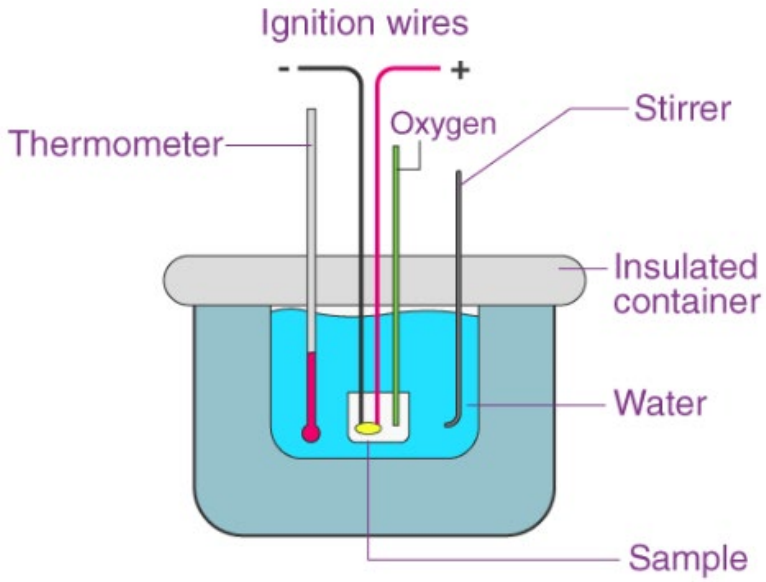
Experiment 1. CALORIMETRY

Objectives

- To determine the specific heat of a metal
- To determine the enthalpy of neutralization for a strong acid-strong base reaction
- To determine the enthalpy of solution for the dissolution of a salt

Introduction



Calorimeter: A laboratory apparatus used for measuring the quantity and direction of heat flow

$$\Delta U = q - P\Delta V$$

Under constant pressure, $q_p = \Delta U + P\Delta V = \Delta H$

$\Delta H < 0$: exothermic reactions, $\Delta H > 0$: endothermic reactions

Introduction

Specific Heat

The energy required to change the temperature of one gram of a substance by 1°C.

$$specific\ heat\ \left(\frac{J}{g\cdot ℃}\right) = \frac{energy\ (J)}{mass\ (g)\times \Delta T\ (℃)}$$

$$-energy\ (J)\ lost\ by\ metal = energy\ (J)\ gained\ by\ water$$

$$-specific\ heatM \times massM \times \Delta TM = -specific\ heatH_{2}O \times massH_{2}O \times \Delta TH_{2}O$$

Introduction

Enthalpy of Neutralization Reaction

The reaction between a strong acid and a strong base is an exothermic reaction.

$$H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l) + heat$$

Enthalpy change can be measured with the equation shown below.

$$\Delta Hn = -specific\ heat(H_2O) \times combined\ masses_{acid\ +\ base} \times \Delta T$$

Introduction

Enthalpy of Neutralization Reaction

The lattice energy (an endothermic quantity) of a salt, and the hydration energy (an exothermic quantity) determine whether the dissolution process is endothermic or exothermic.

$$\Delta Hs = \Delta H_{LE} + \Delta H_{hyd}$$

The enthalpy change of solution for the dissolution of a salt can be expressed as the following equation, and the value can be obtained with the temperature change of the solution.

$$\Delta Hs = \frac{(-energy\ change\ of\ water) + (-energy\ change\ of\ salt)}{mole_{salt}}$$

Experimental procedure

Overview

Three different experiments are complete in a calorimeter. Each experiment requires careful mass, volume, and temperature measurements before and after the mixing of the respective components. Calculations are based on an interpretation of plotted data.

Calorimeter (click!)

Before the beginning of the experiment, remove air from the air space inside the calorimeter with a syringe (the right picture or movie).

Assigned Experimental Parts and Trial….

Odd number of Experimental group: One Trial each

- *_Part A: Cu*
- *_Part B: 1.0 M HCl + 1.0 M NaOH*
- *_Part C: Salt 1 (provided by TA)*

Even number of Experimental group: One Trial each

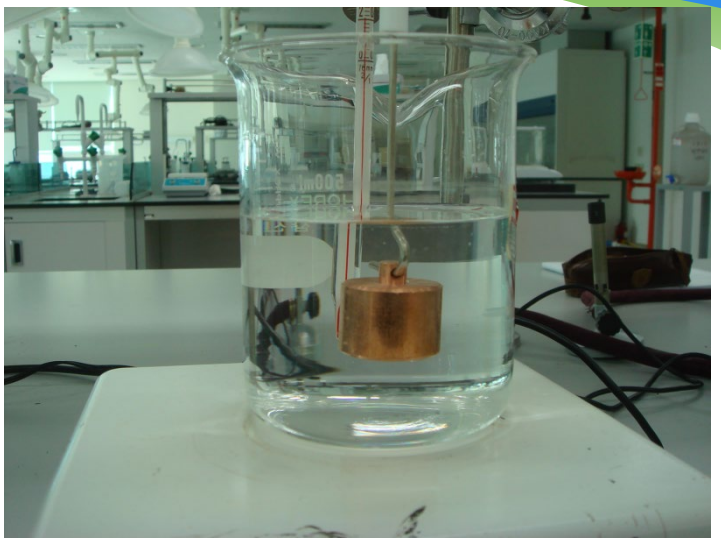
- *_Part A: Fe*
- *_Part B: 1.0 M HNO_3 + 1.0 M NaOH*
- *_Part C: Salt 2 (provided by TA)*

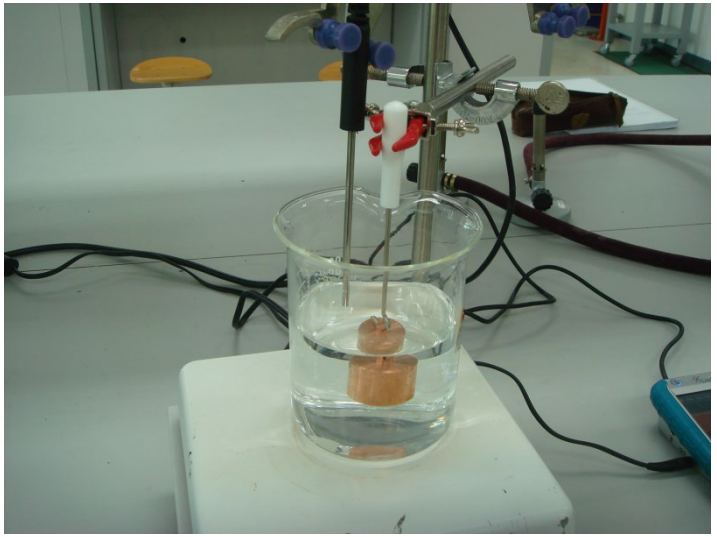
A. Specific Heat of a Metal

1. Prepare the metal *Obtain Cu or Fe dry metal from your TA. Record the number of the metal on the Report Sheet. Measure its mass on your assigned balance. Fill a 500-mL beaker with about 350 mL of water. Heat the water to boiling and maintain this temperature for at least 15 minutes so that the metal reaches thermal equilibrium with the boiling water. Proceed to PART A.2 while the water is heating.*

(Position the metal with a metal hanger hook so that it does not touch the bottom of the beaker as shown in picture. Also, be sure it is below the level of water in the beaker.)


HOT & STIRRER
Lab
Companion
HP-3100





2. Prepare the water in the calorimeter

Thoroughly clean the calorimeter with 3 times of distilled water, wipe it paper towel and dry it.. Measure and record the combined mass of the calorimeter (plastic body, the plastic lid and the stirrer). Connect the thermometer probe to channel 1 of the Vernier computer interface. Connect the interface to the computer using the proper cable. Start the Logger Pro program on your computer.

Using a graduated cylinder, add 200 mL of water and measure the mass of the calorimeter plus water.

Secure the digital thermometer and position thermal sensor below the water surface.

(CAUTION! Be careful not to splash out any of the water in the calorimeter. Also be sure that the metal is fully submerged in the calorimeter.)

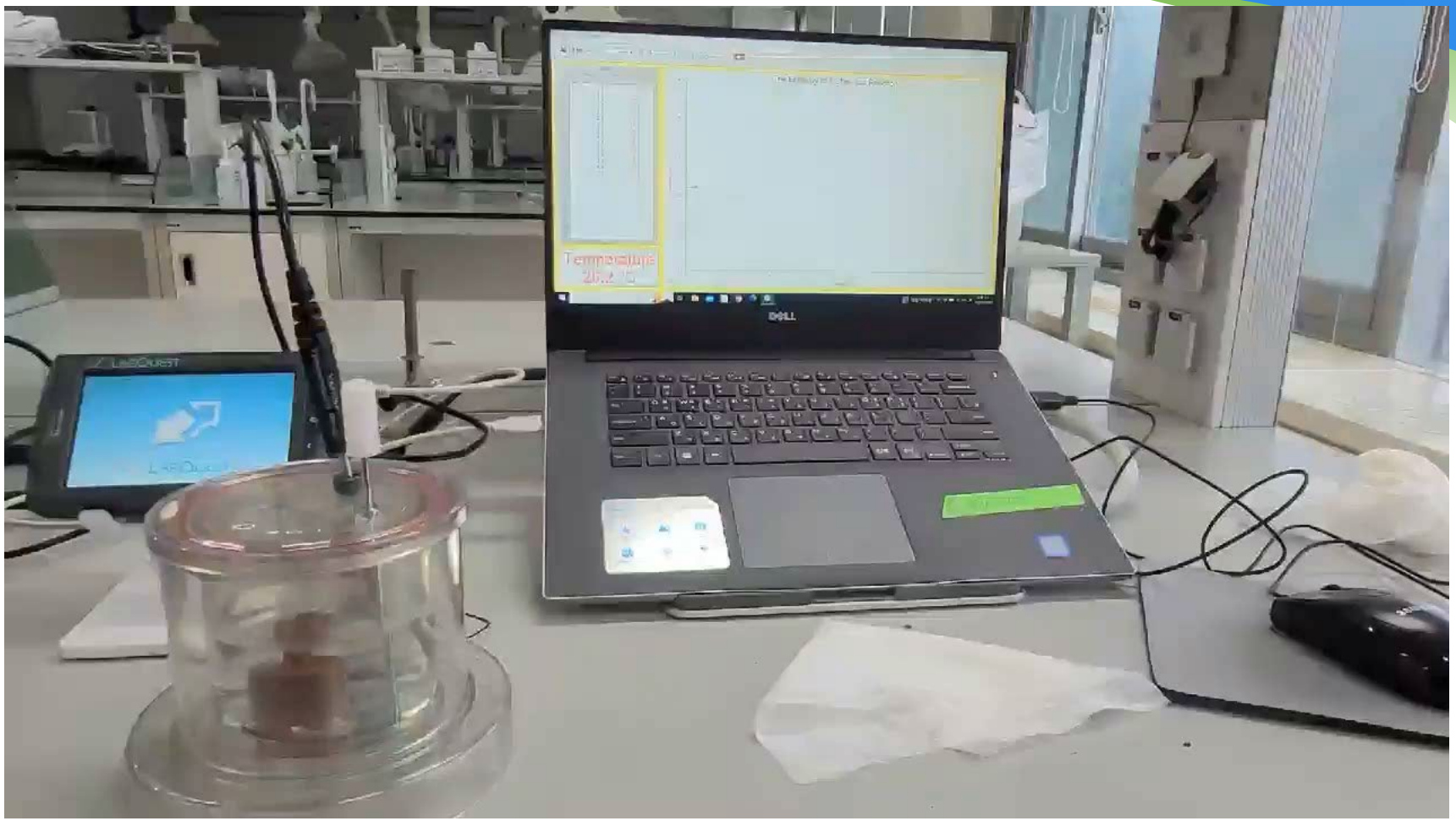
3. Measure and record the temperatures of the metal and water

Once thermal equilibrium has been reached in PARTS A.1. and A. 2, measure and record the temperatures of the boiling water form PART A.1 and the water in the calorimeter from PART A.2.

Record the temperatures.

4. Transfer the hot metal to the cool water and record the data

Remove the metal from the boiling water and quickly transfer only the metal to the water in the calorimeter. Click a [collect] button. Replace the lid and swirl the contents gently. Record the water temperature as a function of time (about 5-second intervals for 1 minute and then 15-second intervals for ~ 5 minutes).


LabQuest
DELL

5. Plot the data.

Plot the temperature (y-axis) versus time (x-axis) by using appropriate software from your data.

Determine the maximum temperature from graph.

B Enthalpy (Heat) of Neutralization for an Acid-Base Reaction:

1.0 M HCl + 1.0 M NaOH or

1.0 M HNO_3 + 1.0 M NaOH

1. Measure the volume and temperature of the acids

Measure 50.0 mL of 1.0 M acid in a clean graduated cylinder. Measure and record its temperature.

2. Measure the volume and temperature of the NaOH

Using a second clean graduated cylinder transfer 50.0 mL of a 1.0 M NaOH solution to the dry calorimeter.

Record the temperature and exact molar concentration of the NaOH solution.


Vernier


SAMCHUN
CHEMICALS
1mol/L - Nitric acid(1N)
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CHEMICALS
1mol/L - Hydrochloric acid solution(1N)
SAMCHUN
CHEMICALS
1mol/L - Sodium hydroxide solution(1N)

3. Collect the data

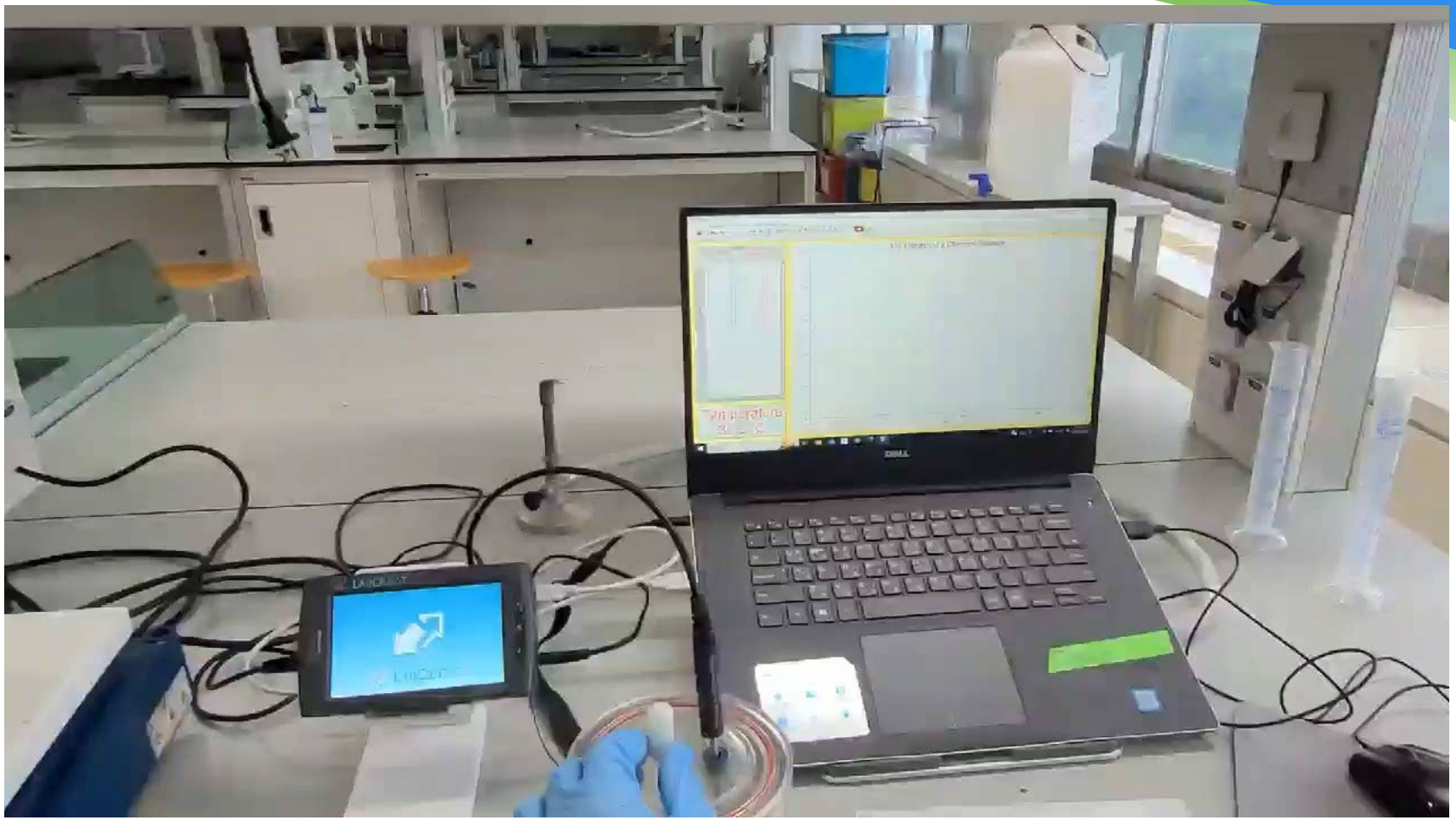
Carefully but quickly add the acid to the base, replace the calorimeter lid, and swirl gently.

Read and record the temperature and time every 5 seconds for 1 minute and thereafter every 15 seconds for ~ 5 minutes.

4. Plot the data

Plot the temperature (y-axis) versus time (x-axis) by using appropriate software from your data.

Determine the maximum temperature from graph.



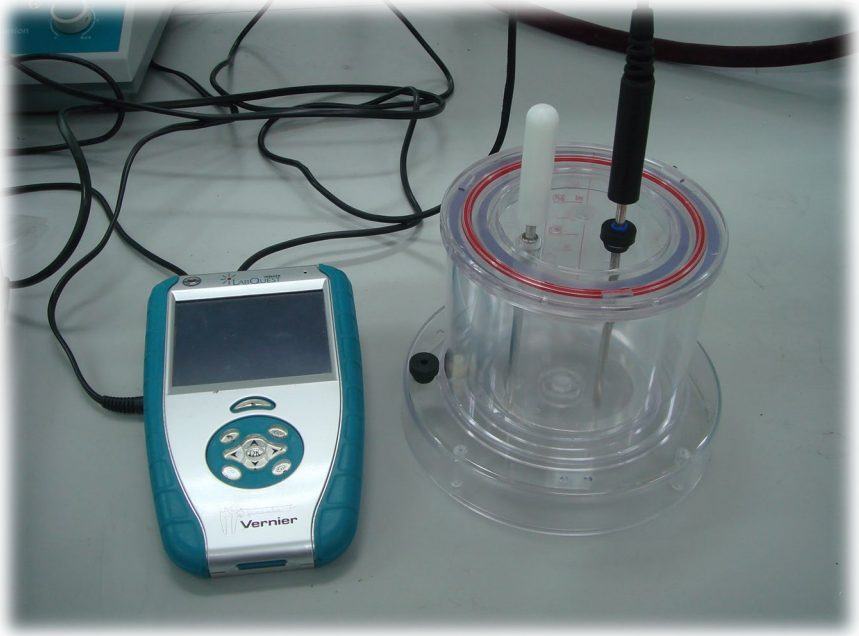
C. Enthalpy (Heat) of Solution for the Dissolution of a Salt

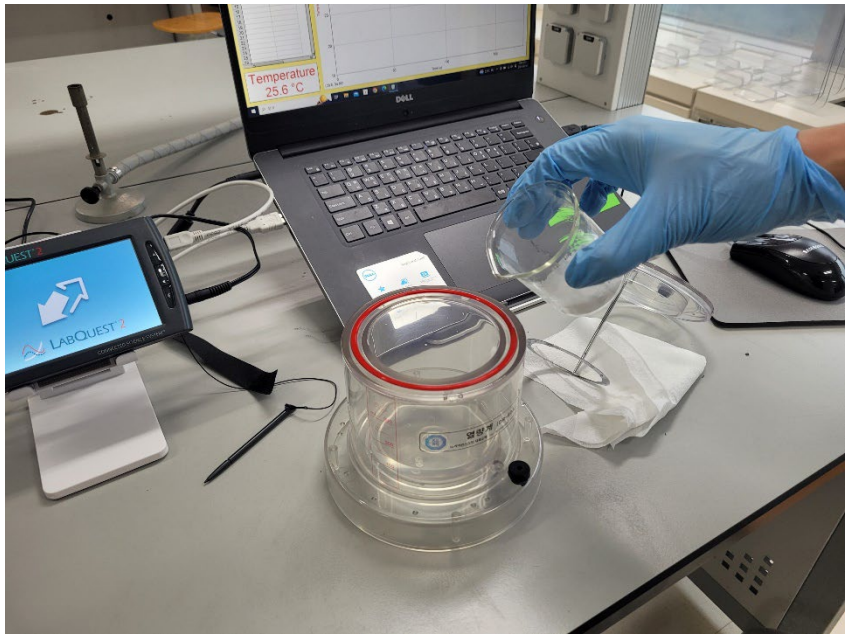
1. Prepare the salt

On weighing paper, measure about 15.0 g of the assigned salt . Record its mass on the Report Sheet.

2. Prepare the calorimeter

Measure the mass of the dry calorimeter. Using your clean graduated cylinder, add ~ 60 mL of distilled water to the calorimeter. Measure the combined mass of the calorimeter and water. Secure the thermometer and position the sensor below the water surface and record its temperature.


Vernier


Temperature
25.6 °C
LABQUEST 2

3. Collect the temperature data

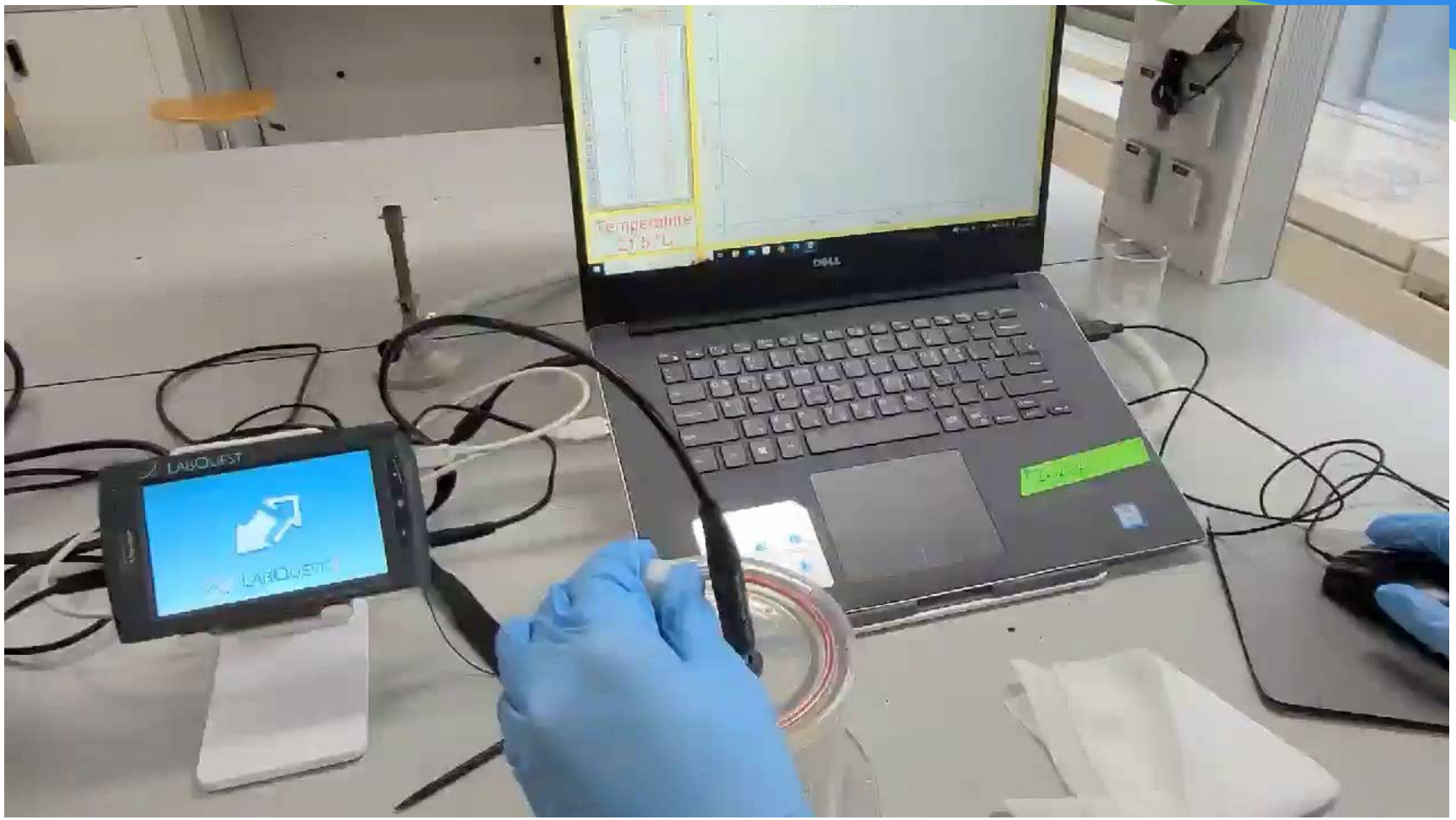
Carefully add (do not spill) the salt to the calorimeter, replace the lid, and swirl gently.

Read and record the temperature and time at 5-second intervals for 1 minute and thereafter every 15 seconds for ~ 5 minutes.

4. Plot the data

Plot the temperature (y-axis) versus time (x-axis) by using appropriate software from your data.

Determine the maximum temperature from graph.


LABQUEST
LABQUEST
DELL

CLEANUP:

Rinse the calorimeter twice with tap water and twice with distilled water and discard in the Waste Acid Solution container in the fume hood. Additional rinses can be discarded in the container.

DISPOSAL:

Dispose of the waste solutions in the Waste Acid Solutions container in the chemical fume hood.