Laboratory Solutions

Measurement Techniques

Tips and Tricks

Selected Solutions

Essential Laboratory Skills

A Guide for Measurement Quality in the Lab

METTLER TOLEDO

Editorial

Dear Reader,

This guide will provide you with helpful insights into essential measurement techniques such as weighing, pH measurement, pipetting and more. We worked to omit tedious theory elaborations and to focus on the practical sides of measuring and analyzing.

Content includes:
- Measurement techniques and principles
- Benefits of various methods
- Application examples
- Selected solutions

Experience shows that modern, well-developed balances and analytical instruments do the most to promote ease of use, operational safety, and accurate results. However, even with state-of-the-art solutions, practical know-how is still required for operators to do "the things" right and achieve reliability and consistency.

May this collection of practical information contribute to the accuracy and the efficiency of your day-to-day measurement tasks.

METTLER TOLEDO

Content

1. General Introduction

1.1 Measuring for Success

All labs strive for accuracy and efficiency. No matter the measurement instrument being used, the goals of accuracy and workflow efficiency are foundational and straightforward. Obtaining measurement accuracy in a world that is constantly changing, however, can be anything but straightforward. And to miss this overarching goal can be detrimental, because undetected errors breed exponentially. One poor-quality result affects not just the measurement in question but every measurement that comes after it. And when accuracy suffers, lab outcomes and profit margins suffer as well: Time-consuming efforts must be repeated. End-users can even come to harm. To have the best chance at obtaining accuracy, a lab operator must first have a clear understanding of basic measurement techniques and the operating principles of equipment he or she is using. This understanding helps the operator recognize and avoid potential error sources. It can also allow them to seek ways to redesign workflows and ultimately increase efficiency. In a modern lab, instruments must "play well together" for reliable sample quality assessment and seamless measuring processes.

1.2 Measurement Accuracy and Workflow Efficiency Impetus

To ensure the ongoing thrive for measurement accuracy and workflow efficiency in any lab, three basic operational building blocks must be applied:

1. **User Training.** Effective training ensures people who use instruments day-in, day-out gain thorough knowledge about the criticality of accuracy in a given process. It also ensures they have the ability to watch and compensate for potential error sources.
2. **Routine Maintenance.** The crucial action of instituting an adequate maintenance schedule for all lab equipment helps to ensure reliable instrument performance and flawless instrument uptime.
3. **Process Security.** Sound data management, workflow automation and user management all help contribute to data integrity and security.

While all three aspects are important, this guide will focus on providing knowledge and tips that supplement in-lab training efforts and help ensure operators understand the intricacies of individual measurement methods. This information will not only help to reduce errors; it will also provide insight into scenarios where automation can help increase productivity.

1.3 Exploring Measurement Principles

Basic measurement techniques covered in this guide include:

- **Weighing** – a key activity in most laboratories, though often underestimated. This guide will help to understand factors influencing weighing and how their effects can be minimized or avoided.
- **Pipetting** – a mainstay of biotech and research labs. While appearing straightforward, liquid handling skills may differ considerably among operators. This guide will help lab personnel mitigate sources of inconsistency for enhanced long-term accuracy.
- **pH Measurement** – an important value for many applications, products and processes. Operators will learn some tips and tricks about meters and electrodes helping to reach correct and reliable pH results time by time.
- **Moisture Content** – critical to many products and industries, it guides everything from product quality and performance to shelf life. This guide briefly explains the principle of halogen moisture analyzers and how precise and reliable results can be achieved in routine moisture analysis.

- **Titration** – its dependability stems from the reliable and stoichiometric course of the titration reaction, generally accepted methods and well-proven instruments. This guide will help operators assess and develop optimal titrations.
- **UV/VIS** – UV/VIS spectroscopy is routinely used in analytical chemistry for the quantitative determination of different analytes, such as transition metal ions, highly conjugated organic compounds and biological macromolecules. This guide presents tips how to get accurate results, quickly.
- **Density & Refractive Index** – provide critical quality control information. Both methods easily deliver fast results which make them ideal for routine analyses. However, an understanding of measurement principles and the application of operational excellence help reach reliable results and keep product attributes stable at target.
- **Melting, Dropping, Boiling, Cloud and Slip Melting Point** – all parameters yield material characterizing values based on the same general methodology: controlled heating until a defined event based on a phase transition is detected. Tips presented about operation and sample preparation are essential and prerequisite for accurate results.
- **Thermal Analysis** – encompasses a range of techniques that allow to characterize materials under controlled temperature and time programs. Operators will learn the different thermal analysis techniques and a systematic approach to method development.

Each section follows a similar structure: the measurement technique itself, principles that support accuracy, tips gained from real-life lab experience, and a reference to other valuable knowledge materials including guides and white papers on the topic.

1.4 Using Methods in Concert

In many modern labs, multiple determinations run in parallel – for example, more than one moisture analyzer or titrator are in use at a time, each assessing a single parameter on one sample. The interplay among instruments creates an overall quality picture. Ongoing quality results may be catalogued in a central repository, such as METTLER TOLEDO's LabX software, for easy recall and trending.
Multiple determinations may also be made in a single sample or sample type. For example, a lab may have a single automated system for determining the conductivity, pH value and alkalinity of water, or multiple titrators combined in one workflow to look at nickel content and hypophosphite content of electroplating samples. Again, a central data repository such as LabX compiles the results of the determinations into a usable quality snapshot. For dedicated METTLER TOLEDO solutions, see chapter 12.

2. Weighing

2.1 Weighing in the Lab

Weighing is one of the most common tasks in the laboratory. Usually, direct or differential weighing tasks are performed. Direct weighing is used to prepare samples, standards, buffers, reagents and the like. Differential weighing determines the weight difference before and after a processing step. Loss of weight methods are a typical application.

Micro, analytical and precision balances have now been perfected to such a degree that, in general, any customer need can be fulfilled. Advances in electronics and software have considerably simplified balance operation and allow direct integration of balances into lab workflows.

2.2 Measurement Principle

Electronic scales and balances apply two measurement principles.

1. Magnetic force restoration (MFR) technology is used for high-resolution applications. The beam of the balance is kept in equilibrium by compensating the weight (mass) of the sample via a magnetic force. Resolution of up to 52 million points has been achieved reaching 1 microgram reading at 52 gram maximum capacity.
2. Strain gage (SG) technology is applied for lower-resolution weighing tasks. Typical resolution is 200 000 points. SG weighs by changing the electrical resistance in relation to the weight (mass) put on a balance and allows for more robust weighing cells.

In both cases, modern electronics and software convert the initial signal to weights of the desired unit and readability.

2.3 Tips and Hints for Weighing

Here are some basic hints about how to position a balance in the lab to achieve optimal weighing results.

- Place the analytical balance on a stable weighing table to avoid disturbance by vibrations. The weighing bench must also be stable enough that the balance display does not change when someone leans on the table or steps up to the weighing station.
- Position the balance directly over the legs of the bench instead of the middle section of a long bench, since this area is subject to the least vibration.
- Avoid wind drafts from air conditioning and ventilation. Do not place the balance next to a door and avoid high traffic places.
- Keep the lab room temperature as constant as possible. Do not expose the balance to direct sunlight in order to avoid warming up the balance. Temperature changes influence the weighing result. Typical drift is 1–2 ppm/°C. Do not exceed the range of –5 to 30 °C (see Figure 1).
- Consider FACT and proFACT. FACT and proFACT are fully automatic time- and temperature-controlled internal adjustment procedures and help avoid environmental interference with weighing results. Thus, analytical balances from METTLER TOLEDO with FACT or proFACT provide consistently correct weighings.
- Keep air humidity ideally in the range of 45–60% relative humidity (RH). Balances should never be operated above or below the measuring range of 20 to 80% RH. Second, a few updates and changes to traditional lab equipment can make big differences in accuracy and weighing task productivity.

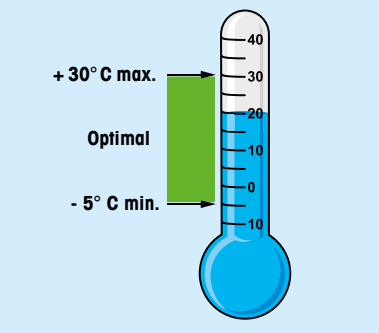


Figure 1. Recommended temperature range for balances

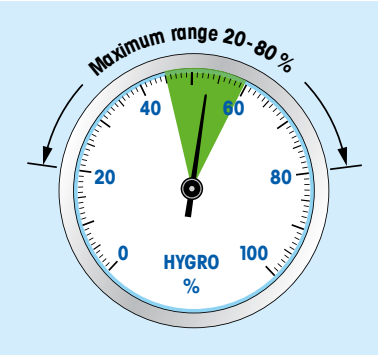


Figure 2. Recommended air humidity

Figure 3. ErgoClip with flask on an XP56 analytical balance

Figure 4. SmartPrep funnel

- Dose directly into your tare container. Place the tare container ergonomically to ease filling procedures. ErgoClips can help. ErgoClips are tare container holders, available for all kinds of vessels and vials. They keep containers well-positioned for weighing. ErgoClips fit all METTLER TOLEDO Excellence XPE, XSE and XA analytical balances.
- Avoid intermediate receptacles and old-style weighing papers to prevent sample loss.
- Consider new METTLER TOLEDO SmartPrep funnels. SmartPrep is an ergonomically designed funnel which fits all volumetric flasks. Made of stain-resistance plastic, it features a large dosing area to avoid spilling and a smooth surface for efficient rinsing. Thus, SmartPrep directly helps to improve accuracy.
- Consider automatic method guidance. Solutions such as METTLER TOLEDO's LabX software can guide through the entire weighing process by prompting each operational step on the balance display. In addition, LabX collects data for later evaluation, archiving purposes or audits and avoids transcription error risk. LabX also speeds up lab work.
- Apply the SmartSample™ workflow solution. METTLER TOLEDO's new RFID-based SmartSample solution ensures results are unquestionably allocated to the right sample.
  The RFID option of Excellence analytical balances writes the sample weight to the RFID tag of a titration beaker when weighing is complete. Also the sample identification can be stored on the RFID tag. The tag is later read by the autosampler and data is sent to the titrator. Because the RFID tag is attached uniquely to a beaker, the beakers can be placed in any sequence on a sample changer (e.g. InMotion™) and results still correlate safely to the appropriate sample. No more beaker numbering; no more writing sample weights on beakers, papers or lab journals; and no more confusing of samples.

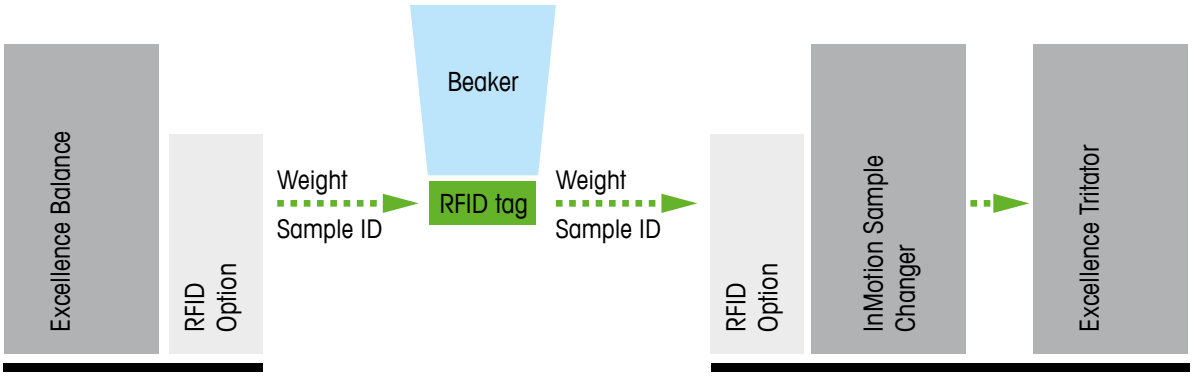


Figure 5. The SmartSample™ workflow principle

2.4 References

Proper Weighing with Laboratory Balances, Guide Book, Mettler-Toledo, 720906, © 01/2015
Dictionary of Weighing Terms, Springer Verlag Berlin, 2009, ISBN 978-3-642-02013-1

3. Pipetting

3.1 Why Discuss Pipetting?

Pipetting – a common method of measuring and transferring small volumes of liquid in the microliter and milliliter range – is probably the most frequently practiced activity in research laboratories. Quality control labs also pipette quite often. To be able to carry out this task quickly and precisely is an absolute prerequisite for successful laboratory work.

A high level of productivity, with corresponding savings in man labor hours, is possible through the use of modern high-quality pipettes and tips.

3.2 Measurement Principles

Air-displacement pipettes
The ideal instrument for effectively dosing small quantities of liquid is an air-displacement pipette. These pipettes are used for a majority of lab work and provide numerous advantages. They operate by placing the end of the tip into a liquid sample, then releasing the plunger button. A partial vacuum is created when the pipette piston is moved up within the pipette body, and the liquid sample moves up the tip to fill the void of the selected volume created by the partial vacuum.

Positive-displacement pipettes
Positive displacement pipettes are frequently seen in laboratory settings. Such pipettes use a disposable piston and capillary system to make a physical void of the selected volume. The piston is in direct contact with the sample. When the piston is moved upward, sample is drawn into the capillary.

Positive-displacement pipettes are recommended for use with aqueous, viscous, dense, volatile and corrosive solutions. Capillaries and pistons of positive-displacement pipettes are disposable to avoid contamination and carry-over.

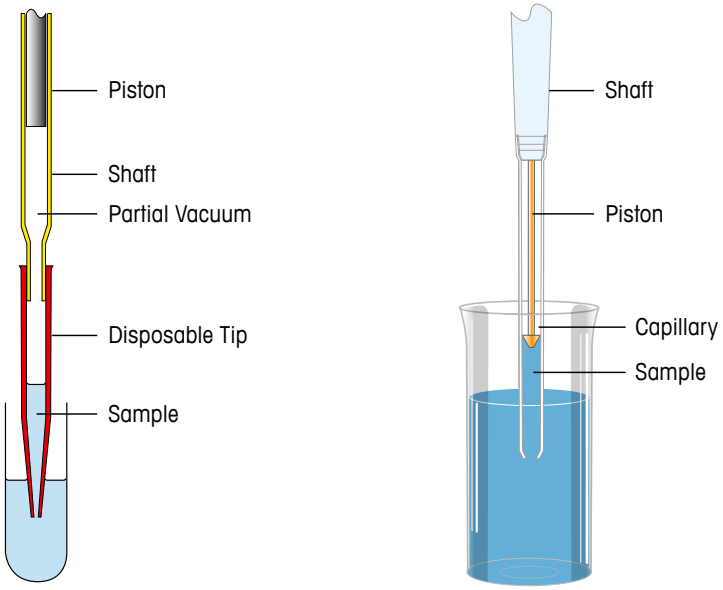


Figure 6. Air- and positive-displacement pipettes

3.3 Tips and Hints for Pipetting

Aspirating at the correct angle
The immersion angle of your pipette tip should be as close to 90 degrees as possible and not deviate more than 20 degrees from vertical. If the angle is greater than this, it can cause too much liquid to be drawn into the tip, resulting in inaccurate aspirations. For example, at an angle of 30 degrees from vertical, up to 0.7% too much liquid can be aspirated.

Consistent pipetting rhythm
Use a consistent pipetting rhythm from sample to sample. Instead of rushing or rapid operation, get into a rhythm for each step in the pipetting cycle.

Smooth plunger action
Maintain consistent speed and smoothness when pressing and releasing the plunger. Uncontrolled aspiration can cause bubbles, splashing, aerosols and contamination of the pipette shaft and piston.

Large volume pipettes
For larger volumes – typically 1 mL or greater – pause about 1 second or more after sample pickup with the tip still in the liquid. This will allow the sample to be fully aspirated. Withdraw the tip only when aspiration is complete.

Pre-rinse tips at least twice
Dispensing liquid from a pipette leaves a coating of the liquid on the tip, making the expelled volume slightly less than it should be. Whenever a new tip is used, pre-rinse at least twice with the liquid being dispensed before pipetting to compensate for this liquid film. Pre-rinsing also helps neutralize capillary effects in micro-volume pipettes and, for macro-volume pipettes, equalizes the air temperature inside the pipette with the sample temperature.

Pre-rinsing exceptions
Pre-rinsing can negatively affect results when pipetting very warm or cold solutions. It is not recommended for pipetting very cold solutions, such as those from an ice bath, or for solutions above 37 °C, as it may result in errors of up to 5%.

Allow time for equilibration
Pipettes are susceptible to variation in the temperature of the samples dispensed. Cold liquids tend to deliver in excess, while warm liquids may deliver smaller volumes than expected. Unless otherwise specified, allow sufficient time for the temperature of your pipettes and liquids to equilibrate before use.

Hand warming effects
When pipetting for long periods, heat from your hand can warm the air inside the pipette, causing it to expand and lead to inaccurate results.
- Avoid continually holding the pipette in the hand between pipetting cycles.
- Always put the pipette back on its stand after pipetting.
- Use pipettes made from high grade PVDF, a low thermal conductivity polymer.

Ensure proper touch-off

The greatest accuracy and sample-to-sample reproducibility are achieved by ensuring that the last remaining droplet dispenses fully and does not adhere to the tip end. Dispensing with the end of the tip resting against the vessel wall reduces or eliminates the amount of sample remaining in the tip. Remove the pipette by sliding the tip end along the side wall to release any remaining droplet at the tip orifice. This technique can increase accuracy by 1% or more.

Air-displacement or positive displacement pipette?

The disposable capillaries and pistons used with a positive-displacement pipette are more expensive compared to disposable air-displacement pipette tips. Thus, air-displacement pipettes are recommended when they will yield the same results (accuracy, precision).

3.4 References

Get Better Results, Quick Guide to Good Pipetting, Mettler-Toledo, © 02/2014
Pipetting Tips and Tricks, Mettler-Toledo, © 01/2013

4. pH and Conductivity Value Determination

4.1 The Principle and Importance of Measuring pH

The pH value indicates how much and how strong acids or leaches are present in a sample. Sample solutions with a pH below 7 are acidic. If the pH is above 7, the solution is basic (also called alkaline). At pH 7.0 the solution is neutral.

We measure pH for many different reasons, including:
- to produce products with defined properties – pH can dramatically alter end-product properties such as appearance or taste
- to lower production costs – production process yield may depend on pH
- to fulfill regulatory requirements
- for research and development

By definition, the pH value is related to the concentration of the hydronium ion H_3O^+ which is formed when an acid such as sulfuric, nitric, citric or acetic is dissolved in water.

The determination of the pH value requires a meter and a suitable sensor. In principle, the meter is a voltmeter. The measuring range usually lies between –2000 mV and +2000 mV with a resolution of 0.1 mV.

The sensor consists of two parts: the pH-sensitive electrode and a reference electrode. These two electrodes are usually combined into one sensor and commonly called a pH electrode. The pH electrode measures an electric potential which depends on the concentration of the hydronium ion. The Nernst equation describes the correlation between the concentration and the measured pH value. The sensing part of a pH electrode is the glass membrane made of specially-developed, high pH-sensitive glasses.

4.2. The Measurement Principle and Importance of Conductivity

Electrical conductivity has been measured in practice for more than 100 years and it is still an important and widely used analytical parameter today. The high reliability, sensitivity, fast response, and the relatively low cost of the equipment make conductivity a valuable, easy-to-use tool for quality control.

Electrical conductivity is a non-specific sum parameter over all dissolved ionic species (salts, acids, bases, and some organic substances) in a solution. This means that this technique is unable to differentiate between diverse kinds of ions. The reading is proportional to the combined effect of all ions in the sample. Therefore, it is an important tool for monitoring and surveillance of a wide range of different types of water (pure water, drinking water, natural water, process water, etc.) and other solvents. It is also used to determine the concentrations of conductive chemicals.

In principle, a conductivity measuring cell consists of an electrode pair, the so-called poles, to which a voltage is applied. The meter measures the current and calculates the conductivity (see Figure 7).

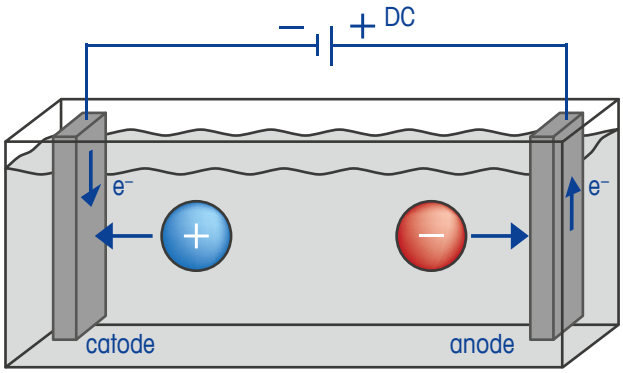


Figure 7. Schematic set-up of a conductivity measuring cell

4.3 Tips and Hints for pH and Conductivity

4.3.1 pH and Conductivity Meters

Manufacturers usually offer a selection of models to cover actual customer needs. Small meters for simple routine tasks or elaborate models with color displays, touchscreens, high resolution, data storage and many more features are available.

- If pH and conductivity results have to flow to process and enterprise control systems, automatic data transfer is recommended to avoid transcription errors, increase data security and improve efficiency. In this case, meters with suitable connection interfaces such as Ethernet, USB and RS232 and suitable software (e.g. LabX) offer the best solution.
- For more basic applications, a smaller meter which offers a printer connection may prove most suitable.
- When pH and conductivity values also have to be measured at various places outside the lab, a portable meter is suggested. Portable meters are protected against water and dust (e.g. IP67) and can store data for later read-out.

4.3.2 pH Electrodes

The user can also choose from a variety of electrodes. Shape of the glass membrane (round, flat, puncture, etc.), shaft material (glass, PEEK, polysulfone) and type of junction are choices that can be made.

Membrane

- The most common electrode membrane shapes for universal use are a cylinder or a sphere.
- A flat membrane is used to measure the pH value on a surface, e.g. on skin or paper.
- A puncture electrode (spear shaped) is used for solid or semi-solid samples as cheese, meat or dough.
- Use a micro electrode for pH measurements in reaction tubes or other small containers.

Spherical	Cylindrical	Spear	Flat	Micro
For low temperature samples: resistant to contraction	Highly sensitive membrane: large surface area, lower resistance	For semi-solids and solids: punctures the sample easily	For surfaces and drop sized samples: very small pH-membrane contact area	Samples in reaction tubes: very narrow electrode shaft

Figure 8. Differently shaped pH membranes

Shafts

- Shafts made from polymers like PEEK and polysulfone absorb mechanical shocks and turn electrodes into "unbreakable" sensors. Hence, polymer shafts are recommended for harsh use.

Junction type

Another point to consider is the type of junction. The junction functions as the bridge between the pH sensitive and the reference electrode. Thanks to the junction, electrolyte flows into the sample and assures electric connection.

- A ceramic frit or similar materials – also called a diaphragm – is the main type of junction. It applies to a wide variety of aqueous samples.
- However, frits can get clogged by sample components such as undissolved particles or proteins reacting with the electrolyte flow.
- Open-hole or movable sleeve junctions can help to avoid clogging. These junctions can be easily cleaned and kept free.

4.3.3 Conductivity Sensors

Choosing the right conductivity sensor is a decisive factor in obtaining accurate and reliable results. The following paragraphs give import information when selecting a conductivity sensor. Table 1 gives an overview.

Chemical resistance

A basic requirement is that no chemical reactions occur between the sample and the sensor. For chemically reactive samples, glass and platinum are often the best choice because they have the best chemical resistance of all commonly used cell materials. For field application and also a lot of laboratory applications, the mechanical stability of the sensor is a more important factor. A conductivity sensor with an epoxy body and graphite electrodes is often used, as this has been shown to be extremely durable and it also has good chemical resistance. For low reactive aqueous solutions and organic solvents, the use of cells made of steel or titanium is often a good alternative.

Cell constant

The next point which should be considered in order to select an optimal sensor is the cell constant and the construction type. A suitable cell constant correlates with the conductivity of the sample. The lower the expected conductivity of the sample, the smaller the cell constant of the sensor should be. Figure 7 shows a set of samples and the range of recommended cell constants which should be used for the measurement. To make a decision between a 2-pole cell and a 4-pole cell the following rough-and-ready rule can be used: For low conductivity measurements, a 2-pole cell should be used. For mid to high conductivity measurements a 4-pole cell is preferred, especially for measurements over a wide conductivity range.

		Configuration	Cell Constant	Measuring Range	Sensor Name
Generalist		4 platinum pole glass shaft	0.80 cm^{-1}	0.01–500 mS/cm	InLab® 710
		4 graphite pole epoxy shaft	0.57 cm^{-1}	0.01–1000 mS/cm	InLab® 731 InLab® 738
Specialist	**Pure water and high precision**	2 titanium pole titanium shaft	0.01 cm^{-1}	0.0001–1000 µS/cm	InLab® Trace
		2 steel pole steel shaft	0.105 cm^{-1}	0.001–500 µS/cm	InLab® 741 InLab® 742
		2 platinum pole glass shaft	0.06 cm^{-1}	0.1–500 µS/cm	InLab® 720
	Micro	2 platinum pole glass shaft	1.0 cm^{-1}	0.01–100 mS/cm	InLab® 751–4mm
		2 platinum poleglass shaft	1.0 cm^{-1}	0.01–112 mS/cm	InLab® 752–6mm
	Bioethanol	2 platinum pole glass shaft	0.1 cm^{-1}	0.1–500 µS/cm	InLab® 725

Table 1. Conductivity Sensor portfolio of METTLER TOLEDO

Norms and standards
Sometimes standards or norms contain requirements concerning the conductivity sensor. If a conductivity measurement is performed according to such a standard, then the chosen senor must completely fulfill all the described requirements.

4.3.4 Sensor Management

ISM – Intelligent Sensor Management – stores sensor identification and calibration data on the sensor. Thus, changeover of electrodes from one to another meter is easy. Conversely, if a method specifies a certain electrode type, no other electrode will be accepted, avoiding mistakes.

For more information and help with electrode selection, go to www.electrodes.net.

4.4 References

A Guide to pH Measurement, Theory and Practice of Laboratory pH Applications, Mettler-Toledo, 51300047, © 03/2013
A Guide to Conductivity Measurement, Theory and Practice of Conductivity Applications, Mettler-Toledo, 30099121, © 08/2013

5. Moisture Content Determination

5.1 Moisture

Moisture affects processability, shelf life, usability and quality of many products such as pharmaceutical substances, plastics and foods. Most substances have an optimum moisture content for attaining maximum quality and obtaining best possible processing. Furthermore, moisture content can impact price, which has led to statutory rules governing the maximum permissible moisture content for some products (as defined by pharmacopeias or national food regulations).

5.2 Measurement Principle

Moisture determinations need to be carried out reliably and at speed to enable quick manufacturing process interventions. One routine method of determining moisture is using a moisture analyzer, preferably with halogen heat source for quick, accurate and consistent results. In moisture analyzers the loss in weight is continuously recorded and drying ends once a defined criterion is reached. The moisture content is automatically calculated from the difference in weight.

The method includes two parts: the heating of the sample and the switch-off criterion.

Sample heating
The type and the shape of the heat source (radiator) are crucial for the speed and reproducibility of the moisture determination. A halogen lamp reaches maximum heating output very fast compared to conventional infrared lamps. In addition, a ring shaped radiator ensures even heating of the entire sample pan area.

Switch-off criterion
The criterion determines the point at which measurement is automatically ended and the result displayed. Halogen moisture analyzers offer two different kinds of switch-off criteria: time control and weight loss per time. In the latter case, the drying process is terminated and the result displayed if the loss in weight (Δg) falls below the prescribed figure over a certain time (Δt). In the former case, the heating process is terminated and results are evaluated after the set time has elapsed.

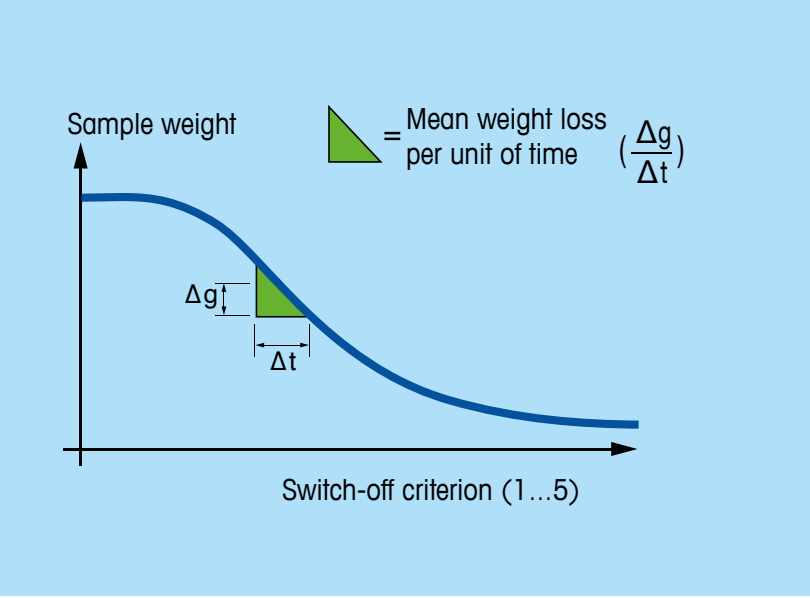


Figure 9. Switch-off criterion

5.3 Tips and Hints for Moisture Determination

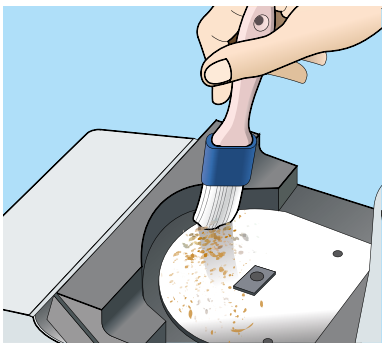


Figure 10. Cleaning of the moisture analyzer

To ensure precise measurement results during routine operation, the following should be observed:

- Keep the sample pan area clean (e.g. using a brush).
- Clean dirt off the temperature sensor and protective glass on the heating module (for details, see operating instructions).
- Only use clean sample pans for moisture determination.
  Using single-use aluminum sample pans guarantees reliable measurements free from the influence of residue remaining from previous samples or cleaning agents.
- Do not use deformed sample pans.
- Ensure even particle size (granulation).
- If necessary, increase the sample surface area by breaking up the sample. This will ensure a better and faster release of moisture during drying (faster diffusion of moisture to the surface).
  The sample should not be heated during preparations as this would cause moisture loss.

Use the right sample volume. Sample size depends on:

- The moisture content of the sample.
- Recommended sample size is 3–5 g for most samples. However, for samples of <0.5% moisture it is 20–30 g
- Homogeneity
  Inhomogeneous samples may require a bigger sample size to represent the entire batch)
- Resolution and minimum weight of the built-in balance
- The kind of sample (liquid, pasty, solid, powdery)
- Always use the same volume of sample to achieve good repeatability.
- Spread the sample evenly over the entire pan (do not build up piles).

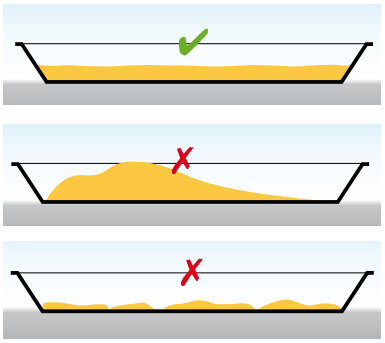


Figure 11. Filling of the sample pan

Temperature: Follow one of the recommendations below.

- Apply the SOP relevant for your sample.
- Apply the same settings as for a similar sample.
- Apply the temperature of the traditional oven method.
- Apply 105 °C for temperature-sensitive samples, or 150 °C for other samples.

5.4 Reference

Guide to Moisture Analysis, Moisture Determination with the Halogen Moisture Analyzer, Mettler-Toledo, © 04/2013

6. Titration

6.1 Titration – a Technique with a Long Tradition

A balance, a burette, a suitable chemical reaction and an indicator suffice to solve many quantitative analytical problems. The analytical technique employed is called titration or titrimetric analysis (titrimetry).

Titration has been applied for centuries to determine the content of a variety of compounds in many different sample types. Compounds analyzed include acids, caustics, salts, and metal ions. Sample types range from pharmaceuticals, food, beverages, water, chemicals and petrochemicals, to electroplating and lubricants. In fact, it is the preferred quantitative chemical analysis for many applications.

Before the first electrode was invented, color indicators were used to show the titration endpoint. Nowadays, automatic titrators, various sensors and sample handling accessories provide fast, reliable and automated titration analyses to help demanding users increase work efficiency and accuracy.

6.2 Measurement Principle

In a titration, part of the sample containing the substance to be analyzed (the analyte) is dissolved in a suitable solvent – quite often deionized water. A second chemical compound, the titrant, is added as a solution of known concentration in a controlled manner until the analyte has reacted quantitatively. From the consumption and concentration of the titrant as well as the weight of sample used in the analysis, the analyte content can be calculated.

Automated titrators follow a defined operation sequence (titration cycle), which is performed until the titration ends. This sequence is basically the same for all models and brands.

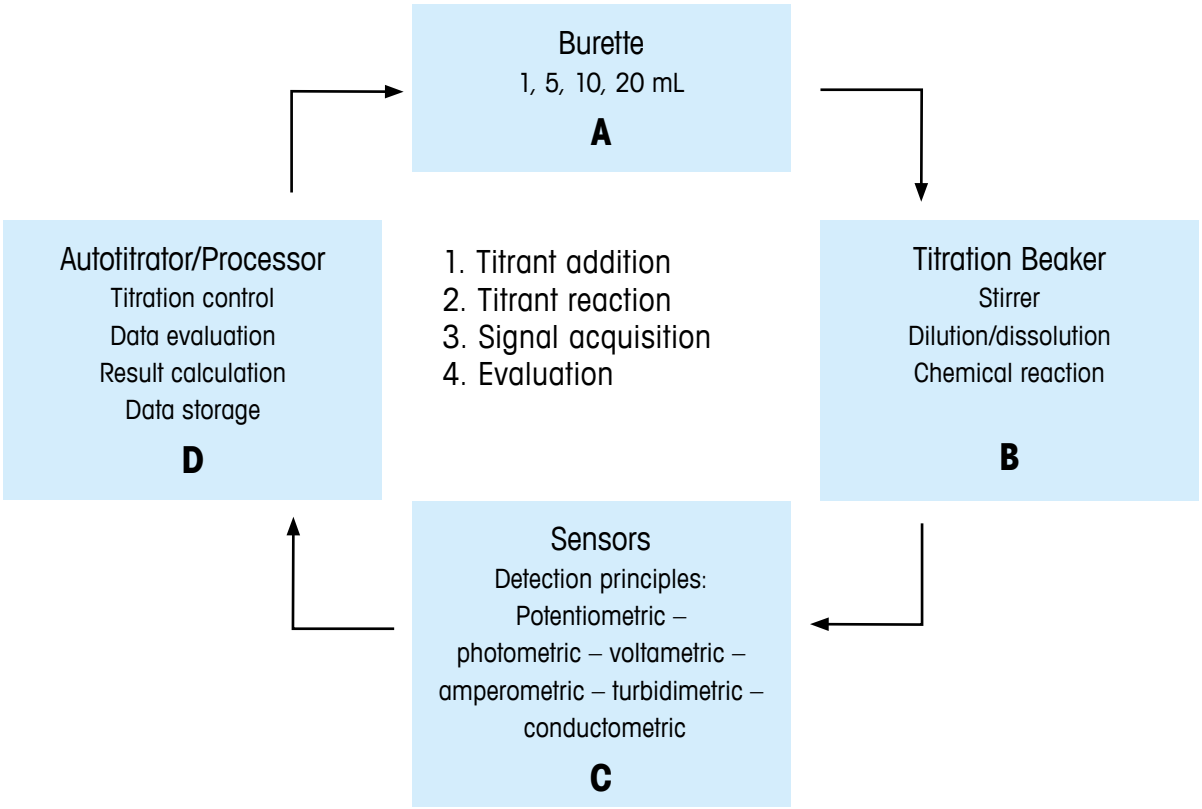


Figure 12. Schematic representation of the fundamental steps in a titrator method (the titration cycle)

6.3 Tips and Hints for Titrations

Some tips and hints have been derived for the four major segments of the titration cycle burette, beaker, sensor and autotitrator of Figure 12.

Burette (A)

- Select the appropriate burette size. Ideally, the titration is completed with a titrant consumption of 20–80% of the burette's nominal volume.
- When newly filling the burette, flush it sufficiently with titrant to ensure complete filling.
- Avoid air bubbles. This may request titrant degassing. If air bubbles still remain in the glass cylinder, empty the burette completely and refill it.
- Clean the burette periodically. Rinse it with deionized water.
- Treat sealing lips of the piston carefully. Avoid scratches and damage to prevent leaks.
- Store the burette appropriately. When not in use for a long period of time, empty the burette and both tubes and rinse them all carefully with deionized water.

Beaker (B)

- Only use clean beakers.
- Set stirrer speed for vigorous stirring while avoiding splashing and vortex formation. If the sample is sensitive to ambient air or the titration reaction is very slow, apply gentle stirring only.
- Set sufficient stirring time. The sample should dissolve completely before titration starts.
- Rinse stirrer and electrode thoroughly after each sample to avoid carry-over. If necessary, apply a conditioning step (period of 30–60 seconds, suitable solvent).

Sensor (C)

- Ensure that the sensor is properly immersed in the sample. When using combined pH electrodes, the junction has to dip into the sample for safe and stable readings.
- Calibrate and adjust the sensor periodically according to SOP requirements or to the manufacturer's recommendation. When doing pH endpoint titration, the electrode has to be calibrated carefully since it directly influences the result. For equivalence point titrations, calibration is less critical. The result is calculated mainly based on changes of the potential rather than on the absolute potential value.
- Sensors may need conditioning. This applies particularly to ion sensitive electrodes (ISEs) or to pH electrodes used in non-aqueous solvents.

Autotitrator (D)

- Activate user management. User management assures that only qualified operators have titrator access. Users can execute only tasks they are assigned to.
- Build methods to include as many work steps as feasible to simplify tasks, ensure correct execution, and increase repeatability.
- Run several test sample series before establishing method SOPs. For more details see Application Brochure 16, Validation of Titration Methods.
- Decide which data you need to captivate (table of measuring values, results, equipment data, etc.). Delete the others. Print it on paper if required. Preferably, store data electronically in the lab database.

6.4 References

Good Titration Practice Brochure, How to Achieve the Best Results, Mettler-Toledo, 51725313A, © 04/2013
Basics of Titration, Titration Theory, Mettler-Toledo, 51725228, © 09/2009
Validation of Titration Methods, Application Brochure 16, Mettler-Toledo, 51724912A, © 03/2015

7. UV/VIS

7.1 UV/VIS Spectroscopy

UV/VIS spectroscopy is a very simple, fast, inexpensive and therefore very popular method used in analytical laboratories. It measures how much light a chemical substance absorbs or transmits across the ultraviolet-visible spectral region. Depending on the amount of light and the wavelength absorbed by a sample, valuable information can be derived, such as sample identity, concentration, or purity.

7.2 Measurement Principle

An UV/VIS spectrophotometer measures the intensity of light passing through a sample. The main components of an UV/VIS spectrophotometer are a light source, a sample holder, a dispersive device to separate the different wavelengths of the light (e.g. a monochromator), and a suitable detector. METTLER TOLEDO's Excellence UV/VIS spectrophotometers combine a long-lasting Xenon flash lamp with a state-of-the art array detector enabling very fast complete spectrum scans for high accuracy and repeatability.

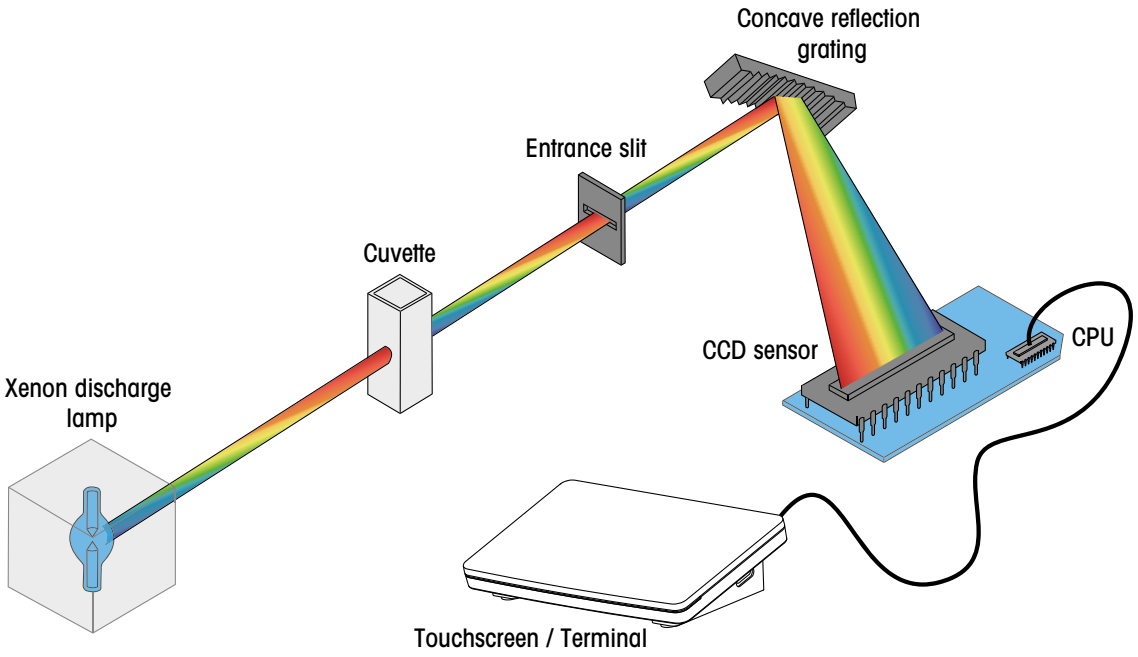


Figure 13. Instrument design of an array spectrophotometer

The transmittance of the sample at different wavelengths is calculated by dividing the light intensity of the sample (I) by the light intensity of a reference or blank (I_0). The transmittance T is often indicated in % T.

$$T=\frac{I}{I_0}$$

For many applications, it is more practical to work with the absorbance, which is the negative logarithm of the transmittance.

$$A=-log(T)$$

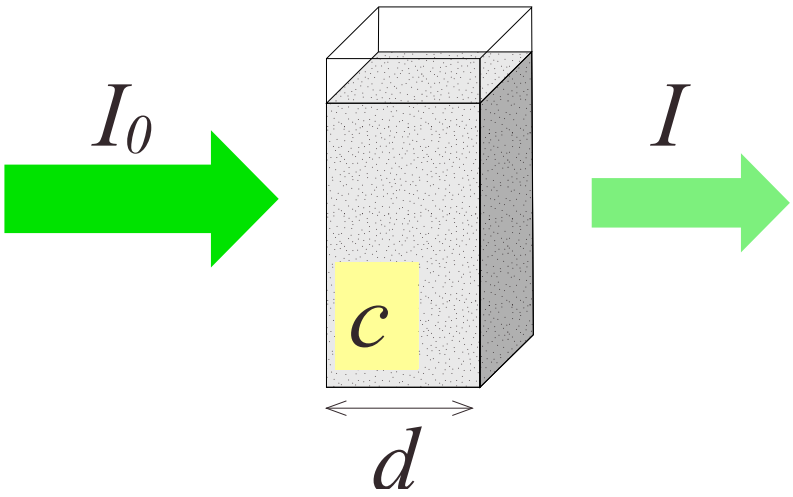


Figure 14. The influencing factors of the Lambert-Beer Law

According to the Lambert-Beer Law, the absorbance of a sample is directly proportional to the concentration of the sample (c), the pathlength of the cuvette (d) and the absorbance coefficient espsilon (ε):

$$A = \varepsilon \cdot c \cdot d$$

The Lambert-Beer Law is central to many applications for determining the concentration of solutions. Besides quantitative analysis, UV/VIS spectroscopy is also used for qualitative analysis. As each molecule absorbs light at specific wavelengths, the UV/VIS spectrum can be used to identify a substance as well as its quality.

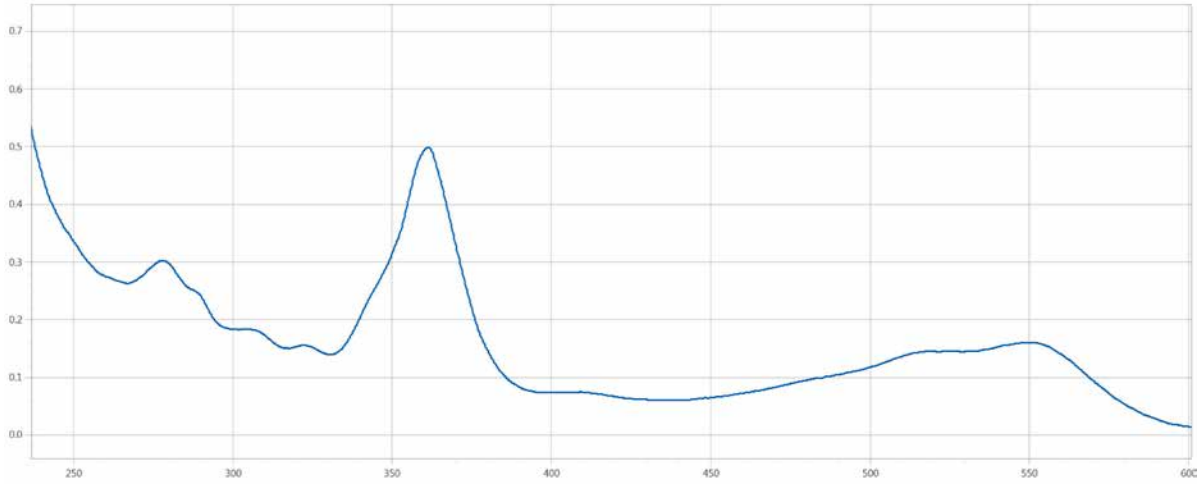


Figure 15. The UV/VIS spectrum of Vitamin B12 shows characteristic peaks at 278, 361 and 550 nm

Micro-volume measurements

Micro-volume measurements are ideal and widely used in the Life Science sector for highly concentrated and small volume samples. By reducing the pathlength of the measurement, higher concentrations can still be measured in the recommended absorbance range of the spectrophotometer. In this way, tedious and error-prone dilution stepsare eliminated. The sample is applied directly onto the measurement platform without the need of a cuvette and as little as 1 µl of sample is sufficient to take a measurement.

The UV5Nano micro-volume spectrophotometer from METTLER TOLEDO is based on the LockPath™ technology, which allows the measurement of the sample solution at two precisely defined pathlengths to guarantee high accuracy. The change from the long pathlength of 1 mm to the short pathlength of 0.1 mm takes place automatically. Therefore, a wide concentration range can be covered with only one measurement.

Figure 16. Sample is applied to the micro-volume platform with a micro-liter pipette

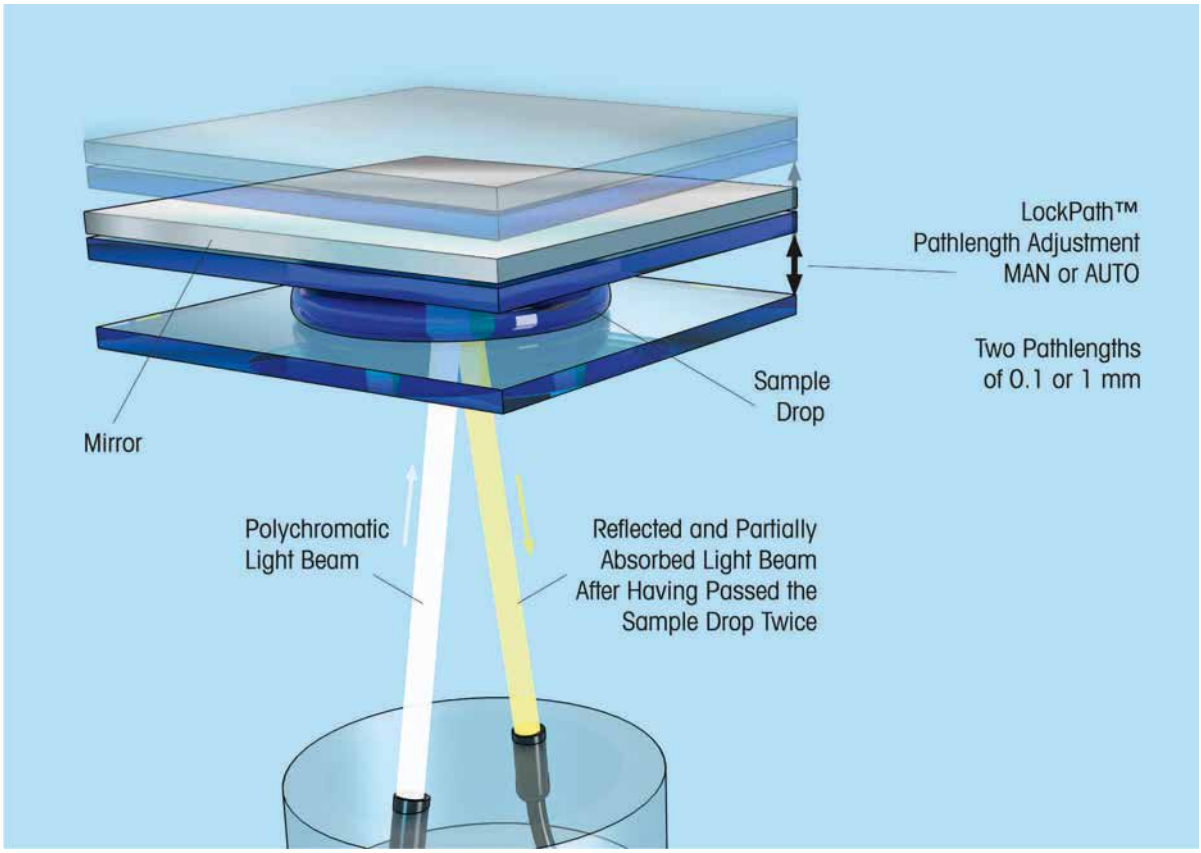


Figure 17. Schematic drawing of the micro-volume platform on METTLER TOLEDO's UV5Nano spectrophotometer showing the change between the short and long pathlength

7.3 Tips and Hints for UV/VIS Spectroscopy

Cuvette selection and handling

- Path length: According to the Lambert-Beer law the absorbance is directly proportional to the cuvettes path length and sample concentration. Selection of an ideal path length (e.g. 2 mm up to 5 cm) can eliminate the need for dilutions. Absorbance in the range of 0.2A to 1.5A generates most accurate results. For highly concentrated samples a micro-volume instrument with a very short pathlength (e.g. 1 mm or 0.1 mm) is ideal.
- Transmittance range: High precision fused quartz cells (QS grade) are recommended for any UV/VIS analysis. For the visible range (>400 nm), disposable PMMA or PS cuvettes are frequently used.
- Positioning: Position the cuvette with the transparent side in the light beam and the cuvette label pointing for blank and sample in the same direction.
- Cuvette handling: Be careful not to leave finger prints on the cuvette. Hold cuvettes only on the frosted sides.
- Cleaning: For thorough inner and outer cleaning use a 60% isopropanol/water solution and wipe with an optical cleaning cloth or lint-free tissue.
- Filling: Avoid using glass pasteur pipettes to fill the cuvette; they could scratch the optical surface. Pipettes with disposable plastic tips are perfect.

Solvent selection

- Transmittance range: The solvent should be transparent throughout the applied region.

Solvent	Pure Water	Hexane	EtOH	MeOH	Dimethyl-sulfoxide	Acetone
λ cutoff	<197	199	207	210	270	331

Table 2. Typical solvents and their cutoff values, indicating the minimal wavelength where the solvents can still be used

- Concentration: Adjust the sample concentration for good absorbance (see section onpath length selection above)
- Side reactions: Take care of possible side reactions between analyte and solvent molecules which may affect the spectrum. Polar solvents (i.e. water, ketones, alcohols, etc) dissolving polar samples can influence the electronic environment of the absorbing chromophore, thus lowering the spectral resolution.

Blank correction

- Fresh: The blank cuvette must consist of a fresh solvent as used for the sample.
- Automation: cuvette changers offer a secure and efficient way to measure a blank cuvette automatically prior to each sample.
- Background correction: The background correction subtracts the measured absorbance value, typically at a wavelength where the analyte has no absorbance, from the measured absorbance value at the wavelength of interest. As an example for direct DNA and protein measurements in the UV range, a background correction is commonly applied at 320 or 340 nm as these molecules do not absorb light in this wavelength range. Therefore, measuring and correcting the background removes any possible interference due to light scattering by particles, air bubbles or a precipitate in the sample.

Effects of pH, temperature and ambient air

- pH: The effects of pH on absorbance spectra can be very large if the conjugated acid or base has a different color (pH indicators Phenolphthalein, methyl red/orange etc.). If the spectrum of the sample under study is found to be affected by pH, a buffer should be used as a control.
- Temperature: Expansion of the solvent, mainly organic solvents, may change the apparent absorbance causing temperature dependency. For samples or solvents with high temperature dependency use a thermostatic sample holder.
- Lid: In order to limit solvent evaporation or water absorption from ambient air in case of hydrophile samples use the lid normally provided with the cuvette.

Micro-volume measurements

- Cleaning: The optical parts of the micro-volume platform, window on the lower side and mirror on the upper side must always be perfectly clean to achieve accurate and repeatable results. Clean the window and mirror twice with distilled water after finishing the measurement series or at the beginning of a measuring sequence prior to the blank measurement. This prevents the new measurement from being contaminated by the remains of an old sample. Use distilled water, analytical grade isopropanol/ethanol or a specific cleaning agent for cuvettes (Hellmanex III), applied with non-scratching optical grade wipes (KIMWIPES Delicate Task Wipers, CODE 34120).
- Pipetting technique: Pipette the sample smoothly onto the micro volume platform to prevent the formation of air bubbles. Use a sufficient amount of sample to fill the area between the upper and lower platform. For the mirror to touch the sample, it should form a nice droplet shape. If required clean the surface with water.

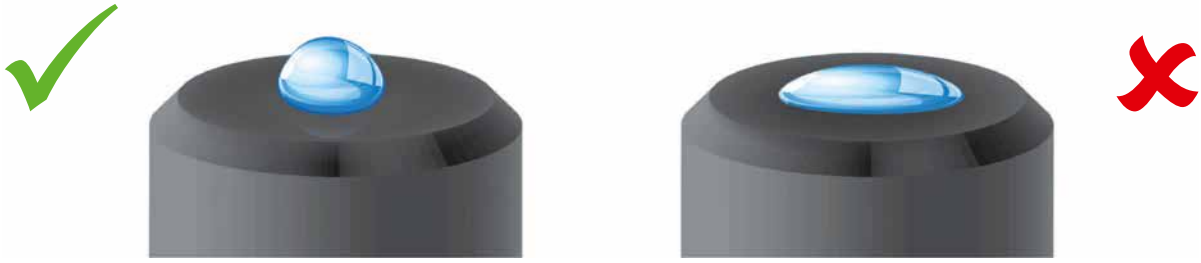


Figure 18. When applying the sample make sure to form a round droplet

7.4 References

UV/VIS Spectrophotometry, Fundamentals and Applications, Mettler Toledo, 30256131, © 09/2015

8. Density – Concentration Determination

8.1 Density

Density (or specific gravity) is a characteristic property of materials. Hence, it can be applied to identify them. Density of liquids and solids depends on temperature. Gas density is additionally influenced by pressure.

The density of solutions depends on the concentration of the dissolved compounds. Once calibrated, density readings can be used to evaluate a compound's concentration. This applies e.g. to sugar (Brix), alcohol and salt. However, a stringent correlation between density and concentration can only be applied to binary mixtures of one compound in one solvent.

8.2 Measurement Principle and Density Meters

Current density meters apply the physical principle of the oscillating U-tube. The oscillation frequency depends on the mass of the U-tube, or more specifically the content of the U-tube. Thus, a few milliliters of sample are applied by syringe or an automatic sample changer to the density meter instrument. The measurement takes 2–3 minutes, needs no reagents and allows the sample to be used again.

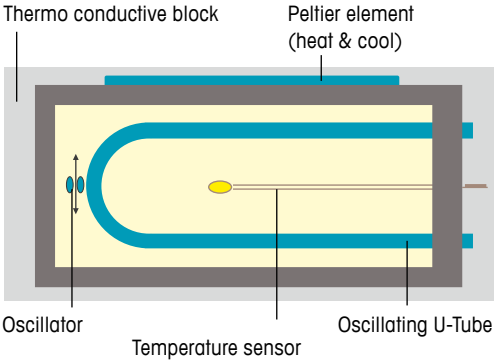


Figure 19. Schematic of a density cell

Rinsing and drying of the U-tube before the next sample can be done automatically. This adds results safety to measurement speed.
Because density depends on temperature, modern density meters are electronically thermostated and compensate density results to 20 °C or any other temperature.

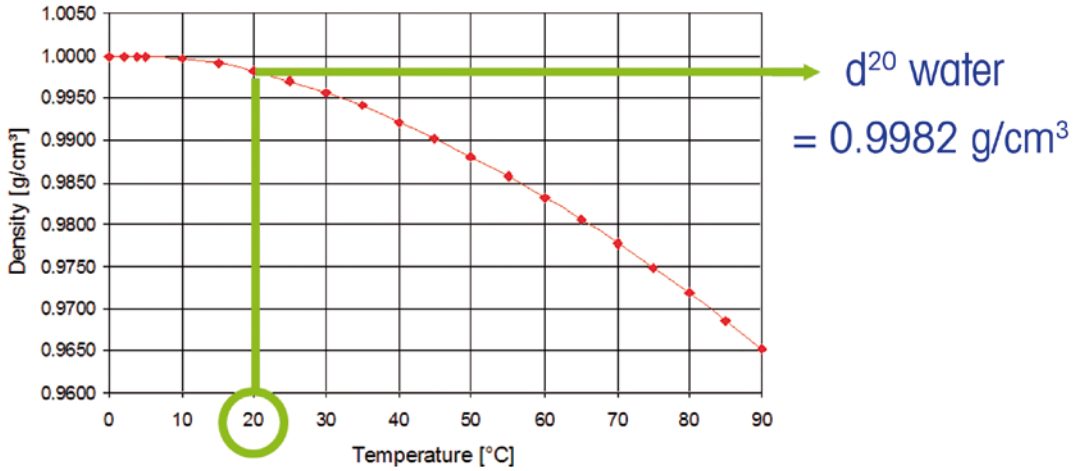


Figure 20. Influence of temperature on water density

8.3 Tips and Hints for Density Measurement

Sampling

Fill the measuring cell properly. Do NOT underfill. If filling is not sufficient, contamination is not flushed and could remain in the cell and yield a false measurement. Make sure that the sample comes out of the cell at least an extra 10 cm, so that contamination can be pushed out and only new sample is left in the cell as shown in Figure 21.

Figure 21. Filling of the density cell. Left: inappropriate. Right: good.

Fill the measuring cell at a slow speed and with a laminar flow (5–10 cm per second) to ensure complete wetting of the cell walls (no trapped bubbles along the walls). Make sure that no air is entrapped in the syringe. The plunger has to be pressed slowly and continuously without stopping.

Manual sample handling with a syringe is always operator-dependent and hence, error-prone. Automatic filling systems ensure that the cell is filled with the correct speed and in a reproducible manner, independent of operators and samples.

Figure 22. Manual sampling is key to obtain accurate density measurement results

Air bubbles

After filling, check to see that the cell is bubble-free. Air bubbles cause erroneous measurements. Even very small quantities of air lead to big density errors. METTLER TOLEDO DM Density Meters have a built-in Bubble Check™ to prevent these errors.

Diameter of the air bubble [mm]	Max. measuring error caused [g/cm³]
2	0.000838
1	0.000052
0.5	0.000003

Table 3. Measuring errors caused by air bubbles

Cleaning

Clean the density cell by rinsing. Afterwards, air-dry the cell. Before rinsing, remove all sample from cell and tubes. For each kind of sample, we recommend rinsing using the following two solvents.

Sample	Solvent 1	Solvent 2
Water based	Water	Acetone or Ethanol (puriss)
Acids	Lots of water	Acetone or Ethanol (puriss)
Fats and oils	Deconex® (0.3 to 0.5% in Water)	Acetone or Ethanol (puriss)
Petrochemicals	Toulene or petrol ether	Hexane or similar if temp. is >30 °C At room temp. use lowboiling petrol ether mixture or acetone
Conc. sugar solutions/syrup	Water (use enough water before rinse with acetone to avoid risk of polymerization	Acetone (puriss)

Table 4. Recommended rinsing solvents

8.4 Reference

How to Achieve Best Results, Day-to-Day Density Measurement, Mettler-Toledo, © 07/2012

9. Refractive Index – Concentration Determination

9.1 Refractive Index

Refractive index is a physical property characteristic of pure liquid samples. Hence, it can be applied to identify liquids such as solvents, oils and the like.

In solutions, the refractive index depends on the concentration of the dissolved compounds. Once calibrated, a refractive index reading can be used to evaluate compound's concentration e.g. sugar (Brix), alcohol and salt. However, a stringent correlation between refractive index and concentration can only be applied to binary mixtures of one compound in one solvent.

9.2 Measurement Principle and Refractometers

The refractive index depends on temperature (it decreases with increasing temperature). That's why refractive index measurements are usually done at a temperature of 20 °C. The refractive index also depends on the wavelength of the light beam used (it increases with increasing wavelength). Today's refractometers use light beams of 589.3 nm wavelength, which is the so-called D-line of sodium. Traditionally we use n as the character for refractive index. Hence, the refractive index is written as n_D^{20}.

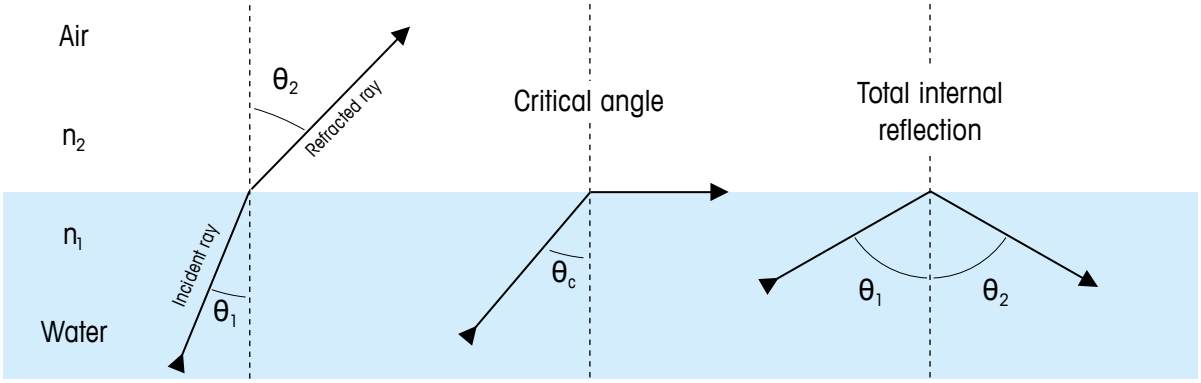


Figure 23. Refraction, critical angle and total reflection of a light beam passing from one material (e.g. water) to another (e.g. air)

In automatic digital refractometers, light is beamed under a broad angle to a prism. The prism is in direct contact with the sample. Depending on the refractive index of the sample, the incoming light is transmitted (=refracted) or totally reflected. The angle of total reflection is determined by a CCD array sensor from which the refractive index of the sample is evaluated.

The measuring cell of modern refractometers is a solid state unit without mechanical parts. Thermostating is integrated, and a few drops of sample are sufficient. That's why modern refractometers are very easy to use and measurement is fast and independent of vibrations.

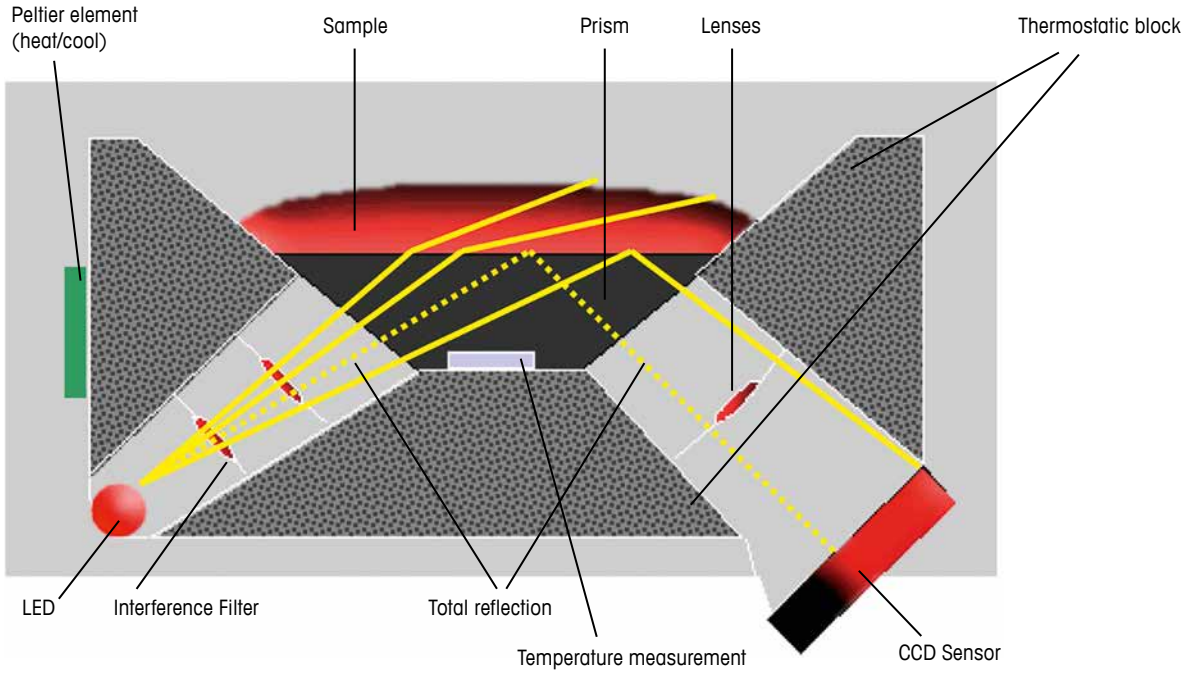


Figure 24. Schematic of a modern refractometer cell

9.3 Tips and Hints for Refractive Index Measurement

Sampling

Use plastic syringes with luer tip, preferably 3-component syringes (i.e. with rubber O-ring) as they allow a much better speed control than cheap 2-component syringes. Add sample to the prism. Stir the sample with the tip of the syringe to remove air cushions between the prism and the sample.
It is especially important for sticky samples to stir carefully and avoid air cushions.

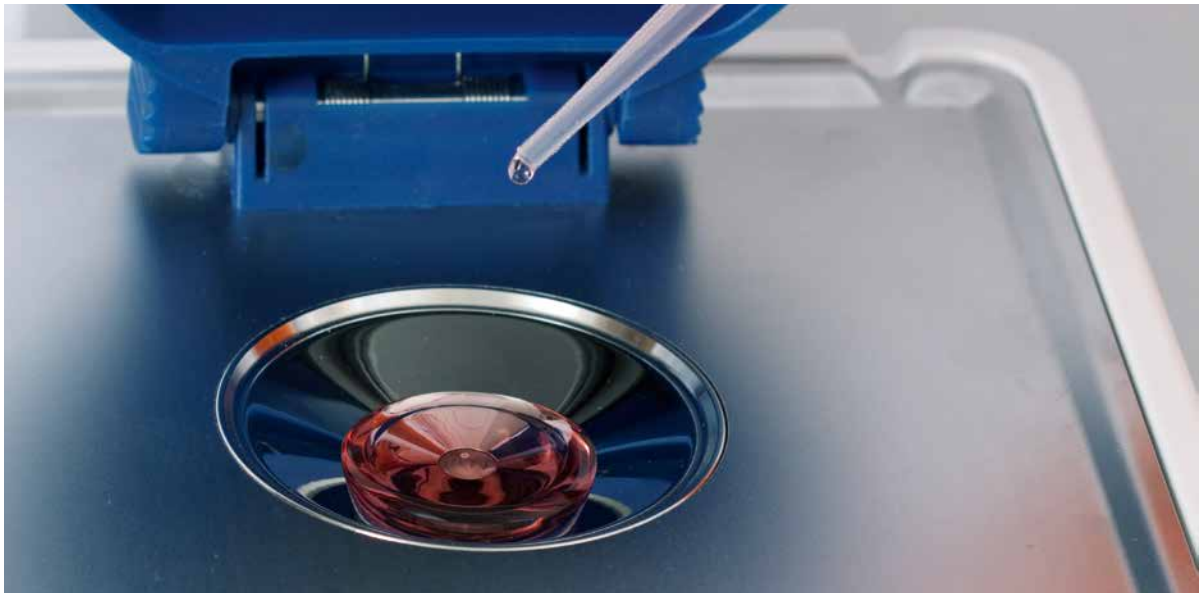


Figure 25. A few drops of sample on the prism of the refractometer are sufficient

Cleaning a refractometer

We recommend syringes to remove the sample (and solvents) from the refractometer cell. This "waste syringe" can be used over and over again (Tip: Mark this syringe so it does not get mixed into your general population, perhaps with black or colored tape.). Using a syringe saves soft tissue cleaning wipes and reduces waste.

Clean with an ideal solvent a few times. The solvent must be able to quickly dissolve the sample. In short:
1. Add the solvent
2. Stir with the "waste syringe"
3. Remove all liquid with the "waste syringe"

A second solvent which allows quick drying (e.g. Acetone) often bears the risk for contamination.
Wipe the prism (cell) dry with a soft tissue. Wait 10 seconds before adding your next sample.

The cleaning procedure can be automated to simplify operation and assure proper cleaning. This mainly applies when sample changers are used (e.g. METTLER TOLEDO SC1, SC30 and FillPal™).

9.4 Reference

How to Achieve Best Results, Day-to-Day Refractive Index Measurement, Mettler-Toledo, © 07/2012

10. Melting, Dropping, Boiling, Cloud and Slip Melting Point

10.1 Melting Point

Melting point determination is one of the oldest methods of identification and testing, particularly for organic substances. Melting point is easy to determine and, since it is a numerical property, can be conveniently tabulated and classified. Since melting point is highly dependent on purity, it can also be used for evaluating the quality of substances.
Pure substances melt at a highly-defined temperature whereas impure, contaminated substances generally exhibit a larger melting interval. The temperature at which all material of a contaminated substance is molten is usually lower than that of a pure substance. This behavior is known as melting point depression.

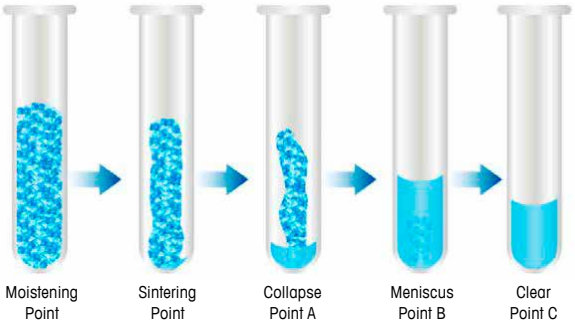


Figure 26. Manual melting point determination

10.1.1 The Melting Point Measurement Principle

The determination of melting point is usually performed in glass capillaries with an internal diameter of approx. 1 mm and a wall thickness of 0.1–0.2 mm. Finely-ground sample is placed in the capillary tube to a filling level of 2–3 mm and heated in an appropriate furnace. The melting process is visually inspected.

Powdered crystalline materials are opaque in the crystalline state and transparent in the liquid state. This distinct difference in optical properties can be measured to determine melting point by recording the percentage of light intensity shining through the substance in the capillary (i.e. the transmittance) in relation to the measured furnace temperature. In the METTLER TOLEDO melting point instruments MP50, MP70 and MP90, a red LED is used as the transmission light source which shines through holes inside the furnace in the lower region of the capillary. The transmitted light is recorded by a video camera.

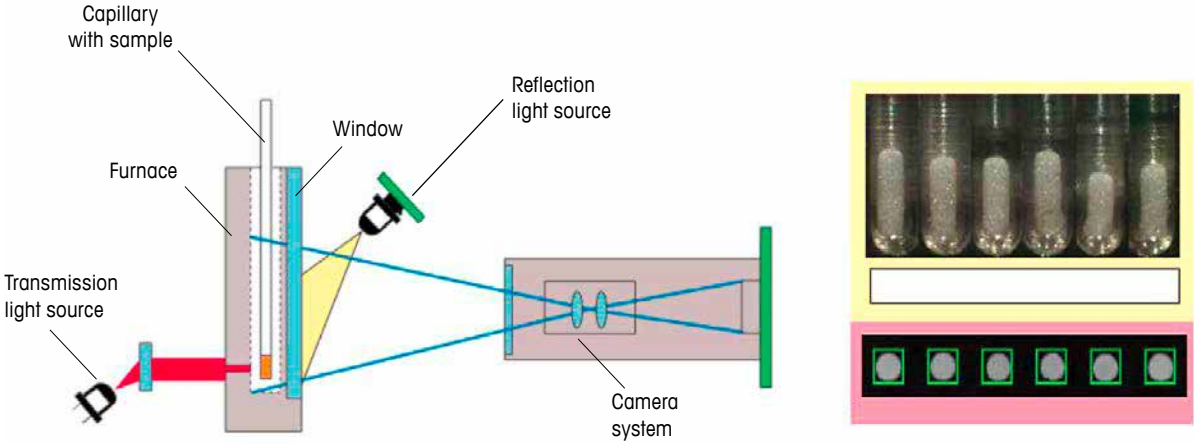


Figure 27. Manual melting point determination

10.1.2 Tips and Hints for Melting Point Sample Measurement

- Heating rate: Usually 1 °C/min. For highest accuracy and non-decomposing samples, use 0.2 °C/min. With substances that decompose, 5 °C/min; for exploratory measurements 10 °C/min.
- Start temperature: This should be set at 3–5 minutes before the expected melting point (3 to 5 times the heating rate).
- End temperature: A successful measuring curve requires an end temperature that is approximately 5 °C above the expected event. Otherwise, use the method parameter "Stop at event" to terminate the temperature program automatically as soon as all samples are completely melted.
- Colored or decomposing samples (azo benzene, potassium dichromate, cadmium iodide) or samples that show a tendency to include air bubbles in the melt (urea) may require either the lowering of threshold value B (meniscus point) or usage of the C value (clear point) as the evaluation criteria because the transmission increase will not be so high during the melting.
- Samples that decompose or sublime (such as sugar or caffeine, respectively): Seal the capillary with a flame. The volatile components produce an overpressure inside the closed capillary that inhibits further decomposition or sublimation.
- Incorrect sample preparation may result in transmission curves that do not exceed the 40% threshold value of point B. It is recommended that you either reduce the threshold value or use the C point for evaluation. Point C is independent of the threshold level (MP70/90 only). In pure, crystalline substances the respective temperature values of points B and C are usually very close. This means a temperature difference of 0.2 °C or less. This difference is within the measurement uncertainty and therefore the respective temperature values can be regarded as equal. Note: the C point can be thermodynamically corrected.
- Use of melting point capillaries that are very precisely manufactured ensuring highly accurate and repeatable results, e.g. capillaries from METTLER TOLEDO, is recommended. If other capillaries are used, the instruments should be calibrated and, if required, adjusted using these capillaries.

10.2 Dropping Point

Synthetic but also naturally-occurring products that are important raw materials for various industry segments do not show a defined melting point. They include ointments, synthetic and natural resins, edible fats, greases, waxes, fatty acid esters, polymers, asphalt and tars. These materials gradually soften as the temperature rises and melt over a relatively large temperature interval. Generally the dropping or softening point test is one of the few easily achievable methods available to thermally characterize such materials. To ensure comparable results, standardized test equipment and conditions, as well as appropriate sample preparation, are required.

10.2.1 The Dropping Point Measurement Principle

In principal, the dropping point is the temperature at which the first drop of the molten substance precipitates from a standardized vessel with a defined orifice under controlled test conditions in a furnace. Manual methods require the visual inspection of the dropping point process, which is tedious as the attention of an operator is required for an extended period of time to continuously watch the test process. The drop point itself is a suddenly occurring event, as the liquefied drop is accelerated by gravity as it escapes the cup. Once this happens, the operator needs to quickly note the temperature. In summary, manual dropping point testing is a time-consuming, error-prone process that is strongly influenced by operator bias.

If human observation is replaced by a device that records and evaluates the dropping point event automatically, the quality of the result is improved greatly. In Dropping Point Excellence instruments from METTLER TOLEDO, a white balanced LED light is shone on the test assembly, which consists of the cup and holder inside the furnace. The reflection is recorded by a video camera. The entire drop point test is video-recorded and image analysis is used to detect the first drop that escapes the sample cup when it passes through a virtual white rectangle located underneath the cup orifice. While detecting this, the furnace temperature is measured and recorded at a resolution of 0.1 °C.

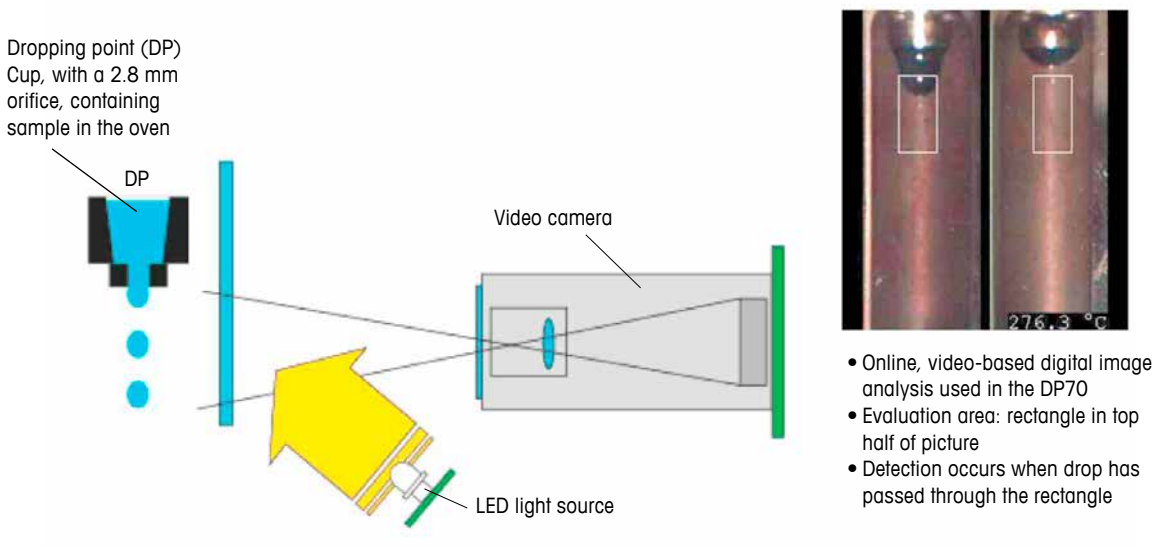


Figure 28. Automatic dropping point determination

The softening point is determined in a very similar way using the same instruments.

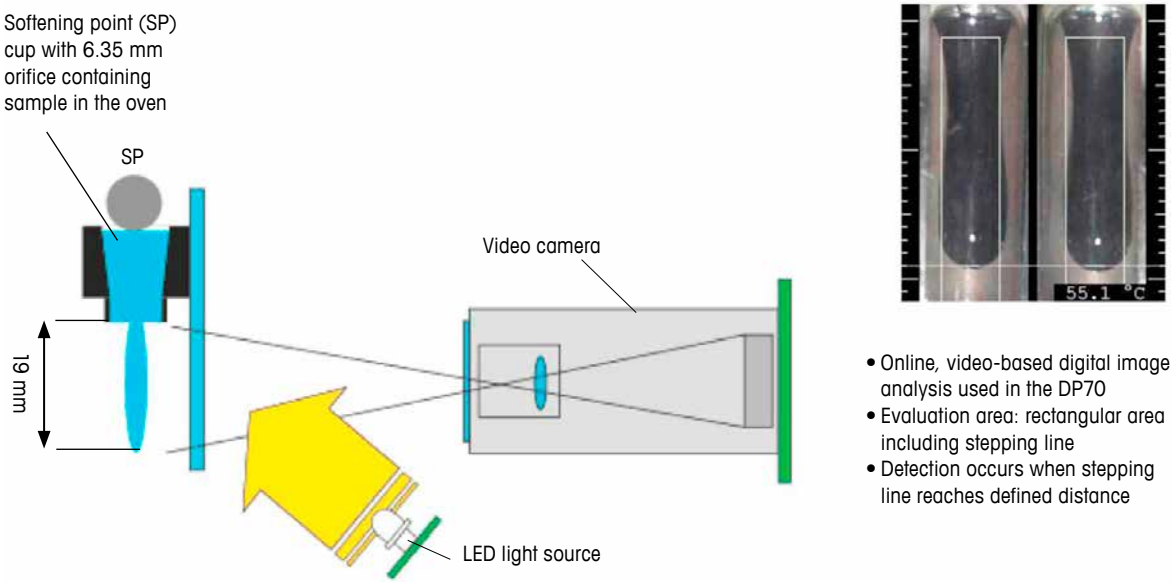


Figure 29. Automatic softening point determination

10.2.2 Tips and Hints for Dropping and Softening Point Sample Measurement

Efficient and reliable sample preparation

The basis for comparable and reliable results in dropping and softening point analysis is repeatable sample preparation. With the DP Excellence sample preparation tool this crucial step is perfectly supported. Benefits include:

- Efficient sample preparation, as four cups can be prepared at a time.
- Minimization of handling errors. Operational security is maximized.
- Avoidance of contaminating the sample cup's outside for better results reliability.

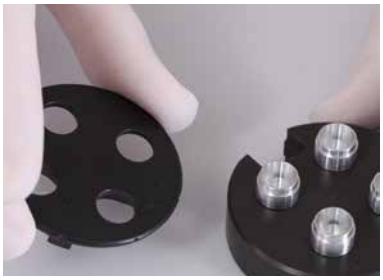


Figure 30. Sample preparation tool

The METTLER TOLEDO sample preparation tool was patented in 2013 (EP2564927, European Patent Office). It augments the DP Excellence instruments to a complete system that facilitates and secures the complete analytical workflow in dropping and softening point analysis.

Sample holder and standard-compliant cups

For dropping and softening point determinations, standardized dropping and softening point cups are used. METTLER TOLEDO offers cups made of chromium-plated brass or aluminum.

The experimental setup required for an automatic dropping and softening point test consists of the sample-containing cup, closed with a lid, and a collection glass underneath to collect the liquefied sample.

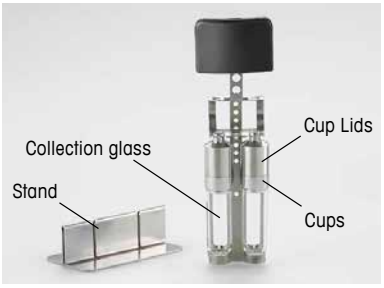


Figure 31. a, b and c: sample carriers and cups

Solid samples

For powdered samples the disk-like funnel is mounted on top of the sample preparation assembly unit which guides the powder into the sample cup underneath. The diameter of the funnel hole corresponds exactly with the aperture of the underlying cup. A small portion of ground sample is filled via the aligned funnel into the cup. The rounded end of the tamping rod is then used to compress the sample in the cup.

This procedure is repeated until the cup is completely filled with sample. The flat part of the tamping rod is then used to compress the sample in order to make it level with the surface of the support disk. The hole of the support disk is then turned to the next cup and the filling procedure is repeated.

Figure 32. Filling the first portion of a sold sample

Lubricants, greases

Sample preparation for lubricant grease follows the original specifications described in the ASTM D556 standard, which is also used in the ASTM D2265 and IP 396 standards.

Bitumen, pitch
After melting, the sample is poured into the cups using the sample preparation tool. The sample is then cooled down to ambient temperature for at least 30 minutes. Excess sample is removed from the cup with a hot knife. Here, the sample preparation tool helps considerably with filling the dropping point cups. Thanks to the support disk, any outside surface contamination is avoided. Removal of excessive sample from the cup is a very easy and repeatable task because the surface of the support disk is level with the rim of the softening point cup.

Resins, rosins
Resins and rosins are prepared in principle in the same way as bitumen. When melting the samples, avoid boiling and air bubbles. Avoid excessive overfilling and remove excess with a hot knife.

Waxes
In principle, wax samples are prepared like other molten samples. Again, the sample preparation tool is used. Carefully pour the molten wax sample into the cup, avoiding the inclusion of air bubbles.

10.3 Boiling Point

The boiling point of a chemical compound is the temperature at which a phase transition from liquid to gas occurs under normal conditions. It is a substance-specific property that can provide useful information about the identity and purity of a substance, and is often used to select an optimal process temperature – such as in determining an ideal storage condition. Knowledge of this property is required for Material Safety Data Sheets (MSDS).

10.3.1 The Boiling Point Measurement Principle

To determine the boiling point, approximately 100 µL of sample is pipetted into a glass tube. A smaller boiling point capillary is then inserted into the filled tube to prevent superheating of the liquid, which would induce boiling retardation and give rise to inaccurate readings. The sample is then inserted into the instrument, and the method is started.
The temperature rises, and gas bubbles are formed within the liquid and escape to the surface. These ascending bubbles reflect the light of the built-in light source and are detected individually. The frequency of the bubbles is measured and is used as the basis for boiling point determination.

Because the boiling temperature is pressure-dependent, a calculation is necessary to derive the boiling point at normal pressure. Most determinations are made at ambient pressure. Ambient pressure is measured with a built-in calibrated barometer, and compensation to sea-level pressure is automatically calculated and applied to the results.

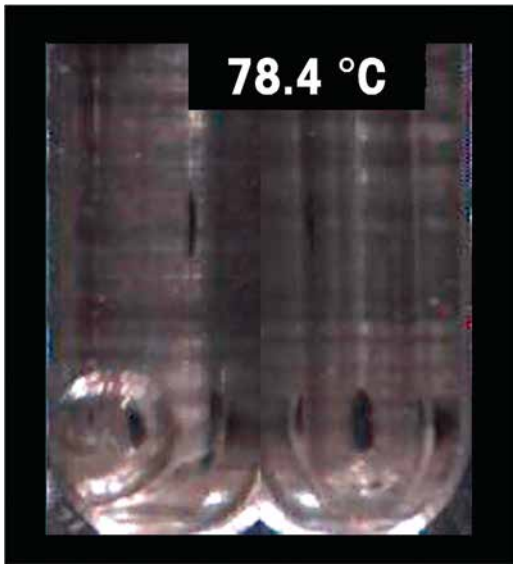


Figure 33. Duplicate, simultaneous boiling point determination

10.3.2 Tips and Hints for Boiling Point Sample Measurement

- Insert the smaller boiling point inner capillary into the boiling point outer capillary to prevent superheating. A new boiling point inner capillary has to be inserted for every measurement.
- Heating rate: Usually 1 °C/min
- Start temperature: This should be set at 3–5 minutes before the expected boiling point (3 to 5 times the heating rate).
- End temperature: A successful measuring curve requires an end temperature that is approximately 5 °C above the expected event. Otherwise, use the method parameter "Stop at event" to terminate the temperature program automatically as soon as both samples have reached their boiling point.
- Colored samples: For dark-colored samples, adjust the manual brightness to an intensity that would allow for best detection of the boiling point.

10.4 Cloud Point

The cloud point of a solution corresponds with the temperature above which a sample becomes turbid. It is most commonly used to conduct quality control verifications to ensure a high level of production and technical performance. Often, cloud point protocols ask for a 1% weight dilution of the substance of interest – usually a surfactant, emulsion, or dispersion – in water. Water solubility of this substance tends to vary inversely with temperature: the higher the temperature, the lower the solubility, and the cloud point is the temperature at which the solution reaches saturation and becomes turbid.

10.4.1 The Cloud Point Measurement Principle

Cloud point determination is typically performed with a 1% weight dilution of the substance of interest in water. Approximately 100 µL of sample is pipetted into a glass tube and inserted into the instrument, and the method can be started.

The solution of interest is transparent at the beginning of the experiment, and when the cloud point is reached, the solution becomes turbid. This turbidity is monitored via transmitted light detection – the higher the temperature above the cloud point, the more turbid the solution, and thus the less light transmitted through the solution. Automatic video camera detection of the decrease in transmitted light intensity is the key to obtaining repeatable and reliable cloud point results.

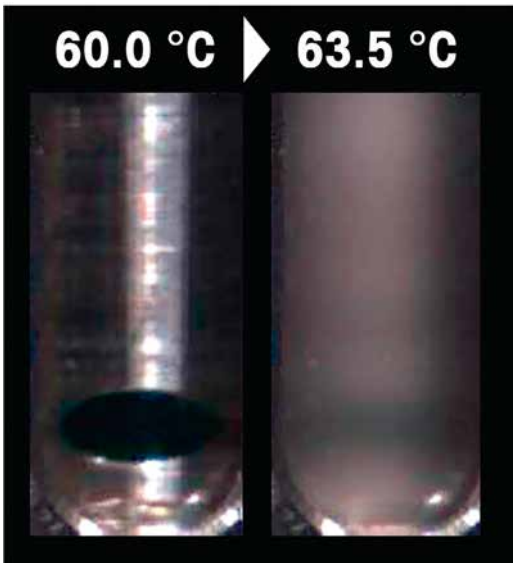


Figure 34. Automatic cloud point determination. At 60.0 °C, the solution is clear. At 63.5 °C, the solution has become turbid and the cloud point is detected

10.4.2 Tips and Hints for Cloud Point Sample Measurement

- Heating rate: Usually 1 °C/min
- Start temperature: This should be set at 3–5 minutes before the expected cloud point (3 to 5 times the heating rate).
- End temperature: A successful measuring curve requires an end temperature that is approximately 5 °C above the expected event. Otherwise, use the method parameter "Stop at event" to terminate the temperature program automatically as soon as both samples have reached their cloud point.

10.5 Slip Melting Point

The Slip Melting Point is often used to characterize fats, oils, and waxes – or any other solids that do not have a defined or sharp melting point. Depending on the composition of the sample and its corresponding slip melting point, the sample can be used in a variety of applications from low to high temperatures: from ice cream to cosmetics. The slip melting point aids in the characterization of products and supports international trade, making standardization and compliance pivotal.

10.5.1 The Slip Melting Point Measurement Principle

Determination of the slip melting point involves the following: An inner slip melting point capillary tube containing a column of fat (approximately 10 mm in length) crystallized under controlled conditions is immersed in water, which is then heated at a specific rate. The temperature at which the column of fat is observed to start rising in the inner capillary tube – due to a combination of buoyancy and the molten outside surface of the column – is recorded as the slip melting point.

The slip melting point of the substance is evaluated via digital image analysis. When the column of substance starts to move upwards, the image processing algorithm determines the slip melting point fully automatically.

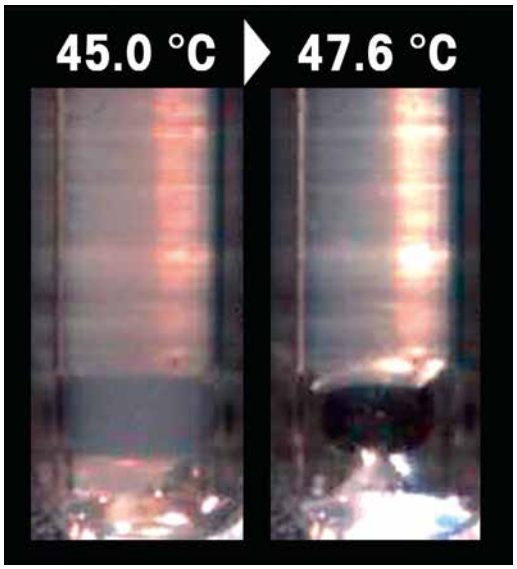


Figure 35. Automatic slip melting point determination. At 45 °C, the sample column still has not moved. At 47.6 °C, the substance has reached its slip melting point

10.5.2 Tips and Hints for Slip Melting Point Sample Measurement

- Heating rate: Usually 1 °C/min
- Start temperature: This should be set at 3–5 minutes before the expected slip melting point (3 to 5 times the heating rate).
- End temperature: A successful measurement requires an end temperature that is approximately 5 °C above the expected event.
- In order to determine the slip melting point reliably, the diameter of the outer capillary must be at least twice as wide as the diameter of the inner capillary: both the outer and inner capillaries from METTLER TOLEDO fulfill this requirement.

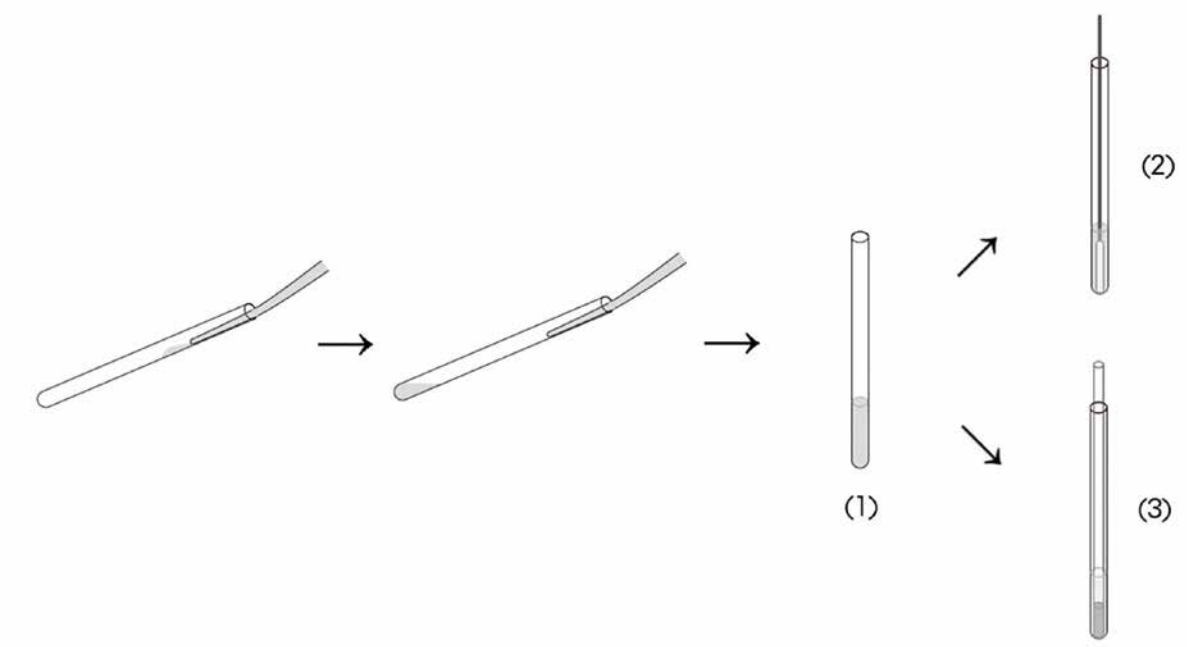


Figure 36. Sample preparation for boiling (2), cloud (1), and slip melting point (3). Insert the pipette tip containing the solution of interest into the boiling point outer capillary so that it touches the inside wall of the capillary, and allow the solution to slowly slide to the bottom of the capillary. If you are preparing a boiling point sample, insert the boiling point inner capillary after sample addition. If you are preparing a slip melting point sample, insert the slip melting point inner capillary containing 10 mm of sample after addition of the solution.

10.6 Reference

Automated Melting & Dropping Point Analysis, A Comprehensive Textbook, Mettler-Toledo, 30097042, © 09/2014

11. Thermal Analysis

11.1 A Brief Explanation of Important Thermal Analysis Techniques

DSC – Differential Scanning Calorimetry

In DSC, the heat flow in and out of both a sample and a reference material is measured as a function of temperature as the sample is heated, cooled or held isothermally at constant temperature. The measurement signal is the energy absorbed or released by the sample in milliwatts.

DSC allows you to:

- detect endothermic and exothermic effects,
- determine peak areas (transition and reaction enthalpies),
- determine temperatures that characterize a peak or other effects, and
- measure specific heat capacity.

DTA – Differential Thermal Analysis

In DTA, the temperature difference between the sample and an inert reference substance is measured as a function of temperature. The DTA signal is °C or K. Previously, only the thermocouple voltage in mV or µV was displayed.

SDTA – Single DTA

This term was patented by METTLER TOLEDO and is a variation of classical DTA that is particularly useful when used with thermogravimetric analysis simultaneously. The measurement signal represents the temperature difference between the sample and a previously measured and stored blank sample.

DTA (and SDTA) allow you to:

- detect endothermic and exothermic effects, and
- determine temperatures that characterize thermal effects.

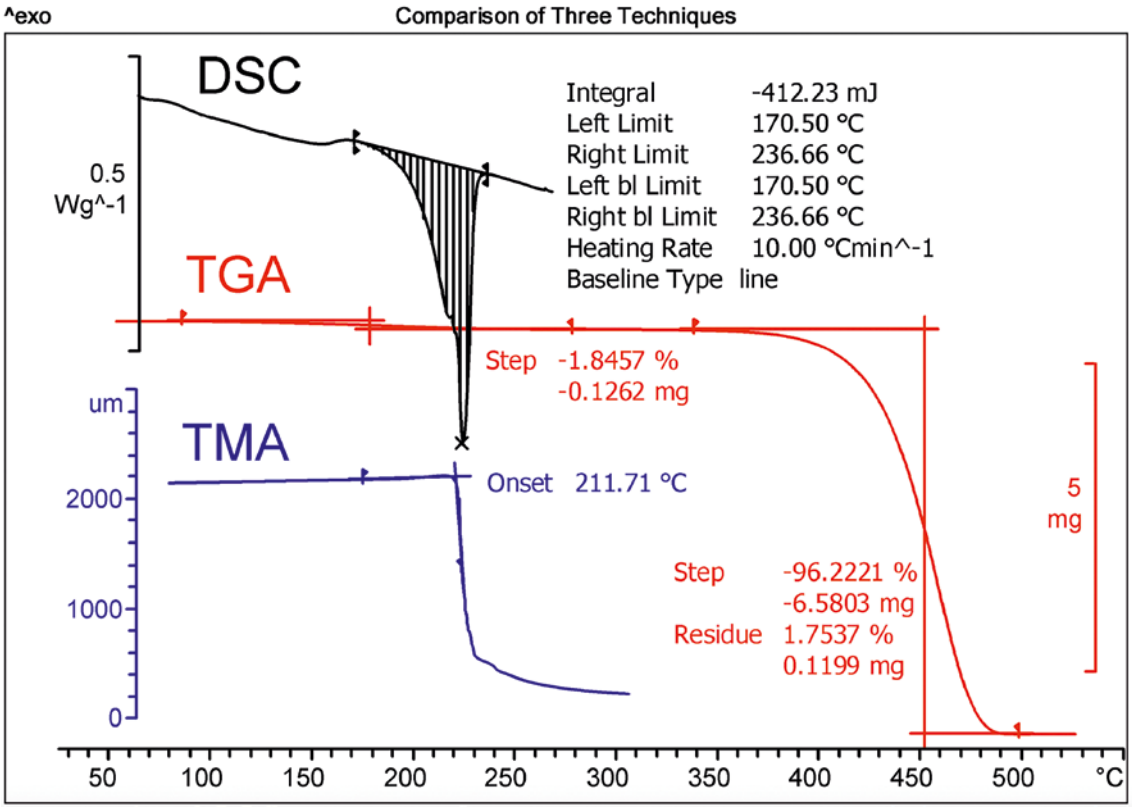


Figure 37. The three techniques used to measure polyamide 6 show different thermal effects. DSC: melting peak of the crystalline part; TGA: drying and decomposition step; TMA: softening under load.

TGA – Thermogravimetric Analysis
TGA measures the weight and hence mass of a sample as a function of temperature. The acronym TG was previously used. Nowadays, TGA is preferred in order to avoid confusion with Tg, the glass transition temperature.

TGA allows you to:
- detect changes in sample mass (gain or loss),
- determine stepwise changes in mass, usually as a percentage of the initial sample mass, and
- determine temperatures that characterize a step in the mass loss or mass gain curve.

EGA – Evolved Gas Analysis
EGA is the name for a family of techniques by means of which the nature and/or amount of gaseous volatile products evolved from a sample is measured as a function of temperature. Important analysis techniques are mass spectrometry and infrared spectrometry. EGA is most often used in combination with TGA because volatile compounds are eliminated in every TGA effect (mass loss).

TMA – Thermomechanical Analysis
TMA measures the deformation and dimensional changes of a sample as a function of temperature. In TMA, the sample is subjected to a constant force, an increasing force, or a modulated force, whereas in dilatometry dimensional changes are measured using the smallest possible load.

Depending on the measurement mode, TMA allows you to:
- detect thermal effects (swelling or shrinkage, softening, change in the expansion coefficient),
- determine temperatures that characterize a thermal effect,
- determine deformation step heights, and
- measure expansion coefficients.

DMA – Dynamic Mechanical Analysis
In DMA, the sample is subjected to a sinusoidal mechanical stress and the force amplitude, displacement (deformation) amplitude and phase shift are determined.

DMA allows you to detect thermal effects based on changes in the modulus or damping behavior. The most important results are:
- temperatures that characterize a thermal effect,
- the loss angle (the phase shift),
- the mechanical loss factor (the tangent of the phase shift),
- the elastic modulus or its components the storage and loss moduli, and
- the shear modulus or its components the storage and loss moduli.

TOA – Thermooptical Analysis
By TOA, we mean the visual observation or the measurement of the optical transmission of a sample, for example in a thermo-microscope. Typical applications are the investigation of crystallization and melting processes as well as polymorphic transitions.

TCL – Thermochemiluminescence
TCL is a technique that allows you to observe and measure weak light emission that accompanies certain chemical reactions.

11.2 Application Overview

Table 5 summarizes which material properties or applications can be analyzed by which thermal analysis technique.

Property or application	DSC	DTA	TGA	TMA	DMA	TOA	TCL	EGA
Specific heat capacity	•••	•						
Enthalpy changes, enthalpy of conversion	•••	•						
Enthalpy of melting, crystallinity	•••	•						
Melting point, melting behavior (liquid fraction)	•••	•		•		•••		
Purity of crystalline non-polymeric substances	•••		•••			•		
Crystallization behavior, supercooling	•••	•				•••		
Vaporization, sublimation, desorption	•••	•	•••			•••		•••
Solid–solid transitions, polymorphism	•••	•••		•		•••		
Glass transition, amorphous softening	•••	•		•••	•••	•		
Thermal decomposition, pyrolysis, depolymerization, and degradation	•	•	•••	•		•		•••
Temperature stability	•	•	•••	•		•		•••
Chemical reactions, e.g. polymerization	•••	•	•				•	
Investigation of reaction kinetics and applied kinetics (predictions)	•••	•	•••					•
Oxidative degradation, oxidation stability	•••	•••	•••	•			•••	
Compositional analysis	•••		•••					•••
Comparison of different lots and batches, competitive products	•••	•	•••	•	•	•••	•	•••
Linear expansion coefficient				•••				
Elastic modulus				•	•••			
Shear modulus					•••			
Mechanical damping					•••			
Viscoelastic behavior				•	•••			

Table 5. Application overview showing the thermoanalytical techniques that can be used to study particular properties or perform certain applications.
••• means "very suitable"
• means "less suitable"

11.3 Method Development – The Analytical Task

Method development begins with precisely defining the information you hope to get from the sample analysis. Typical questions could include:

- At what temperature does the glass transition occur?
- Does the sample exhibit polymorphism?
- How pure is my product?
- What is the moisture content of my sample?

Depending on the analytical task and the information required, you first have to decide which measurement technique to use, for instance as outlined in Table 5.

11.4 Method Development Procedure

The development and validation of methods is of major importance in today's quality assurance systems. The starting point is usually a trial method that is then optimized and validated in several iterative steps. The final result is a validated method that is used for standard operating procedures (SOPs).

The development and validation of a measurement procedure is time-consuming and costly. This means it is important to start with a good trial method from the beginning. The following Figure 38 presents an overview of this process and helps to systematize the development of thermoanalytical methods.

More details about thermal analysis measuring techniques, applications and method development are explained in METTLER TOLEDO's Thermal Analysis Application Handbooks.

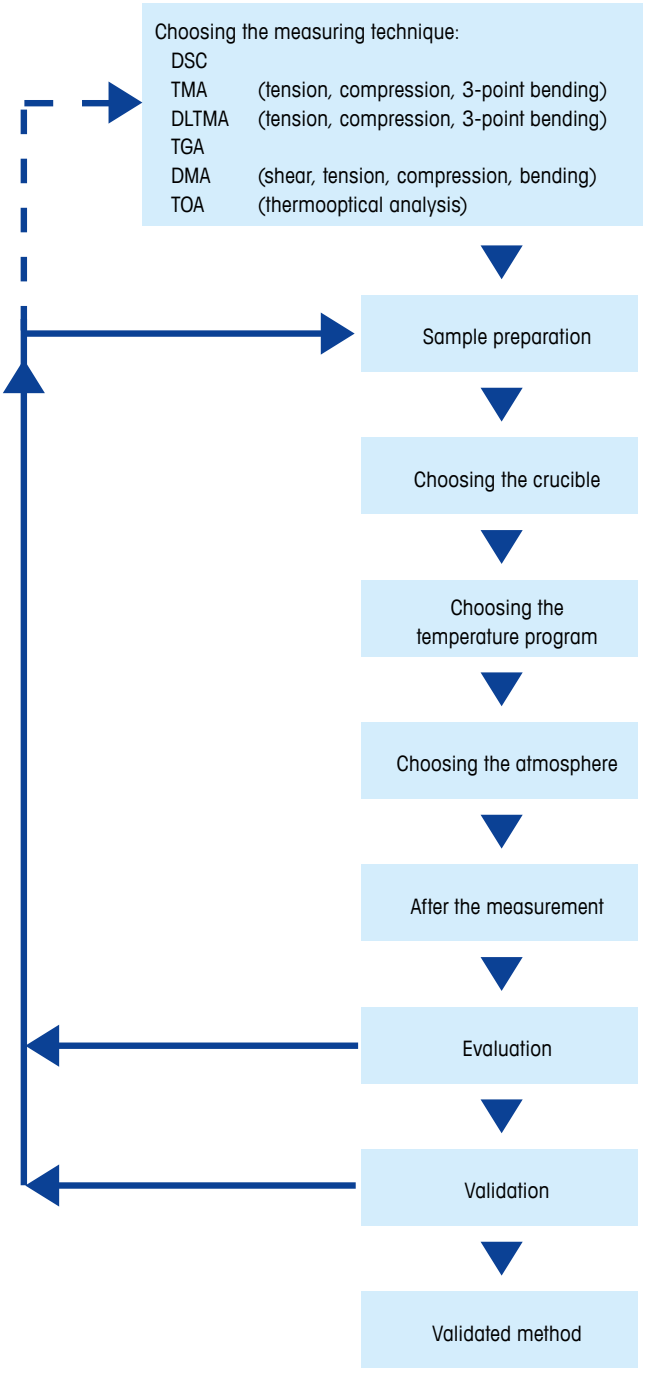


Figure 38. Procedure for developing a thermoanalytical method

11.5 Precision, accuracy, trueness

- For a detailed description of method validation, accuracy, repeatability, measurement errors and other issues related to the quality of data, please consult our "Validation in Thermal Analysis" handbook [www.mt.com/ta-handbooks]. This handbook gives an in-depth description of the terminology used and discusses many examples of DSC, TGA, TMA and DMA analyses.
- A shorter summary entitled "Precision, accuracy, trueness" is given in [UC 29/1].

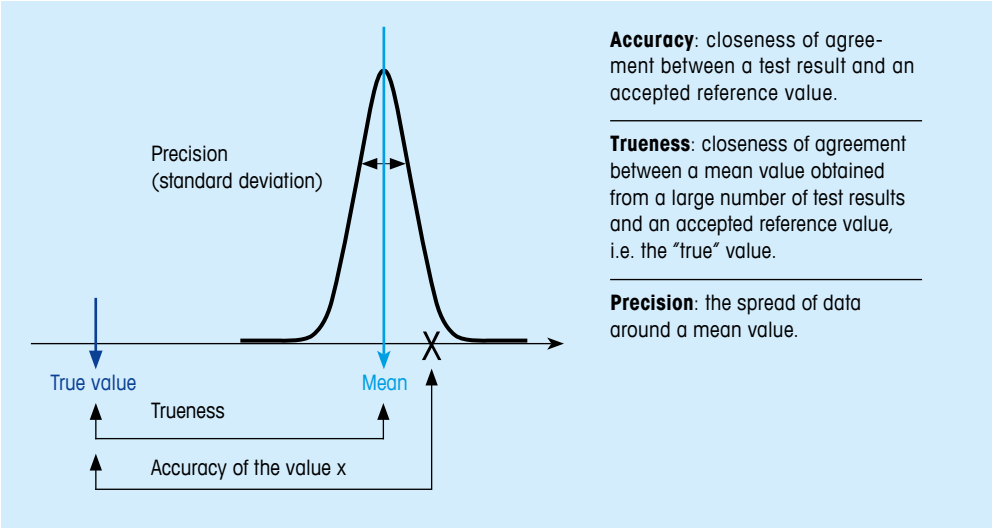


Figure 39. The relationship of accuracy, trueness and precision

11.6 Uncertainty of measurement

The total measurement uncertainty is made up of all the possible errors involved in the individual steps of the analysis. For example, the influence factors shown in the cause-and-effect (or fishbone) diagram play a role in the measurement of the enthalpy of fusion by DSC.

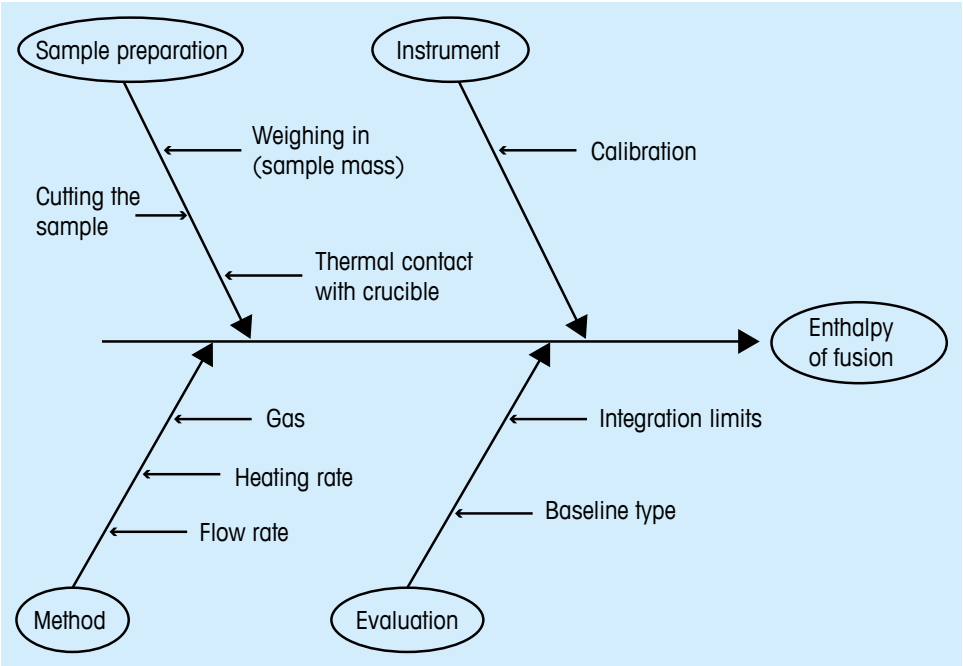


Figure 40. Fishbone diagram of a DSC example

Estimates for the individual contributions of uncertainty for this example are given in the table below:

Source	Uncertainty of measurement
Mass of the test specimen	±20 µg (e.g. reproducibility of the balance; if the mass is about 10 mg, this corresponds to ±0.2%)
Putting the substance into the crucible	negligible
Thermal contact with the crucible	±0.5% (estimate)
Heating rate	negligible
Gas and gas flow	negligible if the instrument has been adjusted under the same conditions as the measurement
Adjustment	±1.5% (uncertainty of the calibration material)
Integration limits and baseline type	±3% (statistics of repeated evaluations)

Table 6. Estimated influence of selected uncertainty factors

The contributions can then be added together according to the rules of propagation of uncertainty to obtain a value for the combined uncertainty:

$$\pm\sqrt{(0.2\%)^2 + (0.5\%)^2 + (1.5\%)^2 + (3\%)^2} = \pm 3.4\% \ (p_c = 68\%)$$

- A more detailed description of measurement uncertainty can be found in [UC 30/1].
- For TGA measurements, it is important to be aware of the minimum sample weight according to USP when measuring very small sample masses or residues. A complete description of the influence of the minimum weight of a balance specifically for TGA is given in [UC 41/14].

11.7 Method validation

There are three ways to obtain validated analytical methods; the details are summarized in the table below. For a detailed description of method validation, please refer to our "Validation in Thermal Analysis" handbook.

Analytical method validation	Inter–laboratory studies	International standards
• The method is designed from the very beginning by the user and tested for the relevant variables (e.g. operator, sample preparation, instrument, environment, accuracy, repeatability). Several iterations to optimize the method parameters might be needed. • The method is exactly that required by the user. • Validation of the method can take a long time.	• A specific analytical method is tested by all the participating labs using multiple specimens. The results are submitted to a central organizing body that evaluates the data and issues recommendations for the expected accuracy of the method. • A large amount of data can be obtained relatively quickly. • Reproducibility (repeatability between different labs) can also be tested.	• A published method can be used as it is described. The accuracy and precision to be expected are given in the standard documentation. • This is the easiest way to obtain a validated method. • The method might not fully meet the requirements or might not include particular tests. • Many international standards are available, for example from ISO, ASTM, and so on. See Chapter 20 in the "Thermal Analysis in Practice" handbook for a complete list of standards relevant to thermal analysis.

Table 7. The three ways to obtain validated analytical methods

11.8 Samples

This chapter describes sample-specific issues. We will begin by discussing some general requirements for sample preparation that apply to DSC, TGA, TMA and DMA. Afterward, we will focus on the sample requirements for individual instruments. We will then finish with sample containers and sample holders, that is, with crucibles for DSC and TGA, and clamping assemblies for TMA and DMA.

11.8.1 General requirements for samples

Some of the requirements for the sample and sample preparation are common for DSC, TGA, TMA and DMA:

Before the measurement

- The sample should be representative of the bulk material [UC 29/1].
- The sample should not be altered thermally or mechanically.
- The sample composition should remain unchanged (moisture, impurities, oxidation).
- The sample should not react during preparation (curing during storage, e.g. induced by light).

During the measurement

- Use the right atmosphere:
  - Inert gas: nitrogen, helium, argon, etc.
  - Reactive gas: air, oxygen, etc.
  - Good interaction between the gas and the sample.
  - No gas exchange with the sample.
  - Limited interaction: self-generated atmosphere.
- Be aware of possible temperature gradients in the sample.
- Make sure that there is good thermal contact between sample and sample holder (flat sample, flat sample holder).
- The sample must not move during measurement because this will cause artifacts.

After the measurement

- Weigh the sample before and after measurement to check for the loss of volatiles or decompostion. ("offline TGA").
- Visual check of sample:
  - Molten sample: melting visible on curve?
  - Discolored sample: is decomposition visible?
  - Gas bubbles: due to decomposition?
  - Deformation of the bottom of the crucible: expansion, explosion?
- Re-evaluate results and prepare a possible second measurement with different parameters.

For further information, see the following literature: [UC 3/1] [UC 29/1].

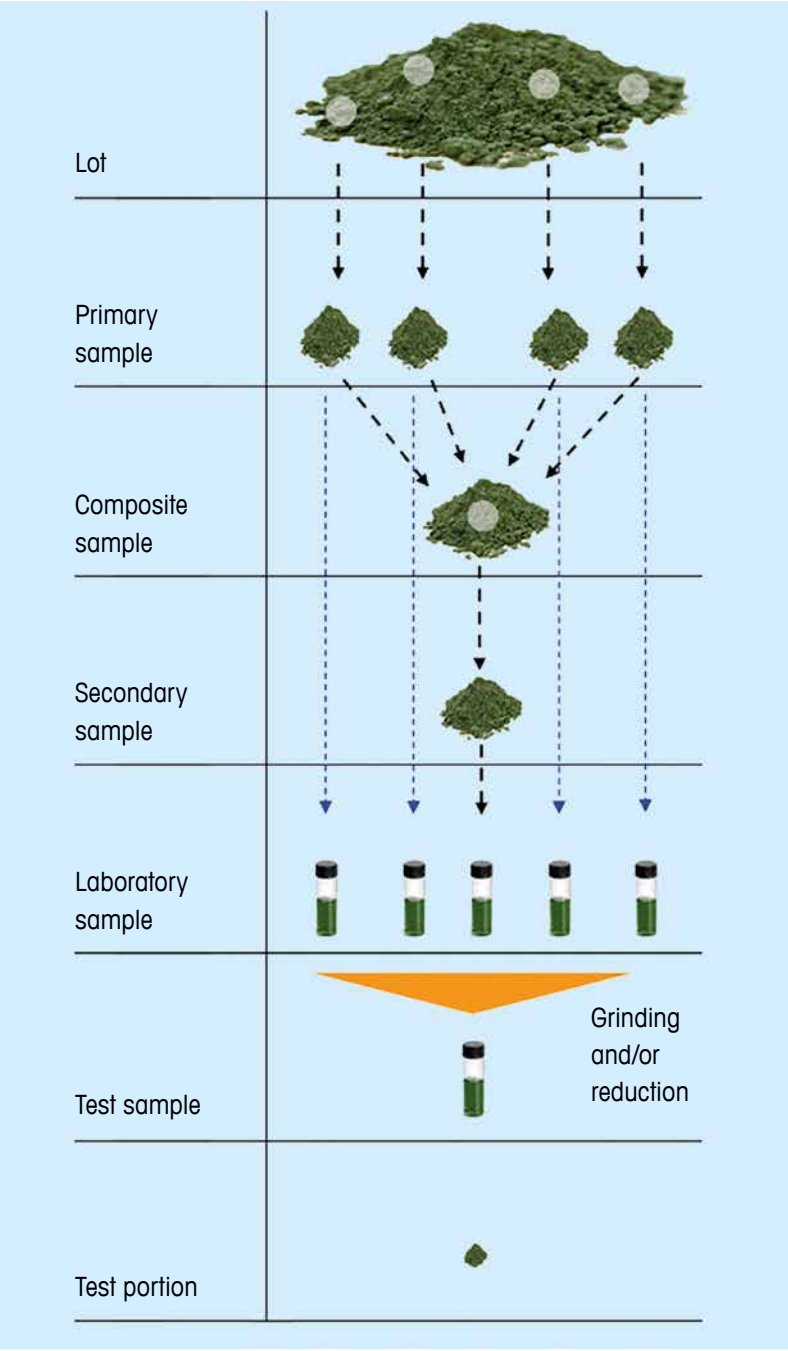
- To check the temperature gradient in the measured sample, place a piece of indium above and below the sample and measure the temperature difference by means of the two onsets (DSC, TGA, TMA, DMA).
- To prevent moisture entering the sample during the waiting time on the robot table, use the lid piercing accessory (DSC, TGA) [UC 20/17].

11.8.2 Sampling

Several important points should be considered during the sampling process. These include:

- Which production lots should be examined?
- At which point or points of a production lot or from which part or parts of a production lot should samples be examined?
- Are the sampling point and the sample size representative of the production lot with regard to possible inhomogeneity? Does the selected sample allow us to draw conclusions about the bulk sample?
- How large should the sample size be with regard to volume and number of items?
- How often should a material property be determined and how many samples should be measured?
- Are the samples taken at different points and then mixed together again to form a composite sample (or aggregate sample) or are they processed separately as test samples?
- Are the samples always representative of the bulk material from which they were taken?

The diagram shows an example of a typical sampling procedure [UC 29/1]:



11.9 Reference

Thermal Analysis in Practice, METTLER TOLEDO, 51725244, © 12/2009

12. Selected Solutions

12.1 Analytical Balances

Product line	Solution	Example
Excellence Line	Analytical Balances • Reliable and fast results • Easy compliance • Highest safety • Sustainable investment • Ergonomic operation Typical models: XPE204, XS204 • Readability: 0.1 mg • Capacity: 0…220 g	
Classic Line	Analytical Balances • For trust and comfort • Durable and robust thanks to metal housing Typical model: MS204 • Readability: 0.1 mg • Capacity: 0…220 g	

The XPE, XS, MS and ML series of analytical balances offer a large portfolio of models to meet any need of the users.

12.2 Precision Balances

Product line	Solution	Example
Excellence Line	Precision Balances • Reliable and fast results • Easy compliance • Highest safety • Sustainable investment • Ergonomic operation Typical model 1: XPE6002S • Readability: 0.01 g • Capacity: 0…6200 g Typical model 2: XS16000L • Readability: 1 g • Capacity: 0…16200 g	
Classic Line	Precision Balances • For trust and comfort • Durable and robust thanks to metal housing Typical model: MS4001S, • Readability: 0.1 g • Capacity: 0…4200 g	

The XPE, XS, MS and ML series of analytical balances include precision balances and scales with a capacity range from 210 g to 64 kg. Resolution reaches from 1 g down to 0.1 mg.

12.3 Moisture Instruments

12.3.1 Halogen Moisture Analyzers

Product line	Solution	Example
Professional Line	HX204 Halogen Moisture Analyzer Readability: 0.1 mg Capacity: 0…220 g • Record Speed from Start to Finish • Premium Performance for Best product Quality • Quality Results, Traceable Reporting • Network Connectivity	
Advanced Line	HC103 Halogen Moisture Analyzer Readability: 1 mg Capacity: 0…42 g • Routine Inspection made Easy • Smart Operation • Bright Display • Rugged Design	

METTLER TOLEDO offers an entire range of moisture analyzers to meet different performance requirements

12.3.2 Karl Fischer Titrators

Product line	Solution	Example
Volumetric KF Titrators	The volumetric Karl Fischer compact titrators V20 and V30 have been designed for specific water content determinations from a few 100 ppm to 100% water, quickly and precisely. • Intuitive user interface • Personal home screen • Solvent Manager – prevents contact with chemicals With V30 only: • Flexible user management • KF automation with Stromboli	

Also available are coulometric KF titrators for water content down to 1 ppm.

12.4 pH Meters and Electrodes

Product line	Solution	Example
Benchtop meter	S220 SevenCompact Universal instrument for measurements of pH, mV/ORP and ions	
Portable IP67 meter	S8 Seven2Go pH/Ion Professional IP67 meter for pH, ion concentration, mV/ORP and rel. mV measurements	
	S2 Seven2Go pH Routine IP67 meter for pH, mV/ORP and rel. mV measurements	
pH Electrodes	InLab Solids Pro IP67 Robust pH specialist to puncture solid or semi-solid food samples (Find your sensor: www.electrodes.net)	
	InLab Routine Pro Refillable pH sensor, precise and fast (Find your sensor: www.electrodes.net)	
	InLab Expert Pro / InLab 413 SG Robust, maintenance-free pH sensors (Find your sensor: www.electrodes.net)	

12.5 Density & Refractometers

Product line	Solution	Example
LiquiPhysics Line (benchtop models)	Refractometers RM40, RM50 METTLER TOLEDO digital refractometers are the perfect solution for Brix measurements and refractive index determinations. Our refractometers can also be expanded to measure density, pH, conductivity, color or optical rotation.	
Portable models	Refracto 30PX Hand held refractometers allow you to determine the refractive index, Brix, Baume or specific gravity (SG) of a sample in the field or on-site	

12.6 Melting, Dropping, Boiling, Cloud and Slip Melting Point

Product line	Solution	Example
DP Excellence Instrument	• Color touchscreeen • One Click® operation • Automatic dropping and softening point determination • Automatic video recording • Two samples can be measured at a time and the mean value is automatically evaluated • Outstanding temperature accuracy ± 0.2°C	
	DP70 • Compact instrument • Room temperature to 400°C DP90 • Control unit with external measuring cell • Temperature range from 400°C to –20°C	
Accessories	The DP70 and DP90 Excellence come with an accessory box that includes innovative tools for accurate and repeatable sample preparation such as cups, cup lids, collector glasses, sample preparation tool, and reference material.	

12.7 Titrators

Product line	Solution	Example
Excellence Line	T9 Titrator, T7 Titrator • Intuitive user Interface • Personal home screen • Flexible user management • Automatic burette recognition • Plug & Play sensors • Hot Plug & Play concept • Modular: tailored exactly to your needs Automation options: Rondolino, InMotion Autosampler • PC software options: LabX express, LabX server, Regulation option (21CFR11), • Full qualification services available	
Sodium Analyzer	Sodium Analyzer Specific sodium determination – simple and accurate. • Reduce sample preparation work • Use safe and inexpensive chemicals • Operation could not be easier thanks to a smartphone Apps-style user interface • No calibration is necessary thanks to the multiple standard addition technique • The integrated algorithm specifically designed for Na+ delivers highly accurate and repeatable results	
Compact Titrators	G10 and G20 Compact Titrators • Intuitive OneClick™ user Interface • Personal Home Screen • Automatic burette recognition • Plug & Play sensors • Automation options: Rondolino • PC software option: LabX express • Installation qualification service available	
EasyPlus	Easy pH Titrator, Easy Cl Titrator • Affordable entry level titrator • Quick start and intuitive operation with app based iTitrate™ user interface • Only a few parameters to be set thanks iTitrate™ intelligence. • Internet support for easy self installation and application database • Unique VPac performance qualification service available	

12.8 Differential Scanning Calorimeter DSC

Product line	Solution	Example
TA Excellence	DSC 2/2+ and DSC 3/3+ Modular system with built in innovative technology perfectly suited for fat crystallization and oxidation studies Can be expanded with valuable options like sample changer or microscope	

13. Conclusion

Lab personnel deal with many different instruments and related equipment on a daily basis. Each instrument may be operated quite differently. Hence, many operators have come to appreciate the unified and easy to understand interface concept introduced by METTLER TOLEDO for easy, straightforward instrument operation.

METTLER TOLEDO analytical instruments, balances and further solutions empower you to perform measuring and analyzing tasks with confidence and achieve correct and precise results. However, we find it is always helpful to understand the basic measurement principles upon which instrumentation is based. This understanding can help you develop better, more time-saving SOPs and ensure accuracy under various real-world conditions.

METTLER TOLEDO experts have been pleased to present the tips and hints included in this guide. It is our hope that this best practice advice helps to ensure you get the most out of your instruments and equipment. It's important to us that you achieve your target of precise and reliable analytical results and are able to manufacture quality products that satisfy your customers.

14. References

Reference used in the creation of this guide follow.

1. Proper Weighing with Laboratory Balances, Guide Book, Mettler-Toledo, 720906, © 01/2015
2. Dictionary of Weighing Terms, Springer-Verlag Berlin, 2009, ISBN 978-3-642-02013-1
3. Get Better Results, Quick Guide to Good Pipetting, Mettler-Toledo, © 02/2014
4. Pipetting Tips and Tricks, Mettler-Toledo, © 01/2013
5. A Guide to pH Measurement, Theory and Practice of Laboratory pH Applications, Mettler-Toledo, 51300047, © 03/2013
6. Guide to Moisture Analysis, Moisture Determination with the Halogen Moisture Analyzer, Mettler-Toledo, © 04/2013
7. Good Titration Practice Brochure, How to Achieve the Best Results, Mettler-Toledo, 51725313A, © 04/2013
8. Basics of Titration, Titration Theory, Mettler-Toledo, 51725228, © 09/2009
9. Validation of Titration Methods, Application Brochure 16, Mettler-Toledo 51724912A, © 03/2015
10. How to Achieve Best Results, Day-to-Day Density Measurement, Mettler-Toledo, © 07/2012
11. How to Achieve Best Results, Day-to-Day Refractive Index Measurement, Mettler-Toledo, © 07/2012
12. Automated Melting & Dropping Point Analysis, A Comprehensive Textbook, Mettler-Toledo, 30097042, © 09/2014
13. Thermal Analysis in Practice, Application Handbook, METTLER TOLEDO, 51725244, © 12/2009

Some further references that may be of interest:

1. Fundamentals of Mass Determination, Springer-Verlag Berlin, 2012, ISBN 978-3-642-11936-1
2. Titration Fundamentals, Mettler-Toledo, 134 pages, 51725311, © 09/2010
3. Titration Automation Guide, Opportunities and Benefits, Mettler-Toledo, 19 pages, © 11/2014
4. Validation in Thermal Analysis, Collected Application Handbook, Mettler-Toledo, 232 pages, 51725141, © 12/2008
5. Analytical Excellence to Improve Customer Processes, Laboratory Catalog 2014/15, Mettler-Toledo, 238 pages, 11795953, © 02/2014

15. Additional Supporting Information

15.1 Webinars

We provide web-based seminars (webinars) on different topics. You can participate in on-demand webinars at any convenient time and place. Live webinars offer the added benefit of allowing you to ask questions and discuss points of interest with METTLER-TOLEDO specialists and other participants.

www.mt.com/webinars

15.2 Comprehensive Application Support

Application database

Our searchable application databases contain several hundreds of applications from different industrial segments. Applications are proven methods with results, detailed method parameters and concluding evaluations.

UserComs

UserComs are periodicals distributed to customers and other persons interested in practical application feedback, expert tips, technical information and latest product news.

The information is intended to give customers new ideas on how to solve analytical problems in their own laboratories. If you have an interesting application that you would like to share with other users, we would be delighted to publish it in UserCom.

Titration applications	**www.mt.com/titration_applications**
Titration UserCom	**www.mt.com/anachem-usercom**
Thermal analysis applications	**www.mt.com/ta-applications**
Thermal analysis UserCom	**www.mt.com/ta-usercoms**
Moisture analyzer applications	**www.mt.com/moisture**

15.3 Segment News

Segment News presents customer application examples, practical tips, industry trends and the latest product news. They focus to a particular industrial segment and are distributed periodically to our customers.
For cost-free subscription go to

www.mt.com/lab-segmentnews

15.4 Lab Library

The Lab Library is a one-stop portal to access knowledge resources such as literature, webinars, product information and much more

www.mt.com/Lab-Library

Good Measuring Practices

Five Steps to Improved Measuring Results

The five steps of all Good Measuring Practices guidelines start with an evaluation of the measuring needs of your processes and their associated risks.

Using this information, Good Measuring Practices provide straight forward recommendations for selecting, installing, calibrating and operating laboratory equipment and devices.

- Preservation of the accuracy and precision of results
- Compliance with regulations, secure audits
- Increased productivity, reduced costs
- Professional qualification and training

Good Weighing Practice™
Guaranteed better weighing results – at your fingertips with GWP®.

Good Pipetting Practice™
Improved Pipetting Techniques – minimize risk with GPP™.

Good Titration Practice™
Dependable titration in practice – reliable results with GTP®.

Good Electrochemistry Practice™
Reliable pH measurements – thanks to GEP™.

Good Density and Refractometry Practice™
Secure density and refractometry results – guaranteed by GDRP™.

Good Melting and Dropping Point Practice™
Reliable thermal values – optimized by GMDP™.

Good Thermal Analysis Practice™
Fast and secure thermal analysis results – with the help of GTAP™.

Good UV/VIS Practice™
Accurate and Reliable Spectroscopy – ensured by GUVP™

Learn more about Good Measuring Practices program
www.mt.com/gp

www.mt.com
For more information

METTLER TOLEDO Group
Laboratory Weighing
Local contact: www.mt.com/contacts

L00439EN A
Global MarCom 2340 MC/MD