CHEM 1405 Notes

Mufaro Machaya

Summer 2024

Contents

Module 1

Quantitative Skills

1.1 Lecture 1: Introduction

References Chapter 1, Sections 1.2 and 1.3 of the textbook.

1.1.1 The Scientific Method

Definition 1.1.1. The Scientific Method is the set of general procedures for acquiring scientific knowledge.

1. Identify the problem
2. Collect past data/perform background research
3. Analyze and organize the data into general summaries of previous observations
4. Suggest probable explanations/hypotheses for the generalizations
5. Perform further experiments to prove or disprove these explanations/theorems

1.1.2 Qualitative vs. Quantitative Data

Definition 1.1.2. Qualitative vs. Quantitative Data

- **Quantitative Data** - Numerical data yielded from *measurements*.
- **Qualitative Data** - Any data yielded from other observation, *including rough estimates*.

- The patient's fever has reached $105.3°F$ - *Quantitative*
- The packet of Candy contains *about* 100 gummy bears - *Qualitative*

1.1.3 Scientific Facts, Laws, Hypotheses, and Theories

- **Scientific Fact** - Reproducible data/observations obtained from an experiment.
- **Scientific Law** - Summarizes scientific facts without interpretation. Accepted as fact but can be changed/contested.
- **Scientific Hypothesis** - Explains or contests scientific laws. Tested by experiments.
- **Scientific Theory** - Scientific hypotheses that are tested and validated as correct/true over a long period of time. *Scientific Theories can never be proven true.*

Example 1.1.1. Facts, Laws, and Theories

- The burning candle generated both heat and light - *Scientific Fact*
- As a candle burns, its wax gradually disappears - *Scientific Fact*
- All burning candles generate heat and light - *Scientific Law*
- Burning candles generate heat as the result of the decomposition of melted wax. - *Scientific Hypothesis*

1.2 Lecture 2: Measurement

1.2.1 Exact vs. Inexact and Accuracy vs. Precision

Definition 1.2.1. Exact vs. Inexact and Accuracy vs. Precision

- **Exact numbers** - Numbers with no uncertainty and are known exactly either in definition, counting, or as simple fractions (cannot be an irrational number).
- **Inexact numbers** - Numbers with some degree of uncertainty.
- **Accuracy** - How close the measured values are to the intended/-goal values
- **Precision** - How close the measured values are to each other

- Measurements require units.
- It is impossible to make exact measurements as all measurements have some degree of uncertainty due to limits of the measuring instrument (systematic error) and random error.

When measuring, one has to keep the certain digits and uncertain digits in mind. The magnitude of uncertainty is indicated with a plus-minus notation alongside the acceptable range.

1.2.2 Significant Figures and Rounding-Off Rules

Significant figures are all the certain digits of measurement plus one digit of uncertainty. When determining significant figures for unknown measurements, the following rules are used:

- Nonzero digits are always significant.
- Leading zeroes are never significant.
- Confined zeroes are always significant.
- Trailing zeroes are only significant if there is a decimal point or the zeroes carry overbars (i.e. are repeating).

Note: Remember that the last significant figure is always uncertain.

Example 1.2.1. Significant Figures

- $14.232 \rightarrow 5$ sig. figs, $\pm\, 0.001$
- $0.0045 \rightarrow 2$ sig. figs, $\pm\, 0.0001$
- $2.075 \rightarrow 4$ sig. figs, $\pm\, 0.001$
- $4300.00 \rightarrow 6$ sig. figs, $\pm\, 0.01$
- $36,003 \rightarrow 5$ sig.figs, $\pm\, 1$
- $6310 \rightarrow 3$ sig. figs, $\pm\, 10$

Rounding Rules

1. If the first digit to be dropped is less than five, then all proceeding digits are just dropped. (ex. $98.623 \rightarrow 98.6$)
2. If the first digit to be dropped is greater than five or is a five followed by all zeroes, the previous digit is increased by one. (ex. $25.0566 \rightarrow 25.06$)
3. If the first digit to be dropped is a five not followed by any other digit or a five followed by only zeroes, then the previous digit is increased by one only if it is odd. If it is even, it will not be incremented. (ex. $63.3500 \rightarrow 63.4$, but $62.65 \rightarrow 62.6$)

1.2.3 Significant Figures and Mathematical Operations

- For multiplication and division, always use the *fewest significant figures.*
- For addition and subtraction, always use the number with the most uncertainty (or the number with the uncertainty digit in the highest place).

Example 1.2.2. Significant Figures with Operations

- $6.038 \times 2.57 \approx 15.5$
- $677 + 39.2 + 6.23 \approx 722$

1.2.4 Scientific Notation

Definition 1.2.2. Scientific notation is a numerical system in which an ordinary decimal number is expressed as a product of a number between 1 and 10 and 10 raised to a power. (as in: $A \times 10^N$) The value N refers to how many places the decimal of a number is moved, where $+N$ is right and $-N$ is left.

Example 1.2.3. Scientific Notation

- $905000 = 9.05 \times 10^5$
- $0.0006030 = 6.030 \times 10^{-4}$
  Note: The trailing zero is kept as it is significant.
- $1.894 \times 10^{-7} = 0.0000001894$
- $1.327 \times 10^5 = 132700$

1.3 Lecture 3: Unit System and Dimensional Analysis

1.3.1 The Metric System

Quantity	Metric System	Customary System	Tool for Measure
Mass	Grams (g)	Pounds (lbs)	Scale
Length	Meters (m)	Inches (in.)/Various	Ruler
Volume	Liters (L)	Fluid Ounces (fl. oz.)/Various	Graduated Cylinder
Temperature	Celsius (°C)	Fahrenheit (°F)	Thermometer

Note: The metric system is based on base 10, meaning that it follows prefixes that get multiplied to each number by a series of ten.

Prefix	Symbol	Value
Tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	k	10^{3}
Hecto	h	10^{2}
Deca	da	10^{1}
Deci	d	10^{-1}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}
Nano	n	10^{-9}
Pico	p	10^{-12}

Note: This can be remembered with: *The Great Mega King Henry Doesn't* [*usually*] *Drink Chocolate Milk Mixed* [*with*] *Nana's Peanuts*. **It is incredibly important that these values and their prefixes are remembered!**

1.3.2 SI Units

SI is the international system of units, and denotes the standard units for each measurement.

- SI Length is in Meters (m) ("Metres" internationally but "Meters" domestically).
- SI Mass is in Kilograms (kg). **Note:** Mass is the total number of matter, weight is mass multiplied by the force of gravity.
- SI Volume is in Liters (L). ("Litres" internationally but "Liters" domestically), where 1 L = 1000 cm^3.
- SI time is in seconds (s).
- SI temperature is in Kelvin (K).
- SI Current is in Amperes (amp).
- SI Amount/Count is in Moles (mol).

Note: When measuring the volume of a solid, use $V = LWH$. For liquids in a graduated cylinder, read from the bottom of the meniscus.

1.3.3 Metric to Metric Conversion

1. Determine what the end goal unit is.
2. Determine what the given unit is.
3. Multiply the given unit by the ratio fraction of the two units, where the initial unit's value is the denominator and the ending unit's value is the numerator.
4. Round the final product to the original number of significant figures.

For English-to-Metric conversions, you will be given the conversion rates between English and Metric conversions. That is all that you need to know for that.

1.3.4 Common Equation Reference

- Density = $\frac{\text{Mass}}{\text{Volume}}$
- Percent Error: $|\frac{\text{Measured Value}-\text{Accepted Value}}{\text{Accepted Value}}| \times 100$

1.3.5 Temperature Conversions

- $K = C + 273.15$
- $C = \frac{5}{9}(F - 32)$
- $F = \frac{9}{5}F + 32$
- 273 K = 0 C
- 373 K = 100 C
- 32 F = 0 C
- 212 F = 100 C

Module 2

Matter

Module 3

Elements

Module 4

Compounds

Module 5

Reactions

Module 6

Moles

Module 7

Intermolecular Forces

Module 8

Solutions