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Curriculum Vitae
August 1, 2013

B.S. (Chem. Eng.), Washington State University, 1960; M.A. (Physics), Kent State University, 1964; M.S., Ph.D. (Astronomy), University of Michigan, 1967, 1969; M.A. (honorary), Yale University, 2009. Member of Technical Staff, AT&T Bell Laboratories, 1969-1984. Distinguished Member of Technical Staff 1984-1996. Professor of Industrial Ecology, of Chemical Engineering, and of Geophysics, Yale University, 1997-. Research history: solar physics (1967-1969); chemical kinetic modeling of gases and droplets in Earth's atmosphere (1970-1995); corrosion of materials by atmospheric species (1973-1996); atmospheric change (1979-1996); industrial ecology and sustainability science (1990-). Author/coauthor of 15 books (translated into six languages, and with total sales of more than 35,000 copies) and over 350 technical papers in various scientific journals.

Summaries of Technical Accomplishments

1. Industrial Ecology

Industrial ecology is an evolving view of industrial operations in which one seeks to design processes and manufacture products in such a way as to minimize and optimize their environmental interactions. Graedel's professional journal articles and senior-authored textbooks (*Industrial Ecology, 2nd edition, 2003; Industrial Ecology and Sustainable Engineering, 2010*) provide much of the perspective and practical techniques that are helping to make this revolutionary approach to industrial practice become reality. He is also the senior author on four related books, *Greening the Industrial Facility*, *Design for Environment, Industrial Ecology and the Automobile*, and *Streamlined Life-Cycle Assessment*. Graedel's environmental assessment matrix, developed while assessing AT&T products, is now a standard industrial tool for streamlined life cycle assessments of the environmental impacts of products, processes, and facilities.

2. *Materials Use, Loss, and Recycling*

The historical reservoir for the materials used by our technological society has been virgin stocks (ore bodies, mineral deposits, and the like). Those stocks may become inadequate or unavailable at some times or places in the future, the profligate use of energy for acquiring virgin materials is increasingly problematic, and the loss of resources by dissipation or discard is often an environmental challenge. These issues can be addressed by developing cycles for the stocks and flows of materials of interest, particularly if the cycles are temporally and spatially resolved. Graedel and colleagues have characterized regional and global cycles, current and historic, for copper, chromium, zinc, iron, nickel, lead, silver, and stainless steel, determining the stocks available in

different types of reservoirs and the related flows. Current work treats a number of other metals, including cobalt, molybdenum, and aluminium.

3. The Criticality of Metals

In recent years, materials scientists and governments have become concerned about the long-term availability of scarce metals of great importance for modern technology. In response, Graedel and colleagues have developed a comprehensive methodology to assess elemental criticality across the entire periodic table, and are applying the methodology to a broad range of materials and products. Simultaneously, they are developing a family of scenarios describing potential metal futures, and the criticality that results from different developmental patterns. The work provides a new basis for assessments of resource sustainability, environmental implications, and related policy initiatives.

4. Atmospheric Composition and Global Change

Long term trends in atmospheric composition are important to regional and global air quality, rates of atmospheric interactions with materials, and, ultimately, the sustainability of the planet. Graedel worked with Jean McRae of Bell Labs to demonstrate that carefully selected urban carbon dioxide data mimicked the long-term trends seen in remote areas. They then studied trends in urban methane and CO concentrations, and were the first (in 1979) to warn of their increase. Methane and CO are now regarded as significant contributors to the warming of Earth caused by human activities. In the mid-1990s, Graedel and Nobel Laureate atmospheric chemist Paul Crutzen wrote both an undergraduate textbook (*Atmospheric Change: An Earth System Perspective*) and a related volume for the lay public (*Atmosphere, Climate, and Change*). A 1994 review of the former in the British journal *Nature* states that the book "does an amazing job of introducing the reader to the large-scale issues of today and the future". The latter won the American Meteorological Society's Louis J. Battan Author's Award in 1995.

5. Sustainability Science and Engineering

The sustainability of the human species and its access to the benefits of modern science and technology over the long-term represents a crucial challenge for all humanity. There are many facets to this issue, but Graedel has emphasized the importance of quantification of many of the concerns and of the connections and constraints that complicate the discussion. In a paper in 2004, he and graduate student Robert Klee pointed out that humans dominate the global cycles of something like half of all the elements in the periodic table. In 2008, he convened a conference on resource linkages, demonstrating that energy availability depends on adequate metal resources, water availability depends on adequate energy, and so forth; such linkages were previously little appreciated and will have to be taken into account in future sustainability planning. The book resulting from that conference is *Linkages of Sustainability*, T.E. Graedel and E. van der Voet, Eds., MIT Press, 2010. He is currently Co-Chair of the U.S. National

Academies Roundtable on Science and Technology for Sustainability, and chaired the committee that produced the 2013 National Research Council report *Sustainability for the Nation: Resource Connections and Governance Linkages*.

One measure of the impact of a scientist's work is the degree to which his or her publications are cited by others. As of August, 2013, Graedel's papers and books have been cited more than 9800 times, placing his citation record among the upper 1/4 of 1% of those of all active scientists.

Principal Current Professional Activities

- Co-Chair, U.S. National Academies Roundtable on Science and Technology for Sustainability
- Chair, Global Metal Flows Group, International Panel on Resource Sustainability, United Nations Environment Programme
- Member, Science Advisory Committee, Ernst Strüngmann Forum
- Member, Advisory Committee, US DOE Critical Materials Institute

Selected Past Professional Activities

- President, Atmospheric Sciences Section, American Geophysical Union (1996-1998)
- Inaugural Chair, Gordon Research Conference on Industrial Ecology (1998)
- Inaugural President, International Society for Industrial Ecology (2003-2004)
- Chair, Ernst Strüngmann Forum on Linkages for Sustainability, Frankfurt, Germany (2008)
- Chair, Committee on Sustainability Linkages in the Federal Government, U.S. National Research Council

Selected Past Governmental Advisory Activities

- Member, National Research Council Board on Atmospheric Sciences and Climate, 1987-1993; Executive Committee, 1989-1993.
- Chair, National Research Council Panel on the Atmospheric Effects of Stratospheric Aircraft, 1993-1994, and principal author of the panel report Atmospheric Effects of Stratospheric Aircraft, National Academy Press, 1994.
- Chair, National Research Council Committee on Grand Challenges in Environmental Sciences, 1999-2000 and principal author of the committee report. This report set the stage for the National Science Foundation's "Biocomplexity and the Environment" initiative in 2001-2006.
- Member, Advisory Committee on Environmental Research and Education, National Science Foundation, 2002-2004, and contributing author to *Complex Environmental Systems: A 10-Year Outlook for the National Science Foundation*, 2003, and *Complex Environmental Systems: Pathways to the Future,* 2005.
- Chair, Committee to Review the U.S. Climate Change Science Program Strategic

Plan, National Research Council. The committee provided formal review (February, 2003) of the draft plan and a second review of the plan's revision (February, 2004). Graedel testified before the U.S. Senate Commerce Committee on this work.

- Member, National Research Council Committee on Critical Materials Impacts, and co-author of the report *Minerals, Critical Minerals, and the U.S. Economy, 2007-2008*.

Selected Invited Presentations

- "Design for Environment Activities in Electronics Manufacturing", 2nd Intl. Conf. On Ecobalance, Tsukuba, Japan, 1996.
- "Green Chemistry and Sustainable Development", International Green Chemistry Conference, Swansea, Wales, 2001.
- "Lessons from the Cycles of Metals", World Engineering Congress, Shanghai, China, 2004.
- "Determining the Criticality of Materials", OECD Conference on Sustainable Resources, Tokyo, 2007.
- "Metal Spectra as Indicators of Development", Gordon Research Conference on Industrial Ecology, New London, NH, 2008.
- "Defining Critical Materials", International Congress of Sustainability Science and Engineering, Cincinnati, OH, 2009.
- "Assessing Metal Criticality", European Union Workshop on Criticality and the EU Raw Materials Initiative", Brussels, Belgium, 2010.
- "The cycles and criticality of metals", Fermor Conference of the British Geological Society, London, UK, 2011.
- "Companion Metals", Tri-Lateral Conference on Materials Criticality, Brussels, Belgium, April 29, 2013.

Honors and Awards

- Named Distinguished Member of Technical Staff, AT&T Bell Laboratories, June, 1984.
- Co-recipient with Paul J. Crutzen of the Louis J. Battan Author's Award of the American Meteorological Society, 1995 for "their book entitled Atmosphere, Climate, and Change, an authoritative and beautifully illustrated introduction to the role of the atmosphere in global change".
- Elected as Fellow, American Geophysical Union, March, 1995, "for extensive works in atmospheric chemistry, for his insight in analyzing trends of greenhouse gases, and for outstanding leadership and service to the atmospheric science community".
- Elected as Fellow, American Association for the Advancement of Science, September, 1998, "for outstanding contributions to the environmental sciences and the new discipline of industrial ecology".
- Society Prize, International Society for Industrial Ecology, 2007, for outstanding contributions to industrial ecology. (This is the highest honor for research in industrial ecology.)

- Elected to U.S. National Academy of Engineering, 2002, “for outstanding contributions to the engineering theory and practice of industrial ecology, particularly for improved methods of life-cycle analysis”.

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Publication List
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BOOKS

1. *Chemical Compounds in the Atmosphere*, T. E. Graedel, Academic Press, New York, 439 pp., 1978.

2. *Atmospheric Chemical Compounds: Sources, Occurrence, and Bioassay*, T. E. Graedel, D. T. Hawkins, and L. D. Claxton, Academic Press, Orlando, FL, 732 pp., 1986.

3. *Atmospheric Change: An Earth System Perspective*, T. E. Graedel and P. J. Crutzen, W.H. Freeman, New York, 446 pp., 1993. (Translated into German, 1994.)

4. *Industrial Ecology*, T.E. Graedel and B.R. Allenby, 412 pp., Prentice-Hall, Englewood Cliffs, NJ, 1995. (Translated into Japanese, 1996.)

5. *Atmosphere, Climate, and Change*, T.E. Graedel and P.J. Crutzen, Scientific American Library, 196 pp., 1995. Translated into Dutch, 1996; German, 1996; Chinese, 1997 and 2007; Japanese, 1997, and Korean, 1997. **This book was awarded the Louis J. Battan Author's Award of the American Meteorological Society, 1995.**

6. *Instructor's Manual for Industrial Ecology*, T.E. Graedel and B.R. Allenby, 327 pp., Prentice-Hall, Englewood Cliffs, NJ, 1995.

7. *Design for Environment*, T.E. Graedel and B.R. Allenby, Englewood Cliffs, NJ: Prentice Hall, Inc., 190 pp., 1995.

8. *Industrial Ecology and the Automobile*, T.E. Graedel and B.R. Allenby, Upper Saddle River, NJ: Prentice-Hall, Inc., 244 pp., 1997.

9. *Streamlined Life Cycle Assessment*, T.E. Graedel, Upper Saddle River, NJ: Prentice Hall, Inc., 310 pp., 1998.

10. *Atmospheric Corrosion*, C. Leygraf and T.E. Graedel, New York: John Wiley & Sons, 354 pp., 2000. (Translated into Chinese, 2002.)

11. *Grand Challenges in Environmental Sciences*, T.E. Graedel, et al., Washington, DC: National Academy Press, 98 pp., 2000.

12. *Industrial Ecology*, Second edition, T.E. Graedel and B.R. Allenby, 412 pp., Prentice-Hall, Englewood Cliffs, NJ, 2003. (Translated into Chinese, 2003; Russian, 2004.)

13. *Greening the Industrial Ecosystem*, T.E. Graedel and J. Howard-Grenville, New York: Springer, 2005. (Translated into Chinese, 2005.)

14. *Industrial Ecology and Sustainable Engineering,* T.E. Graedel and B.R. Allenby, Prentice-Hall, Upper Saddle River, NJ, 2010.

15. *Linkages of Sustainability*, T.E. Graedel and E. van der Voet, Eds., Cambridge, MA: MIT Press, 2010.

16. *Sustainability for the Nation: Resource Connections and Governance Linkages*, T.E. Graedel et al., Washington, DC: National Academy Press, 2013.

REPORTS

1. *Atmospheric Effects of Stratospheric Aircraft: An Evaluation of NASA's Interim Assessmente*, T. E. Graedel et al., Washington, DC: National Academy Press, 1994.

2. *Grand Challenges in Environmental Sciences*, T. E. Graedel et al., Washington, DC: National Academy Press, 2001. This report provided the focus for the reorganized program on environmental sciences at the National Science Foundation.

3. *Planning Climate Change Science: A Review of the Draft U.S. Climate Change Science Program Strategic Plan*, T.E. Graedel et al., Washington, DC: National Academy Press, 2003.

4. *Complex Environmental Systems: Synthesis for Earth, Life, and Society in the 21st Century*, T. E. Graedel et al., Washington, DC: National Science Foundation, 2003.

5. *Materials Count: The Case for Material Flows Analysis*, L. Grayson, T. E. Graedel et al., Washington, DC: National Academy Press, 2004.

6. *Implementing Climate and Global Change Research: A Review of the Final U.S. Climate Change Science Program Strategic Research Plan*, T. E. Graedel et al., Washington, DC: National Academy Press, 2004. This report was the subject of presentations to Congressional staff and committees, and to the press and National Public Radio.

7. *Complex Environmental Systems: Pathways to the Future*, T. E. Graedel et al., Washington, DC: National Science Foundation, 2005.

8. *A Workshop on Data Scope and Data Structures for National Material Accounts*, T.E. Graedel, F.D. Allen, K. Johnson, and D. Rogich, Center for Industrial Ecology, Yale University, 2006. This workshop report was distributed to participants and interested parties – thirty-nine in all.

9. *Critical Mineral Impacts on the U.S. Economy*, R. Eggert, T.E. Graedel, et al., Washington, DC: National Academy Press, 2007.

10. *Anthropogenic Metal Stocks: Scientific Synthesis*, T.E. Graedel, et al., United Nations International Panel on Sustainable Resource Management, Paris, France, 2009.

TECHNICAL PAPERS

1. ``Spectrographic analysis with a small telescope and transmission grating," K. L. Warren and T. E. Graedel, *Amer. J. Phys., 34*, 1056-1057, 1966.

2. ``Radio bursts in the outer corona," F. T. Haddock and T. E. Graedel, *Sky and Telescope, 36*, No. 4, 1968.

3. ``Dynamic spectra of Type III solar bursts from 4 to 2 MHz observed by OGO-III," F. T. Haddock and T. E. Graedel, *Astrophys J., 160*, 293-300, 1970.

4. ``The association of solar optical flares with Type III solar bursts from 4 to 2 MHz observed by OGO-III," T. E. Graedel, *Astrophys. J., 160*, 301-307, 1970.

5. ``16 GHz observations of the eclipse," K. C. O'Brien, T. E. Graedel, G. J. Owens, W. H. Ierley, J. H. Doles, III, and E. R. Nagelberg, *Nature, 226* , 1152-1153, 1970.

6. ``Penetration of solar particles to ionospheric heights at low latitudes," L. J. Lanzerotti and T. E. Graedel, *Nature, 228* , 45, 1970.

7. ``Interplanetary particle associations with Type III solar bursts," T. E. Graedel and L. J. Lanzerotti, *J. Geophys. Res.,76*, 6932-6938, 1971.

8. ``Enhanced abundances of low-energy heavy elements in solar cosmic rays," L. J. Lanzerotti, C. G. Maclennan, and T. E. Graedel, *Astrophys. J. Lett., 173,* L39-L43, 1972.

9. ``Use of magnetometers and asymmetric antenna patterns for attitude determination," A. N. Delfico, T. E. Graedel, and R. Pringle, Jr., *J. Spacecraft and Rockets, 9,* 903-908, 1972.

10. ``Measurements and models of indoor aerosol size spectra," T. E. Graedel and R. M. Lum, *Atmos. Environ., 7,* 827-842, 1973.

11. ``The atmospheric environments encountered by electrical components," T. E. Graedel, *Proc. Holm Seminar on Electric Contact Phenomena-1973*, 62-79, 1973.

12. ``Channel width determination and electronic pulse processing losses in optical particle counters," T. E. Graedel, *J. Aerosol Sci., 5,* 125-131, 1974.

13. ``The effects of variations in bulk meteorological parameters on ozone concentrations," T. E. Graedel, L. A. Farrow, and T. A. Weber, *Proc. Symp. Atmos. Diffusion and Air Pollution, 115-120,* Amer.Meteor. Soc., Boston, 1974.

14. ``Ozone concentrations in New Jersey and New York: statistical association with related variables," S. M. Bruntz, W. S. Cleveland, T. E. Graedel, B. Kleiner, and J. L. Warner, *Science, 186,* 257-259, 1974.

15. ``Measurements of extreme concentrations of tropospheric hydrogen sulfide," T. E. Graedel, B. Kleiner, and C. C. Patterson, *J. Geophys. Res., 79,* 4467-4473, 1974.

16. ``Rapid concentration fluctuations and bimodality of atmospheric aerosol spectra," T. E. Graedel and J. P. Franey, *J. Geophys. Res., 79,* 5643-5645, 1974.

17. ``Sunday and workday behavior of photochemical air pollutants in New Jersey and New York," W. S. Cleveland, T. E. Graedel, B. Kleiner, and J. L. Warner, *Science, 186 ,* 1037-1038, 1974.

18. ``The effect of aerosols on the photochemistry of the troposphere," T. E. Graedel, L. A. Farrow, and T. A. Weber, *Int. J. Chem. Kinetics Symp., 1,* 581-594, 1975.

19. ``Heterogeneous removal of free radicals by aerosols in the urban troposphere," L. A. Farrow, T. E. Graedel, and T. A. Weber, *ACS Symp., 17,* 17-27, 1975.

20. ``Chemical kinetic and data analytic studies of the photochemistry of the troposphere," W. S. Cleveland, L. A. Farrow, T. E. Graedel, and B. Kleiner, *Proc. EPA Conf. on Atmos. Chem. Of N0x,* EPA-600/9-75-003, Section 5E, p. 1-9, 1975.

21. ``Ozone: involvement in atmospheric chemistry and meteorology," T. E. Graedel and L. A. Farrow, in *Ozone Chemistry and Technology*, J. S. Murphy and J. R. Orr, Eds., Franklin Institute Press, Philadelphia, p. 165-175, 1975.

22. ``Field measurements of submicron aerosol washout by snow," T. E. Graedel and J. P. Franey, *Geophys. Res. Lett., 2*, 325-328, 1975.

23. ``Tropospheric halocarbons: estimates of atmospheric chemical production," T. E. Graedel and D. L. Allara, *Atmos. Environ., 10,* 385-388, 1976.

24. ``Sulfur dioxide, sulfate aerosol, and urban ozone," T. E. Graedel, *Geophys. Res. Lett., 3,* 181-184, 1976.

25. ``Environmental testing with giant aerosols: exposure of miniature relays," T. E. Graedel, J. P. Franey, and R. E. Schwab, *Proc. Holm Seminar on Electric Contact Phenomena-1976*, 47-55, 1976.

26. ``Kinetic studies of the photochemistry of the urban troposphere," T. E. Graedel, L. A. Farrow, and T. A. Weber, *Atmos. Environ., 10,* 1095-1116, 1976.

27. ``Contaminant trace gas testing of lead-stabilized polymeric compounds," J. P. Franey and T. E. Graedel, *Proc. 25th Wire and Cable Symp.,* 63-67, 1976.

28. ``Urban kinetic chemistry under altered source conditions," L. A. Farrow, T. E. Graedel, and T. A. Weber, *Proc. Int. Conf. On Photochem. Oxidant,* 137-144, 1976.

29. ``The kinetic photochemistry of natural and perturbed nonurban tropospheres," T. E. Graedel and D. L. Allara, *Proc. Int. Conf. on Photochem. Oxidant,* 467-473, 1976.

30. ``The oxidation of ammonia, hydrogen sulfide, and methane in remote tropospheres," T. E. Graedel, *Proc. Symp. on Nonurban Tropospheric Composition*, 24-1 to 24-16, 1976.

31. ``Urban formaldehyde: observed correlation with source emissions and hotochemistry," W. S. Cleveland, T. E. Graedel, and B. Kleiner, *Atmos. Environ., 11,* 357-360, 1977.

32. ``Remote source sensing by statistical treatment of air quality data," T. E. Graedel, *Atmos. Environ., 11* , 313-319, 1977.

33. ``The photochemistry of the `Sunday Effect'," T. E. Graedel, L. A. Farrow, and T. A. Weber, *Environ. Sci. Technol., 11,* 690-694, 1977.

34. ``Field measurements of submicron aerosol washout by rain," T. E. Graedel and J. P. Franey, *Precipitation Scavenging-1974,* AES Symposium Series, 41, 503-523, 1977.

35. ``The wind boxplot: an improved wind rose," T. E. Graedel, *J. Appl. Meteorol., 16,* 348-350, 1977.

36. ``Air quality reference data for corrosion assessment," T. E. Graedel and N. Schwartz, *Materials Performance, 16* (#8), 17-25, 1977.

37. ``Kinetic photochemistry downwind overwater from urban areas," T. E. Graedel and L. A. Farrow, *J. Geophys. Res., 82,* 4943-4946, 1977.

38. ``The oxidation of ammonia, hydrogen sulfide, and methane in remote tropospheres," T. E. Graedel, J. Geophys. Res., 82, 5917-5922, 1977.

39. ``The homogeneous chemistry of atmospheric sulfur," T. E. Graedel, *Rev. Geophys. Space Phys., 15,* 421-428, 1977.

40. ``Functional group analysis of large chemical kinetic systems," T. E. Graedel, J. Phys. Chem., 81, 2372-2374, 1977.

41. ``Steady state approximations and urban atmospheric chemistry," L. A. Farrow and T. E. Graedel, *J. Phys. Chem., 81,* 2480-2483, 1977.

42. ``Urban kinetic chemical calculations with altered source conditions," T. E. Graedel, L. A. Farrow and T. A. Weber, *Atmos. Environ., 12,* 1403-1412, 1977.

43. ``Urban precursors and their photochemical products," T. E. Graedel in *Man's Impact on the Troposphere: Lectures in Tropospheric Chemistry,* NASA References Publication 1022, p. 149-202, 1978.

44. ``The interaction of hydrogen sulfide with lead-and barium-cadmium-zinc-stabilized Poly(vinyl chloride)," T. E. Graedel, J. P. Franey, W. H. Starnes, Jr., D. C. Hische, and P. C. Warren, *J. Appl. Polym. Sci., 23,* 1769-1779, 1978.

45. ``The oxidation of atmospheric sulfur compounds," T. E. Graedel, *APCA Spec. Conf. Proceedings,* Air Pollution Control Assoc., Pittsburgh, 1978.

46. ``The kinetic photochemistry of the marine atmosphere," T. E. Graedel, *J. Geophys. Res., 84,* 273-286, 1978.

47. ``The effects of entrained species on urban photochemical product concentrations," T. E. Graedel and L. A. Farrow, *Atmos. Environ., 13,* 519-523, 1978.

48. ``Reduced sulfur emission from the open oceans," T. E. Graedel, *Geophys. Res. Lett., 6,* 329-331, 1979.

49. ``Photochemical air pollution in the Northeast United States," W. S. Cleveland and T. E. Graedel, *Science, 204,* 1273-1278, 1979.

50. "Terpenoids in the atmosphere," T.E. Graedel, *Rev. Geophys. Space Phys.,* 17, 937-947, 1979.

51. ``Gaseous hydrogen sulfide determination by discoloration of lead-stabilized PVC," T. E. Graedel and J. P. Franey, *Amer. Ind. Hyg. Assoc. J., 40,* 947-954, 1979.

52 ``Sulfur in the stratosphere," T. E. Graedel and R. D. Cadle, *Physics and Chemistry of the Stratosphere,* NASA Ref. Pub., 1049, 1979.

53. ``Carbon dioxide in the urban atmosphere: dependencies and trends," J. E. McRae and T. E. Graedel, *J. Geophys. Res., 84,* 5011-5017, 1979.

54. ``Atmospheric photochemistry," T. E. Graedel,in *Handbook of Environmental Chemistry,* O. Hutzinger, ed., p. 107-143, Springer, 1980.

56. ``Exploratory data analysis in the geophysical sciences," B. Kleiner and T. E. Graedel, *Rev. Geophys. Space Phys., 18*, 699-715, 1980.

57. ``2D studies of the kinetic photochemistry of the urban troposphere. I. Air stagnation conditions," J. A. Schiavone and T. E. Graedel, *Atmos. Environ., 14,* 163-176, 1980.

58. ``2D studies of the kinetic photochemistry of the urban troposphere. II. Normal convective conditions," T. E. Graedel and J. A. Schiavone, *Atmos. Environ., 14,* 353-361, 1980.

59. ``Formation of photochemical pollutants," T. E. Graedel, *Bull. N.Y. Acad. Medicine, 56,* 881-898, 1980.

60. ``On the possible increase of the atmospheric methane and carbon monoxide concentrations during the last decade," T. E. Graedel and J. E. McRae, *Geophys. Res. Lett., 7,* 977-979, 1980.

61. ``Carbonyl sulfide: potential agent of atmospheric sulfur corrosion," T. E. Graedel, G. W. Kammlott, and J. P. Franey, *Science, 212,* 663-665, 1981.

62. ``The morphology and corrosion resistance of a conductive silver-epoxy paste," J. P. Franey, T. E. Graedel, G. J. Gualtieri, G. W. Kammlott, J. Kelber, D. L. Malm, L. H. Sharpe, and V. Tierney, *J. Materials Sci., 16,* 2360-2368, 1981.

63. ``Inhibition of copper sulfidation by boron implantation," G. W. Kammlott, C. W. Preece, T. E. Graedel, J. P. Franey, E. N. Kaufman, and A. Staudinger, *Corrosion Science, 21,* 541-545, 1981.

64. ``Covercoat retardation of permeation through sheet molding compound," T. E. Graedel and J. P. Franey, *J. Appl. Polymer Sci., 26,* 3933-3938, 1981.

65. ``Chemistry within aqueous atmospheric aerosols and raindrops," T. E. Graedel and C. J. Weschler, *Rev. Geophys. Space Phys., 19,* 505-539, 1981.

66. ``Photochemistry in planetary atmospheres," J. S. Levine and T. E. Graedel, *EOS-Trans. Amer. Geophys. Union, 62,* 1177-1181, 1981.

67. ``The sulfiding of copper by trace amounts of hydrogen sulfide," J. P. Franey, T. E. Graedel, and G. W. Kammlott, in *Atmospheric Corrosion,* ed. W. H. Ailor, New York: John Wiley and Sons, 1982.

68. ``Total organic component data: patterns and trends in the urban atmosphere," T. E. Graedel and J. E. McRae, *Atmos. Environ., 16,* 1119-1132, 1982.

69. ``The kinetic chemistry of dense interstellar clouds," T. E. Graedel, W. D. Langer, and M. A. Frerking, *Astrophys. J. Supplement Ser., 43*, 321-368, 1982.

70. ``Transition metals as heterogeneous catalysts in aqueous atmospheric aerosols: selected considerations," in *Heterogeneous Catalysis: Its Importance to Atmospheric Chemistry,* D. L. Schreyer, ed., AGU Monograph Series, 196-202, 1982.

71. ``Graphical presentation of results from scientific computer models," T. E. Graedel and R. McGill, *Science, 215,* 1191-1198, 1982.

72. ``Aqueous chemistry in the atmosphere," T. E. Graedel, G. P. Ayres, R. A. Duce, H. W. Georgii, D. G. A. Klockow, J. J. Morgan, H. Rodhe, B. Schneider, W. G. N. Slinn, and O. C. Zafinou, in *Atmospheric Chemistry*, ed. E. D. Goldberg, Berlin: Springer-Verlag, 1982.

73. ``Chemistry of the Mount St. Helens effluent," J. P. Friend, R. D. Cadle, T. E. Graedel, A. L. Lazrus, and R. P. Turco, in *Mount St. Helens Eruptions of 1980*, R. E. Newell and A. Deepak, Eds., NASA SP-458, pp. 89-101, 1982.

74. ``On the corrosion resistance of certain ancient Chinese bronze artifacts," L. Soto, J. P. Franey, T. E. Graedel, and G. W. Kammlott, *Corrosion Sci., 23,* 241-250, 1983.

75. ``Authors' reply to comments of Lonneman and Akland," T. E. Graedel and J. E. McRae, *Atmos. Environ., 17,* 668, 1983.

76. ``Effects of organic surface films on the scavenging of atmospheric gases by raindrops and aerosol particles," T. E. Graedel, P. S. Gill, and C. J. Weschler, *Proc. 4th Intl. Conf. on Precipitation Scavenging,* H. R. Pruppacher, R. G. Semonin, and W. G. N. Slinn, Eds., New York: Elsevier, pp. 417-430, 1983.

77. ``Organic films on atmospheric aerosol particles, fog droplets, cloud droplets, raindrops, and snowflakes," P. S. Gill, T. E. Graedel, and C. J. Weschler, *Rev. Geophys. Space Phys., 21*, 903-920, 1983.

78. ``Corrosion of copper by atmospheric sulfurous gases," T. E. Graedel, J. P. Franey, and G. W. Kammlott, *Corrosion Sci., 23,* 1141-1152, 1983.

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80. ``Kinetic studies of raindrop chemistry. I. Inorganic and organic processes," T. E. Graedel and K. I. Goldberg, *J. Geophys. Res., 88*, 10865-10882, 1983.

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