# Solubility product with Cobra4 (Item No.: P3030862)

## Curricular Relevance

| Area of Expertise: | Education Level: | Topic: | Subtopic: | Experiment: |
|---|---|---|---|---|
| Chemistry | University | General Chemistry | Solutions and Mixtures | Solubility product with Cobra4 |

| Difficulty | Preparation Time | Execution Time | Recommended Group Size |
|---|---|---|---|
| Difficult | 10 Minutes | 20 Minutes | 2 Students |

**Additional Requirements:**

- PC with USB interface, Windows XP or higher
- Precision balance, 620 g / 0.001 g

**Experiment Variations:**

**Keywords:**

solubility, dissociation, electrolytic conductance, activity

## Overview

## Short description

### Principle

The solubility of poorly soluble salts is expressed as the solubility product, i.e. the product of the concentration of cations and anions in the solution which are in equilibrium with the solid salt. These concentrations can be determined via conductivity measurements.

Fig. 1: Experimental setup.

## Equipment

| Position No. | Material | Order No. | Quantity |
|---|---|---|---|
| 1 | Cobra4 Mobile-Link 2 incl. accessories: battery, USB cable, charger and SD memory card | 12620-10 | 1 |
| 2 | Cobra4 Sensor-Unit Conductivity+ | 12632-00 | 1 |
| 3 | Conductivity temperature probe Pt1000 | 13701-01 | 1 |
| 4 | Immersion thermostat Alpha A, 230 V | 08493-93 | 1 |
| 5 | External circulation set for thermostat Alpha A | 08493-02 | 1 |
| 6 | Bath for thermostat, makrolon | 08487-02 | 1 |
| 7 | Rubber tubing, i.d. 6 mm | 39282-00 | 3 |
| 8 | Hose clip, diam. 8-16 mm, 1 pc. | 40996-02 | 4 |
| 9 | Retort stand, h = 750 mm | 37694-00 | 2 |
| 10 | Right angle boss-head clamp | 37697-00 | 3 |
| 11 | Universal clamp | 37715-00 | 3 |
| 12 | Magnetic stirrer without heating, 3 ltr., 230 V | 35761-99 | 1 |
| 13 | Magnetic stirring bar 30 mm, cylindrical | 46299-02 | 2 |
| 14 | Erlenmeyer nar.neck,boro.,100ml | 46141-00 | 4 |
| 15 | Powder funnel, upper dia. 65mm | 34472-00 | 1 |
| 16 | Spoon, special steel | 33398-00 | 1 |
| 17 | Mortar w. pestle, 70ml, porcelain | 32603-00 | 2 |
| 18 | Weighing dishes, square shape, 84 x 84 x 24 mm, 25 pcs. | 45019-25 | 1 |
| 19 | Wash bottle, plastic, 500 ml | 33931-00 | 1 |
| 20 | Calcium carbonate 500 g | 30052-50 | 1 |
| 21 | Calcium fluoride, powder, purum, 100 g | 31175-10 | 1 |
| 22 | Standard solution 1413µS/cm(25°C), 460ml | 47070-02 | 1 |
| 23 | Water, distilled 5 l | 31246-81 | 1 |
| 24 | Tubing connector, ID 6-10mm | 47516-01 | 2 |

## Tasks

1. Measure the conductivities of saturated aqueous solutions of the salts calcium fluoride and calcium carbonate at 25 °C.
2. With the aid of tabulated ionic conductivities, calculate the solubility products of the salts from their conductivities.

# Setup and procedure

Set up the experiment as shown in Fig. 1. Dissolve 2 g of $CaF_2$ and 2 g of $CaCO_3$ each in 50 ml of distilled water in separate Erlenmeyer flasks (pulverise the salts with the mortar and pestle before weighing). In addition, prepare a third Erlenmeyer flask with 50 ml of distilled water and a further one with 50 ml of calibration standard solution. Put magnetic stirrer bars in the two flasks with the salts, heat them to approximately 60 °C in the water bath, and subsequently stir them for 30 minutes at room temperature on a magnetic stirrer. To perform the measurements, set the temperature-controlled bath to exactly 25 °C and temperature equilibrate the four Erlenmeyer flasks. Use the calibration solution to calibrate the conductivity probe. Measure the conductivities of the distilled water and the salt solutions, whereby the measuring probe should only be immersed in the clear solutions without stirring up the solid phase. Thoroughly rinse the conductivity probe before each new measurement. Substract the conductance value of the distilled water from that of the salt solutions.

# Theory and evaluation

A poorly soluble salt with the general form $M^{z+}_{v+}\, X^{z-}_{v-}$ (z+ and z- are the charge numbers of the ions) forms anions and cations in aqueous solution according to:

$$M_{v_+}^{Z_+} X_{v_-}^{Z_-} \rightleftharpoons v_+ M^{Z_+} + v_- X^{Z-} \quad (1)$$

Due to the extreme dilution, the equilibrium constant Ks can be replaced by the solubility product L:

$$K_S \approx (C_M^{Z_+})^{v_+} \cdot (C_X^{Z_-})^{v_-} = L \quad (2)$$

In contrast to the equilibrium constant, the solubility product is a function of the concentration (salting-out effect). The saturation concentration $c_S$ of a dissolved salt is as follows:

$$c_S = \frac{c_M^{z+}}{v_+} = \frac{c_M^{z-}}{v_-} \quad (3)$$

Substitution in equation (2) results in:

$$L = v_+^{v_+} v_-^{v_-} c_S (v_+ + v_-) \quad (4)$$

The saturation concentration can be determined conductiometrically. To do so, the ionic conductivities for infinite dilution $\Lambda M$ , $\Lambda X$ are used (Table 1):

$$\chi = c_S (v_+ \Lambda_M + v_- \Lambda_X) \quad (5)$$

$\chi$ Specific conductance of the electrolyte solution

Transposing according to $c_S$, the following is obtained:

$$c_S = \frac{\chi}{v_+ \Lambda_M + v_- \Lambda_X}$$

Substituting in equation (4), the solubility product can now be calculated.

Table 1: Ionic conductivities at infinite dilution

| Ion | Ionic conductivity in $S \cdot cm^2 \cdot mol^{-1}$ |
|---|---|
| $Ca^{2+}$ | 119.0 |
| $F^-$ | 55.4 |
| $CO_3^{2-}$ | 138.6 |

**Data and results**

Solubility products:

$CaF_2$: $4.43 \cdot 10^{-11}$ (lit.: $3.4 \cdot 10^{-11}$) $mol^3 \cdot l^{-3}$

$CaCO_3$: $6.82 \cdot 1^{-8}$ (lit.: $4.96 \cdot 10^{-9}$) $mol^3 \cdot l^{-3}$

The conductivity of solutions is strongly affected by even minute traces of contaminants. Thus, for the measurement of the solubility product of calcium carbonate, the measured value is falsified by dissolved carbon dioxide from the air. As a result of the formation of hydrogen carbonate, the solubility increases and consequently the conductivity also.


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