6 Complete Instruments

Tables A, B, and C contain a comprehensive summary of instruments for analytical atomic spectroscopy, and once again we are indebted to instrument makers for their collaboration in providing details of their instruments. The tables present information available at January, 1977. The trend in instrument design is toward the incorporation of safety devices, automatic controls, and data processing by computer.

Very few new emission spectrometers have appeared on the market this year. Several companies, however, now offer ICP units as standard options. MBLE have introduced the PV 8250 spectrometer system with built-in source unit and read-out by printer, teletype, or computer.

Baird-Atomic have entered the field of AA and introduced a new single-beam instrument, the A5100, which has automatic background correction and curve correction; in addition, the former Shandon Southern range are marketed. Pye Unicam have upgraded their SP 191 model with simultaneous background-correction facility (SP 192) and introduced the SP 2900. Rank Hilger have a new instrument, Atomspek H1551, with built-in background-correction and flame-emission facilities. Varian Techtron have introduced a new model, the AA 175. From Perkin-Elmer there is a range of 3 new instruments, all with microprocessor facilities, and with provision for burner-head safety interlock. Bodenseewerk Perkin-Elmer announce three new instruments, two with double-grating monochromators and two with a microcomputer. An interesting instrument promises to be the Hitachi 170-70 AA spectrometer, which has Polarised Zeeman Effect flameless background correction over the complete wavelength range. An automatic sampler, AS1, for use with electrothermal atomizers has been announced from Bodenseewerk Perkin-Elmer. This allows sampling of up to 30 samples, singly or up to 9 times each, and it is claimed to give significantly improved precision.

Some of the unsolved problems of instrumentation in atomic spectroscopy have been identified by Silvester (1350) as: (i) nebulizer and stray light associated with simultaneous ICP spectrometry; (ii) over-correction by automatic background correctors in AAS; and (iii) speciation and lack of reproducibility in electrothermal AAS. In a recent review of techniques for multi-element analysis, Boumans (1271) concludes that the low-power ICP provides the best balance between cost and performance, but its ease of operation and reliability when in ordinary routine use have yet to be proved.

Walsh (467, 1273) has suggested that special-purpose instruments dedicated to a given analysis could be made by combining atomic spectral lamps with sputtering chambers or flames and resonance monochromators, to produce non-dispersive atomic spectrometers suitable for the analysis of solutions and solids by AAS, AFS, or AES. Flexible systems for use in emission, absorption, or fluorescence spectroscopy can be achieved by the use of spectrometers with either vidicon (104, 591) or image-dissector (309) detectors. These systems incorporate computer control to facilitate the rapid selection of a large number of spectral lines. Using the vidicon, the read-out beam can be inhibited, so as to increase the target's integration time and thus enhance weak signals.

6.1 EMISSION INSTRUMENTS

Whilst there seems to be a continuing trend toward the reduction of analysis time in, for example, the steel industry, by locating the spectrometer close to the source of the sample (65), potential users should perhaps question whether the increased expenditure for this end is appropriate in view of the time spent in other stages of the operation.

As the development of new sources, such as the GDL and the ICP, has extended the range of analysis to many more materials, more stringent requirements have been placed on the spectrometer. New instruments incorporating dual holographic gratings which are now appearing on the market (792) may go some way toward meeting these needs. The high resolution and compactness of the echelle spectrometer make it an attractive instrument for analytical atomic spectroscopy, but to date the limited demand for such spectrometers has kept their price rather high. The historical development and the use of the echelle spectrometer with the d.c. Ar plasma have been reviewed by Cox (1072).

Scanning spectrometers have been described for use with plasmas. One (360), incorporating a 0.5 m Ebert monochromator, uses a stepping scan with a movement of 0.003 nm per step, and it achieves an RSD of 0.01 in the measurement of the intensity of an Hg line; another (1028) employs an oscillating galvanometer mirror to give a scan of *ca.* 100 nm in 10 ms. This system was used for the simultaneous measurement of Mg, Mn, Cd, and Bi in an Ar microwave plasma; an RSD of 0.02 was obtained. A slewed-scan monochromator with rotatable quartz plate for spectral line modulation has been used in an emission/fluorescence flame photometer (577).

Simple flame photometers continue to perform a valuable function in clinical laboratories, and in a wide variety of applications, such as the separation of mixed steels by their Mn content (629). For some elements, the range of these simple instruments may be extended by the incorporation of integrating facilities (418). A new type of filter flame photometer (589) employs wavelength modulation, produced by oscillation of an interference filter, to minimise the effect of background emission; the detection limit for Ca was 10 ng ml^{-1}, and at higher concentrations the RSD was 0.004. A four-channel emission/absorption interference-filter flame photometer for the simultaneous determination of Na, K, Ca, and Mg has been reported (1324). The instrument was used for the analysis of serum, and achieved an RSD less than 0.01. By means of automatic sample dilution and curve correction by computer, a throughput of 120 samples per hour was achieved.

6.2 ABSORPTION INSTRUMENTS

AA equipment available in the Netherlands has been reviewed by Hendrikx-Jongerius and de Galan (1227). The performance of four commercial AA spectrometers was compared for the measurement of $\leqslant 5\ \mu g\ ml^{-1}$ of Cu in the presence of $\leqslant 90$ mg ml^{-1} Zn (1555). The RSDs ranged from 0.015 to 0.028; double-beam operation was found to be advantageous.

Walsh (784) has reviewed recent work at C.S.I.R.O. Australia, on cathodic sputtering in relation to sputtering cells, high-intensity lamps, demountable boosted-output HCLs, and Grimm-type discharge lamps. In spite of promising results, there is, as yet, no widespread use of such systems other than the Grimm lamp. It has been suggested (1334) that the direction of future developments in AA may be in the use of the flame resonance detector and the incorporation of AA detection with chromatographic separation.

The question of absolute analysis by flame AAS was examined by L'vov (144). The difficulties in making absolute measurements based on this analytical technique are discussed in detail. In practice, AA is primarily a single-element technique, but efforts continue to be made to develop a multi-element capability. The two principal practical difficulties are the combination of light from several spectral line sources into one optical beam without loss of a major portion of the original intensity and the simultaneous measurement of several spectral lines. A more fundamental difficulty is the limited dynamic range (*ca.* 2 orders of magnitude), which may not accommodate the concentration ranges of the elements in the sample. The use of an image dissector tube for spectral analysis has been described by Aldous (126, 1169) and applied to the simultaneous determination of Pb, Zn, Ca, and Cd in biological specimens, using electrothermal atomization AA. By means of an electromechanical programming system, a flame AA spectrometer was used (1570) for automatic sequential multi-element analysis. The concentrations of Co, Cr, Cu, Fe, and Ni at which the RSD was 0.07 were found to be 100, 6, 30, 55, and 100 $\mu g\ ml^{-1}$, respectively, and the characteristic concentrations (1% absorption) were 2.0, 0.1, 0.4, 1.1, and 1.2 $\mu g\ ml^{-1}$, respectively. A simple system for the simultaneous measurement of Ca and Mg in sub-nl samples of biological material, using electrothermal atomization and interference filters, has been reported by Antonetti and Grosso (185, 1634). Multi-element capability for Ni, Ca, and Ge, with improved precision and with the elimination of systematic errors, has been achieved (774), using a flame as the atomization cell, in combination with a d.c. arc for emission measurements and an HCL plus a continuum source to provide background correction for AAS. A non-dispersive AA instrument comprising an EDL, flame atomizer, photoresistor detector, and a narrow-band amplifier (756) was found to be possible if the analyte element was separated from its matrix by sorption on, and elution from, an ion-exchange resin. The detection limits using a double-beam non-dispersive AA spectrometer for the measurement of Ag, Bi, Cs, Cu, K, In, Na, and Rb were found (1372) to be comparable with those from conventional single-beam instruments.

Other references of interest —

AA instrument with microprocessor control: 1195.
Double-beam AA instruments: 1052, 1213, 1536.
Double-beam AA instruments with background correction: 1655.
Double-beam AA instruments with electrothermal atomization: 1581.
Zeeman-effect AA spectrometer: 1544.

6.3 FLUORESCENCE INSTRUMENTS

In comparison with thermal excitation techniques, the advantages of atomic fluorescence ought to be the generation of an emission signal against a low background and the ability to modulate that signal to provide additional discrimination. When these advantages are utilised, the minimum resolution required of the spectrometer should be less than that necessary for an equivalent emission system employing arcs, sparks, or plasmas. In practice, when the analyte element is either isolated or in a simple matrix, non-dispersive AF becomes feasible. Advantage has been taken (1188) of the separation afforded by chromatography to achieve non-dispersive AF determination of Mn. There continues to be an interest in developing instruments to exploit the potential of atomic fluorescence methods, though information on the application of these devices to real analytical situations is sparse. For the foreseeable future, the use of AF appears likely to be restricted to a few elements, e.g. Cd, Hg, and Zn, where the technique is particularly sensitive. The state of the art of practical developments in AF analysis has been reviewed by West (718). Temperature-controlled EDLs are the most useful sources for excitation. The feasibility of time-resolved multi-element determinations of simple mixtures by control of the heating rate of an electrothermal atomizer was reported.

Instruments using a continuum as their primary light source with either an air/C_2H_2 flame (770) or a graphite filament atomizer (1584) have been described. Two techniques have been reported for overcoming the problem of scattered radiation. In one system (86, 1168) two light sources are used; a line source to excite the fluorescence radiation and a continuum to provide a measure of the scattered signal. The light sources are modulated at the same frequency, but are out of phase. Initially the channels are balanced to give zero output, and any disturbance of that balance will be due to fluorescence radiation. The other system (402) uses a single light source but two different wavelengths, one being that of the

Table A COMMERCIALLY AVAILABLE EMISSION SPECTROMETERS

Supplier	Model	Type	No. of channels	Reciprocal dispersion/ nm per mm	Wavelength range/nm	Focal length	Type of source	Special features	Applications
Applied Research Laboratories Ltd., Wingate Road, Luton, Beds., England	Quanto-meter 20	D.R.	60 (20 lines)	1.388 or 0.695 0.695 or 0.35	200—800 200—400	0.75 m	Low voltage, high voltage	Air or argon excitation stands; typewriter and digital computer options	Particularly suited to non-ferrous, e.g. Al, Mg, Cu, Zn, and white metals, slags, powders, solutions, including oils
	Quanto-vac 28	D.R.	60 (28 lines)	0.70 or 0.35	175—500	0.5 m	As Quantovac 80	As Quantovac 80, but no air-conditioner	As Quantovac 80, but limited to 28 elements
	Quanto-vac 28C	D.R.	As Quanto-vac 28	0.70 or 0.35	175—500	0.5 m	As Quantovac 28	Complete computer control; teletype or visual display output; off-line computer links	As Quantovac 28
	Quanto-vac 80	D.R.	96 (60 lines)	0.46	170—407	1.0 m	Various; low voltage, high voltage, multi-source (HVS, LV, d.c. arc)	Typewriter, teletype, and digital computer options; single or dual stand options; second stand can be argon or air; built-in instrument air-conditioning	All ferrous and non-ferrous alloys, powders including slags, sinters, ores, rocks, ceramics, soils, etc.; solutions, oils, etc.
	Quanto-meter 80	D.R.	As Quanto-vac 80	0.695 or 0.35	190—610	1.0 m	As Quantovac 80	As Quantovac 80	As Quantovac 80, but excluding determination of C, S, and P
	Quanto-meter 29000B	D.R.	60 (48 lines)	0.35 or 0.175 0.46 or 0.23 0.56 or 0.28 0.695 or 0.35	190—520 190—630 190—705 190—840	1.5 m	As Quantovac 80	Typewriter, teletype, and digital computer options; argon and/or air stands available	As Quantometer 80
	Quanto-meter 33000	D.R.	(64 lines) (8 reference)	0.695 or 0.35	190—610	1.0 m	As Quantovac 80	Automated sequential analysis; computer options also available	As Quantometer 80
	Quanto-vac 33000	D.R.	As Quanto-meter 33000	0.46	170—407	1.0 m	As Quantovac 80	As Quantometer 33000; computer options also available	As Quantovac 80
	Quanto-meter 33000 LA	D.R.	As Quanto-meter 33000	0.695 or 0.35	190—610	1.0 m	H.f. plasma	Automatic loading of up to 24 samples	Solutions
	Q.A. 137	D.R.	48	0.46	185—410	1.0 m	ICP	P.p.b. analysis; computer options also available; direct solids nebulizer can be fitted	Solutions of many materials; ferrous/non-ferrous, slags, clinical and pollution control applications

Baird-Atomic Inc., 125 Middlesex Turnpike, Bedford, Mass. 01730, U.S.A.	SB-1	Phot.	—	1.5 or 0.75	370—740	1.5 m	Arc or spark	Built-in order sorter	General spectrographic analysis
	SH-1	Phot.	—	1.0	450—750	1.5 m	Arc or spark	Built-in order sorter	General spectrographic analysis
	Spectro-met 1000	D.R.	30	0.6 or 0.3	210—590	1.0 m	Arc or spark; modular	Compact, low-cost direct reader with minimum air-conditioning requirements; manual master monitor to check slit alignment	Ferrous metals (except determination of S) using C 193.1 nm, P 214.9 nm in 2nd order; non-ferrous metals, oils
Warner Drive, Springwood Industrial Estate, Rayne Road, Braintree, Essex CM7 7YL, England	Spectro-vac-1000	D.R.	30	0.6 or 0.3	173—767	1.0 m	Arc or spark; modular	Compact, low-cost direct reader with minimum air-conditioning requirements; logarithmic read-out; manual master monitor to check slit alignment; dual stand option	Ferrous and non-ferrous metals, including C, S, and P
	Spectro-met II	D.R.	60	0.294 0.59	190—432 190—863	2.0 m	As Spectromet 1000	Automatic optical servo monitor continuously maintains correct slit alignment; logarithmic read-out; manual master monitor to check slit alignment; temperature-compensated fixed focal length; dual stands for argon and air available	All direct-reader applications above 190 nm
	Spectro-vac II	D.R.	60	0.29	173—432	2.0 m	As Spectromet 1000	As Spectromet II; all photomultipliers in vacuum	All direct-reader applications, including C, P, and S
Jarrell-Ash Div., Fisher Scientific Co., 590 Lincoln St., Waltham, Mass. 02154. U.S.A.	78-090	Phot.	—	1.1 or 0.54	420—970 210—485	1.5 m	Various available in 'Varisource' unit, including spark, low- and high-voltage d.c. arcs. Also versatile 'controlled wave-excitation source'. Plasma	Wadsworth spectrograph; 20 inch camera	General spectrographic analysis
	70-310	Phot.	—	1.0 or 0.24, depending upon grating	180—3000 180—1500 180—750	3.4 m		20 inch camera	General spectrographic analysis
	75-150	Phot.	—	4.4 to 1.1 3.2 to 0.8 1.6 to 0.4	200—6000	0.75 m 1.0 m or 2.0 m		Choice of 3 gratings; nitrogen purging extends range to 175 nm· optional accessories permit use as direct reader or scanning spectrometer	Versatile instrument, particularly suitable for measuring transient spectra
	96-750	D.R.	Up to 50	0.54	168—500	0.75 m	As above, except electronic con-trolled peak current	Computer controlled	Most metallurgical analyses
	96-785	D.R.	Up to 50	0.54	168—500	0.75 m			

(continued)

Table A COMMERCIALLY AVAILABLE EMISSION SPECTROMETERS—*continued*

Supplier	Model	Type	No. of channels	Reciprocal dispersion/ nm per mm	Wavelength range/nm	Focal length	Type of source	Special features	Applications
(continued)	1500	D.R.	Up to 60	0.56 or 0.28 0.34 or 0.17	200—800 or 190—400 200—510 or 190—250	1.5 m	As above	Choice of 2 gratings	All direct-reader applications above 190 nm
	70-314	D.R.	30	As 70-310	As 70-310	3.4 m	As above	Easy interchange to photographic (70-310) version	As for Model 1500
	96-975	D.R.	Up to 50	0.54	168—500	0.75 m	ICP	Computer controlled; 1 variable channel	All solutions
	84-405	Scan.	—	3.3	200—900	0.25 m	Supplied by user	Various scanning spectrometers	Suitable for spectroscopic investigations rather than for analytical applications
	82-410	Scan.	—	1.6 and 3.3	200—900	0.25 m	Tungsten Deuterium		
	82-415	Scan.	—	Depends on grating	Depends on grating selected	0.25 m	As above		
	82-000	Scan.	—	As above	As above	0.5 m	Supplied by user		
	75-150	Scan.	—	As above	As above	0.75 m, 1.0 m, 2.0 m	As above		
Labtest Equipment Co. 11828 La Grange Ave., Los Angeles, Calif. 90025, U.S.A.	310	D.R.	60	0.56	190—900	1.5 m	'Transource' high-voltage-triggered discharge. Low-voltage-triggered d.c. arc. ICP source for solution analysis	Wavelength in first order; CRT; teletype printer or computer readout systems; dual air/inert gas and solution excitation stand	Ferrous and non-ferrous alloys
	V-25	D.R.	40	0.67	170—550	1.0 m			As above
	2100	D.R.	30	0.46	188—455	1.0 m			As above
	71	D.R.	74	0.52	170—900	2.0 m			General purposes
Kontron GmbH 8051 Eching be München, Oskar-von-Miller-Str. 1 West Germany	ICP plasma-spec System 3	D.R.		0.8—1.6 mm	185—700	0.5 to 1 m	ICP	—	General purpose
	System 4		Up to 30	0.23—0.46 mm	187—455	1 m	ICP	—	General purpose

Glen Creston 16 Carlisle Rd. London NW9 0HL, England									
M.B.L.E., Rue des Deux-Gares 80, B-1070, Brussels, Belgium	Philips PV 8300 Vacuum	D.R.	60 (80 lines)	0.55 or 0.46	170—430	1.5 m	Triggered capacitor discharge; 'Monoalternance' discharges up to 500 Hz; d.c.arc; intermittent d.c. arc	Optional dual air/argon excitation stand; readout by printer, teletype, or digital computer systems	Steels, iron, non-ferrous metals, and non-conductive powders; air stand for oils, d.c. arc, etc.
Philips Analytical Dept., Pye Unicam Ltd., York Street, Cambridge, CB1 2PX, England	Philips PV 8350 Vacuum	D.R.	20	0.46	177—410	1 m	As for PV 8300	Integrated spectrometer system including source and readout options as for PV 8300	Steels, iron, non-ferrous metals, non-conductive powders
	Philips PV 8210 Air	D.R.	60 (50 lines)	0.55 or 0.28	190—700	1.5 m	As for PV 8300 *plus ICP	Wavelength range covered in 1st order; remote-controlled roving detector; external excitation; rotrode and inert atmosphere facilities; readout as PV 8300	All direct-reader analyses above 190 nm, particularly non-ferrous metals, solutions, oils, and non-conductive powders
	Philips PV 8250* Air	D.R.	40	0.695 or 0.35 0.83 or 0.42	190—610 190—780	1 m	As for PV 8210	Integrated spectrometer system with built-in source and readout options as for PV 8300	As for PV 8210
Rank Hilger, Westwood Industrial Estate, Margate, Kent, CT9 4JL, England	E1000 Polyvac	D.R.	60	0.293—1.155	159.6—864.3	1.5 m	Various, including high-repetition condensed arc	Dual spark stands; computer-controlled instrument; dual gratings give 7 systems	Ferrous and non-ferrous alloys; geological samples; wear metals in oil
	E952	D.R.	36	0.546 or 0.741	174.0—447.7	0.75 m	As E1000	Curved entrance and exit slits; solid-state electronics or computer controlled; air or vacuum	Ferrous and non-ferrous alloys; wear metals in oils
	Monospek D-400*	D.R.	Single	0.66—15.7	200—22000	1.0 m	As selected	Curved or straight entrance and exit slits; scanning wavelength can be read to 0.01 nm from digital counter; wavelength accuracy ± 0.1 nm with 1200 line per mm grating	Scanning monochromator of particular use for monitoring and examination of plasma sources.

*New equipment since publication of Volume 5

Table A COMMERCIALLY AVAILABLE EMISSION SPECTROMETERS—*continued*

Supplier	Model	Type	No. of channels	Reciprocal dispersion/ nm per mm	Wavelength range/nm	Focal length	Type of source	Special features	Applications
Spectrametrics Inc., 204 Andover St., Andover, Mass. 01810, U.S.A.	AE 2	Phot., D.R.	1	0.06	190—900	0.75 m	Plasma jet	Optimised AE system using a high-dispersion, high-energy-throughput echelle spectrometer and a high-temperature plasma jet excitation source	Routine analysis
	D.R.10	D.R.	20 (inter-changeable cassettes)	0.06	190—900		Plasma jet		Routine quantitative multi-element analysis
Techmation Ltd., 58 Edgware Way, Edgware, Middlesex, HA8 8JP, England	ES 9	Phot.	—	0.06	190—900	0.75 m	Plasma jet, flame, or arc stand	Built-in computer	Qualitative and semi-quantitative analysis; spectroscopic research
	RS 1	D.R.	1 (variable wavelength)	0.06	190—900	0.75 m	Plasma jet, flame, or arc stand		
	Spectra-span III	Phot., D.R.	20 (inter-changeable cassettes)	0.06	190—900	0.75 m	d.c. argon plasma	Optimised AE system using high-dispersion high-energy-throughput echelle grating spectrometer and a high-temperature plasma jet excitation source; built-in micro-processor; most spectral and matrix effects are eliminated	Routine sequential; quantitative analysis and multi-element analysis
Spex Industries Inc., 3880 Park Ave. Metuchen, N.J. 08840, U.S.A.	1870	Scan.	—	1.6	175—1280	0.5 m	—	Multi-purpose unit	Routine analysis
	1702	Phot.	—	1.1	175—1500	0.75 m	—	—	Research
	1704	Phot.	—	0.8	175—1500	1.0 m	—	—	Research
Glen Creston 16 Carlisle Rd London NW9 0HL, England	1802	Phot	—	0.8	180—1500	1.0 m	—	Direct-reading accessory available	Routine analysis
Spectroscandia AB, SF-21660 Nagu Finland	IDES 2080	D.R.	100 (300 lines)	0.16 at 200 0.32 at 400 0.52 at 650 0.63 at 800	200—800	0.5 m	Hollow cathode discharge, plasma, d.c. arc	Channels not preselected, changeable at any time; channel minimum spacing 0.2 nm; wavelength accuracy 0.001 nm; plane samples 0.8 to 0.1 cm; CRT, lineprinter, or teletype readouts; digital computer as standard	Ferrous and non-ferrous metals, slags, powders, ores, geological specimens, trace elements in metal, high accuracy at low and high concentrations

Optica S.A.S., Via Gargano 21, 20139 Milano, Italy	B5†	Phot.	—	0.69—0.36	200—800	1.2 m	All conventional types available	Stigmatic instrument with rotating Ebert grating	General purpose
	B5C†	D.R.	16	0.69 or 0.36	220—420	1.2 m	LV-triggered arc and spark; HV spark, a.c. and d.c. arc	Double spark stand both in air and inert atomsphere; Rotrode for solutions	General purpose; metallurgical analysis, e.g. Al, Pb, Zn, Fe, Cu alloys; wear metals in oils, etc.
	B7V†	D.R.	93	0.37	165—440	1.5 m	LV-triggered arc and spark; HV spark	Air–vacuum instrument with all 92 exit slits accessible from outside for adjustment; many analytical programmes can be arranged in parallel for easy interchange; computer facilities available	Complex analyses involving many spectral lines
	ESA1†	Scan.	—	0.41	200—500	1.0 m	Controlled and non-controlled HV spark; a.c. arc	Scanning monochromator with one channel for analytical line and another channel for reference, using reflected-beam principle.	Metallurgical work; all material excitable with same source parameter
	ESA3†	D.R. + Scan	9	0.36	160—500 (40 nm as poly-chromator)	1.2 m	LV-triggered arc and spark	Combined vacuum mono- and poly-chromater; all excitable elements accessible with scanning system	Routine analysis (including C, S, and P) of iron and steel; non-ferrous alloys
	ESA4†	Scan.	—	0.41	165—500	1.0 m	LV-triggered arc. HV spark; a.c. arc	Scanning vacuum monochromater with one channel for analytical line and another channel for reference; facilities for analysing two elements simultaneously	Metallurgical work; analysis of ferrous and non-ferrous alloys
RSV–Prazisions-mehgerate GmbH., 8031 Hechendorf Pilsensee, West Germany	SPN 3.5†	Phot., D.R.	30	0.14—0.48	200—1000	3.5 m	Glow-discharge lamp, high-medium-, or low-voltage spark, a.c. or d.c. arc, continuous and intermittent	Paschen–Runge mounting specially designed for range below 200 nm; direct-reading attachment available	General analysis

(continued)

†No up-to-date information was available for these instruments when this table was compiled.

Table A COMMERCIALLY AVAILABLE EMISSION SPECTROMETERS—*continued*

Supplier	Model	Type	No. of channels	Reciprocal dispersion/ nm per mm	Wavelength range/nm	Focal length	Type of source	Special features	Applications
(continued)									
Siemens Ltd., Great West House, Great West Road, Brentford, Middlesex, England	SPN 2.0†	Phot., D.R.	30	0.24—0.84	200—1000	2.0 m	As above	As above	As above
	SPN 1.5†	Phot., D.R.	15	0.37—1.1	200—1000	1.5 m	As above	As above	As above
	SPN 1.0†	Phot.	—	0.56—1.7	200—1000	1.0 m	As above	As above	As above
	SPN 1.0† (vac)	Phot.	—	0.4—1.7	300—1300	1.0 m	As above	As above	As above
	Analymat I-air†	D.R.	40	0.31 or 0.54	200—650	1.5 m	Glow-discharge lamp (others available)	Exhibits no background; no matrix effects; linear calibration for all elements 0—100%	As above
	Analymat II-vac†	D.R.	40	0.31 or 0.54	150—490	1.5 m	As above	As above	As above
	Analymat III-vac†	D.R.	40	0.42 or 0.5	110—500	1.0 m	As above	As above	As above
	Analymat IV†	D.R.	250	0.22 2 × 2.5 m spectrum length	2X 200—600	2.0 m	As above	As above	As above
	Analymat V†	D.R.	250	As above	2X 150—600	2.0 m	As above	As above	As above
	Analymat VI†	D.R.	250	As above	2X 120—630	2.0 m	As above	As above	As above
	Analymeter I†	Scan.	—	0.16	200—630	2.0 m	As above	As above	As above
	Analymeter II†	Scan.	—	0.16	150—630	2.0 m	As above	As above	As above
	Analymeter III†	Scan.	—	0.16	110—630	2.0 m	As above	As above	As above
Shimadzu Seisakusho Ltd., 1 Nishinokyo-Kuwabaracho, Nakagyo-ku, Kyoto, Japan	GCT-100† (Czerny–Turner)	Phot., D.R.	3 (max.)	0.83 (1200 grooves /mm)	200—850 (10″ camera)	1.0 m	Modular-source DCA ACA LVS, LVA	High speed	General purpose
	GE-170† (Ebert)	Phot.	—	0.48 1200 grooves /mm)	200—1200 (10″ camera)	1.7 m	HVS S,DCA		General purpose

	GEW-170† (Ebert)	Phot., D.R.	55 (max.)	0.48 (1200 grooves /mm)	200—1200	1.7 m (20" camera)			
	GQM-75†	D.R.	35 (max.)	0.52 (2400 grooves /mm)	190—430 & 510.5 589.0, 518.3	0.75 m	HVS, LVS DCA SG-400	3 kinds of readout electronics are available 1. built-in computer 2. digital, with linearizer 3. pen recorder	General purpose
	GVM-100†	D.R.	60 (max.)	0.46	170—410	1.0 m	HVS, LVS SG-400		Solid, liquid, powder, metal
VEB Carl Zeiss Jena, 69 Jena, Carl-Zeiss Str. 1, German Democratic Republic	PGS-2†	Phot.	—	0.74 or 0.37	200—2800	2.075 m	Arc or spark	Automatic expansion of measuring range; stigmatic depiction; dispersion doubled by double passage of light; pre-disperser for order sorting and isolation; gratings interchangeable; automatic transport of plate holder	General spectrographic analysis; also examination of line profiles, hyperfine structure, etc.
Carl Zeiss Scientific Instruments Ltd., PO Box 43, 2 Elstree Way, Borehamwood, Herts, WD6 1NH England	Q-24†	Phot.	—	0.76	210—550	0.54 m	Arc or spark	Full range of accessories available	General spectrographic analysis

†No up-to-date information was available for these instruments when this table was compiled.

Table B COMMERCIALLY AVAILABLE ATOMIC ABSORPTION SPECTROMETERS

Supplier	Model	Single/ double beam	Monochromator	Grating lines per mm	Reciprocal dispersion/ nm per mm	Resolution /nm	Wavelength range/nm	Readout; scale expansion	Other features
Baird-Atomic Ltd., Warner Drive, Springwood Industrial Estate, Rayne Road, Braintree, Essex CM7 7YL, England	A5100*	Single	0.25 m Czerny–Turner	1200	3.0	0.1	186—860	Digital; ×0.5—40	Automatic background correction; 4-lamp turret; auto zero; integration; curve correction; wavelength scan; flame ignition; gas safety devices; lens optics; emission and fluorescence
	A3400	Single	0.25 m Czerny–Turner	632	6.0	0.2	190—860	Meter or digital; ×25	4-lamp turret; auto zero; curve correction; integration; flame ignition; wavelength scan; emission and fluorescence
	A3600	Single	0.25 m Czerny–Turner	632	6.0	0.2	190—860	Meter or digital; ×25	Integration; flame ignition; emission and fluorescence
Beckman Instruments GmbH, 8 Munich 40, Frankfurter Ring 115, West Germany	1233	Double	Littrow	1200	2.7	0.2	190—860	Meter; ×55	Single- or triple-pass optics; % T; abs. or concentration readout
Beckman-RIIC Ltd., Eastfield Industrial Estate, Glenrothes, Fife, KY7 4NG, Scotland	1236	Double	Littrow	1200	2.7	0.2	190—860	Digital; ×55	As model 1233
	1248	Double	Littrow	1200	2.7	0.2	190—860	Meter; ×10	Auto zero and calibrate; integration
	1272	Double	Littrow	1200	2.7	0.2	190—860	Digital; ×10	As model 1248 plus curvature correction
GCA/McPherson Instrument, 530 Main St., Acton, Mass. 01720, U.S.A.	EU 703	Single	—	1180	2.0	0.1	180—1100	Digital	Modular AA; flame emission; various detectors and gratings available; convertible to single- or double-beam u.v. spectrometer
Hitachi Ltd., Nissei Sangyo Co. Ltd., 15-12 Nishi-Shimbashi, 2-Chome, Minato-Ku, Tokyo, Japan	170-10	Single	Littrow	1440	2.25	0.4	190—900	Meter; ×0.1—1 ×1—10 Digital; (optional)	Single lamp mounting, N_2O–air simultaneously exchanged; concentration readout; continuously variable time constant

	170-30	Single	Littrow	1440	2.25	0.4	190—900	As 170-10	Concentration readout; time-weighted signal averaging; AA/AE measurement; auto zero; N_2O–air simultaneously exchanged
	170-50	Double	Littrow	1440	2.25	0.1	190—900	As 170-10	Background correction; base-line drift correction; curve corrector; time-weighted signal averaging; auto zero
	170-70*	Double	Littrow	1440	2.25	0.1	190—900	Meter/Digital option	Polarized Zeeman effect; flameless background correction over the complete 190—900 nm wavelength range; background correction to 1.7 abs
Instrumentation Laboratory Inc., 113 Hartwell Av., Lexington, Mass. 02173, U.S.A.	351	Double	0.33 m Ebert	1200	2.5	0.03	190—900	Digital; ×50	4-lamp turret; wavelength drive; full time integration of peak height or peak area; auto calibration; curve correction; background correction; dual grating; push-button operation; zoom lens; full automatic safety gas controls
Instrumentation Laboratory (UK) Ltd., Technical Services Div., Edgeley Road Trading Estate, Cheadle Heath, Stockport SK3 0XE, England	251	Double	0.33 m Ebert	1200	2.5	0.03	190—900	Digital; ×50	4-lamp turret; wavelength drive; full time integration; peak height or peak area; off-line calibration; curve correction; background correction; zoom lens; auto gas controls
	151	Single	As 251 in all other features						
Jarrell-Ash Division, Fisher Scientific Co., 590 Lincoln Street, Waltham, Mass. 02154, U.S.A.	Dial Atom III	Single	0.25 m Czerny–Turner	1180	3.3	0.02	193—860	Digital	Laminar-flow burner; integral gas-flow controls; auto zero; concentration calibration; curvature correction; 2-lamp turret
(continued)	82-810	Double; dual channel	0.4 m Ebert	1180	2.08	0.03	190—900	Digital; ×25	Laminar-flow burner; curvature correction; 2-lamp turret

*New equipment since publication of Volume 5

Table B COMMERCIALLY AVAILABLE ATOMIC ABSORPTION SPECTROMETERS — *continued*

Supplier	Model	Single/ double beam	Monochromator	Grating lines per mm	Reciprocal dispersion/ nm per mm	Resolution /nm	Wavelength range/nm	Readout; scale expansion	Other features
(continued)	82-850	Double	0.4 m Czerny–Turner	1180	2.08	0.03	190—900	Digital;	Computer-controlled parameters
Jobin-Yvon, Division d'Instruments, 16-18 Rue du Canal, 91160 Longjumeau, France	New model to be marketed July 1977. No details yet released.								
Perkin-Elmer Corp., Main Ave., Norwalk, Conn. 06856, U.S.A. Perkin-Elmer Ltd., Post Office Lane, Beaconsfield, Bucks. HP9 1QA, England	272*	Single	0.27 m Littrow	1800	1.6	0.2	190—860	Digital; ×0.01—50	High-energy optical system; microprocessor-controlled; auto zero; auto concn.; auto curve correction, with 2 standards; peak height; peak area; integration time selectable from 0.5 to 20 s; flame ignition; optional auto N_2O switching; optional burner-head safety interlock; optional deuterium arc background correction
	372*	Double	0.27 m Littrow	1800	1.6	0.2	190—860	Digital; ×0.01—50	As Model 272, but all mirror optics; automatic gain control; optional deuterium arc double-beam background correction
	373*	Double	0.27 m Littrow	1800	1.6	0.2	190—860	Digital; ×0.01—50	As Model 372, but auto N_2O switching; burner-head safety interlock; optional flame and pressure sensing
	460	Double	0.27 m Littrow	1800	1.6	0.2	190—860	Digital; ×0.01—100	As Model 373, but auto curve correction, with up to 3 standards; integration time selectable from 0.2 to 60 s
	603	Double	0.4 m Czerny–Turner	u.v. 2880 vis. 1440	0.65 1.3	0.03	180—440 400—900	Digital ×0.01—100	As Model 460, but optional 4-speed wavelength drive; no automatic gain control

Bodenseewerk, Perkin-Elmer & Co. GmbH, Postfach 1120, D-7770 Uberlingen, West Germany	400S	Double	0.33 m Czerny–Turner	1800	1.3	0.2	190—860	Meter; ×50 and ×0.2	Auto zero; flame ignition; integration
	400	Double	0.33 m Czerny–Turner	1800	1.3	0.2	190—860	Digital; ×50 and ×0.2	As Model 400S plus auto concn.; curve correction; BCD outlet
	410*	Double	Double grating Czerny–Turner	2800/ 1800	1/ 1.6	0.17/ 0.27	190—860	Digital	As Model 400, but with double-grating monochromator
	420*	Double	0.33 m Czerny–Turner	1800	1.3	0.2	190—860	Digital	As Model 400, but with microcomputer electronic keyboard operation; linearisation with up to 3 standards; EIA RS-232C data outlet
	430*	Double	Double grating Czerny–Turner	2800/ 1800	1/ 1.6	0.17/ 0.27	190—860	Digital	As Model 420, but with double-grating monochromator
Pye Unicam Ltd., York Street, Cambridge CB1 2PX, England	SP 191	Single	Ebert	1200	3.3	0.2	190—850	Digital; ×0.1—25	4-lamp magazine; auto zero; integration; curve correction; emission
	SP 192*	Single	Ebert	1200	3.3	0.2	190—850	Digital; ×0.1—25	As SP 191, but simultaneous background-facility added
	SP 2900*	Double	Ebert	1200	3.3	0.2	190—850	Digital; ×0.1—50	4-lamp magazine; auto zero; integration; curve correction, with average calibration facility; peak height measurement with timer; peak area; emission; simultaneous background correction as accessory
	SP 1950	Double	Ebert	1800	2.2	0.1	190—850	Digital; ×20 and ×0.1	Auto zero and ignition; integration; curve correction
	SP 1900	Double	Ebert	1800	2.2	0.1	190—850	Digital; ×20 and ×0.1	As Model 1950 plus 6-lamp turret
Rank-Hilger, Westwood Industrial Estate, Ramsgate Road, Margate, Kent, CT9 4JL, England	Atomspek H 1550	Single	Czerny–Turner	1200	2.6	0.1	190—850	Digital	6-lamp turret; auto zero and flame ignition; curve correction; integration; background correction optional

(continued)

*New equipment since publication of Volume 5

Table B COMMERCIALLY AVAILABLE ATOMIC ABSORPTION SPECTROMETERS — *continued*

Supplier	Model	Single/ double beam	Monochromator	Grating lines per mm	Reciprocal dispersion/ nm per mm	Resolution /nm	Wavelength range/nm	Readout; scale expansion	Other features
(continued)	Atomspek H 1551*	Single	Czerny–Turner	1200	2.6	0.1	190—850	Digital	6-lamp turret; auto zero; flame ignition; integration; inbuilt background correction; flame emission
Varian Techtron Pty., 679 Springvale Road, Mulgrave, Vic. 3170, Australia	1100	Single	0.25 m Czerny–Turner	1276	2.8	0.2	185—900	Meter/Digital; ×0.3—50	4-lamp turret; auto zero; integration; curve correction; peak reader; f/8 aperture; optional automatic gas-box
Varian Associates Ltd., Instrument Group, 28, Manor Road, Walton on Thames, Surrey, England	AA175*	Single	0.25 m Czerny–Turner	1200	2.8	0.2	185—900	Digital; ×0.3—50	4-lamp turret; reflective optics with quartz overcoat; auto zero; integration; curve correction; peak reader; optional automatic gas-box; simultaneous background corrector, and calculator interface
Varian Instrument Div., 611 Hansen Way, Palo Alto, Calif. 94303, U.S.A.	AA6	Single; dual channel	0.51 m Ebert	638	3.3	0.05	185—1000	Digital; ×0.3—50	Modular construction; auto curve correction; f/10 aperture; optional automatic gas-box, simultaneous background corrector, and calculator interface
VEB Carl Zeiss Jena, 69 Jena, Carl-Zeiss-St. 1, German Democratic Republic	AAS 1†	Single	0.5 m Ebert	1300	1.5	Continuously adjustable	190—820	Meter; ×10	4-lamp turret; auto zero; single- or triple-pass optics; continuously adjustable slit
C Z Instruments Ltd., 2 Elstree Way, Borehamwood, Herts WD6 1NH, England.									
Beckman Instruments, 2500 Harbor Boulevard, Fullerton, Calif. 92634, U.S.A.	485†	Double	Littrow	1200	2.7	0.2	190—860	Meter; ×50	Single- or triple-pass optics; automatic filter selection
	495†	Double	Littrow	1200	2.7	0.2	190—860	Digital; ×100	As model 485

Corning Ltd., Halstead, Essex, CO9 2DX, England	EEL 140†	Single	0.25 m modified Ebert–Fastie	1180	3.5	—	—	Non-linear meter	Single lamp mount;
	EEL 240†	Single	As EEL 140	1180	3.5	—	—	Meter	4-lamp turret; integration
Diano Corporation, P.O. Box 346 75, Forbes Boulevard, Mansfield, Ma. 02048, U.S.A.	Multispect†	Single	Double-grating 0.25 m modified Czerny–Turner	1200	1.5	0.2	190—800	Meter; ×10	3-lamp turret with 3 stabilized power supplies; 4-way gas control; % T abs. or concn. readout
Optica S.A.S., Via Gargano 21, 20139 Milano, Italy	6000†	Single	0.35 m Ebert	—	—	—	—	Digital; ×50	Auto filter insertion; auto concn.; integration; flame temp. regulation; prefocussed water-cooled hollow-cathode lamps available
Seiko Instruments, Tokyo, Japan	SAS 721†	Single	—	—	—	—	—	—	
	SAS 740†	Double; dual channel	—	—	—	—	—	—	Microcomputer and line printer
Shimadzu-Seisakusho Ltd., 1 Nishinokyo-Kuwabaracho, Nakagyo-ku, Kyoto 604, Japan	AA-610S†	Single	Czerny–Turner	1500	1.9	—	190—900	Meter; ×10	Wavelength drive; two lamp holders
	AA-620†	Single	Czerny–Turner	1500	1.9	—	190—900	Meter; ×10	Wavelength drive; two lamp holders; auto ignition; flame monitor; gas pressure monitor
	AA-650†	Double	Czerny–Turner	1200	1.9	—	190—900	Digital; ×180	Wavelength drive; two lamp holders; auto zero; integration; curvature correction; background correction; peak detector; auto ignition; flame monitor; gas pressure monitor
Carl Zeiss, 7082 Oberkochen, Wurttemberg, West Germany	FMD 2†	Single	Ebert	600	2.5	0.05	193—300	Digital	4-lamp turret; 2 stabilized power supplies; curve correction; auto zero; optional auto calibrate and background correction

†No up-to-date information was available on these instruments when this table was compiled.

*New equipment since publication of Volume 5

Table C COMMERCIALLY AVAILABLE ELECTROTHERMAL ATOMIZERS

Supplier	Model	Type	Max. sample volume μl	Control unit	Sensitivity for 1% abs. (s.)/pg Detection limit (d.l.)/pg		Special features
					Cu	Si	
Baird-Atomic Ltd., Warner Drive, Springwood Industrial Estate, Rayne Road, Braintree, Essex CM7 7YL, England.	A3470	Graphite rod	50	Programmable; dry, ash (2 stages), atomize. Max. temp. over 3000 °C	d.l. 5	d.l. 60	Fits most AA spectrometers; air cooled; uses mains power; inert-gas shielding; pyrolytic graphite coating for rods in situ; rapid interchange between flame and electrothermal methods.
Beckman Instruments GmbH, 8 Munich 40, Frankfurter Ring 115, West Germany	1271	Graphite furnace	100	Programmable; dry, ash, atomize, burn off. Max. temp. 3100 °C	d.l. 4 (100 μl)	d.l. 10 (100 μl)	Water-cooled; inert-gas shielding. Safety feature for failure of water or purge gas, gas stop; fits Beckman and Pye Unicam instruments
Instrumentation Laboratory Inc., 113 Hartwell Avenue, Lexington, Mass. 02173, U.S.A. Instrumentation Laboratory (UK) Ltd., Station House, Stamford New Road, Altringham, Cheshire, England.	555	Graphite furnace	100	Programmable; six stages, ramp or step. Max. temp. 3500 °C	d.l. 0.8	d.l. 10	Controlled-temperature furnace, using feedback from a tungsten temperature sensor; true temperature readout; safety interlock system; automatic cell door; automatic cleaning; cell pressurisation; convenient solid-sampling capacity using microboats
Jarrell-Ash Division, Fisher Scientific Co., 590 Lincoln Street, Waltham, Mass. 02154, U.S.A.	MTA-2	Tantalum strip	50	Programmable; dry, ash, atomize. Max. temp. 2400 °C	d.l. 2 (50 μl)	—	Fits most AA spectrometers; inert-gas and hydrogen shielding
	FLA 100	Graphite furnace	50	Programmable; dry, ash, atomize. With ramping and flash atomization	d.l. 10 s. 50	d.l. 50 s. 50	Fits most AA spectrometers; inert-gas shielding, but an air ash possible
S. & J. Juniper & Co., 7 Potter Street, Harlow, Essex, England.	110	Graphite furnace	50	Programmable; dry, ash, atomize, burn out. Max. temp. 3500 °C	s. 30 (10 μl)	—	Water-cooled; inert-gas shielding; all programme stages cover full temperature range

Spectronic Services, E & J Brereton, 4 White Rose Way, Garforth, Leeds LS25 2EF, England.							
Perkin-Elmer Corp., Main Avenue, Norwalk, Conn. 06856, U.S.A.	HGA 2100	Graphite furnace	100	Programmable; dry, ash, atomize. Max. temp. 2800 °C. Ramp accessory provides linear-type ramp temperature increase in all 3 cycles plus auto high temperature at end of programme.	d.l. 2; d.l. 1 pyro-coated tube	d.l. 50; d.l. 10 pyro-coated tube	Pyro-coating accessory available for in situ preparation of pyro-coated tubes; AS-1 automatic sampler available for pre-use automatic insertion of up to 30 samples into the HGA, with automatic triggering of HGA and instrument read cycle
Bodenseewerk Perkin-Elmer & Co. GmbH, Postfach 1120, D-7770 Uberlingen, West Germany	HGA 76	Graphite furnace	100	Programmable; dry, ash (2), atomize. Max. temp. 2700 °C	d.l. 1 (100 μl)	d.l. 10 (100 μl)	Fits Perkin-Elmer and Zeiss AA spectrometers; water-cooled; inert-gas shielding; permits ramp ashing; gas stop operation; closed system; safety feature for failure of water or purge gas
	AS-1*	Auto sampler for graphite furnace	100	Automatic sampling of up to 30 samples once or up to 9 times each	as with HGA-76	as with HGA-76	Fits all Perkin-Elmer AA spectrometers with HGA
Pye Unicam Ltd., York Street, Cambridge CB1 2PX, England.	SP9-01	Graphite furnace	50	Programmable; dry, ash, atomize, tube clean, tube blank, with cancel and delay stages. Max. temp. 3000 °C	s. 44	—	Water-cooled; inert-gas shielding; safety feature for failure of water; tube life indicator and remote recorder control for 1, 2, 3, or all phases
Rank Hilger, Westwood Industrial Estate, Ramsgate Road, Margate, Kent CT9 4JL, England.	H1975/ FA256	Graphite furnace	100	Programmable; dry, ash, wait, atomize. Max. temp. 2600 °C	s. 50	—	Water-cooled; inert-gas shielding; background correction when fitted to Atomspek H 1550
Varian Techtron Pty. Ltd., 679 Springvale Road, Mulgrove, Vic. 3171, Australia.	CRA 90	Graphite furnace (graphite tube), threaded graphite furnace, graphite cup	25	Programmable; dry, ash, atomize. Max. temp. 3000 °C	4 (5 μl)	80 (5 μl)	Fits most AA spectrometers; water-cooled; inert-gas shielding and hydrogen flame option; automatic ramp-hold atomization; pyrolytic graphite coating on cup and tubes

*New equipment since publication of volume 5

Table C COMMERCIALLY AVAILABLE ELECTROTHERMAL ATOMIZERS—*continued*

Suppliers	Model	Type	Max. sample volume μl	Control unit	Sensitivity for 1% abs. (s.)/pg Detection limit (d.l.)/pg		Special features
					Cu	Si	
Barnes Engineering Co., 30 Commerce Road, Stamford, Conn. 06902, U.S.A.	Glomax†	Tantalum strip	50	Programmable; dry, ash, atomize. burn off. Max. temp. 2400 °C	d.l. 10 (50 μl)	—	Fits most AA spectrometers; air-cooled; inert-gas and hydrogen shielding
Optica S.A.S., Via Gargano 21, 20139 Milano, Italy.	CAT 6†	Tantalum strip	50	Programmable; dry, ash, atomize.	d.l. 10 (50 μl)	—	Water-cooled; inert-gas shielding
Shimadzu-Seisakusho Ltd., 1 Nishinokyo-Kuwabaracho, Nakagyo-ku, Kyoto 604, Japan.	GFA-2†	Graphite furnace	50	Programmable; current stabilised, dry, ash, atomize. Max. temp. 3000 °C	d.l. 5	—	Current stabilised to obtain highly reproducible results

†No up-to-date information was available for these instruments when this table was compiled.

fluorescence line and the other a nearby but non-fluorescing line. The out-of-balance signal from these two channels is the fluorescent signal. In a non-dispersive instrument dedicated to the determination of Hg (1270) the problem of monochromation is overcome by using a low-pressure Hg lamp under conditions such that 96% of the radiant energy occurs at 184.9 and 253.7 nm and stray light is minimised by means of diaphragms. More elaborate instruments, incorporating computers, have been reported for combined multi-element AE and AF analysis. In one (612, 642, 1159), a scanning monochromator with either pulsed HCLs or tunable laser and a Ar/H_2 flame or low power current-regulated arc is used. Up to 25 elements in emission and 8 in fluorescence can be analysed, and the measurement of 5 elements in blood requires approximately 100 s per sample. The other system (62) uses an image-dissector echelle spectrometer, with a 1.6 kW Xe arc lamp as the excitation source and a flame atomizer.