ICRN 32

IAPWS Certified Research Need - ICRN

Conductivity of electrolytes in aqueous solutions

The electrical conductivity of aqueous electrolyte solutions has been researched extensively in the past. Most data refer to 25 °C, but conductivity varies with temperature. There are some data available in the literature for the range of 0 °C to 50 °C.

Knowledge of the conductivity in the temperature range of 5 °C up to at least 120 °C however is necessary for cooling water systems, and for selected cases in the steam water cycle of a power plant.

This ICRN is intended to stimulate a compilation of conductivity data for temperatures above 50 °C in a world-wide accessible publication, and the creation of a model for calculation of the conductivity dependence on temperature between 5 °C and 120 °C.

Although encouraging this work, IAPWS is not able under its statutes to provide financial support. The IAPWS contact can provide any further development information and will liaise between research groups

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Conductivity of electrolytes in aqueous solutions

Background

The electrical conductivity of aqueous electrolyte solutions has been researched extensively in the past, just to mention the pioneering work by Kohlrausch in the 1870's. A compilation of data can be found in the CRC Handbook [1], the section on conductivity edited by Petr Vanysek (Northern Illinois University). Many references are given there, but those are not easily accessible without a large university library available.

Most data refer to 25 °C, some also traditionally to 20 °C or 18 °C (room temperature in the course of time). There are some data in the range of 0 °C to 50 °C, for example in references [1][2][3][4], and probably only few at higher temperatures up to 100 °C or even higher [5][6]. An extensive investigation of data at higher temperatures is given in [7].

The temperature dependence of conductivity is of interest for example for:

- Water cooled electric equipment (generators, particle accelerators, ion sources, switchgear), where increased conductivity can lead to destruction of the machine [8]. Especially adverse is that conductivity increases with temperature, such a way to result in exponential heat-up. Usually, temperatures in the range of 10-120 °C are in question.

- Electrical resistance boilers for the production of saturated steam, typical range up to 40 (100) bars.

- Instrument manufacturers. They usually have their own algorithms to refer samples in the range of 10-50 °C to 25 °C [4]. However, there are cooling water systems that operate at higher temperature and conductivity must be measured in-line at temperature. Here also, the range up to 100 °C is realistic; for above (e.g., boiler water), the sample can be sufficiently cooled down.

A common approximation is the thesis that conductivity is inversely proportional to the viscosity of the water [9]. Considering only strong electrolytes, this model misses at least the density of water (conductivity refers to volume, while ionic strength to mass). For weak electrolytes, the degree of ionization which also depends on temperature, must be considered.

A comparison of experimental data on KCl [2][3] indicates an almost linear relationship between 10 °C and 50 °C, while a stronger dependence is obtained with the viscosity model (Figure 1). This becomes critical when values are extrapolated without any experimental reference.

It is possible that much information requested by this ICRN is already available in the literature. In this case, no laboratory work would be required.

Research Needs

Literature research

- Conductivity of strong electrolytes between 5 °C and 120 °C at infinite dilution. Of special interest are KCl, NaCl, Na_2SO_4, Na_3PO_4, NaOH, and HCl. For pure water, sufficient data are available [10].
- For NaOH and Na_3PO_4 data up to a concentration of 5 ppm, a pressure up to 100 bar and a temperature slightly below saturation (drum boiler water)
- If possible, also for weak electrolytes as NH_4^+ (< 10 ppm), HCO_3^- (< 2 ppm) and some basic amines like cyclohexylamine and morpholine (< 10 ppm), as well as for H^+ and OH^-.

Further research

- Development of a state-of-the art model formulation for the temperature dependence of conductivity, conditions as mentioned above.
- Depending on the results obtained by the literature research, experimental verification and extensions may be required.

Anticipated output

- Compilation of conductivity data for temperatures above 50 °C in a world-wide accessible publication.
- A model for calculation of the conductivity dependence on temperature between 5 °C and 120 °C.

Beneficiaries

- Industries for electric equipment, power plants, process water, and steam raising.
- The scientific community for getting a compilation of information spread out in the literature.

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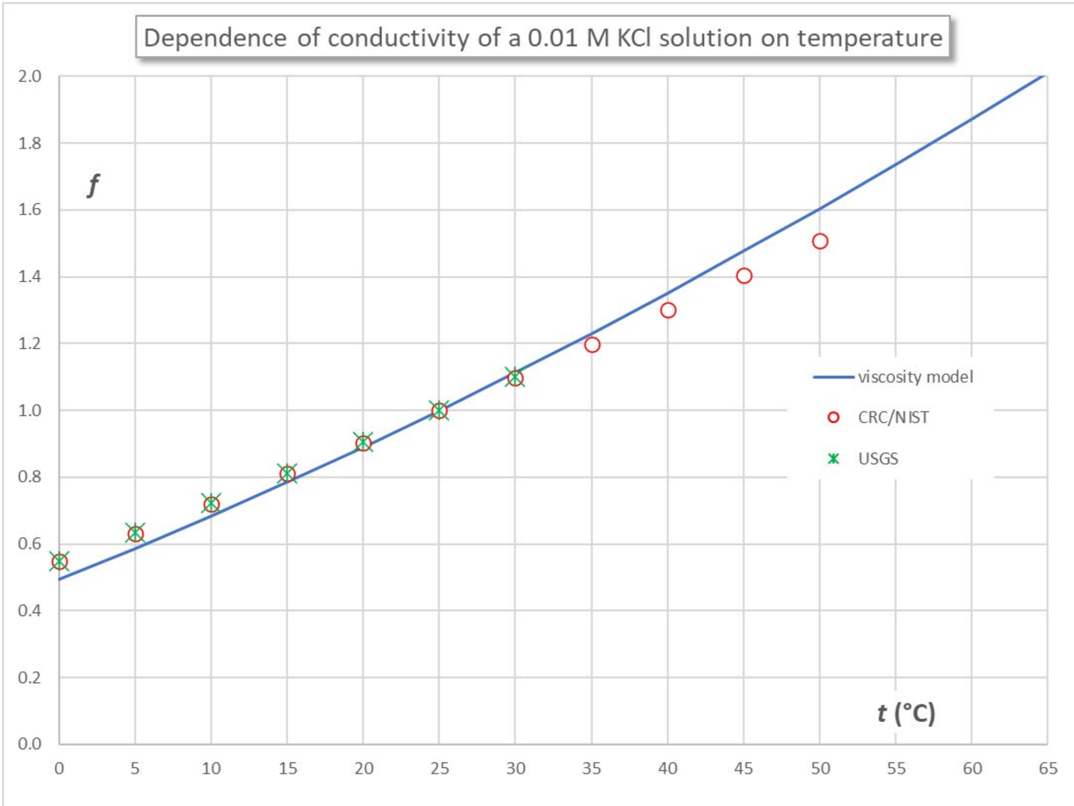

Figure 1. Increase of conductivity of 0.01 M KCl solution with temperature, relative to 25 °C ($f = \kappa_T/\kappa_{25}$). The solid curve is the relation calculated with viscosity and density of water. "CRC/NIST" are data for KCl, as found in in the CRC Handbook [1]; these data are referenced to NIST publications. "USGS" are measurement data from given in a report of the US Geological Survey [3]. The fit of the data to the curve is mediocre and does not permit a solid extrapolation to temperatures above 50 °C. Note: the data refers to a higher concentration than within the scope of this ICRN.