Survey of Chemistry
Lab Manual

WICHE
Western Interstate Comission for Higher Education

NANSLO
NORTH AMERICAN NETWORK OF SCIENCE LABS ONLINE

2016

NANSLO

NANSLO Overview Lab Manual

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NANSLO Mission

NANSLO provides a consortium approach to the development and deployment of high-quality, modular, openly licensed courseware integrating learner-centered and immersive web-based labs using software, video, and robotics for the study of science courses.

The North American Network of Science Labs Online (NANSLO) provides students the ability to conduct lab activities with state-of-the-art science equipment using robotics, software, and web cams over the Internet. From any computer, students can log into a lab interface and manipulate the controls to conduct real-time experiments. The interface also allows participants to communicate with lab partners, ask for assistance from a knowledgeable lab technician, and collect data and images for their assignments.

How NANSLO works

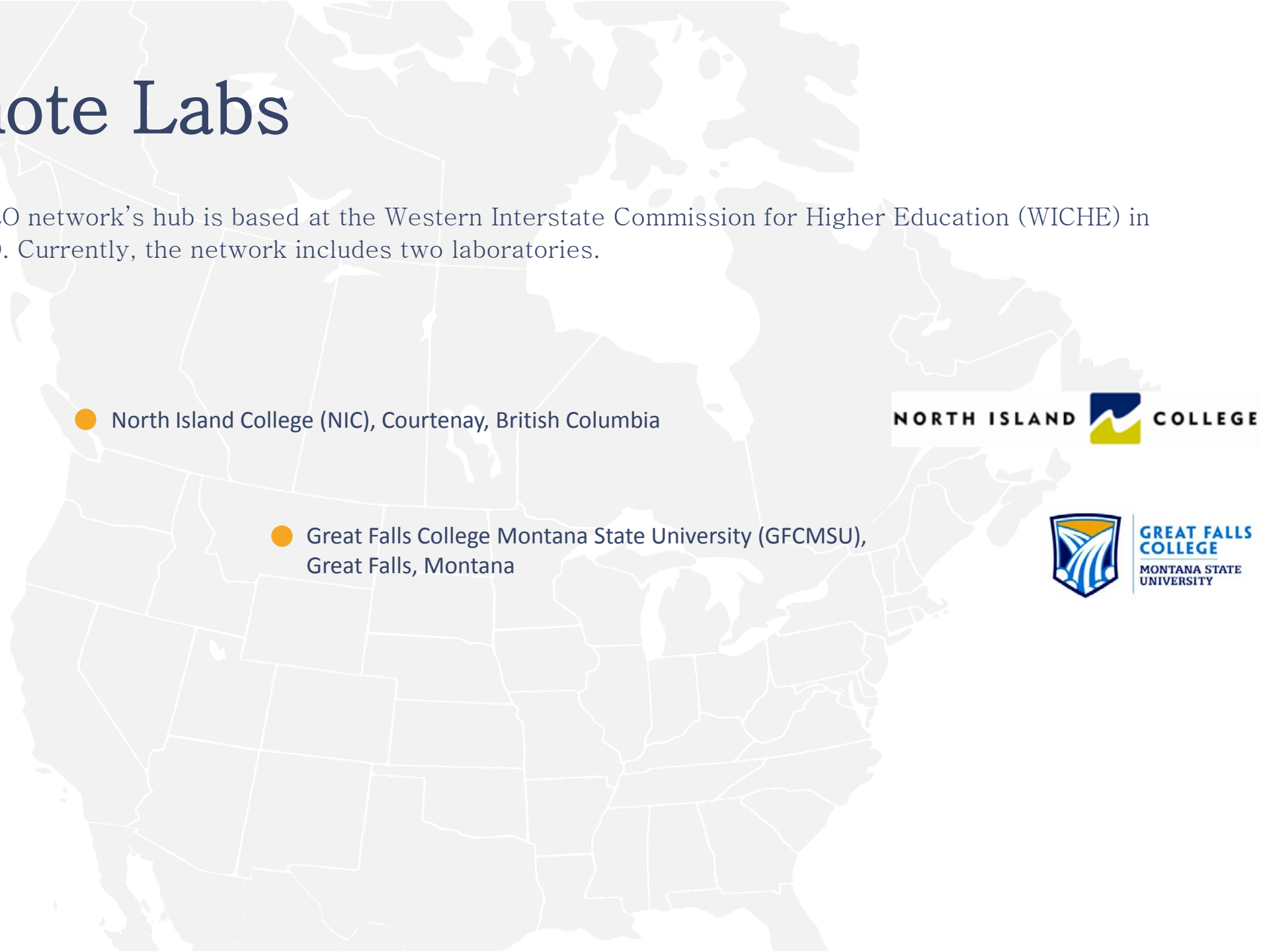
1. Faculty use the centralized scheduling system to reserve a block of time for students to perform assigned NANSLO lab activities.

2. When a reservation is made, a unique URL and PIN are generated. Faculty give their students this information, and students use it to access the scheduling system and select a day and time within the reserved block to complete the lab activity.

3. Once connected to the NANSLO lab, students have access to real scientific lab equipment that lets them:
   - Engage in authentic instrumental experimentation;
   - Collect real-time data and capture it electronically;
   - Experiment with different settings to see the impact on the data being observed and collected;
   - Generate graphs and data to insert into lab reports;
   - Capture high-resolution images;
   - Collaborate with classmates and lab personnel through voice conferencing.

Remote Labs

The NANSLO network's hub is based at the Western Interstate Commission for Higher Education (WICHE) in Boulder, CO. Currently, the network includes two laboratories.



- North Island College (NIC), Courtenay, British Columbia
- Great Falls College Montana State University (GFCMSU), Great Falls, Montana

Lab Equipment

Each lab that you will be conducting uses robotics that you control to complete the experiment. The robotics are attached to scientific equipment that correspond to each specific experiment.

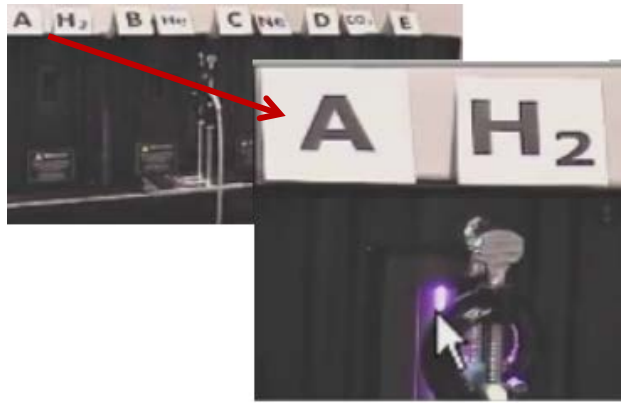
Measurement

- Controllable camera
- Fish tank
- Measuring Tools
- Video camera

Density

- Cube
- Scale balance
- Beaker 1; Beaker 2 with vegetable oil with red food coloring and a metal bolt; Beaker 3 with corn syrup and a ping pong ball; and Beaker 4 with vegetable oil with red food coloring, corn syrup, a metal bolt, and a ping pong ball
- Video camera

Emission Spectrum



- Spectrometer
- Emission lamps
- Gases
- Video camera

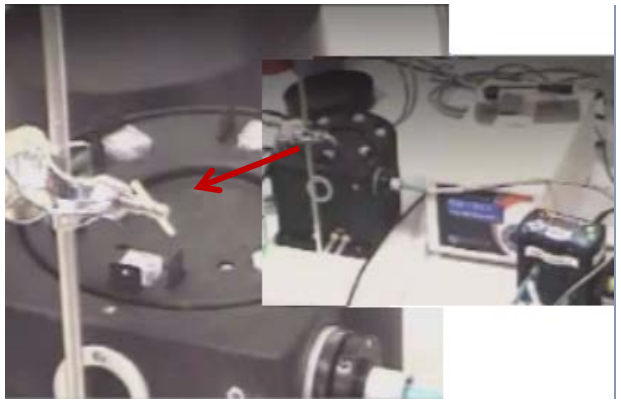
Lab Equipment

Each lab that you will be conducting uses robotics that you control to complete the experiment. The robotics are attached to scientific equipment that correspond to each specific experiment.

Exothermic/Endothermic Reaction

- Beakers with $CaCl_2$ (calcium chloride; NaCl (sodium chloride; $NaHCO_3$ (sodium acetate); NH_4Cl (ammonium chloride); and NH_4NO_3 (ammonium nitrate)
- Water
- Temperature gauge
- Video camera

Beer-Lambert Law (Absorbance/Concentration)



- Spectrometer
- $NiSo_4$
- Pumps
- Cuvettes and cuvette carousel
- Temperature gauge
- Heater unit
- Video camera

Enzyme Kinetics

- Spectrometer
- Enzyme solution
- Glucose Solution
- Pumps
- Cuvettes and cuvette carousel
- Temperature gauge
- Heater unit
- Video camera

Lab Equipment

Each lab that you will be conducting uses robotics that you control to complete the experiment. The robotics are attached to scientific equipment that correspond to each specific experiment.

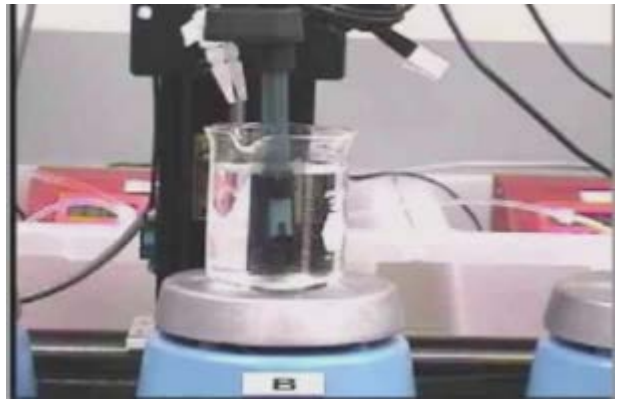
Radiation

- Radiation detector
- Radiation source
- Radiation measuring device
- Shielding – paper, tin foil, and aluminum
- Video camera

Reaction Rate

- Beakers
- Alka-Seltzer tablets
- Water
- Measuring device
- Video camera

Acid/Base Titration

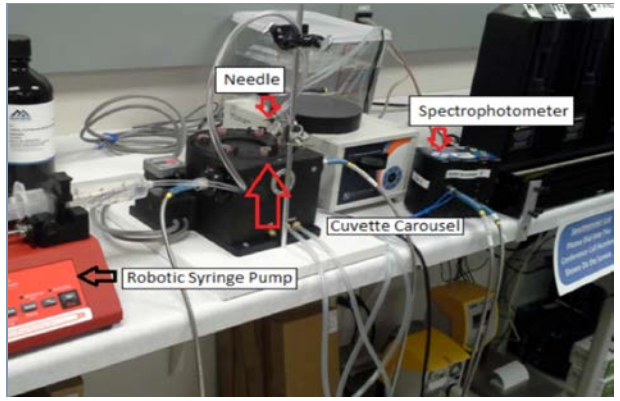


- Probe assembly
- Solutions in beakers
- Rinse beaker
- Acid solution (tank A)
- Base solution (tank B)
- Burettes
- pH and temperature sensors
- Heating unit
- Video camera

Lab Equipment

Each lab that you will be conducting uses robotics that you control to complete the experiment. The robotics are attached to scientific equipment that correspond to each specific experiment.

Membrane Diffusion



- Spectrophotometer
- Cuvettes and cuvette carousel
- Robotic syringe pump

Background Information for Instructor

Materials contained in this section:

- Using this Lab Manual
- NANSLO Network Scheduling System
- Scheduling a Lab
- Faculty Scheduling System Dashboard
- Preparation Tips
- Preparing Students for Success
- Reports and Assessment
- Getting Support
- Instructor Checklist

Using this Lab Manual

	Designed for
NANSLO Overview provides general information about NANSLO, the capabilities it offers to you and your students, our laboratory locations, and the equipment used for the NANSLO lab activities included in this lab manual.	*instructors but may be shared with students*
Background Information for Instructors provides general information for scheduling your assigned NANSLO lab activities; technical tips; things to consider in preparing students for success in these lab activities; reports available for use in determining student completion of lab activities; and a general checklist that can be used in preparing for assigned lab activities.	*instructor use only*
Instructions for Students provides general information for students to use in preparing for each NANSLO lab activity; technical requirements; instructions for making an appointment based on the times you have reserved; functions available on the scheduling system student dashboard; general instructions for completing assigned labs; and a general checklist that can be used in preparing for each assigned lab activity. *NOTE: This complete section should be given to students as it is applicable to all NANSLO lab activities in this lab manual.*	*student use only*
Survey of Biology Lab Activities contains ten lab activities. Each lab activity is complete. It contains a description of the lab activity; its purpose; essential question(s) to be answered; lab activity objectives; pre- and post-lab questions; background information; its applicability in real life and the work place; equipment setup; the control panel and instructions on how to use this web-enabled interface; a lab day checklist; information, observations, and activities to be completed while connected to the NANSLO Laboratory; an area to use in documenting data collected and images captured; analysis questions and procedures; reviewing results; and conclusions and reflections. Each lab activity has been written using an inquiry-based format. *NOTE: This section can be given to students as their lab manual or can be provided in modules as the student is assigned to each lab activity.*	*student use only*

NANSLO Network Scheduling System

In order to use these NANSLO lab activities through a NANSLO laboratory, your Institution must have an agreement with NANSLO to use its services and have a NANSLO Scheduling System Account.

Institution Administrator: Each Institution using NANSLO has appointed an Institution Administrator who enters course and faculty information into the system (see scheduler.nanslo.org for more information about this system.) This centralized system allows institutions from across the country and the world to provide students with access to NANSLO's laboratories and NANSLO lab activities through the Internet.

Username and Password: Your Institution Administrator is responsible for determining who will have access to this scheduling system. Once a faculty member record is entered into the scheduling system by the Institution Administrator, a unique username and password is generated and an email is sent to the primary email address entered.

Faculty Dashboard: If you have been given a username and password by your Institution Administrator, you have access to a Faculty Dashboard. Through that dashboard, you can make reservations, update reservations, send email notification to students who have made appointments for assigned NANSLO lab activities, and view student reports.

Have Questions?

- Is your Institution using NANSLO?
- Who is your Institution Administrator?
- Need more information on using your Faculty Dashboard or making a reservation?

Send your questions to schedulerhelp@nanslo.org. Please include your contact name and number and information on the topic you need help on.

Scheduling a Lab

Ten reservations are required as a reservation is made by you or your Scheduling System Institution Administrator for each lab activity in this Lab Manual. Each reservation generates a unique URL and PIN number that you will provide to your students to enable them to make appointments during the block of time reserved. The information entered for each reservation is:

1. The name of the NANSLO lab activity.
2. A range of dates when that NANSLO lab activity is assigned to your students.
3. The number of students who are assigned to that NANSLO lab activity.
4. The number of students who will work together online. Typically 4 or 5 students work together and use a teleconferencing capability to collaborate.
5. The number of laboratory sessions needed for that reservation are computed (number of students/team size.) Select the number of laboratory sessions needed from the list of available time blocks during the selected date range.
6. Upon completion of a reservation, an email is automatically generated to you if you are associated to the

Lab Usage and Capacity

- NANSLO laboratories offer flexible hours (days and evenings)
- NANSLO laboratories are usually open on Saturday
- Multiple laboratory stations allow large numbers of students to be served at the same time
- Each student group can access different scientific equipment at the same time through the NANSLO laboratory

Faculty Scheduling System Dashboard

If you have been given a username and password by your Scheduling System Institution Administrator, you will have access to a customized dashboard. Use the Faculty Dashboard to:

1. Add reservations and update reservations you have already made.
2. Access Student Rosters to determine which students have and have not made appointments to complete each of these assigned NANSLO lab activities.
3. Access Student Reports to determine which students accessed the NANSLO laboratory, how long they remained online, and viewing any comments appended to individual student records.
4. Review information on reservations made.
5. Edit your profile.
6. Assign a Section ID to your course if not done by the Institution Administrator.

If you have been given a Username and Password by your Scheduling System Institution Administrator, go to scheduler.nanslo.org, select the "I am a faculty or administrator" button, and enter your username and password to access the Faculty Dashboard. Need to know who your Institution Administrator is? Send an email to schedulerhelp@nanslo.org.

Preparation Tips

Unique URL and PIN for Each Reservation: Remember to give students the unique URL and PIN for each reservation made for each NANSLO lab activity.

Try It Out Before Assigning it to Students: NANSLO encourages faculty to try out NANSLO before assigning students a NANSLO lab activity. It helps you answer your student's questions about how to set up an appointment, how to use the equipment, and other basic questions. The measurement activity is a good one to use.

Computer Equipment: Currently NANSLO lab activities cannot be performed on cell phones and tablets. We're working on it. So students need to use a computer for these activities.

Technical Issues and Internet Connectivity: Most students have had very little technical difficult when accessing NANSLO laboratories. However, very slow connections may impact your student's experience especially when viewing the video stream on the NANSLO control panel showing the equipment and activity as it is performed.

Access to NANSLO Control Panel: We are moving toward delivering our control panel using HTML 5; however, in some instances, your students may be required to download a piece of software (Citrix receiver) to their computers.

Campus Firewalls: On occasion, accessing the NANSLO laboratory through campus computers my be an issue. If you are demonstrating a NANSLO lab activity to students, it is a good idea to test it out in advance.

We're Here to Help: Email NANSLO at schedulerhelp@nanslo.org

Preparing Students for Success

- Review the lab information, objectives, and essential questions to identify questions your students may have or to make changes you see appropriate for your course.
- Recommend students make appointments as soon as possible (window for making appointments begins two weeks before the reservation start date) if specific days of the week or times of the day are needed.
- Access your Faculty Dashboard, review your Roster, and remind students that have not made an appointment to do so.
- Discuss or demonstrate how students access the NANSLO laboratory before the start date of the assigned NANSLO lab activity.
- Show students how to capture images on their computer and paste them into a document and how to use a spreadsheet to document data that has been collected.
- Provide additional resources that assist students in understanding the concepts they will be learning in the assigned NANSLO lab activity.
- Share samples of lab reports with your students.
- Encourage students to review tutorials and other material to prepare themselves before connecting to the NANSLO laboratory.
- Remind students to connect to the teleconferencing capability as soon as they connect to the NANSLO laboratory to collaborate with team members and NANSLO lab technicians.
- Let students know that lab technicians are online and available to help them with technical issues.
- After the lab, provide time for students to share and compare results, discuss challenges, and reflect on learning.
- Facilitate group discussions on how these NANSLO lab activities complement everyday life and work experiences.

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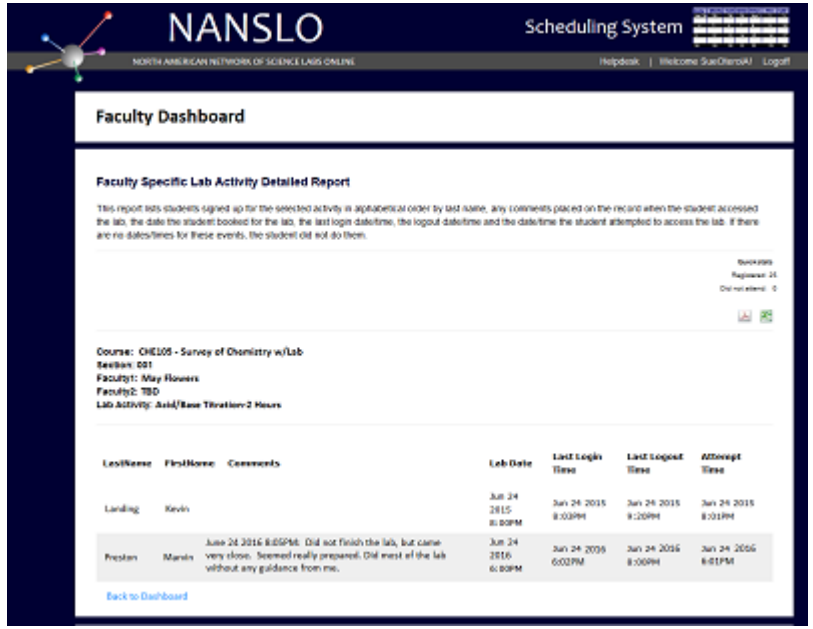
Reports and Assessment

Student Activity Reports: Several reports are available through your Faculty Dashboard you can use determine if students have made an appointment for an assigned NANSLO lab activity and the time spent working through the activity.



Detailed Student Reports provide information about:

- Who made an appointment for an assigned lab.
- Who made an appointment and didn't show up for the lab.
- Who attempted to access the lab on the selected date and time and were unable to log into the lab station computer.
- What time a student logged in and logged out, allowing faculty to determine time spent in the laboratory.
- Notes appended to individual student records by lab technicians.

Student Roster

- Lists the names, contact information, and date and time selected by those students to access the NANSLO laboratory and perform the NANSLO lab activity.

Assessments: The lab objectives and essential questions serve to guide the outcomes for each lab. Look for pre- and post-quizzes, guiding questions, data analysis, and lab reports to assess learning. Rubrics may also be associated with labs to assist in scoring.

Getting Help

Provide information on who to contact

Instructor Checklist

- ❑ Preview lab, watch tutorials
- ❑ Test software
- ❑ Schedule lab
- ❑ Introduce concepts and lab to students
- ❑ Guide students by assigning tutorials on NANSLO and NANSLO lab activities
- ❑ Preview NANSLO lab activities with students and conduct a Q & A session
- ❑ Show examples of same lab procedure done in person
- ❑ Clarify your expectations for outcomes
- ❑ Review Student Activity Reports, and contact students as needed
- ❑ Conduct discussions to review results, challenges, and questions
- ❑ Encourage student reflection and self-assessment for learning
- ❑ Assess outcomes and student learning

Instructions for Students

Material contained in this section:

- Preparing for Each Lab
- Technical Requirements
- Scheduling a Lab Appointment
- Student Dashboard
- Completing a Lab
- Getting Help
- Student Checklist

Preparing for Each Lab

There are ten NANSLO lab activities within this manual. Your instructor will provide dates when each activity will be completed by you and other details on turning in your work and a unique URL and PIN number for EACH activity.

Here are your steps for success.

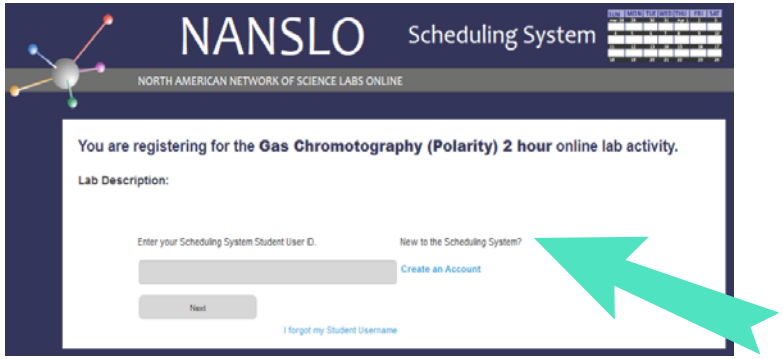
1. Carefully review the entire NANSLO lab activity.
2. Watch any accompanying videos or tutorials one or more times so you have a strong understanding of the content and experiment you will be conducting.
3. Copy any lab report sheets, as necessary, or create the digital documents and spreadsheets you will be using during the experiment.
4. Review the technical requirements for the lab and make sure you have access to a computer, Internet connection, and software that meets these requirements. (see p. XX)
5. Once you receive the unique URL and PIN from your instructor for this NANSLO lab activity, schedule your appointment as soon as possible (the appointment window begins two weeks before the start date of this NANSLO lab activity.) (see p. xx)

Technical Requirements

To prepare for a NANSLO lab activity, you must have:

- An Internet connection.
- Sufficient bandwidth (for example, your Internet Service Provider download speed is 5MB per second). If you have very slow Internet access, it will have an impact on your ability to view the images being transmitted to your computer.
- A computer (Mac or PC) — currently the NANSLO lab activities do not run on iPads, notepads, or cell phones.
- Sufficient knowledge on how to use a computer, e.g., how to use the right and left mouse buttons, capture images using those buttons, open software such as Word to paste images captured, where you have saved files on your computer.
- The appropriate browser to access the NANSLO lab activity. Currently, Google Chrome seems to be most effective; however, you can use Internet Explorer and Mozilla Firefox. Irrespective of the browser you use to access the NANSLO lab activity, the NANSLO web interface opens in Internet Explorer.

Scheduling a Lab Appointment



Using the NANSLO Network Scheduling System

This centralized system allows you to access NANSLO's laboratories and your assigned NANSLO lab activities through the Internet from across the country and the world.

Making your appointment:

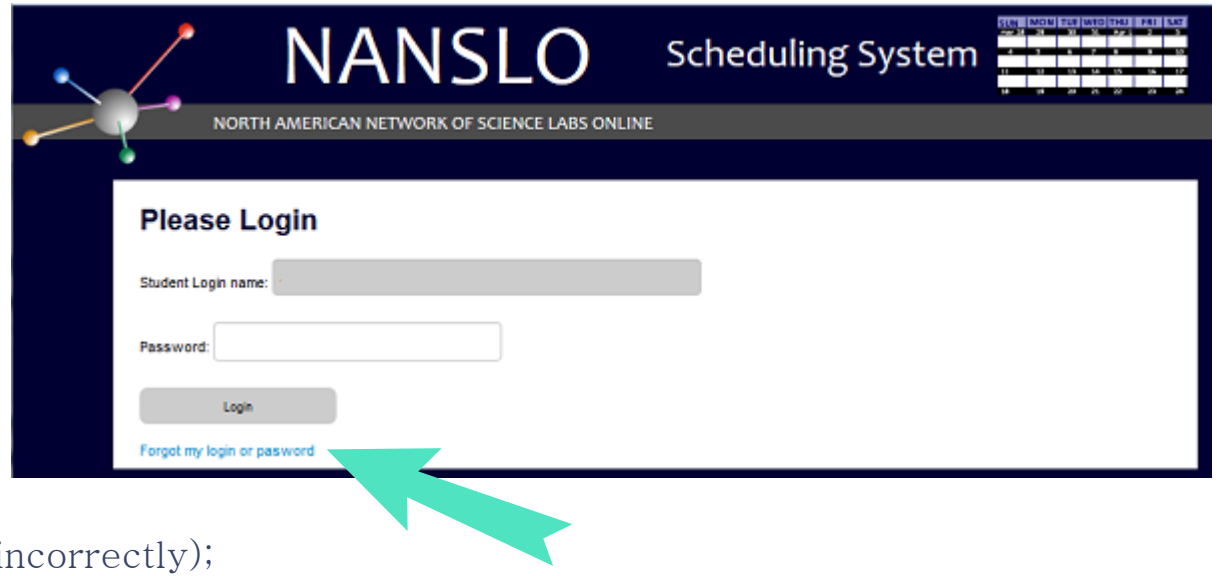
- Your instructor reserves a block of time (dates and times) for you to perform each assigned NANSLO lab activity.
- You will be provided with a unique URL and PIN number for each of these NANSLO lab activities.
- Enter that unique URL and PIN number to schedule an appointment within the specified block of time reserved.
- The system is set up on a first come, first serve basis so make your appointment early. The appointment window begins two weeks before the start date of your assigned lab (the first date selected by your instructor for his/her reservation.)
- An email notification is automatically sent out to you when an appointment is made providing more detailed information about your appointment and the NANSLO lab activity.
- The first time you use the scheduling system, you will also set up your scheduling system account. A username and password is automatically generated for you.
- Write down your scheduling system USERNAME and PASSWORD so you can access your Student Dashboard.
- Use your Student Dashboard to update your appointments and click on the links to those NANSLO lab activities you've made appointments posted on that dashboard to access the NANSLO lab activity on the date/time selected you selected for that appointment.
- See Scheduling a Lab – Students for information on how to set up an appointment, setting up your scheduling system account, and scheduling additional appointments.

Student Dashboard

After creating an account in the scheduling system and making an appointment, you have access to a student dashboard. To access your student dashboard, go to http://scheduler.nanslo.org. Select "I am a student." Enter your username and password.*

Forgot Your Username or Password?

If you have forgotten your username or password, select "Forgot my login or password." The information will be sent to your primary email address.

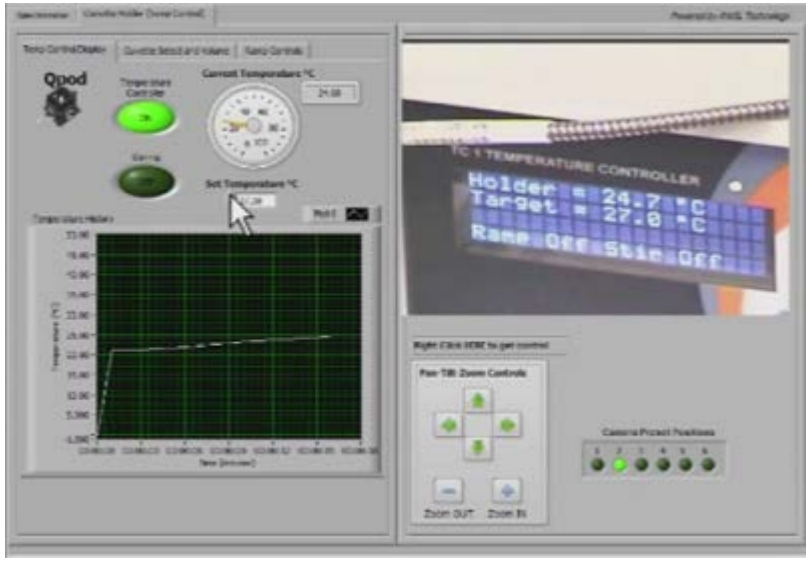


Your Student Dashboard is used to:

- Access your scheduled NANSLO lab activities on the dates and times selected;
- Modify your profile (including your email address, if it has changed or was entered incorrectly);
- Reschedule an appointment when needed;
- Resend the appointment confirmation email; and
- Perform other miscellaneous activities.

YOU DO NOT MAKE APPOINTMENTS through this dashboard.

Completing a Lab



Typically, NANSLO lab activities reference tutorials used to walk you through the specific functions on the NANSLO web interface used to control the scientific equipment for that activity.

Steps for Success:

- Study available NANSLO tutorials prior to the lab.
- Use the control panel to conduct the experiments.
- Record data using the functions available to collect data, create graphs, and take images.
- Copy these elements to the clipboard and then paste them into your lab reports, spreadsheets, or documents prepared for this lab.
- On the day and time of your lab appointment, use your Student Dashboard to access the link to your appointment.
- Use the Voice Conferencing tools to dial in and communicate with team members as soon as you connect to the laboratory. .
- Talk to the lab technicians to answer questions or help with technical issues as they are there to assist you.
- Once you have completed the steps in the laboratory, be sure you have copied and saved your data, graphs, and images for your reports to your computer (not the lab computer.)

You are now ready to review and analyze your results more deeply. Follow the lab and your instructor's directions to conclude the lab report and reflect on your learning.

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Getting Help

Provide information on who to contact

Student Checklist

- ❑ Preview lab, watch tutorials, videos, and pre-lab activities
- ❑ Test software
- ❑ Schedule lab appointment
- ❑ Participate in discussions to prepare for lab
- ❑ Prepare documents needed to record lab work
- ❑ Review tutorials and support materials
- ❑ Complete lab at appointed time
- ❑ Participate in discussions through voice conferencing
- ❑ Analyze data and results and complete assignment
- ❑ Self-assess your learning

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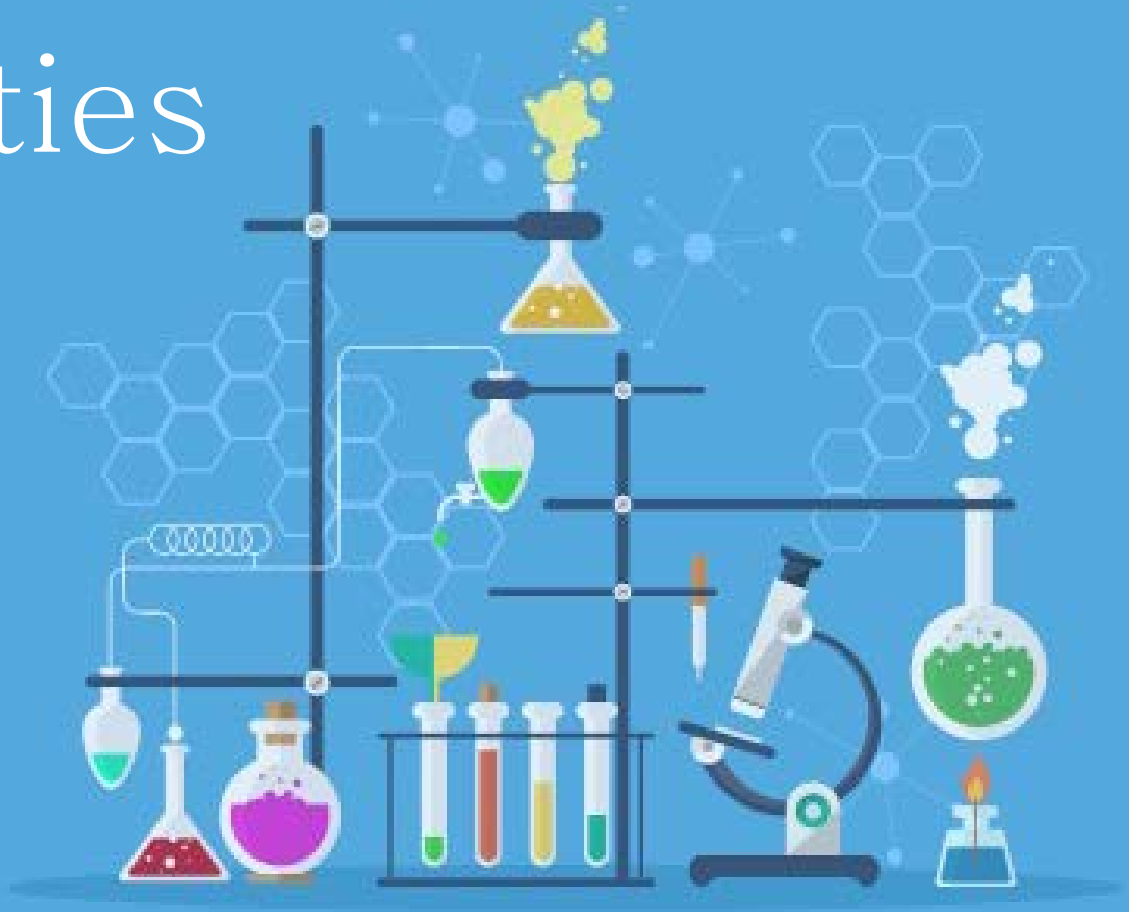
Survey of Chemistry

Lab Activities



NANSLO Survey of Chemistry Introduction

Survey of Chemistry introduces students to basic chemistry concepts. Students learn how to use scientific measurements, convert measurements, connect real world applications to chemical principles learned, use the scientific method tin forming hypotheses, collecting data, interpreting data, and validating and modifying hypotheses, use basic laboratory equipment that supports theoretical principles presented, and prepare laboratory reports.

The NANSLO lab activities included here build on the skills introduced in the Survey of Chemistry course by providing students an opportunity to demonstrate competency in these areas.

Objectives:

- Use scientific measurements and convert measurements.
- Apply the scientific method when completing lab activities.
- Use the scientific equipment appropriately when working on lab activities.
- Demonstrate improvement in learning through pre- and post-lab questions.
- Connect how lab activities performed are used in real world applications by reviewing the examples provided.

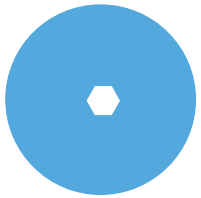
Lab Descriptions

The Survey of Chemistry Lab Manual contains ten lab activities for you to complete all included in this Survey of Chemistry Lab Activities section of this Manual. As a guide, the icons shown here appear on all pages applicable to material included for each of these lab activity.

Measurement

Pages: 33-52

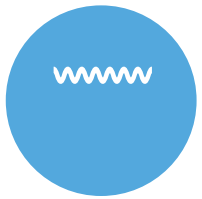
In this lab, you will study the different types of measurements commonly used in labs, conversion between the metric and English systems, and how scientific notation is used to express large numbers. You will apply this understanding by taking remote measurements of temperature and volume of a fish tank.



Density

Pages: 53-70

In this lab, you will explore how to observe, measure, calculate, and compare density of solids and liquids. During this lab you will access the NANSLO lab to take measurements of a solid object to calculate its density using two different methods. You will also collect and compare qualitative data to observe how substances with different densities relate when combined.



Emission Spectrum

Pages: 71-92

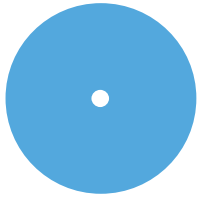
In this lab, you will access the NANSLO lab to collect emission wavelength data to discover and compare the emission spectrum results for different chemicals.

Lab Descriptions

Endothermic/ Exothermic Reactions

Pages: 93-112

In this lab, you will access the NANSLO lab to observe and collect data on the processes of different salts dissolving in water to determine if there is an endothermic or exothermic result.



Radiation

Pages: 156-172

In this lab, you will use the NANSLO lab equipment to measure and compare three different forms of radiation — alpha, beta, and gamma — and determine their strength based on distance and blockage by different shielding materials. In the final activity, you will use your experiment techniques and comparison data to identify an unknown type of radiation.

Beer-Lambert Law

Pages: 113-131

In this lab, you will study the Beer-Lambert law and see first-hand how it is used for analysis.

Reaction Rates

Pages: 173-186

The rate of a chemical reaction is the time it takes for a given amount of a reactant to change into a product. For this lab, you will observe how reaction conditions change the rate of reaction in a mixture of Alka-Seltzer tablets and water.

Enzyme Kinetics

Pages: 132-155

In this lab, you will use the NANSLO lab equipment to experiment with the effects of solute concentration and temperature on reaction rate, measured by spectrum absorption of resulting products.

Acid/Base Titration

Pages: 187-203

Titration is a procedure to analyze a substance for particular compounds and their concentrations. In this lab, you will use remote acid/base titration lab equipment to determine the concentration (molarity) of acid in a sample solution.

Lab Descriptions

Membrane Diffusion

Pages: 204-224

Diffusion is a process where molecules disperse from areas of high concentration to areas of low concentration to establish equilibrium. In this lab, you will experiment with the rate of diffusion across a membrane. A spectrophotometer will be used to track the diffusion of iodine across a membrane. This is accomplished by measuring the light absorbed by the dark color of iodine as it reacts in the starch solution on the other side of the membrane. You will be setting up trials using different temperatures to find the impact of heat on the rate of diffusion.

Measurement

Lab Description:

In this lab, you will study the different types of measurements commonly used in labs, conversion between the metric and English systems, and how scientific notation is used to express large numbers You will also learn to apply this understanding by taking remote measurements of temperature and volume of a fish tank.

Purpose:

To practice measuring volume and temperature, and apply measurement unit conversion and scientific notation to collected data.

Essential Question:

How is measurement used to record data in chemistry?

Objectives:

At the completion of this lab, you should be able to:

1. Identify units of measurement for temperature, volume, mass, and length in metric and English (Imperial) systems.
2. Convert measurements between the metric and English units.
3. Use the NANSLO lab equipment to take length and temperature measurements.
4. Calculate volume in both metric and standard units.
5. Convert temperature between metric and standard units.
6. Express numbers using scientific notation.

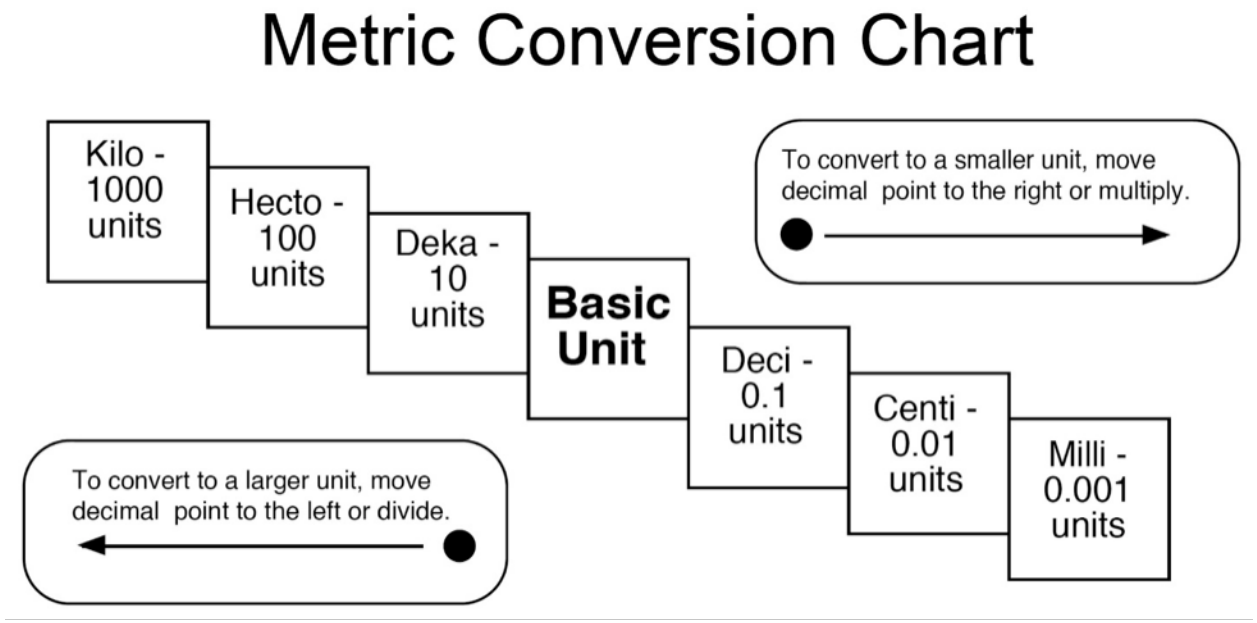
Pre-Lab Questions

These pre-lab questions are to help you think about the measurement lab and self-assess what you know and what you want to know about the topic. By the end of the lab, you should be able to answer these questions in more detail. Compare your answers to see what you have learned.

1. What is the difference between the metric and English (Imperial) system of measurement?
2. Why is the metric system applied to science investigations?
3. How are units converted between the two systems?
4. How is volume measured?
5. What is the difference between mass and weight?
6. What is scientific notation and how is it used?

Background Information

There are 4 basic types of measurements: length, volume, temperature, and mass. There are two main systems of measurement: the English (or Imperial) system and the metric system. The US and the UK are the main users of the English system, while the rest of the world primarily uses the metric system. You will need to become comfortable with conversions within and between the two systems. Since the metric system is a base 10 system, you can make conversions by moving the decimal to the left or right. If you know the prefix and the base unit, you can multiply or divide. For instance, to convert from centimeters to meters, jump two to the left, e.g., 360 centimeters is equal to 3.6 meters.



Background Information

The English (or Imperial) system is not so user friendly. To convert from one unit to another, you need to know the conversion factor. For instance, to go from inches to feet you need to know that there are 12 inches in 1 foot. So, to convert 360 inches to feet, use the conversion factor of 12 inches = 1 foot

$$\frac{360\ \cancel{inches}}{\square} X \frac{1\ foot}{12\ \cancel{inches}} = 3\ feet$$

Conversions between the two systems can also be made. For instance there are 2.54 cm in 1 inch.

$$\frac{360\ \cancel{inches}}{\square} X \frac{2.54\ cm}{1\ \cancel{inches}} = 914.4\ cm$$

Measuring Length: In the metric system, length has a base unit of meter (m).

Measuring Volume: The base unit for volume is liter. One liter is equivalent to 1 cubic decimeter, which is 1 decimeter x 1 decimeter x 1 decimeter. Volume is really a combination of three length measurements (length x width x height).

Measuring Temperature: Temperature can be measured in Fahrenheit °F or Celsius °C. In most science labs, temperature is measured using the Celsius scale. It is called a centigrade thermometer because there are 100 (centi) divisions, i.e., degrees between freezing of water at 0° C and the boiling point of water at 100° C. In Fahrenheit, freezing is 32° F and boiling is 212° F, which is 180 divisions.

To convert between °F and °C, do the following:

From °F to °C: 1) Subtract 32° from °F. 2) Multiply by 5. 3) Divide by 9.

From °C to °F: 1) Multiply °C by 9. 2) Divide by 5. 3) Add 32.

Background Information

Measuring Mass:

Grams are the base unit of mass in the metric system, and mass measures the amount of matter in an object. Mass does not change. Weight, on the other hand, which is commonly mistaken for mass, varies based on gravity. A person's weight is less on the moon than on earth because of gravitational forces, while the mass is always the same. Typically, a digital balance or a triple weight balance is used to measure mass. A digital balance works by tarring, or starting, at zero point and then weighing the object that is placed on the top of the detector. A triple weight balance works by using counterbalance to find the weight that corresponds to the object being measured. The metric base unit of weight is gram (g) while the SI base unit is pound (lb) or ounce (oz).

Scientific notation is a way to refine very large or very small numbers. It makes data easier to record and compare to other numbers. For instance, the number 320000033994 is a very long number that would take you a minute to say accurately. Adding commas helps — 320,000,033,994 — but it would still probably take a minute to come up with "three hundred and twenty quadrillion, thirty-three thousand, nine hundred and ninety-four." If we were collecting data and had to compare two of these numbers, say 444430000 to 320000033994, would that be an easy task to do? It can be done, but it takes some time. At a quick glance, it would be tough to say which one is bigger or smaller. Scientific notation can help. 4.44×10^{9} vs. 3.2×10^{11} is easier to compare. Scientific notation is not difficult, but it does have a set of steps that you will need to follow.

Background Information

Writing Numbers Using Scientific Notation

1. Rewrite your number and put a decimal after the first non-zero digit.
    1. 1234567 will become 1.234567
    2. 0.000000098765 becomes 9.8765
2. Add "x 10" to the end of the digits.
    1. 1.234567 becomes 1.234567 x 10
    2. 9.8765 becomes 9.8765 x 10
3. Count how many place values the decimal has moved from its original placement to its current spot. Write that number as your exponent.
    1. If the number becomes smaller when you move the decimal, the exponent will be positive.
4. 1.234567×10^{6}
    1. If the number becomes bigger when you move the decimal, the exponent will be negative.
5. 9.8765×10^{-8}

Background Information

Important Terms

English or Imperial system – the measurement system used in only a few countries including the United States using feet, pounds, quarts, and seconds as standards of measurement

mass – the property of a body that is a measure of its inertia; commonly taken as a measure of the amount of material it contains and causes it to have weight in a gravitational field

metric system – any decimal system of units based on the meter; for scientific purposes, the Système International d'Unités (SI units)

scientific notation – a method for expressing a given quantity as a number having significant digits necessary for a specified degree of accuracy, multiplied by 10 to the appropriate power, as 1385.62 written as 1.386×10^3

unit conversion – a multi-step process that involves multiplication or division by a numerical factor and selection of the correct number of significant digits

volume – the amount of space occupied by a three-dimensional object, as measured in cubic units (quarts or liters)

weight – the force with which a body is attracted toward the earth or a celestial body by gravity and which is equal to the product of the mass and the local gravitational acceleration

Resources

Scientific Notation. Math is Fun. https://www.mathsisfun.com/numbers/scientific-notation.html
Mass vs. Weight. NASA. http://education.ssc.nasa.gov/massvsweight.asp
The Metric System: Units, Definitions, and History. Science Made Simple. http://www.sciencemadesimple.com/metric_system.html
Volume Formulas. Math.com. http://www.math.com/tables/geometry/volumes.htm

Measurement in Chemistry

Chemistry is divided into five main disciplines: organic, inorganic, physical, biochemical, and analytical. Analytical chemistry specifically involves the development of tools and methods to identify and measure the properties of matter.

Measurement is crucial to the scientific process in all chemistry labs; it is the basis for study and research. The following are some common areas where measurement is an integral part of chemistry in everyday life products.

Pharmaceuticals

Chemists support the development of medications to treat illnesses and conditions. You can imagine the vital role of accurate measurement in producing, testing, and determining correct dosages for human and animal use.

Agriculture and Food

Chemistry measurements are used to set standards for the safety and quality of food, including detecting traces of pesticides and growth hormones, and determining nutritional value for labeling of food products. Cooking is also a form of chemistry and measurement, as you may have experienced when a recipe went wrong!

Water Quality

Every water source for drinking should be tested for safety using chemical analysis and measurement. Levels of lead and other metals, bacteria, radon,

Resources

Analytical Chemistry. American Chemical Society. http://www.acs.org/content/acs/en/careers/college-to-career/areas-of-chemistry/analytical-chemistry.html
Water. United States Environmental Protection Agency. http://www.epa.gov/learn-issues/learn-about-water
Analytical Chemistry. UC Davis ChemWiki.

Measurement Lab

Purpose:

To practice measuring volume and temperature, and apply measurement unit conversion and scientific notation to collected data.

https://www.flickr.com/photos/21708387@N02/

For this lab, measurements will be collected on a remote fish tank housed at a NANSLO lab.

This ecological system has been equipped with sensors to detect:

- dissolved oxygen
- temperature
- pH

You will be viewing measurement of the tank itself, as well as recording the temperature of the water.

Pre-Lab Problems

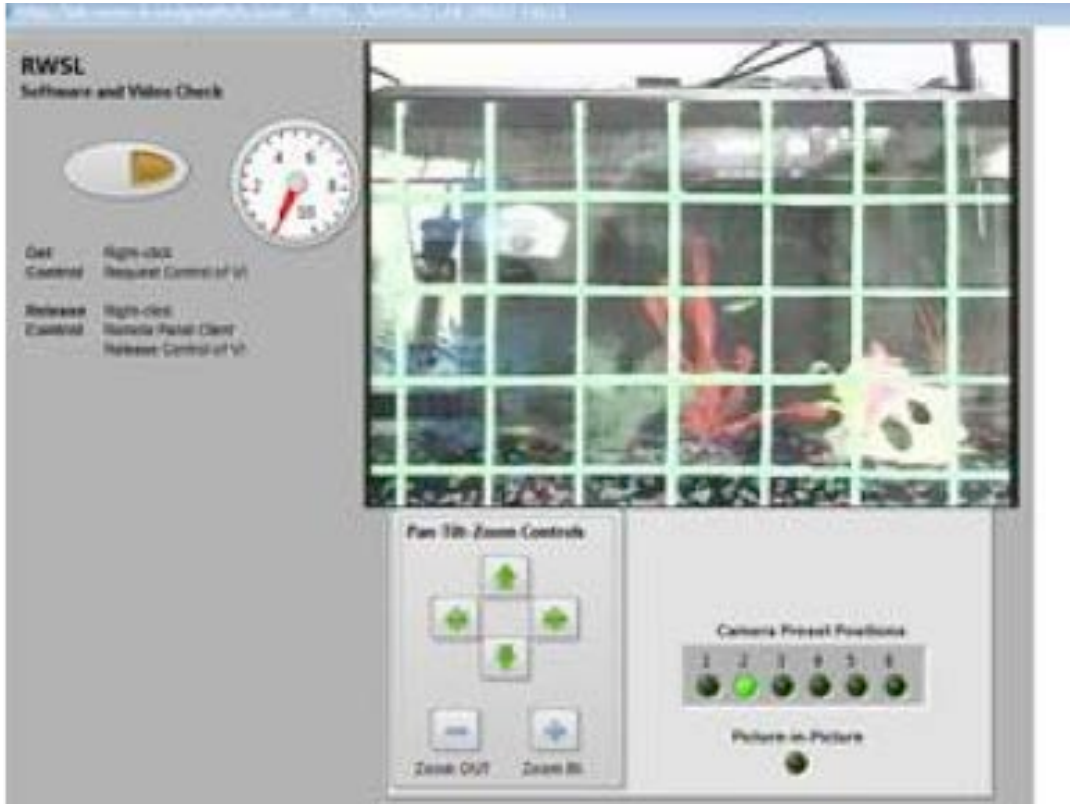
1. Convert 12 inches (in) to centimeters (cm).
2. Convert 400000 milliliters (mL) to kiloliters (kL).
3. What is the temperature in °C if the outside temperature is 43° F?
4. Evaluate your answer to #3. Is it smaller or larger than 43? Does this make sense?
5. Find a food product in your house and record the weight on the label (should be in ounces). Convert the weight to grams.
6. Convert the food weight in #5 to kilograms.
7. Compare your answers for #5 and #6. Do these make sense?
8. Write the following in scientific notation:
   - 1345635000
   - 477777.00000000000
   - 4570000
   - 0.00000000567
9. Convert the following from scientific notation to full number (i.e., normal):
   - 6.789×10^{5}
   - 9.112×10^{-4}
   - 4.56×10^{7}
   - 8.43×10^{-2}

Control Panel

The Control Panel is where you access the equipment controls, collect data, and communicate with others participating at the same time as you.

In this experiment, you will use a video camera to view and zoom into different areas of the aquarium.

You will also use the controls to monitor the sensors that will allow you to record temperature.



Variables and Controls:

1. Temperature reading
2. pH reading
3. Dissolved oxygen reading
4. Message screen
5. Camera image
6. Camera view
7. Camera controls
8. Voice conference

Tutorial

This tutorial introduces you to the lab. You will see how the equipment is set up as well as the view you will have from your control panel. For this lab, you will be using the video camera to record measurements of the tank and take digital and analog readings of temperature.

The demonstration shows how to control the equipment, read the settings, collect data, and collaborate with others. Watch the tutorial a second time, immediately before your lab appointment, to refresh your memory about the function and purpose of the different features in this lab setup.

- Add link when available

Things to Notice / Questions:

1. What does each of the sensors monitor?
2. How will you measure the volume of the tank?
3. How will you capture and record your data?
4. How will you measure the temperature?

Measurement Lab Procedure

Exercise 1: Measuring length and volume

1. Using the NANSLO lab equipment, you will log in and take the indicated measurements and observations at the times you are scheduled to take the lab.
2. Connect to the voice conferencing tool to talk with teammates and the lab technician. Look for the controls and sensor data.
3. Use the video camera to zoom in and record the following measurements:
   - What is the length of the fish tank in inches?
   - What is the length of the fish tank in cm?
   - What is the height of the fish tank in cm?

Exercise 2: Measuring temperature

1. Use the video camera to zoom in and read the analog thermometer in the fish tank. What is the temperature and what are the units?
2. Use the video camera to zoom in and read the digital thermometer in the fish tank. What are the units on the digital thermometer?

Measurement Lab Procedure

Exercise 1: Measuring length and volume

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   - What is the length of the fish tank in inches?
   - What is the length of the fish tank in cm?
   - What is the height of the fish tank in cm?

Exercise 2: Measuring temperature

1. Use the video camera to zoom in and read the analog thermometer in the fish tank. What is the temperature and what are the units?
2. Use the video camera to zoom in and read the digital thermometer in the fish tank. What are the units on the digital thermometer?

Lab Day Checklist

On the day of your scheduled lab, review the items on this checklist to make sure you are prepared before logging into NANSLO.

- ❑ Read and review all lab materials
- ❑ Prepare and organize lab charts and recording materials
- ❑ Watch the lab tutorial again as a review before the lab
- ❑ Log in to your lab session – two options:
  - ❑ Retrieve your email from the scheduler with your appointment info or
  - ❑ Log in to the student dashboard and join your session by going to http://scheduler.nanslo.org
- ❑ NOTE: You cannot log in to your session before the date and start time of your appointment. Use Internet Explorer or Mozilla Firefox.

Measurement Lab Report

Exercise 1: Measuring length and volume

Use the video camera to zoom in and record the following measurements:

1. What is the length of the fish tank in inches?

2. What is the length of the fish tank in cm?

3. What is the height of the fish tank in cm?

Exercise 2: Measuring temperature

1. Use the video camera to zoom in and read the analog thermometer in the fish tank. What is the temperature and what are the units?

2. Use the video camera to zoom in and read the digital thermometer in the fish tank. What are the units on the digital thermometer?

Measurement Lab Analysis

Exercise 1

1. Convert your answer to #1 to cm.
2. Convert your answer to #2 to inches.
3. Do your conversions match your measurements above? Why or why not?
4. What is the volume of the fish tank if the width (i.e., depth) is 20 cm?
5. Convert the volume to liters and gallons.
6. Write your answer in scientific notation.

Exercise 2

1. Convert your answer to #1 to °F.
2. Go back through and convert all of your measurements and your analysis to scientific notation. Put these next to your original answers.
3. Imagine you have been made the ruler of a new island and your first mandate is to pick a units system to adopt for your new nation. Which system would you choose and why?

Reviewing Results

1. How accurate was the data you collected? How do you know?

2. How might an accurate record of temperature be important in a fish tank?

1. What other types of measurements would a biologist be interested in collecting in a fish tank ecosystem? List at least six.
    1.
    2.
    3.
    4.
    5.
    6.

Conclusion and Reflection

Write a thoughtful conclusion to the lab, answering the essential question: How is measurement used to record data in chemistry?

Post-Lab Questions

Answer the following questions as completely as possible. Use evidence from your lab to help support answers where possible. Use these questions to demonstrate your learning. You may want to review your pre-lab answers and see what you have gained in understanding.

1. What is the difference between the metric and English (Imperial) systems of measurement?
2. Why is the metric system applied to science investigations?
3. How are units converted between the two systems?
4. How is volume measured?
5. What is the difference between mass and weight?
6. What is scientific notation and how is it used?

Density

Lab Description:

In this lab, you will explore how to observe, measure, calculate, and compare density of solids and liquids. You will access the NANSLO lab to take measurements of a solid object to calculate its density using two different methods. You will also collect and compare qualitative data on how substances with different densities relate when combined.

Purpose:

To explore the concept of density and use qualitative and quantitative methods to study how objects and liquids with different densities interrelate.

Essential Question:

What are two ways to determine the density of substances, and how is knowing density important in chemistry?

Objectives:

At the completion of this lab, you should be able to:

1. Define density.
2. Use the remote NANSLO equipment to take measurements and make observations related to density.
3. Identify the units used in density measurements.
4. Demonstrate two ways to quantitatively measure density.
5. Describe how qualitative observations can be used to compare densities.
6. Describe an application of density in chemistry.

Pre-Lab Questions

These pre-lab questions are to help you think about the density lab and self-assess what you know and what you want to know about the topic. By the end of the lab, you should be able to answer these questions in more detail. Compare your answers to see what you have learned.

1. What is the difference between density and mass, and how are the two related?
2. What do you need to know in order to calculate the density of a solid object?
3. How might you measure the volume of an irregular shaped object, such as a rock?
4. How is volume related to density?
5. If you know the volume and density of an object, what else can you determine?
6. A block of wood has a mass of 50 g and occupies a volume of 0.4 L. What is the density?
7. An unknown object made of a single material has a mass of 79 g and occupies 10 mL. How can you determine the unknown material?

Background Information

All matter has mass and volume.

Volume is the amount of space an object occupies and is measured by units such as liters (L), gallons (gal), cubic centimeters (cm^3), cubic meters (m^3), or cubic feet (ft^3).

Mass is the amount of matter an object has.

Density is the amount of mass divided by the volume of the object or $D = M / V$

Where M is mass, V is volume, and D is density.

- Density is measured in units of mass divided by volume. For example, grams per milliliter.
- Mass and volume can be different in two objects, but if they are made of the same material their densities will be equivalent.
- Density is a physical property of a material and can be used to compare objects and identify unknowns.

Solid	Density g/c^3
Lead	11.37
Silver	10.57
Copper	8.92
Brass	8.90
Nickel	8.57
Iron	7.90
Aluminum	2.67
Marble	2.60-2.84
Granite	2.65
Rubber	1.10-1.19
Oak	0.80
Pine	0.35-0.50

Resource
Density Calculations – Chemistry Tutorial. TheChemistrySolution.
https://www.youtube.com/watch?v=REtBibhIqfo

Background Information

Quantitative Measurement

To calculate density, you need to measure the mass and volume of the specimen.

Volume: Liquid is measured using a standard graduated cylinder or pipette. With a solid cube or rectangular object, simply measure the length x width x height. If an object is not a regular shape, how can you find the volume? Say you pick up a rock and you want to measure its density. The mass is straightforward — you would use a scale — but the volume would be trickier. One way to figure out volume is to use displacement. Take a container of water with a known volume and drop the rock in. The level of water will rise as the rock takes up space. The difference between the volume of the water with and without the rock is the volume of the rock itself. With the volume and mass known, you can calculate for the unknown density by applying D = M / V.

Qualitative Observations

Talk show host David Letterman used to feature a science segment called "Will it Float." It used the principles of density and buoyancy to determine whether an object placed in water would float. Less dense items will float and more dense items will sink. This is qualitative data and relies on observation rather than knowing or calculating the actual density of material. This lab will look at density qualitatively and quantitatively.

Density Applications

Density has many applications in the sciences, including chemistry.

Researchers are continually looking at ways to measure the density of different types of matter, even at the cellular level. For example, some of the current research includes development of ways to measure density of radicals in plasma in order to study tissue regeneration and targeted treatment effects in medicine. Scientists are working on a way to measure the density of a single cell by a method called buoyant mass. This would provide new insight into cellular processes and research at the cellular level.

Other important applications include the density comparisons of:

- different types of fuel for assessment of heat produced
- different metals to determine content and percentages
- beverages to determine amount of sugars or alcohol
- saltwater to determine changing concentrations
- carbon dioxide to track climate change

https://www.flickr.com/photos/la_riviere/
cropped

Resources

How Can the Study of Density Be Used in the Real World? GlobalPost.
http://everydaylife.globalpost.com/can-study-density-used-real-world-41598.html
Density and Volume - Real-life Applications. Science Clarified.
http://www.scienceclarified.com/everyday/Real-Life-Chemistry-Vol-3-Physics-Vol-1/Density-and-Volume-Real-life-applications.html
Density. ScienceDaily.
https://www.sciencedaily.com/terms/density.htm

Density Lab

Purpose:

To explore the concept of density and use qualitative and quantitative methods to study how objects and liquids with different densities interrelate.

For this lab, measurements will be collected on a remote fish tank housed at a NANSLO lab.

https://www.flickr.com/photos/21708387@N02/

This ecological system has been equipped with sensors to detect:

- dissolved oxygen
- temperature
- pH

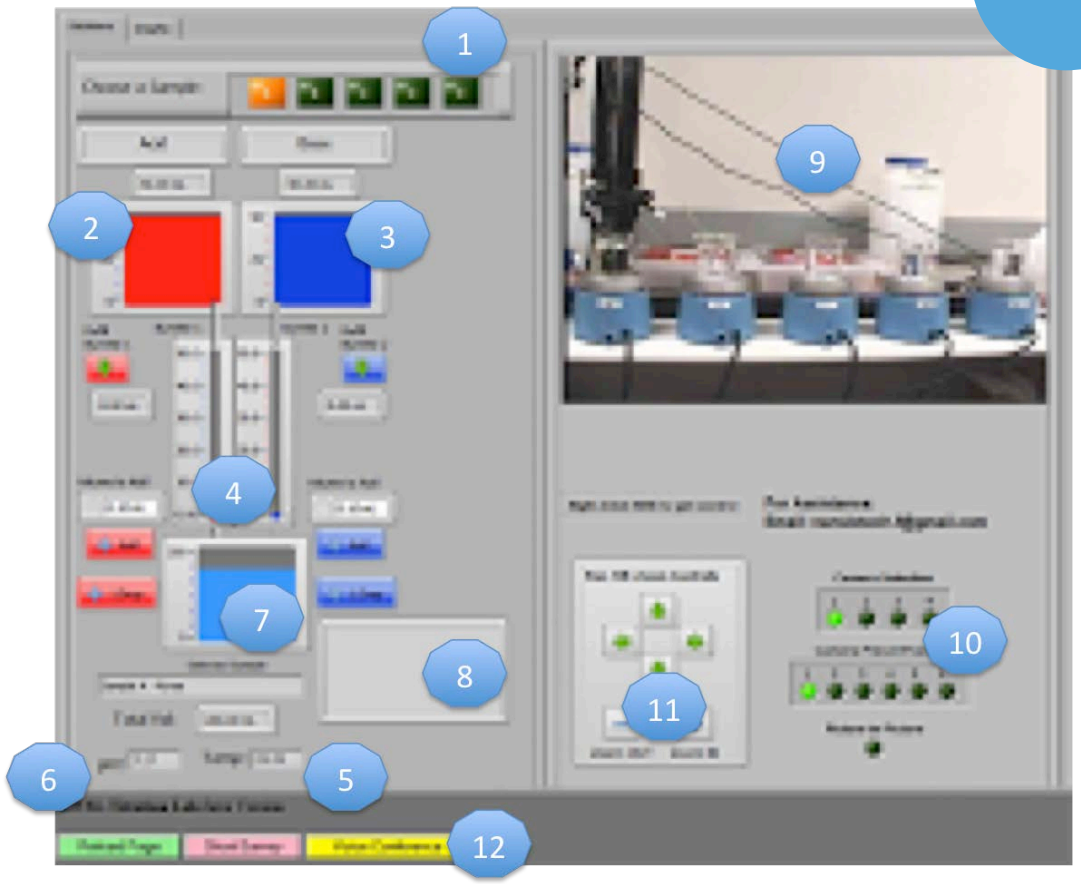
You will be viewing measurement of the tank itself, as well as recording the temperature of the water.

Control Panel

The Density Lab Control Panel is where you access the equipment controls, collect data, and communicate with others participating at the same time as you.

In this experiment, you will use the camera to zoom into the setup and take measurements and make observations.

There are four beakers labeled 1–4. During Exercise 2, you will be using the burettes to add specified amounts of water to the beakers.



Variables and Controls:

1. Selection of beaker
2. Acid tank
3. Base tank
4. Burettes
5. Temperature reading
6. pH reading
7. Volume
8. Message screen
9. Camera image
10. Camera view
11. Camera controls
12. Voice conference

Tutorial

This tutorial introduces you to the density lab. You will see how the equipment is set up as well as the view you will have from your control panel. For this lab, you will be using the video camera to record measurements of the tank and take digital and analog readings of temperature.

The demonstration shows how to control the equipment, read the settings, collect data, and collaborate with others. Watch the tutorial a second time, immediately before your lab appointment, to refresh your memory about the function and purpose of the different features in this lab setup.

- Add link when available

Things to Notice / Questions:

1. How do you join the voice conference?
2. How do you measure a rubix Cube?
3. How can you view a close-up of each beaker?
4. What steps do you take to add water?
5. How do you allow others to take over the controls?

Density Lab Procedure

Exercise 1: Determine the density of a cube quantitatively

1. Using the NANSLO interface, zoom in on the rubix cube. Measure the height and width of the cube. Assume the depth is equivalent to the height. Record in your lab report.
2. Read the measurement on the balance setup with the cube. Record in your lab report.
3. Read the volume measurement of the liquid in Beaker 1. Ask the lab technician to add the cube. Read the volume measurement again. Add this data to your lab report.

Exercise 2: Comparison of density qualitatively

1. Using the NANSLO titration setup, zoom in on Beaker 2. Beaker 2 contains vegetable oil with red food coloring and another substance (a metal bolt). Record what you see in Beaker 2.
2. Using the titration setup, add 10 mL of water to Beaker 2. Record your observations in your lab report.
3. Move to Beaker 3, which contains corn syrup and another substance (a ping pong ball). Record what you observe in Beaker 3.
4. Using the titration setup, add 10 mL of water to Beaker 3. Record your observations in your lab report.
5. Move to Beaker 4, which contains vegetable oil, corn syrup, and the two other substances you identified in Beakers 2 and 3. Record your observations in your lab report.
6. Again add 10 mL of water to the system and record your observations in your lab report.

Lab Day Checklist

On the day of your scheduled lab, review the items on this checklist to make sure you are prepared before logging into NANSLO.

- ❑ Read and review all lab materials
- ❑ Prepare and organize lab charts and recording materials
- ❑ Watch the lab tutorial again as a review before the lab
- ❑ Log in to your lab session – two options:
  - ❑ Retrieve your email from the scheduler with your appointment info or
  - ❑ Log in to the student dashboard and join your session by going to http://scheduler.nanslo.org
- ❑ NOTE: You cannot log in to your session before the date and start time of your appointment. Use Internet Explorer or Mozilla Firefox.

Density Lab Report

Exercise 1: Determine the density of a cube quantitatively

1. Rubix Cube: Measure the height and width of the cube (assume the depth is equivalent to the height)

Dimension	Measurement	Units
Height		
Depth		
Length		

2. Mass of cube: _____ units: _____

3. Beaker 1: Volume displacement

Beaker 1	Starting Volume	Ending Volume	Unit
Height			
Depth			
Length			

Density Lab Report

Exercise 2: Qualitative comparison of density

1. Beaker 2 contains vegetable oil with red food coloring and a metal bolt. Record what you see in Beaker 2.

2. Using the titration setup, add 10 mL of water to Beaker 2. Record your observations.

3. Beaker 3 contains corn syrup and a ping pong ball. Record what you observe in Beaker 3.

4. Using the titration setup, add 10 mL of water to Beaker 3. Record your observations in your lab report.

Density Lab Report

Exercise 2: Qualitative comparison of density

5. Beaker 4 contains vegetable oil, corn syrup, and the two other substances you identified in Beakers 2 and 3. Record your observations in your lab report.

6. Again add 10 mL of water to the system and record your observations in your lab report.

Density Lab Analysis

Exercise 1

1. Calculate the volume of the cube from your measurements. _____ units _____
2. Using the mass measurement from procedure step 2, calculate the density _____ units _____
3. If the volume in the beaker started at 100 mL, what is the volume measurement from the liquid displaced? _____ mL
4. Do your values from #1 and #2 match? If not, provide a reason they may not.

Exercise 2

1. Draw a diagram comparing what you saw in Beakers 2, 3, and 4. Label your drawing.

Density Lab Analysis

1. For each beaker, make a list of the items in it after the water was added and create a list of materials listing them from least dense to most dense.

2. Imagine someone takes a deep breath and jumps into a swimming pool. He immediately floats. Is he more or less dense than water?

3. If the same swimmer goes underwater and breathes out the air in his lungs as bubbles, he starts to sink. Speculate on why the same person will float in the above situation and sink in this one.

4. Identify an instance where density can be used in everyday life.

Reviewing Results

Write a review of your experiment. Include your findings and an explanation of your results.

Conclusion and Reflection

Write a thoughtful conclusion to the lab, answering the essential question: What are two ways to determine the density of substances, and how is knowing density important in chemistry?

Post-Lab Questions

Answer the following questions as completely as possible. Use evidence from your lab to help support answers where possible. Use these questions to demonstrate your learning. You may want to review your pre-lab answers and see what you have gained in understanding.

1. What is the difference between density and mass, and how are the two related?
2. What do you need to know in order to calculate the density of a solid object?
3. How might you measure the volume of an irregular shaped object, such as a rock?
4. How is volume related to density?
5. If you know the volume and density of an object, what else can you determine?
6. A block of wood has a mass of 50 g and occupies a volume of 0.4 L. What is the density?
7. An unknown object made of a single material has a mass of 79 g and occupies 10 mL. How can you determine the unknown material?

Emission Spectrum Lab

Lab Description:

In this lab, you access the NANSLO lab to collect emission wavelength data to discover and compare the emission spectrum results for different chemicals.

Purpose:

To determine the wavelength and frequency of light emitted from a substance in order to help ascertain its chemical makeup.

Essential Question:

How can emission spectra be used to study the makeup of a substance, and how does this apply to chemistry?

Objectives:

At the completion of this lab, you should be able to:

1. Measure the emission spectrum of a source of light using the digital spectrometer.
2. Find the wavelengths at a peak of intensity.
3. Determine where these wavelengths lie on the electromagnetic spectrum.
4. Calculate the frequency of each peak wavelength.
5. Calculate the intensity of each peak wavelength.
6. Compare and contrast the spectra of various light sources.
7. Explain how emission spectra are used to identify elements or molecules.

Pre-Lab Questions

These pre-lab questions are to help you think about the emission spectrum lab and self-assess what you know and what you want to know about the topic. By the end of the lab, you should be able to answer these questions in more detail. Compare your answers to see what you have learned.

1. What is an emission spectrum?
2. How is the spectrum related to chemical composition?
3. How can you find the wavelength using a spectrometer?
4. How can you calculate intensity with a known frequency and wavelength?
5. How can emission spectra be used to identify elements or molecules?
6. Explain why higher frequency waves are more dangerous.

Background Information

Important Terms

amplitude – the absolute value of the height of a wave from the midline to the crest; symbol: a

emission spectrum – the spectrum formed by electromagnetic radiation emitted by a given source, characteristic of the source and the type of excitation inducing the radiation

frequency – the number of cycles or completed alternations per unit of time of a wave or oscillation; symbol: f

nanometer – one billionth of a meter (nm)

photoelectric effect – the phenomenon in which the absorption of electromagnetic radiation, as light, of sufficiently high frequency by a surface, usually metallic, induces the emission of electrons from the surface

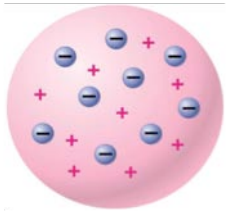
photon – a quantum of electromagnetic radiation, usually considered as an elementary particle, that is its own antiparticle and that has zero rest mass and charge and a spin of one; symbol: γ

wavelength – the distance, measured in the direction of propagation, between two points of the same phase in consecutive cycles of a wave; symbol: λ

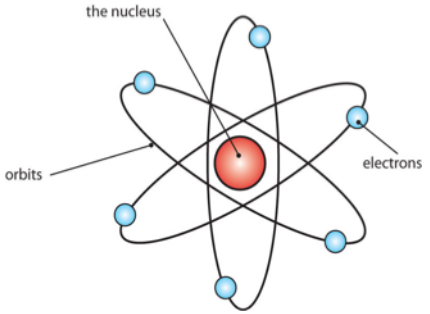
Background Information

It's taken many years and much debate for scientists to agree on the shape and properties of the atom. In 1803, John Dalton was the first chemist to publish the idea that all matter is made up of atoms. Although many of Dalton's theories were correct, his atomic model was not as evolved as the atom we know today. Dalton thought that an atom was a solid, indivisible ball, without electrons or a nucleus.

In 1879, J. J. Thomson, a physicist, discovered the existence of electrons by using a cathode ray tube. He also discovered that the same element could have different atomic weights, now called isotopes. Thomson's atomic model, also known as the plum pudding model, edged closer to the model of today, but he thought that electrons were positioned all throughout the atom with a cloud of positive charge surrounding them.



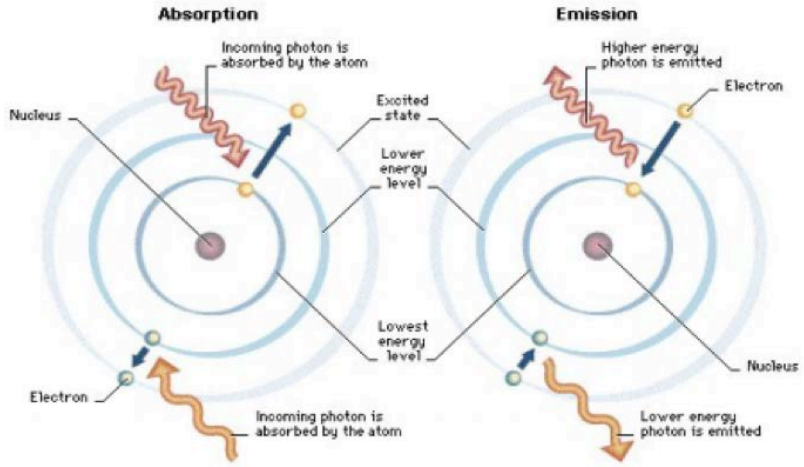
To see if Thomson's model was correct, in 1911 Ernest Rutherford used his famous gold foil experiment to fire radioactive particles through gold foil at zinc sulfide. If Thompson was correct, the particles should have gone straight through the foil, but they did not. While most made it through, some shot off in different directions. This could only mean that an atom was made up of mainly empty space. Rutherford came to the conclusion
that the atom was actually a mix of both Dalton's and Thomson's atomic models. The atom had a solid center, called the nucleus, which contained the protons and neutrons. The electrons were in orbitals around the nucleus, with the majority of

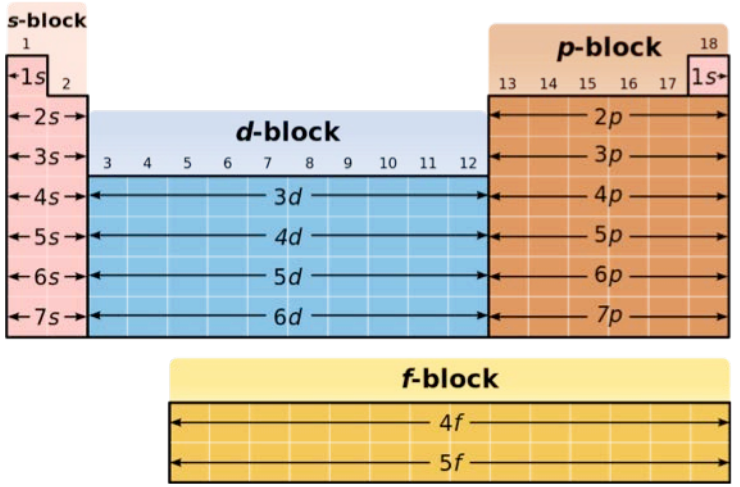


Background Information

Light can act as both a wave and a particle, as discovered by Albert Einstein in 1905. He stated that light is not actually a continuous wave, but rather a collection of wave packets, or photons, that have a certain amount of energy. Since the discovery of a wave's ability to act like particles, it has also been discovered that subatomic particles can act like waves. This means that if an electron were to be dislodged from its orbital after being hit with a photon, it would gain energy. The electron would then fall back into its original orbital and give off that photon in the form of light. Because different frequencies have higher and lower energy levels, they can raise the electron into different level orbitals. This photoelectric effect is defined as the ability for light to dislodge electrons from their orbits in certain metals, creating a current.

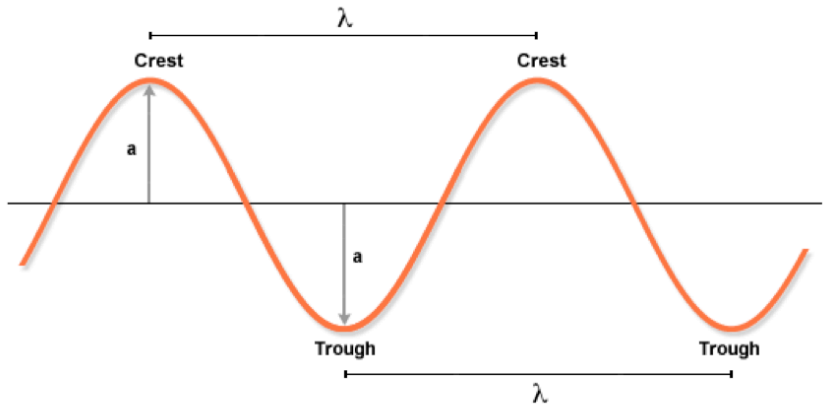
There are electrons in many different orbitals around an element, and there are many different orbitals for them to rise to once they are hit by photons. This means that when the electron falls back into place, there are many different frequencies, or colors, that are emitted by the element. All elements have electrons circling their nuclei in different orbitals. Where an element is on the periodic table determines the type of orbital the outermost electrons are traveling in. Each element and molecule have distinct patterns of color that they emit. This allows us to identify an element or molecule by looking at the visible light it gives off.

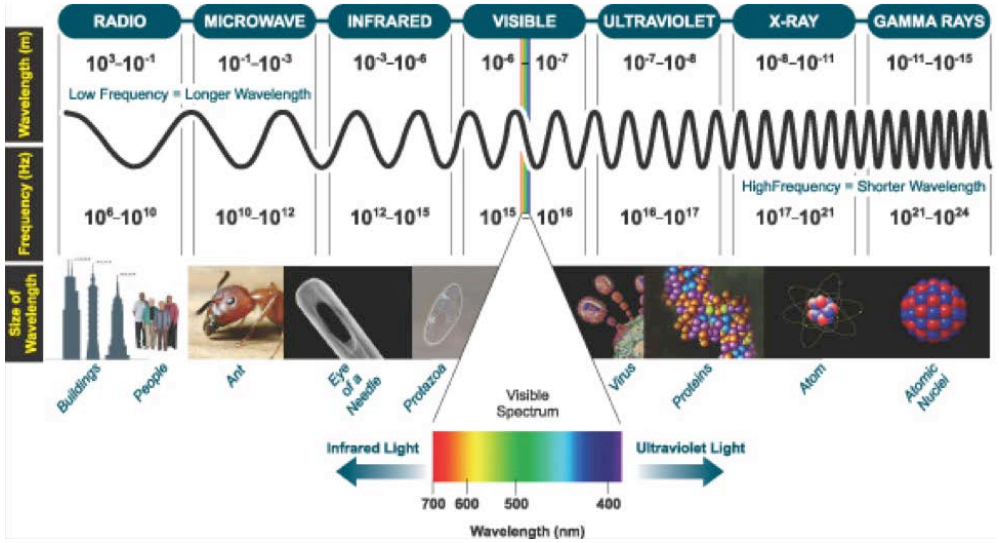




Background Information

Electromagnetic waves are responsible for visible light, radio waves, and X-rays. James Maxwell, a Scottish mathematical physicist, discovered the electromagnetic field by recognizing the relationship between electricity and magnetism. All waves have certain properties. A **wavelength** (λ) is the distance between two identical points on a wave, typically measured at the **crest**, or the highest point. **Amplitude** (a) is the absolute value of the height of a wave from the midline to the crest. **Frequency** (f) is how many times a wave passes a certain point in time. Typically, frequency is measured in one-second intervals, or hertz (Hz). Therefore, 1 Hz is equivalent to 1 wave per second. Wavelength and frequency have an inverse relationship, meaning the higher the frequency the shorter the wavelength. The higher the frequency and the shorter the wavelength, the greater the amount of energy contained in a wave.





Background Information

This explains why red light, no matter how bright, will not produce a current, but even dim blue light will. If light was only a wave, the brightness of the light would affect how much of a current is created because there is more energy in the wave; in reality, it does not. Red light does not have enough energy per photon to dislodge an electron, while blue light does.

In this lab, you will be exploring emission spectroscopy, which involves the examination of the wavelengths of photons discharged by atoms and molecules as they transit from a high energy state to a low energy state. As this happens, a set of wavelengths are emitted by each element or molecule depending on its electronic structure. A study of these wavelengths is used to identify the unique elemental structure of the substance.

Resources

The Atomic Hydrogen Emission Spectrum. ChemGuide.
http://www.chemguide.co.uk/atoms/properties/hspectrum.html
Atomic Emission Spectroscopy. Chemistry Learner.
http://www.chemistrylearner.com/atomic-emission-spectroscopy.html
Atomic Spectra. UC Davis ChemWiki.
http://chemwiki.ucdavis.edu/Core/Physical_Chemistry/Quantum_Mechanics/09._The_Hydrogen_Atom/Atomic_Theory/Electrons_in_Atoms/Atomic_Spectra

Emission Spectrum Applications

Chemical Makeup of Stars

Spectroscopy is widely used in astronomy to learn about the makeup of distant stars and galaxies. Each element emits or absorbs light at characteristic wavelengths. Astronomers can identify the element makeup of stars from the lines in their spectra seen from celestial bodies light-years away.

Spectrum Emission Study in Forensics

Studying the emission spectra of shots from various guns, chemists can detect characteristic factors to help forensic experts determine factors such as the site of a gunshot injury, presence of obstacles, distance, and order of the shot.

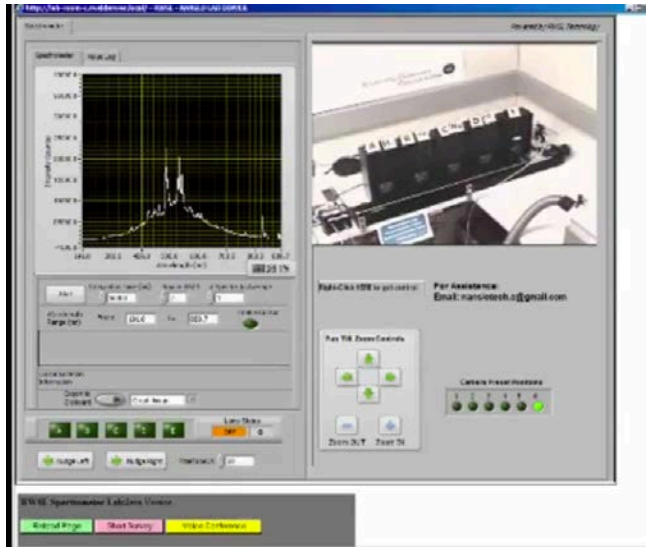
Resource

Spectra School. Learn Chemistry, Royal Society of Chemistry. http://www.rsc.org/learn-chemistry/collections/spectroscopy/introduction#Introduction

Emission Spectrum Lab

Purpose: To determine the wavelength and frequency of light emitted from a substance to help ascertain its chemical makeup.

Spectroscopy involves the examination of the wavelengths of photons discharged by atoms and molecules when changing from a high energy state to a low energy state. This characteristic set of wavelengths depends on the electronic structure of the atoms that make up the substance.



In this lab, you will be viewing five samples heated by lamps. You will study a graphic display screen that shows the wavelength and intensity of light emitted. From this data, you will determine the peak wavelengths of light for each sample. The lab report and analysis sections of the lab will guide you to make further calculations, which you can use to make comparisons between the samples.

Pre-Lab Problems

The energy of a photon is directly proportional to the frequency of the electromagnetic radiation inv

The equation used to calculate the amount of energy in a photon is: $E = hv$

- E = energy (J)
- *h* = Planck's constant (6.62607×10^{-34} J·s)
- *v* = frequency (measured in s^{-1}, or hertz)

The equation to calculate wavelength, frequency, or energy: $c = \lambda v$

Wavelength and frequency are inversely related.

- c = speed of light (299,792,458 m/s)
- λ = wavelength (typically measured in nanometers)
- *v* = frequency (measured in s^{-1}, or hertz)

By using these two equations, it is possible to calculate the wavelength, frequency, or energy of a photon.

1. Determine the type of wave based on its wavelength or frequency, below. If visible light, determine the color. (Note: Make sure to check units. Wavelength could be in either meters or nanometers. You must convert between the two.)
   ① Frequency of 10^{13} Hz
   ② Wavelength of 10^{-13} m
   ③ Wavelength of 530 nm
   ④ Frequency of 10^{-9} Hz
   ⑤ Wavelength of 100 nm
2. A laser emits a light with a frequency of 4.70×10^{11} Hz. Determine the wavelength in nm.
3. A light is found to have energy of 3.18×10^{-19}J. What is the wavelength (nm) and frequency (Hz) of the wave?

Resources

Wavelength/Energy Practice Problems. Basic Chemistry from a Mad Scientist. https://drmadscientist.wordpress.com/2013/06/24/wavelengthpracticeproblems/

Two Equations Governing Light's Behavior: Part Two. ChemTeam. http://www.chemteam.info/Electrons/LightEquations2.html

Calculate the Wavelength When Given the Frequency. ChemTeam. http://www.chemteam.info/Electrons/calc-wavelength-given-freq.html

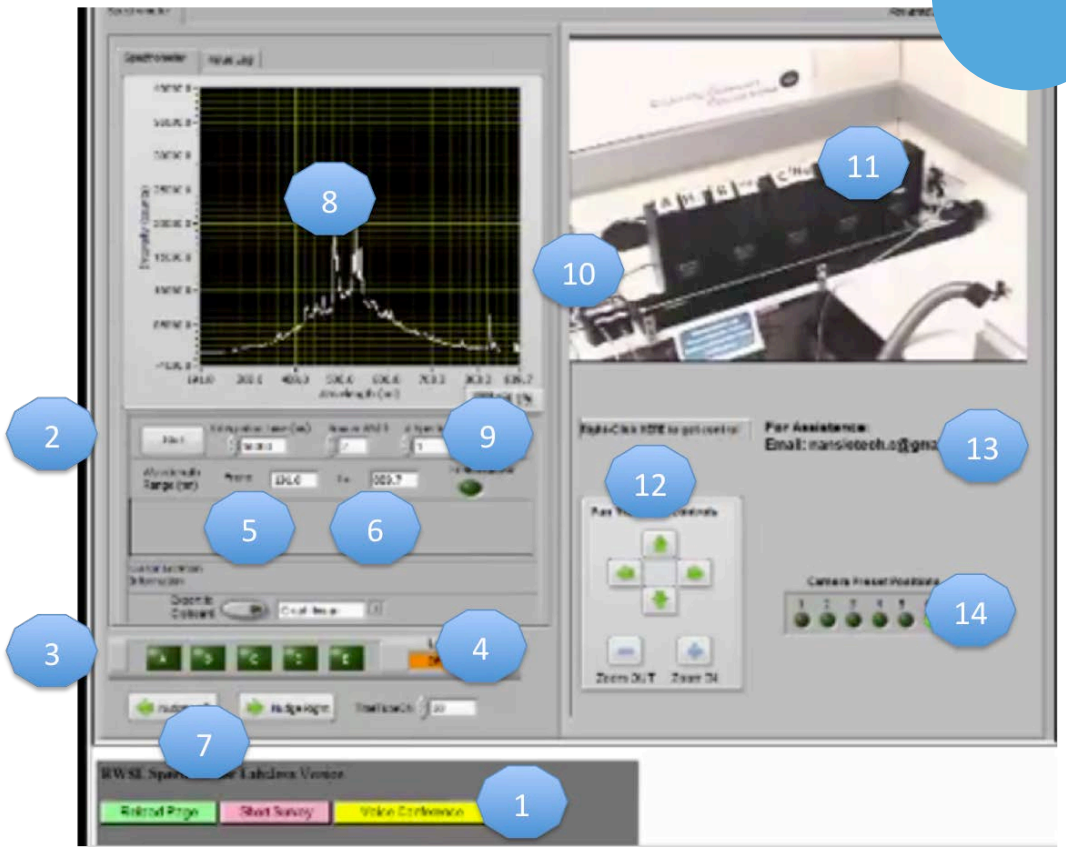
Calculating Energy of a Photon. https://www.youtube.com/watch?v=1Tha7FfuGOQ

Control Panel

The Emission Spectrum Control Panel is where you access the equipment controls, collect data, and communicate with others participating at the same time as you.

In this experiment, you will have five light sources labeled A–E.

Your job will be to determine the optimum wavelengths emitted for each of these light samples.



Variables and Controls:

1. Voice conference
2. Start/pause
3. Light selector
4. Lamp status
5. Wavelength field
6. Intensity field
7. Nudge positioning
8. Spectrum graph
9. Graph selection/zoom controls
10. Spectrograph
11. Light sources
12. Camera position controls
13. User controls
14. Camera selection

Tutorial

This tutorial introduces you to the spectrometer used in this lab. You will see how the equipment is set up as well as the view you will have from your control panel. The demonstration shows how to control the equipment, read the settings, collect data, and collaborate with others. Watch the tutorial a second time, immediately before your lab appointment, to refresh your memory about the function and purpose of the different features in this lab setup.

- http://www.wiche.edu/nanslo/lab-tutorials#emissionspec

Things to Notice / Questions:

- What might be the cause if you can see, but can't operate, the controls?
- How do you change light sources?
- What are you looking for? How are you finding the information you need?
- If you don't see vertical change in the lines of the graph, what could be the cause?
- How do you ask for assistance?

Lab Procedure

1. Using the NANSLO lab equipment, you will log in and perform the indicated activity measurements at the time you are scheduled to take the lab. Feel free to "play around" a little to get comfortable with the equipment before you begin.
2. Be sure to start the spectrometer, so you can view the spectra when the lamps are energized.
3. Use the camera to zoom in on each emission lamp and read the labels to determine what gas is in each one.
4. Use the nudge right and nudge left robot controls to position the fiber optic cable for the spectrometer.
5. While viewing each spectrum, use the cursor to find the wavelength of the three most intense peaks for each of the gases. Record these in the table in your lab report.
6. Also, while each lamp is glowing, zoom in close with the camera and see what color it appears to be. Record this observation in the table.
7. Repeat these measurements for all five lamps.

Lab Day Checklist

On the day of your scheduled lab, review the items on this checklist to make sure you are prepared before logging into NANSLO.

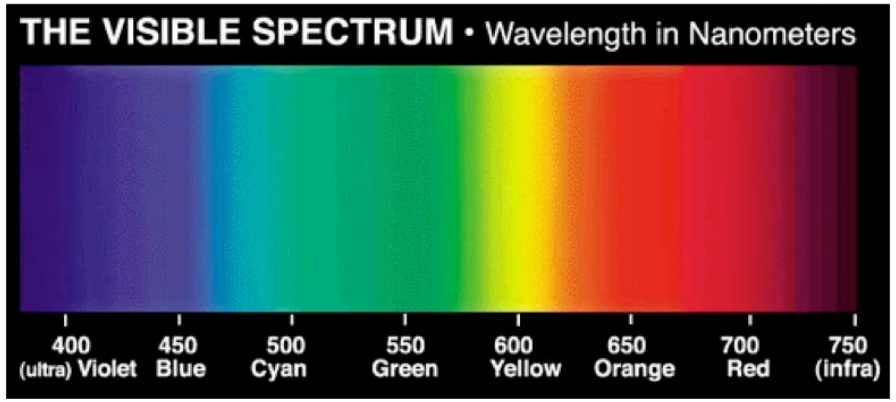
- ❑ Read and review all lab materials
- ❑ Prepare and organize lab charts and recording materials
- ❑ Watch the lab tutorial again as a review before the lab
- ❑ Log in to your lab session – two options:
  - ❑ Retrieve your email from the scheduler with your appointment info or
  - ❑ Log in to the student dashboard and join your session by going to http://scheduler.nanslo.org
- ❑ NOTE: You cannot log in to your session before the date and start time of your appointment. Use Internet Explorer or Mozilla Firefox.

Lab Report Data

Element of Molecule	Visual Color of Lamp	Peak 1 Wavelength (nm)	Peak 2 Wavelength (nm)	Peak 3 Wavelength (nm)
A				
B				
C				
D				
E				

Observation notes:

Lab Analysis



1. Use the wavelengths you recorded and the equations in the Pre-Lab Problems section to determine the frequency and energy of each wavelength.
2. For each lamp, you recorded data for the wavelengths of three peaks. Locate the wavelength on the visible spectrum and determine what color it is; record it for each peak.
3. Calculate the frequency of each peak using the equations in the Pre-Lab Problems section.
4. Calculate the energy of each peak using the equations in the Pre-Lab Problems section.
5. Repeat for each lamp (A-E).
6. You will notice you did not record the data for all of the peaks in each lamp. Speculate on why each spectrum looked different.
7. Calculate the frequency of each peak using the equations in the Pre-Lab Problems section.
8. Calculate the energy of each peak using the equations in the Pre-Lab Problems section.
9. Repeat for each lamp (A-E).
10. You will notice you did not record the data for all of the peaks in each lamp. Speculate on why each spectrum looked

Lab Analysis

A

Element of Molecule in Lamp:_____

Visual Color of Lamp: _____

	Peak 1	Peak 2	Peak 3
Wavelength (nm)			
Location of peak on visual spectrum (color)			
Frequency (Hz)			
Energy (J)			

B

Element of Molecule in Lamp:_____

Visual Color of Lamp:_____

	Peak 1	Peak 2	Peak 3
Wavelength (nm)			
Location of peak on visual spectrum (color)			
Frequency (Hz)			
Energy (J)			

Lab Analysis

C

Element of Molecule in Lamp:_____

Visual Color of Lamp:_____

	Peak 1	Peak 2	Peak 3
Wavelength (nm)			
Location of peak on visual spectrum (color)			
Frequency (Hz)			
Energy (J)			

D

Element of Molecule in Lamp:_____

Visual Color of Lamp:_____

	Peak 1	Peak 2	Peak 3
Wavelength (nm)			
Location of peak on visual spectrum (color)			
Frequency (Hz)			
Energy (J)			

Lab Analysis

E

Element of Molecule in Lamp:_____

Visual Color of Lamp:_____

	Peak 1	Peak 2	Peak 3
Wavelength (nm)			
Location of peak on visual spectrum (color)			
Frequency (Hz)			
Energy (J)			

Reviewing Results

Write a review of your experiment. Include your findings and an explanation of your results.

Conclusion and Reflection

Write a thoughtful conclusion to the lab, answering the essential question: How can emission spectra be used to study the makeup of a substance, and how does this apply to chemistry?

Post-Lab Questions

Answer the following questions as completely as possible. Use evidence from your lab to help support answers where possible. Use these questions to demonstrate your learning. You may want to review your pre-lab answers and see what you have gained in understanding.

1. What is an emission spectrum?
2. How is the spectrum related to chemical composition?
3. How can you find the wavelength using a spectrometer?
4. How can you calculate intensity with a known frequency and wavelength?
5. How can emission spectrums be used to identify elements or molecules?
6. Explain why higher frequency waves are more dangerous.

Endothermic/Exothermic Reactions

Lab Description:

In this lab, you will access the NANSLO lab to observe and collect data on the processes of different salts dissolving in water to determine if there is an endothermic or exothermic result.

Purpose:

To collect and analyze data to determine if salts added to water produce an endothermic or exothermic reaction.

Essential Question:

What is the difference between endothermic and exothermic reactions, and how can this be determined when dissolving different salts in water?

Objectives:

At the completion of this lab, you should be able to:

1. Describe the difference between endothermic and exothermic reactions.
2. Provide examples of each in everyday processes.
3. Collect and analyze data using the NANSLO lab equipment.
4. Interpret graphs and data to determine if results demonstrate endothermic or exothermic reactions.
5. Explain chemical energy factors that determine if a reaction will be endothermic or exothermic.

Pre-Lab Questions

These pre-lab questions are to help you think about the Endothermic and Exothermic Reactions lab and self-assess what you know and what you want to know about the topic. By the end of the lab, you should be able to answer these questions in more detail. Compare your answers to see what you have learned.

1. What is the difference between an endothermic reaction and an exothermic reaction?
2. How might you set up an experiment to see if a specific salt added to water creates an endothermic or exothermic reaction?
3. What can you measure to determine which type of reaction is occurring?
4. What factors involved in the chemical makeup of a solute determine if it will cause an endothermic or exothermic reaction when added to water?
5. What is an example of an exothermic reaction in everyday life?
6. What is an example of an endothermic reaction in everyday life?

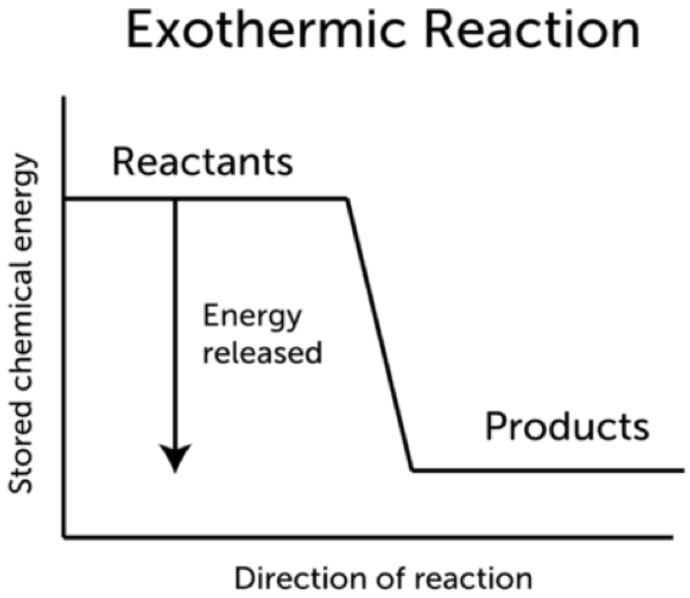
Background Information

In a chemical reaction, reactants are changed in some way to become products. Reactants are to the left of the arrow and products are shown on the right of the arrow.

$$\underbrace{H_2 + O_2}_{\textit{reactants}} \rightarrow \underbrace{H_2O}_{\textit{products}}$$

Any chemical reaction will involve breaking some bonds and making new ones. Energy is needed to break bonds and is then given off when the new bonds are formed. When those bonds are broken and formed, the amount of energy is not equal, so some energy will be absorbed or released during a reaction. A reaction in which heat is given off is called **exothermic**.

In exothermic reactions, the products have a lower energy than the reactants. The lost energy is given off as heat, so the surroundings warm up. If heat energy is absorbed, the reaction is called **endothermic**. The products have a higher energy than the reactants. This energy is absorbed from the surroundings.



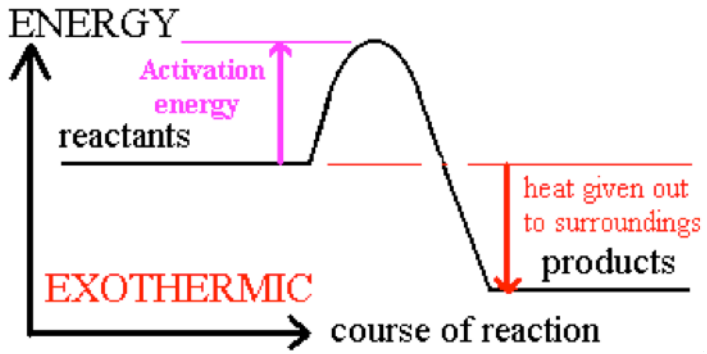
Background Information

In order for a reaction to occur, the reactants must overcome a barrier called activation energy to begin the reaction.

Think about riding a bicycle over a hill. To ride down the hill, you must pedal the bike over the top to reach the other side. In an exothermic reaction, the reactants start at the beginning energy level, as shown in the diagram. Energy input is needed to overcome the "energy hill" to start the reaction.

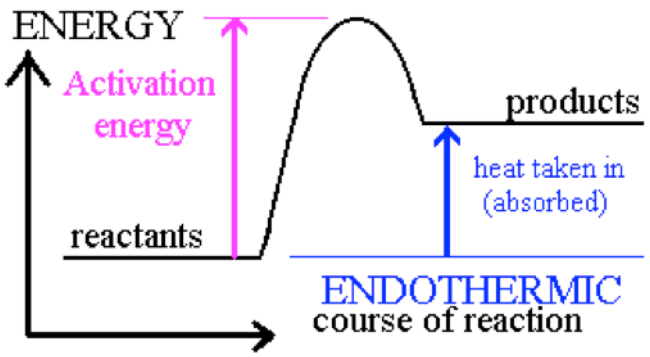
In the exothermic reaction, energy is released into the surroundings, often in the form of heat and products. The products end up at a lower energy level than the reactants.

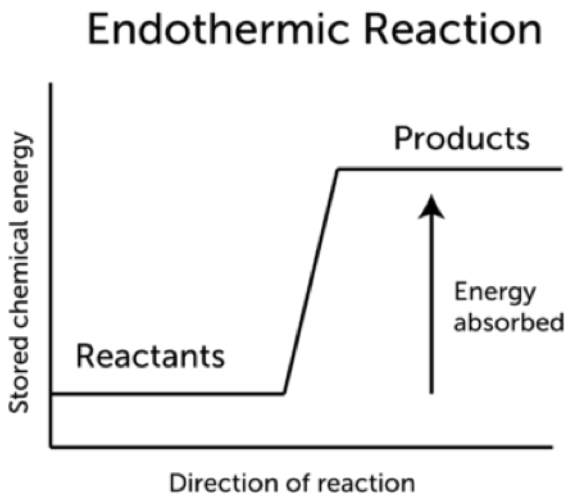
In a reaction such as Alka-Seltzer and water, the activation energy is low, and simply mixing the two provides enough kinetic energy to start the process. The mixture heats up as the energy from the reaction is absorbed by the water.



Background Information

In an endothermic reaction, the energy hill also must be overcome, but the energy barrier is higher and the reaction has to absorb energy from the surroundings. In this case, enough energy is absorbed that the products end up at a higher energy level than the reactants at the start. The surroundings, in this case the water, give up energy and the temperature drops.





Background Information

Salts are interesting examples to study when exploring the differences between endothermic and exothermic reactions, since you can observe both processes. As salt dissolves in water, two exchanges of energy happen. In the first, energy is necessary to pull the positively and negatively charged ions apart. This energy is called the **lattice energy**.

As the water molecules surround the ions from the salt, energy is released into the solution. This energy is called **hydration energy**.

Lattice Energy: Energy needed to separate ions.

Hydration Energy: Energy released as water molecules surround the ions.

Whether the dissolving of a salt in water is an exothermic or endothermic reaction depends on which energy is larger — the lattice or the hydration. If it takes more energy to separate the ions (lattice energy) than is released into the solution (hydration energy), the reaction will be endothermic. As opposed to the opposite conditions, in which the hydration energy is greater than the lattice energy, which result in an exothermic reaction.

Resources

Exothermic vs. Endothermic and K. UC Davis ChemWiki. http://chemwiki.ucdavis.edu/Core/Physical_Chemistry/Equilibria/Le_Chatelier's_Principle/Effect_Of_Temperature_On_Equilibrium_Composition/Exothermic_Versus_Endothermic_And_K

Dissolving Salts in Water. PBS LearningMedia. http://www.pbslearningmedia.org/resource/lsps07.sci.phys.matter.dissolvesalt/dissolving-salts-in-water/

Endothermic/Exothermic Reaction Examples

Examples of Exothermic Reactions (processes that release energy):

- combustion (burning)
- rusting of iron
- mixing water with anhydrous salts (anhydrous salts to hydrous salts)
- mixing water with calcium chloride
- making ice cubes
- formation of snow in clouds
- condensation of water from vapor
- respiration (burning of food in body)
- synthesis (two or more simple substances forming more complex compounds, e.g., Haber Process, except photosynthesis)

Examples of Endothermic Reactions (processes that absorb energy):

- mixing water with ammonium and potassium salts (ammonium chloride dissolved in water)
- separating ion pairs
- baking food
- melting solid salts
- melting ice cubes
- evaporation of water
- dissolving hydrated salts in water
- photosynthesis

Endothermic/Exothermic Lab

Purpose: To collect and analyze data to determine if salts added to water produce an endothermic or exothermic result.

The titration experiment is set up with five beakers and burettes you control virtually to add solutions with precise measurements.

The image at right shows a close-up of the double burettes that add the amounts you specify to the beaker.

Pre-Lab Problems

1. Draw a graph showing how the temperature would change in an exothermic reaction.

2. Classify the following examples as either exothermic or endothermic reactions.

Example	Exothermic Reaction	Endothermic Reaction
Burning wood		
Icy hot pack		
Cold ice pack		
Baking a cake		
Making ice cream		

Pre-Lab Problems

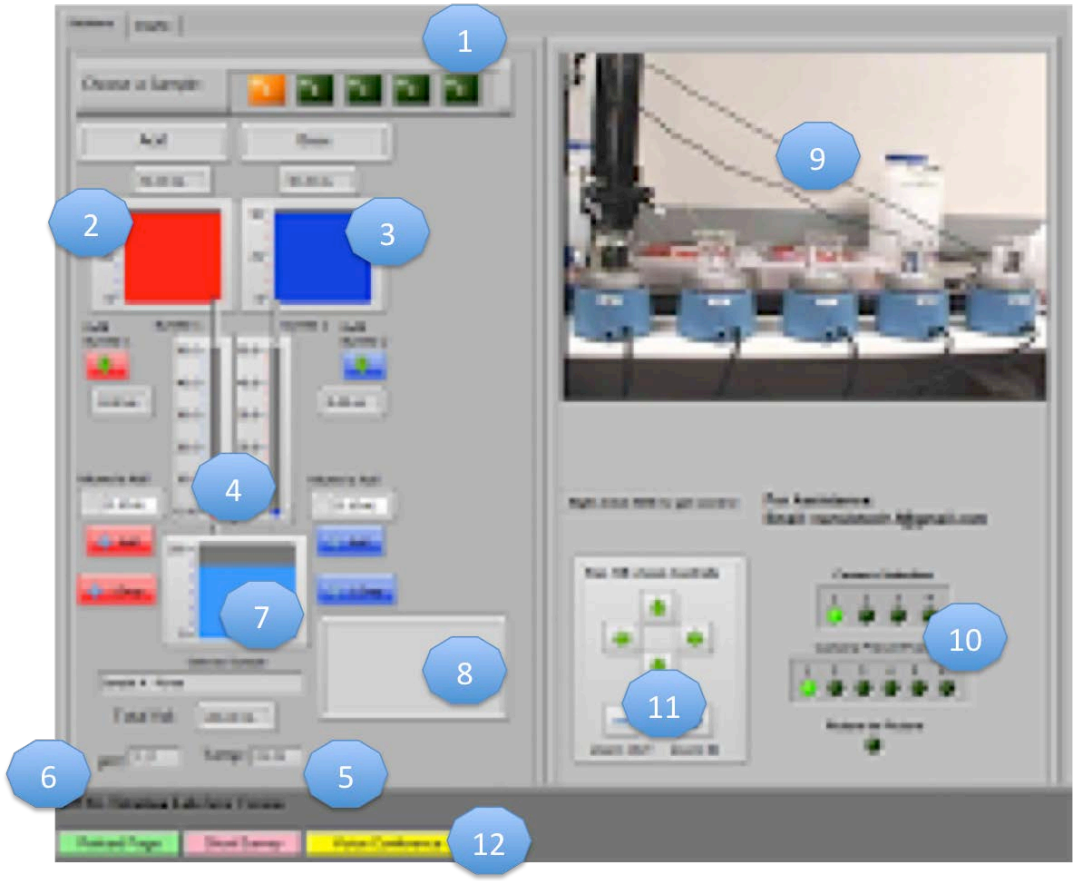
3. Name the salt being added to the water below, and predict whether you think the reaction will be endothermic or exothermic.

Example	Name of Salt	Exothermic Reaction	Endothermic Reaction
$H_2O + NH_4NO_3$			
$H_2O + CaCl_2$			
$H_2O + NaCl$			
$H_2O + NaHCO_3$			
$H_2O + NH_4Cl$			

Control Panel

The Control Panel is where you access the equipment controls, collect data, and communicate with others participating at the same time as you.

In this experiment, you will be changing beakers and adding water to view and track the reaction of different salts dissolving in water. This will include monitoring and recording temperature change, as well as capturing images of the graphs.



Variables and Controls:

1. Selection of beaker
2. Acid tank
3. Base tank
4. Burettes
5. Temperature reading
6. pH reading
7. Volume
8. Message screen
9. Camera image
10. Camera view
11. Camera controls
12. Voice conference

Tutorial

This tutorial introduces you to the Endothermic/Exothermic Reactions lab. You will see how the equipment is set up as well as the view you will have from your control panel. For this lab, you will be adding water to five different beakers to observe reactions and track temperature change.

The demonstration shows how to control the equipment, read the settings, collect data, and collaborate with others. Watch the tutorial a second time, immediately before your lab appointment, to refresh your memory about the function and purpose of the different features in this lab setup.

- Add link when available

Things to Notice / Questions:

1. How do you join the voice conference?
2. What steps do you take to add water to a beaker?
3. How do you keep track of the temperature?
4. How and when do you capture an image of a temperature graph?
5. How do you change from Beaker 1 to Beaker 2?
6. How can you view a close-up of each beaker?

Lab Procedure

1. Using the NANSLO lab equipment, you will log in and take the indicated measurements at the time you scheduled to take the lab.
2. Each beaker contains 10 g of a salt. Using the equipment setup, you will add 20 mL of water to each beaker.
3. After the water is added, record the starting temperature in your lab report.
4. Record temperature over time, as the reaction progresses.
5. In your lab report, record any observations that you make while the reaction is occurring.
6. After the temperature has stabilized, take a screen shot of the temperature graph.
7. Move the apparatus to the next beaker.
8. Repeat steps 2–7 for each of the five beakers.
    - Beaker 1: $CaCl_2$ (calcium chloride)
    - Beaker 2: NaCl (sodium chloride)
    - Beaker 3: $NaHCO_3$ (sodium acetate)
    - Beaker 4: NH_4Cl (ammonium chloride)
    - Beaker 5: NH_4NO_3 (ammonium nitrate) + a penny and an Alka-Seltzer tablet

Lab Day Checklist

On the day of your scheduled lab, review the items on this checklist to make sure you are prepared before logging into NANSLO.

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- ❑ Prepare and organize lab charts and recording materials
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  - ❑ Log in to the student dashboard and join your session by going to http://scheduler.nanslo.org
- ❑ NOTE: You cannot log in to your session before the date and start time of your appointment. Use Internet Explorer or Mozilla Firefox.

Lab Report Data

Complete the table using data you collect during the lab.

Beaker	Beaker Contents	Starting Temperature	Ending Temperature	Time Duration
1				
2				
3				
4				
5				

Observation notes:

Beaker 1:

Beaker 2:

Beaker 3:

Beaker 4:

Beaker 5:

Lab Report Data

Insert images of the temperature graph once each reaction has stabilized.

Beaker 1:

Beaker 2:

Beaker 3:

Beaker 4:

Beaker 5:

Lab Analysis

Add the following to the table below and compare your results.

1. Use the data you collected in the table to calculate the change in temperature (temperature final minus temperature starting). Make sure you indicate if it is an increase (+) or a decrease (−).
2. Identify each reaction as endothermic or exothermic.

Beaker	Beaker Contents	Starting Temperature	Ending Temperature	Time Duration	Change in Temperature	Endothermic or Exothermic?
1						
2						
3						
4						
5						

Reviewing Results

Write a review of your experiment. Include your findings and an explanation of your results. Then answer the following questions.

1. Which reaction absorbed the most heat? Support your answer with data from your activity.
2. Which reaction released the most heat? Support your answer with data from your activity.
3. What affect do you think the penny and Alka-Seltzer tablet had on the reaction in Beaker 5?

Conclusion and Reflection

Write a thoughtful conclusion to the lab, answering the essential question: What is the difference between endothermic and exothermic reactions, and how can this be determined when dissolving different salts in water?

Post-Lab Questions

Answer the following questions as completely as possible. Use evidence from your lab to help support answers where possible. Use these questions to demonstrate your learning. You may want to review your pre-lab answers and see what you have gained in understanding.

1. What is the difference between an endothermic reaction and an exothermic reaction?
2. How might you set up an experiment to see if a specific salt added to water creates an endothermic or exothermic reaction?
3. What can you measure to determine which type of reaction is occurring?
4. What factors involved in the chemical makeup of a solute determine if it will cause an endothermic or exothermic reaction when added to water?
5. What is an example of an exothermic reaction in everyday life?
6. What is an example of an endothermic reaction in everyday life?

Beer-Lambert Law

Lab Description:

In this lab, you will study the Beer-Lambert law and see first-hand how it is used for analysis.

Purpose:

To use the Beer-Lambert law to calculate the concentration of a solute using data collected through spectrophotometry.

Essential Question:

How does the Beer-Lambert law apply to chemical analysis?

Objectives:

At the completion of this lab, you should be able to:

1. Define the Beer-Lambert law and explain how it is applied.
2. Determine what is being measured in a spectrophotometer, and explain the basics of spectrophotometry.
3. Collect and interpret quantitative data.
4. Complete calculations using the Beer-Lambert law.
5. Describe how the Beer-Lambert law is used in chemistry.

Pre-Lab Questions

These pre-lab questions are to help you think about the Beer-Lambert Law lab and self-assess what you know and what you want to know about the topic. By the end of the lab, you should be able to answer these questions in more detail. Compare your answers to see what you have learned.

1. What is the Beer-Lambert law, and how is it used?
2. Why is the absorption or transmission of specific wavelengths important in analysis?
3. How does measuring wavelengths help determine the presence of a compound?
4. What do you expect the spectrum of distilled water to look like? Why?
5. How can the Beer-Lambert law be applied to chemistry?

Background Information

Visible light represents only a very small part of the electromagnetic spectrum. Visible light consists of light with wavelengths from about 3.8 m x 10^{-7} m to 7.8 m x 10^{-7} m (380–780 nm). Substances that have color absorb some wavelengths from the visible region of the spectrum and reflect others. Wavelengths that are not absorbed are transmitted. We inherently know that if something is darker in color, it must be more concentrated. (Think of making Kool-Aid or coffee.) This relationship is called the Beer-Lambert law, after Augustus Beer (a German physicist) and Johann Lambert (a Swiss physicist), but is commonly referred to as Beer's Law. The Beer-Lambert law can be expressed as: $A = abc$

- A = absorbance
- a = molar absorptivity (molarity^{-1}·cm^{-1}), which is a constant that depends on the molecules
- b = path length, or thickness of the liquid the light is shining through (cm)
- c = concentration of the solution (molarity)

Beer's law tells us that the absorbance of a particular species is directly proportional to the concentration of the absorbing species, i.e., darker = more. The measurement of a blank, as described above, allows us to factor out the effects of the environment, including the solvent (in this case, water) and the containers' material (in this case, plastic). So if A can be measured, a = a constant, and b is set, c can then be solved.

Any measurement can have noise, also known as error. The goal of any scientific data collection is to gather data with as little noise as possible, although it can never be totally eliminated. In this lab, you will use a spectrometer with a fiber optic cable to carry the light and help eliminate noise from sending the light beam through the air.

Background Information

Another way to reduce noise is to record a lot of data and average the results. The spectrometer will collect an entire spectrum about once per second. The spectrum consists of many thousands of points, and each time a spectrum is collected, these points are slightly different (due to random noise). If you average two spectra together, you reduce the noise by a factor of √2. If you average three spectra, you reduce the noise by a factor of √3, etc. Of course, the more spectra you average, the longer it takes to get a result. There is a balance between decreasing noise and collecting data in a reasonable amount of time.

As stated earlier, "a" is a value that is unique to each substance you are measuring. So if you know what substance you are measuring, you can look up the value. However, if you don't know the substance, you can create what is known as a standard curve. In a standard curve, you take known values, measure absorbance, and then plot them on a graph.

Let's use Kool-Aid as an example. Say I measure out 1 spoonful of Kool-Aid mix and stir it into 1 cup of water. If I measure the absorbance, I might get a reading of 0.5. If I continue, and I measure out 2 spoonfuls into 1 cup of water, I will get a second reading as shown at right. If I do this enough, I can plot my points and get my standard curve. Now imagine I randomly added powder to 1 cup of water, and I wanted to find out how much powder I added. I could use my curve to find out the amount (i.e., the concentration) of my mixture.

Spoonfuls of Kool-Aid	Absorbance Reading
0	0
1	0.5
2	1.0
2.5	1.25
3	1.5

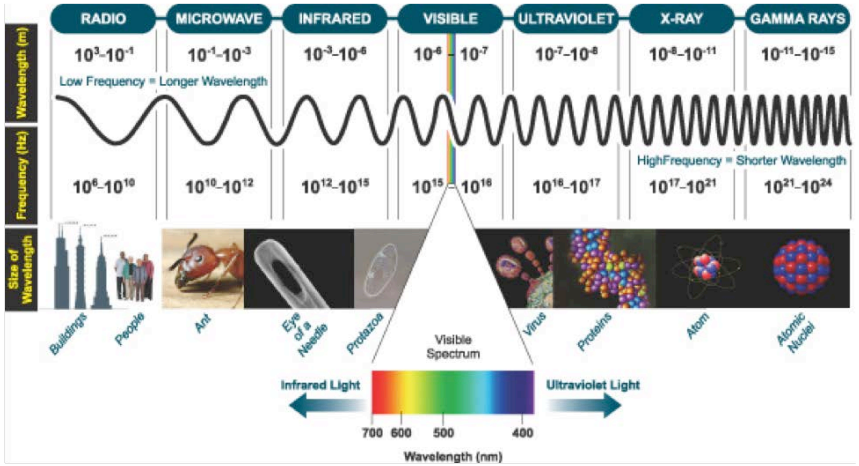
Wavelength is the measurement used in the lab activity, so be sure to use the same wavelength of light for each measurement you take, as you want to compare the same

Explore Beer-Lambert Law

The Beer-Lambert law is used by chemists and other researchers to compare the absorbance of unknown samples. The data collected allow them to determine the concentrations of particular substances in diluted solutions. It is important to know the concentrations of solutions in lab work.

This applies to the identification of a wide range of unknown substance concentrations in analysis of samples. Some areas where this is used include:

- **Medical research:** bacteria concentrations, analysis of fluids
- **Water quality:** the concentrations of various compounds present in water samples
- **Forensics:** detecting the presence and concentrations of substances



A = abc

Resources

The Beer-Lambert Law. ChemGuide. http://www.chemguide.co.uk/analysis/uvvisible/beerlambert.html

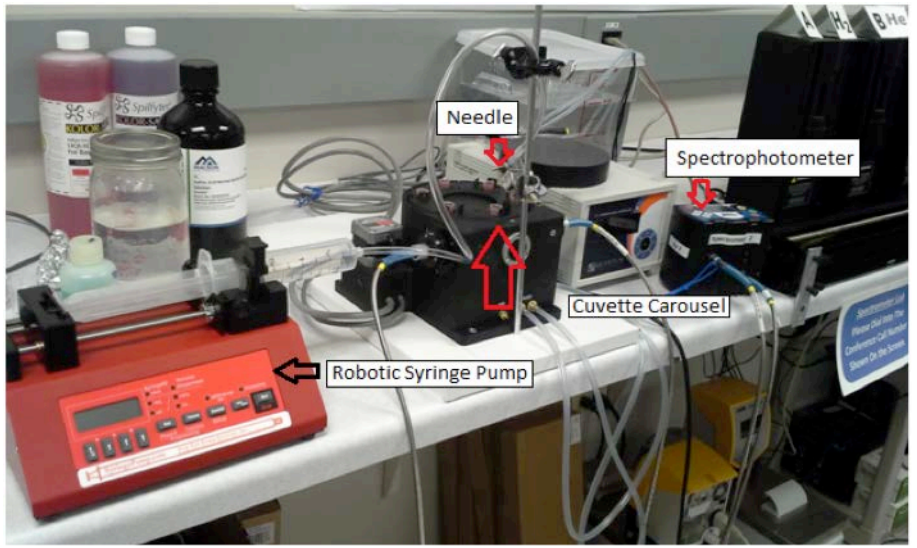
Beer-Lambert Law and Visible Light Spectrometers. Harper College. http://www.harpercollege.edu/tm-ps/chm/100/dgodambe/thedisk/labtech/spec20.htm

Beer-Lambert Law. College of Life Science, National Tsing Hua University. http://life.nthu.edu.tw/~labcjw/BioPhyChem/Spectroscopy/beerslaw.htm

Beer-Lambert Lab

Purpose: To use the Beer-Lambert law to calculate the concentration of a solute using data collected through spectrophotometry.

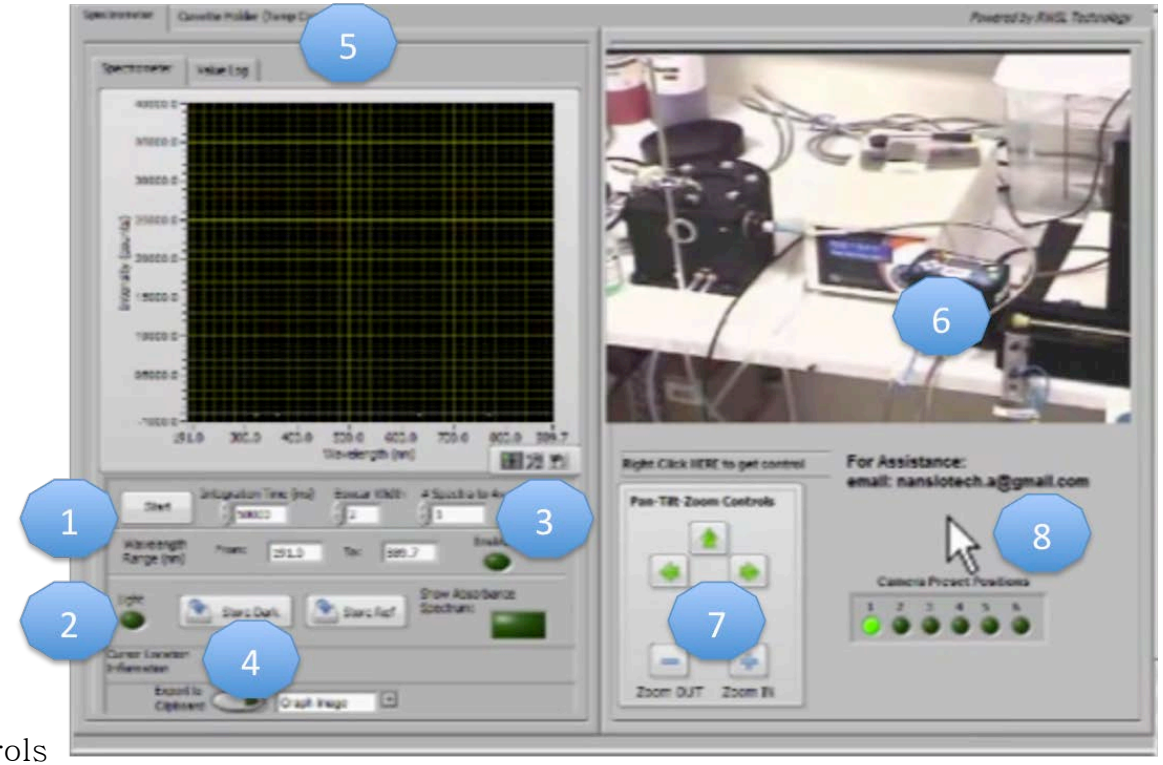
The Beer-Lambert lab is set up with the equipment shown here.



Control Panel

The Control Panel is where you access the equipment controls, collect data, and communicate with others participating at the same time as you.

In this experiment, you will view different samples and collect the spectrum wavelengths. You will also capture images of the graphs and record the wavelength data for the analysis portion of the lab.



Variables and Controls:

1. Start button
2. Light
3. Spectra value
4. Store dark spectrum
5. Temperature control tab
6. Camera view
7. Camera controls
8. Voice conference

Absorbance Spectrometer Tutorial

This tutorial introduces you to the absorbance spectrometer, which is used for several labs. You will see how the equipment is set up as well as the view you will have from your control panel. The demonstration shows how to control the equipment, read the settings, collect data, and collaborate with others. Watch the tutorial a second time, immediately before your lab appointment, to refresh your memory about the function and purpose of the different features in this lab setup.

- http://www.wiche.edu/nanslo/lab-tutorials#beerlambert

Things to Notice / Questions:

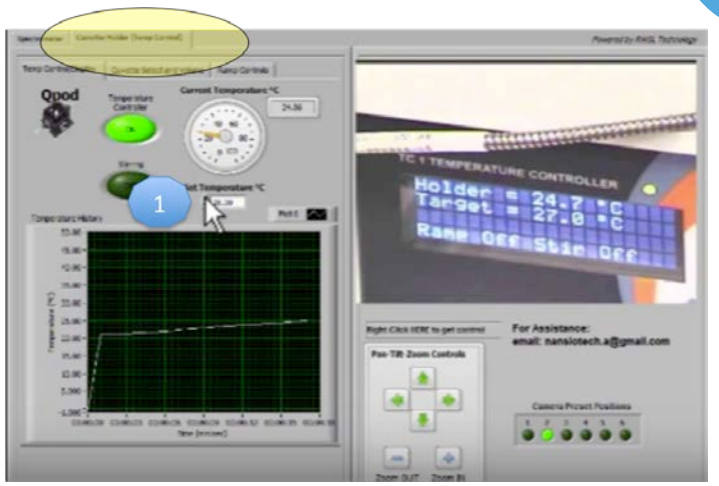
1. How do you store a dark spectrum? Why is this stored?
2. What are you measuring, and how does it relate to the Beer-Lambert Law?
3. How will the graphs help you understand the results?

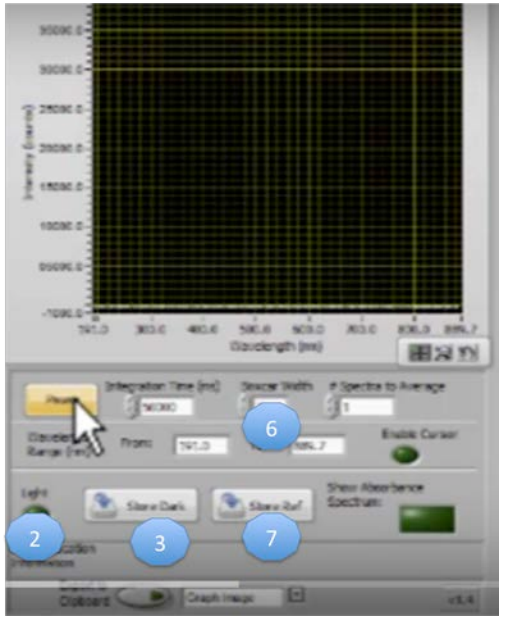
Lab Procedure

Using the NANSLO lab equipment, you will log in and take the indicated measurements at the time you are scheduled to take the lab.

Join the voice conference so you can communicate with the lab technician and other lab partners.

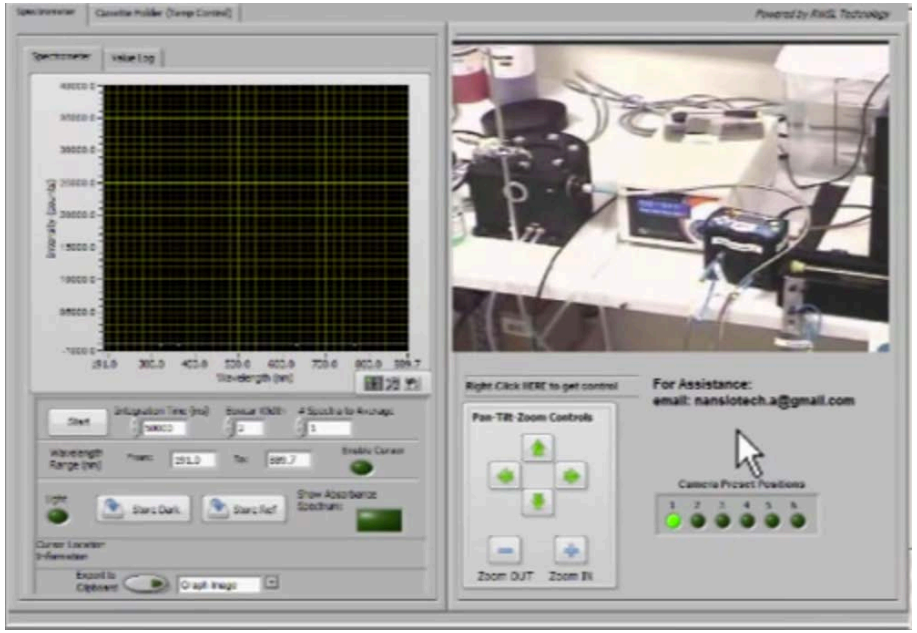
1. Turn on the temperature controller. Ensure the temperature of the system is adjusted to 25.0° C.
2. Ensure the spectrometer's light source is turned off.
3. Store a Dark Spectrum.
4. Ensure that Cuvette 0 (the reference sample) is selected.
5. Turn on the light to see the spectrum of the light source.
6. Play around with the Boxcar Width and # Spectra to Average to get the least noisy spectrum.
7. Store the Reference spectrum.
8. Ask the lab tech for information about the standard $NiSO_4$ solutions. You will use this information to calculate the concentration of each standard solution (during data, the analysis portion of the activity).





Lab Procedure

9. Select one of the $NiSO_4$ standards (Cuvettes 1–4) in the Q pod in the Cuvette Selector tab.
10. Return to the Spectrometer tab to view the absorbance spectrum.
11. Determine the location of λ_{max}.
12. Record the absorbance of the $NiSO_4$ sample at λ_{max} in your lab report. Each student in the group must write the measurement down for later use.
13. Capture an image of the graph and insert in your lab report.
14. Repeat step 9 for all remaining samples, including Cuvette 5, which contains the unknown concentration of $NiSO_4$. If working in a group, be sure to switch controls and share in this process.
15. After each student has collected a complete set of data (and everyone has recorded each data set in lab reports), you can log out of the lab and work on the data analysis portion. If you have time left in your scheduled lab period, you can continue working with your lab partners to analyze the data.



Lab Day Checklist

On the day of your scheduled lab, review the items on this checklist to make sure you are prepared before logging into NANSLO.

- ❑ Read and review all lab materials
- ❑ Prepare and organize lab charts and recording materials
- ❑ Watch the lab tutorial again as a review before the lab
- ❑ Log in to your lab session – two options:
  - ❑ Retrieve your email from the scheduler with your appointment info or
  - ❑ Log in to the student dashboard and join your session by going to http://scheduler.nanslo.org
- ❑ NOTE: You cannot log in to your session before the date and start time of your appointment. Use Internet Explorer or Mozilla Firefox.

Lab Report

Insert images of graphs

Lab Observations and Data
Cuvette 1
Data:

Observation notes:

Lab Observations and Data
Cuvette 2
Data:

Observation notes:

Lab Report

Insert images of graphs

Lab Observations and Data
Cuvette 3
Data:

Observation notes:

Lab Observations and Data
Cuvette 4
Data:

Observation notes:

Lab Report

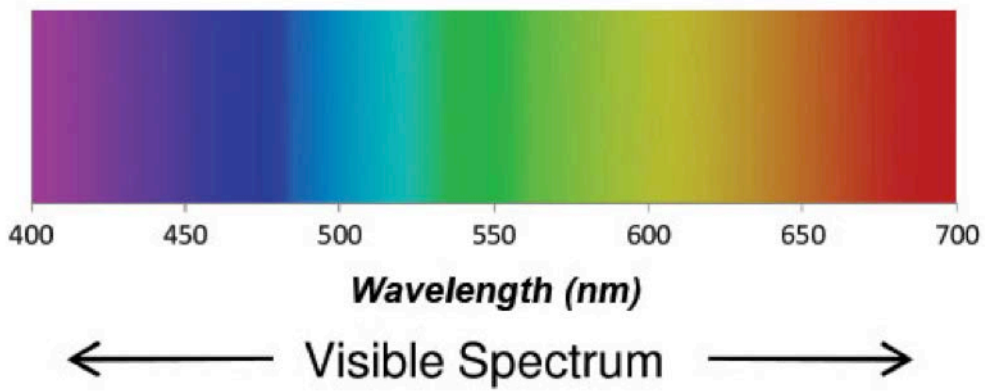
Lab Observations and Data
Cuvette 5
Data:

Observation notes:

Insert images of graphs

Lab Analysis

1. Plot a **standard graph** using the concentration and absorbance values for the standard solutions. Plot the concentrations on the X-axis and absorbance values on the Y-axis. (This can be done in Excel.)
2. From the absorbance of the unknown solution, you can calculate
its concentration using the line equation of the standard cur
3. Why do you have to first take an absorbance measurement o a cuvette filled with distilled water? Why does this measurement
have to be subtracted from the measurements of the $NiSO_4$ samples?
4. Why didn't you just measure one or two samples with known concentrations of $NiSo_4$?
5. Given the wavelength you measured, determine on what part of the visible spectrum it falls?



Lab Analysis

6. The figure to the right demonstrates the relationship between absorbed and reflected colors of light. Absorbed is opposite of reflected on the wheel. For example, if a substance absorbs orange light, it will reflect blue light, and therefore appear blue. Compare the color of the $NiSO_4$ solution to the color of the light it absorbs. Does it agree with the color wheel? What can you deduce from this?

Sakurambo at English Wikipedia [GFDL) http://www.gnu.org/copyleft/fdl.html

7. If a chemical solution is primarily orange in color, approximately what wavelength would you expect λ_{max} to be? Why?

Reviewing Results

Write a review of your experiment. Include your findings and an explanation of your results. Then answer the following questions.

1. How accurate was the data you collected? How do you know?
2. How do the graphs show the maximum wavelength?
3. How does wavelength relate to visible colors?
4. How are visible colors different from absorbed colors?

Conclusion and Reflection

Write a thoughtful conclusion to the lab, answering the essential question: How does the Beer-Lambert law apply to chemical analysis?

Post-Lab Questions

Answer the following questions as completely as possible. Use evidence from your lab to help support answers where possible. Use these questions to demonstrate your learning. You may want to review your pre-lab answers and see what you have gained in understanding.

1. What is the Beer-Lambert Law, and how is it used?
2. Why is the absorption or transmission of specific wavelengths important in analysis?
3. How does measuring wavelengths help determine the presence of a compound?
4. What do you expect the spectrum of distilled water to look like? Why?
5. How can the Beer-Lambert law be applied to chemistry?

Enzyme Kinetics

Lab Description:

In this lab, you will use the NANSLO lab equipment to experiment with the effects of solute concentration and temperature on reaction rate as measured by spectrum absorption of resulting products.

Purpose:

To use absorption spectrometry to calculate the effect of enzymes as catalysts when increasing solute concentration and temperature.

Essential Question:

What factors increase the ability of enzymes to act as catalysts, and how can you calculate results using the absorption spectrum?

Objectives:

At the completion of this lab, you should be able to:

1. Define enzyme, catalyst, and other key terms.
2. Determine the effects of increasing temperature and solute concentration on enzyme kinetics.
3. Determine what is being measured in a spectrophotometer, and explain the basics of spectrophotometry.
4. Collect and interpret quantitative data.
5. Complete tables and graphs with collected data.
6. Summarize findings using evidence from lab exercises.

Pre-Lab Questions

These pre-lab questions are to help you think about the Enzyme Kinetics lab and self-assess what you know and what you want to know about the topic. By the end of the lab, you should be able to answer these questions in more detail. Compare your answers to see what you have learned.

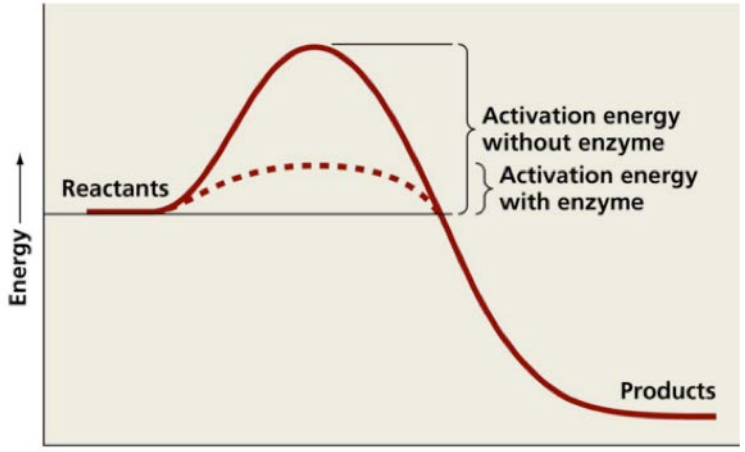
1. What are enzymes?
2. What effect do enzymes have on reaction rates?
3. How does measuring wavelengths help determine the presence of a compound?
4. How does concentration relate to enzyme effects?
5. What happens to reaction rates and enzyme effectiveness when temperature increases?
6. How is the area of enzyme kinetics applied to chemistry?

Background Information

Living organisms contain **enzymes**, which are protein molecules with specific functions and characteristics. Enzymes are vital to all living organisms. Without their actions, chemical reactions would not occur rapidly enough to support life. To illustrate this, think about the process of eating. We know that in a healthy diet, we gain important nutrients. Nutrients are the molecules necessary for organisms to grow, reproduce, and repair themselves. The breakdown of these nutrients provides energy and building blocks for living organisms via chemical reactions that will in turn result in growth, reproduction, and repair; enzymes facilitate all of these functions.

The basic function of any enzyme is to increase the rate of a reaction. Most cellular reactions occur about a million times faster in the presence of an enzyme. Enzymes are also specific, and typically one reactant (called a **substrate**) utilizes the catalyst (another term for enzyme) to produce products.

An enzyme works just like a **catalyst** (in fact, it is one), by lowering the amount of energy it takes to produce a reaction. This energy is called **activation energy** and is required to break existing bonds and start a chemical reaction. For example, to get a rock rolling down a hill, it needs a push. The initial energy to get the rock to roll is the activation energy. A catalyst (aka, enzyme) acts to lower the activation energy of a reaction. It reduces the "nudge" needed to get the rock rolling down the hill. A catalyst is not used up in the reaction and can be employed over and over again.



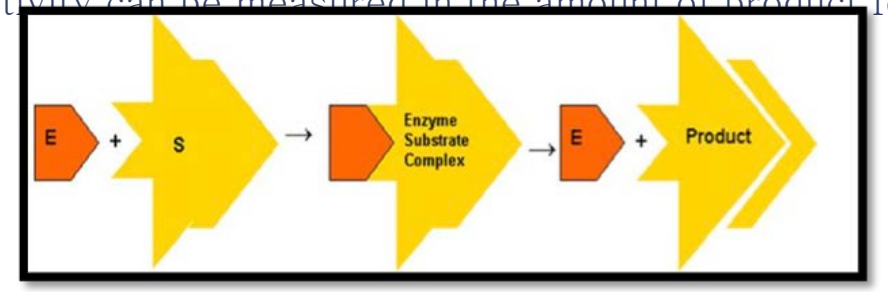
Background Information

As noted, an enzyme is not used up in the reaction; it can be reused when the reaction is complete. And, like all other proteins in a living cell, enzymes are produced from genes in an organism's DNA.

In summary, enzymes are protein biological catalysts used by cells to drive chemical reactions. They are reusable and are produced under the direct control of an organism's genetic material. They work by binding to a specific molecule and putting stress on the bonds of that molecule so the reaction is more likely to occur. If enzymes didn't exist, it might take weeks for our bodies to break down food.

All of these processes are occurring in three dimensions. A protein at its base level is a string of individual units, called amino acids. That string then is twisted and will condense (picture a Slinky). If that twisted string wraps on top of itself, it becomes a jumbled mess (picture a Slinky that has been folded back on itself). The mangled mess has crevices and holes that things can fit in — that's where the substrates go. Substrates will only fit into specific holes, like a lock and key. The enzyme brings two substrate molecules into closer proximity, which allows the bonds to more easily alter; this is what decreases the activation energy.

The figure below shows the breakdown of a large molecule into two smaller molecules, with the use of an enzyme. Enzyme activity can be measured in the amount of product formed, also known as the turnover rate.



Background Information

Environmental factors such as temperature, pH, and substrate concentration can impact enzyme function.

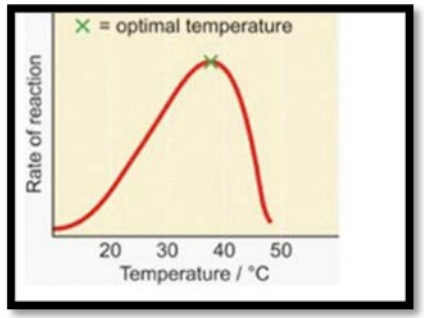
Temperature has two effects on enzymes. It can change the rate of molecular motion (how quickly molecules will bump into each other), and it can cause changes in the shape of an enzyme.

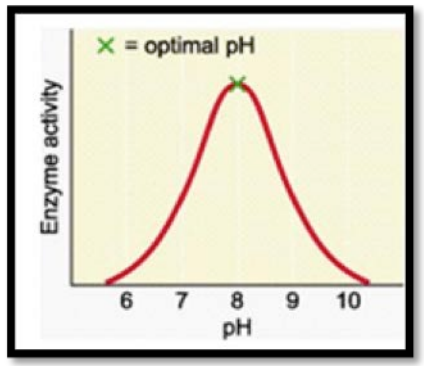
Optimum temperature is the temperature at which the enzyme is the most efficient. When a temperature is raised above the optimum, the enzyme changes its shape — and it may lose the ability to bind to the substrate. If an enzyme is heated enough, the structure is permanently changed, and it loses its biochemical properties. If this happens, the protein is denatured.

Cooking is the denaturation of proteins. Denaturation breaks some of the three-dimensional structures, which makes it easier to digest and helps destroy organisms or toxins that may be present in food.

pH also can affect the structure of an enzyme. Each enzyme has an optimum pH where it works best. Most enzymes perform best in a pH at or near 7 (neutral), which is where most biological activity occurs. pH is a measure of the amount of hydrogen ions in the system; the concentration will determine if the pH is acidic or basic.

The rate of reaction is the fastest at these optimal pH and temperature conditions, but is also influenced by concentration.





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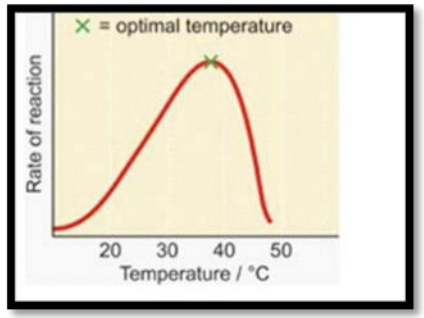
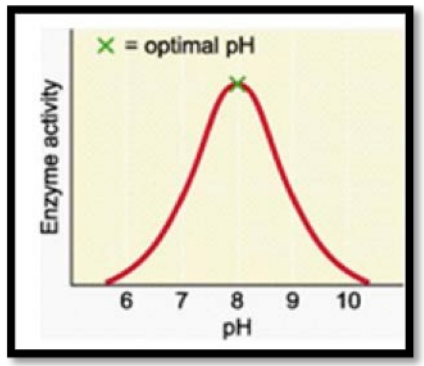




Background Information

Important Terms

activation energy – the minimum amount of energy required to convert a normal, stable molecule into a reactive molecule

amino acids – any one of many acids that occur naturally in living things; includes some which form proteins

catalyst – a substance that causes a chemical reaction to happen more quickly

denature – to modify the molecular structure of a protein (or DNA), especially by heat, acid, alkali, or ultraviolet radiation so as to destroy or diminish some of the original properties and the specific biological activity

enzyme – a chemical substance in animals and plants that helps to cause natural processes (such as digestion)

kinetics – the rate of change in a physical or chemical system

pH – a number between 0 and 14 that indicates if a chemical is an acid or a base

substrate – the substance acted upon by an enzyme.

Resources

Enzyme Kinetics. Columbia University. http://www.columbia.edu/itc/chemistry/chem-c2407/hw/ENZYME_KINETICS.pdf

An Introduction to Enzyme Kinetics. Khan Academy. https://www.khanacademy.org/test-prep/mcat/biomolecules/enzyme-kinetics/v/an-introduction-to-enzyme-kinetics

Enzyme Kinetics. Kimball's Biology Pages. http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/E/EnzymeKinetics.html

Enzyme Applications

Enzymes increase the ability and rate of many different types of chemical reactions. Here a just a few examples of how we depend on enzyme kinetics in everyday life.

Animals

Biochemical reactions occur in human and animal body functions. Many extracellular enzymes are involved in digestion; they break down food into smaller molecules that can be absorbed and used for body processes and growth. These enzymes are located in the salivary glands, stomach, pancreas, and intestines. Other enzymes break open and destroy bacteria.

Plants

Plants depend on intercellular enzymes that catalyze photosynthesis, which is needed to produce the energy that is the basis for all food webs and the source of energy for life.

Food and Drink

Enzymes in yeast have been used for thousands of years to make bread, beer, and wine. Enzyme technology has allowed scientists to isolate and use specific enzymes.

Cleaners

Many detergents include enzymes. These enzymes react with proteins catalyzed at lower temperatures. This has resulted in more efficient and cost-effective cleaning products.

Enzyme Kinetics Lab

This laboratory activity focuses on how different temperatures and different substrate concentrations affect the rate of an enzyme reaction.

We will be using the **enzyme glucose oxidase**. The reaction of the enzyme glucose oxidase with the β-D-glucose produces D-gluconic acid and hydrogen peroxide (H_2O_2). The hydrogen peroxide then reacts with a color-producing chemical to create a pink hue.

β-D-glucose + *O22* + H_2O → *D-gluconic acid* + H_2O_2

You will use a device called a spectrophotometer to measure the concentration of the oxidized dye using absorbance. The higher the solute in a a liquid, the more light is absorbed. A spectrophotometer works by shining a light through a sample and measuring how much comes out the other side. If there is more color, less will transmit through to the detector, which tells us more product has been formed. Water will absorb a little bit of the light, so it is important that the amount absorbed by the water be accounted for by first taking a blank, or reference reading, before you start.

The lab has two exercises.

Exercise 1

You will be examining the effect of glucose concentration on the rate of the reaction. For this experiment, you will want to keep the concentration of the enzyme constant while varying the concentration of glucose.

Exercise 2

You will be increasing temperature to examine how this changes the reaction rate and effectiveness of the enzyme catalyst.

Pre-Lab Problems

1. Do you think you will see an increase or decrease in absorbance as concentration changes? Explain your answer.

2. Do you need a new blank for this experiment? Why or why not?

3. Do you think you will see an increase or decrease in absorbance as temperature changes? Explain your answer.

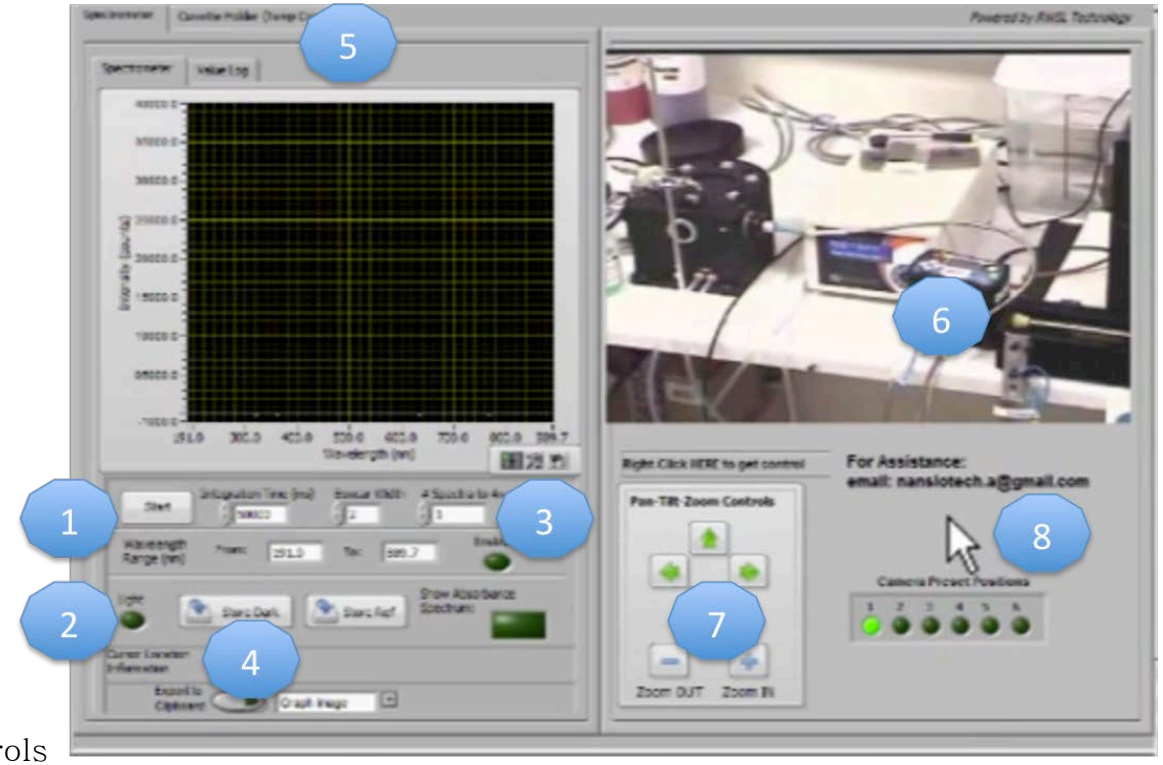
4. What color do you predict the product of the reaction will be? Explain your answer.

5. What is the enzyme used in this experiment?
6. What is the substrate used in this experiment?
7. What solutions should be in the blank?
8. Hypothesis/Prediction: Set this up as an if-then statement. For example: If heat is applied to particles in random motion, then observable differences will be seen in the absorption at various temperatures. This example is meant to be very general. You will need to take your answer to Problem 1 and make it a more specific if-then statement, based on your understanding prior to conduction of the experiment.

Control Panel

The Control Panel is where you access the equipment controls, collect data, and communicate with others participating at the same time as you.

In this experiment, you will view different samples and collect the spectrum wavelengths. You will also capture images of the graphs and record the wavelength data for the analysis portion of the lab.



Variables and Controls:

1. Start button
2. Light
3. Spectra value
4. Store dark spectrum
5. Temperature control tab
6. Camera view
7. Camera controls
8. Voice conference

Absorbance Spectrometer Tutorial

This tutorial introduces you to the absorbance spectrometer, which is used for several labs. You will see how the equipment is set up as well as the view you will have from your control panel. The demonstration shows how to control the equipment, read the settings, collect data, and collaborate with others. Watch the tutorial a second time, immediately before your lab appointment, to refresh your memory about the function and purpose of the different features in this lab setup.

- http://www.wiche.edu/nanslo/lab-tutorials#emissionspec

Things to Notice / Questions:

1. How do you store a dark spectrum? Why is this stored?
2. What are you measuring, and how does it relate to the study of enzymes?
3. How will the graphs help you understand the results?

Lab Procedure

Using the NANSLO lab equipment, you will log in and take the indicated measurements at the time you are scheduled to take the lab. Join the voice conference so you can communicate with the lab technician and other lab partners.

Exercise 1

In this experiment, the stock concentration of enzyme solution is 2 u/mL. Each cuvette used in this experiment will contain 1 mL of a stock glucose solution with a concentration of 0.2 mg/mL; the maximum volume of a cuvette is 4 mL. Create a table and determine the volumes you are going to add to buffer the enzyme solution. Record both volumes in the table in your lab report.

1. Click the cuvette holder tab. Set the volume of enzyme and running buffer to match your first concentration.
2. Set the temperature to 37° C.
3. Select Cuvette 0.
4. Click the spectrometer tab, set the total length of time to collect data to a value between 3–5 minutes. Set the collections interval to a value between 10–20 seconds.
5. Set your dark and reference points.
6. Inject your enzyme and running buffer, and start recording.
7. Click the spectrometer tab and export your data to your lab report. Enter data into your table.
8. Repeat these steps with Cuvette 1 and your second concentration.
9. Repeat steps with Cuvette 2 and your third concentration.
10. Repeat steps with Cuvette 3 and your fourth concentration.

Lab Procedure

Exercise 2

Temperature can have two effects on enzymes: There can be a change in the rate of molecular activity or there can be a change in the shape of the molecule. In Exercise 2, you will explore the change in reaction rate at different temperatures. The reaction rate is defined as the amount of substrate formed per unit of time. You will measure the change in the absorption spectrum as either more or less product is produced.

When the data is graphed, you can determine the slope of the line, which will give you the reaction rate. However, before we can begin, you will need to determine the wavelength at which the product absorbs light maximally. You must keep in mind that even when you are taking your absorbance measurement the reaction will be proceeding, and more enzymatic product will be forming. Do not wait for the numbers to stop changing — they won't!

1. From the graph you collected in Activity 1, identify the wavelength of the highest peak.
2. Click the cuvette holder tab. Set the volumes of enzyme and running buffer to match your fastest reaction in Exercise 1.
3. Set the temperature to 10° C.
4. Select Cuvette 4.
5. Click the spectrometer tab, and set the total length of time to collect data to a value between 3–5 minutes. Set the collections interval to a value between 10–20 seconds.
6. Set your dark and reference points.
7. Inject your enzyme and running buffer, and start recording.
8. Click the spectrometer tab and export your data.
9. Repeat steps 1–8 at 70° C.

Lab Day Checklist

On the day of your scheduled lab, review the items on this checklist to make sure you are prepared before logging into NANSLO.

- ❑ Read and review all lab materials
- ❑ Prepare and organize lab charts and recording materials
- ❑ Watch the lab tutorial again as a review before the lab
- ❑ Log in to your lab session – two options:
  - ❑ Retrieve your email from the scheduler with your appointment info or
  - ❑ Log in to the student dashboard and join your session by going to http://scheduler.nanslo.org
- ❑ NOTE: You cannot log in to your session before the date and start time of your appointment. Use Internet Explorer or Mozilla Firefox.

Enzyme Kinetics Lab Report

Exercise 1

Enzyme activity is measured in units. In this experiment, the stock concentration of enzyme solution is 2 u/mL. Each cuvette used in this experiment will contain 1mL of a stock glucose solution with a concentration of 0.2 mg/mL; the maximum volume of a cuvette is 4 mL. Create a table and determine the volumes you are going to add to buffer the enzyme solution. Record both volumes in your table in your lab report.

Create a data table that shows the concentration, absorbance, and time.

Enzyme Kinetics Lab Report

Exercise 2

Record data and graphs.

Lab Analysis

Exercise 1

1. Using the data from your table in the lab report, create a graph. On the graph you will plot time as the independent variable and absorbance as the dependent variable. You should have three different lines for the concentration ratio variables.

Lab Analysis

Exercise 1

2. Using your graphed data, calculate the slope of the line for the last 5 minutes of the data collected at each concentration. Slope is calculated by first choosing two points on the graph, then determining the change in the horizontal points and the change in the vertical points. For example, your coordinates on the graph at point 1 are
   1 (X-axis) and 6 (Y-axis), and at point 2 the coordinates are 4 (X-axis) and 12 (Y-axis). This means the vertical change is 12 - 6 and the horizontal change is 4 - 1, or vertical change = 6 and horizontal change = 3. To find the slope, you divide the vertical change by the horizontal change. 6 / 3 for a slope of 2. Be sure to include the correct units for your data. What information can you get from this graph?

3. In what way is the rate of the reaction dependent on the concentration of the substrate? How would this change if you were testing the concentration of the enzyme?

4. Based on the data you collected, write a claim-evidence statement. In other words, make a claim based on what you learned in this experiment, and back it up with the data you collected.

Lab Analysis

Exercise 2

1. Create a data table that shows the temperature, absorbance, and time at 10° C, 37° C (from Exercise 1), and 70° C.

2. Using the data, create a graph. On the graph, plot time as the independent variable and absorbance as the dependent variable. You should have three different lines for the temperature variables.

Lab Analysis

Exercise 2

3. Using your graphed data, calculate the slope of the line for the last 5 minutes of the data collected at each temperature. Slope is calculated by first choosing two points on the graph, then determining the change in the horizontal points and the change in the vertical points. For example, your coordinates on the graph at point 1 are
   1 (X-axis) and 6 (Y-axis), and at point 2 the coordinates are 4 (X-axis) and 12 (Y-axis). This means the vertical change is 12 - 6 and the horizontal change is 4 – 1, or vertical change = 6 and horizontal change = 3. To find the slope, you divide the vertical change by the horizontal change. 6 / 3 for a slope of 2. Be sure to include the correct units for your data. What information can you get from this graph?

4. How is the activity of the enzyme affected by temperature?

Reviewing Results

Write a review of your experiment. Include your findings and an explanation of your results. Then answer the following questions.

1. Based on the data you collected, write a claim-evidence statement for each exercise. In other words, make a claim based on what you learned in each experiment, and back it up with the data you collected.

2. What do you predict will happen if the enzyme is boiled (100° C) for 10 minutes?

Conclusion and Reflection

Write a thoughtful conclusion to the lab, answering the essential question: What factors increase the ability of enzymes to act as catalysts, and how can you calculate results using absorption spectrum?

Post-Lab Questions

Answer the following questions as completely as possible. Use evidence from your lab to help support answers where possible. Use these questions to demonstrate your learning. You may want to review your pre-lab answers and see what you have gained in understanding.

1. What are enzymes?
2. What effect do enzymes have on reaction rates?
3. How does measuring wavelengths help determine the presence of a compound?
4. How does concentration relate to enzyme effects?
5. What happens to reaction rates and enzyme effectiveness when temperature increases?
6. How is the area of enzyme kinetics applied to chemistry?

Radiation Lab

Lab Description:

In this lab, you will use the NANSLO lab equipment to measure and compare three different forms of radiation — alpha, beta, and gamma — and determine their strength based on distance and blockage by different shielding materials. In the final activity, you will use your experiment techniques and comparison data to identify an unknown type of radiation.

Purpose:

To conduct experiments to determine and compare the strength of three radiation sources as they relate to changing distances and different shielding materials.

Essential Question:

How can different forms of radiation be measured and compared, and how can this data help you identify an unknown source?

Objectives:

At the completion of this lab, you should be able to:

1. Define ionizing radiation and name the three types used in this lab.
2. Conduct experiments to determine the effects of increasing distance from the radiation source.
3. Conduct experiments to determine the results of using different types of shield materials with different radiation sources.
4. Conduct experiments and interpret results to solve for an unknown radiation type.
5. Collect and interpret quantitative data.
6. Complete tables and graphs with collected data.
7. Summarize findings using evidence from lab exercises.

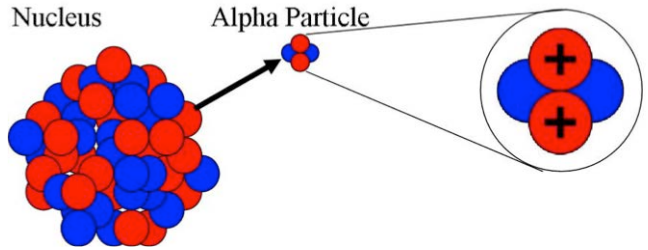
Pre-Lab Questions

These pre-lab questions are to help you think about the Radiation Lab and self-assess what you know and what you want to know about the topic. By the end of the lab, you should be able to answer these questions in more detail. Compare your answers to see what you have learned.

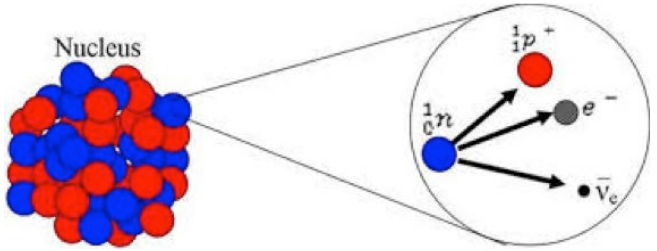
1. What are some characteristics of radiation?
2. How does radiation travel?
3. What impact does distance have on the strength of radiation? Is this the same for all radiation forms?
4. How does shielding work?
5. How can an unknown type of radiation be identified?
6. What types of materials block the most radiation?
7. How is radiation harmful?
8. What are some examples of beneficial applications of radiation?

Background Information

Radiation, the emission of energy, is all around us and can come in many forms. The particular type of radiation we will be discussing in this lab is **ionizing radiation**. Ionizing radiation occurs when an unstable element emits charged particles, or ions, that can travel through space and matter. There are three types of ionizing radiation: **alpha** (α), **beta** (β), and **gamma** (γ) (also called **X-rays)**.

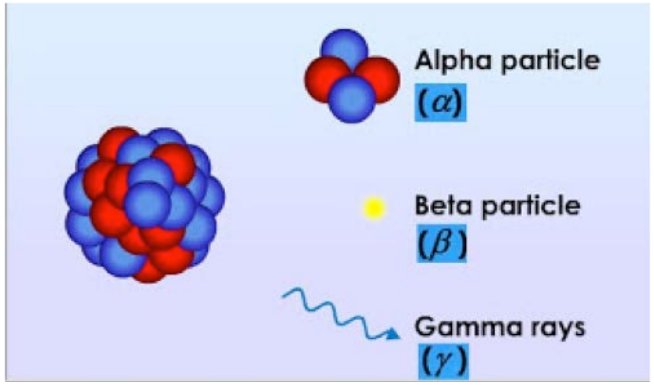


Alpha particles were discovered by Ernest Rutherford in 1899. Alpha particles have two protons and two neutrons, so they have a +2 charge. Alpha particles are the largest of all of the types of radiation, and it is because of their size that they travel the slowest, at 1/20 the speed of light. Alpha particles are emitted by elements that are larger (>106).



Henri Becquerel discovered beta particles in 1900. Beta particles are emitted electrons, and therefore have a charge of −1. The speed of a beta particle varies depending on the amount of energy the particular beta particle has, but all are faster than alpha particles. Beta radiation occurs when the neutron to proton ratio in the nucleus is too high. When this happens, the neutron converts into a proton that stays and an electron that is ejected.

Gamma radiation was also discover by Becquerel in 1896. Gamma radiation is pure electromagnetic energy, meaning it has no mass or charge and travels at the speed of light. Gamma radiation and X-rays are only different in the location of the atom they originate from. Gamma rays come from the nucleus, while X-rays come from the electron field. Gamma radiation is produced when an unstable isotope moves into a more stable energy state.



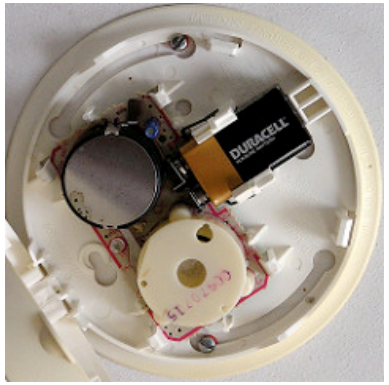
All three types of radiation can be harmful if the dose or exposure time is too long. And it is important to know that they can be stopped by shielding. Because of the different sizes and energies of the radiations, different types of shielding are required for each

Radiation Applications

Nuclear radiation changes atoms or molecules into charged particles. Radiation is found naturally in the ground, water, and air. It is found in building materials and even in food. Radiation also occurs in space, in the form of cosmic rays. It can be harmless or life threatening, depending on the type of radiation, distance from source, and length of exposure. This lab will focus on three types of ionizing radiation. Here are some examples of the how we use each type.

Alpha Radiation

One of the most common uses of alpha radiation is in smoke detectors. Radioactive americium releases alpha radiation. Smoke from a fire absorbs alpha radiation, altering the ionization that triggers the alarm. Alpha particles are normally harmless, but can be potentially dangerous if they are inhaled or swallowed.



https://www.flickr.com/photos/calliope/

Beta Radiation

Beta radiation is used in medicine. These radioactive chemicals are called tracers and are used to locate tumors or other diseased parts when the body is scanned.

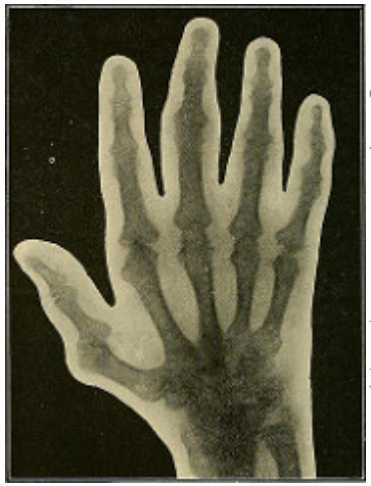
Beta radiation is also used in industry to monitor and control the thickness of materials during manufacturing. The thicker the material, the more radiation is absorbed, and the less radiation reaches the detector. These signals are then used to adjust the equipment to maintain the correct thickness.


https://www.flickr.com/photos/thirteenofclubs/

Radiation Applications

Gamma Radiation

The uses of gamma radiation are most prevalent in medicine. This is the type of radiation used in cancer treatments. X-rays are also typically used to take images of the solid parts of the body (such as teeth and bones), and are also used in industry to find defects in welds.



"The Röntgen rays in medical work" (1907)- public domain

Ionizing radiation is potentially harmful if not used correctly. It all depends on the type of radiation, the length of exposure, and the distance from the source. In general, overexposure to radiation can cause changes in the body's cells and can lead to cancer, blood disease, and other malfunctions in the body.

Resources

Radiation. Center for Nuclear Science and Technology Information of the American Nuclear Society. http://nuclearconnect.org/know-nuclear/science/radiation
What Types of Radiation Are There? Health Physics Society. http://hps.org/publicinformation/ate/faqs/radiationtypes.html
Types of Ionizing Radiation. Mirion Technologies. https://www.mirion.com/introduction-to-radiation-safety/types-of-ionizing-radiation/
Nuclear Chemistry - Radioactivity & Radiation - Alpha, Beta, Gamma. Sciencepost. https://www.youtube.com/watch?v=cOE40P5rHCA
Radiation Basics. United States Nuclear Regulatory Commission. http://www.nrc.gov/about-nrc/radiation/health-effects/radiation-

Radiation Lab

Purpose: To conduct experiments to determine and compare the strength of three radiation sources as they relate to changing distances and different shielding materials.

<insert image of lab set-up>

This laboratory activity focuses on three different kinds of radiation and their characteristic strengths related to distance and three different shields.

You will be using the NANSLO lab equipment to move the source to measure radiation strength at different distances. You will also be testing the strength as radiation passes through three different shielding materials: a piece of paper, a piece of tin foil, and a piece of aluminum.

This data will be collected and compared to assist you in identifying a final unknown radiation source.

Control Panel

The Control Panel is where you access the equipment controls, collect data, and communicate with others participating at the same time as you.

In this experiment, you will test different sources of radiation by changing the distance from the source and using different types of shielding materials.

<Insert photo of labeled control panel when available>

Variables and Controls:

<Insert numbered controls that correlate to labeled image>

Radiation Tutorial

This tutorial introduces you to the radiation lab apparatus. You will see how the equipment is set up as well as the view you will have from your control panel. The demonstration shows how to control the equipment, read the settings, collect data, and collaborate with others. Watch the tutorial a second time, immediately before your lab appointment, to refresh your memory about the function and purpose of the different features in this lab setup.

- <add link when available>

Things to Notice / Questions:

1. How do you change radiation sources?
2. How do you adjust the distance?
3. What other controls will you be using?
4. How do you share the controls with others in your group?

Radiation Lab Procedure

Using the NANSLO lab equipment, you will log in and take the indicated measurements at the time you are scheduled to take the lab.

Exercise 1

1. Using the lab interface, turn on the radiation detector.
2. Record any background radiation.
3. Select a radiation source and take note of the amount of radiation being detected in Position 1.
4. Start by moving the source further away to Positions 2–4. Record the radiation counts at each of these distances.

Exercise 2

1. Move the source to Position 1.
2. Insert a shield material in front of the detector and record the radiation count.
3. Repeat with each of the the shield materials.
4. Select the second radiation type and repeat steps 2 and 3. Record all data in your lab report.

Exercise 3

1. Select the unknown type of radiation.
2. Using the knowledge you have gained, change distance, shielding, or both to determine what type of radiation is being emitted from the source.

Lab Day Checklist

On the day of your scheduled lab, review the items on this checklist to make sure you are prepared before logging into NANSLO.

- ❑ Read and review all lab materials
- ❑ Prepare and organize lab charts and recording materials
- ❑ Watch the lab tutorial again as a review before the lab
- ❑ Log in to your lab session – two options:
  - ❑ Retrieve your email from the scheduler with your appointment info or
  - ❑ Log in to the student dashboard and join your session by going to http://scheduler.nanslo.org
- ❑ NOTE: You cannot log in to your session before the date and start time of your appointment. Use Internet Explorer or Mozilla Firefox.

Radiation Lab Report

Exercise 1

Fill in the table with the results and data from the procedure, including the background radiation and radiation readings at the four positions for each of the three known radiation sources, and the final unknown source (Exercise 3).

Radiation Source	Background Radiation	Position 1	Position 2	Position 3	Position 4
alpha					
beta					
gamma					
unknown					

Radiation Lab Report

Exercise 2

Fill in the table with the results and data from the procedure, including the background radiation and radiation readings using the three different shield materials for each of the three known radiation sources, and the final unknown source (Exercise 3).

Radiation Source	Background Radiation	Paper Shield	Tin Foil	Aluminum
alpha				
beta				
gamma				
unknown				

Exercise 3

Fill in the last table rows in Exercises 1 and 2 to record the measurements for the unknown radiation source.

Radiation Analysis

Exercise 1

1. Create a data table and subtract your background radiation counts from all of your collected experimental data.

2. Which type of ionizing radiation was most impacted by distance? How do you know?

Exercise 2

1. Which type of ionizing radiation was the paper able to block?

2. Which type of ionizing radiation was the tin foil able to block?

3. Which type of ionizing radiation was the aluminum able to block?

Radiation Analysis

Exercise 3

Make a case for the identity of the unknown type of radiation. Explain how you reached your conclusion and support your claim with evidence from your experiments.

Reviewing Results

Write a review of your experiment. Include your findings and an explanation of your results. Then answer the following questions.

1. Given the types of shielding used in this lab, what do you think the most effective shielding will be? Why?
2. Based on the information given, rank the types of radiation (gamma, alpha, and beta) in order of most easily absorbed to hardest to absorb. Explain your answer.

Conclusion and Reflection

Write a thoughtful conclusion to the lab, answering the essential question: How can different forms of radiation be measured and compared, and how can this data help you identify an unknown source?

Post-Lab Questions

Answer the following questions as completely as possible. Use evidence from your lab to help support answers where possible. Use these questions to demonstrate your learning. You may want to review your pre-lab answers and see what you have gained in understanding.

1. What are some characteristics of radiation?
2. How does radiation travel?
3. What impact does distance have on the strength of radiation? Is this the same for all radiation forms?
4. How does shielding work?
5. How can an unknown type of radiation be identified?
6. What types of materials block the most radiation?
7. How is radiation harmful?
8. What are some examples of beneficial applications of radiation?

Reaction Rates

Lab Description:

The rate of a chemical reaction is the time it takes for a given amount of a reactant to change into the product. For this lab, you will observe how reaction conditions change the rate of reaction in an Alka-Seltzer tablets and water mixture.

Purpose:

To determine how surface area affects the reaction rate of Alka-Seltzer and water.

Essential Question:

What are some of the factors affecting reaction rates and how is this applicable to chemistry?

Objectives:

At the completion of this lab, you should be able to:

1. Define reaction rate and explain how and why it is measured.
2. Explain the process of determining reaction rate.
3. Complete reaction rate experiments using virtual equipment.
4. Use collected data to make calculations.
5. Analyze and compare results.
6. Describe an application of reaction rates in biology.

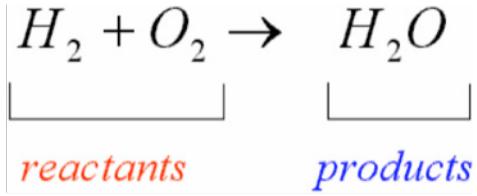
Pre-Lab Questions

These pre-lab questions are to help you think about the reaction rate lab and self-assess what you know and what you want to know about the topic. By the end of the lab, you should be able to answer these questions in more detail. Compare your answers to see what you have learned.

1. What is a reaction rate? Provide an example.
2. What are four factors that affect reaction rate?
3. How does increased surface area of the reactants affect reaction rate?
4. In what circumstances is it important to understand reaction rates in chemistry? Give an example.

Background Information

In a chemical reaction you start with reactants, which are changed in some fashion to become products. Reactants are to the left of the arrow and products are shown on the right of the arrow.



The rate of a chemical reaction is the time it takes for a given amount of a reactant (what you start with) to change into the product (what you end with). Rate is affected by several factors, including:

1) Reactant concentration

2) Temperature

3) Pressure

4) Catalysts

5) Physical state of reactants

In this lab, you will be examining how one of the physical states of the reactants (surface area) affects reaction rate.

Important Terms

catalyst – a substance that causes a chemical reaction to happen more quickly

enzymes – proteins that speed up the rate of a reaction by lowering the amount of energy required for a reaction to take place

equilibrium – a state in which opposing forces or actions are balanced so that one is not stronger or greater than the other

ion – an atom, or group of atoms, that has a positive or negative electric charge from losing or gaining one or more electrons

molarity (M) – a measure of concentration; the number of moles of solute per liter of solution

mole (m) – the amount of pure substance containing the same number of chemical units as there are atoms in exactly 12 grams of carbon-12

products – the resulting substances of a chemical reaction

reactant – a solution with a known chemical makeup and concentration

reaction rate – a measure of the change in the concentration of reactants or products over time in a chemical reaction

Background Information

Chemical Reactions in Cells

Reaction rate applies to biology, since all living cells carry out continuous cycles of chemical reactions to keep functioning. The reaction rates of these processes are interdependent and complex.


USDA 20150320-OSEC-LSC-0098

Metabolism

The series of reactions needed to keep an organism alive is called metabolism. It is imperative that most of these reactions occur at a rapid rate. Since increasing temperature would be detrimental to the cells and body structures, enzymes are used as catalysts.

Medical Applications

Many diseases and conditions can be detected by studying enzymes, including diseases affecting the heart, liver, kidney, pancreas, blood, and digestive tract.

Food Industry

Enzymes are used to control the process of making many different foods, such as:

- Ice cream
- Coffee
- Juice
- Wine
- Beer
- Cheese

Resources

Digestive Enzymes. Biology Online.
http://www.biology-online.org/articles/digestive_enzymes.html
The Central Role of Enzymes as Biological Catalysts. In: The Cell: A Molecular Approach. 2nd ed. Sinauer Associates (via NCBI).
http://www.ncbi.nlm.nih.gov/books/NBK9921/

Reaction Rate Experiment

Purpose: To determine how surface area affects the reaction rate of Alka-Seltzer and water.

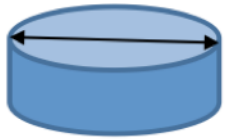
For this lab, you will observe how reaction conditions change the rate of reaction in an Alka-Seltzer tablet and water mixture. The main ingredients of Alka-Seltzer tablets are aspirin, citric acid, and sodium bicarbonate ($NaHCO_3$). When sodium bicarbonate dissolves in water, it splits apart, or dissociates, into sodium (Na^+) and bicarbonate (HCO_3^-).

The bicarbonate reacts with hydrogen ions (H^+) from the citric acid to form water and carbon dioxide, which is a gas that can be seen by the bubbles produced. This reaction is shown below:

$$C_6H_8O_7 + 3NaHCO_3 \rightarrow 3H_2O + 3CO_2 + Na_3C_6H_5O_7$$

Contact area, also known as surface area, can affect a chemical reaction. Alka-Seltzer is commonly packaged as one large tablet with a set surface area. As the tablet is crushed or broken up, the total surface area increases. Instead of one big tablet, there are lots of little tablets, and this affects the rate of the reaction.

Reaction Rate Experiment



Diameter = 1 inch
Height = 0.25 inch

Diameter = 0.5 inch
Height = 0.1 inch

The volume, or space, of one tablet that is 1 inch across and 0.25 inch tall is the same as ten tablets that are 0.5 inch across and 0.1 inch tall. The surface area, which is the contact area with the environment, however, is very different between the two.

Pre-Lab Questions and Calculations:

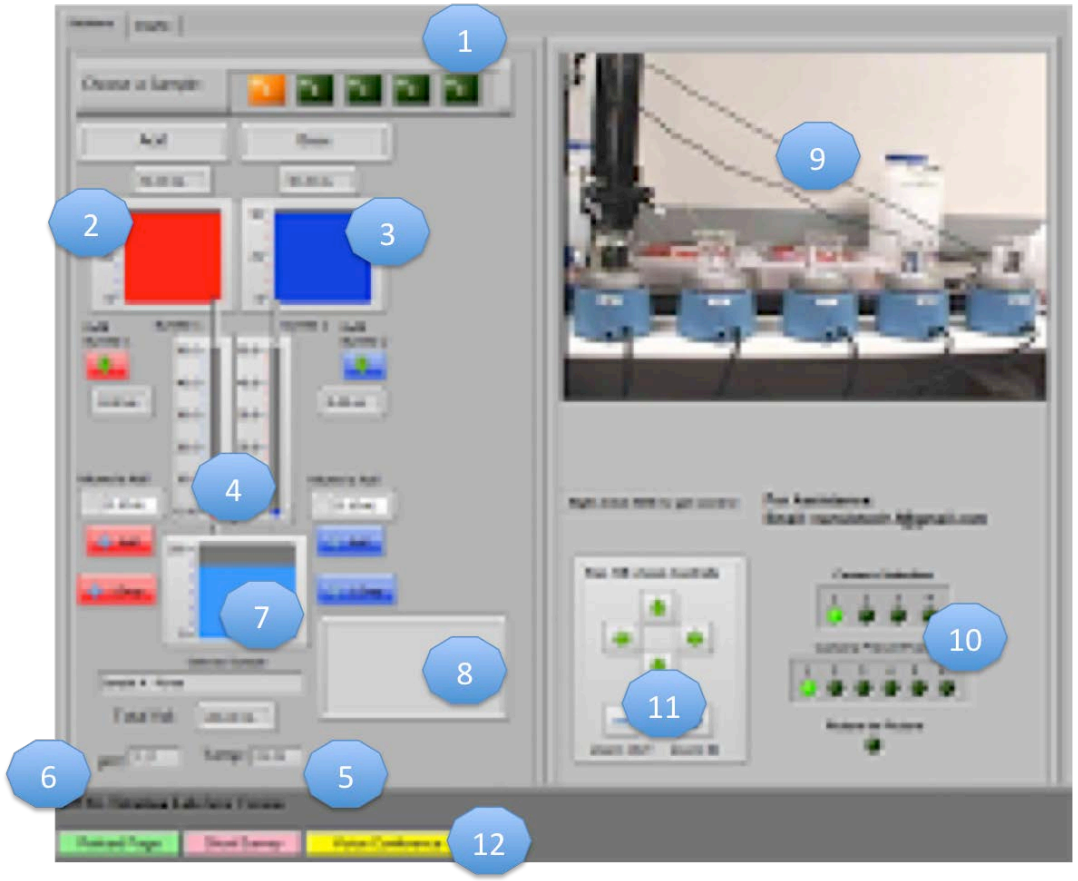
$$C_6H_8O_7 + 3NaHCO_3 \rightarrow 3H_2O + 3CO_2 + Na_3C_6H_5O_7$$

1. What are the products for the above reaction?
2. What are the reactants for the above reaction?
3. Calculate the surface area for the unbroken, large Alka-Seltzer tablet shown above on the left.
4. Calculate the surface area for ten smaller tablets with the given dimensions: diameter = 0.5 inch and height = 0.1 inch.
5. Predict whether a crushed tablet (i.e., more surface area) will react faster or slower than a non-crushed tablet.

Control Panel

The Control Panel is where you access the equipment controls, collect data, and communicate with others participating at the same time as you.

In this experiment, you will be changing beakers and adding water to view and track the reaction rate. This will include monitoring the camera and recording images.



Variables and Controls:

1. Selection of beaker
2. Acid tank
3. Base tank
4. Burettes
5. Temperature reading
6. pH reading
7. Volume
8. Message screen
9. Camera image
10. Camera view
11. Camera controls
12. Voice conference

Tutorial

This tutorial introduces you to the Reactions Rate lab. You will see how the equipment is set up as well as the view you will have from your control panel. For this lab, you will be adding water to different beakers to observe reactions and track changes.

The demonstration shows how to control the equipment, read the settings, collect data, and collaborate with others. Watch the tutorial a second time, immediately before your lab appointment, to refresh your memory about the function and purpose of the different features in this lab setup.

- Add link when available

Things to Notice / Questions:

1. How do you join the voice conference?
2. What steps will you take to add water to a beaker?
3. How will you change from Beaker 1 to Beaker 2?
4. How can you view a close-up of each beaker?
5. How and when will you capture an image?

Reaction Rate Procedure

Using the NANSLO lab equipment, you will log in and take the indicated measurements at the time you are scheduled to take the lab.

1. In this experiment, two compounds will be mixed, and you will predict what will happen. Record your observations on the Lab Report chart.

2. Using the NANSLO interface, zoom in on the Beaker 1. Make observations about what is in the beaker. Take note of the ruler next to the beaker.

3. Predict what will happen in this beaker before you continue.

4. Add 10 mL of water to the beaker. Start your timer, and see how long it takes for the fizzing to stop. Also watch the height of the bubbles/liquid, and record the highest point that the bubbles reach.

5. Repeat with Beakers 2, 3, and 4.

Lab Day Checklist

On the day of your scheduled lab, review the items on this checklist to make sure you are prepared before logging into NANSLO.

- ❑ Read and review all lab materials
- ❑ Prepare and organize lab charts and recording materials
- ❑ Watch the lab tutorial again as a review before the lab
- ❑ Log in to your lab session – two options:
  - ❑ Retrieve your email from the scheduler with your appointment info or
  - ❑ Log in to the student dashboard and join your session by going to http://scheduler.nanslo.org
- ❑ NOTE: You cannot log in to your session before the date and start time of your appointment. Use Internet Explorer or Mozilla Firefox.

Lab Report

Beaker	Pre-lab Observations	Pre-lab Predictions	Reaction Time	Height of Bubbles	Observation Notes and Questions
1					
2					
3					
4					

Reviewing Results

Write a review of your experiment. Include your findings and an explanation of your results. Use the following prompts to guide you.

1. Which beaker had the fastest reaction?
2. Which beaker had the slowest reaction?
3. Which beaker had the most bubbles?
4. Which beaker generated the least bubbles?
5. Speculate on why your answer to #1 had the fastest reaction. Support your answer with evidence.
6. What other measurement would have been useful?
7. Beakers 3 and 4 had seemingly the same conditions, but one was faster than the other. Explain why?

Conclusion and Reflection

Write a thoughtful conclusion to the lab, answering the essential question: What are some of the factors affecting reaction rates and how is this applicable to chemistry?

Post-Lab Questions

Answer the following questions as completely as possible. Use evidence from your lab to help support answers where possible. Use these questions to demonstrate your learning. You may want to review your pre-lab answers and see what you have gained in understanding.

1. What is a reaction rate? Provide an example.
2. What are four factors that affect reaction rate?
3. How does increased surface area of the reactants affect reaction rate?
4. In what circumstances is it important to understand reaction rates in chemistry? Give an example.

Acid/Base Titration

Lab Description:

Titration is a procedure to analyze a substance for particular compounds and their concentrations. In this lab, you will use remote acid/base titration lab equipment to determine the concentration (molarity) of acid in the sample solution.

Purpose:

To determine the concentration of an acid in a sample by adding a known quantity of a base through the process of titration.

Essential Question:

How can titration be used to calculate unknown concentrations of acids in a solution, and how does this apply to chemistry?

Objectives:

At the completion of this lab, you should be able to:

1. Define titration and explain how and why it is used.
2. Explain the process of acid/base titration.
3. Complete acid/base titrations using virtual equipment.
4. Create graphs from collected data and interpret for completing calculations.
5. Calculate the concentration (molarity) of an acid using experiment data.
6. Describe an application of titration in chemistry.

Pre-Lab Questions

These pre-lab questions are to help you think about the titration lab and self-assess what you know and what you want to know about the topic. By the end of the lab, you should be able to answer these questions in more detail. Compare your answers to see what you have learned.

1. What is titration?
2. How does pH help determine how acidic or alkaline a solution is?
3. How does pH relate to acid/base titration?
4. In what circumstances might it be important to know the concentration of acid in a solution?

Background Information

Important Terms

acid – a compound with a pH less than 7, that in a solution donates hydrogen ions and is able to accept an unshared pair of electrons from a base

base – a compound with a pH greater than 7, that in a solution accepts hydrogen ions; also known as alkaline

equivalence point – the point at which chemically equivalent amounts of reactants have reacted to cancel each other out

ion – an atom or group of atoms that has a positive or negative electric charge from losing or gaining one or more electrons

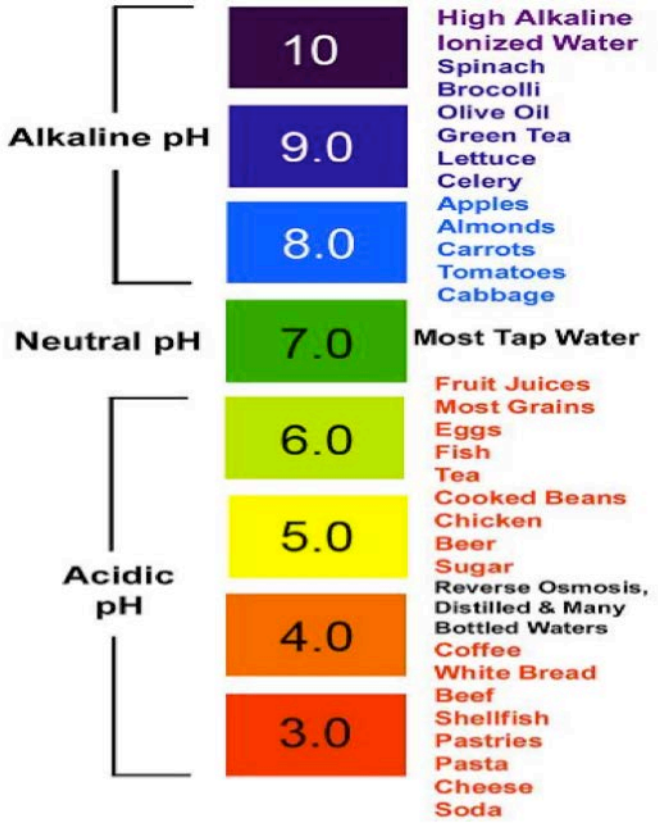
molarity (M) – a measure of concentration; the number of moles of solute per liter of solution

mole (m) – the amount of pure substance containing the same number of chemical units as there are atoms in exactly 12 grams of carbon-12

neutral – an even number of hydrogen ions (+) and hydroxide ions (–), so the solution is neutral; a substance that is neutral has a pH of 7

pH – a number between 0 and 14 that indicates if a chemical is an acid or a base

reagent – a solution with a known chemical makeup and concentration



The pH values of some common substances are shown in the chart above. A pH of 7 is neutral. Substances above 7 are alkaline, and substances below 7 are acidic. Take a look at the pH of some common foods. Any surprises?

Explore Titration

The chemical process of titration is used to support study, analysis, and monitoring of chemicals related to the following fields and processes:

Medical Uses

- Titration is used for analyzing samples of blood and urine to measure the concentration of different chemicals.
- Acids and bases are important in living things to maintain the proper pH for enzymes to work.
- New drugs are tested and analyzed using the process of titration.
- It is used to determine the correct proportion of different medicines in an intravenous drip.
- Titration is also used to monitor blood glucose levels in patients with diabetes, as well as in pregnancy tests and other applications of urinalysis.

Food Industry

- Titration helps identify fat and water content and the presence of vitamins in foods.
- It is used to test for the amount of salt, sugar, and proteins.
- Titration is also used in wine and cheese production to meet standards, test for acidity, and determine product readiness.

Biodiesel

- Titration is used to determine the acidity of waste vegetable oil, one of the primary ingredients in biodiesel production.

Ecology – Water Protection

- Titration is used to test the underwater environment in fresh water and marine water.
- It is used to monitor aquarium pH and other chemical concentrations.
- Titration is a precise method for the determination of the acidity in rain or snow samples associated with acid rain.

Resources

Titratable Acidity. Iowa State University Extension and Outreach. http://goo.gl/tA9Iog
The Big Reveal: What's Behind Nutrition Labels. American Chemical Society. http://goo.gl/rycf8f
Acid-Base Titrations. SparkNotes. http://www.sparknotes.com/chemistry/acidsbases/titrations/section1.rhtml

Titration Experiment

Purpose: To determine the concentration of an acid in a sample by adding a known quantity of a base through the process of titration.

The titration experiment is set up with five beakers and burettes you control virtually to add solutions with precise measurements.

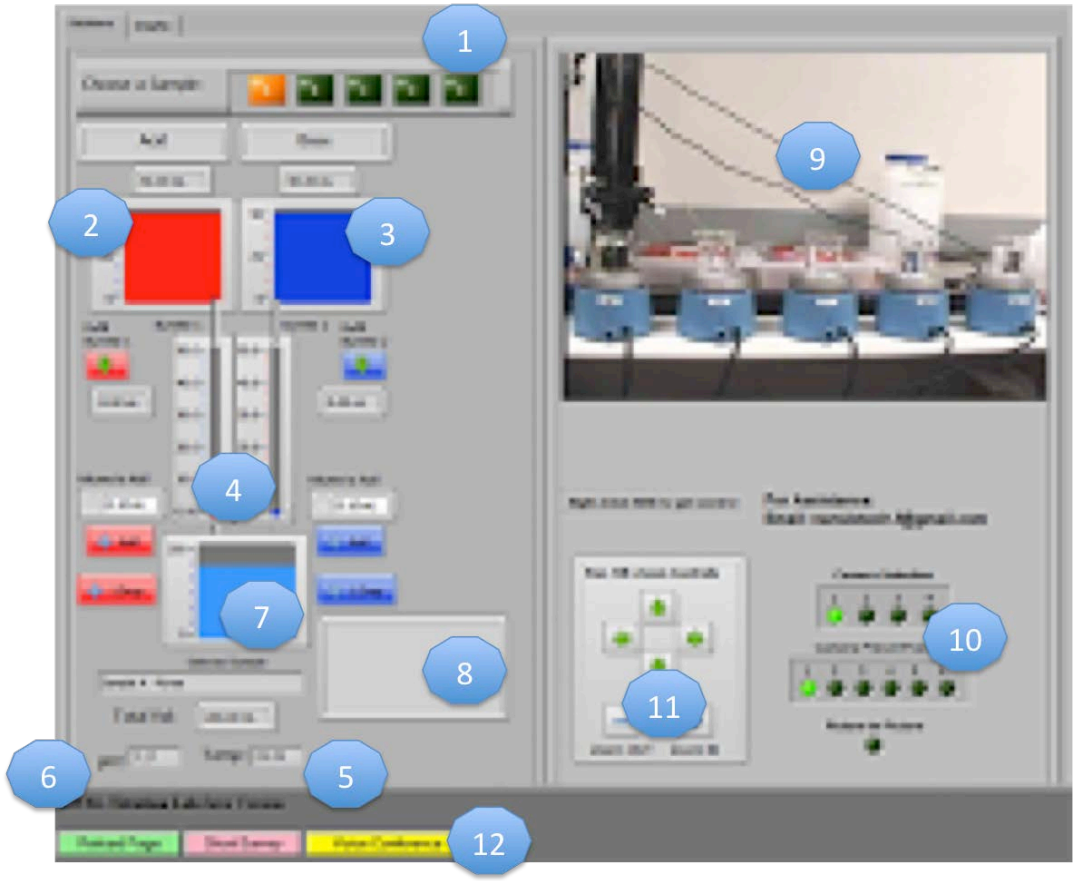
The image at right shows a close-up of the double burettes that add amounts you specify, or drops of solution, to the beaker.

Control Panel

The Titration Lab Control Panel is where you access the equipment controls, collect data, and communicate with others participating at the same time as you.

In this experiment, you will have five beakers labeled A–E. Beaker A is filled with clear water to sterilize the probe after each use.

Each of the other four beakers contains an acidic solution. Your job will be to use titration to determine the concentration in each of these beakers.



Variables and Controls:

1. Selection of beaker
2. Acid tank
3. Base tank
4. Burettes
5. Temperature reading
6. pH reading
7. Volume
8. Message screen
9. Camera image
10. Camera view
11. Camera controls
12. Voice conference

Tutorial

This tutorial introduces you to the titration apparatus, which is used for several labs. You will see how the equipment is set up as well as the view you will have from your control panel. The demonstration shows how to control the equipment, read the settings, collect data, and collaborate with others. Watch the tutorial a second time, immediately before your lab appointment, to refresh your memory about the function and purpose of the different features in this lab setup.

- http://www.wiche.edu/nanslo/lab-tutorials#titration

Things to Notice / Questions:

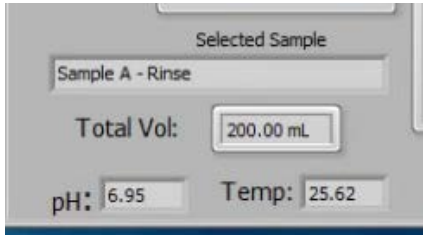
1. Why should you rinse the probe in Beaker A between samples?
2. What might be some reasons why you can't add solution to a beaker?
3. When is it a good idea to switch to using the drop feature?
4. How will you know when you have added enough base solution?
5. How will creating a graph help you visualize your data?

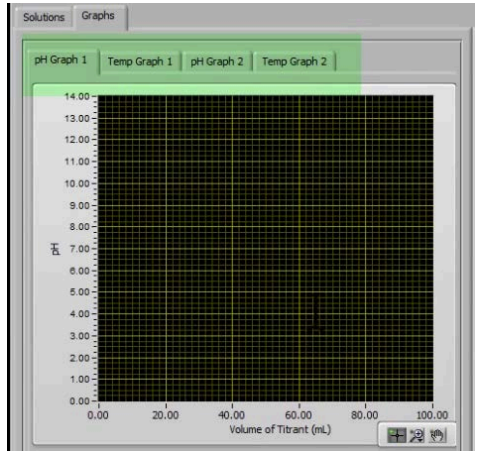
Titration Lab Procedure

Using the NANSLO lab equipment, you will log in and take the indicated measurements at the time you are scheduled to take the lab.

Exercise 1: Qualitative measurement

1. The first titration is qualitative, where you will make observations about how the acid in the beaker reacts with the base you add from the dropper.
2. Slowly add a small amount of base to Beaker B. Keep track of the volume and pH changes by adding data points to a graph.
3. Try adding different volumes and see what happens. For instance, try a tenth of a milliliter up to a few milliliters.
4. See if you can determine the equivalence point. Use the interface to add the volumes. Save the titration graph/data for this run and move on to the next one.
5. If you have lab partners, take turns adding fluid.

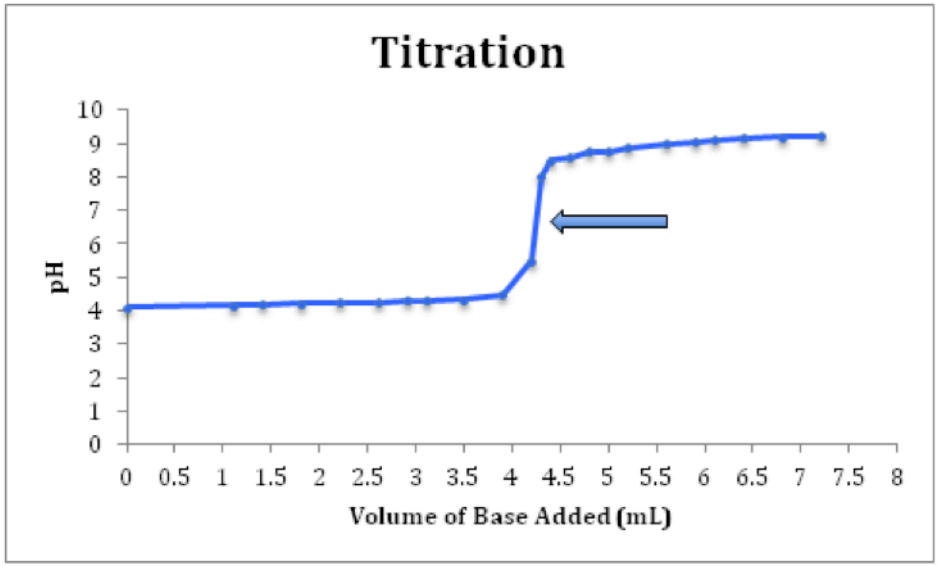




Titration Lab Procedure

Exercise 2: Quantitative measurement

1. From your first measurement, you should have a good guess as to what volume you need to add to reach the equivalent point.
2. This time, try to get close to that, and then add volume slowly around that volume.
3. You have three more titrations to try this.
4. Save the titration graph for each titration to use for your analysis.



Tips for Recording Information

- Keep a record of each step you take in the experiment to refer to after you are finished.
- Make a chart and record the volume, temperature, and pH of the acidic solution in each beaker before adding the base.
- Record the amount you add and wait for the solution to stabilize before recording the changes in temperature, volume, and pH.
- Start a graph and add the data point.
- Continue adding information to your own records and to the computer generated data/graph. This way, you will have two sources of information.

Lab Day Checklist

On the day of your scheduled lab, review the items on this checklist to make sure you are prepared before logging into NANSLO.

- ❑ Read and review all lab materials
- ❑ Prepare and organize lab charts and recording materials
- ❑ Watch the lab tutorial again as a review before the lab
- ❑ Log in to your lab session – two options:
  - ❑ Retrieve your email from the scheduler with your appointment info or
  - ❑ Log in to the student dashboard and join your session by going to http://scheduler.nanslo.org
- ❑ NOTE: You cannot log in to your session before the date and start time of your appointment. Use Internet Explorer or Mozilla Firefox.

Lab Report

Sample B

Start Volume	Start pH	Volume Added	pH	Temperature Change

Observation notes:

Sample C

Start Volume	Start pH	Volume Added	pH	Temperature Change

Observation notes:

Lab Images

Lab Report

Sample D

Start Volume	Start pH	Volume Added	pH	Temperature Change

Observation notes:

Sample E

Start Volume	Start pH	Volume Added	pH	Temperature Change

Observation notes:

Lab Images

Titration Lab Analysis

The purpose of the acid/base titration is to determine the concentration (molarity) of acid in the beaker. Taking a look at the data, you will see there are some constants and some variables. Using the following equation, information, and your data, you will be able to solve for the unknown M of the acid.

Molarity (concentration) of Acid (MA) x the Volume of Acid (VA) is equivalent to Molarity of Base (MB) x the Volume of Base (VB) or

$$MA \times VA = MB \times VB$$

Constants and Variables

Each beaker contained 5.0 mL of HCL acid of unknown concentration and 0.1 M NaOH was added to the beaker to a volume you determined doing the titration.

Use your graphs to find the equivalence point in which the solution was neutralized by reaching a pH of 7. Find the volume of base added at this point on each of your four trials.

MA = concentration of acid, solving for this unknown

VA = volume of acid, 5.0 mL

MB = concentration of base, 0.1 M

VB = volume of base; use your data to find volume of base added to reach equivalence point

Calculate the molarity of the acid for all four of the titrations you performed.

Titration 1 MA =

Titration 2 MA =

Titration 3 MA =

Titration 4 MA =

Reviewing Results

Write a review of your experiment. Include your findings and an explanation of your results. Use the following questions as prompts to include in your review and learning reflection.

1. Were your results consistent for each sample? If not, what might have been the reason?
2. How accurate was the data you collected? How do you know?
3. How do the graphs show the equivalence point?
4. Was temperature a factor in the titration? Explain.

Conclusion and Reflection

Write a thoughtful conclusion to the lab, answering the essential question: How can titration be used to calculate unknown concentrations of acids in a solution, and how does this apply to chemistry?

Post-Lab Questions

Answer the following questions as completely as possible. Use evidence from your lab to help support answers where possible. Use these questions to demonstrate your learning. You may want to review your pre-lab answers and see what you have gained in understanding.

1. What is titration?
2. How does pH help determine how acidic or alkaline a solution is?
3. How does pH relate to acid/base titration?
4. In what circumstances might it be important to know the concentration of acid in a solution?

Membrane Diffusion

Lab Description:

Diffusion is a process in which molecules disperse from areas of high concentration to areas of low concentration to establish equilibrium. In this lab, you will experiment with the rate of diffusion across a membrane. A spectrophotometer will be used to track the diffusion of iodine across a membrane. This is accomplished by measuring the light absorbed by the dark color of iodine as it reacts in the starch solution on the other side of the membrane. You will be setting up trials using different temperatures to find the impact of heat on the rate of diffusion.

Purpose:

To determine the rate of diffusion related to increasing temperature.

Essential Question:

How can diffusion be measured to better understand the movement of molecules?

Objectives:

At the completion of this lab, you should be able to:

1. Define diffusion and identify the conditions necessary for it to occur.
2. Determine what is being measured in a spectrophotometer, and explain the basics of spectrophotometry.
3. Collect quantitative data on the rate of diffusion at different temperatures.
4. Graph the data collected and interpret the data.
5. Explain how temperature impacts molecular movement.
6. Determine the effect of temperature on the diffusion rate of iodine through a dialysis tube membrane.
7. Apply diffusion concepts with specific examples.

Pre-Lab Questions

These pre-lab questions are to help you think about the diffusion lab and self-assess what you know and what you want to know about the topic. By the end of the lab, you should be able to answer these questions in more detail. Compare your answers to see what you have learned.

1. What is diffusion and how does it apply to chemistry?
2. What are the conditions necessary for diffusion to occur?
3. What is a method for determining the rate of diffusion?
4. How does temperature relate to the rate of diffusion in liquids?
5. In what circumstances is it important to know the rate of diffusion?

Background Information

Diffusion is the movement of things from a high concentration to a low concentration. Imagine you are adding cream to coffee. The spot where the cream hits the milk is highly concentrated, and it diffuses out to areas of low concentrations. Perfume works the same way but in the air. Someone wearing the scent is highly concentrated and you can smell it as it diffuses across the room and hits your nose.

Atoms and molecules are in constant motion. Even in a solid state, the molecules exhibit vibrational movement as they move against each other in position. When molecules are in a liquid state, they can be farther apart than in a solid, but not nearly as far apart as in a gas.

Because molecules are in constant motion, the molecules are colliding with each other. This type of motion is called **Brownian movement**. As a substance heats up, the motion becomes faster and molecules collide more frequently. Think for a minute about a drop of food coloring in a glass of water. If the water is hot, the water molecules move faster and the collisions with the food coloring molecules are more frequent, causing the food coloring to diffuse more rapidly. On the other hand, ice water will have the opposite effect. Simple diffusion relies on Brownian motion and temperature.

There is an interesting simulation here, if you want to learn more: http://phet.colorado.edu/en/simulation/states-of-matter-basics

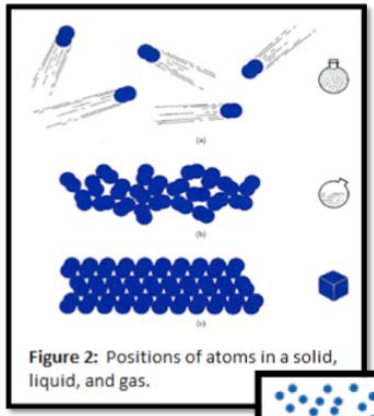


Figure 2: Positions of atoms in a solid, liquid, and gas.

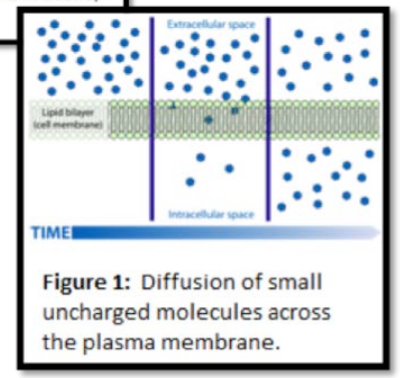


Figure 1: Diffusion of small uncharged molecules across the plasma membrane.

Resources

Diffusion and Osmosis. Khan Academy. https://www.khanacademy.org/science/biology/membranes-and-transport/diffusion-and-osmosis/v/diffusion-and-osmosis
https://www.youtube.com/watch?v=aubZU0iWtgI

Background Information

The life of a cell is dependent on efficiently moving molecules into and out of the cell. A factor of this movement is the cell membrane. Molecules in living things move in a variety of ways, but for the purposes of this lab the focus will be on simple diffusion. Small, uncharged molecules are able to move easily across the cell membrane in a process known as simple diffusion. The process of simple diffusion relies on the inherent nature of molecules to move from high concentration to lower concentration. This laboratory activity will focus on the transport of molecules across a barrier via diffusion, which can be applied to the diffusion process in other situations.

The difference between the highly concentrated substance and the lower concentrated substance is called the **concentration gradient**. Diffusion can only happen if there is a concentration gradient present. When there is no longer a net movement, **equilibrium** has been reached.

There are both qualitative and quantitative methods that can be used to record and observe diffusion. Qualitative data are based on the five senses and observations. For instance in the perfume example, as you get closer to the person, i.e., the concentrated sample, your nose gets overwhelmed, and as you walk away it goes away. Quantitative data, on the other hand, are measured and numerical, and are not subjective to our individual senses. In this lab, we will be using a **spectrophotometer** to quantitatively

Important Terms

absorbance – the measure of the quantity of light absorbed by a sample

Brownian movement – the irregular motion of small particles suspended in a liquid or a gas, caused by the bombardment of the particles by molecules of the medium

concentration gradient – the gradual difference in concentration of a dissolved substance in a solution between a region of high density and one of lower density

cuvette – a straight-sided, optically clear container for holding liquid samples in a spectrophotometer or other instrument

diffusion – an intermingling of molecules, ions, etc., resulting from random thermal agitation

equilibrium – a state of rest or balance

equivalence point – the point at which chemically equivalent
of concentration, the number of moles of solute per liter of solution

solute – the substance dissolved in a given solution

solution – a homogeneous, molecular mixture of two or more substances

solvent – a substance that dissolves another to form a solution

spectrophotometer – an apparatus for measuring the intensity of light in a part of the spectrum, especially as

Diffusion in Chemistry

Dialysis

The process of dialysis involves passing through a tube made of a semipermeable material. On the other side is a liquid of a certain concentration. The blood is passed over the membrane and materials diffuse into or out of the bloodstream.

Smoke Diffusion

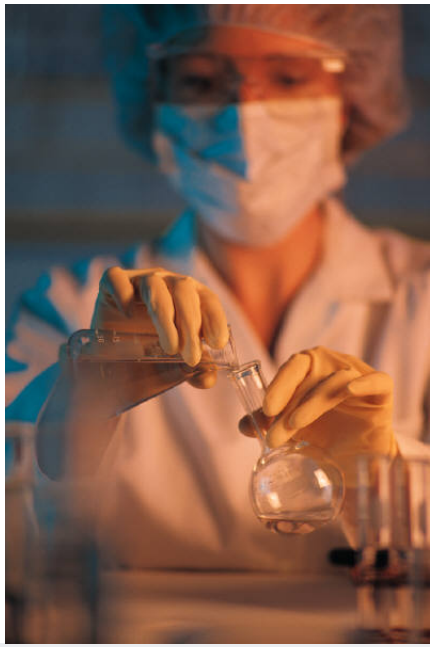
The study of the chemical makeup of smoke and how it diffuses through air is used to determine health risks from forest fires and second-hand smoke.

Animal Physiology- Human Health

Digestion: Particles of food diffuse in the colon. Respiration: Exchange of oxygen and carbon dioxide diffuses between the lungs and bloodstream. Food molecules and oxygen diffuse from the mother's blood to the fetus's blood supply through the placenta.

Alloy Production

Alloys are formed when two or more types of metal are combined, such as steel formed from iron, carbon, aluminum, and other trace metals. Particles within the metals combine from areas of high to low concentration in the process of alloy formation.

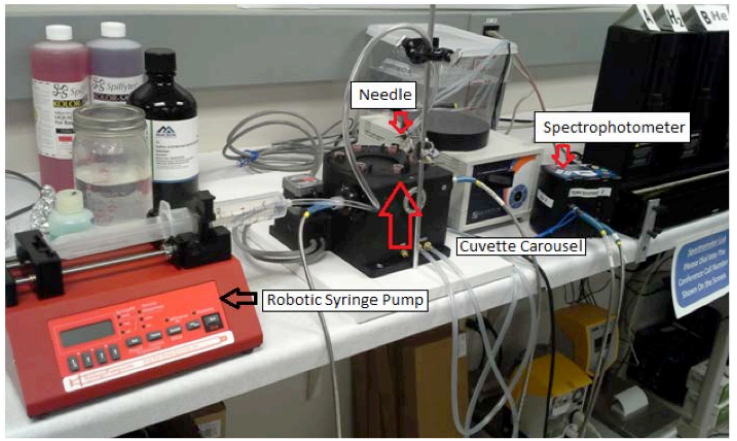


Resources

How Does a Kidney Dialysis Machine Work? HowStuffWorks. http://science.howstuffworks.com/innovation/everyday-innovations/question17.htm

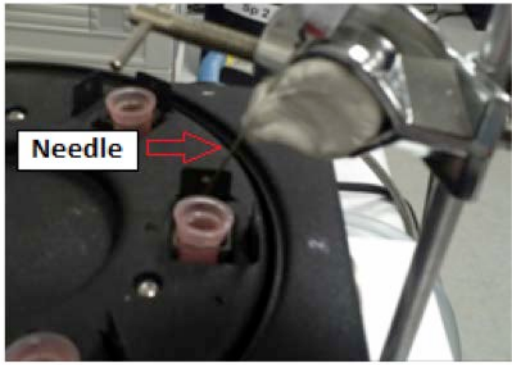
Diffusion Lab

Purpose:
To determine the rate of diffusion related to increasing temperature.



The diffusion lab is set up with the equipment shown here.

This image shows a close-up of a cuvette that contains a starch solution. Each cuvette includes a diffusion membrane insert you will be filling with an iodine solution. The iodine will be added in small amounts using a syringe controlled by a robotic pump.



Diffusion Experiment

How a spectrometer measures diffusion:

When light is directed at a colored liquid, a certain amount of light is absorbed. The more color that is present, the more light gets absorbed. If we watch for a color change as something moves from one liquid to another, we can measure that change by looking at how much light is absorbed.

[Rate of Diffusion = Change in Absorbance/Time]

The independent variable in this experiment will be time. You will have three temperature variables. In the cuvette will be a starch solution; an iodine solution will be in the diffusion membrane insert. The bottom of the pink cup has a permeable barrier that will allow the iodine to pass through. The iodine will be added in small amounts using a syringe controlled by a robotic pump.

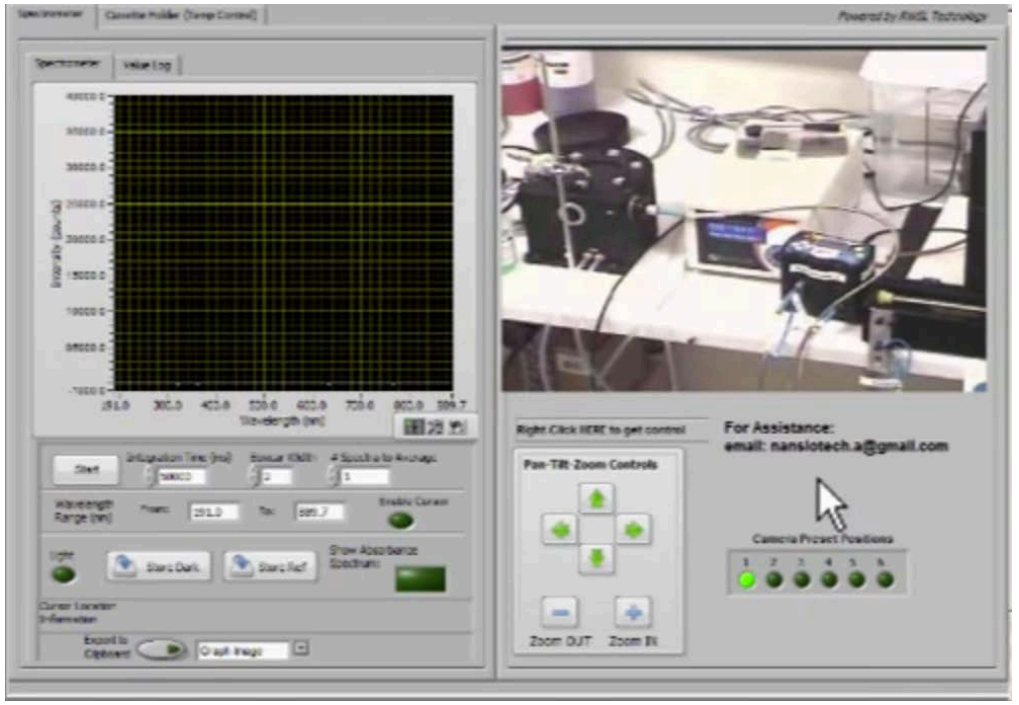
When iodine and starch interact, the iodine diffuses to form a dark pigment. The rate of diffusion can be measured by how much pigment is present. More color equals more iodine, indicating more has diffused.

The cuvettes will be pre-loaded with starch solution (clear) and a small stir-bar to stir the solution. You will be able to select a cuvette by rotating the carousel. You will deliver a small, pre-measured amount of iodine solution (red-brown) with the robotic syringe pump, and it will begin moving through the diffusion membrane into the starch solution and will react chemically with the starch to form a starch-iodine complex (blue-black). You will be able to control the temperature of the cuvette carousel, so you can see how different temperatures affect the rate of diffusion. There are six cuvettes in the carousel, so you will have up to six opportunities to measure diffusion rates.

Diffusion Experiment

The Diffusion Lab Control Panel is where you access the equipment controls, collect data, and communicate with others participating at the same time as you.

In this experiment, you will control the temperature as diffusion occurs. You will be able to track and save the data on the graphs.



Tutorial

This tutorial introduces you to the spectrophotometer, which is used for several labs. You will see how the equipment is set up as well as the view you will have from your control panel. The demonstration shows how to control the equipment, read the settings, collect data, and collaborate with others. Watch the tutorial a second time, immediately before your lab appointment, to refresh your memory about the function and purpose of the different features in this lab setup.

- http://www.wiche.edu/nanslo/lab-tutorials#beerlambert

Things to Notice / Questions:

1. How do you store a dark spectrum? Why is this stored?
2. What is the timer used for?
3. Why do you think stirring is used in this lab?
4. What are you measuring and how does it relate to diffusion?
5. How will the graphs help you understand the results?

Diffusion Lab Procedure

Using the NANSLO lab equipment, you will log in and take the indicated measurements at the time you are scheduled to take the lab.

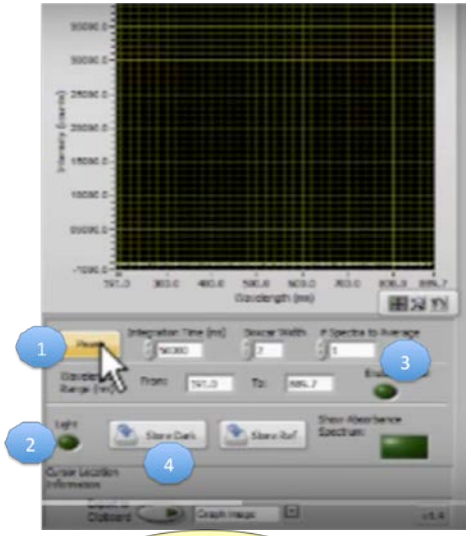
Exercise 1: Diffusion

From the Spectrometer tab

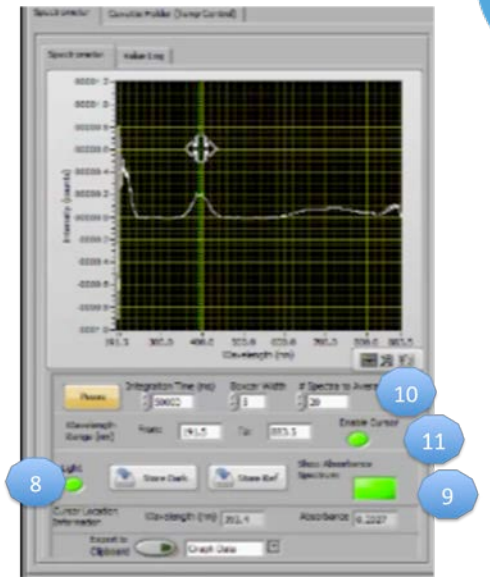
1. Click on the Start button to start the spectrophotometer data feed.
2. Ensure that the spectrophotometer light is turned off.
3. Set # Spectra to Average to a value of 20.
4. Store a dark spectrum.

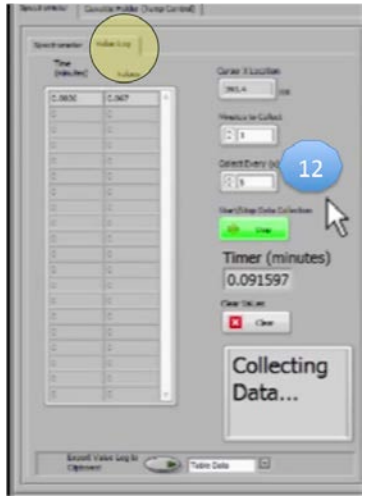
From the Cuvette Holder/Temp Control/Display tab

5. Turn on the Temperature Controller and select an initial temperature of 20° C.
6. Ensure that the stirrer is turned on so the solutions are being mixed. Use camera preset 2 to verify that the Cuvette Holder controller screen says "Stir On."
7. Wait until the temperature has been stable for at least 2 minutes.



Diffusion Lab Procedure





From the Spectrometer tab

8. Turn on the spectrophotometer light.
9. Store a reference spectrum.
10. Select the Show Absorbance Spectrum button to view the absorbance spectrum and Zoom Out on the graph.
11. Turn on the cursor and drag it to 351.8 nm. This is where an absorbance peak will appear when the starch-iodine complex forms.

From the Spectrometer/Value log tab

12. Ensure that Minutes to Collect is set to 10 minutes and Collect Every (x) Seconds is set to 30 seconds.

From the Cuvette Holder/Cuvette Select and Volume tab

13. Select Pump 1 and ensure that Volume to be Added is set to 0.25 mL.
14. Click the Add Volume button and observe the volume in the cuvette increasing from 3.75 to 4.0 mL as the iodine solution is added.

Diffusion Lab Procedure

From the Spectrometer/Value Log tab

15. Click Start.
16. Time and Absorbance data will now be collected every 30 seconds for 10 minutes.
17. You can watch the absorbance peak grow on the Spectrometer tab.
18. Value Log data to the clipboard and paste it into a document.

From the Cuvette Holder/Cuvette Select and Volume tab

19. Select another cuvette on the Cuvette Selector tab to start with a clean starch solution.
20. Another student should take control of the control panel at this point (right click to release your control or take control).
21. Set the temperature to 30° C.
22. Start over with step 2, and collect another set of data.
23. Another student should now take control and set the temperature to any setting between 30° C and 50° C.
24. Start over with step 2, and collect another set of data.
25. If there are students who haven't collected any data, and there is time remaining in your lab period, collect more data sets if you would like. Do not exceed 50° C!

Lab Day Checklist

On the day of your scheduled lab, review the items on this checklist to make sure you are prepared before logging into NANSLO.

- ❑ Read and review all lab materials
- ❑ Prepare and organize lab charts and recording materials
- ❑ Watch the lab tutorial again as a review before the lab
- ❑ Log in to your lab session – two options:
  - ❑ Retrieve your email from the scheduler with your appointment info or
  - ❑ Log in to the student dashboard and join your session by going to http://scheduler.nanslo.org
- ❑ NOTE: You cannot log in to your session before the date and start time of your appointment. Use Internet Explorer or Mozilla Firefox.

Lab Report

Lab Observations and Data

Cuvette 1
Data:

Observation notes:

Cuvette 2
Data:

Observation notes:

Insert images of graphs

Lab Report

Lab Observations and Data

Cuvette 3
Data:

Observation notes:

Cuvette 4
Data:

Observation notes:

Insert images of graphs

Lab Report

Lab Observations and Data

Cuvette 5
Data:

Observation notes:

Cuvette 6
Data:

Observation notes:

Insert images of graphs

Diffusion Lab Analysis

Using the Value Log data, create a graph. On the graph, you will plot time as the independent variable and absorbance as the dependent variable. You should have three different lines for the three temperature variables (or more, if you collected more data).

Analyze the graph by relating the shape of the curve to an underlying mechanism that might govern the phenomenon being studied. Discuss factors involved in diffusion that might cause this curve shape to be true.

Calculate the rate of absorbance change for each of the temperatures with the following equation: *Rate of Diffusion = Change in Absorbance/Time*, and add these values to your data table.

Insert student graph

Diffusion Lab Analysis

With your graphed data, calculate the slope of the line for the last 5 minutes of the data collected at each temperature. Slope is calculated by first choosing two points on the graph, then determining the change in the horizontal points and the change in the vertical points.

For example, if your coordinates on the graph at point #1 are 0.5 (X-axis) and 6 (Y-axis) and at point #2 the coordinates are 4 (X-axis) and 12 (Y-axis), the vertical change is 12 - 6 and the horizontal change is 4 - 0.5, or vertical change = 6 and horizontal change = 3.5. To find the slope, divide the vertical change by the horizontal change. 6 / 3.5 for a slope of 1.7. ***The slope is the rate of diffusion.*** Be sure to include the correct units for your data. Show your calculations, and then plot on a graph the diffusion rate (slope of the last 5 minutes worth of data) vs. temperature. What information can you get from this graph?

On your initial time vs. absorbance graph, interpolate what the absorbance curve would look like at 25° C. On the highest temperature absorbance curve that you graphed, extrapolate out to 40 minutes — what do you think the absorbance would be at that point? Would the values continue to increase linearly?

Membrane systems often have folds in the membrane which function to increase surface area. Based on what you know about molecular movement, explain why it is important for cells to have an increased surface area.

Insert student graph

Reviewing Results

Write a review of your experiment. Include your findings and an explanation of your results. Then answer the following questions.

1. How accurate was the data you collected? How do you know?
2. Was temperature a factor in the diffusion rate? Explain.
3. How do the graphs show the equivalence point?

Conclusion and Reflection

Write a thoughtful conclusion to the lab, answering the essential question: How can diffusion be measured to better understand the movement of molecules?

Post-Lab Questions

Answer the following questions as completely as possible. Use evidence from your lab to help support answers where possible. Use these questions to demonstrate your learning. You may want to review your pre-lab answers and see what you have gained in understanding.

1. What is diffusion and how does it apply to chemistry?
2. What are the conditions necessary for diffusion to occur?
3. What is a method for determining the rate of diffusion?
4. How does temperature relate to the rate of diffusion in liquids?
5. In what circumstances is it important to know the rate of diffusion?