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Science Bridging Course
Unit CH1 - Laboratory guide

In this chapter you will find out:

- Molarity
- Molar solutions
- Methods to prepare solutions
- Saturated solutions
- Acid-base solutions

Definition:

A solution is a homogenous mixture of one or more solute(s) dissolved in a solvent. A solute is a substance that is dissolved in a liquid solvent to produce a solution.

The concentration of a solution refers to the quantity of solute dissolved in a particular quantity of solvent or solution.

Methods used for the calculation of and preparation of solutions:

1. Concentration in moles per litre, molar concentration or molality (mol/L, mol L^{-1}, M)
2. Concentration by percentage (either %w/v or %v/v, or %w/w)
3. Concentration in grams per litre (g/L, or g L^{-1})
4. Preparing solutions by dilution
5. Preparing saturated solutions

The mole

The mole is a unit of measurement used to describe the amount of chemical species (atoms, molecules, ions, electrons, etc.).
One mole contains 6.022×10^{23} particles = **Avogadro´s number**.
The weight in grams of one mole of a substance is the molecular weight (MW), or molar mass, of that substance. To determine the number of moles, *n*, in a given quantity of a substance, you divide the given quantity of the substance by the nmolecular weight:

$$n = \frac{\text{mass of substance (g)}}{\text{molecular weight (g)mol}} = \frac{m}{MW}$$

Molarity

Molarity indicates the number of moles of solute dissolved in a litre of a solution, the symbol is *M*, the unit moles per litre (mol/L).
The concentration of a solution in mol/L can be calculated using the formula

$c = \frac{n}{V}$ (moles per litre)

Concentration = $c = \frac{\text{number of moles of solute (mol)}}{\text{volume (L)}}$
c..... concentration of the solution in moles per litre (mol/L)
n ….. amount of moles of solute (mol)
V ..... volume of solution in litres (L)

Task: https://phet.colorado.edu/en/simulation/molarity

Question:

What determines the concentration of a solution?

- Learn about the relationships between moles, litres, and molarity by adjusting the amount of solute and solution volume. Change solutes to compare different chemical compounds in water.
- Describe the relationships between volume and amount of solute to concentration.
- Explain how solution colour and concentration are related.
- Calculate the concentration of solutions in units of molarity (mol/L).
- Use molarity to calculate the dilution of solutions.
- Compare solubility limits between solutes.

molarity-html-guide.pdf

A molar solution

Molar solutons use the molecular weight of a solute to calculate molar concentration in a litre of solution.
The molecular weight can be found on the chemical bottle label, in a data book or safety data sheet, or by adding together the atomic weights of all of the atoms, which appear in the chemical formula of the substance.

Example:
NaCl: 1 sodium atom 1 x 22.9 g = 22.99 g, 1 chloride atom 1 x 35.45 g = 35.45 g, molecular weight = 58.44 g.
Therefore, a 1 M solution of sodium chloride consists of 58.44 g of NaCl dissolved in 1 L of watrer.

!! If you are using a hydrated salt, the water(s) of hydration must be included in the calculatiion of the molecular weight. !!
We can use the combination of two equations:

$$c = \frac{n}{V}$$

and

$$n = \frac{m}{MW}$$

$\Rightarrow m = c \times V \times MW$,

where
m = mass of solute in grams (g)
c = concentration of solution in moles per litre (mol/L)
V = volume of solution in litres (L)
MW = molecular weight of solute in grams (g)

1M… is pronounced one molar and contains the molecular weight of a chemical dissolved in one litre of water
2M solution … is pronounced a two molar solution and has twice the molecular weight of a chamical dissolved in one litre of water

Example:
Calculation for preparing 1 litre of a 0.5 M copper (II) sulfate solution

Use copper (II) sulfate pentahydrate $CuSO_4.5H_2O$

Molecular weight = *MW* = 63.55 + 32.06 + (4 x 15.99) + 5((2 x 1.008) + 15.99)) = 249.68 g
Concentration *c* = 0.5 M
Volume *V* = 1 L

The quantity of the solid copper sulfate pentahydrate required to make 1 L of 0.5 M solution
m = *c* x *V* x *MW* = 0.5 x 1 x 249.68 = 124.84 g

Example:
Calculation for preparing 250 mL of a 0.2 M solution of sodium carbonate using the anhydrous salt (Na_2CO_3)

MW = 109.99 g
c = 0.2 M
V = 0.25 KL
m = 0.2 x 0.25 x 105.99 = 5.30 g

Method to prepare a solution using a solid chemical in 1 L of destilled or deionised water

- Calculate the amount of chemical required to make 1 L of solution at required molarity
- Weight the amount of chemical using an electronic balance onto a clean, dry watch glass or weighing boat
- Carefully transfer the weighed chemical to a beaker containing about two thirds of the final solution volume of distilled or deionised water (about 500-650 mL). When preparing solutions, the solute is dissolved in a portion of the total volume required and then the volume is made up to the required volume
- Using a wash bottle containing either distilled or deionised water, wash the watch glass or weighing boat into a beaker to remove all traces of weighed chemical
- Stir to dissolve with a stirring rod or on a magnetic stirring platform
- It may be necessary to gently heat the solution to speed up the dissolution of the salt
- Once dissolved transfer the solution to a 1 L measuring cylinder or volumetric flask
- Rinse the beaker, stirring rod and filter funnel using a wash bottle and transfer the washings to the measuring cylinder or volumetric flask
- Make up to 1 L with distilled or deionised water. Make sure that the vessel and solution is at room temperature and that the bottom of the meniscus is in line with the mark on the neck of the volumetric flask on the 1 L mark on the measuring cylinder
- Stopper and mix thoroughly
- Transfer the solution to a labelled reagent bottle.

! Caution: If preparing a solution directly using a volumetric flask the final volume should be measured with the solution and vessel at room temparature, as this is the temperature at which volumetric glassware is calibrated. If heating the solution, a beaker or conical flask should be used rather than a volumetric flask, as heating volumetric glassware may affect its calibration.

Concentration by percentage

The concentration of a solution can be expressed as a percentage concentration as %w/v or %v/v or %w/w.
Where the solute is a solid percentage weight per volume %w/v is used. This is the mass of solute (solid) in grams dissolved in 100 mL of solution

$$\% \frac{w}{v} = \frac{mass\ of\ solute\ (g)}{volume\ of\ solution\ (mL)} x\ 100\%$$

%w/v = mass of solute (g) in 100 mL of solution

Example:
A 2%w/v solution of sodium chloride would be prepared from 2 g of sodium chloride dissolved in water and made up to a volume of 100 mL,where the solute is a liquid percentage volume per volume %v/v. This is the volume of solute (liquid) in millilitres per 100 mL of solution.

$$\% \frac{v}{v} = \frac{volume\ of\ solute}{volume\ of\ solution}\ x\ 100\%$$

%v/v = volume of solute (mL) in 100 mL of solution

Example:
A 5% v/v aqueous solution of ethanol would be prepared by taking 5 mL of pure ethanol and diluting this with water to a volume of 100 mL.

Weight percent %w/w is the mass of solute in grams per 100 g of solution. \it is often used in aqueous commercial preparations, for example in concentrated solutions of acids. A weight percent concentration has the advantage that the solution can be prepared independently of temperature considerations. Generally not used in school science.

$$\% \frac{w}{w} = \frac{mass\ of\ solute}{mass\ of\ solution}\ x\ 100\ \%$$

%w/w = mass of solute (g) in 100 g of solution

Concentration in grams per litre

A solution can be prepared by dissolving a known mass or volume of solute in a known amount of solvent.
Concentration is expressed as grams of solute dissolved in one litre of solution.

Example:
Calculation for preparing 300 mL of a sucrose solution at a concentration of 5 g/L.

As only 300 mL of solution is required, only a fraction of the 5 g will be needed. To find the quantity of sucrose required, the concentration is multiplied by the fraction of litres required:
m=5 g/L x 0,3 L = 1,5 g

This amount of sucrose is weighed out and dissolved in enough water to make up the volume to a total of 300 mL.

Task: https://phet.colorado.edu/en/simulation/concentration

- Watch your solution change colour as you mix chemicals with water. Then check molarity with the concentration meter. What are all the ways you can change the concentration of your solution? Switch solutes to compare different chemicals and find out how concentrated you can go before you hit saturation!
- Describe the relationships between volume and amount of solute to solution concentration.
- Explain how solution colour and concentration are related.
- Predict how solution concentration will change for any action (or combination of actions) that adds or removes water, solute, or solution, and explain why.
- Design a procedure for creating a solution of a given concentration.
- Design and justify a procedure for changing a solution from one concentration to another.
- Identify when a solution is saturated and predict how concentration will change for any action or combination of actions where water or solute change.

concentration-html-guide_en.pdf

Preparing solutions by dilution

Dilution is the proces of adding more solvent to a solution.Solutions can be prepared by diluting a solution of a known hugher concentration to produce solutions of lower concentration. When carrying out a dilution, a define volume of the concentrated solution is measured out and placed in a volumetric flask of required volume and sufficient solvent is then added to make up to the calibration mark.
Calculation of the required volume of the initial concentrated solution to produce the diluted solution is based on the fact that the number of moles of solute is the same before and after the dilution.

$n = c\ V$,

n…. amount of moles of solute (mol)
c……concentration of solution in moles per litre (mol/L)
V…..volume of solution in litres (L)

Since number of moles of solute is not changed, volume of concentrated solution can be calculated as below.
$n1$ (number of moles before dilution) = $n2$ (number of moles after dilution)
$c1V1 = c2V2$
$V1 = c2V2/c1$
$V1$….initial volume ort he volume of concetrated solution (in litres)

$c1$….. concentration of the initial solution or concentrated solution
$V2$ …. Final volume ort he volume of diluted solution (in litres)
$c2$ … concentration of the final or diluted solution

Example:
Preparation of 500 mL of 0.5 M hydrochloric acid (HCl) from a 2 M solution of HCl
2 x $V1$ = 0.5 x .5
$V1$ = 0.125 or 125 mL

This volume of 2 M HCl is measured and placed in a 500 mL volumetric flask containing about 250 mL distilled water. Then enough distilled water is added to make up to the 500 mL mark. The solution shoud be mixed well to obtain a homogeneous solution of 0.5 M HCl.

Example:
Diluting hydrogen peroxide (H_2O_2) solution

The strength of hydrogen peroxide is often expressed in volumes. This relates to the volume of hydrogen peroxide and the number of volumes of oxygen gas it can produce upon decomposition.
Hydrogen peroxide decomposes to water ($2H_2O$) and oxygen (O_2)

- 1 volume (1 mL) of 20-volume hydrogen peroxide will produce 20 volumes (20 mL) of oxygen as a gas
- Taking 10 mL of 20 volume hydrogen peroxide, decomposition of the hydrogen peroxide will produce 20 x 10 mL = 200 mL of oxygen gas

Both 100 volume (30% solution) and 120 volume (35% solution) concentrations are commercially available to puchase. 20 volume (6%) concentration is the common strength of hydrogen peroxide used for science investigations in schools.
Calculation for the preparation of 1 L of a 20 volume (6%) solution of hydrogen peroxide from 100 volume (30%) solution. 100 volume is the initial concentration ond 20 volume is the final concenteratuion.
1 = $c2V2$
$V1 = c2V2/c1$ = 20 x 1/100 mL = 200 mL
200 mL of 100 volume hydrogen peroxide is added to approximately 500 mL of distilled water and made up to 1 L. The diluted solution should be mixed well.
Using percentage concentrations: $V1$ = 6% x 1/30% = 0.2 L = 200 mL

Saturated solutions

The solubility of a solute is the maximum amount that can dissolve at a specified temperature in a specified volume of a paricular solvent. Solubility depends on type of solute, type of solvent and temperature.
A saturated solution is where at a particular temperature no more solute can be dissolved in the solvent.
The solubility of most solids increases with increasing temperature, so a saturated solution prepared at a hugh temperature will contain more dissolved soluter than it would contain at a lower temperature.
A solubility curve compares the amount of solute that will dissolve in a given amount of solvent at various temperatures. Generally the solvent is water and the concentration is provided in grams of solute in 100 g of solvent. Solubility curves are different for different chemicals.

Example:
The solubility of sucrose at 20 ^{o}C is 203.9 g/100 mL of water. The solubility of sucrose at 100 ^{o}C is around 500 g/100 mL of water.

If you try to dissolve 220 g of sucrose in 100 mL of water at 20 ^{o}C then 203.9 g will dissolve forming a saturated solution and the remaining 16.1 g will settle to the bottom of the beaker. The undissolved solute can be separated from the saturated solution by filtration.

Acid – base solutions


Task: https://phet.colorado.edu/en/simulation/acid-base-solutions

- How do strong and weak acids differ? Use lab tools on your computer to find out! Dip the paper or the probe into solution to measure the pH, or put in the electrodes to measure the conductivity. Then see how concentration and strength affect pH.
- Can a weak acid solution have the same pH as a strong acid solution?

- Given acids or bases at the same concentration, demonstrate understanding of acid and base strength by: 1.Relating the strength of an acid or base to the extent to which it dissociates in water 2.Identifying all of the molecules and ions that are present in a given acid or base solution. 3.Comparing the relative concentrations of molecules and ions in weak versus strong acid (or base) solutions. 4.Describing the similarities and differences between strong acids and weak acids or strong bases and weak bases.
- Demonstrate understanding of solution concentration by: 1.Describing the similarities and differences between concentrated and dilute solutions. 2.Comparing the concentrations of all molecules and ions in concentrated versus dilute solutions of a particular acid or base.
- Use both the strength of the acid or base and the concentration of its solution in order to: 1.Describe in words and pictures (graphs or molecular drawings) what it means if you have a: Concentrated solution of a weak acid (or base) or Concentrated solution of a strong acid (or base) or other combinations. 2.Investigate different combinations of strength/concentrations that result in same pH values.
- Describe how common tools (pH meter, conductivity, pH paper) help identify whether a solution is an acid or base and strong or weak and concentrated or dilute.

acid-base-solutions-html-guide.pdf

References:

Science ASSIST: Laboratory notesd: Preparing chemical solutions
Laboratory solution preparation. Flinn Scinetific website
https://www.flinnsci.com/laboratory-solution-preparation/dcat016/
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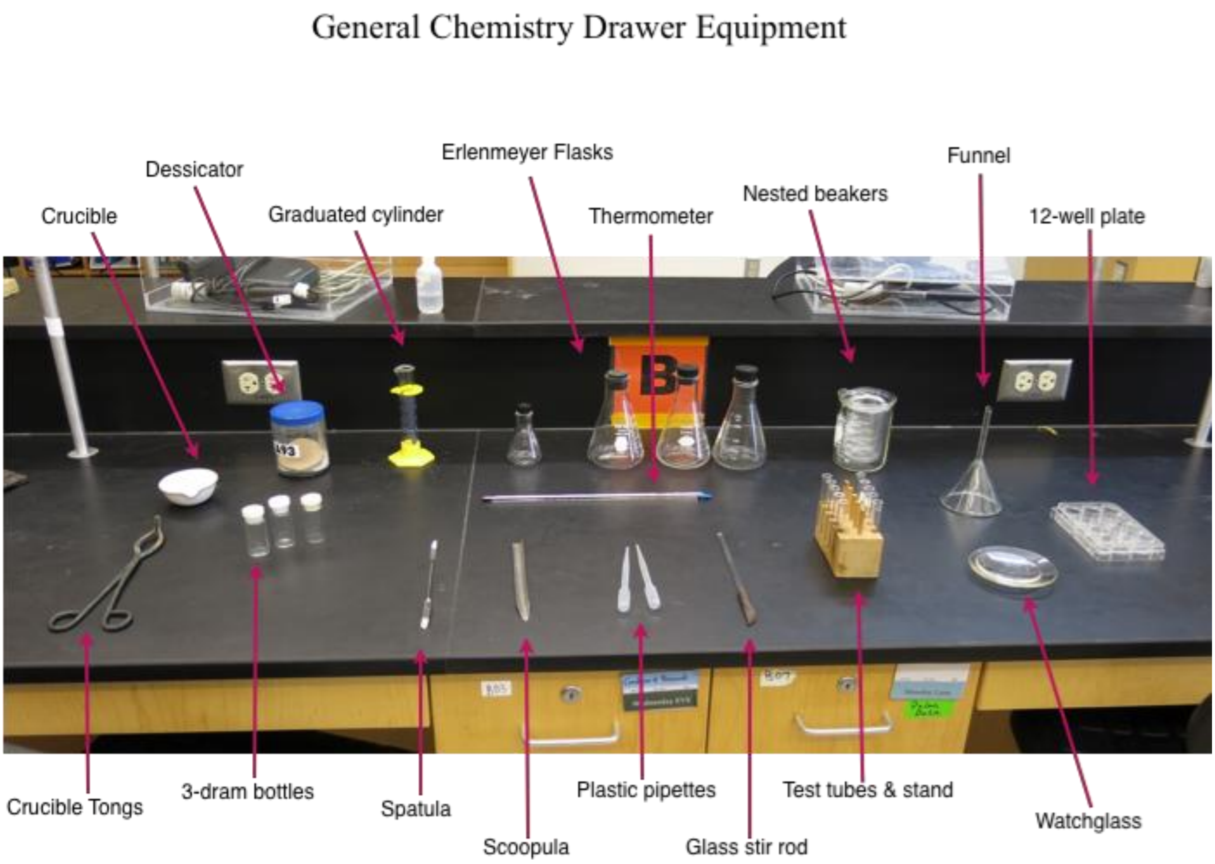
Laboratory equipment



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Beaker

Erlenmeyer flask

Liquid funnel

Burette

Graduated pipet

Volumetric pipet

Graduated cylinder

Test tube rack

Test tube

Test tube holder

Crucible and cover

Evaporating dish

Watch glass

Crucible tongs

Stirring rods

Wash bottle

Spatula

Weighing paper

Ring stand

Utility clamp

Thermometer clamp

Double burette clamp

T

Safety goggles

Safety glasses

Balance

Vortex mixer

Refernces:

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