

2-B.3. Precision and Accuracy

Precision and accuracy are both related to the size of errors or uncertainties, but they are different things and should not be confused with each other. The last significant figure in a measurement determines the precision. Thus 9.613 kilograms has a precision (or uncertainty) of 0.001 kilograms (because the measurement was not 9.612 or 9.614 kilograms.) Precision is an estimate of the absolute size of the error or uncertainty in the measurement (perhaps due to the limitations of the measuring instrument). Hence 9.613 kilograms and 0.026 kilograms have exactly the same precision (0.001 kilograms). Relative precision refers to the size of the error or uncertainty relative to the size of the measured quantity. Hence 0.001 kg out of 9.613 kg is a relative precision of 0.01%, while 0.001 kg out of 0.026 kg is about 4%. Thus, the relative precision associated with 9.613 kg is better than that associated with 0.026 kg. Note that relative precision is dimensionless (usually given as a percentage), but precision is expressed with units. Similar arguments apply to theoretical calculations.

Accuracy expresses the size of the error or departure of a measurement from the exact answer. Unfortunately, we never know the exact answer; thus we can only guess about or estimate the accuracy of any given quantity. Precision frequently is used as our best guess at accuracy. We can infer that the accuracy is no better than some given value. We can only be certain that the accuracy is unsatisfactory to a certain degree. This definition of accuracy is somewhat negative. It is usually expressed in a relative form as a (dimensionless) percent. Errors are usually listed in two categories: systematic and statistical.

Systematic errors come about because a specific and consistent mistake is made in a measurement. For example, a meter stick would expand at an elevated temperature required for a certain experiment. Then length measurements would produce values that are too small. Also, a systematic error might happen if an experimenter consistently uses an instrument poorly. Statistical errors occur if conditions in a measurement fluctuate randomly. For example, consider measuring the diameter of a uniform cylindrical bar with a high precision micrometer. The measuring tool will not always return to exactly the same spot on the bar, and the diameter of the cylinder will not be perfectly uniform. Also, it is impossible to use the micrometer in exactly the same way every time; and this may also produce a random fluctuation in the measured value. (Note that it could also produce a systematic error that is not random.)

When errors are eliminated (or when corrections are made to account for errors), precision and accuracy converge. Eventually precision becomes a good estimate of accuracy.