

Specific conductance, electrometric, Wheatstone bridge

Parameters and codes:

Specific conductance, lab, I-1780-85 ($\mu\text{S}/\text{cm}$ at 25°C): 90095

Specific conductance, lab, automated, I-2781-85 ($\mu\text{S}/\text{cm}$ at 25°C): 90095

1. Application

This method may be applied to all natural, treated, and industrial water.

2. Summary of method

2.1 Specific conductance is determined by using a Wheatstone bridge in which a variable resistance is adjusted so that it is equal to the resistance of the unknown solution between platinized electrodes of a standardized conductivity cell. The ability of a solution to conduct an electric current is a function of the concentration and charge of the ions in the solution and also depends on the rate at which the ions can move under the influence of an electrical potential. As the number of ions per unit volume of solution increases, the rate at which individual ions can move decreases, because of interionic attraction and other effects. For this reason, a graph of total-ion concentration versus specific conductance, even for solutions of a single salt, is a simple straight line only for rather dilute solutions. As specific conductance increases beyond about $5,000 \mu\text{S}/\text{cm}$ at 25°C , the regression line curves, and beyond $50,000 \mu\text{S}/\text{cm}$, the specific conductance is generally an unsatisfactory index of solute-ion concentration.

2.2 The temperature of the electrolyte affects the ionic velocities and, consequently, the conductance. Conductance increases about 2 percent per degree Celsius, which is about the same as the temperature coefficient of viscosity of water.

2.3 In the determination of the specific conductance, preparing a cell having electrodes exactly 1 cm^2 in area and exactly 1 cm apart would be difficult. Moreover, such an exact cell

is unnecessary because a factor called the cell constant (C) can be determined. The cell constant is determined experimentally with a standard solution of known conductance. A 0.00702N potassium chloride solution has a specific conductance of $0.001000 \text{ S}/\text{cm}$ at 25°C . The relation between resistance (R), cell constant (C), and specific conductance (K) is shown in the following equation, where K is known and R is determined:

$$RK=C$$

Thus, if the resistance of the cell, when filled with 0.00702N KCl , is, for example, 350 ohms , the cell constant would be 0.35 for the conductivity cell used. If the conductivity cell having a cell constant of 0.35 is filled with a sample at 25°C and the observed resistance is 865 ohms , the specific conductance of the sample could be derived from the cell-constant equation:

$$\frac{C}{R} = K$$

Substituting values from the example yields the following:

$$\frac{0.35}{865} = 0.00405 \text{ S at } 25^\circ\text{C}$$

2.4 Unless a constant-temperature room or bath is available, adjustment of sample temperature (T) to exactly 25°C is difficult. For most work, specific conductance is computed from the following equation: $\mu\text{S}/\text{cm} = \textcolor{red}{R}$ of 0.00702N

KCl at T of sample measurement $\times 1,000$) $\times (1/R$ of the sample).

2.5 New conductivity cells should be visually checked for cleanliness and platinum uniformity before use. Subsequently, they should be cleaned and replatinized whenever the readings become erratic or indistinct or inspection shows that any platinum black has flaked off. One platinization will usually suffice for a period of several months. To platinize the electrodes, clean them in chromic acid solution and rinse thoroughly in several changes of water. Place the electrodes in a solution of chloroplatinic acid and lead acetate (dissolve 3 g H_2PtCl_6 in 10 mL water to which 20 mg $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$ is added; commercial platinizing solutions are also available), Connect the electrodes to two dry cells ($1\frac{1}{2}$ -V each) in parallel and reverse the direction of the current once per minute for 6 min, or until the shiny platinum surface is covered. Avoid deposition of amorphous platinum on the electrodes.

Repeat the electrolytic process, using 10-percent sulfuric acid to remove chlorine. When not in use, the cell should be kept immersed in distilled water.

2.6 The accuracy and reproducibility of results obtainable depend largely on the type of bridge used, but can approach 2 percent with this equipment. Close attention to temperature is essential for reliable work.

2.7 Additional information on the theory and practice of specific conductance measurements can be found in Daniels and Alberty (1966), and in Scofield (1932),

2.8 This procedure may be automated by the addition of commercially available instrumentation.

3. Interferences None.

4. Apparatus

4.1 *Conductivity cell*: Cells of at least two different cell constants should be available to measure a wide range of conductivities. The table below provides a general guide to the selection of an appropriate cell constant.

Specific conductance ($\mu\text{S}/\text{cm}$ at 25°C)	Cell constant (cm^{-1})
20-1,000	0.2
40-2,000	.5
100-4,000	1.0
200-10,000	2.0
400-20,000	5.0
1,000-40,000	10.0

4.2 *Conductivity meter*, Wheatstone-bridge type or equivalent direct-reading meter.

4.3 *Thermometer*, 0 to 50°C , graduated in 0.1°C . Some direct-reading conductivity meters have automatic temperature compensation built into the meter. Alternatively, a thermistor device as described by Hughes (1966) provides a convenient means of directly computing the necessary temperature correction.

5. Reagent

Potassium chloride solution, 0.00702N:

Dissolve 0.5234 g KCl, dried at 180°C for 1 h, in demineralized water and dilute to 1,000 mL.

6. Procedure

6.1 Meters measuring resistance: The manufacturer's instructions for operation of the bridge should be followed explicitly. A constant-temperature room or 25°C bath simplifies temperature consideration. Where such facilities are not available, the sample should be brought to approximately room temperature before the determination. However, samples in the laboratory are seldom at exactly the same temperature because of the influence of drafts, sunlight, radiators, ovens, and open flames. The temperature of each sample should be determined at the time of measurement.

6.1.1 Prepare a graph of resistance of 0.00702N KCl throughout the operating-temperature range.

6.1.2 Rinse the cell with sample.

6.1.3 Measure the resistance of the sample and record the temperature at the time of measurement. Record temperature to the nearest 0.1°C .

6.1.4 Determine the resistance of 0.00702N KCl at the temperature at which the sample resistance was measured from the graph prepared in step 6.1.1.

6.2 Direct-reading meters with built-in temperature compensators:

6.2.1 Prepare a table of conductance of 0.00702*N* KCl throughout the operating-temperature range. Calculate and enter in table the correction factors where measured conductance deviates from correct conductance.

6.2.2 Immerse probe-type cell in sample. (Cell will have been immersed in deionized water and blotted dry with tissue just before use.)

6.2.3 Measure conductance and temperature, and record both measurements,

6.2.4 Refer to table prepared in 6.2.1 and apply appropriate correction factors to conductance measurements as necessary.

7. Calculations

Specific conductance ($\mu\text{S}/\text{cm}$ at 25°C)

$$= \frac{R \text{ of } 0.00702N \text{ KCl}}{R \text{ of sample}} \times 1000$$

where

R = resistance in ohms.

NOTE 1. Further calculations are unnecessary when measurements are made with a direct-reading meter with builtin temperature compensator.

8. Report

Report specific conductance, MS/cm at 25°C (90095), as follows: less than 1,000 MS/cm , whole numbers; 1,000 MS/cm and above, three significant figures.

9. Precision

9.1 Precision for specific conductance for 36

samples within the range of 9.0 to 2080 $\mu\text{S}/\text{cm}$ can

be expressed as follows:

$$S_T = 0.054X - 3.80$$

where

S_T = overall precision, microsiemens per centimeter, at 25°C ,

and

X = specific conductance, microsiemens per centimeter, at 25°C .

The correlation coefficient is 0.9005.

9.2 Precision for specific conductance for five of the 36 samples expressed in terms of the percent relative standard deviation is as follows:

Number of	Mean	Relative standard deviation
Laboratories	($\mu\text{S}/\text{cm}$ at 25°C)	(percent)
32	9.0	19
31	112	4
28	557	3
36	1170	5
55	2080	47

9.3 Using automated instrumentation, analysis of two test samples by a single laboratory for 25 replicates of each resulted in mean values of 96.9 and 1,664 $\mu\text{S}/\text{cm}$ and standard deviations of 0.8 and 11 $\mu\text{S}/\text{cm}$, respectively.

References

- Daniels, Farrington, and Alberty, R. A., 1966, Physical chemistry (3rd ed.): New York, John Wiley and Sons, 671 p.
- Hughes, L. S., 1966, Use of thermistor-thermometer in determination of specific conductance: U.S. Geological Survey Water-Supply Paper 1822, p. 66.
- Scofield, C. S., 1932, Measuring the salinity of irrigation waters and of soil solutions with the Wheatstone bridge: U.S. Department of Agriculture Circular 232.