Electronics And Instrumentation

8^{th} Semester

Subject: Analytical Instrumentation
Subject code: BT 808

Unit-3

Flame Photometers

5. FLAME AND ITS CHARACTERISTICS

A flame can be described as a steady state gas phase reaction which takes place with emission of light. It is produced by burning a mixture of fuel and air or oxidant in a burner. In flame photometry a variety of fuels can be used and generally air, oxygen or nitrous oxide (N2O) is used as the oxidant. The flame temperature depends on **fueloxidant ratio**. Combination of a given fuel gas with air produces lower temperatures as compared to when O2 is used as oxidant. Alkali and alkaline earth metals are easily excited at low temperatures obtained by using air. However, for heavy metals O2 or N2O are employed as oxidants. The requisite temperature for analysis can be obtained by varying the fuel-oxidant ratio. Table 2 lists some common fuels and oxidants along with range of temperature attainable by using them.

Table 2: Fuel-oxidant mixtures and the attainable temperature

Fuels	Oxidants		
	Air	Oxygen	Nitrous oxide
Propene	2250	3070	---
Acetylene	2470	3320	3220
Hydrogen	2370	3050	---

The most commonly employed flames in flame photometry can be grouped into two types:

1. Flames in which the fuel and oxidant as air or oxygen are well mixed before combustion, these are called **pre-mix or laminar flames** as they exhibit laminar flow.

2. Flames in which the fuel gas and the oxidant are first mixed in the flame itself. They are called **unpremix or turbulent flames** since they exhibit turbulence. These flames are obtained by using suitable burners about which you would learn in subsection . For now, let us learn about the structure and the reactions taking place in the different regions of the flame.

5.1 Structure of Flames

Flames are not uniform in composition, length or cross section. The structure of a premixed flame, supported as a laminar flow is shown in Fig. 7.

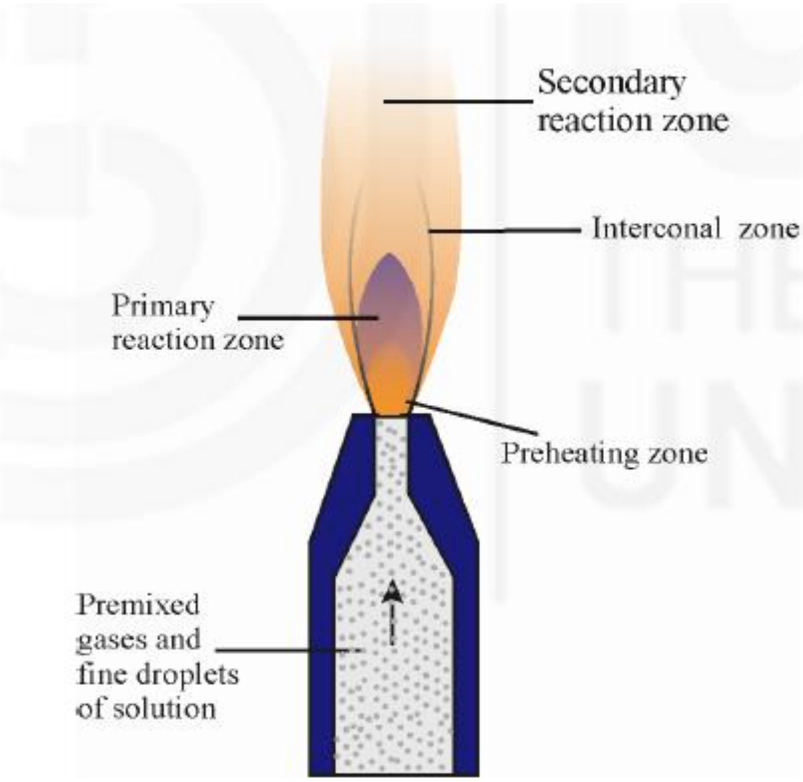

Fig. 7: Schematic structure of a laminar flow flame showing various zones

As seen in the figure, the flame may be divided into the following regions or zones.

i) Preheating zones
ii) Primary reaction zone or inner zone
iii) Internal zone
iv) Secondary reaction zone

The first or the innermost region of the flame is the **preheating zone** where the combustion mixture is heated to the ignition temperature by thermal conduction from the primary reaction zone. The second zone is **the primary reaction zone** or **inner zone**. This zone is about 0.1 mm thick at atmospheric pressure and is visible by virtue of its blue green light ascribed to radicals **.** C_2 and **.** CH. There is no thermodynamic equilibrium in this zone and the concentration of ions and free radicals is very high. This region is not used for flame photometry. Immediately above the primary reaction zone lies the third or **interconal zone** or the **reaction free zone** which can extend up to considerable height. The maximum temperature is achieved just above the tip of the inner zone. The higher temperature favours both production of free atoms and maximum excitation for atomic emission spectroscopy. Therefore, this zone is used for flame photometry. The outermost fourth zone is the **secondary reaction zone**. Within this zone, the products of the combustion processes are burnt to stable molecular species by the surrounding air. The shape of an unmixed flame is generally different. The inner zone can still be recognised, but it is very vague and is thickened. A laminar flame makes a strong hissing noise which gets louder when a liquid is atomised into it. We shall now look into the reactions which are taking place when the element is placed in flame.

5.2 Reactions in Flames

The most important reactions occurring in the flame are given below.

i) Dissociation of molecules

$$MX \rightarrow M + X, \quad K_{mx} = P_m P_x / P_{mx}$$

ii) Formation of compounds with flame components

$$M + Y \rightarrow MY, \quad K_{my} = P_m P_y / P_{my}$$

iii) Ionisation of atoms

$$M \rightarrow M^+ + e^-, \quad K_P = P^{+}_{m^+} \, P^{-}_{e^-} / P_m$$

In these equations, *p* is the partial pressure of the species indicated in the subscript. The partial pressure of the flame gas components is much larger than the partial pressure of the given element. It is, therefore, considered constant and included into the equilibrium constant. The most important of the flame gas components forming compounds with the elements are oxygen, the hydroxyl radical and hydrogen. The most common compounds formed in flames burning with air or oxygen and metal monoxides. For example, a major fraction of alkaline earth elements is present as monoxides unless very fuel rich flames are used. However, alkali metals practically do not form any oxides. Hydroxide species are present for some alkali and alkaline earth elements in hydrocarbon flames. Sodium forms practically no hydroxide, while the concentration of LiOH molecules often exceeds the atomic lithium concentration by a factor of 10. None of the alkali metal hydroxides emit spectral bands in the visible or UV region; whereas the spectral bands of alkaline earth monohydroxide can be used for the determination of these elements.

6. INSTRUMENTATION FOR FLAME PHOTOMETRY

You know by now that in flame photometry the sample is introduced into a flame wherein it undergoes a number of processes leading to the formation of excited atomic species which emit radiation. The radiation is then measured and suitably analysed. The instrument used for the purpose is called **flame photometer** and it consists of the following basic components. **Flame atomiser**: It converts the sample into excited atomic species and consists of the following.

• **Nebuliser and mixing chamber**: It is a means of transporting a homogeneous solution into the flame at a steady rate.

• **Atomiser burner**: Here the fuel and oxidant burn to give a flame that can be maintained in a constant form and at a constant temperature.

Monochromator (or filter): It isolates the light of the wavelength to be measured from that of extraneous emissions.

Detector: It helps in measuring the intensity of radiation emitted by the flame.

Amplifier and Readout Device: It is used to amplify the signal and provides a suitable output.

The schematic diagram showing the layout of various components of a flame photometer is given in Fig. 8.

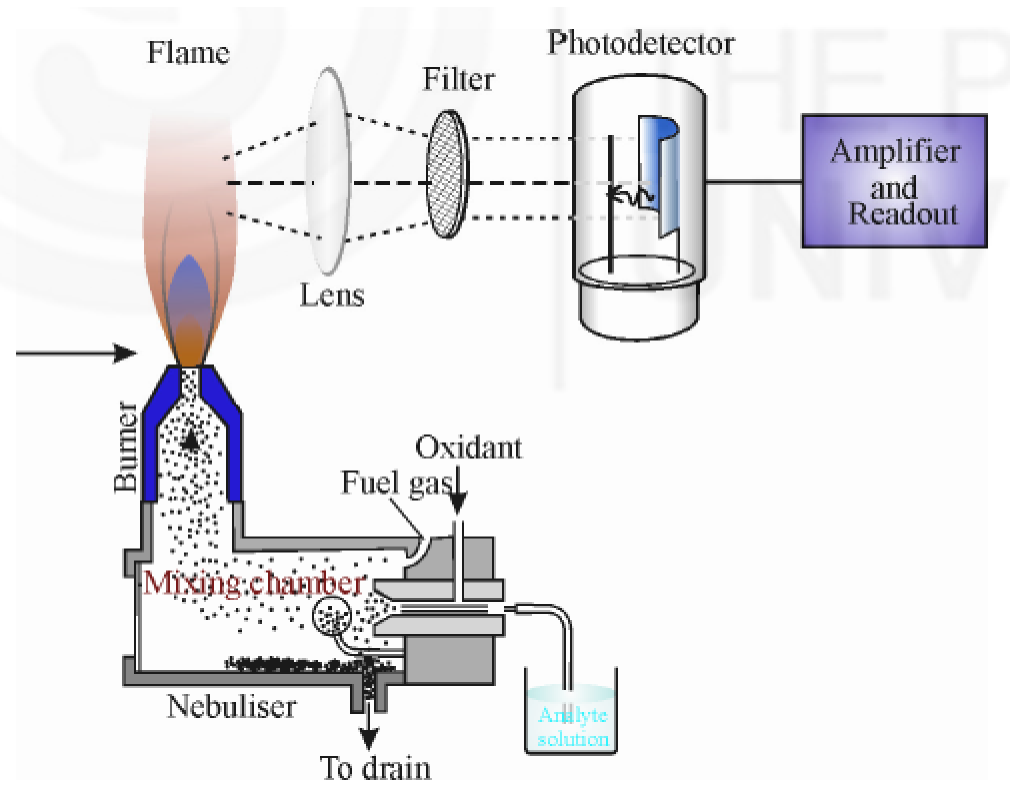

Fig. 8: Schematic diagram showing the layout of various components of a flame Photometer