Name: ______________________________ Date: ________________

# Unit 1

## Advanced Topics in Measurement & Data Processing

- Understand metric units and alternate representations of units.
- Describe and give examples of random uncertainties and systematic errors.
- Describe how the effects of random uncertainties may be reduced.
- State random uncertainty as an uncertainty range (±)
- State the results of calculations to the appropriate number of significant figures.
- State uncertainties as absolute and percentage uncertainties.

### Systematic and Random Errors

**Systematic error**, sometimes called **determinate error**, results from mistakes that are inherent in a particular apparatus or procedure such as a flaw in the design of an experiment or improper calibration of a measuring device. The error is generally reproducible. It affects the results in the same way each time as long as you conduct the experiment again in exactly the same manner. In principle, systematic error can be discovered and corrected, although this is often easier said than done.

For example, suppose we measure the length of the cover of your textbook with a metal ruler. The total length of the ruler expands and contracts depending on the temperature of the room. The ruler might be calibrated assuming the temperature is 20 ˚C, and if the actual room temperature is 25 ˚C, the total length of the ruler must be longer than originally measured. Consequently, any measurement of length at the higher temperature can be expected to give a result that is too short. It is important to recognize that systematic errors have a definite algebraic sign. In the case of our expanded ruler, the error is necessarily negative. There is some control over such systematic errors. For example, if the coefficient of thermal expansion of the ruler is known, the measured length can be corrected to provide the true length. Associated with systematic errors is the term accuracy. An apparatus is said to be accurate to the extent that the systematic errors are minimized.

**Random error**, also called **indeterminate error**, arises from the effect of uncontrolled (and maybe uncontrollable) variables in the measurement. Random error results from inherent random fluctuations of any measurement apparatus. Random error has an equal chance of being positive or negative. It is always present and cannot be corrected. One common source of random error comes from reading an instrument. Different people reading the same instrument may report a range of values representing their subjective interpolation between the markings. Likewise one person reading the same instrument several times might report several different readings. Another indeterminate error results from random electrical noise in an instrument. Positive and negative fluctuations occur with approximately equal frequency and cannot be completely eliminated.

By hypothesis, we assume the correct result (in the sense of random errors) for some measurement can be obtained from the arithmetic mean of an infinite set of measurements. We control random errors by increasing the number of measurements. Unlike systematic errors, random errors have no definite algebraic sign. We denote the size of random errors with notation. We often use the term precision to express the magnitude of the random errors. We call a measurement precise if its random errors are small.

**Assignment:**

*Questions 1–4 refer to the following example:*

Four groups have done an experiment in a calorimeter to determine the heat change of a reaction in aqueous solution, for which the literature value is 38.73 kJ mol-1. The values found by the groups (in kJ mol-1) were:

| | | | |
|---|---|---|---|
| A | 35.1 ± 0.3 | C | 33.2 ± 0.1 |
| B | 36.5 ± 0.5 | D | 34.7 ± 0.2 |

1. Which result is the most precise? Why?

2. Which result is the most accurate? Why?

3. Do you think the major problem is

    a) Random error
    b) Systematic error
    c) both are equally important
    d) It is not possible to tell from the data given.

4. Which of the following is the best way to report the mean result of the group?

    a) 34.875 ± 0.100 kJ $mol^{-1}$
    b) 34.89 ± 0.5 kJ $mol^{-1}$
    c) 34.9 ± 0.8 kJ $mol^{-1}$
    d) 35 ± 2 kJ $mol^{-1}$

5. Repeating an experiment a number of times will lead to a decrease in:

   a) The random error.
   b) The systematic error.
   c) Both the random and the systematic error.
   d) Neither the random nor the systematic error.

6. The mass of an object is measured as 1.652 g and its volume 1.1 $cm^3$. If the density is calculated from these values, to how many significant figures should it be expressed?

   a) 1
   b) 2
   c) 3
   d) 4

7. The time for a 2.00 cm sample of magnesium ribbon to react completely with 20.0 $cm^3$ of 1.00 mol $dm^{-3}$ hydrochloric acid is measured four times by a student. The readings lie between 48.8 and 49.2 seconds. This measurement is best recorded as:

   a) 48.8 ± 0.2 s
   b) 48.8 ± 0.4 s
   c) 49.0 ± 0.2 s
   d) 49.0 ± 0.4 s

8. A student measures the volume of water incorrectly by reading the top instead of the bottom of the meniscus. This error will affect:

   a) Neither the precision nor the accuracy of the readings.
   b) Only the accuracy of the readings.
   c) Only the precision of the readings.
   d) Both the precision and accuracy of the readings.

9. The number of significant figures that should be reported for the mass increase which is obtained by taking the difference between reading of 11.6235 g and 10.5805 g is:

   a) 3
   b) 4
   c) 5
   d) 6

10. Which types of error can cancel when differences in quantities are calculated?

    (I) random errors
    (II) systematic errors

    a) I only
    b) II only
    c) I and II
    d) Neither I nor II