Chemistry 120

Science and Measurement

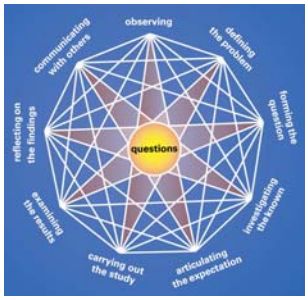
What is Science?

- Concerned with Cosmic Order
- Goals of Science
  - Explanation and understanding
  - Prediction and control
- Empiricism
  - Synthetic knowledge and experience
  - Past as a guarantor of future
  - Nature of evidence

Classic Scientific Method

- Formal Method of asking Questions
  - Recognize a question or problem
  - Formulate a *hypothesis*
  - Predict observable consequences
  - Perform experiments to test hypothesis
  - Make logical conclusions from results
  - Refine hypothesis; if needed test again
  - Formulate rules
- Ask More Questions

A More Realistic Model?



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Harwood, W. S. *J. Coll. Sci. Teaching* **2004**, *33 (7)*, 29–33.

Types of Experiments and Measurements

- *Qualitative*
  - Non-numerical observations
- *Quantitative*
  - Observations with numbers attached
  - Standard units system required, Système International d'Unités (SI Units)
  - Units must <u>always</u> be shown
- Power of Quantitative Measurements

Scientific Laws and Theories

- *Law*: Repeatedly tested Hypothesis that has not been Contradicted
  - Concise statement of a relation that *seems* to always hold under same conditions
  - Once defined, static
- *Theory*: a Unifying Principle that explains Facts and Laws
  - Theories are <u>not</u> hypotheses
  - Continuously revised as new data obtained

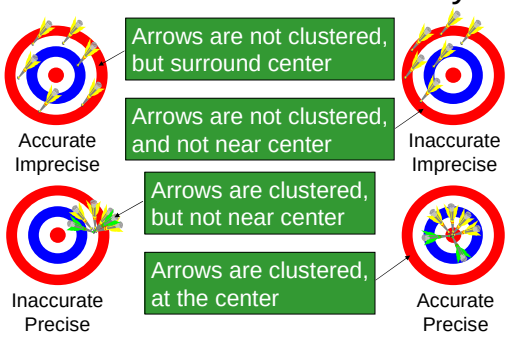
Standard of Evidence in Science

- Supporting Arguments must
  - Be logically constructed
  - Accommodate Ockham's Razor
- Evidence must
  - Be reproducible
  - Be independently verifiable
  - Ultimately be quantitative
- Evidence not up to Standard is rejected

Quality of Measurements

- *Precision*
  - Single measurement (*uncertainty*)
  - Series of measurements (*uncertainty at a given confidence limit* or *standard deviation*)
- *Accuracy*
  - Single measurement (*percent error*)
  - Multiple measurements (*percent error of the average*)
- Accuracy ≠ Precision

Precision versus Accuracy



A Simple Means of Showing Precision

- *Significant Figures* implies Precision
  - Precision assumed to be ±1 in last digit, if not otherwise given
  - Example: 12.57 g (measured to ±0.01 g) is more precise than 12.5 g (±0.1 g)
- Determine Significant Figures by
  - Reading from left to right
  - Starting with first non-zero digit count all digits

Determining Significant Figures

10.7
0.0125
0.0105
0.0150
100
100.
1.00×10^2
1.0×10^2
1×10^2

Rules for Significant Figures

- Special Cases
  - Exact conversion factors (1 kg = 1000 g)
  - Physical constants
  - Counting distinct objects
  - Special numbers like π and e
  - Physical properties as conversion factors
- Significant Figures change depending on Mathematical Operations

Significant Figures and Addition/Subtraction

- Precision in the Answer is Same as least precise Number in the Operation

117.032 + 19.1 = 136.132 =

Significant Figures and Multiplication/Division

- Number of Significant Figures in Answer is Same as the Number of Significant Figures in Term which had Fewest

$$\frac{0.01208}{0.0236} = 0.511864407 =$$

Rules for Rounding

- Last Digit to be Retained is
  - Increased by one if the digit to its right is greater than 5
  - Left unchanged if the digit to its right is less than 5
  - If the digit to its right is 5, then if the retained digit is odd, increase it by one, do nothing if even
- All Digits Right of Last Retained Digit are dropped

Carrying Significant Figures

- Multi-step Calculations
  - Carry "extra" significant figures
  - Round at end to prevent "rounding errors"
- Ways to Indicate "Extra" Figures
  - 106.58_{993} this number has 5 significant figures; subscripted numbers are not significant
  - $106.5\overline{8993}$ this number has 5 significant figures; the last three digits are not significant
  - In both cases precision is assumed to be ± 0.01

Problem Solving

- Read the Question
- Identify Required Quantity
- Devise a Plan to get from Givens to Required Quantity
  - Set up necessary calculations
- Insert Values into Equations and Solve
- Look at the Answer
  - Is it reasonable (order of magnitude, units)?
- Read the Question again

Worked Example

- A platinum sheet is 2.50 cm square and has a mass of 1.656 g. If the density of platinum is 21.45 $g \cdot cm^{-3}$, what is the thickness of the sheet, in millimeters?