# Chapter 2

## Units of Measurements and Calculations

Much bench work in a Chemistry or Biology lab consists of preparation of reagents. This involves:

1) Measuring out mass and volume accurately.
2) Computing the required quantities of mass and volume in order to make solutions of the required concentration.

# Units of Measurements and Calculations

International System of Units or SI Units

| ***Property Measured*** | ***Name of unit*** | ***Symbol*** |
| --- | --- | --- |
| Length | meter | m |
| Mass | kilogram | kg |
| Time | second | s |
| Temperature | Kelvin | K |
| Electric Current | Ampere | A |
| Amount of substance | mole | mol |

# Common prefixes used with SI units

| *Prefix* | *Symbol* | *Factor* | *Example* |
|---|---|---|---|
| pico | p | $10^{-12}$ | 1 picometer = $1x10^{-12}$ m |
| nano | n | $10^{-9}$ | 1 nanogram = $1x10^{-9}$ g |
| micro | µ | $10^{-6}$ | 1 microliter (µ L) = $1x10^{-6}$ L |
| milli | m | $10^{-3}$ | 2 milliseconds (ms) = $2x10^{-3}$ s |
| centi | c | $10^{-2}$ | 5 centimeters (cm) = $5x10^{-2}$ m |
| deci | d | $10^{-1}$ | 1 deciliter (dL) = $1x10^{-1}$ L |
| kilo | k | $10^{3}$ | 1 kilometer(km) = $1x10^{3}$ m |
| mega | M | $10^{6}$ | 3 megagrams (Mg) = $3x10^{6}$ g |
| giga | G | $10^{9}$ | 5 gigameters (Gm) = $5x10^{9}$ m |

# Scientific Notation

- An alternative to using prefixes
- Uses powers of ten to get across size of number
- For example speed of light is 300000000 m/s
- More convenient to write $3x10^8$m/s
- Big numbers
  - More decimal point to the left
  - Count number of jumps necessary to get simple number
  - Number of jumps becomes power of ten
  - Power of ten is positive
- Small numbers
  - More decimal point to the right
  - Count number of jumps necessary to get simple number
  - Number of jumps becomes power of ten
  - Power of ten is negative

# Problems on Scientific Notation

1/ Express 0.00345m in scientific notation
Move decimal point so that there is one significant figure to the left of the decimal point => $3.45 \times 10^{something}$
Decimal point moves to the right => negative power of 10
Takes 3 steps to the right => power is –3
Answer is $3.45 \times 10^{-3}$m
2/Express 0.078s in scientific notation
[ $7.8 \times 10^{-2}$s]
3/Express 94300kg in scientific notation
[ 9.43 x 104kg ]

# Units of Volume

- ***The Cubic Metre ($m^3$)*** :

  This is the S.I. unit. It is the volume of a cube with an edge length of 1 m

- **<u>The Litre:</u>**

  A cube with an edge length of 1 dm contains a volume of 1 cubic decimeter (1 $dm^3$)

  The litre (1L) is a more common name for 1 $dm^3$

- **<u>The cubic centimeter (1 $cm^3$)</u>:**

  This is the volume of a cube with an edge length of 1 cm

  It is also called a milliliter (ml) and is 0.001 L

$1m^3$

Is a thousand times bigger than

1L

Is a thousand times bigger than

$1cm^3$

# Unit Conversion

- For all calculations it is necessary to convert all units to the same system.
- **Length, Area and Volume**
- Length:
  - 1 cm = 1 x $10^{-2}$ m
  - 1 mm = 1 x $10^{-3}$ m
- Area:
  - 1 $cm^2$
  - = 1 x $10^{-4}$ $m^2$
  - 1 $mm^2$ = 1 x $10^{-6}$ $m^2$
- Volume:
  - 1 cm3
  - = 1 x $10^{-6}$ $m^3$
  - 1 mm3 = 1 x $10^{-9}$ $m^2$
- Note: 1 $cm^3$ = 1 ml = 1 cc

# Problems on Unit Conversion

1/ Convert $2.87 x 10^{-2} cm^2$ to $m^2$

- $1 cm^2 = 1 x 10^{-4} m^2$
- take away 4 from the power of ten to change from $cm^2$ to $m^2$
- power goes from –2 to –6
- Answer is $2.87 x 10^{-6}$ $m^2$

2/ Convert $9.2 x 10^{-12} m$ to mm

- [ $9.2 x 10^{-9}$ mm ]

3/ Convert $6.914 x 10^{8} mm^3$ to $m^3$

- [ $6.914 x 10^{-1} m^3 = 0.6914 m^3$ ]

4/ Convert $5.68 x 10^{2} m^3$ to cc

- [ $5.68 x 10^{8}$cc ]

# Density

Density is the ratio of the mass of a substance to its volume.

- SI unit = kg/$m^3$

  (using S.I. units of mass and volume)
- Other units:
  - g/$cm^3$
  - For gases we usually use units of g/L
- Most liquids and solids have densities that range from 0.9 g/$cm^3$ (ice) to 11.3 g/$cm^3$ (lead)
  - density of air = 1.2 g/L

1kg$m^{-3}$

Is the same as

1g/L

Is a thousand times smaller than

1g$cm^{-3}$

# Density

- **Density = mass/volume**
- ***Density in kg/m³ = Density in g/cm³ x 1000***

- *Example*

Q. What is the density of lead if a cube of lead has an edge length of 2 cm and a mass of 90.7 g

In g/cm³ : volume = 2cm x 2cm x 2cm = 8cm³

Density = 90.7g/8 cm³ = 11.3 g/cm³

In kg/m³ : volume = $2 \times 10^{-2} \times 2 \times 10^{-2} \times 2 \times 10^{-2} = 8 \times 10^{-6}$ m³

Density = $90.7\ 10^{-3}$ kg/ $10^{-6}$ m³ = 11337 kg/m³

# Question on Density

Ethylene glycol (antifreeze) has a density of 1.11 $g/cm^3$ (g/mL).

(a) What volume of ethylene glycol will have a mass of 1850g?

(b) Write this volume in litres.

# Uncertainty in measurement

- *Any measurements has an uncertainty of at least one unit in the last digit of the reported value*

Examples:

mass of 2.3g has an uncertainty of 0.1 g

mass of 2.294 g has an uncertainty of 0.001 g

A measured volume of 25.2 ml has an uncertainty of at least 0.1 ml (maybe 0.2 if 0.2 is the smallest graduation on the graduated cylinder used for measuring)

- *all the measured digits in a determination including the last uncertain digit are called significant figures*

# Significant Figures

*Significant figures come from the graduations/scale on the measuring device.*

*Starting with the first nonzero digit on the left, count this digit and all remaining digits to the right*

**this is the number of significant figures**

- **Examples:**
- 1267 m has 4 significant figures
- 55.0g has 3 significant figures
- 70.607 mL has 5 significant figures
- 0.00832407 s has 6 significant figures

# Significant Figures….

- *The number of significant figures can be uncertain in a number that ends with a zero to the left of where the decimal place would fall* e.g. 1300 g

- Using scientific notation is best (less ambiguity) e.g.:

  $1.3 \times 10^3$ g (2 significant figures), $1.30 \times 10^3$ g (three significant figures) or $1.300 \times 10^3$ (four significant figures)

- <u>we assume all zeros written down are significant</u>

# Rules for rounding numbers

*Results calculated from a measurement are as uncertain as the measurement itself*

- when adding or subtracting numbers we round to the same number of decimal places as the number with the least number of decimal places

- when multiplying or dividing we round to the same number of significant figures as the number with the least number of significant figures

# Rules for rounding numbers

- when rounding numbers - if the leftmost digit to be dropped is less than 5 we do not change the remaining digits (for two significant figures 3.4456 rounds to 3.4)

- if the leftmost digit to be dropped is greater than 5 we increase the last digit by 1 (for three s.d 23.387 and 23.3511 round to 23.4)

- *Examples*

(a) Add 1.0023 g and 4.383 g = 5.385 (3 decimal places)

(b) Subtract 421.23 from 486 g

= 64.77 g = 65 g (no decimal places)

# Rules for rounding numbers

- *Example*

(a) Multiply 0.6238 cm by 6.6 cm

4.1 $cm^2$ (2 significant digits)

(b) Divide 421.23 g by 486 ml

0.867 g/ml (3 significant digits)

- *Example*

A bathtub is 13.44 dm long, 5.920 dm wide and 2.54 dm deep. Calculate its volume in Litres

V = l x w x d = 13.44 dm x 5.920 dm x 2.54 dm

= 202 $dm^3$ or 202 L