Sequential-injection analysis (SIA): A useful tool for on-line sample-handling and pre-treatment

A. Economou

In this article, sequential-injection analysis (SIA) is reviewed as a tool for on-line sample manipulation and sample pre-treatment. Although SIA is an established technique for performing solution chemistry, its great potential lies in the scope it offers for the more complicated on-line sample-manipulation stages before the measurement step. This review will demonstrate the scope of SIA in complex sample-handling procedures with examples of on-line sample dilution, dialysis and gas diffusion, extraction (liquid/liquid, gas/liquid and solid-phase), enzymatic and immunological assays, and various other on-line operations.

Keywords: Dilution; Enzymatic analysis; Extraction; Gas diffusion; Immunological analysis; Sequential-injection analysis

Abbreviations: AAS; Atomic absorption spectrometry; ET-AAS; Electrothermal AAS; FIA; Flow-injection analysis; FT-IR; Fourier-transform infrared spectroscopy; HG-AFS; Hydride-generation atomic fluorescence spectroscopy; HPLC; High-performance liquid chromatography; ICP-MS; Inductively coupled plasma mass spectrometry; LC–MS; Liquid chromatography–mass spectrometry; LOV; Lab-on-a valve; μ-TAS; Micro-total analytical systems; SIA; Sequential-injection analysis; SPE; Solid-phase extraction; UV; Ultraviolet

A. Economou*
Laboratory of Analytical Chemistry, Department of Chemistry, Aristotle University of Thessaloniki, Thessaloniki 541 24, Greece

*Tel.: +30 2310 997728; Fax: +30 2310 997719; E-mail: aeconomo@chem.auth.gr.

1. Introduction

Nowadays, flow-oriented methods of chemical analysis are well established. Sequential-injection analysis (SIA) was initially developed as an alternative technique for performing solution chemistry in order to address the main drawbacks of the most widely used flow-analysis methodology, flow-injection analysis (FIA) [1]. A brief historical account of the development of flow-analysis techniques and the main different variations is provided in [2].

A typical FIA manifold is illustrated at the top of Fig. 1. A volume of sample is inserted into the sample loop of a two-position injection valve while a stream of carrier and a stream of reagent are mixed at a confluence point and are flowing constantly through the detector. After the sample loop is filled with the sample, the valve is rotated so that the sample is injected into the flowing carrier stream and physically transported by the carrier to the confluence point where it mixes with the reagent. In the course of its travel through the reaction coil, the sample zone disperses and reacts with the reagent to form a detectable species. The detectable species gives rise to a transient peak when it passes through the flow-cell of the detector.

The heart of an SIA manifold is a multi-position selection valve (Fig. 1, bottom). Fluids are manipulated within the manifold by means of a bi-directional pump. A holding coil is placed between the pump and the common port of the multi-position selection valve. The selection ports of the valve are coupled to sample and reagent reservoirs as well as a detector, as illustrated at the bottom of Fig. 1. The valve is directed to a selection port that is connected to the sample line and a zone of the sample is drawn up into the holding coil by the pump. Then, the selection valve is directed to a port that is connected to a reagent line and a zone of the reagent is drawn up into the holding coil adjacent to the sample zone. Then, the selection valve is switched to a port that is connected to a detector. As the zones move towards the detector through the reaction coil, zone dispersion and overlap occurs, resulting in the formation of a detectable species that is monitored by the detector. The vast majority of SIA procedures are still based on the solution-phase chemistry described above. Comparing SIA and FIA for this simple sample manipulation, the following points can be made:

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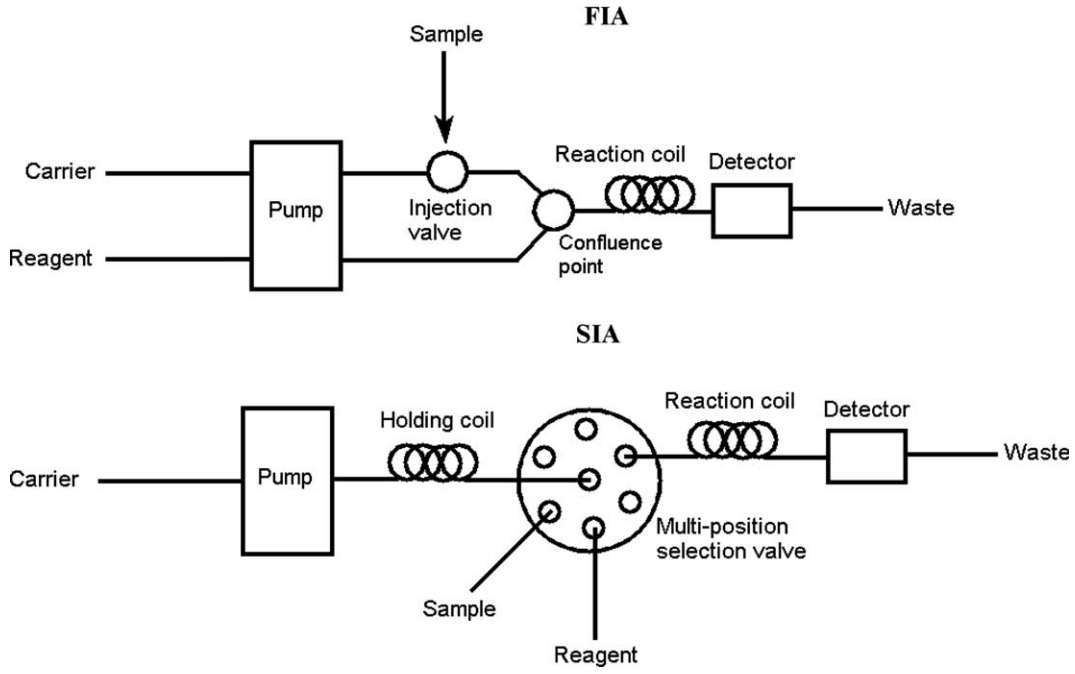

Figure 1. Basic FIA and SIA manifolds.

1. SIA makes use of a simpler, more robust single-channel manifold even with multi-component chemical systems. In FIA, additional flow channels are required for each reagent.
2. In SIA, the multi-channel peristaltic pumps commonly used in FIA are replaced by more accurate, robust syringe pumps.
3. With SIA, the sample and reagent consumptions are drastically reduced.
4. The single-channel operation of SIA enables the use of the same manifold to implement a wide range of assays.
5. In SIA, the selection valve provides a means for performing convenient automated calibration.

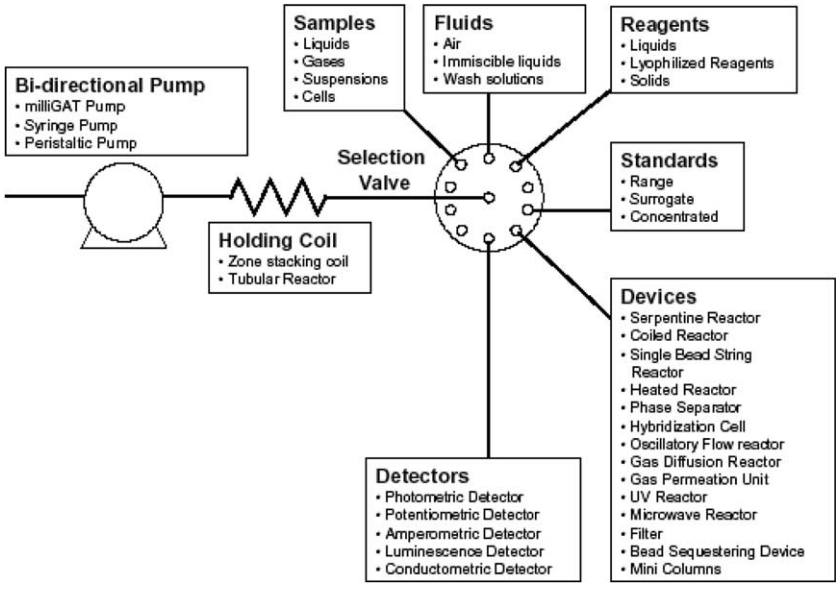

Figure 2. Potential of SIA for automated sample pre-treatment (reprinted with permission from [2]).