# AMSAT CHEM 1H TOPIC#2
# MEASUREMENTS/CALCULATIONS NOTES

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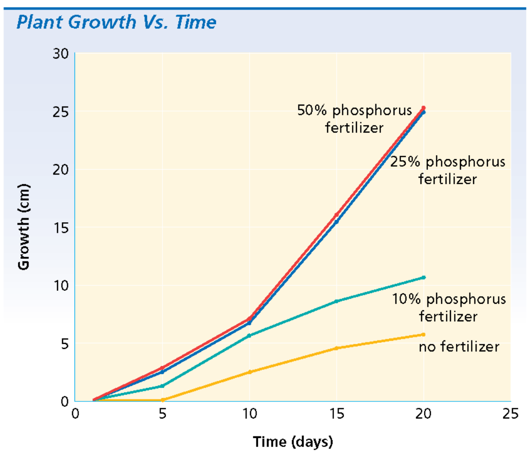
## SCIENTIFIC METHOD SECTION#1

- A logical approach to solving a problem.
- Make an observation
  - Use your senses to obtain information
- Form a question from your observations
  - Formulate a question about observations
- Form a hypothesis
  - A tentative answer to your question
  - A testable (no opinions) if/then or cause/effect statement about your observations and question
    - Basis for making predictions
    - Develop further experiments based on observations
    - "Then" part is the prediction of the hypothesis
      - If an appendix has no function, then we can live without it.

**Visual Concept: Hypothesis**

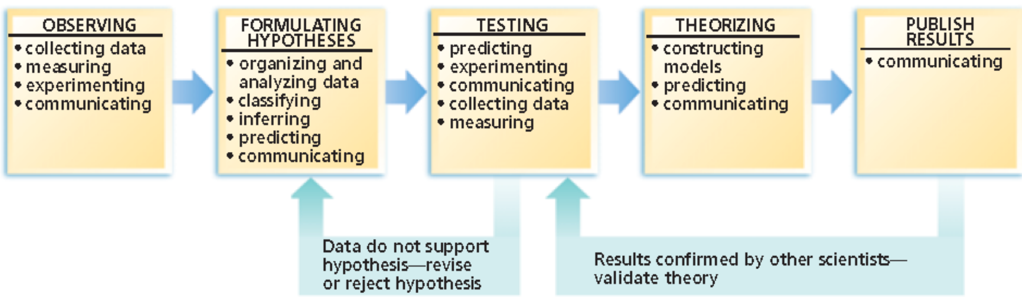



- Develop an experiment to test hypothesis
  - Used to confirm/deny hypothesis
  - Must be reproducible by peers
  - Control
    - Has a known result (outcome): Water freezes @ 0°C
  - Variable
    - Aspect being tested: Water with dissolved salt freezes at ___°C
- Summarize results from an experiment in a conclusion.
  - Discussion of the confirmation/denial of hypothesis
  - Leads to changes in hypothesis

- After numerous experiments, the results may be summarized in a natural law
  - A description of how nature behaves.
  - Not a reason why.
  - Gives a "big" picture from a collection of experiments and observations.
- Finally, a theory is developed to explain "why" nature behaves like described in a natural law.
  - A broad generalization explaining a body of tested facts or phenomena
  - Explains why nature behaves in the way described by the natural law.
  - Model
    - Explains how phenomena occur and how data or events are related
    - Can be visual, verbal, or mathematical
    - May become part of theory if it successfully explains facts/phenomena
- Using the theory, scientists form predictions on similar phenomena
- Experiments
  - Using theory as basis for experiments
  - Can reinforce or force an amendment to theory

**Visual Concept: Scientific Method**

**Scientific Method**




## MEASUREMENTS SECTION#2

- Observing and Collecting data
  - Direct observation
    - See with you own eyes
      - Macro
        - Large
          - Colors on a leopard
      - Micro
        - Need use of an instrument
          - Microscope
  - Indirect observation
    - Cannot see with own eyes
      - Makeup of sun
      - Interior of Earth
  - Types of Observations
    - Quantitative
      - A measurement with a number a unit
        - 24L, 45.6m, etc.
    - Qualitative
      - A measurement using senses or general descriptions
        - The sky is blue and the clouds are fluffy



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- **Sample Problem 1.1** - Qualitative/Quantitative Observations
  Identify as qualitative (a) or quantitative (b).
  (1) dirty water ___ (2) 24in wide___ (3) 3.000ng of U ___ (4) blue jeans ___

  **Visual Concept: Qualitative/Quantitative Data**
- Observation vs. Inference
  - When you observe you become aware using one of your five senses (smell, hear, taste, touch, or sight).
    - A statement describing a fact.
  - An inference is a mental judgment based on an observation.
    - They require thought
    - A statement based on your interpretation of the facts
  - When you wake up in the morning, you observe dark clouds, you observe the cool and humid air, and observe puddles on the ground. You did not see rain but you inferred and decided it rained based on your observations.

| Observations | Inferences |
|---|---|
| The plant is extremely wilted. | That plant is extremely wilted due to lack of water. |
| The car stopped running. | The car stopped running because it was out of gas. |
| The White Sox are leading their division. | The White Sox are leading their division because they are playing well right now. |

- System
  - Specific portion of matter in a given region of space under investigation (study)
- Surroundings
  - Everything outside of the system

| Common SI Units | | |
|---|---|---|
| Length | meter (m)<br>kilometer (km)<br>decimeter (dm)<br>centimeter (cm)<br>millimeter (mm)<br>micrometer (μm)<br>nanometer (nm) | 1 km = 1,000 m<br>1 dm = 0.1 m<br>1 cm = 0.01 m<br>1 mm = 0.001 m<br>1 μm = 0.000 001 m<br>1 nm = 0.000 000 001 m |
| Volume | cubic meter ($m^3$)<br>cubic centimeter ($cm^3$)<br>liter (L)<br>milliliter (mL) | 1 $cm^3$ = 0.000 001 $m^3$<br>1 L = 1 $dm^3$ = 0.001 $m^3$<br>1 mL = 0.001 L = 1 $cm^3$ |
| Mass | kilogram (kg)<br>gram (g)<br>milligram (mg) | 1 g = 0.001 kg<br>1 mg = 0.000 001 kg |
| Temperature | Kelvin (K)<br>Celcius (°C) | 0°C = 273 K<br>100°C = 373 K |

- Quantities
  - a magnitude, size, or amount
  - Number plus unit
    - No naked numbers (or people) in chemistry
      - 24 L
      - 3 tsps
        - What is wrong with 7 tall? ____________
- SI units (*Le Systeme International d' Unites*)
  - Based on Metric System
    - Write seventy-five thousand as 75 000 not 75,000

| Quantity | Quantity symbol | Unit name | Unit abbreviation | Defined standard |
|---|---|---|---|---|
| Length | $l$ | meter | m | the length of the path traveled by light in a vacuum during a time interval of 1/299 792 458 of a second |
| Mass | $m$ | kilogram | kg | the unit of mass equal to the mass of the international prototype of the kilogram |
| Time | $t$ | second | s | the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom |
| Temperature | $T$ | kelvin | K | the fraction 1/273.16 of the thermodynamic temperature of the triple point of water |
| Amount of substance | $n$ | mole | mol | the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12 |
| Electric current | $I$ | ampere | A | the constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to $2 \times 10^{-7}$ newton per meter of length |
| Luminous intensity | $I_v$ | candela | cd | the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency $540 \times 10^{12}$ hertz and that has a radiant intensity in that direction of 1/683 watt per steradian |

| Prefix | Symbol | Factor of Base Unit |
|---|---|---|
| *giga-* | G | 1 000 000 000 |
| *mega-* | M | 1 000 000 |
| *kilo-* | k | 1 000 |
| *hecto-* | h | 100 |
| *deka-* | da | 10 |
| *deci-* | d | 0.1 |

| Prefix | Symbol | Factor of Base Unit |
|---|---|---|
| *centi-* | c | 0.01 |
| *milli-* | m | 0.001 |
| *micro-* | m | 0.000 001 |
| *nano-* | n | 0.000 000 001 |
| *pico-* | p | 0.000 000 000 001 |



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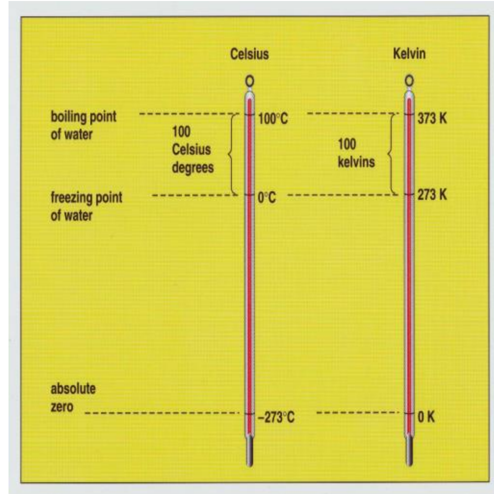
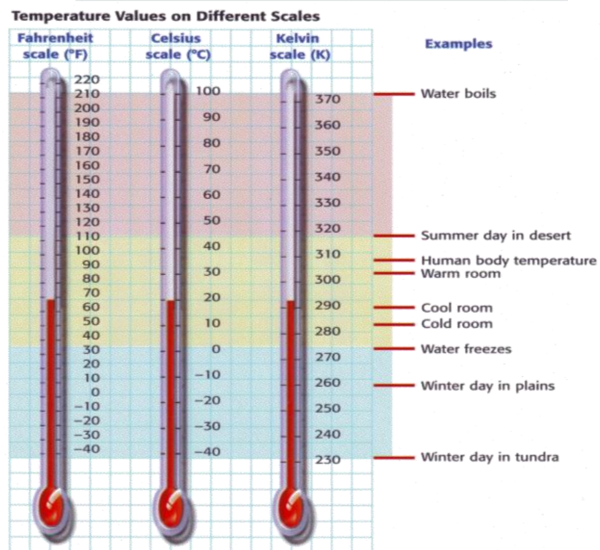
| SI Prefixes | | | | |
|---|---|---|---|---|
| **Prefix** | **Unit Abbr** | **Exponential Factor** | **Meaning** | **Example** |
| **atto** | a | $10^{-18}$ | 1/1 000 000 000 000 000 000 | 1 attometer (am) = 1x$10^{-18}$m |
| **femto** | f | $10^{-15}$ | 1/1 000 000 000 000 000 | 1 femtometer (fm) = 1x$10^{-15}$m |
| **pico** | p | $10^{-12}$ | 1/1 000 000 000 000 | 1 picometer (pm) = 1x$10^{-12}$m |
| **nano** | **n** | **$10^{-9}$** | **1/1 000 000 000** | **1 nanometer (nm) = 1x$10^{-9}$m** |
| **micro** | **μ (mu)** | **$10^{-6}$** | **1/1 000 000** | **1 micrometer (μm) = 1x$10^{-6}$m** |
| **milli** | **m** | **$10^{-3}$** | **1/1000** | **1 millmeter (mm) = 1x$10^{-3}$m** |
| **centi** | **c** | **$10^{-2}$** | **1/100** | **1 centimeter (cm) = 1x$10^{-2}$m** |
| **deci** | **d** | **$10^{-1}$** | **1/10** | **1 decimeter (dm) = 1x$10^{-1}$m** |
| **-** | **-** | **$10^{0}$** | **1** | **1 meter (m)** |
| **deca** | **da** | **$10^{1}$** | **10** | **1 decameter (dam) = 1x$10^{1}$m** |
| **hecto** | **h** | **$10^{2}$** | **100** | **1 hectometer (hm) = 1x$10^{2}$m** |
| **kilo** | **k** | **$10^{3}$** | **1000** | **1 kilometer (km) = 1x$10^{3}$m** |
| **mega** | M | $10^{6}$ | 1 000 000 | 1 megameter (Mm) = 1x$10^{6}$m |
| **giga** | G | $10^{9}$ | 1 000 000 000 | 1 gigameter (Gm) = 1x$10^{9}$m |
| **tera** | T | $10^{12}$ | 1 000 000 000 000 | 1 terameter (Tm) = 1x$10^{12}$m |

* Angstrom is 1x$10^{-10}$ of a meter, 1 Angstrom (Å) = 1x$10^{-10}$m

- Base units
  - Mass – kilogram, kg
    - ____ g = ____ kg
      - 2.2pounds (lbs) = 1 kg
    - Mass vs. weight
      - Mass – amount of matter in an object
      - Weight – gravity's effect on an object's mass
  - **<u>Sample Problem 1.2</u>** – Mass
    Supply the missing number.
    (1) ? g = 2.3kg (2) 345g = ? kg
  - Length – meter, m
    - ____mm = ____cm = ____dm = ____m (2.54cm = 1 inch, 1.609km = 1 mile)
  - **<u>Sample Problem 1.3</u>** – Length
    Supply the missing number.
    (1) ? cm = 0.230m (2) 345 cm = ? mm (3) ? dm = 8.9 m (4) 12 dm = ? cm (5) ? mm = 7.2 dm
  - Time (*t*) – second, s or sec
    - 60s = 1 minute, 60 minutes = 1hr, and 24hr = 1day
  - **<u>Sample Problem 1.4</u>** – Time
    (1) How many seconds in an hour? (2) How many seconds in a day?
  - Amount (*n*) – mole, mol (quantity)
    - 1 mole of parts = 6.022x$10^{23}$ parts
      - In chemistry, parts are atoms, ions, formula units, and molecules
  - **<u>Sample Problem 1.5</u>** – Amount
    (1) How many moles in 1.2x$10^{24}$ eggs? (2) How many parts in 3.0 moles of bacon?
  - Temperature (T) – Kelvin, K
    - 0K is called absolute zero

                - Means at 0K all motion ceases in matter
                    - No colder temperature exists
            - Move up in temperature 1K you also move up by 1°C
                - Same increment (1K = 1°C)
                    - Just different starting points
            - Temperature is the measure of the average kinetic energy in a system
                - Some particles are moving faster, some slower, and some average
                    - Kinetic energy (KE) is the energy of motion
                        - E of a moving baseball
                    - Potential energy (PE) is the energy of relative position
                        - Chemical bonds
                        - A boulder on a cliff
            - Boiling point for water is 100°C (373K)
            - Freezing point for water is 0°C (273K)
            - Kelvin/Celsius conversion
                - K = °C + 273.15
                - °C = K - 273.15
            - Celsius/Fahrenheit conversion
                - °F = 1.8(°C) + 32
                - °C = (°F-32)/1.8



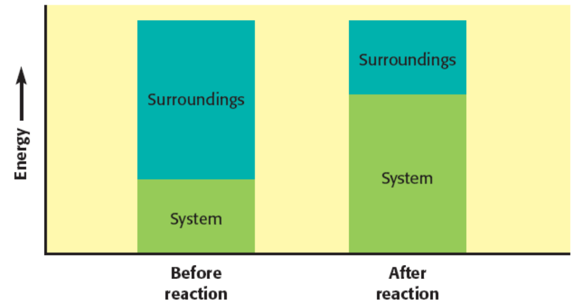

    - **<u>Sample Problem 1.6</u>** – Temperature
      Supply the missing number.
      (1) 30°C = ? K (2) ? °C = 323K (3) 98.6°F = ? °C (4) ? °F = 100°C

- Derived units
    - Created from multiplying or dividing base SI units
        - Area (*l* x *w*) 1m x 1m = 1m$^2$
            - Usually measured in m$^2$ or cm$^2$

| Quantity | Quantity symbol | Unit | Unit abbreviation | Derivation |
|---|---|---|---|---|
| Area | $A$ | square meter | m$^2$ | length × width |
| Volume | $V$ | cubic meter | m$^3$ | length × width × height |
| Density | $D$ | kilograms per cubic meter | $\frac{kg}{m^3}$ | $\frac{\text{mass}}{\text{volume}}$ |
| Molar mass | $M$ | kilograms per mole | $\frac{kg}{mol}$ | $\frac{\text{mass}}{\text{amount of substance}}$ |
| Molar volume | $V_m$ | cubic meters per mole | $\frac{m^3}{mol}$ | $\frac{\text{volume}}{\text{amount of substance}}$ |
| Energy | $E$ | joule | J | force × length |

    - **<u>Sample Problem 1.7</u>** – Area
      How many cm$^2$ in 1m$^2$? (ans: 10,000cm$^2$ )
    - Volume (l x w x h) 1m x 1m x 1m = 1m$^3$
        - Amount of space occupied by an object
        - Usually measured in liters (L) or milliliters (mL)
            - Can be measured in cm$^3$
            - 1L = 1000mL = 1000cm$^3$; 1mL = 1cm$^3$; 1dm$^3$ = 1L
    - **<u>Sample Problem 1.8</u>** – Volume
      (1) How many cm$^3$ in 1 m$^3$? (2) How many dm$^3$ are in 1 m$^3$?
      Hint: start with a known relationship between centimeters and meters.

- Force = m x a = kg x $m/s^2$ = Newton (N)
  - A 1kg mass accelerating @ $1m/s^2$ has a force of 1N
- Pressure = F/A = $N/m^2$ = Pascal
  - $(kg \cdot m/s^2)/m^2 = kg/m \cdot s^2$
- Work = force x distance = (kg x $m/s^2$) • m = kg x $m^2/s^2$
  - Energy = Joule (J) = kg x $m^2/s^2$
    - The capacity to do work or produce heat
      - Forms of energy
        - Kinetic energy
          - KE – Energy of motion
        - Potential energy
          - PE – Energy possessed by object because of their position
    - Measuring energy
      - calorie is the amount of energy needed to raise 1gram (g) of water by 1°C
      - 1 cal = 1g x 1°C, 1 Calorie = 1000 cal = 1 kcal, 1 cal = 4.184 J
        - Law of Conservation of Energy




          - In any process, E is neither created nor destroyed.
          - Changes form
          - Chemical to electrical
- **<u>Sample Problem 1.9</u>** – Energy

(1) A student uses 30.J of energy putting books on a shelf in the classroom. Convert this amount of energy from joules to calories. (ans: 7.2 cal)

(2) Suppose you use 135cal of energy to perform a task. How many joules have you used? (ans: 565J)

(3) The energy content of a small tomato is about 17 Cal. Convert this measurement to joules. (ans: $7.1 x 10^4$J)

    - Heat
      - The total amount of energy (*E*) in a system
        - Can only measure a change (Δ) in *E*, not the actual total *E*
        - Heat flows from hot objects to cold objects
          - A hot highway melts ice cream, not an ice cream freezes a hot highway
    - Types of heat transfer
      - Radiant
        - Through space w/o medium
          - Infrared radiation – fire
      - Convection
        - In liquids
          - Hot particles move away from heat replaced by colder particles until all is same temperature
      - Conduction
        - Transfer of heat from one object to another through direct contact Making measurements
- Uncertain for (2) reasons
  - (1) Instruments are never free of flaws

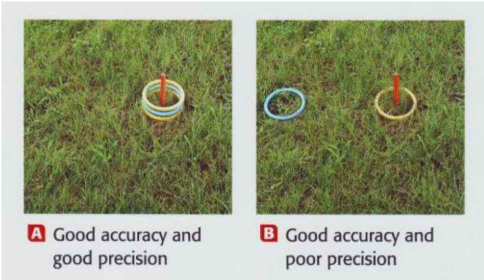
- (2) Involve some estimation
  - Final digit is estimated
    - Estimation
      - Digital display
        - The final digit is the estimated digit
          - Shows 24.62
          - The 2 is an estimated digit
      - Scale
        - Graduated cylinder
          - Read at bottom of meniscus
          - The number you guess is the estimated digit
  - Showing Uncertainty in a measurement
    - The guessed number has uncertainty
      - Show uncertainty by using a (± 0.0x, ±0.x, ± x, etc.)

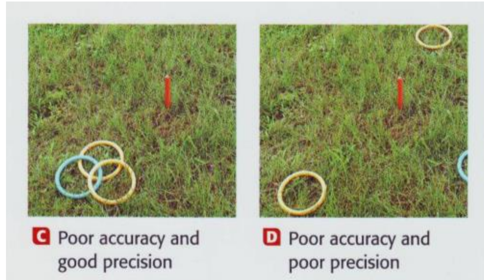
- **Sample Problem 1.10** – Uncertainty
  (1) Write 37.7 with the uncertainty. (2) Write 32 with the uncertainty**.**
- Reliability in Measurements
  - Precision
    - A reliable measurement is one that gives you the same (or very similar) value again and again in the same conditions
      - Set#1; 3.45cm, 3.50cm, 3.40cm
      - Set#2: 3.44cm, 3.42cm, 3.43cm
    - Which set of measurements is the most precise? ________________
  - Accuracy
    - An accurate measurement is exactly or very close to the accepted value (standard)
      - 3.45cm, 3.50cm, 3.40cm
    - Which value is the most accurate when the accepted value is 3.41? ____________

| **Accuracy and Precision** | | | |
|---|---|---|---|
| **Trial #1** | 1.00g | 0.99g | 1.00g |
| **Trial #2** | 0.93g | 1.05g | 0.87g |
| **Trial #3** | 0.94g | 0.93g | 0.95g |
| **Accepted value is 0.93g** | | | |

- **Sample Problem 1.11** – Accuracy and Precision
  Using the chart above, which of the three trials is the most precise? Accurate? Precise and accurate? ___________ ___________ ___________
  - Dartboard Analogy
    - Precise
      - Hitting a spot on the dart board over and over
    - Accurate
      - Hitting the bulls-eye
    - Accurate and precise
      - Hitting the bulls-eye throw after throw

**a** Darts within the bull's-eye mean high accuracy and high precision. **b** Darts clustered within a small area but far from the bull's-eye mean low accuracy and high precision. **c** Darts scattered around the target and far from the bull's-eye mean low accuracy and low precision.




**Visual Concept: Accuracy/Precision**

- Percent error
  - % error = $\frac{\text{value}_{accepted} - \text{value}_{experimental^*}}{\text{value}_{accepted}} \times 100$

    *measured value obtained by experiment

    (+) % error – accepted > experimental

    (-) % error – accepted < experimental

- **Sample Problem 1.12** – Percent Error

  A student measures the mass and volume of a substance and calculates its density as 1.40g/mL. The correct, or accepted, value of the density is 1.30g/mL. What is the percent error of the student's measurement? (ans: -7.7%)
  - Practice

    (1) What is the percent error for a mass measurement of 17.7 g, given that the correct value is 21.2g? (ans: 17%)

    (2) A volume is measured experimentally as 4.26 mL. What is the percent error, given the correct value is 4.15mL? (ans: -2.7%)

## WORKING WITH MEASUREMENTS (NUMBERS) SECTION#3

- Scientific Notation ($Mx10^n$)
  - Measurements > 999 and less than 0.001 need to be written in scientific notation
    - 1000 as $1.000x10^3$
    - 0.005 as $5.0x10^{-3}$
  - Written with 1 number to the left of the decimal
    - $2.0x10^3$m, $3.546x10^{-7}$cm, and $8.90x10^{12}$atoms
  - When converting a standard number into scientific notation
    - Moving decimal to left makes power on ten more positive
      - 94 000 $000x10^0$ transforms into $9.4x10^{0+7} = 9.4x10^7$
    - Moving decimal to right makes power on ten more negative
      - 0.000 008 $34x10^0$ transforms into $8.35x10^{0-6} = 8.35x10^{-6}$
  - Adding/subtracting numbers written in scientific notation
    - Each numbers power on the ten must be the same
      - $9.02x10^2 + 5.69x10^1 + 1.23x10^3 =$
        - $9.02x10^2 + 0.569x10^2 + 12.3x10^2 = 21.889x10^2$
          - Correctly written = $2.1889x10^3$
  - Multiplying/Division
    - With scientific calculator
      - Input first number using exponent button
      - Input function (x or ÷)
      - Input second number using exponent button
        - Example:

          (1) $3.0x10^2 \text{ x } 5.0x10^3 = ?$    (2) $6.0x10^4 \div 3.0x10^3 = ?$

- Without scientific calculator
  - Break number into two parts

    | #1 | #2 |
    |---|---|
    | 6.0 x | $10^2$ |
    | 3.0 x | $10^3$ |

    - 1st part, the number in front of the (x)
      - Multiply or divide these numbers
    - 2nd part, the ($x10^z$)
      - Multiply/divide these numbers
        - Multiply – add powers
        - Divide – subtract denominator power from the numerator power
  - Combine 1st number and 2nd number after the multiplication/division function
  - Move decimal so ONLY 1 number is the left of the decimal point and adjust power on the 10
    - Move decimal to the right
      - Add a (1) to the power on the 10 for each move of the decimal
    - Move decimal to the left
      - Subtract (1) from the power on the 10 for each move of the decimal
    - Example:
      (1) $4.0x10^4 \div 2.0x10^5$ = ? (2) $1.5x10^{-2}$ x $2.0x10^6$ = ?

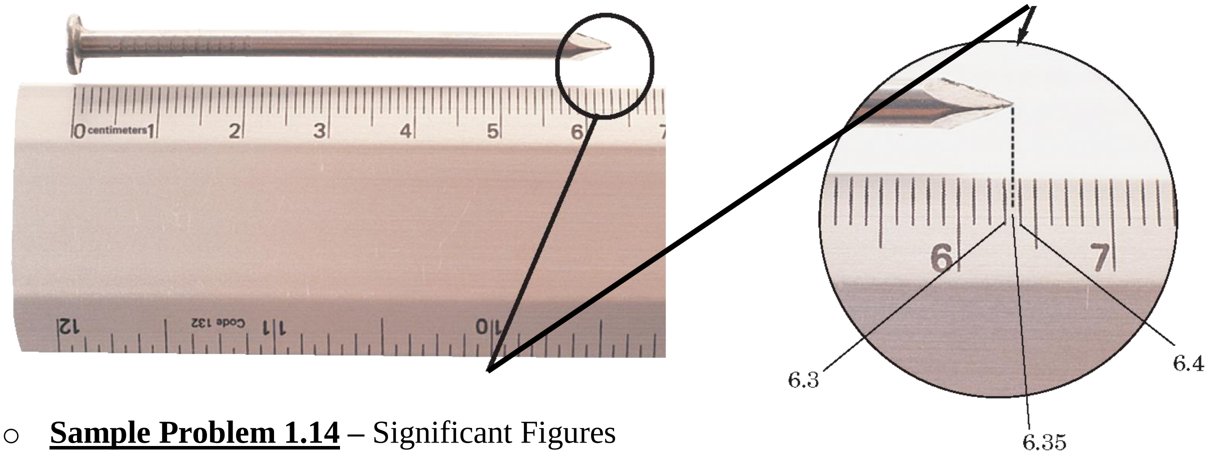
**Visual Concept: Scientific Notation**

- **Sample Problem 1.13** – Working with Scientific Notation
  (1) Convert the following numbers into scientific notation.
  (a) 34 000 (b) 0.0004523 (c) 923 890 000 (d) 0.000 000 003 4
  (2) Solve the following problems without a calculator.
  (a) $3.0x10^3 – 4.0x10^2$ = (c) $5.0x10^3$ x $4.0x10^9$ =
  (b) $9.9x10^{-3} + 1.1x10^{-2}$ = (d) $1.8x10^{-2} \div 6.0x10^{-4}$ =

- Significant Figures (Digits)
  - Significant figures in a measurement consist of all the digits known w/ certainty plus one final digit, which is somewhat uncertain or estimated
  - Process for determining number of sig figs (Atlantic-Pacific rule)
    1) Left side of number is the Pacific and the right side of the number is the Atlantic
    2) Count all nonzero numbers, starting on Pacific side of number.
    3) Does the number have a decimal point?
       Yes – go to 4
       No – go to 5
    4) Count trailing zeros (Atlantic side of number)
    5) Count zeros in between nonzero numbers
       - Never count zeros on the pacific side of the number
         - Do Sig Fig WS in Class (5minutes)
  - Numbers written in scientific notation include only significant digits
    - $2.0x10^3$m (2 s.f), $3.546x10^{-7}$cm (4 s.f), and $8.90x10^{12}$atoms (3 s.f)

**Visual Concept: Significant Figures**

**Visual Concept: Rules for Determining Significant Zeros**




- **Sample Problem 1.14** – Significant Figures
  How many sig figs are in each of the following measurements?
  (a) 28.6 g (b) 3440. cm (c) 910 m (d) 0.046 04 L (e) 0.006 700 0 kg
  - **Practice**
    (1) Determine the number of significant figures in each of the following.
    (a) 804.05 g
    (b) 0.014 403 0 km
    (c) 1002 m
    (d) 400 mL
    (e) 30 000. cm
    (f) 0.000 625 000 kg
    (2) Suppose the value "seven thousand centimeters" is reported to you. How should the number be expressed if it is intended to contain the following?
    (a) 1 sig fig (b) 4 sig fig (c) 6 sig figs

| Rounding Rules | | |
|---|---|---|
| **If the digit following the last digit to be retained is:** | **Then the last digit should:** | **Example (rounded to 3 sig figs)** |
| Greater than 5 | Be increased by 1 | 42.68g → 42.7g |
| Less than 5 | Stay the same | 17.32m → 17.3m |
| 5, followed by nonzero digit(s) | Be increased by 1 | 2.7851cm → 2.79cm |
| 5, not followed by nonzero digit(s), and preceded by an odd digit | Be increased by 1 | 4.635 kg → 4.64 kg (because 3 is odd) |
| 5, not followed by nonzero digit(s), and the preceding significant digit is even | Stay the same | 78.65 mL → 78.6 mL (because 6 is even) |

**Visual Concept: Rules for Rounding**

  - **Practice** – Rounding
    Round the following.
    (1) 0.105 to the hundredth
    (2) 1.23 to the tenth
    (3) 1055 to the tens
    (4) 1.03855 to the hundredth
- Addition/Subtraction w/ Sig Figs
  - The answer must have the same number of digits to the right of the decimal as the measurement w/ the fewest places to the right of the decimal
    - 25.1g + 2.03g = 27.13g
      - Correctly written as 27.1g (1 decimal place)
- Multiplication/Division
  - Answer has the same number of sig figs as the data point w/ the smallest number of sig figs
    - 3.05g/8.470mL = 0.360094451 g/mL

- Correctly written as 0.360g/mL (3 sig figs)

- Ideal numbers
  - Used in conversions or are known to all
    - Such as 1m = 100cm, density of water (1.00g/mL), etc.
  - These numbers are NOT used to determine sig figs for an answer

**Rules for Using Significant Figures in Calculations**

**1. In multiplication and division problems, the answer cannot have more significant figures than there are in the measurement with the smallest number of significant figures.** If a sequence of calculations is involved, do not round until the end.

12.257 m
× 1.162 m ← four significant figures
14.2426234 m$^2$ —round off→ 14.24 m$^2$

0.36000944 g/mL —round off→ 0.360 g/mL
8.472 mL)3.05 g ← three significant figures

**2. In addition and subtraction of numbers, the result can be no more certain than the least certain number in the calculation.** So, an answer cannot have more digits to the right of the decimal point than there are in the measurement with the smallest number of digits to the right of the decimal. When adding and subtracting you should not be concerned with the total number of significant figures in the values. You should be concerned only with the number of significant figures present to the right of the decimal point.

3.95 g
2.879 g
+ 213.6 g
220.429 g —round off→ 220.4 g

Notice that the answer 220.4 g has four significant figures, whereas one of the values, 3.95 g, has only three significant figures.

**3. If a calculation has both addition (or subtraction) and multiplication (or division), round after each operation.**

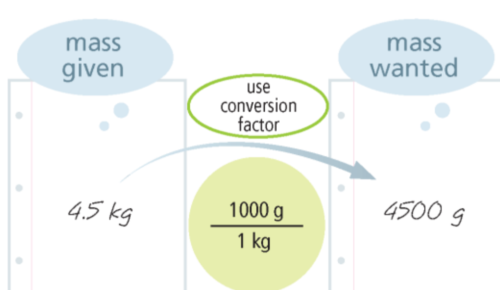
- **Sample Problem 1.15** – Using Sig Figs in an Answer
  Carry out the following calculations. Express each answer to the correct number of significant figures.
  (a) 5.44m – 2.6103m (b) 2.4g/mL x 15.82mL
  - **Practice**
    (1) What is the sum of 2.009g and 0.05681g?
    (2) Calculate the quantity 87.3cm – 1.655cm.
    (3) Calculate the area of a crystal surface that measures 1.34µm by 0.7488 µm.
    (4) Polycarbonate plastic has a density of 1.2g/cm$^3$. A photo frame is constructed from two 3.0mm sheets of polycarbonate. Each sheet measures 28cm by 22cm. What is the mass of the photo frame?

- Dimensional Analysis
  - Mathematical technique using conversion factors to solve problems using quantity sought = quantity given x conversion factor
  - Conversion factors
    - Ratio derived from the equality between two different units
      - Needed to convert from one unit to another unit

**1.** Identify the quantity and unit given and the unit that you want to convert to.

**2.** Using the equality that relates the two units, set up the conversion factor that cancels the given unit and leaves the unit that you want to convert to.

**3.** Multiply the given quantity by the conversion factor. Cancel units to verify that the units left are the ones you want for your answer.

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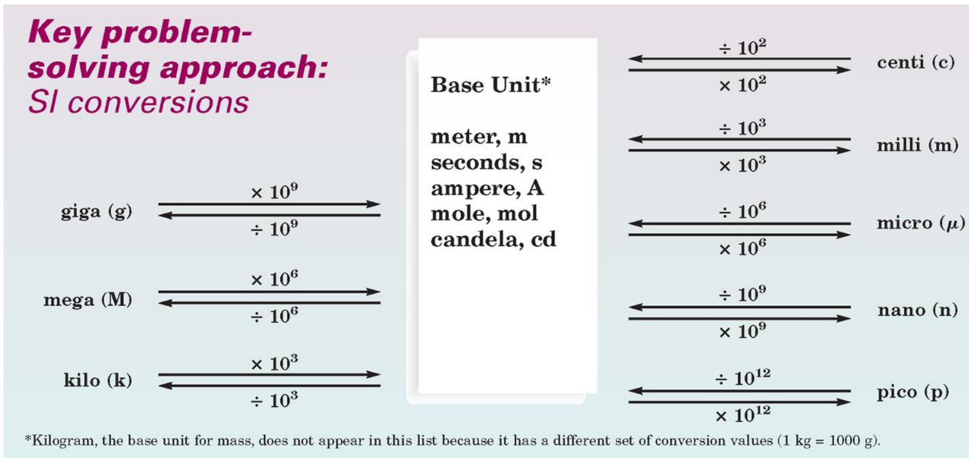
- **Sample Problem 1.16** – Dimensional analysis
  Express a mass of 5.712 grams in milligrams and kilograms. (ans: 5712mg, 0.005712kg)
  - **Practice** – Dimensional Analysis
    (1) What are the (3) conversion factors between quarters and a dollar?
    (2) Convert 46 quarters into dollars.
    (3) Convert 250. cm to inches. (1inch = 2.54cm)
    (4) How many feet in 86cm?
    (5) How many gallons in 39L? (1gal = 3.785L)
    (6) How many $cm^3$ in 2.3gal?
    (7) How many meters in 3.5mi? (1mi = 5280ft)




  - **Practice**
    (1) Express a length of 16.45m in centimeters and kilometers.(Ans: 1645cm, 0.01645km)
    (2) Express a mass of 0.014mg in grams. (Ans: 0.000 014g)
- Density
  - Physical property of matter, amount of matter in a given volume
    - $D = \frac{m}{V}$
      - Write (2) other forms of this equation.
        -
        -
      - Units (labels)
        - $g/cm^3$ or g/mL (solids)
        - g/mL (liquids)
        - g/L (gases)
    - Ratio between mass and volume
      - relates the mass of a substance to a volume of $1cm^3$(solid), 1mL(liquid), or 1L(gas)
    - Can be used in dimensional analysis as a conversion factor, density for water is $1.0g/cm^3$, so $1.0g = 1cm^3$

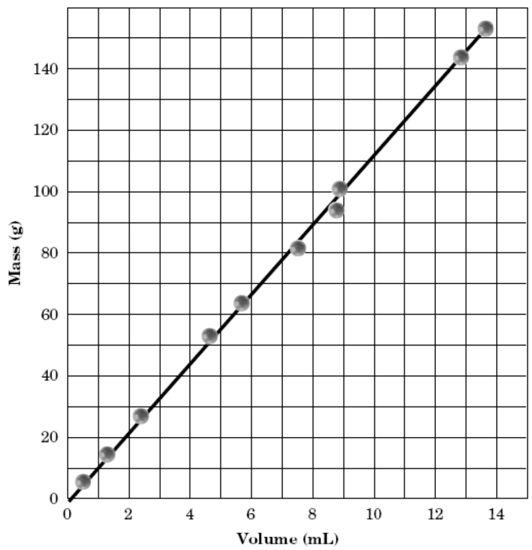
**Visual Concept: Equation for Density**

**Densities of Some Familiar Materials**

| Solids | Density at 20°C (g/cm$^3$) | Liquids | Density at 20°C (g/mL) |
|---|---|---|---|
| cork | 0.24* | gasoline | 0.67* |
| butter | 0.86 | ethyl alcohol | 0.791 |
| ice | 0.92† | kerosene | 0.82 |
| sucrose | 1.59 | turpentine | 0.87 |
| bone | 1.85* | water | 0.998 |
| diamond | 3.26* | sea water | 1.025** |
| copper | 8.92 | milk | 1.031* |
| lead | 11.35 | mercury | 13.6 |

† measured at 0°C
* typical density
** measured at 15°C

**Mass vs. Volume for Lead Samples**




**Mass and Volume Data for Samples of Lead**

| Sample number | Mass (g) | Volume (mL) |
|---|---|---|
| 1 | 5.00 | 0.443 |
| 2 | 15.0 | 1.33 |
| 3 | 24.0 | 2.12 |
| 4 | 52.0 | 4.60 |
| 5 | 64.0 | 5.66 |
| 6 | 81.0 | 7.17 |
| 7 | 95.0 | 8.41 |
| 8 | 101 | 8.94 |
| 9 | 142 | 12.6 |
| 10 | 153 | 13.5 |

- **Practice** – Density
  (1) What is the density of 0.50L of air with a mass of 0.65g?
  (2) What is the mass of a 35cm$^3$ sample of aluminum? The density for aluminum is 2.70g/cm$^3$?
  (3) What is the volume occupied by 160.g of iron? The density of iron is 7.86g/cm$^3$?
  (4) Using the above data for lead, calculate the density for each of the data points. Calculate the average value for the densities.
  1.___ 2. ___ 3. ___ 4. ___ 5. ___ 6. ___ 7. ___ 8. ___ 9. ___ 10. ___
  Average = ____________
  (5) Pick two data points and find the slope of the line.
  (6) Compare the average densities to the slope of the line.

o **Sample Problem – 1.17** - Density
A sample of aluminum metal has a mass of 8.4g. The volume of the sample is 3.1cm$^3$. Calculate the density of aluminum. (ans: 2.7 g/cm$^3$ )

- **Practice**
  (1) What is the density of a block of marble that occupies 310cm$^3$ and has a mass of 853g? (ans: 2.75g/cm$^3$ )
  (2) Diamond has density of 3.26 g/cm$^3$. What is the mass of the diamond that has a volume of 0.350cm$^3$? (ans: 1.14g)

(3) What is the volume of a sample of liquid mercury that has a mass of 76.2g, given that the density of mercury is 13.6g/mL? (ans: 5.60mL)

- Problem solving
  - Analyze
    - Givens and unknowns (unk) – use table
    - Read problem first
      - Circle given
      - Box unk
      - Plan route from given to unk
  - Plan
    - Formulas and chemical principles
    - Rearrange formula for unk variable
    - Determine unit on unk
      - Decide on conversion factor to use in dimensional analysis
    - Draw a picture when necessary
  - Compute
    - Substitute given variables into equation
    - Give answer in correct number of sig figs and with unit
  - Evaluate
    - Use guesstimation (use simpler numbers rounded from original number)
    - Correct units? Correct number of sig figs?
    - Is answer reasonable considering given numbers?
- **Sample Problem 1.18** – Problem Solving
  Calculate the volume of a sample of aluminum that has a mass of 3.057kg. The density of aluminum is $2.70 g/cm^3$. (ans: $1.13x10^3$ $cm^3$ )
  - **Practice**

    (1) What is the volume of a sample of helium that has a mass of $1.73x10^{-3}$g, given that the density is 0.178 47g/L? (ans: 9.69 mL)

    (2) What is the density of a piece of metal that has a mass of $6.25x10^5$g and is 92.5cm x 47.3cmx85.4cm? (ans: 1.67 $g/cm^3$ )

    (3) How many millimeters are in $5.12x10^5$ kilometers? (ans: )

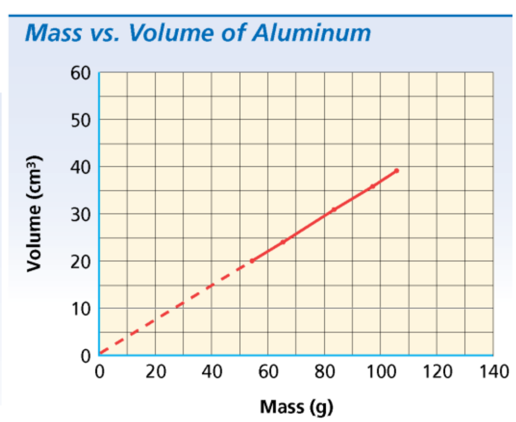
    (4) A clock gains 0.020 seconds per minute. How many seconds will the clock gain in exactly six months, assuming exactly 30 days per month? (ans: $5.2x10^3$s)

**Visual Concept: Direct and Inverse Proportions**

- Direct proportions
  - x α y - thumb rule, as x increases y increases
    - x = ky k is a constant, k = x/y

**Mass-Volume Data for Aluminum at 20°C**

| Mass (g) | Volume ($cm^3$) | $\frac{m}{V}$ ($g/cm^3$) |
|---|---|---|
| 54.4 | 20.1 | 2.70 |
| 65.7 | 24.15 | 2.72 |
| 83.5 | 30.9 | 2.70 |
| 97.2 | 35.8 | 2.71 |
| 105.7 | 39.1 | 2.70 |



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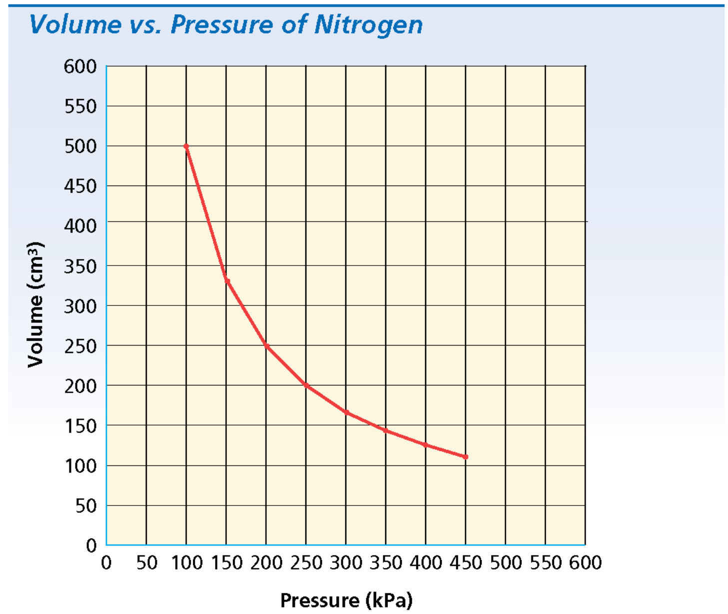
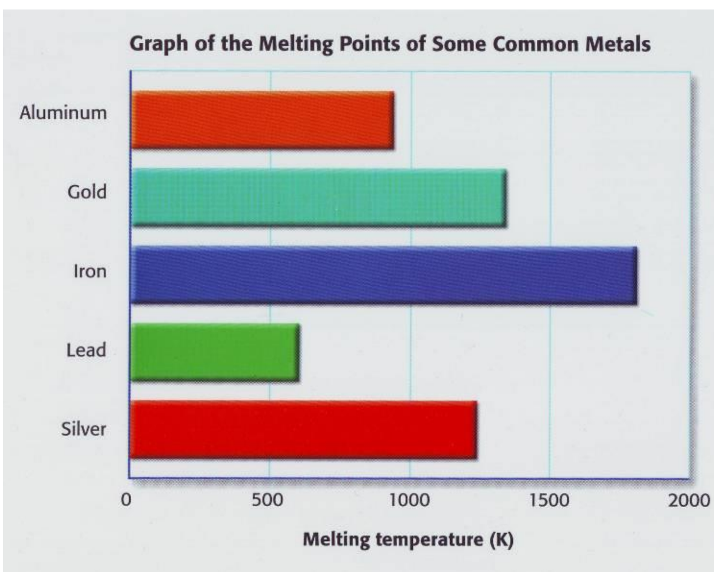
- Inverse proportions
    - x α 1/y  - thumb rule, as x increases, y decreases
        - x = k/y    k is a constant, k = xy

**Pressure-Volume Data for Nitrogen at Constant Temperature**

| Pressure (kPa) | Volume ($cm^3$) | $P \times V$ |
|---|---|---|
| 100 | 500 | 50 000 |
| 150 | 333 | 49 500 |
| 200 | 250 | 50 000 |
| 250 | 200 | 50 000 |
| 300 | 166 | 49 800 |
| 350 | 143 | 50 500 |
| 400 | 125 | 50 000 |
| 450 | 110 | 49 500 |




**Bar Graph (Type of Metal vs. Melting Temperature) (Non-numerical Data)**




**Melting Points of Some Metals**

| Element | Melting temp. (K) |
|---|---|
| Aluminum | 933 |
| Gold | 1337 |
| Iron | 1808 |
| Lead | 601 |
| Silver | 1235 |

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