Excerpt from "The Piedmont Project at Emory University" by Peggy Barlett and Arri Eisen, in, *Teaching Sustainability at Universities: Toward Curriculum Greening*. 2002 Walter Leal Filho, editor. Frankfurt: Peter Lang.

General Chemistry (Drs. Nancy Thornton, Preetha Ram, and Barry Ryan, Department of Chemistry in the College of Arts and Sciences)

Drs. Thornton and Ram have devoted themselves, with the strong support of the rest of their Chemistry Department at Emory, to reshaping the entire introductory chemistry sequence. Part of this restructuring involves incorporating environmental awareness into the traditional general chemistry curriculum. Although this connection between chemistry and the environment may seem obvious, traditional introductory chemistry courses often sacrifice environmental (or any other) everyday context in the effort to cover vast quantities of basic science, leaving application to the students' imagination.

Dr. Thornton's efforts have been focused on the large, introductory lecture course and laboratory sessions of General Chemistry, where she has added environmental examples throughout the course. For example, in the chapter on Atoms, Molecules, and Ions, she added a discussion of radon gas, its radioactivity, and its effects on human health. In addition, the use of oxygen isotopes from ice core data to determine temperature and air composition over history is examined, laying the groundwork for a later discussion on global warming.

In the chapter on Thermodynamics and Energy, fossil fuels and global warming are discussed. Students work out calculations of energy output and carbon dioxide production of different fossil fuels and relate this to energy efficiency and global warming effects. Air composition and pollution are also brought into the course in the section on mixtures and compounds.

Dr. Thornton remarks, "I have greatly enjoyed researching and incorporating material related to this topic into my course. I think students enjoyed learning more about sustainability and how it relates to chemistry. I hope to be able to improve how we present the topic and how we involve the students." The biggest challenge is how to integrate this new material, without sacrificing the other material that forms basic (and critical) building blocks for later courses. One approach that has been piloted by Dr. Barry Ryan, of Public Health and Chemistry, is to offer a separate General Chemistry section that has an environmental focus.

General Chemistry/Freshman Seminar Version (Dr. Preetha Ram, Department of Chemistry)

Another approach to integrating environmental issues into a general, introductory course is to treat one topic—Global Warming—extensively over a period of time. Dr. Ram's course covers the same general chemistry in a small, seminar format, as part of the Emory requirement that every first year student enroll in at least one seminar class, in which enrollment is limited to 16. The topic is broached in assigned readings and is followed with discussion of the issues raised in the articles. Out of the initial discussion came the question, "Why are some gases “greenhouse gases” and some not?" This led to a discussion of three dimensional molecular structure. In a similar manner, the students raised questions such as "How and why are greenhouse gas concentrations changing?" which leads to the introduction of curricular material in order to answer those questions. As a part of this course, students conduct a study of awareness of global climate change among Emory students and learn to interpret the data.

This semester-long approach has the class revisiting the topic of global warming several times from diverse perspectives. Dr. Ram finds that the seminar format gives the teacher the flexibility to try out new ideas that then can be exported to a larger class. The experience of teaching the course has generated pedagogical reflections:

> I have had to take a very critical look at our students’ learning experience and a very close look at our curriculum. I have concluded that it is as important to give students the tools of learning—critical thinking, analysis of problems, collaborative work, as it is to give them content. When thinking about the global warming issue, discussing it in class, hearing other opinions, looking for information and presenting it, students learn as much as when the class focuses in the abstract on gas laws. In fact, their enthusiasm and involvement in a real issue motivates them to learn more.
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> Thanks to our Green Lunch discussions and the readings I have had to do for the course, my understandings of these issues have deepened, and I am eager to learn more. I am also eager to bring up these issues with students.

New Syllabus for General Chemistry
Chem 141
Submitted by Preetha Ram, Nancy Thornton and Barry Ryan

Incorporating Environmental Awareness in the General Chemistry Curriculum

Environmental topics will be introduced to the students in general chemistry in one of two formats in the lectures and through appropriate experiments in the lab.

Syllabus for General Chemistry Chem 141 (Large lecture).

At the beginning of each chapter or as appropriate, we will present an environmental issue that requires mastery of certain chemistry concepts or topics. These issues will be available to the students ahead of time. Students will be asked to find a solution to the problems by looking through the chapter and post their responses on LearnLink. We have jointly identified topics and problems and will use a variety of strategies to involve students in a discussion of the issues. We will also do a student survey at the beginning and end of the semester to gauge student awareness.
Textbook Used in Conjunction with the regular General Chemistry Textbook: "Environmental Chemistry" by Colin Baird

Chapter 1:
Syllabus Topics: The scientific method, Mixtures, compounds
Composition of Air
Assignment: Read the case study: Page 2, " Lake Michigan"
Questions:

What in your opinion was the effect of consuming fish from Lake Michigan?
What does PCB stand for?
Express the concentration of PCB in ppm.
Explain how this study is an example of the use of the scientific method.
Indicate the: data, hypothesis, laws, conclusions – if any.
At O deg C and standard atmospheric pressures, one liter of air contains 0.0446 moles of gas, of which 20.95% is oxygen. What is the concentration of oxygen in air in moles per liter? The mass of one mole of oxygen is 32.0 g. What is the concentration of oxygen in grams per milliliter (mL)? (1 L = 1000 mL).
Calculation of Radon levels in residences: Radioactive material decays by giving off certain subatomic
particles. The radioactivity of an element is measured by its disintegration rate. Radioactive disintegrations are measured in curies (Ci). One Ci equals 3.7 x 1010 disintegrations per second (di/s).
Radon is a radioactive gas that can seep into homes. The Environmental Protection Agency has set an action level of 4.0 picocuries (pCi) per liter of air as the limit for homes. For one liter of air, how many disintegrations per second does this correspond to?

Chapter 2
Syllabus Topics: Unit Conversion, significant figures, isotopes
Assignment: Read the essay on"The Ozone Layer" 13-18

Chapter 3/4
Syllabus Topics: Ionic Equilibrium, Chemical Reactions, Stoichiometry
Assignment: Read the article "Phosphate in natural waters", page 290
Questions:

What is the formula of phosphate? What is its chemical nature – element compound mixture etc.
What is the role of phosphates in detergents?
What is the effect of water pH on phosphate equilibria?
What is Dissolved Oxygen?

Chapter 5
Syllabus Topics: Heat Laws, Thermochemistry
Assignment: Read "Energy Production and its Environmenatal Consequances" 395-414
Questions:

What is global warming?
What are greenhouse gases?
Do they think global warming is a real phenomenon?
What are the advantages and disadvantages in fueling vehicles with compressed natural gas?
How is the octane number rating for fuels determined?
What is the main component of natural gas? Write the equations that describe its combustion.
Does the burning of hydrogen really produce no pollutants?

Calculate the energy output and CO_2 production per mole of different fossil fuels.
Calculate the true cost of different fuels.

Chapter 6
Syllabus Topics: Gases

Assignment: Read "Urban Ozone", p 82-90.
Read the hand about sulfur dioxide (page 135)

Questions:

What is the chemical reaction by which most atmospheric NO Free radical is initially produced?
What is photochemical smog?
What strategies have been used to reduce urban ozone levels?
What is the pH of CO_2 saturated water at 25C. The CO_2 concentration in air is 350 ppm, i.e. 0.00035 atm and the Henry's law constant is 3.4 x 10-2 mol/L/atm at 25C. The ionization constant K_a for H_2CO_3 is 4.5 x 10-7 mol/L at this temperature. Calculate the pH of rainwater at temperature.
What concentration of SO_2 must be reached in polluted air to reach a pH of 4.0 in raindrops without any oxidation of SO_2.

Chapter 7 and 8
Syllabus Topics: The electromagnetic spectrum, absorption of light by molecules, Spectroscopy
Assignment: Read "Urban Ozone", 90-95
Questions:

ΔH for the decomposition of ozone into O_2 and atomic oxygen is 105 kJ /mol. What is the longest wavelength of light that could dissociate ozone in this manner? Which region of sunlight does that fall into?

What is the energy in kilojoules per mole associated with photons having the following wavelengths?

600 nm   2000nm

Chapter 10, 11, 12
Syllabus Topics: Intermolecular forces, solutions, colligative properties
Assignment: Toxicology of PCBs Dioxin, Furans p262
Questions:
How do these chemicals enter the waterways?
What is the relationship between chemical structure of PCBs, dioxins and their solubility in water?
What does DDT stand for? What was it used for and why was its use discontinued?

Chem 141 S: Freshman Seminar Section

The smaller size of the freshman seminar class 141S will allow us to use a more investigative approach to chemistry. In addition to the problems and exercises mentioned above, we will use a four week module developed by the ChemConnections Consortium – an NSF funded multi site initiative. The supporting materials and instructor manual are available from Wiley publishers and also online.
This unit should take about 4 weeks and includes assignments and class demonstrations and lab experiments. There is not adequate time to prepare the lab experiments – however, we could include them in next years labs.

Module Name: Global Warming: What should we do about that?

Global Warming is introduced with reading material from The Wall Street Journal, The Citizen Outlook, International Wildlife and others. Some of the questions explored are: What is global warming? What is a greenhouse gas? How do we determine whether a gas is a greenhouse gas or not? Why are greenhouse gas concentrations changing? What are your personal contributions to the greenhouse gas emissions? Are human activities responsible for the earth's temperature trends?
Culminating Activity: What should we do about global warming?

Syllabus:
This unit covers electromagnetic spectrum, spectroscopy, chemical equations, stoichiometry, bonding, and polarity. There are lab activities associated with it and discussion questions that can be used in class.

We will be using two other units in the seminar class this fall that are not directly related to environmental chemistry but follow the same investigative approach. We will therefore not follow the same sequence of topics as in the large course. We hope to gain experience in handling these units and then offer them in the large lecture course next fall.

More info at: http://chemistry.beloit.edu/

Chemistry Laboratory Exercises with Environmental Emphasis for General Chemistry and Other Laboratories.

1) ***Buffering of Lakes with Carbonate Underlayment versus Lakes without Such Understructure.***

Purpose: To illustrate the effects of environmental buffering on lake acidification.

Materials: Beakers or other containers, calcium carbonate/magnesium carbonate, washed sand sulfuric acid at pH=2.0, i.e., 0.01 M, water, pH meter or other pH measuring equipment such as multi color pH paper.

Methods: Prepare one system with sand at bottom of beaker, the other with calcium/magnesium carbonate in excess. Examine pH as a function of total acid added.

Analysis: Plot pH versus moles of acid added. Discuss buffering effect. Discuss implications for acid rain.

Difficulty: Easy.

Course: General Chemistry

2) ***Henry's Law- Comparison of Water Acidity Associated with Carbon Dioxide, Nitrogen Dioxide, and Sulfur Dioxide***

Purpose: To understand the effects of atmospheric gases on water acidity.

Materials: Beakers or other containers, carbon dioxide, nitrogen dioxide, sulfur dioxide source, e.g., bottled gas, water, pH meter or other pH measuring equipment such as multi color pH paper.

Methods: Deliver known gas concentration of acid gas in a closed system. Measure pH of water after equilibrium is obtained.

Analysis: Determine ratio if total acidity to partial pressure of gas. Develop Henry's Law constant. Discuss implications for acidic deposition.

Difficulty: Moderate to Difficult.

Course: General Chemistry, Analytical Chemistry, Physical Chemistry Laboratory- Depending on degree of sophistication.

3) ***MTBE Solubility from Air and Movement in the Environment***

Purpose: To understand the effects of atmospheric gases on water contamination. This substance has been touted as an oxygenated fuel additive designed to reduce ozone production. However, it is quite soluble in water and has been found to contaminate local water supplies do to dissolution of airborne MTBE into surface water.

Materials: MTBE, water, closed system device sug as a a vial with cap and septum, syringe for GC injection, GC-FID.

Methods: Delivery of MTBE vapor to closed system container with subsequent partitioning into water. Syringe extraction of water and injection into GC-FID for analysis.

Analysis: Examine concentrations in water. Estimate Henry's Law Constant fro MTBE. Work up typical environmental concentrations of MTBE and potential for water contamination. Discuss health effects.

Difficulty: Moderate to Difficult- depending on what is required of the students.

Course: General Chemistry? Organic Chemistry, Physical Chemistry Laboratory- Depending on degree of sophistication.

4) ***Particulate Matter Monitoring with Gravimetric Analysis***

Purpose: To develop skills in high-precision weighing and to develop understanding of an important pollutant in the atmosphere. Manipulation of flow rates, total flows, and masses to determine concentrations.

Materials: Filters, pumps, sampling apparatus, precision microbalance reading to 0.00001 g, filter conditioning chamber.

Methods: Filters are weighed before sampling, and then placed in sampling apparatus. Air is drawn through filters at a fixed rate for a fixed period of time so that the total volume of air sampled can be calculated. Filters are weighed after sampling to get mass collected (typically about 0.0001 g).

Analysis: Weight difference divided by volume of sampled air gives concentrations in μg/m^3.

Difficulty: Easy. Can be made into term project by sampling every 3 or 6 days for a month. Can be made into a more sophisticated laboratory by doing extraction of filter material and analysis of a range of chemical species including sulfates, nitrates, and specific metals. Organics can be done, but require different sampling procedures, media, and extraction techniques.

Course: General Chemistry. Analytical Chemistry. Organic Chemistry, Physical Chemistry Laboratory- Depending on degree of sophistication.

5) *Palmes Analysis for Nitrogen Dioxide*

Purpose: Use of a spectrophotometric method for the analysis of an atmospheric pollutants. More sophisticated laboratory exercise can be set up by requiring students to understand the details of passive diffusion samplers.

Materials: Palmes samplers consisting of a finger-sized acrylic type, plastic caps, and stainless steel screens. Collection reagent is triethanolamine (TEA). Color reagent is standard Saltzmann's reagent. Cost per sample is under $1.

Methods: Samplers are prepared by coating stainless steel screens with TEA and placing them in the enclosed end of a diffusion tube. A removable cap precludes atmospheric sampling until removed. Removal of the cap begins sampling under diffusion control. Students note time of uncapping and capping. Sampling rate is constant so that by knowing time, total amount of air sampled can be determined. Analysis of accomplished by adding reagent directly to the samplers, vortexing, then letting the color "develop" for about 30 minutes. Analysis is by absorbtion at 540 nm with a calibration curve.

Analysis: Determine number of nmoles of NO_2 absorbed and use a short series of calculations to get the average amount of NO_2 in the air during sampling.

Difficulty: Easy. Can be made almost cookbook. Sophistication can be increased through multiple samples and forcing deeper understanding.

Course: General Chemistry. Analytical Chemistry. Physical Chemistry Laboratory- Depending on degree of sophistication

6) *Photodegradation of an Environmental Contaminant*

Purpose: To indicate one of many methods by which contaminants are modified in the environment.

Materials: See below.

Methods: This idea is not really well baked yet. I can envision introducing some material into an air stream and passing the material by a UV source. Concentration could be measured before and after. Alternatively, a photodegradable pesticide could be used with a soil matrix. Concentration again is measured before exposure to UV and after.

Analysis: Perform kinetic analysis assuming first-order loss.

Difficulty: Difficult?

Course: Physical Chemistry Laboratory- due to complexity of the setup

7) ***Equilibrium Affected by Pressure of CO_2***

Purpose: To show effects of increasing partial pressure of carbon dioxide on acidity. Can be associated with global warming issues.

Materials: Beakers or other containers, carbon dioxide, nitrogen dioxide, sulfur dioxide source, e.g., bottled gas, water, pH meter or other pH measuring equipment such as multi color pH paper.

Methods: Deliver carbon dioxide at various partial pressures, measure pH.

Analysis: Determine Henry's Law constant. Evaluate effects associated with doubling current background concentration to 650 ppm.

Difficulty: Easy to Moderate

Course: General Chemistry, Analytical Chemistry, Physical Chemistry Laboratory- depending upon degree of sophistication required of students.

8) ***Heat Content of Fuels- Calorimetry***

Purpose: To improve understanding of the energy content of common fossil fuels.

Materials: Various fuels including natural gas, gasoline, diesel fuel, and coal. Calorimeter- degree of sophistication depends on course.

Methods: Burn known amount of fuel and measure temperature increase in calorimeter.

Analysis: Calculate enthalpic content of fuel in kJ/mol. Discuss in terms of energy needs of the United States.

Difficulty: Easy to Moderate

Course: General Chemistry, Analytical Chemistry, Physical Chemistry Laboratory- depending upon degree of sophistication required of students.

9) ***Battery/Fuel Cell Analysis***

Purpose: To improve understanding of alternative energy sources.

Materials: Batteries ranging from simple flashlight batteries to rechargeable, lead-acid car batteries, and fuel cells. Apparatus for measuring total current flow and battery drain.

Methods: Determine energy content of batteries using total discharge method. Evaluate efficiency of fuel cells.

Analysis: Plot battery voltage versus discharge time, total energy content, and usefulness. Discuss production and waste. Build and evaluate fuel cells.

Difficulty: Easy to Difficult

Course: General Chemistry, Analytical Chemistry, Physical Chemistry Laboratory- depending upon degree of sophistication required of students.

10) ***Stochiometric Analysis of Coal Burning- Dry Laboratory***

Purpose: To improve understanding of coal as a source of energy.

Materials: Data on carbon, sulfur, and trace metal content of various types of coal used in the United States. Information on particulate matter amounts produced from burning coal.

Methods: In this “dry lab” exercise, students will be asked to calculate the amount of carbon dioxide, sulfur dioxide, particulate matter, and trace metals released into the environment through the burning of coal.

Analysis: Stoichiometry of the coal burning process including contaminants in the coal will be the essential analyses completed here.

Difficulty: Easy

Course: General Chemistry.

11) Atmospheric Chemistry- Generation of Ozone

Purpose: To improve understanding of the processes involved with photochemical smog development in urban areas.

Materials: Reaction chamber, e.g., aquarium. Source of volatile organic compound, e.g., isoprene. Source of nitric oxide, e.g., gas bottle. UV source. Ozone measuring apparatus, e.g., IV spectrophotometer adapted for this purpose.

Methods: Ozone precursors including VOCs and NO will be introduced into the reaction chamber and subjected to UV radiation. Ozone production will be observed through absorbtion at UV wavelength associated with ozone.

Analysis: Kinetic analysis. Rate of production of ozone related to [NO], [VOC], and UV intensity. Mechanism speculation.

Difficulty: Diffucult.

Course: Good project for PChem lab.

12) Extraction and Analysis of Metals from Soil

Purpose: To improve understanding of soil contamination.

Materials: Soil samples, various acids and oxidants such as phosphoric acid and hydrogen peroxide, hot plates. Metal analytic methods. Best choices are ICP-MS, and GF-AAS, but single metal wet analytical techniques may also be applicable.

Methods: Soil sample are digested using strong mineral acid and oxidizing agents and heat to release total metal content in acid solution. Metals are then analyzed using appropriate techniques specific to each metal. Various types of soils form various locations could be used.

Analysis: Determine total metal content for each metal and evaluate differences among soil types and origins.

Difficulty: Moderate

Course: Analytical Chemistry.

13) Extraction and Analysis of Organics from Soil

Purpose: To improve understanding of soil contamination.

Materials: Soil samples, hexane, ether, sonicator, GC-FID, calibration standards.

Methods: Soil sample are extracted using organic solvents. Small amount of soil is placed in vial containing extraction solvent. Sonication ensures intimate contact with all soil particles. Supernatant containing extracted organics from soil is analyzed through direct injection into GC-FID calibrated with standards.

Analysis: Students use calibration standards and peak heights/areas from GC trace to determine the amount of organic species in the soil.

Difficulty: Moderate

Course: Organic Chemistry, Analytical Chemistry.

14) Lullwater Pond Analysis- pH, hardness, BOD, COD, chelatable metals, etc.

Purpose: To improve understanding of water contamination in a local ecosystem. Further, environmental awareness can be developed and long-term trends in the environmental health of Lullwater can be developed.

Materials: various kits are available for the spectrophotometric analysis of many species including nitrates, and phosphates. pH requires a pH meter or pH paper. Other materials needed depend on the specifics of the species to be analyzed.

Methods: Water can be collected and analyzed.

Analysis: Students will use spectrophotometric techniques, chelation methods, and some biomonitoring methods to assess environmental state of the Lullawater ecosystem.

Difficulty: Easy to Difficult.

Course: General Chemistry, Analytical Chemistry, and Physical Chemistry depending on the degree of sophistication of the requirements.

15) General VOC Monitoring

Purpose: To improve understanding of organic species concentration in air.

Materials: VOC samplers (about $10/each) consisting od an badge type sampler with a charcoal collecting medium, carbon disulfide, sonicator, GC-FID, calibration standards.

Methods: Passive VOC samplers are placed in a location to be montired for a period of time. After exposure, the samplers are returned to their airtight container and retruned to lab. Extraction of absorbed material on charcoal is effected through a CS_2 solvent extraction. Extracted material is analyzed through direct injection into GC-FID calibrated with standards.

Analysis: Students use calibration standards and peak heights/areas from GC trace to determine the amount of individual organic species collected and the sampling characteristics of the passive sampler to determine airborne concentrations.

Difficulty: Moderate

Course: Organic Chemistry, Analytical Chemistry.

16) Carbon Monoxide Monitoring

Purpose: To determine amount of carbon monoxide in ambient or indoor air.

Materials: Gastight syringes or air sampling bags. GC-FID with reduction column. Known concentration CO for standards.

Methods: Collect air sample in gas tight syringe. Inject sample directly into GC-FID with reduction column. Reduction column converts CO to methane which is then measured by FID. Note that methane in the air comes through quicker as reduction is kinetically slower.

Analysis: Students use calibration standards and peak heights/areas from GC trace to determine the amount of carbon monoxide collected and the sampling characteristics of the passive sampler to determine airborne concentrations.

Difficulty: Moderate

Course: Organic Chemistry, Analytical Chemistry.