Reaction enthalpy of an endothermic reaction - Introduction to entropy with Cobra SMARTsense

Students learn to experimentally record and quantitatively evaluate the heat absorption of an endothermic neutralisation reaction.

Chemistry	Inorganic chemistry	Acids, bases, salts
Chemistry	Physical chemistry	Thermochemistry, calorimetry

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	20 minutes

This content can also be found online at:

https://www.curriculab.de/c/68c02226cc15db000266d736

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Teacher information

Application

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The experiment shows how reaction enthalpies can be determined experimentally and forms a basis for understanding and applying chemical energy conversions.

Chemical reactions can be categorised in terms of their heat balance into **endothermic** and **exothermic** categorise reactions. While energy is absorbed in endothermic reactions, exothermic reactions release energy to the environment in the form of heat. In this experiment, the **molar reaction enthalpy** of an endothermic reaction: Ammonium thiocyanate is added to a barium hydroxide solution, whereupon a decrease in temperature is observed.

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Other teacher information (1/8)

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Prior knowledge

For the experiment, students should have a basic knowledge of neutralisation reactions, endothermic reactions and calorimetry.

Principle

In the experiment, the endothermic reaction of barium hydroxide with ammonium thiocyanate is used and the heat of reaction absorbed from the environment (water) is analysed. For this purpose, ammonium thiocyanate is added to a barium hydroxide solution and the temperature decrease is measured. The amount of heat absorbed and then the reaction enthalpy can be calculated from the temperature difference and the reaction entropy can be introduced to explain the reaction that takes place voluntarily.

Other teacher information (2/8)

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Learning objective

The students learn to experimentally record and quantitatively evaluate the heat absorption of an endothermic neutralisation reaction.

Tasks

The students set up a simple calorimeter into which a barium hydroxide solution is added. The temperature change after the addition of ammonium thiocyanate is recorded quantitatively.

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Other teacher information (3/8)

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In this experiment, a simple calorimeter is to be constructed in which a neutralisation reaction of barium hydroxide with ammonium ions is carried out. The reaction is an endothermic reaction in which heat is absorbed from the environment (water).

The calorimeter consists of two beakers inserted into each other and insulated with a layer of felt. The calorimeter is covered with a suitable foam lid into which the temperature measuring device can be inserted. A barium hydroxide solution is filled into the calorimeter. After adding ammonium thiocyanate, a temperature drop can be observed with constant stirring.

In order to be able to determine the reaction enthalpy from the measurement results, a pre- and post-temperature period are recorded in order to subsequently determine the temperature difference using the three-straight line method.

Other teacher information (4/8)

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One **endothermic** Reaction is a chemical reaction in which the system absorbs heat from the environment. The absorption of heat causes the temperature of the system to drop.

In this calorimetry experiment, hydroxide ions react $(\mathrm{OH^-})$ and ammonium ions $(\mathrm{NH_4^+})$:

- Decomposition of ammonium ions by hydroxide ions: $\mathrm{NH_4^+ + OH^- \rightarrow NH_3 \uparrow + H_2O}$
- Formation of the soluble barium thiocyanate: $\mathrm{Ba^{2+} + 2\,SCN^- \rightarrow Ba(SCN)_2}$

The observed **temperature drop** is directly related to the **reaction enthalpy** and enables their determination.

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Other teacher information (5/8)

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The **reaction enthalpy** ΔH describes the heat generated by a chemical system during a reaction under constant pressure. p absorbs or emits. It is an important factor in determining the **energy turnover** chemical reactions, i.e. whether a reaction is exothermic or not. $(\Delta H < 0)$ or endothermic $(\Delta H > 0)$ proceeds. The reaction enthalpy can be described by the following relationship:

$$\Delta H = \Delta U + p \cdot \Delta V.$$

Here is ΔU the change in the internal energy of the system and $p \cdot \Delta V$ the volume work that the system performs against the external pressure.

In this experiment, hydroxide and ammonium ions react in **aqueous solution,** whereby the volume of the solution changes only slightly (change of $5\ \%$). For this reason, it can be assumed for the experiment that $\Delta V \approx 0$ and consequently $p \cdot \Delta V \approx 0$ is. This simplifies the equation to:

$$\Delta H \approx \Delta U.$$

Other teacher information (6/8)

PHYWE

As the experiment is carried out in a simply constructed student calorimeter, the heat absorbed by the calorimeter must also be taken into account when calculating the reaction enthalpy in addition to the heating of the water. The heat capacity of the calorimeter is determined before the experiment in the same way as P1044100.

In the experiment, the temperature rise ΔT of the solution in the calorimeter, which is caused by the heat released during the reaction. The heat released is calculated using the following equation:

$$Q = -(C_{\mathrm{W}} \cdot m_{\mathrm{W}} + C_{\mathrm{K}}) \cdot \Delta T$$

with the specific heat capacity of the water C_{W} the mass of the salt solution m_{W} and the heat capacity of the calorimeter C_{K}.

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Other teacher information (7/8)

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The amount of heat calculated from the rise in temperature relates to the amount of substance actually used. The molar enthalpy of reaction ΔH_{R} is calculated from the quotient of Q and the amount of substance n:

$$\Delta H_{\mathrm{R}} = \frac{Q}{n(\mathrm{Ba(OH)_2})}.$$

The molar enthalpy of reaction therefore indicates how much energy is released per mole of barium hydroxide during the reaction.

In an endothermic reaction, the measured heat of reaction is $Q > 0$ and thus also $\Delta H_{\mathrm{R}} > 0$.

Other teacher information (8/8)

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The solutions can be produced for everyone to save chemicals!

- **Barium hydroxide solution** $(0,25\ \mathrm{mol/l})$: Add $80\ \mathrm{g}$ Barium hydroxide to $250\ \mathrm{ml}$ distilled water. Mix well and fill up to $500\ \mathrm{ml}$ with distilled water.
- **Ammonium thiocyanate** $(4\ \mathrm{g})$ weigh out in a small beaker.

When using this approach variable, a $600\ \mathrm{ml}$ beaker can be used. You can find these in the PHYWE webshop.

Determination of the heat capacity of the student calorimeter:
The heat capacity of the calorimeter C_{K} can optionally be determined before the actual test is carried out. This can be done analogue to test P1044100. If C_{K} is not determined, an error of about $10\ \%$ when calculating the change in heat quantity $\Delta\, Q$ to be reckoned with.

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Safety instructions

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- The general instructions for safe experimentation in science lessons apply to this experiment.
- All persons in the room must wear safety goggles during the experiment!
- For H and P phrases, please refer to the safety data sheet of the respective chemical.
- *Attention!* The experiment must be carried out under a fume hood, as ammonia gas is produced during the reaction.

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Student information

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Motivation

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Heat is released or absorbed during many chemical reactions. In this process, a **endothermic** Reaction in which a drop in temperature is observed. An example of such a reaction is that in cold packs (also known as instant ice packs). When a cold pack is activated, the inner water bag is crushed and reacts with the salt it contains. This endothermic reaction absorbs heat from the environment, making the pack instantly ice cold.

The experimental determination of the **reaction enthalpy** shows under which conditions and how energy values can be recorded.

Tasks

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How is the reaction enthalpy of an endothermic reaction determined?

1. **Optional:** Build a simple calorimeter from beakers and determine the heat capacity of the calorimeter (P1044100).
2. Fill the calorimeter with barium hydroxide solution and measure the temperature.
3. Add ammonium thiocyanate and record the temperature drop.
4. Calculate the reaction enthalpy of the reaction from the temperature curve.

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Equipment

Position	Equipment	Item no.	Quantity
1	Cobra SMARTsense Temperature - Sensor for measuring temperature -40 ... 125 °C (Bluetooth)	12903-00	1
2	Lid for student calorimeter	04404-01	1
3	Stirring rod	04404-10	1
4	Felt panel, 100 x 100 mm	04404-20	2
5	Beaker, Boro, low shape, 250 ml	46054-00	1
6	Beaker, Boro, low shape, 400 ml	46055-00	1
7	Pipette with rubber cap, l = 100 mm	64701-00	1
8	Measuring cylinder, plastic (PP), tall shape, 100 ml	36629-01	1

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Additional material

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Position	Equipment	Article no.	Quantity
1	Barium hydroxide x 8 H2O, 100 g	CHE-881017631	1
2	Ammonium thiocyanate, 250 g	CHE-881015834	1
3	Water, distilled, 5 litres	31246-81	1

Setup (1/5)

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For measurement with the **Cobra SMARTsense sensors** the **PHYWE measureAPP** required. The app can be downloaded free of charge from the relevant app store (see below for QR codes). Before starting the app, please check whether your device (smartphone, tablet, desktop PC) is running **Bluetooth activated** is.

iOS

Android

Windows

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Setup (2/5)

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The solutions can be produced for everyone to save chemicals!

- **Barium hydroxide solution** $(0,25\ \mathrm{mol/l})$: Add $8\ \mathrm{g}$ Barium hydroxide to $50\ \mathrm{ml}$ distilled water. Mix well and fill up $100\ \mathrm{ml}$ with distilled water.
- **Ammonium thiocyanate** $(4\ \mathrm{g})$ weigh out in a small beaker.

Attention! The experiment must be carried out under a fume hood, as ammonia gas is produced during the reaction.

Setup (3/5)

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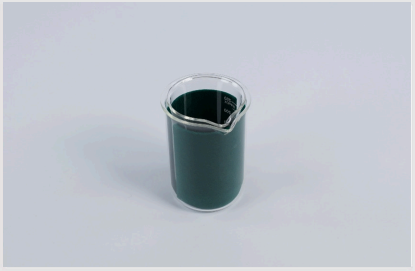
Construction of the student calorimeter:

1. two felt plates are inserted into the larger beaker so that the entire glass wall of the beaker is covered.

2. the second beaker is **carefully!** placed into the larger beaker.

Note: As soon as you feel increased resistance when pushing together, stop immediately! Otherwise there is a risk of the glass breaking.



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Setup (4/5)

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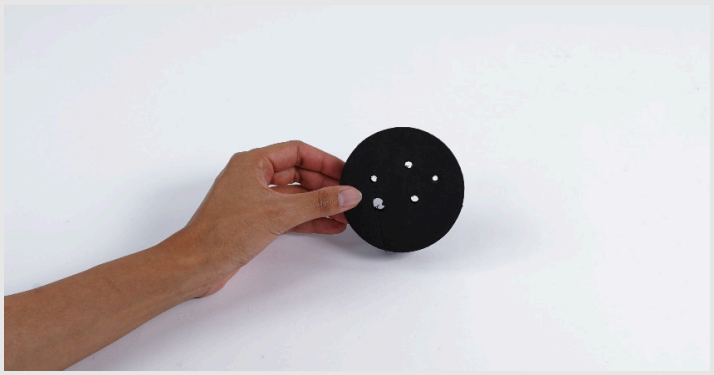
The Cobra SMARTsense temperature can be inserted through one of the holes in the lid of the calorimeter and fixed in place.



Setup (5/5)

PHYWE

The experiment can also be stirred using a glass rod inserted through the large opening in the lid of the calorimeter.

Alternatively, place a stirring fish in the self-built calorimeter and place it on the magnetic stirrer (this is not included as standard).

The cover of the calorimeter with the temperature sensor inserted is initially placed loosely on the edge of the calorimeter.

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Procedure (1/5)

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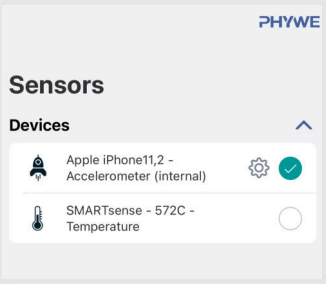
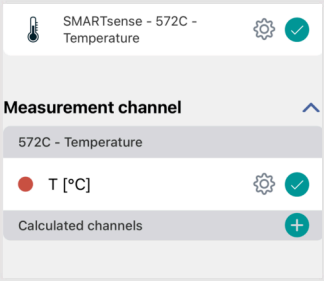
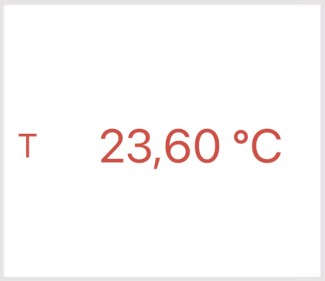
- Start the measureAPP on a mobile device.
- Press the start button on the sensor for approx. 3 seconds.
- Connect the sensor by tapping next to the description of the sensor in the measureAPP.
- Set the measured value display by tapping 0.0 above the diagram.







Procedure (2/5)

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Fill the $0,25\ \mathrm{M}$ barium hydroxide solution into the calorimeter. Care must be taken to ensure that the temperature sensor is at least $1\ \mathrm{cm}$ is immersed in the solution and the rotating stirring fish does not hit the sensor.

Then set the magnetic stirrer and gradually increase the stirring speed until the maximum stable stirring performance is reached.

Make sure that the agitator fish rotates evenly and does not lose control.

Keep the selected stirring speed constant during the entire experiment.

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Realisation (3/5)

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Close the calorimeter with the lid and start measuring the temperature with the Cobra SMARTsense temperature sensor.

Previous period: Wait until a stable temperature has been reached and then draw for at least $60\ \mathrm{s}$ continues to record the temperature.

Procedure (4/5)

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The temperature measurement continues during the following steps and the temperature sensor must remain immersed in the solution at all times!
Remove the lid of the calorimeter as shown in the illustration. Quickly add the ammonium thiocyanate to the barium hydroxide solution in one portion and immediately close the calorimeter again.

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Procedure (5/5)

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Main period: As soon as the ammoinum thiocyanate has been added to the barium hydroxide solution, the neutralisation reaction starts and the temperature of the system drops. During the main period, ensure that the stirring speed remains constant and that the lid of the calorimeter is closed.

Post-period: Then record the temperature data for at least another $100\ \mathrm{s}$.

What drop in temperature did you notice?

Note him.

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Report

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Task 1

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Which statements about the reaction between hydroxide and ammonium ions are correct?

- [ ] The reaction is a neutralisation, which is why the temperature rises.
- [ ] Hydroxide ions are reduced, ammonium ions are oxidised.
- [ ] The reaction produces ammonia gas.
- [ ] Ammonium ions release a proton to hydroxide ions.

Check

Task 2

PHYWE

Which reaction products are formed during the reaction?

- ○ Barium carbonate, nitrogen, water.
- ○ Barium sulphate as precipitate, ammonia, water.
- ○ Barium thiocyanate, ammonia, water.

Check

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Task 3

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Balance the reaction equation.

$$\square\ \mathrm{Ba(OH)_2} \cdot \square\ \mathrm{H_2O} + \square\ \mathrm{NH_4(SCN)} \rightarrow \square\ \mathrm{Ba(SCN)_2} + \square\ \mathrm{NH_3} + \square\ \mathrm{H_2O}$$

1 1 2 8 2 10

Check

Task 4

PHYWE

The temperature of the solution has dropped during the reaction. Which statements are correct?

- ○ If the temperature drops during a chemical reaction, it is an exothermic reaction with $\Delta H_\mathrm{R} < 0$.
- ○ The entropy of the system increases due to the gas evolution and drives the reaction despite the energy absorption.
- ○ The solvent also gives off heat and thus supplies the reaction with energy.
- ○ If the temperature drops during a chemical reaction, it is an endothermic reaction with $\Delta H_\mathrm{R} > 0$.

Check

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Task 5

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Why is this reaction voluntary? Complete the text.

When ammonium thiocyanate reacts with barium hydroxide, the environment becomes significantly _____ because the reaction is _____. Nevertheless, the reaction takes place voluntarily because the _____ of the system increases significantly. This is because the reaction produces a _____ as well as a salt. The formation of _____ in the gas phase leads to a strong _____ in "disorder" (entropy).

gas
increase
entropy
endothermic
ammonia
cooler

Check

Slide	Score / Total
Slide 28: Understanding the reaction	0/2
Slide 29: Summary: Daniell element	0/1
Slide 30: How does the Daniell element work?	0/6
Slide 31: Reaction enthalpy	0/1
Slide 32: Entropy of a reaction	0/6

Total amount 0 / 16

Solutions Repeat

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