Peer-reviewed, Open Access Electronic Resources for Analytical Science Education

Cynthia K. Larive

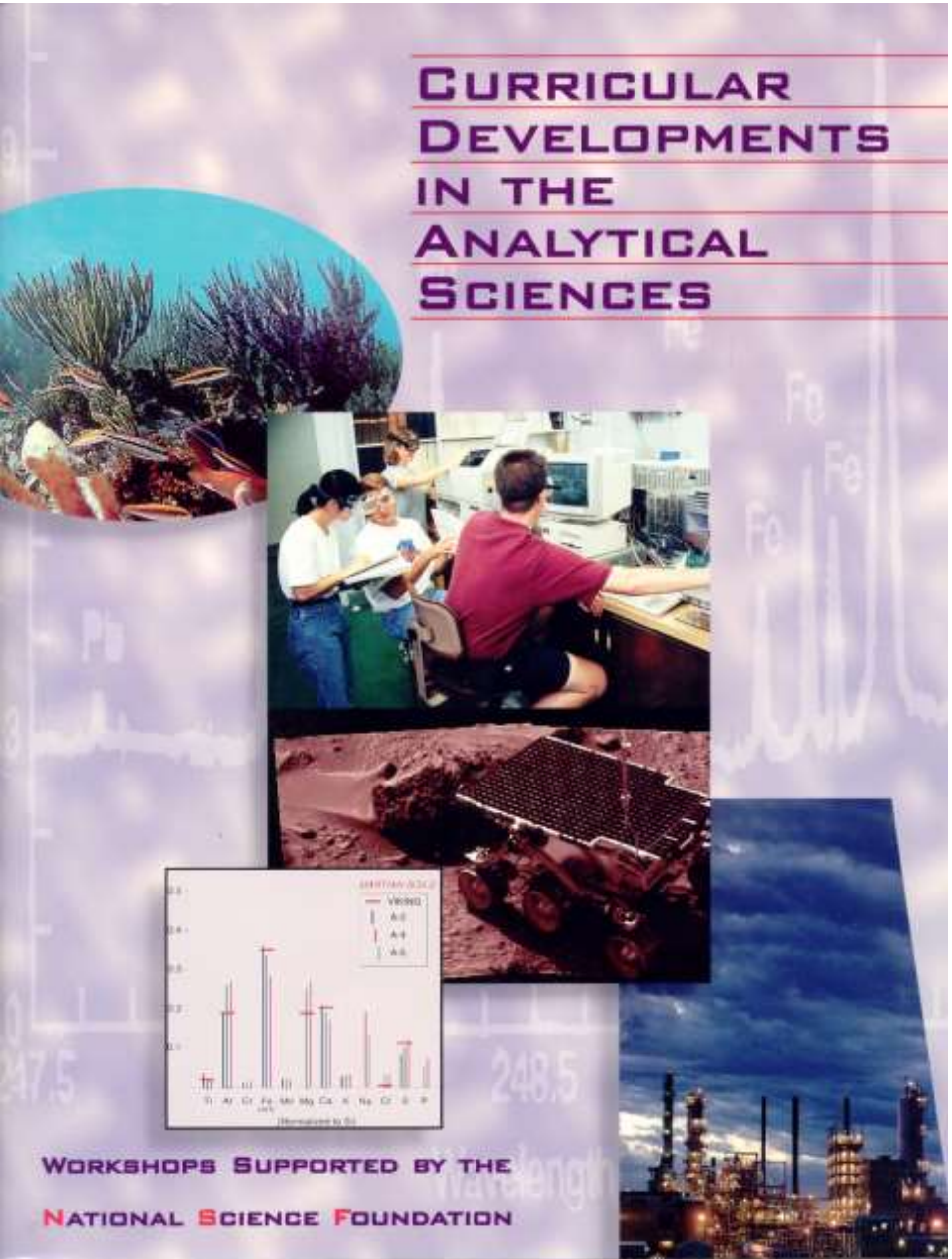
Analytical Sciences Digital Library

University of California - Riverside

Do I need to change the way I teach?

How can we translate the excitement of research to the classroom?

UCR graduate student Kayla Kaiser and undergraduate Vishwa Shah



Organized in the late 1990’s by Ted Kuwana with support from NSF DUE and NSF Chemistry program officers Frank Settle and Henry Blount

http://www.asdlib.org/files/CurricularDevelopment_report.pdf

Challenges to implementing Workshop recommendations

- ✓ PBL and active learning introduces new challenges to instructors and students
  - How does one identify good problems?
  - Problem-solving typically requires
  - Information not available in textbooks
- ✓ Need for the Analytical Chemistry community to interact and share teaching resources and educational strategies

Large Lecture General Chemistry Courses at UCR
Problem-Based Case Studies

Rethinking Chemistry gateway courses at UCR

PORTAL HOME | COLLECTION | COMMUNITY | JASDL | ACTIVE LEARNING | ABOUT »

Analytical Sciences Digital Library (ASDL)

ASDL Home Portal

Welcome to ASDL

The Analytical Sciences Digital Library, ASDL, collects, catalogs, links and publishes peer reviewed web-based discovery materials pertinent to innovations in curricular development and supporting technical resources in the analytical sciences. The ASDL website (www.asdlib.org) is one of several collections initially funded by NSF's National Science Digital Library (NSDL) program, and is currently supported by the Division of Analytical Chemistry of the American Chemical Society. ASDL grew out of discussions at regional and national meetings on ways to implement recommendations from NSF-sponsored workshops that evaluated teaching practices in the analytical curriculum. These recommendations can be found in the workshop report *Curricular Developments in the Analytical Sciences*, available as a pdf.

The Analytical Sciences Digital Library

ASDL Collection
Teach. Learn.

ASDL Community
sharing scientific collections

JASDL
Courseware Labware Educational Practices

Active Learning

Welcome to ASDL!

The ASDL is comprised of four sites: Collection, Community, JASDL, and Active Learning. We hope you will take time to explore each of these sites, and that you find materials or information that are useful in your practice of the analytical sciences. If you find a broken link or other problem, or if you have suggestions to make ASDL better, please contact us. Thanks!

NSF

The Analytical Sciences Digital Library is possible thanks to the support of NSF grants DUE 0121518 to the University of Kansas, DUE 0531941 to the University of California - Riverside, and DUE 0435422 to the University of Illinois Urbana-Champaign.

The Analytical Sciences Digital Library Community is possible thanks to the support of NSF grant DUE-0937751 to DePauw University

Any opinions, findings and conclusions or recomendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation (NSF).

About the Collection

SPOTLIGHT LATEST TAGS

- Analytical Electrochemistry: Basic concepts
- Introduction to Atomic Force Microscopy (AFM) Video Lecture
- ELISA Animated Virtual Laboratory
- Forensic Science Laboratory
- Basics of NMR

ASDL TODAY

New and Noteworthy

Quality Control Analysis for a Local Brewery.

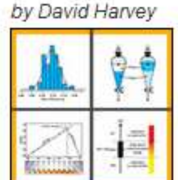
An active-learning laboratory for instrumental analysis

A complete multi-week laboratory project with the theme of quality control for a local microbrewery is described. The analyses of important flavor and aroma

Featured Site

Analytical Chemistry 2.0

by David Harvey



The complete textbook for Quantitative Analysis is freely downloadable. Teach yourself Analytical Chemistry, or be part of a class on the subject. The textbook

ACS partners with ASDL

ASDL is proud to be partnered with the Analytical Chemistry Division of ACS. Read more...

HOME COLLECTION COMMUNITY ACTIVE LEARNING JASDL ABOUT »

Search this site...

ASDL Community

Sharing scientific collections

BROWSE: HOME ASDL COMMUNITY HOME PAGE

Analytical Chemistry & R | Data Set Exchange | Image and Video Exchange | Laboratory Experiments | Problem Exchange | Posters »

About the Community Site

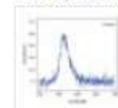
The ASDL's community site provides a forum for the sharing of user-generated content for teaching analytical chemistry. Current forums, which are accessible from the menu bar, include:

- **Analytical Chemistry & R**: The purpose of this forum is to provide a repository for sharing information on using the open-source statistical analysis package *R* for teaching analytical chemistry. If you have interesting applications, user-guides, code, or other *R*-related content, please consider sharing them with colleagues. (This forum *currently under construction and does not include content.*)
- **Data Set Exchange**: The purpose of this forum is to provide a repository for sharing user-generated data sets that illustrate important topics in analytical chemistry. If you have interesting data sets, please consider sharing them with colleagues.
- **Image and Video Exchange**: The purpose of this forum is to provide a repository for sharing of user-generated images, photos, videos, and animations that illustrate important topics in analytical chemistry. Many of the images included here are from the eText *Analytical Chemistry 2.0*. If you have interesting media for your classes and labs, please consider sharing them with colleagues.
- **Laboratory Experiments**: The purpose of this forum is to provide a place for discussing and sharing pedagogical innovations for laboratory courses in analytical chemistry. If you have developed an interesting new experiment—whether it involves a novel sample, a seldom-used instrument, or that illustrates an important concept—consider sharing it with colleagues. Also included in this forum are descriptions and links to interesting experiments published in *The Journal of Chemical Education* and *The Chemical Educator*.
- **Problem Exchange**: The purpose of this forum is to provide a repository for the sharing of user-generated problem sets that illustrate important topics in analytical chemistry and that are suitable for in-class exercises, for out-of-class assignments, or for exams. If you have interesting problem sets, please consider sharing them with colleagues.

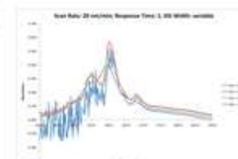
Please contact David Harvey if you wish to contribute content to any of these forums.

Recent Site Wide Posts

David Harvey wrote a new blog post Affect of Slit Width, Scan Rate, and Response Time in the group



Data Set Exchange Forum: 1 week, 1 day ago · View



The data set available here provides spectra for a solution of benzene in methanol recorded from 230-290 nm using a Perkin-Elmer Lambda 4B spectrophotometer at different combinations of slit width, scan rate, and response time. The original spectra were collected in the late 1980s and print copies archived. To create this data set, the spectra were [...]

David Harvey wrote a new blog post Property Control

Charts in the group Analytical Image and Video Exchange: 1 week, 2 days ago · View

Active Learning Materials

Collaborative Learning

ASDL Active Learning Curricular Materials

The materials presented on this website are the product of a collaborative NSF Phase I CCLI award to Thomas Wenzel, Bates College (DUE 0816649), and Cynthia Larive, University of California Riverside (DUE-0817595) and an NSF TUES Type 2 award to Tom Wenzel, Bates College, (DUE 1118600). The goal of this project is to develop active learning resources to support instruction in analytical chemistry courses. These materials are developed through the efforts of a team of collaborators. Additional materials currently under development will round out the analytical chemistry tool kit and expand the collection of context-based materials for classroom and laboratory use.

Links

Get tips on analytical problem solving,
Introduction to Analytical Problem Solving

The Analytical Sciences Digital Library is possible thanks to the support of NSF grants DUE 0121518 to the University of Kansas, DUE 0531941 to the University of California - Riverside, and DUE 0435422 to the University of Illinois Urbana-Champaign.

JASDL

The journal of the analytical sciences digital library

Recently accepted articles

- Forensic Science Laboratory
- Active Learning in Advanced Analytical Chemistry, a course for first year graduate students
- Micro Separations Distance CE
- Adapting the Chemical Analysis of Paintings

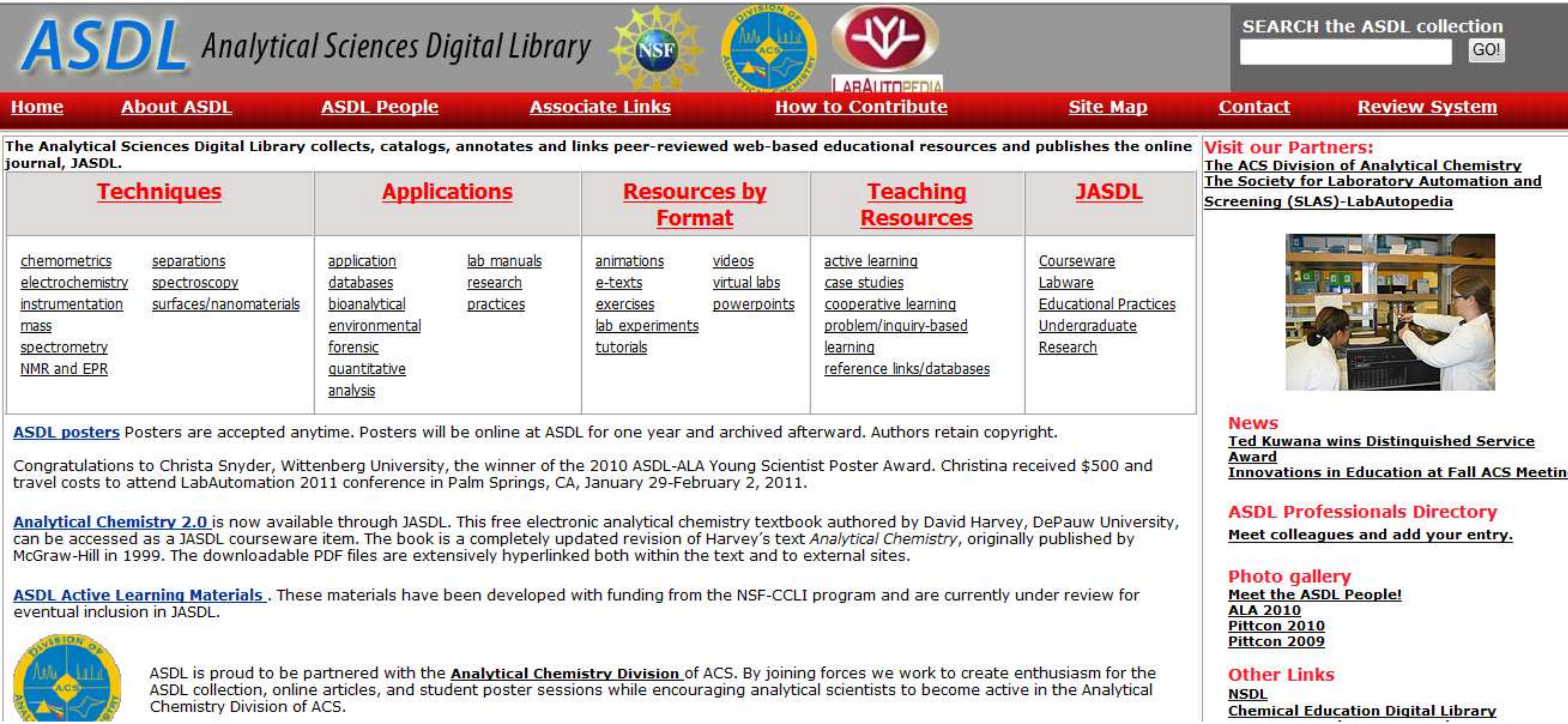
About the journal

The *Journal of the Analytical Sciences Digital Library* (JASDL) seeks to publish original peer-reviewed materials which enhance the pedagogy of Analytical Sciences and related areas. Content in the Journal is divided into three categories: Courseware, Labware, and Educational Practices. Materials included in Courseware are designed to introduce active learning in the classroom. Labware centers on experiments and processes that bring active learning into the laboratory. The section on Educational Practices provides a venue for sharing ideas on pedagogical models. While traditional publication formats are accepted in the Journal, alternate and unconventional media are also accepted for peer-review and publication. These non-traditional formats can include software, webpages, and simulators.

Submissions to the Journal must be original and the author must certify that no copyrighted material is included unless permission has been obtained from the copyright holder for unlimited, royalty free distribution and modification. Once submitted, materials are sent out for review. Reviews are typically returned to the primary author within 3 months. Final publication of accepted materials usually occurs within 6 months. To submit your materials, contact the editor by email.

To be considered for publication, the submitted material must be original and the author must certify that no copyrighted material is included unless permission has been obtained from the copyright holder for unlimited

Analytical Sciences Digital Library



http:/www.asdlib.org

Types of Material in the ASDL Collection

- ✓ Web-based content: textbooks, tutorials, quizzes, lecture notes, experiments
- ✓ Resources/Databases: NIST, SCUBA, TOXNET
- ✓ Simulations, virtual experiments and real-time remote instrument access
- ✓ Videos and animations
- ✓ Innovative pedagogical approaches
- ✓ Learning modules on specific *Analytical Toolbox* topics

The "Look and Feel" of an Analytical Chemistry Text in a Free and Downloadable Format!

Chapter 7

Collecting and Preparing Samples

Chapter Overview

When we use an analytical method to solve a problem, there is no guarantee that our results will be accurate or precise. In designing an analytical method we consider potential sources of determinate error and indeterminate error, and take appropriate steps to minimize their effect, such as including reagent blanks and calibrating instruments. Why might a carefully designed analytical method give poor results? One possibility is that we may have failed to account for errors associated with the sample. If we collect the wrong sample, or if we lose analyte while preparing the sample for analysis, then we introduce a determinate source of error. If we fail to collect enough samples, or if we collect samples of the wrong size, then our precision may suffer. In this chapter we consider how collecting samples and preparing them for analysis affects the accuracy and precision of our results.

Figure 7.1 Certificate of analysis for a production lot of NaBr. The result for iron meets the ACS specifications, but the result for potassium does not.

7A The Importance of Sampling

When a manufacturer lists a chemical as ACS Reagent Grade, they must demonstrate that it conforms to specifications set by the American Chemical Society (ACS). For example, the ACS specifications for NaBr require that the concentration of iron be ≤ 5 ppm. To verify that a production lot meets this standard, the manufacturer collects and analyzes several samples, reporting the average result on the product's label (Figure 7.1).

If the individual samples do not accurately represent the population from which they are drawn—what we call the TARGET POPULATION—then even a careful analysis must yield an inaccurate result. Extrapolating this result from a sample to its target population introduces a determinate sampling error. To minimize this determinate sampling error, we must collect the right sample.

Even if we collect the right sample, indeterminate sampling errors may limit the usefulness of our analysis. Equation 7.1 shows that a confidence interval about the mean, $\overline{X}$, is proportional to the standard deviation, s, of the analysis

Equation 7.1 should be familiar to you. See Chapter 4 to review confidence intervals and see Appendix 4 for values of t.

$$\mu = \overline{X} \pm \frac{ts}{\sqrt{n}} \qquad 7.1$$

where n is the number of samples and t is a statistical factor that accounts for the probability that the confidence interval contains the true value, μ.

Each step of an analysis contributes random error that affects the overall standard deviation. For convenience, let's divide an analysis into two steps—collecting the samples and analyzing the samples—each characterized by a standard deviation. Using a propagation of uncertainty, the relationship between the overall variance, s^2, and the variances due to sampling, s^2_{samp}, and the analytical method, s^2_{meth}, is

For a review of the propagation of uncertainty, see Chapter 4C and Appendix 2.

Although equation 7.1 is written in terms of a standard deviation, s, a propagation of uncertainty is written in terms of variances, s^2. In this section, and those that follow, we will use both standard deviations and variances to discuss sampling uncertainty.

$$s^2 = s^2_{samp} + s^2_{meth} \qquad 7.2$$

Equation 7.2 shows that the overall variance for an analysis may be limited by either the analytical method or the collecting of samples. Unfortunately, analysts often try to minimize the overall variance by improving only the method's precision. This is a futile effort, however, if the standard deviation for sampling is more than three times greater than that for the method.[1] Figure 7.2 shows how the ratio s_{samp}/s_{meth} affects the method's contribution to the overall variance. As shown by the dashed line, if the sample's standard deviation is 3× the method's standard deviation, then indeterminate method errors explain only 10% of the overall variance. If indeterminate sampling errors are significant, decreasing s_{meth} provides only a nominal change in the overall precision.

1 Youden, Y. J. *J. Assoc. Off. Anal. Chem.* **1981**, *50*, 1007–1013.

Brief Table of Contents pages

UC RIVERSIDE
UNIVERSITY OF CALIFORNIA

The Analytical Toolbox

- ✓ JASDL modules oriented around specific topics
- ✓ Toolbox can help students find answers

Analytical Toolbox
Statistics
Sample Preparation
Equilibrium Chemistry
Kinetic Methods
Electrochemistry
NMR
Mass Spectrometry
Separations
Hyphenated Methods
Spectroscopy
Surface Methods

Using the ASDL Toolbox

- ✓ Flexible for use in a variety of educational environments
- ✓ In-class activities
- ✓ Out-of-class assignments
- ✓ Introduction to new techniques
- ✓ Supporting theory
- ✓ Wet and Dry labs

Conventional to Inquiry Based Learning

If Google knows everything – what should I be teaching my students?

“The first principle is that you must not fool yourself, and you are the easiest person to fool.”

-Richard Feynman

Active Learning Content Areas Under Development

- ✓ Separations
- ✓ Equilibrium Chemistry
- ✓ Environmental (Lake Nakuru, Kenya)
- ✓ Q-NMR

www.asdlib.org/ActiveLearning.php

ASDL Active Learning Initiative

Development of Contextual E-Learning Modules for Analytical Chemistry

Inquiry-based undergraduate curricular materials

Learning Outcomes for Undergraduates
Knowledge Outcomes
Skills Outcomes
Affective Outcomes
Learned Abilities

Ewell, P.T., *Accreditation and Student Learning Outcomes: A Proposed Point of Departure*, Council for Higher Education Accreditation (CHEA) Occasional Paper, Washington, DC, September **2001**.

Active Learning Modules: Common Features

- ✓ In-Class Activities
- ✓ Supporting Materials
- ✓ Problem-based Laboratory Exercises
- ✓ Instructors' Manual

Builds on work in progress at ASDL, and takes advantage of peer reviewed resources in the digital library http://www.bates.edu/x65385.xml

Bates College | Chem 212-Separation Science

Chem 212-Separation Science

Syllabus

Equilibrium Unit

- **In-class cooperative learning problems**
- **Textbook to accompany in-class problems**
- **Learning Objectives**
- **Instructor's Manual**
- **Out-of-class problems**

Chromatography Unit

- **In-class cooperative learning problems**
- **Textbook to accompany in-class problems**
- **Learning Objectives**
- **Instructor's Manual**
- **Out-of-class problems**

Elementary Statistics Unit

Peer/Self Evaluation for the Laboratory Project

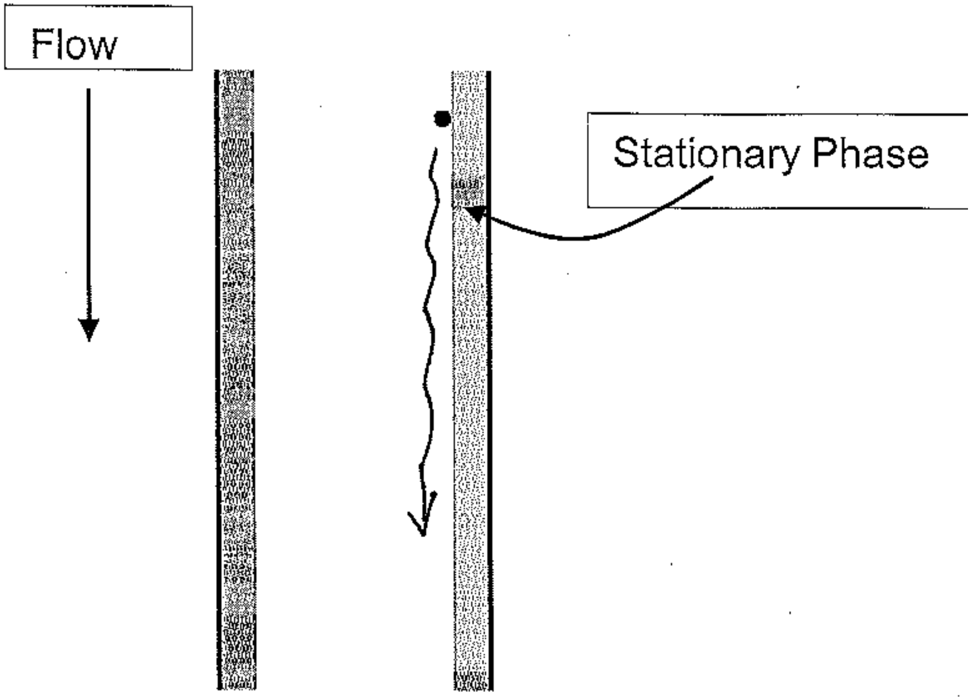
Final Lab Report for the Laboratory Project

Chromatography

- ✓ If using capillary columns, what does this suggest about the desirable diameter for such a column?
- ✓ Is this phenomenon worse in gas or liquid chromatography?
- ✓ How does the contribution to band broadening depend on flow rate?
- ✓ Would this effect be observed in a packed column? If so, how?
- ✓ How could you reduce this effect in a packed column?

Mobile Phase Mass Transport Broadening

Consider a capillary column as shown below.



- ✓ Draw a line representing the path of the molecule.
- ✓ What would this path look like if the flow rate were doubled?
- ✓ Is it important for the molecule to encounter the stationary phase? Think about a situation in which the flow was so fast that the molecule never re-encountered the stationary phase.

Problem-based Approach: Lake Nakuru, Kenya

Interdisciplinary Context-based Module

Beginning in 1993, and occurring in multiple years since, flamingos at Lake Nakuru have been dying by the tens of thousands (40,000 in 2000 alone)

Basis for the Module

What is killing the flamingos at Lake Nakuru?

Heavy metals?

Algal toxins?

Organochlorine pesticides?

Sampling unit

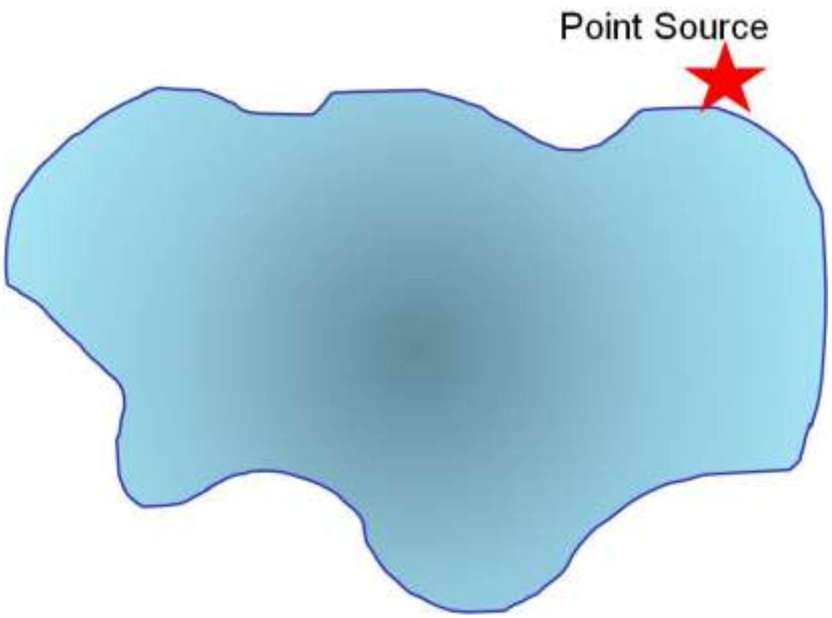
At the end of this assignment students will be able to:

- ✓ Define various sampling strategies
- ✓ Assess the benefits and limitations of different sampling strategies
- ✓ Determine an appropriate sampling plan for an analysis

Sampling units: Example questions

- ✓ Assume you have chosen a judgmental sampling plan to evaluate pollution from a point source into a lake.

- ✓ Use the diagram at right and words to describe your sampling plan.



Designing a Sampling Plan

Key questions to consider:

1. From where within the target population should we collect samples?
2. What type of samples should we collect?
3. What is the minimum amount of sample for each analysis?
4. How many samples should we analyze?
5. How can we minimize the overall variance for the analysis?

What have we learned?

- ✓ Evaluation
  - Improved student learning?
  - Useable in a wide variety of environments?
- ✓ Benefits
  - Student centered “self based “ learning
  - Electronic, free of charge
  - Adaptable
  - Problems inter-dispersed
- ✓ Challenges
  - Time
  - Redeveloping materials for your classroom environment

Goals for the Future

- ✓ Expand analytical toolbox
- ✓ Modify existing content to be more inquiry-based
- ✓ Testing/sharing materials
- ✓ Assessment
- ✓ Development of additional context-based materials

Acknowledgements - ASDL

- NSF DUE 0121518, 0531941, 0816649, 0817595, 0937751
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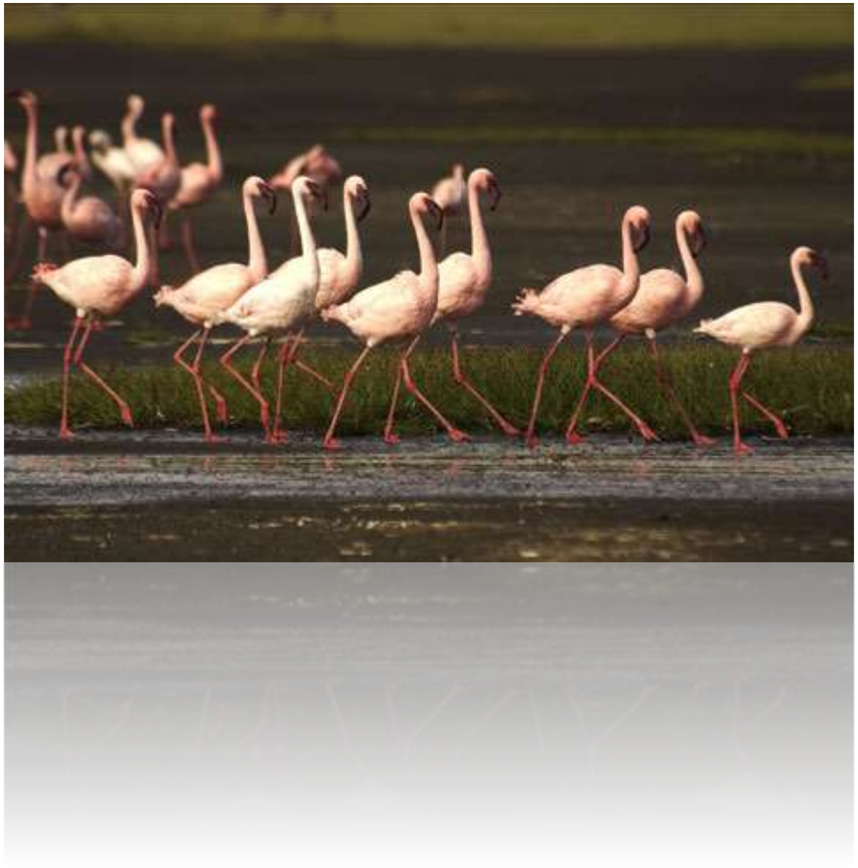
- Members of the ASDL Advisory Board

Ted Kuwana (Managing Director)	University of Kansas
Rick Kelly (Web-collection Editor)	East Stroudsburg University
Alex Scheeline (JASDL Editor)	University of Illinois
Michael Samide (JASDL Assoc Editor)	Butler University
David Harvey (Community Editor)	DePauw University

Module Components

1. *Identifying the Problem*
2. *Sampling*
3. *Sample Preparation*
4. *Gas Chromatography*
5. *Pesticide Analysis by MS*
6. *Method Validation*
7. *Instructor's Guide*



Problem-Based Case Studies

CHEM 001A	**CHEM 001B**	**CHEM 001C**
1. Global Warming (*data analysis*)	1. H_2 Storage* (*gas laws/thermo*)	1. Ocean pH and CO_2* (*solutions/pH*)
2. Liquid Coal* (*rxns/stoich.*)	2. Bio-catalysis/ethanol* (*kinetics*)	2. Photoelectrochemical Cells (*redox/electrochem.*)

UCR Chemistry Case Collection

http://chem.ucr.edu/casestudy/casestudycollection.html

***National Center for Case Study Teaching in Science (NCCSTS)**

http://sciencecases.lib.buffalo.edu/cs/

Problem-Based Case Studies

- **Graduate TA's trained to facilitate case activities in *mandatory recitation sessions*.**
- **Students given articles from the scientific literature as pre-readings.**
- **Students work in collaborative groups to answer mixture of multiple choice and short answer Q's.**

“Flipped Classrooms”

Pre-lecture Activities → In-class Active Learning

C. Wieman, et al., *Science*, 2011, 332, 862-864.

C.H. Crouch & E. Mazur, *Am. J. Phys.*, 2001, 69, 970-977.

Flipped Classrooms in CHEM 001 Series

Video Tutorials & Online Learning Before Lecture → **Problem-based Clicker Cases in Large Lecture Hall**

SENCER-ized Flipped Classrooms

-Focus lecturing on more difficult concepts.

-Bring group problem solving and application to **real-world problems** to the lecture.

-More robust active learning experience...**more impact on student learning**.

Clicker Cases

-Take a traditional Powerpoint lecture, incorporate a real story or overarching issue, and include periodic clicker Q's.

-Foster collaborative learning in large lecture hall; *model discovery learning.*

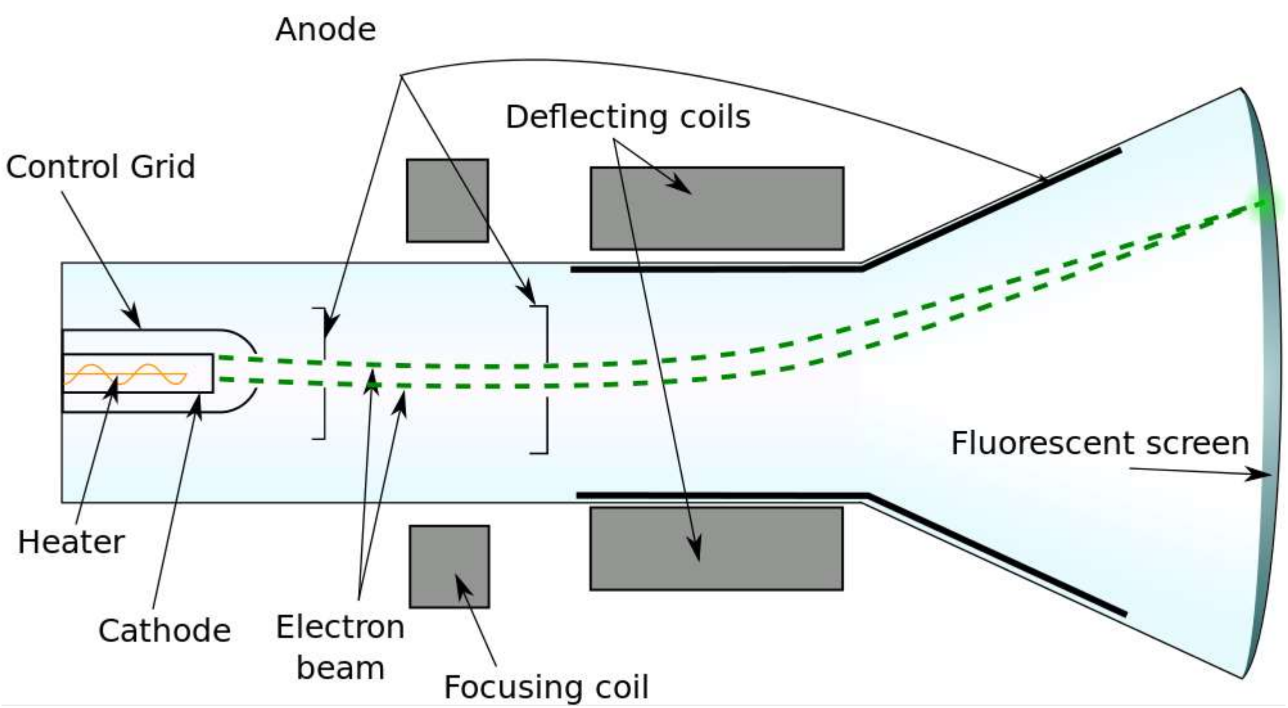
NATIONAL CENTER FOR
CASE STUDY TEACHING IN SCIENCE
UNIVERSITY AT BUFFALO, STATE UNIVERSITY OF NEW YORK

History of the Atom
From Atomism to the Nuclear Model

Jack F. Eichler
Department of Chemistry
University of California, Riverside

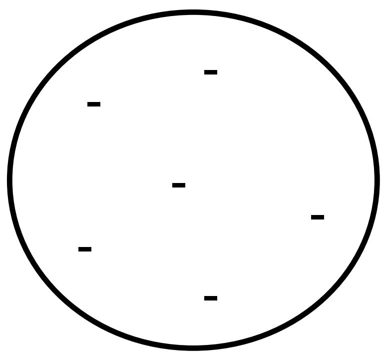
http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=667&id=667

Thomson Cathode Ray Tube (1897)

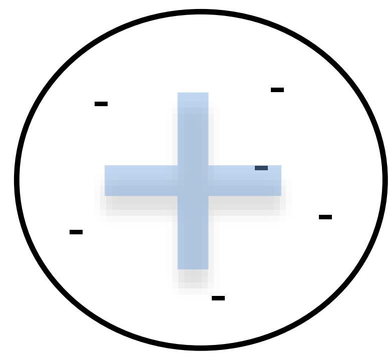


CQ: Which model of the atom is confirmed by the data/observations from the cathode ray tube experiment?

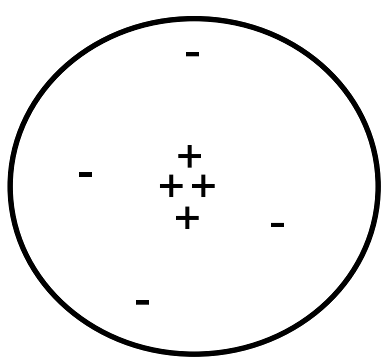
A.



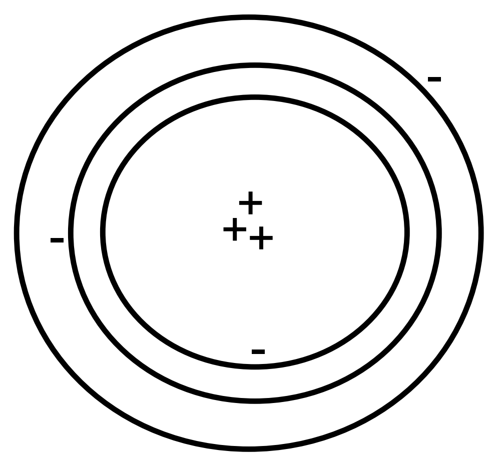
B.



C.



D.



CHEM 001 Clickers

-Approximately 10-20% of lecture time devoted to active learning for ALL students.

-Promotes collaborative learning.

-Highlights interdisciplinary nature of chemistry and connections to real-world problems.

Problem-Based Case Studies

-Graduate TA's trained to facilitate case activities.
-Students given articles from the scientific literature as pre-readings.
-Students work in collaborative groups to answer mixture of multiple choice and short answer Q's.
-Students submit individual responses to short essay Q's.

Example: Problem-Based Case

Analysis

2. Compile a list for each category:

What do I know? | What do I Need to know?

3. Rank the importance of the questions in the "What do I need to know?" column.

“Liquid Coal”

The New York Times

Monday, August 6, 2012
May 25, 2011, *4:53 pm*

Bill Allows Military to Use High-Carbon ‘Liquid Coal’

By JOHN COLLINS RUDOLF

D. Hildebrandt, et al., *Science*, 2009, 323, 1680-1681.
R. Agrawal, et al., *Proc. Nat. Acad. Sci.*, 2007, 104, 4828-4833.

Which of the following explains why it is advantageous/desirable to convert coal to a liquid fuel?

A) Our current energy infrastructure is centered on transporting and using liquid fuels for our ground fleet of cars and tractor trailers, therefore being able to use this infrastructure is more economically viable.

B) Liquid hydrocarbon fuels have a high energy density (e.g., much higher than that of gaseous hydrogen used in fuel cells), therefore can provide the energy required to move ground fleet vehicles (especially tractor trailers).

C) This would provide the U.S. an opportunity to develop a liquid fuel supply without depending as much on foreign oil, which will continue to diminish in supply over the coming years.

D) It is easier to convert coal to liquid fuel than it is to convert petroleum to liquid fuel.

E) A and B and correct.

F) A, B, and C are correct.

G) A, B, C, and D are correct.

The authors state that the goal would be to use this process to make 80,000 barrels of liquid hydrocarbon fuel per day. *How many tons of coal would be required to produce this much liquid fuel?* Use the balanced reactions from question 4:

$3C(s) + 6H_2O(l) \rightarrow 3CO_2(g) + 6H_2(g) \rightarrow 2(-CH_2-)(l) + 4H_2O(l) + CO_2(g)$

1 barrel = 42 gallons
1 gallon = 3.78 L
density of liquid fuel = 0.700 g/mL (assume this is the density of $-CH_2-$)
1 ton = 2,000 lbs
1 lb = 0.45 kg

<u>Individual Question</u> – Your response to this should be typed and delivered to your discussion group TA electronically. Your response should be no longer than one page (12 point font, single spaced).

7. What are the advantages and disadvantages of using coal to produce liquid fuels? If you had to decide whether or not to invest federal funds in developing the CLT (coal-to-liquids) technology, would you support these efforts (be sure to cite evidence from the journal articles in making your final decision)?

Problem-Based Case Studies

CHEM 001A

1. Global Warming
   (*data analysis*)

2. Liquid Coal
   (*rxns/stoich.*)

CHEM 001B

1. H_2 Storage
   (*gas laws/phases*)

2. Enzyme Kinetics
   or
   Bio-catalysis/ethanol
   (*kinetics*)

CHEM 001C

1. Ocean pH and CO_2
   (*solutions/pH*)

2. Photoelectrochemical
   Cells
   (*redox/electrochem.*)

CHEM 112A*

1. Molecules of life
   (*chirality*)

CHEM 112B*

1. Organic LED's
   (*organic polymers*)

CHEM 112C*

1. Vioxx
   (*drug design*)

UCR Chemistry Case Collection:
http://chem.ucr.edu/casestudy/casestudycollection.html

***Dr. Richard Hooley (organic chemistry)**

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WHERE DISCOVERIES BEGIN

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UCR IUIT (Innovative Use of Information Technology in Teaching)