



# We Supply Lab Know-How

TITRATION, ELECTRO-CHEMICAL MEASUREMENTS  
OPTICAL ANALYSIS, VISCOMETRY

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Let's Solve Water

# Contents

3 Preface

4 Titration

6 Electro-chemical Measurements

8 Product Range

12 Optical Analysis Procedure

14 Viscometry



## Titration

Titration is an old method for determining chemical content. It is a technique where an exact volume of a solution of a known concentration of reagent is used to determine the concentration of an unknown substance. The procedure can also be called volumetry.



## Electro-chemical Measurements

Dissolved ions are carrying charges. This property helps to determine important parameters like pH, conductivity, ORP and ion concentrations.



## Optical Analysis

When electromagnetic radiation strikes any substance, some of the radiation is absorbed by the material, some is reflected and some can penetrate it. The change in the electromagnetic radiation caused by the substance can be used to analyze materials.



## Viscometry

Viscometry is a branch of rheology dealing with the determination of viscosity and characterizes the flow properties, the inherent friction of fluids and gases.

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## Dear Readers,

We invite you to browse through the following pages and gain an insight into the solutions we offer, which can help you overcome any challenges and obstacles in your scientific research. Through the combination of our well-known brands - Bellingham + Stanley, SI Analytics and WTW, we have almost 270 years of experience, innovations and concentrated knowledge. We want to share this expertise with you. When you order any of our sensors, instruments, or other equipment, the delivery comes with our experience included. Let us support you with our knowledge.  
We supply Know-How.

Best wishes,

Dr Robert Reining and Ulrich Schwab  
Managing Directors Xylem Analytics Germany

# Titration

Titration is one of the oldest methods for content determination in chemistry. A reagent with a known concentration is added to a dissolved sample until the chemical reaction is complete. The IUPAC (Compendium of Chemical Technology) defines titration as a "Quantitative analysis method, in which a reagent of known concentration (also called standard solution) is added to a sample of known composition, but unknown content creating a chemical reaction of known stoichiometry. The very precisely added volume of the reagent and the applicable calculation factors make it possible to determine the unknown content in the sample.

Titration is also called volumetry. Even when working with a pH electrode, the unit of measurement in titration remains the volume and not the pH-value. Therefore accuracy of the volume is essential for every titration.

## Types of Titration

Titrations can be carried out in different ways. The most well-known is **direct titration**, in which the sample is directly titrated with a suitable standard solution. The amount of reagent that is consumed when the equivalence point (or endpoint) is reached corresponds to the amount of substance to be determined.

Inverse titration belongs to the family of direct titration. Here the reagent solution is present in the sample and is titrated with it. Reasons for an inverse titration can, for example, be easier detection of the equivalence point, resistance of the reactants or a faster reaction rate.

In **back-titration**, a defined amount of reagent A is added to the sample. There must be an excess of reagent A. After a defined reaction time, the excess is titrated with another reagent solution, B. The difference between the original amount of reagent solution A and the remaining reagent A after the reaction corresponds to the amount of the substance to be determined. Both reagent A and reagent B must be exactly measured. Back-titration is applied when the reaction rate between the sample and reagent A is slow or no suitable sensor is available or the equivalence point cannot be determined easily.



In **indirect titration**, the substance to be determined in the sample is in non-titratable form and is first converted into a titratable compound with the aid of a chemical reaction. A well-known example of indirect titration is the determination of nitrogen using the Kjeldahl approach; non-titratable nitrogen compounds are converted into easily titratable ammonium borate.

In **substitution titration** by adding an appropriate substance to the sample containing the substance to be determined, an excess of a readily titratable component is released and this can be titrated directly.

In **phase transfer titration**, the detection of the equivalence point (EQ) occurs in a different phase from the reaction. This is used in surfactant titration using the Epton approach for example.

## Detection of the Equivalence Point

Core elements of a modern titrator are accurate dosing of the titrant and a suitable sensor. Detection may be achieved by color indicators or by means of electrochemical methods. The predominant method is the use of a potentiometer utilizing pH and ORP sensors with indicator and reference electrodes, which can detect potentials according to the electrochemical voltage series.

## Potentiometric

For potentiometric titration, determination of the end or equivalent point is achieved using the chemical potential, which adapts itself to an appropriate electrode. This potential depends on the activity of the ions which the



the Lambert Beer'sche Law that describes the connection between the concentration, the sample properties and absorption:

$$E_{\lambda} = \log_{10} (I_0 / I_1) = \epsilon_{\lambda} \cdot c \cdot d$$

With:

$I_0$ : intensity of the incident light ( $W \cdot m^{-2}$ )

$I_1$ : Intensity of the transmitted light ( $W \cdot m^{-2}$ )

$c$ : concentration of the absorbing substance ( $mol \cdot l^{-1}$ )

$\epsilon_{\lambda}$ : decadic extinction coefficient at wavelength  $\lambda$ . It is specific to the absorbing substance.

$d$ : Path of the light beam through the sample

The color indicator reacts with the titrant at the transition point, whereby the color and therefore the extinction coefficient of the titrated solution changes. This changes the intensity of the light arriving at the sensor.

electrode responds to. If the electrode is "inert", i.e. not sensitive to the ions contained in the solution, it is possible to determine the ORP of the solution. The electrode potentials follow Nernst's equation:

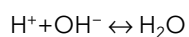
$$U = U_N \cdot \lg a_1 / a_2$$

The potential that adapts itself to a single electrode cannot be measured directly. It is only possible to measure the voltage  $U$  which is the difference between two electrode potentials in a closed circuit.

In most cases, a pH electrode is used. To create a comparison with results that used to be achieved manually using color indicators one can titrate using a fixed pH-value that corresponds to a color change.

Other titrations are performed on an EQ. It is only a case of changing the potential or the pH-value.

In acid-alkali or neutralization titration, acids are titrated with an alkali (or vice versa). The detection of the equivalence point can be achieved with either color indicators or potentiometrically using a glass electrode. The reaction for all acid-alkali titrations is the same, water is formed from a proton and a hydroxide ion.



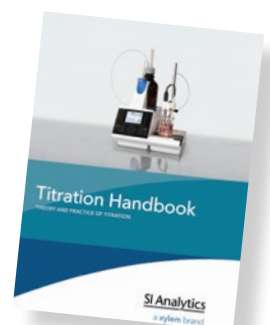
### Photometry

In photometric titration, the color change of an indicator is detected using an optical sensor. The basis for this is

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# Electro-chemical Measurements

Electrochemical measurements are based on the presence of ions in aqueous solutions. There are basically three types of measurement techniques, potentiometry, amperometry and conductometry. This means that in these cases in samples voltages, currents and finally, a combination of both are determined. The most important potentiometric measurement is pH and concentration measurement (ISE), amperometric measurements are used for electrochemical dissolved oxygen measurement. Conductivity measurement is behind pH the most important measurement.

## Potentiometric pH Measurement

The basic measuring unit for potentiometric pH-measurement is the electrochemical potential and is measured using pH-sensitive electrodes. Today, the most commonly used sensor is the glass electrode. It is one of the most sensitive and selective sensors and has a measuring range of up to 14 decades. These highly sensitive sensors are manufactured using a very special glass and specific processing.

The voltage measured is the difference between two electrode potentials in a closed circuit, which form a so-called measuring chain. The reference electrode is held in electrical contact with the measuring solution via a diaphragm, thereby closing the circuit over the measuring solution.

## The Glass Electrode

Under the influence of water, alkali ions separate from glass surfaces and the oxide bridges of the silicate skeleton react by absorbing  $H_2O$  in part to  $OH^-$ -groups. This creates an "expanding layer" of about 500 nm thickness. This expanding layer interacts with hydrogen ions like an ion exchanger: Alkali ions in the expanding layer are exchanged for hydrogen ions in the water.

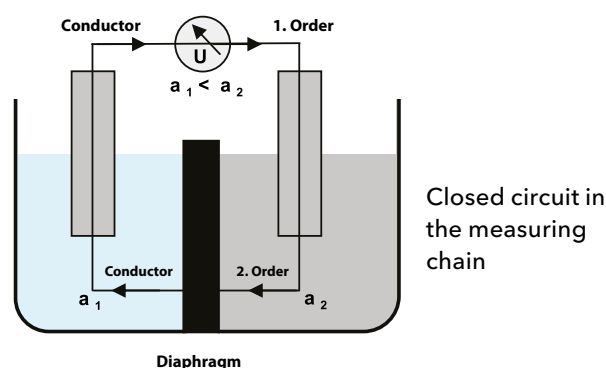
If the alkali concentration in the aqueous solution is low, a reproducible equilibrium forms between the solution and



the glass surface which only depends on the hydrogen ion concentration in the solution and in the expanding layer. The hydrogen ions in the layer cause an electrical potential in the membrane. This potential is described by the so-called Nernst equation and depends on the activity of the hydrogen ions. This is what we call "pH".

The technical design of such an electrode is basically very simple. A glass membrane is melted onto the end of a glass tube as a pH sensor. This membrane is filled with a buffer solution of a known pH-value. An electrode consisting of an AgCl coated silver wire is immersed in this buffer solution. The difference in the potential between the inner and outer surface of the glass membrane is used for measuring the pH-value (Fig. page 6).

This potential of the glass electrode ( $u$ ) is directly proportional to the difference in pH-value between the internal buffer and the measuring solution:  $u = U_N \cdot (pH_{\text{inner value}} - pH_{\text{measuring solution}})$ .





### Types of Diaphragms

The diaphragm of the reference electrode has the largest impact on pH measurement accuracy. A frequent measurement error is the diffusion voltage at the diaphragm. To keep this low, the diaphragm needs to guarantee a good electrical contact to the sample. It also has to be chemically inert and have an electrical resistance as low as possible. Depending on the consistency of the electrolyte (liquid, gel type or solid) different designs are used.

### Ion-selective Measuring Technology

If the surface of a measuring electrode is coated with a substance where interaction only occurs with a specific type of ion, it is possible to measure selectively ions. In a two-probe measuring chain, the ion-selective electrode and the reference electrode are spatially separated from each other; if they are united to form a single probe, we are working with a combination electrode.

Depending on the design, the ion-selective electrodes can be separated into two groups. In solid state electrodes the ion-selective membrane is a solid substance that has direct contact to the measuring solution. Suitable as membrane materials are substances that contain the specific ion in the form of almost insoluble salts and have ion-selective properties.

For the design of solid state electrodes only a few membrane substances are known which are sufficiently insoluble. For the other cases so-called matrix electrodes based on PVC membranes are used. The active part consists of organic compounds which are insoluble in water and have

either complex-forming or ion exchanging properties. These compounds are put into PVC membranes. The contact with a specific ion leads to a voltage signal which can be evaluated.

### Conductivity

Conductivity is a sum parameter for ion concentrations in a sample. The more salt, acid or salt is part of a sample the better is the conductivity. The unit for conductivity is Siemens/m: S/m or often also S/cm.

The range of aqueous solutions starts at ultrapure water with a conductivity of 0.05  $\mu\text{S}/\text{cm}$  at 25 °C. Natural waters frequently show values between 100 and 1000  $\mu\text{S}/\text{cm}$ . At the upper end of the range some alkaline and acids have conductivities of several hundred mS/cm.

Conductivity measurement is an electrochemical measurement. The simplest design of a conductivity cell consists of two equal electrodes provided with an alternate voltage between them. The more ions are dissolved the higher is the current between the electrodes. The conductivity meter uses Ohm's law and the cell constant for calculating the conductivity value.

### Electrochemical Oxygen Measurement

The oxygen concentration in water can also be determined electrochemically. This is a typical amperometric measurement, based on a chemical reaction of oxygen by applying a constant voltage between two electrodes in a membrane covered, electrolyte filled cell. The electrodes consist as a couple of a precious metal and a nonprecious metal. On the surface of precious metal electrode behind the membrane the oxygen will be reduced by means of the electrons coming from the non-precious metal, which dissolves and emits electrodes. The amount of electrons is proportional to the amount of the reacting oxygen.

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# TitroLine® 5000

Titration has never been so easy

The easy choice for automating common titration applications

- Pre-installed standard methods, e.g. for FOS/TAC, acid capacity, total acidity in beverages, chloride etc.
- Linear and dynamic titration to equivalence point
- Titration to pH and mV end points
- Salinity (chloride, sodium chloride)
- pH-value, total acid in foodstuffs
- Determination of protein (Kjeldahl nitrogen in milk and milk products)
- Amount of iodine and peroxide

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# TitroLine® 7800

The universal titrator with IDS-technology

The TitroLine® 7800 can handle a broad variety of titrations from potentiometric titrations with analog and IDS electrodes up to volumetric Karl Fischer titration.

The IDS measuring input is multifunctional. It can be connected to digital sensors to determine the pH and ORP value, conductivity or dissolved oxygen.

- A brilliant TFT display with a wide viewing angle makes it easy to read
- Flexible configurations with exchangeable attachments and logging of attachments and reagent data used
- Uses standard methods for potentiometry and KF titration
- Second digital measuring input for intelligent digital sensors (IDS)



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# Multi 3630 IDS

The all-rounder for pH / ORP, conductivity, dissolved oxygen and turbidity

The Multi 3630 IDS with three universal measurement channels works with all WTW IDS pH, ORP, dissolved oxygen sensors, conductivity measuring cells and turbidity sensors, whether connected by cable or wirelessly via radio link.

- Failsafe because of three galvanically separate universal sensor inputs
- Simultaneous fatigue-free reading of up to three parameters with a brilliant color graphics display
- Equipped for use with an MPP IDS depth probe



# IDS goes wireless

Measure wherever you like, using wireless sensors!

Measure without cables - perfect for wherever cables or devices are in the way, e.g. under extractor hoods, safety workbenches, in a cramped laboratory or just any place where you would like to have an additional hand free.

- Measure wirelessly
- Securely connected
- One wireless module for all parameters



# Digital, multi-parameter laboratory gauges

The perfect partner to the IDS radio controlled system

The inoLab® Multi 9630 IDS and the inoLab® 9620 IDS are the new, wireless equipped, digital, high-performance, three or two channel laboratory instruments with glass-protected color graphic display, high-quality zinc die-cast base as well as a keyboard with antibacterial foil. Several parameters can be determined and documented simultaneously.

- Three or two universal measuring channels
- Digital sensor detection
- Equipped for IDS radio modules



# photoLab® 7600 UV-VIS

## Spectral photometer with OptRF

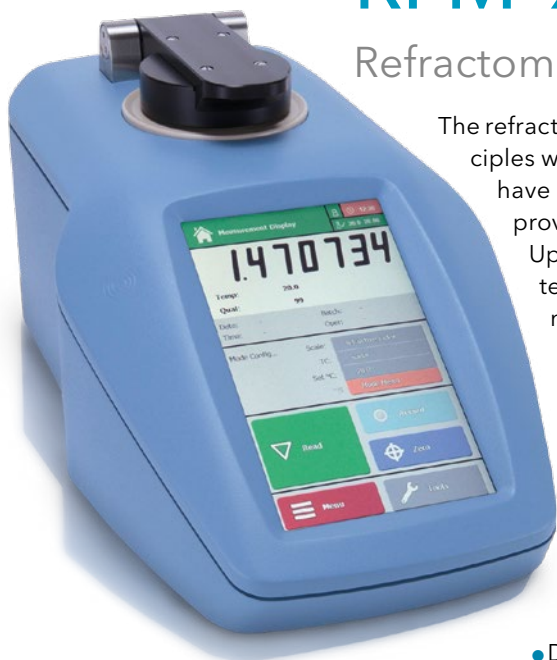
The spectral photometer photoLab® 7600 UV-VIS combines tried and tested routine with pioneering spectral analysis functions and OptRF for reagent-free measuring. This makes it the "Universal Genius" from reference measuring for online systems through to general laboratory analysis with the support of special applications. OptRF has brought online measuring into the lab: using a spectral Scan, COD, nitrate and nitrite in a quartz cuvette can be recorded, calculated and immediately presented as a measured value.

- 190-1100 nm
- OptRF of COD, NO<sub>3</sub>, NO<sub>2</sub> in sewage treatment plants and many surface waters (after pre-tests)
- Extensive programming options
- Complimentary range check for routine analysis
- Fast reference measurement for matrix matching of online sensors
- Faster than the fastest pulping
- Free of charge as there are no reagents or chemicals
- Environmentally friendly and harmless to health



# RFM 900T

## Refractometers



The refractometer series RFM900 combines the latest optoelectronic principles with high durability and easy operation. RFM900 refractometers have RFID (Radio Frequency Identification), which allows users to prove their identity by holding a user chip up to the device housing. Up to 8,000 results can be presented on the meter's display. Peltier temperature control and intelligent temperature management make sure that readings are only accepted when the sample and refractometer temperatures are stable.

The gauges provide operating features that allow the use in an environment controlled by FDA Regulation 21 CFR Part 11. By using a Kalrez seal and the sapphire prism, the device can be used in the most demanding working areas of pharmaceutical, petrochemical, aroma, flavor, perfume and other industries where high RI-values are used. Devices with flow cells are also available.

- Designs for the pharmaceutical and chemical industries
- Largest RI area
- Highest accuracy ( $\pm 0.00002$  RI)
- Method for the mean value (USP / EP / BP)
- Compliant with ASTM D 1218, 1747, 2140 & 5006





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# Capillary viscometry

For the most precise measurements

The viscosity of Newtonian liquids is determined most accurately with capillary viscometers. This measuring method measures the time that a defined amount of liquid needs to flow through a capillary with a known diameter and length. Through its industrial Manufacture of such precisely calibrated capillary viscometers, SI Analytics has created the prerequisites for this method of measurement to be used as a reliable procedure worldwide.

So it is no wonder that these viscosity measuring systems have become globally indispensable tools in the oil industry, by polymer manufacturers and processors, in the pharmaceutical or food industry, in production control and quality assurance.

- High-quality glassware manufacturing for 40 years with strictest manufacturing tolerances, especially for the capillary diameter
- Exclusive use of borosilicate glass 3.3 DURAN® - minimum thermal expansion, highest chemical resistance
- Precise calibration by direct comparison with reference viscometers from the Physikalisch-Technische Bundesanstalt (PTB)
- Wide range of products: various design forms available, e.g. Ubbelohde viscometer according to both DIN 51562 and ASTM D446
- Highest accuracy: Different calibrations for manual measuring (with stopwatch) or automatic measurement with AVS® systems

## ViscoClock plus

Measurement plus data storage

The ViscoClock plus is an electronic timepiece for glass capillary viscometers used for the determination of kinematic and relative viscosity. As a successor to the proven ViscoClock, it now offers the possibility of data storage and easier handling.

Using infrared light barriers, the ViscoClock plus automatically determines the cycle time in the viscometer. The determination of the cycle time using a stopwatch is superfluous. The big display enables easy reading of the measured values as well as additional information: date, time, sample and viscometer identification number.

- Automatic and accurate cycle time measurement at a low price
- Suitable for Ubbelohde, micro Ubbelohde and micro-Ostwald viscometers
- Storage of measured data including time, date, viscometer and sample identification (as PDF or CSV file)
- Stand made of high-performance plastic PPA allows measuring temperatures up to 150°C
- Electromagnetic bleed valve for easy handling of Ubbelohde viscometers
- Usable with all transparent thermostats from SI Analytics

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# Optical Analytical Methods

The "spectrum" means all of the electromagnetic waves of different wavelengths. In history, this spectrum was arbitrarily divided into sections. These usually include wavelength ranges over several orders of magnitude. Analytical procedures that use the change in the radiation when it strikes or penetrates a sample as a measured value, come together under the heading of the spectroscopic process. When these procedures use radiation which is visible to the human eye (Vis, for "visible") and the adjacent areas (ultra-violet, UV and infrared, IR), it is called an optical measurement.

Light moves in a vacuum at the speed of light  $c$ . In all other media its speed is lower. Refractometers determine a substance-specific constant, the refractive index, from the ratio between the speed of light in a vacuum and its speed in the medium that is to be determined. Polarimetry uses the characteristic of certain substances to turn the plane of oscillation of polarized light. When passing through a known thickness of a layer of the substance to be measured, the plane of the polarized light beam is rotated to an angle specific to the substance.

One of the most used optical analysis methods, however, is photometry, which uses the range in wavelengths from about 190 nm to 1100 nm.

## Photometry

Like many other spectroscopic methods, photometry uses the decrease in intensity of the incidental light in relation to the intensity after passing through a sample with a known thickness layer, the so-called Transmission  $T$ .

$$T\% = 1/10 \times 100\%$$

The absorption or extinction ( $E$ ) is the decrease in light intensity:



$$E_{\lambda} = -\log(T)$$

The extinction  $E_{\lambda}$  (absorbance of the material for light of Wavelength  $\lambda$ ) is given by the Lambert-Beer law.

If the color of a liquid sample (exclusively) is directly related to the concentration of a substance being searched for, the concentration can be determined directly from the turbidity. But in most cases, the change in the intensity of the light is caused by the visible coloring of a liquid which occurs through a chemical reaction and stands in stoichiometric dependence on the concentration of the substance to be measured. Here, we see a direct relationship to many titration methods that use the same measuring principle and have a comparable measurement structure.

## Setting Up the Measurement

A lamp produces polychromatic light. This shines through an aperture and falls onto a monochromator (e.g. a prism or optical lattice) from where it is directed through another aperture then through a measuring cuvette containing the liquid to be measured. After passing through the sample, the remaining light falls on a detector that determines the intensity of the light and compares it with the intensity emitted originally. The result is the so-called extinction, the reduction of light intensity caused by the sample.

As with pH-measurement, viscometry, and photometric titration, glass is at the heart of the technology. Without special high quality glass and rare know-how in glass process-



ing, the development of quality equipment in this field is impossible.

### Concentration

The concentration of a substance to be measured is determined on the basis of a calibration curve. This is created by measuring a series of dilutions from a standard of the substance to be measured using a known concentration. Modern photometers calculate the calibration curve from the individual measurements of a dilution series and then determine the concentration of the sample automatically.

### Absorption Maxima

Many substances absorb light. Using a photometer one can determine the ranges of wavelength where they absorb the light particularly strongly. The device allows the whole spectral range to be scanned and one or more maxima can be identified. These maxima are the optimum measuring wavelengths for determining concentration.

### Multi-wavelength and multiple measurements

By comparing multiple measurements against each other, it is possible to carry out more complex analytical tasks. It is the changes in optical properties over time or over different wavelengths that will be determined. In this way, the conversion rates of a reaction in relation to temperature or added substances can be determined in a series of concentration measurements.



### No Reagents Necessary

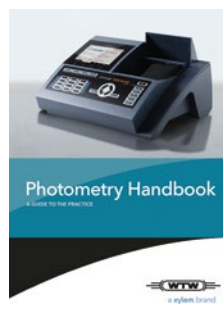
As well as measuring methods where a chemical reaction generates a concentration-dependent color change, there are many substances which can be measured without a color reaction, if they absorb light in the wavelength range used by the photometer. The photometric measurement of RNA, DNA and protein concentrations are examples of such measurements. In sewage treatment plants, optical sensors, which determine the cumulative parameters of "Chemical Oxygen Demand" (COD) by means of direct spectral measurements, have been in use for about ten years.

In the laboratory, under certain conditions, this technology also allows the fast and direct, reagent-free and therefore environmentally friendly measurement of COD, nitrate and nitrite content without the need of the pulping process. The usual chemical color reactions in photometry at times use toxic and environmentally harmful substances, which makes reducing the use of these chemicals beneficial. For important cumulative parameters, such as COD, which constantly need to be determined in sewage treatment plants, elaborate pulping processes are necessary and are not feasible without appropriately equipped laboratories. This rules out a systematic, widespread measurement of this parameter in environmental analysis, for example.

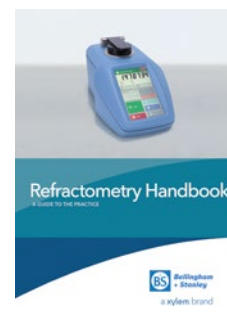
### The Outlook

COD constantly need to be determined in sewage treatment plants. Traditional measurement requires elaborate pulping processes, which must be done in appropriately equipped laboratories. This rules out a systematic, widespread measurement of this parameter in environmental analysis, for example.

Using the OptRF method, it is possible to locate organic impurities and their causes quickly, clearly and inexpensively. This makes more widespread monitoring of pollutants that get into the surface, ground and drinking water because of damage to sewerage systems, by accidents or over-fertilization in agriculture more practical.



On request



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# Viscometry

Viscometry, a branch of rheology, deals with the determination of viscosity and characterizes the internal friction of liquids and gases. Rheological measuring methods are predominantly mechanical methods, as they are based on the mechanical tension values and deformation of the sample.

When there is a fluid medium between two plane-parallel plates, some force is required to shift the top plate. The liquid flows into the gap, thereby forming a layered flow. The liquid particles directly adjacent to the plates adhere firmly to the surface by means of adhesion forces. Thus, the liquid layer adjacent to the moving plate takes on the speed of the plate. All the following layers fall behind in proportion to their distance from the moving plate. This is due to cohesive forces, which counteract the mutual displacement of the individual layers.

Glass capillary viscometers are exclusively used for measuring the viscosity of samples with ideal flow behavior, so-called Newtonian fluids. In these, the viscosity remains constant during any change in shear rate.

## Newtonian Fluids

According to Newton's law of viscosity, the shear stress  $\tau$  is proportional to the shear rate  $\dot{\gamma}$  :

$$\tau = \eta \cdot \dot{\gamma}$$

In this case,  $\tau$  is obtained as a quotient of the force  $F$  in relation to the interface  $A$  of the liquid, which the force is applied to; the shear rate  $\dot{\gamma}$  is the differential quotient from the velocity  $v$  to  $y$  (orthogonal to the flow direction). The proportionality factor  $\eta$  is called the dynamic viscosity. The ratio of the dynamic viscosity  $\eta$  and density  $\rho$  is called the kinematic viscosity  $\nu$ :

$$\nu = \frac{\eta}{\rho}$$

Due to the different sizes, shapes and interactions of the molecules,  $\eta$  can change significantly.



As liquid molecules flow and energy is expended, they are pushed against each other. The number of molecules that have this energy depends on the temperature and is described by the Boltzmann distribution. This leads to the following relationship:

$$\eta = k \cdot e^{-\frac{E_{visk}}{RT}}$$

Where  $k$  is the proportionality factor,  $E_{visk}$  is the activation energy of viscous flow,  $R$  the gas constant and  $T$  is the absolute temperature. Accordingly, in liquids with increasing temperature,  $\eta$  decreases exponentially. As a rule, the decrease is higher in proportion to the absolute values of the viscosity and the lower the temperature. This effect is of great practical use, e.g. in lubrication technology.

In viscometry with glass capillary viscometers on the other hand, the dependence on pressure is negligible; only pressure increases from 10 to 100 bar (or higher) lead to a significant increase in the viscosity of liquids.

## The Measuring Principle of Capillary Viscometry

In capillary viscometers, the required speed gradient necessary for measuring viscosity is achieved by using a laminar tube flow within a measuring capillary. Under idealized conditions (laminar, isothermal, stationary flow state, Newtonian flow behavior of the liquid, pressure independence the viscosity), the liquid moves in coaxial layers in the direction of the pressure gradient through the capillary, generating a parabolic velocity profile.



The Hagen-Poiseuille law is the basis for the description of viscosity for all viscometers that work according to the capillary principle:

$$\frac{V}{t} = \frac{\pi r^4 \Delta p}{8L\eta}$$

V is the flow of volume through the capillary, r is the inner radius,  $\Delta p$  is the difference in pressure between the beginning and end, and L the length of the capillary. The flow rate can be measured manually using a stopwatch or automatically.

### Method for Determining Viscosity

The absolute value of the kinematic viscosity  $\nu$  is calculated from the flow rate using the calibration constant. The starting point is the model of a laminar tube flow described by the Hagen-Poiseuille's Law above. The driving pressure is the hydrostatic pressure of the liquid column in the form of the mean pressure level. For a given viscometer, all constants, as well as geometric information about characteristic sizes, the so-called Viscometer constant K, can be summarized resulting in the following linear relationship between  $\nu$  and time t:

$$\nu = K \cdot t$$

Due to the unavoidable tolerances in the manufacture of the equipment, it is only possible to calculate a guideline value for the constant K from the measurements of a

viscometer. The precise value of K is determined by the calibration of the viscometer.

When using the flow model based on Hagen-Poiseuille's law will be additional pressure losses at the end of the capillary are not considered. However, due to the finite capillary length, the losses in pressure at entry and exit have an effect on the measuring accuracy. Due to these additional pressure losses, the measured flow rate  $t_g$  is greater than the time t, which is a result of the Hagen-Poiseuille's law. The difference between the measured and theoretical flow rate ( $t_g - t$ ) has been named the Hagenbach-Couette correction time ( $t_{H, HC}$  correction) by its developers. The result is the following corrected working equation for glass capillary viscometers:

$$\nu = K \cdot (t_g - t_h)$$

The lower the flow rate the higher the Hagenbach-Couette correction time.

### Handling of Capillary Viscometer

The capillary diameter determines the measuring range of the viscometer. When selecting a viscometer, the viscosity of the substance to be examined needs to be estimated by estimating the flow rate (without HC correction).

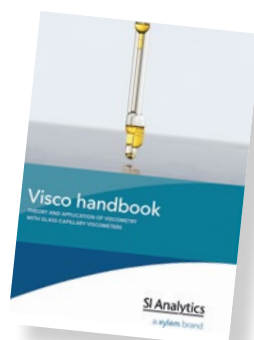
Viscosity is highly dependent on temperature. Therefore, viscometers need to be thermostatically controlled during all measurements. This is where automatically controlled liquid viewing thermostats can be used for example.

To measure the flow rate, liquid is sucked into the calibrating ball by the application of negative pressure on the capillary tube. When measuring the cycle time manually, it is important for the detection of the meniscus that the ring mark is at eye level. The time span that is measured, is the time it takes for the lower vertex of the meniscus to sink from the upper edge of the upper ring mark to the upper edge the lower ring mark.

In viscometry the structure of the glass is also at the heart of the experiment. The quality of the measurement results is directly dependent on its quality and workmanship.

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# Xylem |'zīləm|

- 1) The tissue in plants that carries water up from the roots;
- 2) A leading global water technology company.

We are a global team with a common goal: to create innovative solutions to meet the need for water in the world. The focus of our work is the development of new technologies that improve the way water is used, its treatment and its reuse in the future. We support customers from the municipal water and wastewater management sector, from industry and the private and commercial building technology sectors with products and services for efficiently extracting and treating water and wastewater, analyzing and monitoring it and returning it to the environment. In addition, Xylem has a product portfolio which includes intelligent and smart measuring technologies as well as network technologies and innovative infrastructures for data analysis in the water, electricity and gas industries. We have strong, long-standing relationships with customers in more than 150 countries who know us for our strong combination of leading product brands and application expertise, born from a tradition of innovation.

**For more information on how Xylem can help you, visit [www.xylem.com](http://www.xylem.com)**



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