

## Flame Photometry

Flame photometry (more accurately called flame atomic emission spectrometry) is a branch of atomic spectroscopy in which the species examined in the spectrometer are in the form of atoms. The other two branches of atomic spectroscopy are atomic absorption spectrophotometry (AAS, see Standardbase technique: Atomic Absorption Spectrophotometry) and inductively coupled plasma-atomic emission spectrometry (ICP-AES, a relatively new and very expensive technique not used in Standardbase experiments). In all cases the atoms under investigation are excited by light. Absorption techniques measure the absorbance of light due to the electrons going to a higher energy level. Emission techniques measure the intensity of light that is emitted as electrons return to the lower energy levels.

Flame photometry is suitable for qualitative and quantitative determination of several cations, especially for metals that are easily excited to higher energy levels at a relatively low flame temperature (mainly Na, K, Rb, Cs, Ca, Ba, Cu).

This technique uses a flame that evaporates the solvent and also sublimates and atomizes the metal and then excites a valence electron to an upper energy state. Light is emitted at characteristic wavelengths for each metal as the electron returns to the ground state that makes qualitative determination possible. Flame photometers use optical filters to monitor for the selected emission wavelength produced by the analyte species. Comparison of emission intensities of unknowns to either that of standard solutions (plotting calibration curve), or to those of an internal standard (standard addition method), allows quantitative analysis of the analyte metal in the sample solution.

The intensity of the light emitted could be described by the Scheibe-Lomakin equation:

$$I = k \cdot c^n$$

where:

$c$  = the concentration of the element

$k$  = constant of proportionality

$n \sim 1$  (at the linear part of the calibration curve), therefore the intensity of emitted light is directly proportional to the concentration of the sample.

Because of the very narrow and characteristic emission lines from the gas-phase atoms in the flame plasma, the method is relatively free of interferences from other elements. Therefore the flame photometry (as with other atomic spectroscopy methods) is very sensitive; measuring concentration of ppm magnitude (part per million, e.g.  $\text{mg kg}^{-1}$ ) usually does not cause any problem. The optimal concentration range of the solutions for the measured metal ion is  $10^{-3}$ - $10^{-4}$   $\text{mol dm}^{-3}$ . Typical precision for analysis of dilute aqueous solutions are about  $\pm 1$ -5% relative.



Figure 1: Photograph of a flame photometer

The flame photometers are relatively simple instruments (fig. 1.). There is no need for source of light, since it is the measured constituent of the sample that is emitting the light. The energy that is needed for the excitation is provided by the temperature of the flame (2000-3000 °C), produced by the burning of acetylene or natural gas (or propane-butane gas) in the presence of air or oxygen. By the heat of the flame and the effect of the reducing gas (fuel), molecules and ions of the sample species are decomposed and reduced to give atoms, e.g.:  $\text{Na}^+ + \text{e}^- \rightarrow \text{Na}$ . Atoms in the vapour state give line spectra. (Not band spectra, because there are no covalent bonds hence there are not any vibrational sub-levels to cause broadening).

The most sensitive parts of the instrument are the aspirator and the burner. The gases play an important role in the aspiration and while making the aerosol. The air sucks up the sample (according to Bernoulli's principle) and passes it into the aspirator, where the bigger drops condense and could be eliminated.

The monochromator selects the suitable (characteristic) wavelength of the emitted light. The usual optical filters could be used. The emitted light reaches the detector. This is a photomultiplier producing an electric signal proportional to the intensity of emitted light (fig. 2.)

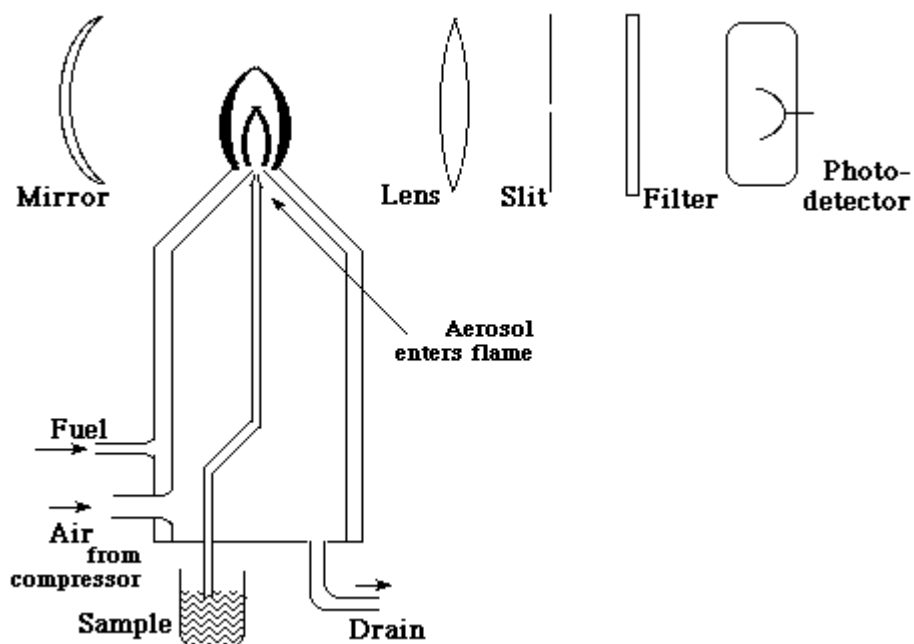


Figure 2: Principle of flame photometers, source: <http://www.resonancepub.com/atomicspec.htm>

Flame photometry has many advantages. It is a simple, relatively inexpensive, high sample throughput method used for clinical, biological, and environmental analysis. On the other hand, the low temperature makes this method susceptible to, particularly, interference and the stability (or lack thereof) of the flame and aspiration conditions. Many different experimental variables affect the intensity of light emitted from the flame. Fuel and oxidant flow rates and purity, aspiration rates, solution viscosity, concomitants in the samples, etc. affect these. Therefore, careful and frequent calibration is necessary for good results and it is very important to measure the emission from the standard and unknown solutions under conditions that are as nearly identical as possible.

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For further information see:

<http://www.chem.usu.edu/~sbialkow/Classes/361/flame.html>

[http://www.designinfo.com/LearnMore/Labware\\_Scientific\\_Instruments/Analytical\\_Instruments/Spectrometers/Flame\\_Photometers](http://www.designinfo.com/LearnMore/Labware_Scientific_Instruments/Analytical_Instruments/Spectrometers/Flame_Photometers)

<http://www.resonancepub.com/atomicspec.htm>

Reference textbooks:

- Sawyer, Heineman, Beebe: Chemistry Experiments for Instrumental Methods (Wiley, New York, US, 1984.)
- D. C. Harris: Quantitative Chemical Analysis (4th Ed., W. H. Freeman and Company, New York, US, 1995.)
- D. A. Skoog - D. M. West - F. J. Holler: Fundamentals of Analytical Chemistry (Saunders College Publishing, Fort Worth, US 1992.)
- J. Kenkel: Analytical Chemistry for Technicians (Lewis Publishers, Boca Raton, US 1994.)