# Module 3: Chemical Monitoring & Management

## Some teaching points

### 1. Chemical equilibrium
Although the syllabus does not specifically say that students should be able to apply Le Chatelier's principle to situations other than ammonia synthesis or $CO_2$ dissolution, *Conquering Chemistry* assumes that students should be able to work the same sorts of exercises as in the previous syllabus. This is the reason for Exercises 3 to 7 on pages 205–6.

**Change in number of moles and pressure.** In the absence of any discussion of the gas laws, it is necessary to explain carefully the relation between number of moles of gas and total pressure:
In a container of fixed volume, the pressure of a gas mixture is proportional to the number of moles of gas present, irrespective of the chemical nature of the gases in the mixture. So if we double the number of moles, we double the total pressure. If in a chemical reaction, 2 moles of gaseous reactants combine to form one mole of product
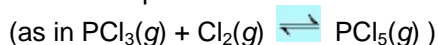
   (as in $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$ )
 then as the reaction proceeds from left to right, the number of moles in a reaction vessel of fixed volume decreases and therefore the pressure in the reaction vessel decreases.

A useful summary of the qualitative features of chemical equilibrium is on page 315–6; the photo on page 316 is particularly informative for adding or removing a reactant.

The photos on page 329 (in the Industrial Chemistry option) are equally relevant to this module.

### 2. Qualitative analysis of anions and cations
It should be stressed that the tests commonly used to identify ions are consequences of the solubility rules of Table 8.1 on page 205 of *CCPC* (reproduced inside the back cover of *CCHSC*). Although the syllabus suggests that students do not need to memorise these rules, there are great advantages in doing so. Having to flip back to such a table every time a test is described makes for very slow progress in problem solving.

Students also need to be careful whether a particular test exclusively identifies the ion present or whether it just indicates one of several possibilities. For example getting a precipitate with sulfate does not prove that the solution contains lead ions: it could also contain barium, calcium or silver ions (though surprisingly the silver ion is not on the list for consideration). Getting a precipitate with iodide would eliminate barium and calcium.

Although a systematic approach to identifying ions is used in *CCHSC* (using HCl, $H_2SO_4$, NaOH in that order for cations, $HNO_3$, $Ba^{2+}$ in acid solution, $Ag^+$, then $Ba^{2+}$ in alkaline solution for anions), tests can be done in a variety of different sequences, particularly if only one cation or anion is present. Hence students need to develop skill in interpreting results. Practice on many different exercises is the best way of developing this skill.

Although hydrogen sulfide has traditionally been used in the identification of cations *CCHSC* deliberately avoids it, because of both the unpleasant smell and high toxicity of hydrogen sulfide. Sodium sulfide is reluctantly used in Chapter 8 for the detection of heavy metals in environmental water.

## 3. Quantitative analysis (sulfate in fertiliser)

The present module requires students to perform just one quantitative analysis, namely sulfate in fertiliser. This introduces students to **gravimetric analysis** and is the only place gravimetric analysis is treated (apart from the analysis of mixtures in the early part of the preliminary course). The design and performance of gravimetric analyses require care to avoid

(a)  losses due to the small (but sometimes significant) solubility of the compound being precipitated

(b)  excess mass of precipitate due to co-precipitation of impurities with the required precipitate

(c)  losses due to the formation of the precipitate as very small particles that pass through the filter paper or sintered glass crucible

(d)  losses due to mechanical spillage or due to incomplete transfer of precipitate from beaker to filter (glass or paper)

These are the sorts of issues students need to discuss to 'evaluate the reliability of results ... and to propose solutions to problems ...' (Section 9.4.3 RC DP 4).

## 4. Back titration

With the five analyses listed in Section 9.4.3, RC DP 3 of the original (1999) syllabus, it was fairly clear that back titration was required (it's virtually impossible to determine nitrogen or ammonia without it). However when four of these analyses (including the nitrogen analysis) were deleted in 2002, there was no longer any indication in the syllabus document that back titration was required. Hence I deleted it from *CCHSC*. However there was a question involving it in the 2005 HSC exam paper! It seems that students do need to be aware of the technique of back titration and to work some exercises (an example of syllabus creep that used to plague the pre-2000 syllabus?). Hence the following:

Direct titrations as used in Sections 5.8 to 5.12 on pages 157–65 work well if the reaction between the substance to be analysed and the reactant in the burette (the titrant) occurs rapidly. If the reaction is slow because it needs heating or if the substance being titrated is present as a solid, then in a direct titration the endpoint can easily be overshot. A way of avoiding this is to use what is called a **back titration**. A known excess of a reagent is added to the sample to be analysed, sufficient time or heat is provided for the reaction to go to completion and then the amount of excess is determined by a direct titration with some other solution. The following example illustrates.

The ammonium ion concentration in a fertiliser was determined as follows. 1.037 g of the finely ground fertiliser was added to 100 mL 0.213 mol/L sodium hydroxide in a conical flask. This mixture was gently heated for 15 minutes to drive off all the ammonia. The reaction occurring is

$$NH_4^+(aq) + OH^-(aq) \rightarrow H_2O(l) + NH_3(g)$$
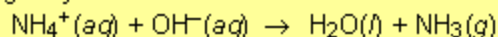
After cooling the solution was titrated with 0.314 mol/L hydrochloric acid solution. 38.3 mL was required. Calculate the percentage of $NH_4^+$ and of N in the fertiliser.

The reaction in the final titration is simply

$$OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$$
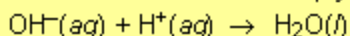
The final titration tells us how much of the original sodium hydroxide solution did *not* react with ammonium ion:

Number of moles of HCl used in the titration = 0.0383 × 0.314

= 0.01203 mol

This is the number of moles of NaOH left over after reaction with $NH_4^+$.

Number of moles of NaOH originally provided = 0.100 × 0.213

= 0.0213 mol

$$\begin{pmatrix} \text{number of moles of NaOH} \\ \text{that reacted with } NH_4^+ \end{pmatrix} = \begin{pmatrix} \text{number of moles of} \\ \text{NaOH provided} \end{pmatrix} - \begin{pmatrix} \text{number of moles} \\ \text{of NaOH left over} \end{pmatrix}$$

= 0.0213 − 0.01203

= 9.27 × 10⁻³ mol

Molar mass of $NH_4^+$ = 14.0 + 4 × 1.0 = 18.0 g/mol

mass of $NH_4^+$ = 9.27 × 10⁻³ × 18.0 g

= 0.167 g

Hence percentage $NH_4^+$ in the fertiliser = $\dfrac{0.167}{1.037} \times 100$

= **16.1%**

The percentage of N is just 14.0/18.0 times this, namely **12.5%**.

Some exercises involving back titration are included in the set for pages 223–4 in the Further Exercises section.


## 5. Air pollutants

Table 7.2 on page 238 lists the main air pollutants and their sources. Some of these ($CO_2$, $SO_2$ and $NO_2$) were also discussed on pages 121–6. *Pollution from burning fossil fuels* on pages 286–8 of *CCPC* should be re-visited while studying this section.

The main sources of the major air pollutants listed in Table 7.2 on page 238 are:

1. transport (cars, trucks, trains, planes, ships)
2. electricity generation
3. metals processing and heavy industry
4. mining
5. homes and commercial activities (offices, shopping centres)

6.	agricultural pursuits (fertilisers, pesticides, hydrocarbons and other volatile organic compounds, particulates)

The operation of catalytic converters in motor car exhausts is described on page 240–1. Such catalysts were also mentioned on pages 297 of *CCPC* where there is a photo of one. All the commercial catalytic converters in use today are dual bed ones, meaning that there are small particles of both platinum and rhodium deposited on the surface of the ceramic support. Such catalytic converters for removing NO, CO and hydrocarbons are (confusingly) referred to as both dual bed (two catalysts) and three-way converters (three types of compounds removed).

## 6. Ozone destruction in the stratosphere

It is essential to appreciate that one chlorine atom can destroy thousands of ozone molecules (in what we call a chain reaction): this is why very small concentrations of CFCs in the atmosphere can destroy a significant proportion of the ozone in the stratosphere.

It is also important to appreciate that $Cl + O_3 \rightarrow ClO + O_2$ and $ClO + O \rightarrow Cl + O_2$ alone do not explain the ozone hole: they explain a general reduction of ozone throughout the whole stratosphere. It is the liberation of $Cl_2$ from $HCl + ClONO_2$ and the subsequent formation of extra $Cl$ atoms that cause the dramatic reduction in ozone concentrations that are observed over the Antarctic in spring (pages 253–6).

## 7. Water quality criteria and types of water pollution

Page 263 lists eleven criteria for assessing water quality. Perhaps we could add to this list colour and smell (though these are consequences of the presence of various organic compounds, organisms or metal ions). Students probably need to memorise rough values of several of these criteria for clean water and how the values for polluted water vary (higher or lower) from these – such as for TDS. pH, DO, BOD and faecal coliforms. See for example Table 8.1 on page 264.

**The major types of water pollution and their main sources are:**

1.	oxygen demanding wastes — sewage, food processing, chicken farms, animal feed lots, stormwater run-off
2.	disease-causing agents — as for 1
3.	nutrients — as for 1 plus fertiliser run-off from farms
4.	salinity and total dissolved solids — land clearing, deforestation, soil erosion from farms
5.	suspended solids — as for 4
6.	heavy metals — mining and heavy industry
7.	acid drainage — mining and clearing of certain land types
8.	synthetic organic chemicals such as pesticides, paints, plastics and oil — industry, farming, oil transport, consumer carelessness
9.	radioactivity — nuclear reactors, hospitals and other users of radiotracers
10.	thermal pollution (*CCPC* pages 241-2) — power stations and factories using rivers or lakes for cooling

Or presenting some of this information in a different way, the major sources of water pollution are
1.	sewage
2.	food processing plants, chicken farms, animal feed lots
3.	urban storm water run-off
4.	agricultural run-off

5. erosion from land clearing and farming
6. mining
7. industry (metals processing, fuel refining, manufacture of plastics, paints, pesticides, pharmaceuticals, fertilisers and general chemicals
8. electricity generation