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Novel strategies in flow-injection analysis*

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Abstract: An overview of the most recent advances in flow-injection analysis, and the future trends and potential of this powerful technique are presented.

Keywords: *Flow-injection analysis.*

Introduction

Flow-injection analysis is now a solidly established analytical technique judging by the large number of papers published in the last twelve years (≃1500), the variety of applications reported in areas such as clinical chemistry and environmental, industrial and agricultural analysis, in addition to the growing availability of commercial instruments. In Table 1 [1–56] are listed the most relevant publications of general interest (books, reviews, etc.) on generic and specific aspects of FIA published to date. Worthy of note among these are the four monographs written so far, the Japanese journal exclusively devoted to FIA and a large number of reviews dealing with theoretical and practical aspects of FIA. Due mention should also be made of the excellent review by FIA's pioneers [20], who give an interesting overview of the state of the art in FIA. This paper aims to testify the fast growth of FIA in contrast to other analytical techniques, and to review its applications in different areas, particularly those referred to above.

There are a number of reasons accounting for the impact and expansion of FIA within the analytical community [57], the most relevant of which are as follows:

(A) The great simplicity of flow injection configurations;
(B) Their versatility and flexibility for adaptation to particular purposes;
(C) The low cost of the different components;
(D) The good reproducibility of the measurements;
(E) The high sampling frequency achieved;
(F) The increased selectivity resulting from the kinetic nature of flow-injection measurements [58];
(G) The ease with which continuous separation techniques can be implemented on flow-injection manifolds;

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Table 1
General publications on flow injection analysis

Type of publication	Remarks	References
Books:	First monograph on FIA (Růžička and Hansen)	1
	Short overview in Japanese (Kina)	2
	State of the art until 1985 (Valcárcel and Luque de Castro)	3
	Flow injection atomic spectroscopy (multiauthor book edited by Burguera)	4 (in press)
Periodical:	Journal of FIA (edited by Ishibashi and published by the Japanese Association for FIA)	
Reviews on:		
General aspects		5–20
Specific aspects:	Amperometric detection	21, 22
	Atomic absorption detection	23, 24
	Chemiluminescence detection	25
	Differential kinetics	26
	Diode array detectors	27
	Flame photometric detection	28
	Kinetic-based determinations	29
	Luminescence detection	30
	Potentiometric detection	31
	Spectroscopic detection	32
	Immobilized enzymes	33
	Continuous separations	34
	Dialysis	35
	Gas-diffusion	36
	Ion-exchange	37
	Liquid–liquid extraction	38
	Injection valves	39–41
Applications:	Agricultural analysis	42, 43
	Clinical analysis	44–46
	Enology	47
	Environmental analysis	48–50
	Food analysis	51
	Industrial analysis	52
	Pharmaceutical analysis	53–55
	Speciation	56

(H) The advantages offered by FIA as a means to introduce samples into atomic spectroscopic instruments (AAS, ICP, etc.), and to develop chemiluminescence-based methods;
(I) The decreased sample and reagent consumption;
(J) The suitability of FIA configurations for use with immobilized enzymes.

Despite these assets, some FIA papers show a negative trend, namely the mere adaptation of earlier manual methods which are only slightly improved by the use of FIA. This is no doubt that FIA lends itself readily to developments in routine research. FIA research should ideally be aimed to: (a) consolidate its theoretical foundation; (b) improve troublesome analytical methodologies with respect to instability of the analytical reaction ingredients, reagent and sample consumption, linear calibration ranges, selectivity, rapidity, etc.; (c) develop new operational modes and configurations and improve the performance of the large number of options described; (d) adapt FIA to

real problems in medicine, nutrition science, the industrial and ecological fields, pharmacy, etc. and (e) develop new, better and more versatile FIA analysers.

In this paper are discussed the most relevant innovations introduced in FIA technology in the last two or three years. For coherence, innovations will be categorized according to the four general units making up an FIA manifold, namely, propulsion, sampling, transport-reaction and detection systems.

Propulsion systems

The units used to propel fluids along FIA systems can be readily adapted to the researcher's needs in designing new modes or practical alternatives. Broadly speaking, commercially available propulsion systems are of such good quality that they hardly ever pose serious problems.

The flow gradients provided by some propulsion systems have not yet been wholly exploited. Such gradients can be created by two types of impulsion units, namely: (a) the gravity-based device designed by Ríos *et al.* [59], which results in increased sensitivity and sampling frequency (washing effect); (b) the pump delivery system proposed by Toei [60], which allows the easy establishment of programmed flow patterns and which has been associated with the stopped-flow mode to perform enzymatic assays. Yet, the potential of these units in differential kinetic determinations as a means of maximizing the reaction rate differences between two or more chemical systems has not yet been fully exploited.

The simplest way of modifying impulsion systems involves stop-and-go sequences giving rise to the halting of the reacting plug in various zones of the reactor (non-kinetic stopped-flow) or at the detector (kinetic stopped-flow), to increase reaction development through increased contact time with a reagent or to monitor the reaction evolution, respectively, through the manipulation of the delay time to create concentration gradients widening the scope of reaction studies, and showing the usefulness of FIA in different areas of automated analysis as demonstrated by Hungerford *et al.* [61].

A modification of the stopped-flow technique, the doubly stopped-flow variant has so far only been applied to the determination of two different forms of an analyte (free and bound SO_2) [62]. Yet, its scope could be potentially extended to a broad spectrum of applications in the area of simultaneous analysis, implemented both by kinetic and non-kinetic stopped-flow.

A configuration designed by Rocks and Riley involves the synchronization of the stop-and-go of the propulsion system with the motion of aspiration probes for sample, reagent and carrier as a basis for a controlled flow dispersion mode [63], but which, surprisingly, has not been met with much interest.

The most recent innovation in these systems is the iterative change of the flow direction, used by Betteridge *et al.* to control dispersion and introduce apparent changes in the reactor length [64]. Purer analytical applications such as multidetection and manipulation of the kinetics of the process within the dynamic range of the detector, as well as calculations of kinetic parameters are aspects of great interest [65], which could and should be tackled with the application of multidetection to simultaneous determinations and liquid–liquid extraction without separation units.

The potential of impulsion systems would be further increased by the use of highly precise flow-rate control systems provided with feed-back units ensuring a constant flow-rate throughout the systems operation. The electromagnetic flow-meter designed by

Hooley and Dessy [66] possesses the desirable characteristics, as does that proposed by Candwell, based on measurements of the potential generated by the liquid fluid [67]. There are also commercial systems (Hewlett–Packard, Knauer, Molyter, etc.) of this type based on different principles and allowing the flow-rate to be precisely evaluated in the FIA working range.

Sampling systems

The most characteristic part of an FIA system is the sample (or reagent in reverse FIA) insertion unit. Improvements in this device [39–41] have been aimed in four directions: (a) simplification of conventional units to facilitate handling, manufacture and automation; (b) modifications to improve performance or developments of new modes; (c) adaptation of heterogeneous and solid samples; (d) adaptation to on-line process control.

(a) Hydrodynamic injection devices [68] involving no valves could be said to be the simplest sampling systems. Nevertheless, the need for intermittent pumping also calls for the use of two pumps working alternately in cycles synchronized by a timer. Despite their only apparent simplicity, they have allowed the inclusion of the injection system in integrated microconduits [69] which were otherwise unfeasible. The rather simple commutation system recently proposed by Zagatto *et al.* [70] uses a single electronically controlled pump.

The device reported by Chipperfield and Worsfold, consisted of a modified glass syringe activated by a solenoid [71], that proposed by Williams *et al.*, a pneumatic four-way stream-sampling valve [72], the continuous-flow injected devised by Kapavan and Magno [73] and the most elementary version of the rotary valve proposed by Riley *et al.* [74], are the most representative examples of truly simplified injection systems.

(b) The improved performance obtained from the use of these systems is the result of:

(1) designing more complex single valves with more ports and allowing the simultaneous insertion of different fluids (samples or sample/reagent) into the FIA system. Representative examples are the magnetic eight-way valve used by Wasberg and Ivaska [75] and the versatile pneumatically-operated two-layer rotary valve described by Jørgensen *et al.* [76], which allows time-controlled introduction of sample volumes, and loop-controlled sample volumes in one or two loops, as well as the implementation of ion-exchange preconcentration procedures. Multi-purpose valves have also been designed by Toei and Baba [77] for either simultaneous injection of sample and reagent or only the sample, and by Erickson *et al.* [78], who use a valve with six ports on the front rotor connected in adjacent pairs of the back plate, so that six of them are individually accessible, giving a total 12 ports which provide the user with a wide range of options, namely: simultaneous sample/reagent injection, pH gradient in its original [79] and improved [80] versions; asymmetric double pH gradient, gradient scanning standard addition method [81] complex interference studies, etc.

(2) Using assemblies either in parallel to carry out simultaneous determinations by injection of the sample into different carriers/reagents [82], or to implement the merging zones mode in its symmetric and asymmetric [83] versions, or in series, applied to non-kinetic (reagent injection) [84] and differential kinetic [85] determinations, or in the exploitation of gradients [86]. Possibly, the most versatile commercially available valve assembly is that of FIAtron included in the SHS-200 analyser.

(3) Modifications of the sample loop endowing systems with much enhanced versatility

without detracting from the system simplicity. Such modifications can involve the inclusion of a second injection valve (secondary valve) in the loop of the main or primary valve (nested loop system [87]), to accommodate a redox [87], ion-exchange [88] or enzymatic [89] column (this allows the elimination of the blank signal, of great relevance to enzymatic-clinical analysis) or to hold a reagent other than that in the carrier or with a different pH [80]. The loop of the secondary valve can also contain the donor flow or be a part of the donor zone of a dialysis unit, the acceptor zone residing in the loop of the primary valve [90]. These dialysis units can also be located in the loop of a single injection system, the donor flow (sample) being a continuous stream circulating across the membrane donor zone (simultaneous separation and preconcentration system) for a predetermined time [91].

(c) The lack of reproducibility in the results obtained for solid–liquid heterogeneous samples and the impossibility of analysing solid samples used to be two conflicting aspects of the use of FIA systems for routine analyses. The handling of gas samples containing SO_2 was solved by Mottola *et al.* in 1980 [92], thus potentially extending the application of FIA to any type of gas analytes, a potential which has not been properly exploited so far.

The manifest irreproducibility of the results obtained for heterogeneous solid–liquid samples has been accounted for by Harrow and Janata [93] in demonstrating that blood cells are teleologically "designed" to be very efficient stirring elements, so that whole blood specimens are dispersed differently than are homogeneous calibration solutions because they disturb the radial dispersion/axial dispersion ratio differently from these. The five-valve system used by these authors for standard additions allows this effect to be minimized [94].

The shortcomings involved in the direct analysis of solid samples by FIA has been overcome by Bergamin *et al.* for steel samples by use of an on-line electrolytic dissolution unit where dissolution is accomplished in a few seconds and the dissolved material passes directly on-line to a flow-injection manifold so that 20–40 samples per hour can be handled for the determination of aluminium [95]. A similar unit is currently being studied in our laboratory for determination of different analytes in plants and soils. The solid sample is treated with a solvent (acid, basic, organic) to ensure dissolution of the analyte. After a given time under the appropriate working conditions, the dissolved material is passed through the injection system and the solid residues are automatically wasted (Fig. 1).

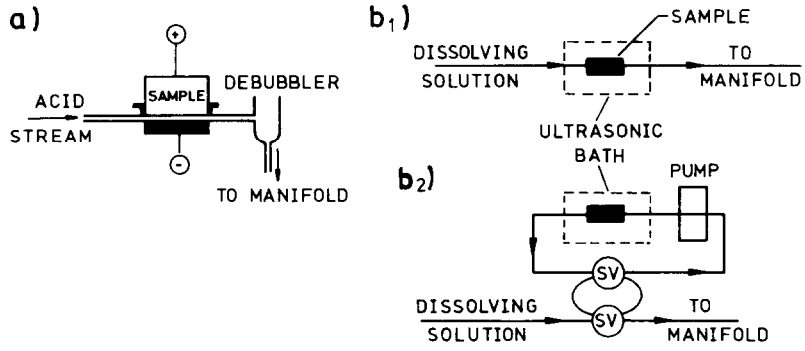

Figure 1
Approaches for direct introduction of solid samples into a flow injection manifold: (a) by use of an electrical discharge (for metallurgical samples) (Ref. 95); (b) by ultrasonic irradiation in an open (b_1) or open-closed (b_2) configuration.

(d) The chemical process industry is beginning to accept FIA for process-monitoring, even process-control applications. One reason for such acceptance could be as follows: compared with typical manual wet-chemistry methods of analysis, FIA is more flexible and convenient and provides a quicker response, greater reproducibility and reliability, and lower costs. One problem that bars wider use of FIA at the moment, according to some experts, is the lack of sample-preparation systems allowing analysers to accept mixtures of solids, oil and water, perform onstream liquid–liquid extractions, handle radioactive materials and deal with samples at high temperatures (above 250°C). A number of researchers and equipment manufacturers, however, are on the verge of solving some of these difficulties, as shown above. Hence, flow-injection systems are serious candidates for a new generation of chemical on-line analysers. Nevertheless, although it is true that FIA has shown explosive growth over the last six years, and most of the individual component parts needed to build a flow-injection system have been well tested over longer periods of time, hardly any information on the application of these systems in process analysis can be found in the literature. No multi-purpose process analyser based on this principle is available commercially.

Figure 2 summarizes the possibilities of FIA in on-line process control [96, 97]. For valuable samples, a sampling system with return of the sample excess after the loop filling is appropriate. Configuration n-FIA_1 is the most convenient when small carrier (C) volume held in the loop when the valve is switched to the filling position does not interfere with the system. The n-FIA_2 and n-FIA_3 configurations include a separation unit, S.U., which can accomplish continuous or intermittent separation whenever the injection valve should be filled. When the loss of small amounts of sample (0.2–1.0 ml min^{-1}) is tolerable, simpler systems such as reverse FIA (r-FIA) set-ups or completely

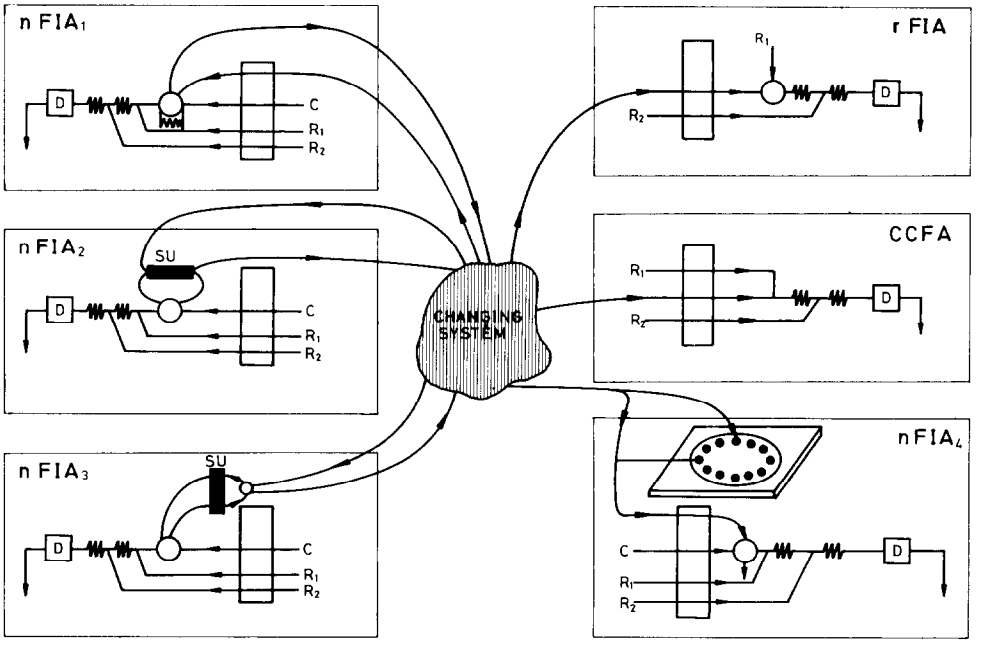

Figure 2
Potential use of FIA as process controller (for details, see text).

continuous manifolds (CCFA) can be used for accurate determination of the analyte concentration or only for the comparative evolution of the system (oscillations in the monitored parameter), respectively, should be known. Finally, a normal FIA configuration (n-FIA_4) without return with a sampler collecting samples from the system at preselected intervals and taking them directly to the injection system from the process line, or a combination of both can be used to accomplish near real-time monitoring.

Finally, special mention should be made to the commutation systems described by the Brazilian FIA team headed by Bergamin, whose ingenuity has been repeatedly demonstrated in the large variety of commutators designed for a host of purposes, namely: sample injection, zone sampling, merging zones, zone trapping and many other modes which have solved a large number of problems [40].

Transport and reaction systems

The transport zone located between the injection and detection points can be modified by introducing different types of valves, separation and reaction units or other devices.

Valves located in the transport system can serve different purposes, the commonest being that of diverting circulated flow to the detector (stopped-flow technique) and that of selecting different streams to switch between streams of different pHs or containing different reagents, or to include masking agents or washing solutions [41]. The injection valves located in transport systems are used for rather different purposes such as the intermittent use of separation systems (ion-exchange, usually) included in the valve loop [87] or as suppliers of eluting solutions [98]. The researcher can find other uses for these valves by introducing suitable modifications or designing new types. Thus, the four-channel selecting valve proposed by Rocks *et al.* allows two samples inserted in the FIA system to be stored in order to increase the reaction time in slow systems, and results in a four-fold sampling frequency [99]. The inclusion of a normal selecting valve in conventional FIA systems is the basis for the open-closed mode proposed by Ríos *et al.* [100].

The broadened potential resulting from the inclusion of separation units into the transport system has been recently shown by our research team [34]. The present popularity of gas-diffusion units lies in their convenience of application to the determination of analytes unusual in gas-diffusion/FIA such as dissolved gases [101] or previously generated hydrides [102], and the individual or differential determination of two or more analytes [103]. Liquid–liquid extraction, one of the separation techniques most frequently coupled with FIA [34], can be improved through the design of new extraction units [38], although there is a trend to the extraction of the analyte into the organic phase without later phase separation by creating microemulsions with the aid of surfactants [104] or ultrasound [105] or by inverting the flow direction [65]. The absence of separation enormously simplifies the process and the extraction system, thereby facilitating the study of mechanisms and kinetics of processes transfer between immiscible phases. The ion-exchangers usually employed for preconcentration of minor species or separation of the analyte(s) with later sequential elution [34] can be improved by using controlled-pore glass modified with active groups. These groups perform the change function and result in improved packing of organic exchangers [106], or are placed in the flow-cell to accomplish simultaneous preconcentration and detection. Precipitation which has been used in FIA for nephelometric purposes only, has also been employed for direct [107] and indirect (conversion techniques) [108] determination of

cationic and anionic species, respectively, by AAS. Despite the fact that HPLC has been only sporadically used for over eight years, the advantages associated with its use have not been taken full advantage of as it has been devoted almost exclusively to the speciation of inorganic phosphorus [109], and no attention has been paid to the possibilities offered for other applications, such as determination of isoenzymes, exhaust combustion products, pesticides, biological compounds, etc.

Despite the ease whereby successive reagent streams can be incorporated into FIA systems, solid reactors are being increasingly used to simplify manifolds by eliminating unnecessary streams, avoiding dilution of the sample bolus and cutting down consumption of expensive reagents (enzymatic analyses and immunoassays). Examples of this trend are the solid-state peroxyoxalate chemiluminescence reactor designed by Frei *et al.* [110] and the passive membrane reactor used by Dasgupta *et al.* to introduce several reagents into the FIA system [111]. Enzyme reactors are widely used in FIA [33] on a variety of supports. Immunoassays have been recently adapted to FIA by Guilbaut *et al.* [112] and will probably reach a degree of development similar to that of enzymatic reactors, as a result of the use of well-known devices such as the mixing chamber, used by Miller *et al.* for the study of drug-protein binding, on account of its capability for creation of wide gradients [113]. Nevertheless, the most recent trend in this respect is the location of the reaction system in the detection unit, as shown in the following section.

Other modifications improving the possibilities of the transport system are the so far comparatively sparse use of surfactants [114, 115] to enhance chemiluminescence. Other trends in this area are the application to different units in the FIA system (particularly the transport zone) to energy other thermal, namely ultrasounds, which dramatically accelerate numerous heterogeneous processes (whether catalysed or not) [105], or powerful luminous radiation, which can be used for direct, indirect and simultaneous determinations [116]. A clear trend in transport FIA systems is miniaturization [69], which relies on the parallel development of the remainder of FIA components [117].

Detection systems

A distinctive feature of FIA is the variety of detection techniques which can be used, namely photometry, fluorimetry, amperometry, atomic absorption spectrometry, etc. This is one of the most powerful tools in developing new FIA strategies. Trends in this area will be classified according to whether the system concerned provides one (single detection) or more (multidetection) analytical signals per injected sample bolus.

Single detection

The coupling of FIA with new detection systems generally results in improved performance. In this way, enthalpimetric methods are endowed with increased sensitivity and sampling rate [118], and the problems posed by photometrically unstable species and blank-related uncertainties in thermal lens absorptiometry [119] are minimized. The development of new electrochemical detectors has so far been a very fruitful research line. Van Staden has designed coated tubular solid-state chloride [120] and bromide [121] electrodes with a faster response and better hydrodynamic features than earlier counterparts. Heinemann *et al.* have proposed a detector with a voltammetric cell connected in series to an amperometric cell, and thus combining the wealth of information provided by voltammetry and the higher selectivity and better detection limit typical of amperometry [122]. Belal *et al.* have designed a carbon fibre array

electrode made up of 12,000 independent carbon fibres which decreases the background current and improves the peak resolution and the reproducibility of amperometric measurements [123]. A four electrode (two counter carrying electrodes and two probe electrodes) conductimeter has been used by Matsumoto *et al.* to effectively eliminate interferents in the determination of organic acids in citrus fruits [124]. Optosensing at active surfaces is a new detection principle recently introduced by Ruzicka and Hansen [125] and combining the use of optical fibre with the monitoring of the reflectance of the light falling on a surface accommodating immobilized reagents or over which a suitable photometric reagent circulates. In the latter case, the reflectant surface is a microporous membrane acting as a gas-diffusion unit (Fig. 3).

The potential of this approach can be further increased by using a reagent immobilized on different supports and placed in the flow cell. There is a growing trend in analytical chemistry to introduce the reagents required for the analysis in the detector [126]. Thus, there are FIA methods making use of enzymes [127] and reagents [128] immobilized on controlled-pore glass or silica gel and involving bio- and chemiluminescent detection, respectively. Both yield satisfactory results and feature re-usability, high sampling frequency, low sample and reagent consumption, so that they compare well with conventional continuous flow analysers. The adaptation of these methodologies to more common detection techniques such as photometry, fluorimetry or reflectance spectroscopy no doubt result in a further appealing advantage. The selectivity of enzymatic method should be improved by using separation, kinetic and differential techniques [33]. An interesting way to increase selectivity is the joint use of the stopped-flow mode and enzymes immobilized at the detection point by using gel, CPG, the flow-cell walls or the sensor itself (enzymatic electrodes [129]) as supports. A variant of the use of enzymes within the flow-cell is the use of passive membranes [111]. Another promising alternative is the use of chromogenic or fluorescent reagents on the aforesaid supports and, especially, on ion-exchangers. These last offer interesting possibilities such as the

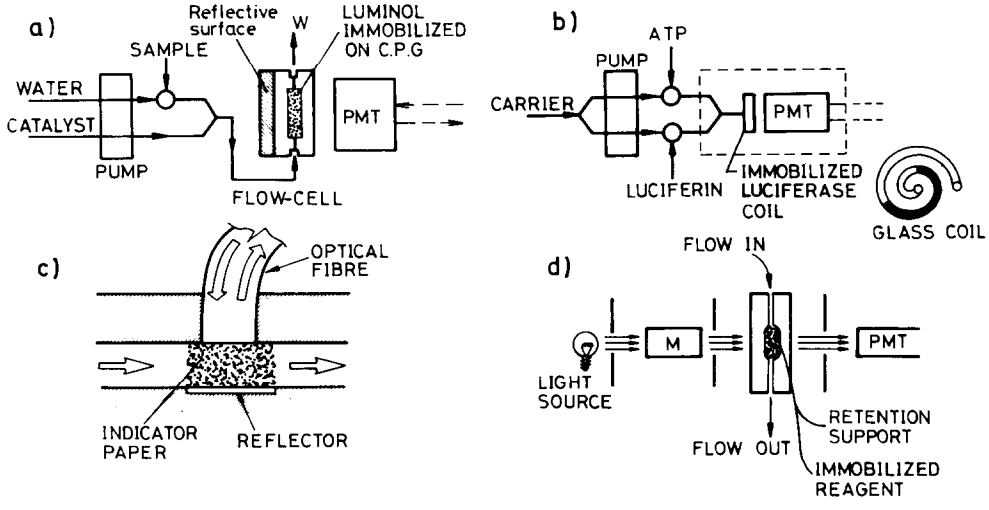

Figure 3
Coupled reaction-detection systems in FIA: (a) chemiluminescence system (Ref. 128); (b) bioluminescence system (Ref. 127); (c) reflectance by optosensing active surfaces (Ref. 125); (d) absorptiometry (Ref. 130).

retention of the reagent-analyte complex on the resin or the selective retention of the analyte on the ion-exchanger and later reaction with a suitable reagent [130]. The use of optical fibre will allow the minaturization of FIA detection systems and the construction of optosensors by incorporation of reagents and/or dyes onto the tip of optical fibres.

Multidetection

Two or more analytical signals from the same injected sample bolus can be obtained by: (i) by passing the reacting bolus through the flow-cell several times; (ii) by using a fast-scan detector and (iii) by employing as many detectors as required.

(a) The repeated passage of the sample bolus through the detector can be accomplished by entrapment in an open-closed system [100] or by iterative flow inversion [65]. The envelope of the maxima or minima of the series of peaks obtained in the first case defines a kinetic curve which allows application of conventional kinetic methods (both differential or not) [131] and calculation of partial reaction orders, rate constants, stoichiometries, etc. [132]. The iterative inversion of the flow can be aimed at different purposes, namely improvement of analyte-reagent mixture, increased reaction times in slow-kinetic processes, analyte preconcentration, simultaneous determinations, etc.

(b) The inclusion of fast-scan detectors in FIA is a logical step in the evolution of this technique, because these dynamic detectors add to the dynamic character of flow-injection analysis and dramatically increase the information provided by conventional detectors, thereby broadening the knowledge on the physical and chemical processes occurring in the hydrodynamic system. Because of the vast information provided by these detectors, they must be commanded through a microcomputer effecting data acquisition and treatment.

Janata and Růžička [133] designed a FIA flow-cell coupled to a fast-scan voltammetric detector whereby they performed low-frequency ($1.8\ s^{-1}$) three-dimensional scans. The cell was later improved ($0.6\ s^{-1}$) by Heinemann *et al.* by using the above-described dual voltammetric electrode detector [122]. Recently, De Abreu and Purdy [134] designed a 32-gold-electrode-array thin-layer flow-cell resulting in scan frequencies as high as those at which the microcomputer can effect data collection. Studies under way on the simultaneous determination of organic chlorinated compounds by the FIA-cyclic voltammetry association have allowed our research team to show its potential in multideterminations [135].

Spectroscopic detectors have evolved in much the same way as electrochemical detectors. The incorporation of Fourier Transform Infrared Spectrometry (FT-IR) has allowed the determination of compounds difficult to detect by other techniques e.g. the analysis for aliphatic esters in non-aqueous samples [136] and the monitoring of reaction kinetics and calculation of structure parameters by using supercritical fluids [137] at scan frequencies of 0.7 and 0.25 s, respectively. Hansen has reported the joint determination of Na, K and Ca by atomic emission spectroscopy with a fast-scan monochromator capable of scanning from 300 to 800 nm every 0.1 s [138]. Nevertheless, image detectors is an even better alternative to mobile monochromators e.g. diode array detectors, which allow the simultaneous determination of a spectrum at scan frequencies of 0.1 s, without the trouble arising from the potential ruff and irreproducibility involved in the use of components which are subject to fast, precise movements. The diode array spectrophotometer is the most frequently used of these detectors as it is included in a host of commercial instruments usable in FIA without modification. The excellent scan-

rate of these instruments makes them most suitable for the simultaneous determination of two or more analytes by the normal [139] or derivative [140] mode. A useful application of these devices associated with FIA is the development of dilution and amplification methods using the absorbance measurements at wavelengths other than the maximum or a sum of absorbance values at the maximum and at wavelengths close to that of maximum absorption, respectively, as analytical signal [141]. Non-determinative studies performed with the aid of these detectors include those on chemical solution equilibria [142], reaction kinetics, elimination of matrix effects, dispersion, etc. [143].

In all cases, the application of chemometric methods to flow-injection analysis is of great use, especially with samples involving background absorbances or multi-analyte systems, and for optimization of operational parameters or filtering of data from the detector [144].

The use of several detectors is of little interest because of the lack of flexibility and high price and is probably the least exploited area of multidetection. But the simultaneous use of pH meter and optical detector (usually photometric [145]) is no doubt the most common.

Conclusion

From the exposition above, it is apparent that future FIA trends will most probably fall into one of two categories, namely: technologically a higher degree of automation and miniaturization and a growing application of chemometrics is foreseeable. Particularly, one may predict increased use of optical fibre and new detection modes as well as the improvement of reactor features (especially enzymatic reactors) and coupled reaction–detection systems.

In problem solving, FIA trends are likely to be oriented to multi-detection, the improvement of the performance of analytical procedures and process control with emphasis on biotechnological analysis.

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