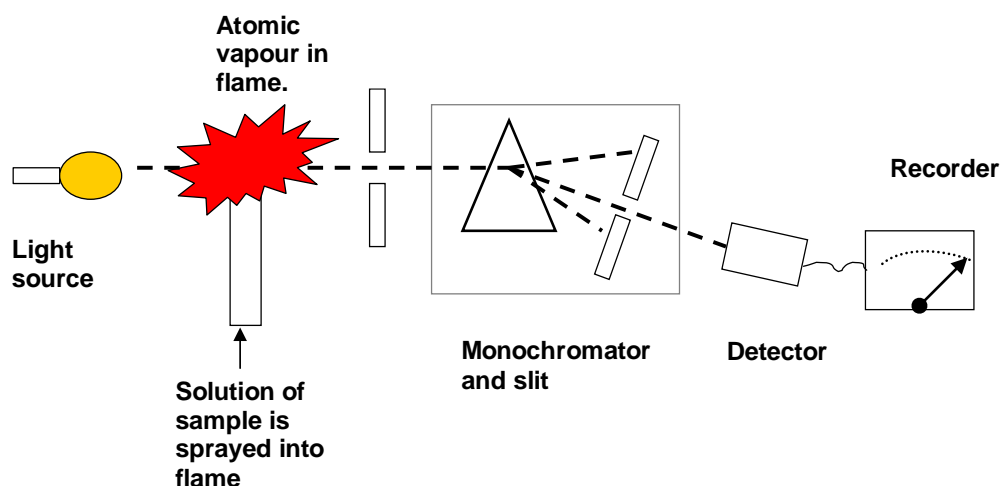# ATOMIC ABSORPTION SPECTROMETRY (AAS)

AAS is by far the most sensitive and accurate of the techniques involving spectrometry. This technique was invented by an Australian Sir Allan Walsh back in the early 1950s.

The instrument used is called an **Atomic Absorption Spectrophotometer.** A cross-section of this instrument is shown below.

Atomic vapour in flame.

Recorder

Light source

Solution of sample is sprayed into flame

Monochromator and slit

Detector

HOW DOES AN ATOMIC ABSORPTION SPECTROMETER WORK?

- The light source emits light of various wavelengths, which includes those the solute in the sample solution will absorb the most. The light is chopped into **pulses.** The same effect can be produced by continuously turning a torch on and off.

- The sample solution is sprayed into a very hot flame (much hotter than a Bunsen burner flame). The solution turns into an atomic vapour which contains the atoms of the solute to be analysed in the form of an atomic gas.

- The atomic particles in the flame will absorb radiation from the light source. They will absorb the wavelength required to excite their electrons. The more concentrated the sample solution the stronger the absorption of light.

- The light which was not absorbed by the solute particles in the flame will now pass into the **monochromator and slit.** Together they will select the wavelength of light that is known to be absorbed the strongest by the sample solution. When the light passes through the prism it is broken up into its different constituent wavelengths as was seen earlier. The different wavelengths exit the prism at different angles. The slit at the right hand side of the prism is positioned in such a way so that only light of the most absorbed wavelength will reach the **detector**. It is important that the wavelength of highest absorbance is known prior to analysis so that the slit can be positioned appropriately. The unwanted wavelengths (those that the solution will not strongly absorb) will not reach the detector as their exit angles will not coincide with the position of the slit.

- The recorder will display the results as absorbance readings. The most concentrated solutions will have the highest absorbances.

How is the light emitted as excited electrons revert back to the ground state prevented from interfering with the results?

Many metallic elements will emit light when their excited electrons revert back to the ground state. The hot flame used in AAS is hot enough to excite the electrons of many elements. If this emitted light reaches the detector it will interfere with the absorbance readings. This problem is partially overcome through the use of a slit that is between the flame and monochromator. This slit allows only the light moving in one direction (from the light source) to pass into the monochromator. Emitted light is scattered out in every direction and only a very small percentage of it will pass through the slit. The use of **pulsed** light also helps combat the effect of emitted light. The pulsed light will produce a very different signal to that of the emitted light which is moving in a solid and steady stream. The detector has been adjusted so that it will only detect pulsed light.

APPLICATIONS OF AAS

As is the case with most techniques involving spectrometry, AAS is mainly used for applications involving metals. Such applications include:

- Urine and blood analysis
- Testing for air and soil pollution
- Analysis of mineral and soil samples
- Analysis of metals present in engine oils
- Very accurate in the ranges of ppm and ppb

EXAMPLE 1

A town's water supply is believed to be contaminated with chromium due to the activities of a local factory. Chromium is a suspected carcinogen (cancer causing substance) and water with concentrations of 0.05 mg L^{-1} or higher is believed to be too dangerous for human consumption.

A sample of the town's water is analysed by using AAS and its absorbance recorded. A set of standard solutions containing varying concentrations of chromium is also analysed. The results are presented in a table.

Concentration of chromium (ppb)	Absorbance reading
0	0.00
0.20	0.050
0.40	0.090
0.60	0.135
0.80	0.186
1.0	0.225
unknown	0.067

(a) Construct a calibration curve and determine the concentration of chromium in ppb in the sample of water.

Standard curve showing the concentration of chromium versus absorbance

~0.3 ppb
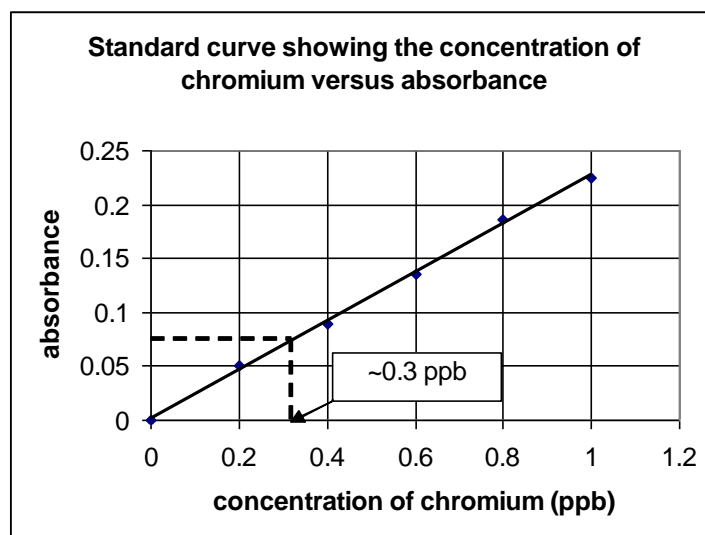
(b) Convert the concentration from ppb to mg L^{-1} and so determine if the town's water supply is contaminated.

10^9 mL of water $\rightarrow$ 0.3 g of chromium
1000 mL of water $\rightarrow$ x g

$x = 0.3 \times \dfrac{1000}{10^9} = 3.0 \times 10^{-7}$ g

So 1L of water contains 3.0×10^{-7} g of chromium. All that remains now is to convert the mass of chromium into mg:

$3.0 \times 10^{-7} \times 1000 = 3.0 \times 10^{-4}$ mg of Cr

Therefore concentration = 3.0×10^{-4} mg L^{-1}

No, the water is not contaminated.

(c) If a person were to drink a 250 mL glass of water contaminated with chromium of concentration 85 ppb, what mass of chromium would they ingest? Density of water = 1.00 g mL^{-1}

10^9 mL of water $\rightarrow$ 85 g of Cr
250 mL of water $\rightarrow$ x g of Cr

$x = 85 \times \dfrac{250}{10^9} = 2.1 \times 10^{-5}$ g of chromium

EXAMPLE 2
How can AAS be used to identify a solution of unknown identity?

Solution

If a solution is suspected of being contaminated with metal ions it can be qualitatively analysed using AAS. This solution will mostly absorb one particular wavelength of light. Different wavelengths of light can be experimented with until the one that provides the highest absorbance is found. This information can be compared with the absorbances of known metals.

EXAMPLE 8

"Milo" milk drink contains iron which is essential for health. A 10 mL sample of Milo was diluted to 100 mL. The absorbance of the diluted "Milo" solution and a series of standards were measured using AAS. The results are shown below:

Concentration of chromium (ppb)	Absorbance reading
0.0	0.090
1.0	0.081
2.0	0.151
3.0	0.222
4.0	0.288
Sample	0.192

(a) What is the concentration (ppm) of iron into the diluted sample of Milo?

(b) What is the concentration (ppm) of iron in the undiluted (original) sample of Milo?

(c) What mass of iron would you consume by drinking a 300 mL glass of Milo?

(d) Why was the sample of Milo diluted in order to measure its absorbance?

Solution

(a) Construct a standard curve and compare the absorbance of the diluted sample with that of the standards. The concentration is about 2.65 ppm.
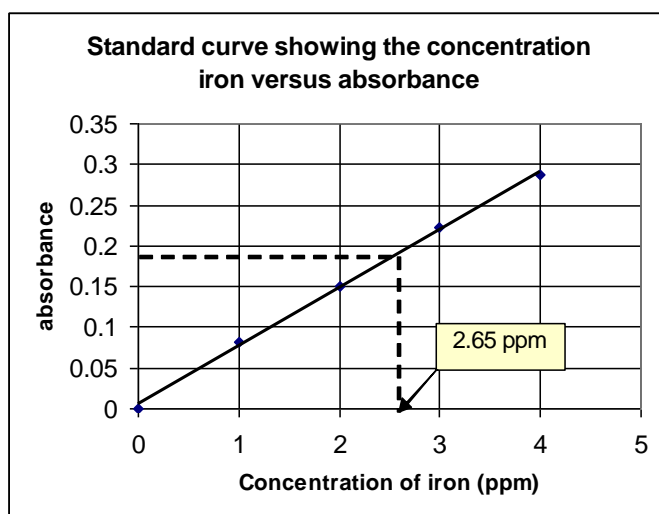
(b) In the undiluted sample, the concentration of Fe must be higher because this was the original solution before any water was added.

10 mL original Milo sample (undiluted)

Add H_2O (90 mL)
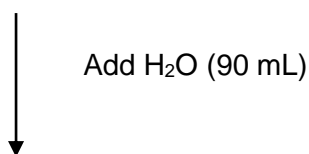
100 mL of diluted Milo sample (2.65 ppm)

The diluted sample contains 10 times more water (100 divided by 10 = 10) than the original solution. Therefore, by proportion the undiluted sample must be 10 times more concentrated:

$2.65 \times \dfrac{100}{10} = 26.5$ ppm

or using $C_1V_1 = C_2V_2$

C_1 = 2.65 ppm
C_2 =?
V_1 = 100 mL
V_2 = 10 mL

$C_2 = \dfrac{2.65 \times 100}{10} = 26.5$ ppm

(c) 10^6 mL of Milo $\rightarrow$ 26.5 g
300 mL of Milo $\rightarrow x$ g

$x = 26.5 \times \dfrac{300}{10^6} = 8.0 \times 10^{-3}$ g

(d) If the Milo was not diluted, its concentration may have been so high that its absorbance reading would have been outside the range of the calibration graph. A very concentrated solution may have an absorbance reading of 1 (100% absorbance). Such a solution cannot be compared to a standard curve because once a solution reaches this maximum absorbance, any solution of higher concentration will also have an absorbance of 1.