processor to perform all its control functions in real time without delaying the instrument unduly, and still do data reduction. Indeed, manufacturers of all microcomputer-controlled instruments are finding that programming—or software—is a major problem, just as it is with larger computers.

There are no commercial infrared or ultraviolet spectrometers for laboratory use designed around microprocessors, although Wilks of South Norwalk, Connecticut, is introducing an infrared instrument for process control applications. (The user must supply all the programming for the microprocessor, an enormous task for the uninitiated.) But microprocessor instruments are probably not far away. Beckman Instruments, Fullerton, California, is offering an infrared spectrometer with digital data output, for easier linking to a computer, and GCA/McPherson of Acton, Massachusetts, is marketing a new, completely digital ultraviolet spectrometer controlled by a separate Monroe calculator with programs on magnetic cards. New Perkin-Elmer ultraviolet spectrometers are also digitally controlled, and hence compatible with computer operation and data reduction, although no computer or calculator is supplied. A word of warning—electrical compatibility with a computer is not sufficient; logical compatibility, often not provided, is needed too.

In spectrofluorometers, one company offers a unit with a microprocessor that is used only for data processing. Two others that now offer digital instruments controlled by minicomputers expect within a year to offer versions with microprocessor control and data handling.

Fourier transform infrared spectrometry (see accompanying article) is another area where minicomputers, now used with the instruments to handle the large volume of data processing, may well be replaced by the combination of microprocessors and special circuits for some applications before very long. Raman spectrometers, which are now available as digital instruments controlled by minicomputers, also appear to be prime candidates for microprocessors.

All in all, one has the impression that the next few years will see a number of new, more versatile, and more reliable instruments based on microprocessors, as users begin to expect more intelligent instruments and manufacturers come to grips with the power and the complexity of computerized analytical devices.

—ALLEN L. HAMMOND

Fluorescence Spectroscopy: Finally of Interest

Fluorescence spectroscopy is one of the easiest, most sensitive, and most neglected techniques of analytical chemistry. Instruments to measure fluorescence have been available since the 1940's, but only in the past 2 years has the use of fluorescence spectroscopy for quantitative analysis been of significant interest to large numbers of researchers. According to Richard Passwater of the American Instrument Company in Silver Spring, Maryland, researchers have been forced to turn to fluorescence by their needs for more and more sensitive measurements. Instrument manufacturers claim that another reason for the burgeoning popularity of this technique is that their companies' efforts to introduce spectrofluorometers of greater sophistication and reliability at lower prices has, apparently, paid off.

This year at the Pittsburgh Conference, investigators reported a wide variety of applications of fluorescence spectroscopy. Clinical investigators, for example, are using it to detect lead poisoning of children. Other researchers are using it to identify the sources of oil spills and to monitor the presence of hazardous substances in the environment. And food companies are using fluorescence spectroscopy, combined with liquid chromatography, to determine amounts of various nutrients in their products in order to comply with labeling requirements. To aid in these applications, the instrument manufacturers this year introduced on their medium-priced instruments features that were previously available only on high-priced instruments.

J. Julian Chisolm and Dean Brown of Johns Hopkins University and Baltimore City Hospital are standardizing a technique, based on fluorescence spectroscopy, that provides a quick, easy, and sensitive way to screen children for lead poisoning. In conjunction with researchers at the Center for Disease Control in Atlanta, they are in the process of introducing their method to clinicians throughout the country.

When children are poisoned by lead, their synthesis of heme is blocked. This causes zinc protoporphyrin, a precursor of heme, to build up and appear in their blood. Zinc protoporphyrin fluoresces (that is, it absorbs light of a specific wavelength and subsequently emits light of a different wavelength) so it can be detected in trace amounts in extremely small quantities of blood. Brown claims that he needs only the blood obtained when a child's finger is pricked to detect as little as 4 nanograms of zinc protoporphyrin per milliliter of blood.

Two symposiums at the Pittsburgh Conference were devoted to the use of analytical techniques for the identification of oil spills, and many of the results reported were based on fluorescence spectroscopy. The Coast Guard, in particular, is developing a way of using fluorescence, along with a few other methods, to "fingerprint" oil spills. They hope to show that they can identify polluters with such accuracy that their results can be accepted by the courts as evidence. In one case, widely reported by the news media last year, the Coast Guard used their fingerprinting technique to identify a tanker that dumped about 100,000 gallons of oil off the Florida Keys.

A crucial aspect of the Coast Guard's oil technique is the use of double-beam fluorescence spectroscopy. Double-beam spectrofluorometers differ from most other spectrofluorometers, which send all their light to one sample chamber, because these double-beam instruments split the input light and send it to two sample chambers. Janet Sheridan and J. Richard Jadamer of the Coast Guard Research and Development Center in Groton, Connecticut, explained their use of the method at one of the symposiums on oil spillage. They place a sample of oil from a spill in one chamber of the instrument and a sample of oil they suspect comes from the source of the spill in a second chamber. The double beam of light passes through both sample chambers, and the fluorescence of both samples is measured. Then, the light emitted when the oil from the suspected source fluorescences is subtracted, by the electronics of the instrument, from the light emitted when the oil from the spill fluoresces. If the oils in the two chambers are the same, the instrument will register no net fluorescence.

Until recently, no spectrofluorometers that met the Coast Guard's requirements of a medium price (about $20,000) and for double beams were available. Double beams were previously available only on

$40,000 instruments. They are conventionally used to subtract the light fluoresced by the solvent the sample is dissolved in from the light fluoresced by the sample, thus correcting for fluorescence of the solvent. Last year, however, Perkin-Elmer Corporation in Norwalk, Connecticut, came out with a medium-priced double-beam spectrofluorometer and this year Farrand Optical Company in Valhalla, New York, introduced a similar instrument. According to Louis Capasso of Farrand, his company was stimulated to produce its new instrument by the Coast Guard's demands.

Instrument designers have long been plagued by the problem of correcting fluorescence spectra for instrument-based distortions. If these corrections are not made, data from one instrument are not comparable to data from another. And, although corrected spectra have been available for a decade, the corrections have not always been perfectly reliable nor available on medium-priced instruments. All the instrument companies that exhibited at the Pittsburgh Conference are now offering fully corrected spectra on medium-priced instruments. This year, however, Perkin-Elmer introduced a new way to correct spectra on their medium-priced instruments. This company is correcting their spectrofluorometer's distortions with a microprocessor (see accompanying article). The Perkin-Elmer double-beam spectrofluorometer can, as an option, be hooked up to a microprocessor. This use of microprocessor enables Perkin-Elmer to increase the ease of operation of their instrument and the reliability of their corrections but does not increase the cost of their instrument.

Donald Helman of the American Instrument Company reported at one of the oil spill symposiums that another kind of correction often proves important in fluorescence spectroscopy—correction for the light absorbed by the solvent in which the sample is dissolved. Since many solvents absorb light of the same wavelength as light absorbed by the sample, measurements of the amount of light directed at the sample do not always indicate how much light is available for it to absorb. This problem occurs, for example, when fluorescence of oils is measured. Oils are usually dissolved in cyclohexane which, like the oils, absorbs light in the ultraviolet region of the spectrum. To correct for this effect, American Instrument Company introduced this year a medium-priced instrument in which the light absorbed by the solvent is measured and subtracted from the light recorded as being available for absorption by the sample.

Since fluorescence spectroscopy is as much as 1000 times as sensitive as the more widely used technique of ultraviolet absorption (in which only the light absorbed is measured to determine how much of a given compound is present), its increasing popularity among analytical chemists is not unexpected. Now that new applications of fluorescence spectroscopy are being reported and now that manufacturers have begun introducing features on their $20,000 instruments that were previously available only on $40,000 instruments, industry representatives agree that the recent trend toward the use of fluorescence spectroscopy is likely to continue.—GINA BARI KOLATA

Surface Analysis: Multiple Techniques for Monolayers

If anything characterized the Pittsburgh Conference, it was the smell of money. Although forbidden by conference rules to make sales on the exhibition hall floor, instrument makers aggressively showed their wares, and many company representatives claimed to have the kind of solid leads to sales that have been lacking in earlier Pittsburgh Conferences. Instrumentation for the analysis of solid surfaces was no exception, despite the fact that little in the way of anything new was offered.

It is a cliché to point out that the advent of ultrahigh vacuum techniques two decades ago has enabled researchers to invent a panoply of electron, ion, and x-ray spectroscopic techniques capable of characterizing solid surfaces, and in fact has led to the establishment of the discipline of surface science. Nonetheless, apart from the fundamental research laboratories, the use of these so-called clean surface methods has only been slowly appreciated. Thus, in the past, manufacturers have had to sell the very idea of surface science to a skeptical audience before they could tout the advantages of their own instruments.

John Yates, Jr., of the National Bureau of Standards (NBS), Gaithersburg, Maryland, has completed a survey of some 104 academic, government, and industry laboratories. This study turned up about 60 experimental techniques that investigators use to study surfaces. Many of these, of course, are not restricted to surface analysis, and, of those that are, only a few are widely used and thus are of interest to commercial manufacturers.

The makers of instruments of commercial importance have concentrated on techniques that involve measuring the kinetic energies of electrons emitted from the surface of a solid subjected to either electron beams or to x-ray or ultraviolet radiation. Auger electron spectroscopy (AES) has been the workhorse of these electron spectroscopies, partly because identification of chemical elements (except hydrogen and helium) on solid surfaces can be obtained by technicians with relatively inexpensive equipment ($50,000 and up).

Auger electrons are secondary electrons ejected from a solid when a beam of electrons with energies of several thousand electron volts first knocks out an inner shell electron, creating an electron vacancy (hole) which is quickly filled by a less tightly bound electron. The energy lost by the latter electron is imparted to a second outer electron which becomes the Auger electron and whose kinetic energy (5 to 2000 ev) is the difference between the energy imparted to it and its binding energy. This energy difference is unique to each element and thus provides the means of chemical identification. Auger electrons are readily scattered by atoms in the solid as they travel toward the surface, and therefore only those electrons created within the first 3 to 30 angstroms from the surface (1 to 10 monolayers) escape with the characteristic energy and are measured.

By focusing a beam of inert gas ions onto the solid surface, researchers can systematically etch away the surface. In addition to merely cleaning contaminants from the surface, such sputter-etching provides a way to observe the concentration of one or more elements with depth, because the peak in the Auger spectrum characteristic of each element can be monitored as a function of etching time. The height of each Auger peak is presumed to be proportional to the concentration of a given element.

In the last 2 years, instrument makers have developed scanning Auger systems in which the electron beam can be focused to a diameter of about 5 micrometers and scanned across the surface much as in a scanning electron microscope (SEM). This scanning capability in