

**Weighing the right way
with METTLER TOLEDO.**

The proper way to work with
electronic analytical and
microbalances.



The proper way to work with electronic analytical and microbalances

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Introduction

Weighing is one of the most frequent operations in the lab. Modern micro, semimicro and analytical balances (readability 0.1 µg to 0.1 mg) have been perfected to such an extent today that in general no special weighing rooms are needed.

Technological progress in electronics has allowed considerable simplification of the operation, drastic shortening of the weighing times and the balances to be made so adaptable that today they can be integrated directly in a production process.

However, this progress is associated with the danger that too little attention is paid to disturbing influences of the surroundings. These mostly concern physical effects that are measurable for micro, semimicro and analytical balances and can not be suppressed by them since actual weight changes are involved (e.g. slow evaporation, moisture gain), or forces that act on the weighing sample and the weighing pan (e.g. magnetism, electrostatic charge) and are also recognized by the balance as weight changes.

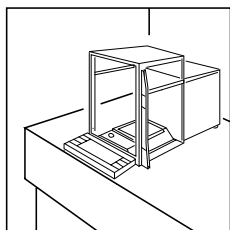
With the information described here, our aim is to indicate the most important points that must be noted when working with micro, semimicro and analytical balances if weighing results of high quality are required.

After some brief pointers concerning the location and the proper operation of the balances, the disturbing influences due to the surroundings on the weight determination are discussed in detail. Many of the influences are recognizable by a slow change in the weight display (drift).

Since correct interpretation of the technical data is also of immense importance in the assessment of a weighing result, the most common technical terms are explained at the end.

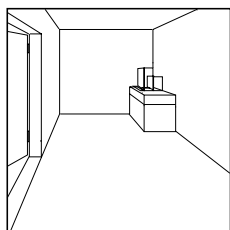
Location of the balance

The accuracy or reliability of weighing results is closely associated with the location of the balance. The following points should be considered in determining the location of an analytical balance.



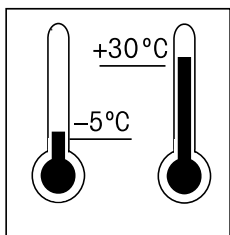
Weighing bench

- It should transmit as few vibrations as possible,
- not sag when work is carried out on it (e.g. stable lab bench, stone bench),
- be antimagnetic (no steel plate),
- be protected against electrostatic charges (no plastic or glass),
- stand on the floor or be fixed to the wall, but not both at the same time (avoidance of simultaneous transmission of vibrations from wall and floor),
- remain reserved as a workstation for the balance.



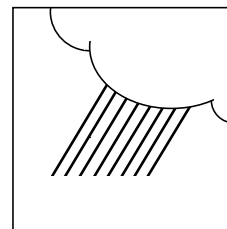
Work room

- It should be as insusceptible to shock and vibrations as possible,
- have only one entrance (to avoid drafts),
- have as few windows as possible (danger of direct sunlight),
- the corners of the room should be kept free for the weighing bench since these are the most rigid positions of a building with the smallest vibrations.



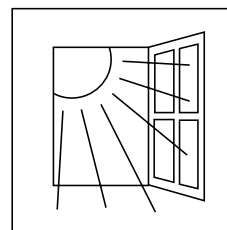
Temperature

- The room temperature should be kept as constant as possible to avoid temperature drift (typically 1–2 ppm/°C),
- Weighing should never be performed near radiators,
- METTLER TOLEDO balances with proFACT (professional fully automatic calibration technology) can compensate virtually all the remaining temperature drift. proFACT should thus always be switched on.



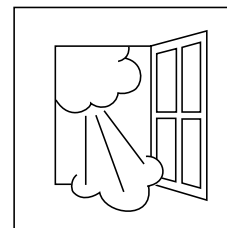
Atmospheric humidity

- The relative humidity should be between 45 and 60%. Constant monitoring is advisable with microbalances (correct changes when possible).



Light

- Avoid direct sunlight (e.g. wall with no windows).
- Lighting fixtures should be installed at a sufficient distance from the weighing bench to avoid disturbing thermal radiation, especially when light bulbs are used. Fluorescent lamps are less critical.

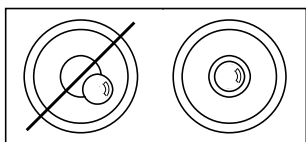


Air

- Never weigh in the vicinity of air conditioners or units with fans (e.g. computers),
- avoid weighing close to radiators as in addition to heat (temperature drift) powerful air currents are often produced in the vicinity of such apparatus,
- never weigh next to a door.

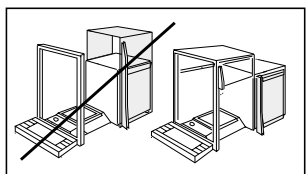
Operation of the balance

Micro, semimicro and analytical balances are measuring instruments of the highest precision. The following points will help you obtain reliable weighing results rapidly.



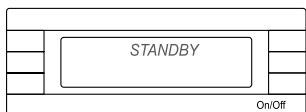
Leveling

- Check that the air bubble is in the center of the level and if necessary correct this by turning the leveling feet. Then calibrate the balance.



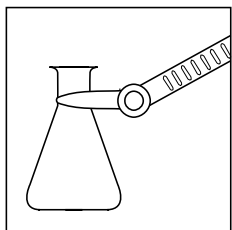
Draft shield

- With METTLER TOLEDO balances with a configurable draft shield (e.g. the AT series) adjust this so that the opening of the draft shield is minimal.
- With METTLER TOLEDO balances with a conventional draft shield (e.g. AG), open only wide enough to allow convenient loading of the weighing sample (avoidance of air turbulence and temperature changes).



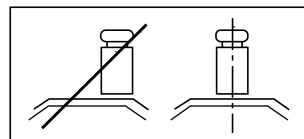
Switching on

- Always leave the balance connected to the power supply and switched on so that a thermal equilibrium can be established in the balance.
- Use only the tare bar to switch the balance off; it is then in the standby mode and the electronics are still energized (no warm-up influences).



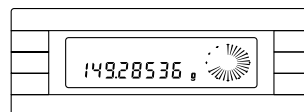
Weighing vessel

- Use the smallest possible weighing vessel.
- Avoid weighing vessels made of plastic, and in the case of atmospheric humidity below 30–40% those made of glass since these can become electrostatically charged (see page 11, Electrostatics).
- The weighing vessel and the sample it contains should have the same temperature as the surroundings. Temperature differences lead to air currents and to a change in the moisture film on the weighing vessel and sample (see page 9, Temperature).



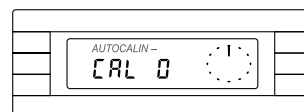
Weighing pan

- Place the weighing sample in the middle of the weighing pan to avoid cornerload errors.
- With micro and semimicro balances the weighing pan should first be loaded once briefly (initial weighing effect) after a relatively long pause (>30 min).
- Remove the weighing sample from the weighing pan on completion of the weighing operation. This prevents a change in the temperature and atmospheric humidity in the weighing chamber due to the weighing sample.



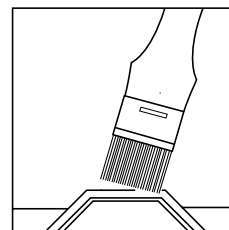
Reading

- Check that the balance displays exactly zero at the start of the weighing and tare if need be. This avoids zero errors.
- Adjust the automatic vibration detector ASD = AT to suit your needs. If the symbol of the stability detector goes off (= release of the weighing result), immediately read off the result.



Calibration

- Calibrate the balance regularly above all if you are operating the balance for the first time, after a location change, after leveling, after large temperature variations, and humidity or atmospheric pressure changes. In the case of METTLER TOLEDO balances with proFACT, which calibrate themselves automatically, this procedure is unnecessary.



Care and maintenance

- Keep the weighing chamber and weighing pan clean.
- Use only clean weighing vessels for weighing.

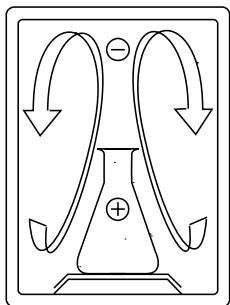
Physical influences

If the weight display is unstable, the result slowly increases or decreases or quite simply if wrong values are displayed, this is often due to undesired physical influences.

The most frequent causes are:

- incorrect handling of the weighing sample,
- unsuitable location of the balance,
- moisture gain or loss by the weighing sample,
- electrostatically charged weighing samples or vessels,
- magnetic weighing samples or vessels.

In the next section we shall demonstrate these influences, explain the reasons for them and describe possible corrective measures.



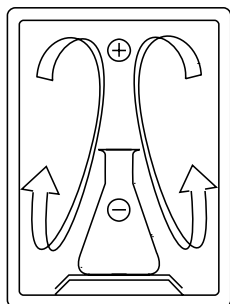
Temperature

Effect: The weight display of a weighing sample changes constantly in one direction.

Reason: There is a temperature difference between the weighing sample and the surroundings that leads to air currents along the weighing vessel. The air flowing along the side of the vessel generates a force in an upward direction that falsifies the weighing result: the sample appears lighter (dynamic buoyancy). The effect does not die away until a temperature equilibrium is established.

The change in the moisture film that coats every sample is hidden by the dynamic buoyancy. The moisture film changes with temperature. The following applies: a cold object appears heavier, a warm object lighter. Attention must be paid to this effect especially in differential weighings with microbalances (monitor temperature).

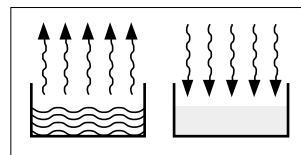
Example: You can test the dynamic buoyancy with the following experiment: Weigh a conical or similar flask, record the weight,



hold the flask in your hand for about 1 minute, repeat the weighing: the flask appears lighter. (The perspiration on your hand plays a minor role in this effect. Otherwise the sample would have become heavier!)

Corrective measures:

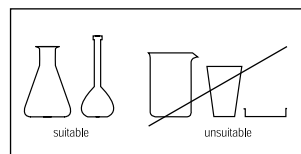
- Never weigh samples taken directly from a dryer or refrigerator,
- acclimatize weighing sample to the temperature of lab or weighing chamber,
- hold samples with tweezers,
- never put your hand in the weighing chamber, otherwise the chamber would warm up,
- choose sample vessels with a small surface area.



Moisture gain/evaporation

Effect: The weight of a weighing sample slowly increases or decreases.

Reason: You are measuring the weight loss of volatile substances or the evaporation of water. The weight increase is due to a hygroscopic weighing sample (atmospheric moisture gain). You can reproduce this effect with alcohol and silica gel.

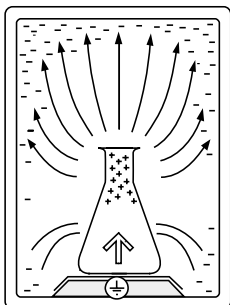
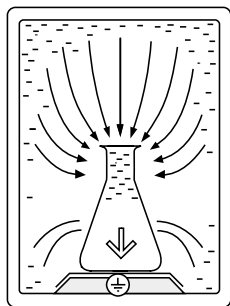


Corrective measures:

- Use clean and dry weighing vessels and keep the weighing pan free from dirt, contaminants and water drops,
- use vessels with a narrow neck,
- mount cover or insert stopper,
- use METTLER TOLEDO triangular holder (210435) instead of cork or cardboard supports (both can gain or lose water to a considerable extent).

Electrostatics

Effect: A weighing vessel shows different weights on each weighing. The weight display is unstable. The reproducibility of the result is poor.



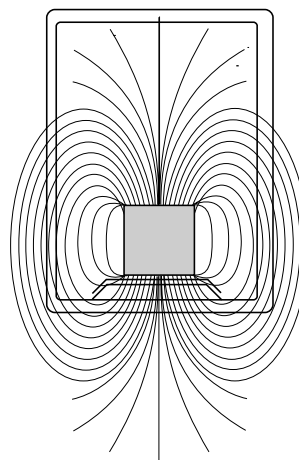
Reason: Your weighing vessel has become electrostatically charged. Materials with a high degree of electrical insulation such as the majority of weighing vessels (glass, plastic) can become electrostatically charged. This charging occurs primarily through friction during the handling or transport of materials (especially of powders and granules). If the air is dry (less than 40% relative humidity = relatively poor surface conductivity), these electrostatic charges can no longer be discharged or at least only very slowly over a period of hours.

The weighing errors arise through the electrostatic forces that act between the weighing sample and the surroundings. The following holds: if the weighing sample and the surroundings have the same electric charge (+, + or -, -) they repel each other, if the charges are different (+, - or -, +) they attract each other. These electrostatic charges can be measured by micro, semimicro and analytical balances and lead to the weighing errors described. A plastic vessel that has been rubbed with a wool or silk cloth shows exactly this effect.

Corrective measures: The electrostatic charge of the weighing sample must be discharged or screening employed. The following possibilities exist:

- Increase atmospheric moisture by means of a humidifier or by appropriate setting of the air conditioning. Particular attention should be paid to this in winter in heated rooms (ideally 45–60% rel. atmospheric humidity).
- Screen electrostatic forces (place weighing vessels in a metal container).
- Use different weighing vessels.

Plastic	Glass	Metal
poor	good	very good



- Use commercially available antistatic guns. However, they are not effective with every type of material.
- Ground the balance (and hence the weighing pan). This is achieved automatically with METTLER TOLEDO balances via the three-pin power plug.

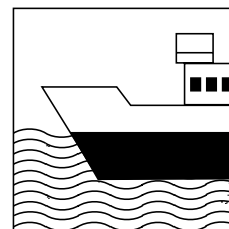
Magnetism

Effect: The weight of a weighing sample depends on its position on the weighing pan. The reproducibility of the result is poor.

Reason: You are weighing a magnetic material. Magnetic objects and iron exert a mutual attraction. The additional forces that arise are thus wrongly interpreted as a load.

Corrective measures:

- If possible demagnetize the ferromagnetic weighing sample (iron, steel, nickel, etc.).
- Since the magnetic force decreases with increasing distance, the sample can be distanced further from the weighing pan by use of a nonmagnetic support (e.g. beaker, aluminum stands).
- The same effect can be achieved by means of a hanger (built in as standard with most METTLER TOLEDO micro, semimicro and analytical balances).
- Wherever possible, METTLER TOLEDO uses nonmagnetic materials to keep this effect to a minimum.
- Screen magnetic forces (place weighing sample in a vessel made of mumetal).

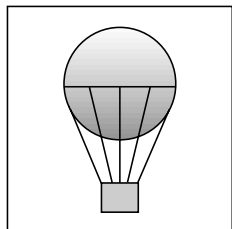


Static buoyancy

Effect: A weighing sample weighed in air and in a vacuum does not have the same weight.

Reason: «A body experiences a loss in weight equal to the weight of the medium it displaces» (Archimedes' principle).

This principle provides an explanation of why ships float, a



balloon rises or why the weight of a sample is affected by the atmospheric pressure.

The medium that surrounds our weighing sample is air. The density of air is approximately 1.2 kg/m^3 (depending on the temperature and atmospheric pressure). The buoyancy of the weighing sample (body) is thus 1.2 kg/m^3 .

Example: If we place a 100 g calibration weight in a beaker on a beam balance and then add water to an identical beaker on the other weighing pan until the weighing beam is in equilibrium, the two masses, weighed in air, weigh 100.000 g.

If we then enclose the beam balance with a bell jar and generate a vacuum in it, the weighing beam will tilt to the side with water since the water displaces more air owing to the larger volume and has hence experienced a greater buoyancy. In vacuum there is no buoyancy.

	Calibration weight	Water
Weight in air	100.000 g	100.000 g
Density	8000 kg/m^3	1000 kg/m^3
Volume	12.5 cm^3	100 cm^3
Buoyancy	$12.5 \text{ cm}^3 \times 1.2 \text{ mg/cm}^3$	$100 \text{ cm}^3 \times 1.2 \text{ mg/cm}^3$
	= 15 mg	= 120 mg
Weight in vacuum	100.015 g	100.120 g

Corrective measures:

- Since the balance is calibrated with calibration weights of density 8.0 g/cm^3 in the weighing of samples of different density an air buoyancy error arises. In weighings with high measurement accuracy (above all microbalances), the displayed weight should be corrected accordingly.
- In weighings on different days (differential weighings, comparative weighings), check atmospheric pressure, atmospheric humidity and temperature and calculate the air buoyancy correction.

Procedure to determine the mass:

1. Calculate air density

$$a \approx \frac{0.348444 \times p - (0.00252 \times t - 0.020582) \times h}{273.15 + t}$$

a = air density in kg/m^3

p = atmospheric pressure in hPa (mbar)

h = relative atmospheric humidity in %

t = temperature in $^{\circ}\text{C}$

2. Air buoyancy correction

$$m \approx R \frac{1 - \frac{a}{8000 \text{ kg/m}^3}}{1 - \frac{a}{p}}$$

m = mass
 R = balance display
 p = density of weighing sample in kg/m^3

Example:

Balance display 200.0000 g

Atmospheric pressure 1018 hPa

Relative atmospheric moisture 70%

Temperature 20°C

Density of weighing sample 2600 kg/m^3

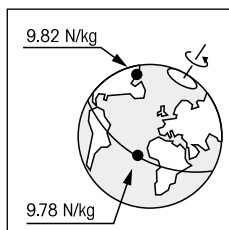
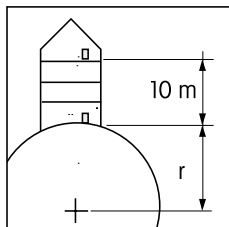
$$a \approx \frac{0.348444 \times 1018 - (0.00252 \times 20 - 0.020582) \times 70}{273.15 + 20} \text{ kg/m}^3$$

$$a \approx 1.2029 \text{ kg/m}^3$$

$$m \approx 200.0000 \text{ g} \frac{1 - \frac{1.2029}{8000}}{1 - \frac{1.2029}{2600}} \approx 200.0625 \text{ g}$$

Remark:

- Work is normally performed in the lab without correction (systematic error). With a small amount of weighing sample the error can be disregarded.



Gravitation

Effect: The weight display changes when the weighing is performed 10 m higher (e.g. from the first floor to the fourth floor of a building).

Reason: To determine the weight of a body, the balance measures the gravitational force, i.e. the force of attraction between the earth and the weighing sample. This force depends essentially on the latitude of the location and its height above sea level (distance from the center of the earth). The following holds:

1. The further a weight from the center of the earth, the smaller the gravitational force acting on it. It decreases with the square of the distance.
2. The nearer a location to the equator, the greater the centrifugal acceleration due to the rotation of the earth which counteracts the force of attraction (gravitational force). The force acting on a mass is therefore greatest at the poles and smallest at the equator.

The weight change is thus based on a reduction in the gravitational force.

Example: In the case of a 200 g weight that shows exactly 200.00000 g on the first floor, the following weight results on the fourth floor (10 m higher):

$$200.00000 \text{ g} \frac{(r_{\text{Earth}})^2}{(r_{\text{Earth}} + 10 \text{ m})^2} \approx 200.00000 \text{ g} \frac{(6370\,000 \text{ m})^2}{(6370\,010 \text{ m})^2} \approx 199.99937 \text{ g}$$

Corrective measures:

- Calibrate the balance whenever it is moved.
- Use balances with built-in proFACT (professional fully automatic calibration technology), e.g. METTLER TOLEDO analytical balances of the AT series.

Technical terms

Analytical balance

METTLER TOLEDO balances with a readability of 1 d (1 digit)
 $= 0.1 \text{ mg} = 0.0001 \text{ g}$

FACT

Fully Automatic Calibration Technology. State-of-the-art calibration technology from METTLER TOLEDO. The calibration is constantly monitored by a microprocessor and automatically triggered if sensitivity deviations occur.

Linearity

The linearity expresses how well the balance is capable of following the linear relation between the load and the displayed value. Here, the characteristic weighing curve is imagined as a straight line between zero and maximum load.

On the other hand, the nonlinearity defines the width of the band within which a positive or negative deviation of the measured value from the ideal characteristic curve can occur.

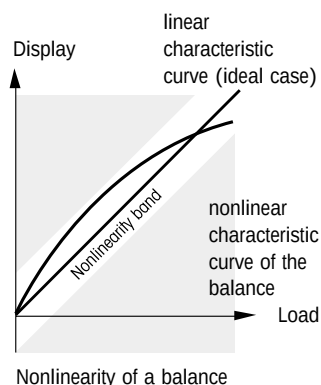
The deviation from the linear course of the characteristic curve is for the METTLER TOLEDO AT261, for instance, maximum $\pm 0.15 \text{ mg}$ over the entire weighing range of 200 g.

Microbalance

METTLER TOLEDO balances with a readability of 1 d (1 digit)
 $= 1 \text{ } \mu\text{g} = 0.000001 \text{ g}$

Readability

The readability of a balance is the smallest difference between two measured values that can be read on the display. With a digital display this is the smallest numerical increment, also called a scale division.



Standard readabilities (or scale divisions) are, for example
 with analytical balances 0.1 mg readout increment
 with semimicro balances 0.01 mg readout increment
 You can change the readability of an AT: In the analytical range
 for instance from 0.1 mg to 0.2 mg, 0.5 mg or 1 mg.

Reproducibility

The reproducibility is a measure of the ability of a balance to supply the same result in repetitive weighings with one and the same load under the same measurement conditions.

Particularly with high resolution balances (semimicro range), the magnitude of the reproducibility is a property that depends not only on the balance. The reproducibility is also affected by the ambient conditions (drafts, temperature fluctuations, vibrations) and in part by the skill of the person performing the weighing.

The following example shows a typical series of measurements, performed on a semimicro balance with a readability of 0.01 mg.

$x_1 = 27.51467 \text{ g}$
 $x_2 = 27.51466 \text{ g}$
 $x_3 = 27.51468 \text{ g}$
 $x_4 = 27.51466 \text{ g}$
 $x_5 = 27.51465 \text{ g}$
 $x_6 = 27.51467 \text{ g}$
 $x_7 = 27.51467 \text{ g}$
 $x_8 = 27.51466 \text{ g}$
 $x_9 = 27.51468 \text{ g}$
 $x_{10} = 27.51467 \text{ g}$

Let us now determine the mean value and the reproducibility of this series of measurements:

Mean value:

$$\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i$$

x_i : i th result of the series

N : Number of measurements (weighings), usually 10

The mean value is $\bar{x} = 27.514667 \text{ g}$

Standard deviation:

$$s = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2}$$

The standard deviation s is used as a measure of the reproducibility. Consequently, the reproducibility of the measurement series is $s = 0.0095$ mg.

The uncertainty in the measurement result is around two to three times the reproducibility
 $u \approx 2s \dots 3s$

i.e. the true result x lies within the interval
 $x - u < x < x + u$

In our series of measurements is $u \approx 2 \times s \approx 2 \times 0.01$ mg
 $= 0.02$ mg so that we can specify the weighing result by
 $x \pm u = 27.51467 \text{ g} \pm 0.02 \text{ mg}$

The very lowest measured value to be expected for this load with the balance used in the above series of measurements is thus 27.51465 g and the largest is 27.51469 g, which agrees well with the series of measurements.

Semimicro balance

METTLER TOLEDO analytical balances with a readability of 1 d (1 digit) = 0.01 mg = 0.00001 g.

Sensitivity drift

Temperature coefficient of the sensitivity: The temperature variation of the sensitivity is the reversible deviation of the measured value owing to the influence of a temperature change of the surroundings. It is given by the temperature coefficient of the sensitivity (TC), which specifies the percentage deviation of the weight display (or sample weight) per degree Celsius.

The temperature coefficient of the sensitivity is 0.0001%/°C for the AT. This means that for a temperature change of 1 degree Celsius the sensitivity changes by 0.0001% or one millionth. The temperature coefficient can be calculated as follows:

$$TC \approx \frac{\Delta E}{\Delta T} = \frac{\left(\frac{\Delta R}{m}\right)}{\Delta T} = \left(\frac{\Delta R}{m \times \Delta T}\right)$$

ΔE is the change in the sensitivity and ΔT the temperature change. The sensitivity change is equal to the result change ΔR divided by the weighing load m , or after taring by the sample weight.

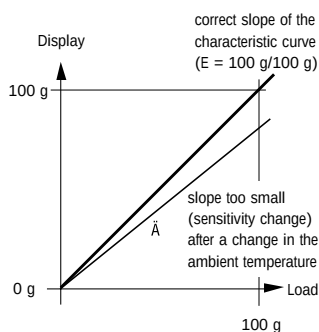
With this information the deviation of interest of the measurement result at a specified temperature change can be calculated by rearranging the above equation. For the display value we then obtain:
 $\Delta R = (TC \times \Delta T) m$

If you weigh a load (sample weight) of 100 g on the AT and the ambient temperature in the laboratory has changed by 5 °C since the last calibration, this can lead to the following maximum result change ΔR (with the temperature coefficient of the AT of 0.0001%/°C):
 $\Delta R = (TC \times \Delta T) m = (0.0001\%/^{\circ}\text{C} \times 5^{\circ}\text{C}) \times 100 \text{ g} = 0.5 \text{ mg}$

If, on the other hand, the load were only 100 mg, that is 1000 times less, the maximum deviation would also be correspondingly less and amount solely to 0.5 µg.

Ultra-microbalance

METTLER TOLEDO balances with a readability of 1 d (1 digit) = 0.1 µg = 0.0000001g.



Effect of the temperature variation on the measurement result. The temperature variation of a balance causes a change in the correct slope of the characteristic curve owing to the influence of the ambient temperature, i.e. an increase or as shown above a decrease.

References

METTLER TOLEDO Dictionary of Weighing Terms
The new METTLER TOLEDO AT Analytical Balance
METTLER TOLEDO operating instructions

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