

Improving Chemistry Education by Offering Salient Technology Training to Preservice Teachers

A Graduate-Level Course on Using Software To Teach Chemistry

Daniel C. Tofan

Department of Chemistry, Eastern Kentucky University, Richmond, KY 40475; daniel.tofan@eku.edu

The importance of training chemistry teachers in computer technology does not need an elaborate rationale. Almost every aspect of teaching high school and college chemistry makes use of computers. Formal training of teachers in such technology, however, is less common. The Department of Chemistry at this institution offers a B.A. program with an option in chemistry teaching. The main purpose of the degree is to train high school teachers, a job that is quite in-demand in Kentucky. However, little is done to make sure that the chemistry teachers we train are computer literate. The only such course required by the program is a general education course that presents basic concepts such as using e-mail and word processors. Even graduate students who serve as teaching assistants do not necessarily have the computer skills necessary to make them effective teachers in today's society.

It seems that formal training in using computer software for chemical education is needed, yet not currently offered in many programs. Usage of computers has been reported by others in lower-level chemistry curricula (1–7) or in chemical education research (8–9), and the number of literature papers that deal with computer-based learning is in the thousands. No one, however, reports the development of a course dedicated to teaching computer-based tools to future chemistry teachers. This paper briefly describes a new course offered for the first time at EKU in fall 2007. The online supplement discusses details concerning the organization of the course, including topics covered, assessment, and student feedback.

Developing and Implementing the Course

The course mainly focused on publishing tools, computer languages for data storage and retrieval, drawing software, virtual labs, and data collection software. The design of the course was driven primarily by local needs. Teaching assistant (TA) training and the structure of the teacher preparation program at EKU were the primary driving forces behind the first offering of this course. Current literature selections were also consulted to provide the students with tools generally used by the community. CONFCHM (CONFerences on CHEMistry), offers online conferences in chemistry education and research on particular topics that have been helpful in this approach, as well as recent works in the literature, which report on the use of Blackboard (10–11), Excel (12–20), the Web (21–22), online instruction and assessment (23), Java and Javascript software (24–25), virtual labs (26–29), chemical drawing tools (30), and probeware in connection with computers for teaching general chemistry (31–33). A compelling argument has been made recently (34) about the importance of developing collaborations between chemical educators and computer scientists in teaching and

research. This, coupled with the instructor's qualifications and research interests, prompted the introduction of some sort of programming in this course, which would foster the development of software for use in chemical education.

Course Logistics

From a curricular point of view, the course was cross-listed as Chemistry Special Topics CHE 501/701/805. A total of 12 students took this course in Fall 2007 (5 undergraduate and 7 graduate students). Two of the undergraduate students were chemistry teaching majors, and one of the graduate students was working towards an M.A. degree in secondary education. These three students took the course to help in their intended profession (future high school teachers). Five graduate students were TAs in the Chemistry department (two of whom were international students) and took this as a 800-level course to fulfill one of their degree requirements. The rest of the students took the course as an elective. Two undergraduates dropped the course close to the mid-semester. Their reason for withdrawing from the class was because of the software programming covered in the course, which they found quite difficult. All other students completed the course successfully.

The course was offered as a three-hour lecture–discussion class and was taught once a week in a computer lab equipped with a SmartBoard. A lesson plan was created for each session and distributed to students. The first hour to hour-and-a-half was taught in lecture style. The instructor presented each software package, explained why it is useful in teaching chemistry, and showed its main features. For the second part of the session, students were asked to work in pairs on tasks distributed by the instructor as part of the lesson plan. Tutorials were posted online for software packages that required more explanation than the instructor could give in the lecture part. Students used the tutorials to complete the assignments in class whenever possible. Homework assignments were given for each new topic. Some homework was an extension of what was done in class (such as completing XML or database projects), in other cases new assignments needed to be completed (such as Web site, spreadsheet, or tutorial creation). Further examples of such assignments are provided in the online supplement.

Assignments and Assessment

All assignments needed to be uploaded into the Blackboard course management system by the due date. A blog was created for each topic. Each student was able to upload multiple assignments into their section of the blog and append comments if desired. Only the instructor had access to all the blog sections. Students could not see other students' entries before the due date, but were allowed to see the entries afterwards. This dis-

couraged dishonest practices. While some assignments were identical for the entire class, in other cases students had to pick from a list of suggested assignments in order to promote variety in the tasks completed. For example, on the topic of Microsoft Office 2007, students had to pick one task each to complete (out of two or three possible) from task lists for Word, Excel, and PowerPoint.

Three categories were used to assess the students' performance in this course. The majority of the points were given for homework: most assignments were graded on a three-point scale, with larger assignments graded on a six-point scale. In grading each assignment, the following criteria were considered: the usefulness of the document produced (when a student had to choose among tasks); the quality of the work done; how the work compared to the rest of the class (when similar tasks were assigned); and whether it was on time (small deductions were applied for late submissions).

Student projects comprised the second assessment category. For this assignment due at the end of the semester, each student had to create a project based on one or more tools presented in the course. Each project had to be completed using software appropriate to the topic, and summarized in the form of a poster. A PowerPoint presentation of the project was also required. Each project was graded on a six-point scale. All project presentations were given during the last meeting of the class. One-page versions of each poster created, as well as some of the more interesting homework assignments, are included as part of the online supplement.

The third category for assessment applied to graduate students only. These students had to identify a recent article in this *Journal* (or an equivalent journal) that dealt with using computers in chemical education. An oral presentation of the literature paper was required. The presentation was graded on a six-point scale and points were assigned based on the relevance of the paper, the quality of the results and conclusions presented, the manner of presentation, and feedback from peers. Two undergraduate students offered to give presentations (not required) for extra credit (up to three points). A total of nine good papers were presented to the class in one session.

No final exam or midterms were given. Letter grades were assigned based on a 90/80/70% scale. The final grade distribution was seven A's and three B's (in addition to the two W's representing the undergraduate students who withdrew from the course).

Feedback about the Course from Students

Students were given an exit survey in Blackboard and asked to provide feedback about the course. Most questions were in multiple-choice format, although a few essay questions were added as well. All 10 students enrolled took the survey. The majority of the students were satisfied with this course and they definitely appreciated the no-exams approach to assessment. Opinions were divided regarding the variety of software programs or other technical elements presented—some wanted to see less, some wanted more. Two students indicated that they wanted to see Java programming being taught, which could have been a possibility. However, it is impossible to teach the Java syntax, concepts, and applications for chemistry (or anything else, for that matter) in just one semester. Special topics courses

are typically not offered as two-semester sequences. Some programming background is needed in order to understand a complex, object-oriented language such as Java. The audience for this course simply does not have such a background. Thus, the only real programming taught in this class was the structured query language (SQL). Even this proved to be challenging for some students, as evident from the feedback received (Microsoft Access was regarded as the most difficult topic) and the fact that two students withdrew because of difficulties with SQL.

Students found the drawing programs among the most useful, followed, surprisingly, by XML, which they actually struggled with for a while. Also surprising is that only half the class found MS Office programs useful. Students also did not like Virtual Lab, most likely because of its limited capabilities and somewhat less friendly authoring tool.

Conclusions

Considering the very diverse audience that took this course (remarkable in itself, considering the class size), a compromise between publishing tools and programming should probably be found. Regardless of the topics presented, a course that teaches teachers how to better use computer software in their jobs is highly recommended, inexpensive, and easy to implement. In this day and age, it is imperative that high school teachers be aware of the variety of software products that are available for teaching chemistry.

Literature Cited

- Meyer, D. E.; Sargent, A. L. *J. Chem. Educ.* **2007**, *84*, 1551–1552.
- Pearson, J. K. *J. Chem. Educ.* **2007**, *84*, 1323–1325.
- Jones, R. B. *J. Chem. Educ.* **2000**, *77*, 1085–1087.
- Kantardjiev, K. A.; Hardinger, S. A.; Willis, W. V. *J. Chem. Educ.* **1999**, *76*, 694–697.
- Yang, E.-M.; Greenbowe, T. J.; Andre, T. *J. Chem. Educ.* **2004**, *81*, 587–595.
- Lundberg, P. *J. Chem. Educ.* **1997**, *74*, 1489–1490.
- Young, J. A. *J. Chem. Educ.* **1970**, *47*, 758–759.
- Hood, B. J. *J. Chem. Educ.* **1994**, *71*, 196–200.
- Breneman, G. L. *J. Chem. Educ.* **1983**, *60*, 731.
- Cartwright, A. *J. Chem. Educ.* **2000**, *77*, 699.
- Rodgers, S. *J. Chem. Educ.* **2000**, *77*, 700.
- Page, T. R.; Boots, C. A.; Freitag, M. A. *J. Chem. Educ.* **2008**, *85*, 159.
- Coleman, W. F. *J. Chem. Educ.* **2002**, *79*, 896.
- Denton, P. *J. Chem. Educ.* **2000**, *77*, 1524–1525.
- Howard, E.; Cassidy, J. *J. Chem. Educ.* **2000**, *77*, 409–411.
- Harris, D. C. *J. Chem. Educ.* **1998**, *75*, 119–121.
- Greathouse, J. A. *J. Chem. Educ.* **1997**, *74*, 1279.
- Billo, E. J. *J. Chem. Educ.* **1996**, *73*, A40.
- Moseley, C. G. *J. Chem. Educ.* **1996**, *73*, 62.
- Al-Khlaifat, A.; AlRifai, R. *Chem. Educat.* **2002**, *7*, 384–386.
- Pence, L. E.; Pence, H. E. *J. Chem. Educ.* **2008**, *85*, 1449–1452.
- Markwell, J.; Brooks, D. W. *J. Chem. Educ.* **2008**, *85*, 458–459.
- Koch, J.; Van Der Sluys, W. G. *J. Chem. Educ.* **2001**, *78*, 1696–1698.
- Coleman, W. F.; Fedosky, E. W. *J. Chem. Educ.* **2006**, *83*, 173–174.

25. Barrie, P. J. *J. Chem. Educ.* **2005**, *82*, 958–960.
26. Stone, D. C. *J. Chem. Educ.* **2007**, *84*, 1488–1496.
27. Woodfield, B. F.; Andrus, M. B.; Waddoups, G. L.; Moore, M. S.; Swan, R.; Allen, R.; Bodily, G.; Andersen, T.; Miller, J.; Simmons, B.; Stanger, R. *J. Chem. Educ.* **2005**, *82*, 1728–1735.
28. Woodfield, B. F.; Catlin, H. R.; Waddoups, G. L.; Moore, M. S.; Swan, R.; Allen, R.; Bodily, G. *J. Chem. Educ.* **2004**, *81*, 1672–1678.
29. Martínez-Jiménez, P.; Pontes-Pedrajas, A.; Climent-Bellido, M. S.; Polo, J. *J. Chem. Educ.* **2003**, *80*, 346–352.
30. Sandberg, K. A. *J. Chem. Educ.* **2006**, *83*, 1601.
31. Baksa, K. *J. Chem. Educ.* **2007**, *84*, 1611.
32. Koehler, B. P.; Orvis, J. N. *J. Chem. Educ.* **2003**, *80*, 606–608.
33. Carvalho-Knighton, K. M.; Keen-Rocha, L. *J. Chem. Educ.* **2007**, *84*, 727–730.
34. Haines, R. S.; Woo, D. T.; Hudson, B. T.; Mori, J. C.; Ngan, E. S. M.; Pak, W.-Y. *J. Chem. Educ.* **2007**, *84*, 967–970.

Supporting JCE Online Material

<http://www.jce.divched.org/Journal/Issues/2009/Sep/abs1060.html>

Abstract and keywords

Full text (PDF)

Links to cited URLs and JCE articles

Supplement

Details of course logistics, course topics, student assessment, feedback, online tutorials, and example student-produced material

Development of a new graduate level course on using software in teaching

Supplemental materials

Contents

Course organization	2
Topics covered	3
Web and BlackBoard	3
Microsoft Office 2007 (Word, Excel, PowerPoint)	4
Microsoft Access 2007	6
XML	8
Drawing software	9
Virtual labs	10
Vernier LoggerPro	11
Adobe Captivate	11
Assessment	12
Feedback	15
Table 1	15
Table 2	16
Table 3	16
Table 4	17
Table 5	18
Table 6	18
Table 7	19
Table 8	19
Table 9	20
Online tutorials	22
Student produced materials (class assignments)	22

Course organization

The course was offered as a 3 hour lecture/discussion and was taught once a week at 6 PM in a computer lab. A lesson plan was created for each session and distributed to students. The first hour to hour and a half was taught in lecture style. The instructor presented the software package, explained why it is useful in teaching chemistry, and showed its main features. For the second part of the session, students were asked to work in pairs on tasks distributed by the instructor as part of the lesson plan. Tutorials were posted online for software packages that required more explanation than the instructor could give in the lecture part. Students used the tutorials to complete the assignments in class whenever possible. Homework assignments were given for each new topic. Some homework was an extension of what was done in class, in other cases new assignments needed to be completed.

All assignments needed to be uploaded into the BlackBoard course management system by the due date. A blog was created for each topic. Each student was able to upload multiple assignments into their section of the blog and append comments if wanted. Only the instructor had access to all the blog sections. Students could not see other students' entries before the due date but were allowed to see them afterwards. This discouraged dishonest practices. While some assignments were identical for the entire class, in other cases students had to pick from a list of suggested assignments in order to promote variety in the tasks completed. For example, on the topic of Microsoft Office 2007, students had to pick one task each to complete (out of two or three possible) from Word, Excel and PowerPoint lists.

Students were required to sign a confidentiality agreement during the first meeting. The agreement stipulated that all data that they had access to was to be maintained confidential, and that all documents produced as part of the course may be used later for instructional purposes.

The courses spanned 15 weeks total. The first 13 weeks were used for teaching and in-class assignments, and the last two were used for student presentations (explained in the assessment section).

Topics covered

The main focus of the course was on publishing tools, data storage and retrieval, drawing software, virtual labs and data collection. Topics are described in detail as follows.

Web and BlackBoard

One session was spent on creating web pages and using the BlackBoard CMS. Students were instructed to search the internet for a free web editor and create a skeleton for a website.

Alternatively, they could use Adobe Dreamweaver as part of their homework assignment (we did not have a license in the computer lab used to teach the course, but it was available on other school computers). The class consensus was to install and use 1stPage 2000, a full-featured, free, visual HTML editor. The task was to create a website listing the student's information and interests, then to create links to at least 10 but not more than 20 chemistry related websites that they considered interesting, and to explain their choices of the websites.

For the second part of the class, features of the BlackBoard system specific to instructors were presented. Students were shown how to use the grade book, how to create question pools and tests, how to post assignments, etc. The assignments given consisted of:

- Creating a 10 question pool containing multiple choice questions pertaining to general chemistry labs
- Creating a 5 question pool containing algorithmic questions written using the equation editor in BlackBoard
- Creating a test that used the two question pools and posting it, with a set number of attempts and expiration date

Two additional BlackBoard sections were created for the course. Each student was a “TA” in one section and a “student” in another. Students were able to create assignments in one section and take assignments in the other, thus testing both the instructor and the student view in BlackBoard.

The last part of the BlackBoard assignment was to upload the webpage created in the web editor, saved as a single HTML file, into the blog section created for this topic.

Microsoft Office 2007 (Word, Excel, PowerPoint)

Since most students already had experience using Microsoft Office, emphasis was placed on a number of new features that the 2007 version offers, and other additional tools as described below. For MS Word, the new equation editor was presented. This editor makes writing subscripts and superscripts much easier, which was a useful feature for writing chemical

formulas and equations. An alternative was presented in the form of the chemical equation package from *efofex.com*. This program installs on top of MS Word and allows writing formulas by typing symbols and indexes inline, and then it converts the text automatically to a formatted display based on an internal algorithm. For example, typing “H2SO4” in the editor box leads to “H₂SO₄” in the text body once the editor is closed. The same applies to chemical equations, etc. This editor is easier to use and clearly has more features for writing chemical symbolism than the Word equation editor, but it is not free.

For Excel, students were taught how to download and upload the grade book from BlackBoard, how to create a quadratic equation solver for equilibrium problems, and how to apply VLOOKUP functions in grading keys.

For PowerPoint, the new text formatting features were presented, and a skeleton of the periodic table was built by creating shapes and arranging them in the appropriate order on a custom sized slide.

Assignments given consisted of:

- Creating a unit conversion sheet for general chemistry (Word/Excel)
- Creating a tutorial for the determination of the atomic radius for the three types of cubic unit cells (Word/PowerPoint)
- Creating a grade book that calculated student grades based on weighted categories (quizzes, exams, homework etc) and using the VLOOKUP function to assign letter grades (Excel)

- Creating a grading key for a lab experiment that took into account the experimental data and assigned a grade based on how close the student answer was to the provided answer (Excel)
- Creating a tutorial that explains how galvanic cells work (PowerPoint)
- Creating a flow chart that helps solve one particular type of problem in general chemistry, such as balancing redox reactions (PowerPoint)

All three programs were covered in one session and the homework was due the following week.

Microsoft Access 2007

Access was covered separately from the other three Office programs due to its complexity. Three weeks were spent on Access and SQL alone. Students were for the most part unfamiliar with Access and its use. The topic was divided in two parts. In one session, a database was created using the visual tools provided by Access 2007. The database was designed to be used by someone who would manage a stockroom. Features needed were: student rosters, lists of equipment and cost associated, and a way of keeping track of breakages and inventory. Students learned how to create forms for entering data, how to design queries to extract data, and how to create reports to present results. A self paced Access tutorial was provided [1] and sample student rosters were made available for data entry.

The second part of Access (covered in two weeks) consisted of analyzing a real database and using the SQL language for writing queries that provide information needed. A self-paced SQL tutorial was provided [2] and students worked in pairs to learn the SQL constructs needed in order to obtain the data required. The database was provided by the instructor and contained real

attendance records from one semester of the introductory chemistry open lab at ECU. The following tasks needed to be completed by writing SQL queries:

- Find students who had to be removed from the lab in all experiments (this query was built in class as an example)
- Find a student's attendance record given the student ID number
- Find a student's attendance record given the student last and first name
- Find students who attended a particular experiment; display the day they attended, times of check in and check out; sort alphabetically
- Find students who did not attend a particular experiment; sort alphabetically
- Find students who missed all experiments; sort alphabetically
- Find students that did not fill out a safety sheet; sort alphabetically
- Find how many students attended lab per experiment, per day of the week; sort by experiment number and by day of the week
- Find who worked at a particular workstation during a given week; display student info, which day and times; sort by day and time attended
- List all the majors for all the students enrolled, and how many of each major; sort by most popular major
- Find what unknowns were assigned to a particular student in a particular experiment

The following reports needed to be built based on some of the queries above and printed:

- Generate a list of all students, sorted alphabetically, to be used for sales of glasses and video cd's
- Generate a report showing the results obtained by all students on a particular experiment
- Generate a list of all students, sorted alphabetically, showing how many labs each student had missed

A copy of the database containing all the queries and reports, plus pdf versions of the reports that were generated, were uploaded into BlackBoard by each student.

XML

The purpose of this topic was to learn how to create structured documents for storing text-based data. The principles of using XML as a content tagging language were presented, and students were shown the conceptual and practical similarities and differences between XML and HTML. A self paced XML tutorial was presented [3]. Students learned about elements, attributes, element hierarchy, PCDATA content, DTD validation, etc. A brainstorming session was held, where the class had to come up, under the instructor's guidance, with the skeleton of a document template that could be used to store data about a chemical element. The template was then to be expanded to create the entire periodic table in XML. Once consensus was reached regarding what elements and attributes to use and how to organize them, a free XML editor was installed (XMLShell [4]), and students started to create the XML structure visually. This particular XML editor was chosen because it offers copy and paste options for nodes, and allows data to be

viewed in tree format as well as expanded as a complete XML document. The structure and data can be edited in either view.

As homework, students had to populate the template with data about the chemical elements. Each student was assigned approximately 10 elements based on the periodic table groups. The total time spent on this topic was three weeks. Students found XML complicated, especially because any small error in the structure would lead to an invalid document. At the end of the three weeks, the entire Periodic Table was available in XML format. However, putting all the XML together and performing data validation on the entire tree was a daunting task that was not undertaken by anyone taking the course.

Drawing software

Two different types of drawing software were discussed under this topic. First, chemical structure drawing programs were introduced. We chose to use freeware only, and so programs covered were ISIS Draw and ChemSketch 10. One graduate student had more experience using these programs and was invited to show the rest of the class how to draw structures and reactions.

The second type of software introduced was Adobe Illustrator. As a tutorial, we used a paper written by a student who had completed an independent study project a year ago on how to use Illustrator to draw various equipment for labs. Students found Illustrator difficult to use. Not only did it have many tools that they needed to learn how to use, but also some talent was needed to draw the required shapes and put them together into something useful. Thus, for homework assignments, Illustrator was only optional. Not surprisingly, students chose not to use this

software. As a result of this, all assignments turned in consisted of structures and reactions drawn with one of the other two products.

Virtual labs

The Virtual Lab developed using Java by the ChemCollective group from Carnegie Mellon University [5] was used to demonstrate how to perform virtual experiments on the computer. The features of the Virtual Lab are rather limited. The main “instruments” available are a pH meter, a thermometer, and a “species concentration meter”, which basically shows the concentration of each species present in solution. The main objection against the latter was that it is not a realistic representation of what a student would have available in the lab. In some cases that gauge was useful, but for the most part we chose to leave it out.

The ChemCollective group provides quite a few sample activities that they developed. Students were told to run a few of them and understand how to manipulate the virtual benchtop. A number of automatically graded problems were also available. Students were asked to install the virtual lab on their computers and perform activities. As an assignment, students had to choose between:

- Coming up with a new activity that represents a simple experiment that could be performed and solved using the Virtual Lab program; or
- Using one of the automatically graded activities (online) to create a problem for an existing lab experiment to be used as a prelab

As part of the assignment, a small tutorial had to be written on how to use the tool. Students were allowed to work in pairs on this assignment. Creating a new activity required the use of the

provided authoring tool and the copying of a few XML files into a specific folder in order for the Virtual Lab to read and recognize the new activity.

Vernier LoggerPro

The LoggerPro 3.5 software from Vernier is currently used in our General Chemistry labs for data collection (second semester only). Our TA's do not know how to use this program and thus they need to be trained. One week of this course was spent presenting the main features of LoggerPro and how it can be used for data collection and analysis. Students connected a few probes and collected some fake data for later processing using the software. They ran the tutorials provided by Vernier in order to get familiar with its features.

As homework, each student had to create a new LoggerPro file to be used for an actual experiment. Creating calculated columns was the most important part of this exercise. Some of the files created are now used in our labs in place of the originals provided by Vernier. We added a few extra features to make the files more useful and more visually appealing.

Adobe Captivate

The last major topic presented in the course was Adobe Captivate and its use to create animated tutorials. Since this program was presented right after LoggerPro, most students chose to use it to create a small tutorial for a particular feature of LoggerPro. Captivate records mouse movements and mouse clicks and creates storyboard-like tutorials. This proved to be a very useful tool to create video tutorials for programs that have a learning curve, such as LoggerPro. The animations created can be saved as Flash files for display on the web. Narration can be added if desired.

The last session of the course dedicated to instruction was used to present a “medley” of other software tools that could be used in education. Students in the class were invited to present programs that they were familiar with that were not included in the course. Among the software presented during this session were: Inspiration (a program that creates self arranging diagrams, schemes and concept maps), Microsoft Publisher (desktop publishing), Web of Science, Mathematica, Microsoft Visual SourceSafe (document manager for groups), Open Office (Java based open source alternative to MS Office), PDF Split and Merge (for joining and splitting pdf files), and Office Printer (for creating labels). To end on a fun note, MS Streets and Trips and Google Earth were also part of the medley.

Assessment

Three categories were used to assess the students’ performance in this course. The majority of the points were given for homework. Most assignments were graded on a 3 point scale (good = 3, average = 2, poor = 1, unacceptable = 0, not turned in = -1). SQL and XML assignments were graded on a 6 point scale, since they required more effort. In grading each assignment, the following were taken into consideration: the usefulness of the document produced (when the student had to choose), the quality of the work done, how it compared to the rest of the class (when assignments were similar), and whether it was late (some small deductions were applied).

The second category was represented by student projects. At the end of the semester, each student had to create a “project”, based on one or more tools presented in the course. A list of possible projects was given as a source of inspiration, but students were encouraged to come up with their own ideas. Most students, as expected, chose projects from the list suggested. Each

project had to be executed using appropriate software based on its nature and summarized in the form of a poster. A PowerPoint presentation of the project was also required. Each project was graded on a 6 point scale. The projects executed by students are listed below:

- A concept map for General Chemistry I. Ten chapters of the current general chemistry book in use at ECU (McMurry-Fay 8th edition) were summarized in the form of a large poster and a concept map was created using the Inspiration software. Images and graphs were included to catch attention and make the poster visually attractive.
- A guide to IUPAC naming of organic compounds, including functional groups
- A guide to common chemistry laboratory equipment and safety rules applicable to undergraduate labs
- A website for nomenclature of inorganic compounds. The website was created as a single HTML file and summarized as a poster. Examples were given, and crossword puzzle games were included.
- A tutorial on how to calculate pH in acid-base titrations. Strong-strong and strong-weak cases were covered, and titration curves were included. Calculations for each stage of the titration (before, at and after the equivalence point) were treated in detail. Pictures of the titration apparatus were added to make the poster appear less math intensive than it really is.
- A tutorial on how to determine the pH of an aqueous solution. This poster covered strong and weak acids and bases, hydrolysis of salts, and buffers. It also included a list of everyday life chemicals and what their approximate pH's are.

- A LoggerPro tutorial using Captivate. One student wrote a complete tutorial for LoggerPro using Captivate and summarized the various sections on the poster in the form of slides taken from Captivate. This tutorial is now used in our labs.
- A Virtual Lab experiment for deriving solubility rules for ionic compounds. This project was an original idea that a student proposed. He used the virtual lab's ability to show solid compounds as such in order to derive solubility rules (the ones taught in general chemistry) by performing a virtual experiment. While not all compounds could be represented, the concept was neat and illustrative for this topic that many beginning students struggle with.
- A visual Periodic Table. All elements were displayed in a format that included pictures of element samples (when available), the representation of the crystal structure (when known), a summary of the physical properties of the element, and a list of common facts and trivia about the element. The poster was created by joining individual slides for each element into one large PowerPoint file. The poster is scalable to large dimensions, and is visually appealing. A minimum size of 42x56 inches is recommended for the small print (facts about the elements) to be readable without much effort.

All project presentations were given during the last meeting of the class. Posters have been displays inside the hallways of the ECU Chemistry Department.

The third category for assessment applied to graduate students only. Each student had to identify a recent article in the Journal of Chemical Education (or an equivalent journal) that dealt with using computers in chemical education. An oral presentation of the literature paper was required.

The presentation was graded on a 6 point scale and points were assigned based on the relevance of the paper, the quality of the results and conclusions presented, the manner of presentation, and feedback from peers. Two undergraduate students offered to give presentations (not required) for extra credit (up to three points). A total of nine good papers were presented to the class in one session.

There was no final exam or midterms given. Letter grades were assigned based on a 90/80/70 percent scale. The final grade distribution was 8 A's and 2 B's (in addition to the 2 W's).

Feedback

Students were given an exit survey in BlackBoard and asked to provide feedback about the course. Most questions were in multiple choice format but a few essay questions were added as well. All 10 students enrolled took the survey. Tables 1-6 summarize feedback received through the multiple choice questions and Tables 7-9 show the feedback received through the essay question.

Table 1

Question:	Number answered “yes”	Number answered “no”
Are you happy that you took this course?	10	0
Are you happy with the course format?	7	3
Are you happy with the fact that no exams were	10	0

given?		
Would you take another ChemEd course if offered?	7	3
Would you take another ChemEd course from the same instructor?	9	1

Table 2

Question: How do you feel about the number of software products presented?	Number answered
Just the right number were presented	5
Too many were presented	3
Too few were presented	2

Table 3

Question: What do you think about the usefulness of the software presented?	Number answered
Most is useful in teaching chemistry	7
Some of it is useful but some not	3
Most is not useful in teaching chemistry	0

Table 4

Question: Which software did you find most useful? Check as many as applicable.	Number answered
Web development	5
Blackboard	3
MS Office (except Access)	5
Access	3
XML	6
Drawing programs	7
Virtual lab	4
LoggerPro	3
Captive	3
Other	1

Table 5

Question: Did you find the papers presented by your colleagues useful?	Number answered
Yes, most of them	4
Only about half of them or so	5
Did not like most	1

Table 6

Question: Did you feel that your project will contribute to improving the way we teach chemistry?	Number answered
Definitely	4
Probably	6
Definitely not	0

Table 7

Question: What other programs would you have liked to see?
Some programs related to java
A program that can derive a enzyme sequence
I think most programs were covered pretty well, I found most of the programs very useful but wish that we could spend more time on a few of them
Chem Office, Scifinder, MDL Crossfire Commander
JAVA or something related to it.

Table 8

Question: Which programs did you NOT like very much? Please elaborate.
I did not like Access, but only because it was something I was not very familiar with. Maybe with some more practice I would understand how to use it better.
Virtual Lab...the program is too buggy
I think it is not easy to learn language and follow, I think you also observed that almost all students having problem with Access, I feel probably you think something better way to improve this situation.
Virtual Lab: Although a very good program, way to difficult to understand in a week and design

a lab on top of it.
Access - system is complicated and hard to pick up in a short amount of time. Probably should have spent more time going over the logic in example queries, etc. before turning us loose. I've seen offerings for 2 & 3 day introductory seminars for Access - there was too much to cover in too short a time.
Virtual Lab and LoggerPro. Both were very finicky and I found them hard to work with.
Access, it was presented well but it was hard to grasp
Virtual Lab. I didn't feel that it was as user-friendly as it could have been and it didn't have the capabilities of other virtual activities. If you want to show how limited the capabilities were previously and show how far virtual activities have come it is a good "before" model.

Table 9

Question: What else would you like to add about this class? Suggestions?
I enjoyed this class very much, I learned a lot about different programs, but not as much as I would have liked. Maybe instead of 10 programs on the syllabus, use 5 and spend some time on each of them so we can get a better understanding of the actual programs
A bit more clarification on what is expected of each HW assignment. Especially towards the end, where the assignments expectations were not clear in fact what was desired was not exactly clear.

I would like to encourage group study/work so that you can share knowledge and learn more, it will be better if it is applied for in class assignments.

Honestly I liked everything you taught in this class.

I was expecting some basics related to java to be taught in the class.

You should explain few examples or problems related to a software, instead of just giving tutorial (ofcourse you did for some in the begining which made our work easy for those softwares).

I found this class to be very helpful. I learned about a lot of tools that will be useful in my career.

In general, it's hard to integrate instruction for people with so many different pre-existing levels of knowledge/understanding. In many cases I feel like I had insufficient practice/experience before trying to take on an assignment in a new system, but in systems with which I was familiar the tasks were pretty easy.

I think it is a very useful course for anyone planning to go into teaching. All the programs and software we used are definitely ones that would be helpful for students and teachers.

Online tutorials

1. Access 2007 tutorial. <http://www.fgcu.edu/support/office2007/access/index.asp> (accessed September 2007)
2. SQL tutorial. <http://www.w3schools.com/sql/default.asp> (accessed September 2007)
3. XML tutorial. <http://www.w3schools.com/xml/default.asp> (accessed October 2007)
4. XMLShell. <http://www.softgauge.com> (accessed October 2007)
5. The Chemistry Collective. <http://www.chemcollective.org> (accessed November 2007)

Student produced materials (class assignments)

1. Conversion sheet (3 pages)
2. XML example (5 pages)
3. VSEPR tutorial (PowerPoint, 2 pages)
4. Virtual lab experiment and answer key (4 pages)
5. ChemSketch example (4 pages)
6. Captivate tutorial example (4 pages)

Fun with Conversions

Prefix	Symbol	Factor	Prefix	Symbol	Factor
Yotta	Y	10^{24}	Deci	d	10^{-1}
Zetta	Z	10^{21}	Centi	c	10^{-2}
Exa	E	10^{18}	Milli	m	10^{-3}
Peta	P	10^{15}	Micro	μ	10^{-6}
Tera	T	10^{12}	Nano	n	10^{-9}
Giga	G	10^9	Pico	p	10^{-12}
Mega	M	10^6	Femto	f	10^{-15}
Kilo	k	10^3	Atto	a	10^{-18}
Hecto	h	10^2	Zepto	z	10^{-21}
Deka	da	10^1	Yocto	y	10^{-24}

SI Base Units

Base Quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

SI Derived Units

Derived Unit	Measures	Derivation	Formal Definition
hertz (Hz)	frequency	/s	s^{-1}
newton (N)	force	$kg \cdot (m/s^2)$	$kg \cdot m \cdot s^{-2}$
pascal (Pa)	pressure	N/m^2	$kg \cdot m^{-1} \cdot s^{-2}$
joule (J)	energy or work	$N \cdot m$	$kg \cdot m^2 \cdot s^{-2}$
watt (W)	power	J/s	$kg \cdot m^2 \cdot s^{-3}$
coulomb (C)	electric charge	$A \cdot s$	$A \cdot s$
volt (V)	electric potential	W/A	$kg \cdot m^2 \cdot s^{-3} \cdot A^{-1}$

Conversion Factors

Volume	Length
1 Liter = 10^{-3} m^3	1 meter = 39.370 inches
1 Liter = 1000 mL	1 meter = 1000 millimeters
1 Liter = 1 dm^3	1 meter = 100 centimeters
1 Liter = .264 gallon	1000 meters = 1 kilometer
	1 mile = 5,280 feet
	1 foot = .3048 meters
	1 foot = 12 inches

Mass	Pressure
1 kilogram = 1000 grams	1 atmosphere = 1.01325 bars
1 pound = 0.45359 kilograms	1 atmosphere = 760 mmHg = 760 torr
1 gram = 1000 milligrams	1 atmosphere = 101325 pascals
1 ton = 907. 2 kilograms	1 atmosphere = 14.696 pounds per square inch (psi)

Temperature
Kelvin to Celsius $\text{K} - 273.15 = ^\circ\text{C}$
Kelvin to Fahrenheit $1.8(\text{K} - 273.15) + 32 = ^\circ\text{F}$
Fahrenheit to Celsius $^\circ\text{C} = (5/9)(^\circ\text{F} - 32)$

Avogadro's number = 6.022×10^{23}

For more unit conversions look at this site :

http://www.chemie.fu-berlin.de/chemistry/general/units_en.html

Dimensional Analysis Examples

1. Convert 12.34 moles of arsenic into grams of arsenic. The molecular weight of arsenic is 74.92 grams/mole. (mole to gram conversion)

$$12.34 \text{ moles As} * \frac{74.92 \text{ grams As}}{1 \text{ mole As}} = 924.5 \text{ grams As}$$

2. If the pressure in your tire is 12323 pounds per square inch, what is this value in torr? (pressure conversion)

$$12323 \text{ pounds per square inch} * \frac{1 \text{ atm}}{14.696 \text{ psi}} * \frac{760 \text{ torr}}{1 \text{ atm}} = 637281 \text{ torr}$$

3. What is the density of water in kg/m³ (d=1.00 g/cm³)? (volume and mass conversion)

$$\frac{1.00 \text{ grams}}{1 \text{ cm}^3} * \frac{1 \text{ kilogram}}{1000 \text{ grams}} * \left(\frac{100 \text{ cm}}{1 \text{ meter}} \right)^3 = 1000 \text{ kilograms/meters}^3$$

4. If it is 23°C outside what is this temperature in °F? (temperature conversion)

$$23^\circ\text{C} = \frac{5}{9}(\text{°F} - 32)$$
$$\text{°F} = 73.4$$

5. A man is 6 feet tall. How many meters is that? (length conversion)

$$6 \text{ feet} * \left(\frac{.3048 \text{ meters}}{1 \text{ foot}} \right) = 1.829 \text{ meters}$$

6. Convert 25,000,000 nanometers to kilometers.

$$25,000,000 \text{ nanometers} * \frac{10^{-9} \text{ meters}}{1 \text{ nanometer}} = .025 \text{ meters}$$

7. How many atoms of helium are in 4 moles of He gas? (mole to atom conversion)

$$4 \text{ moles He} * \frac{6.022 \times 10^{23} \text{ atoms He}}{1 \text{ mole He}} = 2.41 \times 10^{24} \text{ atoms of He}$$

```

<?xml version="1.0" ?>
<!-- Created by XmlShell on 10/4/2007 4:46:34 PM -->
- <periodicTable>
- <group name="5B" number="5" commonName="transition metals" block="d">
- <element period="4" symbol="V" name="Vanadium" atomicNumber="23">
  <atomicMass units="amu">50.9415</atomicMass>
- <isotopeList>
- <isotope massNumber="47" natural="no">
  <exactMass units="amu">46.954907</exactMass>
  <abundance units="%">0</abundance>
- <radioactivity>
  <decay mode="ec" />
  <halfLife units="m">32.6</halfLife>
</radioactivity>
</isotope>
- <isotope massNumber="48" natural="no">
  <exactMass units="amu">47.952254</exactMass>
  <abundance units="%">0</abundance>
- <radioactivity>
  <decay mode="ec" />
  <halfLife units="d">15.98</halfLife>
</radioactivity>
</isotope>
- <isotope massNumber="49" natural="no">
  <exactMass units="amu">48.948517</exactMass>
  <abundance units="%">0</abundance>
- <radioactivity>
  <decay mode="ec" />
  <halfLife units="d">337</halfLife>
</radioactivity>
</isotope>
- <isotope massNumber="50" natural="yes">
  <exactMass units="amu">49.9471609</exactMass>
  <abundance units="%">0.250</abundance>
  <radioactivity />
</isotope>
- <isotope massNumber="51" natural="yes">
  <exactMass units="amu">50.9439617</exactMass>
  <abundance units="%">99.750</abundance>
  <radioactivity />
</isotope>
- <isotope massNumber="52" natural="no">
  <exactMass units="amu">51.944780</exactMass>
  <abundance units="%">0</abundance>
- <radioactivity>
  <decay mode="beta-" />
  <halfLife units="d">3.76</halfLife>
</radioactivity>
</isotope>
- <isotope massNumber="53" natural="no">
  <exactMass units="amu">52.944342</exactMass>
  <abundance units="%">0</abundance>
- <radioactivity>
  <decay mode="beta-" />
  <halfLife units="m">1.61</halfLife>

```

```

    </radioactivity>
  </isotope>
</isotopeList>
- <electronicProperties>
  - <electronConfig>
    <level label="1s">2</level>
    <level label="2s">2</level>
    <level label="2p">6</level>
    <level label="3s">2</level>
    <level label="3p">6</level>
    <level label="4s">2</level>
    <level label="3d">3</level>
  </electronConfig>
  <electronAffinity units="kJ*mol-1">50.6</electronAffinity>
  <electronegativity scale="Pauling">1.63</electronegativity>
  - <ionizationEnergies units="kJ*mol-1">
    <first>650.9</first>
    <second>1414</second>
    <third>2830</third>
    <fourth>4507</fourth>
    <fifth>6298.7</fifth>
    <sixth>12363</sixth>
    <seventh>14530</seventh>
    <eighth>16730</eighth>
  </ionizationEnergies>
  <atomicRadius units="pm">135</atomicRadius>
  <ionicRadius type="Pauling" oxidationState="+1">88</ionicRadius>
  <ionicRadius type="Pauling" oxidationState="+5">59</ionicRadius>
  <valence>5</valence>
  - <oxidationStates>
    <state>+1</state>
    <state>+2</state>
    <state>+3</state>
    <state>+4</state>
    <state>+5</state>
  </oxidationStates>
</electronicProperties>
- <macromolecularProperties standardState="s">
  <density units="kg*m-3">6110</density>
  <hardness scale="Moh">7</hardness>
  <meltingPoint units="K">2183</meltingPoint>
  <boilingPoint units="K">3680</boilingPoint>
  <criticalTemperature units="K">no data</criticalTemperature>
  - <enthalpies units="kJ*mol-1">
    <fusion>22.8</fusion>
    <vaporization>453</vaporization>
    <atomization>515</atomization>
  </enthalpies>
  <entropy units="J*mol-1*K-1">28.9</entropy>
  - <crystalStructure spaceGroup="Im-3m" cellType="bcc">
    - <cellParams>
      <a units="pm">303</a>
      <b units="pm">303</b>
      <c units="pm">303</c>
      <alpha units="deg">90.000</alpha>
    </cellParams>
  </crystalStructure>
</macromolecularProperties>

```

```

    <beta units="deg">90.000</beta>
    <gamma units="deg">90.000</gamma>
  </cellParams>
</crystalStructure>
  <molarHeatCapacity units="J*mol-1*K-1">24.9</molarHeatCapacity>
</macromolecularProperties>
</element>
- <element period="5" symbol="Nb" name="Niobium" atomicNumber="41">
  <atomicMass units="amu">92.90638</atomicMass>
  - <isotopeList>
    - <isotope massNumber="89" natural="no">
      <exactMass units="amu">88.91349</exactMass>
      <abundance units="%">0</abundance>
      - <radioactivity>
        <decay mode="ec" />
        <halfLife units="h">1.1</halfLife>
      </radioactivity>
    </isotope>
    - <isotope massNumber="90" natural="no">
      <exactMass units="amu">89.911263</exactMass>
      <abundance units="%">0</abundance>
      - <radioactivity>
        <decay mode="ec" />
        <halfLife units="h">14.6</halfLife>
      </radioactivity>
    </isotope>
    - <isotope massNumber="91" natural="no">
      <exactMass units="amu">90.906989</exactMass>
      <abundance units="%">0</abundance>
      - <radioactivity>
        <decay mode="ec" />
        <halfLife units="years">700</halfLife>
      </radioactivity>
    </isotope>
    - <isotope massNumber="92" natural="no">
      <exactMass units="amu">91.907192</exactMass>
      <abundance units="%">0</abundance>
      - <radioactivity>
        <decay mode="ec" />
        <halfLife units="years">3.7E7</halfLife>
      </radioactivity>
    </isotope>
    - <isotope massNumber="93" natural="yes">
      <exactMass units="amu">92.9063772</exactMass>
      <abundance units="%">100</abundance>
      <radioactivity />
    </isotope>
    - <isotope massNumber="94" natural="no">
      <exactMass units="amu">93.907282</exactMass>
      <abundance units="%">0</abundance>
      - <radioactivity>
        <decay mode="beta-" />
        <halfLife units="years">24000</halfLife>
      </radioactivity>
    </isotope>
  </isotopeList>
</element>

```

```

- <isotope massNumber="95" natural="no">
  <exactMass units="amu">94.906834</exactMass>
  <abundance units="%">0</abundance>
- <radioactivity>
  <decay mode="beta-" />
  <halfLife units="d">34.97</halfLife>
</radioactivity>
</isotope>
- <isotope massNumber="96" natural="no">
  <exactMass units="amu">95.908099</exactMass>
  <abundance units="%">0</abundance>
- <radioactivity>
  <decay mode="beta-" />
  <halfLife units="h">23.4</halfLife>
</radioactivity>
</isotope>
- <isotope massNumber="97" natural="no">
  <exactMass units="amu">96.908096</exactMass>
  <abundance units="%">0</abundance>
- <radioactivity>
  <decay mode="beta-" />
  <halfLife units="h">1.23</halfLife>
</radioactivity>
</isotope>
</isotopeList>
- <electronicProperties>
- <electronConfig>
  <level label="1s">2</level>
  <level label="2s">2</level>
  <level label="2p">6</level>
  <level label="3s">2</level>
  <level label="3p">6</level>
  <level label="4s">2</level>
  <level label="3d">10</level>
  <level label="4p">6</level>
  <level label="5s">1</level>
  <level label="4d">4</level>
</electronConfig>
<electronAffinity units="kJ*mol-1">86.1</electronAffinity>
<electronegativity scale="Pauling">1.6</electronegativity>
- <ionizationEnergies units="kJ*mol-1">
  <first>652.1</first>
  <second>1380</second>
  <third>2416</third>
  <fourth>3700</fourth>
  <fifth>4877</fifth>
  <sixth>9847</sixth>
  <seventh>12100</seventh>
</ionizationEnergies>
<atomicRadius units="pm">145</atomicRadius>
<ionicRadius type="Pauling" oxidationState="+1">100</ionicRadius>
<ionicRadius type="Pauling" oxidationState="+5">70</ionicRadius>
<valence>5</valence>
- <oxidationStates>
  <state>+1</state>

```

```
<state> +3</state>
<state> +4</state>
<state> +5</state>
</oxidationStates>
</electronicProperties>
- <macromolecularProperties standardState="s">
  <density units="kg*m-3">8570</density>
  <hardness scale="Moh">6.0</hardness>
  <meltingPoint units="K">2750</meltingPoint>
  <boilingPoint units="K">5017</boilingPoint>
  <criticalTemperature units="K">no data</criticalTemperature>
- <enthalpies units="kJ*mol-1">
  <fusion>26.8</fusion>
  <vaporization>690</vaporization>
  <atomization>733</atomization>
</enthalpies>
<entropy units="J*mol-1*K-1">36.4</entropy>
- <crystalStructure spaceGroup="Im-3m" cellType="bcc">
  - <cellParams>
    <a units="pm">330.04</a>
    <b units="pm">330.04</b>
    <c units="pm">330.04</c>
    <alpha units="deg">90.000</alpha>
    <beta units="deg">90.000</beta>
    <gamma units="deg">90.000</gamma>
  </cellParams>
</crystalStructure>
  <molarHeatCapacity units="J*mol-1*K-1">24.6</molarHeatCapacity>
</macromolecularProperties>
</element>
</group>
</periodicTable>
```

Valence Shell Electron Pair Repulsion Theory (VSEPR)

Bonds are made of electrons. Electrons are negative so therefore they repel each other. Bonds and lone pairs form as far apart from each other as possible.

This theory can be used to determine the electron structure or molecule structure

A special VSEPR notation is used to describe molecular geometries.

We denote the central atom in a structure as "A"
Terminal atoms as "X"
Lone Pairs of electrons as "E"

VSEPR Notations, Electron-Group Geometry, and Molecular Geometry

Number of Electron Groups	Electron-Group Geometry	Number of Lone Pairs	VSEPR Notation	Molecular Geometry	Ideal Bond Angles	Example
2	Linear	0	AX ₂	Linear 	180°	BeCl ₂
3	Trigonal planar	0	AX ₃	Trigonal planar 	120°	BF ₃
3	Trigonal planar	1	AX ₂ E	Angular 	120°	SO ₂

Number of Electron Groups	Electron-Group Geometry	Number of Lone Pairs	VSEPR Notation	Molecular Geometry	Ideal Bond Angles	Example
4	Tetrahedral	0	AX ₄	Tetrahedral 	109.5°	CH ₄
4	Tetrahedral	1	AX ₃ E	Trigonal pyramidal 	109.5°	NH ₃
4	Tetrahedral	2	AX ₂ E ₂	Angular 	109.5°	OH ₂

Number of Electron Groups	Electron-Group Geometry	Number of Lone Pairs	VSEPR Notation	Molecular Geometry	Ideal Bond Angles	Example
5	Trigonal bipyramidal	0	AX ₅	Trigonal bipyramidal 	90°, 120°, 180°	PCL ₅
5	Trigonal bipyramidal	1	AX ₄ E	Seesaw 	90°, 120°, 180°	SF ₄
5	Trigonal bipyramidal	2	AX ₃ E ₂	T-shaped 	90°, 180°	ClF ₃

Number of Electron Groups	Electron-Group Geometry	Number of Lone Pairs	VSEPR Notation	Molecular Geometry	Ideal Bond Angles	Example
5	Trigonal bipyramidal	3	AX ₂ E ₃	Linear 	180°	XeF ₂
6	Octahedral	0	AX ₆	Octahedral 	90°, 180°	SF ₆
6	Octahedral	1	AX ₅ E	Square pyramidal 	90°	BrF ₅

Number of Electron Groups	Electron-Group Geometry	Number of Lone Pairs	VSEPR Notation	Molecular Geometry	Ideal Bond Angles	Example
6	Octahedral	2	AX_4E_2	Square planar	90°	XeF_4

Procedure:

Using the virtual lab experiment “Limiting Reagents Problem”, create an experiment to determine the amount of Silver Nitrate in a solution. Write out your experiment with your steps taken and equipment used. Clearly write your answers in three significant figures in grams.

Problem Description:

- 1.) The solution labeled “Solution 3” in the virtual lab stockroom contains an unknown amount of AgNO_3 . Design and perform an experiment to determine the mass of AgNO_3 that was present in the “Solution 3” solution.
- 2.) The solution labeled “Solution 4” in the virtual lab stockroom contains an unknown amount of NaCl . Design and perform an experiment to determine the mass of NaCl that was present in the “Solution 4” solution.

Post-Lab Questions:

- 1.) What was the limiting reactant? What evidence do you have to support this?
- 2.) What evidence was there that a chemical reaction was occurring?
- 3.) What steps may have been performed differently if this experiment were performed in an actual lab?

ANSWER KEY

Experiment 1: Limiting Reagents Problem

Pre-Lab Questions:

- 1.) $\text{NaCl}_{(\text{aq})} + \text{AgNO}_{3(\text{aq})} \rightarrow \text{NaNO}_{3(\text{aq})} + \text{AgCl}_{(\text{s})}$
- 2.) $\text{AgNO}_3 = 169.87\text{g}$
 $\text{NaCl} = 58.442\text{g}$
 $\text{AgCl} = 143.32\text{g}$
- 3.) Student prediction only. No wrong answer.

Procedure:

Question 1:

1. Add solid NaCl into flask labeled “Solution 3” in small increments. (About 0.1 g) AgCl(s) will begin to form in the flask. Continue adding NaCl until the amount of AgCl (as shown in the solution info section of virtual lab) no longer increases when you add the salt. When AgCl stops forming, you will be adding excess NaCl. This means that AgNO₃ is the limiting reagent.
2. Determine the mass of AgCl that was formed. This will be shown in the solution info section of virtual lab. (example: ~.95g of NaCl will be added, forming ~2.32g AgCl)
3. Using the mass found in step 2. You can then determine the amount of AgNO₃ that must have been present in the initial solution. The mole:mole ratio in this reaction is 1:1. This means that you can use the grams of either NaCl or AgCl to find the molar values. Using the mole value you can then solve to find the grams of AgNO₃ present. This value will vary as each student’s unknown solution may be different on virtual lab. Check mole:mole ratio and math to convert from mole to gram.

Question 2

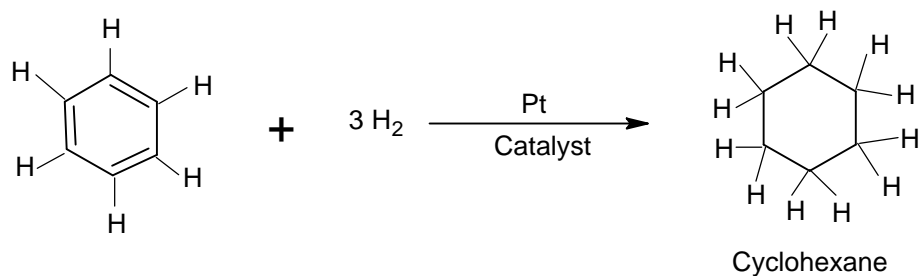
This experiment will be set up and performed the same way as the previous one. Except this time you will be adding AgNO₃ to flask labeled “Solution 4” and determining the amount of NaCl present in the solution. Check mole:mole ratios and mathematical conversions.

Post-Lab Questions:

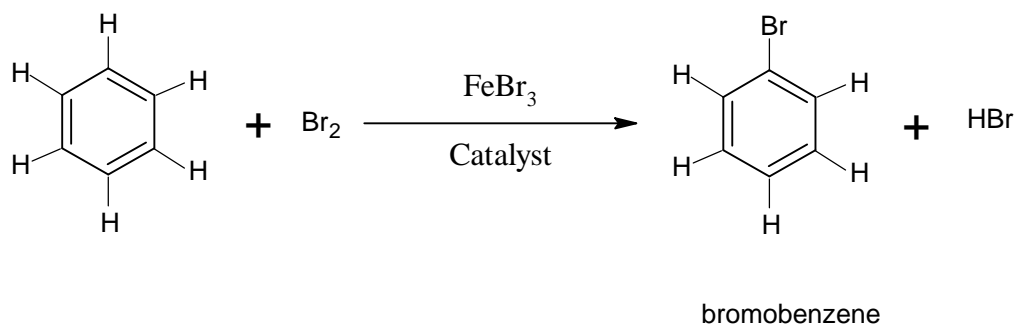
- 1.) The limiting reactant is AgNO_3 . By converting the grams of AgNO_3 and grams of NaCl to molar values, you will find AgNO_3 have a smaller mole value even with a greater gram value. This means that with a 1:1 ratio, AgNO_3 will get used up before NaCl .
- 2.) On the virtual lab website as you add NaCl or AgNO_3 , you will start to actually see a substance (AgCl) being formed at the bottom of the flask. Also by observing the solution info to the right, you will see the value of AgCl in the solution increase to its maximum value.
- 3.) While it is convenient to just look at the solution info on the virtual lab, finding the answer will not be as simple in an actual lab. You would have to watch the precipitant form until it does not appear to get any larger and there is a lot of excess salt. Then you would have to use a method of separating the solid from the liquid and drying the solid to get an accurate weight. In an actual lab it is easy to see that there is much more room for physical error in finding the correct answer. You would also have to take the safety procedures into consideration.

Reactions of Aromatic Compounds

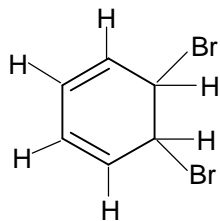
Benzene is stable due to its electron delocalization. But benzene can be hydrogenated with difficulty. The following reaction is carried out at significantly higher temperatures and pressures than are similar reactions for alkenes:



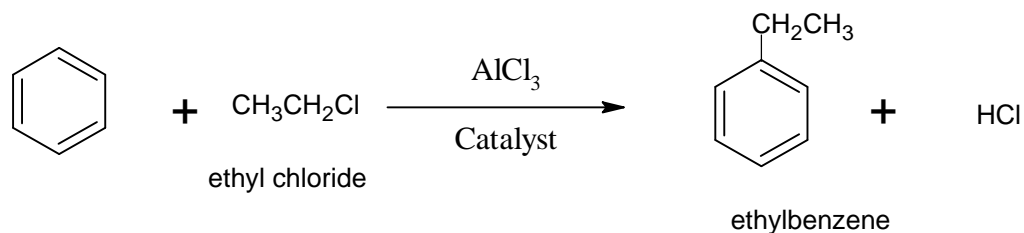
Substitution reaction: The most common reaction is with halogens, in which an atom or group of atoms replaces an atom or groups of atoms in another molecule.



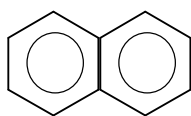
If the reaction were an addition reaction, electron delocalization would be destroyed in the product and the molecule would not have the aromatic characteristic of chemical unreactivity.



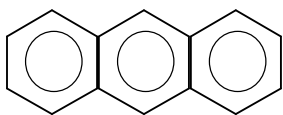
Alkyl groups can be introduced into the ring system by allowing benzene to react with an alkyl halide using AlCl_3 as the catalyst:



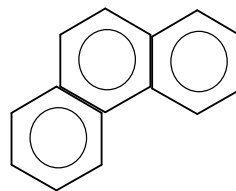
Much larger number of compounds can be generated from substances in which benzene rings are fused together. Some of these are polycyclic aromatic hydrocarbons, like naphthalene, which is used in mothballs. These and many other similar compounds are present in coal tar. Some of these compounds with several rings act as powerful carcinogens.



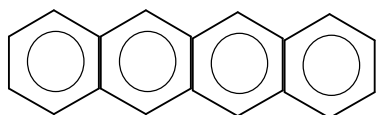
Naphthalene



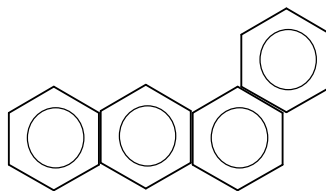
Anthracene



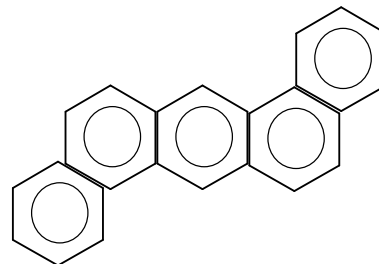
Phenanthrene



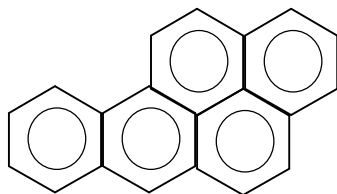
Naphthacene



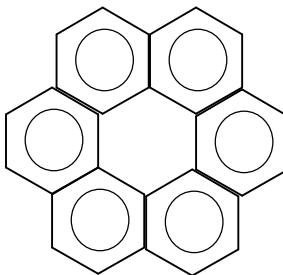
Benzanthracene



Dibenzanthracene

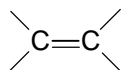


Benzopyrene

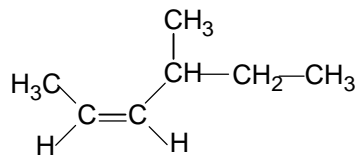
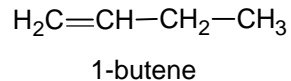


Coronene

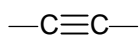
Important Functional Groups

Functional Group**Name****Examples**

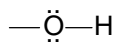
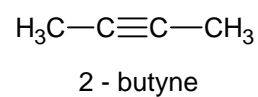
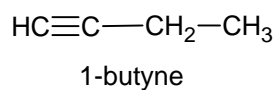
Carbon-carbon
double bond



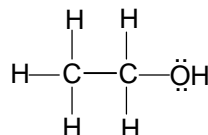
4-methyl-cis-2-hexene



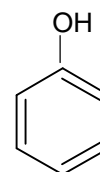
Carbon-carbon
triple bond



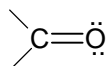
Hydroxyl



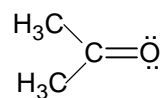
Ethanol(ethyl alcohol)



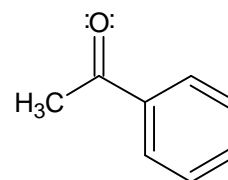
Phenol



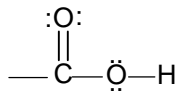
Carbonyl



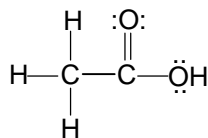
acetone



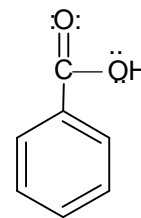
Acetophenone

Functional Group**Name****Examples**

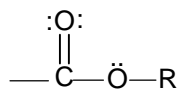
Carboxyl



Acetic acid

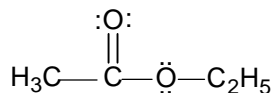


Benzoic acid

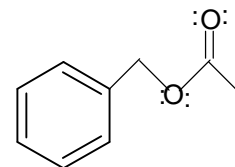


(R = hydrocarbon)

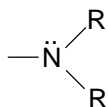
Ester



ethyl acetate

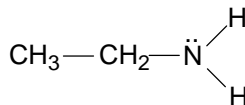


benzyl acetate

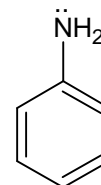


(R = H or hydrocarbon)

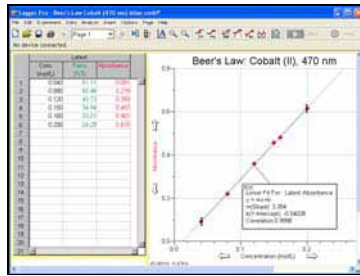
Amine



ethyl amine



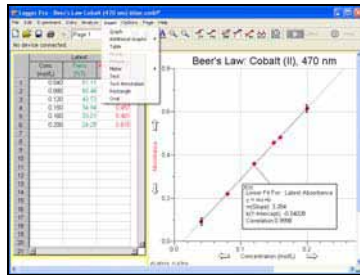
Aniline



Slide 1

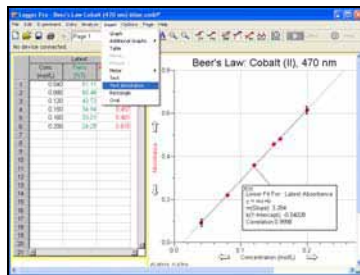
Slide notes:

Text Captions: Select the Insert menu



Slide 2

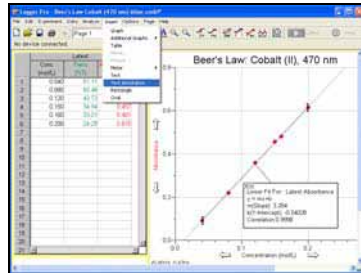
Slide notes:



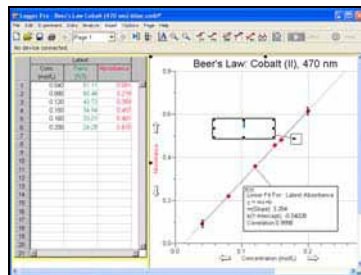
Slide 3

Slide notes:

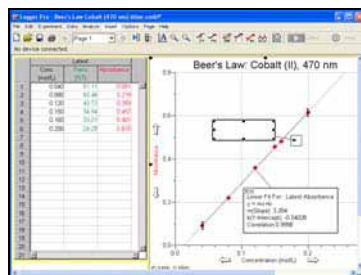
Text Captions: Select the Text Annotation menu item



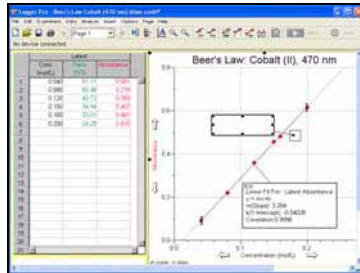
Slide 4
Slide notes:



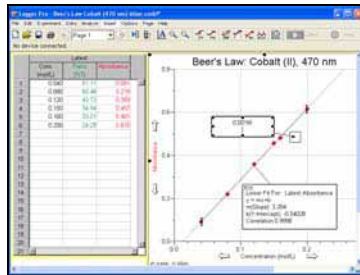
Slide 5
Slide notes:
Text Captions: Select the text box



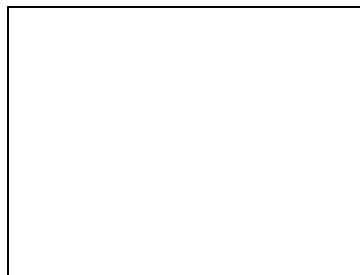
Slide 6
Slide notes:



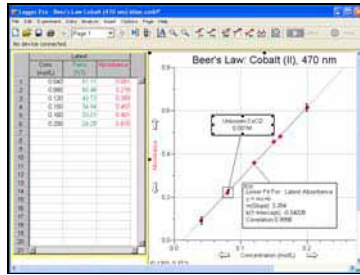
Slide 7
Slide notes:



Slide 8
Slide notes:



Slide 9
Slide notes:



Slide 10
Slide notes: