**Titration errors (titrations.info)**

There are several types of errors that can make titration result differ from the reality.

First, there is an intrinsic error of the method - end point is not identical with equivalence point and colour changes of indicators are not instant. Reasons of this difference are discussed in details in the [end point detection](http://www.titrations.info/titration-end-point-detection) and [acid-base titration end point detection](http://www.titrations.info/acid-base-titration-end-point-detection) sections.

In some cases excess of the titrant must be used as it is titrant colour that signals end point. While this is also intrinsic characteristic of the method, it can be adjusted for by blind trials.

Then, there are errors that can be connected with volumetric glass accuracy. These can be adjusted for by careful [calibration of the glassware](http://www.titrations.info/volumetric-glass-calibration). If for some reason calibration can't be done, we can minimalize errors using A class volumetric glass. We can also minimalize errors carefully selecting volumes of pipettes and burettes used. As it is discussed in the [volumetric glassware](http://www.titrations.info/pipette-burette) and [selection of sample size and titrant volume](http://www.titrations.info/titrant-and-sample-volume) sections, using 50 mL burettes and about 80-90% of their volume guarantees the smallest possible relative error of titration (it doesn't guarantee accuracy of the determination). Also using large (20 or 25 mL) single volume pipettes means smaller relative errors.

Finally, there are thousands of possible random errors, that can't be adjusted for. Some of them are typical human errors, that can be limited by sticking to lab procedures, but as long as there is a human operator involved, they will be never completely eliminated. Some of possible cases are:

* Misjudging the colour of the indicator near the end point - this is probably the most common one. Not only colour change is sometimes very delicate and slow, but different people have different sensitivity to colours. This is not the same as being colour blind, although these things are related.
* Misreading the volume - at any moment, and due to whatever reason. This can be for example a parallax problem (when someone reads the volume looking at an angle), or error in counting unmarked graduation marks. When reading the volume on the burette scale it is not uncommon to read both upper and lower value in different lighting conditions, which can make a difference.
* Using contaminated solutions - for example when two different solutions are transferred using the same pipette and pipette is not rinsed with distilled water in between.
* Using diluted titrant and diluted titrated solution - if the burette and/or pipette was not rinsed with transferred solution after being rinsed with distilled water. In effect titrant (or titrated substance) is slightly diluted.
* Using solutions of wrong concentration - titrant we use may have different concentration then expected. This can be due to incorrect standardization, error in copying the concentration, contamination of the bottle content, titrant decomposition, solution being kept in open bottle and partially evaporated and so on.
* Using wrong amount of indicator - as discussed in the [acid-base titration indicators](http://www.titrations.info/acid-base-titration-indicators) section, in the case of single colour indicators amount added can shift end point.
* Using dirty glass - if glass was not properly cleaned before use it may be contaminated with old reagents, which can react with new ones, changing their concentration. Also, dirty glass is not properly wetted by the solutions and they can form droplets on the glass surface (see [volumetric glassware cleaning](http://www.titrations.info/glass-cleaning) section for a picture) making exact volume measuring impossible.
* Rinsing burette and/or pipette with wrong solution - if the burette or pipette is not dry before use, it has to be rinsed with the solution that will be transferred. Using just distilled water for rinsing will mean transferred solution is slightly diluted. Obviously it is important only when transferring sample, titrant or stoichiometric reagents used for back titration. Small errors in amounts of other substances (buffers, acids used to lower pH in redox titrations, solutions masking presence of interfering substances and so on) are not that important.
* Not filling burette properly - if there is an air lock in the burette stopcock it can block the flow of the titrant, but it can also at some moment flow with the titrant; after that we have no idea what was the real volume of solution used.
* Not transferring all solid/liquid when preparing samples - it may happen that part of the solid was left in the funnel during transferring it into flask, or it was simply lost. It is also not uncommon to forget to rinse walls of the glassware after solution was transferred - it may happen both to solution pipetted to some vessel, or to titrant that formed droplet on the flask wall and was not rinsed with distilled water. If the pipette is not clean, some of the solution can be left inside in form of drops on the glass.
* Transferring excess volume of liquid - by blowing pipette for example, or by incorrectly levelling meniscus with the mark on the single volume pipette.
* Not transferring all the volume - shaken pipette may lose a drop of the solution when it is being moved between flasks, one may also fill the single volume pipette levelling not the meniscus, but the upper edge of the solution with pipette mark.
* Using wrong reagents - sounds stupid, but happens now and then. Too many possibilities to list, but we have to remember - if the reaction doesn't proceed as expected, it won't hurt to check if burette is not filled with something different then expected. Or perhaps there is no indicator in the solution?
* Titrating at wrong temperature (other then glassware was calibrated for). This is a very common problem. Quite often we have no choice other, then to calibrate the glass once again. This is time consuming and - especially in the student lab - almost impossible without additional arrangements.
* Titrating at wrong temperature (other then the method was designed for). Some indicators are sensitive to temperature changes, see for example [pH indicators](http://www.titrations.info/acid-base-titration-indicators) section. Some reactions need correct temperature range to keep stoichiometry (avoid side reactions).
* Losing solution - too vigorous swirling can end in liquid splashing from the titration flask before the end point had been reached. It may also happen that some titrant lands on the table instead of inside the flask.
* Leaking burette - sometimes burettes leak slowly enough to allow titration, but will loose several tenths of millilitre if left for several minutes after titrant level has been set to zero and before titration started.

These are just examples. Every day in every lab in the world old mistakes are repeated and new cases are recorded.

Finally, each titration has its own quirks. They are usually related to chemical characteristics of titrant and other substances involved - NaOH used as a titrant tends to adsorb atmospheric CO2, KMnO4 and thiosulfate slowly decompose and so on.

Retrieved 9th March 2022 from <http://www.titrations.info/titration-errors>

**Random Error and Systematic Error**

**Definitions**

All experimental uncertainty is due to either random errors or systematic errors. **Random errors** are statistical fluctuations (in either direction) in the measured data due to the precision limitations of the measurement device. Random errors usually result from the experimenter's inability to take the same measurement in exactly the same way to get exact the same number. **Systematic errors**, by contrast, are reproducible inaccuracies that are consistently in the same direction. Systematic errors are often due to a problem which persists throughout the entire experiment.

Note that systematic and random errors refer to problems associated with making measurements. ***Mistakes*** made in the calculations or in reading the instrument ***are not considered in error analysis***. It is assumed that the experimenters are careful and competent!

**How to minimize experimental error: some examples**

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| **Type of Error** | **Example** | **How to minimize it** |
| **Random errors** | You measure the mass of a ring three times using the same balance and get slightly different values:  17.46 g, 17.42 g, 17.44 g | Take more data. **Random errors** can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations. |
| **Systematic errors** | The cloth tape measure that you use to measure the length of an object had been stretched out from years of use. (As a result, all of your length measurements were too small.)  The electronic scale you use reads 0.05 g too high for all your mass measurements (because it is improperly tared throughout your experiment). | **Systematic errors** are difficult to detect and cannot be analyzed statistically, because all of the data is off in the same direction (either too high or too low). Spotting and correcting for systematic error takes a lot of care.   * How would you compensate for the incorrect results of using the stretched out tape measure? * How would you correct the measurements from improperly tared scale? |

Retrieved 8 August from:

<https://www2.southeastern.edu/Academics/Faculty/rallain/plab193/labinfo/Error_Analysis/05_Random_vs_Systematic.html>