

Carl Anthony Koval

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Juniata College, Huntingdon, PA 16652
B.S., summa cum laude, 1974, GPA: 4.0/4.0

Academic Positions:

Chair, Dept. of Chemistry and Biochemistry, Univ. of Colorado at Boulder
July 2015 - present

Director, Joint Center for Artificial Photosynthesis (JCAP), California Institute of Technology, February 2013-December 2014

Assistant Director for Science, Joint Center for Artificial Photosynthesis (JCAP), California Institute of Technology, July 2012 – January 2013

Associate Director for Research, Renewable and Sustainable Energy Institute (RASEI), Univ. of Colorado at Boulder, August 2010 – June 2012

Co-Director, Renewable and Sustainable Energy Institute (RASEI), Univ. of Colorado at Boulder, July 2009 – July 2010

Faculty Director, Initiative on Renewable and Sustainable Energy, Univ. of Colorado at Boulder, January 2006 – June 2009

Chair, Dept. of Chemistry and Biochemistry, Univ. of Colorado at Boulder
July 1998 - June 2001

Professor of Chemistry at the University of Colorado
August 1992 - present

Fellow, Cooperative Institute for Research in Environmental Sciences
University of Colorado, January 1990 - June 1992

Associate Professor of Chemistry at the University of Colorado
September 1987 - August 1992

Assistant Professor of Chemistry at the University of Colorado
August 1980 - August 1987

Departmental Assistant Scientist at Purdue University
November 1978 - June 1980, Advisor D.W. Margerum

Honors and Awards:

ACS Colorado Section Award, 1996.
Faculty Fellowship, Council on Research and Creative Work
University of Colorado, AY 1995/96
Visiting Associate Professor, California Institute of Technology
January 1 - March 22, 1992.
National Research Council Senior Research Associate, Solar Energy
Research Institute, January 1 - July 31, 1989
Faculty Associate in Chemistry, California Institute of Technology,
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Professional Societies:

American Chemical Society
Electrochemical Society
Society for Electroanalytical Chemistry

PUBLICATIONS

116. O. R. Luca, C. L. McCrory, N. F. Dalleska, C. A. Koval, "The Selective Electrochemical Conversion of Preactivated CO₂ to Methane, *J. Electrochem. Soc.*, (2015) 162, H473-H476.
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114. Kavita M. Jeerage, Richard D. Noble, Carl A. Koval, "Investigation of Aqueous Lithium Iodide/Triiodide Electrolyte for Dual-Chamber Electrochemical Actuators," *Sens, Act. B* (2007) 125, 180-188.
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111. Dean Camper, Collin Becker, Carl Koval, Richard Noble, "Diffusion and Solubility Measurements in Room Temperature Ionic Liquids Using a Dual-Channel Pressure Decay Apparatus," *Ind. Eng. Chem. Res.* (2006) 45, 445 -450.
110. Richard D. Noble and Carl A. Koval, "Review of Facilitated Transport Membranes," *Materials Science of Membranes for Gas and Vapor Separation*, John Wiley and Sons, Ltd. (2006) 411-435.
109. Mya A. Norman, Christine E. Evans, Anthony R. Fuoco, Richard D. Noble, Carl A. Koval "Characterization of a Membrane-Based, Electrochemically Driven Pumping System Using Aqueous Electrolyte Solutions," *Anal. Chem.* (2005) 77, 6374-6380..
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106. Mya Norman, Richard Noble, Carl Koval, "Electrochemical Pumping of DMF Electrolyte Solutions Across Membranes," *J. Electrochem. Soc.* (2004) 151, E364-E371.
105. Dean Camper, Paul Scovazzo, Carl Koval, Richard Noble, "Gas Solubilities in Room Temperature Ionic Liquids," *Ind. Eng. Chem. Res.* (2004) 43, 3049-54.
104. Paul Scovazzo, Jesse Kieft, Dan Finan, Carl Koval, Richard Noble, "Gas Separations Using Non-Hexafluorophosphate [PF₆] Anion Supported Ionic Liquid Membranes," *J. Memb. Sci.* (2004) 238, 57-63.
103. Paul Scovazzo, Joe Poshusta, Daniel DuBois, Carl Koval, Richard Noble, "Electrochemical Separation and Concentration of <1% Carbon Dioxide from Nitrogen," *J. Electrochem. Soc.*, (2003) 150, D91-98.
102. Michelle L. Goyette, Theresa L. Longin, Richard D. Noble, Carl A. Koval, "Selective Photofacilitated Transport of Sodium Ions Through Liquid Membranes: Key Factors in Experimental Design, Transport Results and Comparison with a Mathematical Model," *J. Memb. Sci.* (2003) 212, 225-35.
101. Paul Scovazzo, Ann E. Visser, James H. Davis, Jr., Robin D. Rogers, Carl A. Koval, Dan L. DuBois, and Richard D. Noble, "Supported Ionic Liquid Membranes and Facilitated Ionic Liquid Membranes," *ACS Sym. Ser.* (2002) 818, 69-87.
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91. Karen J. Buechler, Richard D. Noble, Carl A. Koval, Theresa M. Zawistowski, Caroline H. Nam, "Design and Evaluation of a Novel Controlled Periodic Illumination Reactor to Study Photocatalysis," Ind. Eng. Chem. Res., (1999) 38, 1258-63.
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52. Jeffrey G. Sczechowski, Carl A. Koval, Richard D. Noble, "Improved Photoefficiencies for TiO₂ Photocatalytic Reactors Through Use of Controlled Periodic Illumination," Photocatalytic Purification and Treatment of Water and Air, D.F. Ollis and H. El-Ekabi (Eds.) Elsevier Science Publishers B.V., (1993) 645-49.
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4. C. A. Koval, F. C. Anson, "Electrochemistry Of The $\text{Ru}^{3+,2+}$ Couple Attached To Graphite Electrodes," Anal. Chem. (1978) 50, 223-29.
3. R. R. Gagne', C. A. Koval, T. J. Smith, "Binuclear Complexes Of Macrocyclic Ligands: A Mixed-Valence Cu(II)Cu(I) Complex Which Exhibits Unusual Temperature Dependent Behavior," J. Am. Chem. Soc. (1977) 99, 8367-68.
2. R. R. Gagne', J. L. Allison, R. S. Gall, C. A. Koval, "Models For Copper Containing Proteins: Structure And Properties Of Novel Five-Coordinate Cu(I) Complexes," J. Am. Chem. Soc. (1977) 99, 7170-78.
1. A. P. Brown, C. A. Koval, F. C. Anson, "Illustrative Electrochemical Behavior Of Reactants Irreversibly Adsorbed On Graphite Electrode Surfaces," J. Electroanal. Chem. (1976) 72, 379-87.

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11. Koval, C.A., Evans, C.E., Noble, R.D., Norman, M.A., "Electrochemical High Pressure Pump," U.S. Patent No. 8,343,324 B2, Jan. 1, 2013.
10. Thoen, P., Koval, C.A., Noble, R.D., "Unexpectedly Large Selectivities for Olefin Separations Utilizing Silver in Ion-Exchange Membranes, U.S. Patent No. 5,498,823, March 12, 1996.
9. J. Sczechowski, C. Koval, R.D. Noble, "Use of Controlled Periodic Illumination for an Improved Method of Photocatalysis and an Improved Reactor Design," U.S. Patent No. 5,439,652, Aug. 8, 1995.
8. J. Pelligrino, R. Rabago, C. Koval, R. Noble, "Enhancing Performance of Perfluorinated Ionomer Membranes Via Dopant Incorporation" U.S. Patent No. 5,417,832, May 23, 1995.
- 5-7. M. R. DuBois, R. D. Noble and C. A. Koval, "Methods of Production of Novel Molybdenum-Sulfide Dimers and Reactions of the Same." U.S. Patent No. 5,391,791, Feb. 21, 1995, U.S. Patent No. 5,414,194, May 9, 1995, U.S. Patent No. 5,430,225, July 4, 1995.
4. N.S. Foster, C.A. Koval, R.D. Noble, "Reversible Photodeposition and Dissolution of Metal Ions," U.S. Patent No. 5,332,508, Sept. 20, 1993.
3. R. D. Noble, C. A. Koval, L. Nixon, G. F. Slaff, "Method for Preparing Magnetizable Porous Particles" U.S. Patent No. 5,110,624, May 5, 1992.
- 1,2. R. D. Noble, C. A. Koval, L. Nixon, G. F. Slaff, "Stationary Magnetically Stabilized Fluidized Bed for Protein Separation and Purification." U.S. Patent No. 5,084,169, Jan. 28, 1992, U.S. Patent No. 5,130,027, July 14, 1992.

PRESENTATIONS

(i - invited presentation; p - poster presentation)

142. Basic Energy Sciences Advisory Committee Meeting, Bethesda, MD, July 13, 2017, "Basic Research Needs for Catalysis Science to Transform Energy Technologies." (i)
141. Renewable Energy Summit, University of Wyoming, Laramie, WY, June 14, 2016, "Solar Energy Storage, Hydrogen Economy, Solar Fuels and Artificial Photosynthesis." (i)
140. Portland Oregon Section of the American Chemical Society, Willamette University, OR, February 12, 2015, "Development of Solar-Fuels Generators." (i)
139. Pacific Northwest National Laboratory, Richland, WA, May 9, 2014, "Development of Scalably Manufacturable Solar-Fuels Generators." (i)
138. 247th National ACS Meeting, Dallas, TX, March 18, 2014, "Development of Integrated Solar-Fuel Generators." (i)
137. Thirty-Sixth DOE Solar Photochemistry Research Meeting, Annapolis, MD, June 2, 2014, "Development of Scalably Manufacturable Solar-Fuels Generators." (i)
136. Basic Energy Sciences Advisory Committee Meeting, Bethesda, MD, Feb. 27, 2014, "Development of Integrated Solar-Fuels Generators." (i)
135. Hydrogen Technology Advisory Committee, NREL, Golden, CO, October 30, 2013, "JCAP Research Overview." (i)
134. 224th Meeting of the Electrochemical Society, San Francisco, CA, Oct. 28, 2013, "Integrated and Scalable Solar-fuels Generators." (i)
133. Telluride Workshop on Solar Solutions to Energy and Environmental Problems, Telluride, CO, Aug. 9, 2013, "Towards Scalably Manufacturable Solar-Fuels Generators." (i)
132. Clean Energy Action, Boulder, CO, Nov. 29. 2011, "Transforming Energy. Educating Leaders" (i)
131. Boulder Chamber, Boulder, CO, June 20, 2011, "RASEI Overview for the Boulder Chamber" (i)
130. Applied Mathematics Colloquium, Univ. of Colorado, Oct. 15, 2010, "The Renewable and Sustainable Energy Institute at CU-Boulder." (i)
129. Rocky Mountain Institute, Boulder, CO, May 20, 2010, "The Renewable and Sustainable Energy Institute at CU-Boulder." (i)
128. College of Engineering and Applied Science Advisory Council, Univ. of Colorado, Apr. 23, 2010, "The Renewable and Sustainable Energy Institute at CU-Boulder." (i)
127. ConocoPhillips Research Laboratory, Bartlesville, OK, Feb. 10, 2010, "The Renewable and Sustainable Energy Institute at CU-Boulder." (i)
126. 8th National Conference on Science, Policy and the Environment, Washington, DC, Jan. 16, 2008, "Developing Campus-Wide Initiatives on Climate-Change, Energy Use and Sustainability."
125. Student Hosted Colloquia Series at Stanford University, October 25, 2007, "Electrocatalysis, Electrochemical Carbon Dioxide Sequestration, and Creating an Energy Initiative" (i)
124. National ACS Meeting, Chicago, IL, March 25, 2007, "Chemistry, chemical engineering, and membrane science: 20+ years of collaboration" (i).
123. Energy Forum and Expo, Grand Junction, CO, February 23, 2007, "Renewable and Sustainable Energy Research at the University of Colorado – Boulder" (i).

122. 232nd National ACS Meeting, San Francisco, CA, Sept. 10, 2006, " Applications of electro-osmotic flow across ionomer membranes induced by electrolysis of iodide / triiodide electrolytes" (i).
121. 232nd National ACS Meeting, San Francisco, CA, Sept. 12, 2006, " Properties of Imidazolium-based Room Temperature Ionic Liquids that Effect CO₂ Solubility and Selectivity for CO₂/N₂ and CO₂/CH₄ Gas Separations" (i).
120. Gordon Research Conference in Electrochemistry, Buellton, CA, Feb. 15,16 2006, "Does Nafion Have Pores?" (p).
119. Dept. of Chemistry, Iowa State University, Sept. 30, 2005, "Utilizing Electrochemistry and Membranes to Pump Fluids: The Accidental Discovery of a Mass Transfer Diode?" (i).
118. Gordon Research Conference in Electrochemistry, Ventura, CA, Jan. 23, 24, 2005, "Generating Pressure with No Moving Parts in Electrochemical Cells" (p).
117. 206th Meeting of the Electrochemical Society, Honolulu, HI Oct. 6, 2004, Use of Ionic Liquids for Membrane-based and Electrochemically-driven Gas Separations." (i).
116. 15th Annual Meeting of the North American Membrane Society, Honolulu, HI, June 28, 2004, "Facilitated Membrane Transport in Ionic Liquids and Electrolyte Solutions," (i).
115. 204th Meeting of the Electrochemical Society, Orlando, FL, Oct. 13, 2003, "Use of Ionic Liquids in Electrochemical Processes."
114. Gordon Research Conference in Electrochemistry, Ventura, CA, Jan. 19, 2003, "Electrochemical Process for Selective Removal of Carbon Dioxide from the Atmosphere," (p).
113. 202nd Meeting of the Electrochemical Society, Salt Lake City, UT, Oct. 22, 2002 "Selective Separation and Concentration of Carbon Dioxide Using Electrochemically Modulated Complexation."
112. 202nd Meeting of the Electrochemical Society, Salt Lake City, UT, Oct. 22, 2002, " Kinetics of Electron Transfer Reactions Between Aquo Ferric Ion and Hydrophobic Ferrocene Derivatives at Water-Benzylcyanide Interfaces."
111. Northern Arizona Univ., Flagstaff, AZ, Feb, 21, 2002, "Efficient Electrochemical Processes for the Removal of Carbon Dioxide from the Atmosphere," (i).
110. IUPAC 8th International Symposium on Macromolecule-Metal Complexes, Tokyo, Japan, September 6, 1999, "Polymeric Membrane Materials as Ligands for Ag(I) Ions: Design and Use for Hydrocarbon Separations," (i).
109. Gordon Research Conference in Electrochemistry, Ventura, CA, Jan. 19, 1999, "Electron Transfer at Liquid-Liquid Interfaces," (p).
108. Colorado State University, Fort Collins, CO, July 17, 1998, "Photomodulation and Photopumping in Facilitated Transport Membranes," (i).
107. 193rd Meeting of the Electrochemical Society, San Diego, CA, May 6,1998, "Effects of Controlled Periodic Illumination on Photocatalytic Reactions at TiO₂ Films," (i).
106. Dept. of Chemistry and Biochemistry High School Teachers Conf., Univ. of Colorado, Boulder, CO, Oct. 11, 1997, "Energy as a Tool to Teach Chemistry," (i).
105. 214th National ACS Meeting, Anaheim, CA, Sept. 8, 1997, "Poly(vinyl alcohol)-Silver Nitrate Facilitated Transport Membranes for Benzene-Cyclohexane Separations," (i).
104. TwentyFirst DOE Solar Photochemistry Research Conference, Copper Mountain, CO, June 9, 1997, "Photomodulation and Photopumping in Membranes Containing Photoactive Carriers," (p,i).
103. Univ. of Wyoming, Laramie, WY, March 14, 1997, "Facilitated and Photofacilitated Membrane Transport:

Moving Molecules With Photo- and Complexation Chemistry," (i).

102. Gordon Research Conference in Electrochemistry, Ventura, CA, Jan. 16, 1997, "Electrochemical Gas Separations," (i).

101. Waseda University, Tokyo, Japan, Aug. 26, 1996, "Electrochemically Modulated Complexation: A Novel Process for the Selective Separation of Gases," (i).

100. Tokyo University of Agriculture and Technology, Tokyo Japan, Aug. 23, 1996, "Electrochemically Modulated Complexation: A Novel Process for the Selective Separation of Gases," (i).

99. International Congress on Membranes and Membrane Processes, Yokohama, Japan, Aug. 20th 1996, "Importance of Membrane Transport to the Development of Sensors and Instruments for the Analysis of Hydrocarbons" (i).

98. Twentieth DOE Solar Photochemistry Research Conference, French Lick, IN, June 11, 1996, "A Closer Look at the Reduction of Alkyl Bromides By "Hot Electrons?" at p-InP Photocathodes," (p,i).

97. Colorado ACS Section Meeting, Golden, CO, November 11, 1996, "Facilitated Transport Membrane Separations -An Alternative To Distillation For Purification Of Hydrocarbons" (i).

96. 211th National ACS Meeting, New Orleans, LA, March 27th, 1996, "Photoelectrochemistry of GaInP₂ Capped p-GaAs Electrodes" (i).

95. 211th National ACS Meeting, New Orleans, LA, March 24th, 1996, "Kinetic Evidence for Parallel Pathways in the Facilitated Transport of Alkenes Through Ag(I)-exchanged Nafion Membranes" (i).

94. Gordon Research Conference in Electrochemistry, Ventura, CA, Jan. 18, 1996, "An Electrochemists View of a Recent NSF-EPRI Workshop on Electroseparations."

93. 1995 International Chemical Congress of the Pacific Basin Societies, Honolulu, HI, Dec, 18, 1995, "Effects of Controlled Periodic Illumination on the Photocatalytic Oxidation of Organic Compounds at Titanium Dioxide" (i).

92. 4th Pacific Polymer Conference, Koloa, Hawaii, Dec. 13, 1995, "Potential Uses of Membranes containing Ag(I) for Separation of Olefins and Aromatic Compounds from Alkanes," (i).

91. World Environmental Congress, London, Ontario, Sept. 21, 1995, "Electrochemically Modulated Complexation of Gases: A Novel and Energy Efficient Process for the Selective Separation of Gases" (i).

90. Nineteenth DOE Solar Photochemistry Research Conference, Tamiment, PA, June 6, 1995, "Mechanistic Aspects of Photoconversion at Semiconductor-Liquid Junctions and in Facilitated Transport Membranes," (p,i).

89. 209th National ACS Meeting, Anaheim, CA, April 2, 1995, "Facilitated Transport of Organic Molecules in Ion-Exchange Membranes" (i).

88. U.S. -Japan San Diego, CA, March 13, 1995, "Effects of Controlled Periodic Illumination on the Photoefficiency of the Photocatalytic Oxidation of Organic Compounds at Titanium Dioxide" (i).

87. The Margerum Symposium/Reunion, Purdue University, West Lafayette, IN, October, 15, 1994, "Using Electro-, Photo-, and Coordination Chemistry to Selectively Separate and Concentrate Chemical Species" (i).

86. 36th Rocky Mountain Conference on Analytical Chemistry, Denver, CO, August 2, 1994, "Separation and Concentration of Gases Using Electrochemically Modulated Complexation".

85. NIST Workshop on Environmental Separations, Boulder, CO, July 19, 1994, "Using Titanium Dioxide Photocatalysis to Treat Aqueous Waste Streams Containing Metal and Organic Contaminants" (i).

84. Eighteenth DOE Solar Photochemistry Research Conference, Tahoe City, CA, June 6, 1994, "Mechanistic Aspects of Photoconversion at Semiconductor-Liquid Junctions and in Facilitated Transport Membranes," (i).

83. 6th Meeting of the North American Membrane Society, Breckenridge, CO, May 23, 1994, "Unexpectedly Large Selectivities for Alkene/ Aromatic/ Alkane Separations in Ion-exchange Membranes" (i,p).
82. 207th National ACS Meeting, San Diego, CA, March 16, 1994, "Unexpectedly Large Selectivities for Olefin Separations Utilizing Silver Ion in Ion-exchange Membranes".
81. Gordon Research Conference in Electrochemistry, Ventura, CA, Jan.18, 1994, "The Use of Controlled Periodic Illumination to Increase Photoefficiencies for Heterogeneous Photocatalysis." (p)
80. Seventeenth DOE Solar Photochemistry Research Conference, Delevan, WI, June 8, 1993, "Selective Adsorption and Concentration of Chemical Species Using Photochemistry in Membranes," (p,i).
79. 183rd Meeting of the Electrochemical Society, Honolulu, Hawaii, May 9,1993, "Novel Separation Processes Utilizing Electrochemically Modulated Complexation" (i).
78. 205th National ACS Meeting, Denver, CO, April 2, 1993, "Factors that Effect the Selectivity and Productivity of facilitated Transport through Ionomer Membranes Exchanged with Ag(I)" (i).
77. 1st International Conference on TiO₂ Photocatalytic Purification and Treatment of Water and Air, Ontario, Canada, Nov. 11, 1992, " Reversible Photoreductive Deposition and Oxidative Dissolution of Copper Ions in TiO₂ Aqueous Suspensions: Potential Applications to Volume Reduction of Waste Streams." (i).
76. Sixteenth DOE Solar Photochemistry Research Conference, Delevan, WI, June 3, 1992, "Reaction Kinetics and Product Distributions In Photoelectrochemical Cells," (i).
75. Workshop on Chemically Specific Separation Processes, Gratz Austria, June 29, 1992, "Chemical Complexation Chemistry," (i).
74. California Institute of Technology, Pasadena, CA, March 11, 1992, "Concentrating Organic Molecules and Metal Ions Using Electrochemical and Photoelectrochemical Cycles," (i).
73. California Institute of Technology, Pasadena, CA, March 2, 1992, "Electron Transfer at Semiconductor Electrodes: Kinetics Two Dimensional Materials and Reactions of Hot Carriers," (i).
72. Colorado School of Mines, Golden, CO, October 15, 1991, "Novel Separation Processes Using Membranes and Electrochemistry."
71. Fifteenth DOE Solar Photochemistry Research Conference, Snowmass, CO June 4, 1991, "Measurement of Electron Transfer Rate Constants at 2-Dimensional Semiconductro/Solution Interfaces," (i,p).
70. Colorado Center for Environmental Management Workshop, May 22, 1991, Denver, CO, "Concentration and Removal of Organic Pollutants Via Electrochemically Modulated Complexation." (i).
69. 179th Meeting of the Electrochemical Society, Washington, D.C., May 9,1991, "Redox Systems Capable of Hot Electron Detection in Photoelectrochemical Cells."
68. 179th Meeting of the Electrochemical Society, Washington, D.C., May 8, 1991, "Development and Characterization of a Titanium Dioxide-Based Semiconductor Photoelectrochemical Detector
67. 179th Meeting of the Electrochemical Society, Washington, D.C., May 7, 1991, "Electrochemical Kinetics at Two-Dimensional Semiconductro Electrodes."
66. Gordon Research Conference in Electrochemistry, Ventura, CA, Jan. 21, 1991, "Selective and Energy Efficient Separation Processes in Membranes and Thin Films." (i)
65. Northwestern University, Evanston, Illinois, Nov. 12, 1990, "Selective Separations Utilizing Facilitated Transport Membranes" (i)
64. Gordon Conference in Physical Electrochemistry, New London, NH, July 31, 1990, "Electron Transfer Reactions at Metal Semiconductor Electrodes." (i)

63. University Coal Research Contractor's Review Meeting, Pittsburgh, PA, July 18, 1990, "Indirect Electrolysis Process for Removal of Pollutants from Coal Liquids." (i)
62. U.S. - Israel Binational Workshop, Jerusalem, Israel, June 26, 1990, "Chemical Evidence for Hot Carrier Reactions at the Semiconductor-Solution Interface." (i)
61. Fourteenth DOE Solar Photochemistry Research Conference, Lake Harmony, PA, June 7, 1990, "Chemical Evidence for Hot Carrier Reactions at the Semiconductor-Solution Interface." (i)
60. 177th Meeting of the Electrochemical Society, Montreal, Canada, May 7, 1990, "The Electrochemistry of a Water-Soluble Iron Porphyrin and Its Exploitation for Removal and Concentration of Environmentally Hazardous Materials via Electrochemically Modulated Complexation." (i)
59. Gordon Research Conference on Electrochemistry, Ventura, CA, Jan 18, 1990, "Facilitated Transport of Neutral Molecules Through Solvated Ionomer Membranes."
58. Cooperative Institute for Research in Environmental Sciences, Boulder, CO, Dec. 13, 1989, "New Separation Processes Utilizing Membranes Molecules and Magnets".
57. University of Colorado, Boulder, CO, Nov. 27, 1989, "New Separation Processes Utilizing Membranes Molecules and Magnets".
56. Thirteenth DOE Solar Photochemistry Research Conference, Silvercreek, CO, June 13, 1989, "Electron Transfer at Semiconductor Electrodes. Recent Experimental and Theoretical Results." (i,p)
55. 175th Meeting of the Electrochemical Society, Los Angeles, CA, May 10, 1989, "A New Formulation for Image Potential Energies at the Semiconductor/Solution Interface." (i)
54. University of Louisville, April 28, 1989, "Hot and Cold Electron Transfer Reactions at Semiconductor Electrodes." (i)
53. University of Colorado, Boulder, CO, Apr. 25, 1989, "The Fleischmann and Pons Cold Fusion Experiments - An Electrochemistry Perspective."
52. ACS Meeting, Dallas, TX, Apr. 10, 1989, "Electron Transfer Reactions at Ideal Semiconductor-Solution Interfaces." (i)
51. Electrochemistry Gordon Research Conference, Jan. 18, 1989, "Observation of Hot Carrier Photoelectrochemical Processes." (p)
50. IBM, Endicott, NY, Dec. 1, 1988, "Decomposition of Organic Compounds By Photoelectrolysis at Semiconductor Particles." (i)
- 48 & 49. AIChE National Meeting, Washington, D.C., Nov. 29 & Dec. 2, 1988, "Concentration and Removal of Nitrogen and Sulfur Containing Compounds from Liquid Phases Using Electrochemically Reversed Chemical Complexation." & Use of Electrochemically Modulated Complexation Reactions for Selective Separations."
47. 196th National ACS Meeting, Los Angeles, CA, Sept. 27, 1988, "Photoelectrochemical Reduction of a Cu(I) Complex to Copper Metal By Hot Carriers." (i)
46. AIChE Summer National Meeting, Denver, CO, Aug. 22, 1988, "Facilitated Transport of Liquid Phase Olefins Through Ion-Exchange Membranes."
45. Twelfth DOE Solar Photochemistry Research Conference, Airlie House, Va., May 25, 1988, "Fundamental Aspects of Electron Transfer at Tungsten Diselenide and Indium Phosphide Semiconducting Electrodes." (i)
44. 172nd Meeting of the Electrochemical Society, Honolulu, HI, Oct. 21, 1987, "Electron Transfer Kinetics at an Ideally Polarizable Nonilluminated Semiconductor / Solution Interface." (i)

42 & 43. 194th National ACS Meeting, New Orleans, LA, September 1 & 3, 1987, "Facilitated Transport of Molecules in Liquid Membranes" & "WSe₂/CH₃CN - An Ideal Polarizable Semiconductor/Solution Interface?" (i & i)

41. 29th Rocky Mountain Conference, Denver, CO, August 4, 1987, "Antichromatography - Separations via Facilitated Transport" (i).

40. E.I. Du Pont de Nemours, Inc., Wilmington, DE, July 17, 1987, "The Effects of Molecular Size on Bimolecular, Electrochemical and Photoinduced Electron Transfer Reactions" (i).

39. Eleventh DOE Solar Photochemistry Research Conference, Tahoe City, CA, June 9, 1987, "WSe₂/CH₃CN - The Ideally Polarizable Semiconductor/Solution Interface?" (i,p).

38. 193rd National ACS Meeting, Denver, CO, April 7, 1987, "Electrochemistry of Metallocenes at Tungsten Diselenide Electrodes" (i)

37. University of Colorado, Boulder, CO, October 20, 1986, "Steric Effects in Electron Transfer Reactions or Redox Reactivity of Metal Ions in Sugar Coated Grease"

36. Electron Donor-Acceptor Interactions Gordon Research Conference, Plymouth, NH, August 13,14, 1986, "Electron Transfer Reactivity of Metal Ions Encased in Sugar-Coated Grease" (i,p).

34,35. Inorganic Gordon Research Conference, Wolfboro, NH, August 5 and 6, 1986, "Electron Transfer Reactivity of Metal Ions Encased in Sugar-Coated Grease" (p) and "Chemical Aspects of Facilitated Transport Through Liquid Membranes" (p).

33. Tenth DOE Solar Photochemistry Research Conference, Niagara-on-the-Lake, Ontario, June 10, 1986, "Chemical Probes of Charge Transfer at Semiconductor Liquid Junctions," (i).

32. 169th Electrochemical Society Meeting, Boston, MA, May 6, 1986, "The Use of Structurally Related Redox Series to Investigate Steric Effects in Electron Transfer Reactions," (i).

31. The Dow Chemical Company, Midland, MI, April 28, 1986, "Relevant and Desirable Properties of Chemical Carriers That Are Utilized for Facilitated Transport" (i).

29,30. Los Alamos National Laboratory, Los Alamos, NM, March 26 and 27, 1986, "Chemical Aspects of Facilitated Transport of Gaseous Molecules Through Liquid Membranes" (i) and "The Electrochemistry of Metallocenes at InP and WSe₂ Semiconducting Electrodes" (i).

28. University of Arizona, Tucson, AZ, March 24, 1986, "The Electrochemistry of Metallocenes at InP and WSe₂ Semiconducting Electrodes."

27. University of Minnesota, Minneapolis, MN, January 16, 1986, "The Use of Structurally Related Redox Series to Investigate Steric Effects in Electron Transfer Reactions," (i).

26. California Institute of Technology, Pasadena, CA, December 6, 1985, "The Use of Structurally Related Redox Series to Investigate Steric Effects in Electron Transfer Reactions," (i).

25. Purdue University, West Lafayette, IN, November 5, 1985, "The Use of Structurally Related Redox Series to Investigate Steric Effects in Electron Transfer Reactions," (i).

24. University of Wyoming, Laramie, WY, October 22, 1985, "The Use of Structurally Related Redox Series to Investigate Steric Effects in Electron Transfer Reactions," (i).

23. 27th Rocky Mountain Conference, Denver, CO July 15, 1985, "Kinetic Aspects of Facilitated Transport Through Liquid Membranes."

22. Ninth DOE Solar Photochemistry Research Conference, Lake Mohonk, NY, June 3, 1985, "The Effects of Surface Energetics and Surface Oxide Layers on the Cyclic Voltammetry of Metallocenes at Nonilluminated p-type and n-type Indium Phosphide Electrodes" (i,p).

- 20,21. 167th Electrochemical Society Meeting, Toronto, Canada, March 13, & 15, 1985, "The Effects of Surface Energetics and Surface Oxide Layers on the Cyclic Voltammetry of Metallocenes at Nonilluminated p-InP Electrodes" (i) "The Use of Electrochemical Methods and Structurally-Related Redox Series to Investigate Steric Effects on Electron Transfer Kinetics" (i).
- 18,19. Pittsburgh Conference and Exposition, New Orleans, LA, February 28, 1985, "Homogeneous and Heterogeneous Electron Transfer Reactivity for Members of Structurally-Related Redox Series" (i) and "The Effects of Surface Energetics and Surface Oxide Layers on the Cyclic Voltammetry of Metallocenes at Nonilluminated p-InP Electrodes" (i).
17. Middlebury College, Middlebury, VT, February 13, 1985, "Electron Transfer Reactivity - Steric Effects and Semiconductor Electrodes" (i).
16. University of Vermont, Burlington, VT, February 12, 1985, "Electron Transfer Reactivity - Steric Effects and Semiconductor Electrodes" (i).
15. Gordon Research Conference, Santa Barbara, CA January 23, 1985, "Are Homogeneous or Heterogeneous Electron Transfer Reactions More Sensitive to Steric (Distance) Effects?"
14. University of Texas, Austin, TX, November 29, 1984, "Electron Transfer Reactivity - Steric Effects and Semiconductor Electrodes" (i).
13. Texas A & M University, College Station, TX, November 28, 1984, "Electron Transfer Reactivity - Steric Effects and Semiconductor Electrodes" (i).
12. University of Houston, Houston, TX, November 27, 1984, "Electron Transfer Reactivity - Steric Effects and Semiconductor Electrodes" (i).
11. Solar Energy Research Institute, Golden, CO, October 2, 1984, "Electron Transfer Reactivity - Steric Effects and Semiconductor Electrodes." (i)
10. Colorado State University, Fort Collins, CO, September 19, 1984, "Electron Transfer Reactivity - Steric Effects and Semiconductor Electrodes." (i)
9. XXIII International Conference on Coordination Chemistry, Boulder, CO, "An Iron (II) Macrocyclic Complex Which Acts As A Host for Dissolved Carbon Monoxide And Thereby Facilitates The Transport of CO Through Liquid Membranes" (p).
8. Gordon Conference on Electrochemistry, Santa Barbara, CA, January 24, 1984, "Cyclic Voltammetry of Substituted Ferrocenes at Nonilluminated, Highly-doped p-InP Electrodes."
7. 186th National ACS Meeting, Washington, D. C., August 31, 1983, "Steric Effects in Electron Transfer Reactions of Transition Metal Complexes. Homogeneous and Heterogeneous Reactivity of Sterically-Hindered Redox Series."
6. 25th Rocky Mountain Conference, Denver, CO, August 16, 1983, "Steric Effects in Electron Transfer Reactions I. Synthesis and Homogeneous Reactivity of Sterically-Hindered Redox Series."
5. Analytical Chemistry Workshop for Students and Faculty, Boulder, CO, June 28, 1983, "Electrochemical Energy Conversion."
- 4 & 3. 184th National ACS Meetings, Kansas City, MO, August, 1982 "Kinetics of the Multielectron Reaction Between Tl (III) And Binuclear Ruthenium(II) Complexes," & "Nonadiabatic Electron Transfer Reactions."
2. Midwestern Universities Analytical Chemistry Conference, Purdue University, West Lafayette, IN, October 3, 1981, "Nonadiabatic Electron Transfer Reactions Between Transition Metal Complexes."
1. Midwestern Universities Analytical Chemistry Conference, Iowa State University, Ames, IA, October 4, 1980, "Determination Of The Self-Exchange Electron Transfer Rate Constant For A Cu(III)/Cu(II) Tripeptide Complex by ¹H NMR Line-Broadening."

RESEARCH FUNDING

50. Department of Energy, "Workshop on High Efficiency Conversion of Solar Energy to Electricity and Fuels", \$24,200, Aug. 1, 2008 - July 31, 2009.
49. University of Colorado Technology Transfer Office, "Low Power Electrochemical Pumps for Manipulation of Biological Fluids", \$25,000, Jan. 1, 2006 – May 31, 2007 (with R.D Noble).
48. National Renewable Energy Laboratory, "Gallium Phosphide Nitride for Photoelectrochemical Hydrogen Production", \$33,688, Sept. 1, 2005 - August 31, 2006.
47. Rockwell Scientific Co. LLC/DARPA, "Morphing at Large Stress and Strain through Electrochemical Actuation and Tailored Structure Design," \$405,787, Oct 1, 2004 - Mar. 31, 2006 (w/R.D. Noble, K. Maute, M. Dunn).
46. National Renewable Energy Laboratory, "Gallium Phosphide Nitride for Photoelectrochemical Hydrogen Production", \$32,867, Sept. 1, 2004 - August 31, 2005.
45. Dept. of Defense / AFOSR, "Generation of Mechanical Motion Using Active Transport", \$839,612, Apr. 15, 2003 - Apr. 14, 2005 (w/ R.D. Noble and D. Gin).
44. Membrane Applied Science and Technology Center, "Separations Using Ionic Liquid Membranes", \$105,000, Jan. 1, 2002 - Dec. 31, 2004 (with R.D Noble).
43. National Renewable Energy Laboratory, "Gallium Phosphide Nitride for Photoelectrochemical Hydrogen Production", \$27,554, Aug. 29, 2003 - August 28, 2004.
42. National Renewable Energy Laboratory, "Gallium Phosphide Nitride for Photoelectrochemical Hydrogen Production", \$36,561, July 29, 2002 - August 28, 2003.
41. National Renewable Energy Laboratory, "Photovoltaic Cells Based on Sensitization of Nanocrystalline TiO₂ Films with Quantum Dots", \$113,190, June 1, 2000 - Dec. 31, 2003.
40. National Renewable Energy Laboratory, "Novel Electrochemical Methods for Carbon Dioxide Recovery and Utilization," \$62,379, January 1, 2000 - December 31, 2000. (with R.D. Noble).
39. American Chemical Society - Petroleum Research Fund, "Experimental Study of Photomodulation in Facilitated Transport Membranes," \$60,000 requested for Sept. 1, 1998 - Aug. 31, 2000.
38. National Science Foundation, "Basic Investigation of Controlled Periodic Illumination on Photocatalytic Reactions and Selectivity," \$75,000, May 15, 1999 – April 30, 2000 (with R.D. Noble).
37. National Science Foundation, "Investigations of Composite Facilitated Transport Membranes for Separations of Unsaturated Hydrocarbons," \$70,000, Feb. 1, 1998 - Jan. 31, 2000 (with R.D. Noble and C.N. Bowman).
36. Center for Separations Using Thin Films, "Development of Novel Acid/Base Facilitated Transport Membranes for Separation of Ketones, Alcohols and Thiophenes," \$35,500, Jan. 1, 1997 - Dec. 31, 1999.
(with R.D. Noble and T. Sammakia, total award = \$105,000).
35. National Renewable Energy Laboratory, "Study of Nitridation Techniques for Photoelectrochemical Cells for Hydrogen Generation", \$22,667, July 1, 1997 - June 30, 1998.
34. Department of Energy, "Mechanistic Aspects of Photoconversion at Semiconductor Liquid Junctions and in Facilitated Transport Membranes," \$310,000, March 15, 1994 - March 14, 1997.
33. Center for Separations Using Thin Films, "Development of QCM(EQCM), AFM, and SERS for Studying Absorption and Transport Phenomena in Membranes," \$10,000, Jan. 1, 1996- Dec. 31, 1996.
(with R.D. Noble and K.L. Rowlen)

32. Center for Separations Using Thin Films, "New Materials for Selective Absorption and/or Transport of Aromatic Hydrocarbons," \$52,500, Jan. 1, 1994 - Dec. 31, 1996.
(with R.D. Noble, total award = \$105,000).
31. Chevron Research and Technology, "Use of Ion-Exchange Supports for Facilitated Transport Membranes with Enhanced Selectivity," \$33,000, June 14, 1994 - June 14, 1996.
(with R.D. Noble and C.N. Bowman, total award = \$100,000).
30. National Science Foundation, "Use of Ion-Exchange Supports for Facilitated Transport Membranes with Enhanced Selectivity," \$65,000, February 1, 1994 - January 31, 1996.
(with R.D. Noble and C.N. Bowman, total award = \$200,000).
29. Center for Separations Using Thin Films, "Electrochemically Modulated Complexation for Gas Separation and Concentration," \$45,000, Jan. 1, 1993 - Dec. 31, 1995.
(with R.D. Noble, total award = \$90,000).
28. Sandia National Laboratories, "Photodeposition and Recovery of Environmentally Hazardous Metal Ions at Illuminated Titanium Dioxide Particles and Films," \$50,000, Mar. 16, 1993 - Jun. 15, 1994.
27. International Business Machines Corp., "Optimal Reactor Design and Analysis for Waste Treatment Using Photodecomposition of Environmentally-Hazardous Organic Compounds," \$100,000, January 1 1991 - December 31, 1993, (with R.D. Noble, total award = \$221,346).
26. Department of Energy, "Reaction Kinetics and Product Distributions in Photoelectrochemical Cells," \$303,985, March 15, 1991 - March 14, 1994.
25. BP America, "Effects of Reaction and Transport Mechanisms on the Performance of Facilitated Transport Membranes," \$100,000, Jun. 1, 1989 - Dec. 31, 1993 (with R.D. Noble, total award = \$245,625).
24. Environmental Protection Agency, "Removal and Concentration of Pollutants Based on Electrochemically Modulated Complexation," October 1, 1990 - March 31, 1993, \$100,000.
(with R.D. Noble, total award = \$216,852).
23. Solar Energy Research Institute, "Research and Development Assessment of the Solar / Photocatalytic Process," \$77,992, November 15, 1990 - March 14, 1993.
22. Center for Separations Using Thin Films, "New Reversible Complexing Agents for Oxygen/Nitrogen Separations," \$15,000, Jan. 1, 1992 - Dec. 31, 1992, (with T. Koch, total award = \$30,000).
21. Center for Separations Using Thin Films, "Acid Gas Separations Using Ion-Exchange Membranes," \$45,000, Jan. 1, 1990 - Dec. 31, 1992. (with R.D. Noble, total award = \$90,000)
20. Hewlett-Packard Company, "Workshop on Analytical Chemistry," \$53,850, May 1, 1991- Apr. 30 1992 (with Anyl./Env. division faculty).
19. Pittsburgh Energy Technology Center, "Indirect Electrolysis Process for the Removal of Pollutants From Coal Liquids", \$92,783, Oct. 1, 1988 - Sept. 31, 1991.
(with R.D. Noble, total award = \$194,959).
18. International Business Machines Corp., "Mechanistic Studies of the Photodecomposition of Organic Compounds at Illuminated Titanium Dioxide Particles," \$12,500, May 1, 1990 - May 9, 1991.
(with R.D. Noble, total award = \$25,000)
17. Hewlett-Packard Company, "Workshop on Analytical Chemistry," \$41,153.
(with Anyl./Env. division faculty), Apr. 1, 1990 - Mar. 31, 1991.
16. Colorado Institute for Research in Biotechnology and Synergen Inc., "Protein Separatins Using Magnetically Stabilized Fluidized Beds", \$10,000, Dec. 1, 1989 - Jun. 30, 1990.
(with R.D. Noble, total award = \$20,000).

15. National Science Foundation, "New Electrochemical Processes for the Removal of Heterocyclic Organic Compounds from Hydrocarbon Phases", \$79,509, June 1, 1988 - May 31, 1990.
(with R.D. Noble, total award = \$160,000).
14. Department of Energy, "Investigation of Redox Processes at Semiconductor Electrode-Liquid Junctions," \$305,000, Aug. 1, 1987 - Mar. 14, 1991.
13. Synergen, Inc., "Magnetically Stabilized Fluidized Beds," \$3,150, Jun. 1 - Aug. 31, 1989.
12. International Business Machines Corp., "Removal of Organic Compounds from Exhausted Copper Plating Baths by Photodecomposition at Titanium Dioxide Particles," \$25,000, Nov. 1, 1988 - Oct 31, 1989.
11. National Research Council, Resident Research Associate at the Solar Energy Research Institute, "Photoelectrolysis at Lattice Matched Superlattice Electrodes," \$23,900, Jan. 2 - July 31, 1989.
10. Petroleum Research Fund (ACS), "Selective Facilitated and ElectroFacilitated Transport of Carbon Monoxide Across Liquid Membranes," \$35,000, May 1, 1986 - Aug. 31, 1988.
9. Department of Energy, "Chemical Probes of Charge Transfer at Semiconductor Liquid Junctions," \$208,454, May 15, 1984 - May 14, 1987.
8. National Science Foundation, "Electro- and Photofacilitated of Molecules Through Liquid Membranes," \$29,870, Jan. 1, 1986 - Dec. 31, 1986.
7. Biomedical Research Support Program (CU), "Vacuum/ Atmospheres Controlled Atmospheres Glove Box," \$18,446, Sept. 20, 1983.
6. National Bureau of Standards, "Electrochemistry in Facilitated Transport," \$2,582, June 1, 1983 - Aug. 31, 1983.
5. Council on Research and Creative Work (CU), "A Novel Method for Investigating the Kinetic Factors Responsible for Efficient Photo-electrochemical Solar Energy Conversion," \$3,600, June 13, 1983 - June 12, 1984.
4. National Science Foundation, "Synthesis and Kinetic Studies of Molecules That Exhibit Unusually Slow Electron Transfer Reactivity," \$168,000, June 1, 1982 - Nov. 30, 1985.
3. Summer Research Initiation Faculty Fellowship (CU), "Homogeneous Kinetic Modeling of Electrocatalysis," \$3,889, July 1, 1981 - Aug. 31, 1981.
2. Petroleum Research Fund (ACS), "The Relationship Between Homogeneous Electron Transfer Catalysis and Electrocatalysis at Chemically Modified Electrodes," \$10,000, June 1, 1981 - Aug. 31, 1983.
1. Research Corporation, "Kinetic Investigation of Polynuclear Complexes in Electrocatalysis at Chemically Modified Surfaces," \$14,000, Nov. 1, 1980 - Dec. 31, 1982.

RESEARCH PERSONNEL DIRECTED

Postdoctorals Directed:

Dr. Christine Evans (2003-05) – Developing High Pressure in Electrochemical Cells
(co-directed with Prof. Richard Noble from CHEN)

Dr. Teresa Longin (1995-97), faculty, University of Redlands, Redlands, CA

Dr. Barbara Serr (1989-90, Dow Chemical Co., Antioch, CA

Dr. Takayuki Suzuki (1995-96) faculty, Tokyo Denki University, Japan

Chemistry and Biochemistry Ph.D.'s Directed (27)

Robin L. Austermann (1985)

"The Effects of Surface Energetics and Surface Oxide Formation on the Cyclic Voltammetry of Metallocenes at Non-illuminated P-Type and N-Type Indium Phosphide Electrodes."

Garrett M. Brown (1991)

"Photocatalysis and Photoelectrochemical Detection at Semiconducting Titanium Dioxide."

Debra L. Bryant (1997)

"Development of New Materials for the Facilitated Transport of Unsaturated Organic Compounds."

Todd G. Deutsch (2006)

"Sunlight, Water and III-V Nitrides for Fueling the Future"

Steven M. Drew (1989)

"The Electrochemistry and Coordination Chemistry of Water Soluble Iron Porphyrins and Their Application to Novel Separation Processes."

Nancy S. Foster-Mills (1994)

"Remediation of Aqueous Waste Streams Containing Metal Ions and Organic Compounds Using Semiconductor Photocatalysis."

Michelle L. Goyette (2001)

"Experimental Verification of a Mathematical Model Describing Photofacilitated Transport in Liquid Membranes."

Markus D. Groner (1999)

"Effect of Surface Layers on Electron Transfer at Semiconductor/Liquid Interfaces."

Jason Howard (1992)

"Electron Transfer at Semiconducting Metal Dichalcogenide-Liquid Interfaces."

- Michael E. Ketterer (1985)
 "The Synthesis, Electrochemistry and Homogeneous Reactivity of Co(III) Pentaalkylamine Complexes and Their Use as Model Reactants for Nonadiabatic Electron Transfer Reactions."
- Lori Nixon (1992)
 "The Effects of Magnetic Stabilization on Liquid Fluidized Beds Used in Downstream Bioprocessing."
- Mya A. Norman (2005)
 "Pumping Without Mechanical Parts: Development of a Low Voltage Electrochemical Fluid Pump Utilizing Membrane Transport and Redox Chemistry"
- Karen L. Norrod (1998)
 Effects of Adsorbates and Coatings on Surface-Enhanced Raman Spectroscopy"
- John B. Olson (1987)
 "The Electrochemistry of Metallocenes on Tungsten Diselenide Semiconducting Electrodes."
- Roberto Rabago (1994)
 "Synthesis and Transport Properties of Doped PFSA Polymers"
- Cindy M. Reidsema (1986)
 "Steric Effects in Electron Transfer Reactions: Kinetic and Thermodynamic Evidence for Nonadiabaticity in Reactions Involving Selected Transition Metal Complexes."
- Zelideth E. Reyes (1986)
 "Kinetic and Thermodynamic Aspects of Facilitated Transport Through Liquid Membranes."
- Sarah K. Roberts (2000)
 "Separation of Organic Mixtures Using Facilitated Transport and Composite Membranes."
- Charles J. Rutkowski (1986)
 "Electron Transfer Reactions Between Thallium(III) and Binuclear Ruthenium Complexes."
- Peter R. Segar (1989)
 "Observation of Hot Carriers in p-Type Indium Phosphide Electrochemical Cells."
- Heather O. Shafer (2000)
 Electron Transfer Reactions of Hydrophobic Metallocenes with Aqueous Redox Couples at Liquid-Liquid Interfaces."
- Barton B. Smith - (1989)
 "Theoretical Investigation of the Solid Liquid Interface with Focus on the Electrochemical Interface."

Terry Spontarelli - (1989)
"Separation of Olefins by Facilitated Transport Through an Ion-Exchange Membrane."

Paul M. Thoen - (1993)
"The Competitive Facilitated Transport of Organic Compounds Through Ag⁺-Incorporated Ion-Exchange Membranes."

Robert Torres, Jr. - (1993)
Hot Electron Reactions in p-Type Indium Phosphide Photoelectrochemical Cells."

David K. Watts - (1996)
"Photoelectrochemistry of Novel III-V Semiconductor Electrodes."

Douglas Wedman - (1993)
"Electrochemically Modulated Complexation Techniques and Electrostatics Applied to Chemical Separations."

Chemistry and Biochemistry M.S.'s Directed (5)

Ross M. Gustafson (1988)
"Determination of Half-Reaction Entropy Change and Electrochemical Rate Constant for a Series of Substituted Metallocenes."

Leonard Kaljevic (2000)
"Composite Facilitated Transport Membranes: Effects of Interfacial Area and Crosslinking Density on Membrane Transport"

David Manley (1994)
"Facilitated Transport Membranes: Investigations Into New Applications and Morphological Effects on Transport"

Lisa L. Staley (1992)
"New Reversible Complexing Agents for Oxygen/Nitrogen Separations"

Thanh To - (1995)
"Modulating and Controlling the Rates of Interfacial Mass Transport"