Learning Objectives

- Understand why samples need to be digested.
- Know what type of elements are detected by using AA or AE
- Recall practical applications of AA or AE (what businesses use these methods)

Sample Preparation for Atomic Absorption or Atomic Emission

Chemists employ atomic spectrophotometers to determine the identity and/or concentration of a metallic species. Samples must be in liquid form before being placed in the analyzer. In order to do this, a chemist will use certain acids (nitric or hydrochloric) to extract the metallic component of a sample. This process is called digestion and will not affect the analysis of the sample.

Figure \(\PageIndex{1}\): A chemist adding acid to soil samples. After the digestion process, samples will be analyzed for phosphorus and potassium. Image taken from: https://upload.wikimedia.org/wikipedia/...le_acidity.jpg

Once the sample has transformed into liquid form, it enters the spectrophotometer by a capillary tube. Then, it is atomized, or transformed into fine mist, by a flame. A light source (cathode lamp) bombards the misted sample. The metallic atoms inside the sample gain energy from the light source and jump to excited states. At different intervals of time, the excited atoms release energy and fall back to their ground states. This quantized energy that is involved in the absorption (AA) or emission (AE) process corresponds to a fingerprint wavelength pattern that can be used to identify a specific metal atom.
Video: A combination of animation, commentary, and application to supplement the lab experience with FAA spectroscopy.

Applications

AA or AE spectrometers have been used in many different industrial and academic settings. For example, a medical laboratory could detect the type and amount of toxic metals that could be present in patient's urine or blood. Environmental scientists could monitor metal pollutants in soil and water. The pharmaceutical industry uses these machines to determine if a metal catalyst after a drug has been purified. Lastly, the mining industry would utilize these devices to detect the quantity and presence of precious metals like gold and silver.
Academic and industrial laboratories consider several factors before selecting spectrometer. For example, some labs require a large number of samples to be analyzed in one day while other labs might use the instrument occasionally. Specific analyzers might require a smaller amount of sample. In addition, a toxicology lab might need an instrument to report values in micro or nanograms. Lastly, academic (more often than industrial) facilities must consider the cost of the analyzer before purchasing.

Other options besides flame based AA/AE are graphite furnace (GFAA) and inductively coupled plasma (ICP-AE or ICP-OES). With the GFAA method, a furnace is used to excite the metallic sample. This technique can detect lower concentrations of metal than a flame AA/AE. Also, smaller volumes of sample are needed for a GFAA. ICP machines utilize a plasma (gas with charged ions) for the excitation process. Some of these instruments can directly analyze solid samples. Unfortunately, ICP-AE instruments are slower in producing data. Peruse Table \( \PageIndex{1} \) and note the general differences between the instruments.

### Table \( \PageIndex{1} \): Common instrument attributes for spectrometers.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Levels of detection</th>
<th>Volume of sample required</th>
<th>Elements analyzed per unit of time</th>
<th>Range of cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flame AA/AE</td>
<td>High ppb</td>
<td>&gt; 5.0 mL</td>
<td>1 element per 3-10 seconds</td>
<td>$15,000-$25,000</td>
</tr>
<tr>
<td>Graphite Furnace AA</td>
<td>Mid ppb</td>
<td>&lt; 5.0 mL</td>
<td>1 element per 2-3 minutes</td>
<td>$40,000-$70,000</td>
</tr>
<tr>
<td>ICP-AE</td>
<td>Mid ppb</td>
<td>&gt; 5.0 mL</td>
<td>73 different elements per minute</td>
<td>$70,000-$100,000</td>
</tr>
</tbody>
</table>

Units of Low Concentration: Parts per billion (ppb)

The letters ppb represent a concentration parts per billion. This translates to the metal atom being one part while the sample contains a billion parts. Imagine measuring one inch in 16,000 miles or counting one cent in $10 million dollars. These two values are comparable to one ppb. In water chemistry, ppb is often referred to as µg of contaminant per liter of a sample. Table \( \PageIndex{1} \) above shows that a flame AA/AE detects only large amounts of ppb. This would be
the least sensitive technique of the three listed.

Exercise \(\PageIndex{1}\): Analysis of Materials Using AA and AE

Click on this link about Forensic science and bushfires in Australia and answer the questions below.

a. In this article, what material are scientists analyzing? Why are they doing this?
b. What method-AA or AE are they using to determine the metals of interest?
c. What metals does this article mention?
d. Why are they using XRD in this article?

Answer a

They are comparing different types of matches (unburned and burned) for arson investigations (wildfires)

Answer b

They used ICP-AE (you just need to be concerned with the AE part).

Answer c

Mg, Al, Ca, Fe, Zn, and Ba

Answer d

They used XRD (x-ray diffraction) to determine which burned matches corresponded to the unburned matches (comparing different brands).

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