Measurements: Module-2

In each of these modules you will see brief discussions of the concepts and some problems to practice. Prior to working on these modules, it is strongly recommended that you watch the videos posted by Dr. Graham Dobereiner for the corresponding module. This approach would immensely help you to succeed in this course.

MEASUREMENTS

- The standard units are the 'SI units', namely the International System of Units (*French: Le Systéme International d' Unités*). All SI units are based on a set of seven measured base units.

The Seven Fundamental SI Units of Measure

Physical Quantity	Name of Unit	Abbreviation
Mass	kilogram	kg
Length	meter	m
Temperature	kelvin	K
Amount of substance	mole	mol
Time	second	s
Electric current	ampere	A
Luminous intensity	candela	cd

- **Derived units** involve a combination of base units, the above table lists some of the derived units.

Some Derived Quantities

Quantity	Definition	Derived Unit (Name)
Area	Length times length	m^2
Volume	Area times length	m^3
Density	Mass per unit volume	kg/m^3
Speed	Distance per unit time	m/s
Acceleration	Change in speed per unit time	m/s^2
Force	Mass times acceleration	$(kg \cdot m)/s^2$ (newton, N)
Pressure	Force per unit area	$kg/(m \cdot s^2)$ (pascal, Pa)
Energy	Force times distance	$(kg \cdot m^2)/s^2$ (joule, J)

- Decimal multipliers are often used to adjust the size of the base units when the base units are too small or too large.

Some Prefixes for Multiples of SI Units

Factor	Prefix	Symbol	Example
$1{,}000{,}000{,}000 = 10^9$	giga	G	1 gigameter (Gm) $= 10^9$ m
$1{,}000{,}000 = 10^6$	mega	M	1 megameter (Mm) $= 10^6$ m
$1{,}000 = 10^3$	kilo	k	1 kilogram (kg) $= 10^3$ g
$100 = 10^2$	hecto	h	1 hectogram (hg) = 100 g
$10 = 10^1$	deka	da	1 dekagram (dag) = 10 g
$0.1 = 10^{-1}$	deci	d	1 decimeter (dm) = 0.1 m
$0.01 = 10^{-2}$	centi	c	1 centimeter (cm) = 0.01 m
$0.001 = 10^{-3}$	milli	m	1 milligram (mg) = 0.001 g
*0.000 001 $= 10^{-6}$	micro	μ	1 micrometer (μm) $= 10^{-6}$ m
*0.000 000 001 $= 10^{-9}$	nano	n	1 nanosecond (ns) $= 10^{-9}$ s
*0.000 000 000 001 $= 10^{-12}$	pico	p	1 picosecond (ps) $= 10^{-12}$ s

* For very small numbers, it is becoming common in scientific work to leave a thin space every three digits to the right of the decimal point.

TEMPERATURE SCALES

- We should be familiar with three temperature scales namely,

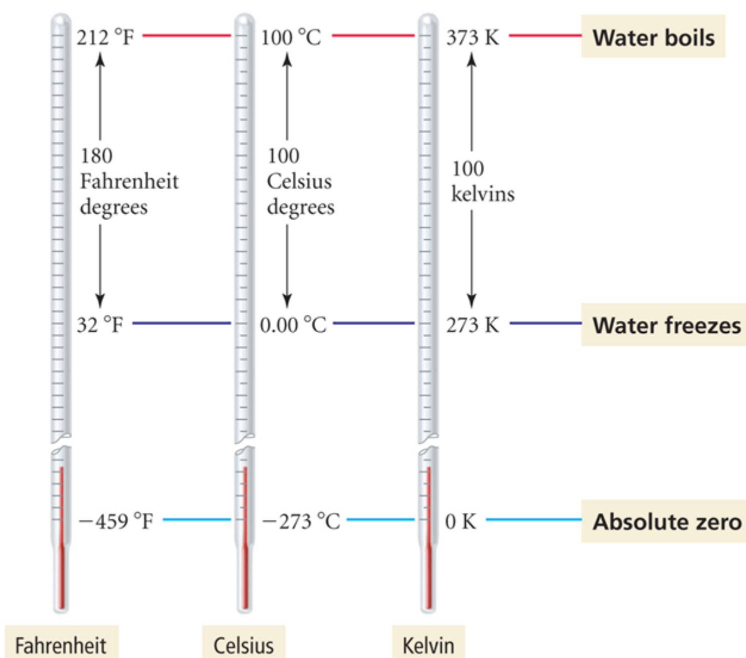
  (a) Fahrenheit (°F)

  (b) Celsius (°C)

  (c) Kelvin (K). Note: it is not degrees kelvin
- The Fahrenheit scale is widely used in United States outside the laboratories, in this scale,

  (a) the freezing point of water: 32 °F

  (b) the boiling point of water: 212 °F
- In the Celsius scale the freezing point of water is 0 °C and the boiling point of water is 100 °C and this range is divided by 100 degrees.
- In most instances we'll be using kelvin (K) scale in our calculations. However, we will be given numerical problems where the temperatures are given in Fahrenheit or Celsius scales. In such cases we have to convert the temperature from Fahrenheit to Celsius scale or to kelvin scale before performing the calculations. The illustration shows the relationship between different temperature scales.



- The following equations are employed to convert temperatures in one scale to another.
- Fahrenheit to Celsius scale:

$$°C = (\text{given temperature in } °F - 32°F) \times \frac{5\ ℃}{9\ ℉}$$

- Celsius to Fahrenheit scale

$$°F = \frac{9\ ℉}{5\ ℃} \times (\text{given temperature in } °C) + 32°F$$

- Celsius to kelvin scale

$$K = (\text{given temperature } °C) + 273.15\ °C \times \frac{1\ K}{1\ ℃}$$

Example: 1

Convert 224 °C to temperature in Fahrenheit scale.

$$°F = \frac{9\ ℉}{5\ ℃} \times (224 \text{ in } °C) + 32°F$$

$$= 435\ °F$$

Note: the answer is in three significant figures

Example: 2

Helium has a boiling point of – 452 °F, convert this temperature to Celsius scale.

$$°C = (-452\ °F - 32°F) \times \frac{5\ ℃}{9\ ℉}$$

$$= -269\ °C$$

Example: 3

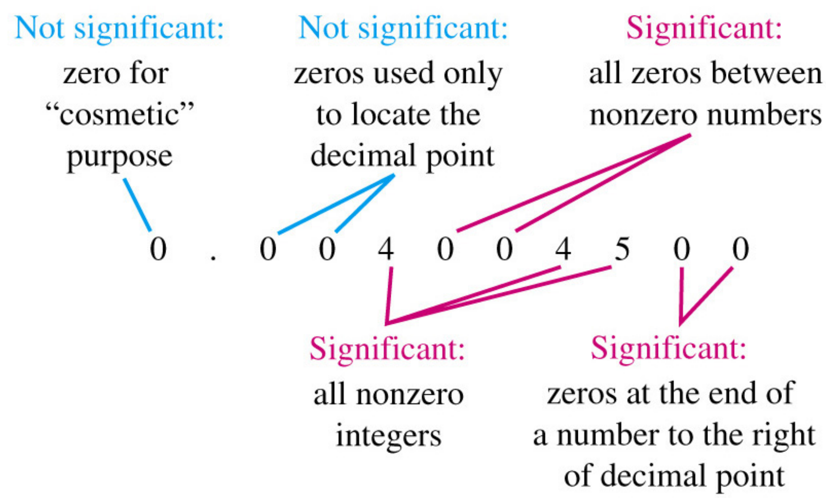
The melting point of mercury – 38.9 °C, convert this temperature to kelvin scale.

$$K = (-38.9\ °C) + 273.15\ °C \times \frac{1\ K}{1\ ℃}$$

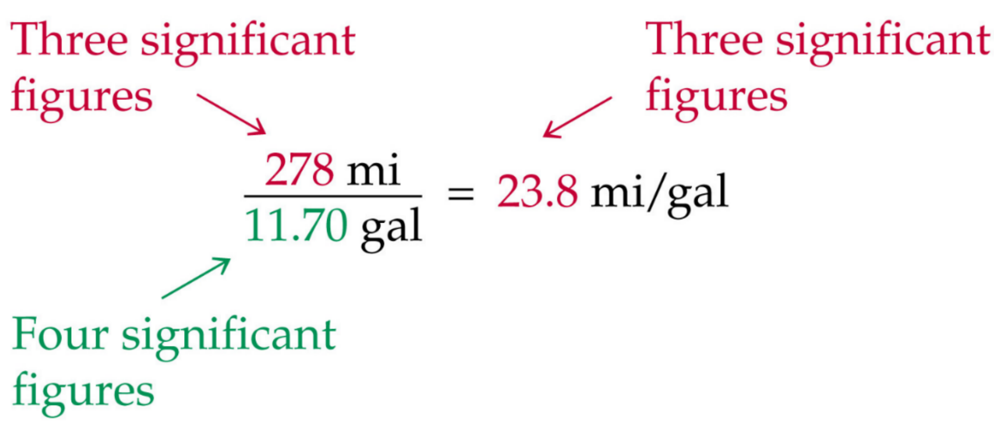
$$= 234.3\ K$$

SIGNIFICANT FIGURES

- Determining the number of significant figures during any calculations is absolutely essential to arrive at a meaningful answer.



- In multiplication/division calculations, the number of significant figures in the answer cannot be greater than the number of significant figures in any one of the original numbers.



Examples for multiplications:

2.8×4.5039

$= 12.61092$

= 13 (after rounding off to two significant figures)

Multiplying with exact numbers:

An exact number like say, 9, does not determine the number of significant figures.

$5.0\ g \times 9 = 45\ g$

The answer has two significant figures because 5.0 g has two significant numbers

- While performing addition or subtraction the answer cannot have more digits to the right of the decimal point than any of the original number.

$$\begin{array}{r} 5.74 \\ 0.823 \\ +\ 2.651 \\ \hline 9.214 \end{array} = 9.21$$

It is sometimes helpful to draw a vertical line directly to the right of the number with the fewest decimal places. The line shows the number of decimal places that should be in the answer.

$$\begin{array}{r} 4.8 \\ -\ 3.965 \\ \hline 0.835 \end{array} = 0.8$$

- Scientific notation:

$$5983 = 5.983 \times 10^{3}$$

3 2 1

$$0.00034 = 3.4 \times 10^{-4}$$

1 2 3 4

Calculations in chemistry may involve very large numbers or very small numbers. When working with very large and very small numbers, we use scientific notation, and it can be expressed in the form

$$N \times 10^{n}$$

where N is a number between 1 and 10 and n, the exponent a positive or negative integer.

Example: 4

Express 782.541 in scientific notation

$782.541 = 7.82541 \times 10^{2}$

The decimal point is moved to the left by two places and $n = 2$.

Example: 5

Express 0.00000212 in scientific notation

2.12×10^{-6}

The decimal point is moved to the right by two places and $n = -6$.

To multiply numbers in scientific notations, we multiply N1 and N2 in the usual way, but add the exponent together.

Example: 6

$(8.0 \times 10^4) \times (5.0 \times 10^2) = (8.0 \times 5.0)\ (10^{4+2})$

$= 40 \times 10^6$

$= 4.0 \times 10^7$

Example: 7

$(4.0 \times 10^{-5}) \times (7.0 \times 10^3) = (4.0 \times 7.0)\ (10^{-5+3})$

$= 28 \times 10^{-2}$

$= 2.8 \times 10^{-1}$

To divide numbers in scientific notations, we divide N1 by N2 in the usual way, but subtract the exponents.

Example: 8

$(6.9 \times 10^7) \div (3.0 \times 10^{-5}) = (6.9 \div 3.0) \times (10^{7-(-5)})$

$= 2.3 \times 10^{12}$

Example: 9

$(8.5 \times 10^4) \div (5.0 \times 10^9) = (8.5 \div 5.0) \times (10^{4-9})$

$= 1.7 \times 10^{-5}$

Practice Problems

1. Add these numbers with correct number of significant numbers

$$\begin{array}{r} 89.332 \\ +\ 1.1 \\ \hline \\ \hline \end{array}$$

Answer: 90.4

2. Do the subtraction and give the answer with the correct number of significant numbers, round-off if needed.

$$\begin{array}{r} 2.097 \\ -\ 0.12 \\ \hline \\ \hline \end{array}$$

Answer: 1.98

Carry out following arithmetic operations and round off answers to the correct number of significant figures:

3. 8.16 cm × 5.1355 cm **Answer:** 41.9 cm^2

4. 0.01154 kg ÷ 88.3 mL **Answer:** 1.31×10^{-4} kg/mL

5. (2.64×10^3 cm) + (3.27×10^2 cm) **Answer:** 2.97×10^3 cm

6. 28.8262 L + 0.12 L **Answer:** 28.95 L

7. 9.1 g – 4.682 g **Answer:** 4.4 g

8. (7.1×10^4 dm) × (2.2654×10^2 dm) **Answer:** 1.6×10^7 dm^2

9. 6.54 g ÷ 86.5542 mL **Answer:** 7.56×10^{-2} g/mL

10. $(7.55 \times 10^4 \text{ m}) - (8.62 \times 10^3 \text{ m})$ **Answer:** 6.69×10^4 m

11. Determine the number of significant figures in the following measurements:

(a) 478 cm, **Answer:** Three

(b) 6.01 g, **Answer:** Three

(c) 0.825 m, **Answer:** Three

(d) 0.043 kg, **Answer:** Two

(e) 1.320×10^{22} atoms, **Answer:** Four

(f) 5000 mL. **Answer:** Ambiguous,

Four, if written as 5.000×10^3 mL; three, if written as 5.00×10^3 mL; two, if written as 5.0×10^3 mL; one, if written as 5×10^3 mL;

12. Give answers to the following problems with correct number of significant figures and express the answer in scientific notations.

(a) $0.0095\, m + (8.5 \times 10^{-3}\, m)$ **Answer:** 1.8×10^{-2} m

(b) $653 \text{ kg} \div (5.75 \times 10^{-8} \text{ kg})$ **Answer:** 1.14×10^{10}

(c) $850{,}000 \text{ J} - (9.0 \times 10^5 \text{J})$ **Answer:** -5.0×10^4 J

(d) $(3.6 \times 10^{-3}\, cm) \times (3.6 \times 10^{6}\, cm)$ **Answer:** 1.3×10^4 cm^2

13. A roll of aluminum foil has a mass of 1.07 kg. What is its mass in pounds?

Answer: 2.36 lb

14. The planet Venus, the hottest planet in the solar system, has a surface temperature of 7.3×10^2 K. Convert this temperature to °C and °F.

Answer: 4.6×10^2 °C and 8.6×10^2 °F

15. Crystallographers report bond distances in Å units (Å=10^{-10} m), convert the following bond distances to *pm*, *μm*, *cm* and *m*.

(a) 1.24 Å (b) 2.45 Å (c) 1.822 Å (d) 2.102 Å

Answer:

(a) 124 pm; 1.24×10^{-4} µm; 1.24×10^{-8} cm; 1.24×10^{-10} m

(b) 254 pm; 2.54×10^{-4} µm; 2.54×10^{-8} cm; 2.54×10^{-10} m

(c) 182.2 pm; 1.822×10^{-4} µm; 1.822×10^{-8} cm; 1.822×10^{-10} m

(d) 210.2 pm; 2.102×10^{-4} µm; 2.102×10^{-8} cm; 2.102×10^{-10} m