

**Texas A&M University-Kingsville**

**CHEM 5412, Green Chemistry**

**Course Description:**

The course is for graduate students majoring in a field of science and engineering. The aim of this course is to provide the future chemists and engineers with the tools required to enable them to to minimise the environmental impact of the chemistry and processes. The course highlights and emphasizes the designing of environmentally friendly chemical processes (*Green Chemistry*) that are both economically and technologically feasible. Utilizing strong pragmatic emphasis on measurement and metrics analysis, green chemistry concepts and principles will be discussed and exemplified with numerous real-life case studies including a brief section on President's Green Chemistry Challenge award.

**Name of Instructor:**

Dr. Apurba Bhattacharya

**Office Location:**

Room 156 B, Nierman Hall. Telephone: (361) 593-2664

**Office Hours:**

2:00- 4:00 PM, Monday through Friday, or by appointment.

**Course Lecture Location:**

TBA

**Required Texts:**

Green Chemistry Designing Chemistry for the environment, Edited by Paul T Anastas and Tracy C. Williamson; , ACS Symposium Series 626; 1996.

**Recommended Reading(s):**

Selected Journal Articles.

**Course Objectives.**

The objectives of this course are to provide the students with

1. A fundamental understanding of basic chemistry/technology principles within the framework of Green Chemistry.
2. Knowledge directed towards to the development of latest technologies and methodologies for environmentally benign processes (“green chemistry”) currently practiced in various industrial sectors (commodity-chemical, fine-chemical and pharmaceutical) with an emphasis on the design, manufacture, and use of chemicals and processes that have little or no pollution potential or environmental risk and are both economically and technologically feasible.
3. Hands-on skills to assess the “greenness” of chemical reactions and synthesis plans. The course will equip graduates with an understanding of the drives for sustainability, and the necessary skills in green chemistry for a career in areas including research, process development, environmental and legal services, consultancy and government.

### **Course Outline:**

#### Green Chemistry: Designing Environmentally friendly processes.

Green Chemistry differs from conventional chemistry in several different categories including nature of starting materials, reagents, reaction conditions and target molecule. The scope of Research and Development in this area is enormous. But due to obvious time limitations I intend to concentrate on the following specific areas of chemistry supported by selected examples of processes currently practiced in various industries.

Introduction and overview.

Why Green Chemistry?

- Toxicity of chemicals
- Accidents with chemicals
- Waste and minimisation
- Sustainability (including social, political & economic factors)
- The green political movement
- The role and responsibilities of chemists

What is Green Chemistry?

- Definition and overview of the twelve principles of Green Chemistry.

----- 1 week

Principles of Green Chemistry.

1. Waste Minimisation/Prevention. Establishing a full mass balance. Waste treatment/recycle

2. Synthetic Efficiency. Green Chemistry Metrics. Individual Reactions Analysis. Atom Economy, E-factor, & Reaction Mass Efficiency (RME) Radial Pentagon “Material Footprint” Criteria for Recycling & Reclaiming Materials Minimum Atom Economy & Maximum E-factor Analysis Probability Analysis for Achieving RME Target Thresholds Survey of Organic Reaction Classes  
Synthesis Plans Analysis: Synthesis Tree Algorithms for Linear and Convergent Plans Raw Material Cost Estimate Material Efficiency & Synthetic Elegance Ranking Parameters Optimisation & Good Synthesis Strategies Illustrated & Detailed Survey of Example Plans for Pharmaceuticals Trade off with economics
3. Less Hazardous Materials in Synthesis
4. Designing Safer Products
5. Safer Solvents and Auxiliaries. Critical review of organic solvents typically used  
Critical review of: ionic liquids, scCO<sub>2</sub>, water, fluoros phase chemistry, solvent-free /, solid phase chemistry. Examples of green reagents
6. Energy Efficiency. Quantifying and minimising use of utilities and, other inputs. Photochemistry, Microwave chemistry, Sonochemistry, Electrosynthesis, Energy Sources
7. Renewable Feedstocks, Sustainability measures. Biomass vs Fossils
8. Minimal Derivatisation
9. Catalysis, Recovery, recycle, reuse. Heterogeneous. Solid acids. Templated silica. Polymer-supported reagents. Homogeneous. Phase transfer. Biocatalysis. Photocatalysis
10. Design for Degradation. Rules for degradation
11. In Process Controls. Realtime analysis. Process analytical technology (PAT)
12. Hazard Minimisation. Process safety and thermal hazards. Appreciation of chemical engineering concepts. Process intensification

----- 5 weeks.

Alternative Starting Materials.

- a) Aromatic amines via novel substitution without the formation of salts ; the Monsanto process.
- b) Professor Michael J. Krische. University of Texas at Austin (President’s Green Chemistry Challenge award)  
Hydrogen-Mediated Carbon–Carbon Bond Formation)  
Production of adipic acid catechol and hydroquinone without using benzene.

----- ---1 week

Alternative synthesis and reagents.

- a) Catalytic Processes in Environmentally benign chemistry.  
Synthesis of acetaldehyde, hydroquinone, zeolites (size and shape selective catalysis), enzyme catalysts including cross linked co polymers (CLEC).
- b) Phase transfer catalysis; Merck process.

- c) Waste-free HF acylation chemistry: Hoechst Celanese process for the production of ibuprofen and acetaminophen. (President's Green Chemistry Challenge award)
- d) Resolution-racemization technology; Hoechst Celanese process for S-ibuprofen and p-Hydroxyphenyl Glycine.
- e) Novel Green Synthesis for  $\beta$ -Amino Acids Produces the Active Ingredient in Januvia™ Merck & Company (President's Green Chemistry Challenge award)
- f) Organic reactions in water. Quasi-Nature Catalysis: Developing Transition Metal Catalysis in Air and Water. (President's Green Chemistry Challenge award)

----- 3 weeks

The Concept of Atom Economy.

Alternate energy sources; application of microwave and ultrasound in semicontinuous chemical processes.

Conclusion. Outlook for the future.

----- 2 weeks

**Student learner outcomes:**

At the successful completion of this course, you will demonstrate understanding of the key elements of the sources and causes of environmental pollution and abatement of pollutants via emphasizes the designing of environmentally friendly chemical processes (*green chemistry*) by completion of an assessment exam.

**Method(s) of evaluation and grading procedures:**

- Evaluation of the course objectives will be assessed by the evaluation of two major examinations (hour exams) and a comprehensive final examination.

Examination 1	100pts
Examination 2	100pts
Examination 3, Comprehensive (Final)	200pts
-----	
Total	400 pts

- Due to time constraints no make-up examinations will be given. A student who can document an excused absence receives a grade based on his/her exam average. A grade of zero will be recorded for unexcused absences. From time to time there will be unannounced quizzes.

- Seminar Program. Students are strongly encouraged to attend the seminars offered in the Department of Chemistry. They will earn 10(bonus points)/1000 points basis if they attend the seminars.

**Policies for attendance, excused absences, make-up exams, late assignments, early final exams, cell phones, etc.:**

Successful performance in this class requires that you attend class. Make-ups for missed exams are granted only for excused (official university) absences. Please note that attendance policies may vary by college. No late assignments will be accepted.

Graduating seniors who need to schedule an early final should inform the instructor early in the semester. Students should turn off and stow their cell phones during class.

**Disability statement** (See pages 2 & 11 of Student Handbook):

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disability. If you believe you have a disability requiring an accommodation please contact the Disability Resource Center (DRC) as early as possible in the term. DRC is located in the Life Service and Wellness building at 1210 Retama Drive, or call (361) 593-3024.

**Academic misconduct statement** (see page 23, section 100 of student handbook):

You are expected to adhere to the highest academic standards of behavior and personal conduct in this course and all other courses. Students who engage in academic misconduct are subject to university disciplinary procedures. Make sure you are familiar with your Student Handbook, especially the section on academic misconduct, which discusses conduct expectations and academic dishonesty rules.

**Forms of academic dishonesty:**

- 1) **Cheating:** Using unauthorized notes or study aids, allowing another party to do one's work/exam and turning in that work/exam as one's own; submitting the same or similar work in more than one course without permission from the course instructors; deception in which a student misrepresents that he/she has mastered information on an academic exercise that he/she has not mastered; giving or receiving aid unauthorized by the instructor on assignments or examinations.
- 2) **Aid of academic dishonesty:** Intentionally facilitating any act of academic dishonesty. Tampering with grades or taking part in obtaining or distributing any part of a scheduled test.
- 3) **Fabrication:** Falsification or creation of data, research or resources, or altering a graded work without the prior consent of the course instructor.
- 4) **Plagiarism:** Portrayal of another's work or ideas as one's own. Examples include unacknowledged quotation and/or paraphrase of someone else's words, ideas, or data as one's own in work submitted for credit. Failure to identify information or essays from the Internet and submitting them as one's own work also constitutes plagiarism.
- 5) **Lying:** Deliberate falsification with the intent to deceive in written or verbal form

as it applies to an academic submission.

- 6) **Bribery:** Providing, offering or taking rewards in exchange for a grade, an assignment, or the aid of academic dishonesty.
- 7) **Threat:** An attempt to intimidate a student, staff or faculty member for the purpose of receiving an unearned grade or in an effort to prevent reporting of an Honor Code violation. Please be aware that the University subscribes to the Turnitin plagiarism detection service. Your paper may be submitted to this service at the discretion of the instructor.

**Other Forms of Academic Misconduct:**

- 1) Failure to follow published departmental guidelines, professor's syllabi, and other posted academic policies in place for the orderly and efficient instruction of classes, including laboratories, and use of academic resources or equipment.
- 2) Unauthorized possession of examinations, reserved library materials, laboratory materials or other course related materials.
- 3) Failure to follow the instructor or proctor's test-taking instructions, including but not limited to not setting aside notes, books or study guides while the test is in progress, failing to sit in designated locations and/or leaving the classroom/ test site without permission during a test.
- 4) Prevention of the convening, continuation or orderly conduct of any class, lab or class activity. Engaging in conduct that interferes with or disrupts university teaching, research or class activities such as making loud and distracting noises, repeatedly answering cell phones/text messaging or allowing pagers to beep, exhibiting erratic or irrational behavior, persisting in speaking without being recognized, repeatedly leaving and entering the classroom or test site without authorization, and making physical threats or verbal insults to the faculty member, or other students and staff.
- 5) Falsification of student transcript or other academic records; or unauthorized access to academic computer records.
- 6) Nondisclosure or misrepresentation in filling out applications or other university records.
- 7) Any action which may be deemed as unprofessional or inappropriate in the professional community of the discipline being studied.

**Non-academic misconduct** (see page 23, section 100 of the student handbook):

The university respects the rights of instructors to teach and of students to learn. Maintenance of these rights requires campus conditions that do not impede their exercise. Campus behavior that interferes with these rights will not be tolerated; examples include

- 1) interfering with the instructor's ability to conduct the class,
- 2) causing inability of other students to profit from the instructional program, or
- 3) any interference with the rights of others.

An individual engaging in such disruptive behavior may be subject to disciplinary action. Such incidents will be adjudicated by the Dean of Students under non-academic procedures.

Ongoing behaviors or single behaviors considered distracting (e.g., coming late to class,

performing a repetitive act that is annoying, sleeping or reading a newspaper in class, etc.) will be addressed by the faculty member initially either generally or individually. Cases in which such annoying behavior becomes excessive and the student refuses to respond to the faculty member's efforts can be referred to the Dean of Students. In the case of serious disruptive behavior in a classroom the instructor may first request compliance from the student and if it is not received, an instructor has the authority to ask the student to leave the classroom. If the student fails to leave after being directed to do so, assistance may be obtained from other university personnel, including University Police Department. An individual engaging in such disruptive behavior is subject to disciplinary action. Such incidents will be adjudicated by the Dean of Students under non-academic procedures to determine if the student should be allowed to return to the classroom.

**Harassment /Discrimination** (See page 23, section 200 of Student Handbook):

Texas A&M University-Kingsville will investigate all complaints that indicate sexual harassment, harassment, or discrimination may have occurred by the facts given by the complainant. Sexual harassment of anyone at Texas A&M University-Kingsville is unacceptable and will not be tolerated. Any member of the university community violating this policy will be subject to disciplinary action. A person who believes he/she has been the victim of sexual harassment, harassment, or discrimination may pursue either the informal or the formal complaint resolution procedure. A complaint may be initially made to the complainant's immediate supervisor, a department head, any supervisory employee, the Dean of Students (593-3606), or the Office of Compliance (593-4758). Regardless of who the complaint is filed with, the Compliance Office will be notified of the complaint so it can be investigated.

**Six-drop policy:**

The following provision (new in Fall 2007) does not apply to students with Texas public college or university credits prior to Fall 2007. The Texas legislature has enacted a limit to the number of course drops allowed to a student without penalty. After a student has dropped six courses, a grade of QF will normally be recorded for each subsequent drop. If you need additional information on Senate Bill 1231 and how it affects you, please contact the Registrar's Office in College Hall, Room 105.

**Comments:**

- I will not take formal attendance but class attendance is a very practical necessity. Please note that attendance policies may vary by college). No late assignments will be accepted. Graduating seniors who need to schedule an early final should inform the instructor early in the semester. Students should turn off their cell phones during class.
- The syllabus is intended to be informational and not contractual. The instructor reserves the right to amend, alter, change, delete, or modify the syllabus with notice (announced during the lecture season) in any manner that is deemed necessary and in the best interest of the Department of chemistry and Texas A & M University-Kingsville.

- It is the responsibility of the student to keep the original graded copies of all materials (exams, problem set, in-class assignments, etc.) that have been returned for his/her records. Graded final exams are retained by the instructor for his/her permanent records.