CHAPTER 2

Instrumentation

2.1 LIGHT SOURCES

The increasing range of applications of lasers has necessitated that work relating to specific areas, *e.g.*, laser AFS in flames, be reported in the appropriate Sections (see 1.1.1 and 1.3). Only developments in laser sources, and those studies that are of a novel or fundamental natures will be dealt in this Section.

There has been considerable interest in using lasers to promote ionization of atomic species with subsequent detection of the liberated electrons. Techniques based on this principle can measure concentrations of elements below the ppb level. The term 'single atom' detection is frequently quoted by some authors; it must be stressed that this is somewhat misleading and the measurement is often of individual atoms from a much larger atom population.

The detection of individual atoms of Cs using *resonance ionization spectroscopy* has been the subject of additional work by Young *et al.* (52, 558) (*ARAAS*, 1977, **7**, 32) and has also been discussed in a review by Robinson (79). It has been suggested that the two-photon method used to ionize Cs is only applicable to a few other alkali metals because the combined two-photon energy from currently available lasers is insufficient to ionize most other elements. However, it has been shown that it is possible to extend the range of application of this technique by using two lasers simultaneously. Atoms absorb one photon from each laser and reach a much higher energy level than with a single laser. Ionization ensues by the absorption of a third photon from either laser. This procedure has been applied to the detection of Na (79).

Bekov *et al.* (1366) used a three-laser excitation system with field ionization to detect individual atoms of Yb. A narrow beam of Yb atoms was excited into Rydberg states by radiation from three tunable pulsed dye lasers and ionization was effected by a field voltage pulse of 12–14 kV cm^{-1}. The authors claimed that their method is preferable to direct laser ionization for heavy elements with complex spectra, and for those with ionization potentials greater than 6 eV. It was also claimed that the laser power required was reduced by several orders of magnitude.

O'Haver and Harnly (138, 956) compared the radiant intensity of a 300 W Eimac *continuum source* with that of conventional HCLs over the spectral range 194 nm (As) to 589 nm (Na). They used an echelle spectrometer with a band-pass of 0.002–0.006 nm and compensated mathematically for the residual difference in resolution between the continuum and line-source emission profiles. Surprisingly, the Eimac lamp was reported to be 2–500 times more intense than conventional HCLs for the 29 lines in the region studied. An echelle spectrometer, which must be used for AAS measurements with the Eimac source, has a lower overall light throughput than a medium resolution monochromator typically used with HCLs. A comparison of the relative light fluxes through the two types of system showed that the Eimac–echelle combination resulted in a greater light throughput at wavelengths above 300 nm, but lower throughputs below 300 nm, and, in some cases, significantly worse AAS detection limits.

There has been renewed interest in the development of high-intensity or boosted-discharge *hollow-cathode lamps* for AAS and AFS. Myers (137) described a demountable high-intensity HCL with interchangeable cylindrical cathodes and with the secondary high-current booster discharge in line with the direction of the light emission. This configuration

was reported to give better AAS sensitivity, at the same lamp emission intensity, than lamps with the booster-discharge at right angles to the direction of light emission. Increased emission intensities were reported for Al, Cu, Mo, Ti and V with almost no loss in sensitivity by comparison with EDLs or other high-intensity HCLs. When operated at 10 times the intensity of a conventional HCL, the cylindrical high-intensity lamp produced absorbance values of not less than 90% of the equivalent HCL. Sullivan and Gough (682) used boosted-discharge lamps for non-dispersive flame AFS and obtained detection limits (water matrix) of < 0.2 ng ml^{-1} for Ag, Cd, Cu and Zn and 1.5 ng ml^{-1} for Ni.

Novak and Browner (947, 957) have evaluated pulsed and continuously operated microwave EDLs, r.f. EDLs and HCLs. They found that under their operating conditions pulsed r.f. EDLs showed less self-reversal than pulsed HCLs, and that pulsed lamps gave improved analytical sensitivities for AAS and AFS measurements of Cd, Hg and Zn (957). The resonance intensity ratios of r.f. to microwave EDLs were: Hg greater than 1, Cd equal to *ca.* 1, Zn less than 1. The authors suggest that the maximum intensities have not yet been reached and that pulsed r.f. EDLs will become important sources for AFS. Whiteside and Price (1343) reported the development of r.f. EDLs for I and P. They measured I in aqueous solutions in the range 50–100 μg ml^{-1} and P in steels from 10–30 μg g^{-1} using ETA–AAS.

Other references of interest —

Studies of quenching of fluorescence: 147.
Effective cross-section in photoionization: 1337.
Ionization studies on Ba: 1338.
Laser microprobe analysis: 174.
Comparison of HCL and flow discharge source: 795.
Determination of C in cast-iron glow discharge: 43.
Electron temperatures in HCL discharge: 779.
Multi-element analysis of steels in boosted glow discharge: 687.
Simplex optimization of pulsed operation of HCL: 349, 778.

2.2 OPTICS

2.2.1 Background Correction

Bath *et al.* (958) described a background-correction system for AAS in which a double-windowed HCL was placed between the H lamp and the graphite furnace. The continuum radiation passed directly through the open-ended cathode of the analyte HCL. This ensured precise optical alignment of the two beams. The inconvenience and expense of double-windowed HCLs was offset by using a continuously pumped demountable HCL.

Zeeman-effect background-correction systems are becoming increasingly used in AAS and their application has been reviewed (400). Murphy and Stephens (1146) reported the use of the Zeeman effect in AAS with commercially available HCLs powered by r.f. sources and maintained in a magnetic field. They showed that for Cu, Fe and Zn HCLs the intensity and stability characteristics of normal d.c. operation could be maintained under Zeeman-effect conditions.

2.2.2 Optical Systems

Lipari and Plankey (946) described a *continuum source* instrument for AFS. Wavelength modulation was incorporated by using an oscillating interference filter, which acted both as a spectral isolator and a background corrector device. Detection limits using Ar sheathed air/C_2H_2 flames were 0.02 μg ml^{-1} and 0.0025 μg ml^{-1} respectively, for Cu and Mg in serum. The equipment is to be evaluated for an ETA system.

Wavelength modulation using an oscillating mirror has been used in conjunction with a rapid scanning spectrometer for multi-element determinations by AES (418). This system is an improved version of that reported earlier (*Analyst*, 1976, **101**, 753) with a higher resolution grating and improved galvanometer mirror size. The system was tested using ETA–AAS and AES with both carbon cup ETA–MIP, and nebulization/desolvation–MIP.

Spectral isolation employing a sputtering low-pressure discharge as a resonance monochromator has been used for the analysis of metals in steels using a glow discharge source (523).

Other references of interest —

Modular Michelson interferometer for Fourier transform spectroscopy, u.v. to mid-i.r.: 766.

Off-axis imaging for improved resolution and high spectral intensities: 1012.

Stigmatic spectrograph image intensifier system: 1087.

2.3 DETECTORS AND DATA PROCESSING

2.3.1 Introduction

The use of *rapid-scanning photoelectric detectors* (imaging-type detectors), such as vidicon television camera tubes and solid-state photodiode arrays, for AAS and AES was first reported in 1973 (*ARAAS*, 1973, **3**, Ref. 1285). In the years following, many applications of multi-element determinations were described. This year, for the first time since 1973, a decline in their reported usage has occurred and much of the published work describes the data processing systems which are so important for the efficient application of imaging-type detectors to multi-element AES and AAS.

Almost all the publications reporting other detection systems, including photographic emulsions and conventional photoelectric devices (photomultiplier tubes), describe developments in data processing.

2.3.2 Rapid Scanning Photoelectric Devices

The most popular detectors of this type are SSIDs. Chuang, Natusch and O'Keefe (949) have used a 1024-element *photodiode array* for multi-element FAAS. Up to three analytes were determined simultaneously and the authors' findings concurred with those of previous workers in that detection limits were poor compared with conventional single-element analysis. A further disadvantage is the limited wavelength range obtainable if resolution is to be maintained. Bubert *et al.* (1065) used a 5-element array, with individual diode outputs, of the type first evaluated for multi-element FAES by Boumans *et al.* (*Spectrochim. Acta*, 1972, **27B**, 247). They have developed an improved readout system and have compared SNR performance with photomultiplier tubes (PMTs). A linear dynamic range of more than 5 orders of magnitude, referred to the noise level, was claimed. A photodiode array detector has been coupled to an ICP spectrometer by Horlick and co-workers (874, 1269). They have developed an elegant and ingenious way of improving selectivity by using a hardware cross-correlator to store a reference spectrum (765). In operation, the reference spectrum is multiplied by the sample spectrum and integrated to indicate the presence of common features in the spectrum. Spectral interferences are thus minimized, and it is suggested that this procedure provides similar selectivity to the 'lock-and-key' detection system of FAAS. Codding and Hwang (404) have also described the application of cross–correlation using a photodiode array for FAES. Unlike Horlick's system, however, theirs did not perform real-time correlation, because recall of the reference spectrum from computer memory was required.

Little further work with *vidicon detectors* has been reported, though Pardue and co-workers remain active in this field. Hoffman and Pardue (1008) have adapted an autoranging amplifier to a vidicon spectrometer. They report some improvement over the system without autoranging, including an extended linear dynamic range.

Image-dissector (ID) tubes have sensitivities similar to those of photomultiplier tubes. During the last few years, their use for multi-element work has provided improved detection limits and enabled higher resolution than either SSIDs or vidicons. Felkel and Pardue (905) have separately coupled a silicon-target vidicon tube and an ID tube to an echelle grating spectrometer for multi-element determinations with a d.c. plasma source (Spectrometrics model 53000). They found improved resolution and greater dynamic range with the ID, which also gave limits of detection similar to those obtained with photomultiplier tube detection. The same authors have used the image-dissector echelle spectrometer for multi-element analysis by FAAS (557, 925). Limits of detection were reported to be lower than with the silicon-target vidicon.

Other references of interest —

SSID interfaced with a microprocessor-based signal sampling electronic circuit: 939.

SNR studies of photodiode arrays used with ICPs: 1454.

2.3.3 Emission Spectroscopy

Photographic detection/recording, though now little used for quantitative spectroscopy, still has certain advantages over photoelectric methods. Wide wavelength coverage is available in a single exposure, while high resolving power is retained. The use of photographic detectors with ICPs requires a higher standard of microphotometric performance compared with conventional excitation sources in order to exploit their improved precision. Some workers have examined microphotometric measurement methods with a view to improving their performance. Torok and Hafenscher (1044) examined scattered-light interference in a microphotometer, which had led to S-shaped characteristic curves. Procedures for correcting these measurement errors were described. McGonagle and Holcombe (793, 190) predicted microphotometric conversion errors by means of a computer simulation program. They emphasized the importance of microphotometer slit width in reducing errors. Zimmer and Heltai (1047) have modified a Zeiss GII microphotometer to obtain improved signal stability and a reduction in the amount of scattered light.

Advances in *direct-reading* OES have involved mostly data processing. Ajhar *et al.* (117) have described a digital readout system with bus type data transfers. Jarrell *et al.* (87) demonstrated how computer correction for matrix background effects reduces the need for separate calibration when the concentrations of major components change. A new curve-fitting equation was described by Crawford (84, 1418) and was claimed to produce more exact calibration curves over a concentration range up to 4 orders of magnitude. The use of APL (a programming language) to convert the output of a Jarrell-Ash ICP spectrometer into a reportedly more manageable form has now been published by Capar and Dusold (1165). Further data manipulations, such as calculation and presentation of results, statistical tests and archival storage, were carried out by a remote computer. Automatic background correction in a sequential OES spectrometer has been described by Walters (1439). The background was determined on both sides of the analytical line sequentially at programmable positions. Haas *et al.* (115) have applied this principle to a direct-reading spectrometer used for ICP–OES. A minicomputer-controlled stepping motor automatically stepped the entrance slit along the focal curve of the polychromator, enabling emission intensities at preselected wavelengths in the region of the analysis line to be measured. An intriguing procedure for correcting drift in a direct-reading emission spectrometer has been

described by Chapman and Gordon (767). A 1000-W tungsten-halogen lamp was used to provide a reference signal for each optical channel, using identical optical components to those used in the measuring procedure. This avoided the need to use analytical reference standards to make drift corrections.

Other references of interest —
BASIC algorithms for ICP–OES: 882.
Computational procedures for characterizing spark sources: 774.
FORTRAN program for analysis of spectral data: 1005.
Microprocessor-controlled readout system for PMTs: 398.

2.3.4 Absorption Spectroscopy

The use of on-line data processing and instrument control by *microprocessors* is increasing. New commercial instruments incorporating microprocessors are described in Section 2.4.2. Franke (993) has reviewed their use in analytical instrumentation with reference to FAAS. Routh (139, 1353) has described how, when compared with analogue electronics, they give improved accuracy and precision and extend the analytical working range for many elements. A useful paper by Futrell and Morrow (216) explained the interfacing of any commercial double-beam atomic absorption spectrometer to a programmable calculator. The interface electronics were easily constructed, and the calculator could be removed from the instrument for off-line use. Heinemann and Prinz (1294) have described a computer program for calculating concentrations from absorbance values with a desk calculator.

A low-cost data-processing system described by Stockdale, Whiteside and Newstead (135) used magnetic card programs that allowed the choice of calibration and curve-correction method best suited to a particular analysis. They also developed programs for standard addition calibrations, automatic sampling systems and calibration with CRMs. The authors suggested that the greatest benefit of using these programs would be derived in work with ETA.

Two particular problems associated with ETA methods are the transient nature of the signals and the need for a highly effective *background-correction* system. Lundberg (781) has described a digital system capable of recording both peak height and peak area. Siemer (776) has cautioned users of instruments which exploit continuum-source background correction that inadequate rejection of d.c. emission from a graphite furnace can occur.

Some improved techniques for constructing *calibration curves* have been presented. Andrews (841) used a numerical method based on the assumptions that the relationship between absorption reading and concentration is described by an exponential equation and that the concentrations of standard solutions form an arithmetic progression. A computer program, CURVE, has been used (212) to calculate theoretical calibration graphs, taking into account the influences of hyperfine structure, variable emission and absorption line half-widths, and atomization processes.

Other references of interest —
Automatic sample preparation and data handling in AAS: 296.
Categorization by trace metal content using ETA–AAS and pattern recognition techniques: 634.
Errors in computer data handling: 1002.
Microprocessor-based low-pass filter: 976.
Resonance monochromator for AAS: 140.

2.4 COMPLETE INSTRUMENTS

2.4.1 Emission Instruments

Plasma sources (especially ICPs) are now firmly established in OES and are incorporated into many new commercial instruments. A sophisticated new direct-reading spectrometer from Jobin-Yvon, the JY–48 (119), makes use of a holographic diffraction grating to obtain a reduction of stray light, increased SNR, higher dispersion and larger spectral coverage than those obtained with ruled gratings. The computer controlled instrument is available with both arc/spark and ICP sources. A lower priced alternative to a direct-reading spectrometer, also from Jobin-Yvon, is the JY38P (85). This instrument (*ARAAS*, 1977, **7**, 54) can determine sequentially up to 38 elements. It uses an ICP source and a high-resolution holographic grating monochromator. Butterworth and Lloyd (920) have evaluated an ICP spectrometer, the ARL 34000/ICP, for steel analysis; good long- and short-term precision was obtained, the only difficulty reported being corrosion of the plasma torch when test solutions contained fluoride. The ARL 34000 Quantometer with 'Unisource' spark excitation was also evaluated for this application by Butterworth and Irons (919); although short-term precision was acceptable, the long-term stability was inferior to that of an ARL QV80 spectrometer. A new polychromator design has extended the useful wavelength range of the Angstrom V-70 optical emission spectrometer (168). Two diffraction gratings were placed in series, and the second grating was illuminated by the zero-order radiation from the first grating. Wavelength ranges for the two gratings were 160–440 nm and 400–790 nm. Horlick and co-workers (874, 1269, 765) have constructed an ICP spectrometer using a *photodiode array detector* (see Section 2.3.2.).

The use by Yeung *et al.* of a Fabry–Perot *interferometer* for multi-element FAES has been previously described (*ARAAS*, 1976, **6**, Ref. 735) and at that time detection limits were poor. A second-generation instrument has now been evaluated by Korba and Yeung (1243, 1317). Improved optics yielded detection limits and linearity of response that compare favourably with those in conventional single-element analysis. Results were presented for simultaneous determinations of up to 3 elements in tap-water, standard orchard leaves, steel, urine and blood serum.

Spectral interferences in FAES were automatically corrected in a Russian *double-beam spectrometer* (603), which used a high-transmission high-resolution double-grating monochromator, 2 PMTs and a 2-channel d.c. amplifier.

Other references of interest —

New spectrograph for the v.u.v.: 1050.

Study of the characteristics of a copper arc: 1367.

2.4.2 Absorption Instruments

Most new commercial instruments incorporate *microprocessors*. Apart from the obvious benefits of convenience and ease of operation, microprocessors are frequently claimed to improve the analytical performance of instruments, giving improved precision, accuracy and dynamic range when compared with instruments with analogue signal processing. The most sophisticated of this new generation of instruments is probably the Perkin-Elmer model 5000 atomic absorption spectrometer. This is a double-beam instrument with background correction, which allows fully automated sequential multi-element analyses (126, 128, 1163). A microcomputer stores analytical parameters for up to 6 elements in 6 separate memories. These parameters, once established, can be stored on magnetic card to facilitate re-use of the program. The microcomputer not only receives analytical data and performs instrument calibrations but also controls all mechanical settings. Thus wavelength, gas flow, flame conditions, and lamp are automatically changed for each element to be

determined. Finally, the use of an automatic sampler avoids the need for continuous operator attention. Very rapid analysis has been claimed (128) with 300 determinations (6 elements in 50 samples) being performed in as little as 30 min.

A new atomic absorption spectrometer from Instrumentation Laboratories is the model 551. This is a double-beam instrument with a microcomputer performing all those functions now regarded as normal in such equipment; *e.g.*, touchbutton selection of operating parameters, automatic calibration, etc. An additional feature, however, is a visual CRT display providing rather more flexibility than instruments with only digital or hard-copy display (134). Further applications of the use of the Instrumentation Laboratories model 751 (*ARAAS*, 1977, **7**, Refs. 1054, 1063) have now been published (332, 1256). These include the analyses of river waters, drinking waters, cements, steels, ores, fertilizers and gunshot residues. The working range may be increased for this instrument by determining the same element in both channels but at different wavelengths.

Several new atomic absorption spectrometers have been reported in the USSR (320, 334, 340, 1022, 1028), and at least two of these incorporate microcomputers.

Continuum source AAS generally suffers from problems of poor detection limits, reduced linear working ranges and stray light interferences, unless a high-performance monochromator is used. Cochran and Hieftje (964) developed a selective spectral-line modulation atomic absorption instrument which partly overcame these problems. Radiation from an Eimac continuum source was directed through the analytical flame cell and then a mirrored chopper directed the radiation alternately through and around a second cell containing a preselected concentration of the analyte. In this way selective modulation was achieved and a medium resolution monochromator could be used. Analytical sensitivities similar to those obtained by conventional line-source AAS were obtained, though detection limits were litttle improved over those of conventional continuum-source AAS.

A problem of using AAS for *multi-element analysis* is the multiplexing of radiation from suitable line sources. Salin and Ingle (125) have succeeded in combining the radiation from 4 sequentially pulsed HCLs by means of carefully aligned beam splitters, and directing the combined beams through a single monochromator. A multi-slit mask was mounted in the focal plane of the monochromator and all radiation was focussed onto the same PMT by means of a mirrored funnel. It was claimed that this relatively inexpensive system could be made by adapting an existing single-element instrument. A multi-element FAAS spectrometer using a photodiode array detector has been evaluated by Chuang *et al.* (949). This system is described in Section 2.3.2.

An *automatic sampler* for FAAS has been produced by Perkin-Elmer (701). The model AS-50 features a key-board with built-in 8-bit microcomputer, which can be used to control the sampling system and the parent spectrometer. Instrumentation Laboratories have introduced an automatic sampler for their graphite-furnace atomizer (1354), based on Matousek's design (*ARAAS*, 1977, **7**, Ref. 489) in which samples were nebulized for 1–100 s into the furnace at 150 °C. It is to be expected that besides the obvious autosampler advantages of speed and convenience, precision should be improved, since the difficulty of reproducible pipetting of microsamples has been removed.

Other references of interest —

Computer-controlled photon-counting spectrometer: 790.

Zeeman atomic absorption spectrometer with an improved spectral lamp: 449.

2.4.3 Fluorescence Instruments

A difficulty of FAFS, which may be largely responsible for the absence of any current commercial instruments, is that of obtaining sufficiently stable high-intensity light sources. However, Michel *et al.* (5, 144, 716) have developed a sophisticated instrument using a

high pressure xenon arc or EDLs, and it was claimed that the lack-of-stability problem of the EDLs had been overcome by their reproducible preparation using a *simplex algorithm*. Another common problem of FAFS, the introduction of stray light into the monochromator, was minimized by using a double monochromator system. This, together with a background correction procedure, led to a high SNR. Although detection limits have not been quoted, the determination of Cd in urine at concentrations of <0.5 ppb has been described. The production of instruments such as this could lead to a new surge of popularity for FAFS.

Wavelength modulation for an Eimac continuum source atomic fluorescence spectrometer has been achieved by use of an oscillating interference filter between the source and the flame (149, 946). Detection limits for Cu and Mg were an order of magnitude poorer than those obtained by other flame spectrometric techniques; the major noise was probably from flame flicker due to the wide band-pass filter used. The authors suggested that the system might be more effective if used with a low background atomizer such as an ETA. In an instrument described by Ullman *et al.* (153), wavelength modulation was achieved by the use of a quartz refractor plate/torque-motor assembly in the monochromator.

Other flame AFS instruments have been described by Dittrich *et al.* (69), who used an EDL source with ETA, and by Gough and Meldrum (685), who used a cathodic sputtering source.

2.4.4 Magnetically Induced Optical Rotation

This technique has been examined by Stephens (1380) for the spectrometric determination of Hg. Radiation from an EDL was passed through a silica-tube atom reservoir positioned between crossed polarizers within a longitudinal oscillating magnetic field. When the a.c. components of the transmitted radiation were measured, the photomultiplier tube signal was proportional to the angle of rotation of the plane of polarization, and to the analyte concentration. Picogram detection limits were claimed and the selectivity was said to be as good as that of AAS. Moreover, the system was insensitive to continuum background absorption and source drift.

2.5 NEW COMMERCIAL INSTRUMENTS

2.5.1 Emission and Plasma Spectrometers

The use of ICP sources for emission spectroscopy continues. Spex Industries have introduced the 1269, a scanning spectrophotometer for research purposes, for which a claim of very high resolution is made. It has a focal length of 1.26 m and a reciprocal dispersion of 0.65 nm mm^{-1}.

Spectroscandia AB have closed down and presumably the IDES 2080 has been withdrawn.

2.5.2 Atomic Absorption Spectrometers

The increasing use of microprocessors continues and video screen displays are being introduced. Perkin-Elmer have replaced or renumbered their range of AAS instruments; the 280 replaces the 272 and the 380 the 372, both these models being microprocessor controlled. The 560 replaces the 460, with the addition of statistics, and the 703 replaces the 603. Instrumentation Laboratories have introduced three new instruments, all of which are microcomputer controlled. Each has optional background correction, alpha-numeric printers and wavelength scan facilities. The 551 has a five-standard calibration and a memory that will store up to 10 calibration curves simultaneously. A video screen displays standard conditions for each element together with a working curve, and will also show

transient absorbance signals. The 157 and 257 have a two-standard calibration, which can be up-graded to five standards if required. Pye Unicam have withdrawn the SP1950 and and SP1900 and have introduced the SP9, a single-beam instrument with deuterium background correction. The 'computer' version of the SP9 has curve correction with up to five standards in fixed or variable ratios, peak height or peak area read-out and full statistics. Varian have introduced a new single-beam instrument, the AA275, and two double-beam instruments, the AA475 and AA775. The AA275 and AA475 are both microprocessor controlled with a three-standard calibration, and the AA775 is fully microprocessor controlled with a five-standard calibration, statistics, and standard additions calibration. The AA775 has a minimum resolution of 0.05 nm.

There are two new electrothermal atomizers; Perkin-Elmer have replaced the HGA2200 with the HGA400, which has direct programming, by keyboard entry, of temperature, range time, hold time, gas, and other spectrophotometer controls, and digital display of temperature, time and programme status. Pye Unicam have two versions of the SP9 graphite-tube furnace. The SP9 video furnace has video display of status and storage for 9 furnace programmes. The SP9 fits all Pye Unicam AAS instruments and has digital display of remaining time; both instruments have built-in autosampler controls. S. & J. Juniper have ceased production of the 110 graphite furnace.

Table 2.5A 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 34000C	DR	48	0·465 0·520 0·347 or 0·694 0·930 or 0·465 or 0·310	170–407 193–456 190–610 190–820	1.0 m 1.0 m 1.0 m 1.0 m	Low voltage, high voltage or d.c. arc	Fully computer controlled to provide direct concentration print-out; full range of options including dual cassette, dual floppy discs, visual-display units, fast printers, remote terminals and computer links etc; air or Ar excitation stands	As 34000D but particularly suited to the analysis of highly alloyed materials; computer options available to allow incorporation into plant systems
Applied Research Laboratories Ltd., En Vallaire, CH–1024 Ecublens/ Lausanne, Switzerland	Quanto-meter B34000C	DR	60	As 34000C	As 34000C	As 34000C	Low voltage and/or high voltage and/or d.c. arc	As 34000C. twin stand facility including Ar, air, hollow cathode, rotrode, plasma, etc.	As B34000D; offers comprehensive computer options to handle multiple and complex alloy programmes
Applied Research Laboratories Ltd., 9545 Wentworth Street, P.O. Box 129, Calif., U.S.A.	Quanto-meter 34000D	DR	48	As 34000C	As 34000C	As 34000C	As 34000C	Fully calculator controlled to provide direct concentration print-out; optional local and remote printers; Ar or air excitation stands	All ferrous and non-ferrous materials and powders, including slags, rocks, soils, etc.
	Quanto-meter B34000D	DR	60	As 34000C	As 34000C	As 34000C	As B34000C	As 34000D; twin stand facility including Ar, air, hollow cathode, rotrode, plasma, etc.	As 34000D; allows for expansion to include a large number of elements and the use of twin stand combinations such as Ar/air where necessary
Société Francais d'Instruments de Controlée d'Analyses, B.P. No. 3, F–78320, Le Mesnil St., Denis, France	Quanto-34000/ Ag Cap meter	DR	48	0·465	170–407	1.0 m	Low voltage	As 34000C; remote aerosol generator excitation head	Allows analysis of large castings, forgings etc remote from instrument
	Quanto-test	DR	10	0·70	2000–4000	0.3 m	Low voltage	Small transportable Quantometer with GO–NO GO inspection type electronics	Size and operation allows rapid on the spot analysis of incoming and out going materials
	Quanto-scan	Scan./ DR	Unlimited	0·80 0·60 0·50 0.40	190–880 190–670 175–550 175–460	1.0 m 1.0 m 1.0 m 1.0 m	Low voltage, high voltage d.c. arc	Automated scanning grating for wavelength range studies; profile facilities and electronics providing quantitative analysis on chosen spectrum lines	Low cost instrument offers an unlimited choice of elements; suitable for semi-research and general applications where sample throughput is low

	*Quanto-scan computer controlled	Scan./ DR	Unlimited	As Quantoscan	As Quantoscan	As Quanto-scan	As Quantoscan	As Quantoscan but computer controlled wavelength selection	As Quantoscan
Baird-Atomic Inc., 125 Middlesex Turnpike, Bedford, Mass. 01730, U.S.A.	Spectro-met 1000	DR	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	DR	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	DR	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 Ar and air available	All direct-reader applications above 190 nm
	Spectro-vac II	DR	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'. ICP	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; N_2 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	DR	Up to 50	0.54	168–500	0.75 m	As above, except electronic controlled peak current	Computer controlled	Most metallurgical analyses
	96–785	DR	Up to 50	0.54	168–500	0.75 m			

(continued)

* New equipment since publication of volume 7

Table 2.5A 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	DR	Up to 60	0.56 or 0.28 0.34 to 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	DR	30	As 70–310	As 70–310	3.4 m	As above	Easy interchange to photographic (70–310) version	As for Model 1500
	*82–484	Scan.	—	1.5–120	Depends on grating	0.275 m	Supplied by user	25 mm wide focal plane at exit	With detector arrays
	*82–485 *82–486 *82–487	Scan.	—	1.5–120	As above	0.275 m	As above	Easily Interchangeable gratings	Suitable for spectroscopic investigations rather than for analytical applications
	82–410	Scan.	—	1.6 and 3.3	200–900	0.25 m	Tungsten deuterium	Various scanning spectrometers	
	82–020	Scan.	—	Depends on grating	Depends on grating	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	DR	60	0.56	190–900	1.5 m	'Transource' high-voltage-triggered discharge. Low-voltage-triggered d.c. arc	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	DR	40	0.67	170–550	1.0 m			As above
	2100	DR	30	0.46	188–455	1.0 m			As above
	71	DR	74	0.52	170–900	2.0 m	ICP source for solution analysis		General purposes
M.B.L.E., Rue des Deux-Gares 80, B–1070, Brussels, Belgium	Philips PV 8300 Vacuum	DR	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; glow discharge, hollow cathode	Optional dual air/Ar excitation stand; choice of programmable calculator and computer configurations with dual cassettes on floppy discs; rapid printer VDU extension options	Steels, iron, non-ferrous metals, and non-conductive powders; air stand for oils, d.c. arc, etc.
Philips Analytical Dept., Pye Unicam Ltd.,	Philips PV 8350 Vacuum	DR	40	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

York Street, Cambridge, CB1 2PX, England	Philips PV 8210 Air	DR	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
	Phllips PV 8250 Air	DR	40	0.695 or 0.35 0.59 or 0.35 0.92 or 0.46 0.46 or 0.23	190–610 190–531 190–820 190–410	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	DR	60	0.293–1.155	156–880	1.5 m	Various, including high-repetition condensed arc, ICP, GDL	Solid state electronics: computer control available. Dual gratings give 12 standard systems to select optimum dispersion and wavelength coverage. Special grating if required. dual spark stands	Ferrous and non-ferrous alloys; geological samples; wear metals in oils
	E960	DR	36	0.546 or 0.741	174.0–447.7	0.75 m	As E1000	Curved entrance and exit slits; solid-state electronics. Computer control available; air or inert gas discharge stands	Ferrous and non-ferrous alloys; wear metals in oils
	Monospek D–400	DR	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
Spectrametrics Inc., 204 Andover St., Andover, Mass. 01810, U.S.A.	AE 2	Phot., DR	1	0.06	190–800	0.75 m	Plasma jet	Optimized AE system using a high-dispersion, high-energy-throughput echelle spectrometer and a high temperature plasma jet excitation source	Routine analysis
	DR 10	DR	20 (inter-changeable cassettes)	0.06	190–800		Plasma jet		Routine quantitative multi-element analysis
Techmation Ltd., 58 Edgware Way, Edgware, Middlesex, HA8 8JP, England	ES 9	Phot.	—	0.06	190–800	0.75 m	Plasma jet, flame, or arc stand	Built-in computer	Qualitative and semi-quantitative analysis; spectroscopic research
	RS 1	DR	1 (variable wavelength)	0.06	190–800	0.75 m	Plasma jet, flame, or arc stand		

* New equipment since publication of Volume 7

Table 2.5A 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
Spex Industries Inc., 3880 Park Ave., Metuchen, N.J. 08840, U.S.A.	1870	Scan./ Phot.	—	1.6	175–1280	0.5 m	—	Multi-purpose unit	Routine analysis
	1702	Scan./ Phot.	—	1.1	175–1500	0.75 m	—	—	Research
	1704	Scan./ Phot.	—	0.8	175–1500	1.0 m	—	—	Research
Glen Creston, 16 Carlisle Rd., London NW9 0HL, England	1802	Scan./ Phot.	—	0.8	180–1500	1.0 m	—	Direct reading accessory available	Routine analysis
	*1269	Scan.	—	0.65	180–1500	1.26 m		Very high resolution	Research
VEB Carl Zeiss Jena, 69 Jena, Carl-Zeiss Str. 1, German Democratic Republic	PGS–2	Phot.	—	0.74 or 0.37 0.76	200–2800	2.075 m	Arc or spark	Atlas for spectra evaluation; wide choice of precision diffraction gratings; high resolving power; dispersion doubling or multiplying as required; automatic transport of cassette; wavelength scale for quick orientation of the user within the spectra; wide range of accessories available including LMA–10 laser-microspectral analyser	General spectrographic analysis; also examination of line profiles, hyperfine structure, etc.
Carl Zeiss Scientific Instruments Ltd., PO Box 43, 2 Elstree Way, Boreham Wood, Herts, WD6 1NH England	Q–24	Phot.	—	0.76 (at 250 nm)	210–550	0.54 m	Arc or spark	High light intensity, variable slit width ranging from 0.001–0.3 mm; built-in slit shutter and step filter; wavelength scale for quick orientation; atlas for spectra evaluation; full range of accessories available including LMA–10	General spectrographic analysis

* New equipment since publication of volume 7

Table 2.5B COMMERCIALLY AVAILABLE PLASMA SPECTROMETERS

Supplier	Model	Type	No. of Channels	Reciprocal dispersion/ nm per mm	Wavelength range/nm	Focal length	Generator		Special features	Applications
							Output power	Operating frequency/ MHz		
Applied Research Laboratories Ltd., Wingate Road, Luton, Beds., LU4 8PU, England	Quantometer 34000/ICP	DR	48	0.695 or 0.347 0.930 or 0.465 or 0.310	190–610 190–820	1.0 m	2 kW r.f. ICP	r.f.	Full computer controlled to provide direct concentration print-out; full range of options including dual cassette; dual floppy discs; visual display units; fast printers, remote terminals and computer links etc.	All ferrous and non-ferrous powders including slags, rocks, soils etc; particularly suited to the analysis of highly alloyed materials; computer options available to allow incorporation into plant systems
EDT Research Ltd., 14 Trading Estate Road, London, NW10 7LU	MPS 600	DR	6 or 8		190–500	0.5 m	20–150 W MIP	2450	Multi-channel concave grating polychromator fitted with quartz refractor plate; data presentation: sequential through channels; optional printer or punch tape units; simultaneous multi-element analysis for μl sample solutions; fully programmable system for desolvation, ashing and vaporization of samples	High absolute senstivity with pg detection limits for several elements
Jarrell-Ash Div., Fisher Scientific Co., 590 Lincoln St., Waltham, Mass. 02154, U.S.A.	96–975	DR	Up to 50	0.54	168–500	0.75 m	2 kW r.f. ICP	r.f.	Computer controlled; variable channel; concentration print-out	All solutions
	96–988	DR	Up to 50	0.54	168–500	0.75 m			Computer controlled; N+1 channel scanning monochromator attachment; spectrum shifter attachment for automatic background correction; special K and Li channels; Data Management System	Simultaneous multi-element determinations of trace elements down to ppb levels in aqueous and organic solutions
V. A. Howe & Co. Ltd., 88 Peterborough Road, London SW6 3EP										
Jobin-Yvon, Division d'Instruments, 16–18 Rue du Canal, 91160 Longjumeau, France	JY 38P	Scan.		1.0	175–750	1.0 m	1.5–2.5 kW r.f. ICP	27.12	Czerny–Turner monochromator; wavelength scanning, 0.005 or 0.125 nm per step at 0.3 to 3500 nm per min with recorder synchronisation; computer system	Metals and alloys, rare earths, soils and minerals, water pollutants, pharmaceutical control, biomedical analysis, blood and serum

(continued)

Table 2.5B COMMERCIALLY AVAILABLE PLASMA SPECTROMETERS—*continued*

Supplier	Model	Type	No. of Channels	Reciprocal dispersion/ nm per mm	Wavelength range/nm	Focal length	Generator		Special features	Applications
							Output power	Operating frequency/ MHz		
(continued)										
EDT Research Ltd., 14, Trading Estate Road, London, NW10 7LU	JY 48P	DR	48	0.45 at 175–450 0.58 190–590 0.69 210–710 0.80 240–850	168–800	1.0 m	1.5–2.5 or 5.0 kW r.f. ICP	27.12	Paschen Runge mounting 1 m diameter, air or vacuum, 86 positions of multipliers; fully automatic read-out; computer option	Metals (C, S and P), oils, water, soils and minerals, biomedical analysis
Kontron GmbH, 8057 Eching bei Munchen, Oskar-von-Miller Str. 1, West Germany	†Plasma-spec System 3	Scan.		0.8–1.6	150–450 or 190–700	0.6 m	4 kW optional to 7 kW r.f. ICP	27.12		General purpose
	Plasma-spec System 4	DR	Up to 30	0.23–0.46	187–455	1.0 m	4 kW optional to 7 kW r.f. ICP	27.12		General purpose
Labtest Equipment Co., 11828 La Grange Avenue, Los Angeles, Calif. 90025 U.S.A.	Plasma-scan 700	Scan.	—	—	250–850	0.35 m		2 kW	Czerny–Turner monochromator; microprocessor control; enclosed sample pumping system; computer read-out system.	General purposes
M.B.L.E., Rue des Deux Gares 8, B–1070 Brussels, Belgium	Philips PV 8210	DR	60 (50 lines)	0.55 or 0.28	190–700	1.0 m		r.f.	Wavelength range covered in 1st order; remote controlled roving detector; read-out by printer, teletype or digital computer systems	All direct reader analyses above 190 nm, particularly, non-ferrous metals, solutions, oils and non-conductive powders
Philips Analytical Dept., Pye Unicam Ltd., York Street, Cambridge, CB1 2PX, England	Philips PV 8250 Air	DR	40	0.695 or 0.35 0.59 or 0.35 0.92 or 0.46 0.46 or 0.23	190–610 190–531 190–820 190–410	1.0 m		r.f.	Integrated spectrometer system with built-in source and readout options as for PV 8210	As for PV 8210
	Philips PV 8350 Vacuum	DR	40	0.46	177–410	1.0 m		r.f.	Integrated spectrometer system including source and readout options as for PV 8210	Steels, iron, non-ferrous metals, non-conductive powders

Rank Hilger, Westwood Industrial Estate, Margate, Kent, CT9 4JL, England	E1000 Polyvac	DR	60	0.293–1.155	159·6–864.3	1.5 m	r.f.	Computor controlled instrument; dual gratings give 7 systems	Ferrous and non-ferrous alloys, geological samples, wear metals in oils
	E960	DR	36	0.546–0.741	174.0–447.7	0.75 m	r.f.	Curved entrance and exit slits; solid-state electronics or computer controlled; air or vacuum	Ferrous and non-ferrous alloys, wear metals in oils
Spectrametrics Inc., 204 Andover Street, Andover, Mass. 01810, U.S.A.	Spectra-span III	Photo. DR	20 Inter-change-able cassettes	0.06	190–800	0.75 m	plasma d.c. arc	Optimized AES system using high-dispersion high-energy throughput echelle grating spectrometer; integral microprocessor	Routine sequential, quantitative analysis and multi-element analysis
Techmation Ltd., 58 Edgeware Way, Edgeware, Middlesex, HA8 8JP, England	Spectra-span IV							High sensitivity even in presence of complex matrix solutions with solid contents up to 20%	Quantitative and qualitative analysis of trace concentrations including refractories and some non-metals

† No up to date information supplied.

Table 2.5C 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
Baird-Atomic Inc., 125 Middlesex Turnpike, Bedford, Mass. 01730, U.S.A.	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; wavelength scan; 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
	1236	Double	Littrow	1200	2.7	0.2	190–860	Digital; ×55	As model 1233
Beckman-RIIC Ltd., Turnpike Road, Cressex Industrial Estate, High Wycombe, Bucks, HP12 3NR, England	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 Instruments, † 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.,† Mori 17th Bldg., 26–5 Toranomon, 1-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

Nissei Sangyo, Instruments Inc., 392 Potorero Ave., Sunnyvale, Calif. 94086, U.S.A.	170–30	Single	Littrow	1440	2.25	0.4	190–900	As 170–10	Concentration readout; time-weighted signal averaging; AAS/AES measurement; auto zero; N_2O–air simultaneously exchanged
Nissei Sangyo GmbH, 4 Dusseldorf, Am Wehrhahn 41, West Germany	170–50	Double	Littrow	1440	2.25	0.1	190–900	As 170–10	Background correction, channel balance free system, 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., 68 Jonspin Road, Wilmington, Mass. 01887, U.S.A. Instrumentation Laboratory (UK) Ltd., Kelvin Close, Birchwood Science Park, Warrington, Cheshire	751	Double, dual channel	0.33 m Ebert (both channels)	1200	2.25	0.04	180–1000	0.01–1000×	Microcomputer controlled; calibration curve linearized in both channels, using up to 5 standards; background correction functions in channel A and channel B simultaneously; readout will display A,B A/B or A-B. Automatic gas box is standard feature; optional 4-lamp turret, wavelength scan, and built-in alpha-numeric printer
	551*	Double	0.33 m Ebert	1200	2.25	0.04	180–1000	0.01–1000×	Microcomputer controlled; calibration curve linearized using up to 5 standards; memory will store up to 10 calibration curves simultaneously; video screen displays standard conditions for each element, the working curve, and will show transient signals. Fully automatic fail safe gas box is standard feature; optional background correction, 4-lamp turret, wavelength scan, and alpha-numeric printer

(continued)

† No up to date information supplied

* New equipment since publication of Volume 7

Table 2.5C 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)	257*	Double	0.33 m Ebert	1200	2.25	0.04	180–1000	0.01–1000×	Microcomputer controlled; calibration curve linearized using 2 standards or 5 standards (optional). Fully automatic gas box is standard feature; optional background correction, 4-lamp turret, wavelength scan and alpha-numeric printer with statistics
	157*	Single	0.33 m Ebert	1200	2.25	0.04	180–1000	0.01–1000×	Microcomputer controlled; calibration curve linearized using 2 standard or 5 standards (optional). Fully automatic gas box is standard feature; optional background correction, 4-lamp turret, wavelength scan and alpha-numeric printer with statistics
	251	Double	0.33 m Ebert	1200	2.25	0.04	180–1000	0.01–1000×	High speed digital electronics; full-time-integration, peak area and peak height; off-line calibration curve correction. Autogasbox is standard feature; optional background correction, 4-lamp turret, wavelength scan
	151	Single	0.33 m Ebert	1200	2.25	0.04	180–1000	0.01–1000×	High speed digital electronics; full-time-integration, peak area and peak height; off-line calibration curve correction. Autogasbox is standard feature; optional background correction, 4-lamp turret, wavelength scan

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
V. A. Howe & Co. Ltd., 88 Peterborough Road, London, SW6 3EP, England	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
	82–850	Single	0.4 m Czerny–Turner	1180	2.08	0.03	190–900	Digital	Computer-controlled parameters
Perkin-Elmer Corp., Main Ave., Norwalk, Conn. 06856, U.S.A. Perkin-Elmer Ltd., Beaconsfield, Bucks. HP9 1QA, England	280	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 conc.; 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
	380	Double	0.27 m Littrow	1800	1.6	0.2	190–860	Digital; ×0.01–50	As Model 280 but all mirror optics; automatic gain control; auto N_2O switching; burner head safety interlock; optional flame and pressure sensing by microcomputer burner control; optional deuterium arc double-beam background correction
	560	Double	0.27 m Littrow	1800	1.6	0.2	190–860	Digital; ×0.01–100	As Model 380 but auto curve correction, with up to 3 standards; statistics; integration time selectable from 0.2 to 60 s
	703	Double	0.4 m Czerny–Turner	u.v. 280 vis. 1440	0·65 1.3	0.03	180–440 400–900	Digital; ×0.01–100	As Model 560 but optional 4-speed wavelength drive; no automatic gain control

(continued)

* New equipment since publication of Volume 7

Table 2.5C 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)	5000	Double	0.4 m Czerny–Turner	u.v. 280 vis. 1440	0.65 1.3	0.03	170–475 170–900	Digital; ×0.01–100	Completely automated sequential AA system; instrument can analyze up to 6 elements with minimal operator participation; all analytical parameters, including lamp current, wavelength selection, resolution, gas flows, standardization and signal read out can be entered and stored using magnetic cards; double-beam background correction for all u.v. and visible wavelengths; when instrument is used in conjunction with HGA–500 it will provide sequential analysis for up to 6 elements with same analytical ease as with flame
Bodenseewerk, Perkin-Elmer & Co. GmbH, Postfach 1120, D–7770 Uberlingen, West Germany	400	Double	0.33 m Czerny–Turner	1800	1.3	0.2	190–860	Digital; ×50 and ×0.2	Auto zero, auto concentration, integration, curve correction, BCD outlet, automatic flame ignition
	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
	422	Double	0.33 m Czerny–Turner	1800	1.3	0.2	190–860	Digital	As Model 400, but with microcomputer electronic keyboard operation; linearization with up to 3 standards; EIA RS-232C data outlet
	432	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 12PX, 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; ×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
	Data Centre	—	—	—	—	—	—	—	Fully microprocessor controlled data processing by programmable calculator; 3 types of curve correction; statistics; standard additions and other data handling; full calculator ability retained
	*SP9	Single	Ebert	1200	4.7	0.2	190–850	Digital; ×0.5–25	4-lamp turret; gas control module with full safety interlocks. Deuterium background corrector; scale expansion and curvature correction; burner interlock as standard
	*SP9 Computer	—	—	—	—	—	—	—	Curve correction with up 5 standards in fixed or variable ratios; peak height or peak area; full statistics; running mean
Rank-Hilger, Westwood Industrial Estate, Ramsgate Road, Margate, Kent, CT9 4JL, England	Atomspek H 1580	Single	Czerny–Turner	1200	2.6	0.1	190–850	Digital	6-lamp turret; auto zero and flame ignition; curve correction; integration; programmable calculator
Shimadzu-Seisakusho Ltd. 14–5 Uchikanda, 1-chome, Chiyoda-ku, Tokyo, 101, Japan	AA–625	Single	Czerny–Turner	—	1.9	0.2	190–700 expandable to 900	Meter or digital	Quantitative flame emission; flameless capacity; flow lines for air, C_2H_2 and N_2O

(continued)

* New equipment since publication of Volume 7

Table 2.5C 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)									
V. A. Howe & Co. Ltd., 88 Peterborough Rd., London, SW6 3EP, England	AA-630	Single	Czerny-Turner	—	1.9	0.2	190-900	Meter or digital	Quantitative/qualitative flame emission; flameless capacity; flow lines for air, Ar, C_2H_2, N_2O, H_2; flame monitor; gas pressure monitor; wavelength drive
	AA-640	Single	Czerny-Turner	—	1.9	0.2	190-900	Meter or digital	Automatic background correction; quantitative and qualitative flame emission; flameless capacity; flow lines for air, Ar, C_2H_2 N_2O, and H_2; flame monitor; gas pressure monitor; wavelength drive; integration
	AA-650	Double	Czerny-Turner	1200	1.9	0.2	190-900	Meter or digital	Automatic background correction; quantitative and qualitative flame emission; built in peak catcher; flameless capacity; flow lines for air, Ar, C_2H_2 N_2O, and H_2; flame monitor; gas pressure monitor; wavelength drive; integration
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 $\times$0.3-50	4-lamp turret; auto zero; integration; curve correction; peak reader; f/8 aperture; optional automatic gas-box
Varian Assoc. Ltd., Instrument Group, 28 Manor Road, Walton on Thames, Surrey, England	AA-275*	Single	0.25 m Czerny-Turner	1200	3.3	0.2	185-900	Digital; $\times$0.001-100	Reflective optics with quartz overcoat; microprocessor system with three-standard calibration, optional automatic gas control, background correction, 2-lamp turret
Varian Instrument Div., 611 Hansen Way, Palo Alto, Calif. 94303, U.S.A.	AA-475*	Double	0.25 m Czerny-Turner	1200	3.3	0.2	185-900	Digital; $\times$0.001-100	Reflective optics with quartz overcoat; microprocessor system with three-standard calibration, optional automatic gas control, background correction, 2-lamp turret

	AA–575	Double	0.25 m Czerny–Turner	1200	3.3	0.2	185–900	Digital; ×0.001–100	Reflective optics with quartz overcoat; fully microprocessor controlled, three-standard calibration, optional automatic gas control, background corrector and 4-lamp turret
	AA–775*	Double	0.33 m Czerny–Turner	1800	1.6	0.05	185–900	Digital; ×0.001–100	Reflective optics with quartz overcoat; fully microprocessor controlled, five-standard calibration with statistics and standard additions calibration; optional automatic gas control, background corrector and 4-lamp turret
	AA–6	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 Str. 1, German Democratic Republic Carl Zeiss Scientific Instruments Ltd., PO Box 43, 2 Elstree Way, Boreham Wood, Herts, WD6 1NH, England	AAS1	Single	0.50 m Ebert	1300	1.5	—	190–820	Meter; ×10	4-lamp burner; single or triple pass optics; autozero

* New equipment since publication of Volume 7

Table 2.5D COMMERCIALLY AVAILABLE ELECTROTHERMAL ATOMIZERS

Supplier	Model	Type	Max. sample volume μl	Control unit	Senstivity 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., 68 Jonspin Road, Wilmington, Mass. 01887, U.S.A. Instrumentation Laboratory (UK) Ltd., Kelvin Close, Birchwood Science Park, Warrington, Cheshire	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 pressurization; convenient solid sampling capacity using microboats
Jarrell-Ash Division, Fisher Scientific Co., 590 Lincoln Street, Waltham, Mass. 02154, U.S.A.	FLA 100	Graphite furnace	50	Programmable, dry, ash, atomize; 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
Perkin-Elmer Corp., Main Avenue, Norwalk, Conn. 06856, U.S.A.	HGA-400 *	Graphite furnace	100	Microprocessor unit provides up to 8 steps of controlled heating; temperature, ramp time, hold time,	d.l. 2	d.l. 20	High-speed temperature sensor accessory permits rapid heating to temperature between 600 and 3000 °C for optimal atomization;

Perkin-Elmer Ltd., Beaconsfield, Bucks, HP9 1QA, England				gas and other furnace and spectrophotometer control functions are programmed by direct keyboard entry. Digital displays provide readout of temperature, time and programme status			AS–1 furnace auto-sampler available for automatic insertion of up to 30 samples into the HGA with automatic triggering of HGA and instrument read cycle, for unattended operation
	HGA–500	Graphite furnace	100	Microprocessor unit provides up to 9 steps of controlled heating; temperature, ramp time, gas and other furnace and spectrophotometer control functions are programmed for each step by direct keyboard entry; digital displays provide readout of temperature, time and programme status. Up to 6 complete programmes can be stored and recalled at the touch of one key	d.l. 2	d.l. 20	Furnace control programmes for up to 6 different elements may be stored in 6 programme memories; when used in combination with the AS–1 furnace auto-sampler and the model 5000 AA spectrophotometer, up to 30 samples may be analyzed for up to 6 elements each without operator attention; programme parameters for more than 6 elements can be stored on magnetic cards and recalled with the push of one button; the optical temperature sensor and digital gas flow control for 2 different gases add to the versatility of the furnace programme
Bodenseewerk Perkin-Elmer & Co. GmbH, Postfach 1120, D–7770 Uberlingen, West Germany	HGA–500	Graphite furnace	100	Microcomputer controlled up to nine program steps for drying, ashing, sample pretreatment, atomize, tube clean, tube blank etc; max. temp. 3000 °C	s. 4 d.l. 0.5	s. 30 d.l. 5	Fits Perkin-Elmer and Zeiss AA spectrophotometers; water-cooled, inert gas shielding, safety features for failure of water purge gas or tube break; ramp or stepwise increase of temperature plus isothermal phase in each of the steps; recorder and peak reader control in each step preselectable; gas stop or mini flow selectable; temperature controlled maximum power heating for atomization

(continued)

* New equipment since publication of volume 7

Table 2.5D COMMERCIALLY AVAILABLE ELECTROTHERMAL ATOMIZERS—*continued*

Supplier	Model	Type	Max. sample volume μl	Control unit	Senstivity for 1% abs. (s.)/pg Detection limit (d.l.)/pg		Special features
					Cu	Si	
(continued)	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–500	as with HGA–500	Fits all Perkin-Elmer AA spectrophotometers with HGA
	MHS–1	Mercury/Hydride system	50 ml	System with automatic programming for trace determination of Hg, As, Se, Sb, Te, Bi, Sn	(Hg) s. 5 ng d.l. 1 ng	(As) 1 ng 2 ng	Fits all Perkin-Elmer AA spectrophotometers
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
	SP9 Video Furnace *	Graphite tube furnace	50	6 phases each programmable to 3000 °C; linear or non-linear ramp on each phase; 9 ramp rates; temperature or voltage control	s. 3 d.l. 2	s. 25 d.l. 15	Video display of parameters and status; storage of 9 furnace programs; gas stop on all phases; built-in Autosampler controls
	SP9 Furnace*	Graphite tube furnace	50	4 phases each programmable to 3000 °C; 9 ramp rates between phases 1 and 2; temperature or voltage control	s. 3 d.l. 2	s. 25 d.l. 15	Selectable autozero and gas stop; fault indication and interlocks; digital display of remaining time
	SP9 Furnace Autosampler *		40	Automatic sampling of 38 samples and 2 wash positions. Selectable number of readings per sample	—	—	Fits all Pye Unicam spectrophotometers; cup identification; wash system interlock; automatic stop after last sample
Rank Hilger, Westwood Industrial Estate, Ramsgate Road, Margate, Kent, CT9 4JL, England	H1475	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 1551

Shimadzu-Seisakusho Ltd., 14–5 Uchikanda, 1-chome, Chiyoda-ku, Tokyo, 101, Japan V. A. Howe & Co. Ltd., 88 Peterborough Road, London, SW6 3EP, England	GFAZ	Graphite furnace	50	Programmable, dry, ash, atomize; max. temp. 3000 °C	5	—	Current stabilized to obtain reproducible results
Varian Techtron Pty. Ltd., 679 Springvale Road, Mulgrave, Vic. 3170, Australia	CRA 90	Graphite furnace (graphite tube), (threaded graphite tube), (graphite cup)	25	Programmable, dry, ash, atom ze; max. temp. 3000 °C	4	80	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 7