

## 1.5 Uncertainty in Measurement

- There are two types of numbers:
  - *exact numbers* (known as counting or defined).
  - *inexact numbers* (derived from measurement).
- All measurements have some degree of uncertainty or *error* associated with them.

### Precision and Accuracy

- **Precision:** how well measured quantities agree with each other.
- **Accuracy:** how well measured quantities agree with the “true value.”
- Figure 1.24 is very helpful in making this distinction.

### Significant Figures

- In a measurement it is useful to indicate the exactness of the measurement. This exactness is reflected in the number of significant figures.
- Guidelines for determining the number of significant figures in a measured quantity are:
  - The number of significant figures is the number of digits known with certainty plus one uncertain digit. (Example: 2.2405 g means we are sure the mass is 2.240 g but we are uncertain about the nearest 0.0001 g.)
  - Final calculations are only as significant as the least significant measurement.
- Rules:
  1. Nonzero numbers and zeros between nonzero numbers are always significant.
  2. Zeros before the first nonzero digit are not significant. (Example: 0.0003 has one significant figure.)
  3. Zeros at the end of the number after a decimal point are significant.
  4. Zeros at the end of a number before a decimal point are ambiguous (e.g., 10,300 g). Exponential notation eliminates this ambiguity.
- Method:
  1. Write the number in scientific notation.
  2. The number of digits remaining is the number of significant figures.
  3. Examples:
    - 2.50 x 10<sup>2</sup> cm has 3 significant figures as written.
    - 1.03 x 10<sup>4</sup> g has 3 significant figures.
    - 1.030 x 10<sup>4</sup> g has 4 significant figures.
    - 1.0300 x 10<sup>4</sup> g has 5 significant figures.

### Significant Figures in Calculations

- Multiplication and division:
  - Report to the least number of significant figures (e.g., 6.221 cm x 5.2 cm = 32 cm<sup>2</sup>).
- Addition and subtraction:
  - Report to the least number of decimal places (e.g., 20.4 g – 1.322 g = 19.1 g).
- In multiple step calculations always retain an extra significant figure until the end to prevent rounding errors.

