

The degree of uncertainty in measurements

Every measurement has a certain degree of uncertainty. This uncertainty derives from the measuring instrument and from the skill¹ of the person doing the measuring. Errors in chemistry are classified as systematic (or determinate) and random (or indeterminate). A systematic error is caused by a defect in the instrument or by an incorrect method or technique of the analyst. This type of error is often called 'determinate' because its cause can be determined and so it can be theoretically eliminated.

An example of a systematic error is the one caused by a dirty glass pipette, which will always deliver less than the intended volume of liquid. A systematic error is characterised by the fact that it is repetitive and that it has a definite direction (either by defect or by excess – either positive or negative).

Random or indeterminate errors are unavoidable and are due to random events occurring during the measuring process. Indeterminate errors can be minimized just repeating the same measurement many times. Since random errors can be positive as well as negative, the average of several measurements is going to be more reliable than any single measurement, and the value obtained with a series of measurements will tend to scatter² around the true value. We must remember that a true value is that value that would be obtained by a perfect measurement, but since there is no perfect measurement in chemistry, we can never really know the true value. In order to get as close as possible to the theoretical true value, we must always consider the reality of error. In measuring, accuracy and precision are two important but separate concepts. Accuracy refers to how closely multiple measurements of the same quantity cluster³ around the true value. Precision refers to how closely multiple measurements of the same quantity cluster to one another. The classic illustration distinguishing the two is to consider a target: if the centre of the target (or bull's eye) represents the true value of a measurement, arrows surrounding the bull's eye indicate a high degree of precision. Arrows surrounding the bull's eye and at the same time are very close to one another indicate both accuracy and precision. A simple but clear example is the following. Imagine you are counting the number of people

in a room. If there are a lot of people moving about in the room the measurement might be difficult. You might count them three or four times and get a different value each time. This is the table of the numbers obtained by two people counting the people moving in a room:

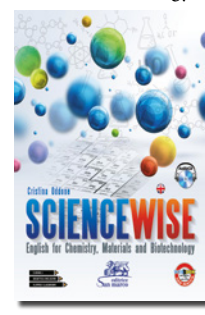
	Person A	Person B
1 st measurement	43	44
2 nd measurement	45	51
3 rd measurement	44	52
4 th measurement	45	47
Average value	44.25	48.5

If we know that the real number of the people in the room is 48, we can define A's measurements as precise but not accurate (the values are very close to each other but not close to the true value), while B's measurements are accurate but not precise (the numbers are not very close to each other but the average figure is near the true value).

GLOSSARY

- 1** a special ability in a task
- 2** to distribute
- 3** to gather, to form a group





ACTIVITIES

1 Decide if the following sentences are true or false, and then correct the false ones.

- 1 It is possible to obtain a perfect measurement.
- 2 There are two types of errors in chemistry.
- 3 A determinate error is the same as a systematic error.
- 4 An imperfection of the instrument may cause a systematic error.
- 5 Random errors have a definite direction.
- 6 Repeating the same measurement help get closer to the true value.
- 7 Accuracy and precision refer to the same concept.
- 8 Several measurements of the same quantity that are very close to one another but not very close to the true value, indicate a high degree of accuracy.

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2 Read the text again and find words with the following Italian meanings.

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|---------------------|------------------------------|
| 1 Grado | 5 Affidabile |
| 2 Casuale | 6 Bersaglio |
| 3 Sporco | 7 Freccia |
| 4 Inevitabile | 8 Centro del bersaglio |

3 Write questions for the following answers.

- 1
In systematic and random errors.
- 2
Because it has a specific cause.
- 3
It is repetitive and it has a definite direction.
- 4
No, they are unavoidable.
- 5
Repeating the same experiments more times.
- 6
No, they are separate concepts.

4 Write the definitions or the explanations for the following key words found in the text, then use them to build up a summarising paragraph.

- 1 Types of errors
.....
- 2 Features of systematic errors
.....
- 3 Features of random errors
.....
- 4 How to minimize random errors
.....
- 5 Accuracy
.....
- 6 Precision
.....

5 Discuss the following quotation by Sigmund Freud with your classmates: "From error to error, one discovers the entire truth".