Stage 2 Chemistry

**Monitoring the Environment:** Volumetric Analysis

**Science Understanding**

* Concentrations can be described by using a number of standard conventions.
* Calculate concentration and interconvert units, including: mol L-1, g L-1, %w/v, ppm, and ppb.
* Apply SI prefix conventions to quantities.
* Knowledge of the mole ratios of reactants can be used in quantitative calculations.
* Perform stoichiometric calculations when given the reaction equation and the necessary data.
* A titration can be used to determine the concentration of a solution of a reactant in a chemical reaction.
* Describe and explain the procedure involved in carrying out a titration, particularly rinsing glassware and determining the end-point.
* Determine the concentration of a solution of a reactant in a chemical reaction by using the results of a titration.

**Concentration**

Concentration can be described using many different standard conventions. In general it is:

We can use the units of the concentration to determine what the units of the solute and solvent should be. Some common units of concentration are mol L-1 and gL-1.

mol L-1 would be \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ie

g L-1 would be \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ie

Other units of concentration are %w/v, %w/w, ppm and ppb.

% means per 100, so %w/v means \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

%w/w means \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

ppm means parts per million, eg \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

ppb means parts per billion, eg \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate the molar concentration when 0.20 mol of hydrochloric acid is dissolved in 500.0 mL of water.
2. Calculate the molar concentration when 10.6 g of sodium carbonate is dissolved in 200.0 mL of water.
3. Calculate the number of moles contained in 500.0 mL of 0.22 mol L-1 sulfuric acid.

**Converting Between Units**

x molar mass

mol L-1

x 103

ppb

ppm

x 103

g L-1

x 10

%w/v

*The SI prefixes will be provided for you.*

1. 0.00250 g of sodium hydrogen carbonate is dissolved in 200 mL of water: MNaHCO3 = 84.008
   1. in g L-1:
   2. in molar concentration (mol L-1):
   3. in % w/v:
   4. in ppm:
   5. in ppb:
   6. in g mL-1:
2. Convert 0.015 mol L-1 sodium chloride (NaCl) to g L-1:
3. The Government regulations state that the concentration of sulfur dioxide (SO2) in wine is no more than 88 ppm. Convert this to mol L-1.

**Using Mole Ratios in calculations**

A balanced equation provides the mole ratios of the substances that react. This enables unknown quantities to be calculated.

The relative amounts (in moles) of substances reacting or produced during a reaction are indicated by the coefficients in the balanced equation for the reaction.

Given the equation for a reaction, the quantity of one reactant or product involved in a chemical reaction can be used to determine the quantity of another reactant or product.

*Mole ratios can be used in a number of ways. One simple way is to use fractions, always with the unknown at the top. The* ***n(unknown)*** *can then be found by multiplying* ***n(known)*** *by the mole fraction.*

1. The complete combustion of propanol (C3H7OH) is represented by the following equation:

C3H7OH (g) + O2(g) CO2(g) + H2O(g)

* 1. Balance the equation.
  2. What is the reacting mole ratio of:
     1. propanol to oxygen
     2. propanol to carbon dioxide?
  3. If 220 g of propanol is completely burnt, calculate,
     1. the mass of oxygen required
     2. the mass of carbon dioxide produced.

1. Hydrochloric acid was used to dissolve 4.5 g of sodium carbonate

Na2CO3 + 2HCl CO2 + H2O + 2NaCl

* 1. Calculate the mass of hydrochloric acid required to completely dissolve the sodium carbonate
  2. If the concentration of hydrochloric acid was 0.22 mol L-1, what volume of hydrochloric acid would be required to dissolve the sodium carbonate?

1. Use the following equation to answer this question.

C5H12(g) + 8O2(g) 5CO2(g) + 6H2O(g).

When 180 g of pentane (C5H12), undergoes complete combustion, calculate

* 1. The mass of oxygen that will react with this mass of pentane.
  2. The mass of carbon dioxide produced from the combustion of this amount of pentane.

1. Consider the following equation:

H2SO4 + NaOH Na2SO4 + H2O

* 1. Balance the equation.
  2. Calculate the number of moles in 25 mL of H2SO4 of concentration 0.500mol L-1.
  3. Hence calculate the number of moles of sodium hydroxide (NaOH) required to completely react with this amount of sulfuric acid.
  4. Calculate the mass of NaOH required to react with the 25 mL of sulfuric acid.

**Titrations**

A titration is a technique that enables a chemist to measure the concentration of a substance in a solution. It involves using glassware that is calibrated for an exact volume.

This volumetric analysis, involving a titration is a *quantitative analysis* because it involves finding the *amount* of a substance in a solution.

There are 3 practical tasks associated with titrations:

* **preparation of the solutions to be used in the titration**:
  1. the ***standard solution*** to be used in the titration,
  2. the solution under analysis may have to be ***diluted***.
* **preparation of the glassware to be used in the titration**, the rinsing procedures.
* **performing the titration**, including recording the burette readings.

**Rinsing**

Rinsing of the apparatus is important to ensure *accurate* and *precise* results.

With each apparatus, we either want to control the \_\_\_\_\_\_\_\_\_\_\_\_\_ or the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

If we want to control the moles, it is important that no more of the solution is added.

Therefore our final rinse is with \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Examples of this are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

When we want to control the concentration, it is important that the solution is not diluted. We still rinse with water to remove any unwanted chemicals, but the final rinse is done with whatever solution the apparatus is about to contain.

Examples of this are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Volumetric Flask**

* Wash and rinse with distilled water
* Pour substance into volumetric flask, ensuring everything weighed goes in by rinsing the watchglass and funnel into the flask
* Fill roughly one third with water and swirl to dissolve the substance
* Fill to the graduation mark, going slowly and dropwise when you get close.
* Stopper and invert several times to make sure it is homogenous

***Note: If you overshoot the graduation mark, you must start again!!***

**Volumetric Pipette**

* Wash and rinse with distilled water
* Rinse with the solution to be used
* Fill to above the graduation mark and slowly let it down until the bottom of meniscus lies on the mark. Ensure there are no bubbles.
* Keep the pipette vertical and transfer to the flask. Touch the tip of the pipette to the side of the angled flask
* Let the pipette drain for 10-15 seconds after emptying, do not shake to remove last drop

**Burette**

* Wash and rinse with distilled water
* Rinse with solution to be used, ensure that tap and portion below tap is also rinsed
* Fill the burette. Ensure that portion below tap is full with no bubbles, funnel is removed and no droplets that may drop in are above the graduation marks.
* Record initial volume in the burette
* Perform the titration by allowing the solution to slowly run into the conical flask, swirling the contents as you do
* If at any time droplets of the solution are left on the sides of the flask, they should be rinsed down with distilled water
* The end point should be approached dropwise
* The end point is when the first permanent change (colour or precipitate) is observed
* Record the final volume

1. A student overfills his volumetric flask so removes some of the excess liquid from the top. Explain why this is not an appropriate thing to do and the effect it may have on the results.
2. Why would bubbles in the pipette be a problem? What effect would they have on the results?
3. Explain why drops on the inside of the conical flask need to be rinsed down and why the water used to do so does not change the results.

**An example titration type calculation**

An acid-base titration was performed to determine the concentration of a dilute sample of calcium hydroxide Ca(OH)2. A standard solution of 0.0934 mol L-1 hydrochloric acid was used for the titration, and methyl orange was the indicator. 20.0 mL samples of the calcium hydroxide were placed in a conical flask and the results of the titration are shown in the table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Titration No. | 1 | 2 | 3 | 4 |
| **Final** V mL | 24.2 | 48.1 | 23.8 | 47.7 |
| **Initial** V mL | 0 | 24.2 | 1.00 | 23.8 |
| **Titre value mL** |  |  |  |  |

1. Name the apparatus used to deliver the calcium hydroxide to the conical flask.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. With what should the conical flask have been rinsed? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Name the apparatus used to deliver the hydrochloric acid. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. What is meant by a standard solution? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Describe how the end-point of the titration is determined.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Complete the last row of the table above.
   1. Use this to calculate the average titre for the titration \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   2. Explain why you would ignore the first value of the row.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate the concentration of the calcium hydroxide by following the steps below.

Ca(OH)2 + 2HCl CaCl2 + 2H2O

* 1. Calculate the *number of moles of hydrochloric acid* used to reach the end point.
  2. Use the reacting mole ratio to calculate the *number of moles of calcium hydroxide* that reacted with the hydrochloric acid.
  3. Calculate the *concentration* of calcium hydroxide.
  4. Check significant figures for all answers!

The concentration of ethanol (C2H5OH) in an alcoholic beverage may be determined by titrating a diluted sample of the beverage that has been acidified, with a potassium permanganate solution. The permanganate oxidises the ethanol.

1. Use the following skeleton half equations to write the overall reaction

MnO4- Mn2+

C2H5OH CH3COOH

*20.0 mL of the beverage was diluted to 200.0 mL. A 20.0 mL sample of this diluted beverage was acidified and then titrated with 0.050 mol L-1 potassium permanganate solution. The titre obtained was 21.20 mL.*

1. Calculate the moles of permanganate needed to reach the end point
2. Calculate the moles of ethanol in the diluted solution
3. Find the concentration of the diluted beverage solution, and hence the concentration of the original beverage in %w/v

**Indirect or Back Titrations**

Some titrations cannot be carried out directly. This is often due to one of the reactants not being soluble or being volatile, the reaction being slow or the end point hard to determine. When this is the case the excess reagent or product of the initial reaction is titrated instead.

**Example**

A student was asked to determine the concentration of ammonia, a volatile substance, in a commercially available cloudy ammonia solution used for cleaning.

First the student pipetted 25.00 mL of the cloudy ammonia solution into a 250.0 mL conical flask. 50.00 mL of 0.100 mol L-1 HCl(aq) was immediately added to the conical flask which reacted with the ammonia in solution. The excess (unreacted) HCl was then titrated with 0.050 mol L-1 Na2CO3(aq).

21.50 mL of Na2CO3(aq) was required. Calculate the concentration of the ammonia in the cloudy ammonia solution.

1. Write a balanced equation for each reaction

Reaction 1:

Reaction 2:

1. Calculate the total number of moles of HCl that was added in reaction 1.
2. Calculate the number of moles of Na2CO3 that was required in reaction 2.
3. Use mole ratio to determine the moles of excess HCl that reacted in reaction 2. *Important note: this is the same amount of HCl that was left over from the first reaction*
4. Find the number of moles of HCl that reacted in the first reaction. *This is the total amount – the excess amount, ie answer from* ***2*** *– answer from* ***4***
5. Use mole ratio to determine the moles of NH3 that reacted in the first reaction
6. Calculate the concentration of the NH3 in mol L-1.
7. Convert your answer to %w/v.

The concentration of ozone, O3, in a sample of polluted air was determined by using the following procedure:

Step 1: 30.0 L of polluted air was bubbled through a solution containing excess iodine ions

O3(g) + 2I-(aq) + 2H+(aq) O2(g) + I2(aq) + H2O(l)

Step 2: The iodine formed in step 1 was then titrated with 2.00 x 10-3 mol L-1 sodium thiosulfate, Na2S2O3, solution using starch as an indicator. The titre obtained was 17.84 mL

2S2O32-(aq) + I2(aq) S4O62-(aq) + 2I-(aq)

1. Find the moles of thiosulfate that was required in the titration
2. Find the number of moles of iodine that was formed from the reaction with ozone
3. Find the number of moles of iodide ions that reacted in step 1 and hence find the moles of ozone present in the 30.0 L sample.
4. Find the concentration of ozone present expressed in ppm