What's In Our Stars?

TEACHER PROCEDURES

TeachEngineering

What's In Our Stars? Teacher Procedures

1. Computer Prep

Installing and preparing the computer application

2. Equipment Prep

Setting up the lab equipment and samples

3. Data Collection

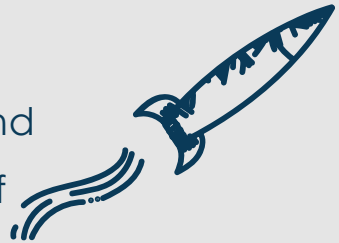
Running the experiment and collecting data

4. Post-Lab

Interpreting and analyzing the data collected

Dear Teacher:

Spectroscopy is a topic that can be as simple or as complex as one makes it. In developing this activity, I have been sucked into its "black hole" (pun intended…) many times. I would begin by looking up the absorption spectra of hydrogen and before long I was converting the wavenumbers of bond stretching at a specific wavelength for aldehydes! You know your students best but, to *paraphrase* the U.S. Navy, my advice would be: Keep It Super Simple! (K.I.S.S.).



—Another Teacher

1. Computer Prep

This section covers the software applications used by students to complete this activity.

I recommend familiarizing yourself with these steps before going through with students.

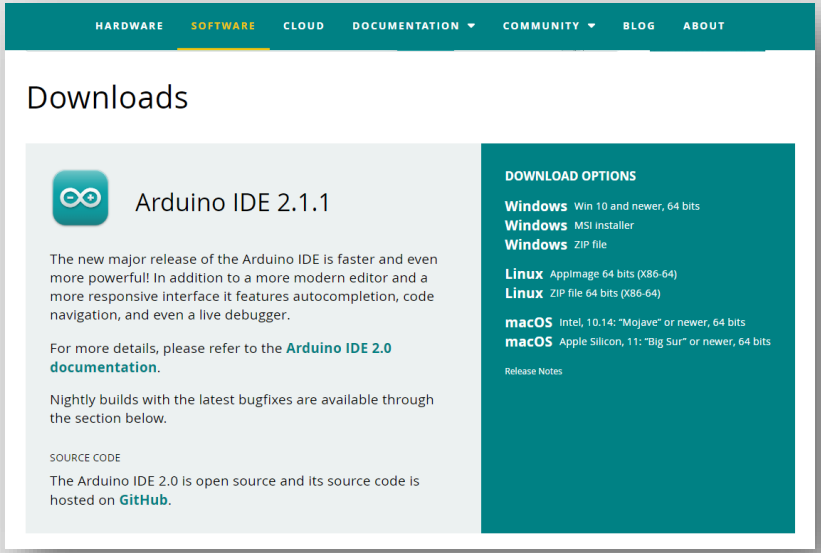
Additionally, for the sake of time, I would have students complete these steps in class the day prior to conducting the activity.

ARDUINO IDE

1. Go to https://www.arduino.cc/en/software and select the software that is appropriate for your students' devices.

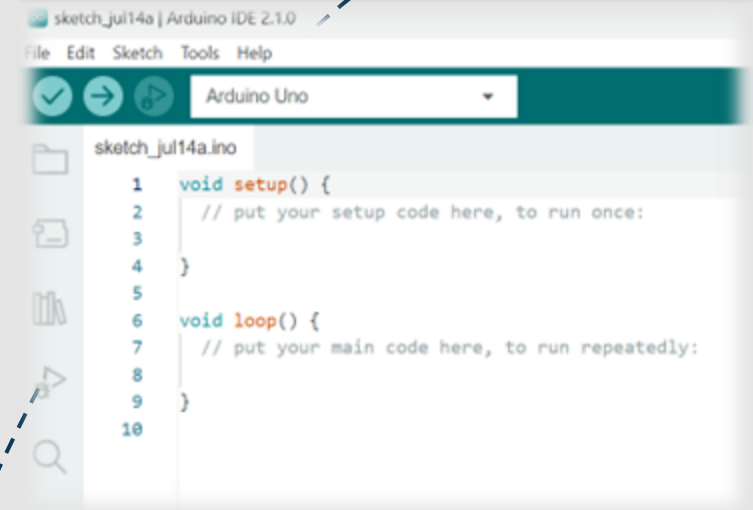
2. Have students download and install the software program.

3. Alternatively, students may use the web-based version also accessed using the link above.

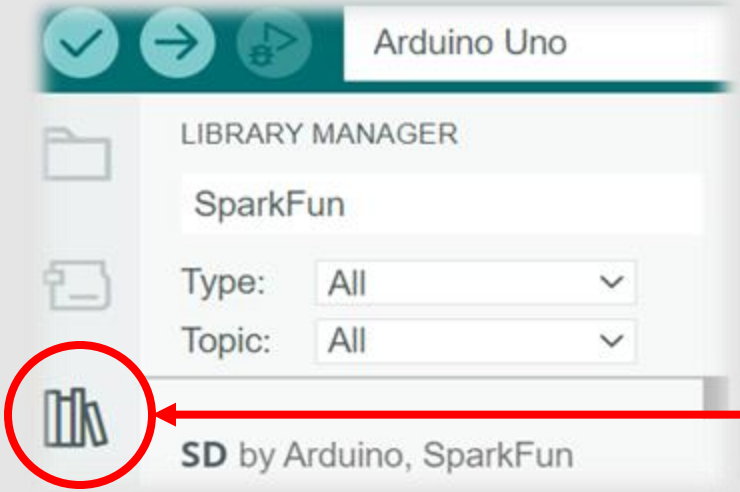


SPARKFUN LIBRARY

1. Once installed, open Arduino IDE.



2. Click on the books icon on the task bar located on the left-hand side.

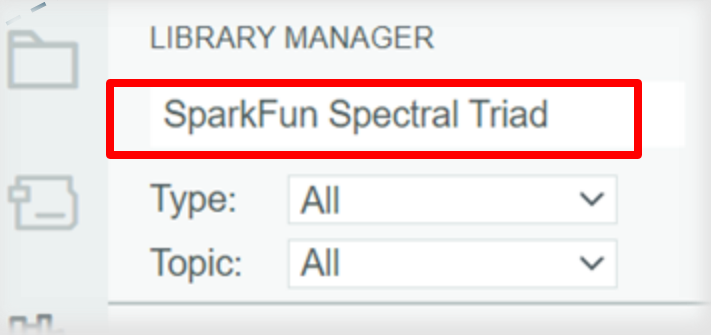


SPARKFUN LIBRARY (cont.)

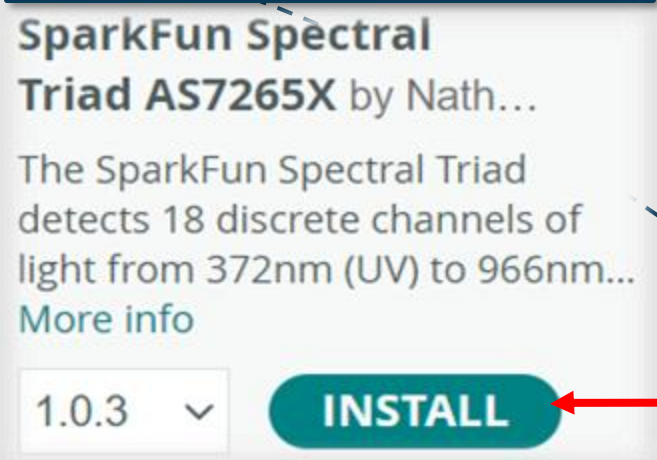
Specifics about the Spectral Triad AS7265X library commands can be found at this **LINK**

(scroll down about 2/3 of the page to "AS7265x Arduino Library Overview").

3. Type in "SparkFun Spectral Triad" into the search bar.



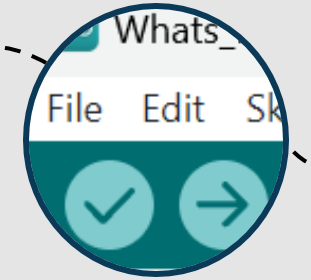
4. Select Install.



ACTIVITY CODE

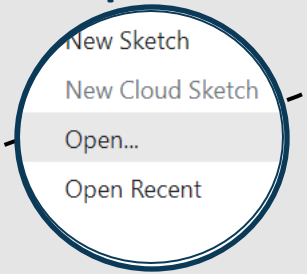
*Be sure that you and your students have already downloaded the code to a chosen location (e.g., desktop).

1. File



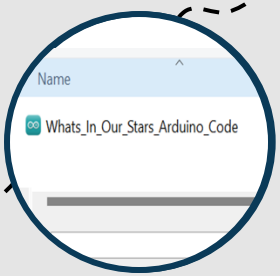
Click on "File" in the upper left-hand corner.

2. Open



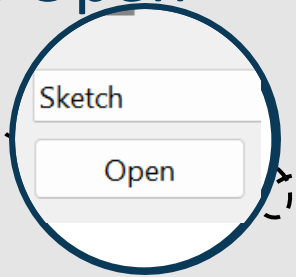
Select "Open" from the dropdown menu.

3. Locate



Locate the file for the code: "Whats_In_Our_Stars_Arduino_Code".
(be sure you have unzipped the activity folder first)

4. Open



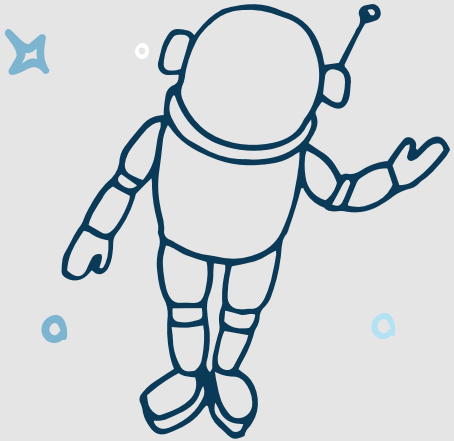
Select "Open" in the bottom right-hand corner.

EXCEL

Ensure that students have access to Microsoft Excel before proceeding.

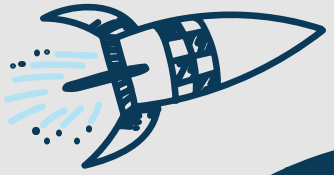
DATA STREAMER

Download and Enable the Data Streamer add-in for Microsoft Excel. See Microsoft's "How To" **HERE.**



DASHBOARD

Locate and open the Excel workbook "Whats_In_Our_Stars_Excel_Dashboard" provided with the activity files.

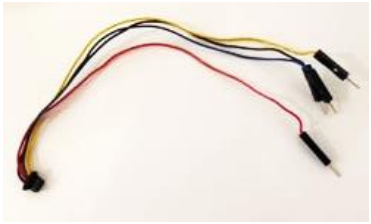


2. Equipment Prep

This section includes procedures for wiring/hooking up the spectrometer and preparing the samples.

SPECTROMETER SETUP

SparkFun Triad Spectroscopy Sensor



SparkFun 4-pin Qwiic connect cable (or 4 jumper cables)

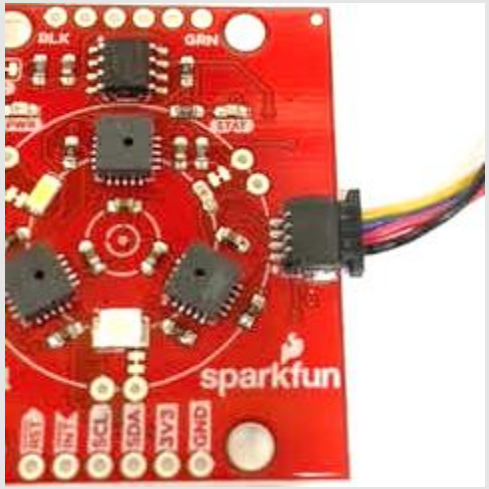
Scissors

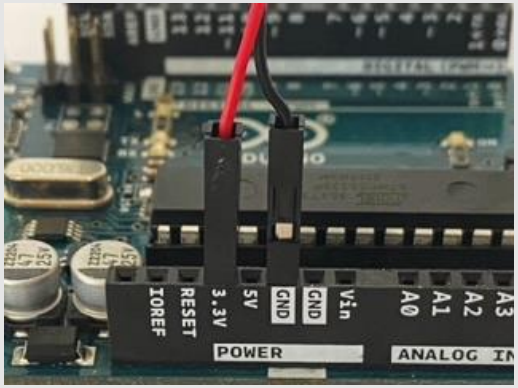
Arduino Uno Board

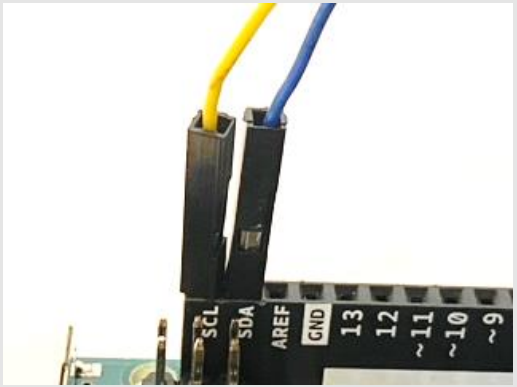
USB-C to USB-A cable

Black cardstock or thin cardboard cut into a 3”x 3” square

SPECTROMETER SETUP



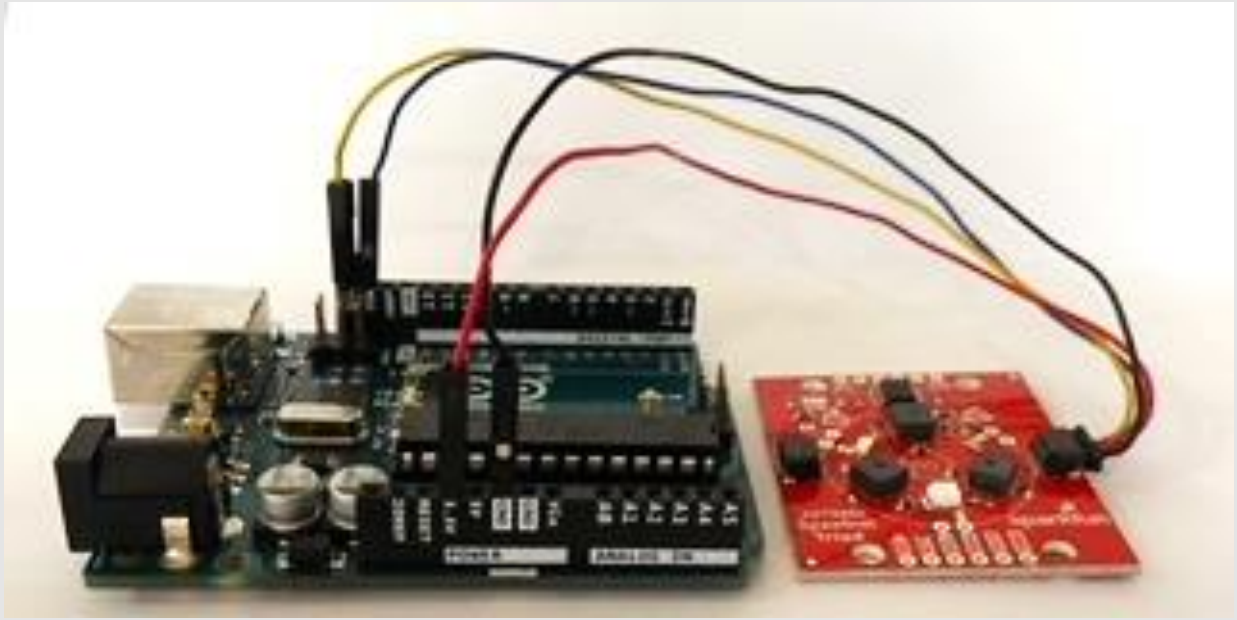




- **Black = GND**
- **Red = 3.3V**
- **Blue = SDA**
- **Yellow = SCL**

Connect the triad sensor to the Arduino, making sure that each colored cable goes to the correct pin! (see above)

SPECTROMETER SETUP

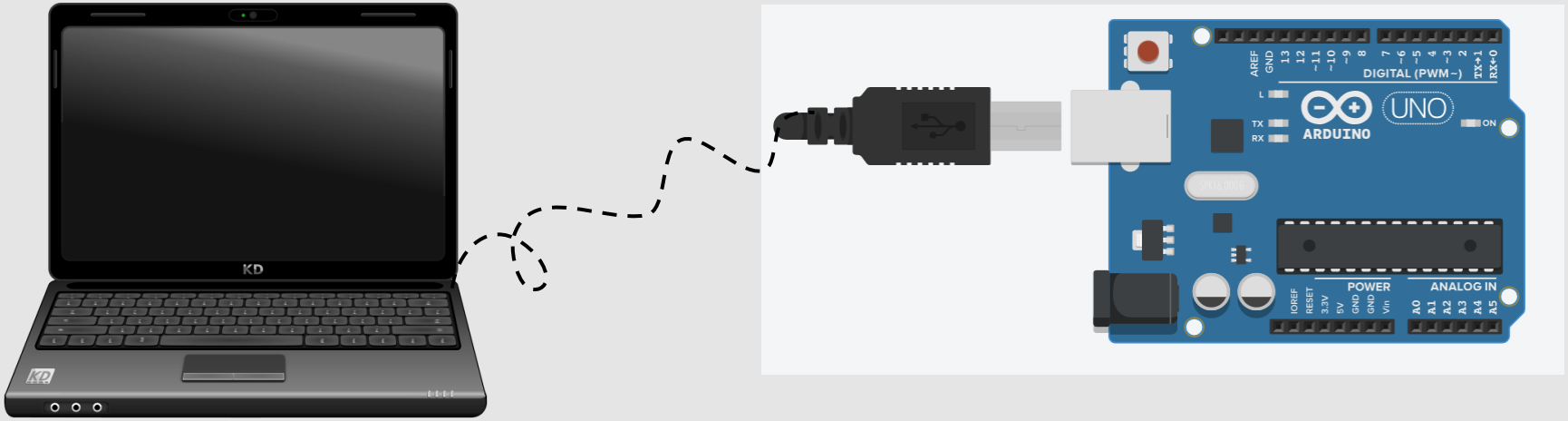


- **Black = GND**
- **Red = 3.3V**
- **Blue = SDA**
- **Yellow = SCL**

Connect the triad sensor to the Arduino, making sure that each colored cable goes to the correct pin! (see above)

SPECTROMETER SETUP

Use the provided USB cable to connect the spectrometer to your device.



SAMPLE PREPARATION

Select 3* different substances for students to use as their samples.

Some Helpful Hints:

- Materials may be solids or liquids, though for ease I recommend choosing either 3 solids or 3 liquids.
- When/if choosing 3 solid substances, try to choose ones that look similar with the naked eye (e.g., table salt, Epsom salt, and sugar).
- Ideally, sample substances would be made from elements hydrogen (Z= 1) to iron (Z=26), as these elements are formed due to fusion within stars.
- Some suggestions are listed on the following slide, but feel free to use anything you like!
- **A "Sample Tracker" document is provided for you to use if you wish :)**

**You can always do more than 3 substances per group! However, this will add prep time, supplies needed, and time to complete the lab.*

SAMPLE PREPARATION

Ideas for the 3 different substances to use as samples.

When/if choosing 3 solid substances, try to choose ones that look similar with the naked eye (e.g., table salt, Epsom salt, and sugar).

- Table Salt ($NaCl$)
- Baking Soda ($NaHCO_3$)
- Potassium Nitrate (KNO_3)
- Vinegar/Acetic Acid (CH_3COOH)
- Table Sugar/Sucrose ($C_{12}H_{22}O_{12}$)
- Aluminum Foil (Al)
- Epsom Salt ($MgSO_4$)
- Cornstarch ($C_6H_{10}O_5$)

- Pencil Lead/Graphite (C)
- Play Sand (SiO_2)
- Hydrofluoric Acid - any molarity (HF)
- Phosphoric Acid - any molarity (H_3PO_4)
- Chalk/Calcium Carbonate ($CaCO_3$)
- Iron Filings (Fe)
- Magnesium Ribbon (Mg)
- Vegetable Oil ($C_{18}H_{34}O_2$)

SAMPLE PREPARATION

Once you have your selected substances, place them into containers such as those shown below. Create enough cups of each chosen sample substance for each group to have one set.

Write the name of the substance on each sample cup. (e.g., Iron Filings)

Make sure that the substance labeled "Unknown" is the same as either known A, B, or C! Otherwise, students won't be able to identify it!

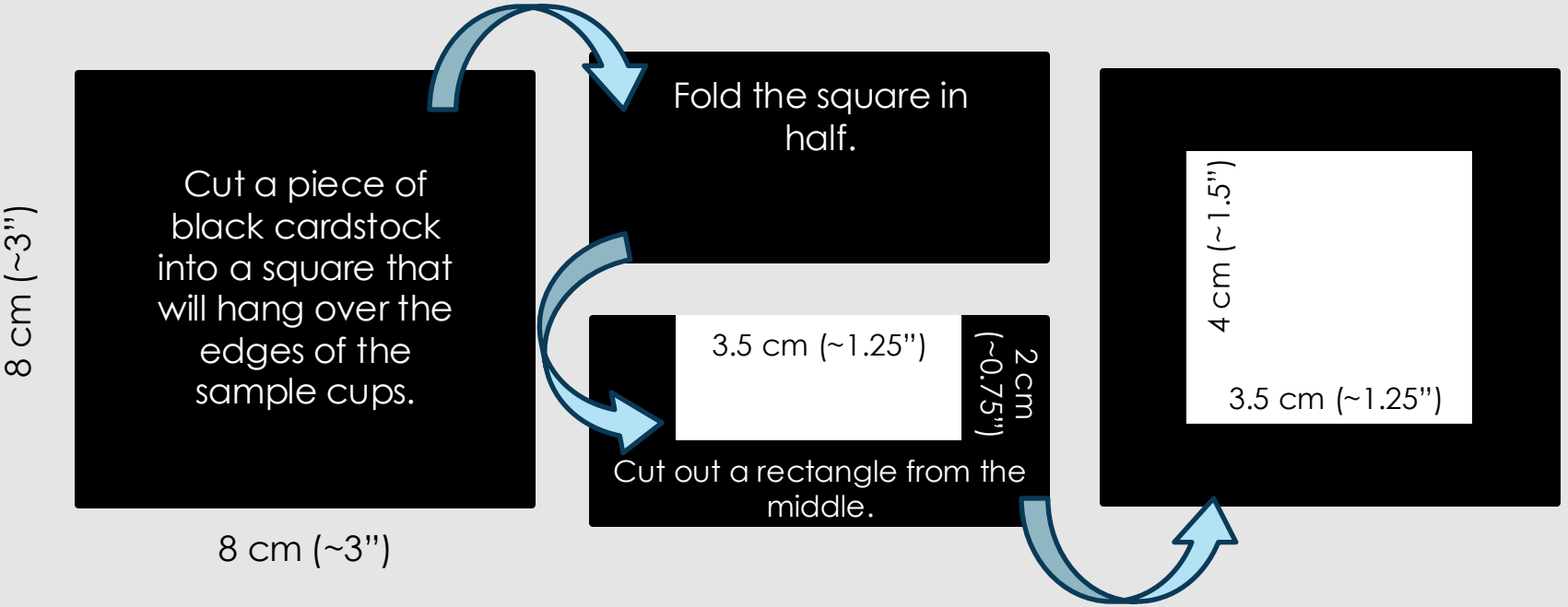
} x Number of Lab Groups

SAMPLE PREPARATION - EXAMPLE

Remember to create enough cups of each sample substance for each group to have one full set.
Use the "sample tracker" to assist in organizing which substance is "A," "B," and "C."

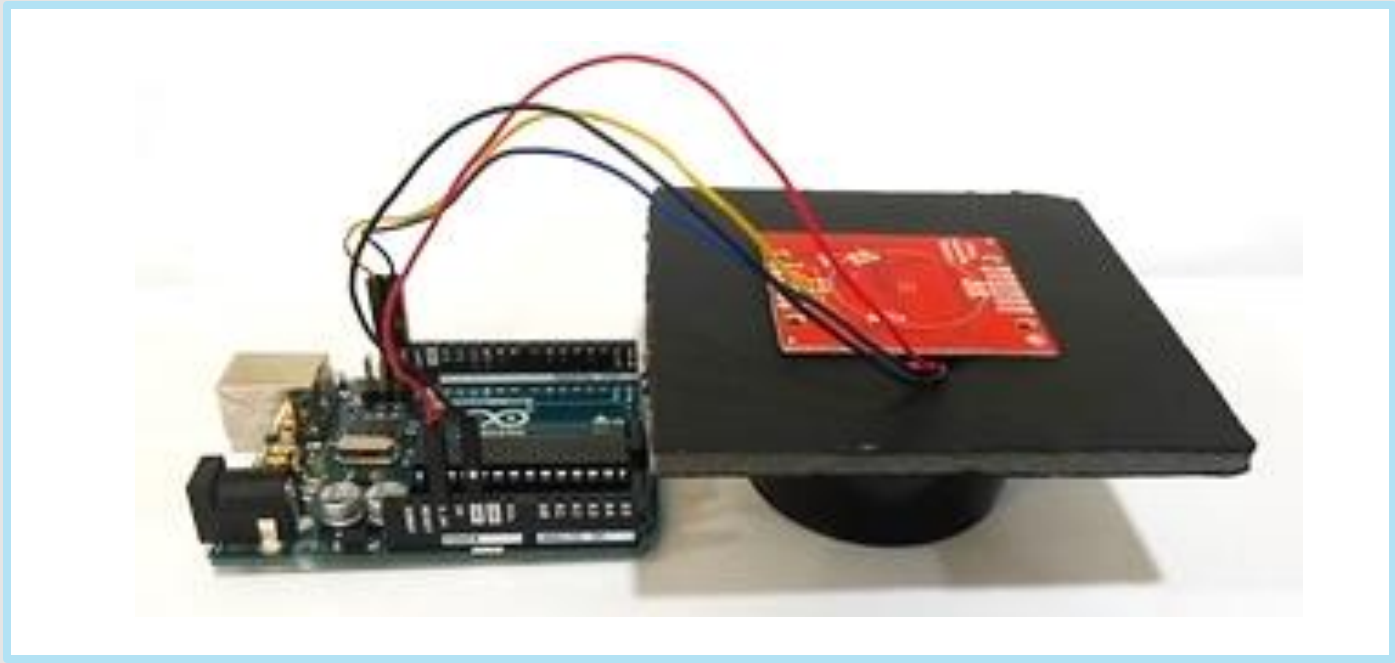
SAMPLE SETUP

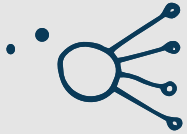
Once you have your spectrometer set up, and your samples selected and portioned into containers, you'll need to create a "cover" to place over the sample cup for the sensor to sit on and to eliminate ambient light.



COMPLETE SETUP

Once you have your spectrometer set up, and your samples selected and portioned into containers for student use, the setup should look like the image below:





3. Data Collection

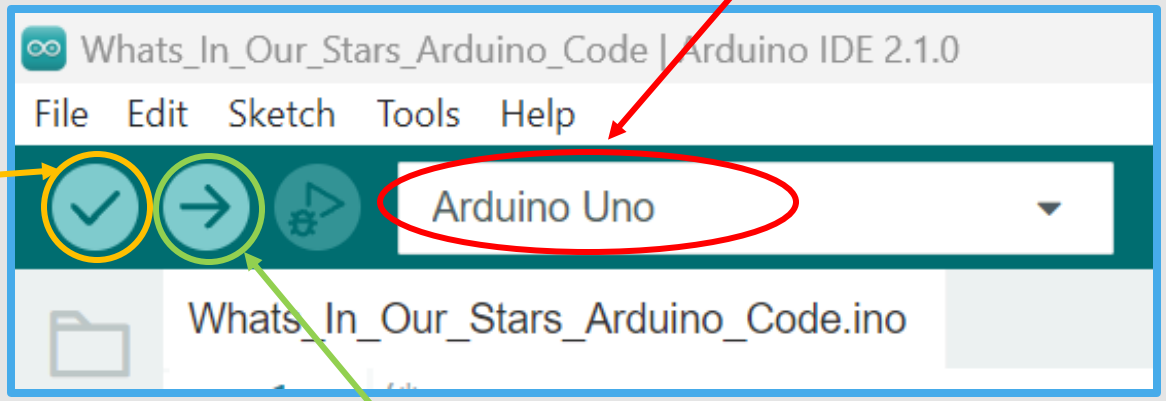
Part 3 describes how to conduct the experiment and collect data on “lab day.”

DATA COLLECTION –

Part 1: Arduino IDE

1. Select your device from the dropdown menu.

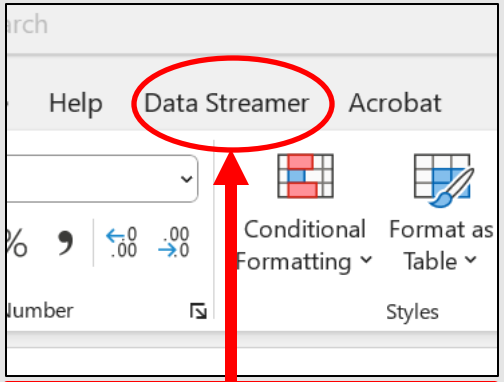
2. Verify the sketch code.



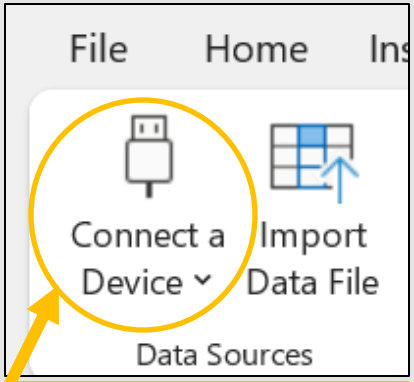
3. Upload the code to the Arduino.

DATA COLLECTION –

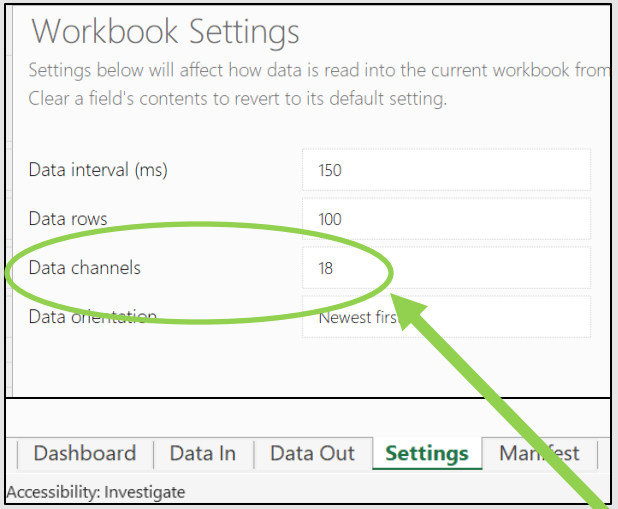
Part **2**: Excel Dashboard



1. Select "Data Streamer" from the top menu bar.



2. Select "Connect a Device" from the top menu bar, then "Arduino."



3. Select the "Settings" Sheet from the bottom menu and make sure "Data channels" is set to **18**.

DATA COLLECTION –

Part 3: Check Dashboard Data Table

- The table on the first sheet should look like the one to the right. →
- If it does, you are good to go! You can skip to Slide 29.
- If you have any of the "Average Intensity" cells showing the error "#REF", follow the directions on the next slide.

	Wavelength	Average Intensity
INFRARED	410nm	#DIV/0!
	435nm	#DIV/0!
	460nm	#DIV/0!
	485nm	#DIV/0!
	510nm	#DIV/0!
VISIBLE	535nm	#DIV/0!
	560nm	#DIV/0!
	585nm	#DIV/0!
	610nm	#DIV/0!
	645nm	#DIV/0!
	680nm	#DIV/0!
	705nm	#DIV/0!
	730nm	#DIV/0!
	760nm	#DIV/0!
	810nm	#DIV/0!
	860nm	#DIV/0!
	900nm	#DIV/0!
	940nm	#DIV/0!

DATA COLLECTION –

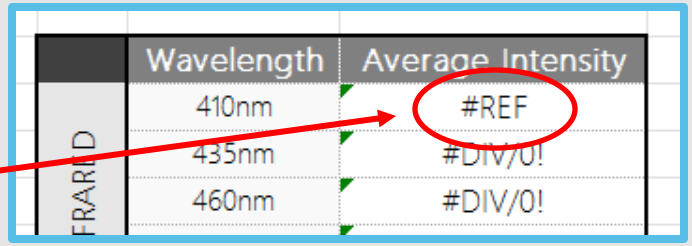
*Part 3A: Dashboard

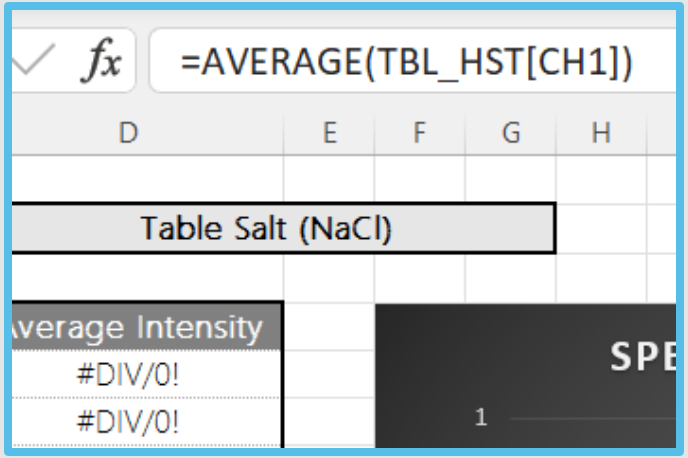
Data Table **TROUBLESHOOTING**

1. The error "#REF" indicates that the reference cells for the formula are not found, but the good news is, it's an easy fix!

2. Click on the Average Intensity for 410nm.

3. Type the following formula into the cell: **=AVERAGE(TBL_HST[CH1])**





DATA COLLECTION –

*Part 3A: Dashboard

Data Table **TROUBLESHOOTING**

4. Each cell formula going down the column should increase by 1 channel.

5. See the table to the right for the correct formulas for Average Intensity at each wavelength.

6. You can copy and paste the formulas for each wavelength from the next slide!

	Wavelength	Average Intensity
INFRARED	410nm	=AVERAGE(TBL_HST[CH1])
	435nm	=AVERAGE(TBL_HST[CH2])
	460nm	=AVERAGE(TBL_HST[CH3])
	485nm	=AVERAGE(TBL_HST[CH4])
	510nm	=AVERAGE(TBL_HST[CH5])
VISIBLE	535nm	=AVERAGE(TBL_HST[CH6])
	560nm	=AVERAGE(TBL_HST[CH7])
	585nm	=AVERAGE(TBL_HST[CH8])
	610nm	=AVERAGE(TBL_HST[CH8])
	645nm	=AVERAGE(TBL_HST[CH10])
	680nm	=AVERAGE(TBL_HST[CH11])
	705nm	=AVERAGE(TBL_HST[CH12])
	730nm	=AVERAGE(TBL_HST[CH13])
	760nm	=AVERAGE(TBL_HST[CH14])
	810nm	=AVERAGE(TBL_HST[CH15])
	860nm	=AVERAGE(TBL_HST[CH16])
	900nm	=AVERAGE(TBL_HST[CH17])
	940nm	=AVERAGE(TBL_HST[CH18])

DATA COLLECTION –

*Part **3**A: Dashboard

Data Table **TROUBLESHOOTING**

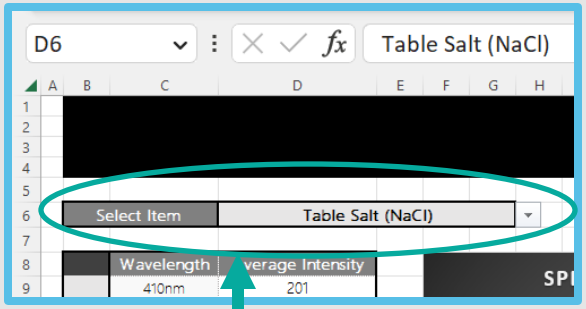
Click on the text box to the right →,

Select all the text, then copy, and paste!

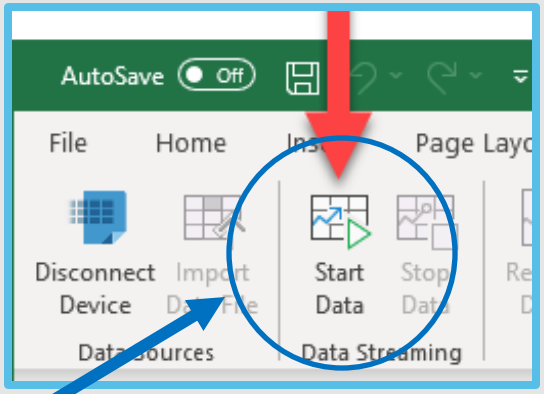
```
=AVERAGE(TBL_HST[CH1])
=AVERAGE(TBL_HST[CH2])
=AVERAGE(TBL_HST[CH3])
=AVERAGE(TBL_HST[CH4])
=AVERAGE(TBL_HST[CH5])
=AVERAGE(TBL_HST[CH6])
=AVERAGE(TBL_HST[CH7])
=AVERAGE(TBL_HST[CH8])
=AVERAGE(TBL_HST[CH9])
=AVERAGE(TBL_HST[CH10])
=AVERAGE(TBL_HST[CH11])
=AVERAGE(TBL_HST[CH12])
=AVERAGE(TBL_HST[CH13])
=AVERAGE(TBL_HST[CH14])
=AVERAGE(TBL_HST[CH15])
=AVERAGE(TBL_HST[CH16])
=AVERAGE(TBL_HST[CH17])
=AVERAGE(TBL_HST[CH18])
```

DATA COLLECTION –

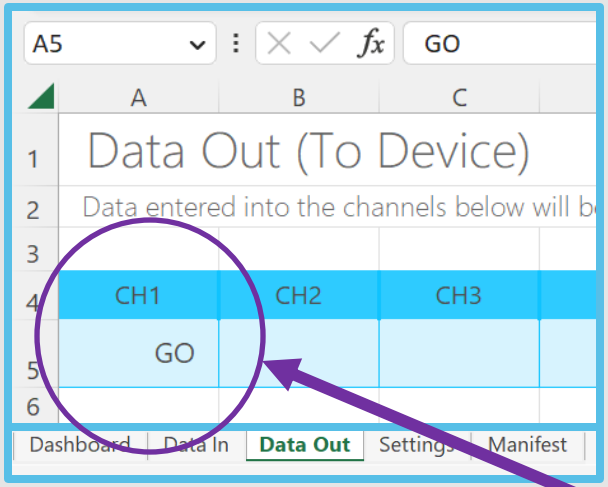
Part **4**: Start Data



4. On the Dashboard Sheet, select the substance name from the dropdown menu.



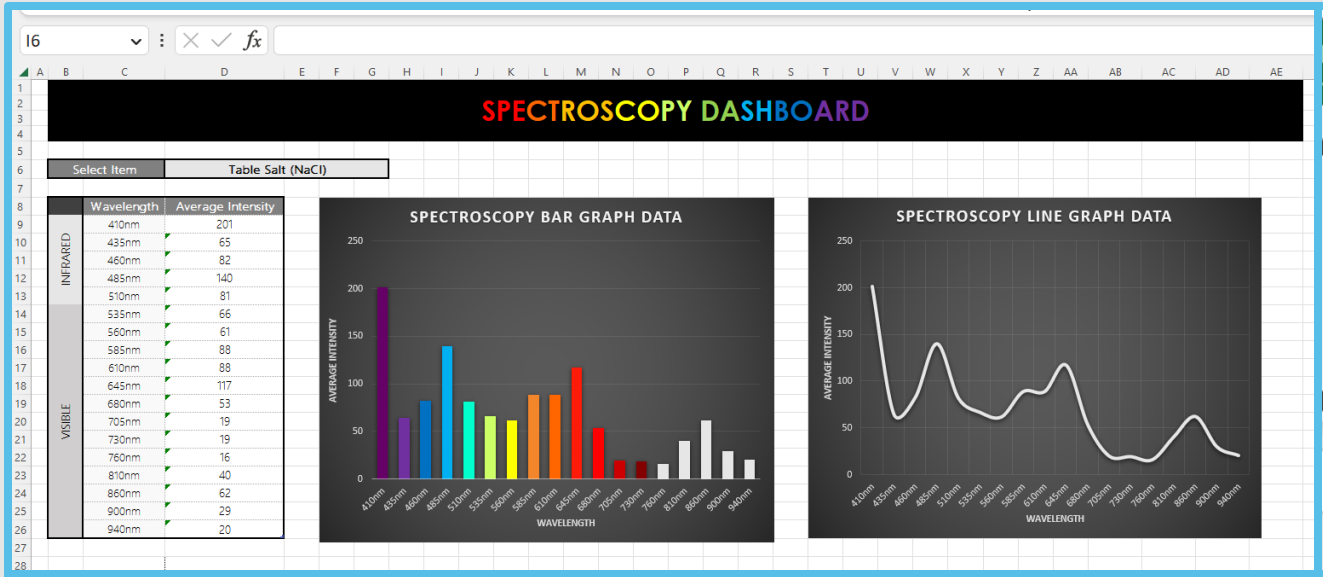
5. Click "Start Data" from the Data Streamer menu bar.

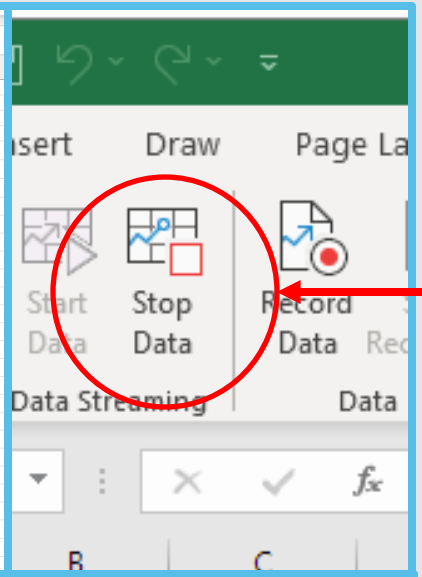


6. Click on the "Data Out" Sheet from the bottom menu. Then type "GO" into cell A5 and hit Enter.

DATA COLLECTION –

Part **5**: Collect Data



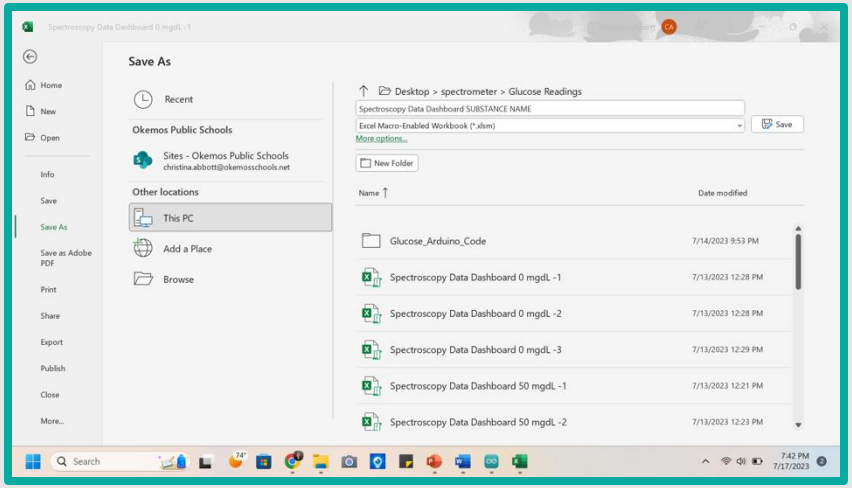


Return to the Dashboard Sheet using the menu at the bottom of the screen. You should now see values in the data table for average intensity, a bar graph, and a line graph created for you.

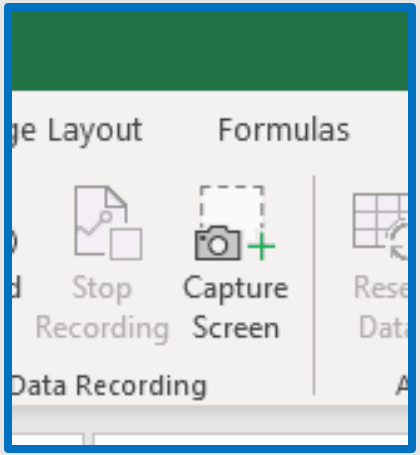
Once the values have stabilized **(~10 seconds)**, click "Stop Data" toward the top of the screen.

DATA COLLECTION –

Part **6**: Save Data



OPTION #1: Select "File," then "Save As."
Suggestion: Save files using the following pattern:
"ClassPeriod_Group#_SameName"
"ClassPeriod_GroupInitials_SameName"
e.g., "Hr1_ABC_TableSalt"



OPTION #2: Select "Capture Screen"

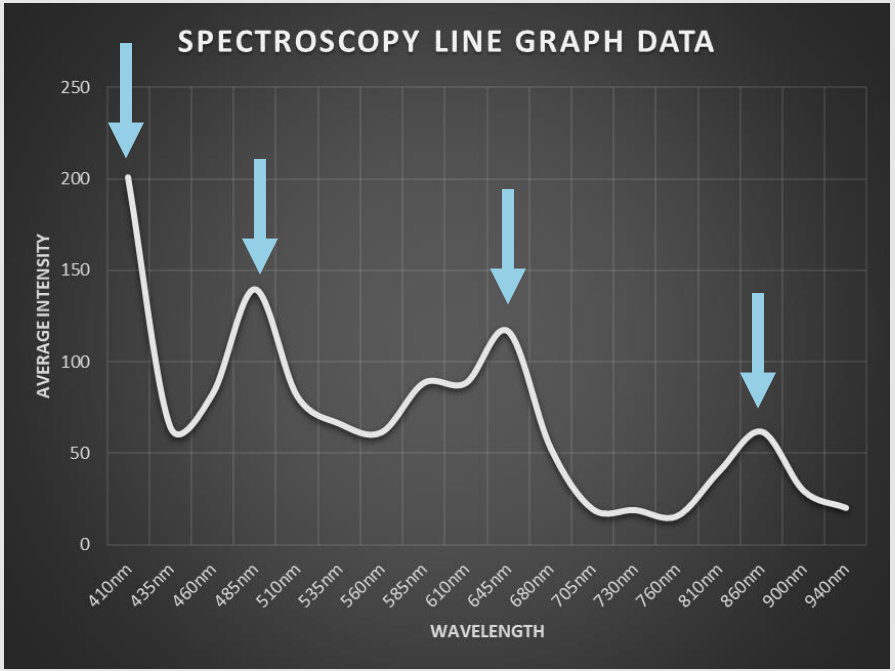
Within the Data Streamer menu is "capture screen"; this creates an image of the sheet shown that students can save.

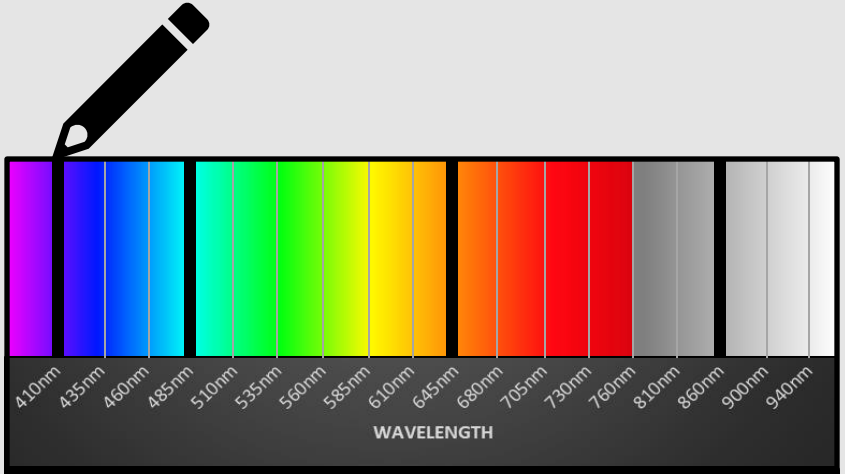
OPTION #3: Use the "Print Screen" shortcut.

Using this keyboard shortcut does the same thing as screen capture above, but automatically saves the image to your "screenshots" folder.

DATA COLLECTION –

Part **7**: Record Data



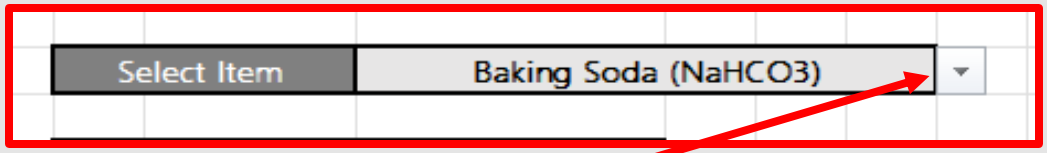


Identify the wavelength values where "peaks" occur on the line graph (see left).

On the student worksheet, use a black marker to draw lines on the provided spectrum at each of the wavelengths where a peak occurred.

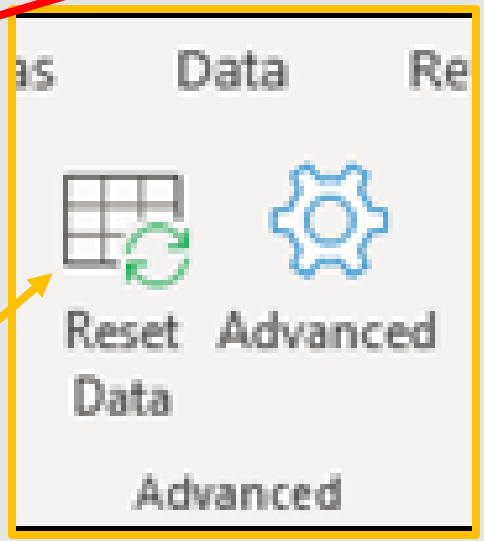
DATA COLLECTION –

Part 8: Reset Data



1. Select the next substance to be sampled from the dropdown menu on the dashboard.

2. Click on the "Reset Data" icon under the data streamer menu.



3. Press the reset button on the Arduino.

DATA COLLECTION –

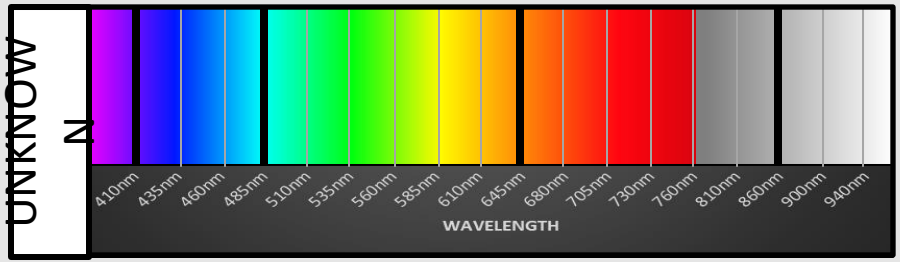
Part **9**: Repeat

Repeat the steps to collect data for each of the known samples and the unknown sample.

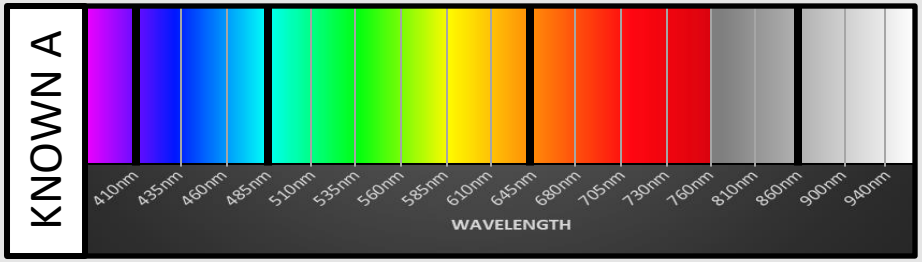
4. Post Lab

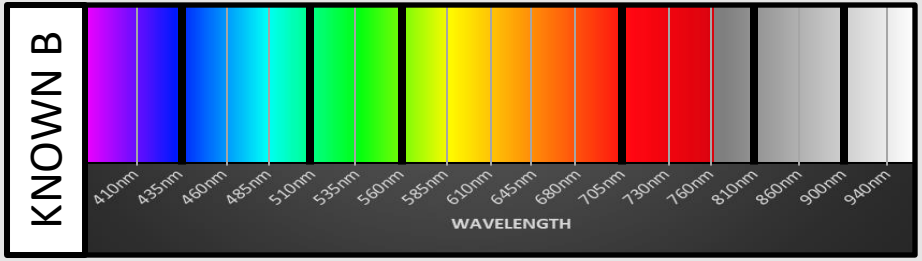
Final steps of the lab activity are included in this section, including how to analyze the data collected and identify the unknown substance.

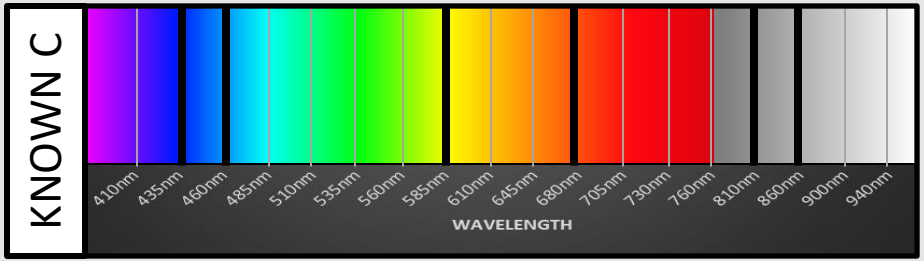
DATA ANALYSIS



MATCH !



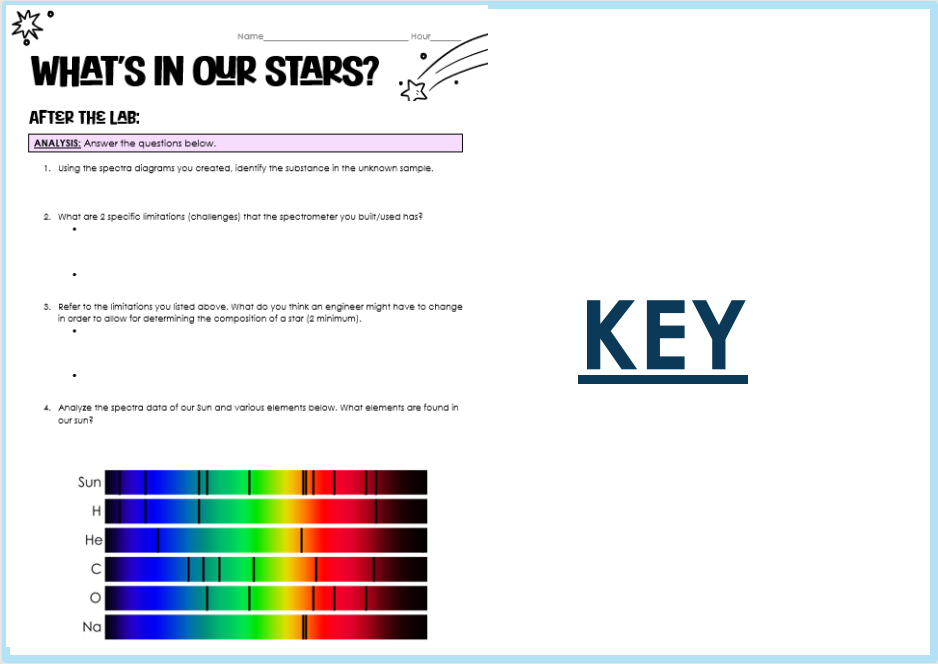




Once data and graphs are collected for the 3 known samples and 1 unknown, compare the unknown graph and spectrum to the knowns to identify the sample.

COMPLETE STUDENT HANDOUT

After identifying their unknown substance, students should complete the analysis questions on the student handout.



Name_____ Hour_____

WHAT'S IN OUR STARS?

AFTER THE LAB:

ANALYSIS: Answer the questions below.

1. Using the spectra diagrams you created, identify the substance in the unknown sample.

2. What are 2 specific limitations (challenges) that the spectrometer you built/used has?
   -
   -

3. Refer to the limitations you listed above. What do you think an engineer might have to change in order to allow for determining the composition of a star (2 minimum).
   -
   -

4. Analyze the spectra data of our Sun and various elements below. What elements are found in our sun?

Sun
H
He
C
O
Na

KEY

Sources

Kramida, A., Ralchenko, Yu., Reader, J. and NIST ASD Team (2022). NIST Atomic Spectra Database (version 5.10), [Online]. Available: https://physics.nist.gov/asd. National Institute of Standards and Technology, Gaithersburg, MD. DOI: https://doi.org/10.18434/T4W30F

Seidle, Nathan (Nate). Spectral Triad (AS7265x) Hookup Guide, [Online]. Available: https://learn.sparkfun.com/tutorials/spectral-triad-as7265x-hookup-guide?_ga=2.208195537.274963032.1659022095-1771007873.1658366162. SparkFun Electronics. Licensed by CC BY-SA 4.0