

**CE4591 Environmental Engineering Chemical Processes, Fall 2008
Problem Set 6**

Due: Friday, 11/21 by 5 p.m.

Solutions will be posted on the Web. Problem sets will be graded for completeness, and one problem (selected at random) will be graded in detail. Each problem set contributes 2.5% towards your final grade. Remember that for problems done with MINEQL, you must print out and attach the header file so that I can see your input.

1. Problem 15.3 (p. 454) in the text. Realize that the CaCO_3 is added to pure water. Some CaCO_3 is added to pure water that is open to the atmosphere; not all of the solid dissolves and the equilibrium pH is 8.1. What is the solubility product for CaCO_3 ?

SOLUTION: The solubility product will be for the reaction:



and the solubility product will be defined as:

$$K_{sp} = [\text{Ca}^{2+}][\text{CO}_3^{2-}]$$

Thus, to find the solubility product, we need to know the activities of Ca^{2+} and CO_3^{2-} . Because it is an open system, the CO_2 activity can be calculated from the pH (8.1) and the $p\text{CO}_2$ in the atmosphere (370 μatm).

$$K_a = (\text{H}_2\text{CO}_3^*/\text{CO}_2) = 10^{-6.3} \text{ (mole/L-} \mu\text{atm)}$$

$$\Rightarrow [\text{H}_2\text{CO}_3^*] = (10^{-6.3} \text{ (mole/L-} \mu\text{atm)})(370 \times 10^{-6} \text{ atm}) = 1.2 \times 10^{-9}$$

$$K_{a1} = (\text{HCO}_3^-/\text{H}^+)(\text{H}_2\text{CO}_3^*/\text{CO}_2)$$

$$\Rightarrow [\text{HCO}_3^-] = K_{a1} [\text{H}_2\text{CO}_3^*]/[\text{H}^+] = 6.7 \times 10^{-6} \text{ M}$$

$$K_{a2} = (\text{CO}_3^{2-}/\text{H}^+)(\text{HCO}_3^-)$$

$$\Rightarrow [\text{CO}_3^{2-}] = K_{a2} (\text{HCO}_3^-)/[\text{H}^+] = 3.95 \times 10^{-9} \text{ M}$$

To obtain the $[\text{Ca}^{2+}]$ activity, it is suggested that we use the charge balance equation:

$$[\text{H}^+] + 2[\text{Ca}^{2+}] = [\text{OH}^-] + [\text{HCO}_3^-] + 2[\text{CO}_3^{2-}]$$

If activity coefficients are ignored, all quantities (except $[\text{Ca}^{2+}]$) are known, so we can rearrange to solve for this unknown:

$$[\text{Ca}^{2+}] = 1/2 ([\text{OH}^-] + [\text{HCO}_3^-] + 2[\text{CO}_3^{2-}] - [\text{H}^+]) = 1/2 (10^{-5.9} + 6.7 \times 10^{-6} + 2(3.95 \times 10^{-9}) - 10^{-8.1})$$

$$[\text{Ca}^{2+}] = 4.0 \times 10^{-6} \text{ M}$$

Continuing to ignore activity coefficients, the solubility product would be:

$$K_{sp} = [\text{Ca}^{2+}][\text{CO}_3^{2-}] = (4.0 \times 10^{-6})(3.95 \times 10^{-9}) = 1.58 \times 10^{-14} = 10^{-14.2}$$

This value is close to the solubility product for Dolomite ($10^{-14.2}$). This discrepancy arises in part because we ignored activity coefficients and thereby underestimated the $[\text{Ca}^{2+}]$ concentration.

2. Problem 15.5 (p. 455) in the text. Use MINEQL. The mineral name for $\text{Mn}(\text{OH})_2$ is pyrochroite, and for MnCO_3 is rhodochrosite. Part C will require some thinking. Solubility diagrams can be generated directly in MINEQL or the data can be copied to the clipboard and pasted into Excel for graphing.

15.5A. Draw a solubility diagram for $[\text{Mn}^{2+}]$ as a function of pH if $\text{Mn}(\text{OH})_2$ controls the Mn solubility and MnCO_3 does not exist. Assume a total dissolved carbonate concentration of 2×10^{-6} M.

SOLUTION: This problem is easily solved using MINEQL. We must be sure that H_2O , H^+ , Mn^{2+} , and CO_3^{2-} are checked as components. The header file would contain:

MINEQL+ Header file for pyrochroite.mns

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Ce4501 Environmental Engineering Chemical Processes Fall:

Chemical Processes for Environmental Engineering Teh Fu Yen, 2007 This book deals with basic principles such as chemical equilibrium as well as chemical processes These concepts make up the basic tools necessary to design a more efficient system to solve environmental problems This book can be used as a textbook for a university level course It can also serve as an excellent source for professional research in the field of environmental engineering or environmental science

Green Engineering David T. Allen, David R. Shonnard, 2001-09-06 A chemical engineer's guide to managing and minimizing environmental impact Chemical processes are invaluable to modern society yet they generate substantial quantities of wastes and emissions and safely managing these wastes costs tens of millions of dollars annually Green Engineering is a complete professional's guide to the cost effective design commercialization and use of chemical processes in ways that minimize pollution at the source and reduce impact on health and the environment This book also offers powerful new insights into environmental risk based considerations in design of processes and products First conceived by the staff of the U S Environmental Protection Agency Green Engineering draws on contributions from many leaders in the field and introduces advanced risk based techniques including some currently in use at the EPA Coverage includes Engineering chemical processes products and systems to reduce environmental impacts Approaches for evaluating emissions and hazards of chemicals and processes Defining effective environmental performance targets Advanced approaches and tools for evaluating environmental fate Early stage design and development techniques that minimize costs and environmental impacts In depth coverage of unit operation and flowsheet analysis The economics of environmental improvement projects Integration of chemical processes with other material processing operations Lifecycle assessments beyond the boundaries of the plant Increasingly chemical engineers are faced with the challenge of integrating environmental objectives into design decisions Green Engineering gives them the technical tools they need to do so

Green Sustainable Process for Chemical and Environmental Engineering and Science Inamuddin, Rajender Boddula, Abdullah M. Asiri, 2020-06-23 Green Sustainable Process for Chemical and Environmental Engineering and Science Organic Synthesis in Water and Supercritical Water provides an in depth review of purification and extraction methods for medicinal analytical engineering and bioactive compounds utilizing green chemistry protocols It focuses on the synthesis of natural products and drugs using industrial green solvents water supercritical water and more The book explores applications in organic synthesis and processing including aqueous and non aqueous promoted reactions Aqueous media and supercritical water involved in organic synthesis are discussed for industrial use Final sections cover green solvent assisted organic synthesis such as addition rearrangement condensation and more Provides a broad overview of green solvents for sustainable organic synthesis Compares water and supercritical water as green solvents vs conventional solvents Outlines eco friendly organic synthesis and chemical processes using water supercritical water Includes industrial pharmaceutical

production development using water and supercritical water as solvents Outlines synthetic methods for polymers drugs etc using water and supercritical water as solvents

Chemistry, Thermodynamics, and Reaction Kinetics for Environmental Engineers Jeff Kuo, 2024-09-25 This book aims to be the preeminent university chemistry textbook for environmental engineers It provides undergraduate and graduate environmental engineering students with basic concepts and practical knowledge about chemistry that they would need in their professional careers It focuses on the fundamental concepts of chemistry and its practical applications e g understanding fate and transport of chemicals pollutants in the environmental as well as the chemical physicochemical processes applied in environmental engineering industry This book also serves as a valuable resource for entry level professionals to solidify their fundamental knowledge in environmental engineering chemistry This book Presents the fundamentals of chemistry with focus on the needs of environmental engineers Explains how an understanding of chemistry allows readers a better understanding of the fate and transport of chemicals in the environment as well as various treatment processes Examines the fundamentals of chemical reaction equilibrium from learning the basics of thermodynamics Presents the basic types and designs of reactors as well as reaction kinetics

Environmental Engineering in the Process Plant Nicholas P. Chopey, 1992-01-01 *Sustainable Chemical Processes and Products* Gijbert Korevaar, 2004 **Chemical Processes for Pollution Prevention and Control** Paul Mac Berthouex, Linfield C. Brown, 2017-10-04 This book examines how chemistry chemical processes and transformations are used for pollution prevention and control Pollution prevention reduces or eliminates pollution at the source whereas pollution control involves destroying reducing or managing pollutants that cannot be eliminated at the source Applications of environmental chemistry are further illustrated by nearly 150 figures numerous example calculations and several case studies designed to develop analytical and problem solving skills The book presents a variety of practical applications and is unique in its integration of pollution prevention and control as well as air water and solid waste management **Chemical Processes for a Sustainable Future** Trevor Letcher, Janet Scott, Darrell Patterson, 2015-11-09 This comprehensive book approaches sustainability from two directions the reduction of pollution and the maintaining of existing resources both of which are addressed in a thorough examination of the main chemical processes and their impact Divided into five sections each introduced by a leading expert in the field the book takes the reader through the various types of chemical processes demonstrating how we must find ways to lower the environmental cost of both pollution and contributions to climate change of producing chemicals Each section consists of several chapters presenting the latest facts and opinion on the methodologies being adopted by the chemical industry to provide a more sustainable future A follow up to *Materials for a Sustainable Future* Royal Society of Chemistry 2012 this book will appeal to the same broad readership industrialists and investors policy makers in local and central governments students teachers scientists and engineers working in the field and finally editors journalists and the general public who need information on the increasingly popular concepts of sustainable

living **Green Engineering** Allen, 2001 *Analysis, Synthesis, and Design of Chemical Processes* Richard Turton, Richard C. Bailie, Wallace B. Whiting, Joseph A. Shaeiwitz, Debangsu Bhattacharyya, 2012-06-27 The leading integrated chemical process design guide Now with extensive new coverage and more process designs More than ever effective design is the focal point of sound chemical engineering Analysis Synthesis and Design of Chemical Processes Fourth Edition presents design as a creative process that integrates both the big picture and the small details and knows which to stress when and why Realistic from start to finish this updated edition moves readers beyond classroom exercises into open ended real world process problem solving The authors introduce integrated techniques for every facet of the discipline from finance to operations new plant design to existing process optimization This fourth edition adds new chapters introducing dynamic process simulation advanced concepts in steady state simulation extensive coverage of thermodynamics packages for modeling processes containing electrolyte solutions and solids and a concise introduction to logic control What You Have Learned summaries have been added to each chapter and the text s organization has been refined for greater clarity Coverage Includes Conceptualization and analysis flow diagrams batch processing tracing process conditions and product design strategies Economic analysis capital and manufacturing costs financial calculations and profitability analysis Synthesis and optimization principles PFD synthesis simulation techniques top down and bottom up optimization pinch technology and software based control Advanced steady state simulation goals models solution strategies and sensitivity and optimization studies Dynamic simulation goals development solution methods algorithms and solvers Performance analysis I O models tools performance curves reactor performance troubleshooting and debottlenecking Societal impact ethics professionalism health safety environmental issues and green engineering Interpersonal and communication skills improving teamwork and group effectiveness This title draws on more than fifty years of innovative chemical engineering instruction at West Virginia University and the University of Nevada Reno It includes suggested curricula for single semester and year long design courses case studies and practical design projects current equipment cost data and extensive preliminary design information that can be used as the starting point for more detailed analyses About the CD Rom and Web Site The CD contains the newest version of CAPCOST a powerful tool for evaluating fixed capital investment full process economics and profitability The heat exchanger network software HENSAD is also included The CD also contains an additional appendix presenting preliminary design information for fifteen key chemical processes including four new to this edition shift reaction acid gas removal via physical solvent H₂S removal from a gas stream using the Claus process and coal gasification The CD also includes six additional projects plus chapters on outcomes assessment written and oral communications and a written report case study Sixty additional projects and twenty four more problems are available at www.che.cemr.wvu.edu publications projects [Green Chemistry and Engineering](#) Concepción Jiménez-González, David J.C. Constable, 2011-02-22 The past present and future of green chemistry and green engineering From college campuses to corporations the past

decade witnessed a rapidly growing interest in understanding sustainable chemistry and engineering Green Chemistry and Engineering A Practical Design Approach integrates the two disciplines into a single study tool for students and a practical guide for working chemists and engineers In Green Chemistry and Engineering the authors each highly experienced in implementing green chemistry and engineering programs in industrial settings provide the bottom line thinking required to not only bring sustainable chemistry and engineering closer together but to also move business towards more sustainable practices and products Detailing an integrated systems oriented approach that bridges both chemical syntheses and manufacturing processes this invaluable reference covers Green chemistry and green engineering in the movement towards sustainability Designing greener safer chemical synthesis Designing greener safer chemical manufacturing processes Looking beyond current processes to a lifecycle thinking perspective Trends in chemical processing that may lead to more sustainable practices The authors also provide real world examples and exercises to promote further thought and discussion The EPA defines green chemistry as the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances Green engineering is described as the design commercialization and use of products and processes that are feasible and economical while minimizing both the generation of pollution at the source and the risk to human health and the environment While there is no shortage of books on either discipline Green Chemistry and Engineering is the first to truly integrate the two

Chemistry for Environmental Engineering Armen S. Casparian, Gergely Sirokman, 2015-12-28 This book presents the basic principles of chemistry in a quick and clear presentation All introductory chemistry topics are discussed as are some organic chemistry topics which are necessary for a good foundation to understand engineering applications Readers will find quick and clear explanations and many solved problems for reference

Chemistry for Environmental Engineering Clair N. Sawyer, Perry L. McCarty, 1978 Considered the definitive text for the first course in chemistry for environmental engineers This text has a two fold purpose 1 bring into focus those aspects of chemistry which are particularly valuable to environmental engineering practices and 2 lay a groundwork of understanding in the area of specialized quantitative analysis commonly referred to as water and wastewater analysis

Physicochemical Treatment Processes Lawrence K. Wang, Yung-Tse Hung, Nazih K. Shamas, 2007-11-13 The past 30 years have seen the emergence of a growing desire worldwide to take positive actions to restore and protect the environment from the degrading effects of all forms of pollution air noise solid waste and water Because pollution is a direct or indirect consequence of waste the seemingly idealistic demand for zero discharge can be construed as an unrealistic demand for zero waste However as long as waste exists we can only attempt to abate the subsequent pollution by converting it to a less noxious form Three major questions usually arise when a particular type of pollution has been identified 1 How serious is the pollution 2 Is the technology to abate it available and 3 Do the costs of abatement justify the degree of abatement achieved The principal intention of the Handbook of Environmental Engineering series is to help readers formulate answers to the last two questions

The traditional approach of applying tried and true solutions to specific pollution problems has been a major contributing factor to the success of environmental engineering and has accounted in large measure for the establishment of a methodology of pollution control. However, realization of the ever increasing complexity and interrelated nature of current environmental problems makes it imperative that intelligent planning of pollution abatement systems be undertaken.

Green Sustainable Process for Chemical and Environmental Engineering and Science Rajender Boddula, Mohd Imran Ahamed, Abdullah M. Asiri, 2020-11-24. Green Sustainable Process for Chemical and Environmental Engineering and Science. Green Solvents for Biocatalysis delivers an in depth overview of biocatalysis in green solvents for industrial applications also including outlines of sustainable methodologies in the area of organic chemistry, agriculture, analytical chemistry and engineering and pharmaceutical sciences. The book provides unique content in the area making it a great source for information for undergraduate, postgraduate students, faculty, R D professionals, production chemists, environmental engineers and industrial experts.

Environmental Chemistry Teh Fu Yen, 1999. Precipitation and stabilization, Ion exchange, Coagulation, Oxidation and reduction, Corrosion, Aeration and stripping. Chemistry for Environmental Engineering, 1985.

Reaction Mechanisms in Environmental Engineering James G. Speight, 2018-08-13. Reaction Mechanisms in Environmental Engineering: Analysis and Prediction describes the principles that govern chemical reactivity and demonstrates how these principles are used to yield more accurate predictions. The book will help users increase accuracy in analyzing and predicting the speed of pollutant conversion in engineered systems such as water and wastewater treatment plants or in natural systems such as lakes and aquifers receiving industrial pollution. Using examples from air, water and soil, the book begins with a clear exposition of the properties of environmental and inorganic organic chemicals that is followed by partitioning and sorption processes and sorption and transformation processes. Kinetic principles are used to calculate or estimate the pollutants half lives while physical chemical properties of organic pollutants are used to estimate transformation mechanisms and rates. The book emphasizes how to develop an understanding of how physico chemical and structural properties relate to transformations of organic pollutants. Offers a one stop source for analyzing and predicting the speed of organic and inorganic reaction mechanisms for air, water and soil. Provides the tools and methods for increased accuracy in analyzing and predicting the speed of pollutant conversion in engineered systems. Uses kinetic principles and the physical chemical properties of organic pollutants to estimate transformation mechanisms and rates.

Advanced Physicochemical Treatment Processes Lawrence K. Wang, Yung-Tse Hung, Nazih K. Shamas, 2007-11-10. The past thirty years have witnessed a growing worldwide desire that positive actions be taken to restore and protect the environment from the degrading effects of all forms of pollution: air, water, soil and noise. Because pollution is a direct or indirect consequence of waste, the seemingly idealistic demand for zero discharge can be construed as an unrealistic demand for zero waste. However, as long as waste continues to exist, we can only attempt to abate the subsequent pollution by converting it to a less noxious form. Three

major questions usually arise when a particular type of pollution has been identified 1 How serious is the pollution 2 Is the technology to abate it available and 3 Do the costs of abatement justify the degree of abatement achieved This book is one of the volumes of the Handbook of Environmental Engineering series The principal intention of this series is to help readers formulate answers to the last two questions above The traditional approach of applying tried and true solutions to specific pollution problems has been a major contributing factor to the success of environmental engineering and has accounted in large measure for the establishment of a methodology of pollution control However the realization of the ever increasing complexity and interrelated nature of current environmental problems renders it imperative that intelligent planning of pollution abatement systems be undertaken

Green Chemical Engineering S. Suresh, S. Sundaramoorthy, 2014-12-18

While chemical products are useful in their own right they address the demands and needs of the masses they also drain our natural resources and generate unwanted pollution Green Chemical Engineering An Introduction to Catalysis Kinetics and Chemical Processes encourages minimized use of non renewable natural resources and fosters maximized pollution prevention This text stresses the importance of developing processes that are environmentally friendly and incorporate the role of green chemistry and reaction engineering in designing these processes Focused on practical application rather than theory the book integrates chemical reaction engineering and green chemical engineering and is divided into two sections The first half of the book covers the basic principles of chemical reaction engineering and reactor design while the second half of the book explores topics on green reactors green catalysis and green processes The authors mix in elaborate illustrations along with important developments practical applications and recent case studies They also include numerous exercises examples and problems covering the various concepts of reaction engineering addressed in this book and provide MATLAB software used for developing computer codes and solving a number of reaction engineering problems Consisting of six chapters organized into two sections this text Covers the basic principles of chemical kinetics and catalysis Gives a brief introduction to classification and the various types of chemical reactors Discusses in detail the differential and integral methods of analysis of rate equations for different types of reactions Presents the development of rate equations for solid catalyzed reactions and enzyme catalyzed biochemical reactions Explains methods for estimation of kinetic parameters from batch reactor data Details topics on homogeneous reactors Includes graphical procedures for the design of multiple reactors Contains topics on heterogeneous reactors including catalytic and non catalytic reactors Reviews various models for non catalytic gas solid and gas liquid reactions Introduces global rate equations and explicit design equations for a variety of non catalytic reactors Gives an overview of novel green reactors and the application of CFD technique in the modeling of green reactors Offers detailed discussions of a number of novel reactors Provides a brief introduction to CFD and the application of CFD Highlights the development of a green catalytic process and the application of a green catalyst in the treatment of industrial effluent Comprehensive and thorough in its coverage Green Chemical Engineering An Introduction to Catalysis

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