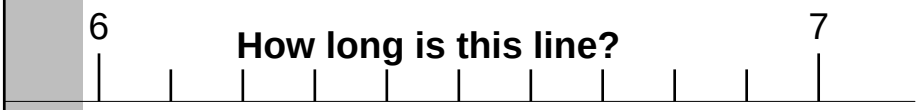
Chapter 3
Experimental Error

I. Significant Figures

II. Types of Error

III. Propagation of Uncertainty

I. Significant Figures



Significant Figures

- All the digits known with certainty PLUS the first uncertain digit.
- All the digits that must be used to reflect the accuracy of the measuring instrument.

I. Significant Figures (cont.)

Calculations with Sig Figs:

1. Multiplication/Division

   answer can have no more sig figs than the factor with the **least number of sig figs**

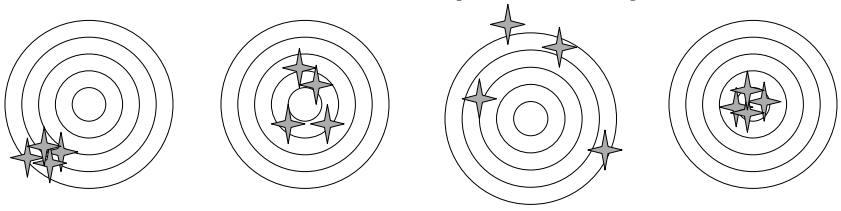
2. Addition/Subtraction

   answer can have only as many decimal places as the **least number of decimal places** in the numbers being added or subtracted

II. Types of Error

Accuracy – measure of the **correctness** of a result

Precision – measure of the **reproducibility** of a result



Lo accuracy
Hi precision

Hi accuracy
Lo precision

Lo accuracy
Lo precision

Hi accuracy
Hi precision

II. Types of Error (cont.)

Every measurement contains some degree of error:

1) Gross Error
   - Major mistake
   - Start over
2) Systematic (Determinate) Error
   - Consistently off in one direction
   - Affects accuracy
   - Can be eliminated with calibration
3) Random (Indeterminate) Error
   - Inherent to any measurement (can be reduced)
   - Positive or negative error
   - Affects precision

III. Propagation of Uncertainty

Every measurement has an inherent uncertainty.

⇓

This uncertainty "propagates" through calculations.

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The uncertainty in the calculated values must be accounted for.

III. Propagation of Uncertainty (cont.)

Dealing with error propagation:

A. General Case (Appendix C)

B. Adding/Subtracting

C. Multiplying/Dividing

D. Other Operations (Table 3-1, pg 49)

Table 3-1 Summary of rules for propagation of uncertainty

Function	Uncertainty	Function[a]	Uncertainty[b]
$y = x_1 + x_2$	$e_y = 2\sqrt{e_{x_1}^2 + e_{x_2}^2}$	$y = x^a$	$\%e_y = a\%e_x$
$y = x_1 - x_2$	$e_y = 2\sqrt{e_{x_1}^2 + e_{x_2}^2}$	$y = \log x$	$e_y = \frac{1}{\ln 10}\frac{e_x}{x} \approx 0.434\,29\frac{e_x}{x}$
$y = x_1 \cdot x_2$	$\%e_y = 2\sqrt{\%e_{x_1}^2 + \%e_{x_2}^2}$	$y = \ln x$	$e_y = \frac{e_x}{x}$
$y = \frac{x_1}{x_2}$	$\%e_y = 2\sqrt{\%e_{x_1}^2 + \%e_{x_2}^2}$	$y = 10^x$	$\frac{e_y}{y} = (\ln 10)e_x \approx 2.302\,6\,e_x$
		$y = e^x$	$\frac{e_y}{y} = e_x$

a. x represents a variable and a represents a constant that has no uncertainty,

b. e_x/x is the relative error in x and $\%e_x$ is $100 \times e_x/x$.

Table 3-1
Quantitative Chemical Analysis, Seventh Edition

III. Propagation of Uncertainty (cont.)

Dealing with error propagation:

A. General Case (Appendix C)
B. Adding/Subtracting
C. Multiplying/Dividing
D. Other Operations (Table 3-1, pg 49)
E. Mixed Operations