Chapter 1 Lecture Notes

Significant Figures and Calculations

Significant Figures

Some instruments are capable of measuring with greater reliability than others. When making a measurement, it is important to represent that measurement to the correct degree of uncertainty. The digits that are known with certainty plus an additional digit that contains some uncertainty (estimated) are referred to as the "significant figures" ("sig figs") in the measurement.

What temperature is indicated on the thermometer in the figure?
a. 33°C  b. 32°C  c. 32.4°C  d. 32.45°C  e. no correct answer

How many sig figs are written in the measurement?
a. 1  b. 2  c. 3  d. 4  e. no correct answer

How many digits are known with certainty? How many are estimated?
a. 1 and 1  b. 1 and 2  c. 2 and 1  d. 2 and 2  e. no correct answer

How many sig figs are present in the following values, assuming that they are measured values? (Units have been omitted, but could be grams (g), liters (L), centimeters (cm), etc., rules are provided on page 18-19)

<table>
<thead>
<tr>
<th>Value</th>
<th>a. 1</th>
<th>b. 2</th>
<th>c. 3</th>
<th>d. 4</th>
<th>e. no correct answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.00005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.05000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.00 x 10²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0 x 10²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rounding

To obtain the correct number of sig figs, it is often necessary to "round off" a value (e.g., from the many "extra" digits on a calculator screen). Some of the rules are as follows:

- If the digit following the last significant figure is 1, 2, 3, or 4, then round "down."
- If the digit following the last significant figure is 6, 7, 8, or 9, then round "up."
• If the digit following the last significant figure is a 5 (with no other non-zero digits after the 5), round \textit{down} if the last sig fig is \textit{even} and round \textit{up} if the last sig fig is \textit{odd}.

The rule about "5’s" is necessary to avoid \textit{statistical bias} in your calculations. Statistically speaking, you round \textit{down} 4 out of 9 times (\textit{i.e.}, 1, 2, 3, 4) and round \textit{up} 4 out of 9 times (\textit{i.e.}, 6, 7, 8, 9).

\begin{align*}
1 & \quad 2 & \quad 3 & \quad 4 & \quad 5 & \quad 6 & \quad 7 & \quad 8 & \quad 9 \\
\text{these 4 digit} & \quad \text{these 4 digit} & & & & & & & \\
\text{round down} & \quad \text{round up} & & & & & & & \\
5.33 & & & & & & & & \\
& & & & & & & & \\
5.36 & & & & & & & & \\
& & & & & & & & \\
\end{align*}

Note that this rule only applies when there are no other non-zero digits following the "5". If there is anything other than a zero after the "5", then the number must be \textbf{rounded up}. This follows the same logic as above, but on a larger "number line."

\begin{align*}
1 & \quad 2 & \quad 3 & \quad \ldots & \quad 47 & \quad 48 & \quad 49 & \quad 50 & \quad 51 & \quad 52 & \quad \ldots & \quad 97 & \quad 98 & \quad 99 \\
\text{these 49 digit} & \quad \text{these 49 digit} \quad \text{these 49 digit} \quad \text{these 49 digit} & & & & & & & \\
\text{round down} & \quad \text{round up} & & & & & & & \\
5.328 & & & & & & & & \\
& & & & & & & & \\
5.366 & & & & & & & & \\
& & & & & & & & \\
\end{align*}

When the \textit{only non-zero} digit following the last significant figure is a 5, it is necessary to round down half of the time and round up half of the time.

\begin{align*}
5.25 & \quad 5.35 \\
\text{round to two sig figs} & \quad \text{round to two sig figs} \\
\end{align*}
Round the following numbers to three sig figs.

<table>
<thead>
<tr>
<th>Number</th>
<th>a. 1.23</th>
<th>b. 1.24</th>
<th>c. no correct answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.23478</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.23678</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.235</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.225</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2350</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2251</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2249</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculations

**Significant Figures in Calculations:** There are two different rules that must be applied for determining the proper number of sig figs in the result of a calculation, depending on whether the calculation involves multiplication/division or addition/subtraction.

- **Multiplication/Division:** only as many sig figs in the answer as the factor with the least sig figs

How many significant figures should be used in the answer below (assuming measured values)?

\[
\frac{8.259 \times 1.2}{3.33} = 2.9762162
\]

a. 2 sig figs  
   b. 3 sig figs  
   c. 4 sig figs  
   d. no correct answer

- **Addition/Subtraction:** only as many digits to the right of the decimal point in the answer as the factor with the least digits to the right of the decimal point

How many significant figures should be used in the answers below (assuming measured values)?

a.

\[(121.9) + (5.66) - (119.2935) = 8.2665\]

a. 1 sig figs  
   b. 2 sig figs  
   c. 3 sig figs  
   d. 4 sig figs  
   e. 5 sig figs
b. 

\[
\begin{array}{c}
17.2935 \\
5.66 \\
+121.9 \\
\hline
144.8535
\end{array}
\]

a. 3 sig figs  b. 4 sig figs  c. 5 sig figs  d. 6 sig figs  e. 7 sig figs

Scientific or Exponential Notation

Very large and very small numbers (and normal size numbers too) are often written as a coefficient between 1.0000… and 9.9999… times a power of 10. This works well to show the actual number of significant figures too. When a problem is set up with all numbers in this notation it is often easy to mentally estimate a ballpark figure to check your answer.

Examples

\[
\begin{array}{ccc}
9.99 \times 10^{10} & 1.0010 \times 10^{-14} & 2.562 \\
5.3 \times 10^{1}
\end{array}
\]

Dimensional Analysis: One way to approach many of the required calculations is to use "dimensional analysis". In dimensional analysis, the units of a known quantity are transformed into the units of the desired quantity through a series of "conversion factors."

- Start with a quantity that has been given in the problem.
- Systematically convert from the starting units to the desired units.
- Units cancel when they are on the opposite sides of (above and below) the division line.

**Fundamental SI units of measure**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>kilograms</td>
<td>kg</td>
</tr>
<tr>
<td>Length</td>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>Temperature</td>
<td>Kelvin</td>
<td>K</td>
</tr>
<tr>
<td>Amount of substance</td>
<td>mole</td>
<td>mol</td>
</tr>
<tr>
<td>Time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>Electrical current</td>
<td>ampere</td>
<td>A</td>
</tr>
<tr>
<td>Luminous intensity</td>
<td>candela</td>
<td>cd</td>
</tr>
</tbody>
</table>
Mixing units is a common feature. You will use mix units in your second lab when you
determine density (g/ml or g/cm³).

Determine the density of milk in grams/mL. One gallon of milk weighs 8.50 pounds. The
average cow produces 53 pounds of milk a day. How many gallons does she produce each
day?

Prefixes for large/small amounts

<table>
<thead>
<tr>
<th>Large amounts</th>
<th>Small amounts</th>
</tr>
</thead>
<tbody>
<tr>
<td>giga</td>
<td>deci</td>
</tr>
<tr>
<td>G</td>
<td>d</td>
</tr>
<tr>
<td>$10^9 = 1,000,000,000$</td>
<td>$10^{-1} = 0.1$</td>
</tr>
<tr>
<td>mega</td>
<td>centi</td>
</tr>
<tr>
<td>M</td>
<td>c</td>
</tr>
<tr>
<td>$10^6 = 1,000,000$</td>
<td>$10^{-2} = 0.01$</td>
</tr>
<tr>
<td>kilo</td>
<td>milli</td>
</tr>
<tr>
<td>k</td>
<td>k</td>
</tr>
<tr>
<td>$10^3 = 1,000$</td>
<td>$10^{-3} = 0.001$</td>
</tr>
<tr>
<td>hecto</td>
<td>micro</td>
</tr>
<tr>
<td>h</td>
<td>µ</td>
</tr>
<tr>
<td>$10^2 = 100$</td>
<td>$10^{-6} = 0.000 001$</td>
</tr>
<tr>
<td>deka</td>
<td>nano</td>
</tr>
<tr>
<td>da</td>
<td>n</td>
</tr>
<tr>
<td>$10^1 = 10$</td>
<td>$10^{-9} = 0.000 000 001$</td>
</tr>
<tr>
<td></td>
<td>pico</td>
</tr>
<tr>
<td></td>
<td>$10^{-12} = 0.000 000 000 001$</td>
</tr>
<tr>
<td></td>
<td>atto</td>
</tr>
<tr>
<td></td>
<td>$10^{-15} = 0.000 000 000 000 001$</td>
</tr>
<tr>
<td></td>
<td>femto</td>
</tr>
<tr>
<td></td>
<td>$10^{-18} = 0.000 000 000 000 000 001$</td>
</tr>
</tbody>
</table>

How many seconds are there in 7.5 years? (No leap years!)

a. $2.3652 \times 10^8$ s   b. $2.365 \times 10^8$ s   c. $2.4 \times 10^9$ s   d. $2.4 \times 10^8$ s   e. $2.3 \times 10^7$ s

• "Exact Values" in Calculations: Some values that are used in calculations are not measured; rather they represent an exact relationship that contains no uncertainty (e.g., 7 days in a week, 2 atoms of hydrogen in a water molecule, 1000 grams in a kilogram, etc.). It is useful think of such exact values as having an infinite number of sig figs since they do not impose any limit on the number of sig figs in the final calculated value.

Which of the values in the above calculation of seconds is not an exact value?

a. seconds  b. minutes  c. hours  d. days  e. years

• "Intermediate Values" in Calculations: At times it may be convenient to calculate an intermediate value as part of a longer calculation. In such a case, you should
keep at least two "extra" digits (beyond those required by the sig figs) in your intermediate value—and only round to the proper number of sig figs for the final reported value. Failure to do this may result in a "rounding error."

\[ (7.5 \text{ y}) \frac{(365 \text{ d})}{(1 \text{ y})} \frac{(24 \text{ h})}{(1 \text{ d})} = 65,700 \text{ h (unrounded)} = 66,000 \text{ h or } 6.6 \times 10^4 \text{ h (correctly rounded)} \]

-------------------------

incorrect early rounding

\[ (7.5 \text{ y}) \frac{(365 \text{ d})}{(1 \text{ y})} = 2,737.5 \text{ d} \quad \text{of intermediate} \quad (2700 \text{ d}) \frac{(24 \text{ h})}{(1 \text{ d})} = 65,000 \text{ h (rounding error)} \]

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**Periodic Table**

The periodic table is a very useful way to organize all of the known elements in the universe. The elements are arranged in order of "atomic number" and lined up so that elements with similar chemical and physical properties are in the same column. It then becomes apparent that these properties of the elements repeat themselves in a regular fashion—that is, a "periodic" repetition of the element properties in each row of the table.

On most periodic tables, the "atomic number" is indicated above the element symbol, and the "atomic mass" is indicated below the symbol. The two most common systems used for labeling the columns are shown on the top periodic table.
Questions:

1. What are groups?  
   a. rows  
   b. columns

2. What are periods?  
   a. rows  
   b. columns

3. Where are metals?  
   a. right of the dashed elements  
   b. the dashed elements  
   c. left of the dashed elements

4. Where are non-metals?  
   a. right of the dashed elements  
   b. the dashed elements  
   c. left of the dashed elements

5. Where are semi-metals?  
   a. right of the dashed elements  
   b. the dashed elements  
   c. left of the dashed elements

6. Where are the main group elements?  
   a. middle group  
   b. combined groups (1A-8A)  
   c. bottom group d. top row e. bottom row

7. Where are the transition metals?  
   a. middle group  
   b. combined groups (1A-8A)  
   c. bottom group d. top row e. bottom row

8. Where are the innertransition metals?  
   a. middle group  
   b. combined groups (1A-8A)  
   c. bottom group d. top row e. bottom row

9. Where are the actinides?  
   a. middle group  
   b. combined groups (1A-8A)  
   c. bottom group d. top row e. bottom row

10. Where are the lanthanides?  
    a. middle group  
    b. combined groups (1A-8A)  
    c. bottom group d. top row e. bottom row

11. Where are the alkaline earths?  
    a. 1A  
    b. 2A  
    c. 6A  
    d. 7A  
    e. 8A

12. Where are the halogens?  
    a. 1A  
    b. 2A  
    c. 6A  
    d. 7A  
    e. 8A

13. Where are the alkali metals?  
    a. 1A  
    b. 2A  
    c. 6A  
    d. 7A  
    e. 8A

14. Where are the Noble gases?  
    a. 1A  
    b. 2A  
    c. 6A  
    d. 7A  
    e. 8A

15. Where are the chalcogens?  
    a. 1A  
    b. 2A  
    c. 6A  
    d. 7A  
    e. 8A

Know the elements with symbols provided.
**Temperature (SI units = Kelvin = K)**

K = kelvin = absolute temperature (has an absolute zero)

<table>
<thead>
<tr>
<th>Kelvin scale</th>
<th>Celsius scale</th>
<th>Fahrenheit scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 373.15 K</td>
<td>T = 100°C</td>
<td>T = 212°F</td>
</tr>
<tr>
<td></td>
<td>boiling point of water</td>
<td></td>
</tr>
<tr>
<td>T = 273.15 K</td>
<td>T = 0°C</td>
<td>T = 32°F</td>
</tr>
<tr>
<td></td>
<td>freezing point of water</td>
<td></td>
</tr>
<tr>
<td>T = 0 K</td>
<td>T = -273.15°C</td>
<td>T = -459.67°F</td>
</tr>
<tr>
<td></td>
<td>absolute zero</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Celsius to Fahrenheit</th>
<th>Fahrenheit to Celsius</th>
<th>Kelvin to Celsius to Kelvin</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_F = \left( \frac{9°F}{5°C} \times T_C \right) + 32°F )</td>
<td>( T_C = \frac{5°C}{9°F} \times \left( T_F - 32°F \right) )</td>
<td>( T_K = T_C + 273.15 )</td>
</tr>
<tr>
<td>( T_C = T_K - 273.15 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What is \( T_F \) when \( T_C = 30°C \)? What is \( T_C \) when \( T_F = 68°F \)? What is \( T_K \) when \( T_C = 100°C \)?
Properties

Intensive properties – do not change with amount (temp, mp, bp, density, etc.)
Extensive properties – do change with amount (length, vol, mass, etc.)

Physical properties – mp, bp, color, conductivity, solubility, odor, etc.
Chemical properties – how chemicals react with other chemicals

Accuracy – refers to how close a measurement is to the true value
Precision – refers how well a number of measurements agree with one another

"X" shots are precise, but not accurate.  
a. 1  b. 2  c. 3  d. 4

"X" shots are accurate, but not precise.  
a. 1  b. 2  c. 3  d. 4

"X" shots are precise and accurate.  
a. 1  b. 2  c. 3  d. 4

"X" shots are not precise and not accurate.  
a. 1  b. 2  c. 3  d. 4