Unit 3: Chemical Calculations – Tutorial 01

These standards were selected because they allow us to make precise measurements and because they are reproducible and unchanging.

The Seven Fundamental Units of Measurement (SI)

Physical Property	Name of Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature	kelvin	K
luminous intensity	candela	cd
amount of substance	mole	mol

SI units are based on the seven fundamental units listed. All other units of measurement are derived from them. The metric and SI systems are *decimal systems, in which prefixes are used to indicate fractions and multiples of ten.* The same prefixes are used with all units of measurement.

Common Prefixes Used in the SI and Metric Systems

Prefix	Abbreviation	Meaning	Example
mega-	M	10^6	1 megameter (Mm) = 1×10^6 m
kilo-*	k	10^3	1 kilometer (km) = 1×10^3 m
deci-	d	10^{-1}	1 decimeter (dm) = 1×10^{-1} m
centi-*	c	10^{-2}	1 centimeter (cm) = 1×10^{-2} m
milli-*	m	10^{-3}	1 milligram (mg) = 1×10^{-3} g
micro-*	μ†	10^{-6}	1 microgram (μg) = 1×10^{-6} g
nano-*	n	10^{-9}	1 nanogram (ng) = 1×10^{-9} g
pico-	p	10^{-12}	1 picogram (pg) = 1×10^{-12} g

**These prefixes are commonly used in chemistry.*

Atomic weights

atomic mass unit (amu): An early observation was that carbon and hydrogen have relative atomic masses, also traditionally called **atomic weights (AW),**

Atomic mass unit which is defined as *exactly* $\frac{1}{12}^{th}$ *of the mass of an atom of a particular kind of carbon atom, called carbon-12.*

Atomic Mass Unit = Mass of single atom of $^{12}_{6}C$ $\times \frac{1}{12}$

This is identified as a 1 amu in the past.

Calculate the value of the atomic mass unit.

Relative atomic mass

This is the ration of which a mass of a certain atom of interest to that of $\frac{1}{12}^{th}$ the mass of $^{12}_{6}C$ atom.

$$relative\ atomic\ mass = \frac{mass\ of\ the\ atom}{mass\ of\ ^{12}_{6}C\ atom \times \frac{1}{12}}$$

1. Mass of an atom of Ca is 9.97×10^{-26} kg. Calculate the R.A.M. if the mass of $^{12}_{6}C$ is 19.926×10^{-27} kg.

2. Relative atomic mass of the element **M** is 60. If the atomic mass unit is 1.66×10^{-24} g, then calculate the atomic mass of **M**.

3. Ratio of the atomic masses of **P** and **R** is 2/5. Calculate ratio of the relative atomic masses of **P**/**R**.

4. The relative atomic mass of an element **X** is 150. Calculate its' atomic mass in amu.

5. Mass of a single atom is 2 and its relative atomic mass is 80. Calculate the relative atomic mass of **Y** if the mass of a single atom is 3.

6. Mass of an atom **Q** is 10 times the value of $^{12}_{6}C$. Calculate the atomic mass of **Q** using amu.

Determination of the average atomic masses using percentage abundance

Average atomic mass = Σ [(isotope mass) × (fractional isotope abundance)]

1. Three isotopes of magnesium occur in nature. Their abundances and masses, determined by mass spectrometry, are listed in the following table. Use this information to calculate the atomic weight of magnesium.

Isotope	% Abundance	Mass (amu)
$^{24}_{12}$Mg	78.99	23.98504
$^{25}_{12}$Mg	10.00	24.98584
$^{26}_{12}$Mg	11.01	25.98259

2. The atomic weight of gallium is 69.72 amu. The masses of the naturally occurring isotopes are 68.93 amu for ^{69}Ga and 70.92 amu for ^{71}Ga. Calculate the percent abundance of each isotope.

3. Naturally occurring iron consists of four isotopes with the abundances indicated here. From the masses and relative abundances of these isotopes, calculate the atomic weight of naturally occurring iron (Use only two decimal places).

Isotope	Isotopic Mass (amu)	% Natural Abundance
^{54}Fe	53.9396	5.82
^{56}Fe	55.9349	91.66
^{57}Fe	56.9354	2.19
^{58}Fe	57.9333	0.33

Measuring matter accurately

1. Calculate the mass of a single atom of Na if the relative atomic mass is 23.

2. Calculate the mass of a single atom of Mg if the relative atomic mass is 24.

3. If the mass of a single atom of X is 3.2×10^{-23}g, then calculate the relative atomic mass of X.

4. Calculate the number of mols of Na and atoms of Na in 2.3 g of Na. (Na = 23)

5. Calculate the number of mols of Cu and atoms of Cu in 19.05 g of Cu. (Cu -63.5)

6. Calculate the mass of a single molecule of water. (H_2O=18)

7. Calculate the mass of single molecule of $C_6H_{12}O_6$. (C =12, H=1, O=16)

8. Calculate the mass of a single molecule of C_2H_5OH.

9. Calculate the number of mols of molecules, number of molecules and total number of atoms in 180 g of H_2O.

10. Calculate (a) number of mols of molecules (b) number of molecules (c) total number of atoms in 3.6 g of $C_6H_{12}O_6$.

11. Calculate the total number of atoms in 7.8 g of C_6H_6.

12. Calculate the total number of O atoms in 20 g of $H_2C_2O_4$.

13. Calculate the followings in 11.44 g of $Na_2CO_3.10H_2O$.
    a. Total number of mols

    b. Total number of water molecules

    c. Total mols of Na ions.

    d. Total mols of O atoms.

    e. Weight percentage of O.

14. Calculate the number of O atoms in 11.44 g of $Na_2SO_4.10H_2O$.

1. Calculate the mass of Na_2CO_3 in 4.81×10^{22} molecules of Na_2CO_3.

2. Calculate the mass of Cr in 4.82 g of $Cr_2(SO_4)_3.5H_2O$. Cr-52

3. Helium is an important gaseous element that is used at low temperature for experimental diving tanks and balloons. Calculate the number of mols of He in 6.46 g of He sample.

4. Calculate the number of O atoms present in 3.92 g of $Cr_2(SO_4)_3$ sample.

5. Calculate the number of mols of proton mols in 0.48 g of $^{12}_{6}C$.

6. Calculate the number of mols of electron mols in 2.4088×10^{22} atoms of Mg^{2+} ions.

7. The density of a NaOH aqueous solution with respect to NaOH is 0.16 g cm^{-3}. You are provided with 50 cm^3 of this solution. If you are provided with a 100 cm^3 solution of $CaSO_4$ and they both have equal number of ions, calculate the density of the $CaSO_4$ solution. (Na = 23, Ca= 40, S= 32, O =16)

8. Calculate the number of molecules of $Sr(NO_3)_2$ that is present in 0.106 g of $Sr(NO_3)_2$. Sr = 88.

9. (1) Calculate the volume of 220 g of $CO_2(g)$ at STP.

(2) Calculate the number of mols present in 20 mL of HCl solution having an overall density of 1.16 g cm^{-3} and (w/W)% 60. (Cl – 35.5, H-1)

(3) If the number of mols of KOH in 100 mL solution having an overall density of 2.24 g cm^{-3} is 0.48 mol, calculate the weight percentage of KOH in the sample. (K-39)

(4) A NaOH solution contains 70% NaOH by weight. If 200 mL of this solution contains 1.4 mol of NaOH then calculate the density of the solution.

10. (1) If the volume of SO_2 in STP is 13.44 mL, then calculate the number of mols of SO_2 in that sample.

(2) Calculate the volume at STP of a sample containing 24.088×10^{20} molecules of N_2.

(3) A certain mass of Ca is reacted with H_2O to produce 4.48 dm^3 of H_2 gas at the room temperature. Calculate the amount of H_2O mixed to the Ca sample.

(4) Calculate the mass of 112 mL volume of CO_2 at the STP.

(1) A 42.4 g of a sample there is a mixture of K and Fe. By reacting this mixture with water at STP, it gave a volume of 8.96 L of gas at STP. Calculate the mols of Fe in the sample (Fe- 56, K-39)

11. (a) Calculate the mass of NaCl that contains the total number of mols of ions present in 285 g of $MgCl_2$. (Na -23, Cl-35.5, Mg-24)

(b) Calculate the mass of Ca of which there is an equal number of Ca atoms present in 12.8 g sample of S. (S- 32, Ca – 40)

(c) Each of compound Z contains 2 atoms of Na. The mass percentage of Na in this sample is 10%. Calculate the molecular mass of Z.

(d) There is 36% H_2O in $MSO_4.xH_2O$. Calculate the value of **x** in this sample. (H-1, O-16, S-32 and M -64)

(e) Molar mass of compound X is 160. The mass percentage of oxygen in this sample is 80%. Calculate the total number of atoms of O.

(f) Compound R contains 4 atoms of Mg and its mass percentage is 20%. Calculate the molar mass of the compound. (Mg-24)

12. What is the mass of 0.100 mol of each of the substances given below: (Na =23, C =12, O =16, N =14, B =11, C =12, S =32, Ca =40)
    (a) Sodium carbonate, Na_2CO_3
    (b) Ammonium tetraborate, $(NH_4)_2B_4O_7$
    (c) Calcium cyclamate, $Ca(C_6H_{12}NSO_3)_2$

13. How many moles of sodium nitrate are in 1.70 grams of sodium nitrate, $NaNO_3$, a substance used in fertilizers and to make gunpowder.

14. Ammonium sulphate, $(NH_4)_2SO_4$, is a fertilizer used to supply both nitrogen and sulphur. How many grams of ammonium sulphate are in 35.8 moles of $(NH_4)_2SO_4$.

15. A 0.500 mol sample of table sugar, $C_{12}H_{22}O_{11}$, weighs how many grams?

16. A solution of zinc chloride, $ZnCl_2$, in water is used to soak the ends of wooden fenceposts to preserve them from rotting while they are stuck in the ground. One ratio used is 840 grams $ZnCl_2$ to 4 L water. How many moles of $ZnCl_2$ are in 840 grams of $ZnCl_2$? (Zn = 65, Cl =35.5)

17. In the early 1970s, thallium sulphate, Tl_2SO_4, a powerful poison, was illegally used in poison baits to control predators such as coyotes on western rangelands. Hundreds of eagles died after taking these baits. A 1.00 kilogram can of Tl_2SO_4 contains how many moles of this compound? (Tl =204, S =32, O =16)

18. Borazon, one crystalline form of boron nitride, BN, is very likely the hardest of all substances. If one sample contains 3.02×10^{23} atoms of boron, how many atoms and how many grams of nitrogen are also in this sample? (B =11, N =14)

19. If iodine is not in a person's diet, a thyroid condition called goitre develops. Iodized salt is all that it takes to prevent this disfiguring condition. Calcium iodate, $Ca(IO_3)_2$, is added to table salt to make iodized salt. How many atoms of iodine are in 0.500 moles of $Ca(IO_3)_2$? How many grams of calcium iodate are needed to supply this much iodine? (Ca =14, I =127, O =16)

20. Ammonium carbonate, $(NH_4)_2CO_3$, is used as a fertilizer and to manufacture explosives. How many atoms of nitrogen are in 0.665 moles of this substance? How many grams of ammonium nitrate supply this much nitrogen? (N =14, C= 12, O =16)

21. Sodium perborate, $NaBO_3$, is present in "oxygen bleach". It acts by releasing oxygen, which has bleaching ability. How many grams of sodium perborate are in 4.65 moles of $NaBO_3$? (Na =23. B =11, O =16)

22. Barium sulphate, $BaSO_4$, is given to patients as a thick slurry in flavoured water before X-rays are taken of the intestinal tract. The barium blocks the X-rays, and the tract therefore casts a shadow that is seen on the x-ray film. How many grams are in 0.568 mole of barium sulphate. (Ba =137, S =32, O =16)

Calculations related to industrial scale acids and Bases.

We need two data for such calculations. (i) mass percentage of the sample (ii) density of the sample.

(1) Assume a NaOH solution to contain 60% NaOH by mass. This means that there is 60 g of NaOH in each 100 g sample.
(2) Density of the sample is 0.8 g cm^{-3}. This means that each 1 mL sample contains a mass of 0.8 g.

1. Calculate the number of mols of NaOH present in 20 mL sample described above.

2. A sample of H_2SO_4 contains 98%(w/w) purity and its density is 1.2 g cm^{-3}. Calculate the concentration of this solution.

3. A commercial H_3PO_4 sample contains a density of 1.32 g cm^{-3} and its w/w percentage purity is 90%. Calculate the concentration of H_3PO_4.

4. Commercial HCl solution contain 1.25 g cm^{-3} density and its percentage purity as weight is 70%. Calculate the concentration.

5. A $H_2C_2O_4$ sample has a density of 1.43 g cm^{-3} and its weight percentage is 60%. Calculate the concentration of the solution.