Environmental Catalysis
CHE650

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Course Overview

The objective of this course is to provide the student in introduction to the role of catalysis in abating pollutant emissions and developing future environmentally friendly energy technologies. A review of catalysis fundamentals, including modern preparation and characterization techniques, will be provided. With the fundamental foundation in place, the remainder of the course will focus on catalytic technologies used for the betterment of the environment and human population. A review of mobile and stationary pollution abatement technologies will be provided including automobile catalytic converters, diesel truck emission control, and catalytic abatement of chemical plant emissions. The use of catalysis for "green" alternative energy processes will also be reviewed including fuel cell systems, bio-fuel production, bio-fuel refining, and CO_2 sequestration. For each technology, the discussion will cover both the chemistry occurring on the catalyst surface as well as the engineering involved in the overall process.

The majority of the course will follow the textbook "Catalytic Air Pollution Control" authored by Ronald Heck and Robert Farrauto, both well known for their work in the field of environmental catalysis. Students will also be assigned readings from relevant research journal articles and patents to reinforce the lecture material and introduce them to the research topics currently ongoing in academia and industry.

Course Objectives

1. Reinforce the students existing knowledge of catalysis chemistry and catalytic reactor engineering.
2. Introduce the student to modern catalytic pollution abatement and emerging "green" catalytic processes. The student will be introduced to both the chemistry occurring on the catalyst as well as the engineering of the catalytic system.
3. Provide the student an overview of modern catalyst preparation, performance testing and surface characterization techniques.

Rationale

We live in a world where pollution knows no boundaries. As a society, we have already learned that the development of more efficient pollution abatement technologies must occur in parallel to the advancement of industrial processes. Over the past several decades, catalysts have been a central component in many pollution abatement processes. Emission control of harmful pollutants using catalytic systems have been in use for almost 50 years. Catalysts allow pollutants to be destroyed at lower temperatures and to desirable products relative to non-catalytic systems. The most well-known application is that of the automobile catalytic converter that enhances the oxidation of carbon monoxide and unburned hydrocarbons to carbon dioxide and water and the reduction of nitric oxides to nitrogen at temperatures consistent with those of the modern internal combustion engines.

The success of the automobile catalyst increased confidence of plant engineers to use catalysts for other environmental applications. Control of emissions from diesel engines, power plants, chemical plants, restaurants, commercial aircraft, motorcycles, etc are but a few of the newest applications. "Green" energy generation processes will avoid the pollution issue altogether. We are currently seeing the emergence of fuel cells as a "green" power source for stationary and mobile sources where catalysts play a key role. Beyond fuel cells, catalysts will play a role in many other future "green" energy generation processes.

This practical course is specifically designed to introduce students to heterogeneous catalysts and their role in the control of harmful emissions from stationary and mobile source**s**. The course builds on and applies the fundamentals that are covered in other courses, such as surface chemistry and materials science, transport phenomena, reactor design, thermodynamics, fluid mechanics and material and energy balances. Unlike other pollution control and prevention courses, it does not have regulations and case studies as the main focus, rather, it will prepare students to understand how catalysts are prepared, manufactured, designed, and operated in the real world.

Textbook

"Catalytic Air Pollution Control"; RJ Farrauto, RM Heck, ST Gulati; Wiley

Office Hours

- Anytime via email/phone
- Face-to-Face discussion before class (contact in advance to arrange time & location)

Grading & Assignments

Mid-Term Exam	25%
Final Exam	30%
Quiz (2)	20%
Homework (7-8)	15%
Discussion Topics	10%

Homework:

7 to 8 Homework assignments will be given. These homework assignments will consist of objective questions relating to the lecture to help reinforce key topics, AND/OR may involve reading literature related to the class topic. Assignments will be graded. Late assignments will be accepted at a penalty for being late (10% each week, max 50%). **While not required, I encourage completing assignments in groups of 3-4 students (4 maximum). When submitting as groups, the same grade is given to all students.**

Homework must be your own (team's) work. It is never acceptable to reproduce thoughts or concepts found online. You must answer in your words. **Homework assignments must be submitted in class in hardcopy form.**

Discussion Topics:

A topic or open-ended question will be distributed one week prior to class. During class this topic will be discussed as a group for 20-30min. The purpose of this "discussion period" is to reinforce lecture topics through a 2-way dialog and give students an opportunity to share their thoughts. Each week during the discussion, 2-3 students would share their idea to the class in a short (~3min) verbal explanation. After each student presents their idea, the class would have the opportunity to discuss the idea in more depth (is it feasible, do others agree/disagree, etc.). The following guidelines apply.

- ~10 topics will be discussed throughout the semester. This is in addition to homework.
- Each student must prepare a short response (~1-page) **typed <u>hard-copy</u>** to be submitted in class.
- Each student must submit their response as a paper copy in class the day this topic is discussed. No credit is given to responses submitted outside of class.
- Submissions are graded based on content.
- Submissions are graded based on (1) thoughtful content, (2) proper format. "Thoughtful content" means your response must be original (your work/thoughts!) and concisely provide some details or your idea/thoughts.

Distribution of Notes, Assignments, Solutions, & general class communication

- All lecture notes, assignments, solutions, etc. will be distributed via Moodle class page.
- Class lecture is largely powerpoint presentation based. Slide decks will be posted the day of class ahead of the lecture.
- Urgent class messages will be sent via email.

Course Lectures

Lecture	Topic	Book Section
1	**Introduction** Why "Environmental Catalysis"? Air Pollution & Clean Energy Introduction to Air Pollution Introduction to Catalytic Air Pollution Control Catalyst Fundamentals	**Chapter 1**
2	**Catalyst Materials and Preparation** Physical Structure of a Catalyst Common Carrier Materials Monolithic Supports Catalyst Synthesis and Manufacturing	**Chapter 2**
3	**Catalyst Characterization and Deactivation** Analytic Techniques for Catalyst Characterization Common Mechanisms for Catalyst Deactivation	**Chapter 3 & 5**
4	**Reactor Design for Environmental Catalysis** Fundamental Processes Occurring During Catalysis Surface Kinetics Fundamentals of Reactor Design Monolithic Substrates	**Chapter 1, 4, & 7**
5	**Catalytic Oxidation of Volatile Organic Compounds** Traditional Industrial Abatement Processes Ambient Air Cleanup	**Chapter 11**
(Oct-9)	**QUIZ**	
6	**CO & Hydrocarbon Abatement** Power Plant Emissions Low Temperature CO Oxidation	**Chapter 13**
	Mid-Term Review	
(Oct-23)	**Mid-term exam (in-class)**	

Lecture	Topic	Book Section
7	**Reduction of NOx** Nonselective Catalytic Reduction Selective Catalytic Reduction	**Chapter 12**
8	**Gasoline Engines and Emission Control** Design & Operation of Gasoline Automobile Engine Emissions and Regulations Evolution of Catalytic Converter	**Chapter 6 & 7**
9	**Diesel Engine Design** Design & Operation of a Diesel Engine Emissions and Regulations	**Chapter 8**
10	**Diesel Engine Emission Control** Emission Control Strategies Particulate Filters Diesel Catalyst Supports	**Chapter 8 & 9**
11	**Other Environmental Applications** Ozone abatement in aircraft Small Engine Exhaust Abatement	**Chapter 10, 14**
(Nov-27)	**QUIZ**	
12	**Green Energy Catalysis: Fuel Cells** Fuel Cells & Small Scale Hydrogen Generation	**Notes**
13	**Green Energy Catalysis: Bio-Fuels** Bio-fuel/Bio-diesel Biomass to Fuel Conversion *Final Exam Review*	**Notes**
(as scheduled)	**Final Exam (in-class)**	