

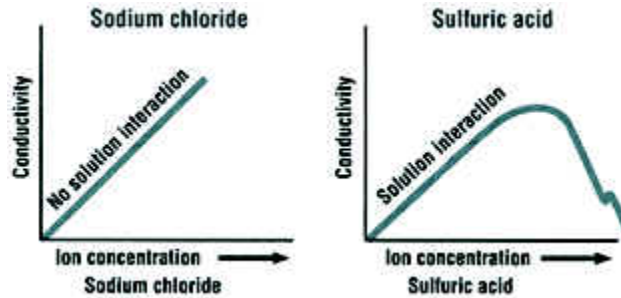
# Introduction to Conductivity

## Definition

Conductivity is the ability of a material to conduct electric current. The principle by which instruments measure conductivity is simple - two plates are placed in the sample, a potential is applied across the plates (normally a sine wave voltage), and the current is measured. Conductivity (G), the inverse of resistivity (R) is determined from the voltage and current values according to Ohm's law.

$$G = I/R = I \text{ (amps)} / E \text{ (volts)}$$

Since the charge on ions in solution facilitates the conduction of electrical current, the conductivity of a solution is proportional to its ion concentration. In some situations, however, conductivity may not correlate directly to concentration. The graphs below illustrate the relationship between conductivity and ion concentration for two common solutions. Notice that the graph is linear for sodium chloride solution, but not for highly concentrated sulfuric acid. Ionic interactions can alter the linear relationship between conductivity and concentration in some highly concentrated solutions.



## Units of Measurement

The basic unit of conductivity is the siemens (S), formerly called the mho. Since cell geometry affects conductivity values, standardized measurements are expressed in specific conductivity units (S/cm) to compensate for variations in electrode dimensions. Specific conductivity (C) is simply the product of measured conductivity (G) and the electrode cell constant (L/A), where L is the length of the column of liquid between the electrode and A is the area of the electrodes (see Figure 1).

$$C = G \times (L/A)$$

If the cell constant is 1 cm<sup>-1</sup>, the specific conductivity is the same as the measured conductivity of the solution. Although electrode shape varies, an electrode can always be represented by an equivalent theoretical cell.

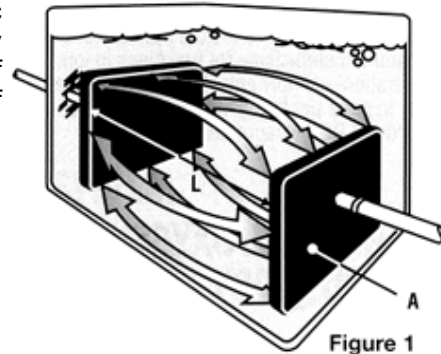


Figure 1

The following table shows optimum conductivity ranges for cells of three different constants:

Cell constant	Optimum Conductivity Range (µS/cm)
0.1	0.5 to 400
1.0	10 to 2000
10.0	1000 to 200,000

## Conductivity Temperature Compensation

Conductivity measurements are temperature dependent. The degree to which temperature affects conductivity varies from solution to solution and can be calculated using the following formula:

$$G_t = G_{t_{cal}} \{1 + \alpha(T - T_{cal})\}$$

where:  $G_t$  = conductivity at any temperature  $T$  in °C,  $G_{t_{cal}}$  = conductivity at calibration temperature  $T_{cal}$  in °C,  $\alpha$  = temperature coefficient of solution at  $T_{cal}$  in °C.

Substance at 25°C	Concentration	Alpha (a)
HCl	10 wt%	1.56
KCl	10 wt%	1.88
H <sub>2</sub> SO <sub>4</sub>	50 wt%	1.93
NaCl	10 wt%	2.14
HF	1.5 wt%	7.20
HNO <sub>3</sub>	31 wt%	31.0

Common alphas ( $\alpha$ ) are listed in the table above. To determine that  $\alpha$  of other solutions, simply measure conductivity at a range of temperatures and graph the change in conductivity versus the change in temperature. Divide the slope of the graph by  $G_{t_{cal}}$  to get  $\alpha$ .

All meters have either fixed or adjustable automatic temperature compensation referenced to a standard temperature - usually 25°C. Most meters with fixed temperature compensation use a  $\alpha$  of 2%/°C (the approximate  $\alpha$  of NaCl solutions at 25°C). Meters with adjustable temperature compensation let you to adjust the  $\alpha$  to more closely match the  $\alpha$  of your measured solution.

### Conductivity Meter Calibration and Cell Maintenance

Conductivity meters and cells should be calibrated to a standard solution before using. When selecting a standard, choose one that has the approximate conductivity of the solution to be measured. The conductivity of some common solutions is shown in the table below.

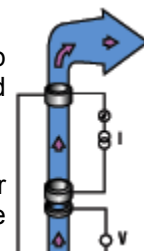
Solution	Conductivity
Absolute pure water	0.055 $\mu$ S/cm
Power plant boiler water	1.0 $\mu$ S/cm
Good city water	50 $\mu$ S/cm
Ocean water	53 mS/cm

A polarized or fouled electrode must be cleaned to renew the active surface of the cell. In most situations, hot water with a mild liquid detergent is an effective cleanser. Acetone easily cleans most organic matter, and chlorous solutions will remove algae, bacteria or molds. To prevent cell damage, abrasives or sharp objects should not be used to clean an electrode. A cotton bud works well for cleaning but care must be taken not to widen the distance of cell.

### Conductivity Cells

Most conductivity meters have a two-electrode cell (see illustration) available in either dip or flow-through styles. The electrode surface is usually platinum, titanium, gold-plated nickel, or graphite.

The four-electrode cell uses a reference voltage to compensate for any polarization or fouling of the electrode plates. The reference voltage ensures that measurements indicate



actual conductivity independent of electrode condition, resulting in higher accuracy for measuring pure water.

### **Important Features to Consider**

- **Auto-ranging:** Meter automatically selects the appropriate range for measurement. There is no need to change the dial, multiply values on the display, or turn the potentiometer.
- **Temperature compensation:** A cell with built-in temperature sensor allows the meter to make adjustments to the conductivity or TDS readings based on changes in solution temperature.
- **TDS conversion factor:** When a solution does not have a similar ionic content to natural water or salt water, then a TDS conversion factor is needed to automatically adjust the readings.
- **Adjustable temperature coefficients:** The TDS of certain samples, such as alcohols and pure water, are affected by changes in temperature. An adjustable temperature coefficient allows the user to compensate for temperature changes on the solution being measured.
- **Adjustable cell constant:** Adjusts the reading on the display to reflect use of a cell with a constant other than  $k=1.0 \text{ cm}^{-1}$ .