Influence of Temperature on Electrical Conductivity of Diluted Aquaeous Solutions

Dr. H. Wagner, Dr. P. Wuhrmann

presented by Heini Maurer

swan ANALYTICAL INSTRUMENTS

IAPWS Technical Guidance Document

The conductivity of ionic solutions varies with temperature. Ionic mobilities are themselves temperature dependent and, when weak bases (such as ammonia and amines) are present, there is an additional influence of temperature on their dissociation. Commercial instrumentation may compensate for deviation from a reference temperature (normally 25 ºC) to variable degrees of accuracy.

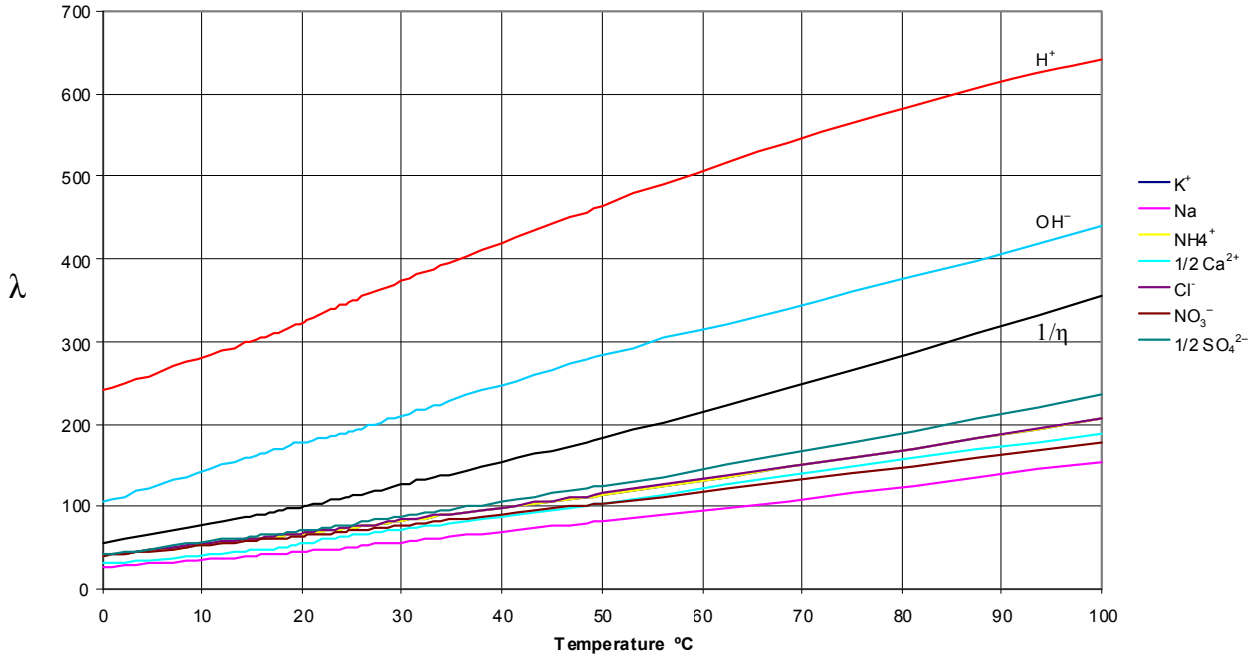
However, to minimize errors arising from the differing temperature dependencies of conductivities of the various species that may be present, it is beneficial to adjust the sample temperature to be as close to the reference temperature as practicable.

Dependence of the equivalent ionic conductivity λ on the ion type

Li^+	Na^+	K^+	NH_4^+	$½Ca^{2+}$	H^+	OH^-	Cl^-	NO_3^-	HCO_3^-	$½CO_3^{2-}$	$½SO_4^{2-}$
38.7	50.9	74.5	74.5	60	350	198	75.5	70.6	44.5	69.3	79

Table 1:
Equivalent ionic conductivity in water at 25°C (extremely diluted solutions)

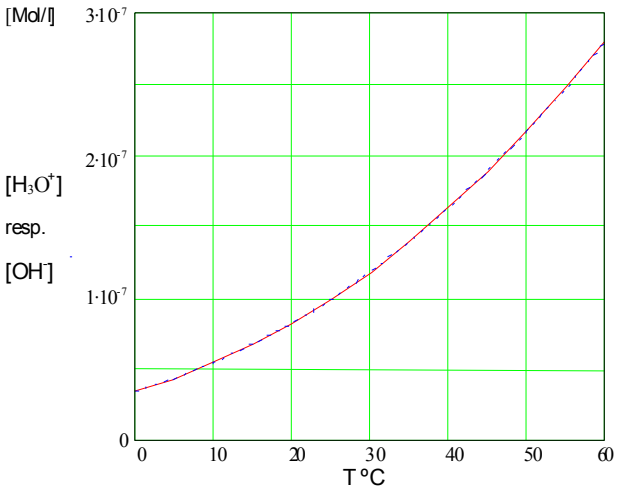
Dependence of the equivalent ionic conductivity on temperature

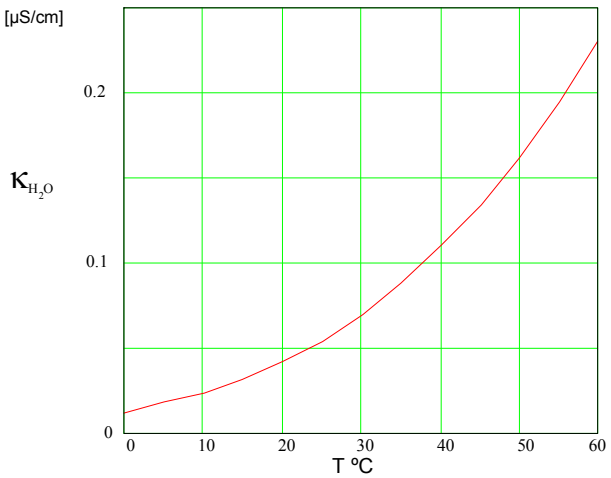


The curves of the equivalent ionic conductivity follow, to a large extent, the inverse viscosity of water. This data validates the description of the steady ion flow with the Stokes equation which means the temperature dependence is mainly determined by the viscosity of the solution.

Conductivity Diagrams of Water-Steam-Cycle Samples

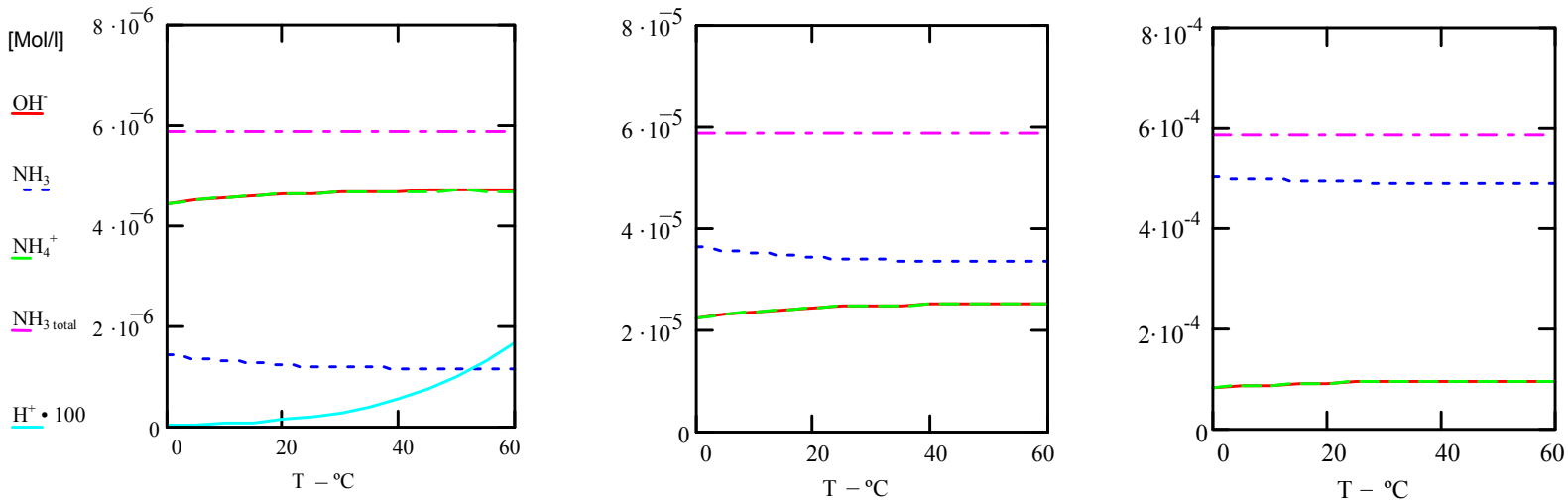
The relation of conductivity and temperature is for pure water unique. A certain temperature corresponds with a certain conductivity, and vice versa.





Dissociation and specific conductivity of water from 0 to 60 ºC

Ammonia in water



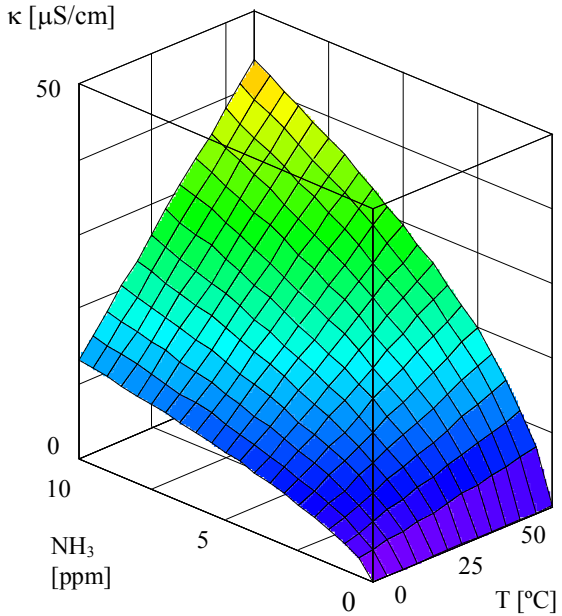
0.1 ppm NH_3, pH 8.4

1 ppm NH_3, pH 9.4

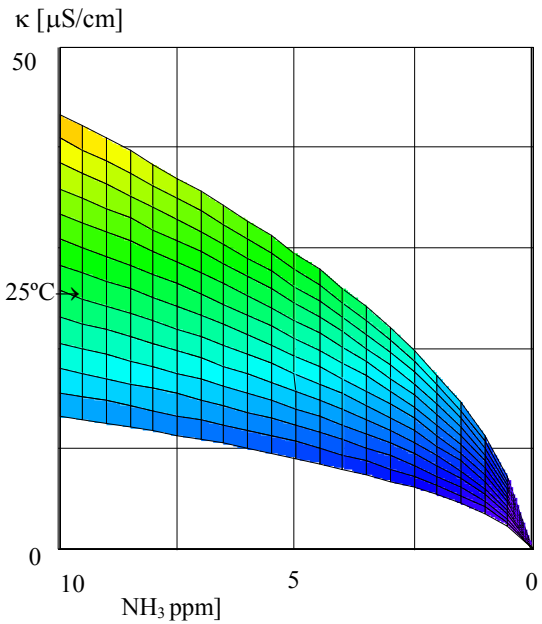
10 ppm NH_3, pH 9.98

Figure 4:
Concentrations of NH3 , $NH4^+$, OH^- (and H^+) from 0 to 60ºC for NH3 overall concentrations 0.1, 1 and 10 ppm

Ammonia



5a

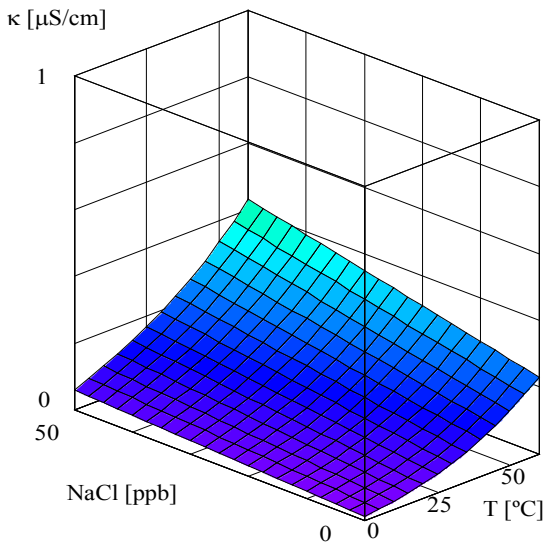


5b

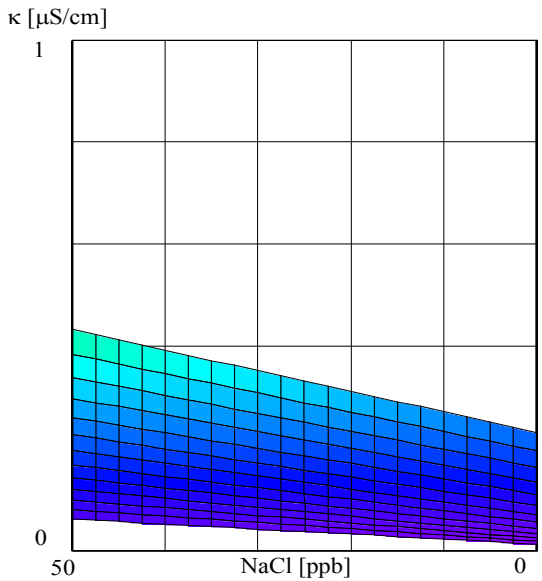
a: Specific conductivity of NH3 solutions with a total NH3 concentration from 0 to 10 ppm at temperatures from 0 to 60°C

b: projection of the isotherm conductivity curve onto the k-[NH3]-surface

NaCl and CO_2



6a

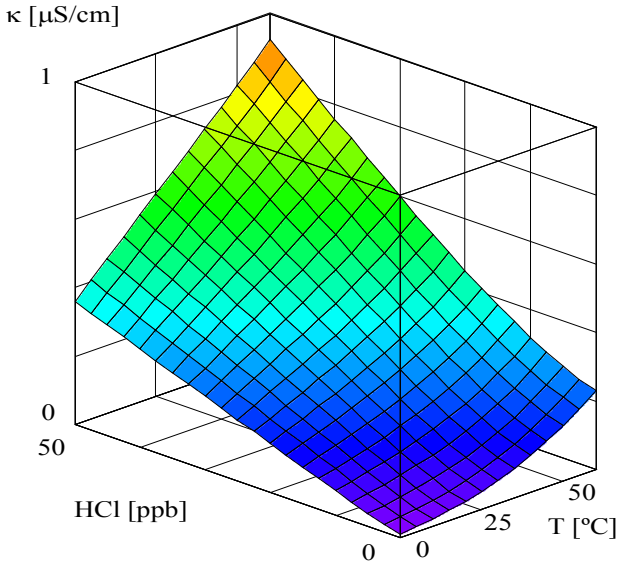


6b

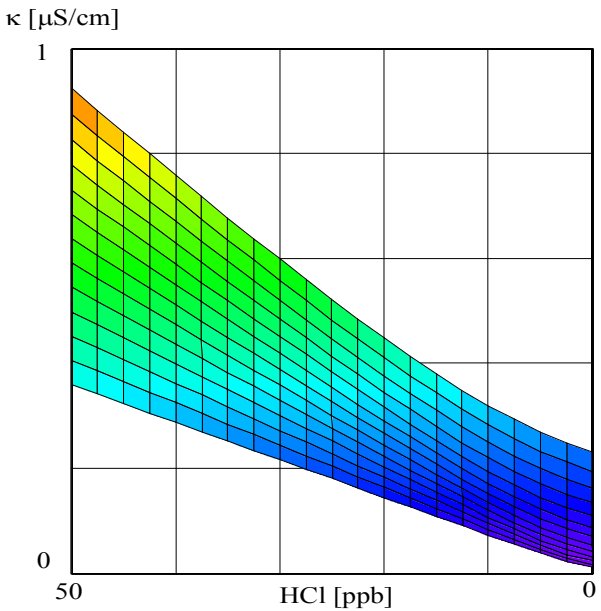
a: Conductivity of 0÷50 ppb NaCl, 0÷60ºC

b: Projection of isothermic curves on to the k-[NaCl]-surface

Hydrochloric acid



7a

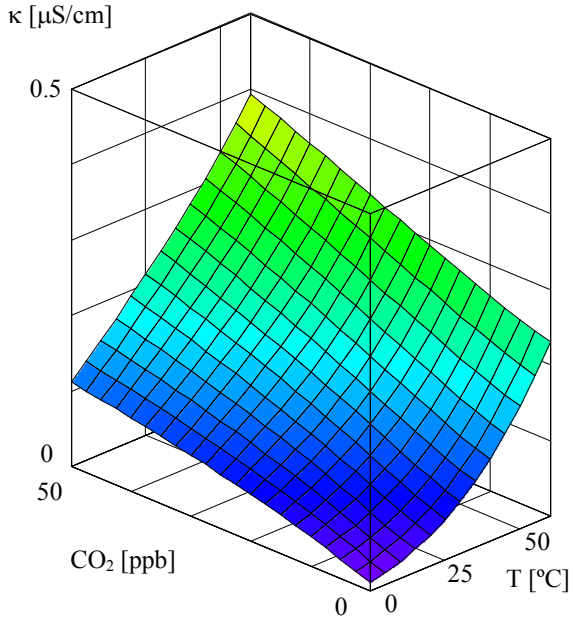


7b

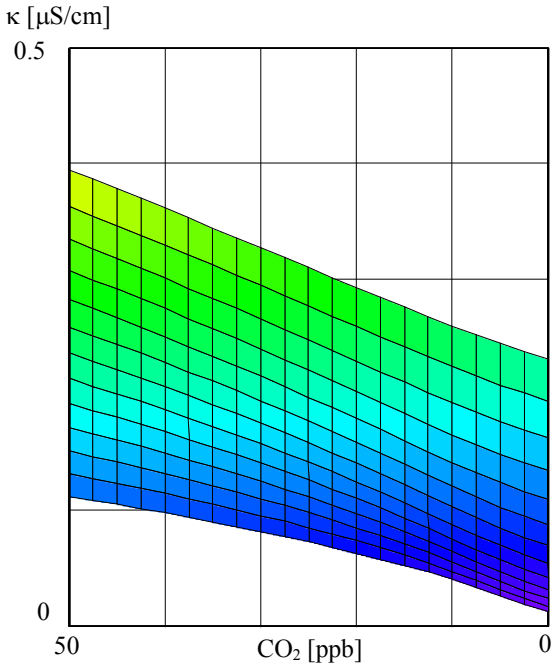
a: Conductivity from 0÷50 ppb HCl, 0÷60ºC

b: Projection of isotherm conductivity curves onto the k-[HCl]-surface

CO_2



8a



8b

a: Conductivity from 0÷50 ppb CO 2 , 0÷60ºC

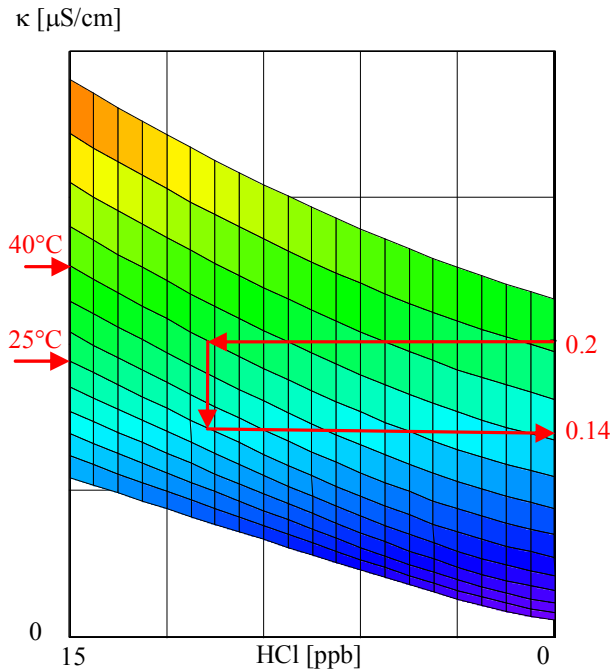
b: Projection of isotherm conductivity curves onto k-[CO 2]-surface.

Conversion of conductivity to 25°C

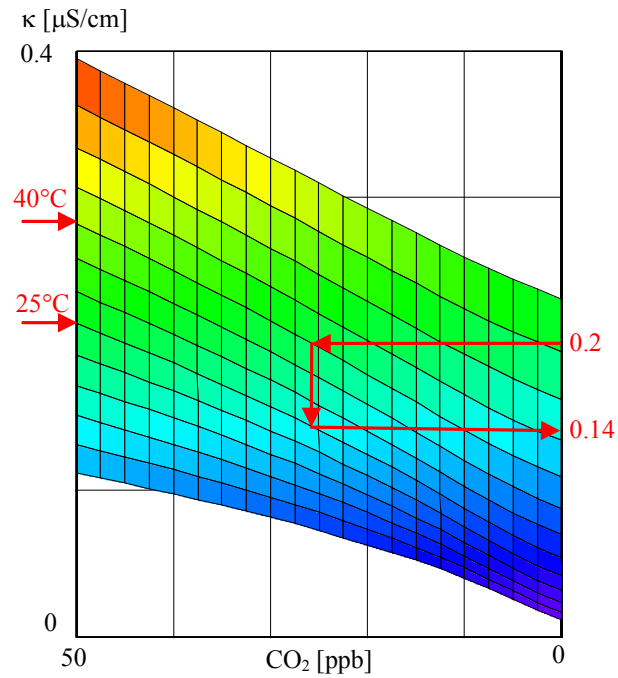
	Na^+	K^+	NH_4^+	Ag^+	$½Ca^{2+}$	Cl^-	NO_3^-	$½SO_4^{2-}$	OH^-	H^+
$\lambda_{25\,°C}$	50.9	74.5	74.5	63.5	60	75.5	70.6	79	192	350
$\lambda_{50\,°C}$	82	115	115	101	98	116	104	125	284	465
$Q_{i\ 50\,°C}$	**0.621**	**0.648**	**0.648**	**0.629**	**0.612**	**0.651**	**0.679**	**0.632**	**0.676**	**0.753**

Table 3: Quotients $\lambda_{i,25^0C} / \lambda_{i,50^0C}$

Acid conductivity and CO_2

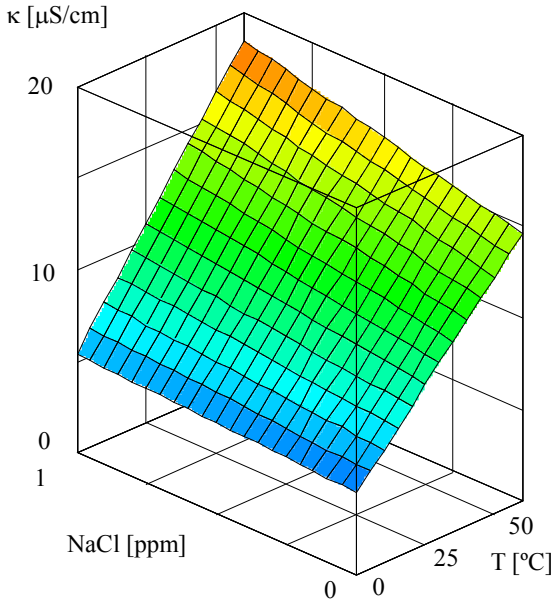


9a Isotherm conductivity
0÷15 ppb HCl, 0÷60ºC



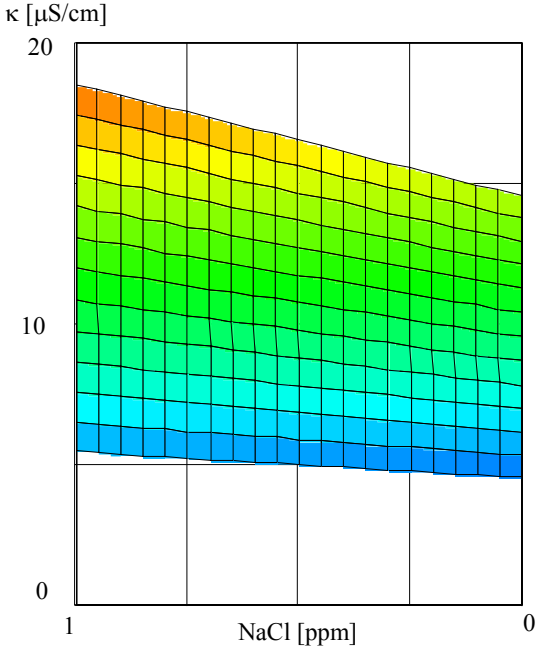
9b Isotherm conductivity
0÷50 ppb CO2 , 0÷60ºC

NaCl in feedwater



10a

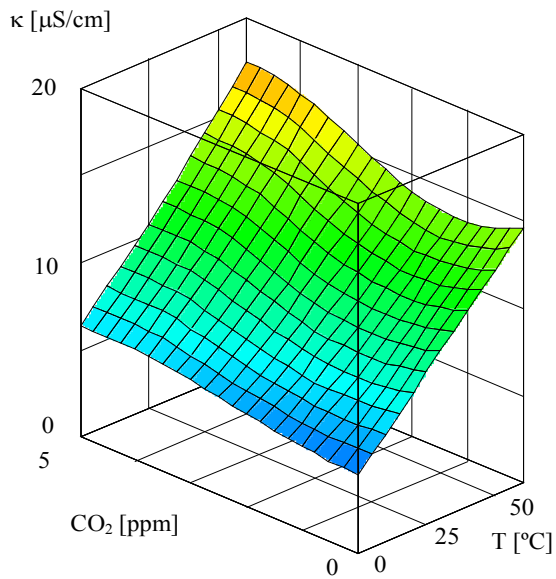
Conductivity of 1.5 ppm NH3 and 0÷1 ppm NaCl, at 0÷60ºC



10b

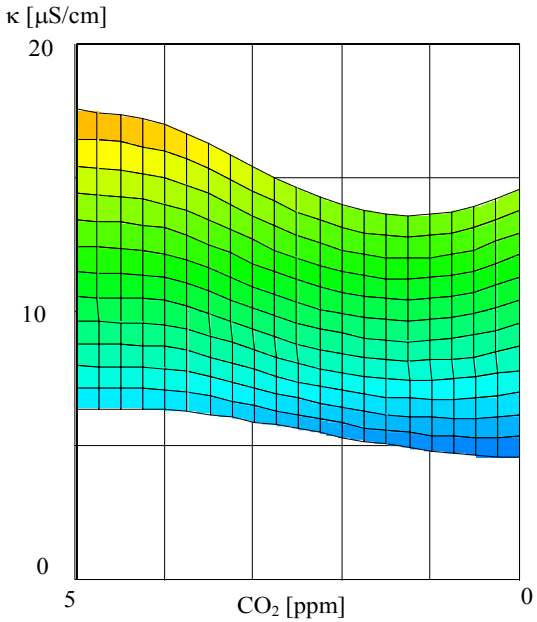
Projection of the isotherm conductivity curve onto the k-[NaCl]-surface

CO_2 in alkalized condensate



11a

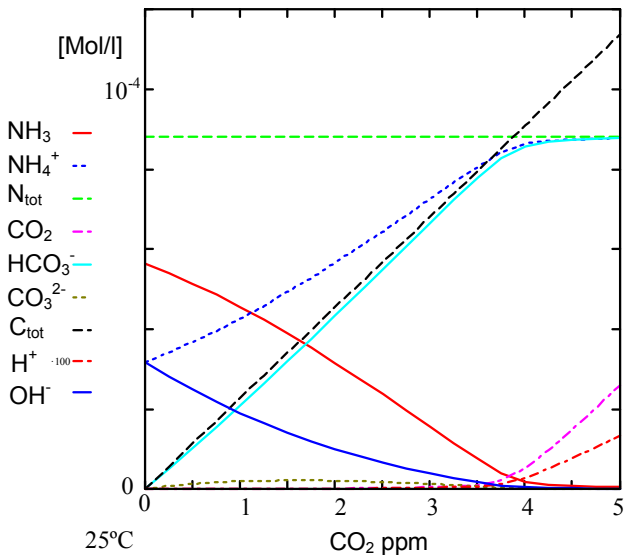
Conductivity of 1.5 ppm NH3 and 0÷5 ppm CO2, at 0÷60ºC



11b

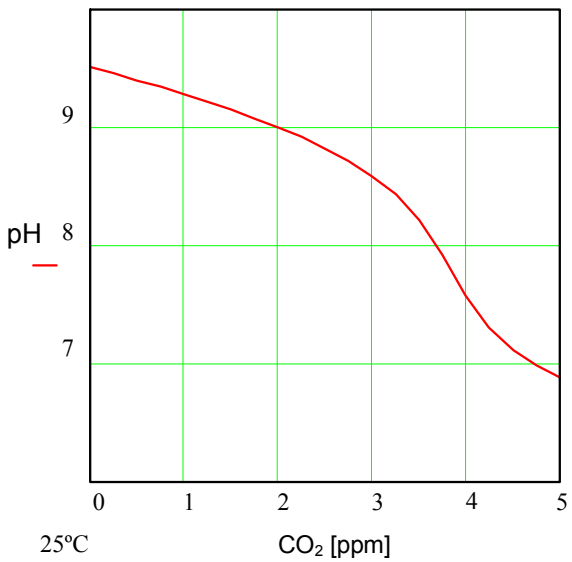
Projection of the isotherm conductivity curve on the k-[CO2]-surface

CO_2 in alkalized condensate



12a

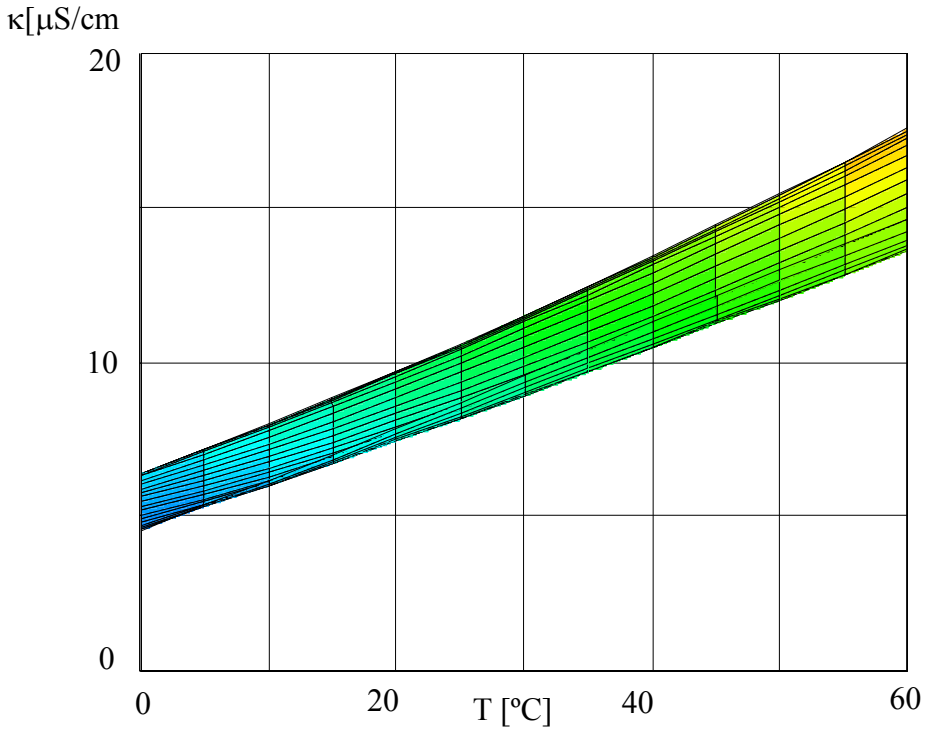
Concentration NH3, $NH4^+$, CO2, $HCO3^-$, $CO3^{2-}$, H^+, OH^-, at 25°C



12b

pH with 1.5 ppm NH3 and 0÷5 ppm CO2, at 25ºC

Projection on the conductivity-temperature-surface



Projection of the conductivity diagram Fig. 11a onto the k-T-surface.
The curves for the different but fixed CO2-concentrations are more or less proportional to each other.
The approximation holds even for this rather complex example.

Conclusion

The temperature conversion of the conductivity, within the range from 25 °C to 50 °C, depends only a little on the chemical composition of the sample. This is due to the fact that the temperature coefficients $Q_{i,T} = \frac{\lambda_{i,25°C}}{\lambda_{i,T°C}}$ of all the ions are of approximately the same dimension which is proportional to the ratio of the reciprocal viscosity $\frac{1/\eta_{25°C}}{1/\eta_{T°C}}$ of water.

Consequently, the conversion of a conductivity value to 25 °C can be approximated by a single equation that is applicable to samples composed of any electrolytes.