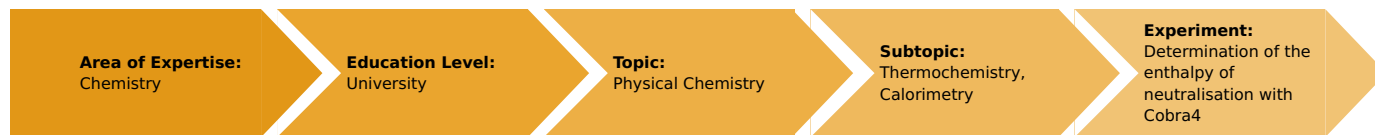


# Determination of the enthalpy of neutralisation with Cobra4

(Item No.: P3020861)

## Curricular Relevance



### Difficulty



Intermediate

### Preparation Time



10 Minutes

### Execution Time



10 Minutes

### Recommended Group Size



2 Students

### Additional Requirements:

- PC with USB interface, Windows XP or higher
- Precision balance, 6,200 g / 0.01 g

### Experiment Variations:

### Keywords:

Enthalpy of neutralisation, Calorimetry, Heat capacity

## Overview

### Short description

#### Principle:

When a strong acid is neutralised with a strong base in dilute solution, the same amount of heat is always released. If the reaction takes place under isobaric conditions, this heat is known as the enthalpy of neutralisation. The chemical reaction which generates this heat is the reaction of protons and hydroxyl ions to form undissociated water. It therefore correlates to the enthalpy of formation of water from these ions.

#### Tasks:

1. Measure the temperature change during the neutralisation of a dilute potassium hydroxide solution with dilute hydrochloric acid.
2. Calculate the enthalpy of neutralisation.

## Safety instructions



### Potassium hydroxide

H302: Harmful if swallowed.

H314: Causes severe skin burns and eye damage.

P280: Wear protective gloves/protective clothing/eye protection/face protection.

P305+351+338: IF IN EYES: Rinse cautiously with water for several minutes,: Remove contact lenses if present and easy to do. Continue rinsing.

P310: Immediately call a POISON CENTER or doctor/physician.

### Hydrochloric acid

H290: May be corrosive to metals.

P234: Keep only in original container.

P406: Store in corrosive resistant container.

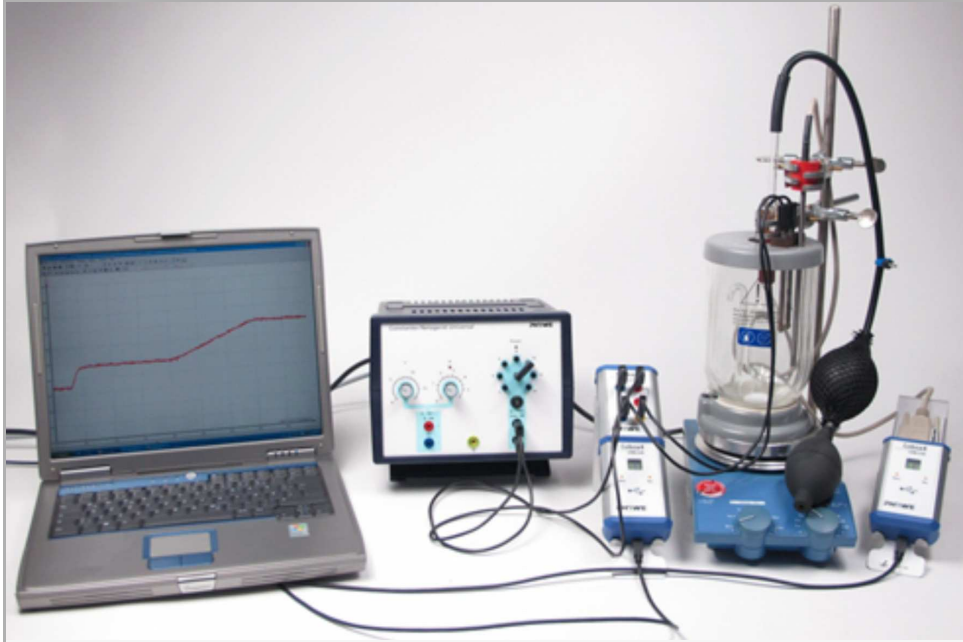
P390: Absorb spillage to prevent material damage.

## Equipment

Position No.	Material	Order No.	Quantity
1	Cobra4 Wireless/USB-Link incl. USB cable	12601-10	2
2	Cobra4 Sensor-Unit Energy: Current, voltage, work, power	12656-00	1
3	Cobra4 Sensor-Unit Temperature	12640-00	1
4	curricuLAB measureLAB	14580-61	1
5	Calorimeter, transparent, 1200 ml	04402-00	1
6	Delivery pipette	04402-10	1
7	Heating coil with sockets	04450-00	1
8	PHYWE power supply, universal DC: 0...18 V, 0...5 A / AC: 2/4/6/8/10/12/15 V, 5 A	13504-93	1
9	Connecting cord, 32 A, 500 mm, black	07361-05	4
10	Magnetic stirrer with heater MR Hei-Standard	35751-93	1
11	Magnetic stirring bar 30 mm, oval	35680-04	1
12	Separator for magnetic bars	35680-03	1
13	Supp.rod stainl.st.,50cm,M10-thr.	02022-20	1
14	Universal clamp	37715-00	2
15	Right angle boss-head clamp	37697-00	2
16	Pipettor	36592-00	1
17	Rubber bulb, double	39287-00	1
18	Pinchcock, width 15 mm	43631-15	1
19	Volumetric flask 500 ml, IGJ19/26	36551-00	2
20	Beaker, high, BORO 3.3, 100 ml	46026-00	1
21	Beaker, high, BORO 3.3, 600 ml	46029-00	1
22	Pasteur pipettes, 250 pcs	36590-00	1
23	Rubber caps, 10 pcs	39275-03	1
24	Wash bottle, plastic, 500 ml	33931-00	1
25	Potassium hydroxid for 1l 1mol solution amp.	31425-00	1
26	Hydrochloric acid for 1mol solution amp.	30271-00	1
27	Water, distilled 5 l	31246-81	1

## Task


1. Measure the temperature change during the neutralisation of a dilute potassium hydroxide solution with dilute hydrochloric acid.
2. Calculate the enthalpy of neutralisation.



## Set-up and procedure



When handling chemicals, you should wear suitable protective gloves, safety goggles, and suitable clothing. Please refer to the appendix for detailed safety instructions.

- Set up the experiment as shown in Fig. 1.
- Combine the Cobra4 Sensor-Unit Energy and the Cobra4 Sensor-Unit Temperature with the Cobra4 USB-Links.
- Connect the power supply with Cobra4 Sensor-Unit Energy but leave the heating coil unconnected.
- Start the PC and connect each Cobra4 USB-Link with a USB socket of the computer.
- Start the software "measureLAB" , and choose the experiment from the start screen (choose "PHYWE experiments", search for "P2030661", and click on the folders that contain this experiment). All necessary presettings will be loaded.

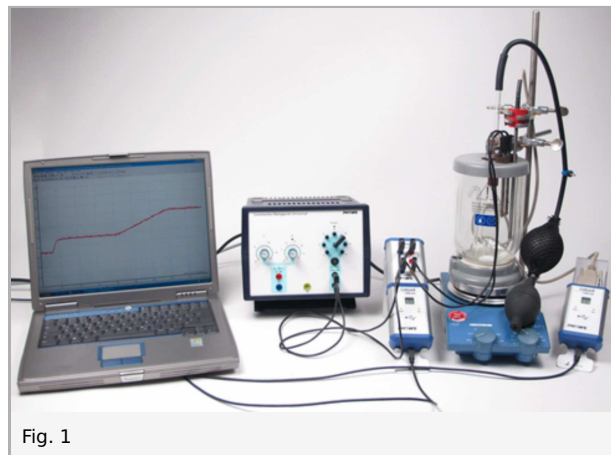


Fig. 1

- Prepare the potassium hydroxide solution required ( $c_{\text{KOH}} = 2 \text{ mol/l}$ ) by dissolving one ampoule of potassium hydroxide for 1 l of 1 M solution in a 500 ml volumetric flask and topping off with water to the calibration mark. Proceed in a similar fashion with a second 500 ml volumetric flask using 1 ampoule of hydrochloric acid for 1 l of 1 M solution to produce hydrochloric acid of the same concentration ( $c_{\text{HCL}} = 2 \text{ mol/l}$ ).
- Fill the calorimeter with approximately 750 g water and 60 g of the 2 M potassium hydroxide solution (both weighed to an accuracy of 0.1 g).
- Using a delivery pipette and a pipettor, draw around 50 ml of the 2 M hydrochloric acid from a small glass beaker. The exact mass of the hydrochloric acid contained in the delivery pipette is calculated from the difference between the masses of the filled and the empty delivery pipette (accuracy 0.1 g). The 600 ml beaker is used as a pipette stand.
- Put the oval magnetic stirrer bar into the calorimeter and switch on the magnetic stirrer (Caution: Do not mistakenly switch on the heating unit!).
- Push the delivery pipette through the cap of the calorimeter from below and mount the lid on the calorimeter vessel. Now attach the pipette to the support rod using a clamp in such a manner that the opening is above the level of the liquid and that the stirrer bar can rotate unhindered. Insert the heating coil and the temperature probe into the lid of the calorimeter and fix them in position.
- Wait until a temperature equilibrium has been reached (approximately 10 min). Start the measurement with a click on in the icon strip. Wait 3 to 4 minutes, then blow the hydrochloric acid out of the delivery pipette into the potassium hydroxide solution in the calorimeter. To do this, first clamp a pinchcock onto the tube of the rubber bulb, blow up the air reservoir of the rubber bulb and quickly release the pinchcock.
- Continue to measure until a new equilibrium has been reached. Now, perform electrical calibration to determine the total heat capacity of the calorimeter. To do this, supply 10 V AC to the Cobra4 Sensor-Unit Energy for the electric heating and then put the free ends of the heating coil connection cables into the output jacks. The system is now continuously heated and the supplied quantity of energy is measured.
- When approximately 4000 Ws are transferred, switch off the heating by pulling the connection cables out of the heating coil. Continue to measure for another three minutes, then stop temperature recording with a click on in the icon strip.

## Results and evaluation

### Results

The results of a typical experiment are shown in Fig. 2. Given the simple nature of the determination, the agreement is very satisfactory. However, the student should be aware of possible sources of random and systematic error in this experiment, such as the volume between the end of the syringe barrel and the bulb that is neglected here, the accuracy of the reading of the gas volume in the syringe and fluctuations in the temperature. The size and relevance of these and other errors should be critically discussed.

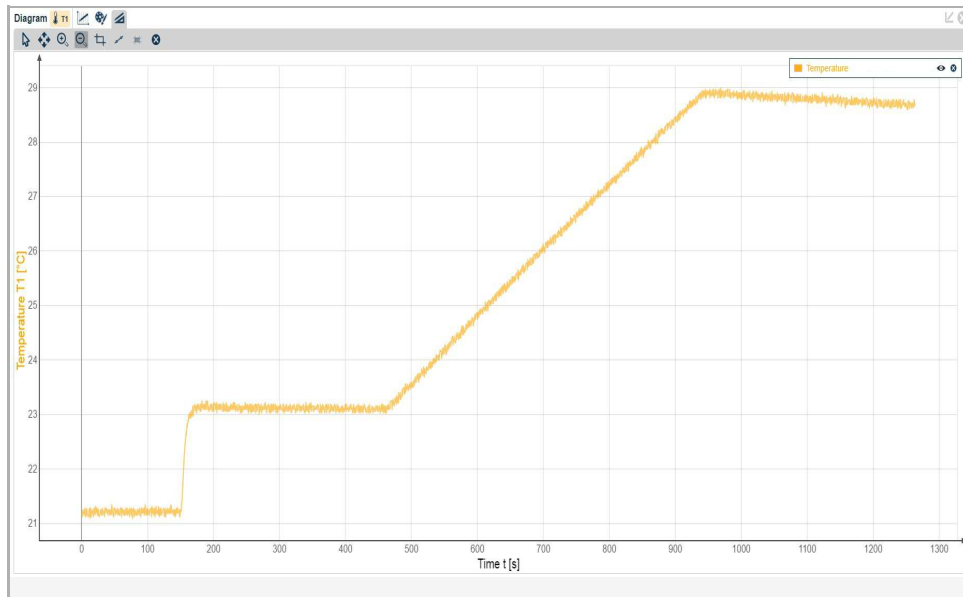


Fig. 2: Temperature- time curve of the neutralisation of potassium hydroxide with hydrochloric acid and for determining the heat capacity of the system.

In the case of the neutralisation of weak acids and bases, additional heat effects arise from dissociation, hydration and association of molecules, so that the value of the enthalpy of neutralisation will differ to that given above. The heat capacity of the system must be determined in order to be able to determine the system change in enthalpy  $\Delta H$ . This is undertaken, after completion of the neutralisation reaction, by introducing a specific amount of heat into the filled calorimeter using electrical heating. The electrical energy  $W_{el} = I \cdot U \cdot t$  which is converted into heat  $Q$  causes an increase in temperature  $\Delta T_{cal}$ . From this the heat capacity of the system  $C_{sys}$  can be calculated using equation (1).

$$Q = I \cdot U \cdot t = C_{sys} \cdot \Delta T_{cal} = W_{el} \quad (1)$$

Using the heat capacity of the system, the enthalpy of neutralisation  $\Delta H_n$  can be calculated from the temperature increase  $\Delta T$  of the neutralisation reaction for a known amount  $n$  of converted hydrochloric acid.

$$\Delta H_n = -\frac{C_{sys} \cdot \Delta T_{cal}}{n} = -\frac{\rho_{HCl}}{c_{HCl} \cdot m_{HCl}} = C_{sys} \cdot \Delta T \quad (2)$$

- $n$  Amount of hydrochloric acid introduced
- $c_{HCl}$  Concentration of hydrochloric acid (= 2 mol/l)
- $m_{HCl}$  Mass of hydrochloric acid introduced
- $\rho_{HCl}$  Density of hydrochloric acid (= 1.0344 g/ml for 2 M HCl at 20°C)
- $\Delta H_n$  Enthalpy of neutralisation
- $C_{sys}$  Heat capacity of system

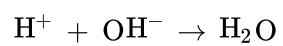
For reasons of simplification it is assumed that the heat capacity of the dilute salt solution differs only negligibly from that of water.

**Enthalpy of neutralisation:**

$$\Delta H_n = -57.7 \frac{\text{kJ}}{\text{mol}}$$

**Evaluation**

The value of the enthalpy of neutralisation  $\Delta H_n$  for the reaction of strong acids with strong bases is independent of which strong acid or base is used, because the heat of reaction is generated by the reaction of hydrogen and hydroxyl ions to form water.



$$\Delta H_n = -57.3 \frac{\text{kJ}}{\text{mol}}$$