# MULTICAPILLARY NEBULIZER FOR SIMULTANEOUS NEBULIZATION OF TWO OR MORE LIQUIDS

PATENTED TECHNOLOGY

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## ABSTRACT

The research group "Atomic-mass spectroscopy and analytical chemistry under extreme conditions" of the University of Alicante has developed a new pneumatic multicapillary nebulizer that it allows the simultaneous nebulization of two or more liquids - miscible or immiscible between them- through different independent liquid input capillaries, and provided with a single exit orifice for the aerosol generated. The device offers the possibility of simplifying the analysis process and reducing the consumption of resources (i.e., time, sample and reagents). In addition, a high mixing efficiency is achieved, with stable emulsions and excellent aerosol characteristics. Moreover, it can be connected to any commercial spray chamber. A laboratory-constructed prototype is available for any demonstration. This device can be used as a sample preparation and liquid sample introduction system in spectrometric techniques within the field of chemical analysis. The research group is looking for companies interested in transferring this technology for commercial exploitation.

## INTRODUCTION

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), Microwave Induced Plasma Optical Emission Spectrometry (MIP-OES) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) are spectrometric techniques that allowing the detection, identification and quantification of elements in samples.

With these techniques, the samples are usually introduced as a liquid, since the analyte is homogeneously distributed within the sample, so preparing the calibration standard is much easier and most of the metal-containing species can be dissolved. The most common way to transport the liquid sample towards the plasma is in the form of an aerosol which can be generated by a nebulizer.

There are different nebulizer types: pneumatic, thermal, hydraulic, ultrasonic, electrostatic, rotary, etc. The first one is being the most used as a liquid sample introduction system since it is easy to handle, robust and low cost. The market offers a variety of conventional nebulizers of this type and micronebulizers (working at low liquid flow rate), or direct injection nebulizers (the aerosol is directly introduced into the plasma, without using a spray chamber or injector tube).

For most of the elemental analytical methods, the sample has to be properly prepared for the experimental technique used. This sample preparation is laborious and complex, which often causes errors and uncertainty, and increases the total analysis time. Recently, new liquid sample introduction systems have been developed to enable the simultaneous nebulization of one or more solutions. These multiple nebulizer-based systems have a clear advantage over conventional ones, since all or part of the sample preparation is performed by mixing the sample and reagent aerosols. In this way, all or part of the sample preparation can be

performed in a quick, easy and efficient way.
Currently, three different multiple nebulizer-based system types are known:

1) Systems that incorporate several spray chambers, each one being equipped with a conventional nebulizer. These systems are complex to handle and a low mixing efficiency is achieved.

2) Systems that incorporate several conventional nebulizers in a modified spray chamber. These systems are easier to handle in comparison with the preceding ones. However, the mixing efficiency critically depends on the nebulizer position in the spray chamber.

3) Systems that incorporate one nebulizer with several aerosol outlet orifices and several independent liquid input capillaries (multinebulizers). In these systems, the greater proximity between the aerosol outlet orifices could increase the mixing efficiency.

A common problem of these multiple nebulization-based systems is the fact that the total nebulizing gas flow rate is divided among the various nebulizers or exit orifices of the nebulizer. Therefore, they usually work under non-optimal nebulizing gas flow rate conditions. This fact adversely impacts on the aerosol transport to the plasma. Moreover, most of these systems have additional problems, such as blocking risk and memory effects, which make them undesirable from an analytical point of view, since they do not allow the analysis of complex real samples (e.g., sea water, wastewater, etc.).

Therefore, it is necessary to develop multiple nebulizer-based systems that enable the sample preparation in aerosol phase, having a low blocking risk, low memory effect, high chemical and mechanical robustness, being easy to handle, having high analyte transport efficiency and universal application to any complex real samples.

## TECHNICAL DESCRIPTION

In order to overcome the limitations described above, **a novel multicapillary pneumatic nebulizer** has been developed which allows the **simultaneous nebulization of different liquids**, miscible or immiscible between them, by means of several independent liquid input capillaries with **a single aerosol outlet orifice**.

As shown in Figure 1, the nebulizer outer body (1) comprises a pressure chamber (2) for the flow of a nebulizing gas and an inlet tube (3) of said gas and an outlet orifice (4) thereof, open to the outside. Within the pressure chamber a plurality of liquid input capillaries (5) is housed, said capillaries preferably arranged in parallel, whose outputs (6) are commonly positioned in the area of the aerosol outlet orifice and whose inputs are connected to liquid feeding tubes (7), so that each liquid input capillary is connected to a separate liquid feeding tube. Liquid flows to be nebulized are aspirated or pumped through the various feeding tubes and through the liquid input capillaries of the nebulizer, located within the pressure chamber. At the exit of the liquid input capillaries, the liquid flows interact with the gas flow at high or low speed, and at high or low pressure in the pressure chamber; liquid and gas flows mix together, forming the aerosol which is pushed towards the outlet orifice of nebulizer expelling the nebulized product to the outside.

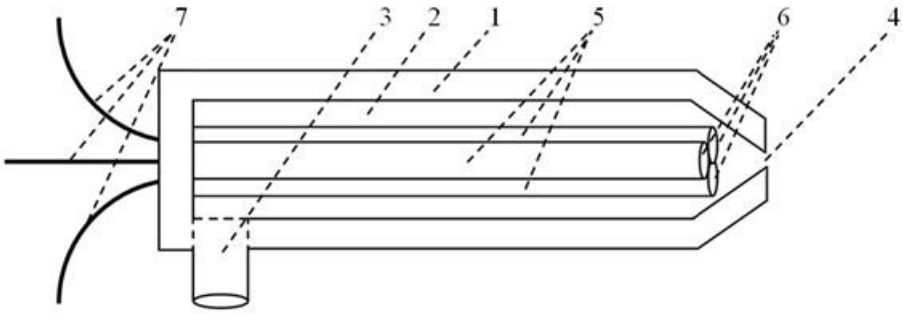


*Figure 1. The multicapillary nebulizer comprises: (1) nebulizer outer body; (2) pressure chamber; (3) gas inlet; (4) output orifice of the aerosol; (5) liquid input capillaries (sample, calibration standards, reagents, solvents, etc.); (6) exit orifices of the liquid input capillaries; (7) liquid feeding tubes.*

The developed device can adopt several embodiments, providing a high versatility to adapt to different applications. For example, Figure 2 shows several embodiments, without limiting them, using different quantities and geometries of the liquid input capillaries.

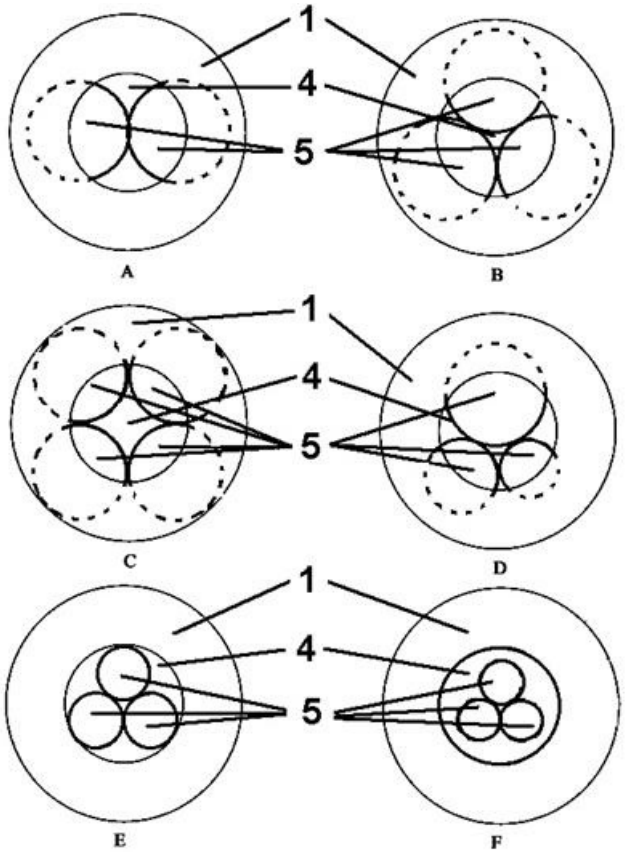


*Figure 2. Some of the possible embodiments of the multicapillary nebulizer (front view) showing a different quantity (2, 3 or 4) and/or a different geometry (symmetry and diameter) of the liquid input capillaries and their location and dimension relative to the exit orifice of the aerosol, wherein: (1) nebulizer outer body (4) exit orifice of the aerosol and (5) liquid input capillaries.*

## TECHNOLOGY ADVANTAGES AND INNOVATIVE ASPECTS

### MAIN ADVANTAGES OF THE TECHNOLOGY

This multicapillary nebulizer has the following advantages over current multiple nebulizer devices of the state of the art:

- A **high mixing efficiency** between different nebulized liquids in the aerosol droplets is achieved because the mixing takes place under turbulent conditions of high pressure and speed.
- Even if liquids are not miscible, the device obtains **stable emulsions** during the time in which the droplet is transported to the plasma.
- It can work either in a conventional way (by nebulizing a single liquid: sample or calibration standard), or by combining the sample preparation and sample introduction by **simultaneous nebulization of different liquids**.
- **The work** performed manually **is reduced** and **simplified**.
- **Uncertainty** is **reduced** and accidental **errors** in the analysis process are eliminated.
- Significant **time saving**.
- The amount of **samples** and **reagents are reduced.**
- **Some processes are intensified** due to the high pressure and speed of liquid flows in the mixing zone.
- The nebulizing gas flow is not divided between different exit orifices, so the **working conditions** are equal to the optimum working conditions of the spectrometer. In this way, the quantity of liquid input capillaries can be adjusted to the specific application of the nebulizer.
- It can be constructed using **adequate dimensions** to allow the connection to any commercial spray chamber (for all manufacturers and models of spectrometers based on plasma).
- Depending on the geometry of the exit orifice of the aerosol, an **aerosol with excellent characteristics** can be achieved over a wide range of liquid flow leading to different nebulization mechanisms.

### INNOVATIVE ASPECTS

This multicapillary nebulizer allows **simultaneous mixing** and **nebulization** of **two or more liquids, miscible or not**.

This device differs from other conventional nebulizers or multiple nebulizers, by the **large number of independent liquid input capillaries** with a single exit orifice of the aerosol.

## CURRENT STATE OF DEVELOPMENT

A laboratory-constructed prototype has been developed that it is available for any demonstration (*Figure 3*).

Experiments and tests have been performed to confirm its reliability, reproducibility, robustness and that it is easy to handle.

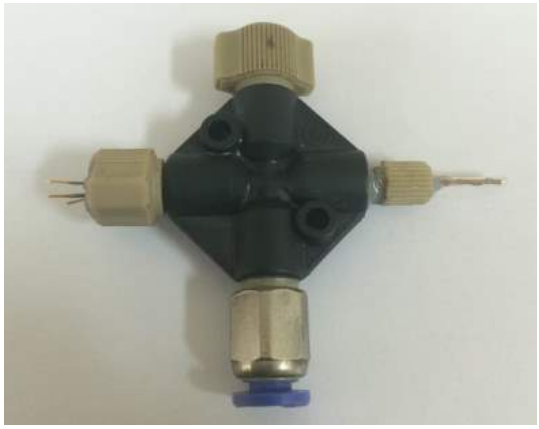

*Figure 3. Photograph of the laboratory-constructed prototype*

## MARKET APPLICATIONS

The present invention falls within the field of liquid nebulization technologies. Specifically, this device allows mixing and nebulizing two or more liquids, which makes it particularly suitable for **sample preparation** and **liquid sample introduction** in spectrometric techniques in the field of chemical analysis.

The multicapillary nebulizer can be used for the following:

- **Sample dilution** (allowing the automatization of the dilution process).
- **Internal standard calibration** (allowing interference corrections).
- **Standard addition calibration** (allowing the automatization and simplification of the process).
- **Isotopic dilution analysis**.
- **Derivatization** and **chemical vapour generation of analytes** (allowing chemical reactions to take place in aerosol phase between the analytes of the sample and calibration standards, and one or more reagents).
- **Organic sample analysis** (allowing the organic sample analysis in the plasma by emulsifying with aqueous solutions. A high mixing efficiency is achieved and the formation of carbon deposits on the exit orifice of the injector tube is removed).
- **Liquid-liquid extraction** (reducing the experimental time, analyte losses and sample contamination. In addition, large sample amounts, expensive organic reagents and/or toxic ones are not required).
- **Discrete samples/standards introduction** (directly introducing the analyte in a discrete way in aerosol phase into the spray chamber, removing diffusion problems).
- **Medical and Health related:**
    - o Diagnostic: Forensic science.
    - o Therapeutic: Drug delivery and other equipment.
    - o Clinical medicine:
        - Pulmonary medicine.
        - Ophthalmology, ear, nose and throat diseases.
- **Other electronics related**: analytical and scientific instrumentation (other analytical and scientific instrumentation).

## COLLABORATION SOUGHT

Companies interested in acquiring this invention for **commercial exploitation** by:

- Patent license agreement.
- Searching for financial support in order to develop new applications, adapt to specific requirements of the company, etc.
- Technology and knowledge transfer agreements.
- Preparing technical reports and providing scientific advice to companies.
- Providing specific training adapted to company requirements.
- Services of standardization, calibration, development of national and international technical standards, etc.
- Providing technical support in those techniques that require highly skilled researchers or sophisticated instruments that are not available to the company.
- Personal exchange for a defined period of time (for learning a technique, etc.).
- Equipment rental to customers who wish to carry out their own tests (at the Department of Analytical Chemistry or Technical Services Research (SSTTI) of the University of Alicante).

## INTELLECTUAL PROPERTY RIGHTS

The present invention is protected by patent rights:

- Title: “Nebulizador multiconducto, uso de dicho nebulizador y método para la nebulización de dos o más líquidos”.
- Application number: P201431797
- Application date: 4th December 2014

## RESEARCH GROUP PROFILE

- Professional, scientific and technical activities: scientific research and development (research and experimental development on natural sciences and engineering).
- Education: higher education.

## MARKET APPLICATION (4)

Agri-food and Fisheries
Pollution and Environmental Impact
Medicine and Health
Chemical Technology