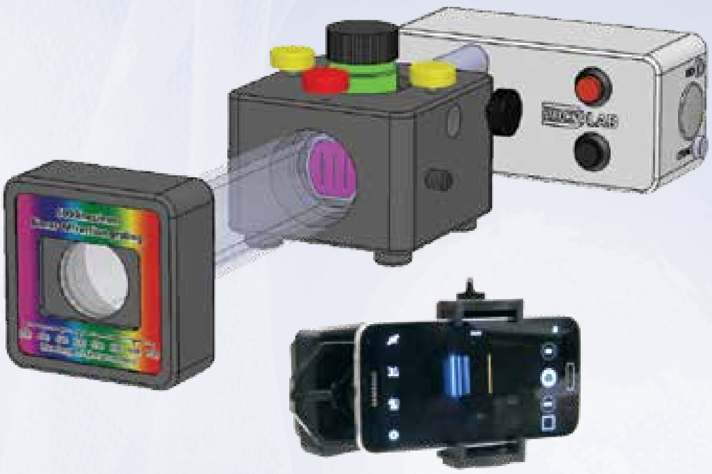
microLAB

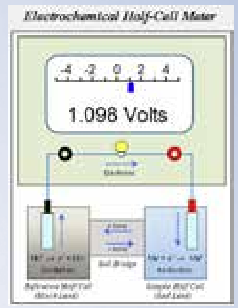
ELECTRONIC DATA ACQUISITION FOR TEACHING AND RESEARCH

Product Resource Guide

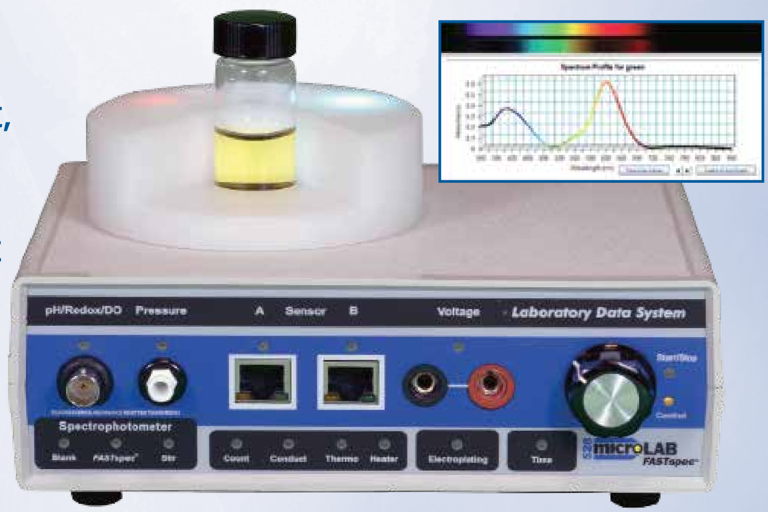
Visual Spectrometer / Atoms First



Conceptual – and Quantitative – Electrochemistry



Measurement, Analysis, and Sample Management



"It used to be that students spent a three-hour lab gathering data. Now they can focus on what the data means and decide quickly whether or not they need to do the experiment over. The discovery process—how the numbers relate to a concept—takes place in the lab, not later when students are writing their lab report."

DR. CAROLYN MOTTLEY,
LUTHER COLLEGE

ENGAGING THE NEXT GENERATION IN SCIENCE

1.888.586.3274

microlabinfo.com

About This Product Resource

This is not your usual catalog. It is an illustrated story of how MicroLab can help your students – and ours - visualize and understand important chemistry concepts. It is organized around twelve key general chemistry concepts identified by a recent University of Arizona survey of 85 U.S. universities (page 6). Experimental data has been contributed by our students and colleagues.

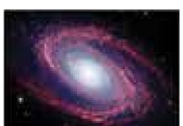
This reflects MicroLab's roots in Chemical Education. You can easily integrate MicroLab into your existing lab curriculum. Both proof-of- concept and inquiry experiments can be carried through to their conclusion in a 2-3 hour lab period. MicroLab can make lab a place where students learn, not just a place to collect data.

There are no hidden costs to adopting MicroLab for your courses. Software is included, with a free site license, free student downloads, and periodic free updates posted on our web site. MicroLab equipment packages are shown on pages 33 and 35.

A MicroLab FS-528 with included sensors and software site license will make almost every instrumental measurement required in general and environmental chemistry and biology.

Here are a few things to watch for as you read this catalog:

- ***Visualization:*** *MicroLab's software seamlessly converts quality data into live, colorful, interactive graphic displays that fit the experiment and concepts to be developed. Students visualize chemical relationships as the data arrives.*
- ***Small samples and high resolution:*** *MicroLab measures small changes with 16 times greater precision than most educational equipment.* ***Chemical samples can be smaller, less expensive, and much safer.***
- ***Research Extensions:*** *The MicroLab FS-528 and its flexible software allow students to add "research extensions" to an experiment, almost always with the equipment already at hand and in the same lab period.*
- ***Universal Sensors:*** *Watch for MicroLab's Universal Sensors. They provide unique capability, and can be used with any brand of laboratory data acquisition equipment.*


MicroLab's Universal Sensors

Outreach to our larger community is a responsibility of all of us who work in science and engineering. Here is Prairie View A&M University's "STEM-Mobile" developed by Dr. Hylton McWhinney, Professor of Chemistry, to bring real science to Texas students and schools. MicroLab is proud to play a small part in this program.

MicroLab ***provides innovative, affordable, computer-based instruments, software, and curriculum that build solid understanding of chemical principles and engage students in inquiry and research.***

Expand Lab Content

Increase Understanding

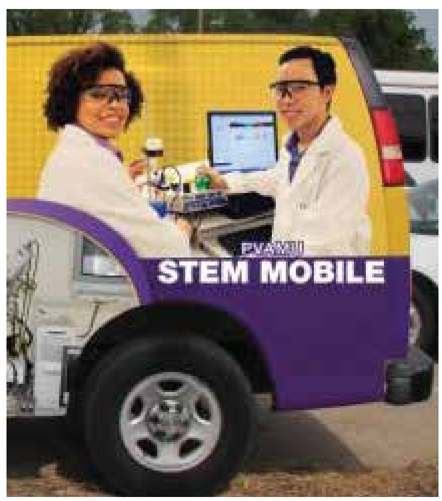
Build Inquiry Skills

Reduce Chemical Costs

Improve Safety

Save Lab Time

Solid Technical Support



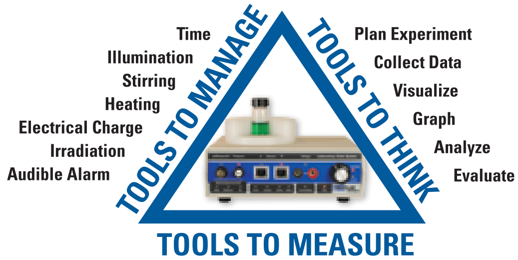
Outreach


Engagement

CONTENTS

Tools to Engage Your Students in Hands-On Science

A good laboratory provides three kinds of tools:
(1) **Physical Tools** to help manage your sample and experimental conditions—to illuminate, stir, and heat;
(2) **Electronic Tools** to measure and control; and
(3) **Software Tools** to help you plan, visualize, analyze and evaluate your experiment.



Temperature • Pressure • pH • Light/Spectrophotometry • Counts
Conductance • Voltage/Electrochemistry • Time

The MicroLab FS-528 *and its integrated 360-880nm* ***FASTspec™*** *scanning spectrophotometer will make almost every instrumental measurement required in general and environmental chemistry and biology.*

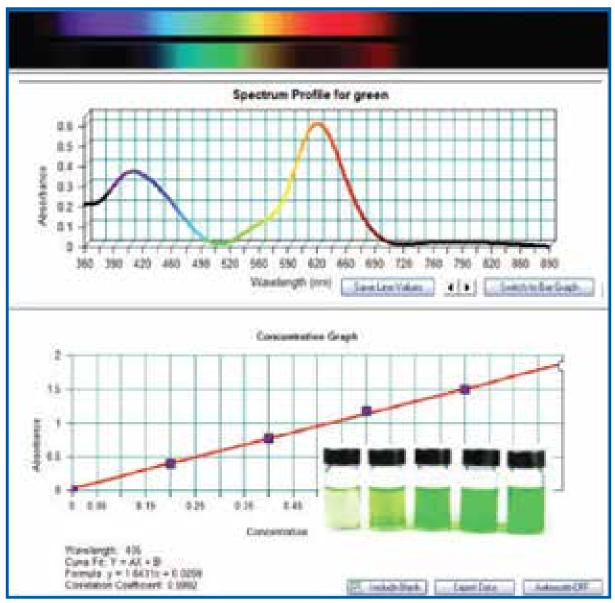
The name **MicroLab** takes on a new meaning with our new fifth-generation FS-528 Laboratory Data system. The FS-528 is really a stand-alone "Micro-Laboratory". It will provide almost every measurement, analysis, and sample management tool a student needs for a small-sample chemistry experiment, and will do so with almost research-grade precision. The 528 is a game-changer in computer-based lab instrumentation.

Five innovative new functions have been added:

- software-controlled rotating field magnetic stirring and
- adjustable sample illumination for small-sample titrations;
- a constant temperature heater for kinetics experiments;
- a regulated power supply for electroplating and coulometric experiments; and
- a new tactile control for interactive "real time control" of experimental conditions.

Integrated sensors and sensor amplifiers eliminate clutter from the lab bench, reduce cost, and create MicroLab's signature low noise, high resolution measurements. Small changes in chemical and biological systems are clearly visible.

MicroLab's patented FASTspec™ scanning spectrophotometer opens a new spectrum of applications not possible with traditional spectrophotometer designs.



MicroLab's ***FASTspec™*** *helps students visualize absorption spectra by calculating and displaying both visual and graphical information, as illustrated by this Beer's Law data.* ***FASTspec™*** *will simultaneously measure Fluorescence, Absorbance, Scatter, Transmission, and Turbidity.*

MICROLAB ADVANTAGES

- **Cost-effective:** Serves the function of a Spec-20, pH meter, manometer, precision thermometer, conductance meter and more.
- **Better use of time:** Many measurements can be taken in a short time. Students have time to run an experiment, evaluate it, modify their approach, and try again.
- **Immediate feedback:** MicroLab's software plots titration and photometric curves and other data as the student measures them. This immediate feedback greatly enhances the impact of the experiment.
- **Communication:** Results are displayed in a clear, large format so that students and the instructor can see, discuss, and evaluate.
- **Standard electrodes:** MicroLab uses standard laboratory electrodes for pH, thermocouple, etc.
- **Small footprint:** MicroLab instruments are an unobtrusive addition to the bench top. There are no extraneous wires or gadgets on the bench or to store and keep track of.
- **High Resolution:** Low noise, high resolution data is valued by researchers because it provides a clear view into an experiment. MicroLab provides affordable, research-quality data for students.

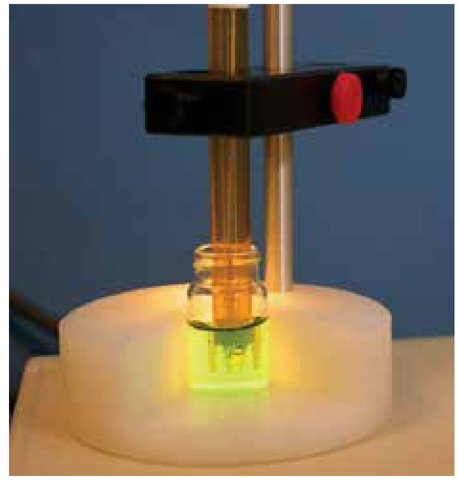
What's New at MicroLab

"Green" chemistry has meaning beyond small environmentally-safe samples.

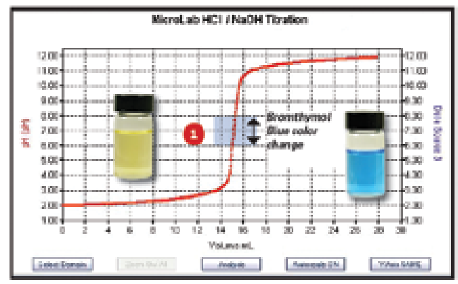
MicroLab's high resolution, low noise measurements — 16 times more precise than most educational laboratory instruments— make small changes in a chemical system clearly visible . Smaller (often by a factor of ten), safer, and less expensive samples are the standard. Requirements for laboratory space and air exchange can be reduced.

The FS-528 integrates hardware tools for sample management and software tools for experiment design and analysis into the measurement system. Students and instructors can, in a 2-3 hour lab period, work together to plan, conduct, analyze, evaluate, and carry an experiment through to a conclusion. Learning takes place in the lab, with knowledgeable help at hand.

Here are some examples of these new tools.



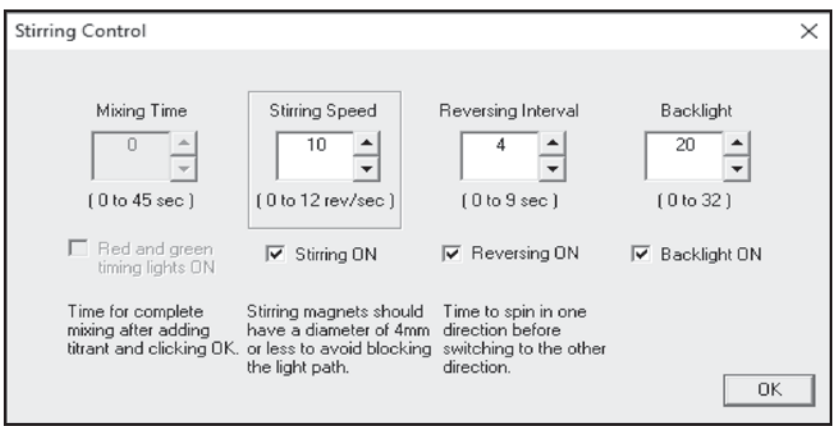
pH Titration with backlighting

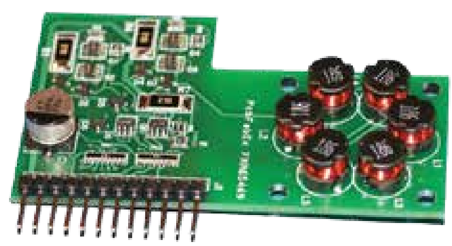


Strong acid/Strong base

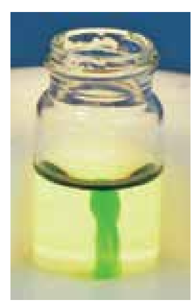
Rotating Magnetic Field Stirring

Students can use small chemical samples and the MicroLab 528 to quickly create titration curves. An internal magnetic stir motor located below the 28 mL spectrophotometer titration vial spins a stir bar in the vial. Because there are no moving parts in the motor, the rotational speed and spin direction may be changed instantaneously to produce either laminar mixing (below left, with unidirectional rotation) or more effective turbulent mixing (right) . Reversing the spin direction every few seconds destroys the vortex. A programmed mixing time elapses after each addition of titrant before measurements are made.





Magnetic stir motor



Laminar Mixing with vortex

Turbulent Mixing

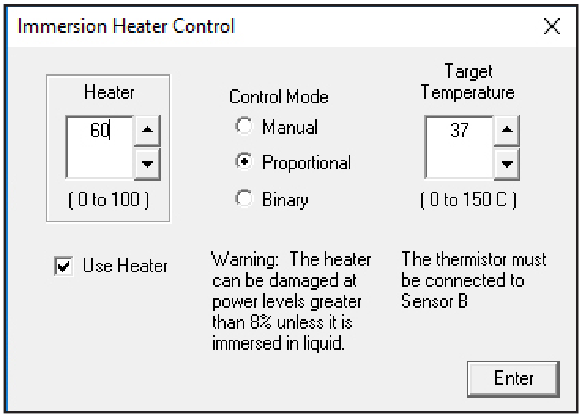
Integrated Sample Illumination – Titrations and Kinetics:

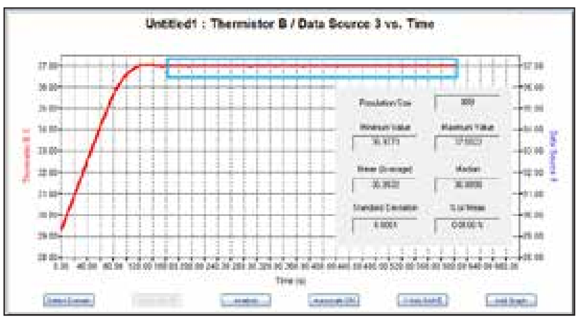
A removable translucent illuminated titration module fits over the spectrophotometer vial holder. It reflects light from software-controlled white, green, and red LED's mounted in the top of the cabinet. The white LED's provide backlighting so students can watch kinetic reactions fade, or indicators change color during a titration. Green and Red LED's signal "OK to add titrant", or "Stirring ". Twenty-eight mL vial shown.

At the end of each programmed stirring period, all of the LED's go off briefly while the spectrophotometer records solution absorbance, and in the case of titrations, pH and titrant volume.

Constant Temperature Systems – Closed Loop Experiment Control

Temperature control is important for many kinetics experiments. The MicroLab 528's software-controlled 20-watt heater and a thermistor will control temperature in the spectrophotometer vial or in an external stirred 100 mL constant temperature bath. Proportional control reduces the heater power as the target temperature is approached. In the binary control mode the heater is on below the target temperature and off above it. Closed loop control is common in industry and important as a concept in 2-year Chemical Technology programs.



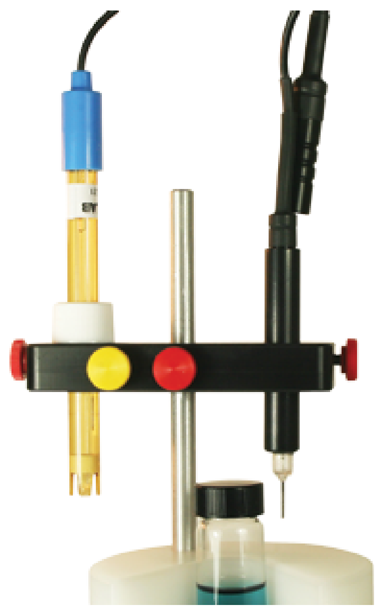


This graph shows a 10-minute temperature stability test using 20 mL of water, stirred, in the MicroLab spectrophotometer vial. After reaching the target temperature of 37.0 °C in about 2-1/2 minutes, the MicroLab heater maintained an average temperature (blue box) of 36.993 °C with a standard deviation of ± 0.0061 °C, or 0.017%.

20-watt variable power heater and sample illumination module

Electrode Holder

The Model 107 electrode holder will hold a pH electrode, a heater, and a thermistor. It holds its electrode in the spectrophotometer vial for titrations or controlled temperature kinetics experiments, or in a beaker to the side for larger volume titrations or to operate a constant temperature bath. The electrode holder includes a funnel to direct titrant from a micropipette or drop dispenser into the vial. Micropipette additions may be also made directly into the vial.



Basic Measurements

pH/Redox /DO
Gas Pressure
Temperature
Conductance
Voltage/Electrochemistry
Time
Counts/drops
Thermocouple
Light
Millivolts
Milliamperes
pH/Indicator Titrations

FASTspec™ Scanning Spectrophotometry

360-880nm
Transmission
Absorbance
Scatter
Fluorescence
Color Comparison
Turbidity
Beer's Law
Kinetics
Spectral Profiles
Spectrophotometric Titrations
Backscatter Turbidity

New Tools for Electrochemistry

The **MicroLab 528's** black and red "Voltage" banana jacks play double duty. For spontaneous electrochemical experiments such as the electrochemical series and the Nernst equation, they measure DC voltage ± 2500 mV with a resolution of ± 0.076 mV. For **forced electrochemical experiments** such as electroplating, these banana jacks provide an adjustable regulated 0-5 volt DC power supply delivering up to 750 mA.

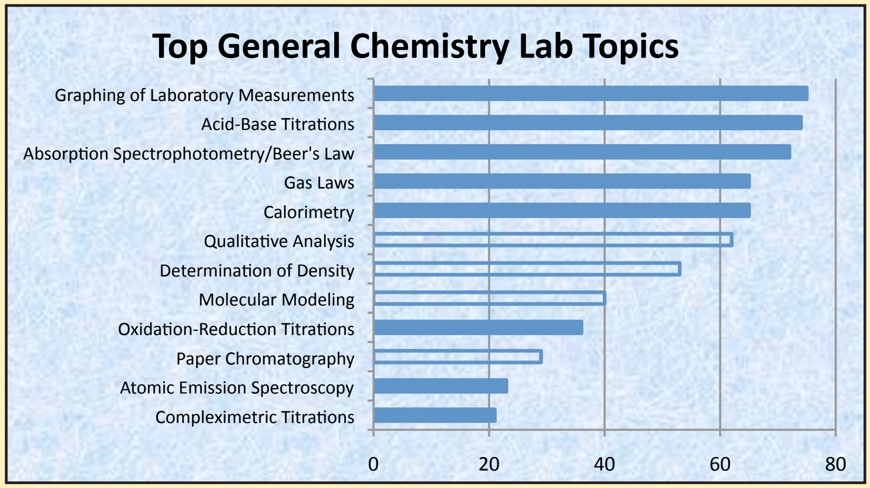
College and University General Chemistry Lab Content

A recent national survey of university general chemistry laboratory programs recognized twelve areas of content, shown in the table to the right, as the most important. The MicroLab FS-528 supports all of the instrumental measurements required to explore these topics.

Keeping Current

Content, however, is only part of the picture. A recent report on engineering education said that the "half-life" of an engineer's content knowledge is about five years. Only half of the content an engineer knows today will be useful five years from now. One can substitute the name of almost any profession for Engineering. The challenge of exponential growth in our knowledge base affects us all.

For both students and professionals, developing the ability to synthesize new concepts from experimental data and observation is as important as learning what is known today.



Twelve laboratory topics are key to the general chemistry programs in 78 major universities surveyed by Dr. Steve Brown of the University of Arizona. The MicroLab FS-528 supports all of the instrumental measurements (highlighted) required for these topics.

Software

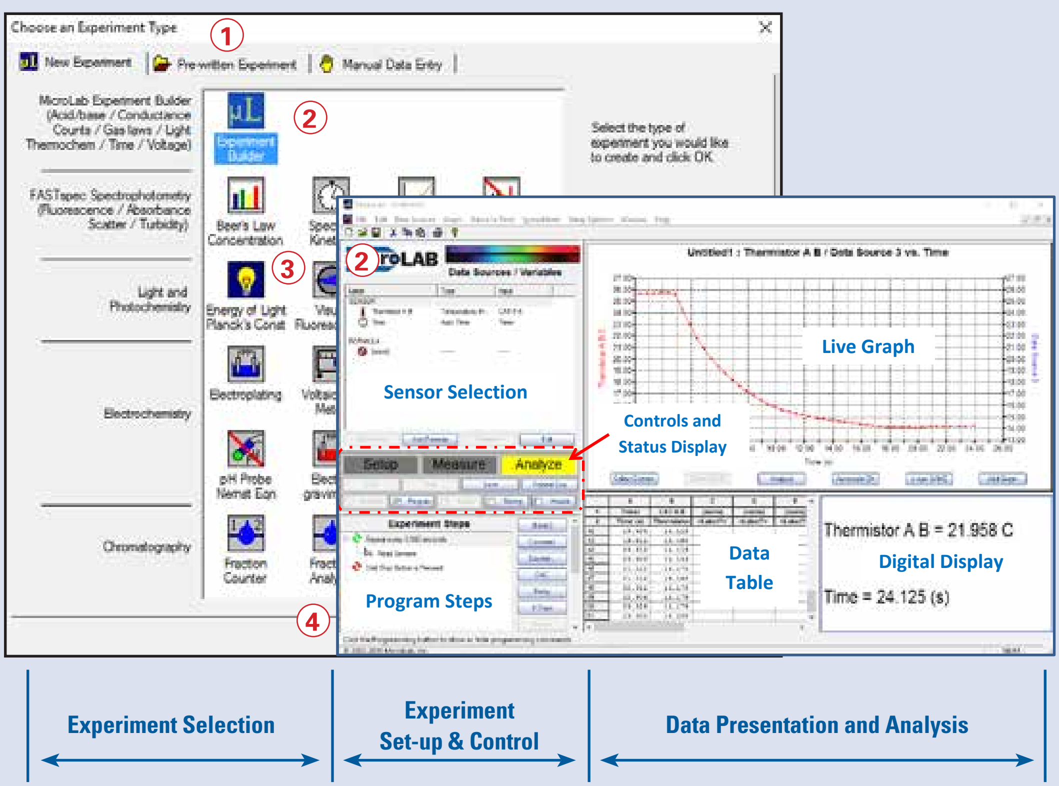
MicroLab's software operates on four levels to match the goals of the experiment and the proficiency of the student.

① Pre-written "tabbed" **"Proof-of Concept" experiments** are accessible with a mouse click. They provide quick and reliable data to compare with known theory.

② Students use MicroLab's "Drag-and drop" **Experiment Builder** tools to select sensors and data presentation for **application and inquiry experiments**. They can design experiments and collect, organize, and evaluate data, and then synthesize new concepts from experimental results. Science educators call this "inquiry-based learning". It is what a researcher does.

③ **Instrument programs (Icons)** provide an intuitive display and analysis of complex spectrophotometric and electrochemical data, as illustrated in this flyer.

④ Finally, advanced students and researchers can click to reveal a toolbar (shown in "Program Steps") that enables them to design **original programs for data acquisition and control**.

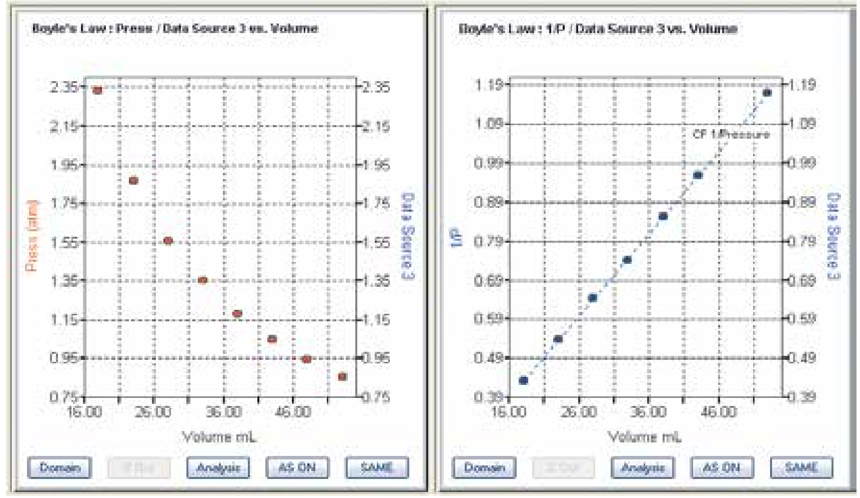


Graphing, Gas Laws and Proof-of-Concept Experiments

Fourth in importance in the Arizona General Chemistry survey, gas law experiments provide opportunity for quick, accurate, and inexpensive experience with graphing and mathematical modeling. Graphing of laboratory data appears most often in the Arizona survey.

Boyle's Law

The two graphs to the right illustrate gas pressure – volume data from a pre-written Boyle's Law "Proof-of-Concept" experiment. This experiment used MicroLab's internal 0-2 atmosphere pressure sensor and a simple plastic syringe to define sample volume. The left graph shows the pressure-volume relationship while the right graph plots volume vs 1/P, calculated in real time as the data comes in. Both graphs plot simultaneously on the monitor. Eight data points collected in a few minutes enable students to visualize the concept and provide "experimental proof" of the 1/P relationship. Up to four different live graphs may be plotted simultaneously.



This pre-written "Proof-of-Concept" experiment plots two graphs simultaneously. The straight line relationship apparent in the V vs 1/P graph indicates an inverse relationship between Volume and Pressure.

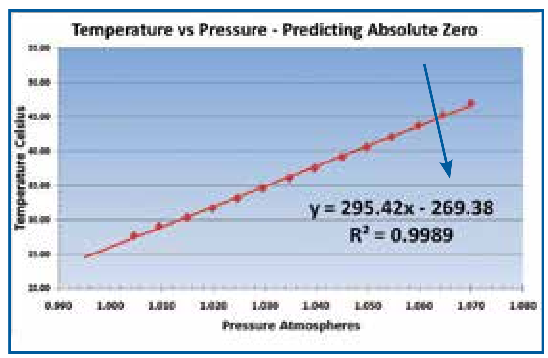
The Boyle's Law gas pressure-volume "Proof-of-Concept" experiment involves only a pressure syringe and the FS-528 internal pressure sensor.

This can also be conducted as an inquiry experiment, by plotting only the P / V graph, and then asking students to find a mathematical model (equation) that can make a straight line out of this data.

Absolute Zero

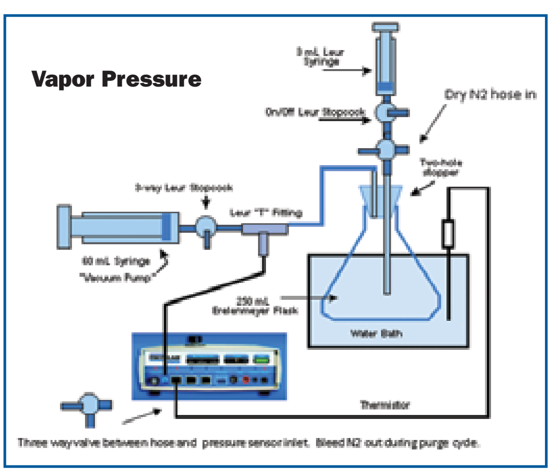
This graph shows pressure increase as an air sample in a 10 oz tonic water bottle was heated in a water bath from 28 degrees to 47 degrees. Plotting T vertically and extrapolating the T / P regression line to zero pressure, the intercept predicts a value for absolute zero of minus 269.38 °C. Low noise, high resolution measurements produce a result within 1.3% of the -273.15 °C theoretical value. MicroLab data can be transparently exported into Excel.

Data by Doug Schumacher and Kiran Krimi, Luther College.

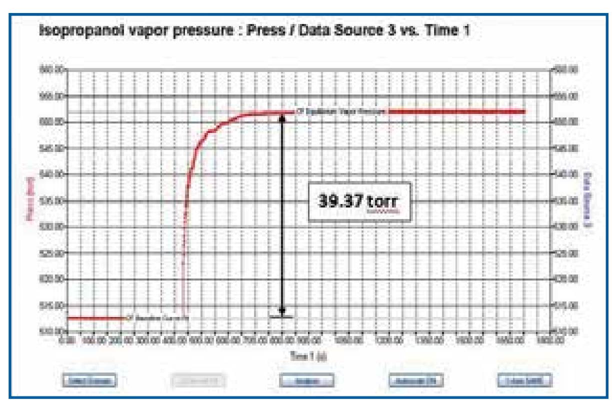


Vapor Pressure

Vapor pressure of liquids at different temperatures can be easily measured with MicroLab.This sample was pulled to a slight vacuum (512 torr) with a syringe prior to injection of an alcohol sample. This keeps the two-hole stopper tight. The vapor pressure of this sample was 39.37 torr. The baseline was extremely stable before and after injection and vaporization. The sample flask can be easily flushed with dry nitrogen prior to sample injection.



The **Model 116 Gas Pressure Apparatus** includes the Luer syringes, four Luer stopcocks, a Luer "T" and hose and hose connectors. The two-hole stopper and flask or bottle are provided by the user. Experiments include **Boyle's Law, the Gay-Lussac Law, Absolute Zero, Vapor Pressure, and gas production and stoichiometry.**



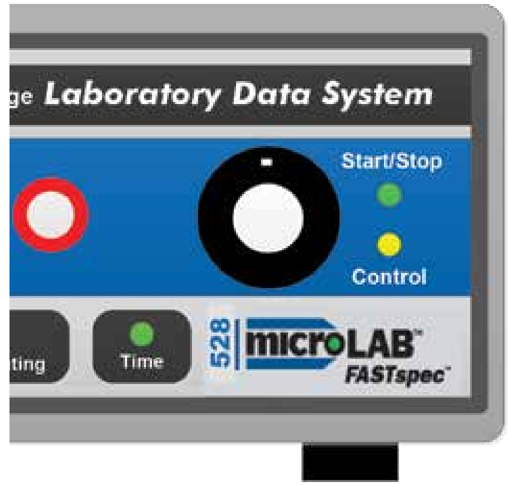
Real-time Experiment – Student Communication

The MicroLab 528's ability to provide real-time visual and tactile communication between the student and the experiment is unique in the industry.

As in research instruments, LED's indicate the status of sensor inputs and controls.

The new tactile rotary control may be "clicked" to start or stop the experiment. The green LED changes from steady "ON" (ready) to flashing when data is being collected.

If a control function is selected (light, stirring, heater), the yellow "control" LED switches on . The control can then be rotated to change a selected variable during an experiment. A short "click" moves the control to another variable. In a photometric titration, this variable could be stir rate. Students are "in the loop" all of the time. They are not just observers



What's Important?

Lab should be a place where students learn, not just a place to collect data.

MicroLab's founders and development team collectively bring about 280 years of experience in college and university teaching and research to this problem. Here are some things we and our MicroLab-user colleagues believe are important:

High resolution, low noise measurements are important. MicroLab measures small changes with 16 times greater precision than most educational equipment. Chemical samples can be smaller, less expensive, and much safer. High resolution, low noise data is valued by researchers because it provides a clear view into an experiment. MicroLab provides this view for students.

Live, high quality graphs help students visualize relationships between experimental variables. These students are observing the supercooling and freezing of a 1 mL acetic acid sample.

Visualization is important. MicroLab's software seamlessly converts quality data into live, highly visual graphic displays that fit the experiment and concepts to be developed. MicroLab's interactive graphic displays help students visualize chemical principles, as the data arrives.

Versatility is important. Inquiry is being able to ask, when an experiment is completed, "is there more to it?". There usually is "more to it". The MicroLab FS-528 and its flexible software allows students to add "research extensions" to an experiment, almost always with the equipment already at hand and in the same lab period.

Bench space is Important. MicroLab serves the function of many single-purpose instruments. It is an unobtrusive addition to the bench top. There are no extraneous wires or gadgets on the bench or to store and keep track of.

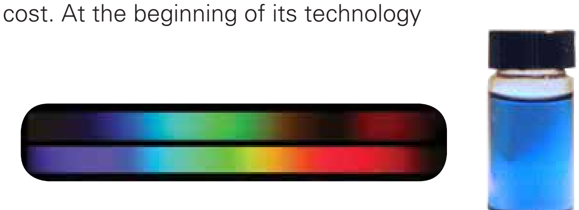
Time is important. Many measurements can be taken in a short time. Students have time to run an experiment, evaluate it, modify their approach, and try again—in the lab with the instructor participating. Students understand the concepts when they leave the lab.

Rugged reliability is important. Down-time in a lab is costly and frustrating. MicroLab's equipment is designed to industrial standards and manufactured with industrial components. Our ISO-9001 certified U.S. facility manufactures for NASA and the military on the same assembly line. As a result, only about 0.4% of our installed instrument base is returned for repair each year. After the 5-year warranty period, repair and recalibration costs a flat $75.

Affordability and a long useful life is important. The new 528 uses state-of-the-art electronic integration and manufacturing practices to deliver significantly increased capability at a lower cost. At the beginning of its technology life-cycle, the 528 will have a long useful life.

Solid technical support is important. MicroLab's technical support is provided by experienced college chemistry faculty. It is available free by telephone or e-mail.

MicroLab can reallocate the way we use our laboratory time.



Absorption spectrum of FD&C Blue No. 1 – MicroLab Visual Spectrometer

Measurement of Temperature

MicroLab provides two types of temperature sensors.

Thermistors, or thermally-sensitive resistors, produce the largest response to temperature change of any thermal sensor, but are more limited in range than thermocouples. The **Model 103 Thermistor** is an industrial grade temperature sensor mounted in a 1/16 inch diameter stainless steel tube. This gives low thermal mass and fast response. This sensor follows the Steinhart-Hart third-order log polynomial calibration equation, and with its factory calibration is accurate to ± 0.2° C in the range 0-70° C. Its calibrated range can easily be extended from - 10 to + 110° C by calibrating with MicroLab software.

The Model 103's thermistor is electrically insulated from its shaft and can be used with a pH probe without interaction. This sensor can be read in Celsius or Fahrenheit degrees, or in Kelvins.

Thermocouples are usually thought of as high temperature sensors, used for example for mapping flame temperature. Type K thermocouples are quite linear over the range -200 to + 1000° C.

However, when used with a MicroLab 528, the resolution of a Type K thermocouple is 0.04° C, and it can serve as well in room-temperature biology or chemistry experiments requiring observation of small temperature changes.

A standard Type K calibration is provided, and thermocouples may also be calibrated with MicroLab software.

Thermistor

Model 103

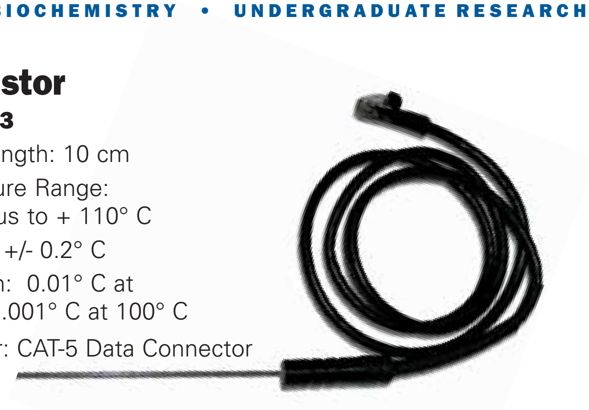
Sensor Length: 10 cm

Temperature Range:
-10° Celsius to + 110° C

Accuracy: +/- 0.2° C

Resolution: 0.01° C at
20° C to 0.001° C at 100° C

Connector: CAT-5 Data Connector



"MicroLab's software is an enormous aid for non-major students to visualize data collection in real time, and leads them to clearly understand the concept of the lab."

Dr. Angie Sower
Montana State University-Bozeman

The **Model 109 type K thermocouple** has a six-inch long, 1/8" stainless steel shaft with a molded plastic handle. Its retractable cable stretches from 12" to 48"and is terminated with a standard industrial thermocouple plug.

The MicroLab Advantage:

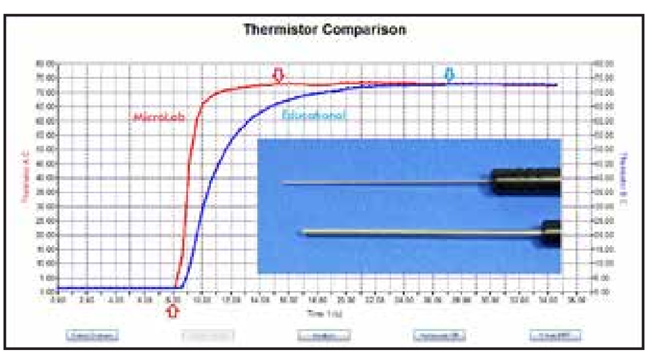
What Makes a Good Temperature Sensor?

- Quick response to track rapidly changing chemical reactions.
- Low thermal mass, to take little heat from the sample.
- High resolution and low noise, to see small changes.
- Rugged and long life.

MicroLab's industrial stainless steel thermistors are half the diameter and about 1/3 the thermal mass of common educational thermistors. However, we have never had one broken. [Placing the tip in a flame will damage any thermistor].

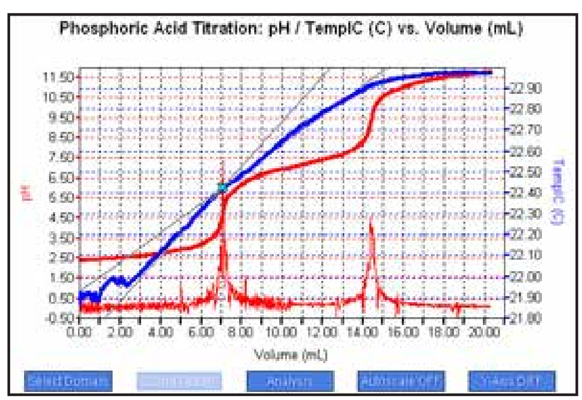
The example below shows the response of a MicroLab and a traditional thermistor moving from ice water to hot water at 73 °C. MicroLab's time to equilibrium (red) was almost a factor of three faster than common educational sensors (blue).

Your data will track the experiment almost three times better than a traditional sensor.



Heat of Reaction

The blue line in this phosphoric acid titration data shows the importance of high resolution, low noise temperature measurements. The rate of temperature change (slope) during neutralization of the first hydrogen is greater than that for the second. Removal of the first hydrogen has a greater heat of reaction than the second. The total temperature change in this experiment was only about 0.9 degrees C. The titration was run in a Styrofoam cup.



Acid-Base Chemistry

Second in importance in the University of Arizona survey of general chemistry laboratory topics, acid-base titrations provide both quantitative and qualitative insight into chemical systems.

The most common application of titrations is quantitative: How much of the analyte is present? This is usually implemented with an equivalence-point / indicator titration.

There is a lot more information available if one is able to track and plot volume with respect to pH, temperature, conductance, or other solution properties. The examples presented here illustrate the difference between **strong and weak acid titrations with strong base, choice of chemical indicators, buffer regions, calculation of pKa, and the use of derivative plots to accurately locate end-points.**

None of these concepts can be developed easily with manual titrations.

Model 121 pH Electrode
pH range: 0-14 pH units
Resolution: 0.001 pH
Temp range: 0-80° C
Connector: BNC

Counting Drops

Drop counters and an inexpensive drop dispenser are a useful and cost-effective alternative to burettes. They will not break and their resolution is about 50% better than a burette. And they do not get tired or distracted. A drop counter is calibrated by counting the number of drops required to fill a 10.00 mL graduated cylinder. MicroLab's formula tool is used to convert drops directly into volume during the titration.

MicroLab's patented Model 226 Drop Counter uses a reflective infra-red sensor that counts drops. A background correction circuit measures and subtracts background light making the unit immune to changes in room lighting. An internal circuit inserts a 25 millisecond "dead time" at the detection of each drop, eliminating false counts from fragmented drops. Although this limits the maximum count rate to about 40 drops per second, aqueous drops coalesce into a stream at about eight drops per second.

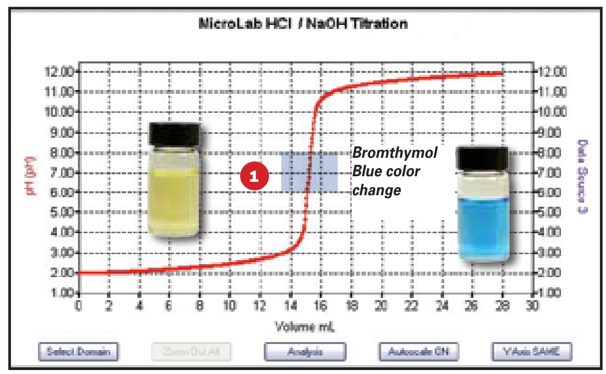
More important to accurate results are stir rate and solution mixing, the response time of the pH electrode (close to one second), and the reaction rate of the compounds involved. Strong acids react more quickly than weak acids. The result is that, if the drops are closer together than about 1.5 seconds, the pH reading does not reflect the true chemistry going on in the solution.

Strong Acids and Indicators

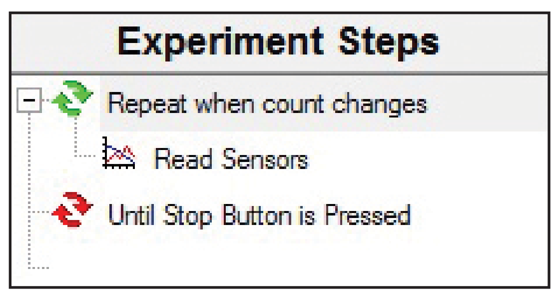
The graph to the right is a classic strong acid / strong base titration curve. It used 30 mL of base, involved about 900 data points, and required about 18 minutes to collect.

The end point in this reaction occurred at pH 7.0. (1)

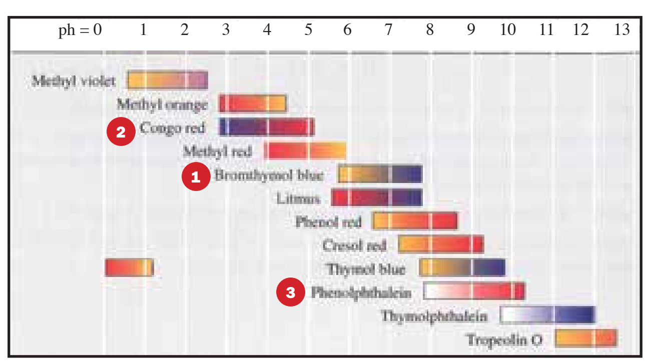
Good indicators for this reaction would be Bromthymol blue (pH 6-8), or phenol red (6.5-8.5). Methyl orange, traditionally used for this reaction, will produce an early end point. Addition of one drop, easily visible in the data table (sample data table on opposite page) represents a volume change of 0.2%.



Strong acid-strong base titrations exhibit a sharp end point because there is no buffer region.



The MicroLab experiment can be modified to read the pH sensor when the next drop passes the drop counter. This gives maximum, consistent stir time for each drop.



To obtain meaningful results, indicators have to be matched to the pH of the end point of an acid-base reaction.

Creating Constant Volume Drops

Accurately counting drops is only half of the task. Equally important is a source of repeatable, constant volume drops. A burette, because of its large pressure head change during a titration and relatively large drop size (0.05 mL), is a poor choice for a drop dispenser.

Both drop size and drop rate are dependent on a drop dispenser's pressure head. **MicroLab's** classic **Model 2260 syringe-based drop dispenser** will deliver 30 mL with a pressure head change of 5 cm – about 16% of the 32 cm pressure head change observed with delivery of 30 mL from a burette. One stopcock sets drop rate and the other controls on/off. It's drop size is about 0.034 mL.

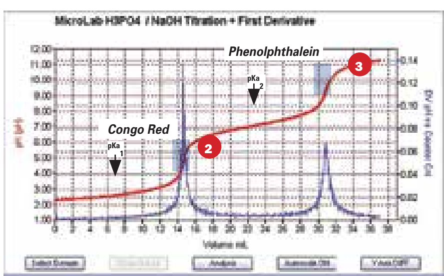
MicroLab's new precision **Model 154 Constant Volume Drop Dispenser** has a 50 mL titrant reservoir and will deliver 30 mL with a 1 cm change in pressure head - about 3% that of a burette. Drop rate is easily controlled by a multi-turn needle valve, and a stopcock controls on/off after drop rate is set. Drop volume is also about 0.034 mL, and a drop volume / drop count graph is linear with five 9's in its correlation coefficient.

Model 226 Drop Counter
Model 158 non-corrosive clamp

Power: + 5 V, from MicroLab
Output pulse: TTL
Dimensions: 1.6" x 2.9" x 0.5"
LED flashes on the drop counter each time a drop is detected.
The 226 includes holders for temperature and pH probes.

Weak Acids and pKa's

The phosphoric acid titration shown below illustrates the type of data this system will produce. Removal and neutralization of the first and second hydrogens show clearly as inflections in the graph. A first derivative plot identifies the end points – one can match the maximum derivative value and pH with volume to calculate end point to a titrant volume within 0.034 mL. pKa values – the pH at the center of the each of the buffer regions – can be observed in the data table (below) and estimated on the graph.



First derivative peaks mark the neutralization of the first and second hydrogens of phosphoric acid. pKa values can be read at the mid-point of each buffer region, where the weak acid is half neutralized: [HA] = [A-].

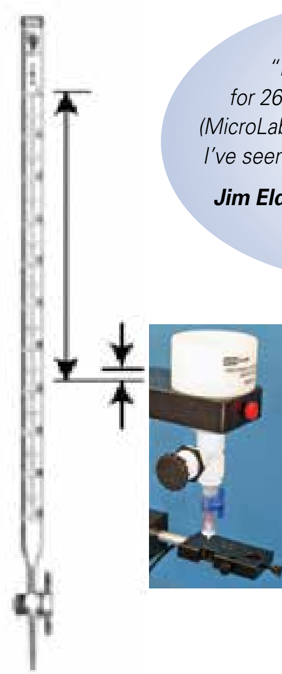
This experiment yielded pKa values of 2.62 for the first hydrogen and 7.03 for the second hydrogen. The pH of the two equivalence points are 4.5 (2) and 9.5 (3), making Congo Red and Phenolphthalein excellent indicator choices, respectively.

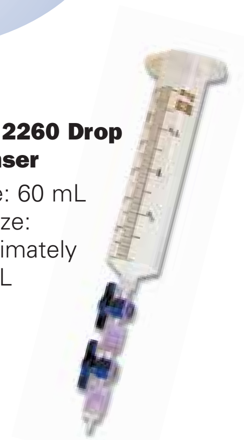
	A	B	C	D	E
1	Counter	pH Connect	f(x)= Cou	pH vs Count	(none)
2	Counter Cnt	pH (pH)	Volume mL	DV pH vs Co	<Label?>
439	436.00	4.25	14.485	0.0482	
440	437.00	4.32	14.518	0.0682	
441	438.00	4.39	14.551	0.0903	
442	439.00	4.50	14.585	0.1370	
443	440.00	4.66	14.618	0.1003	
444	441.00	4.70	14.651	0.0528	
445	442.00	4.77	14.684	0.0729	
446	443.00	4.85	14.718	0.0923	
447	444.00	4.95	14.751	0.0923	

This data table shows the pH, volume, and the value of the pH / volume derivative for each drop of titrant delivered. The end point volume can be determined to one drop or, in this experiment, 0.033 mL.

"I worked in industry for 26 years, and these boxes (MicroLab's) are as good as anything I've seen in a professional setting."

Jim Elder, Eastfield College, TX





Model 2260 Drop Dispenser

Volume: 60 mL
Drop size: Approximately 0.03 mL

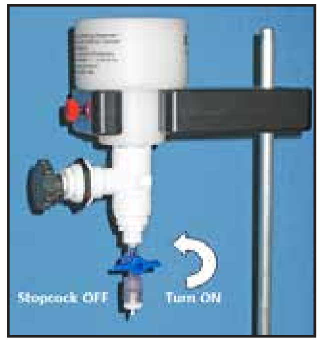
Model 154 Constant Volume Drop Dispenser with model 156 non-corrosive clamp

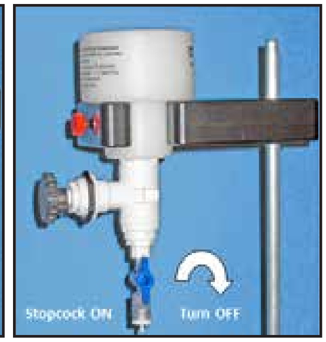
Volume: 50 mL
Drop size: Approximately 0.03 mL.
Teflon seal, multi-turn needle valve for easy adjustment of drop rate. Chemically-resistant polypropylene titrant reservoir.

The MicroLab Advantage

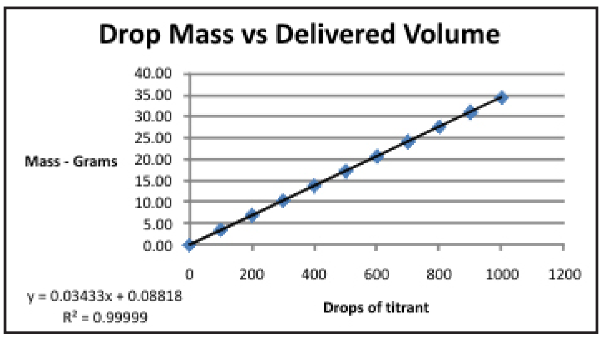
Creating and Counting Constant Volume Drops

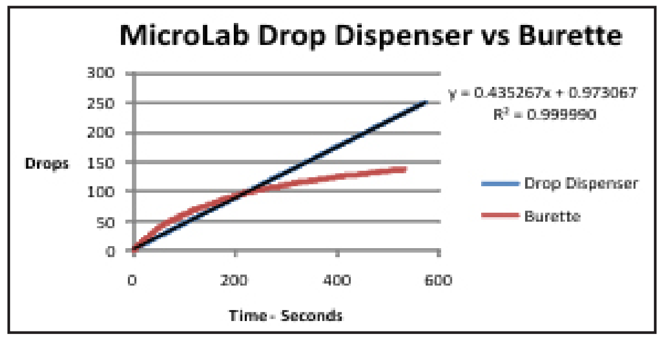
MicroLab's unique Model 154 Constant Volume / Constant Flow Drop Dispenser is easy to adjust and control. You can use it by itself for timed constant flow-rate titrations, or with our patented Model 226 IR reflective Drop Counter for automated titrations.



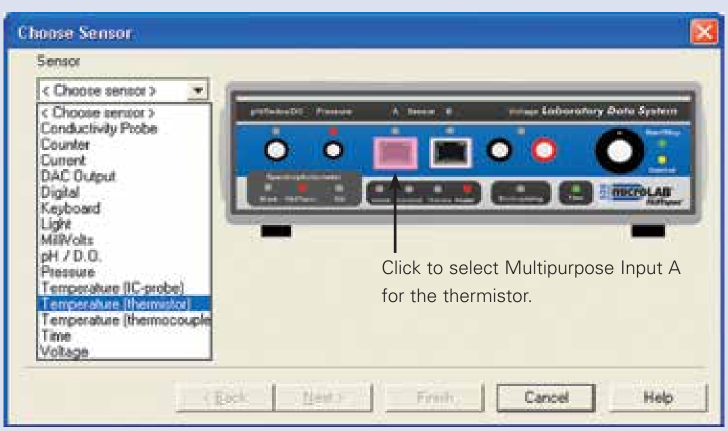


- The multi-turn rotary needle valve makes it easy to adjust the drop rate. The small 90-degree stopcock allows students to effortlessly pause a titration, then resume at the same drop rate.
- The small change in pressure head made possible by the wide titrant reservoir keeps the drop size constant, as demonstrated by the mass/volume plot below which is linear with five 9's in the correlation coefficient.
- Its constant flow rate is illustrated by the second graph, which also is linear with five 9's in the correlation coefficient. Note the rapid fall-off in drop rate with a burette.
- MicroLab's Drop Counter works on front-surface reflection from the drop. Competing drop counters depend on the drop to refract the light beam, and thus are critical in alignment. MicroLab's front-surface reflection scatters the reflected light. The sensitive volume is a sphere about 1 cm in diameter that just touches the side of the drop counter. It is easy to align and can withstand some jostling. Internal circuits measure and compensate for changing light in the room and for fragmented drops.

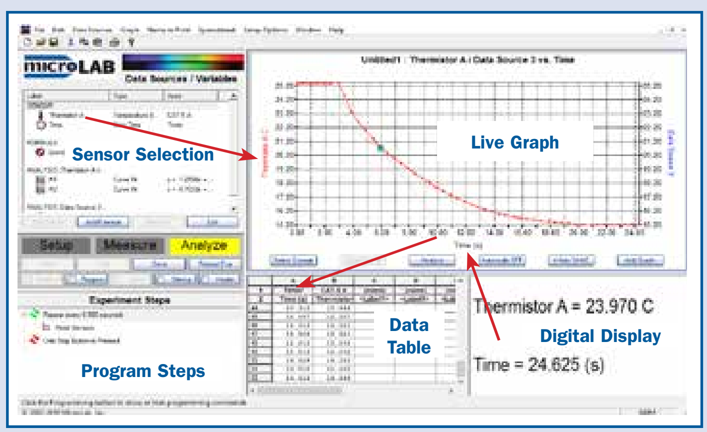




Software: Sensor Selection and Experiment Design



The "Choose Sensor" screen allows one to select the measurement and designate the input assigned to that sensor.



The data display is set up by dragging selected sensors to graph axes and displays. Sensors appear first in the Data Sources/Variables and Digital Display sections. They may be dragged from these locations to the graph and data table. This graph shows cooling caused by fractional distillation of one drop of shaving lotion. The two regression lines show successive evaporation of two of the low-boiling components.

Sensor Calibration

Sensor calibration is an essential skill in experimental science. A student can calibrate a sensor in a few minutes using MicroLab software and readily available standards. An accurately calibrated sensor is the first step toward a successful measurement.

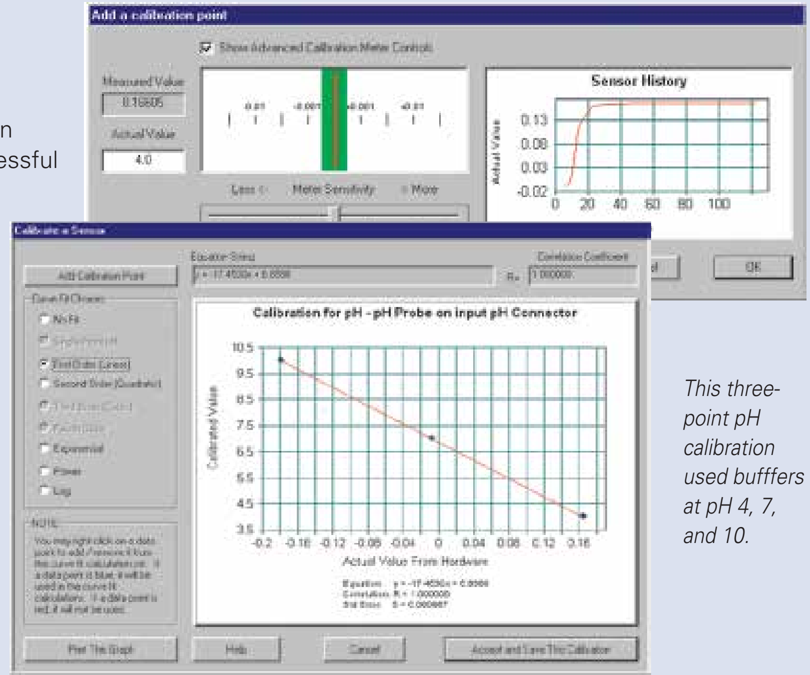
Need for sensor equilibration

Inadequate sensor equilibration is a major source of calibration error. MicroLab's unique calibration screen displays the rate of change of the sensor signal and a history of the sensor output. It stabilizes when the sensor is at equilibrium with its standard.

Need for multiple calibration points

Although two points define a straight line, three or more points are required to define a curve or to validate a calibration graph. MicroLab's unique multi-point curve fitting software will calibrate any sensor that produces a voltage or a current and has a linear, polynomial, exponential, power, or log response.

Included in the curve fit options is the Steinhart-Hart equation for calibration of thermistors.



This three-point pH calibration used bufffers at pH 4, 7, and 10.

Information from Light – and Atoms First

Light, it has been said, is the language of atoms. Listen carefully, and they will tell you who they are, how many of them are present, and if they are paired up with other atoms.

Rated third and eleventh in importance in the Arizona General Chemistry survey, absorption and emission spectrophotometry are key content in all four years of the college and university chemistry curriculum. Spectrophotometry is the most widely-used analytical tool in health and environmental sciences.

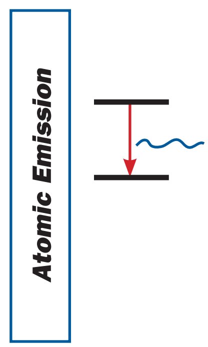
Recent interest in "Atoms First" general chemistry organization has left a vacant spot early in the general chemistry lab. Instructors are discussing atomic spectra, electron structure, and bonding. Students aren't yet able to deal with the traditional lab topics of reactions and wet chemistry.

Consider MicroLab's atomic spectra and energy of light experiments (pages 14-16). These experiments are visual, conceptual, quick, and inexpensive. They immediately involve students in graphical analysis of data, the number one topic in the Arizona survey. And they support the Atoms First lecture material.

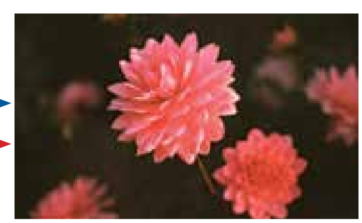
Consider following with labs involving color, Beer's law, scatter and turbidity, and fluorescence (pages 17-26). These topics are visual, interesting, conceptually understandable, and have wide "real-world" application. They don't require understanding of chemical reactions. And they can all be done with the basic "Intro" MicroLab package at extremely low chemical cost.

MicroLab's patented ***FASTspec***™ brings a broad spectrum of affordable, precision experiments not only to general chemistry, but to analytical, physical, and biochemistry. ***FASTspec***™'s ability to make simultaneous transmission/absorbance and scatter/fluorescence measurements, with excitation in the 360-880 nm range, is unmatched by any other single instrument.

Check out ***FASTspec***™'s many applications on following pages 17-26. And note its comparison with a research-grade instrument on page 26.



The elements present in a fireworks display determine the colors produced. Calcium is one of the elements involved in this display.



The color of this flower is caused by selective absorption of colors from the incident white light, and reflection of the remaining colors. Solutions transmit the unabsorbed colors.

Atomic Spectra

Measurement of atomic emission spectra is the foundation on which our understanding of the electronic structure of atoms is built.

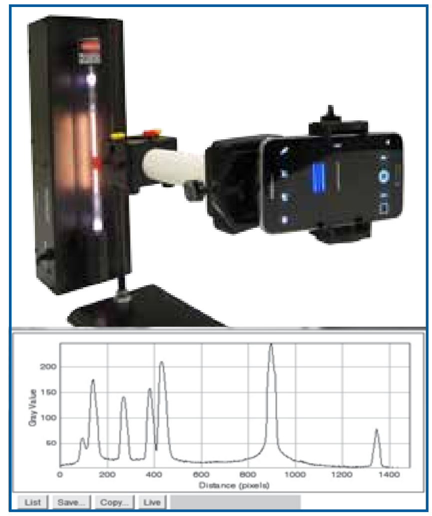
Would you like your students to …

- **Understand atomic emission spectra?**
- **See real emission spectra in full color, as well as the spectral profile graph?**
- **Learn to quickly calibrate a spectrometer using a known spectral source, and then use this calibration to identify unknown spectral lines with an accuracy of about 1 nm.**
- **Have individual access to a 1000+ channel visible region diode array spectrophotometer with 1 nm accuracy and 4 nm FWHM?**

Would you like to pay less than $200 for this instrument?

Check out MicroLab's new Model 141 Visual Spectrometer. It is rugged, affordable, and easy-to-use. Couple it with our Model 243 web camera and mount, a point-and-shoot camera, or a cell phone camera, the included fiber optic adapter, and powerful, free image analysis software from the National Institutes of Health and you have a powerful calibrated emission spectrophotometer.

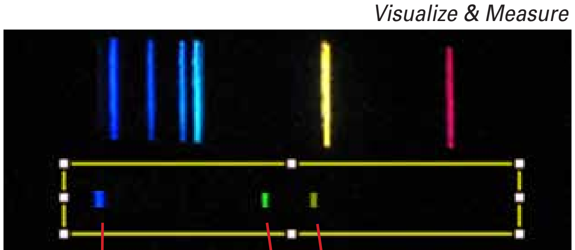
Use it with MicroLab's FS-528 ***FASTspec***™ scanning spectrophotometer, and students will bridge the gap between visual observation and quantitative measurement of color and absorbance (pages 17-20).



Light from the helium source is captured by the Visual Spectrometer, photographed and displayed by a cell-phone camera, and its spectral profile plotted with Image J software.

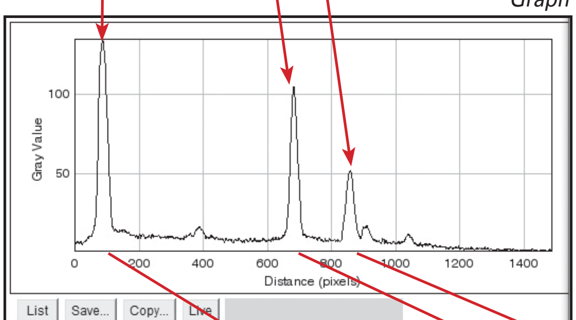
Measuring Atomic Spectra

Visualize & Measure



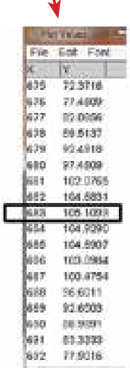
This is a point-and-shoot camera photo of the spectrum of an unknown gas with a fiber-optic mercury spectrum in wavelength alignment below it. The student draws the yellow analysis box with a mouse, wide enough to cover both the reference and unknown spectra.

Graph



Clicking "Analysis" and "Plot Profile" produces an Image J plot for this mercury reference spectrum. The plot shows three distinct peaks at known spectral lines of 436 nm (violet), 546 nm (green), and 578 nm (yellow). The list view to the left shows the 546 nm line peaking at 683 pixels.

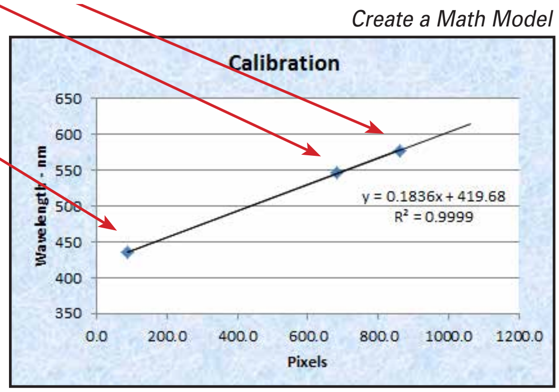
436 nm 546 nm 578 nm

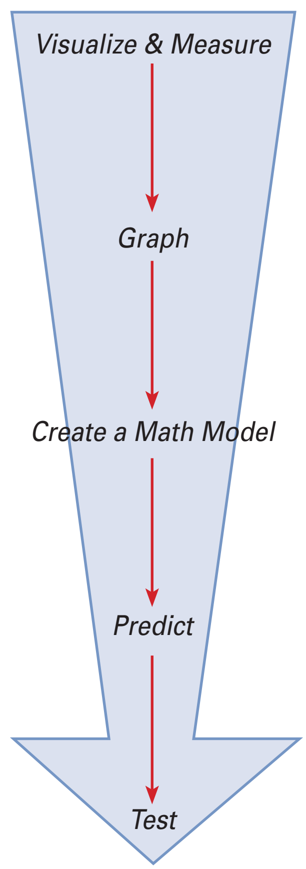


This Excel calibration chart correlates pixel position with wavelength. The regression equation shows that each pixel represents 0.1836 nm, with 419.68 nm as the Y-intercept. Note the quality of data – four nine's in the correlation coefficient.

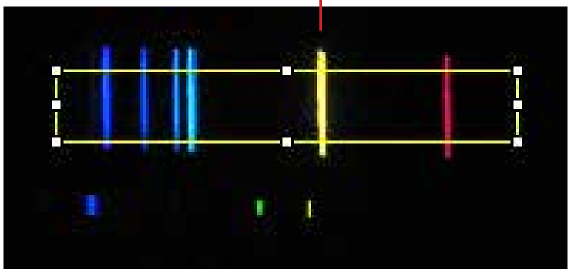
A	B
Wavelength -nm	Pixel Position
436	89
546	683
578	862

Create a Math Model

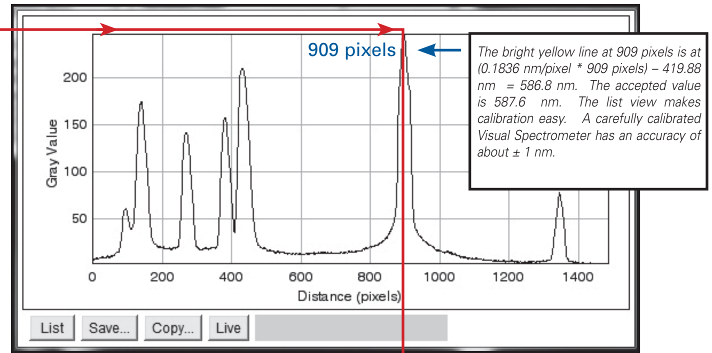




Atomic Spectra



The Image J analysis window was moved up into the unknown spectrum in this photo. The result of this analysis is shown to the right. Six spectral lines are clearly visible. Note high sensitivity in the blue.



The calibration equation is used to convert the pixel position of each line into wavelength. The yellow line is at 909 pixels. Note that this spectrum has 1400 channels.

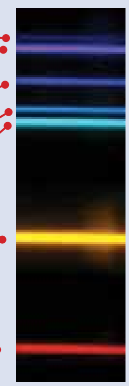
Wavelength = 0.1836 * pixel position + 419.68nm

Predict: Wavelength = (0.1836 * 909 pixels) + 419.68 nm

Wavelength = 586.6 nm

True Helium Wavelengths

Violet	443.7 nm
Violet	447.1 nm
Blue	471.3 nm
Blue	492.2 nm
Cyan	501.6 nm
Yellow	587.6 nm
Red	667.78 nm



Error = (587.6 nm – 586.6 nm)/587.6 nm = 0.170%

The Spectrometer's sensor is an inexpensive digital point-and-shoot or cell phone camera. Point-and-shoot or SLR cameras work better because their sensors are larger, but cell phones give acceptable results. Even a 3 MB camera has a sensor that is about 2000 pixels across. This is about 20 times the resolution of a $500 educational diode array spectrophotometer.

Because the camera's CCD sensor is designed to take high quality colored pictures, it is sensitive across the whole visible spectrum. Inexpensive diode array spectrophotometers have poor sensitivity in the blue.

Data analysis is provided by powerful image analysis software.

Image J is a photographic pixel density analysis program developed for life-sciences researchers by the National Institutes of Health. It is available without charge on their website: http://rsweb.nih.gov/ij/

Image J is extremely easy to use –in this application the student just draws a box around the spectrum of interest, clicks the mouse, and the intensity profile of the spectrum is calculated and displayed.

A Versatile High-performance Spectrometer

The optical part of this instrument is MicroLab's Model 141 Visual Spectrometer. It measures both atomic emission spectra and molecular absorption spectra. A large 500 line/mm diffraction grating and an adjustable 3-position slit work with the focusing lens to produce sharp slit images and bright spectral lines.

MicroLab's Visual Spectrometer measures both atomic emission and molecular absorption spectra. It has two light inputs, both entering from the large end of the spectrometer block. The bottom input comes via a flexible fiber-optic cable and presents a reference spectrum. The upper light source is from an atomic emission discharge tube or a white light source for solution absorption spectra (the sample vial sits in the block). Light from the two light sources pass through the same slit; spectra can be viewed simultaneously in wavelength alignment.

The variable slit assembly can place three different slits in the light path. Students can see the effect of changing slit width on resolution (smaller is better) and on light throughput (larger is better).

The fiber optic cable adapter places the reference spectrum at the bottom of the slit. Light entering through the slot illuminates the top of the slit. This produces two spectra, one above the other, in wavelength alignment. For absorption spectra, the upper input can handle both a blank and the sample.

MicroLab's Model 243 web camera/mount fits over the Visual Spectrometer grating. You can also use a small tripod to hold a point-and-shoot camera. The grating/lens area is covered with a black cloth to shoot the photo. A cell phone camera can simply be held up to the grating or mounted with our Model 141CPM cell phone mount. Pre-recorded photographic spectra are available on our website.

The Energy of Light – Planck's Constant

The relationship between color and energy of light is basic to understanding of atomic emission and molecular absorption spectra, and to our understanding of the behavior of electrons.

This relationship can be demonstrated at four different conceptual levels, depending on the level of the course. These concepts are identified to the right with their supporting graphs.

Planck's constant and the measured wavelengths of the atomic emission spectra of excited hydrogen atoms were historically used to support the Bohr electron model. It and spectral measurements are commonly used today to calculate the electron energy level changes within an atom.

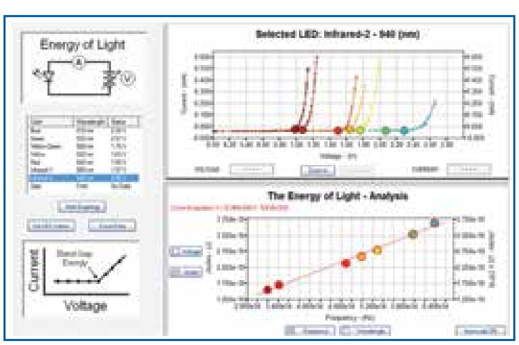
Students can use MicroLab's Model 214 to determine Planck's constant by easily measuring the band-gap voltage of a series of LED's of different wavelengths. LED's emit light when sufficient voltage is applied to force electrons to jump the energy gap between the N (electron excess) and P (electron-deficient) semi-conductor layers in the LED.

The color of light is determined by the energy difference across the energy band-gap in the LED semiconductor. Band-gap is determined by the chemistry of the semiconductor, which is selected to create LED's of different colors.

Students can determine the band gap energy of a selected LED, and therefore the relationship between energy and the color of light it produces, by simply rotating the voltage control until light just starts to be produced by the LED. They press the "Mark" button when they see light production begin, recording the band gap energy in software.

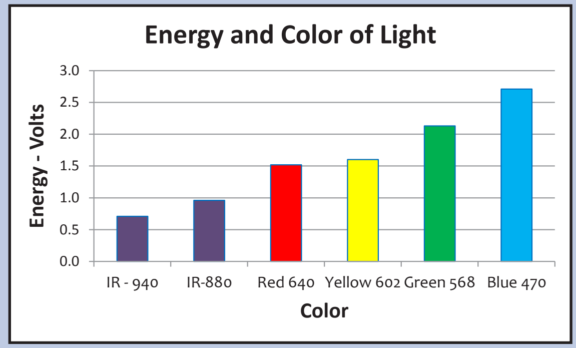
The applied voltage and the current through the LED are reported both digitally and graphically on the MicroLab display, as well as live with colored bar graphs on the Energy of Light module. The left (red) LED bar graph shows current through the experimental LED, and the right (green) LED bar graph reports applied voltage.

Students can view the initiation of current with the LED current bar graph at the same time they see visible light beginning to be produced by the LED. This display also enables them to observe electron movement with the two infra-red LED's, which produce light invisible to the eye. Seven LED's are provided, with wavelengths from 940 nm to 470 nm. An eighth switch position and a socket permit use of a user-designated LED.

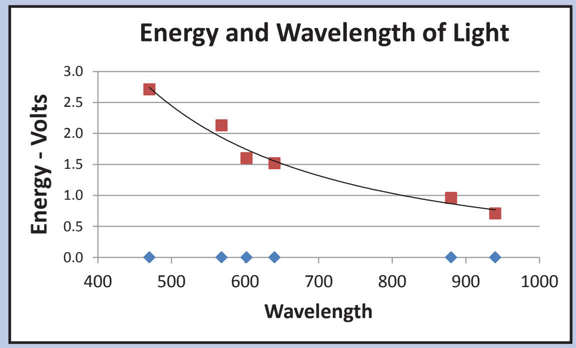


The Excel graphs presented on this page show student data illustrating the four key concepts. The experiment takes only about 20 minutes –more than one lab group can share an Energy of Light Module.

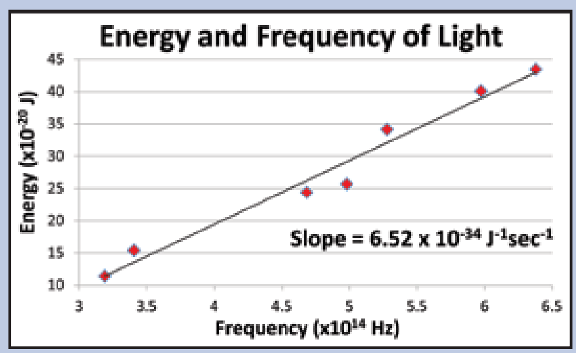
The MicroLab data display for this experiment shows current vs voltage plots for the seven LED's, with each band-gap voltage marked. It also plots energy vs wavelength or frequency (frequency shown) on the lower graph. If desired, energy and wavelength information may be transferred from the data table to Excel.



Concept 1: *The energy of light increases as color changes from infra-red to violet.*



Concept 2: *The energy of light is inversely proportional to the wavelength (λ) of light.*



Concept 3: *The energy of light is directly proportional to the frequency of the light wave.*

Concept 4: *The mathematical proportionality between energy (E) and frequency (λ) of light is known as Planck's Constant (h): $E = h\nu$.*

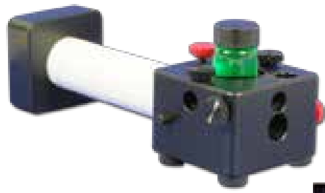
Planck's Constant *is the slope of the energy-frequency graph.*

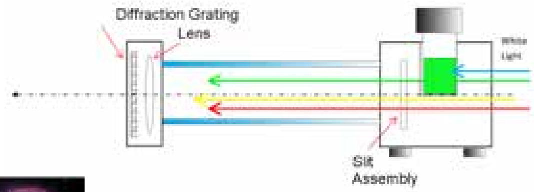
Its accepted value is 6.63 x 10-34 j-1sec-1, within about 1.6% of this measurement.

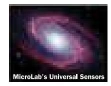
Molecular Absorption Spectra, Color, and *FASTspec*™

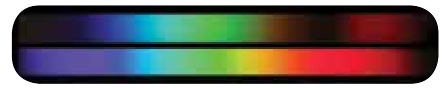
Absorption spectrophotometry is the most common tool in analytical chemistry. Measurements are quick, accurate, inexpensive, and usually take little sample preparation. However, although spectrophotometry is based on color, it is almost always taught with instruments that present a sterile black-and-white view of a conceptually colorful and interesting science.

Absorption spectrum of the sample is viewed above the reference spectrum.









Students can use MicroLab's Visual Spectrometer and our ***FS-524 FASTspec***™ scanning spectrophotometer to bridge the gap between visual, conceptual observation and quantitative measurement of absorption spectra.

If you place a vial of colored liquid in the Visual Spectrometer and look at a white light source (the sky, or an incandescent white light bulb), you can view the absorption bands together with a continuous white reference spectrum (above). This food dye sample looks green because it absorbs blue/violet and red light. The absorption bands are real and highly visual.

Working from measured absorbance data, MicroLab's ***FASTspec***™ scanning spectrophotometer creates the same visual display (below, with the blank now on top) to provide students both visual and quantitative display of absorption spectra with every scan.

Color: It's what's absorbed that counts.

Ask a freshman what is going on in this vial, and they will say "it is giving off yellow light"!

"It's giving off yellow light!"

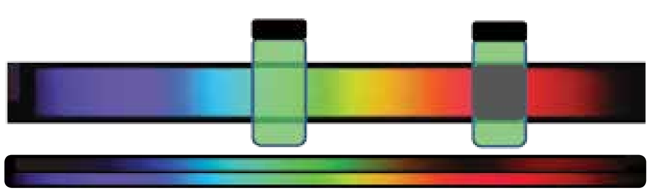
The key to understanding absorption spectrophotometry is knowledge that color is not "given off", but is what is left when some wavelengths are absorbed from a white spectrum.

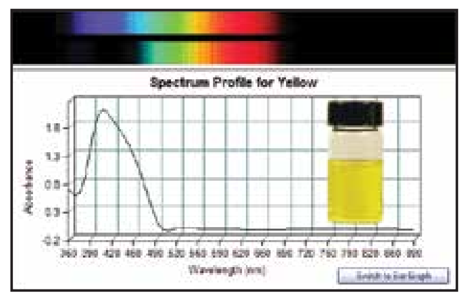
Students think percent transmission – colors that are passed through a sample. But spectrophotometry works on absorbance – colors that are taken out. Some quick experiments with our Visual Spectrometer and the ***FASTspec***™ scanning spectrophotometer make this point well.

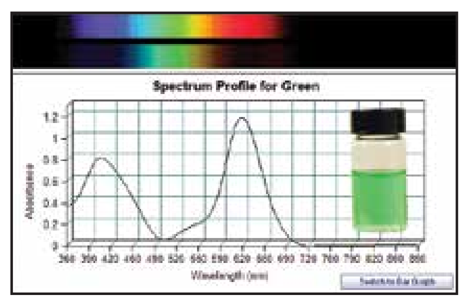
Working from measured absorbance data, our new ***FASTspec***™ scanning spectrophotometer creates a display that provides students both visual and quantitative views of absorption spectra with every scan.

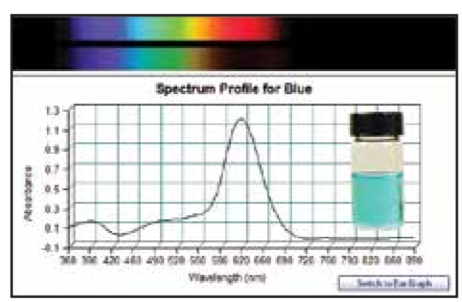
A photographic image of the "blank" transmission spectrum is at the top, with a copy of the sample spectrum right below, but covered in software with a black overlay. The density of the black overlay is proportional to the absorbance at each wavelength. Students can relate the transmission minima or absorption maxima on the graph to actual absorption of light by the sample.

Here is another way to observe this. Make an absorbance or transmission scan (transmission shown here) of your sample. Then hold the sample vial in the "blank" area and slowly move it across the visual "blank" spectrum. You can see the sample selectively absorb colors from the "white" spectrum. You can try this yourself right on the computer screen or even with the spectrum printed below on this page – just run a vial across the spectrum below and watch for absorption bands





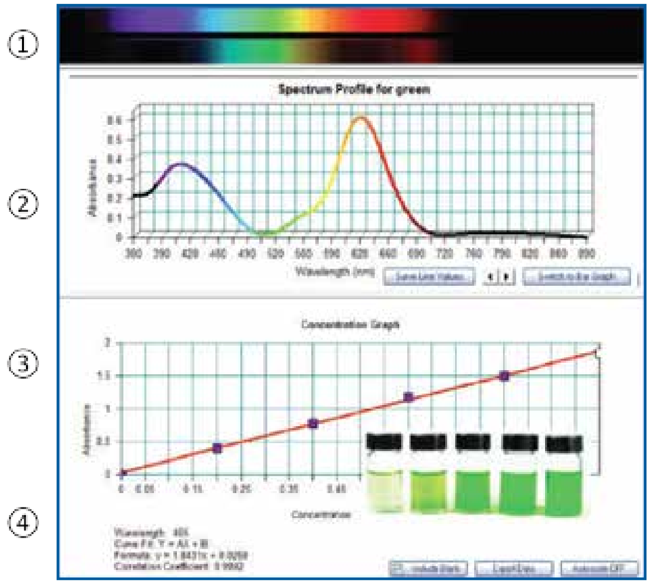


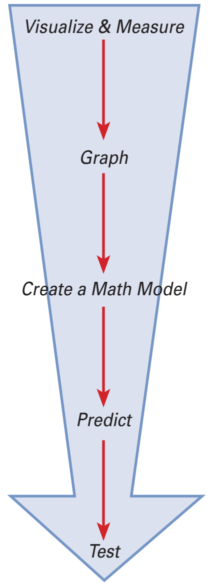


Pictured here are FASTspec spectral absorbance profiles for yellow, green, and blue food dye. Chemists use absorbance instead of transmission units because it is the color that is absorbed that counts. And absorbance is directly proportional to concentration. Note that the green spectral profile has components of both yellow and blue. The green dye is a mixture of the yellow and blue dyes.

Visualization, Beer's Law , and Mathematical Models: MicroLab's Integrated FASTspec™ Spectrophotometer

Our patented ***FASTspec***™ scanning spectrophotometer provides simultaneous 360-880 nm high resolution measurement of Fluorescence— Absorbance—Scatter—Transmission, plus 880 nm international standard turbidity measurements and stirred spectrophotometric titrations.



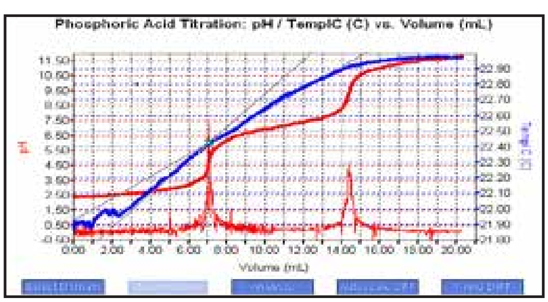


All MicroLab data appears live as the experiment runs, in simultaneous visual, digital and graphic displays. The ***FASTspec***™ Beer's Law data above illustrates this sequencing from ① visual display of the data (top, visual reference spectrum above the visual absorption spectra of a green sample), ② graphic presentation of the spectral absorbance, ③ creation of a graph and math model (equation) relating absorbance to concentration, and finally to ④ the ability to use the equation to predict the concentration of an unknown sample.

Note the correlation coefficient for the Beer's Law plot: 0.9992. Variation in the vials is the principal source of error. Vial sized 28mL and 14mL included, minimum sample volume 7 mL, path length 2.24 cm. An optional Model 186 vial adapter/vial pack adds two additional path lengths 1.66 cm and 1.1 cm and minimum volumes 4 mL and 1.5 mL.

pH, Drop Counting, and Titrations: MicroLab titrations may be performed in the stirred 28 mL spectrophotometer vial pictured above, or as a traditional larger scale laboratory titration. This graph shows data from a MicroLab phosphoric acid titration conducted in nested Styrofoam cups to track heat of reaction. The first derivative plot shows endpoints to 0.03 mL for the first and second hydrogen removal. The blue line shows a 0.9 degree Celsius increase in temperature during the titration, with the slope changing as the heat of reaction decreases after removal of the first hydrogen. The BNC input also accepts Redox, DO, and ion-specific electrodes.

High resolution data makes visualization easy. Students quickly turn graphs into concepts.



Integrated Sample Illumination —Titrations and Kinetics:

A removable translucent illuminated titration module fits ove
spectrophotometer vial holder. It reflects light from software-co
and red LED's mounted in the top of the cabinet. The white LE
backlighting so students can watch kinetic reactions fade, or in
during a titration. Green and Red LED's signal "OK to add titran
28 mL vial shown.

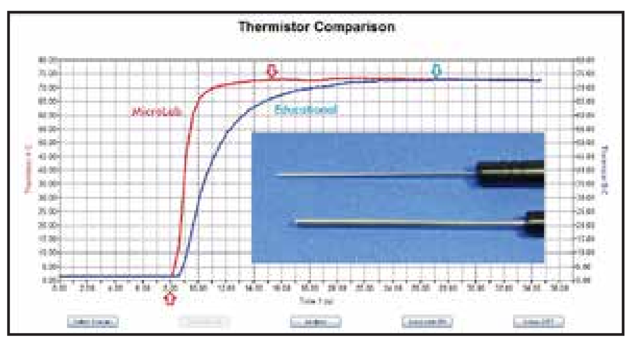
Fluorescence and Scatter: MicroLab prov
excitation wavelengths 360-880 nm to ob
fluorescence or scatter. Fluorescence me
this web cam shot into the sample vial of
at 405 nm, are made against a dark backg
angles to the excitation beam. They can be

Pressure: 0-2000 torr, resolution ± 0.03 torr. Boyle's Law, absolute zero, vapor pressure, plant respiration. Leur hose fitting.

Integrated Stirring Motor: The 528 's stirring motor consists of
produce a rotating magnetic field which spins the magnetic stir bar
instantly reversible.

Temperature Control: A software-controlled 20-watt, test-tube s
kinetics experiments. It will fit in the 28mL spectrophotometer vial

Counter, Conductance, Thermocouple, and Heater: Inputs are
resolution ±0.03, ±0.3 uS. K thermocouple: -200 to + 1000 C, resol



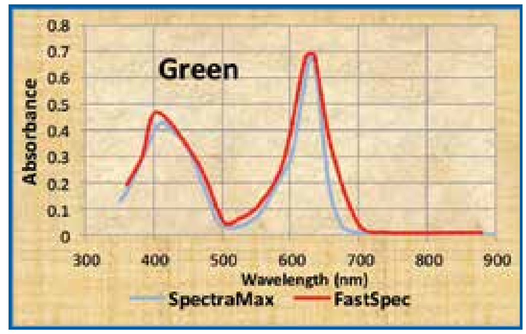
r the
ontrolled white, green,
D's provide adjustable
dicators change color
t", or "Stirring ".

vides sixteen different
serve or measure
easurements, such as
f chlorophyll excited
ground and at right
e very sensitive.

I'm continually amazed at the research quality data we get from MicroLab. We can do things in teaching and undergraduate research at a small institution that we never dreamed possible.

Dr. Tom Kuntzleman, Spring Arbor University

Spectral Profiles: Spectral profiles serve two purposes: (1) to choose an analytical wavelength for Beer's Law experiments, and (2) to identify unknown compounds by comparing their spectral profiles with known compounds.

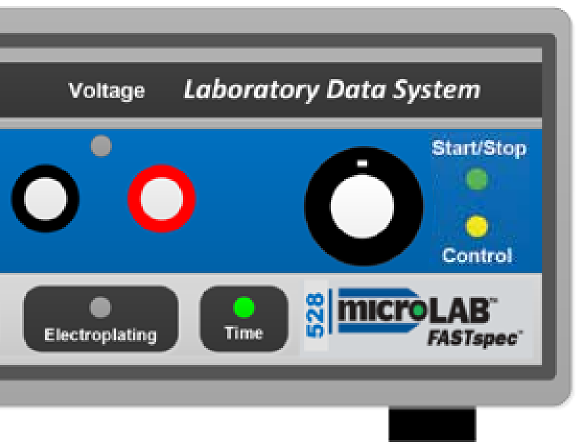


Since UV-VIS molecular absorption spectra change smoothly with wavelength, a mathematical curve fit to ***FASTspec***™'s accurately-spaced narrow-band absorbance measurements produces a spectral profile very similar to measurements made by a research-grade spectrophotometer.

FASTspec™ point measurements report photometric precision of better than ± 0.1%. Beer's Law and Kinetics experiments produce excellent results. One-hundred point spectral profile data may be exported directly to Excel.

MicroLab has made our labs much more economical. Experiments use smaller samples, run more quickly, and students use their time more effectively.

Virginia Wairegi, Rice University



f small ferrite core coils placed below the vial. These
in the vial. Variable stir rate 1-12 revolutions per second,

sized heater will maintain a controlled temperature for
(top of page).

e on the back panel. Conductance 0-2000, 0-20,000 uS,
ution ±0.04 C.

Real Time Control: The real-time rotary control is new to the MicroLab interface family. Students can use it to control software-selected experimental variables such as stir rate, heater power, voltage applied to electro-chemical cells, etc. The "push" function is used for start/stop or to step beween user-controlled variables.

Voltage: The Electrochemical Series and Electroplating: The two "Voltage" banana jacks play double duty. In the voltage mode, they serve as a **voltage input port** with four ranges - ± 10 volts, ± 2.5 volts, ± 1.0 volts, and ± 100 mV. This serves electrochemical series and Nernst Equation experiments.

In the **Electroplating** mode, these jacks provide an adjustable regulated 0-5 volts, 750 mA power supply for electroplating / coulometry experiments including atomic mass , Avogadro's Number, and coulometric titration experiments. Software calculates coulombs and moles of electrons delivered.

Timers: Two automatic or programmable timers plus real-time clock. Time resolution 0.001 sec.

Cyclic Voltammetry: The optional Model 170 Cyclic Voltammetry module plugs into MicroLab Port A. It uses Pine Instruments screen-printed electrodes and can scan with ± 2500 mV 1-20 mV steps.

Multi-purpose Sensor Inputs: Two multi-purpose inputs accept sensors for temperature, light, and all of the MicroLab expansion modules such as Energy of Light, Cyclic Voltammetry, and others.

MicroLab uses exclusively industrial-grade sensors. These are rugged, withstand student use well, and have a long service life. When coupled with MicroLab's low noise, high resolution signal processing, they produce near research-grade data.

This chart compares the response of a MicroLab 103 Stainless Steel Thermistor with a standard educational thermistor as both are moved from ice water to water at 73 degrees C.

The MicroLab thermistor will track the experiment almost three times better than the educational thermistor.

It used to be that students would spend a three-hour lab gathering data. Now, students can focus on what the data means; this enables them to decide quickly whether or not they need to do the experiment over. The discovery process—how the numbers relate to a concept—takes place in the lab, not when the students are writing their lab report.

Dr. Carolyn Mottley, Luther College

Beer's Law

Beer's Law is the workhorse of analytical chemistry. However, selection of a wavelength for Beer's Law experiments is counter-intuitive. Students find it hard to understand because it is the light that is absorbed that counts, not what comes through the colored sample. Conventional wisdom is to choose green light for a green sample. What is going on here? You have to think absorbance.

Beer's Law is a mathematical statement of the relationship between absorbance (Log 1/T) of a solution at a specific wavelength, and the concentration of this solution.

A absorbance = **a** molar absorptivity constant ***b** path length ***C** concentration

Here's how it works with MicroLab:

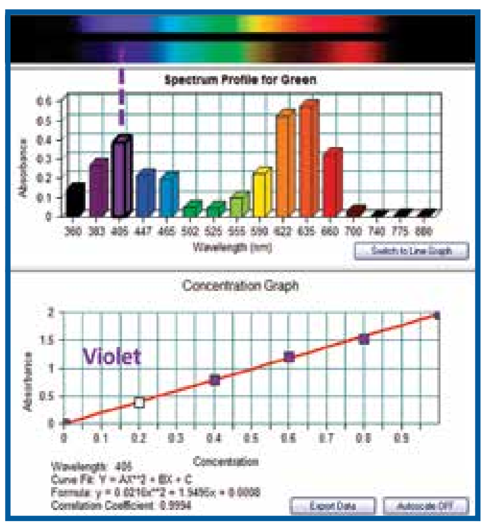
These four figures represent spectral scans of the five green food dye samples pictured above, using MicroLab FS-524's ***FASTspec***™ scanning spectrophotometer.

The difference between these graphs is the choice of analytical wavelength, which determines the molar absorptivity constant of the sample. The slope of the Absorbance / Concentration graph is determined by the molar absorptivity constant and the path length. Path length is held constant by using the same diameter vials.

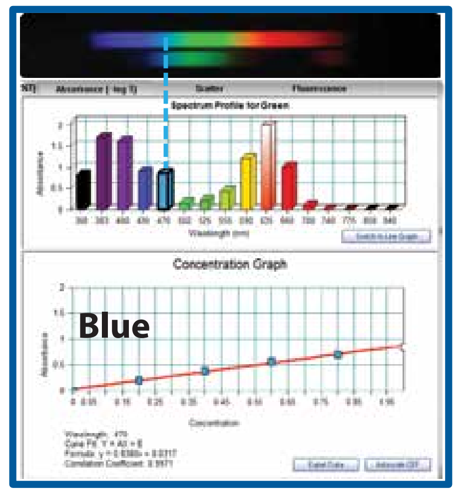
Compare visual absorption spectra of blank and sample. Identify absorption bands. →

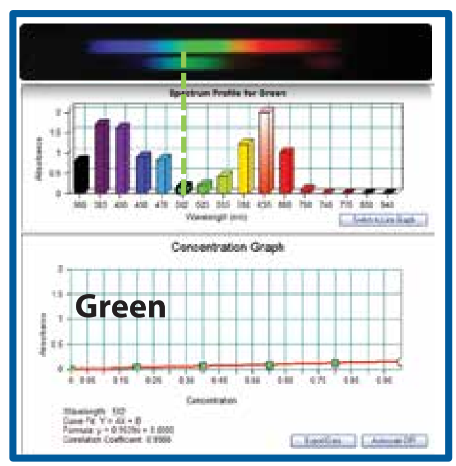
Associate visual and graphic displays of absorption spectra. Choose analytical wavelength. Either a traditional line graph or a color-bar histogram of the spectral profile may be selected. The analytical wavelength graphed may be selected by clicking on a color-bar. →

Correlate Beer's Law sensitivity with wavelength and the molar absorptivity constant (slope). →



Spectral profiles may be displayed as a histogram (above) or as a line graph (page 18).



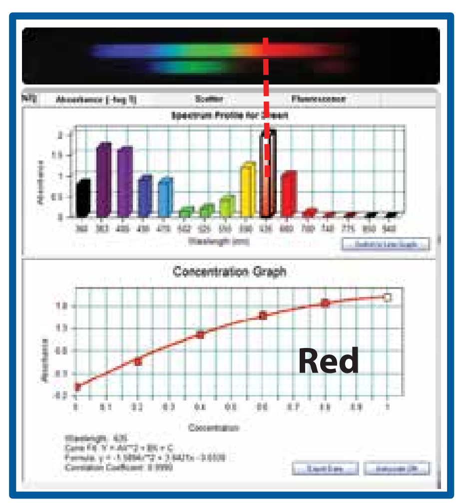


The first graph **violet** has a greater slope and thus greater analytical sensitivity than the **blue** measurement because the molar absorptivity is greater at the violet wavelength.

The **green** measurement has the least sensitivity because the absorbance of the sample is least in the green region.

The **red** measurement illustrates the effect of deviations from Beer's Law at high absorbance. When absorbance is high, very small amounts of stray light become significant and lower the observed absorbance at the detector. A non-linear curve fit works for concentration, though the errors in measuring an unknown become much greater as the curve flattens out.

All of this can be explored easily with a few mouse clicks.



Path Length

Using the Model 186 Vial/Adapter kit, the FASTspec™ sample holder will accept vials of three different path lengths – 2.25 cm, 1.66 cm, and 1.10 cm. One can compensate for more concentrated samples by choosing a vial with lesser path length. And one can experimentally demonstrate the effect of the path length variable in Beer's Law.

A = abC, where A is absorbance, a is the molar absorptivity constant for that wavelength, b is the path length, and C the concentration.

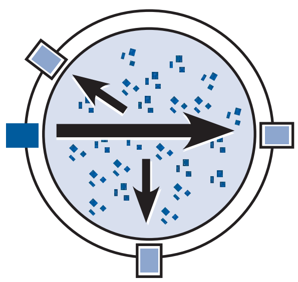
The 186 Vial/Adapter kit includes five each vials 3 mL and 7 mL, as well as two vial adapters. The FS-528 is provided with five each 14 mL and 28 mL vials, both of 2.25 cm path length.

The spectrophotometer light beam goes through the bottom of the vial; liquid must be at least 1 cm deep.

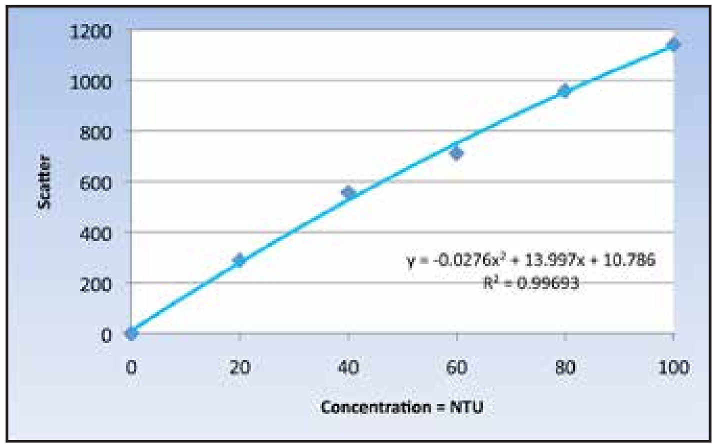
Turbidity is the scattering of light from colloids and particulates in a suspension.

Nephelometry is the measurement of light scattered 90 degrees to the a light beam shining into the sample. The Nephelometric turbidity unit (NTU) is based internationally on scatter of 880 nm infra-red light. This light scatters well and is generally not absorbed by colored samples.

FASTspec™ nephelometry measurements first use a blank to read absolute LED intensity at the 180 degree position. This is referenced by subsequent scatter measurements to compensate for long term drift in the LED. As turbidity increases, the sample will absorb its own scattered light. To compensate, highly turbid samples are read with the backscatter detector. ***FASTspec***™ can read scatter at sixteen different excitation wavelengths.



FASTspec™ *measures turbidity with 90° scattered light (low range) and backscattered light (high range).*

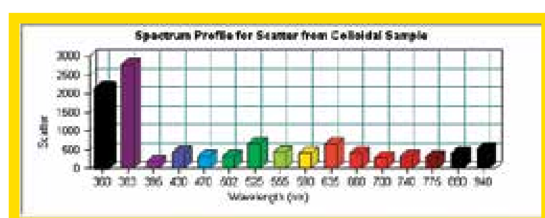


This graph, generated with NIST-traceable turbidity standards and a MicroLab FS-528, shows increasing light scatter as the concentration of colloidal particles in the sample is increased. Note that self-absorption of the scattered light causes the calibration graph to be a second order curve rather than a straight line. A two-point calibration presumes a straight line and will not give accurate results. Data by Dr. Richard Hermens, Eastern Oregon University.

Colloids will scatter light while solutions do not, as is illustrated by this laser beam passing through a KCl solution and an apparently clear sample containing a very small amount of clay. This is called the "Tyndall effect".

"You have an exceptional product. Money is very tight, and I wouldn't be spending this much of it if I didn't think that the MicroLab units were the best such devices on the market. I think that they will transform and reinvigorate the way we teach chemistry at Oglethorpe.

-Dr. Keith Aufderheide Professor of Chemistry, Oglethorpe University



Scattering of light is wavelength-dependent and is related to the size of the colloidal particle. This ***FASTspec***™ *90-degree scatter spectrum of the clay sample to the left shows that the very small colloidal particles in this sample scatter best short wavelength UV light. Experiment by Doug Crebs, Stone Child College, MT*

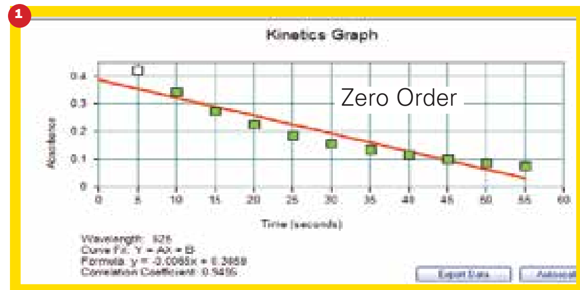
Kinetics

These plots of kinetics data from a crystal violet reaction with sodium hydroxide show 1 zero order (absorbance vs time, 2 first order (ln absorbance vs time), and 3 second order (1/absorbance vs time).

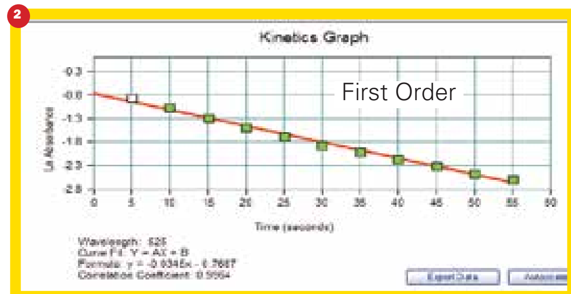
These graphs show absorbance data recorded at 525 nm. Measurements may be made at intervals from 2-120 seconds between points. All sixteen wavelengths are scanned for each data point. This experiment was sampled every five seconds and ran for 55 seconds.

Because all wavelengths are scanned for each data point, one can monitor two different simultaneous reactions with different reaction orders or rate constants if the reactants are different colors.

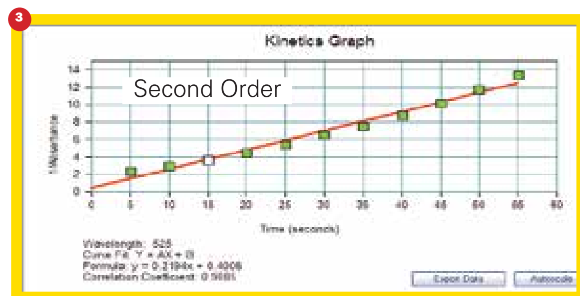
The reaction of crystal violet with sodium hydroxide slowly produces a colorless solution. This is a first order reaction.



When Absorbance of the crystal violet solution is plotted with respect to time, a concave curve results. A linear regression does not fit the data. The reaction is not zero order.



When the natural log of absorbance (ln A) is plotted with respect to time a straight line results. The slope of this line, determined with the linear regression, is the psuedo rate constant for the reaction. The linear fit of this data indicates that the reaction is first order.

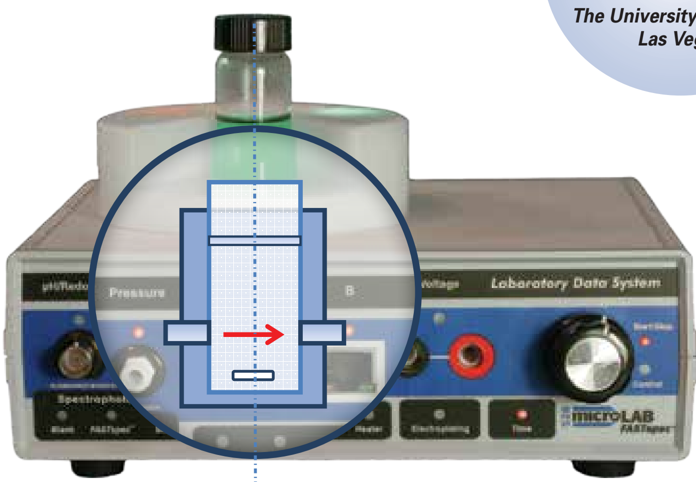


When 1 / absorbance of the crystal violet solution is plotted with respect to time, a curved line results. A linear regression does not fit the data. The reaction is not second order. This reaction ran 55 seconds.

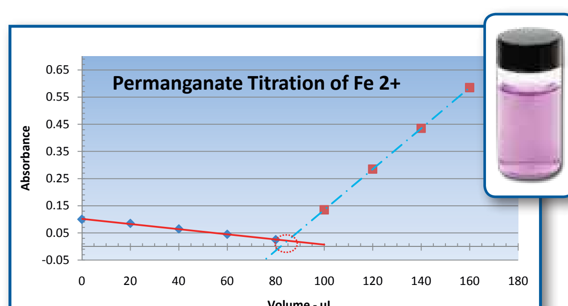
MicroLab has given us a great step forward in Physical Chemistry lab.

-Dr. Clemens Heske
The University of Nevada Las Vegas

Spectrophotometric Titrations



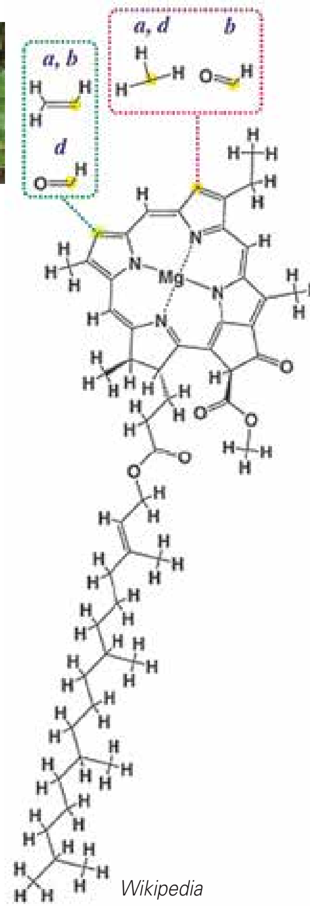
*MicroLab's **FASTspec**™ micro-spectrophotometric titrations are fast, safe, and inexpensive. With micropipette additions of titrant, students monitor changes in absorbance spectra of acid-base indicators, Redox indicators, or complex ion solutions. They can measure not only absorbance, scatter, or fluorescence at specific wavelengths 360-880 nm, but also simultaneously measure pH, in the course of the titration.*



Nine data points and two intersecting regression lines quickly determine the equivalence point of this permanganate titration of Fe2+. Mixing is fast and effective with a small stir bar in MicroLab's sample vial, and a stir plate placed below the MicroLab. Addition of 160 uL of KMnO4 to a 15.0 mL Fe2+ sample causes dilution of only about 1% in the initial sample.

Fluorescence

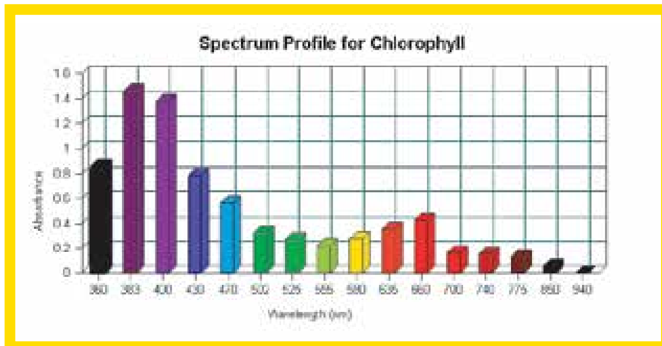
Chlorophyll is a candidate for the most important molecule in the world. It captures energy from the sun to drive the green plant's photosynthesis reaction, producing sugar and oxygen to support life.



Wikipedia

One can learn a lot about chlorophyll and other fluorescent molecules from the ***FASTspec***™ spectrophotometer.

Chlorophyll is the green pigment in plants. The conjugated bonds (alternate single/double bonds) in the ring of atoms around the central magnesium atom absorb violet and red light (***FASTspec***™ absorbance spectra on the right)



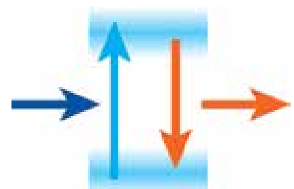
Chlorophyll shows two absorbance peaks - one in the violet and one in the red.

In a living plant, energy from violet and red light absorbed by the chlorophyll molecule energize electrons which are transferred to other molecules to drive the photosynthesis reaction.

If the chlorophyll is extracted from the plant, held in a solution, and struck by photons of blue or red light, there are no receptor molecules for these energetic electrons. The chlorophyll molecule then loses energy principally by fluorescence in the red region of the spectrum, as illustrated in this photograph.

*View down into the **FASTspec**™ vial showing fluorescence of chlorophyll.*

400 nm light was used to excite this sample. The fluorescence is greatest nearest the LED (left), and by the time the 400 nm light is 3/4 of the way across the vial, most of the 400 nm photons have been absorbed and can no longer drive fluorescence.



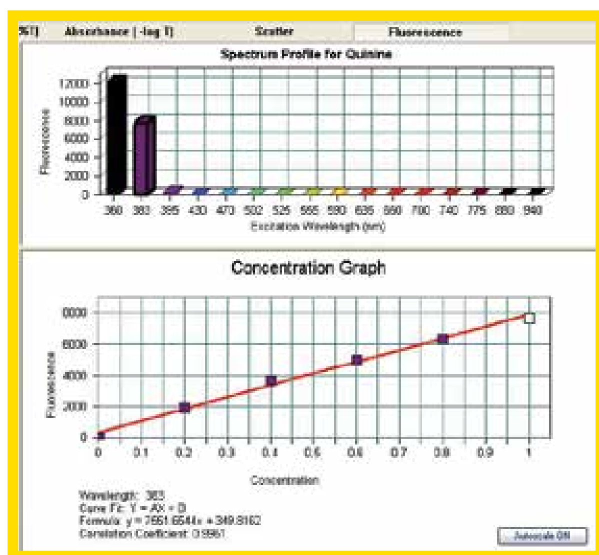
Light produced during fluorescence is always lower energy than the light that excited the molecule.

I am excited about the new updated MicroLab. We are interested in more units because they work extremely well for us.
Dr. Norm Hudson, Valparaiso University

Quantitative Analysis with Fluorescence

MicroLab's internal ***FASTspec***™ scanning spectrophotometer will identify optimum excitation wavelengths for fluorescence and will illustrate the relationship between concentration and fluorescence. It is effective for a number of common substances, such as quinine in tonic water, illustrated here.

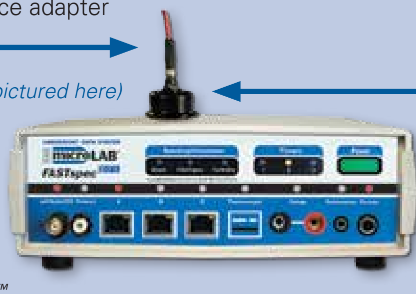
The quinine solution appears clear but absorbs in the ultra-violet. When excited at 383 nm, a blue fluorescence results. The intensity of the fluorescence is related to the quinine concentration. This plot shows the fluorescence/concentration relationship for quinine with 383 nm excitation. The histogram shows the fluorescence produced for each excitation wavelength.



Measuring Fluorescence with MicroLab's *FASTspec*™ and a Diode Array Spectrophotometer

Model 213 Fiber optic cable and ***FASTspec***™ fluorescence adapter

(MicroLab FS-524 pictured here)



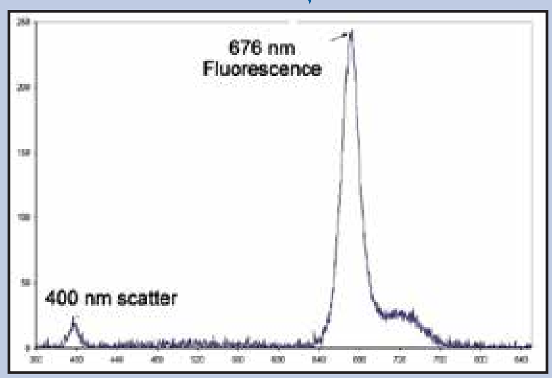
Microlab ***FASTspec***™ provides sixteen narrow-band excitation sources of equal intensity. 360-940 nm.

Fluorescence is picked up by the fiber optic cable and transferred to a diode array spectrophotometer.

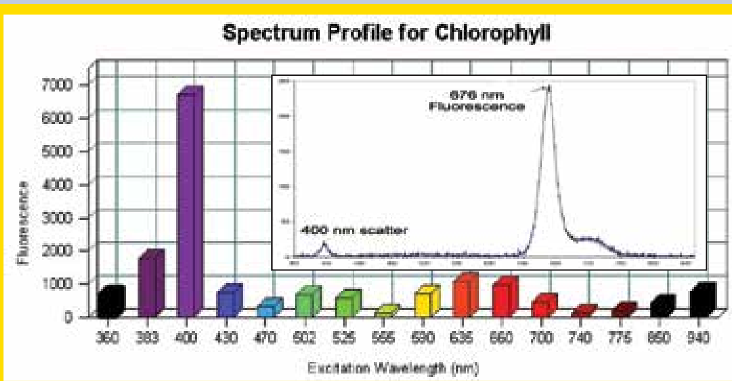
Flourescence is visible to the eye with the light shield removed.

FASTspec™ excites the sample, one wavelength at a time. (400 nm excitation in this example.)

FASTspec's broadband sensors measure fluorescence at right angles to the excitation beam. Detectors view fluorescence against a dark background, providing high sensitivity and a dynamic range of 65,000.



The diode array spectrophotometer plots the fluorescence emission spectrum for each excitation wavelength. The selected excitation source remains on while the spectrum is collected. In this example, chlorophyll fluoresces in the red peaking at 676 nm. A small amount of scatter from the 400 nm excitation source is visible. Spectrophotometer output is Excel compatible. The fact that the fluorescent emission wavelength is always longer than the excitation wavelength is called "Stokes shift".



MicroLab ***FASTspec***™ software reports fluorescence observed at each excitation wavelength with a histogram and an Excel-compatible data table. This chlorophyll sample is best excited at 400 nm and 635-660 nm.

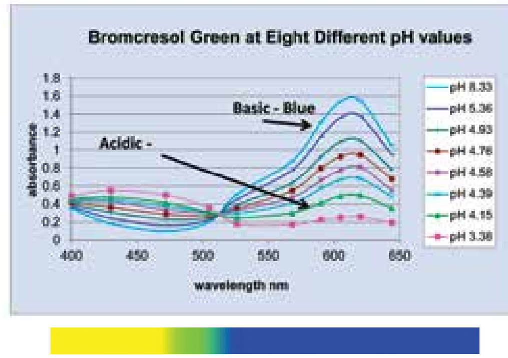
FASTspec™ software will also simultaneously plot and curve-fit fluorescence intensity against sample concentration for each excitation wavelength. 360-940 nm scans take about two seconds.
(See concentration plot at the bottom of page 21.)

The combination of a ***MicroLab FASTspec***™ scanning spectrophotometer and a diode array spectrometer (such as the MicroLab / Avantes 2048 channel 211C, shown here) provide an exceptional and affordable view of the fluorescence excitation and emission characteristics of many common molecules, such as the chlorophyll in this example. The excitation scan (lower left) takes about two seconds, and each diode array measurement (center right) takes about one second. Instruments that provide similar information cost tens of thousands of dollars.

Indicators

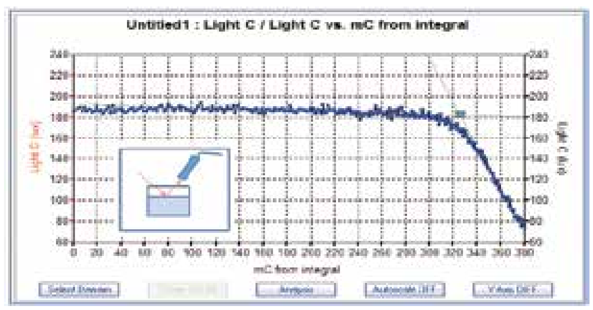
Acid-base indicators exist in two forms that have different colors. One (the acid form) has an additional proton added to its molecular structure. The cross-over point at which the acid and basic forms of the indicator have equal absorptivity is called the "isosbestic point".

This visible region absorbance spectrum of Bromcresol Green indicator at eight buffered pH values, plotted here in Excel, was collected with eight scans with MicroLab's ***FASTspec***™. The indicator's isosbestic point is at about 525 nm. Since the basic form is blue and the acidic form is yellow, the cross-over point for this indicator is green. Data provided by Dr. Mike Seymour, Hope College.



Titrations with Light

MicroLab's **Model 112 Light Sensor** can monitor change in light transmission as the indicator changes during a titration by placing it in a test tube immersed in the solution. One can also monitor light reflected from the solution surface, as in this coulometric titration of ascorbic acid using a starch indicator. Data provided by Dr. Mike Collins, Viterbo University.



The end point can be detected with reflected light in this starch-indicator coulometric titration of ascorbic acid.

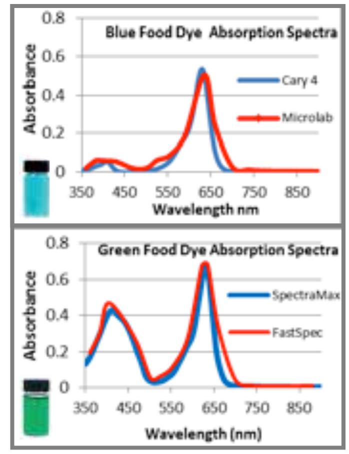
Diode Array Spectrometry

The **Model 211C MicroLab/Avantes 2048** channel diode array spectro-photometer does an excellent job isolating close-together spectral lines in atomic emission spectra, and for long integration time measurements of weak fluorescence spectra. It operates on power delivered from the host PC via its USB cable. Software is included. One good diode array spectrophotometer in a lab will provide adequate student access to these measurements.

MicroLab / Avantes 211C
Diode Array Spectrophotometer

Optical bench:	Symmetrical Czerny-Turner
Focal length	75 mm
Wavelength range:	360-1100 nm
Slit width:	25 microns
Resolution:	1.2 nm FWHM
Stray light:	Less than 0.1%
Detector:	CCD linear array, 2048 channels
Signal to noise ratio:	250 : 1
A/D Converter	14 bits
Integration time:	1.2 mS - 10 minutes
Interface & Power	USB
Dimensions:	175 x 110 x 44 mm; 716 grams

This inside bottom view of the **MicroLab FS-528** shows the rotating magnetic field stirring motor below the spectrophotometer vial holder. The FS-528 is manufactured in the U.S. by an ISO-9001 certified company that manufactures MicroLab products on the same production line and with the same standards as used for their NASA and military products.



FASTspec™ *spectral profiles agree quite closely with measurements made by research grade spectrophotometers. Spectral profiles serve two qualitative purposes: (1) to choose an analytical wavelength for Beer's Law experiments, and (2) to identify unknown compounds by comparing spectra with known compounds. Absolute accuracy is more important for single-wavelength Beer's Law concentration measurements than for spectral profiles.*

What Makes a Good Spectrophotometer? Good Spectral Profiles. Clear Visual Displays. Stable, High Resolution Photometry.

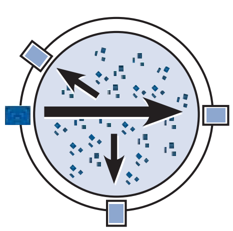
Every spectrophotometer design involves trade-offs – trading one kind of performance for another, or for cost. *The* ***FASTspec™*** *design trades absolute accuracy of spectral profile measurements for (1) significantly increased accuracy in single-wavelength Beer's Law absorption measurements, and (2) the ability to make simultaneous transmission, absorbance, turbidity, scatter, and fluorescence measurements.* Sixteen narrow-band excitation wavelengths 360-880 nm are available for fluorescence and scatter measurements.

Spectral Profiles:

MicroLab's ***FASTspec™*** scanning spectrophotometer takes advantage of the broad nature of UV-VIS molecular absorption spectra that causes spectral absorbance profiles, with the exception of rare earth compounds, to change smoothly with wavelength. Thus a mathematical curve fit to a relatively small number of carefully spaced absorbance measurements 360-880 nm can produce a spectral profile very similar to a 2000 point measurement made over the same wavelength range by a research-grade diode-array spectrophotometer.

The graphs to the right compare FS-528 ***FASTspec™*** spectral profiles for green and blue food dyes 360-880 nm with those taken by Spectramax and Cary 4 UV-VIS research spectrophotometers.

How does the *FASTspec™* scanning spectrophotometer work?



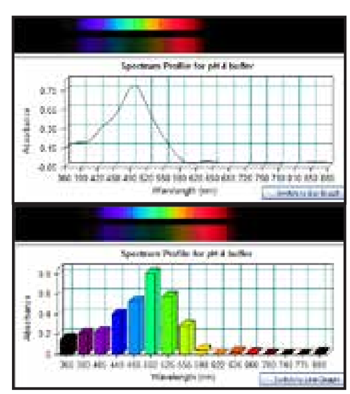
FastSpec™ *makes three different simultaneous measurements for each wavelength Transmittance/Absorbance; → Scatter and Fluorescence, ↓ and Backscatter.↖*

MicroLab's ***FASTspec™*** spectrophotometer generates its spectrum with precision narrow bandwidth (10-20 nm FWHM) light-emitting diodes (LED's) spaced about 24 nm apart in the range 360-770 nm, with an outlier at the 880 nm international standard for measuring turbidity and nephelometry. These are arranged concentrically around the sample, each pair of LED's driving three precision detectors. The sample is exposed to the light beam for less than 100 milliseconds for each wavelength, minimizing the chance of photochemical damage.

Diode array spectrophotometer sensors use many micron-sized light sensors (pixels) arranged in an array across a small projected spectrum. It is difficult and expensive to make these pixels of uniform sensitivity. A sorting process takes place during manufacturing that puts the best sensors in higher priced instruments. The result is that educational diode array spectrophotometers often report variation in photometric accuracy of ± 10 % or more.

FASTspec™ uses dedicated high quality industrial photodiodes, and reports photometric precision of better than ± 0.1%. This is what counts for Beer's Law and Kinetics experiments. Look at the quality of Beer's Law data presented on page 20. The correlation coefficient for these Beer's Law plots is 0.999. Variation in the vial is the principal source of error.

MicroLab's ***FASTspec™*** *presents a selectable traditional line graph spectral profile display as well as a histogram display that correlates color with wavelength. A photographic "blank" and "sample" display (top) correlate visual observation with graphic and mathematical displays of absorption spectra.*



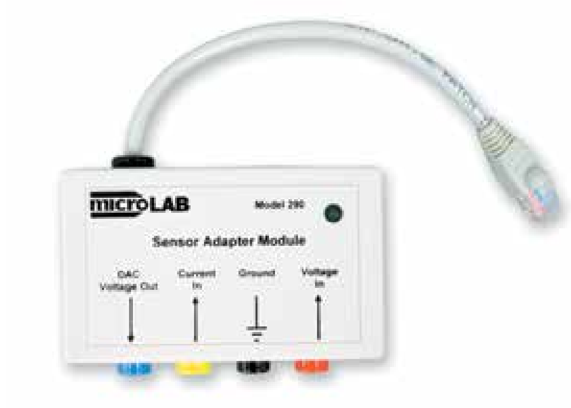
Sensor Adaptor Module

The MicroLab **Model 290** Sensor Adaptor Module provides a way to connect custom-built sensors to the MicroLab interfaces through color-coded banana plug connections. The module's CAT-5 connection to a sensor port also provides access to current and voltage inputs as well as digital to analog converter output. The Sensor Adapter Module will support coulometric titrations in analytical chemistry.

Input: DC Voltage: +/- 2.5 volts

DC Current: +/- 25 mA, 2.5 mA, 250 uA

Output: 0 to± 2500 mV, 0 to + 5000 mV DC, software controlled from MicroLab's internal D/A converter



Dissolved Oxygen Electrode

The **Model 127** Dissolved Oxygen Electrode's output signal is proportional to oxygen concentration, and is in the range of 25-35 mV in air-saturated water at 25° C. Range is 0-14 mg/L dissolved oxygen, resolution .0025mg/L. Replaceable membrane included.

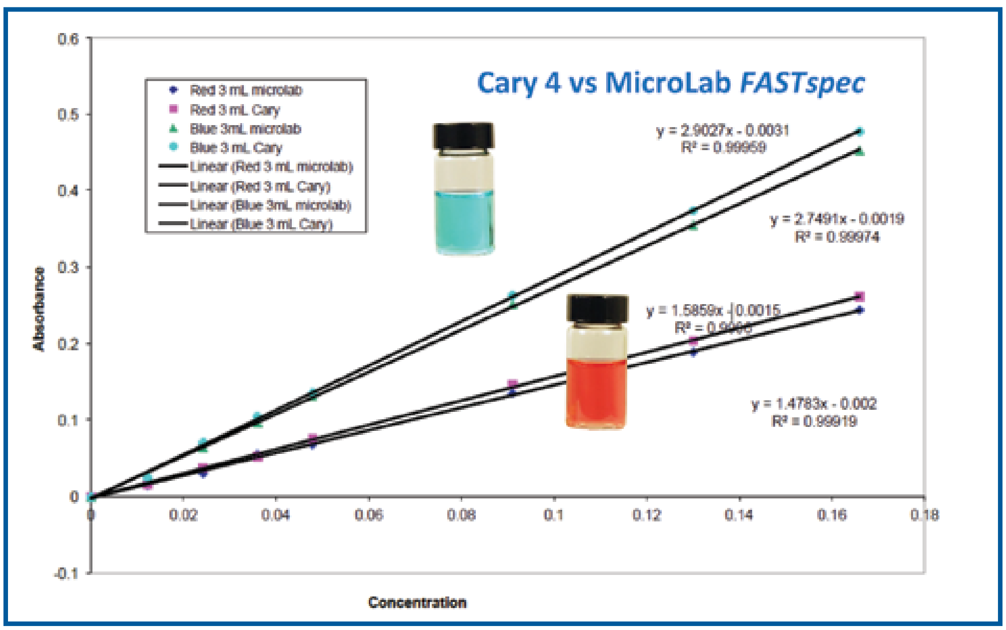
RPI Chemistry has been using the MicroLab interfaces for several years with great success. Our greatest achievement has been the student response when they realize they have designed and created their own experiment. The look of accomplishment and sometimes surprise as the experiment proceeds is fantastic.

Dr. Liz Sprague,
Renesselaer Polytechnic Institute.

FASTSpec™:
High Resolution makes small changes visible – and small samples possible.

Why should a freshman be concerned about data quality important in analytical or physical chemistry? Because what they see is what really happened. Students don't make excuses for bad MicroLab data. They clearly see cause-and-effect relationships in their data. And this low noise and high resolution shows up in all MicroLab data – temperature, pH, pressure, conductance, voltage, etc.

This chart shows Beer's Law concentration plots for blue and red food dye samples , made with Cary 4 and MicroLab ***FASTspec***™ spectrophotometers. The Cary 4 data shows a slightly greater slope than ***FASTspec***™ for both samples because of its narrower bandwidth. However, the correlation coefficients for the Cary and ***FASTspec***™ regression lines differed by only one unit in the fourth decimal place: 0.9990 ± 0.0001.



The measured photometric precision and stability of the MicroLab ***FASTspec***™ approaches that of the Cary 4 research spectrophotometer. MicroLab students work with good spectrophotometric data. *Data by Dr. Mike Seymour, Hope College.*

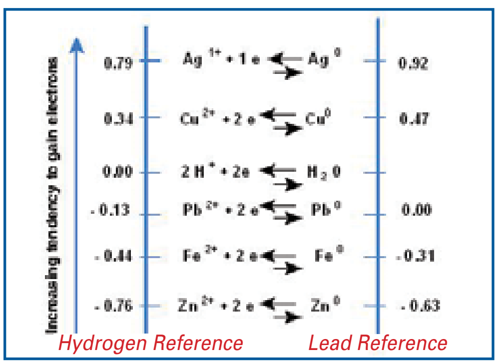
Spontaneous Electrochemical Reactions

Several concepts concerning spontaneous electrochemical reactions can be easily developed or demonstrated in the laboratory.

- Oxidation and Reduction
- The Electrochemical Series
- The effect of ion concentration on cell potential (The Nernst Equation).
- The effect of the number of electrons transferred on the slope of Nernst Equation data.

These experiments involve only a MicroLab 528, its voltage test lead, and MicroLab's **Model 152 Multi-EChem Half Cell Module.**

This module provides space for eight user-designated electrochemical metal/ion half-cells. These cells are coupled by small channels to a central aqueous potassium nitrate salt bridge surrounded by a polyethylene barrier with 20-60 micron pores. This barrier prevents mixing of the half-cell solutions and provides adequate motion of ions to maintain an extremely stable cell potential.



The Electrochemical Series orders ions and elements in terms of increasing tendency to gain electrons. Any half reaction can take electrons from any half reaction below it. Left scale numbers use hydrogen as a reference electrode (convention), right scale numbers are from a MicroLab experiment using lead ion/ lead as a reference. The order of the series is the same regardless of choice of reference.

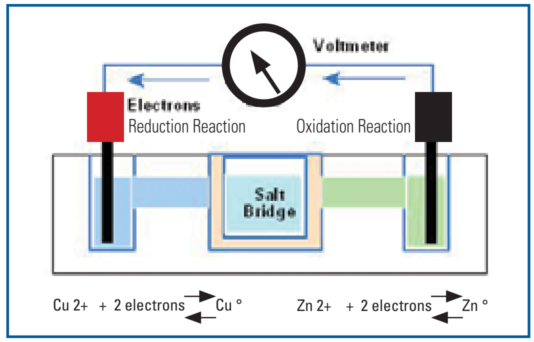
The Multi-EChem design provides three advantages:

(1) Connection of half-cell pairs is easily implemented and clearly visualized.

These may be different metal/ion pairs to develop the electrochemical series, or different concentrations of the same metal/ion pair to create concentration cells.

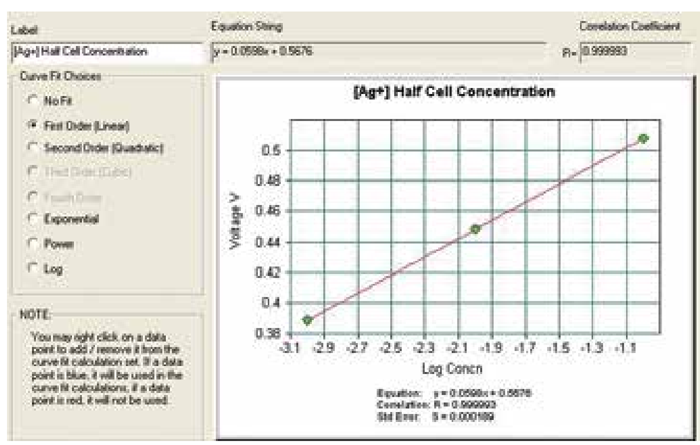
(2) The salt bridge does not dry out and electrochemical cell voltages are extremely stable for long periods of time.

(3) The polypropylene body of the module is rugged and chemically resistant. Its non-skid feet keep it securely in place on the lab bench. It will have a long service lifetime.



One can experimentally develop the electrochemical series by comparing a series of metal/ion pair half cells against one "reference" metal/ion half cell.

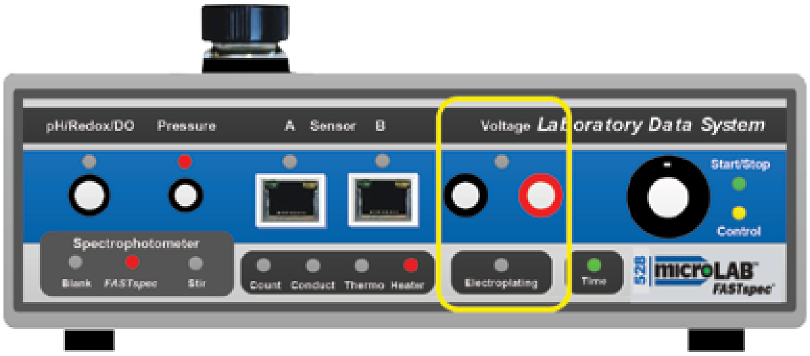
*The **Model 152** Multi-EChem Half Cell Module has space for eight half-cells, each equally accessing a central salt bridge through a porous cylinder. A milled "overflow" area prevents spills and mixing of solutions. A positive voltage reading indicates that electrons are running into the black lead from the oxidation reaction and out of the red clip to the reduction reaction.*



This plot of log [Ag+] concentration vs cell voltage confirms the Nernst equation prediction that cell potential will be directly proportional to log [Ag+]. The slope is 0.0598 volts/decade.

Multi-EChem Half Cell Module.	
Solution volume for each half cell:	3.2 mL
Overflow volume for each half cell:	2.5 mL
Salt bridge well volume:	3.2 mL
Mass:	196 g
Dimensions:	10.1 cm diameter x 3.1 cm high
Stability over time:	Better than 1 mV over 30 minutes

Forced Electrochemical Reactions



Electrochemistry is somewhat of a step-child in the general chemistry curriculum.

Often left for quick treatment at the end of the semester, "hands-on" electrochemistry labs are thought difficult and expensive.

This need not be true. Here are some new tools that use small samples and will make electrochemistry understandable, affordable, easy and fun to teach – and to learn!

MicroLab 528's black and red "Voltage" banana jacks play double duty. For **spontaneous electrochemical experiments** such as the electrochemical series and the Nernst equation, they measure DC voltage ± 2500 mV with a resolution of ± 0.076 mV.

For **forced electrochemical experiments** such as electroplating, these banana jacks provide an adjustable regulated 0-5 volt DC power supply delivering up to 750 mA.

The **Model 272 Electrochemistry Module** provides a controlled voltage and integrates instantaneous current for electroplating (electrogravimetric) experiments, or for coulometric titrations that generate the titrant through electrochemical oxidation or reduction in a solution.

Experiments include:

- Electroplating - qualitative demonstration of electrochemical reduction and its industrial applications.
- Electro-gravimetric experiments - measurement of mass and charge transfer. Given experimental data for mass, coulombs of charge transferred, and any two of the three following parameters, calculate the third: (a) Avogadro's number, (b) Ionic charge, and (c) atomic mass.

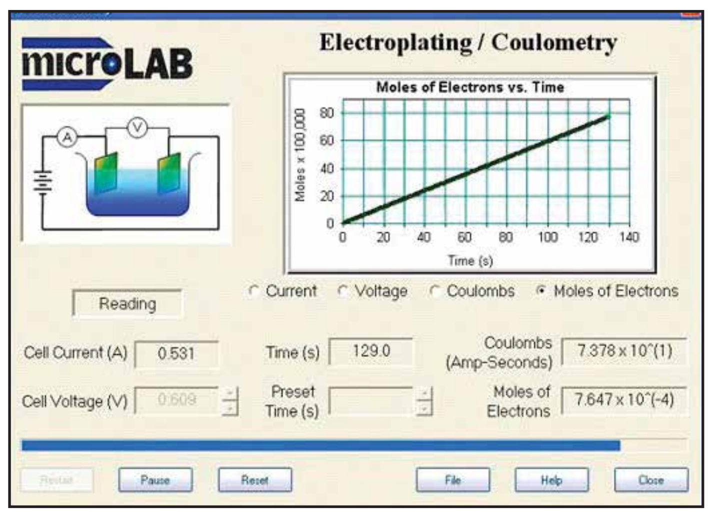
"Microlab software is not just easy to use. It is also the kind of software, with it's logic and graphical interface, that prepares students to make the transition to PC-based software in high-end stand-alone instruments like HPLC, NMR, and UV-Vis in research and advanced courses as well as on the job."

Dr. Mike Collins, Viterbo University

Determination of Atomic Mass

MicroLab's Electroplating / Coulometry software permits the student to set the voltage applied to the electrochemical cell and to monitor time, cell current in amps, and coulombs of charge and moles of electrons delivered during the experiment. Data from an electroplating experiment to determine the atomic mass of copper is illustrated in the box below. This data shows an experimental atomic mass for copper of 61.3 grams/mole.

–Data from Dr. Tim Sorey, Central Washington University.



<u>**Determining the Atomic Mass of Copper**</u> Ionic charge = +2. Reduction equation: $Cu^{2+} + 2e \rightarrow Cu^0$

Duration of experiment: 912 seconds Voltage: Held constant at 0.65 volts. Average Current: 0.52 amps (current sensitive to electrode size and spacing)

Mass of copper deposited: 0.155 g (carefully dry and weigh electrode after experiment is complete)

Number of coulombs delivered: 474.2 coulombs (from display)

Number of moles of electrons delivered: 4.92×10^{-3} moles (from display)

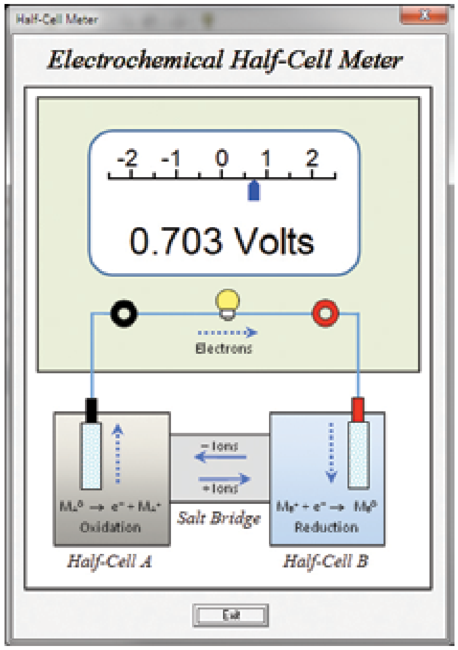
Each atom of Cu^{2+} requires two electrons:

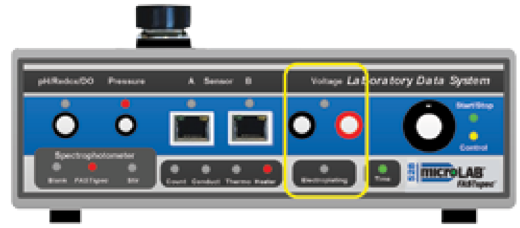
Number of moles of Cu atoms: (4.92×10^{-3} moles electrons) * (1 mole Cu atoms / 2 moles of electrons)

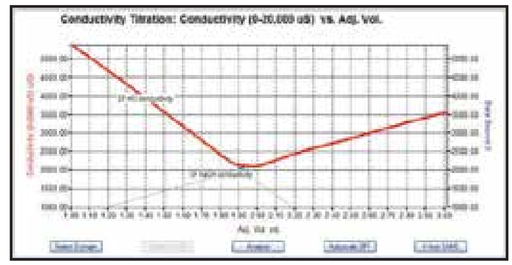
Atomic mass = (0.155g Cu) / (2.46×10^{-3} mole Cu) = 61.3 g/mole. Accepted value 63.5 g/mole

Which Way Do Electrons Go?

For a beginner, probably the most difficult part of an electron-transfer experiment is figuring out which way the electrons are moving. In the old days we had center-zero moving needle galvanometers, and you could see which way the needle leaned. Today we have digital voltmeters that protest if the electrons are going the "wrong" way by putting a negative sign in front of the voltage number. The convention is that electrons running into the black (negative) lead of a voltmeter produce a positive voltage display.







This graph shows conductivity change during a titration of silver nitrate with sodium chloride. Minimum conductivity occurs when all of the silver ion is converted into insoluble silver chloride.

MicroLab's electrochemistry software display can help with this. It gives three types of display:

- If electrons go in the black FS-528 voltage jack, the meter reads to the right and the voltage sign in the digital display is positive.
- Blue arrows show the direction of electron motion, and a light bulb lights up to show the motion of electrons though a load.

Generic oxidation and reduction reactions are written in the correct direction.

If the position of the cells is reversed placing the oxidation reaction on the right, the meter reverses, the voltage sign turns negative, the electron motion arrows turn red and reverse, and the reactions reverse.

Conductance Sensor

Use the **MicroLab Model 160** Conductance Sensor to measure accurately the conductance of solutions. The sensor is very useful for measuring the salinity of environmental samples, for measuring total dissolved solids (TDS), or for tracking titrations which consume or produce ions.

Chemical concepts such as solubility, weak and strong electrolytes, acids/bases can be explored easily.

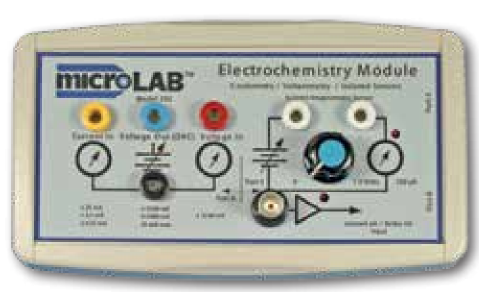
Conductance Ranges: 0-2,000 uS, resolution 0.03 uS

0-20,000 uS, resolution 0.3 uS

Cell Constant: 1.0

Electrochemistry Module
Coulometry / Voltammetry / Isolated Sensors

MicroLab's Model 292 Coulometric Titration Module connects coulometry and voltammetry experiments to MicroLab's Port A general purpose input.



Because the cell current in a coulometric experiment will interfere with other electrochemical measurements in the same solution, the Model 292 module includes circuits used in medical electronics to provide 2 kV electrical isolation for the sensor amplifiers. pH, REDOX, ISE, and amperometric end points may be tracked with no interference between the coulometric titration and the monitoring electrode.

A manual control permits the operator to set the voltage applied to the amperometric detector.

Redox – ORP Electrode

The **Model 125** Redox Electrode is useful for oxidation reduction potential titrations. It includes a gel filled reference electrode and connects to the MicroLab interface via the BNC input plug.

Voltage Range with any of the MicroLab interfaces: +/- 2500 mV

Resolution: 76 μvolts

Connector and Cable: 30 inch cable with BNC

Model 133 - **Dual banana plug voltage lead** for four-range AC/DC voltage input of the 507, 522, 524, 528.

Cable Length: 18 inches

Four Voltage Ranges:

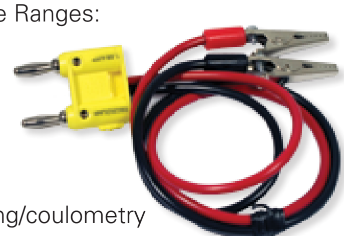
± 100 mV

± 1.0 volt

± 2.5 volts

± 10.0 volts

Electroplating/coulometry power out: 0-5 volts, 750 mA max.



Inquiry, Experiment Design, and Software

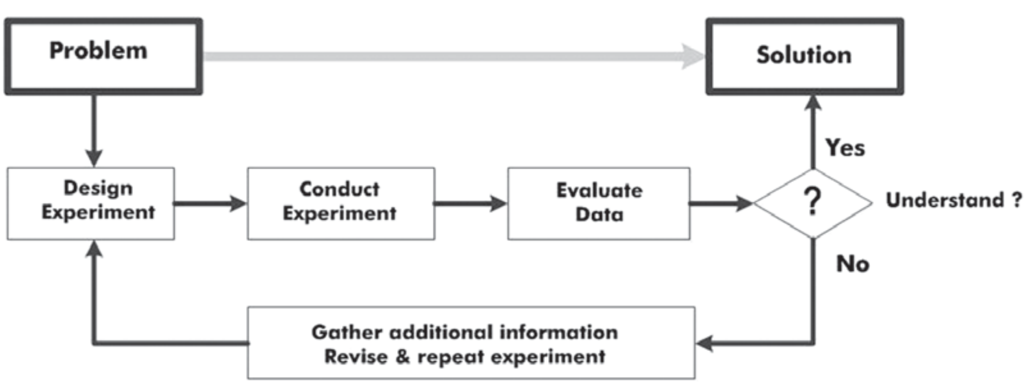
Computers can do a lot more for your lab students than just quickly collect data using small, inexpensive, and safe samples. Both POGIL and the Science Writing Heuristic advocate an inquiry process that starts with a question about a real chemical system.

Experiment design, data analysis, and evaluation are the most complex parts of an experiment. With MicroLab, fast data acquisition gives time during the lab period for students and instructor to work together on experiment design and data analysis.

Students and their instructor turn these questions into an experiment. They conduct the experiment, discuss, analyze and evaluate their results, and use their observations to develop a model of the system – a model that explains the behavior they observe.

With additional runs through this plan / work / evaluate cycle, students can test and improve their model, and can build better understanding of the chemical concept.

Because data acquisition with MicroLab is fast, there is time at the beginning of the lab period for students and instructor to work together to design the experiment, and time later in the period to evaluate and analyze the data. They have time to revise and run the experiment again if necessary.



FS-528 Performance Specifications

BNC Input:

pH 0-14 pH, resolution 0.0015 pH unit
Standard industrial pH electrode

REDOX ± 2500 mV, resolution 76 μV
Standard industrial REDOX electrode.

Dissolved Oxygen, Galvanic sensor
0-14 mg/L, resolution 0.0025 mg/L

Ion Selective Electrodes ± 2500 mV
Uses standard industrial BNC IS electrodes

Pressure

0-2 atm (0-1500 torr), resolution 0.04 torr. Factory calibrated in torr, atm, inches Hg, kPa. Leur-lock input fitting

MicroLab Multi-purpose Sensor Inputs (2)

Industry-standard Category-5 data connectors accept MicroLab sensors (temperature, light, and many more) and user-designed sensors.

Voltage input: ± 2500 mV, Resolution 76 μV

Current input: ± 25.0 mA, 2.5 mA, 250 μA
Resolution 0.76 μ,A 0.076 μA, 0.0076μA

Digital to analog converter (DAC) output, ± 2.5 volts, 0-5 volts, 25 mA, 1 millivolt steps

Digital input: TTL Logic Levels . Amber LED indicates Logic 1 input.

Digital output: TTL Logic Levels. Source or sink 25 mA. Green LED indicates Logic 1 output. Software control of experiments

Sensor power supply:
±5 VDC, 50 mA, regulated

Heater

12 VDC, 0-20 watt, pulse width modulation

Electroplating / Coulometry

Adjustable / Regulated 0-5 VDC
750 mA, logs voltage, current, coulombs, moles of electrons delivered.

Thermocouple

Industrial type K thermocouple input,
-200 to + 1000 °C, resolution 0.04 °C

Banana Jack Voltage Input

Four ranges, software selected.
± 10 volts , ± 2.5 volts, ±1.0 volts, ± 100 mV
Resolution 300 μV, 76 μV, 30 μV, 3 μV

Conductance

0-2000 μS, resolution 0.03μS
0-20,000 μS, resolution 0.3 μS

Counter

TTL logic levels, for drop counter and radiation counters.

Independent software-controlled timers

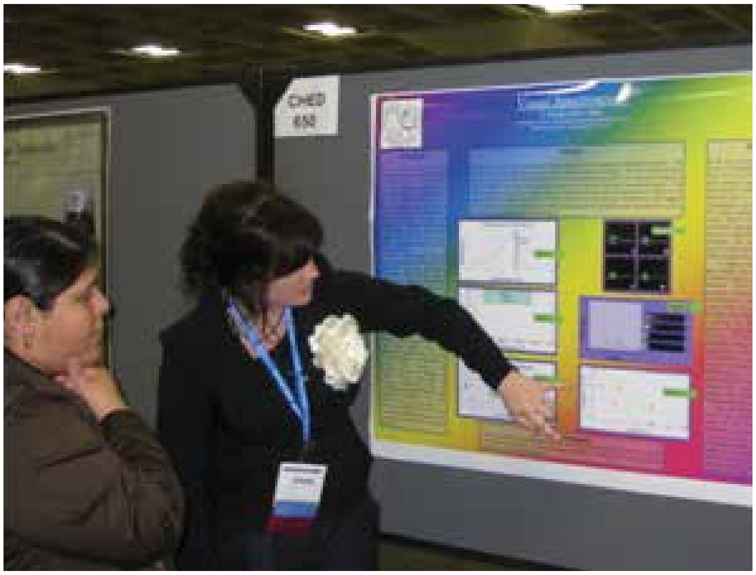
(Two) Read in seconds, minutes, hours. Resolution 0.001 seconds. Real time clock, programmable.

FASTspec™ Scanning Spectrophotometer

360-880 nm, Simultaneous Fluorescence/ Absorbance / Scatter / Transmission, Color comparisons, Water quality tests. Timed Kinetics at 16 wavelengths. Turbidity & nephelometry at 880 nm international standard wavelength.

Power Supply

90-264 VAC, international power supply, or 12VDC for battery-powered field operation.



Undergraduate Research

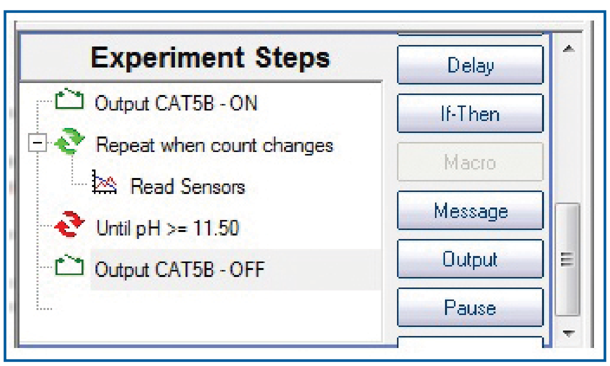
MicroLab's high quality data and software versatility suit it well to undergraduate research. Presented on this page are new products that save time for repetitive titrations in research projects, and which provide affordable access to reversible electrochemical systems. Undergraduate research engages students in inquiry and develops communication skills.

Automated Drop Dispenser

MicroLab's new **Model 254 Automated Drop Dispenser** adds a teflon-lined industrial control solenoid to our Constant Flow Drop Dispenser. Operating under software control from a the MicroLab 528 12VDC output, the 254 will stop titrations after a predetermined time period or when the solution reaches a predetermined pH, conductance, or other measured property.

This experiment control capability provides an introduction to closed-loop control typical of industrial processes and research experiments.

The program listed below will stop a titration when the pH exceeds 11.5 pH units.

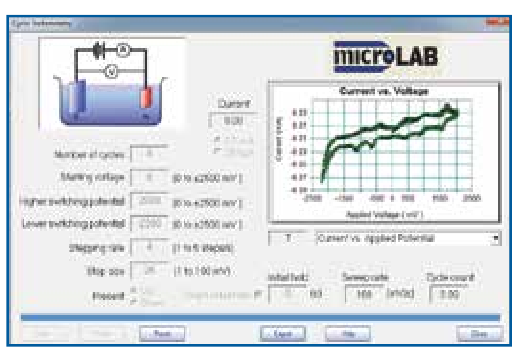


Cyclic Voltammetry:

MicroLab's affordable Model 170 Cyclic Voltammetry Module uses inexpensive Pine Instruments disposable screen-printed electrodes (10 included). It connects to the FS-528's Port A multipurpose input, will scan with 1-20 mV steps, and can plot current vs appolied voltage or current vs voltage referenced to an Ag/AgCl electrode.

Cyclic voltammogram of a phthalocyanine compound. Data by Dr. Erin Anderson, National Cancer Institute.

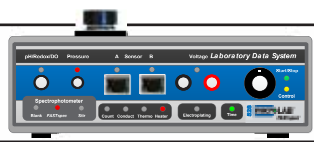
All MicroLab data may be exported into Excel for further analysis with a single mouse click.



MicroLab Equipment Packages

MicroLab instruments may be purchased in five different packages with increasing sensor capability. Additional sensors can be added later. When purchased as part of a "package" (listed here or you can design your own – please call) their cost is discounted. Sensor packages are listed by chemical measurement.

There are no hidden costs. With addition of a computer, MicroLab packages are completely operational on delivery. A site license for MicroLab's high quality software is included with every instrument. You may load the software on lab computers and college networks. Students may download free personal copies of the software from the MicroLab web site to make graphs and reports at home. Periodic upgrades are available free from the MicroLab web site. MicroLab software runs on PC's running XP, Windows 7, Windows 8, Windows 10, and on Mac's with Windows emulators.



MicroLab FS-528 Equipment Packages

Spectrophotometry		Intro FS-528-I	Advanced 528-A	Titrations FS-528-T	Conductance FS-528-C	Comprehensive FS-528-C2
Absorbance/Transmission Beer's Law, Kinetics Fluorescence, Turbidity, Backscatter Beer's Law path length experiments Controlled temperature kinetics	Integrated ***FASTspec*** ***380***-880 nm scanning spectrophotometer	●	●	●	●	●
	Model 183 Vial Pack and two stir bars	●	●	●	●	●
	Model 186 multi-path length dapter/Vial pack					●
	Model 257 20 Watt Heater		●	●	●	●
Thermochemistry / Gas Laws						
Freezing/boiling points Supercooling Heat of reaction Absolute zero Boyles Law Vapor pressure	Model 103 Thermistor	●	●	●	●	●
	Integrated 0-2 atm pressure sensor	●	●	●	●	●
	Model 2011 Gas Pressure Syringe	●	●	●	●	●
	Model 116 Gas Pressure Apparatus					●
	Model 109 Stainless Steel Thermocouple					●
Acid-Base Chemistry / Titrations						
Titrations Visual and spectrophotometric indicator end-points.	Model 106 Sample Illumination Module	●	●	●	●	●
	Integrated rotating magnetic field stirring	●	●	●	●	●
pH, buffers, Ka, Indicators, titration curves, spectrophotometric titrations	Model 121 pH electrode		●	●	●	●
	Model 107 pH electrode holder		●	●	●	●
	Model 136 Micropipette, 100 uL		●	●	●	●
Drop-counting titrations Titration Curves 1st & 2nd derivative plots	Model 226 IR Drop Counter, non-corroding clamp			●	●	●
	Model 154 Constant Volume Drop Dispenser, non-corroding clamp			●	●	●
Electrochemistry						
Electroplating, Avogadro's number Atomic Mass	Integrated 0-5 volt, 750 mA regulated power supply	●	●	●	●	●
Half-Cells Electrochemical Series, Nernst Equation	Model 133 Voltage Lead	●	●	●	●	●
	Model 151 Metal Kit		●	●	●	●
	Model 152 Half-cell module		●	●	●	●
Ionization Conductance Titrations	Model 160 Conductance Electrode				●	●
Redox Titrations	Model 125 Redox Probe					●

MicroLab Special Topic Packages

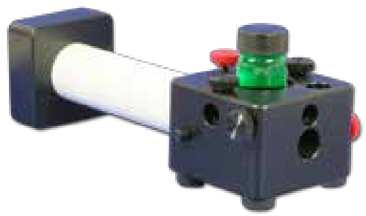
Atoms First: Light, Energy, and Atomic Models

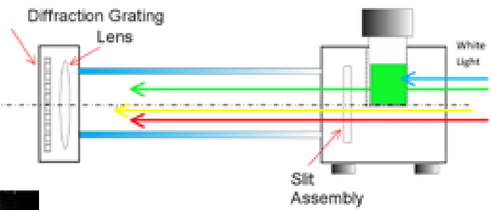
Faculty using an "Atoms First" general chemistry organization experience a vacant spot early in the general chemistry lab. They are discussing atomic spectra, electron structure, and bonding. Traditional lab topics of reactions and wet chemistry don't fit. MicroLab's "Atoms First" experiments provide hands-on experience with light and color, Planck's Law, atomic spectra, and atomic models.

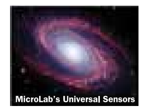
MicroLab's patented **Model 141 Visual Spectrometer** is rugged, affordable, and easy-to-use. Couple it with a point-and- shoot, cell phone or Web camera, the included fiber optic reference spectrum adapter, and free Image J pixel analysis software from the National Institutes of Health, and you have a powerful calibrated emission spectrophotometer with 1 nm resolution.

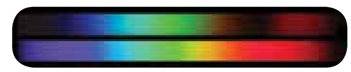
Students can observe and measure both atomic emission spectra and molecular absorption spectra.

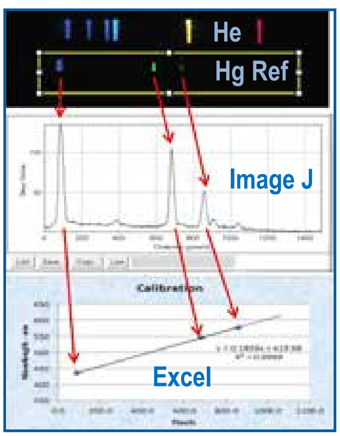
Absorption spectrum of the sample is viewed above the reference spectrum.

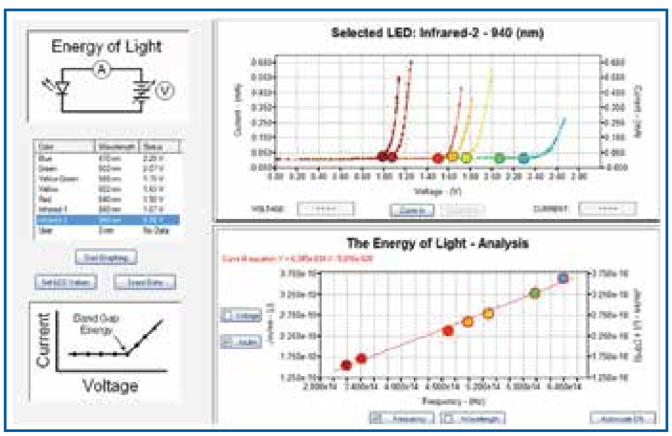










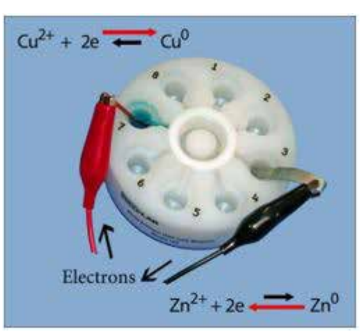


Our new interactive **Model 214 Energy of Light** module uses measurement of LED bandgap energy to demonstrate the energy and color of light, and to determine Planck's constant ± 5%.

Getting Started in Electrochemistry

Here is a quick, affordable way to get your students started with electrochemistry. The MicroLab electroplating / conductivity and half-cell modules are unique, rugged, require small amounts of chemicals, and will last a long time. To explore electrochemical series and Nernst equation experiments, your students must be able to measure voltage. This can be done with a MicroLab FS-522/524/528, another brand of lab interface that measures voltage, or a simple digital voltmeter that you might have on hand, purchase locally, or purchase from MicroLab.

The metal kit contains two each 5 cm lengths of wire representing seven elements: Cu, Ni, Fe, Pb, Zn, Al, and Ag (one wire) Sandpaper is provided to clean the metal samples before each measurement. Sample experiments are available on our web site.



Model 232 half-cell Module

Model 151 Metal Kit

Model 232 Electrochemistry Module

MicroLab's Model 141-CPM Cell Phone Mount will accept almost any cell phone with any camera placement. The tilted mount places the center of view in the spectral green at about 550 nm, with red to the outside and violet to the inside. Because there is almost no background light in the system, the camera sensitivity will increase to detect very dim spectral lines. The user can zoom the camera display to increase the visible resolution. It produces excellent results with both emission and absorption spectra.

SAMPLE MICROLAB COLLEGE AND UNIVERSITY ADOPTIONS

RESEARCH UNIVERSITIES

- Auburn University, AL
- Columbia University, NY
- Kansas State University
- Montana State University
- North Carolina State University
- Northwestern University, IL
- Rensselaer Polytechnic Institute, NY
- Rice University, TX
- The University at Albany, NY
- University of British Columbia
- University of Georgia
- University of Nevada - Las Vegas
- University of Texas - El Paso
- University of Western Ontario

COMPREHENSIVE UNIVERSITIES

- California State University - Bakersfield
- California State University - Northridge
- California State University - Stanislaus
- Colorado State University - Pueblo
- Delaware State University
- Florida International University
- McNeese State University, LA
- Missouri Western State University
- North Carolina Central University
- Prairie View A&M University, TX
- Southeast Missouri State University
- University of Alaska - Anchorage
- University of Michigan, Flint
- University of Massachusetts, Lowell
- University of North Carolina - Wilmington
- University of the Virgin Islands
- West Chester University, PA
- Youngstown State University, OH

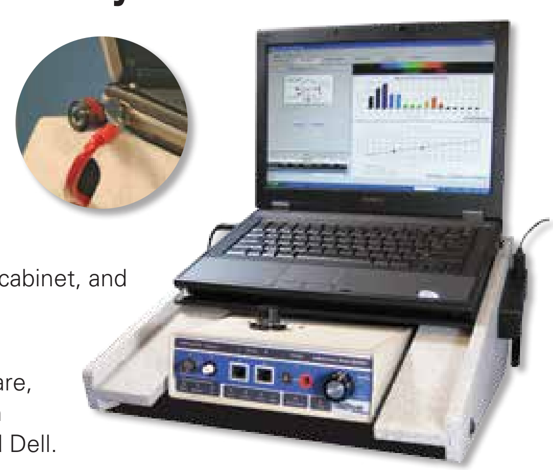
FOUR YEAR COLLEGES/ UNIVERSITIES

- Brigham Young University, HI
- Carroll University, WI
- College of St. Benedict/St. John's University
- Eastern Oregon University
- Gonzaga University, WA
- Hope College, MI
- Indiana Wesleyan University
- Luther College, IA
- Montana Tech
- St. Mary's University, MN
- Spring Arbor University, MI
- University of St. Thomas, TX
- U.S. Military Academy, West Point
- Valparaiso University, IN
- Viterbo University, WI

TWO YEAR COLLEGES:

- American River College, CA
- Bismarck State College, ND
- Brazosport College, TX
- Columbia Basin College, WA
- Eastfield College, TX
- Houston Community College, SW, TX
- Middlesex Community College, CT
- Midland Community College, TX
- Mount Hood Community College, OR
- Mott Community College, MI
- North Iowa Area Community College
- Pasco-Hernando CC, FL
- Raritan Valley Community College, NJ
- Richland College, TX
- Salt Lake City Community College, UT
- San Jacinto College, TX
- Stark State College of Technology, OH
- Tidewater Community College, VA
- Washtenaw Community College, MI

MicroLab's Compact Laboratory: Solving Bench Space and Security Problems



Adequate bench space and computer security are problems in many labs. MicroLab's Compact Laboratory – the **MCL** - can help.

MCL integrates MicroLab's FS-528 ***FASTspec***™ lab interface, sensor storage, and a portable computer in a compact, rugged, and easily secured package.

MCL's 14.5" x 17" footprint on a lab bench is just slightly larger than an open laboratory manual. The computer keyboard is safely located five inches above the lab bench. Non-skid rubber feet hold the cabinet securely in place. Inside storage secures the computer power pack and cables. Only AC power, mouse, and network cables leave the cabinet, and networking can be provided wirelessly. The cabinet can store vertically to save space.

The MCL cabinet can be purchased separately, or for convenience as a package containing a MicroLab FS-528 lab interface, a Dell computer with mouse, sensors, software, and the compact desk cabinet with sensor storage and security cable. There are no hidden costs and only one item to order. Warranty and support are provided by both MicroLab and Dell.

MicroLab Compact Laboratory	
Model 802 MCL MicroLab Compact Laboratory Cabinet	
Model 802 MCL Cabinet plus Dell Latitude 14 5000 Series network-certified laptop computer, USB mouse, security cable and lock	

March 22, 2020

COMPUTER-BASED DATA ACQUISITION TOOLS AND SOFTWARE FOR CHEMISTRY

MicroLab's FS-528 *FASTspec*™

NEW 5th Generation Features!

Constant Temperature Heater System
Sample Illumination
Rotating Field Magnetic Stirring
Real-time Tactile Control
Regulated Electroplating/Coulometry Power Supply
Cyclic Voltammetry

*FAST*spec™ Scanning Spectrophotometry 360-880 nm

Patented *FAST*spec™ Technology
Fluorescence
Absorbance
Scatter
Transmission
Beer's Law
Kinetics
Spectral Profiles
Color Comparison
Turbidity / Nephelometry
Backscatter Turbidity
Spectrophotometric pH/ Indicator Titrations

Basic Measurements

pH/Redox /DO
Gas Pressure
Temperature
Light
Conductance
Voltage/Electrochemistry
Time
Counts/drops
Thermocouple
Volts/Millivolts
Milliamperes

PLUS, MicroLab's advanced software operates at four levels:

- **Prewritten programs provide quick, accurate data for proof-of concept experiments.**
- **Instrument programs provide intuitive display of complex spectrophotometric and electrochemical data.**
- **Drag-and-Drop Experiment design tools encourage inquiry experiments.**
- **Advanced programming tools support original research.**

Software

All MicroLab products include software and a FREE site license. You can place copies of the software on all your departmental computers, at common access points for students, or even make copies for students for their personal PC's.

Warranty

MicroLab equipment is designed and manufactured in the US. We stand behind the quality of our product and provide a five year warranty on all MicroLab products. If you ever have a problem with a piece of MicroLab equipment, call us and make it our problem.

An action or design is called **GREEN** *when it wastes little.*

- *Lab is the most expensive space and time in a college or university. In Chemistry and Biology, it is also potentially the most dangerous.*
- *Lab is the best place to engage students in real science, to become serious about developing inquiry skills, to practice safety, and to learn about sustainability.*
- *In a college or university chemistry laboratory, Green has a broader meaning than "waste little".*

GREEN *means…*

- *greater concern for safety.*
- *smaller chemical samples – often by a factor of ten.*
- *reduced cost and environmental impact.*
- *reduced requirement for air exchange, for water supply, and for space on the lab bench.*
- *using one small, affordable, and accurate instrument for many tasks.*
- *efficient use of laboratory time*

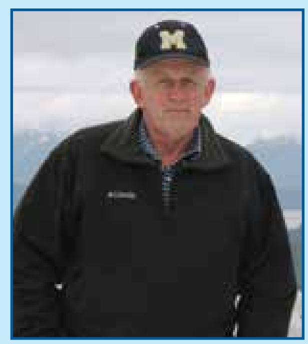
MICROLAB *brings these "Green" advantages into your laboratory. With three U.S. patents recently granted, MicroLab's technology and software are at the cutting edge. Our instruments and software are rugged, affordable, and quick to learn.*

MicroLab provides one more kind of "Green": reduced demand on faculty time. You can count on …

- *equipment and software that work;*
- *small samples that are easy and safe to prepare;*
- *students who are engaged and learning; plus*
- *immediate telephone or e-mail support from a team that counts more than 280 years of experience in college/university research and teaching.*

We look forward to visiting with you about your laboratory and curriculum needs.

John R. Amend, President **Norbert J. Pienta**, Chairman of the Board



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