

# Experiments in Chemistry

for MiLAB™



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# Experiments by Sensors



## Conductivity

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## pH

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## Pressure (150 –1150 mbar)

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## **Temperature (0°C to 1250°C)**

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# Preface

This book contains 16 Chemistry experiments for students designed for use with MiLAB™ and einstein™ Sensors. MiLAB™ comes pre-installed on the einstein™Tablet or can be installed on any Android or IOS tablet and paired with a LabMate™.

## einstein™Tablet+ and einstein™LabMate™ Devices

### einstein™Tablet+

The einstein™Tablet includes the following:

#### 8 built-in sensors:

- Heart Rate
- Light
- Relative Humidity
- Temperature
- UV
- GPS
- Microphone (sound)
- G-sensor (accelerometer)

+ 4 ports for external sensors

### einstein™LabMate

The einstein™LabMate includes the following:

#### 6 built-in sensors:

- Heart Rate
- Temperature
- Humidity
- Pressure
- UV
- Light

+ 4 ports for external sensors

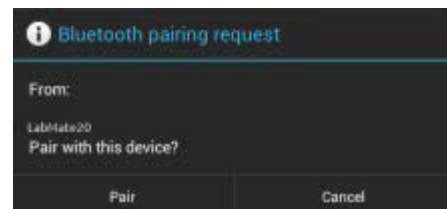
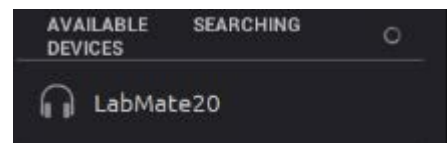
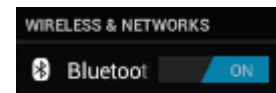
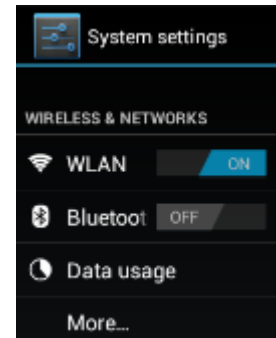
External sensors can be connected to either of these devices by inserting the sensor cable into one of their sensor ports.

## Using the einstein™LabMate

To use MiLAB™ on a non-einstein™ device, one must first pair with an einstein™LabMate via Bluetooth.

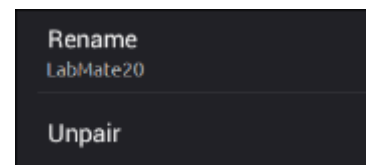
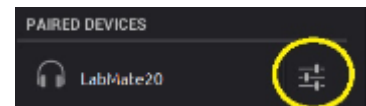
### Pairing with an Android device

1. Make sure the einstein™LabMate is on and not paired with any other device.
2. On your tablet select the Main Menu button and then the System Settings icon.
3. Select the Bluetooth OFF/ON to turn the Bluetooth ON.
4. Once the Bluetooth setting is ON, the device will begin searching for Bluetooth devices.
5. Once the einstein™LabMate is discovered, it will appear in the list of discoverable devices.
6. Select the einstein™LabMate to connect. Your device will show a quick pairing message, followed by a Bluetooth pairing request.
7. Select Pair to approve the pairing process.
8. Once successfully paired, the einstein™LabMate will appear under paired devices.
9. NOTE: Please be patient. As every device is different, the pairing time can vary from a few seconds to a few minutes.



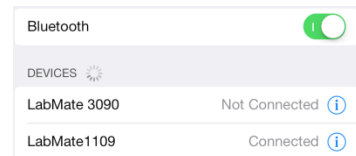
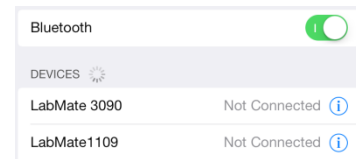
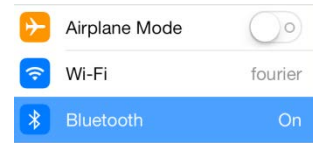
## Unpairing

1. On the Android device, select the Main Menu button > System Settings icon > Bluetooth.
2. Select the icon next to einstein™LabMate that is listed under Paired Devices.
3. A new window will appear showing, Rename and Unpair. Select Unpair.



## Pairing with an iOS device

1. Make sure the einstein™LabMate is on and not paired with any other device.
2. Select Settings
3. Select the Bluetooth OFF/ON to turn the Bluetooth ON.
4. Once the Bluetooth setting is ON, the device will begin searching for Bluetooth devices.
5. Once the einstein™LabMate is discovered, it will appear in the list of discoverable devices.
6. Select the einstein™LabMate to connect.
7. Once successfully paired, the word Connected will appear next to the einstein™ Lab Mate



## Unpairing

1. Select Settings
2. Select the paired einstein™LabMate.



## Working with Graphs in MiLAB

The experiments in this book require the use of the MiLAB program to analyze the results.

### Understanding Graphs

In general graphs in MiLAB represent the data from one or more sensors along the y (or vertical) axis vs. time along the x (horizontal) axis.

By default graphs in MiLAB auto scale which means you can see the entire graph displayed.

To zoom in on one part of the graph touch the screen and spread 2 fingers.

To zoom back out pinch two fingers together.



Pinch to Zoom out



Spread to Zoom in

**Note:** You can also spread and pinch along the x or y-axis to zoom in or out on these axes.

Double tap on the graph to return to the original auto scale graph.

You can also move the graph or axes by touching and dragging them.

### Analyzing a Graph

Analyzing the information contained in a graph is one of MiLAB's most important and powerful functions.

To analyze a graph:

- Run an Experiment.
- In order to use MiLAB's analysis functions you must select at least one point on the graph – this is known as a cursor. Many functions require two cursors.

**Note:** if you are using more than one sensor, both points must be on the same plot line.

## Working with Cursors

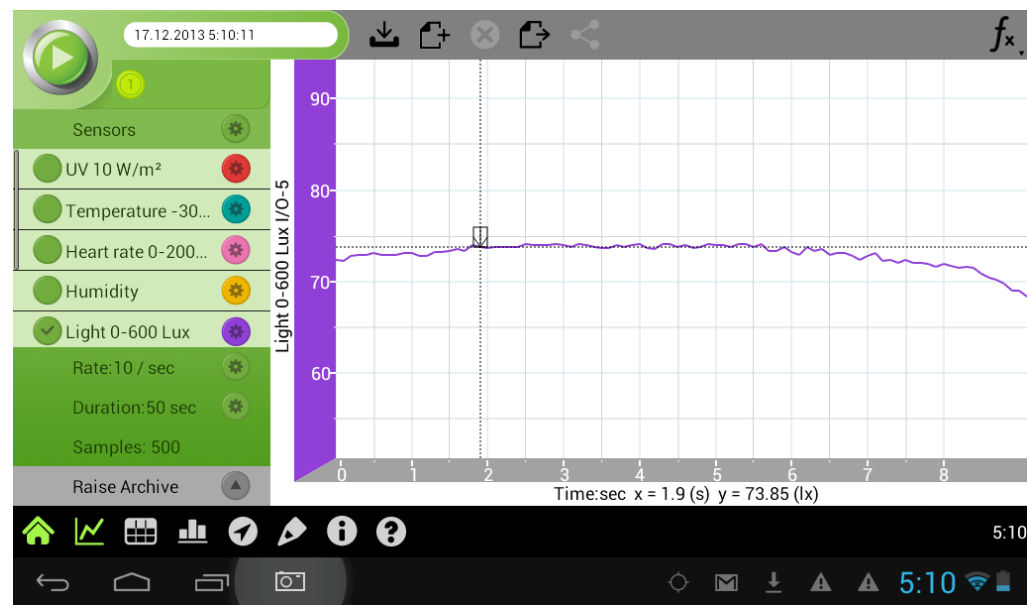
You can display up to two cursors on a graph simultaneously.

Use one cursor to display individual data recording values, to select a curve or, if you are using three or more sensors, to reveal a hidden Y-axis.

Use two cursors to analyze the data in the graph.

### To display the first cursor:

In graph view, tap any point on a plot line. MiLAB will now display the coordinate values.



### To display the second cursor:

Once the first cursor is placed, tap any point on the same plot line.



When there are 2 data points selected; the differences between the 2 points will appear at the bottom of the graph window.

- dX refers to the value between the X axis of the 2 points.
- dY refers to the value between the Y axis of the 2 points.

### Moving a cursor

- Touch and hold a cursor then drag it left and right on a single plot line
- Tap the plot line of a different sensor to move the cursor to that plot line.

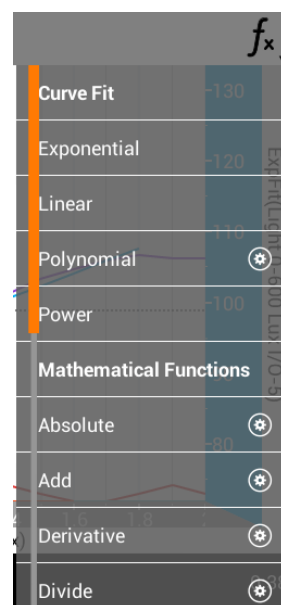
### To remove a cursor:

- Tap and hold a cursor, flick it quickly off the screen in any direction.  
The cursor will disappear from the plot line

## Working with Functions

Once you have selected a cursor, this will activate the Functions button ( $f_x$ ).

Touch the Functions button to access the list of tools available to you.

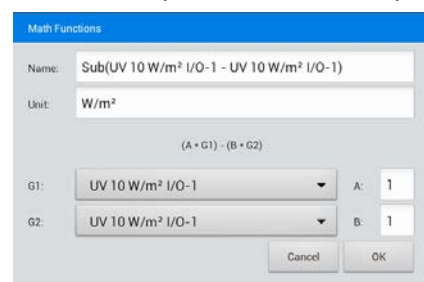


Touch one of these to apply the function.

After you select a function a new plot line will appear on the graph displaying the results.

Some functions, such as **Subtract**, require you to compare 2 plot lines. To compare two plot lines:

- Place two cursors on one of the plot lines.
- Touch the Function button ( $f_x$ ).
- Touch the Setup button (⚙️) next to the desired function.
- In the Setup menu G1 will be the plot line you selected.



- Use the G2 dropdown menu to select the plot line you would like to compare it to.
- Touch **Okay**.
- A new plot line will appear on the graph displaying the results.



## Experiment Layout

Each experiment includes the following parts:

- **Introduction:** A brief description of the concept and theory
- **Equipment:** The equipment needed for the experiment
- **Equipment Setup:** Illustrated guide to assembling the experiment
- **Data Logger Setup:** Recommended setup
- **Procedure:** Step-by-step guide to executing the experiment
- **Data Analysis**
- **Questions**
- **Further Suggestions**


## Sealing

Many of the experiments in this book, especially those involving pressure measurements are dependent on the flasks or test tubes being tightly sealed. Following is a guide to ensure that these experiments run smoothly.

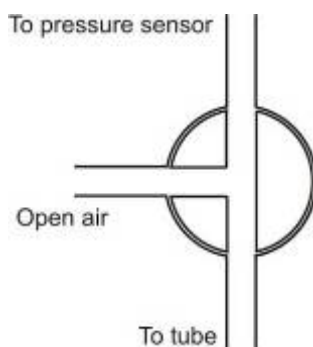
**Note:** To ensure a tight seal you may need to use a material such as modeling clay to seal any openings.

**Note:** You may want to consider purchasing the *einstein™* Pressure Kit which is specifically designed for these types of experiments.

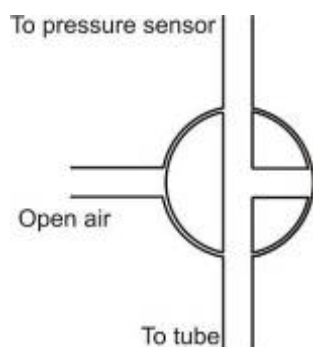
Once you have sealed the flask or test tube, you can test the seal.

1. Select **Play** (  ) to begin recording data.
2. (If your setup includes three-way valves) Turn the three-way valves to enable free air flow from the surrounding air.

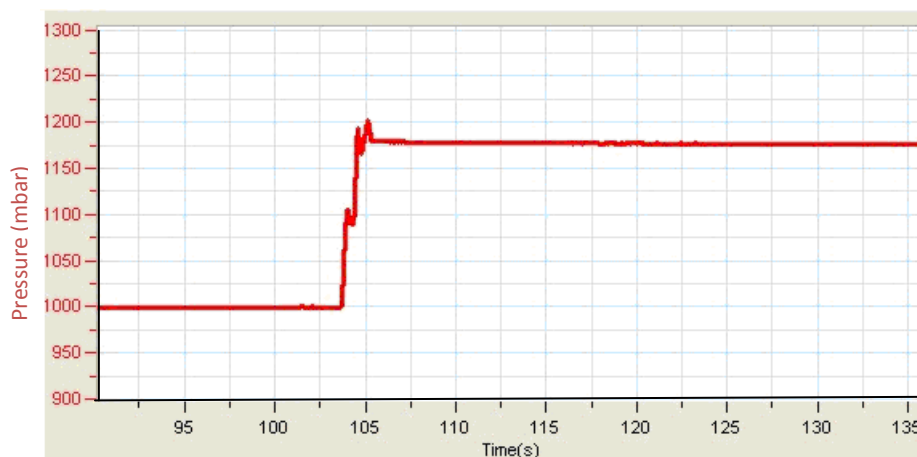
The readings should now indicate the atmospheric pressure.



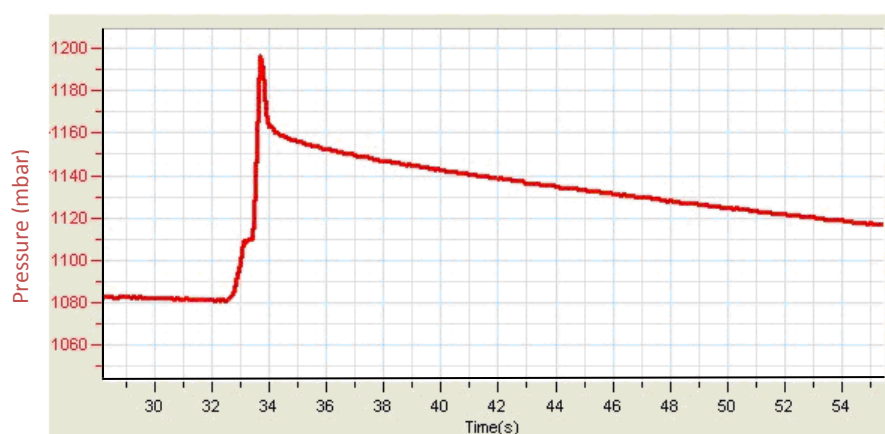
3. (If your setup includes three-way valves) Turn the three-way valves to seal the system from the surrounding air.




4. Press the stoppers. The pressure should rise a little and then remain constant.



5. If the pressure drops (see Figure below) there is a leak. Check your seals carefully and use a material such as modeling clay to seal off any possible openings. Repeat step 4. If that doesn't help, replace the stopper.



6. After you are satisfied that the containers are sealed, Select **Stop** (  ).



## Safety Precautions

- Follow standard safety procedures for laboratory activities in a science classroom.
- Proper safety precautions must be taken to protect teachers and students during the experiments described in this book.
- It is not possible to include every safety precaution or warning!
- Fourier assumes no responsibility or liability for use of the equipment, materials, or descriptions in this book.

## Chapter 1

# Acid - Base Titration: Reaction of NaOH with HCl

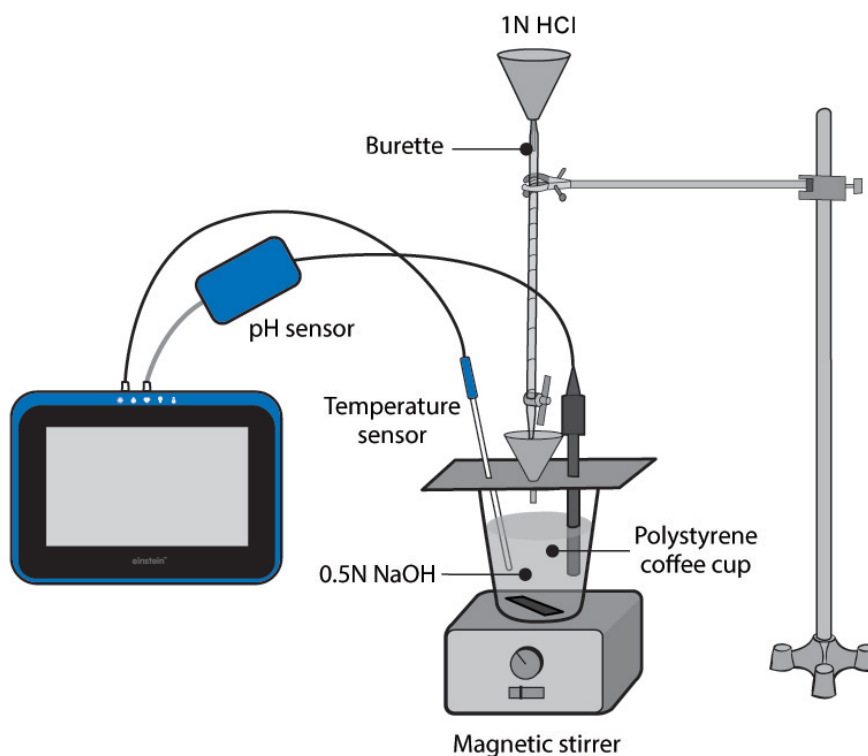


Figure 1



## Introduction

In aqueous solutions, adding bases to water leads to an increase in the pH of the solution, while the addition of acids leads to a decrease in the pH. The changes in the pH can be followed using either specific dyes, called indicators, or a pH electrode. Acids and bases neutralize, or reverse, the action of one another. By adding a known amount of acid to a basic solution, until it completely neutralizes it, the amount of the base can be determined. This procedure is called: Acid - Base Titration. During neutralization, acids and bases react with each other to produce ionic substances, called salts.

In this experiment, changes in pH and temperature, occurring while an acid (hydrochloric acid) is added to a base (sodium hydroxide) solution, are followed using a pH electrode and a Temperature sensor.



## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- A pH sensor and electrode
- A Temperature sensor (-40°C to 140°C)

- A polystyrene coffee cup
- 50 ml burette pipette
- A glass funnel
- 0.5N NaOH
- 100 ml of 1N HCl solution
- Magnetic stirrer
- Safety goggles

## 123 Equipment Setup



1. Launch MiLAB.
2. Connect the pH electrode to one of the ports on the einstein™Tablet or einstein™LabMate.
3. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
4. Select pH and Temperature sensors.
5. Assemble the equipment as illustrated in Figure 1.

## Data Logger Setup

Program the sensors to log data according to the following setup:

pH	
Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	2000 sec

## Procedure

1. Prepare a polystyrene cover for the polystyrene coffee cup. The cover should be flat and larger than the circumference of the coffee cup (see Figure 1).
6. Pierce three holes in the cover: One for the pH electrode, one for the Temperature sensor and one for the glass funnel.
7. Add 50 ml 0.5 N NaOH solution to the coffee cup.
8. Place the coffee cup on a magnetic stirrer.
9. Place the cover on the cup.
10. Select **Play** () to begin recording data.
11. Wait until readings from the sensors are stable.
12. Start stirring the NaOH solution in the coffee cup.
13. Add, drop-by-drop, 1 N HCl solution from the burette to the cup, through the glass funnel.
14. Follow changes in pH and temperature registered on the monitor.
15. As the pH just starts to change, stop the flow of HCl and note the volume of HCl added until that point.
16. Renew the flow of HCl following pH changes very carefully.
17. Stop the flow of HCl as soon as the pH level reaches stabilizes.
18. Save your data by selecting **Save** ()





## Data Analysis

1. On the graph, select the initial pH value of the solution and the final pH value.
2. How did the pH value change during the neutralization process? What was the volume of HCl added when the pH started to change? Compare it to the volume of HCl added when the NaOH was completely neutralized.
3. On the graph, select the time when the pH began to change and then select the point of neutralization. How much time did it take?
4. On the graph, select the initial temperature and the final temperature, how did the temperature change?
5. Calculate the heat of reaction: C- water capacity,  $\Delta T$  - temperature change, M - mass.

$$Q = mc\Delta T$$

**Note:** Water specific heat capacity at 25°C is 4.18 (J/g\*°C).

An example of the graph obtained in this experiment is shown below:

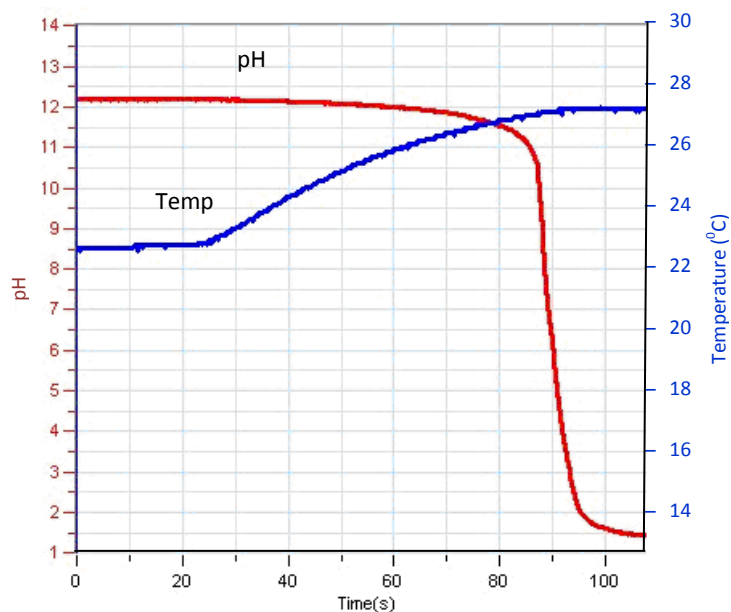


Figure 2



## Questions

1. Did you observe a fast pH change? Explain the difference in the short time interval needed for the completion of the drastic changes of pH and that of the whole neutralization process.
2. Is the neutralization reaction an exothermic reaction? Base your conclusions on the experiment you performed.
3. Try to assume the results of acid - base reaction at different concentrations of NaOH added to the coffee cup. What will be the pH change in each case? What will be the extent of change in the temperature?
4. What will be the effect of reacting other acids (such as, for example, acetic acid) with NaOH?



## Further Suggestions

1. Use different concentrations of NaOH with a constant concentration of HCl.
2. Calculate unknown concentrations of the titrated NaOH (or HCl). This can be achieved by setting the flow of acid (or base) from the burette pipette at a constant rate (by calculating the amount of titrant added to the solution).
3. Examine the effect of increasing the water and/or the surrounding temperature, on the reaction.
4. Perform acid-base reactions with different types of acids and/or bases: A weak acid with a strong base and vice versa.

## Exothermic Reactions: Dissolution of NaOH in Water

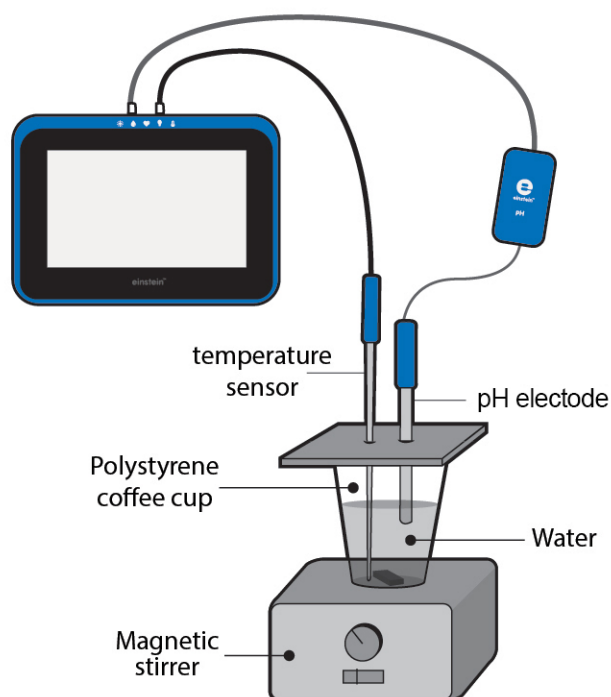


Figure 1



### Introduction

Nearly all chemical reactions involve either the release or absorption of heat. These reactions are classified as either exothermic or endothermic. An exothermic process is a chemical reaction in which heat generated is released. When we perform an exothermic reaction in a flask, it initially warms. Later, heat from the flask flows to the surrounding air until a temperature balance is established. A calorimeter is the device used to measure the heat absorbed or generated during a chemical reaction.

The heat of reaction can be calculated from the following equation:

$$q = C\Delta t$$

Where  $q$  = quantity of heat generated released/absorbed,  $C$  = heat capacity, and  $\Delta t$  = temperature change.

In this experiment we follow the temperature changes that occur during the dissolution of sodium hydroxide in water. A polystyrene coffee cup will serve as a calorimeter.



## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- A pH sensor and electrode
- A Temperature sensor (-40°C to 140°C)
- A polystyrene coffee cup
- 10 g NaOH
- Magnetic stirrer
- Safety goggles



## Equipment Setup

1. Launch MiLAB.
2. Connect the pH sensor to one of the ports on the einstein™Tablet or einstein™LabMate.  
Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.  
Select pH and Temperature sensors.





## Data Logger Setup




Program the sensors to log data according to the following setup:

<b>pH</b>	
<b>Temperature (-40°C to 140°C)</b>	
Rate:	Every 1 sec
Duration:	5000 sec



## Procedure

1. Prepare a polystyrene cover to the polystyrene coffee cup. The cover should be flat and larger than the circumference of the coffee cup. Pierce two holes in the cover; one for the pH electrode, the other for the Temperature sensor.
2. Pour 100 ml of tap water into the coffee cup.
3. Place the coffee cup on a magnetic stirrer.
4. Place the cover on the cup, but leave a narrow opening so that NaOH can be added.
5. Select **Play** (  ) to begin recording data.
6. Wait until readings from the sensors are stable.
7. Start stirring the water in the coffee cup.
8. Add 2 g crystalline NaOH to the cup and immediately adjust the cover so that the cup is sealed as well as possible.
9. Follow changes in pH and temperature registered, until the readings stabilize.
10. Select **Stop** (  ) to stop collecting data.
11. Repeat this experiment, this time in a transparent beaker (this part of the experiment can be performed in parallel to the first part, using two pH electrodes and two Temperature sensors).
12. Add 100 ml water to the beaker and insert a pH electrode and Temperature sensor into the beaker.
13. Start stirring the water.

14. Select **Play** (  ) to begin recording data.
15. Add 2 g of solid NaOH to the water.
16. Follow changes in pH and temperature registered, until the readings stabilize.
17. Select **Stop** (  ) to stop collecting data.
18. Save your data by selecting **Save** (  ).

## Data Analysis

1. How did the pH change during the dissolution process?  
On the graph, select the initial pH value and then the final pH value.
  - a. Note the difference between the two values
  - b. Note how much time it took to reach the final pH value?
  - c. Note the difference between the two pH values?
  - d. Note the temperature change during the process
2. Calculate the heat of the reaction: C- water capacity,  $\Delta t$  - temperature change.

**Note:** Water specific heat capacity at 25 °C is 4.18 (J/g\*°C).

An example of the graph obtained in this experiment is shown below:

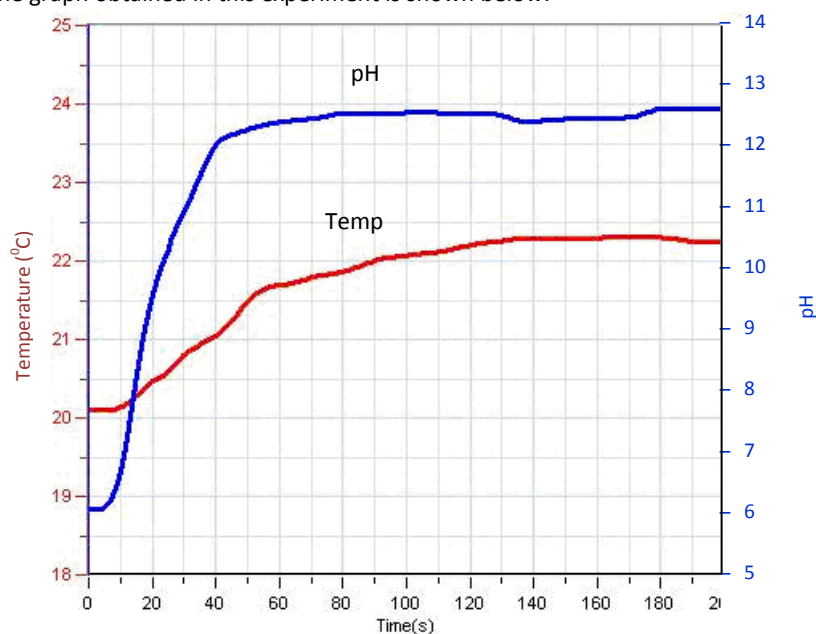


Figure 2



## Questions

1. Was the pH change fast? Compare the time span of the pH changes with that of the temperature changes.
2. Explain the difference in the time span needed for the pH changes and the temperature changes.
3. Is the dissolution of NaOH an exothermic reaction? Is it a vigorous reaction? Base your conclusions on the experiment you performed.
4. Try to guess what the results of the dissolution would be according to different amounts of NaOH in water. What will the pH change be in each case? What will be the temperature change?



## Further Suggestions

1. Dissolve different amounts of NaOH in water. Follow changes in pH and temperature in each case. Calculate the heat of the reaction in each case.
2. Examine the effect of increasing the water and/or the surrounding temperature, on the dissolution of NaOH.
3. Examine the effect of water pH on the dissolution of NaOH. Follow the heat of the reaction in a buffer solution. Alternatively, dissolve KOH or  $\text{NH}_4\text{OH}$  in the water, prior to the dissolution of NaOH.
4. Perform an additional exothermic reaction. Dissolve anhydrous  $\text{CuSO}_4$  (white crystals) in water. Dissolution of Copper Sulfate in water forms a blue hydrated copper ion.

## Chapter 3

# Reduction and Oxidation (Redox) Reactions: Copper Chloride with Aluminum

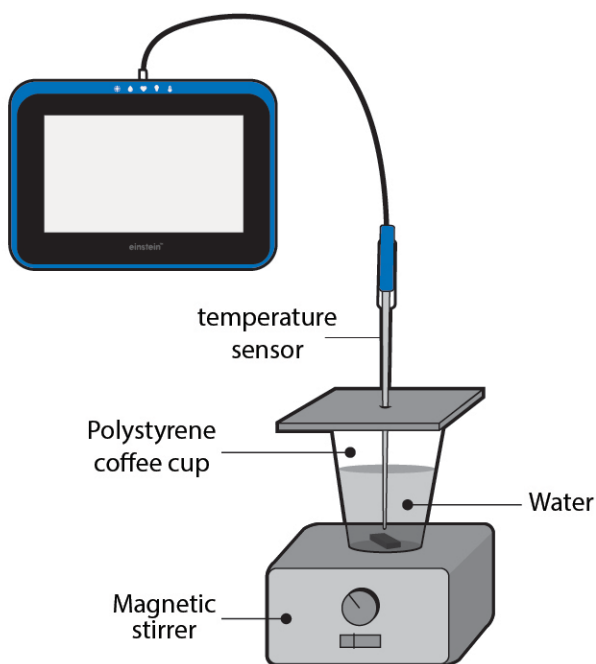


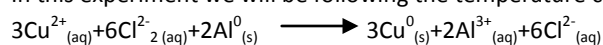
Figure 1

### Introduction

Redox reactions primarily involve the transfer of electrons between two chemicals. The compound that loses an electron is said to be oxidized, the one that gains an electron is said to be reduced.

A compound that is oxidized is referred to as a reducing agent, while a compound that is reduced is referred to as the oxidizing agent.

The oxidation number is a number identical with the valence or number of bonds that an atom can form but with the addition of a + sign to indicate missing electrons or a – to indicate additional electrons. Thus, the oxidation number of chlorine in hydrochloric acid is -1, while it is +1 in hypochlorous acid. Similarly we can say that the oxidation number of chlorine in chloric acid (HClO<sub>3</sub>) is +5, and in perchloric acid (HClO<sub>4</sub>) +7. In this experiment we will be following the temperature changes that occur during redox reaction:



Aluminum, Al, was oxidized to Al<sup>3+</sup>, Cu<sup>2+</sup> was reduced back to Cu.

The heat of reaction can be calculated from the following equation:

$$q = C\Delta t$$

Where  $q$  = quantity of heat generated/absorbed,  $C$  = heat capacity, and  $\Delta t$  = temperature change.



## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- Temperature sensor (-40°C to 140°C)
- Polystyrene coffee cup
- 5 g CuCl<sub>2</sub>
- Magnetic stirrer
- Aluminum paper
- Safety goggles



## Equipment Setup

1. Launch MiLAB™.
2. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
3. Make sure that only the Temperature sensor is selected.
4. Assemble the equipment as illustrated in Figure 1.



## Data Logger Setup




Program the sensors to log data according to the following setup:

Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	200 sec



## Procedure

Always wear safety goggles.

1. Prepare a polystyrene cover to the polystyrene coffee cup. The cover should be flat and larger than the circumference of the coffee cup. Pierce a hole in the cover for the Temperature sensor.
2. Pour 50 ml of tap water into the coffee cup.
3. Place the coffee cup on a magnetic stirrer.
4. Place the cover on the cup but leave a narrow opening so that CuCl<sub>2</sub> can be added.
5. Select **Play** (  ) to begin recording data. Wait until readings from the sensors are stable.
6. Start stirring the water in the coffee cup.
7. Add 5 g crystalline CuCl<sub>2</sub> to the cup and immediately replace the cover so the cup will be as well sealed as possible.
8. Add the aluminum paper to the cup.  
Follow changes in temperature registered on the monitor, until no further changes in temperature are observed.
9. Select **Stop** (  ) to stop collecting data.
10. Save your data by selecting **Save** (  ).



## Data Analysis

1. On the graph, select the starting and final temperatures. What is the difference between them? How did the temperature change during the redox reaction? How long did it take for the reaction to reach the final temperature?
2. Calculate the heat of reaction.

**Note:** Water specific heat capacity at 25 °C is 4.18 (J/g\*°C).

An example of the graph Temperature vs. Time obtained in this experiment is shown below:

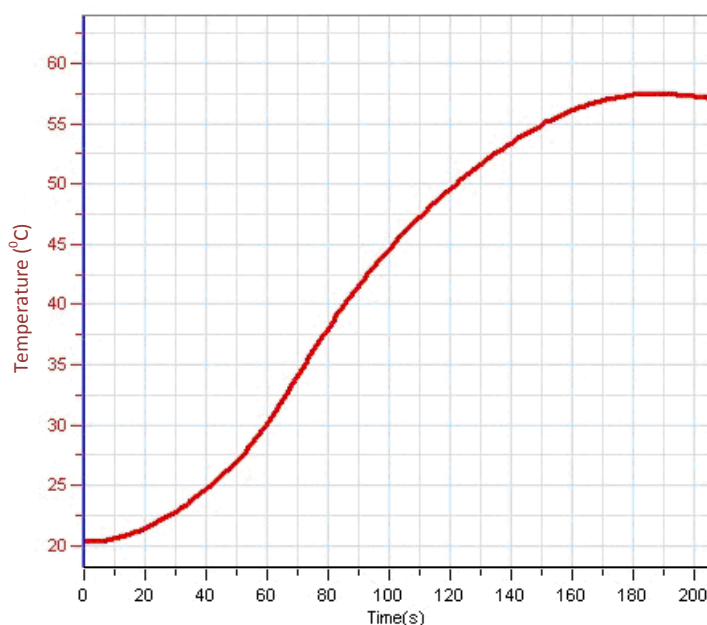


Figure 2

## Questions

1. What changes occurred in the color of the aluminum paper?
2. Write the reaction that took place and write the redox equation.
3. Which atom has reduced, and which was oxidized?

## Further Suggestions

1. Drop a piece of iron into a solution of copper chloride. Write the reaction that occurs, and the redox equation.
2. Drop a piece of zinc metal into dilute hydrochloric acid. Hydrogen (H<sub>2</sub>) is given off. Write the general equation and redox equation. Which atom was reduced? Which atom was oxidized?

## Endothermic Reactions: Dissolution of Ammonium Nitrate in Water

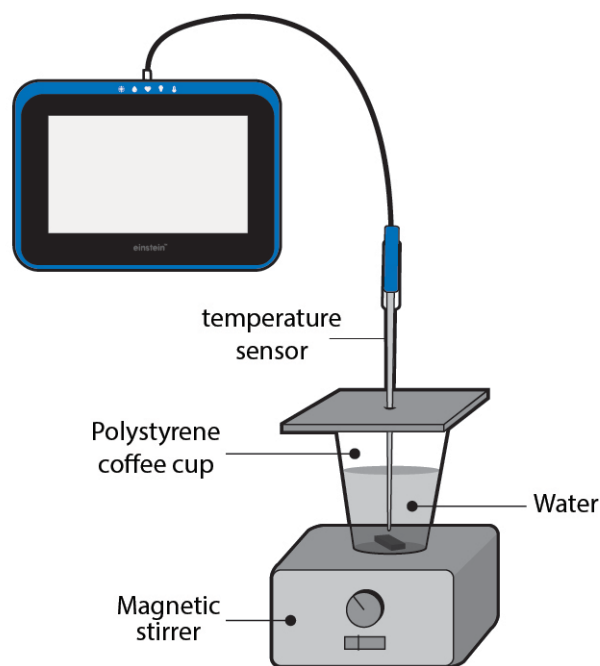


Figure 1

### Introduction

An endothermic process is a chemical reaction in which heat is absorbed. When we perform an endothermic reaction in a flask, it initially cools. Later, heat from the surroundings flows to the flask until the temperature balance is established.

In this experiment we follow temperature changes occurring during the dissolution of crystalline ammonium nitrate in water.

The heat of the reaction can be calculated from the following equation:

$$q = C\Delta t$$

Where  $q$  = quantity of heat generated/absorbed,  $C$  = heat capacity, and  $\Delta t$  = temperature change.

### Equipment

- einstein<sup>TM</sup>Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein<sup>TM</sup>LabMate
- Temperature sensor (-40°C to 140°C)
- 5 g  $\text{NH}_4\text{NO}_3$
- Polystyrene coffee cup
- Magnetic stirrer

- Safety goggles

## 123 Equipment Setup

1. Launch MiLAB.
2. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
3. Make sure that only the Temperature sensor is selected.
4. Assemble the equipment as illustrated in Figure 1.

## Data Logger Setup




Program the sensors to log data according to the following setup:

### Temperature (-40°C to 140°C)

Rate:	Every 1 sec
Duration:	500 sec

## Procedure

Prepare a polystyrene cover to the polystyrene coffee cup. The cover should be flat and larger than the circumference of the coffee cup. Pierce a hole in the cover, and insert the Temperature sensor.

1. Pour 50 ml of tap water into the coffee cup.
2. Place the coffee cup on a magnetic stirrer.
3. Place the cover on the cup but leave a narrow opening so that  $\text{NH}_4\text{NO}_3$  can be added.
4. Select **Play** () to begin recording data.
5. Wait until readings from the sensors are stable.
6. Start stirring the water in the coffee cup.
7. Add 5 g crystalline  $\text{NH}_4\text{NO}_3$  to the cup and immediately replace the cover to ensure that the cup is completely covered.
8. Follow changes in temperature registered on the monitor until no further changes in temperature are observed.
9. Select **Stop** () to stop collecting data.
10. Save your data by selecting **Save** ()

## Data Analysis

1. On the graph, select the starting temperature then select the final temperature.
2. How did the temperature change during the dissolution of crystalline ammonium nitrate in water?
3. What is the difference between the two values?
4. How long did it take for the reaction to reach the final temperature?
5. Calculate the heat of the reaction.

**Note:** Water specific heat capacity at 25 °C is 4.18 (J/g\* °C).

An example of the graph Temperature vs. Time obtained in this experiment is shown below:

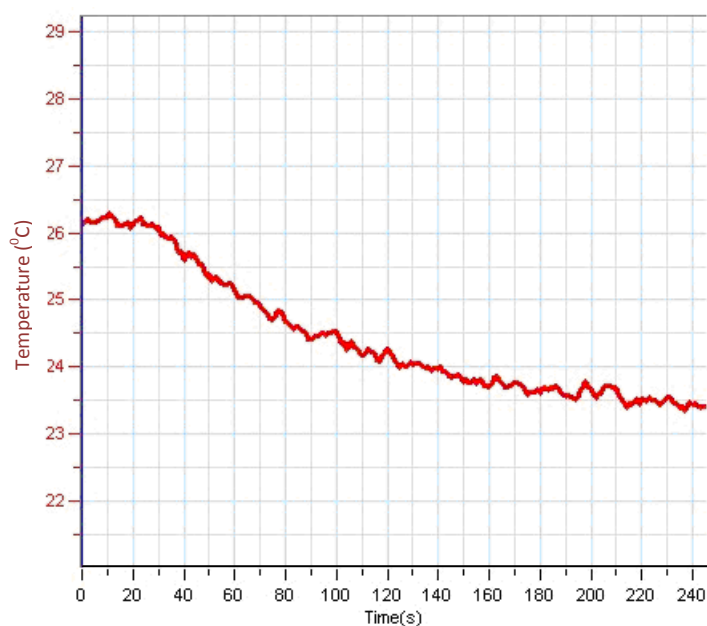


Figure 2



## Questions

1. What kind of chemical reaction is the dissolution of ammonium nitrate in water? Base your conclusions on the experiment you performed.
2. Try to assume the results of the dissolution of different amounts of  $\text{NH}_4\text{NO}_3$  in water. How would the temperature change?
3. What would be the effect of warming the water prior to the dissolution of  $\text{NH}_4\text{NO}_3$ ? What would be the effect of cooling the water?



## Further Suggestions

1. Dissolve different amounts of  $\text{NH}_4\text{NO}_3$  in water. Follow changes in temperature in each case. Calculate heat of the reaction in each case.
2. Examine the effect of increasing the water and/or the surrounding temperature, on the dissolution of  $\text{NH}_4\text{NO}_3$ .

## Endothermic Reactions: Mixing Crystals of Barium Hydroxide and Ammonium Isothiocyanate

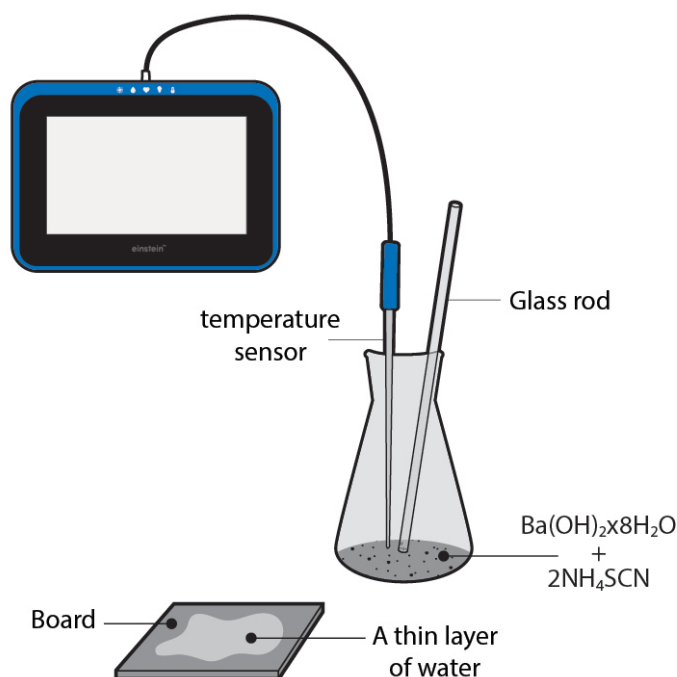
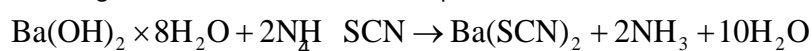


Figure 1

### Introduction

When the two crystalline substances  $\text{Ba(OH)}_2 \times 8\text{H}_2\text{O}$  and  $\text{NH}_4\text{SCN}$  are thoroughly mixed in a flask, a heat absorbing or endothermic reaction develops:



The gaseous substance Ammonia ( $\text{NH}_3$ ), formed in this reaction, can be easily detected due to its pungent smell.

If the flask, which feels very cold to the touch, is set on a board covered with a thin layer of water, the flask and board freeze together.

In this experiment we follow temperature changes that occur while mixing crystalline barium hydroxide octahydrate and ammonium isothiocyanate and experience the reaction flask and the board freezing together.

The heat of reaction can be calculated from the following equation:

$$q = C\Delta t$$

Where  $q$  = quantity of heat generated/absorbed,  $C$  = heat capacity, and  $\Delta t$  = temperature change.



## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- Temperature sensor (-40°C to 140°C)
- 2 g of  $\text{Ba}(\text{OH})_2 \times 8\text{H}_2\text{O}$
- 4 g of  $\text{NH}_4\text{SCN}$
- Wooden or a plastic board, approximately 5 cm x 5 cm
- 100 ml glass flask
- 10 cm glass rod
- Safety goggles



## Equipment Setup

1. Launch MiLAB.
2. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
3. Make sure that only the Temperature sensor is selected.
4. Assemble the equipment as illustrated in Figure 1.




## Data Logger Setup

Program the sensors to log data according to the following setup:

Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	200 sec



## Procedure

1. Pour water on the board until it is covered with a thin layer of water.
2. Weigh 2 g of  $\text{Ba}(\text{OH})_2 \times 8\text{H}_2\text{O}$  in a 100 ml glass flask.
3. Insert the Temperature sensor into the barium hydroxide crystals in the flask.
4. Weigh 4 g of ammonium Isothiocyanate.
5. Select **Play** (  ) to begin recording data.
6. Wait until readings from the Temperature sensor are stable.
7. Add the weighed  $\text{NH}_4\text{SCN}$  to the flask containing  $\text{Ba}(\text{OH})_2 \times 8\text{H}_2\text{O}$ .
8. Place the flask on the water covered board, as demonstrated in Figure 1B.

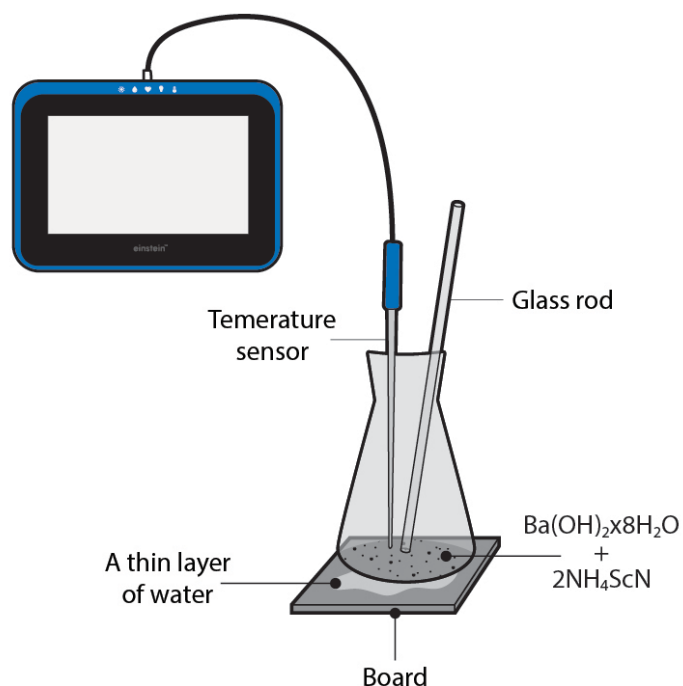


Figure 1B

1. Thoroughly mix the substances in the flask with a glass rod.
2. Follow the temperature changes in the flask, until no further changes in temperature are observed.
3. When the temperature stabilizes, select **Stop** (🟢) to stop collecting data.
4. Save your data by selecting **Save** (💾).
5. Try to remove the flask from the board.

## Data Analysis

1. On the graph, select the initial temperature, and then select the final temperature. How did the temperature change during this chemical reaction? What is the difference between the two values?
2. How long did it take for the reaction to reach the final temperature?  
Calculate the heat of reaction.

**Note: Water specific heat capacity at 25 °C is 4.18 (J/g\*°C).**

3. Describe what happened when you tried to pick up the flask.

An example of the Temperature vs. Time graph obtained in this experiment is shown in the graph below.

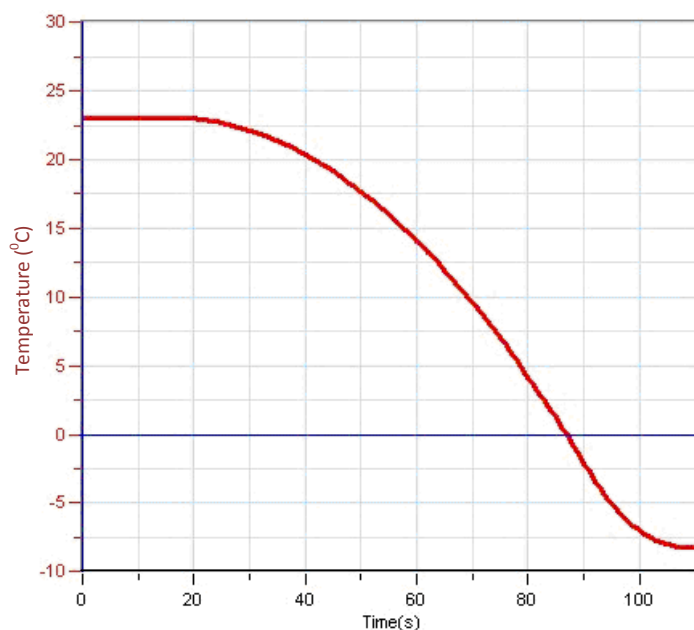


Figure 2



## Questions

1. What changes in the temperature in the flask did you observe? Explain your results.
2. What kind of chemical reaction occurred in the flask?
3. Explain what happened when you tried to lift up the flask.



## Further Suggestions

1. Change the relative amounts of  $\text{Ba}(\text{OH})_2 \times 8\text{H}_2\text{O}$  and  $\text{NH}_4\text{SCN}$  and follow the temperature change in each case.
2. Perform an additional endothermic reaction: Dissolution of  $\text{KNO}_3$  in water (25 g in 50 ml water).
3. Follow the rate of ammonium release in the reaction, using a Pressure sensor. In this way the reaction rate can be measured.



## Endothermic Reactions: Reaction of Citric Acid Solution with Baking Soda

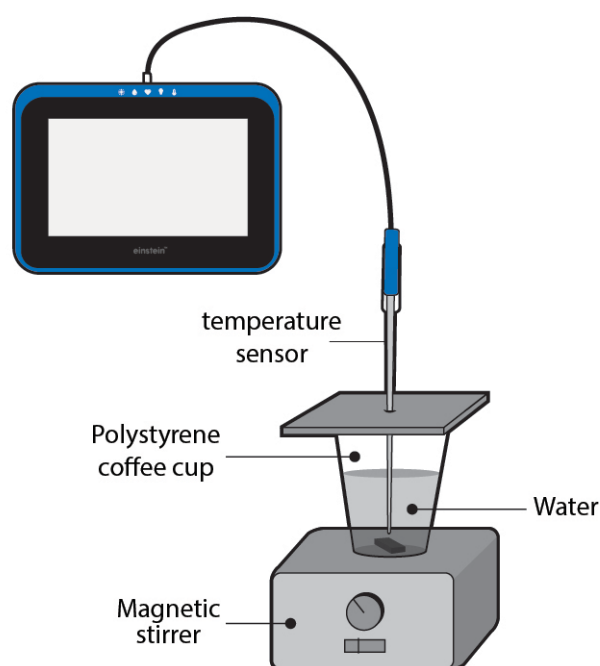


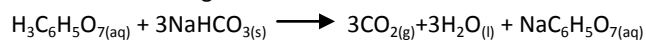
Figure 1



### Introduction

An endothermic process is a chemical reaction in which heat is absorbed. When we perform an endothermic reaction in a flask, it initially cools. Later, heat from the surroundings flows to the flask until temperature balance is established.

In this experiment we follow temperature changes occurring during the reaction between citric acid solution and baking soda.



The heat of reaction can be calculated from the following equation:

$$q = C\Delta t$$

Where  $q$  = quantity of heat generated/absorbed,  $C$  = heat capacity, and  $\Delta t$  = temperature change.



## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- Temperature sensor (-40°C to 140°C)
- 25 ml citric acid  $\text{H}_3\text{C}_6\text{H}_5\text{O}_7$  solution
- 15 g baking soda  $\text{NaHCO}_3$
- Polystyrene coffee cup
- Magnetic stirrer
- Safety goggles



## Equipment Setup

1. Launch MiLAB™.
2. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
3. Make sure that only the Temperature sensor is selected.
4. Assemble the equipment as illustrated in Figure 1.



## Data Logger Setup




Program the sensors to log data according to the following setup:

Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	500 sec



## Procedure

Obtain and wear safety goggles.

1. Prepare a polystyrene cover to the polystyrene coffee cup. The cover should be flat and larger than the circumference of the coffee cup. Pierce a hole in the cover, and insert the Temperature sensor.
2. Pour 25 ml citric acid into the coffee cup.
3. Place the coffee cup on a magnetic stirrer.
4. Place the cover on the cup, but leave a narrow opening so that the baking soda ( $\text{NaHCO}_3$ ) can be added.
5. Select **Play** (  ) to begin recording data. Wait until readings from the sensors are stable.
6. Start stirring the water in the coffee cup.
7. After 20 seconds add the baking soda ( $\text{NaHCO}_3$ ) to the cup and immediately replace the cover to ensure that the cup is sealed.
8. Follow changes in temperature registered on the monitor, until no further changes in temperature are observed.
9. Select **Stop** (  ) to stop collecting data.
10. Save your data by selecting **Save** (  ).

## Data Analysis

1. On the graph select the initial temperature, then select the final temperature. How did the temperature change during this chemical reaction? What was the difference between the two values?
2. How long did it take for the reaction to reach the final temperature?  
Calculate the heat of the reaction.

An example of the Temperature vs. Time graph obtained in this experiment is shown below:

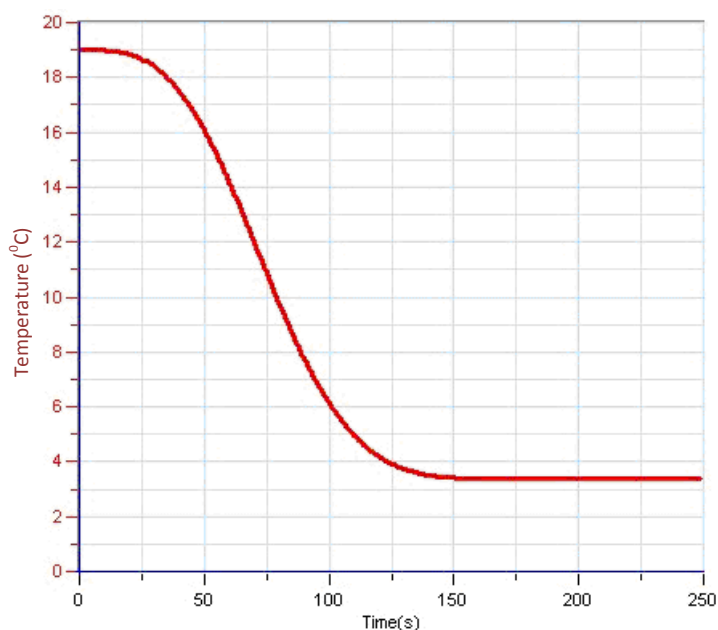


Figure 2

## Questions

1. What kind of chemical reaction takes place when mixing citric acid solution and baking soda? Base your conclusions on the experiment you performed.
2. Try to assume the results of mixing different amounts of baking soda in a citric acid solution. What will be the extent of the temperature change?

## Further Suggestions

1. Change the relative amounts of citric acid and baking soda. Follow changes in temperature in each case. Calculate the heat of reaction in each case.
2. Follow the rate of CO<sub>2</sub> release in the reaction, using the CO<sub>2</sub> sensor.

## Chemical Catalysis: Decomposition of $\text{H}_2\text{O}_2$ in the Presence of $\text{MnO}_2$

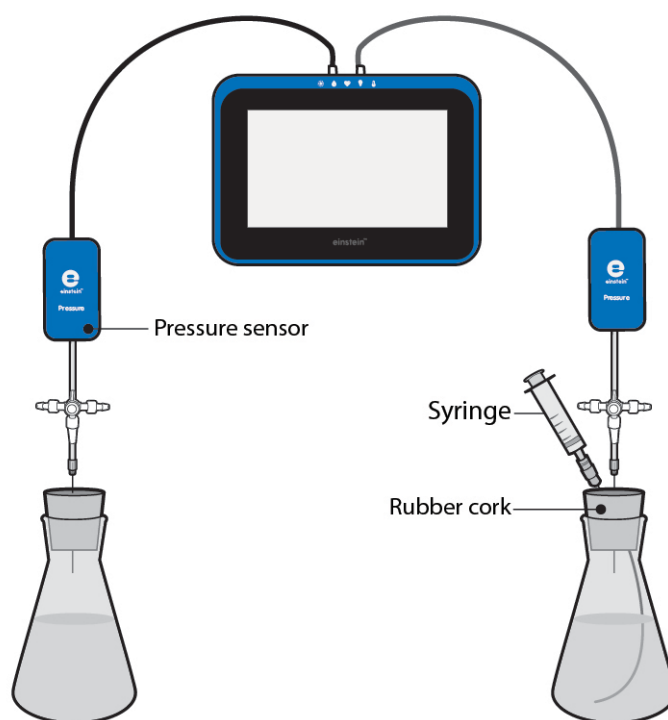


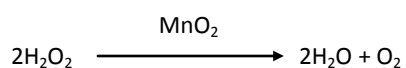
Figure 1



### Introduction

A catalyst is a chemical that increases the rate of a reaction. This process is called catalysis. A catalyst takes part in a reaction but is not consumed by the reaction. The catalyst enters the reaction in one step and is regenerated in another step.

A pure solution of  $\text{H}_2\text{O}_2$  is stable. But when a catalyst, such as  $\text{MnO}_2$ , platinum metal or  $\text{Fe}^{+2}$  ions are added, it rapidly decomposes to water and molecular oxygen.



In this experiment we follow the release of molecular oxygen resulting from the decomposition of  $\text{H}_2\text{O}_2$  in the presence of  $\text{MnO}_2$  using Pressure sensors.



## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- Two 100 ml glass bottles
- Two rubber corks, one for each of the bottles
- Two 10 ml plastic syringes
- Two 20-gauge syringe needles
- Three short latex tubes
- 3% H<sub>2</sub>O<sub>2</sub> solution
- Crystal MnO<sub>2</sub>
- Two Pressure sensors (150 – 1150 mbar)
- Two three-way valves
- Safety goggles

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## Equipment Setup

1. Launch MiLAB.
2. Connect the Pressure sensors to ports on the einstein™Tablet or LabMate.
3. Select Pressure sensors.
4. Assemble the equipment as illustrated in Figure 1 and Figure 2.
5. A syringe needle (20-gauge) is inserted through the cork, until its tip projects out slightly (see Figure 2).

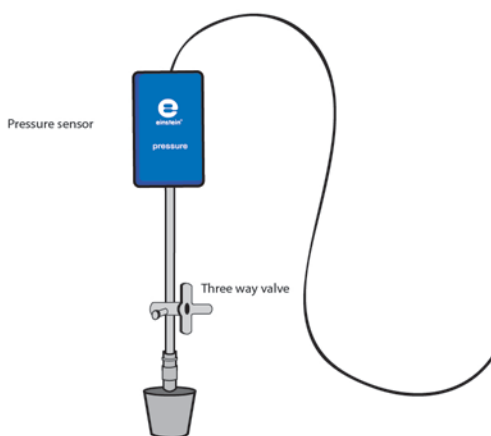


Figure 2

6. At the other end of the syringe, projecting out of the upper side of the cork, a three-way valve (the one used in infusions) is attached via a very short latex tube. It's length must be just enough to hold together the valve and the syringe. A Pressure sensor is connected to the valve.
7. Turn the valve until its opening is directed vertically. In this position, air can flow through the valve.
8. Insert an additional needle into one of the corks. A syringe filled with 3% H<sub>2</sub>O<sub>2</sub> solution will be attached to this needle later.
9. For this experiment the flasks must be tightly sealed. For more information see: **Sealing**.






## Data Logger Setup

Program the sensors to log data according to the following setup:

Pressure (150 – 1150 mbar)	
Rate:	Every 1 sec
Duration:	500 sec



## Procedure

1. Mark the bottles with labels 1 and 2.
2. Fill the plastic syringe with 2 ml of 3% H<sub>2</sub>O<sub>2</sub> solution.
3. Add 8 ml water and 2 ml 3% H<sub>2</sub>O<sub>2</sub> solution to bottle 1.
4. Add 8 ml water and a few crystals of MnO<sub>2</sub> to bottle 2. Gently mix the solution.
5. Close the bottles tightly with the rubber corks.
6. Attach the syringe filled with H<sub>2</sub>O<sub>2</sub> solution to bottle 2 through the additional needle inserted through the cork.
7. Select **Play** (  ) to begin recording data.
8. Follow the pressure level registered on the computer monitor.
9. Check that the air in the flasks is at atmospheric pressure (about 1000 mbar).
10. Inject the H<sub>2</sub>O<sub>2</sub> solution into bottle 2 and immediately turn the valves of the two bottles, to stop airflow through them.
11. Follow changes in pressure registered on the computer monitor during the experiment.
12. Select **Stop** (  ) to stop collecting data.
13. Save your data by selecting **Save** (  ).



## Data Analysis

1. On one graph select the initial pressure and the final pressure. Do the same for the second graph.
2. How did the pressure change in each of the bottles?
3. Find the difference between the two sets of values.
4. Calculate the reaction rate of H<sub>2</sub>O<sub>2</sub> decomposition. Create a differential graph by subtracting the Pressure graph of the control flask from that of the experimental flask:
  - a. Use the cursor to select the beginning and end points of the plot line from the flask in which the MnO<sub>2</sub> was added.
  - b. Select **Function**
  - c. In the **Functions** drop-down menu select the **Setup** button next to the **Subtract equation**.
  - d. In the **G1** drop-down menu, select **Pressure** (from the flask with MnO<sub>2</sub>). In the **G2** drop-down menu select **Pressure** (from the control flask).
  - e. Select the new plot line
  - f. Select **Function**
  - g. Select **Linear Fit** from the Function menu
  - h. The slope of the fit line is the net reaction rate.

An example of the graph obtained in this experiment is shown below:

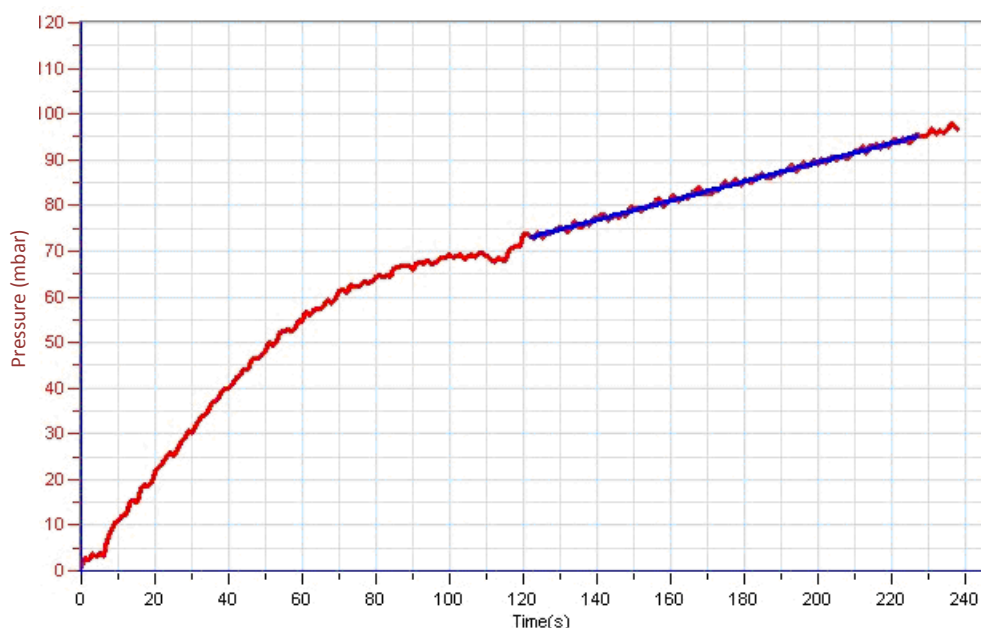


Figure 3



## Questions

1. How is the pressure affected by the decomposition of  $\text{H}_2\text{O}_2$ ?
2. Compare the changes in pressure in the two flasks. Did you observe a change in flask 1? In flask 2? Explain the differences.
3. Which of the flasks serves as a control? Explain.
4. Why is a control system needed in the experiment?
5. What is the effect of adding  $\text{MnO}_2$  crystals to the flasks?
6. What would be the effect of adding increasing amounts of  $\text{MnO}_2$  on the reaction rate?
7. What would be the effect of raising the temperature in the bottles during the experiment on the  $\text{H}_2\text{O}_2$  decomposition rate?



## Further Suggestions

1. Add increasing amounts of  $\text{MnO}_2$  to the reaction mixture and follow the reactions.
2. Calculate the reaction rate obtained in each experiment.
3. Compare the effect of different types of chemical catalysts:  $\text{HBr}$ ,  $\text{HI}$ ,  $\text{Fe}^{+2}$  ions, platinum metal.
4. Change the concentration of  $\text{H}_2\text{O}_2$  added to the reaction mixture. Compare the effect of reactant concentrations on the reaction rate along with that of the catalyst.
5. Follow the temperature changes that occur during the reaction. Evaluate the effect of temperature on the decomposition rate of  $\text{H}_2\text{O}_2$ .

## Effects of Variations in Air Temperature on Air Pressure: The Combined Gas Law

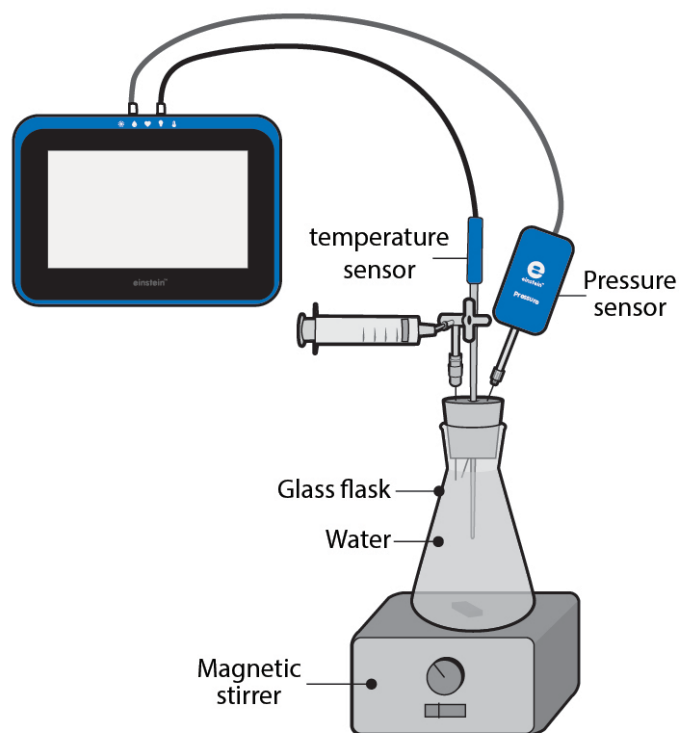


Figure 1



### Introduction

The volume of gases is affected by temperature. As stated in the Gay-Lussac's Law, a sample of gas at a fixed pressure increases in volume linearly with temperature:

$$V \propto T \quad \text{or} \quad V/T = \text{constant}$$

Gay-Lussac's Law combined with Boyle's Law can be expressed in one statement - *the Combined Gas Law*.

This law states that the volume occupied by a given amount of gas is proportional to the absolute temperature divided by the pressure:

$$PV/T = \text{constant}$$

In this experiment we investigate the relationship between pressure and temperature and their effect on gas behavior, by measuring the effect of warming a constant volume of air trapped in a sealed flask on its pressure.





## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- 50 ml glass flask
- Rubber cork
- Two 20-gauge syringe needles
- Three short latex tubes
- Three-way valve
- Temperature sensor (-40°C to 140°C)
- Pressure sensor (150 – 1150 mbar)
- Stand
- Magnetic stirrer
- Safety goggles

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## Equipment Setup

1. Launch MiLAB.
2. Connect the Pressure sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
3. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
4. Make sure that only the Temperature and the Pressure sensors are selected.
5. Assemble the equipment as illustrated in Figure 2 below.
6. A syringe needle (20-gauge) is inserted through the cork, until its tip projects slightly out of the cork (Figure 2).

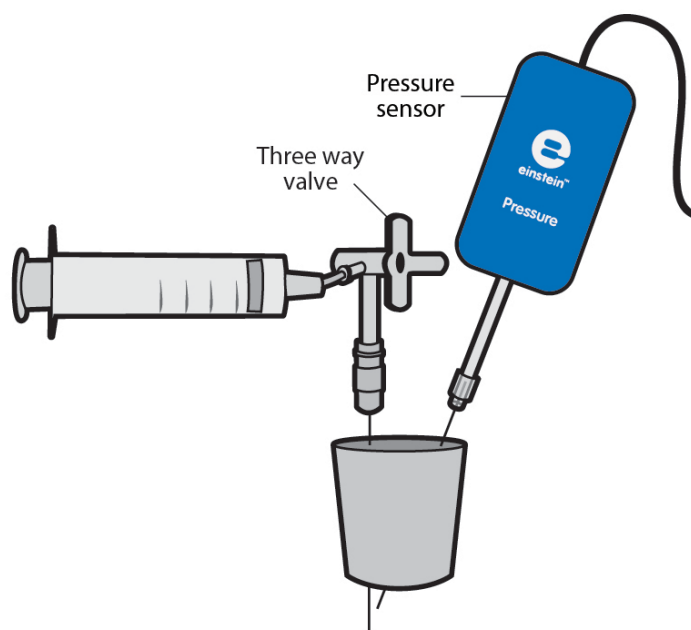


Figure 2

7. At the other end of the needle, projecting out of the upper side of the cork, attach a three-way valve. Attach a Pressure sensor to the other end of the valve.
8. Turn the valve until its opening is directed horizontally. In this position, air can flow through the valve from the flask to the surroundings.

- For this experiment the flasks must be tightly sealed. For more information see: **Sealing**.






## Data Logger Setup

Program the sensors to log data according to the following setup:

Pressure (150 – 1150 mbar)	
Rate:	Every 1 sec
Duration:	500 sec
Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	500 sec



## Procedure

- Assemble the equipment as illustrated in Figure 1 above.
- Pierce a hole in the cork, big enough to insert the tip of the Temperature sensor. Alternatively, make a narrow slot on the side of the cork.
- Fill the glass flask with water. Leave a small volume of air in the flask, to prevent water from reaching the needles.
- Insert the Temperature sensor into the hole or the slot prepared in the cork.
- Cork the flask and start stirring.
- Make sure the pressure in the flask equals atmospheric pressure (around 1000 mbar). Then turn the valve to prevent air entering the flask.
- Select **Play** (  ) to begin recording data.
- Follow changes in pressure registered on the screen.
- Start warming the flask. Turn the warming button of the magnetic stirrer to a middle position. Follow changes in pressure for about 5 minutes.
- Select **Stop** (  ) to stop collecting data.
- Save your data by selecting **Save** (  ).

## Data Analysis

Compare the pattern of changes in the pressure with that of temperature: Did you find any similarity between the two of them?

An example of the original graphs obtained in this experiment is shown below:

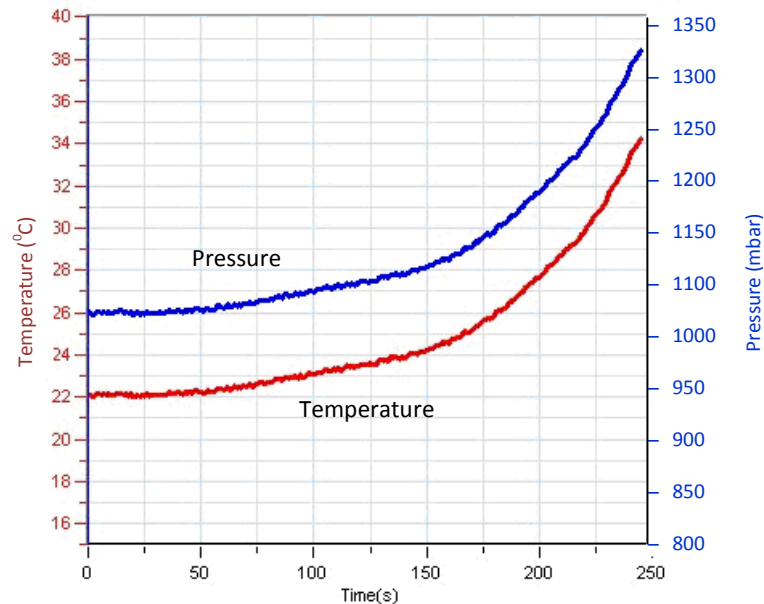


Figure 3

## Questions

1. Changes in temperature and in pressure displayed a non-linear curve. Why?
2. What would be the shape of the curves if the flask was warmed in a bath?
3. What would be the effect of cooling the flask on the pressure?
4. Suppose that the water volume in the flask was reduced. What would be the effect of warming the flask compared to the results in the present experiment?

## Further Suggestions

1. Warm the flask for a while. Then, stop warming the flask. As the temperature stabilizes, start cooling the flask. Follow the changes in pressure measured in the flask.
2. Perform the experiment with different water volumes in the flask. Compare the effect of warming or cooling on the pressure in each instance.

# Hess's Law: The Conservation of Energy in Chemistry

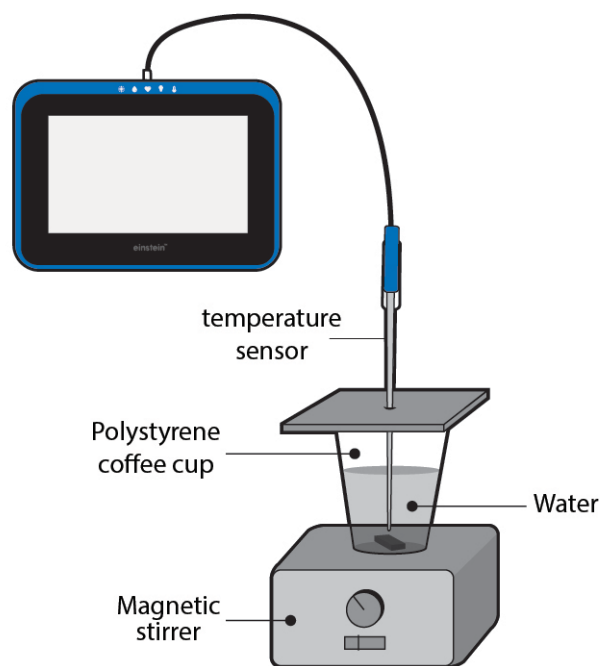


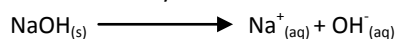
Figure 1



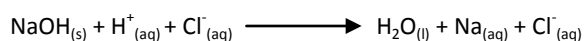
## Introduction

According to Hess's Law, if a reaction can be carried out in a series of steps, the sum of the enthalpies (total energy) of the individual steps should equal the enthalpy for the overall reaction. The reactions we will be using in this experiment are:

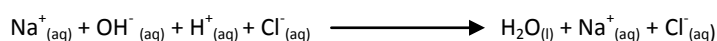
1. Solid sodium hydroxide dissolved in water to form an aqueous solution of ions.



2. Solid sodium hydroxide reacts with aqueous hydrochloric acid to form water and an aqueous solution of sodium chloride.



3. Solutions of aqueous sodium hydroxide and hydrochloric acid react to form water-ioned aqueous sodium chloride.





## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- Temperature sensor (-40°C to 140°C)
- 250 ml beaker
- Polystyrene coffee cup
- Magnetic stirrer
- 50 ml of 1.0 M NaOH
- 50 ml of 1.0 M HCl
- 100 ml of 0.5 M HCl
- 100 ml of water
- 4 g of solid NaOH
- Safety goggles

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## Equipment Setup

1. Launch MiLAB.
2. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
3. Make sure that only the Temperature sensor is selected.
4. Assemble the equipment as illustrated in Figure 1.



## Data Logger Setup



Program the sensors to log data according to the following setup:


Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	500 sec



## Procedure

Always wear safety goggles at all times

1. Prepare a polystyrene cover for the polystyrene coffee cup. The cover should be flat and larger than the circumference of the coffee cup. Pierce a hole in the cover, and insert the Temperature sensor.
2. Pour 100 ml tap water into the coffee cup.
3. Place the coffee cup on a magnetic stirrer.
4. Place the cover on the cup, but leave a narrow opening so that NaOH can be added.
5. Select **Play** (  ) to begin recording data.
6. Wait until readings from the sensors are stable.
7. Start stirring the water in the coffee cup.
8. Reaction #1:
  - a. Add 2 g crystalline NaOH to the cup and immediately replace the cover ensuring that it is sealed.
  - b. Follow the temperature changes until the temperature stabilizes.
  - c. Select **Stop** (  ) to stop collecting data.

- d. Save your data by selecting **Save** (  ).
9. Reaction #2:  
Repeat the dissolution reaction (steps 3-12) using 100 ml of 0.5 M HCl instead of water.

**Caution:** Handle the HCl and NaOH with great care.

10. Reaction #3:  
Repeat steps 3-12, initially measuring out 50 ml of 1.0 M HCl into the beaker.  
In step 9, instead of solid NaOH, add 50 ml of 1.0 M NaOH.

## Data Analysis

For each reaction, note the initial and final temperatures. Find the temperature change ( $\Delta t$ ) for each reaction.

Determine the mass of 100 ml of solution for each reaction (assume the density of each solution is 1 g/mL).  
Calculate the heat released by each reaction.

1.  $q$ , ( $c_p=4.18\text{J/g} \cdot ^\circ\text{C}$ )  $q = C_p \times m \times \Delta t$   
Find  $\Delta H$  ( $\Delta H = -q$ )
2. Calculate moles of NaOH used in each reaction.
3. Determine  $\Delta H/\text{mol NaOH}$  in each of the three reactions.
4. Combine the heat of reaction ( $\Delta H/\text{mol}$ ) from steps 1 and 3.

An example of the graph obtained in this experiment is shown below:

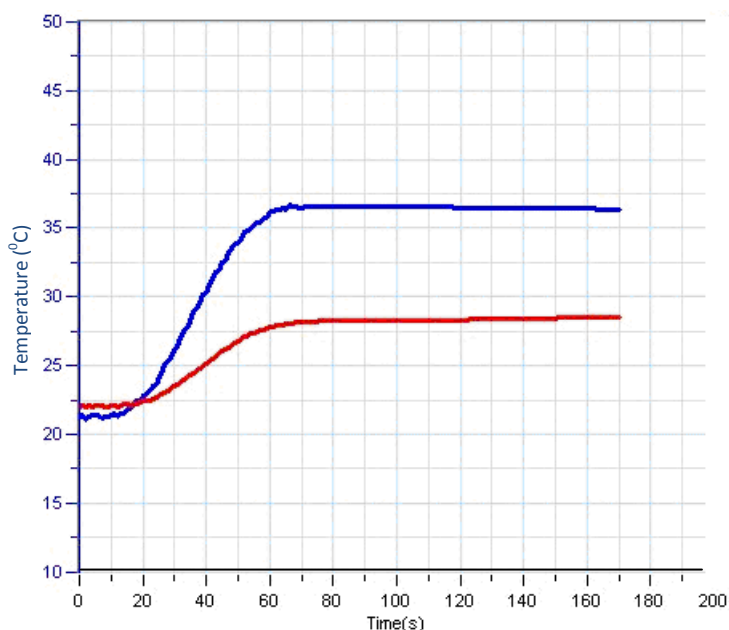


Figure 2



## Questions

1. According to your data, is the heat of all the reactions equal to the sum of heat of the individual reactions?
2. Find the percentage error for the experiment.



## Further Suggestions

Dissolve different amounts of NaOH. Follow the changes in temperature.

1. Follow the pH changes in each reaction.
2. Dissolve anhydrous  $\text{CuSO}_4$  in water and  $\text{CuSO}_4 \times 5\text{H}_2\text{O}_{(\text{s})}$  in water and calculate Hess' Law for:  
$$\text{CuSO}_4(\text{s}) + 5\text{H}_2\text{O} \longrightarrow \text{CuSO}_4 \times 5\text{H}_2\text{O}$$

# Heat of Combustion

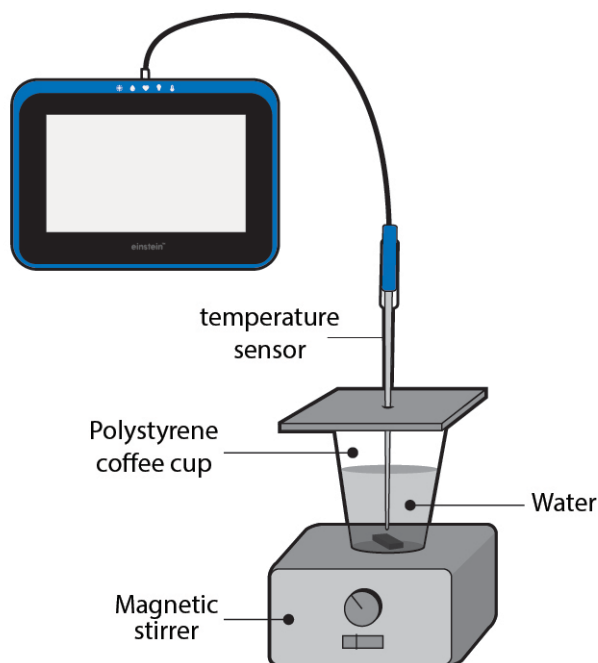
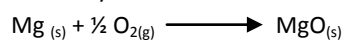


Figure 1

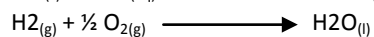
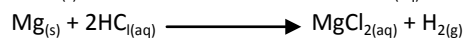
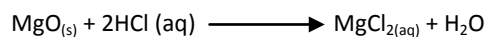


## Introduction

According to Hess's Law, if a reaction can be carried out in a series of steps, the sum of the enthalpies (total energy) of the individual steps should equal the enthalpy change for the overall reaction. In this experiment we will use Hess's Law to analyze a reaction that would be difficult to understand just by direct measurement. We will study the heat of combustion of magnesium ribbon:



This equation can be obtained by combining







## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- Temperature sensor (-40°C to 140°C)
- 250 ml beaker
- Polystyrene coffee cup
- $\text{Mg}_{(s)}$  – Magnesium ribbon 0.5 g
- 1 g  $\text{MgO}$
- 500 ml of 1M HCl
- Magnetic stirrer
- Safety goggles



## Equipment Setup

1. Launch MiLAB.
2. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
3. Make sure that only the Temperature sensor is selected.
4. Assemble the equipment as illustrated in Figure 1.



## Data Logger Setup

Program the sensors to log data according to the following setup:




### Temperature (-40°C to 140°C)

Rate:	Every 1 sec
Duration:	500 sec



## Procedure

Always wear safety safety goggles

1. Prepare a polystyrene cover for the polystyrene coffee cup. The cover should be flat and larger than the circumference of the coffee cup. Make a hole in the cover for the Temperature sensor.
2. Pour 100 ml 1.0 M HCl into the coffee cup.
3. Place the coffee cup on a magnetic stirrer.
4. Put the cover on the cup, but leave a narrow opening so that  $\text{MgO}$  can be added.
5. Select **Play** (  ) to begin recording data.  
Wait until readings from the sensors are stable.
  - a. Reaction #1:  
Start stirring the HCl in the coffee cup.  
Add 1 g crystalline  $\text{MgO}$  to the cup and immediately replace the cover so that the cup will sealed.
  - b. Follow the changes in temperature registered on the monitor, until no further changes are observed.
  - c. Select **Stop** (  ) to stop collecting data.
  - d. Save your data by selecting **Save** (  ).
6. Reaction #2:  
Repeat the reaction (steps 2 - 5) using 0.5 g of magnesium ribbon rather than magnesium oxide powder.

## Data Analysis

1. One at a time, select the locations on the graph when each reaction was generated.
2. Find the temperature change ( $\Delta t$ ) for each reaction.
3. Calculate the heat released by each reaction,  $q$ .  $q = Cp\Delta t$   $cp = 4.18 \text{ J/g}^\circ\text{C}$ ,  $m = 100 \text{ g}$  of HCl solution.
4. Convert joules to kJ in your final answer.
5. Determine  $\Delta H$  ( $\Delta H = q$ ).
6. Determine the moles of MgO and Mg used.
7. Calculate  $\Delta H/\text{mol}$  MgO and Mg.

An example of the graph obtained in this experiment is shown below:

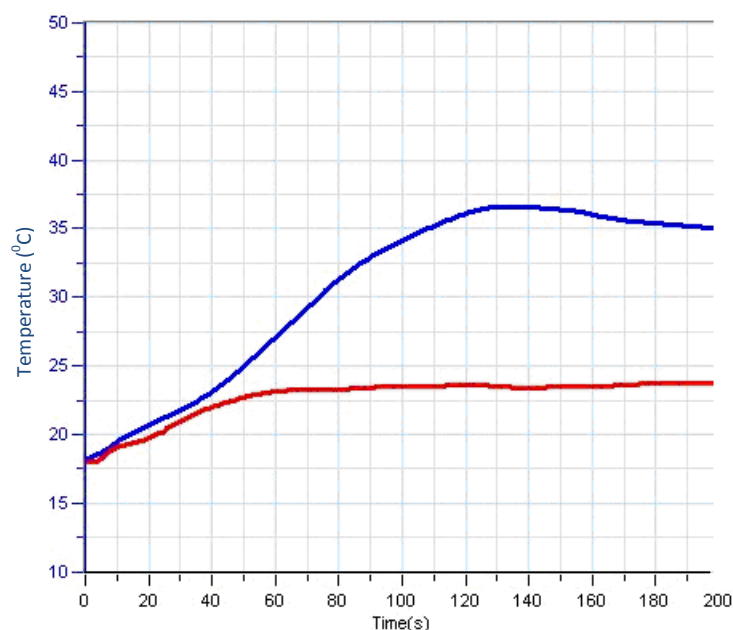
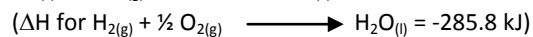
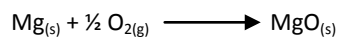


Figure 2

## Questions

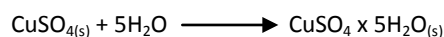
Determine  $\Delta H/\text{mol}$  Mg for the reaction:



Determine the percentage error for the answer you obtained for Question #1. The accepted value is 602 KJ.

## Further Suggestions

Determine the heat of reaction that would result from the following equation:



# Saltwater Conductivity

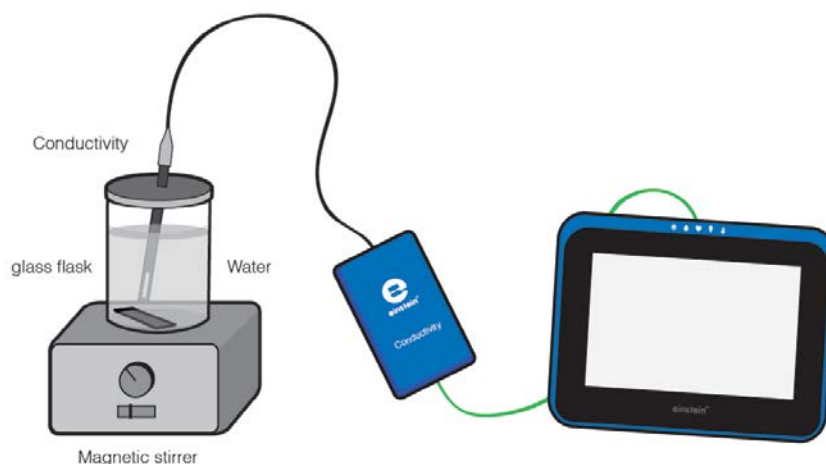
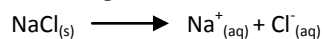


Figure 1



## Introduction

Dissolving solid sodium chloride in water releases ions according to the following equation:



In this experiment we will study the effect of increasing sodium chloride concentration on conductivity. We will be measuring conductivity as the ion concentration of the solution being monitored is gradually being increased by the addition of concentrated NaCl drops.



## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- 200 ml distilled water
- Conductivity sensor (0-20 mS)
- 250 ml glass flask
- 50 ml Sodium Chloride solution
- Magnetic stirrer
- Safety goggles

123

## Equipment Setup

1. Launch MiLAB.
2. Connect the Conductivity sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
3. Make sure that only the Conductivity sensor is selected.
4. Assemble the equipment as illustrated in Figure 1.



## Data Logger Setup





Program the sensors to log data according to the following setup:

Conductivity	
Rate:	25 / sec
Duration:	1 sec



## Procedure

Always wear safety goggles.

1. Pour 40 ml of distilled water into the flask and place it on a magnetic stirrer.
2. Insert the Conductivity electrode into the flask.
3. Select **Play** (  ) to begin recording the conductivity of the solution in the flask.
4. Collect the data manually: Select **Play** (  ) each time you wish to record a data sample.
5. Start stirring the water in the flask.
6. Add one drop of Sodium Chloride solution to the distilled water. Stir to ensure thorough mixing.
7. Select **Play** (  ) to measure the conductivity of the solution in the flask.
8. Repeat this process 9 times until you have added a total of 10 drops to the water.
9. Change the rate of stirring during the experiment and follow its effect on the rate of change in conductance.
10. Save your data by selecting **Save** (  ).



## Data Analysis

1. Calculate the rate of change in conductance obtained in the process:
2. Select the plot line of the graph.
3. Select **Function**.
4. Select **Linear fit** from the Function dropdown menu.
5. The slope of the fit line is the rate of change in conductance.

An example of the graph of conductivity and conductance changes, obtained in this experiment, is shown below. The linear line is the linear fit.

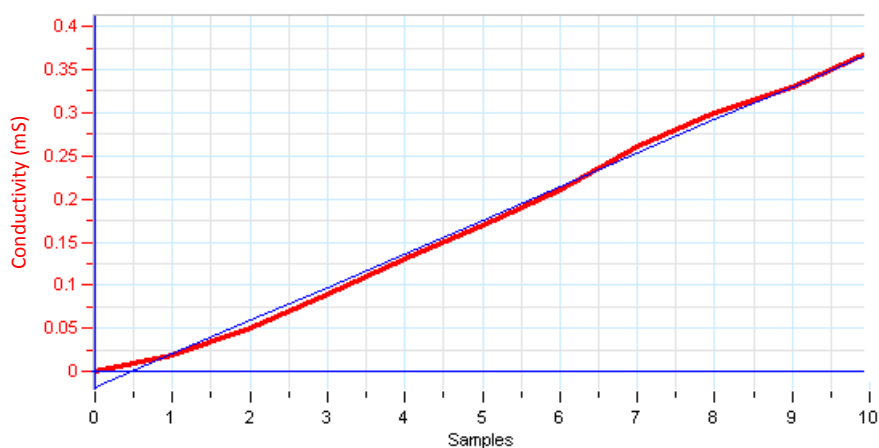


Figure 2



## Questions

1. Describe the change in conductivity as the concentration of NaCl solution was increased.
2. What kind of mathematical relationship does there appear to be between conductivity and concentration?



## Further Suggestions

1. Add a solution of  $\text{CaCl}_2$  (with the same concentration) in place of NaCl.
2. Try this experiment again but change the stirring rate. What is the effect on conductivity? Explain this phenomenon.

## Exploring a Flame

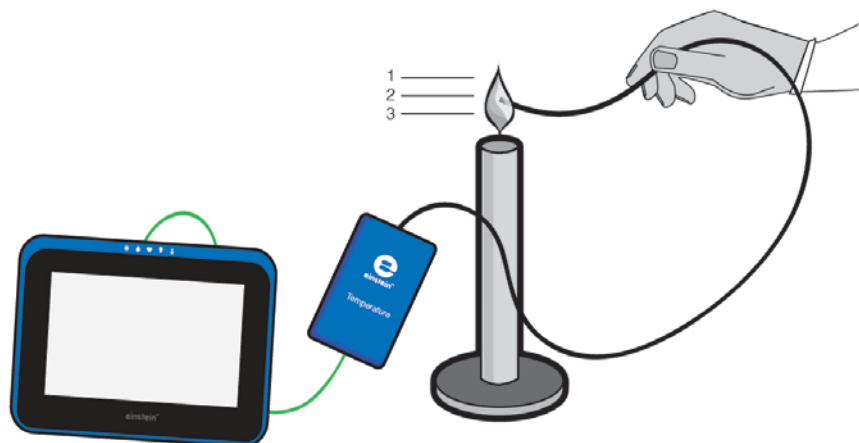


Figure 1

### Introduction

A flame does not have a uniform temperature. Temperature differences within a flame can be mapped with a thermocouple (a highly sensitive, fast responding Temperature sensor ranging from 0°C to 1250°C). In the following experiment, we are going to explore a candle flame in three characteristic areas labeled with **1**, **2** and **3** in Figure 1.

### Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- Candle
- Matches
- Thermocouple Type K (0°C to 1250°C)

### **123** Equipment Setup

1. Launch MiLAB.
2. Connect the Thermocouple sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
3. Make sure that only the Thermocouple sensor is selected.



## Data Logger Setup

Program the sensor to log data according to the following setup:




### Temperature (0°C to 1250°C)

Rate: 10 / sec

Duration: 100 sec



## Procedure

1. Light a candle and let it burn for approximately two minutes before starting the experiment.
2. Select **Play** (  ) to begin recording data.  
Record the room temperature before you bring the sensor to the flame (note that the thermocouple is very sensitive and responds quickly).
3. Monitor the temperature in three different areas of the flame (see Figure 1):
  - a. The top of the yellow area.
  - b. The middle of the yellow area.
  - c. The top of the dark area around the wick.
4. Select **Stop** (  ) to stop collecting data.
5. Save your data by selecting **Save** (  ).



## Data Analysis

Plotting Temperature vs. Time shows us that the flame is hottest at the top and gets cooler the lower you dip the sensor:

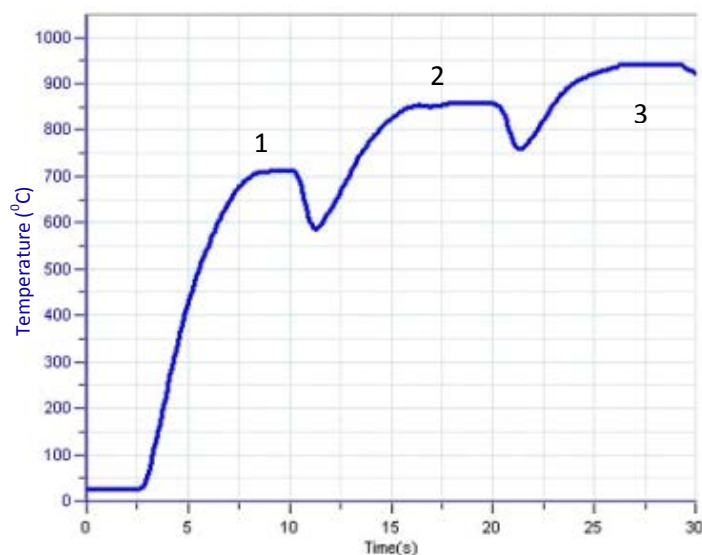


Figure 2



## Questions

1. What are the temperatures in each of the flame zones? (1, 2 & 3).
2. Try to explain the temperature differences within the flame.

## Freezing and Melting of Water

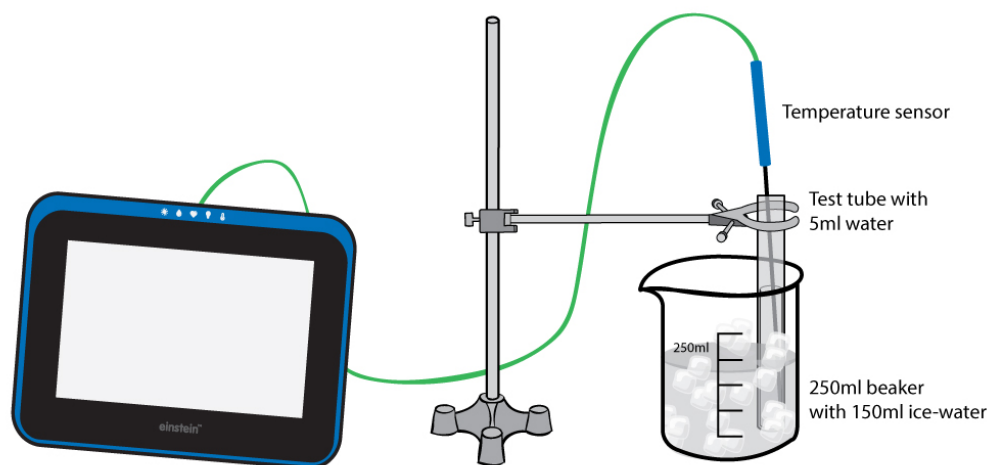


Figure 1



### Introduction

Freezing is the process of matter turning from the liquid state into the solid state. Melting is the process of solids turning into the liquid state. This occurs at the so-called freezing or melting temperature respectively. In this experiment, we investigate the freezing and melting temperatures of water.



### Equipment

- einstein™ Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™ LabMate
- Stand with utility clamp
- Graduated cylinder
- Beaker (250 ml)
- Test tube
- Glass rod for stirring
- Water
- Ice cubes
- Salt
- Temperature sensor (-40°C to 140°C)
- Safety goggles



## 123 Equipment Setup

Launch MiLAB.




1. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
2. Make sure that only the Temperature sensor is selected.  
Assemble the equipment as illustrated in Figure 1.

## Data Logger Setup




Program the sensors to log data according to the following setup:

Temperature (-40°C to 140°C)	
Rate:	Every 10 sec
Duration:	2000 sec

## Procedure (Part I, Freezing)

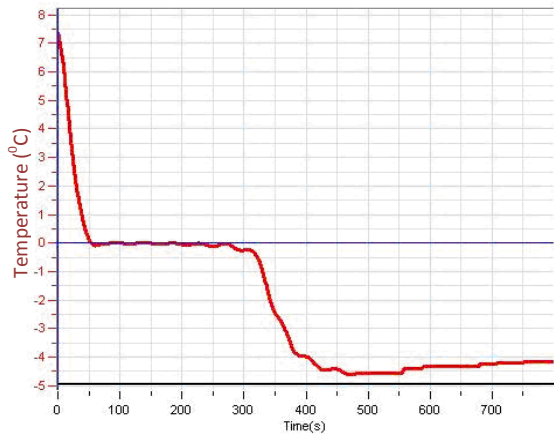
1. Pour at least 150 ml of ice cubes and cold water into a 250 ml beaker.
2. Put 1 ml of water into a 5 ml test tube and fix it to the stand with a clamp. You have to adjust the test tube so that the sample is below the ice water level.
3. Place a Temperature sensor into the water inside the test tube.
4. Select **Play** () to begin recording data.
5. Add about five spoons of salt to the beaker and stir with a glass rod.
6. After about 15 minutes select **Stop** () to stop recording while keeping the test tube in the ice-water bath.
7. Save your data by selecting **Save** ()

## Procedure (Part II, Melting)

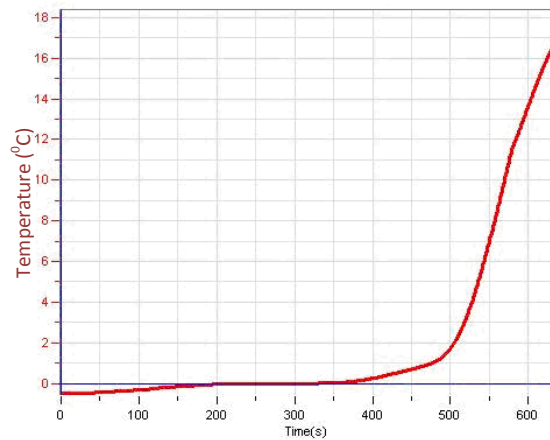
1. Select **Play** () to start recording data again, raise the test tube and fix it into a position above the ice-water bath. Dispose of the ice water and add 150 ml warm tap water to the beaker. Lower the test tube into the warm water.
2. After another 15 minutes select **Stop** () on the upper tool bar to stop recording data.
3. Save your data by selecting **Save** ()



Examples of the graphs obtained in the experiments are shown below:



**Part I: Freezing water**



**Part II: Melting the frozen water**

1. What happened to the water temperature during the freezing stage and during the melting stage?
2. What were the freezing point and the melting point of the water?
3. How does the freezing point of water compare to the melting point?
4. What is the behavior of the kinetic energy of the water within the test tube? Does it increase, decrease or remain the same, when:
  - a. The temperature changes at the beginning and the end of Part I.
  - b. The temperature remains constant in Part I.
  - c. The temperature changes at the beginning and the end of Part II.
  - d. The temperature remains constant in Part II.
5. Did the potential energy increase or decrease in those parts of Question 4, where kinetic energy remained constant?

## Another Look at Freezing Temperature

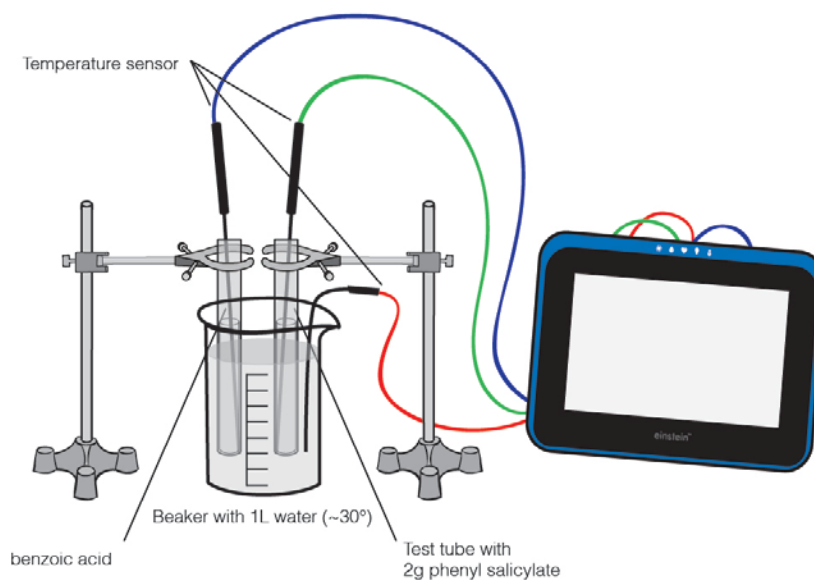


Figure 1



### Introduction

In Experiment 15: *Freezing and Melting of Water*, we saw that the temperature of pure water remains constant at its freezing temperature during the freezing and melting process. Now we are going to observe the freezing process of phenyl salicylate. Furthermore, we will observe the effect on the freezing point, when a small amount of another substance (e.g. benzoic acid) is dissolved in the phenyl salicylate.



### Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- Three Temperature sensors (-40°C to 140°C)
- 1 liter (or larger) Beaker
- Test tube with 2 g phenyl salicylate
- Test tube with 2 g phenyl salicylate and a few milligrams of benzoic acid
- Glass rod for stirring

## 123 Equipment Setup



1. Launch MiLAB.
2. Connect the Temperature sensors to ports on the einstein™Tablet or einstein™LabMate.
3. Make sure that only the Temperature sensors are selected.
4. Assemble the equipment as illustrated in Figure 1.

## Data Logger Setup

Program the sensors to log data according to the following setup:

Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	1000 sec

## Procedure

1. Pour about 1 L of water into a beaker. The water should be at about 30°C. Insert one of the Temperature sensors into this beaker to monitor the water temperature.
2. To melt your samples, prepare a second beaker with hot water (60 to 80°C).
3. Place the two sample test tubes into the hot water until you see a clear liquid in both test tubes.
4. Place a Temperature sensor in each sample test tube and move them quickly to the beaker containing the 30 °C water.
5. Select **Play** () to begin recording data.
6. Stir your samples slightly as long as they are melted.
7. Pay attention to the test tubes, as the clear liquid will soon contain increasing amounts of white precipitates, until the liquid is completely *frozen*.
8. Save your data by selecting **Save** ()

## Data Analysis

1. What was the freezing point of pure phenyl salicylate according to your data?
2. What was the freezing point of the benzoic acid-phenyl salicylate mixture?

An example of the graph obtained in this experiment is shown below:

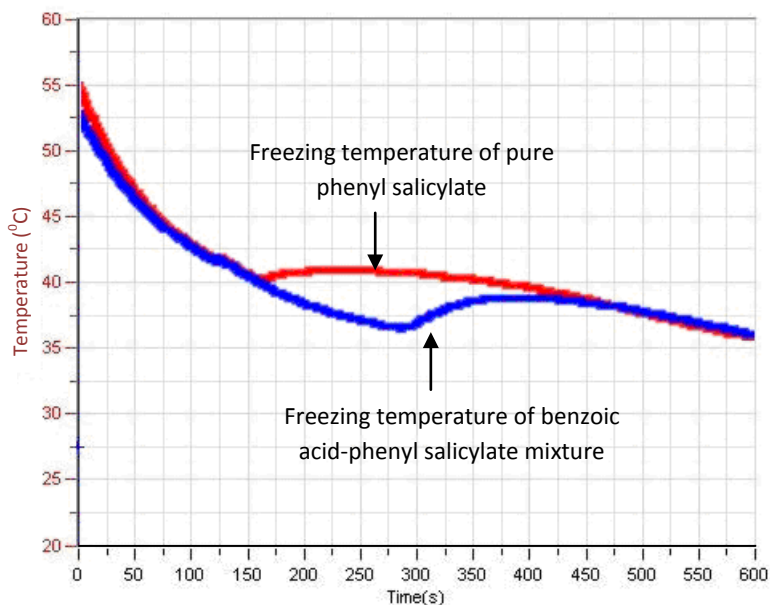


Figure 2

## Questions

1. Based on this experiment and its result, what method could a chemist use to check whether or not an unknown liquid is pure?
2. Why does the freezing point change by dissolving another component in phenyl salicylic acid?
3. Does the nature of this change depend on the freezing point of the dissolved compound?

# Energy Content of Foods

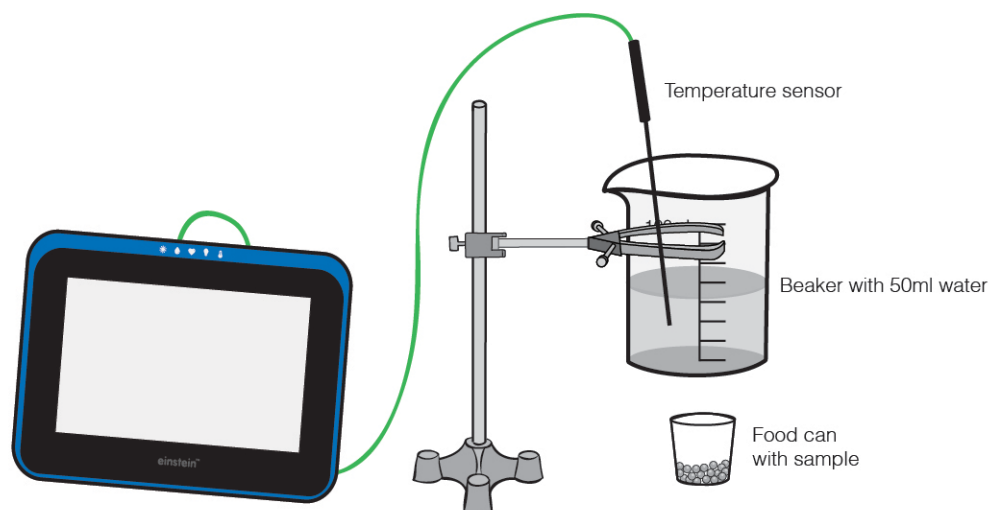


Figure 1



## Introduction

All human activity requires *burning* calories to generate the necessary energy. In this experiment, we are going to determine the energy released (in kJ/g) by three food samples (popcorn, marshmallows and peanuts) by *burning* them. The released energy heats a known amount of water and can be calculated from the first equation. You obtain the energy content by dividing the obtained heat with the mass of the burnt food (second equation):

$$Q = C_p \Delta T$$

- $C_p$  = Heat capacity of the water
- $\Delta T$  = Temperature change of the water
- $Q$  = Quantity of heat emitted/absorbed

$$E_{\text{food}} = Q/m_{\text{food}}$$

- $E_{\text{food}}$  = Energy content of the food
- $m_{\text{food}}$  = Mass of the burnt food



## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB™ and einstein™LabMate
- Temperature sensor (-40°C to 140°C)
- Stand with ring stand
- Lid or a small can ( $\leq 50$  ml) to hold the food
- Small can (100 – 200 ml) to hold the water
- Three food samples – popcorn, marshmallows and peanuts
- Scale
- Two stirring rods
- Graduated cylinder
- Cold water
- Matches
- Safety goggles



## Equipment Setup

Launch MiLAB.

1. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
2. Make sure that only the Temperature sensor is selected.
3. Assemble the equipment as illustrated in Figure 1.






## Data Logger Setup

Program the sensors to log data according to the following setup:

Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	200 sec

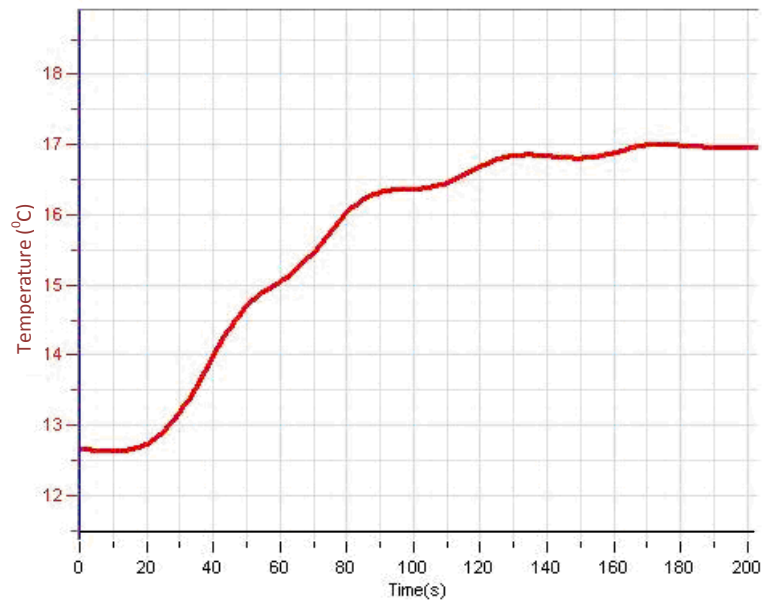


## Procedure

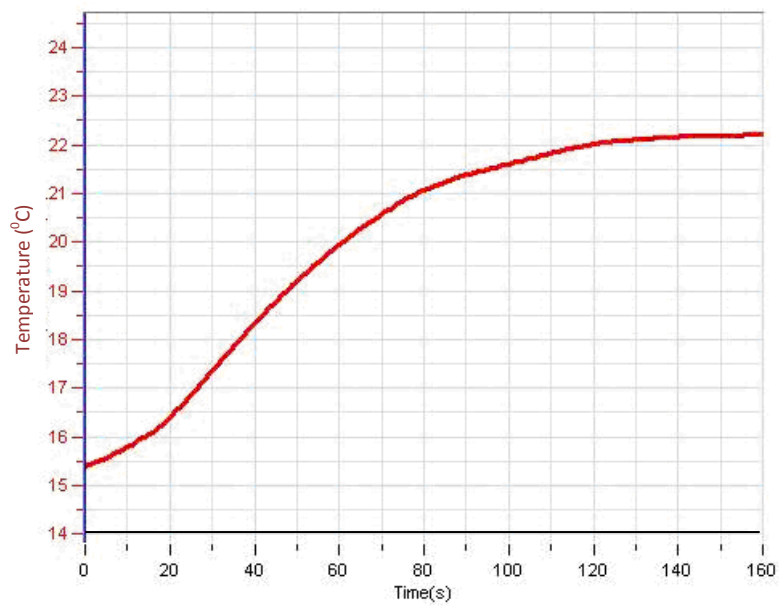
1. Determine the mass of the food sample that you are going to measure by weighing it.
2. Add 50 ml cold water to the water can and determine its exact mass by weighing it.
3. Place the first food sample into the food can. Note that the samples will light more easily if they are ground up; especially the peanuts.
4. Place the food can with the sample directly under the water can.
5. Insert the Temperature sensor into the water (it must not touch the bottom).
6. Start stirring the water sample in the water can.
7. Select **Play** (  ) to begin recording data.
8. Wait approximately one minute before you light the food sample by using a match.
9. Continue stirring the water sample until the temperature stops rising.
10. Select **Stop** (  ) to stop collecting data.
11. Save your data by selecting **Save** (  ).

12. Repeat procedure 1-12 for the other two food samples.

Examples of the graphs obtained in this experiment are shown below:



**Figure 2: Burning of 4.4 g peanuts**



**Figure 3: Burning of 0.5 g popcorn**



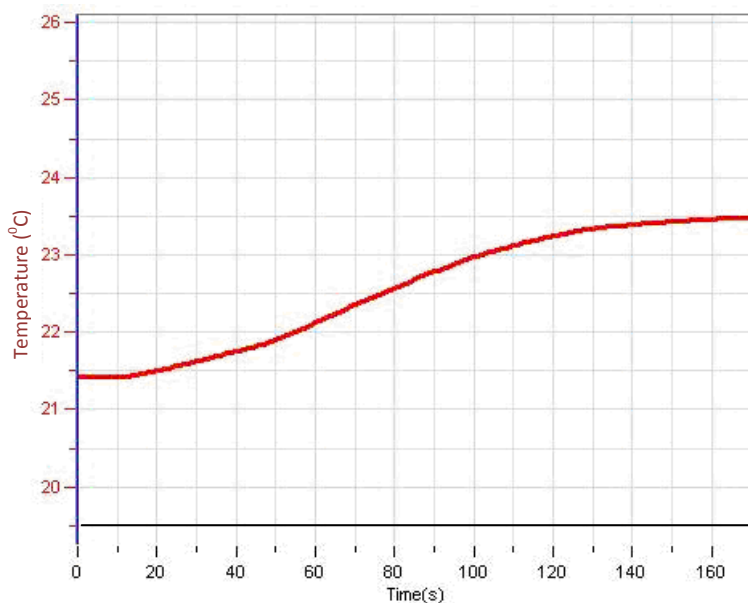


Figure 4: Burning of 3.6 g marshmallows

## Data Analysis

- Select the water temperature at the beginning of the experiment, and then select the highest temperature recorded.
  - What was the water temperature change ( $\Delta T$ ) for each food sample?
  - Calculate the heat ( $Q$ ) absorbed by the water according to the first equation.
  - Weigh the remains of the food samples to determine the mass of what was left over.
- Subtract this from the original weight of the food to arrive at  $m_{\text{food}}$  – the mass of the food that was burned.

**Note:** The specific heat capacity of water at 25° C is 4.18 J/g°i.

## Questions

- Which food had the highest energy content (in kJ/g)?
- Food energy is expressed in a unit called Calories (4.18 kJ). How many calories would a bag of 50 g peanuts have?
- Peanuts have a high fat content. Marshmallows and popcorn have high carbohydrate content. What generalization can you make from your results about the relative energy content of fats and carbohydrates?

## Energy Content of Fuels

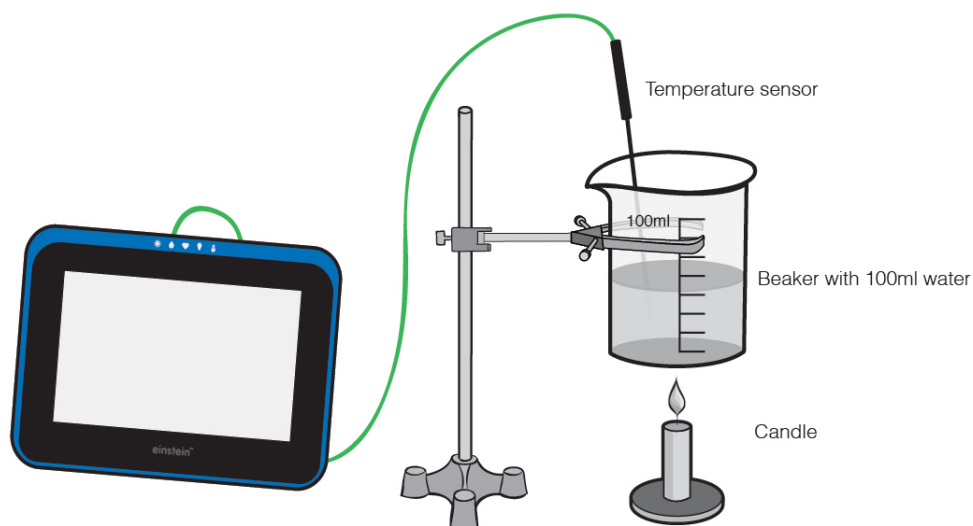


Figure 1



### Introduction

In this experiment, you will find and compare the heat generated by two different fuels: Paraffin wax and methanol. Paraffin is a member of a group of compounds called alkanes. Important alkanes used as fuels are gasoline and diesel oil.

Methanol and Ethanol are used as gasoline additives and gasoline substitutes.

In this experiment, we are going to compare the energy content of paraffin and methanol by measuring their heat of combustion.

To determine the heat of combustion, we first calculate the energy used to heat a known amount of water by burning paraffin and methanol with the following formula:

$$Q = C_p m \Delta T$$

$Q =$  Heat  
 $m =$  Mass of water  
 $\Delta T =$  Temperature change of the water  
 $C_p =$  Heat capacity of the water



## Equipment

- einstein™Tablet with MiLAB or Android /IOS tablet with MiLAB and einstein™LabMate
- Temperature sensor (-40°C to 140°C)
- Stand with ring stand
- Beaker or a small can (250 ml)
- Scale
- Graduated cylinder
- Cold water
- Stirring rod
- Candle
- Methanol burner (e.g. from a Fondue set burner)
- Matches
- Safety goggles

## 123

## Equipment Setup

Launch MiLAB.

1. Connect the Temperature sensor to one of the ports on the einstein™Tablet or einstein™LabMate.
2. Make sure that only the Temperature sensor is selected.
3. Assemble the equipment as illustrated in Figure 1.



## Data Logger Setup

Program the sensors to log data according to the following setup:




### Temperature (-40°C to 140°C)

Rate:	Every 1 sec
Duration:	200 sec



## Procedure

Determine the mass of the empty water vessel.

1. Add 100 ml cold water into the beaker and weight it to determine its exact mass.
2. Weight the candle to determine its mass.
3. Place the beaker a ring stand.
4. Insert the Temperature sensor into the water (it must not touch the bottom).
5. Start stirring the water sample in the water can.
6. Select **Play** (  ) to begin recording data.
7. Wait approximately 30 seconds before lighting the candle.
8. Continue stirring the water sample while it heats up.
9. Extinguish the flame when the water reaches a temperature of 40°C.
10. After the temperature stops rising select **Stop** (  ) to stop recording data.
11. Save your data by selecting **Save** (  ).

12. Weigh whatever remains of the candle (including the wax drippings) to determine the mass of the candle.
13. Weigh the methanol burner to determine its mass.
14. Replace the candle with a methanol burner and repeat the experiment with 200 ml of water.
15. Cover the burner with a piece of metal upon extinguishing it and let it cool down to room temperature.
16. Weigh to determine the mass of the methanol burner and leftover fuel.



## Data Analysis

Examples of the graphs obtained in this experiment are shown below:

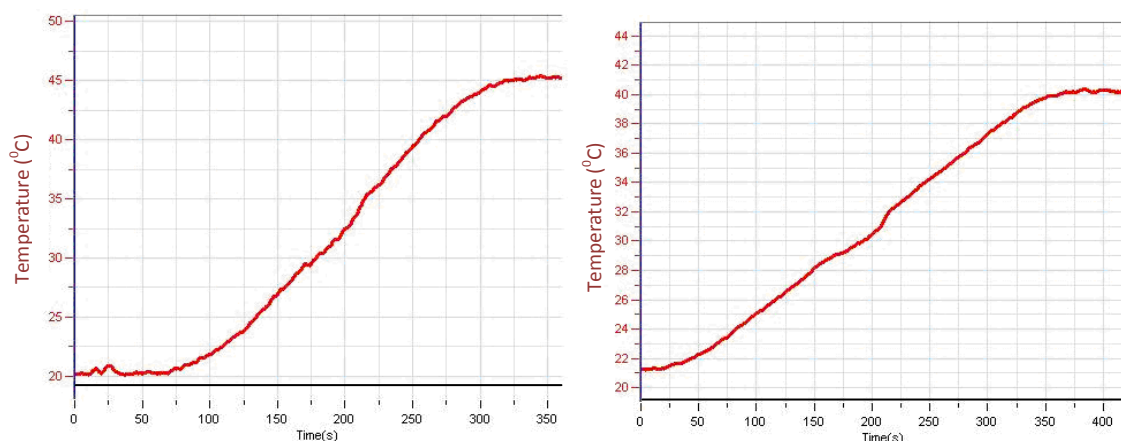


Figure 2

1. For both graphs mark the beginning temperature and the highest temperature reached.
2. Determine the mass of the water heated.
3. How much did the temperature of the water change ( $\Delta T$ )?
4. Calculate the heat ( $Q$ ) absorbed by the water according to the given equation.
5. Determine the mass of burnt paraffin and methanol.
6. Calculate the %-efficiency for both experiments. Divide your experimental value [kJ/g] by the appropriate literature values and multiply the answer by 100. The literature values are 41.5 kJ/g (paraffin) and 30.0 kJ/g (ethanol).



## Questions

1. Which fuel produces more energy per gram burned? Give an explanation for the difference (hint: methanol  $\text{CH}_3\text{OH}$  is an *oxygenated* molecule, paraffin  $\text{C}_{25}\text{H}_{52}$  does not contain oxygen).
2. Suggest some advantages of using ethanol (or paraffin) as a fuel.
3. Discuss the heat loss factors contributing to the inefficiency of the experiment.



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