of Electrochemical Methods in a Coulometric Titration Experiment," *J. Chem. Ed.* **1998**, *75*, 775.

T. Goscinska, "Laboratory-Made Electrochemical Sensors for Adsorptive Stripping Voltammetry," *J. Chem. Ed.* **1998**, *75*, 1038.

L. Sipos, "Inhibition of Sulfite Oxidation by Phenols: Screening Antioxidant Behavior with a Clark Oxygen Sensor," *J. Chem. Ed.* **1998**, *75*, 1603.

M. M. Walczak, D. A. Dryer, D. D. Jacobson, M. G. Foss, and N. T. Flynn, "pH-Dependent Redox Couple: Illustrating the Nernst Equation Using Cyclic Voltammetry," *J. Chem. Ed.* **1997**, *74*, 1195.

J. A. Herrera-Melián, J. M. Doña-Rodriguez, J. Hernández-Brito, and J. Pérez-Peña, "Voltammetric Determination of Ni and Co in Water Samples," *J. Chem. Ed.* **1997**, *74*, 1444.

J. Wang and C. Maccà, "Use of Blood-Glucose Test Strips for Introducing Enzyme Electrodes and Modern Biosensors," *J. Chem. Ed*. **1996**, *73*, 797.

P. García-Armada, José Losada, and S. de Vicente-Pérez, "Cation Analysis Scheme by Differential Pulse Polarography," *J. Chem. Ed.* **1996**, *73*, 544.

J. Swim, E. Earps, L. M. Reed, and D. Paul, "Constant-Current Coulometric Titration of Hydrochloric Acid," *J. Chem. Ed.* **1996**, *73*, 679.

R. Gostowski, "Teaching Analytical Instrument Design with LabVIEW," *J. Chem. Ed.* **1996**, *73*, 1103.

C. W. K. Chow, D. E. Davey, M. R. Haskard, D. E. Mulcahy, and T. C. W. Yeow, "Potentiometric Stripping Analysis," *J. Chem. Ed.* **1994**, *71*, 71.

M. D. Koppang and T. A. Holme, "Introducing Dynamic Electrochemistry in the Physical Chemistry Curriculum: Hydrogen Adsorption at a Platinum Electrode," *J. Chem. Ed*. **1992**, *69*, 770.

M. E. Gomez and A. E. Kaifer, "Voltammetric Behavior of a Ferrocene Derivative," *J.*

Chem. Ed. **1992**, *69*, 502.

G. E. Kalbus and V. T. Lieu, "Dietary Fat and Health: An Experiment on the Determination of Iodine Number of Fats and Oils by Coulometric Titration," *J. Chem. Ed.* **1991**, *68*, 64.

J. L. Town, F. MacLaren, and H. D. Dewald, "Rotating Disk Voltammetry Experiment," *J. Chem. Ed.* **1991**, *68*, 352.

P. Lanza, "Multiple Analysis by Differential Pulse Polarography," *J. Chem. Ed.* **1990**, *67*, 704.

D. Martin and F. Mendicuti, "Polarographic Determination of Composition and Thermodynamic Stability Constant of a Complex Metal Ion," *J. Chem. Ed*. **1988**, *65*, 916.

J. G. Ibáñez, I. González, and M. A. Cárdenas, "The Effect of Complex Formation upon the Redox Potentials of Metallic Ions," *J. Chem. Ed*. **1988**, *65*, 173.

M. Bertotti, J. M. Vaz, and R. Telles, "Ascorbic Acid Determination in Natural Orange Juice as a Teaching Tool of Coulometry and Polarography," *J. Chem. Ed*. **1985**, *62*, 445.

T. J. Farrell, R. J. Laub, and E. P. Wadsworth, Jr., "Anodic Polarography of Cyanide in Foodstuffs," *J. Chem. Ed*. **1987**, *64*, 635.

E. Briullas, J. A. Garrido, R. M. Rodríguez, and J. Doménech, "A Cyclic Voltammetry Experiment Using a Mercury Electrode," *J. Chem. Ed*. **1987**, *64*, 189.

L. Piszczek, A. Ignatowicz, and K. Kielbasa, "Application of Cyclic Voltammetry for Stoichiometry Determination of Ni(II), Co(II), and Cd(II) Complex Compounds with Polyaminopolycarboxylic Acids," *J. Chem. Ed*. **1988**, *65*, 171.

R. S. Pomeroy, M. B. Denton, and N. R. Armstrong, "Voltammetry at the Thin-Film Mercury Electrode," *J. Chem. Ed*. **1989**, *66*, 877.

J. I. Gardiazabal and R. Schrebler, "An Inexpensive Electrode and Cell for Measurement of Oxygen Uptake in Chemical and Biochemical Systems," *J. Chem. Ed*. **1983**, *60*, 677.

D. G. Marsh, D. L. Jacobs, and H. Veening, "Analysis of Commercial Vitamin C Tablets by Iodometric and Coulometric Titrimetry," *J. Chem. Ed*. **1973**, *50*, 626.

E. Grimsrud and J. Amend, "Coulometry Experiments Using Simple Electronic Devices," *J. Chem. Ed*. **1979,** *56*, 131.

Chapter 18 Fundamentals of Spectrophotometry

M. F. Harris and J. L. Logan "Determination of Log $K_{\text{octanol-water}}$ Values for Four Drugs," *J. Chem. Ed.* **2014**, *91*, 915.

R. V. Flores, H. M. Solá, J. C. Torres, R. E. Torres, and E. E. Guzmán "Effect of pH on the Heat-Induced Denaturation and Renaturation of Green Fluorescent Protein," *J. Chem. Ed.* **2013**, *90*, 1248.

O. A. El Seoud, C. Loffredo, P. D. Galgano, B. M. Sato, and C. Reichardt, "Have Biofuel, Will Travel: A Colorful Experiment and a Different Approach to Teach the Undergraduate Laboratory," *J. Chem. Ed.* **2011**, *88*, 1293.

F. Nyasulu and R. Barlag, "Colorimetric Determination of the Iron(III)-Thiocyanate Reaction Equilibrium Constant," *J. Chem. Ed.* **2011**, *88*, 313.

G. Wilczek-Verá and E. D. Salin, "Understanding Fluorescence Measurements through a Guided-Inquiry and Discovery Experiment," *J. Chem. Ed.* **2011**, *88*, 216.

W. C. Galley, O. M. Tanchak, K. G. Yager, and G. Wilczek-Verá, "Excited-State Processes in Slow Motion," *J. Chem. Ed.* **2010**, *87*, 1252.

A. P. Umali, E. V. Anslyn, A. T. Wright, C. R. Blieden, C. K. Smith, T. Tian, J. A. Truong, C. E. Crumm, J. E. Garcia, S. Lee, M. Mosier, and C. P. Nguyen, "Analysis of Citric Acid in Beverages: Use of an Indicator Displacement Assay," *J. Chem. Ed.* **2010**, *87*, 832.

J. Bai, K. Flowers, S. Benegal, M. Calizo, V. Patel, and S. W. Bishnoi, "Using the Enzymatic Growth of Nanoparticles to Create a Biosensor," *J. Chem. Ed.* **2009**, *86*, 712.

S. G. Cessna, T. L. S. Kishbaugh, D. G. Neufeld, and G. A. Cessna, "A Multiweek, Problem-Based Laboratory Project Using Phytoremediation to Remove Copper from Soil," *J. Chem. Ed.* **2009**, *86*, 726. A general chemistry project employing multiple analytical methods.

M. A. Hoch, C. B. Russell, D. M. Steffen, G. C. Weaver, and J. R. Burgess, "Assessment of Antioxidant Capacities in Foods: A Research Experience for General Chemistry Students," *J. Chem. Ed*. **2009**, *86*, 595.

K. M. Maloney, E. M. Quiazon, and R. Indralingam, "Measurement of Iron in Egg Yolk: An Instrumental Analysis Experiment Using Biochemical Principles," *J. Chem. Ed*. **2008**, *85*,

399.

D. J. Williams, T. J. Flaherty, C. L. Jupe, S. A. Coleman, K. A. Marquez, and J. H. Stanton, "Beyond λ_{max}: Transforming Visible Spectra into 24-Bit Color Values," *J. Chem. Ed*. **2007**, *84*, 1873.

C. J. Fenk, N. Kaufman, and D. G. Gerbig, Jr., "A New Colorimetric Assay of Tabletop Sweeteners Using a Modified Biuret Reagent," *J. Chem. Ed*. **2007**, *84*, 1676.

H. Van Ryswyk, E. W. Hall, S. J. Petesch, and A. E. Wiedeman, "Extending the Marine Microcosm Laboratory," *J. Chem. Ed*. **2007**, *84*, 306. Nitrate analysis with nitrate reductase in place of Cd.

M. M. Areco, M. dos Santos Afonso, and E. Valdman, "Zinc Biosorption by Seaweed Illustrated by the Zincon Colorimetric Method and the Langmuir Isotherm," *J. Chem. Ed*. **2007**, *84*, 302.

L. M. Brigandi, P. A. Leber, and C. H. Yoder, "Synthesis and Analysis of Copper Hydroxy Double Salts," *J. Chem. Ed*. **2005**, *82*, 1662.

P. Hooker, "Mineral Analysis of Whole Grain Total Cereal," *Chem. Ed*. **2005**, *85*, 1223.

K. E. Ginion and C. H. Yoder, "Preparation and Analysis of Libethenite ($Cu_2(PO_4)OH$," *J. Chem. Ed*. **2004**, *81*, 394.

B P. Huddle and J. C. Stephens, "Analysis of Carbon Monoxide in Blood," *J. Chem. Ed*. **2003**, *80*, 441.

M. H. F. B. Soares, L. A. Ramos, and E. T. G. Cavalhiero, "Spectrophotometric Determination of Total Sulfite in White Wine Samples Using Crude Extracts from Flowers," *J. Chem. Ed*. **2002**, *79*, 1111.

J. Gordon and S. Harman, "Graduated Cylinder Colorimeter: Investigation of Path Length and the Beer-Lambert Law," *J. Chem. Ed*. **2002**, *79*, 479.

S. T. Deal, C. E. Farmer, and P. F.Cerpovicz, "Carbohydrate Analysis: Can We Control the Ripening of Bananas?" *J. Chem. Ed*. **2002**, *79*, 479.

K. S. Patel, A. Shukla, A. Goswami, S. K. Chandavanshi, and P. Hoffmann, "A New Spectrophotometric Method for the Determination of Total and Ferric Iron in Rain Water at the ppb Level," *Fresenius J. Anal. Chem.* **2001**, *369*, 530. A good experiment or research project. Fe^{3+} decreases during daylight hours when sunlight plus reducing agents (organic matter?) convert Fe^{3+} into Fe^{2+}. At night, oxidation by O_2 restores Fe^{3+}.

L. A. Simonson, "Tablet Analysis Using Gravimetric Dilutions," *J. Chem. Ed.* **2001**, *78*, 1387.

E. Keszei, M. G. Takács, and B. Vizkeleti, "A Straightforward Method to Determine Equilibrium Constants from Spectrophotometric Data," *J. Chem. Ed.* **2000**, *77*, 927.

J. Han, T. Story, and F. Han, "A Spectrophotometric Method for Quantitative Determination of Bromine Using Tris(2-carboxyethyl)phosphine," *J. Chem. Ed.* **1999**, *77*, 976.

M. Lahti, J. Vilpo, and J. Hovinen, "Spectrophotometric Determination of Thiocyanate in Human Saliva," *J. Chem. Ed.* **1999**, *76*, 1281.

P. Seymour, "Chromium Pollution: An Experiment Adapted for Freshman Engineering Students," *J. Chem. Ed.* **1999**, *76*, 927.

M. J. Donlin, R. F. Frey, C. Putnam, J. K. Proctor, and J. K. Bashkin, "Analysis of Iron in Ferritin, the Iron-Storage Protein," *J. Chem. Ed.* **1998**, *75*, 437.

C. Higginbotham, C. F. Pike, and J. K. Rice, "Spectroscopy in Sol-Gel Matrices," *J. Chem. Ed.* **1998**, *75*, 461.

C. L. Cobb and G. A. Love, "Iron(III) Thiocyanate Revisited: A Physical Chemistry Equilibrium Lab Incorporating Ionic Strength Effects," *J. Chem. Ed.* **1998**, *75*, 90.

D. Lozano-Calero, P. Martín-Palomeque, and S. Madueño-Loriguillo, "Determination of Phosphorus in Cola Drinks," *J. Chem. Ed.* **1996**, *73*, 1173.

R. F. Dallinger, "Synthesis and Characterization of Potassium Tris(oxalato)ferrate(III) Trihydrate: A Spectrophotometric Method of Iron Analysis," *J. Chem. Ed.* **1995**, *72*, 936.

L. J. Stock III, "The Use of Erythrosin B in Undergraduate Spectrophotometry Experiments," *J. Chem. Ed.* **1995**, *72*, 926.

J. Lieberman, Jr., and K. J. Yun, "A Semimicro Spectrophotometric Determination of the K_{sp} of Silver Acetate at Various Temperatures," *J. Chem. Ed*. **1988**, *65*, 729.

K. W. Street, "Method Development for Analysis of Aspirin Tablets," *J. Chem. Ed*. **1988**, *65*, 915.

M. A. Grompone, "Determination of Iron in a Bar of Soap," *J. Chem. Ed*. **1987**, *64*, 1057.

Chapter 19 Applications of Spectrophotometry

Spectrophotometry

Y. R. Smith, E. Crone, and V. Subramanian, "A Simple Photocell to Demonstrate Solar Energy Using Benign Household Ingredients," *J. Chem. Ed*. **2013**, *90*, 1358.

P. Chenprakhon, B. Panijpan, and P. Chaiyen, "An Experiment Illustrating the Change in Ligand pK_a Upon Protein Binding," *J. Chem. Ed*. **2012**, *89*, 791.

E. Klotz, R. Doyle, E. Gross, and B. Mattson, "The Equilibrium Constant for Bromothymol Blue: A General Chemistry Laboratory Experiment Using Spectroscopy," *J. Chem. Ed*. **2011**, *88*, 637.

H. Egts, D. J. Durben, J. A. Dixson, and M. H. Zehfus, "A Multicomponent UV Analysis of α- and β-Acids in Hops," *J. Chem. Ed*. **2011**, *88*, 117.

P. Chenprakhon, J. Sucharitakul, B. Panijpan, and P. Chaiyen, "Measuring Binding Affinity of Protein–Ligand Interaction Using Spectrophotometry: Binding of Neutral Red to Riboflavin-Binding Protein," *J. Chem. Ed.* **2010**, *87*, 829.

D. P. Mascotti and M. J. Waner, "Complementary Spectroscopic Assays for Investigating Protein-Ligand Binding Activity," *J. Chem. Ed.* **2010**, *87*, 735. Spectrophotometric titrations.

H. Sariçayir, M. Uce, and A. Koca, "In Situ Techniques for Monitoring Electrochromism," *J. Chem. Ed*. **2010**, *87*, 205.

A. Ladstätter-Weißenmayer, A. Richter, J. P. Burrows, M. Kanakidou, R. J. Law, T. Wagner, and P. Borrell, "A Graduate-Level Online Module for Teaching Remote Sensing of Tropospheric NO_2 from Space," *J. Chem. Ed.* **2009**, *86*, 750.

J. T. Mitchell-Koch, K. R. Reid, and M. E. Meyerhoff "Salicylate Detection by Complexation with Iron(III) and Optical Absorbance Spectroscopy," *J. Chem. Ed.* **2008**, *85*, 1658.

B. Grung, E. Nodland, and G. M. Førland "Multivariate Curve Resolution Methods Illustrated Using Infrared Spectra of an Alcohol Dissolved in Carbon Tetrachloride," *J. Chem. Ed.* **2007**, *84*, 1193. Chemometric principal component analysis with commercial software.

C. Rodríguez-Rodríguez, J. M. Amigo, J. Coello, and S. Maspoch "An Introduction to Multivariate Curve Resolution-Alternating Least Squares: Spectrophotometric Study of

the Acid-Base Equilibria of 8-Hydroxyqunolin-5-sulfonic Acid," *J. Chem. Ed.* **2007**, *84*, 1190. Chemometric procedure running with MatLab.

R. Wanke and J. Stauffer, "An Advanced Undergraduate Chemistry Laboratory Experiment Exploring NIR Spectroscopy and Chemometrics," *J. Chem. Ed.* **2007**, *84*, 1171. Multicomponent calibration procedure.

E. B. Walker, D. R. Davies, and M. Campbell, "Quantitative Measurement of Trans-Fats by Infrared Spectroscopy," *J. Chem. Ed.* **2007**, *84*, 1162.

D. B. Craig and E. R. Nichols, "Spectroscopic Measurement of the Redox Potential of Cytochrome c for the Undergraduate Biochemistry Laboratory," *J. Chem. Ed.* **2006**, *83*, 1325.

P. Liang, B. Adhyaru, W. L. Pearson, and K. R. Williams, "The Binding Constant of Estradiol to Bovine Serum Albumin," *J. Chem. Ed.* **2006**, *83*, 294. Measuring an equilibrium constant with tritium-labeled estradiol and liquid scintillation counting.

K. P. Alter, J. L. Molloy, and E. D. Niemeyer, "Spectrophotometric Determination of the Dissociation Constant of an Acid-Base Indicator Using a Mathematical Deconvolution Technique," *J. Chem. Ed.* **2005**, *82*, 1682.

G. T. Rushton, B. Furmanski, and K. D. Shimizu, "Plastic Antibodies: Molecular Recognition with Imprinted Polymers," *J. Chem. Ed.* **2005**, *82*, 1374.

J. R. Paddock, A. T. Maghasi, W. R. Heineman, and C. J. Seliskar, "Making and Using a Sensing Polymeric Material for Cu^{2+}," *J. Chem. Ed.* **2005**, *82*, 1370.

D. Xiao, L. Lin, H. Yuan, M. M. F. Choi, and W. Chan, "A Passive Sampler for Determination of Nitrogen Dioxide in Ambient Air," *J. Chem. Ed.* **2005**, *82*, 1231.

M. P. Wentland, S. Raza, and Y. Gao, "96-Well Plate Colorimetric Assay for K_i Determination of (±)-2-Benzylsuccinic Acid, and Inhibitor of Carboxypeptidase A, " *J. Chem. Ed.* **2004**, *81*, 398.

A. Kniesel and M. K. Bellamy, "Measuring Breath Alcohol Concentrations with an FTIR Spectrometer, " *J. Chem. Ed.* **2003**, *80*, 1448.

K. R. Williams, B. Adhyaru, R. Pierce, and S. G. Schulman, "Binding Constants for Complexation of Bilirubin to Bovine Serum Albumin," *J. Chem. Ed.* **2002**, *79*, 115.

K. R. Williams and L. H. Tennant, "Micelles in the Physical/Analytical Chemistry Laboratory: Acid Dissociation of Neutral Red Indicator," *J. Chem. Ed.* **2001**, *78*, 349.

A.-M. G. Vasilarou and C. A. Georgiou, "Enzymatic Spectrophotometric Reaction Rate Determination of Glucose in Fruit Drinks and Carbonated Beverages," *J. Chem. Ed.* **2000**, *77*, 1327.

K. Keszei, M. G. Takács, and B. Vizkeleti, "A Straightforward Method to Determine Equilibrium Constants from Spectrophotometric Data," *J. Chem. Ed*. **2000**, *77*, 927.

G. A. Ibañez, A. C. Olivieri, and G. M. Escandar, "Determination of Equilibrium Constants of Metal Complexes from Spectrophotometric Measurements," *J. Chem. Ed*. **1999**, *76*, 1277.

J. Hernández-Benito, S. González-Mancebo, E. Calle, M. P. García-Santos, and J. Casado, "A Practical Integrated Approach to Supramolecular Chemistry. II. Kinetics of Inclusion Phenomena," *J. Chem. Ed.* **1999**, *76*, 422.

J. Hernández-Benito, S. González-Mancebo, E. Calle, M. P. García-Santos, and J. Casado, "A Practical Integrated Approach to Supramolecular Chemistry. I. Equilibria in Inclusion Phenomena," *J. Chem. Ed.* **1999**, *76*, 419.

G. S. Patterson, "A Simplified Method for Finding the pK_a of an Acid-Base Indicator by Spectrophotometry," *J. Chem. Ed.* **1999**, *76*, 395.

X. Huang, J. Yang, W. Zhang, Z. Zhang, and Z. An, "Determination of the Critical Micelle Concentration of Cationic Surfactants," *J. Chem. Ed.* **1999**, *76*, 93.

V. L. McDevitt, A. Rodríguez, and K. R. Williams, "Analysis of Soft Drinks: UV Spectrophotometry, Liquid Chromatography, and Capillary Electrophoresis," *J. Chem. Ed.* **1998**, *75*, 625.

S. Pandey, M. E. R. McHale, A.-S. M. Horton, S. A. Padilla, A. L. Trufant, N. U. De La Sancha, E. Vela, and W. E. Acree, Jr., "Kinetics-Based Indirect Spectrophotometric Method for Simultaneous Determination of MnO_4^- and $Cr_2O_7^{2-}$," *J. Chem. Ed.* **1998**, *75*, 450.

G. P. Smestad and M. Grätzel, "Demonstration Electron Transfer and Nanotechnology: A Natural Dye-Sensitized Energy Converter," *J. Chem. Ed.* **1998**, *75*, 752.

M. J. Charles, N. W. Martin, and H. Z. Msimanga, "Simultaneous Determination of Aspirin, Salicylamide, and Caffeine in Pain Relievers by Target Factor Analysis," *J. Chem. Ed.* **1997**, *74*, 1114.

S. Pandey, J. R. Powell, M. E. R. McHale, and W. E. Acree, Jr., "Quantitative Determination

of Cr(III) and Co(II) Using a Spectroscopic H-Point Standard Addition Method," *J. Chem. Ed*. **1997**, *74*, 848.

H. N. Po and K. S.-C. Huang, "An Inorganic Spectrophotometry Experiment for General Chemistry," *J. Chem. Ed.* **1995**, *72*, 62. (Method of continuous variation)

K. G. Strothkamp and R. E. Strothkamp, "Fluorescence Measurements of Ethidinium Binding to DNA," *J. Chem. Ed*. **1994**, *71*, 77.

G. Dado and J. Rosenthal, "Simultaneous Determination of Cobalt, Copper, and Nickel by Multivariate Linear Regression," *J. Chem. Ed.* **1990**, *67*, 797.

J. L. Sohl and A. G. Splittgerber, "The Binding of Coomassie Brilliant Blue to Bovine Serum Albumin," *J. Chem. Ed.* **1991**, *68*, 262.

C. Cappas, N. Hoffman, J. Jones, and S. Young, "Determination of Concentrations of Species Whose Absorption Bands Overlap Extensively," *J. Chem. Ed.* **1991**, *68*, 300.

J. J. Cruywagen and J. B. B. Heyns, "Spectrophotometric Determination of the Thermodynamic Parameters for the First Two Protonation Reactions of Molybdate," *J. Chem. Ed*. **1989**, *66*, 861.

H. A. Rowe and M. Brown, "Practical Enzyme Kinetics," *J. Chem. Ed*. **1988**, *65*, 548.

R. W. Ramette, "Equilibrium Constants from Spectrophotometric Data," *J. Chem. Ed*. **1967**, *44*, 647.

R. W. Ramette, "Formation of Monothiocyanatoiron(III): A Photometric Equilibrium Study," *J. Chem. Ed.* **1963**, *40*, 71.

Luminescence

S. S. Jain, C. N. LaFratta, A. Medina, and I. Pelse, "Proflavine-DNA Binding Using a Handheld Fluorescence Spectrometer: A Laboratory for Introductory Chemistry," *J. Chem. Ed*. **2013**, *90*, 1215.

G. Wilczek-Vera and E. D. Salin, "Understanding Fluorescence Measurements through a Guided-Inquiry and Discovery Experiment in Advanced Analytical Chemistry Laboratory," *J. Chem. Ed.* **2011**, *88*, 216.

C. A. Katz, Z. J. Calzola, and J. K. N. Mbindyo, "Structure and Solvent Properties of Microemulsions," *J. Chem. Ed.* **2008**, *85*, 263. Experiment includes fluorescence of pyrene in microemulsion and micelles.

C. D. Esposti and L. Bizzocchi, "Absorption and Emission Spectroscopy of a Lasing Material: Ruby," *J. Chem. Ed.* **2007**, *84*, 1316.

C. M. Ingersoll and C. M. Strollo, "Steady-State Fluorescence Anisotropy to Investigate Flavonoids Bindong to Proteins," *J. Chem. Ed.* **2007**, *84*, 1313.

E. F. Healy, "Quantitative Determination of DNA-Ligand Binding Using Fluorescence Spectroscopy," *J. Chem. Ed.* **2007**, *84*, 1304. See also T. P. Silverstein, "Quantitative Determination of DNA-Ligand Binding: Improved Data Analysis," *J. Chem. Ed.* **2008**, *85*, 1192. Scatchard analysis.

B. M. Hutchins, T. T. Morgan, M. G. Ucak-Astarlioglu, and M. E. Williams, "Optical Properties of Fluorescent Mixtures: Comparing Quantum Dots to Organic Dyes," *J. Chem. Ed.* **2007**, *84*, 1301.

R. J. Clarke and A. Oprysa, "Fluorescence and Light Scattering," *J. Chem. Ed.* **2004**, *81*, 705.

S. R. Goode and L. A. Metz, "Emission Spectroscopy in the Undergraduate Laboratory," *J. Chem. Ed.* **2003**, *80*, 1455.

T. Masiello, N. Vulpanovici, and J. W. Nibler, "Fluorescence Lifetime and Quenching of Iodine Vapor," *J. Chem. Ed.* **2003**, *80*, 914.

L. Poulsen, A. Z. Ruiz, S. U. Pedersen, and P. R. Ogilby, "Characterization of the Behavior and Properties of an Excited Electronic State: Electron-Transfer Mediated Quenching of Fluorescence," *J. Chem. Ed*. **2003**, *80*, 819.

A.-C. Ribou, J. Vigo, and J.-M. Salmon, "C-SNARF-1 as a Fluorescent Probe for pH Measurement in Living Cells: Two-Wavelength-Ratio Method versus Whole-Spectral-Resolution Method," *J. Chem. Ed*. **2002**, *79*, 1471.

M.-C. Sheffield and T. M. Nahir, "Analysis of Selenium in Brazil Nuts by Microwave Digestion and Fluorescence Detection," *J. Chem. Ed.* **2002**, *79*, 1345.

N. J. Crane, R. C. Mayrhofer, T. A. Betts, and G. A. Baker, "Cyclodextrin Inclusion Complexes with a Solvatochromic Fluorescent Probe," *J. Chem. Ed*. **2002**, *79*, 1261.

M. A. Fisher, D. Johnston, and D. A. Ritt, "Experimental Design and Polyelectrolyte Effects on Ligand Binding to Nucleic Acids," *J. Chem. Ed.* **2002**, *79*, 374. (Scatchard plot)

E. J. Harbron and P. F. Barbara, "The Poisson Distribution and Single-Molecule Spectroscopy," *J. Chem. Ed.* **2002**, *79*, 211.

K. R. Williams, B. Adhyaru, R. Pierce, and S. G. Schulman, "The Binding Constant for

Complexation of Bilirubin to Bovine Serum Albumin," *J. Chem. Ed*. **2002**, *79*, 115.

G. A. Baker, T. A. Betts, and S. Pandey, "Fluorescence Polarization as a Tool to Pinpoint Vesicle Thermal Phase Transitions," *J. Chem. Ed.* **2001**, *78*, 1100.

H. Mays, "Luminescence Quenching in Microemulsion Studies," *J. Chem. Ed*. **2000**, *77*, 72.

A. M. Hundzinski and B. D. Anderson, "Resonance Energy Transfer in Peptides," *J. Chem. Ed.* **1999**, *76*, 416.

S. Pandey, T. L. Borders, C. E. Hernández, L. E. Roy, G. D. Reddy, G. L. Martinez, A. Jackson, G. Brown, and W. E. Acree, Jr., "Comparison of Analytical Methods: Direct Emission versus First-Derivative Fluorometric Methods for Quinine Determination in Tonic Waters," *J. Chem. Ed.* **1999**, *76*, 85.

S. Pandey, M. E. R. McHale, K. S. Coym, and W. E. Acree, Jr., "Bilinear Regression Analysis as a Means to Reduce Matrix Effects in Simultaneous Spectrophotometric Determination of Cr(III) and Co(II)," *J. Chem. Ed.* **1998**, *75*, 878.

J. van Stam, S. Depaemelaere, and F. C De Schryver, "Micellar Aggregation Numbers—A Fluorescence Study," *J. Chem. Ed.* **1998**, *75*, 93.

M. J. Charles, N. W. Martin, and H. Z. Msimanga, "Simultaneous Determination of Aspirin, Salicylamide, and Caffeine in Pain Relievers by Target Factor Analysis," *J. Chem. Ed.* **1997**, *74*, 1114.

H. Gsponer, G. A. Argüello, and G. A. Argüello, "Determinations of pK_a from Luminescence Quenching Data," *J. Chem. Ed*. **1997**, *74*, 968.

K. G. Strothkamp and R. E. Strothkamp, "Fluorescence Measurements of Ethidium Binding to DNA," *J. Chem. Ed.* **1997**, *71*, 77.

J. Peterson, "Fluorometric Determination of Aluminum," *J. Chem. Ed.* **1996**, *73*, 262.

H. E. Gsponer, G. A. Argüello, and G. A. Argüello, "Determination of pK_a from Luminescence Quenching Data," *J. Chem. Ed.* **1996**, *73*, 968.

J. Weinstein-Lloyd and J. H. Lee, "Environmental Laboratory Exercise: Analysis of Hydrogen Peroxide by Fluorescence Spectroscopy," *J. Chem. Ed.* **1995**, *72*, 1053. (Flow injection)

M. F. R. Prieto, M. C. R. Rodríguez, M. M. González, A. M. R. Rodríguez, and J. C. M. Fernández, "Fluorescence Quenching in Microheterogeneous Media: A Laboratory Experiment Determining Micelle Aggregation Number," *J. Chem. Ed*. **1995**, *72*, 662.

J. J. Inestal, F. González-Velasco, and A. Ceballos, "Determination of Ligand-Macromolecule Binding Constants by a Competitive Spectrofluorometric Technique," *J. Chem. Ed.* **1994**, *71*, A297.

B. Marciniak, H. Kozubek, and S. Paszyc, "Estimation of pK_a* in the First Excited Singlet State," *J. Chem. Ed.* **1992**, *69*, 247.

S. W. Bigger, K. P. Ghiggino, G. A. Meilak, and B. Verity, "Illustration of the Principles of Fluorimetry," *J. Chem. Ed*. **1992**, *69*, 675.

S. A. Tucker, V. L. Amszi, and W. E. Acree, Jr., "Primary and Secondary Inner Filtering: Effect of $K_2Cr_2O_7$ on Fluorescence Emission Intensities of Quinine Sulfate," *J. Chem. Ed*. **1992**, *69*, A8.

G. Dado and J. Rosenthal, "Simultaneous Determination of Cobalt, Copper, and Nickel by Multivariate Linear Regression," *J. Chem. Ed.* **1990**, *67*, 797.

Flow Injection Analysis

S. Petrozzi, "An Open-Ended Experiment: Development from Batch to Automated Flow Injection Analysis for Phenolics Determination," *J. Chem. Ed*. **2009**, *86*, 1311.)

J. E. T. Andersen, "Exercise in Quality Assurance: A Laboratory Exercise," *J. Chem. Ed*. **2009**, *86*, 733. (Statistics of calibration curves from spectrophotometry conducted by batch procedures or flow injection.)

S. K. Lunsford, J. Widera, and H. Zhang, "Detection of Catechol by Potentiometric-Flow Injection Analysis in the Presence of Interferents," *J. Chem. Ed*. **2007**, *84*, 1471.

A. Economou, P. D. Tzanavaras, and D. G. Themelis, "Sequential-Injection Analysis: Principles, Instrument Construction, and Demonstration by a Simple Experiment," *J. Chem. Ed.* **2005**, *82*, 1820.

L. A. Ramos, K. R. Prieto, E. T. G. Cavalheiro, and C. C. S. Cavalheiro, "Determination of Hypochloride in Bleaching Products with Flower Extracts to Demonstrate the Principles of Flow Injection Analysis," *J. Chem. Ed.* **2005**, *82*, 1815.

J. C. Penteado, L. Angnes, J. C. Massini, and P. C. C. Oliveira, "FIA-Spectrophotometric Method for Determination of Nitrite in Mean Products," *J. Chem. Ed.* **2005**, *82*, 1074.

E. Economou, D. Papargyris, and J. Stratis, "Automated Flow-Injection Instrument for Chemiluminescence Detection Using a Low-Cost Photodiode Detector," *J. Chem. Ed.*

2004, *81*, 406.

S. M. Drew, "Integration of National Instruments' LabVIEW Software in the Chemistry Curriculum," *J. Chem. Ed.* **1996**, *73*, 1107.

M. K. Caroll and J. F. Tyson, "An Experiment Using Time-Based Detection in Flow Injection Analysis," *J. Chem. Ed*. **1993**, *70*, A210.

J. A. Nóbrega, A. A. Mozeto, and R. M. Alberici, "Reaction Kinetics in Flow-Injection Spectrophotometric Experiment," *J. Chem. Ed.* **1991**, *68*, 966.

C. L. Stults, A. P. Wade, and S. R. Crouch, "Investigation of Temperature Effects on Dispersion in a Flow Injection Analyzer," *J. Chem. Ed*. **1988**, *65*, 645.

A. Ríos, M. Dolores, L. de Castro, and M. Valcárcel, "Determination of Reaction Stoichiometries by Flow Injection Analysis," *J. Chem. Ed*. **1986**, *63*, 552.

Immunoassay

J. L. Powers, K. D. Rippe, K. Imarhia, A. Swift, M. Scholten, and N. Islam, "A Direct, Competitive Enzyme-Linked Immunosorbent Assay (ELISA) as a Quantitative Technique for Small Molecules," *J. Chem. Ed*. **2012**, *89*, 1587.

R. I Wilson, D. T. Mathers, S. A. Mabury, and G. M. Jorgensen, "ELISA and GC-MS as Teaching Tools in the Undergraduate Environmental Analytical Chemistry Laboratory," *J. Chem. Ed.* **2000**, *77*, 1619.

P. B. O'Hara, J. A. Sanborn, and M. Howard, "Pesticides in Drinking Water: Project-Based Learning Within the Introductory Chemistry Curriculum," *J. Chem. Ed.* **1999**, *76*, 1673.

L. A. Inda, P. Razquin, F. Lampreave, M. A. Alava, and M. Calvo, "Rapid, Sensitive, Enzyme-Immunodotting Assay for Detecting Cow Milk Adulteration in Sheep Milk," *J. Chem. Ed.* **1998**, *75*, 1618.

G. L. Anderson and L. A. McNellis, "Enzyme-Linked Antibodies: A Laboratory Introduction to the ELISA," *J. Chem. Ed.* **1998**, *75*, 1275.

Chapter 20 Spectrophotometers

G. A. Mabbott, "Teaching Electronics and Laboratory Automation Using Microcontroller Boards," *J. Chem. Ed.* **2014**, *91*, 14589.

J. Asheim, E. V. Kvittingen, L. Kvittingen, and R. Verley, "A Simple, Small-Scale Lego Colorimeter with a Light-Emitting Diode (LED) used as a Detector," *J. Chem. Ed.* **2014**, *91*, 1037.

R. L. McClain, "Construction of a Photometer as an Instructional Tool for Electronics and Instrumentation," *J. Chem. Ed.* **2014**, *91*, 747.

E. Kehoe and R. Lee Penn, "Introducing Colorimetric Analysis with Camera Phones and Digital Cameras: An Activity for High School or General Chemistry," *J. Chem. Ed.* **2013**, *90*, 1191.

J. R. Vanderveen, B. Martin, and K. J. Ooms, "An Inexpensive Visible Light Spectrophotometer," *J. Chem. Ed.* **2013**, *90*, 894.

D. R. Albert, M. A. Todt, and H. F. Davis, "A Low-Cost Quantitative Absorption Spectrophotometer," *J. Chem. Ed.* **2012**, *89*, 1432.

B. Shepherd and M. K. Bellamy, "A Spreadsheet Exercise to Teach the Fourier Transform in FTIR Spectrometry," *J. Chem. Ed.* **2012**, *89*, 681.

Q. S. Hanley, "Fourier Transforms Simplified: Computing an Infrared Spectrum from an Interferogram," *J. Chem. Ed.* **2012**, *89*, 391.

B. T. Wigton, B. S. Chohan, C. McDonald, M. Johnson, D. Schunk, R. Kreuter, and D.Sykes, "A Portable, Low-Cost LED Fluorimeter for Middle School, High School, and Undergraduate Labs," *J. Chem. Ed.* **2011**, *88*, 1182; *ibid*., 1188.

T. L. Tan and G. B. Lebron, "Determination of Carbon Dioxide, Carbon Monoxide, and Methane Concentrations in Cigarette Smoke by Fourier Transform Infrared Spectroscopy," *J. Chem. Ed.* **2011**, *88*, 383.

Y. Tang, X. Zeng, and J. Liang, "Surface Plasmon Resonance: An Introduction to a Surface Spectroscopy Technique," *J. Chem. Ed.* **2010**, *87*, 742.

D. J. Soldat, P. Barak, and B. J. Lepore, "Microscale Colorimetric Analysis Using a Desktop Scanner and Automated Digital Image Analysis," *J. Chem. Ed*. **2009**, *86*, 617.

W. R. Algar, M. Massey, and U. J. Krull, " Assembly of a Modular Fluorimeter and Associated Software: Using LabView in an Advanced Undergraduate Analytical Chemistry Laboratory," *J. Chem. Ed*. **2009**, *86*, 68.

F. Wakabayashi, "Resolving Spectral Lines with a Periscope-Type DVD Spectroscope," *J. Chem. Ed*. **2008**, *85*, 849.

J. D. Shuttlefield and V. H. Grassian, "ATR-FTIR Spectroscopy in the Undergraduate Chemistry Laboratory," *J. Chem. Ed.* **2008**, *85*, 279, 283. Attenuated total reflectance.

J. W. Hovick, M. Murphy, and J. C. Poler, "'Audibilization' in the Chemistry Laboratory: An Introduction to Correlation Techniques for Data Extraction," *J. Chem. Ed.* **2007**, *84*, 1316.

G. B. Cordon and M. G. Lagorio, "Absorption and Scattering Coefficients: A Biophysical Chemistry Experiment Using Reflectance Spectroscopy," *J. Chem. Ed.* **2007**, *84*, 1167.

R. Smith and K. Cantrell, "Modeling the Effect of Polychromatic Light in Quantitative Absorbance Spectroscopy," *J. Chem. Ed.* **2006**, *84*, 1021.

J. E. Thompson, "A Simple Method for Rapidly Obtaining Absorption Spectra with a Spectronic-20D+ Spectrometer," *J. Chem. Ed.* **2006**, *83*, 913.

J. Zimmermann, A. van Dorp, and A. Renn, "Fluorescence Microscopy of Single Molecules," *J. Chem. Ed.* **2004**, *81*, 553.

J. D. Fischer and J. E. Whitten, "Spectroscopic Monitoring of the Heterogeneous Catalytic Decomposition of Gaseous Ammonia, " *J. Chem. Ed.* **2003**, *80*, 1451.

J. P. Blitz and D. G. Klarup, " Signal-to-Noise Ratio, Signal Processing, and Spectral Information in the Instrumental Analysis Laboratory," *J. Chem. Ed.* **2002**, *79*, 1358.

G. A. Lorigan, B. M. Patterson, A. J. Sommer, and N. D. Danielson, "Cost-Effective Spectroscopic Instrumentation for the Physical Chemistry Laboratory," *J. Chem. Ed.* **2002**, *79*, 1264.

J. Tellinghuisen, "Exploring the Diffraction Grating Using a He-Ne Laser and a CD-ROM," *J. Chem. Ed.* **2002**, *79*, 703.

M. A. Thal and M. J. Samide, "Applied Electronics: Construction of a Simple Spectrophotometer," *J. Chem. Ed.* **2001**, *78*, 1510.

P. Bernazzani and F. Paquin, "Modular Spectrometers in the Undergraduate Chemistry Laboratory," *J. Chem. Ed.* **2001**, *78*, 796.

F. Aberásturi, A. I. Jiménez, and J. J. Arias, "UV-Visible First-Derivative Spectrophotometry Applied to an Analysis of a Vitamin Mixture," *J. Chem. Ed.* **2001**, *78*, 793.

F. Rocha and B. F. Reis, "A Low-Cost Device for Automatic Photometric Titrations," *J. Chem. Ed.* **2000**, *77*, 258.

M. G. Lagoria, "Reflectance Spectroscopy Using Wine Bottle Glass," *J. Chem. Ed.* **1999**, *76*,

1551.

H. C. Allen, T. Brauers, and B. J. Finlayson-Pitts, "Illustrating Deviations in the Beer-Lambert Law in an Instrumental Analysis Laboratory: Measuring Atmospheric Pollutants by Differential Optical Absorption Spectrometry," *J. Chem. Ed.* **1997**, *74*, 1459.

S. Saxena, R Upadhyay, and P. Upadhyay, "A Simple and Low-Cost Air Sampler," *J. Chem. Ed.* **1996**, *73*, 787. (Spectrophotometric analysis of SO_2, NO_2, and H_2CO)

J. L. Guiñon and J. Garcia-Anton, "Experimental Study of Monochromators in UV-Vis and IR Spectrophotometers," *J. Chem. Ed.* **1992**, *69*, 77.

T. Matsuo, A. Muromatsu, K. Katayama, and M. Mori, "Construction of a Photoelectric Colorimeter," *J. Chem. Ed*. **1989**, *66*, 329, 848.

Chapter 21 Atomic Spectroscopy

E. Moraes, N. S. A. da Silva, C. de L. M. de Morais, L. S. das Neves, and K. M. G. de Lima "Low-Cost Method for Quantifying Sodium in Coconut Water and Seawater for the Undergraduate Analytical Chemistry Laboratory: Flame Test, A Mobile Phone Camera, and Image Processing," *J. Chem. Ed.* **2014**, *91*, 1958.

B. Néel, G. A. Crespo, D. Perret, T. Cherubini, and E. Bakker, "Camping Burner-Based Flame Emission Spectrometer for Classroom Demonstrations," *J. Chem. Ed.* **2014**, *91*, 1655.

B. K. Niece and J. F. Hauri, "Determination of Mercury in Fish: A Low-Cost Implementation of Cold-Vapor Atomic Absorbance for the Undergraduate Environmental Chemistry Laboratory," *J. Chem. Ed.* **2013**, *90*, 487.

D. W. Randall, R. T. Hayes, and P. A. Wong, "A Simple Laser Induced Breakdown Spectroscopy (LIBS) System for Use at Multiple Levels in the Undergraduate Chemistry Curriculum," *J. Chem. Ed.* **2013**, *90*, 456.

C. N. LaFratta, S. Jain, I. Pelse, O. Simoska, and K. Elvy, "Using a Homemade Flame Photometer to Measure Sodium Concentration in Sports Drink," *J. Chem. Ed.* **2013**, *90*, 372.

J. A. Bowden, B. A. Nocito, R. H. Lowers, L. .J. Guilette, Jr., K. R. Williams, and V. Y. Young, "Environmental Indicators of Metal Pollution and Emission: An Experiment for

the Instrumental Analysis Laboratory," *J. Chem. Ed.* **2012**, *89*, 1057. ICP-atomic emission experiment.

R. C. Chinni, "A Simple LIBS (Laser-Induced Breakdown Spectroscopy Laboratory Experiment to Introduce Undergraduates to Calibration Functions and Atomic Spectroscopy," *J. Chem. Ed.* **2012**, *89*, 678.

S. O. Fakayode, A. G. King, M. Yakubu, A. K. Mohammed, and D. A. Pollard, "Determination of Fe Content of Some Food Items by Flame Atomic Absorption Spectroscopy: A Guided-Inquiry Learning Experience," *J. Chem. Ed.* **2012**, *89*, 109.

J. F. Hauri and B. K. Niece, "Leaching of Silver from Silver-Impregnated Food Storage Containers," *J. Chem. Ed.* **2011**, *88*, 1407.

S. Armenta and M. de la Guardia, "Determination of Mercury in Milk by Cold Vapor Atomic Fluorescence," *J. Chem. Ed.* **2011**, *88*, 488.

J. V. Cizdziel, "Mercury in Environmental and Biological Samples Using Online Combustion with Sequential Atomic Absorption and Fluorescence Measurements," *J. Chem. Ed.* **2011**, *88*, 209.

L. R. Butler, M. R. Edwards, R. Farmer, K. J. Greenly, S. Hensler, S. E. Jenkins, J. M. Joyce, J. A. Mann, B. M. Prentice, A. E. Puckette, C. M. Shuford, S. E. G. Porter, and M. C. Rhoten, "Investigation of the Use of *Cucumis sativus* for Remediation of Chromium from Contaminated Environmental Matrices," *J. Chem. Ed.* **2009**, *86*, 1095.

M. K. Donais, G. Whissel, A. Dumas, and K. Golden, "Analyzing Lead Content in Ancient Bronze Coins by Flame Atomic Absorption Spectroscopy," *J. Chem. Ed.* **2009**, *86*, 343.

M. Meigham, J. MacNeil, and R. Falconer, "Determining the Solubility Product of $Fe(OH)_3$: An Equilibrium Study with Environmental Significance," *J. Chem. Ed.* **2008**, *85*, 254. The experiment would be enhanced by accounting for iron-hydroxide complexes in the solution.

J. D. Weidenhamer, "Circuit Board Analysis for Lead by Atomic Absroption Spectroscopy in a Course for Nonscience Majors," *J. Chem. Ed.* **2007**, *84*, 1165.

D. L. Van Engelen, S. W. Suljak, J. P. Hall, and B. E. Holmes, "Undergraduate Introductory Quantitative Chemistry Laboratory Course: Interdisciplinary Group Projects in Phytoremediation," *J. Chem. Ed.* **2007**, *84*, 128. A semester-long course employing multiple analytical methods in the context of group research projects.

C. S. Seney, K. V. Sinclair, R. M. Bright, P. O. Momoh, and A. D. Bozeman "Development of a Multiple-Element Flame Emission Spectrometer Using CCD Detection," *J. Chem. Ed.* **2005**, *82*, 1826.

K. M. Blyth, L. R. Mullings, D. N. Phillips, D. Pritchard, and W. van Bronswijk, "Preparation, Analysis, and Characterization of Some Transition Metal Complexes," *J. Chem. Ed.* **2005**, *82*, 1667.

P. R. M. Correia and P. V. Oliveira, "Simultaneous Atomic Absorption Spectrometry for Cadmium and Lead Determination in Wastewater," *J. Chem. Ed.* **2004**, *81*, 1174.

A. Bazzi, B. Kreuz, and J. Fischer, "Determination of Calcium in Cereal with Flame Atomic Absorption Spectroscopy," *J. Chem. Ed.* **2004**, *81*, 1042.

M. Duxbury, "Determination of Minerals in Apples by ICP-AES," *J. Chem. Ed.* **2003**, *80*, 1180.

A. S. Kooser, J. L. Jenkins, and L. E. Welch, "Inductively Coupled Plasma–Atomic Emission Spectroscopy: Two Laboratory Activities for the Undergraduate Instrumental Analysis Course," *J. Chem. Ed.* **2003**, *80*, 86.

W. Wang and B. J. Finlayson-Pitts, "Measurement of Trace Metals in Tobacco and Cigarette Ash by Inductively Coupled Plasma–Atomic Emission Spectroscopy," *J. Chem. Ed.* **2003**, *80*, 83.

D. L. Giokas, E. K. Paleologos, and M. I. Karayannis, "Micelle-Mediated Extraction of Heavy Metals from Environmental Samples," *J. Chem. Ed.* **2003**, *80*, 61.

J. I. Selco, J. L. Roberts, Jr., and D. B. Wacks, "The Analysis of Seawater: A Laboratory-Centered Learning Project in General Chemistry," *J. Chem. Ed.* **2003**, *80*, 54.

V. J. Porter, P. M. Sanft, J. C. Dempich, D. D. Dettmer, A. E. Erickson, N. A. Dubauskie, S. T. Myster, E. H. Matts, and E. T. Smith, "Elemental Analysis of Wisdom Teeth by Atomic Spectroscopy Using Standard Additions," *J. Chem. Ed.* **2002**, *79*, 1114.

F. M. Dunnivant, "Analytical Problems Associated with the Analysis of Metals in a Simulated Hazardous Waste," *J. Chem. Ed.* **2002**, *79*, 718.

F. M. Dunnivant and J. Kettel, "An Environmental Chemistry Laboratory for the Determination of a Distribution Coefficient," *J. Chem. Ed.* **2002**, *79*, 715.

M. A. Page, B. W. Smith, and K. R. Williams, "ICP in the Physical Chemistry Laboratory: Determination of the Plasma Temperature," *J. Chem. Ed.* **2002**, *79*, 364.

V. T. Breslin and S. A. Sañudo-Wilhelmy, "The Lead Project: An Environmental Instrumental Analysis Case Study," *J. Chem. Ed.* **2001**, *78*, 1641.

K. S. Kostecka, "Atomic Absorption Spectroscopy of Calcium in Foodstuffs in Non-Science-Major Courses," *J. Chem. Ed.* **2000**, *77*, 1321.

S. A. Mabury, D. Mathers, D. A. Ellis, P. Lee, A. M. Marsella, and M. Douglas, "An Undergraduate Experiment for the Measurement of Trace Metals in Core Sediments by ICP-AES and GFAAS," *J. Chem. Ed.* **2000**, *77*, 1611.

R. J. Stolzberg, "Optimizing Signal-to-Noise Ratio in Flame Atomic Absorption Spectrophotometry Using Sequential Simplex Optimization," *J. Chem. Ed.* **1999**, *76*, 834.

B. P. Buffin, "Removal of Heavy Metals from Water: An Environmentally Significant Atomic Absorption Spectrometry Experiment," *J. Chem. Ed.* **1999**, *76*, 1678.

R. John and D. Lord, "Determination of Anionic Surfactants Using Atomic Absorption Spectrometry and Anodic Stripping Voltammetry," *J. Chem. Ed.* **1999**, *76*, 1256.

R. S. Woosley and D. J. Butcher, "Chemical Analysis of an Endangered Conifer," *J. Chem. Ed.* **1998**, *75*, 1592.

M. N. Quigley and F. Vernon, "Determination of Trace Metal Ion Concentrations in Seawater," *J. Chem. Ed.* **1996**, *73*, 671.

P. G. Markow, "Determining the Lead Content of Paint Chips," *J. Chem. Ed.* **1996**, *73*, 178.

R. J. Kieber and S. B. Jones, "An Undergraduate Laboratory for the Determination of Sodium, Potassium, and Chloride," *J. Chem. Ed.* **1994**, *71*, A218.

M. A. Williamson, "Determination of Copper by Graphite Furnace Atomic Absorption Spectrophotometry," *J. Chem. Ed*. **1989**, *66*, 261.

Chapter 22 Mass Spectrometry

V. Homem, A. Alves, and L. Santos "Development and Validation of a Fast Procedure to Analyze Amoxicillin in River Waters by Direct-Injection LC–MS.MS," *J. Chem. Ed.* **2014**, *91*, 1961.

N. L. Stock and R. E. March, "Hands-on Electrospray Ionization–Mass Spectrometry for Upper-Level Undergraduate and Graduate Students," *J. Chem. Ed*. **2014**, *91*, 1244.

D. S. Gross and H. Van Ryswyk, "Examination and Manipulation of Protein Surface Charge

in Solution with Electrospray Ionization Mass Spectrometry," *J. Chem. Ed*. **2014**, *91*, 1240.

D. J. Weiss, C. Harris K. Maher, and T. Bullen, "A Teaching Exercise to Introduce Stable Isotope Fractionation of Metals into Geochemistry Courses," *J. Chem. Ed*. **2013**, *90*, 1014

M. Eibisch, B. Fuchs, J. Schiller, R. Süβ, and K. Teuber "Analysis of Phospholipid Mixtures from Biological Tissues by Matrix-Assisted Laser Desorption and Ionization Time-of-Flight Mass Spectrometry," *J. Chem. Ed.* **2011**, *88*, 503.

D. A. Rosado, Jr., T. S. Masterson, and D. S. Masterson, "Using the Mini-Session Course Format to Train Students in the Practical Aspects of Modern Mass Spectrometry," *J. Chem. Ed.* **2011**, *88*, 178.

D. H. Kim, C. D. Eckhert, and K. F. Faull, "Utilization of Negative Ion ESI-MS and Tandem Mass Spectrometry to Detect and Confirm the NADH-Boric Acid Complex," *J. Chem. Ed.* **2011**, *88*, 106.

C. W. Harmon, S. A. Mang, J. Greaves, and B. J. Finlayson-Pitts, "Identificaiton of Fatty Acids, Phospholipids, and Their Oxidation Products Using Matrix-Assisted Laser Desorption Ionization Mass Spectrometry and Electrospray Ionization Mass Spectrometry," *J. Chem. Ed.* **2010**, *87*, 186.

I. J. Arnquist and D. J. Beussman "Incorporating Biological Mass Spectrometry into Undergraduate Teaching Labs, Part 2: De Novo Peptide Sequencing Using Electrospray Tandem Mass Spectrometry," *J. Chem. Ed.* **2009**, *86*, 966.

I. J. Arnquist and D. J. Beussman "Incorporating Biological Mass Spectrometry into Undergraduate Teaching Labs, Part 2: Peptide Identification via Molecular Mass Determination," *J. Chem. Ed.* **2009**, *86*, 382.

I. J. Arnquist and D. J. Beussman "Incorporating Biological Mass Spectrometry into Undergraduate Teaching Labs, Part 1: Identifying Proteins Based on Molecular Mass," *J. Chem. Ed.* **2007**, *84*, 1971.

N. C. Dopke and T. N. Lovett "Illustrating the Concepts of Isotopes and Mass Spectrometry in Laboratory Courses: A MALDI-TOF Mass Spectrometry Laboratory Experiment," *J. Chem. Ed.* **2007**, *84*, 1968.

C. T. Reimann, A. Mie, C. Nilsson, and A. Cohen "Introduction to Biological Mass

Spectrometry: Determining Identity and Species of Origin of Two Proteins," *J. Chem. Ed.* **2005**, *82*, 1215.

L. S. Sunderlin, V. Ryzhov, L. M. M. Keller, and E. R. Gaillard, "Measuring Gas-Phase Basicities of Amino Acids Using an Ion Trap Mass Spectrometer," *J. Chem. Ed.* **2005**, *82*, 1071.

A. Weinecke and V. Ryzhov, "Fundamentals of Biomolecule Analysis by Electrospray Ionization Mass Spectrometry," *J. Chem. Ed.* **2005**, *82*, 99.

H. C. Stynes, A. Layo, and R. W. Smith, "LC-MS of Metmyoglobin at pH = 2," *J. Chem. Ed.* **2004**, *81*, 266.

M. Solow, "Introduction of Mass Spectrometry in General Chemistry: Quantification of MTBE or DMSO in Water," *J. Chem. Ed.* **2004**, *81*, 1172.

J. D. Persinger, G. C. Hoops, and M. J. Samide, "Mass Spectrometry for the Masses," *J. Chem. Ed.* **2004**, *81*, 1169.

A. E. Counterman, M. S. Thompson, and D. E. Clemmer, "Identifying a Protein by MALDI-TOF Mass Spectrometry," *J. Chem. Ed.* **2003**, *80*, 177.

D. N. Blauch, M. D. Schuh, and F. .A. Carroll, "Determination of Natural Abundances of Krypton and Xenon Isotopes Using Mass Spectrometry," *J. Chem. Ed.* **2002**, *79*, 584.

H. R. Bergen, III, L. M. Benson, and S. Naylor, "Determination of Aspartame and Caffeine in Carbonated Beverages Utilizing Electrospray Ionization–Mass Spectrometry," *J. Chem. Ed.* **2000**, *77*, 1325.

Chapter 23 Introduction to Analytical Separations

C. A. Lucy, L. L. M. Glavina, and F. F. Cantwell, "A Laboratory Experiment on Extracolumn Band Broadening in Liquid Chromatography," *J. Chem. Ed*. **1995**, *72*, 367.

P.. S. Szalay, "A Simple Experiment in the Separation of a Solid-Phase Mixture and Infrared Spectroscopy for Introductory Chemistry," *J. Chem. Ed.* **2008**, *85*, 285. Solvent extraction with pH control to separate the components.

D. L. Giokas, E. K. Paleologos, and M. I. Karayannis, "Micelle-Mediated Extraction of Heavy Metals from Environmental Samples," *J. Chem. Ed*. **2003**, *80*, 61.

J. Hein and M. Jeannot, "Drug Distribution: A Guided-Inquiry Laboratory Experiment in

Coupled Homogeneous and Heterogeneous Equilibria," *J. Chem. Ed*. **2001**, *78*, 224.

D. M. Downey, D. D. Farnsworth, and P. G. Lee, "Growth and Decay: An Experiment Demonstrating Radioactivity Relationships and Chelate Solvent Extraction Separations," *J. Chem. Ed*. **1984**, *61*, 259.

Chapter 24 Gas Chromatography

S. A. Radford, R. E. Hunter, Jr., D. B. Barr, and P. B. Ryan, "Liquid-Liquid Extraction of Insecticides from Juice," *J. Chem. Ed*. **2013**, *90*, 483. Solid-phase extraction–gas chromatography–mass spectrometry experiment.

B. O. Johnson, F. M. Burke, R. Harrison, and S. Burdette, "Quantitative Analysis of Bisphenol A Leached from Household Plastics by Solid-Phase Microextraction and Gas Chromatography-Mass Spectrometry (SPME-GC-MS)," *J. Chem. Ed*. **2012**, *89*, 1555.

R. N. Mead and P. J. Seaton, "GC-MS Quantitation and Identification of Bisphenol-A Isolated from Water," *J. Chem. Ed*. **2011**, *88*, 1130.

L. T. Alty, "Analysis of Fatty Acid Methyl Esters in Egg Yolk Using GC-MS," *J. Chem. Ed*. **2009**, *86*, 963.

B. Anzivino, L. J. Tilley, L. R. Ingalls, A. B. Hall, and J. E. Drugan, "Got a Match? Ion Extraction GC-MS Characterization of Accelerants Adsorbed in Charcoal Using Negative Pressure Dynamic Headspace Concentration," *J. Chem. Ed*. **2009**, *86*, 55.

P.-Y. Chao, Y.-Y. Chuang, G. H. Ho, S.-H. Chuang, T.-C. Tsai, C.-Y. Lee, S.-T. Tsai, and J.-F. Huang, "Study of Molecular-Shape Selectivity of Zeolites by Gas Chromatography," *J. Chem. Ed*. **2008**, *85*, 1558.

J.-M. Lavoie, E. Chornet, and A. Pelletier, "Identification of Secondary Metabolites in Citrus Fruit Using Gas Chromatography and Mass Spectroscopy," *J. Chem. Ed*. **2008**, *85*, 1555.

D. Riccio, D. C. Wood, and J. M. Miller, "Using Single Drop Microextraction for Headspace Analysis with Gas Chromatography," *J. Chem. Ed*. **2008**, *85*, 965.

Y. Wang, J. Ocariz, J. Hammersand, E. MacDonald, A. Bartczak, F. Kero, V. Y. Young, and K. R. Williams, "Determination of Cinnamaldehyde in Cinnamon by SPME-GC-MS," *J. Chem. Ed*. **2008**, *85*, 957.

C. Henck and L. Nally, "GC-MS Analysis of γ-Hydroxybutyric Acid Analogs: A Forensic

Chemistry Experiment," *J. Chem. Ed*. **2007**, *84*, 1813.

D. C. Stone, "Teaching Chromatography Using Virtual Laboratory Exercises," *J. Chem. Ed*. **2007**, *84*, 1488.

R. D. Barrows, "Quantitative Comparison of Three Standardization Methods Using a One-Way ANOVA for Multiple Mean Comparisons," *J. Chem. Ed*. **2007**, *84*, 839. Gas chromatography experiment.

R. H. Douglas, C. A. Muldowney, R. Mohamed, F. Keohane, C. Shanahan, J. Walsh, and P. V. Kavanagh, "Detection and Quantification of Valerenic Acid in Commercially Available Valerian Products," *J. Chem. Ed*. **2007**, *84*, 8299. Gas chromatography-mass spectrometry analysis of pharmaceuticals.

B. Hartzell-Baguley, R. E. Hipp, N. R. Morgan, and S. L. Morgan, "Chemical Composition of Latent Fingerprints by Gas Chromatography-Mass Spectrometry," *J. Chem. Ed*. **2007**, *84*, 689.

J. Richer, J. Spencer, and M. Baird, "Identification of Glue Vapors Using Electron Impact and Chemical Ionization Modes in GC-MS," *J. Chem. Ed*. **2006**, *83*, 1196.

D. Mayotte, C. J. Donahue, and C. A. Snyder, "Analysis of the Thickening Agents in Automotive Greases by GC-MS," *J. Chem. Ed.* **2006**, *83*, 902.

F. C. C. Moura, F. G. Pinto, E. N. dos Santos, L. O. F. do Amaral, and R. M. Lago, "Experiments on Heterogeneous Catalysis Using a Simple Gas Chromatograph," *J. Chem. Ed.* **2006**, *83*, 417.

T. J. Dwyer and J. D. Fillo, "Assaying α-Dicarbonyl Compounds in Wine: A Complementary GC-MS, HPLC, and Visible Spectrophotometric Analysis," *J. Chem. Ed.* **2006**, *83*, 273.

A. E. Witter, "Quantitative Determination of Butylated Hydroxytoluene in Chewing Gum Using GC-MS," *J. Chem. Ed.* **2005**, *82*, 1538.

M. M. Warnke, A. E. Erickson, and E. T. Smith, "Simplex Optimization of Headspace-Enrichment Conditions of Residual Petroleum Distillates Used by Arsonists," *J. Chem. Ed.* **2005**, *82*, 1082.

R. M. Sobel, D. S. Ballantine, and V. Ryzhov, "Quantitation of Phenol Levels in Oil of Wintergreen Using Gas Chromatography-Mass Spectrometry with Selected Ion Monitoring *J. Chem. Ed.* **2005**, *82*, 601.

W. W. Hope, C. Johnson, and L. P. Johnson, "Tetraglyme Trap for the Determination of Volatile Organic Compounds in Urban Air," *J. Chem. Ed.* **2004**, *81*, 1182.

K. A. Mowery, D. E. Blanchard, S. Smith, and T. A. Betts, "Investigation of Impostor Perfumes Using GC-MS," *J. Chem. Ed.* **2004**, *81*, 87.

D. M. McInnes and D. Kampbell, "Bubble Stripping to Determine Hydrogen Concentrations in Ground Water: A Practical Application of Henry's Law" *J. Chem. Ed.* **2003**, *80*, 516.

M. Sittidech and S. Street, "Environmental Analysis in the Instrumental Lab," *J. Chem. Ed.* **2003**, *80*, 376. (Determination of acrolein and acrylonitrile in water by solid-phase microextraction and gas chromatography-mass spectrometry.)

A. E. Witter, D. M. Klinger, X. Fan, M. Lam, D. T. Mathers, and S. A. Mabury, "Quantitative Determination of Nicotine and Cotinine in Urine and Sputum Using a Combined Solid-Phase Microextraction-Gas Chromatography/Mass Spectrometry Method" *J. Chem. Ed.* **2002**, *79*, 1257.

J. P. Crowley et al., "Classroom Research: GC Studies of Linoleic and Linolenic Fatty Acids Found in French Fries," *J. Chem. Ed.* **2002**, *79*, 824.

C. J. Donahue, "Fractional Distillation and GC Analysis of Hydrocarbon Mixtures," *J. Chem. Ed.* **2002**, *79*, 721.

J. R. Hardee, J. Long, and J. Otts, "Quantitative Measurement of Bromoform in Swimming Pools Water Using SPME with GC-MS," *J. Chem. Ed.* **2002**, *79*, 633.

G. Knupp, P. Kusch, and M. Neugebauer, "Identification of Flavor Components in Perfumes by Hadspace Solid-Phase Microextraction and Gas Chromatography-Mass Spectrometry," *J. Chem. Ed.* **2002**, *79*, 98.

T. M. Olson, A. C. Gonzalez, and V. R. Vasquez, "Gas Chromatography Analyses for Trihalomethanes," *J. Chem. Ed.* **2001**, *78*, 1231.

D. A. Soderman and S. J. Lillard, "Determination of Arson Accelerants by GC-MS," *J. Chem. Ed.* **2001**, *78*, 1228.

J. L. Zabzdyr and S. J. Lillard, "Determination of Blood Alcohol Content," *J. Chem. Ed.* **2001**, *78*, 1225.

J. D. Bender, A. J. Catino III, K. R. Hess, M. E. Lassman, P. A. Leber, M. D. Reinard, N. A. Strotman, and C. S. Pike, "A Biochemical GC–MS Application for the Organic Chemistry Laboratory: Determination of Fatty Acid Composition of *Arabidopsis thaliana*

Lipids," *J. Chem. Ed.* **2000**, *77*, 1466.

R. I Wilson, D. T. Mathers, S. A. Mabury, and G. M. Jorgensen, "ELISA and GC–MS as Teaching Tools in the Undergraduate Environmental Analytical Chemistry Laboratory," *J. Chem. Ed.* **2000**, *77*, 1619.

S. C. Hodgson, R. J. Casey, J. D. Orbell, and S. W. Bigger, "Use of a Dynamic Headspace GC–MS Method for the Study of Volatile Organic Compounds in Polyethylene Packaging," *J. Chem. Ed.* **2000**, *77*, 1631.

R. C. Galipo, A. J. Canhoto, M. D. Walla, and S. L. Morgan, "Analysis of Volatile Fragrance and Flavor Compounds by Headspace Solid Phase Microextraction and GC-MS," *J. Chem. Ed.* **1999**, *76*, 245.

P. B. O'Hara, J. A. Sanborn, and M. Howard, "Pesticides in Drinking Water: Project-Based Learning within the Introductory Chemistry Curriculum," *J. Chem. Ed.* **1999**, *76*, 1673.

P. Fleurat-Lessard, K. Pointet, and M.-F. Renou-Gonnord, "Quantitative Determination of PAHs in Diesel Engine Exhausts by GC–MS," *J. Chem. Ed.* **1999**, *76*, 962.

A. G. Sykes and G. Caple, "Bridging Native American Culture and Chemistry: Gas Chromatography Experiments That Examine Native Foods," *J. Chem. Ed.* **1999**, *76*, 392.

J. V. Arena and T. M. Leu, "Deconvolution of Gas Chromatograms with Excel," *J. Chem. Ed.* **1999**, *76*, 867.

D. T. Quach, N. A. Ciszkowski, and B. J. Finlayson-Pitts, "A New GC-MS Experiment for the Undergraduate Instrumental Analysis Laboratory in Environmental Chemistry: Methyl-*t*-butyl Ether and Benzene in Gasoline," *J. Chem. Ed.* **1998**, *75*, 1595.

R. S. Woosley and D. J. Butcher, "Chemical Analysis of an Endangered Conifer," *J. Chem. Ed.* **1998**, *75*, 1592.

J. Notestein, N. Hélias, W. E. Wentworth, J. G. Dojahn, E. C. M. Chen, and S. D. Stearns, "Qualitative GC Experiment Using Selective Photoionization Detector," *J. Chem. Ed.* **1998**, *75*, 360.

A. L. Smith, E. J. Thorne, and W. Nadler, "Inexpensive Detector for Gas Chromatography," *J. Chem. Ed.* **1998**, *75*, 1129.

J. W. Wong, K. K. Ngim, T. Shibamoto, S. A. Mabury, J. P. Eiserich, and H. C. H. Yeo, "Determination of Formaldehyde in Cigarette Smoke," *J. Chem. Ed*. **1997**, *74*, 1100.

R. A. Kjonaas, J. L. Soller, and L. A. McCoy, "Identification of Volatile Flavor Components

by Headspace Analysis: A Quick and Easy Experiment for Introducing GC/MS," *J. Chem. Ed*. **1997**, *74*, 1104.

M. J. Yang, M. L. Orton, and J. Pawliszyn, "Quantitative Determination of Caffeine in Beverages Using a Combined SPME-GC/MS Method," *J. Chem. Ed*. **1997**, *74*, 1130.

L. C. Brazdil, "Oxygenates in Gasoline," *J. Chem. Ed.* **1996**, *73*, 1056.

R. Guisto-Norkus, B. Gounili, P. Wisniecki, J. A. Hubball, S. R. Smith, and J. D. Stuart, "An Environmentally Significant Experiment Using GC/MS and GC Retention Indices in an Undergraduate Analytical Laboratory," *J. Chem. Ed.* **1996**, *73*, 1176.

S. E. Kegley, K. J. Hansen, and K. L. Cunningham, "Determination of Polychlorinated Biphenyls (PCBs) in River and Bay Sediments," *J. Chem. Ed.* **1996**, *73*, 558.

R. C. Brush and G. W. Rice, "Trihalomethanes Produced in Humic Acid Reactions," *J. Chem. Ed.* **1994**, *71*, A293.

M. E. Jones, "A Simple-to-Build Thermal-Conductivity GC Detector," *J. Chem. Ed.* **1994**, *71*, 995.

W. C. Welch and T. G. Greco, "An Experiment in Manual Multiple Headspace Extraction for Gas Chromatography," **1993**, *70*, 333.

R. J. Kominar, "The Preparation and Testing of a Fused-Silica Gas Chromatography Capillary Column," *J. Chem. Ed*. **1991**, *68*, A249.

C. N. Yarnitzky, "A Sonar Detector for Gas Chromatographs," *J. Chem. Ed.* **1990**, *67*, 712.

R. C. Graham and J. K. Robertson, "Analysis of Trihalomethanes in Soft Drinks." *J. Chem. Ed*. **1988**, *65*, 735.

S. L. Tackett, "Determination of Methanol in Gasoline by Gas Chromatography," *J. Chem. Ed*. **1987**, *64*, 1059.

G. W. Rice, "Determination of Impurities in Whiskey Using Internal Standard Techniques," *J. Chem. Ed*. **1987**, *64*, 1055.

Chapter 25 High-Performance Liquid Chromatography

S. E. Stitzel and R. E. Sours, "High-Performance Liquid Chromatography Analysis of Single-Origin Chocolates for Methylxanthine Composition and Provenance Determination," *J. Chem. Ed*. **2013**, *90*, 1227.

S. E. Stitzel and R. E. Sours, "High-Performance Liquid Chromatography Analysis of Single-Origin Chocolates for Methylxanthine Composition and Provenance Determination," *J. Chem. Ed.* **2013**, *90*, 1227.

Y. Mei-Ratliff, "Determination of the Antibiotic Oxytetracycline in Commercial Milk by Solid-Phase Extraction: A High-Performance Liquid Chromatography (HPLC) Experiment for Quantitative Instrumental Analysis," *J. Chem. Ed*. **2012**, *89*, 656.

F. Gandía-Herrero, A. Simón-Carillo, J. Escribano, and F. García-Carmona, "Determination of Beet Root Betanin in Dairy Products by High-Performance Liquid Chromatography (HPLC)," *J. Chem. Ed*. **2012**, *89*, 660.

M. P. Bindis, S. L. Bretz, and N. D. Danielson, "Preparation and Characterization of a Polymeric Monolithic Column for Use in High-Performance Liquid Chromatography," *J. Chem. Ed*. **2011**, *88*, 675.

E. T. Smith and M. Hill "Constructing a LabView-Controlled HPLC System," *J. Chem. Ed.* **2011**, *88*, 317.

J. C. Penteado and J. C. Masini, "Exploring Liquid Sequential Injection Chromatography to Teach Fundamentals of Separation Methods," *J. Chem. Ed*. **2011**, *88*, 235.

R. E. Leacock, J. J. Stankus, and J. M. Davis, "Simultaneous Determination of Caffeine and Vitamin B6 in Energy Drinks by High-Performance Liquid Chromatography," *J. Chem. Ed*. **2011**, *88*, 232.

A. Alcázar, J. M. Jurado, and A. G. González, "Gradient Scouting in Reversed-Phase HPLC Revisited," *J. Chem. Ed*. **2011**, *88*, 74.

C. J. Fenk, N. M. Hickman, M. A. Fincke, D. H. Motry, and B. Lavine, "Identification and Quantitative Analysis of Acetaminophen, Acetylsalicylic Acid, and Caffeine in Commercial Analgesic Tablets By LC-MS," *J. Chem. Ed*. **2010**, *87*, 838.

A Carlin-Sinclair, I. Marc, L. Menguy, and D. Prim, "The Determination of Methylxanthines in Chocolate and Cocoa by Different Separation Techniques: HPLC, Instrumental TLC,

and MECC," *J. Chem. Ed*. **2009**, *86*, 1307.

A. L. Miller, P. Vaughn, and T. M. Sirvent, "Effects of Storage Conditions on Lycopene Stability in Tomato Extracts," *J. Chem. Ed*. **2009**, *86*, 1304.

R. A. Shalliker, S. Kayillo, and G. R. Dennis, "Optimizing Chromatographic Separation: An Experiment Using an HPLC Simulator," *J. Chem. Ed*. **2008**, *85*, 1265.

T. M. Danenhower, L. J. Force, K. J. Petersen, T. A. Betts, and G. A. Baker, "HPLC Analysis of α- and β-Acids in Hops," *J. Chem. Ed*. **2008**, *85*, 954.

J. D. Freeman and E. D. Niemeyer, "Quantification of Tea Flavonoids by High Performance Liquid Chromatography," *J. Chem. Ed*. **2008**, *85*, 951.

W. F. Chan and C. W. Lin, "High-Pressure Liquid Chromatography: Quantitative Analysis of Chinese Herbal Medicine," *J. Chem. Ed*. **2007**, *84*, 1982.

D. J. Buessman, "The Mysterious Death: An HPLC Lab Experiment," *J. Chem. Ed*. **2007**, *84*, 1809.

D. C. Stone, "Teaching Chromatography Using Virtual Laboratory Exercises," *J. Chem. Ed*. **2007**, *84*, 1488.

V. Canales and C. Teixeira da Costa, "Quantitative HPLC Analysis of Rosmarinic Acid in Extracts of *Melissa officinalis* and Spectrophotometric Measurement of Their Antioxidant Activities," *J. Chem. Ed*. **2007**, *84*, 1502.

C. Strong and J. Ruttencutter, "Biochemical Applications in the Analytical Chemistry Lab," *J. Chem. Ed.* **2004**, *81*, 1706.

H. C. Stynes, A. Layo, and R. W. Smith, "LC-MS of Metmyoglobin at pH = 2," *J. Chem. Ed.* **2004**, *81*, 266.

E. Sottofattori, R. Raggio, and O. Bruno, "Milk as a Drug Analysis Medium: HPLC Determination of Isoniazid," *J. Chem. Ed.* **2003**, *80*, 547.

M. B. Jensen, "Integrating HPLC and Electrochemistry: A LabVIEW-Based Pulsed Amperometric Detection System," *J. Chem. Ed.* **2002**, *79*, 345.

S. M. Joseph and J. A. Palasota, "Combined Effects of pH and Percent Methanol on HPLC Separation of Benzoic Acid and Phenol," *J. Chem. Ed.* **2001**, *78*, 1381.

J. Cannon, D. Li, S. G. Wood, N. L. Owen, A. Gromova, and V. Lutsky, "Investigation of Secondary Metabolites in Plants," *J. Chem. Ed.* **2001**, *78*, 1234.

E. J. Volker, D. DiLella, K. Terneus, C. Baldwin, and I. Volker, "The Determination of

Ergosterol in Environmental Samples," *J. Chem. Ed.* **2000**, *77*, 1621.

J. Huang, S, Maybury, and J. C. Sagebiel, "Hot Chili Peppers: Extraction, Cleanup, and Measurement of Capsaicin," *J. Chem. Ed.* **2000**, *77*, 1630.

E. Dolan, Y. Zhang, and D. Klarup, "The Distribution Coefficient of Atrazine with Illinois Soils," *J. Chem. Ed.* **1998**, *75*, 1609.

L. M. Wingen, J. C. Low, and B. J. Finlayson-Pitts, "Chromatography, Absorption, and Fluorescence: A New Instrumental Analysis Experiment on the Measurement of Polycyclic Aromatic Hydrocarbons in Cigarette Smoke," *J. Chem. Ed.* **1998**, *75*, 1599.

G. K. Ferguson, "Quantitative HPLC Analysis of a Psychotherapeutic Medication: Simultaneous Determination of Amitriptyline Hydrochloride and Perphenazine," *J. Chem. Ed.* **1998**, *75*, 1615.

G. Ferguson, "Quantitative HPLC Analysis of an Analgesic/Caffeine Formulation: Determination of Caffeine," *J. Chem. Ed.* **1998**, *75*, 467.

V. L. McDevitt, A. Rodríguez, and K. R. Williams, "Analysis of Soft Drinks: UV Spectrophotometry, Liquid Chromatography, and Capillary Electrophoresis," *J. Chem. Ed.* **1998**, *75*, 625.

M. Situmorang, M. T. B. Lee, K. Witzeman, and W. R. Heineman, "Liquid Chromatography with Electrochemical Detection (LC-EC): An Experiment Using 4-Aminophenol," *J. Chem. Ed.* **1998**, *75*, 1035.

R. S. Woosley and D. J. Butcher, "Chemical Analysis of an Endangered Conifer," *J. Chem. Ed.* **1998**, *75*, 1592.

P. J. Walsh, D. K. Smith, and C. Castello, "Resolution of *trans*-Cyclohexane-1,2-diamine and Determination of the Enantiopurity Using Chiral Solid-Phase HPLC Techniques and Polarimetry," *J. Chem. Ed.* **1998**, *75*, 1459.

S. A. Van Arman and M. W. Thomsen, "HPLC for Undergraduate Introductory Laboratories," *J. Chem. Ed*. **1997**, *74*, 49.

A. M. Bonser and O. A. Moe, "Labeling Histidines in Cytochrome c," *J. Chem. Ed.* **1996**, *73*, 794.

F. Ortega, E. Velez, and R. Somanathan, "Synthesis and Use of Reverse-Phase Silica Gel for HPLC in Undergraduate Chemistry," *J. Chem. Ed.* **1996**, *73*, A26.

C. D. Tran and M. Dotlich, "Enantiomeric Separation of Beta-Blockers by High Performance

Liquid Chromatography," *J. Chem. Ed.* **1995**, *72*, 71.

C. A. Lucy, L. L. M. Glavina, and F. F. Cantwell, "A Laboratory Experiment on Extracolumn Band Broadening in Liquid Chromatography," *J. Chem. Ed.* **1995**, *72*, 367.

P. Luo, M. Z. Luo, and R. P. Baldwin, "Determination of Sugars in Food Products: Using HPLC and Electrochemical Detection at a Cu Electrode," *J. Chem. Ed.* **1993**, *70*, 679.

J. P. Williams, K. J. West, and K. L. Erickson, "Separation of Aspirin from Acetaminophen and Caffeine in an Over-the-Counter Analgesic Tablet: A Solid-Phase Extraction Method," *J. Chem. Ed*. **1992**, *69*, 669.

V. T. Remcho, H. M. McNair, and H. T. Rasmussen, "HPLC Method Development with the Photodiode Array Detector," *J. Chem. Ed*. **1992**, *69*, A117.

C. H. Clapp, J. S. Swan, and J. L. Poechmann, "Identification of Amino Acids in Unknown Dipeptides" *J. Chem. Ed*. **1992**, *69*, A122.

D. T. Harvey, S. Byerly, A. Bowman, and J. Tomlin, "Optimization of HPLC and GC Separations Using Response Surfaces," *J. Chem. Ed*. **1991**, *68*, 162.

B. A. Bidlingmeyer and S. Schmitz, "The Analysis of Artificial Sweeteners and Additives in Beverages by HPLC," *J. Chem. Ed*. **1991**, *68*, A195.

D. E. Goodney, "Analysis of Vitamin C by High-Pressure Liquid Chromatography," *J. Chem. Ed*. **1987**, *64*, 187.

Chapter 26 Chromatographic Methods and Capillary Electrophoresis

P. A. E. Piunno, A. Zetina, N. Chu, A. J. Tavares, M. O. Noor, E. Petryayeva, U. Uddayasankar, and A. Veglio, "A Comprehensive Microfluidics Device Construction and Characterization Module for the Advanced Undergraduate Analytical Chemistry Laboratory," *J. Chem. Ed*. **2014**, *91*, 902.

T.-C. Chao, S. Bhattacharya, and A. Ros, "Microfluidic Gel Electrophoresis in the Undergraduate Laboratory Applied to Food Analysis," *J. Chem. Ed*. **2012**, *89*, 125.

S. Teerasong and R. L. McClain, "A Student-Made Microfluidic Device for Electrophoretic Separation of Food Dyes," *J. Chem. Ed*. **2011**, *88*, 465.

M. C. Chia, C. M. Sweeney, and T. W. Odom, "Chemistry in Microfluidic Channels," *J. Chem. Ed*. **2011**, *88*, 461.

L. A. Holland, "Capillary Electrophoresis," *J. Chem. Ed.* **2011**, *88*, 254. A compendium of experiments.

A Carlin-Sinclair, I. Marc, L. Menguy, and D. Prim, "The Determination of Methylxanthines in Chocolare and Cocoa by Different Separation Techniques: HPLC, Instrumental TLC, and MECC," *J. Chem. Ed*. **2009**, *86*, 1307.

A. P. Timerman, A. M. Fenrick, and T. M. Zamis, "Isolation of Invertase from Baker's Yeast: A Four-Part Exercise in Protein Purification and Characterization," *J. Chem. Ed.* **2009**, *86*, 379. Gel filtration and gel electrophoresis.

A. D. Burum and A. G. Splittgerber, "A Static Method as an Alternative to Gel Chromatography," *J. Chem. Ed.* **2008**, *85*, 1257.

M. R. Bresler and J. P. Hagen, "Surfactant Adsorption: A Revised Physical Chemistry Lab," *J. Chem. Ed.* **2008**, *85*, 269.

J. A. Poce-Fatou, M. Bethencourt-Nuñez, C. Moreno, J. U. Pinto-Ganfornina, and F. U. Moreno-Dorado, "A Lab Experiment to Illustrate the Physicochemical Principles of Detergency," *J. Chem. Ed.* **2008**, *85*, 266.

C. A. Katz, Z. J. Calzola, and J. K. N. Mbindyo, "Structure and Solvent Properties of Microemulsions," *J. Chem. Ed.* **2008**, *85*, 263. Experiment includes fluorescence of pyrene in microemulsion and micelles.

L. S. Brunauer and K. K. Davis, "Size Exclusion Chromatography: An Experiment for High School an Community College Chemistry and Biotechnology Laboratory Programs," *J. Chem. Ed*. **2008**, *85*, 683.

B. T. Nash, "Determination of the Subunit Molecular Mass and Composition of Alcohol Dehydrogenase by SDA-PAGE," *J. Chem. Ed*. **2007**, *84*, 1508.

H. Van Ryswyk, E. W. Hall, S. J. Petesch, and A. E. Wiedeman, "Extending the marine Microcosm Laboratory," *J. Chem. Ed*. **2007**, *84*, 306. Ion chromatography of sea water.

D. L. Van Engelen, S. W. Suljak, J. P. Hall, and B. E. Holmes, "Undergraduate Introductory Quantitative Chemistry Laboratory Course: Interdisciplinary Group Projects in Phytoremediation," *J. Chem. Ed.* **2007**, *84*, 128. A semester-long course employing multiple analytical methods in the context of group research projects.

G. Anderson, J. E. Thompson, and K. Shurrush, "An Inexpensive Device for Capillary Electrophoresis with Fluorescence Detection," *J. Chem. Ed*. **2006**, *83*, 1677.

M. Solow, "Weak Acid pK_a Determination Using Capillary Zone Electrophoresis," *J. Chem. Ed*. **2006**, *83*, 1194.

D. D. Jackson, C. S. Abbey, and D. Nugent, "DNA Profiling of the D1S80 Locus: A Forensic Analysis for the Undergraduate Biochemistry Laboratory," *J. Chem. Ed*. **2006**, *83*, 774. Polymerase chain reaction and slab gel electrophoresis.

A.. Bazzi, B. Kreuz, J. Wuokila, and A. Maqboul, "Separation and Determination of Cr(III) and Cr(VI) with Cation-Exchange Chromatography and Atomic Absorption Spectroscopy," *J. Chem. Ed.* **2005**, *82*, 435.

D. B. Craig, "Equilibrium Gel Filtration Chromatography for the Measurement of Protein-Ligand Binding," *J. Chem. Ed.* **2005**, *82*, 96.

C. J. Pursell, B. Chandler, and M. M. Bushey, "Capillary Electrophoresis Analysis of Cations in Water Samples," *J. Chem. Ed.* **2004**, *81*, 1783.

P. R. Haddad, M. J. Shaw, J. E. Madden, and G. W. Dicinoski, "Computer-Based Undergraduate Exercise Using Internet-Accessible Simulation Software for the Study of Retention Behavior and Optimization of Separation Conditions in Ion Chromatography," *J. Chem. Ed.* **2004**, *81*, 1293.

R. J. Whelan, T. E. Hannon, R. N. Zare, and D. J. Rakestraw, "Application of Ion Chromatography to the Investigation of Real-World Samples," *J. Chem. Ed*. **2004**, *81*, 1277.

J. L. Beckers, "The Determination of Caffeine in Coffee: Sense of Nonsense?," *J. Chem. Ed.* **2004**, *81*, 90. (Electrophoresis, liquid chromatography, and spectrophotometry)

G. González-Gaitano and G. Tardajos, "Chemical Equilibrium in Supramolecular Systems as Studied by NMR Spectrometry ," *J. Chem. Ed.* **2004**, *81*, 270. (Equilibrium studies of compounds binding to cyclodextrins.)

R. T. Almaraz and M. Kochis, "Microscale Capillary Electrophoresis: A Complete Instrumentation Experiment for Chemistry Students a the Undergraduate Junior and Senior Level," *J. Chem. Ed.* **2003**, *80*, 216.

K. Xia and G. Pierzynski, "Competitive Sorption Between Oxalate and Phosphate in Soil: An Environmental Chemistry Laboratory Using Ion Chromatography," *J. Chem. Ed.* **2003**, *80*, 71.

M. B. Jensen, "Integrating HPLC and Electrochemistry: A LabVIEW-Based Pulsed

Amperometric Detection System," *J. Chem. Ed.* **2002**, *79*, 345. Anion-exchange separation of sugars.

K. Sinniah and K. Piers, "Ion Chromatography: Analysis of Ions in Pond Waters," *J. Chem. Ed.* **2001**, *78*, 358.

J. P. Loke, D. Hancock, J. M. Johnston, J. Dimauro, and G. S. Denyer, "Teaching Experimental Design Using an Exercise in Protein Fractionation," *J. Chem. Ed.* **2001**, *78*, 1528.

F. Welder and C. L. Coyler, "Using Capillary Electrophoresis to Determine the Purity of Acetylsalicylic Acid Synthesized in the Laboratory, *J. Chem. Ed.* **2001**, *78*, 1525.

T. L. Fisher, I. D. Reingold, and T. L. Fitzsimmons, "Thin-Layer Electrophoresis," *J. Chem. Ed.* **2001**, *78*, 1241.

H. B. Herman, J. R. Jezorek, and Z. Tang, "Analysis of Diet Tonic Water Using Capillary Electrophoresis," *J. Chem. Ed.* **2000**, *77*, 743.

M. Boyce and E. Spickett, "Separation and Quantification of Preservatives Using Ion Pair HPLC and CZE," *J. Chem. Ed.* **2000**, *77*, 740.

J. A. Gruenhagen, D. Delaware, and Y. Ma, "Quantitative Analysis of Non-UV-Absorbing Cations in Soil Samples by High-Performance Capillary Electrophoresis," *J. Chem. Ed.* **2000**, *77*, 1613.

W. P. Gardner and J. E. Girard, "Analysis of Common Household Cleaner-Disinfectants by Capillary Electrophoresis," *J. Chem. Ed.* **2000**, *77*, 1335.

D. A. Storer and A. M. Sarquis, "Measuring Soil Phosphates Using Ion–Exchange Resins," *J. Chem. Ed.* **2000**, *77*, 748.

M. Boyce, "Separation and Quantification of Simple Ions by Capillary Zone Electrophoresis," *J. Chem. Ed.* **1999**, *76*, 815.

T. G. Strein, J. L. Poechmann, and M. Prudenti, "Micellar Electrokinetic Capillary Chromatography in the Undergraduate Curriculum: Separation and Identification of the Amino Acid Residues in an Unknown Dipeptide Using FMOC Derivatization," *J. Chem. Ed.* **1999**, *76*, 820.

C. P. Palmer, "Demonstrating Chemical and Analytical Concepts in the Undergraduate Laboratory Using Capillary Electrophoresis and Micellar Electrokinetic Chromatography," *J. Chem. Ed.* **1999**, *76*, 1542.

S. Demay, A. Martin-Girardeau, and M.-F. Gonnord, "Capillary Electrophoretic Quantitative Analysis of Anions in Drinking Water," *J. Chem. Ed.* **1999**, *76*, 812.

D. S. Hage, A. Chattopadhyay, C. A. C. Wolfe, J. Grundman, and P. B. Kelter, "Determination of Nitrate and Nitrite in Water by Capillary Electrophoresis," *J. Chem. Ed.* **1998**, *75*, 1588.

F. A. Valenzuela, T. K. Green, and D. B. Dahl, "Synthesis and Separation of a Diastereomeric Sulfonium Ion by Capillary Zone Electrophoresis," *J. Chem. Ed.* **1998**, *75*, 1590.

M. A. Janusa, L. J. Andermann, N. M. Kliebert, and M. H. Nannie, "Determination of Chloride Concentration Using Capillary Zone Electrophoresis," *J. Chem. Ed.* **1998**, *75*, 1463.

V. L. McDevitt, A. Rodríguez, and K. R. Williams, "Analysis of Soft Drinks: UV Spectrophotometry, Liquid Chromatography, and Capillary Electrophoresis," *J. Chem. Ed.* **1998**, *75*, 625.

C. L. Bering, J. J. Kuhns, and R. Rowlett, "Purification of Bovine Carbonic Anhydrase by Affinity Chromatography," *J. Chem. Ed.* **1998**, *75*, 1021.

L. Thompson, H. Veening, and T. G. Strein, "Capillary Electrophoresis in the Undergraduate Instrumental Analysis Laboratory: Determination of Common Analgesic Formulations," *J. Chem. Ed*. **1997**, *74*, 1117.

S. Conradi, C. Vogt, and E. Rohde, "Separation of Enantiomeric Barbiturates by Capillary Electrophoresis Using a Cyclodextrin-Containing Run Buffer," *J. Chem. Ed*. **1997**, *74*, 1122.

C. Vogt, S. Conradi, and E. Rohde, "Determination of Caffeine and Other Purine Compounds in Food and Pharmaceuticals by Micellar Electrokinetic Chromatography," *J. Chem. Ed*. **1997**, *74*, 1126.

E. D. Conte, E. F. Barry, and H. Rubinstein, "Determination of Caffeine in Beverages by Capillary Zone Electrophoresis," *J. Chem. Ed.* **1996**, *73*, 1169.

S. D. Johnson, "An Empirical Formula from Ion Exchange Chromatography," *J. Chem. Ed.* **1996**, *73*, 1179.

S. F. Russo and A. Radcliffe, "Separations Utilizing Gel Filtration and Ion-Exchange Chromatography," J. Chem. Ed. 1991, 68, 168.

Chapter 27 Gravimetric and Combustion Analysis

E. Davis, K. Cheung, S. Pauls, J. Dick, E. Roth, N. Zalewski, C. Veldhuizen, and J. Coeler, "Gravimetric Analysis of Bismuth in Bismuth Salicylate Tablets," *J. Chem. Ed.* **2015**, *92*, 163.

W. R. Furlong, M. A. Rubinski, and R. Indralingam, "The Method of Continuous Variation: A Laboratory Investigation of the Formula of a Precipitate," *J. Chem. Ed.* **2013**, *90*, 937.

N. Koga, T. Kimura, and K. Shigedomi, "Laboratory Inquiry for Determining the Chemical Composition of a Component in Daily Use Detergent: Sodium Sesquicarbonate," *J. Chem. Ed.* **2011**, *88*, 1309.

E. J. Bushong and C. H. Yoder, "Synthesis and Characterization of Rouaite, a Copper Hydroxy Nitrate," *J. Chem. Ed.* **2009**, *86*, 80. Nitrate determination with nitron.

L. A. Shaver, "Determination of Phosphates by the Gravimetric Quimociac Technique," *J. Chem. Ed.* **2008**, *85*, 1097. Precipitation of quinoline 12-molybdophosphate.

C. A. Trujillo, "The Empirical Formula of Silver Sulfide," *J. Chem. Ed.* **2007**, *84*, 1682. Thermogravimetric analysis.

K. M. Blyth, L. R. Mullings, D. N. Phillips, D. Pritchard, and W. van Bronswijk, "Preparation, Analysis, and Characterization of Some Transition Metal Complexes," *J. Chem. Ed.* **2005**, *82*, 1667. Combustion analysis of carbon.

L. M. Brigandi, P. A. Leber, and C. H. Yoder, "Synthesis and Analysis of Copper Hydroxy Double Salts," *J. Chem. Ed*. **2005**, *82*, 1662.

K. E. Ginion and C. H. Yoder, "Preparation and Analysis of Libethenite ($Cu_2(PO_4)OH$," *J. Chem. Ed*. **2004**, *81*, 394.

J. I. Selco, J. L. Roberts, Jr., and D. B. Wacks, "The Analysis of Seawater: A Laboratory-Centered Learning Project in General Chemistry," *J. Chem. Ed.* **2003**, *80*, 54.

S. S. Clareen, S. R. Marshall, K. E. Price, M. B. Royall, C. H. Yoder, and R. W. Schaeffer, "The Synthesis and Analysis of Ammine Complexes of Copper and Silver Sulfate," *J. Chem. Ed.* **2000**, *77*, 904.

J. D. Willey, G. B. Avery, Jr., J. J. Manock, S. A. Skrabal, and C. F Stehman, "Chemical Analysis of Soils," *J. Chem. Ed.* **1999**, *76*, 1693.

N. Carmosini, S. Ghoreshy, and M. C. Koether, "The Gravimetric Analysis of Nickel Using a Microwave Oven," *J. Chem. Ed*. **1997**, *74*, 986.

N. H. Snow, M. Dunn, and S. Patel, "Determination of Crude Fat in Food Products by Supercritical Fluid Extraction and Gravimetric Analysis," *J. Chem. Ed*. **1997**, *74*, 1108.

T. M. Harris, "Revitalizing the Gravimetric Determination in Quantitative Analysis Laboratory," *J. Chem. Ed*. **1995**, *72*, 355.

R. Q. Thompson and M. Ghadiali, "Microwave Drying of Precipitates for Gravimetric Analysis," *J. Chem. Ed*. **1993**, *70*, 170.

J. O. Hill and R. J. Magee, "Advanced Undergraduate Experiments in Thermoanalytical Chemistry," J. *Chem. Ed*. **1988**, *65*, 1024.

Chapter 28 Sample Preparation

S. A. Radford, R. E. Hunter, Jr., D. B. Barr, and P. B. Ryan, "Liquid-Liquid Extraction of Insecticides from Juice," *J. Chem. Ed*. **2013**, *90*, 483. Solid-phase extraction–gas chromatography–mass spectrometry experiment.

H. F. Rossi, III, J. Rizzo, D. C. Zimmerman, and K. M. Usher, "Extraction and Quantitation of FD&C Red Dye #40 from Beverages Containing Cranberry Juice," *J. Chem. Ed*. **2012**, *89*, 1551.

Y. Mei-Ratliff, "Determination of the Antibiotic Oxytetracycline in Commercial Milk by Solid-Phase Extraction: A High-Performance Liquid Chromatography (HPLC) Experiment for Quantitative Instrumental Analysis," *J. Chem. Ed*. **2012**, *89*, 656.

I. Lavilla, M. Costas, F. Pena-Pereira, S. Gil, and C. Bendicho, "Quantitative Ultrasound-Assisted Extraction for Trace-Metal Determination," *J. Chem. Ed*. **2011**, *88*, 480.

M. E. O'Donnell, B. A. Musial, S. Lowry Betz, N. D. Danielson, and D. Ca "Investigating the Retention Mechanisms of Liquid Chromatography Using Solid-Phase Extraction Cartridges," *J. Chem. Ed*. **2009**, *86*, 61.

D. Riccio, D. C. Wood, and J. M. Miller, "Using Single Drop Microextraction for Headspace Analysis with Gas Chromatography," *J. Chem. Ed*. **2008**, *85*, 965.

Y. Wang, J. Ocariz, J. Hammersand, E. MacDonald, A. Bartczak, F. Kero, V. Y. Young, and K. R. Williams, "Determination of Cinnamaldehyde in Cinnamon by SPME-GC-MS," *J.*

Chem. Ed. **2008**, *85*, 957.

M. A. Jeannot, "Analysis of Iron in Lawn Fertilizer: A Sampling Study," *J. Chem. Ed*. **2006**, *83*, 243.

O. A. Sadik, A. K. Wanekaya, and G. Yevgeny, "Pressure-Assisted Chelating Extraction as a Teaching Tool in Instrumental Analysis," *J. Chem. Ed*. **2004**, *81*, 1177.

D. Harvey, "Two Experiments Illustrating the Importance of Sampling in Quantitative Chemical Analysis," *J. Chem. Ed*. **2002**, *79*, 360. Analysis of variance.

F. A. Settle and M. Pleva, "The Weakest Link Exercise," *Anal. Chem*. **1999**, *71*, 538A. Analysis of variance.

P. B. O'Hara, J. A. Sanborn, and M. Howard, "Pesticides in Drinking Water: Project-Based Learning Within the Introductory Chemistry Curriculum," *J. Chem. Ed.* **1999**, *76*, 1673. (solid-phase extraction experiment)

R. G. Freeman and D. L. McCurdy, "Using Microwave Sample Decomposition in Undergraduate Analytical Chemistry," *J. Chem. Ed*. **1998**, *75*, 1033.