

# Spreadsheets

For the purposes of the ring strain energy experiment, you will become increasingly aware of the usefulness of spreadsheet programs for data analysis. By programming spreadsheets, you can essentially eliminate the need for calculators and thus make your life *much* easier! There are a number of useful functions explained in the following 'how to guide' that will help you with organizing and analyzing your data. Also, if you do not have a spreadsheet program at home, and you wish to analyze your data there, please visit [www.openoffice.org](http://www.openoffice.org): you can download free open source software similar to Microsoft Office with many of the same features at this site.

## 0. Disclaimer:

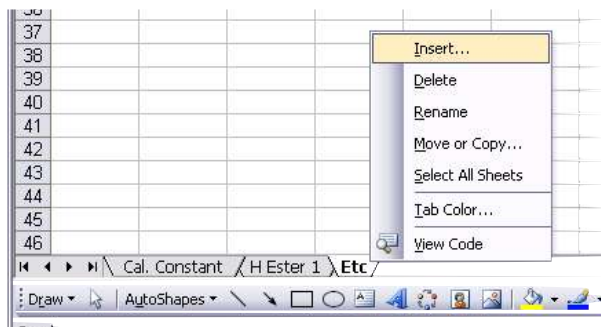
While you can automate many calculations, you should always double check the function outputs against a graphical display to ensure you did not make errors in entering or reading data!

## 1. Importing and Setting up data

By pressing the "=" sign in a cell, the spreadsheet will recognize it as a function. By pressing any cell and any math operator (+, -, \*, /) the spreadsheet will act as a calculator to carry out the function. This is useful, in that by changing the values of one cell, you can instantly determine the output of a variety of mathematical operations!

### Multiple Spreadsheets saves time

You can arrange all of your run data onto one spreadsheet. As shown in the figure, you can do this by right clicking on the tabs at the bottom of the spreadsheet. From this menu you can rename, and insert new sheets.



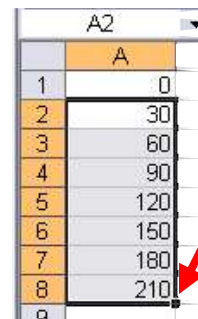
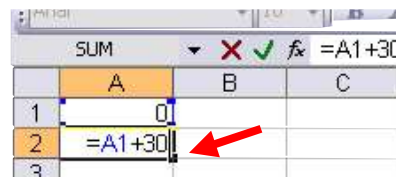
### Useful Tip:

In order to see the function in any given cell, push **F2**

### Filling down:

As an alternative to typing 0,30,60... up to 25-30 minutes, you can use the fill down function to repeat sequences of numbers and functions. The following instructions can be modified for any similar situation!

- 1) Select your "zero" time cell, type in 0. In this case, the zero cell is A1
- 2) In the cell directly below, type = **A1+30**
- 3) After typing in this function, you can left click on the lower right corner (as noted in the figure by the arrow) and drag down to fill. Alternatively, you can select cell "A2" and any number of cells below it, push "**CTRL+D**" and the same action will be performed

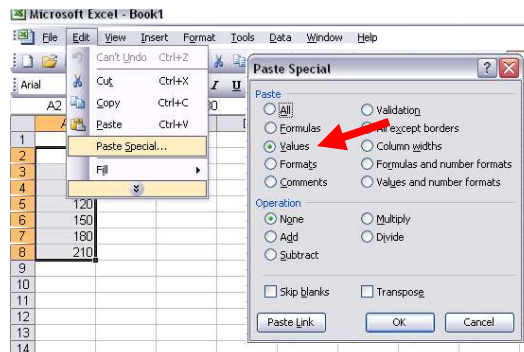


### Problems with the online temperature conversions:

If you happen to notice that you cannot change cells while editing your data, it is likely locked (some of the spreadsheets for temperature conversion are in this format). To resolve this issue, copy and paste your raw data to a new spreadsheet.

### Shortcuts for copy/paste

- 1) Pushing **CTRL+C** while any cell(s) are highlighted will copy the information from those cells
  - 2) Pushing **CTRL+V** will paste the copied cells
- If you notice that pasting in your temperatures is giving odd results (i.e. not what you copied) you are likely pasting in formulas rather than data. Check this with **F2**. To resolve this issue, right click the cell or cells you have selected to paste to or go to **edit**, and use "paste special". Use "values" to paste only the data you have selected, not the formulas!



## 2. Initial Data Analysis

Below is an extremely simplified version of the data you will acquire during this experiment.

0	23.000
30	22.500
60	22.000
90	24.500
120	26.000
150	25.500
180	25.000
210	24.500

### The min/max functions.

With all of your data points very close together, looking for the minima maxima of temperature ranges can be tedious.

- 1) Type `=min(selected cell)` : the minimum of the data is displayed
- 2) The same action can be performed with `=max(numbers)` to find the maximum.

The results of these functions are displayed below:

8	210	24.500
9		
10	MIN	22.000
11	MAX	26.000
12		
13		

The screenshot shows a spreadsheet with data in column B (rows 1-8) and the use of MIN and MAX functions in rows 10 and 11. The formula bar shows `=MIN(B1:B8)` and `MIN(number1, [number2], ...)`.

	A	B	D
1	0	23.000	
2	30	22.500	
3	60	22.000	
4	90	24.500	
5	120	26.000	
6	150	25.500	
7	180	25.000	
8	210	24.500	
9			
10	MIN	=MIN(B1:B8)	
11	MAX	MIN(number1, [number2], ...)	
12			

and

### Averages: PUT THAT CALCULATOR DOWN!

After determining the minimum and maximums of your temperature data, you will need to take an average.

To do this: 1) Select a cell, type `=average (cells you wish to take an average of)`. The average is displayed.

You should verify that these data occur at realistic points in the graph.

IN	22.000
AX	26.000
verage	=average(B10:B11)

10	MIN	22.000
11	MAX	26.000
12	average	24.000

## 3. Determining $T_{ave}$ and projecting temperature data for Delta T

### Overview

You will determine a  $T_{ave}$  : the time at which the temperature rise due to the bomb is at a halfway point.

You will use a spreadsheet to determine line equations ( $y=mx+b$  : **temperature=slope\*time + intercept correction**)

You will then use the  $T_{ave}$  in the linear equations to predict the temperatures at  $T_{ave}$

The two data points for upper and lower temperature will be used to find Delta T

### $T_{ave}$

$T_{average}$  is the time at which the average temperature, as determined above, occurs in your data. You can find this by associating the average temperature directly with one of you data points, making an educated guess, or developing a slope and intercept to associate the average temperature with a time. (see linest functions)

## "Trend lines" without graphs: The LINEST function

After determining the minimum and maximum of your temperature data, you will need to "project" the actual delta T for your data. You can do this graphically, which will be discussed a bit later. Alternatively, you can use the linest function to perform linear regressions. With this function you will eventually be able to "paste" in run data to a spreadsheet, make the spreadsheet do the work for you and **instantly display slope,  $r^2$ , intercept and error values for each of these data!**

The first linear regression (trend line) is for your lower range temperatures → before the bomb.

Select a cell in your spreadsheet, type in  
`=linest([known y's],[known x's],[const],[stats])`

For known y's: lower range of temperatures  
 comma

For known x's: lower range of temperatures  
 comma

For const : nothing  
 comma

For stats : TRUE

End parentheses.

Press "**Enter**"

	A	B	C	D	E	F	G
	0	23.000		LOWER TEMPERATURE LINE			
	30	22.500		=linest(B1:B3,A1:A3,,TRUE)			
	60	22.000					
	90	24.500					
	120	26.000					
	150	25.500					
	180	25.000					
	210	24.500					

The slope of the "trend line" is now displayed. The next step is to convert this function to an array function. Select a 2x3 set of cells, with the upper left corner being the cell with the linest function. Note the placement of the first selected cell: it is important you select the cell with the 'linest function' FIRST.

	D	E	F
	LOWER TEMPERATURE LINE		
	-0.01667		

While the cells are selected, press **F2**. This will display the function.

Press **CTRL + SHIFT + ENTER** This will display the array function:

The data is displayed as such: This data is synthetic, and no error is displayed in this example. Your spreadsheets will more than likely display a non zero number! These values will be very useful for the error propagation segment of the lab write-up.

	D	E	F
	LOWER TEMPERATURE LINE		
	-0.01667	23	
	0	0	
	1	0	

**Slope (M)**      **Intercept (B)**  
**M error**      **B error**  
**R<sup>2</sup>**            **R<sup>2</sup> error**

The regression for the upper temperature range is identical with different x and y ranges.

**Note:** The cells of the array function *cannot* be altered, and you will receive a warning if you attempt to do so. However, the data supplying the array function *can* be altered. To change data ranges of an array function, you will need to select the entire range of cells of the array function, again selecting the upper left cell containing the function, press **F2**. While the function is displayed, you may make changes to the x and y data ranges. After making the changes, press **CTRL + SHIFT + ENTER** and the data will be updated.

### T<sub>ave</sub> and the linest function:

Similar to the regressions done for the lower and temperature ranges, you can use this function on the linear portion of the data occurring after you initiated the bomb to find T<sub>ave</sub>. By limiting the data points selected for this line to the sharply linear portion of heat transfer, you can determine a line equation.

## Projecting $T_{ave}$ into Temperatures.

By rearranging the equation

$$y = m \cdot x + b \text{ to } x = (y - b) / m$$

you can determine the time at which the average temperature occurred.

Select  $y$  as your average temperature,  $b$

as determined in the array function, and  $m$  as determined in the array function. This will display the  $T_{ave}$ . Double check your input values to ensure the displayed value is plausible.

A	B	C	D	E	F	G	H	I
0	23.000		LOWER TEMPERATURE LINE				Tave projection	
30	22.500		-0.01667	23			0.066667	18.16667
60	22.000		0	0			0.009623	0.897527
90	24.500		1	0			0.979592	0.408248
120	26.000							
150	25.500		UPPER TEMPERATURE LINE				TAVE:	$=(B12-I2)/H2$
180	25.000		-0.01667	28				
210	24.500		0	0			TAVE:	87.5
			1	0				
<b>MIN</b>	<b>22.000</b>							
<b>MAX</b>	<b>26.000</b>							
<b>average</b>	<b>24.000</b>							

## In search of Delta T

With  $T_{ave}$  determined, you can apply the slopes and intercepts from the upper and lower temperature lines to find the projected temperatures, if heat transfer were to be instantaneous!

$$\text{Type} = ([\text{cell with } m: \text{slope}] * [\text{cell with } T_{ave}] + [\text{cell with } b: \text{intercept}])$$

The calculation for the upper temperature projection is shown below:

UPPER TEMPERATURE LINE		TAVE:	87.5
-0.01667	28		
0	0		
1	0		
Lower Temp at Tave		21.54167	
Upper Temp at Tave		$=D7*16+E7$	

Lastly, use the spreadsheet to perform a subtraction

$$\text{type} = ([\text{upper temp at Tave cell}] - [\text{lower temp at Tave cell}])$$

Delta T is then displayed in the cell!

Lower Temp at Tave	21.54167
Upper Temp at Tave	26.54167
Delta T	$=H12-H11$
Delta T	5.000

## 4. Further Analysis:

Use the spreadsheet for analysis of your kilojoules consumed and final analysis of the energy of the compound is highly recommended for consistency and the ability to track down mistakes. Please refer to the lab manual for the example spreadsheet regarding this topic. You should take the time to develop a template spreadsheet to which you can paste temperature data, make a few minor adjustments, input mass data for the wire, ester, etc, and determine a value for the energy of the ester within a few minutes.

## Graphical Analysis:

A relatively simple way to locate errant data points and to ensure your input of data was correct is to make a graph.

MENU BAR: INSERT → CHART

Select xy scatter plot, and press next

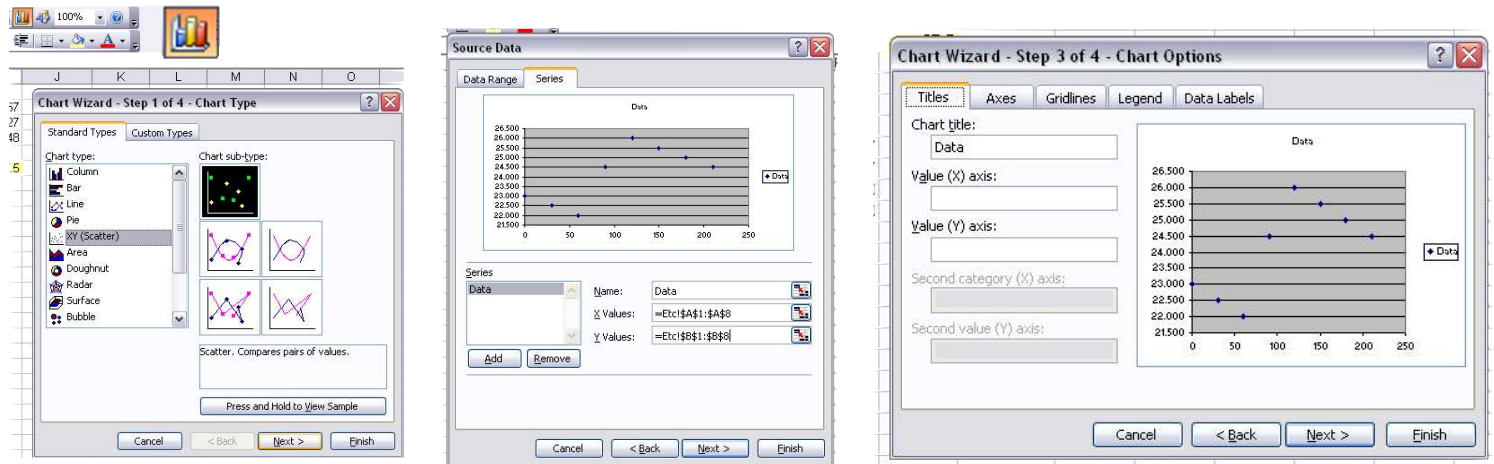
Using the series tab, select all of your data points onto one series

You should also add series with **only** the data from the lower and upper temperature ranges

After adding the data series, click next

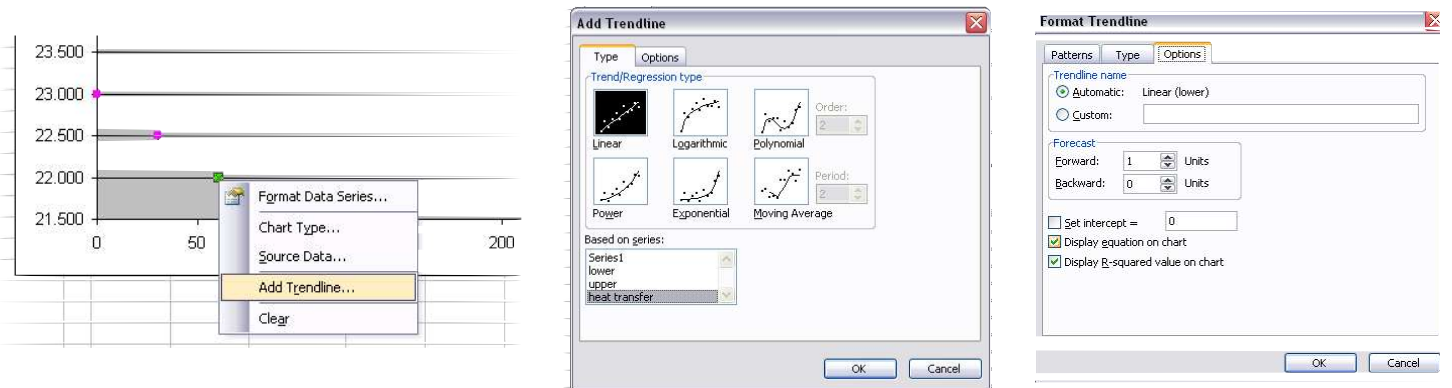
The next menu will allow you to adjust axis titles and parameters → next

Lastly, you will probably find the display of the graph in the same window as your raw data to be advantageous. (as a new object in your current spreadsheet).



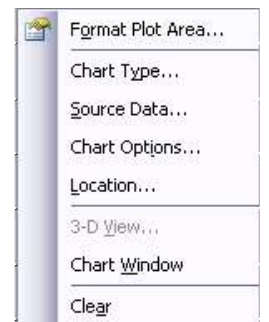
### Adding and manipulating trend lines:

After creating your graphs, you can add trend lines to determine a line equation and  $R^2$  values. Right click on a data series and select add trendline. From the trendline menu, you can select any of your data series. Make sure linear is selected.



From the options menu you should display equation on chart and display an R-squared value. You can also "forecast" the trendline: this can provide a graphical interpretation of the linear equations you determined from the linest functions. You can also compare this value to the values provided by the linest function. Assuming the data ranges are identical, they should provide the same output

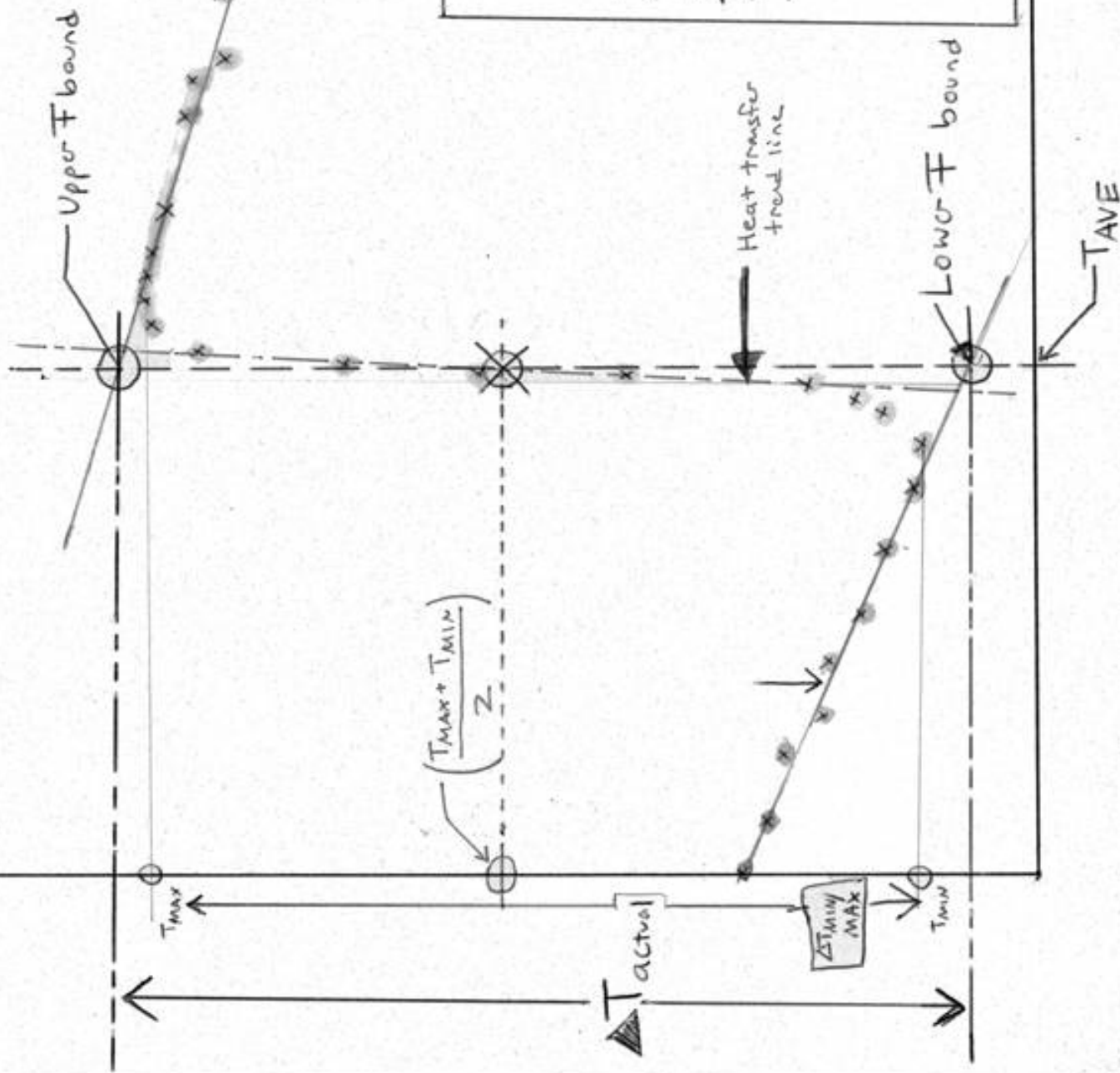
**Right clicking** on the background of the graph will provide you with a menu from which you can change the source data and format of the graph!



Lastly, to increase the decimal display of a cell, use these buttons:



# SAMPLE DATA ANALYSIS



Legend for the data series:

- T MIN/MAX PROJECTIONS to temp
- RAW DATA
- DATA TRENDS
- Heat Transfer Trend
- INSTANTANEOUS  $\Delta T$  TRANSFER
- TAVE PROJECTION TO
- PROJECTION LINES
- actual

\*  $\Delta T_{MIN/MAX}$  greatly underestimates  $\Delta T_{actual}$