# KRONOS

## Educational Flash Photolysis Spectrometer

**Ultrafast** SYSTEMS

**KRONOS**
Flash Photolysis Spectrometer

FLASH LAMP

LED

LENS

SAMPLE

LENS

FILTER    DETECTOR

**Ultrafast** SYSTEMS

This manual has been provided for information only and product specifications are subject to change without notice. Any change will be reflected in future printings.

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Should you experience any difficulties with your system or need any technical information, please visit our website at www.Ultrafast.Systems. Other technical support, warranty or non-warranty, should be forwarded to your local representative and Ultrafast Systems. Support can be obtained by phone (USA: +1-941-3602161; Europe: +421-233-418866) or email (support@ultrafast.systems).

Please provide us with your contact information, the model and serial number of the product, and a detailed description of the problem.

If an instrument or a component is to be returned, you will be given an RMA number, which you should reference in your shipping documents.

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# 1.   Preface

This document contains user information for the Kronos flash photolysis spectrometer. Kronos is conceived to be a simple, user-friendly device for demonstrating to chemistry students the fundamental principles of Chemical Kinetics.  Every process labeled as "chemical" occurs as the result of chemical bonds being broken or formed, i.e. nuclei change their spatial positions with respect to each other.  Chemical Kinetics is one of the major divisions of Physical Chemistry and is basically the quantitative study of the rates and mechanisms of chemical reactions.  Chemical change can be induced in a variety of ways; the one employed in Kronos is by absorption of light.  Thus, the instrument serves also as a way of introducing the student to the concepts and practice of Photochemistry.

Read this Documentation carefully before operating the spectrometer for the first time. Special attention should be given to Section 2: General Safety.

# 2.    General Safety

The Kronos flash photolysis spectrometer is designed and manufactured for kinetic analysis of chemical specimen by means of ultrafast transient absorption spectrometry. And it is not sold, nor intended for, nor should ever be used for any other purpose. The product should be used solely in accordance with the instructions provided.

## 2.1  Hazards

Take extra caution when operating or servicing this equipment:

- If this equipment is used in a manner not specified in this manual, the protection provided by this equipment may be impaired.

- Handle the cuvette with care. Check the cuvette for damage or cracks and replace any damaged ones immediately.

- Use extreme caution in handling the cuvette when it is filled with liquid. Always remove the cuvette before changing contents. Never fill or refill the cuvette when it is in the sample holder.

- The optimal operation temperature of Kronos is at or near room temperature.

## 2.2  Electrical Safety

Observe these general warnings when operating or servicing this equipment:

- Read all warnings on the unit and in the operating instructions.

- Kronos uses a large capacitor to charge the Xe flash lamp. Dangerous voltage levels are expected to persist even after unplugging the unit.

- Do not disassemble or open the spectrometer case. Doing so may damage the excitation light source and risk electric shock.

- Do not use this equipment in or near water.

- Dry the exterior of the cuvette prior to placing it in the holder. Using a cuvette with a wet exterior or one that is leaking liquid can result in malfunction, shorting of electrical components or electric shock.

# 3.  Product Specifications

**Table 1:** Product specifications of Kronos.

## General Specifications

| | |
|---|---|
| Footprint (L x W) | 135 mm x 105 mm |
| Weight | 1 kg |
| UL94 | V-0 |
| UL796 | Meets requirements |
| USB cable | 28 AWG shielded |
| Power source | USB connection<br>Supplied current: 500 mA<br>Supplied voltage: 5 V |
| Operating temperature | 15 to 40 °C |
| Operating relative humidity | 10 to 70% (non-condensing) |

## Spectrometer Specifications

| | |
|---|---|
| Spectral coverage | 450 -750 nm |
| Spectral resolution | Depends on the filter used. Typically, ~10 nm |
| Temporal resolution | ~100 µs |
| Time window | ≥ 15 ms |

## Detector Specifications

| Detector type | Silicon PIN |
|---|---|
| Active area | 3.6 x 3.6 mm (13 mm$^2$) |
| Wavelength range | 350 to 1100 nm |
| Rise time | 14 ns |
| Bias voltage | 10 V |

2.125

Manufacturer: Ultrafast Systems
Kronos Model: KR-6
Input: 5V DC
Max Current: 0.5 A

1.00

CE

Made in the U.S.A.
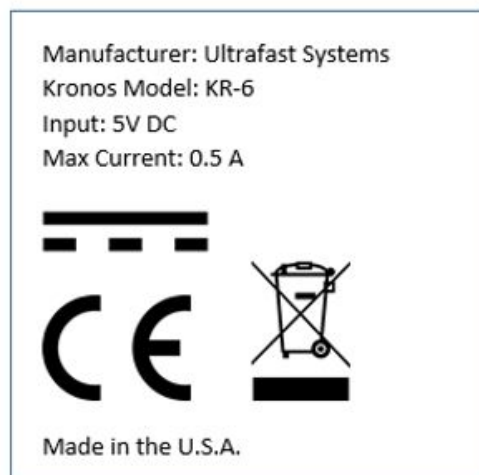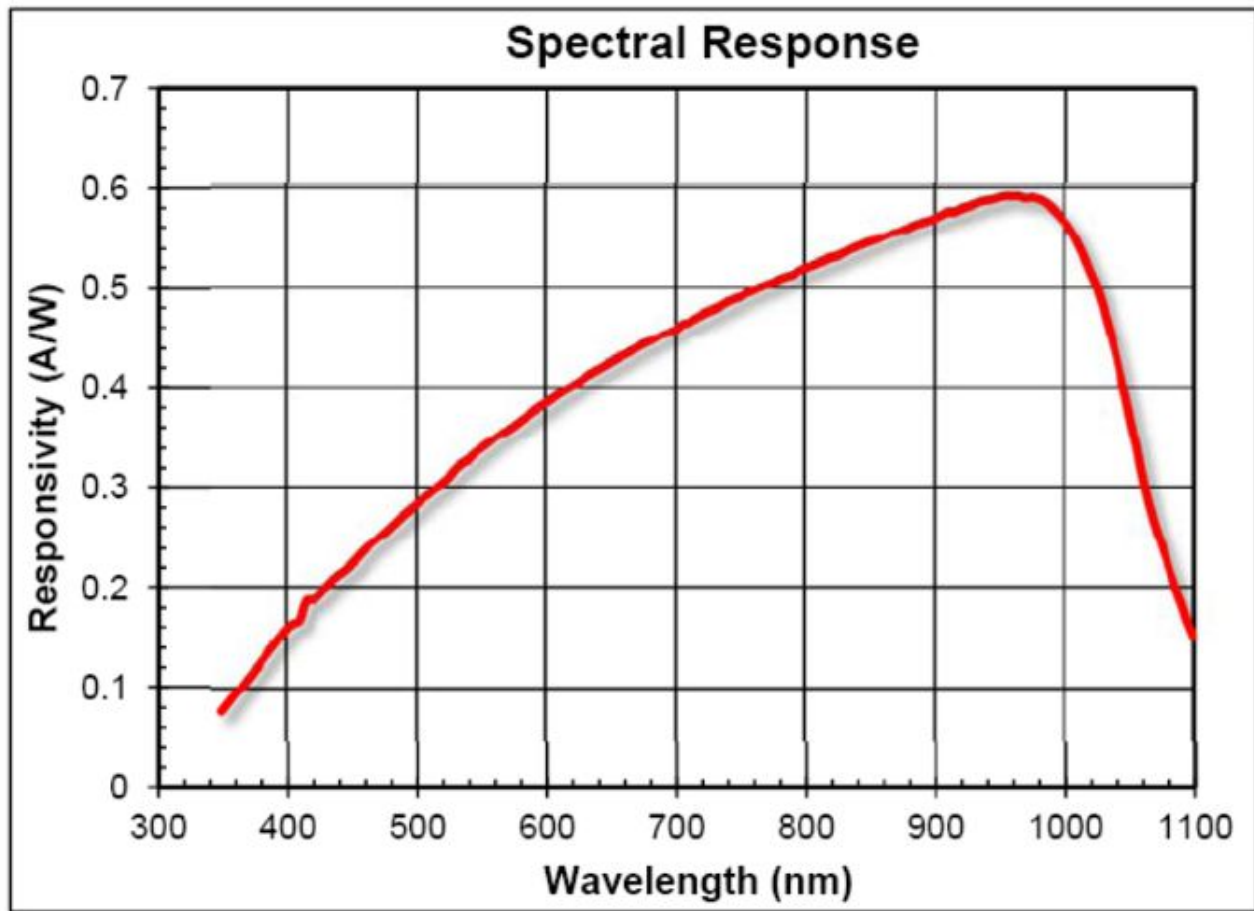
**Figure 1:** Spectral response of detector.

Kronos produces a 2-dimensional Time-Current data matrix in a form of an ASCII (.CSV file) which can be easily processed with free or commercially available spreadsheet or graphing software, e.g. Microsoft Excel, OriginLab Origin, etc.

# 4.   Unpacking and Inspection

The Kronos spectrometer is carefully packaged at the factory to minimize the possibility of damage during shipping. Inspect the box for external signs of damage or mishandling. Inspect the contents for damage. If there is visible damage to the instrument upon receipt, inform the shipping company and Ultrafast Systems immediately.

# 5.  Hardware

The Kronos is shown in Figure 2a and b, highlighting the simple design that makes Kronos very easy to use. Holes are machined into the housing which allows rapid replacements of standard square filters and cuvettes. The detection filters are mounted in a customized holder. Figure 2c shows the simplified optical layout of the Kronos.
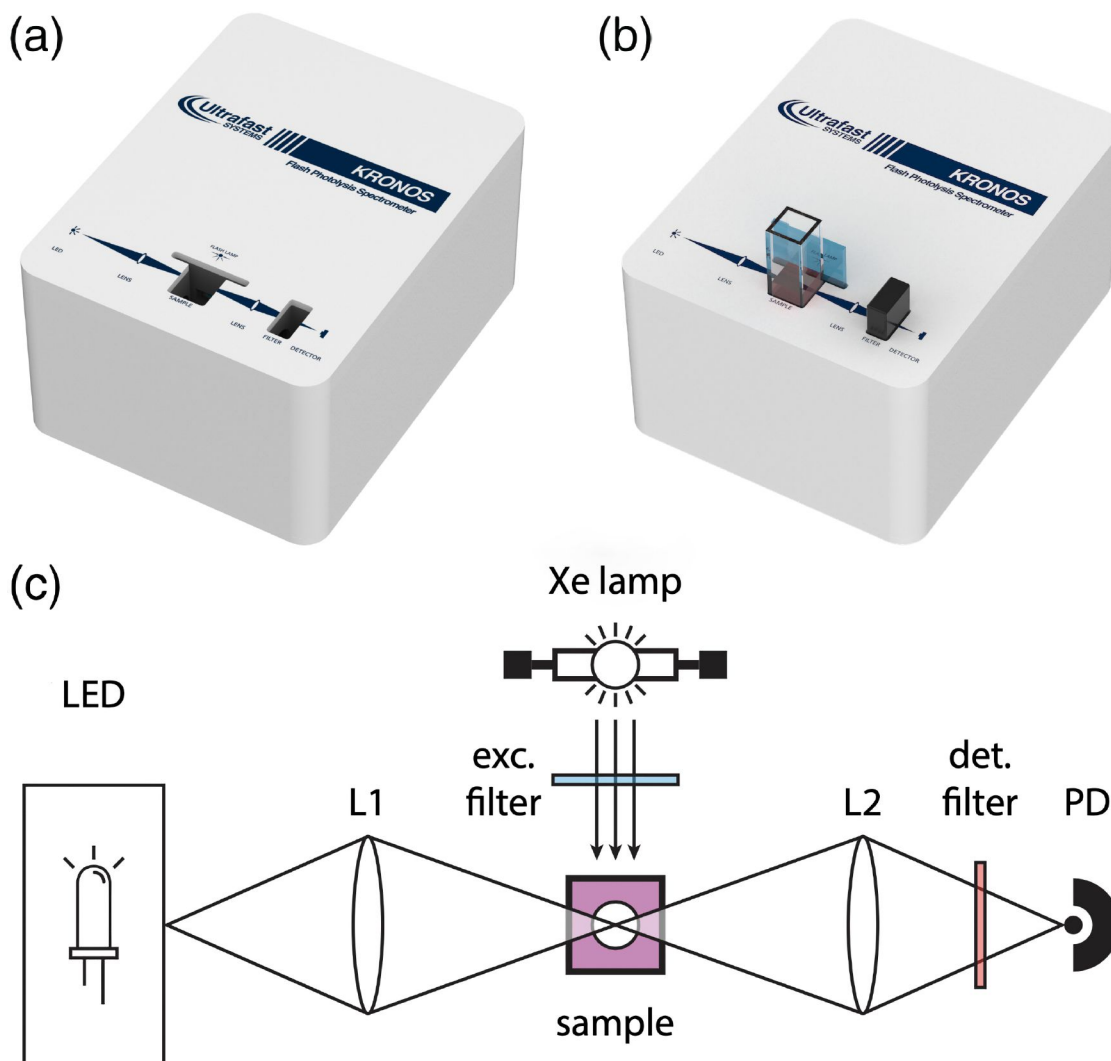


**Figure 2:** 3D render of Kronos

(a)  without components inserted

(b)  fully loaded with a cuvette, excitation, and detection filters

(c)  Schematic optical layout of the Kronos

**Table 2:** Kronos optical components.

| KRONOS | |
|---|---|
| **LED:** | LED probe source |
| **Xe lamp:** | Xe flash lamp pump source |
| **Sample:** | 10mm × 10mm cuvette holder |
| **L1, L2:** | Lenses |
| **PD:** | Silicon photodiode |
| **Exc. filter:** | Holder for 25mm × 25mm × 2mm filters (for excitation wavelength selectivity) |
| **Det. filter:** | Holder for 0.5"- diameter filters (for detection wavelength selectivity) |

**Table 3:** Excitation colored glass filters included with the Kronos.

| Excitation colored glass filters transmitted wavelengths (nm): | |
|---|---|
| 300-450 + >700 | 400-700 |

**Table 4:** Detection dielectric interference filters included with the Kronos with center wavelengths listed.

| Detection dielectric interference filters, 10 nm bandwidth, center lines at (nm): | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 450 | 480 | 500 | 520 | 540 | 560 | 580 | 600 | 620 | 640 | 660 | 680 | 700 |

# 6. Software

Table 5: UI elements in the Kronos software.

| ELEMENT | DESCRIPTION |
| --- | --- |
| Photodiode $I_0$ | Amount of probe light reaching the photodiode (Probe intensity, y-axis) |
| Range | Related to detector gain and LED intensity<br>**Absorption mode:** Leave it on Auto<br>**Emission mode:** Adjust the range slider to achieve sufficient signal-to-noise |
| Absorption/Emission | Select either Absorption or Emission experiment modes |
| Run | Starts measurement |
| Save | Save data in CSV format<br>**first column:** time, in units of seconds<br>**second column:** light intensity, in units of amperes |
| Exit | Exit the program |
| Average | Number of scans to average across |
| Time window | Time scan range (x-axis). Use smaller time windows for faster processes. |
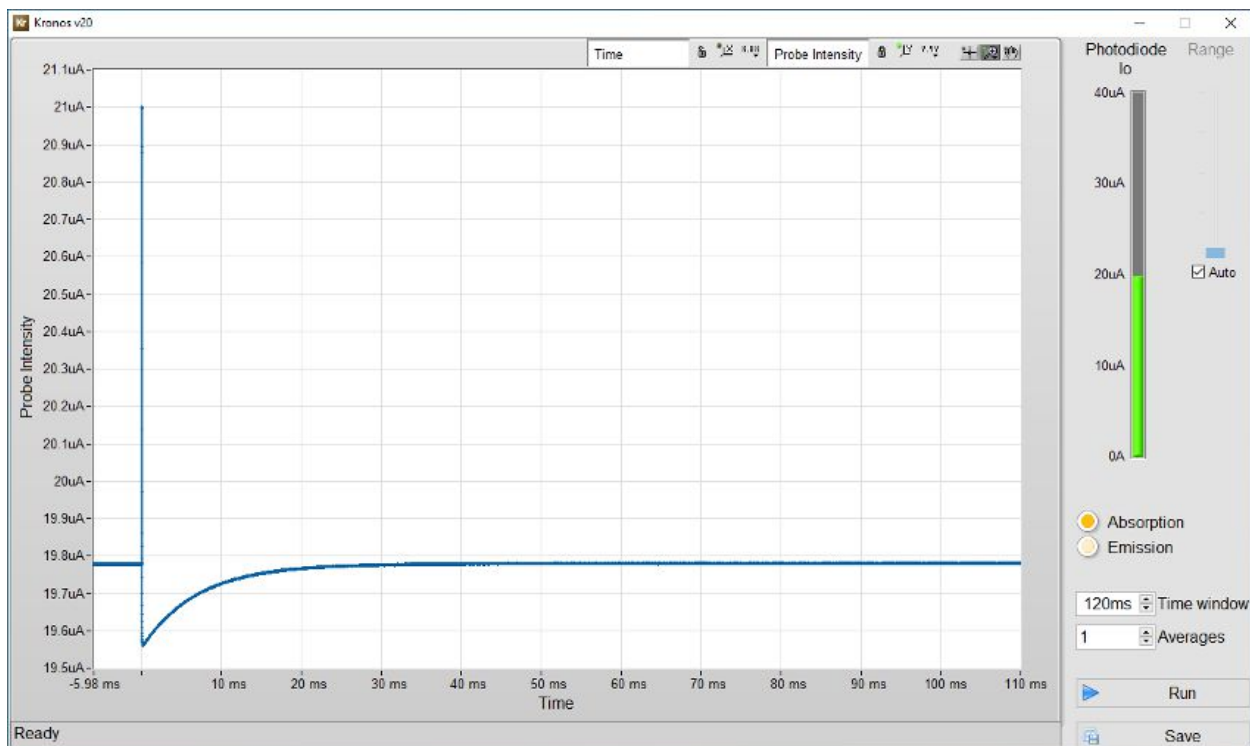
**Figure 3:** Screenshot of the Kronos software.

Figure 3 shows the Kronos UI. By default, the software will adjust the axis scales automatically: the Y-axis range will adjust to display the signal only, showing the large spike around time = 0. The default X-axis setting is "Auto Scale". To change this, right click anywhere on the plot and choose the desired option. Alternatively, you can use the graph controls on the top right of the screen, just above the graph display.

| ELEMENT | | DESCRIPTION |
|---|---|---|
| 🔓 | 🔒 | Axis Autoscale mode OFF and ON |
| X | Y | Autoscale axis once |
| ✋ | | Pan graph |
| 🔍 | | Select between graph zoom modes: |
| | | Select X and Y region to zoom in |
| | | Select X region to zoom in, keep Y limits unchanged |
| | | Select Y region to zoom in, keep X limits unchanged (default) |
| | | Autoscale both X and Y axes once to fit graph |
| ✛ | ✛ | Zoom out and in |

Table 6 shows the graph controls on the top of the screen allow you to zoom in the graph after measurements have been completed. By default, cursor mode on the graph is y-axis zoom.

# 7.  Using Kronos

## 7.1  Setting Up Kronos

The Kronos is initialized by follow the steps below:

1.  Connect Kronos to the PC via a USB cable.

2.  Wait until Windows recognizes the new USB device.

3.  Start the Kronos software. Refer to the Appendix if Kronos does not initialize the correct COM port.

## 7.2  Preparing Kronos for Experiments

Before performing any experiments, look for a white glow in the Kronos interior. This means Kronos is powered up. Remove any samples and allow the LED probe light to be incident on the photodiode and check that the photodiode meter displays a value. This will be I0, i.e., the baseline intensity before any pump-induced changes.

In absorption mode during data acquisition, the Kronos will wait for approximately 2 sec between flashes to allow enough time for the flash capacitors to recharge.

## 7.3  Choosing the Excitation and Detection Wavelengths

Kronos uses a Xe lamp and LED for the pump and probe light, respectively. Both are broadband light sources and their spectra is shown in Figure 4. By using an appropriate filter, one of the square colored glass filters, you can select which wavelength to pump (excite) the sample with, and what range of wavelengths is measured by the detector. The filters isolate the wavelength of interest by transmitting said wavelengths and blocking the others.

## Xenon flash lamp spectrum

(a)

## LED spectrum

(b)
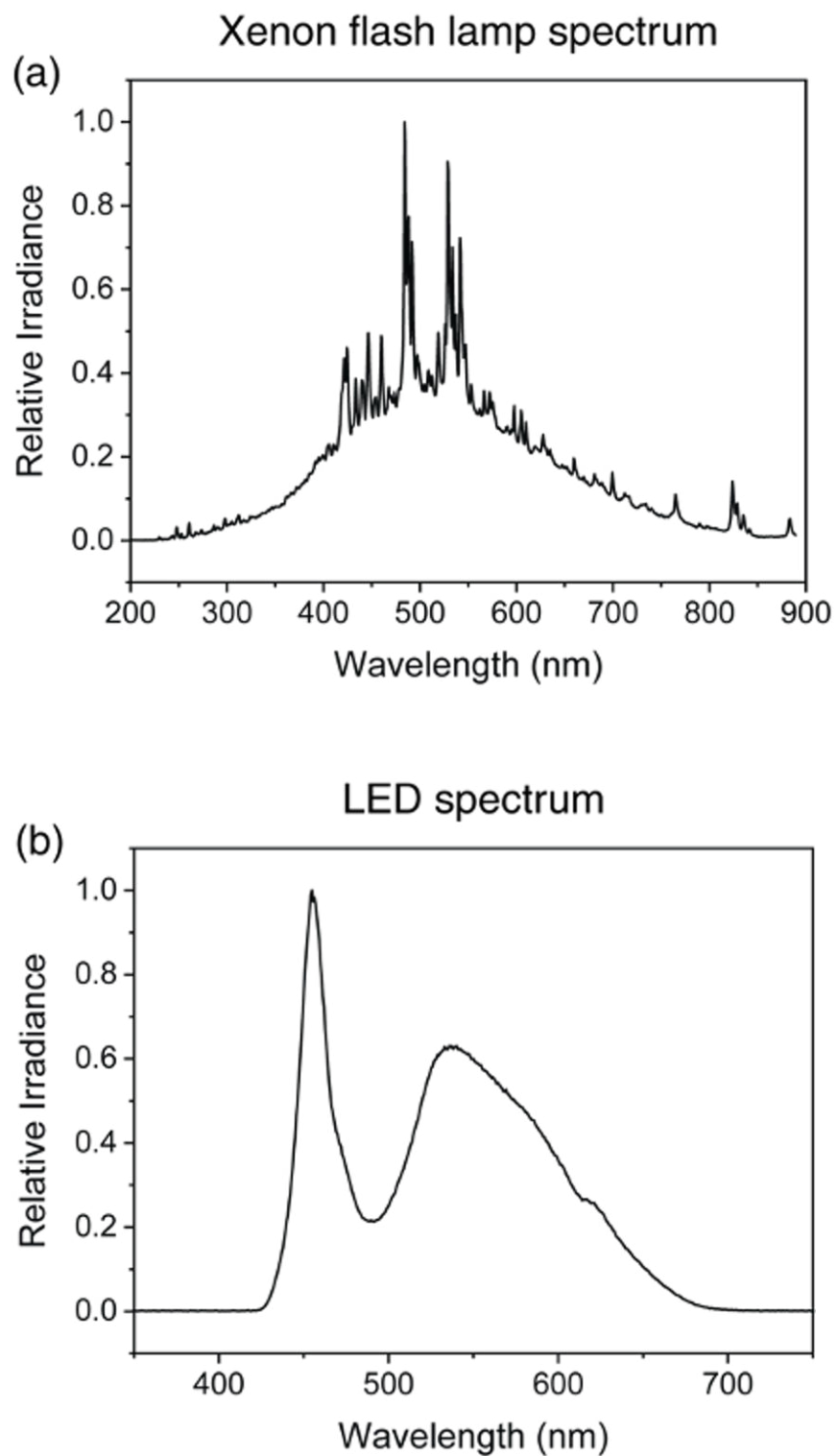
**Figure 4:** Spectra of Kronos light sources:

(a) Xenon flash lamp for the pump

(b) LED for the probe.

Figure 5 shows the transmission spectra of the two colored glass filters included with Kronos. Any incident light within the high transmittance regions can pass through the filters easily. For example, the dark blue filter, 300-450 nm + >700 nm, has high transmittance around 350 nm and allows the Xe lamp to function as a UV/blue light source. If you wish to pump with a separate wavelength region (e.g. 500 nm), simply use the lighter blue filter, 400-700 nm, which is transparent in that region.
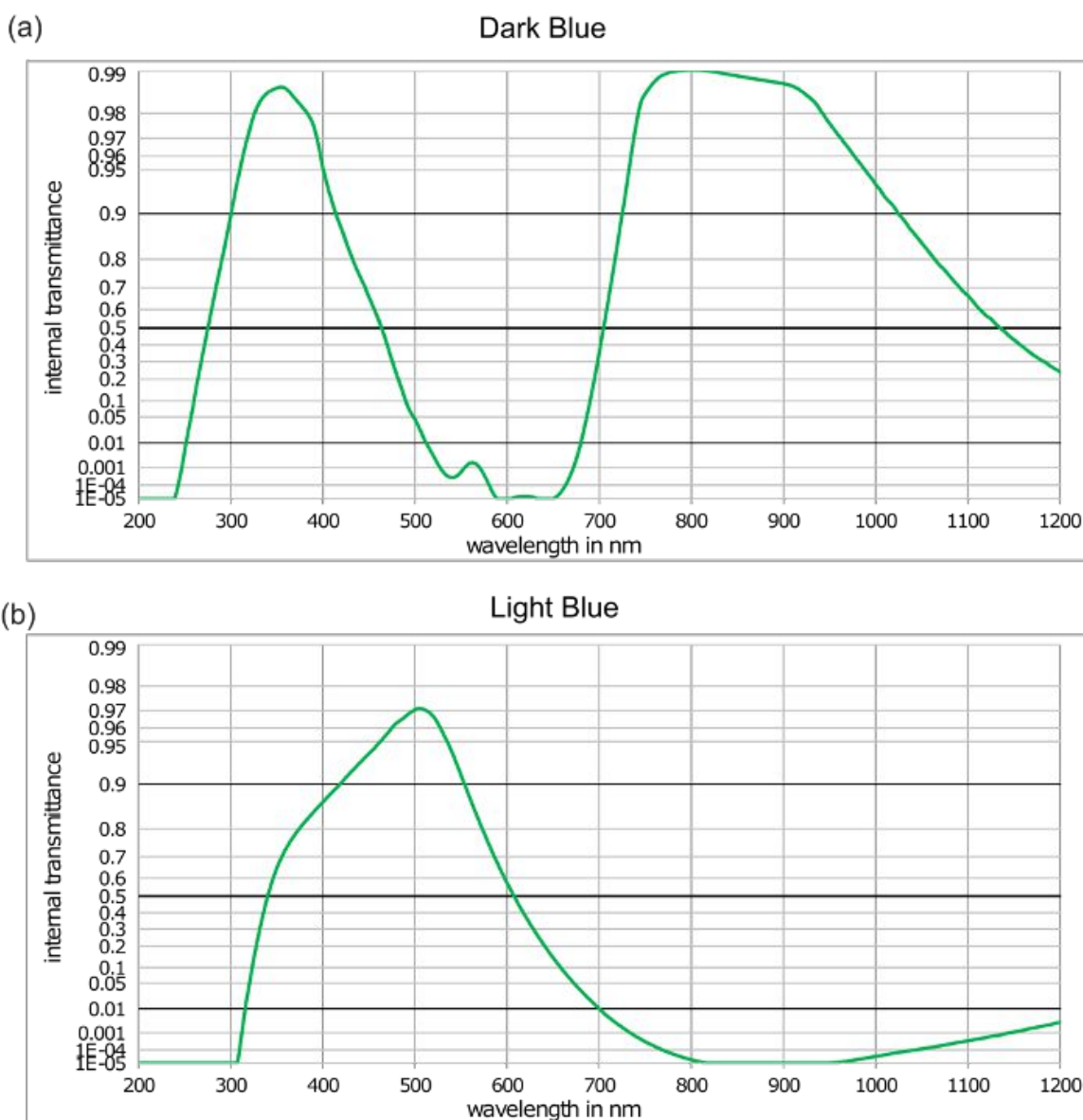


**Figure 5:** Transmission spectrum of

(a) dark blue or 350-400 + >700

(b) light blue or 400-700 colored glass excitation filters

The detection wavelength range is manually selected by using a 0.5" bandpass filter. The labeled broad rectangular slit on top of the Kronos housing accommodates one such filter mount. Figure 6 shows the transmission spectrum of the 600 nm bandpass filter included with Kronos. These filters have a bandwidth, or full width at half maximum of 10 nm (in this scenario, 595 nm to 605 nm). Any incident light within this bandwidth has high transmittance.
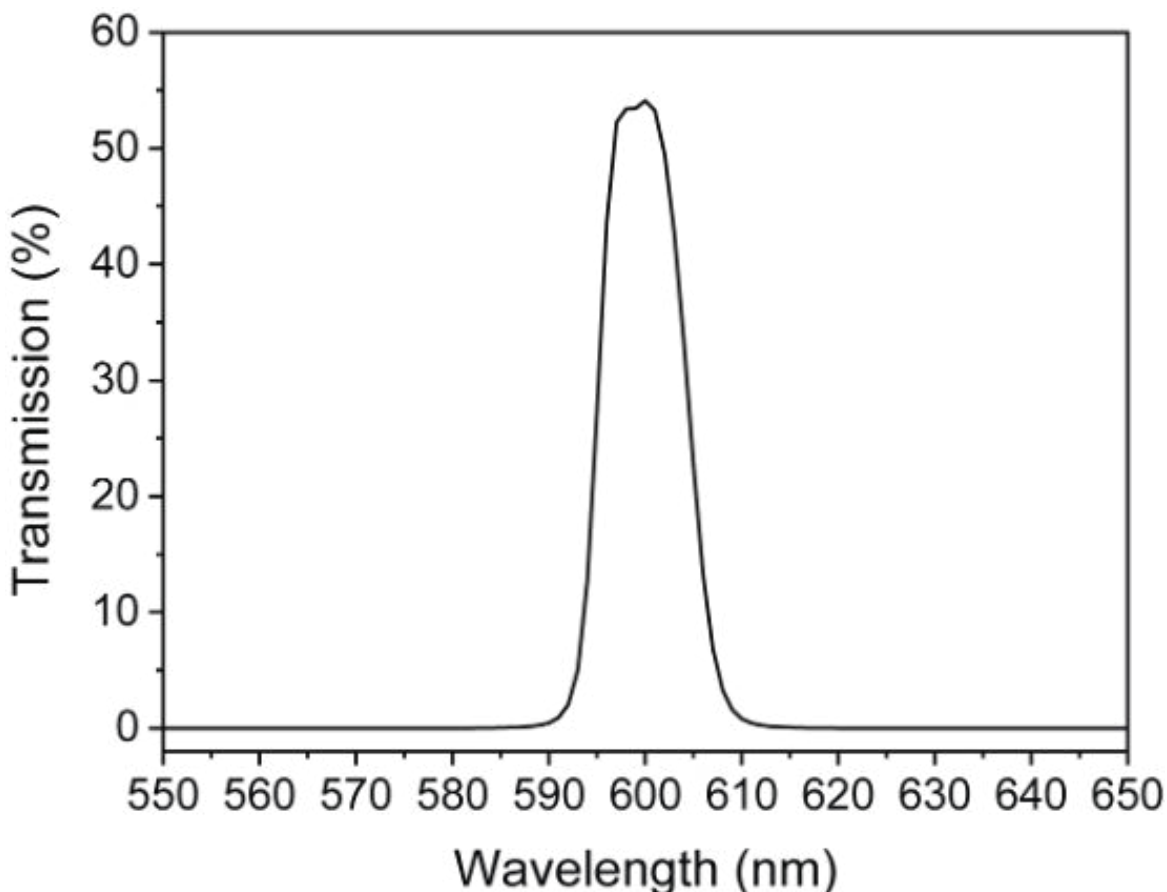


**Figure 6:** Transmission spectrum of 600 nm detection dielectric interference filter.

## 7.4  Acquiring Data

Place a filled cuvette into the sample area and select the appropriate parameters for averaging and time window. For absorption measurements, click on the Absorption radio button. Ensure the Range is set to auto and do not disable this for absorption measurements. The software will automatically adjust the detector gain and LED intensity. In absorption mode, both LED and Xe light sources will be activated.

For emission measurements, click on the Emission radio button. Make sure the Range is not set to Auto, i.e., the check box should be empty. In this mode, only the Xe source will be activated. Trial and error are required to select the appropriate Range using the slider to obtain good signal-to-noise.

Click on the <Run> button and allow the measurement to complete. You may notice a large spike (an artifact) in the first 50 μs present in the absorption kinetics. This is mainly due to electromagnetic interference in the circuitry and is intrinsic to the equipment. Since the temporal resolution of the Kronos is around 100 μs, you can safely reject the artifact and simply use the datapoints after the artifact.

Click on the <Save> button to save the data as a CSV file that can be processed in graphing or spreadsheet software. The file contains two columns: the first column is the time data, in units of milliseconds; the second column is the probe intensity data, in units of current (amperes). A sample graph is shown in Figure 7.
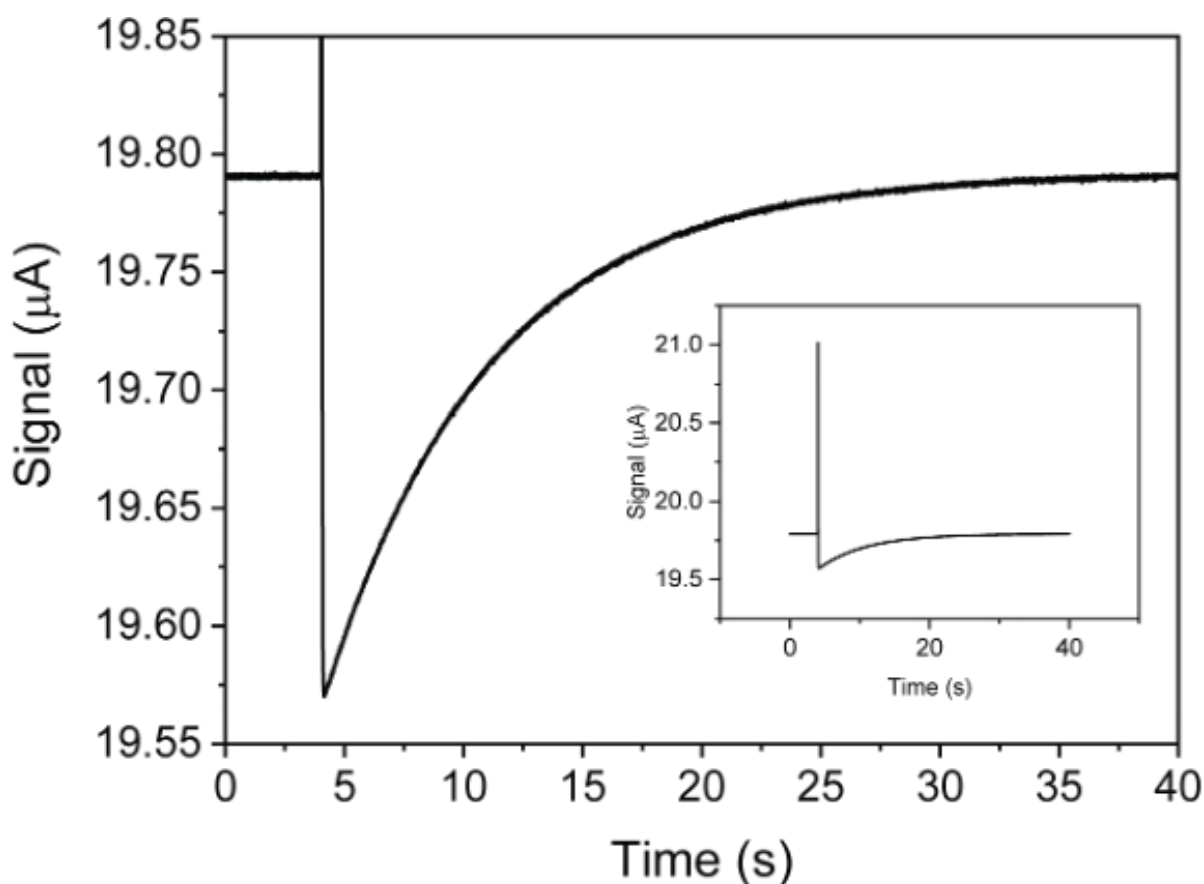


**Figure 7:** Various reference samples used for different experiments in Kronos. The inset shows the full curve; note the strong spike due to the flash lamp.

# 8. Familiarizing Yourself with the Reference Samples

**Table 7:** Various reference samples used for different experiments in Kronos.

| Experiment | Base catalysis of cis-trans isomerization of Congo Red | Activation Energy of One Spiropyran |
|---|---|---|
| Chemical | Congo Red | 1',3'-dihydro-1',3',3'-trimethyl-6-nitrospiro (2H-1-benzopyran-2,2'-2H-indole) |
| Supplier | Sigma-Aldrich | Sigma-Aldrich |
| Product ID | C6277 | 273619 |
| Excitation wavelength (nm) | < 500 nm | <400 nm |
| Detection wavelength (nm) | 600 nm | 600 nm |
| Additional chemicals | Sodium hydroxide, ethanol | Toluene |

Table 7 shows the various standard experiments that are possible with Kronos. This section serves to provide experiment ideas for the user.

## 8.1 Base Catalysis of the cis-trans Isomerization of Congo Red

The absorption spectrum of a solution of CR in its trans-ground state in 20% water/ethanol is shown in Figure 9. The dye absorbs strongly throughout the visible range and peaks at ~510 nm.
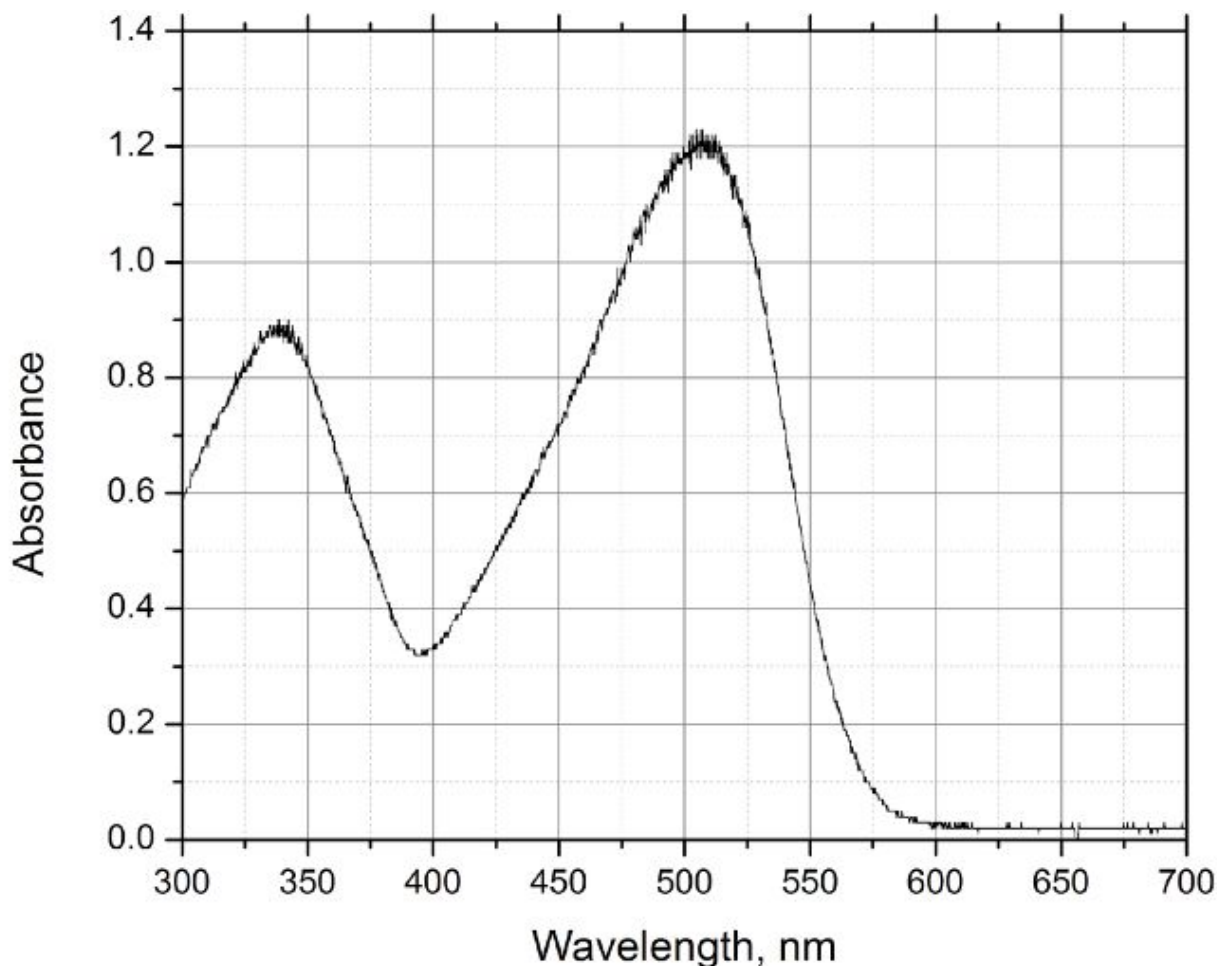
**Figure 9:** Ground state absorption spectrum of Congo Red (trans conf.) in 20% water/ethanol.

When excited, the electronic structure of the dye shifts, causing the −N=N- bond to become torsionally flexible. This causes CR to flip rapidly and lose the imparted energy. CR goes from a trans-excited state to a cis-ground state that is still at a higher energy state than the trans-ground state.

This photo-reaction provides an excellent opportunity for the user to follow the progress of a thermal cis-trans isomerization and measure its rate on timescales that cannot be achieved by traditional mixing methods.  Using both acids and bases which function as catalysts, this experiment allows the user to find the bimolecular rate constant for catalysis by OH- ions.

To perform the experiment, create a light red solution of 80% ethanol as the solvent and CR dye. Then, using 0.1 M NaOH make several solutions containing 0 to 0.1 mM OH- ions with the same CR concentration in the water/ethanol mixture. Insert the dark blue filter into the excitation filter slot and the 580 nm dielectric filter into the detection filter slot. Set range to auto, average 1, and press <Run> to obtain a time profile similar to that in Figure 10.
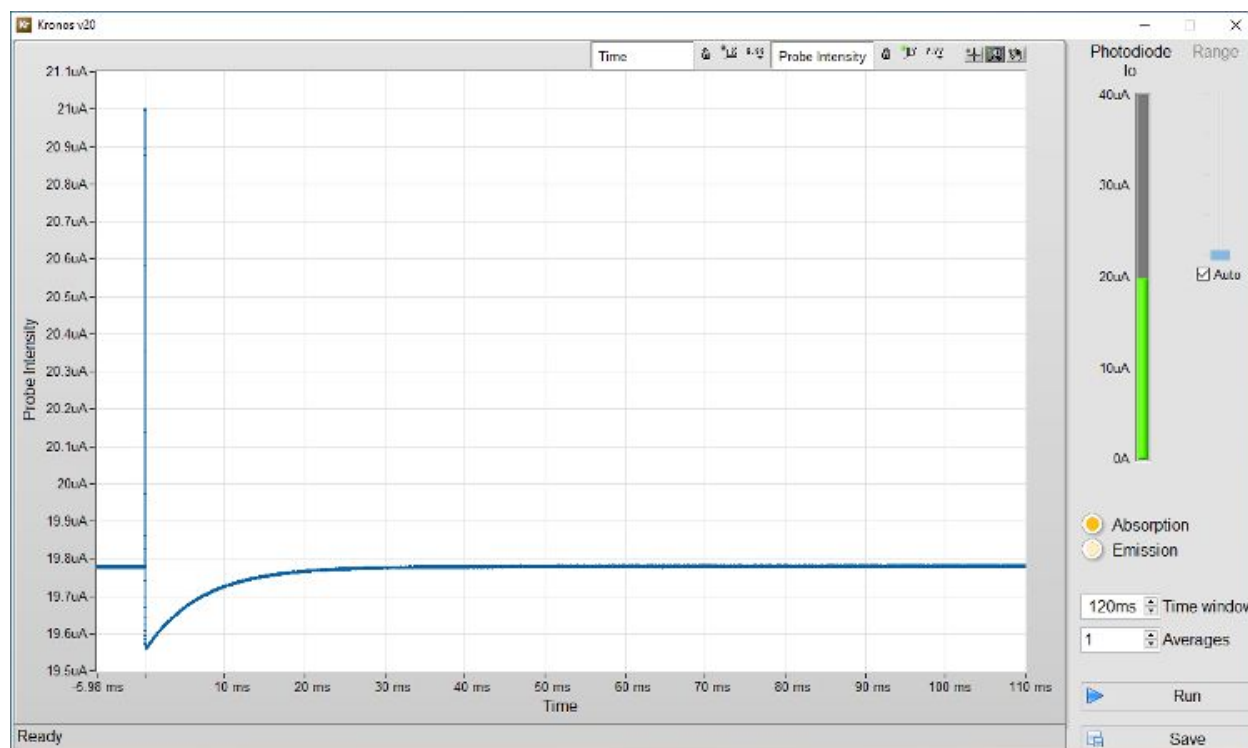
**Figure 10:** Kinetic profile of Congo Red in 20% water in ethanol.

In Figure 10, the large spike is a result of the Xe flash lamp. Ignoring the large spike and looking at data after 100 µs, the signal drops from ~19.8 mA to ~19.6 mA. Subsequently, the value increases back to the baseline over tens of milliseconds. The flash induces a fast photochemical response, much faster than what the Kronos can resolve, and subsequently generates the ground state of the cis-form. This absorbs light, causing the detector to register a drop in transmission. Then, the excited cis-state returns to the trans-state ground-state over many milliseconds.

Adjust averaging as desired, then measure the other samples you have prepared and save their averaged data sets, adjusting the time scale as needed.

Evaluating the rate constants for the cis-trans conversion of CR as a function of [OH-], you can obtain a curve similar to the one shown in Figure 11. You should find that the decays follow an exponential rate law with a constant that is a linear function of [OH-] and the slope of the line (or the best fit of the regression) is the bimolecular rate constant for the catalytic process.
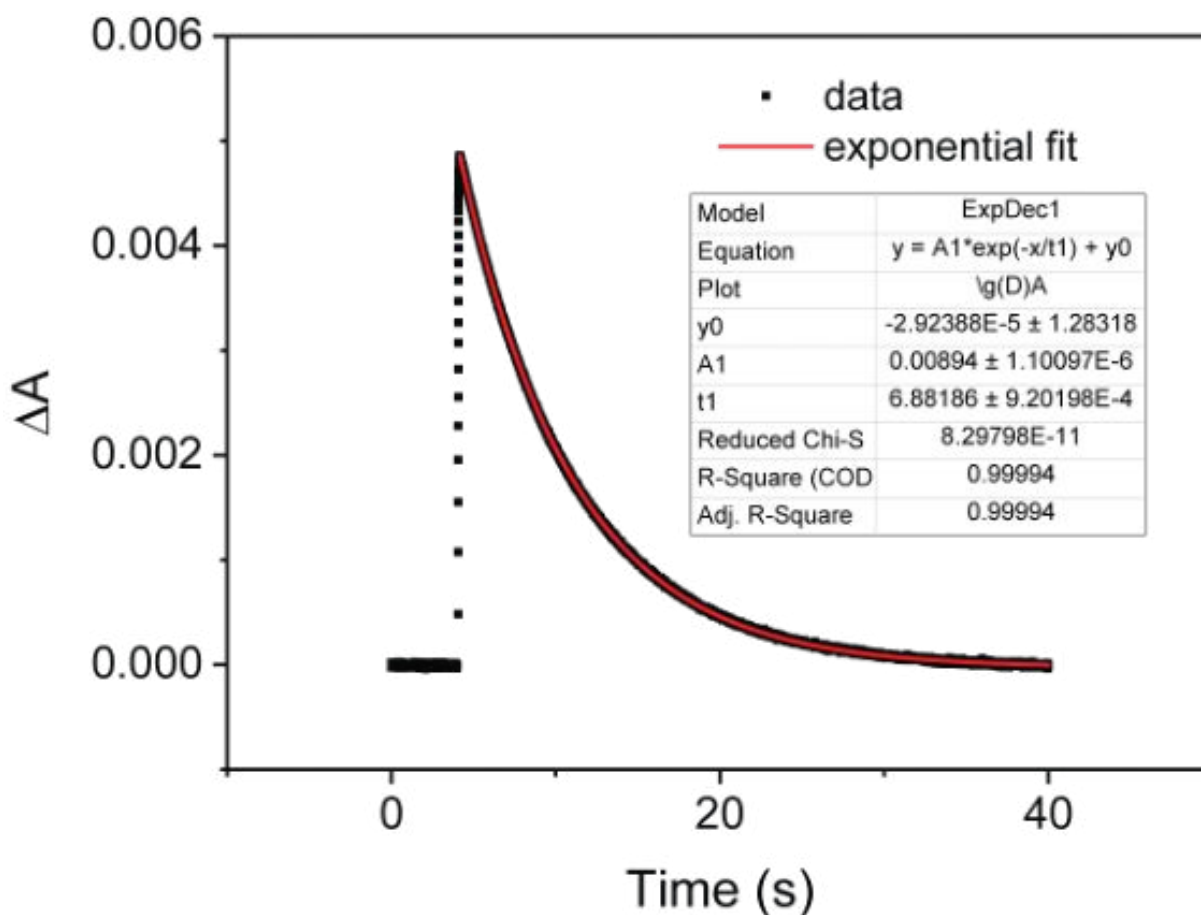
**Figure 11:** Calculated and fitted ΔA plot.

## 8.2 Determination of the Activation Energy of the Thermal Back Reaction of One Spiropyran in Toluene

This section uses a scientific publication for reference: Piard, Jonathan, "Influence of the Solvent on the Thermal Back Reaction of One Spiropyran" Journal of Chemical Education. 2014, **91**, 2105-2111.

$6\text{-}NO_2$-BIPS undergoes a photochemical ring-opening reaction to yield an isomeric colored merocyanine form (MC isomer) when irradiated with UV light. It has been proposed that the MC isomer is a zwitterion, as shown in Figure 12.
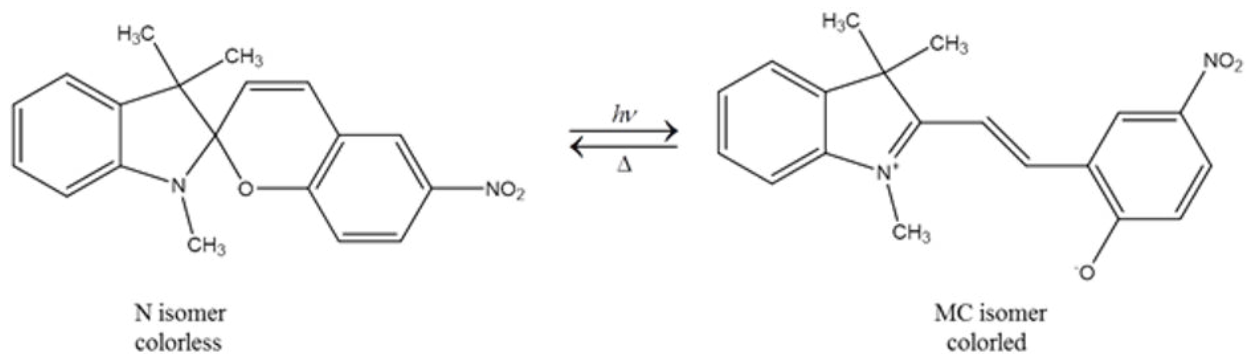
**Figure 12:** Structure and photochromic reaction of 6-NO$_2$-BIPS.

N isomer
colorless

MC isomer
colorled

In this experiment, the kinetics of the back reaction will be measured for a range of temperatures in order to determine the activation energy, $E_a$, of the back reaction. The literature reported value for $E_a$ = 62.5 kJ mol$^{-1}$.
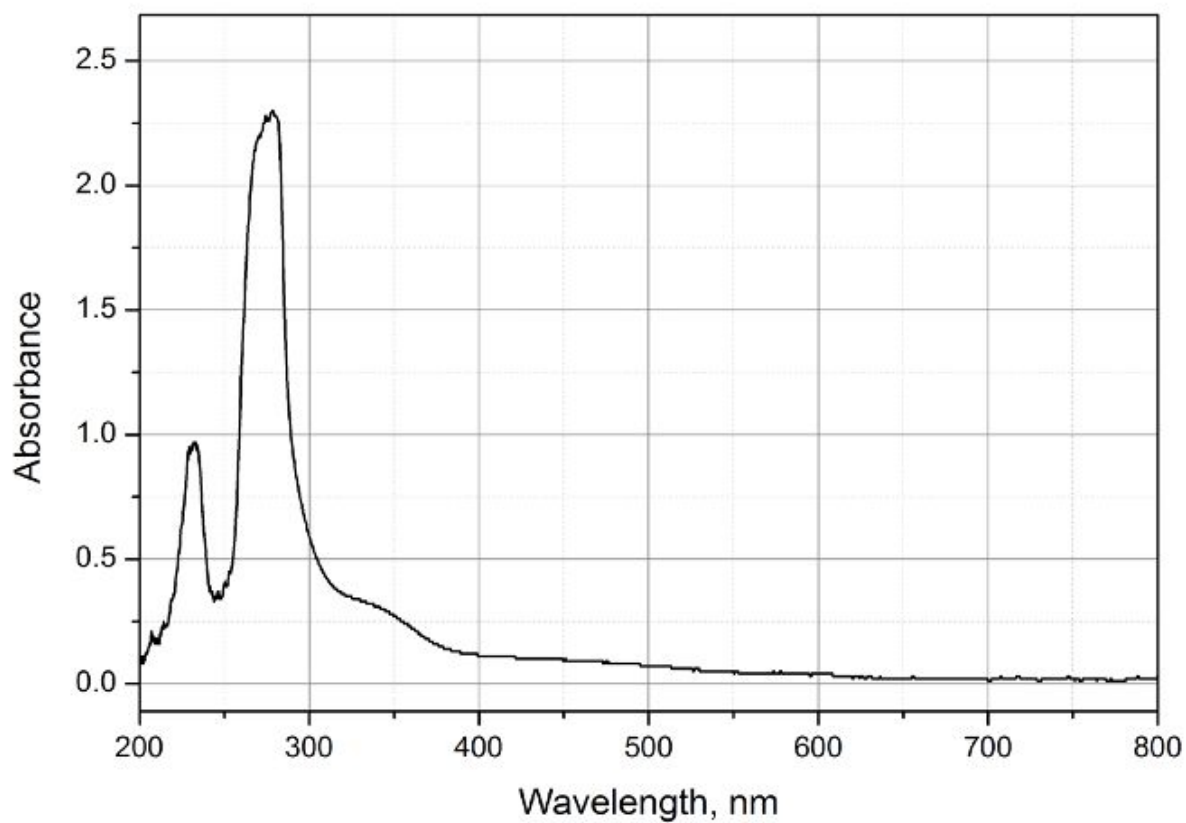


**Figure 13:** Ground state absorption spectrum of One Spiropyran in toluene.

Prepare a 5.0 × 10$^{-6}$ M solution of 6-NO$_2$-BIPS in toluene. Using a hot bath, record the absorption of the sample with 5 different temperatures between 30 and 60 °C. Figure 14 shows an example of measurements done at five varying temperatures.
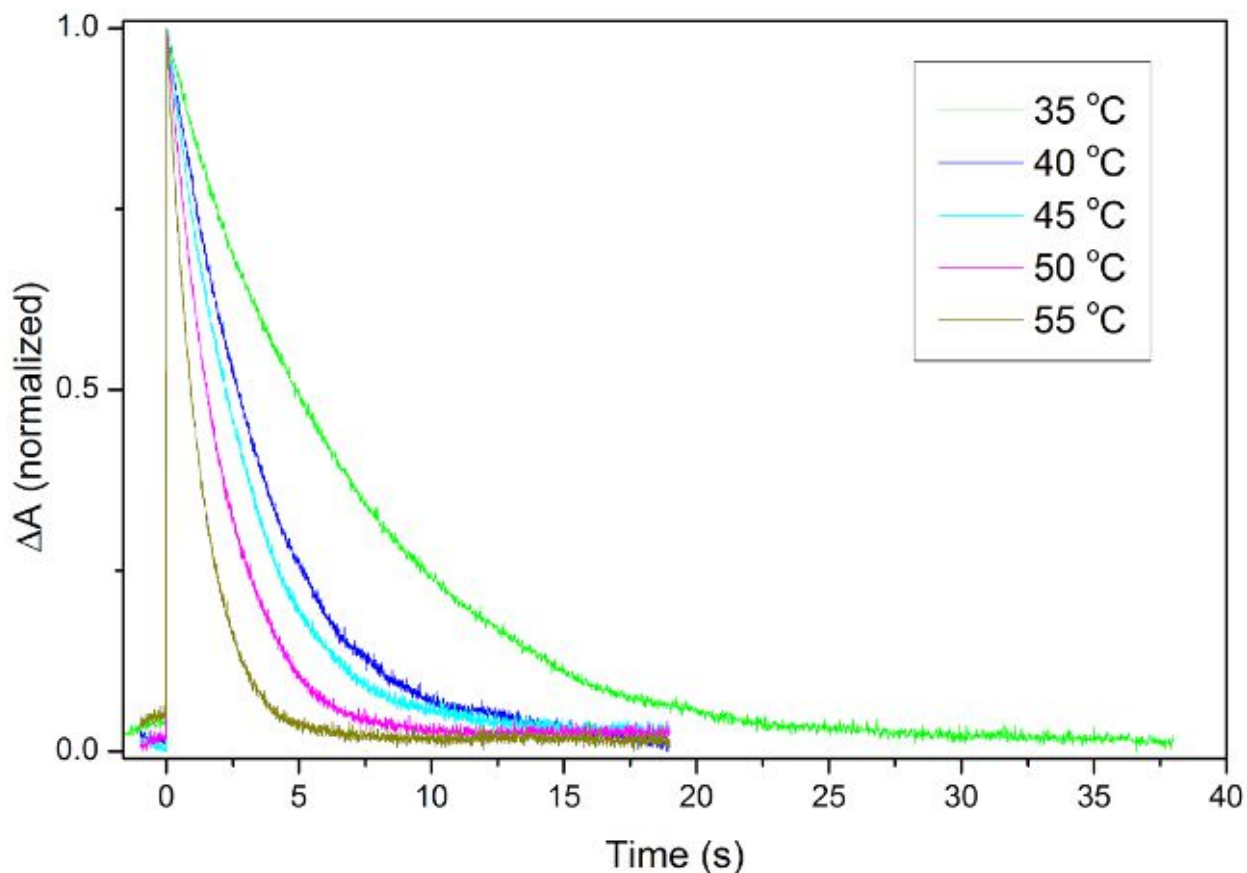


**Figure 14:** Transient absorption of Spiropyran in Toluene at 600 nm detection wavelength.

An example of the generated absorbance vs. time profile is shown in Figure 15 for a temperature of 55°C. Also shown in this plot is the fitted exponential decay function (red line) calculated using OriginLab Origin, a commercial graphing software. This fit provides the lifetime of the back reaction, which in this example is 1.29 seconds. Once lifetimes at five different temperatures are obtained, a plot like the one in Figure 16 can be obtained. Using Origin, a line is fit through the five data points and the slope of this line is used to calculate the activation energy, E$_a$, of the back reaction.
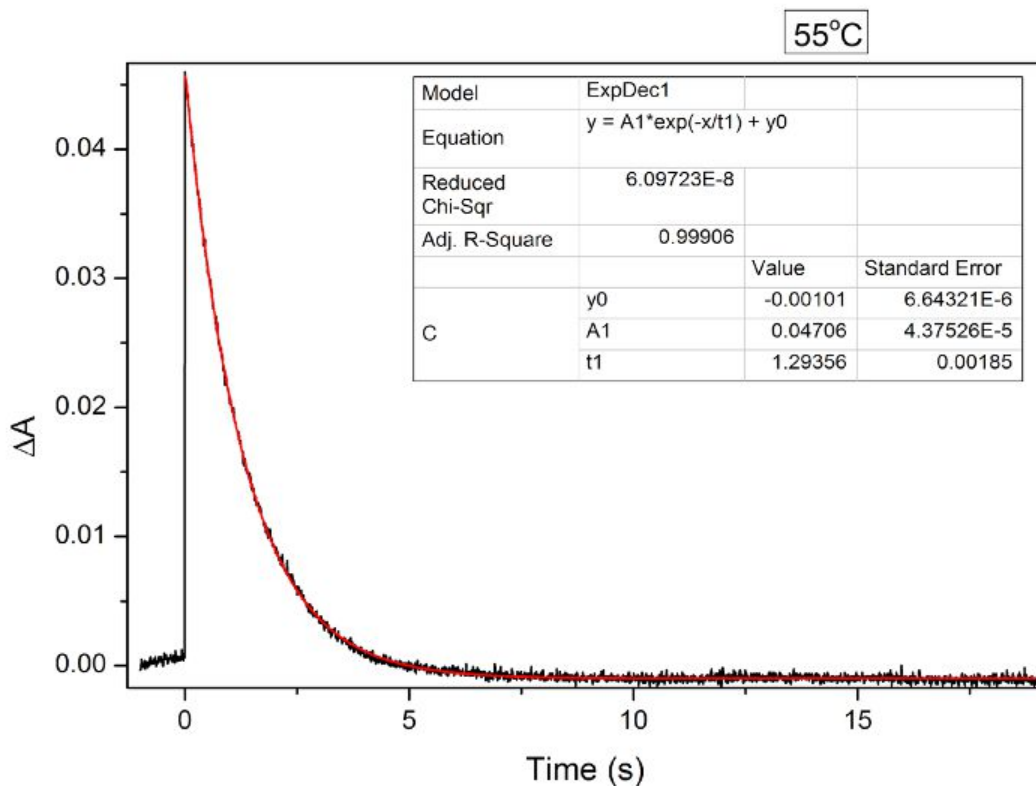
**Figure 15:** Example decay and exponential fit for 55°C measurement.
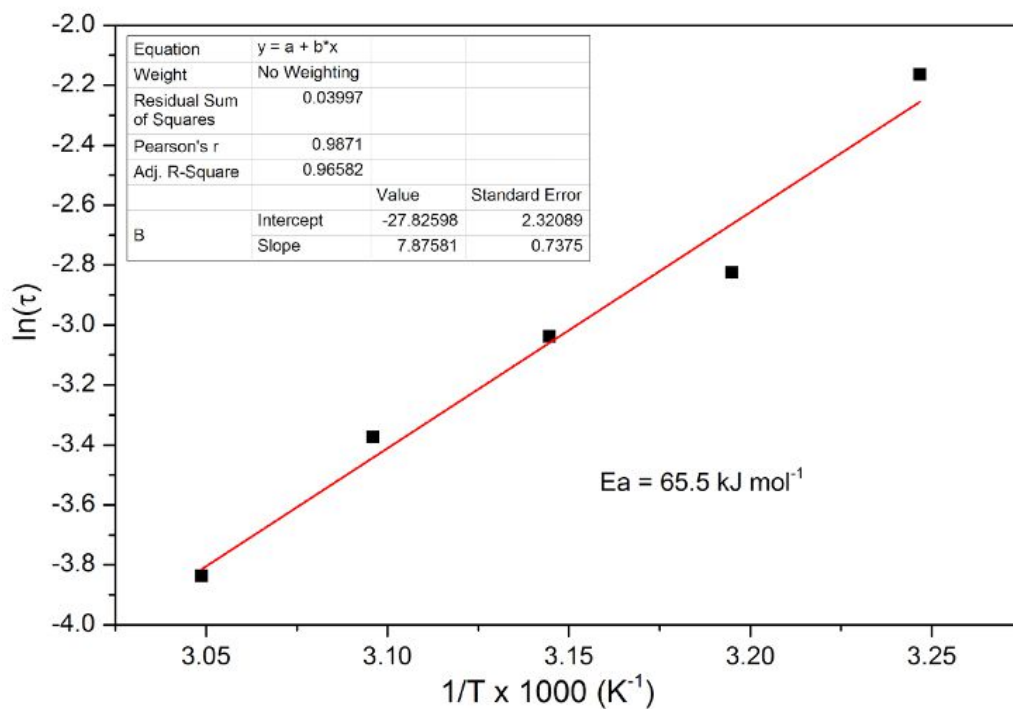


**Figure 16:** Actual data example of ln(τ) as a function of 1000/T.

# 9.  Operation of Kronos

## 9.1  Start-Up

1. Switch on the Kronos. The LED will start immediately, and you should be able to see a white glow inside the enclosure

2. Start the Kronos software

## 9.2  Choose Experiment Mode and Set Parameters

1. Choose Absorption or Emission mode for your experiments

2. Set the number of times to average and the time window

## 9.3  Finding the Signal

1. Place the appropriate excitation and detection filters for your sample. A prior UV/vis absorption measurement would help determine which are appropriate

2. Prepare your sample and place it in the Kronos sample holder

## 9.4  Acquiring Data

1. Click on the <Run> button and allow the scan to complete

2. Click on the <Save> button to export data

## 9.5  Shutdown

1. Remove the sample and any filters added

2. Click on the <Exit> button to close the Kronos software

3. Unplug the USB connector

# 10.  Basic Theory

This section aims to provide some background for the user to be aware of flash photolysis spectroscopy. It does not aim to be a comprehensive guide on the intricacies of the technique and its physics. For more details and on how to interpret the data, the user is encouraged to read books on optical spectroscopy and scientific literature.

Most chemical reactions that occur via a series of simple, or elementary processes, which can proceed at different rates.  An elementary process is a single step reaction where there are no chemically-identifiable intermediates. Elementary processes are best used to understand the fundamental principles of photochemical kinetics. For a given complex reaction, its rate will be determined by the rate of the slowest of the participating elementary reactions. The major advantage of using light to initiate reactions is that in this way it is relatively straightforward to initiate elementary processes.

## 10.1  Transient Optical Spectrometry

Optical spectrometry (sometimes also called optical spectroscopy) is a general term used to describe measurements done with light, and how matter interacts with light. Depending on the type of processes that occur, their features and timescales, spectroscopists will choose different instruments to perform such experiments. The most basic optical spectroscopic techniques are steady state measurements like absorption or fluorescence spectroscopy. While lacking time related information, they provide immense spectral information that prompts measurements that record the change of the sample over time. Such experiments measure the changes of the sample's properties, such as absorbance. Measuring the change in absorbance over time is called transient absorption (TA) spectroscopy.

Transient absorption measurements can range from 'slow' to 'ultrafast', because different processes that occur at different speeds, or more accurately, timescales. The faster the processes the sample undergoes, the shorter the excitation and probe sources need to be, requiring more expensive instruments. Femtosecond ($10^{-15}$ s) TA provides information in the sub-picosecond ($10^{-12}$ s) timescales. These timescales are useful to extract information related to electron behavior, but requires specialized and expensive instrumentation. One of its 'slow' counterparts is flash photolysis, where no specialized equipment is required. To perform such measurements, a reasonably 'fast' pulsed light source and an appropriate detector is sufficient.

TA spectroscopy is also known as pump-probe spectrometry: the pump (in Kronos, the flash lamp) excites the sample and generates photogenerated carriers that is the interrogated by the probe

light (LED). The goal is to measure the pump-induced probe change. By taking the difference between the transmitted and initial signal, and doing a logarithmic calculation, the change in absorption [ΔA] at a particular wavelength can be obtained,

$$\Delta A(t) = -\log\left[\frac{I_{\text{pump-on}}(t)}{I_{\text{pump-off}}(t)}\right]$$

In such measurements, kinetics data is represented in signal vs relative time units, e.g. delay time. The data is relative to a quantity called 'time zero'. Time zero describes the instance when the pump and probe pulses overlap in time at the target, i.e., the sample.

This time zero in flash photolysis is arbitrarily set since it is essentially a single shot measurement. A distinct feature of time zero is the sudden increase in signal, assuming the pump and probe beams are also overlapping in space. Depending on the user, it can be just before the signal amplitude rises, or when the signal is maximum. This manual uses the former definition.

## 10.2 Photochemistry

Materials in this section have been adapted from "A Qualitative Theory of Molecular Organic Photochemistry" (http://www.columbia.edu/itc/chemistry/photochem/courseworks/06MMP_Chapter6.pdf). The paper serves as a good introduction to photochemistry. Interested and curious readers are strongly encouraged to read it in its entirety.

When a molecule **R**, the reactant, absorbs energy (*hv*), it undergoes a photophysical process to an excited molecule (**\*R**). The excited molecule can then relax back to the ground state non-radiatively (photophysical). It can also undergo photochemical processes to form a product (**P**) in a single step or via an intermediate (**I**). One can think of photophysical processes that do not change the sample and reversible, whereas photochemical processes result in a different chemical outcome and are generally irreversible.
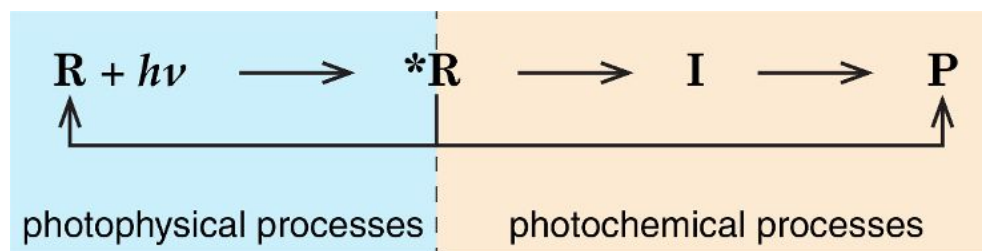


**Figure 17:** Photophysical and photochemical sequence in light-matter interactions.

## 10.3 Chemical Kinetics

### 10.3.1 Reaction Rate

The rate of a chemical reaction is expressed as the variation with time of the concentration of either reactants or products. In solution phase reactions, as studied here, the units of reaction rate are concentration units per second, i.e. mole per liter per second, $M\ s^{-1}$.

In the (elementary) reaction,

$$A + B \longrightarrow C \qquad\qquad (2)$$
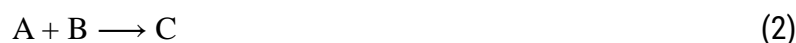
The rate (change in concentration as a function of time) is expressed in the form of a derivative

$$Rate = -\frac{d[A]}{dt} = -\frac{d[B]}{dt} = \frac{d[C]}{dt} \qquad\qquad (3)$$

### 10.3.2 Rate Expression and Rate Constant

The rate expression containing a constant of proportionality or rate constant, k, is

$$-\frac{d[A]}{dt} = k[A][B] \qquad\qquad (8)$$

This equation tells us that since the concentrations of the reactants decrease during the reaction, then the rate (but not the rate constant) decreases with time elapsed. Thus, the rate constant provides the spectroscopist with a useful measure of the velocity of a reaction, an important quantity to determine when studying chemical kinetics.

### 10.3.3 Order of Reaction

In the previous rate equation (Equation 8) the concentrations of A and B both appear to the first power, i.e., this reaction is first order with respect to both [A] and [B], and overall second order reaction.

In the dimerization reaction for the elementary process,

$$2A \longrightarrow C \qquad\qquad (4)$$

the rate expression is will be

$$-\frac{d[A]}{dt} = k[A][A] = k[A]^2 \qquad\qquad (9)$$

For this reaction, it is second order in [A] and overall second order.

Also, the symbolic elementary process

$$A \longrightarrow P \qquad \qquad (10)$$

would be expected to have a rate equation

$$-\frac{d[A]}{dt} = k[A] \qquad \qquad (11)$$

and the reaction is first order in [A] and overall first order. Orders higher than 2, fractional and zero orders are found in special cases. These are not considered here because they are not relevant to Kronos.

**NOTE:** It is important to realize that assignment of order by inspection is only valid for elementary reactions; it does not apply for stoichiometric equations.

## 10.3.4 Experimental Approach

The data that are obtained in a kinetics experiment could look something like those shown in Figure 18. The change in concentration of reactant A (open circles) and product B (filled circles) as a function of time can be observed; M relative concentration of the species (A or B).
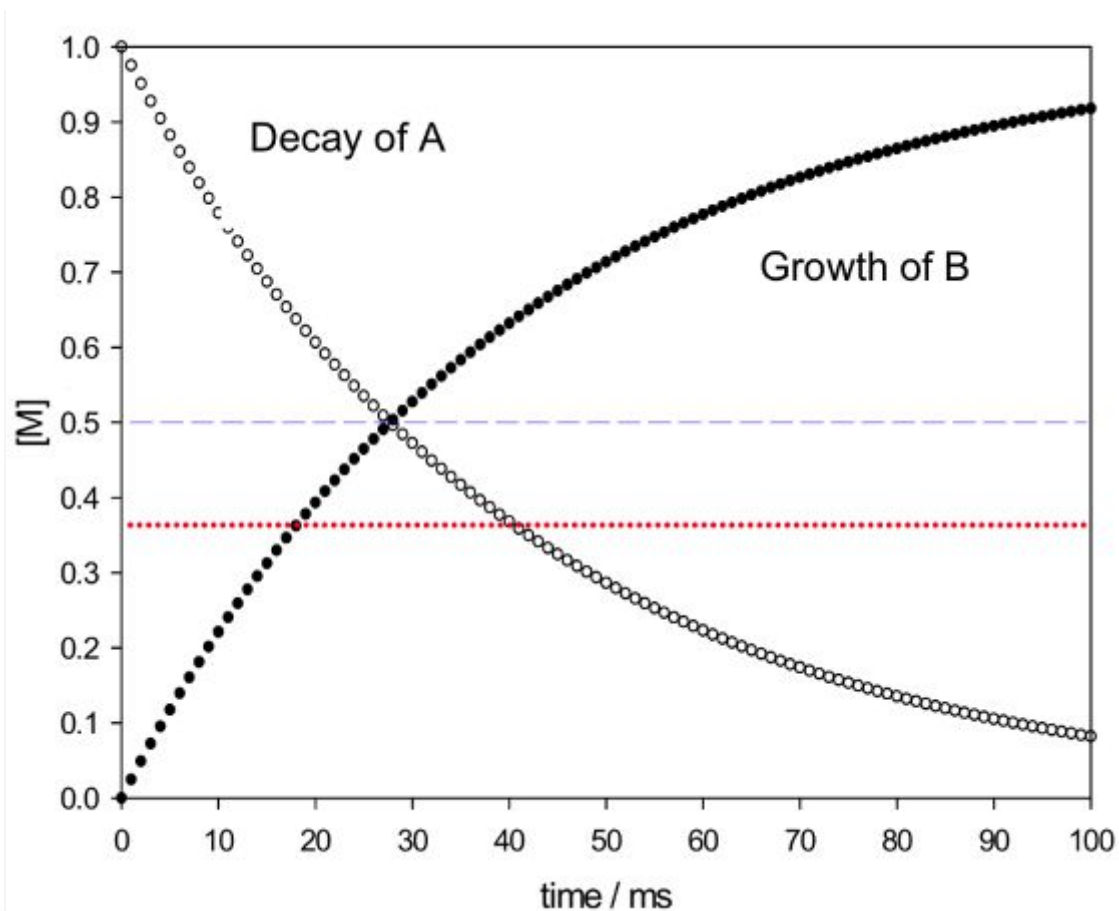


**Figure 18:** Concentration time profiles of reactant and product.

The blue line is drawn at the point of 50% reaction (half of the initial concentration of A has been converted into B). By inspection this occurs after an elapsed time of about 28 milliseconds. This represents the half-life of the reaction. The red line is drawn when 1/e (~37%) of the initial concentration of A has been converted to B; this represents the reaction lifetime. To evaluate your experiment for values such half-life, rate constants, activation energies and more refer to your chemistry textbook in chapters about kinetics and integrated rate laws.

# 11. Maintenance and Troubleshooting

## 11.1 Maintenance

Kronos does not contain any consumable items or spare parts. The exterior of Kronos can be cleaned with a soft cloth moisten with ethanol. Never use acetone. Replace the lids to ensure no contaminants or dust will fall into the modules. Avoid cleaning inside the modules due to the risk of optics and crystal contamination, and accidental misalignment. If absolutely necessary, ensure sufficient ventilation to minimize fume concentration in the modules.

Clean optical surfaces allow for optimal reflection or transmission of laser power. Contaminants on the optics can reduce the efficiency of the system. Touching the polished surface of the optics in anyway, even with new gloves, can cause contamination. It is crucial that optics are handled at the ground edges only. Exercise caution when handling optics and when cleaning them. Always inspect the optics before and after cleaning them. Use a magnification device and a bright light to spot small defects and contaminants.

Clean optics in increasing level of contact. Use non-contact methods by blowing off dust and other contaminants with compressed air. Be careful not to use excessive pressure that might cause the optics to slip or crack.

If blowing is not sufficient to remove remnant contaminations, e.g. oils, spectroscopic-grade methanol is the recommended solvent for cleaning optics. Other solvents and poorer grades can leave residues or degrade the optical coatings. Always read the associated data sheets and MSDS sheets prior to using any solvent.

Prepare a single piece of high-quality lens tissue, folded neatly, and lightly moistened with the solvent. Gently use the tissue for one wipe and one direction only and discard it immediately. Use a new tissue for subsequent passes. Reusing the tissue or reversing direction can drag contaminants back across the cleaned surface, causing residual streaks and potential damage.

## 11.2 Troubleshooting

This section aims to provide the user with some solutions to common problems.

| If the problem is… | Here's what to do… |
|---|---|
| **There is no white glow in the Kronos when the USB is plugged in.** | Plug the USB connector in snugly and check that the computer can detect the Kronos. It will appear as a COM port connection. |
| **There is no light detected on the photodiode (PD level is zero or very low).** | Check that the instrument is plugged in and turned on, and there is no obstruction in the light path. You can verify the unit is turned on by watching for a white glow emitted by the LED light. Remove any filters that were placed in the slit before the detector. |
| **There is a signal, but it is noisy or fluctuating significantly.** | 1. Remove the sample and filters and check that the photodiode reads a strong baseline intensity. Contact your local representative or Ultrafast Systems if no light is detected.<br>2. Try to average across more scans if the baseline intensity falls within the recommended range.<br>3. Ensure the Range is set to Auto (checked box) when performing absorption measurements. For emission measurements, ensure Auto is turned off (unchecked box) and play around with the slider and clicking run. |
| **The photodiode reads the baseline correctly, but when I place my sample inside and do a measurement, I see no observable change.** | Check the photoresponse of your sample and that appropriate filters are placed in the slit. Make sure to familiarize yourself with Section 8: Acquiring Data on page prior to performing measurements. |
| **I can reliably measure the reference samples and get consistent data, but when I place my sample for measurements, I do not see any signal.** | The sample response could be too weak or fast for the Kronos to detect. If you have access to a laser pump-probe setup like the EOS or Helios, you can try to perform your measurements there. |

# 12.  Appendix

The Kronos software has an advanced settings window for experienced users. The settings can be accessed by pressing **CTRL + SHIFT + C** on the keyboard from the main window of the Kronos software.

In this window, you can change the COM port and the default graphing unit from current to ΔA. Changing the latter will instruct the software to automatically perform calculations to convert the light intensity data. Teaching lab instructors and technicians should ensure this setting is always set to display current for educational purposes. Students should be able to calculate it themselves.

# 13.  Warranty

Ultrafast Systems warrants that the spectrometer system (the Product), that is the subject of this sale, (a) conforms to Ultrafast Systems' published specifications and (b) is free from defects in materials and workmanship.

The Product is warranted to conform to Ultrafast Systems' published specifications and to be free from defects in materials and workmanship for a period of twelve (12) months from the date of installation. If the Product is found to be defective during the warranty period, the Product will either be repaired or replaced at Ultrafast Systems' option.

To exercise this warranty, write to or call your local Ultrafast Systems office or representative, or contact Ultrafast Systems headquarters in Sarasota, Florida. You will be given prompt assistance and return instructions. Send the Product, freight prepaid, to the indicated service facility. Repairs will be made, and the instrument returned, freight prepaid. Repaired Products are warranted for the remainder of the original warranty period.

## Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from:

1. Unauthorized repair or modification that was performed without written approval by Ultrafast Systems.

2. Operation outside the environmental specifications of the Product, leading to the Product being subjected to unusual physical, thermal or electrical stress.

This warranty does not apply to misuse, abuse, accident or negligence in use, improper installation storage, transportation or handling not specifically authorized by Ultrafast Systems.

This warranty does not apply to fuses, batteries, or damage from battery leakage.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. Ultrafast Systems shall not be liable for any indirect, special, or consequential damages resulting from the purchase or use of its products.

# 14. Notice

## 14.1  Confidentiality & Proprietary Rights

### 14.1.1 Reservation of Title

The Ultrafast Systems programs and all materials furnished or produced in connection with them ("Related Materials") contain trade secrets of Ultrafast Systems and are for use only in the manner expressly permitted. Ultrafast Systems claims and reserves all rights and benefits afforded under law in the Programs provided by Ultrafast Systems.

Ultrafast Systems shall retain full ownership of Intellectual Property Rights in and to all development, process, align or assembly technologies developed and other derivative work that may be developed by Ultrafast Systems. Customer shall not challenge or cause any third party to challenge the rights of Ultrafast Systems.

### 14.1.2 Preservation of Secrecy and Confidentiality and Restrictions to Access

Customer shall protect the Ultrafast Systems Programs and Related Materials as trade secrets of Ultrafast Systems and shall devote its best efforts to ensure that all its personnel protect the Ultrafast Systems Programs as trade secrets of Ultrafast Systems. Customer shall not at any time disclose Ultrafast Systems' trade secrets to any other person, firm, organization, or employee that does not need (consistent with Customer's right of use hereunder) to obtain access to the Ultrafast Systems Programs and Related Materials. These restrictions shall not apply to information (1) generally known to the public or obtainable from public sources; (2) readily apparent from the keyboard operations, visual display, or output reports of the Programs; 3) previously in the possession of Customer or subsequently developed or acquired without reliance on the Ultrafast Systems Programs; or (4) approved by Ultrafast Systems for release without restriction.

## 14.2  Service Information

The user should not attempt any maintenance or service of the system or optional equipment beyond the procedures outlined in this manual. Any problem that cannot be resolved should be referred to Ultrafast Systems.

**Ultrafast**
**SYSTEMS**