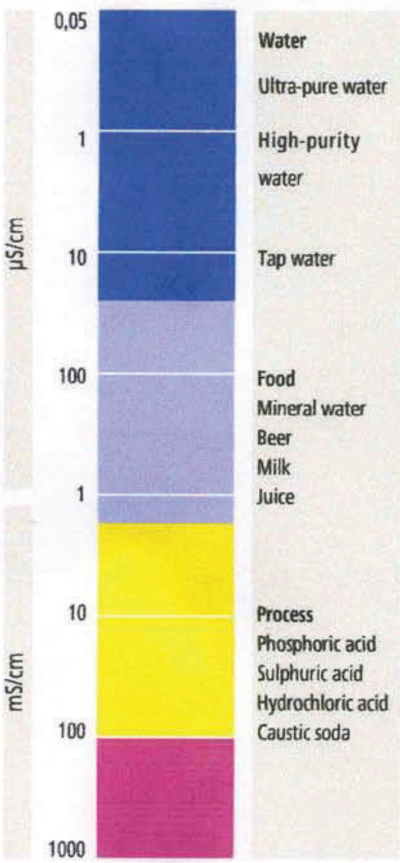
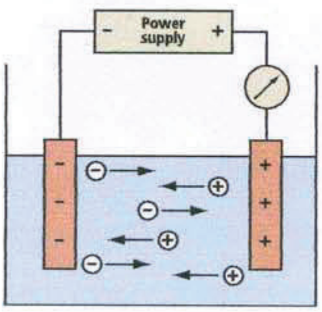
Measuring conductivity. A little theory

What is conductivity and why is it measured?
Conductivity is the capacity a solution has for conducting an electrical current.
Conductivity is a measurement of the total concentration of ions in a solution.
It is used in a wide variety of industries. In some cases the nature of the ions is a known factor and it is used to determine their concentration. For example in the food industry a conductivity meter is used to measure the salinity of the samples and it is applied in quality control. However, measuring conductivity in waste water, industrial effluents, etc. helps provide readings on their total ionic strength. Generally speaking, measuring conductivity is a quick and easy way of determining the ionic strength of a solution. The main disadvantage is that it is a non-specific technique.



How is conductivity measured?
A complete system for measuring conductivity includes these basic components:
- A conductivity cell.
- A temperature probe.
- An instrument for measuring.

The conductivity meter measures the electrical conductivity of the ions in a solution. To do this, it applies an electrical field between two electrodes and measures the electrical resistance of the solution. To prevent changes occurring in the substances, or the deposit of a layer on the electrodes, etc., alternating current is used.



The units of measurements which are normally used are S/cm. Other alternative forms of expressing the conductivity are Salinity and Total Dissolved Solids (TDS).

Salinity
This refers to the NaCl concentration of a hypothetical solution with the same conductivity as the study sample. It is expressed in ppm or g/l of NaCl.

TDS *(Total Dissolved Solids)*
Conductivity can be used as an indicator of the quantity of materials dissolved in a solution.
It is expressed in ppm or g/l of $CaCO_3$.

The effect of temperature
The conductivity of a solution is very dependent on temperature. This has a dual effect on electrolytes: it affects how far they dissolve and ion mobility.
The conductivity of a solution increases with temperature. This increase is normally expressed as %/ °C, and is called the Temperature Coefficient (TC). As a rule, aqueous solutions have a TC of almost 2%/ °C.

Substance @ 25°C	Concentration %	Temperature Coefficient, TC
HCl	10	1.56
KCl	10	1.88
NaCl	10	2.14
HF	1.5	7.20

Temperature compensation consists of calculating, applying the TC, the conductivity value of a sample at a temperature known as the Reference, normally 25 °C (EN 27888).
To apply this compensation, some CRISON conductivity cells hold an internal temperature sensor, in other cases it needs to be acquired separately.

Calibrating with standards

This involves adjusting the values read by the instrument and the cell, according to the values of certain standard solutions, see page 84.

Calibration is very important for obtaining highly accurate readings.

CRISON instruments allow calibration to be performed on one, two or three points, depending on the model.

One-point calibration

This form of calibration is acceptable when measuring conductivity values around that of the standard used. This is the most common type of calibration. In this type, 1413 µS/cm is the most commonly-used standard.

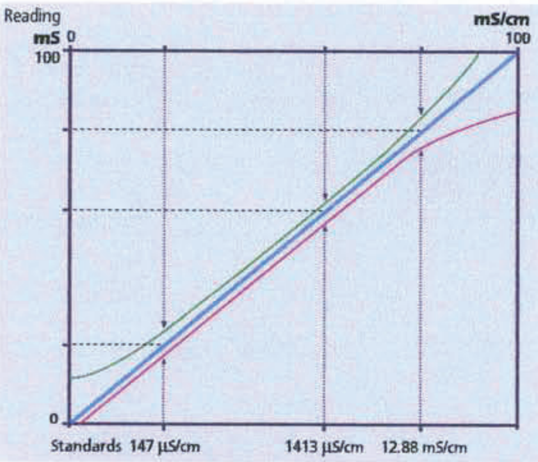
Two-point calibration

Two-point calibration is recommended for work in low or medium conductivity regions where accuracy is required. The 147 S/cm and 1413 µS/cm standards should be used for low conductivity regions, and 1413 µS/cm and 12.88 mS/cm for medium conductivity.

If you are calibrating with more than one standard, we recommend that you start with the one with the lowest conductivity to avoid contamination problems.

Three-point calibration

Three-point calibration is recommended when conductivities of the samples to be measured cover a wide range of conductivities.



— Ideal response of a cell C = 1 cm-1
— Non-linear response of a cell in high conductivity
— Non-linear response of a cell at the ends of the range

Frequency of calibration

This depends on the accuracy required by the user and the effect of the samples on the cell.

Calibration lasts for a long time if the measuring plates are not subjected to any kind of alteration.

Stirring and conductivity

Stirring improves the quality of measurements by increasing the speed and reproducibility of the measurements.

Stirring should always be done at average speed.

GLP (Good Laboratory Practice)

Good laboratory practices in the measurement of χ

GLP recommendations attempt to guarantee the quality and validity of analyses performed in laboratories.

The requirements are as follows:

- The instrument must perform a auto-test.
- The instrument must compensate automatically for analogue drift
- There should be a password to protect the measurement programmes.
- The value of the measurement should only appear when the point of stability is reached. It should be impossible to get an incorrect reading.
- Possibility of printing out reports, with the date and time of the measurement or calibration in the header.
- Easy access to the instrument's programs.
- Details of calibration.
- "Calibration expired" message.
- Fixed and compulsory calibration protocol with 1 or 2 certified standards which the instrument can recognise.
- Calibration and measurement under identical conditions.
- Time control for the duration of the measurement and stirring speed.
- It should be impossible to obtain a measurement if the calibration is wrong.

The GLP 31 and 32 conductivity meters have been especially designed to comply with the precise specifications given in the GLP.

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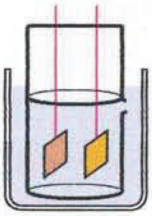
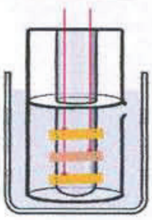
The conductivity cell. A little theory

There are various types of cell on the market:
- With two electrodes. This is the traditional system.
- With four electrodes. Used in dirty media with high conductivity levels.
- Induction. Used with very high conductivity and in highly-corrosive mediums.

The type of conductivity meter the user has will determine the type of cell he/she will use.
CRISON offers different types of cell with two electrodes, which cover the range usually used for lab measuring.



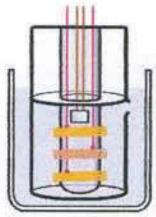
TWO ELECTRODES
GLASS + REFERENCE



Two-electrode cell

Comprises two, or even three, metal electrodes. The cell is usually displayed as two 1 cm^2 metal plates with a 1 cm separation between them. This is equivalent to a 1 cm^{-1} constant.

These days, the number, form, material and size of the plates varies from model to model, but with a single aim: to improve measurement. i.e. the conductivity meter and the cell together display a wide-ranging scale of measurement with a high degree of precision.



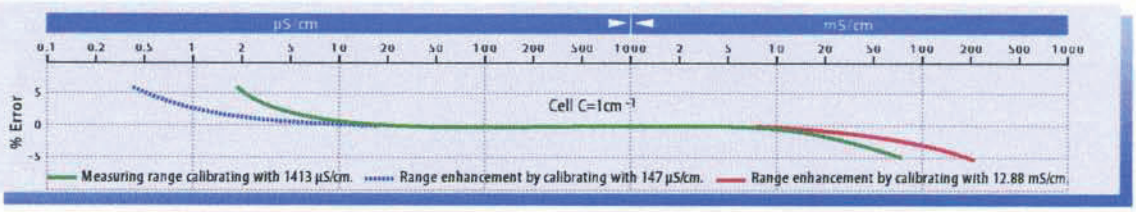
Cells with temperature sensors

The appearance on the market of cells with integrated temperature sensors means that conductivity and temperature can be measured simultaneously, thus allowing automatic correction of the effect that temperature will have on the conductivity of the sample.

Cell constant

The constant is an intrinsic feature of the cell. It will depend on cell geometry and is expressed as cm^{-1}.
No single cell is capable of measuring the full range of conductivity with a sufficient degree of precision. That is why cells with different constants are used which will allow the user to take exact measurements on different ranges.
Cell with a constant of $C = 1\ cm^{-1}$. This is the most universal one because it allows low to relatively-high conductivities to be measured.
Most CRISON conductivity meters can be calibrated with various standard solutions of low, medium and high conductivity, reducing the number of errors displayed by the cells at the extremes of the scale. See graphs with the behaviour of the cells with the different conductivity meters.

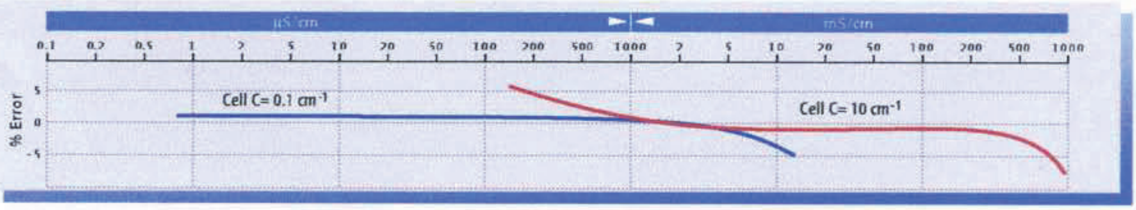
Response from a standard cell with a constant of C=1 cm^{-1}



Cells with other constants.

When conductivities which fall outside the measurement range of the C=1 cm^{-1} cell are to be measured, or the errors displayed by this cell are not admitted, cells with other constants must be used.
- $C = 0.1\ cm^{-1}$, for the low-conductivity area.
- $C = 10\ cm^{-1}$ for high-conductivity areas.

Response from standard cells with constants of C=0.1 and 10 cm^{-1}



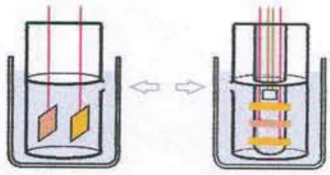
The conductivity cell. Essential parts and practical considerations

Connector
Most lab conductivity cells are fixed-cable with banana connectors. When the cell has an integrated temperature sensor, it must be connected separately.
In portable instruments the classic banana connector has been replaced by multiple connectors which include the temperature sensor connection.

Body material
It can be made of glass or plastic. Plastic is stronger.

Measurement plates material
The material from which the measurement electrodes are made also varies.
Traditionally platinum-electrode cells have been used. Platinum is normally electrolitically coated with chloro-platinum acid, giving it a rough finish known as "platinum black". This increases the measurement surface area and improves cell response.
These days platinum cells with a glass body are still being used in the lab. Other materials are used in industry to endow the cells with mechanical and chemical strength. The most frequently-used materials are titanium, stainless steel and graphite.

Immersion depth



The liquid must cover the air outlet hole

Minimum volume of sample
This will depend on the shape of the measurement receptacle. Normally a few ml will be sufficient.

Cell life
Cells can be used indefinitely, providing the necessary maintenance is given and, of course, that they do not break.

Re-platinising
By re-platinising the measurement plates of a platinum cell are coated electrolytically. This increases the speed and precision of the reading.
CRISON recommends sending the cells for re-platinising to our after-sales service, since the reagents required are expensive, this operation is not performed very frequently and there is a certain risk involved in handling highly-corrosive reagents.

Most frequent problems, possible causes and action
- Conductivity measurement different from the value expected.
  Check that the cell used is the appropriate one for the measurement range.
  Check that the cell is not dirty and that there are no air bubbles between the plates.
  Recalibrate using the appropriate standard solution.
- Slow response or instability
  Check that the cell is not dirty and that there are no air bubbles between the plates.
  If a platinum cell is used, it may need re-platinising.
- Unaccepted cell constant.
  Check that the standard solutions are in good condition and that the value of the cell constant is the same as the one selected on the instrument.

Price-quality ratio
In practice, the quality of the instrument and cell used has a direct bearing on the reliability of a measurement. CRISON only supplies top quality conductivity meters and cells because experience has proven them to be a better investment over the mid- to long-term.

Guarantee
CRISON cells are guaranteed for 6 months.
The guarantee only covers manufacturing defects.
The guarantee does not cover defects that may arise from incorrect use, handling, application or maintenance, or as a result of premature wear inherent to certain samples.