Resistivity | Conductivity

Resistivity | conductivity measurement of purified water.
Most laboratory water purification systems contain a resistivity or conductivity meter and cell to monitor the purity level of the water. Resistivity is the reciprocal of conductivity and either may be used to inexpensively monitor the ionic purity of water. Resistivity or conductivity of water is a measure of the ability of the water to resist or conduct an electric current.
The ability of water to resist or conduct an electric current is directly related to the amount of ionic material (salts) dissolved in the water. Dissolved ionic material is commonly referred to as total dissolved solids or TDS. Water with a relatively high TDS will have a low resistivity and a high conductivity. The opposite is true for water with low TDS.

The standard for monitoring the purity of water by electrical resistance is termed specific resistance corrected to 25°C or R-25. Specific resistance for this purpose is based on the resistance of an electrical current between two 1 cm square plates spaced 1 cm apart as measured at 25°C. The space between the plates is a 1 cm cube. Most resistivity | conductivity cells or probes are designed for inline or bench-top use and are shaped to fit in a pipe or a beaker for measurement. Therefore, most probes are round in shape and have been given a coded multiplier to compensate for the different shape and spacing relative to the standard shape. This multiplier is called a cell constant and is used to correct or compensate the probe in relation to a standard. Most resistivity | conductivity meters allow you to program the cell constant into the meter to improve the accuracy of the reading.

Resistivity | conductivity meters will also measure temperature. This is required so the meter can display the resistivity | conductivity corrected to 25°C. As the water or solution is being measured, both resistance | conductance and temperature are being measured. Since resistivity | conductivity will change with temperature, the meter must be able to correct for differences in temperature. For example, the resistivity of a solution will decrease with an increase in temperature. Conductivity will increase with an increase in temperature. In order to allow for universal comparison of resistivity | conductivity readings, the temperature of the solution must be corrected to a standard temperature. The standard for most applications is 25°C. Therefore, the meter cell combination must be able to compensate for temperature above and below 25°C. Typically, once the resistivity | conductivity and temperature are measured, the corrected resistance | conductance is displayed based on the internal calculations programmed into the meter. Many meters allow you to turn the temperature compensation off in order to comply with quality requirements (USP 24) or calibration standards.

The resistivity of absolute pure water is 18.2 (rounded) MΩ × cm at 25°C or 0.055 micro-siemens/cm. Water of this quality must be measured inline (closed system) in order to prevent atmospheric interference of the reading. As water is drawn from a water purification system that is showing 18.2 MΩ × cm purity, carbon dioxide from the atmosphere is immediately absorbed into the solution. The carbon dioxide reacts with water forming carbonic acid in solution.

$$CO_2 + H_2O \rightarrow H_2CO_3$$

Carbonic acid disassociates in water forming counter ions, which conduct electrical current.

$$H_2CO_3 \rightarrow H^+ \leftrightarrow HCO_3^-$$

This will drop the specific resistance of the water to below 8 or 10 MΩ × cm in less than a minute.

As previously mentioned, a specific resistance 18.2 MΩ × cm (million ohms) at 25°C is considered to be absolute pure water. This only accounts for the dissolved ionic impurities commonly found in water. Organic materials found in water cannot be directly detected by resistivity | conductivity. Total organic carbon (TOC) analysis or a chromatographic method is needed to screen water for this type of generic or specific contaminant.

Natural or municipally treated waters will contain an infinite range of TDS. Some water sources may have a TDS below 50.0 ppm or over 800.0-ppm. The type of dissolved material found in a water supply may also vary. Typically, potable waters will contain a certain amount of calcium, magnesium and sodium with counter ions such as carbonates, sulfate and chloride. These materials originate from water contact with rocks and minerals found in the Earth's crust. As water passes through the crust, these materials are dissolved and carried into rivers, lakes and reservoirs used for potable water distribution. Simply stated, sodium chloride (NaCl table salt) will dissolve in water to form disassociated ions.

$$NaCl + H_2O \rightarrow Na^+ + Cl^- + H_2O$$

The same will happen with the other mineral salts as they dissolve. These mineral salts provide the means for water to conduct an electric current. Therefore, specific resistance or conductance can be used to estimate the amount of TDS in a given water supply. It should be noted that TDS might fluctuate considerably from any source. For example, a water sample having a specific resistance of 4000 Ω × cm would contain about 125.0 ppm of TDS. A sample with a 600 Ω × cm specific resistance would have TDS of about 835.0 ppm. Thus, TDS can be estimated rather quickly and inexpensively by specific resistance.

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