The Pittsburgh Conference: A Special Instrumentation Report

"You have to be crazy to come here in March," was a comment frequently heard earlier this month at the 28th annual Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, which has been held in Cleveland for the past 10 years. But perhaps the commenters meant crazy like a fox, because more than 12,000 scientists and technicians registered at the show and more than 320 instrument and equipment companies showed up to display their wares; both figures are new records that reenforce the reputation of the conference as the world's largest and most important conference on chemical instrumentation. Shielded from distractions by the scarcity of divertissements in downtown Cleveland, the conference participants were able to spend five full days listening to papers, examining many new refinements in instrumentation, and generally making the exhibitors' cash registers ring. Potential employers were out in force looking for analytical chemists and offering some graduating Ph.D.'s starting salaries approaching $30,000. (The one gloomy note of the convention was that many academic scientists thought these high starting salaries would make it virtually impossible to obtain high-quality analytical chemists as postdoctoral fellows.) The instrument companies displayed lavish hospitality in their suites, and the mood of the conferees in the elevators and exhibition halls was exceptionally convivial. By any of these indicators, it seems clear that the instrument industry is going to have an even better year than last year and that the scientific economy, as measured by the purchase of instruments, is going to remain strong.

Ion Cyclotron Resonance: Fourier Transform Mass Spectrometry

Fourier transform techniques have been responsible for major improvements in infrared and nuclear magnetic resonance spectrometry by making it possible to obtain whole spectrums in the same amount of time required by conventional spectrometers to observe just a single point in the spectrum. The techniques give greater sensitivity and speed, and permit the use of much smaller samples. Now it appears that these benefits can be extended to mass spectrometry by the development of Fourier transform ion cyclotron resonance (FT-ICR) spectrometers. FT-ICR has the potential to make mass spectrometry even more valuable in some areas where it is already heavily used and to place it in some areas where it has so far received little application.

Ion cyclotron resonance techniques depend on the fact that ions (which in this case are generated by exposing gaseous molecules to an electron beam) precess in a cycloidal path when exposed to an appropriate combination of magnetic and electric fields. When the sample chamber is irradiated with energy at radio frequencies, each orbiting ion absorbs energy (resonates) at a frequency characteristic of its mass. By sweeping through the frequency spectrum slowly and recording the frequencies at which energy is absorbed, it is possible to identify the mass of each ion present and thus obtain a mass spectrum. In operation, this technique is similar to that by which a spectrum is obtained in nuclear magnetic resonance spectrometry. In practice, the radio frequency is generally held constant and the magnetic field varied to obtain the spectrum.

Conventional ion cyclotron resonance mass spectrometry has not been a very successful technique for routine analysis, particularly since it is not much good for samples with masses greater than 400 daltons. It also requires about 10 minutes to obtain a spectrum over the mass range 15 to 400. Varian, Inc., of Palo Alto, California, sold about 27 conventional spectrometers before the company dropped out of the field about 10 years ago. Other companies have flirted with the technique, but no one is now selling conventional ion cyclotron resonance spectrometers. This situation may change with the application of Fourier transform techniques.

Fourier transform was first applied to ion cyclotron resonance spectrometry about 3 years ago by Melvin Comisarow and Alan G. Marshall of the University of British Columbia in Vancouver. They fitted the sample chamber with a computer-controlled oscillator that sweeps through the radio-frequency spectrum as rapidly as possible, exciting all the ions in the sample chamber (the spectrum is too broad to stimulate it all simultaneously). The decay of the kinetic energy of the excited ions then induces a complex signal in a second plate in the cell. This analog signal is amplified, converted into digital form, and stored in a minicomputer for numerical Fourier transformation. A large number of signals can be accumulated before the transformation, and the ultimate sensitivity is proportional to the square root of the number obtained. A complete mass spectrum can be obtained in as little as 20 milliseconds, but higher resolution can require several seconds. The upper mass limit of the spectrum is determined only by the strength of the magnetic field. William J. Horsley of the Nicolet Technology Corporation, Mountain View, California, says he has obtained a spectrum of a compound with a mass of 5000 daltons.

The FT-ICR spectrometer, says Charles L. Wilkins of the University of Nebraska, has the potential for resolution better than that obtainable with the best commercial instruments now available, and at a substantially lower price. Comisarow has already demonstrated a mass resolution of 1 part in 250,000 and expects to improve on this. In contrast, a conventional, inexpensive mass spectrometer, such as a quadruple, has a resolution of about 1 part in 1000, and the best instruments available have a guaranteed resolution of about 1 part in 150,000. This kind of increase in resolution is not observed with Fourier transform nuclear magnetic resonance spectrometry.

Unlike conventional mass spectrometers, Wilkins says, the FT-ICR spectrometer has its highest resolution at the low mass end of the scale. It is thus the only available instrument, for example, that is capable of distinguishing between helium-3 and tritium solely on the basis of mass. The instrument should thus find a ready application, he says, in monitoring groundwater around a nuclear power plant to check for leakage of coolant water. It would also be useful for monitoring events in a fusion power plant, since those are two of the major species that would be involved.

One potential application of FT-ICR that has been widely discussed is gas chromatography–mass spectrometry. There are several commercial systems available for performing mass spectrometry on the effluent from a gas chromatograph. But these instruments, Wilkins says, require as much as 1 second to produce a spectrum and have a resolution of only about 1 part in 1000. The FT-ICR spectrometer, in contrast, can produce a spectrum with a resolution of 1 part in 20,000 or 30,000—good enough for elemental analysis—in less than 200 milliseconds. Wilkins and Michael L. Gross are now developing a prototype interface to connect the gas chromatograph to the instrument.

There are apparently only three FT-ICR spectrometers in existence. Comisarow has one that he has constructed himself, Nicolet has a prototype commercial instrument, and Wilkins and Gross have one that is almost finished. The Nicolet people have been promising for at least a year that their instrument will be on the market soon, but they have had problems obtaining what they consider to be satisfactory relative peak intensities (that is, if there are 9 parts of an isotope with mass 91 and 1 part with mass 92, the relative peak intensities should be 9 to 1). Wilkins suggests that this problem may result both from cell design and from the fact that the ions are out of phase with each other since they are not excited simultaneously. Nicolet hopes to solve the problem, but may bring the instrument out soon anyway. Nicolet president Jerry Holcombe says that the instrument will probably be available to customers this summer. The selling price is expected to be about $150,000, which compares favorably with the $400,000 cost of a conventional ultrahigh-resolution instrument.

Many people may not need to wait for a commercial instrument, however. There are now available a large number of used nuclear magnetic resonance spectrometers in which the magnets do not produce fields sufficiently homogeneous for high resolution. Because of differences between the two techniques, however, these magnets still have more than enough homogeneity for FT-ICR. Anyone with a reasonable knowledge of electronics and Fourier transform technology should thus be able to construct his own spectrometer at relatively little expense.

Before too many people plunge into the field, however, it will be necessary for the potential of FT-ICR to be demonstrated in practice. That is what the three active groups are doing now. Wilkins and Gross, for example, are planning to compare spectrums obtained on their instrument with those obtained on an ultrahigh-resolution MS-5076 spectrometer produced by AEI Scientific Apparatus. In this way, they hope to provide benchmarks to show precisely how good the technique is. The other investigators are using different approaches to accomplish the same end. The experiments to date have been only prototypes which serve to indicate some of the features of the FT-ICR method, but the results are encouraging and of sufficient interest to warrant further application of the technique.

—THOMAS H. MAUGH II

Smart Instruments: Microprocessors Not the Whole Story

One evident characteristic of the Pittsburgh Conference was the spate of new products either introduced or not previously shown at the laboratory equipment exposition. Many of the new instruments were equipped with microprocessors; it would not be much of an exaggeration to say that every other booth prominently featured microprocessor-controlled apparatuses of an astounding variety. At the same time, it was abundantly clear that these ultraminiature processor units were far from the whole laboratory computer story. For the most part, data-handling applications and laboratory automation systems continue to require programmable calculators or minicomputers. Some of the minicomputer data systems exhibited were, however, actually built around one or more microprocessors.

Microprocessors are programmable integrated circuits on one or a few silicon chips and are the equivalent of the central processor unit of a computer. Because they pack so much computing power into such a small space for, in many cases, only a few dollars, these circuits have been hailed as the devices that will make the "electronics revolution" really take off. Intelligent instruments for laboratory use that can control and monitor their own operation and log and manipulate the data they produce are expected to be one manifestation of this revolution.

What probably characterizes the progress made by microprocessors in instrumentation this year is that they are no longer confined to the top-of-the-line Cadillac models. Embracing this trend wholeheartedly is the family of instruments shown by the Perkin-Elmer Corporation, Norwalk, Connecticut. Perkin-Elmer introduced 20 new instruments at the 1977 Pittsburgh Conference, and 12 of them incorporate microprocessors to handle various aspects of instrument control or data reduction. For example, the company exhibited three new atomic absorption spectrophotometers that span the low-to-medium price-performance range (base price from $6000 to $9000), and all are microprocessor-controlled. It is, said a Perkin-Elmer spokesman, still possible to buy an atomic absorption apparatus without a microprocessor, but no one from the company will show one unless specifically asked.

The number and variety of microprocessor-equipped instruments at the Pittsburgh Conference was far too great to permit even listing them all. The following three examples may, however, indicate the ways manufacturers are using the tiny computing chips.

The Varian Instrument Division, Palo Alto, California, displayed two atomic absorption spectrophotometers equipped with the "computer on a chip." The top-of-the-line model, a double-beam instrument, incorporates all digital circuitry, a feature that reduces instrumental sensitivity to external sources of electrical noise. A microprocessor-like preprogrammed circuit, operated by way of a keyboard, is used to enter the flame setting desired, to monitor the gas-flow system, and to shut down the instrument in emergencies. A second microprocessor, operated from a separate keyboard, can do some kinds of data handling, such as reporting concentrations, peak heights, peak areas, and the mean value of a series of measurements. An optional automatic sample dispenser permits automated injection of up to 25 different samples in succession. The price of the spectrophotometer ranges from $9,600 to $12,900, depending on the options selected.

Not all instrument settings are by way of the microprocessors; certain parameters which are not changed often, such as lamp brightness, must be entered via rotary switches. This necessity precludes total automation because a remote computer cannot physically turn switches. A Varian spokesman says it would be too expensive to completely automate the spectrophotometer. The company also exhibited a lower-priced ($6600 base price) instrument that uses one microprocessor to control the gas and flame operation only.

Orion Research Inc., Cambridge, Massachusetts, introduced a digital specific