

## Chemistry Division - Marion Thurnauer

### Description

Chemistry has been a core capability at Argonne National Laboratory since its founding to explore the peaceful uses of atomic energy. The Chemistry Division conducts a program of long-term fundamental research that addresses problems in the chemical and nuclear sciences that are related to the mission-oriented activities of the Department of Energy. The Chemistry Division maintains a large number of laboratories for organic, inorganic, physical chemistries and for work with radioactive materials. Our current research encompasses a wide range of programs including nanoscience, radiation and photochemistry, photosynthesis, metal clusters, theoretical and experiment chemical dynamics, carbon chemistry, actinide element and separation science, and computational molecular materials studies. The work is supported predominantly by Basic Energy Sciences, Department of Energy. For more information see <http://www.chm.anl.gov>.

### Scientific Facilities

#### Chemistry Hot Cell Complex

This shielded radiological facility is designed to allow work with highly radioactive materials or large amounts of moderately radioactive materials through the use of remote manipulators. Most of this facility is currently maintained in standby conditions. The cave complex is a three story reinforced concrete structure of monolithic construction. The Hot Cell Facility houses 12 isolated hot laboratories, providing experimental flexibility within one main cell complex. A common shielded transport corridor on the first and second floors of the facility allows for entrance and exit of highly radioactive materials from any cell without disrupting work being done in other cells. Maximum shielding strength is provided on the lower floor of the facility. Magnetite concrete walls, 1.2 m thick, shield against 1 million curies of 1 MeV gamma radiation or a point source emitting  $10^{12}$  fission neutrons per second. Three of the four cells on the lower level have this shielding capability. The fourth cell on the lower floor is constructed of ordinary concrete and houses a high purity atmosphere (less than 25 parts per million oxygen and water vapor) originally designed for plutonium metallurgical work. The upper floor provide shielding against 1,000 curies of 1 MeV gamma radiation. There are 40 windows in the Hot cell facility, each containing a zinc bromide solution of density  $2.5 \text{ gm/cm}^3$ . Thirty seven of these window stations are equipped with master-slave manipulators. Materials requiring high-level shielding are transported around the cell complex by a system of radio controlled carts. These carts are remotely operated and travel to any of the 12 cells. The loading dock of the complex can handle shipping casks weighing up to 31.8 tonnes (35 tons). A main crane inside the facility can haul up to 4.5 tonnes. Facility equipment includes a Cobalt-60 source (5000 to 10000 curies) for gamma irradiation.

#### M-Wing Facility

This laboratory complex is an integrated, purpose-built facility designed for work with alpha-emitting radionuclides (transuranium actinides) when exposure levels are expected to be below those requiring the shielded cave facility. It is co-located with the Hot Cell Complex in M-Wing of Argonne's Chemistry Division. Conventional and radiological fume hoods, gloved box enclosures, controlled atmosphere enclosures, and vacuum line facilities are available for the synthesis and characterization of both organic and inorganic materials containing radioactive materials in gaseous, liquid, or solid samples. A full array of radioanalytical counting equipment, including  $\alpha$ -,  $\beta$ -, and  $\gamma$ -spectrometers, multiple-sample-capable liquid scintillation and  $\gamma$ -counters and a gas-flow proportional counter are available. Conventional instrumentation located within this facility (and so available for the characterization of radioactive materials) include a variety of UV-visible-near IR spectrophotometers, FT-infrared spectrometers, a full array of electrochemical equipment, Mössbauer spectrometer, a 300 MHz NMR spectrometer, a variety of gas and liquid chromatographs, several calorimeters, single crystal and powder X-ray diffractometers and a rapid kinetics spectrometer are in place along with the appropriate expertise for their use. A completely equipped organic synthesis laboratory is also available. Expertise and equipment appropriate to the application of all manner of conventional separations techniques for radioactive materials are also present. Our in-depth understanding of radioactive materials and their effects on materials and

people allow measured judgments to be made of the hazards associated with various types of radioactive materials. Finally, our Health Physics unit includes a number of fully qualified expert technicians, a Health Physicist, and all standard radiation detection and monitoring equipment.

### Actinide Facility

The Actinide Facility is mandated to assist with experiments at the Advanced Photon Source (APS) that involve samples containing these elements. The Actinide Facility is a component of our infrastructure for handling radioactive samples, developing safety protocols and sample containment, and advising experimenters. The Facility is co-located with the M-Wing complex hot laboratories in M-Wing of Argonne's Chemistry Division. M-Wing, together with the Facility, have personnel familiar with the handling of radioactive materials, administrative protocols, and many of the technical requirements for the wide variety of synchrotron-based experiments available at the APS. All analytical capabilities associated with the M-Wing Facility are also available for characterization of samples prepared within this Actinide facility.

### Basic Energy Sciences Synchrotron Radiation Center (BESSRC)

BESSRC at the Advanced Photon Source (APS), Argonne National Laboratory is formed of scientists from the Chemistry, Materials Science, Geosciences and Physics Divisions at ANL and researchers from Northern Illinois University. Intense x-rays from APS are used for spectroscopy (EXAFS spectroscopy, XANES spectroscopy scattering, time-dependent spectroscopy of excited states) high-energy diffraction, scattering (magnetic Compton scattering, elastic and inelastic scattering, small-angle scattering), EXAFS and XANES spectroscopy of actinides and lanthanides, mineral-liquid interface characterization by x-ray scattering and spectroscopy.

### Electron Paramagnetic Unit

High-resolution, multi-frequency (9GHz –140 GHz), pulsed (100 ns time resolution) and continuous wave (cw) electron paramagnetic resonance (EPR) spectroscopic techniques are available in the Chemistry division at ANL. We have four spectrometers: commercial cw X-band (9 GHz) and Q-band (35 GHz) Bruker ESP300E and cw X-band Varian E9 spectrometers, home-built pulsed X-band and cw/pulsed D-band (140 GHz) EPR machines. EPR spectroscopy is a method that is highly sensitive to free radicals and requires samples with unpaired electrons. When an electron is placed in a magnetic field, the states that have the magnetic moment oriented in different directions with respect to the applied field have different energies. Transitions between these states may be induced by absorption of light in the microwave region and the method for detecting these transitions is called electron paramagnetic resonance spectroscopy.

### Mass Spectrometry Unit

The purpose of the Mass Spectrometry Unit is to aid researchers in their chemical characterization and identification endeavors through molecular weight determinations and structure of novel synthetic, natural products, peptides, proteins, polymers, and unknown chemical compounds. Mass analyses are conceptually performed by "weighing individual charged molecules". Structural, purity, quantitative analyses, and separation techniques interfaced with MS are available. Structural analyses include molecular weight analysis, GC, HPLC, and tandem MS. Mass spectrometry unit has five mass spectrometers including laser desorption and high resolution (40,000) mass spectrometers.

### NMR Unit

The nuclear magnetic resonance (NMR) unit is concerned with the chemical identification and structural analysis of organic and inorganic substances in liquid or solid form. The unit is equipped with six NMR spectrometers that are able to perform modern 2D/3D NMR analyses on complex mixtures. A new system is also available for special use for hazardous and radioactive materials, having complete multi-nuclear analysis capabilities. Two high-field NMR systems have been modified for use in magnetic resonance imaging (MRI) experiments. The MRI systems are linked to the Chemistry Division computation network where complex algorithms are used to analyze large NMR data arrays for visualization and display. The unit has personnel familiar with the handling of radioactivity or chemical agents (weapons of mass destruction), establishing safety protocols and sample containment, and advising experimenters.

### Pulsed electron accelerators (20-MeV electron linac, 3-MeV Van de Graff)

The Argonne pulse radiolysis facility is made up of two accelerators, a 20-MeV linac and a 3 MeV Van de Graaff. Although the accelerator was designed for chemical research, it has been used for a wide variety of experiments. Recent nonchemical experiments include the verification of radiation monitors under pulse conditions, the determination of cavity modes induced in cavities by a short pulse of electrons, the verification of the theory of wakefield acceleration, the role of x-rays in materials embrittlement and generation of shockwaves in liquid hydrogen detectors for muon accelerators. For chemical experiments, the moderate energy of the electron accelerator (maximum energy of 21 MeV transient mode, 14 MeV steady state mode) generates transient species without excessive nuclear activation. The pulse width can be varied from 25 ps to 10 ms. In liquids, transient concentrations up to 20 mM can be generated with the 25-ps pulse and concentrations more than 10 mM can be generated with the longest pulse. Instrumentation for the measurement of chemical processes allows kinetic spectrophotometric absorption and emission and fast conductivity measurements. A 2-ps streak camera with custom software is available for fast emission measurements. Very high time resolution measurements that make use of the short pulse capability of the Linac can also be made. All data acquisition equipment is computer interfaced to provide accurate data reduction. Sample preparation and handling facilities are available for solid, and handling facilities are available for solid, liquid, and gaseous samples.

The low noise of the 3-MeV Van de Graaff accelerator makes it an ideal tool for the use of magnetic resonance measurements of radicals and radical ions. Irradiations are possible using pulses as short as 10 ns. Continuous DC irradiation is also possible. Spin resonance equipment, including time-resolved fluorescence-detected magnetic resonance equipment is available for use. These provide sensitive and selective measurement of radical systems. Facilities for low-temperature studies are also available.

### Biological Materials Growth Facility

This facility produces photosynthetic microorganisms, photosynthetic proteins, and pigments 99% enriched in  $^2\text{H}$  and other stable isotopes that are uniquely useful for analysis of electron transfer and hierarchical structures in photosynthesis by a variety of spectroscopies and particle scattering. We have been growing cyanobacteria, thermophile mutant cyanobacteria, and algae both protonated and deuterated, in quantities of tens of grams for about 4 decades.

The facility is poised to embark into a new area, the study of algal and bacterial biofilm formation with emphasis on a better understanding of how bacteria and algae attach, grow and detach.

The Research Development Testing & Evaluation (RDT&E) Dilute Facility of Environmental Systems Division is physically located in the Chemistry Building. The facility is designed and certified to accept and handle concentrations of chemical agents. The facility is composed of two laboratories which meet all of the safety and security requirements of Army Regulation 50-6. There are joint efforts with CHM to purchase an advanced GC/FT-IR instrument and ongoing collaborations in research.

## Analytical Tools

### Analytical Tool

High-Field Nuclear Magnetic Resonance (NMR) Spectroscopy

### Description

Chemical characterization tool

### Typical Uses

Identification of chemical warfare agents through H-1, F-19 and P-31 isotopes

### Sample Requirements

Solubility in common solvents

### Sample Preparation

Dissolve analyte in deuterated solvent within NMR sample tube

### Detection Limits

10<sup>2</sup>g – 1 mg

### Accuracy

Quantitation to +/- 2%

### Typical Interferences

None

### Facility

Chemistry Division NMR Laboratory

### Contacts

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### Key Words

NMR; Chemical warfare agents

## Analytical Tool

GC-Matrix Isolation FTIR-Mass Spectrometer

## Description

The system consists of a conventional Gas Chromatograph coupled with both a mass spectrometer and a matrix isolation Fourier transform infrared spectrometer. Samples are introduced by either conventional or pyrolytic injection, and products allowed to elute through a chromatographic column to separate individual analytes. Analytes are then simultaneously detected by both mass spectrometry and matrix isolation FTIR spectroscopy. This dual detection system allows accurate determination of the structure of unknown eluants, differentiation of closely related compounds and sensitive detection of trace levels of minor components of complex mixtures.

## Typical Uses

The system is used for accurate determination of the structural characteristics of unknown organic compounds including individual components of complex matrices/mixtures. A wide range of compounds can be determined. Any GC amenable compound can be analyzed by conventional injection. Utilizing pyrolytic injection, organic polymers (natural or synthetic) can be characterized (by analysis of component monomers).

## Sample Requirements

System requires only very small samples. Depending on the complexity of the mixture, and the concentration of the analyte(s) of interest in the mixture, mg size samples are often sufficient for accurate analysis. In some cases, where the concentration of the analytes of interest are in high concentration, as little as a few tens of micrograms may be sufficient for analysis.

## Sample Preparation

Dependant on the type of sample to be analyzed. Analytes of interest may be solids, liquids or gaseous. May be pure compounds, complex mixtures or absorbed in (or on) an inert matrix (rock, soil or absorbant)

## Detection Limits

Individual eluants are detected at the level of hundreds of monograms per compound. Detection limits for individual compounds are structure dependant

## Accuracy

System is intended to identify the structural characteristics of unknown organic compounds. In most cases structures can be assigned with a very high degree of confidence.

## Typical Interferences

Ability to detect and assign individual eluants is limited only by (i) the ability to separate individual eluants of interest from other sample components by GC. This varies depending on the specific nature of the eluant and the complexity of the matrix/mixture.

## Facility

Chemistry Division

## Contacts

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## Key Words

infrared

## Analytical Tool

Kratos MALDI III mass spectrometer

## Description

This instrument is particularly useful for high molecular weight samples such as proteins and is capable of analyzing samples containing species with molecular weights greater up to and beyond 100,000. One to two microliters of the sample in solution is mixed with or deposited on a UV-absorbing matrix on a stainless steel target and allowed to dry. The sample must be soluble in a solvent that will air-dry. Liquid matrices cannot be used. The laser light (337 nm) strikes the target and ions and neutrals are desorbed. The matrix greatly increases the desorption efficiency. MALDI produces both positive and negative ions of the form (M+H)<sup>+</sup> and (M-H)<sup>-</sup>. Fullerenes do not require matrix and produce radical ions. The technique also produces multiply charged ions, usually up to +3, as well as dimers, trimers, etc.

## Typical Uses

Large organic molecule identification, protein characterization tool. MALDI is an ionization technique for large and/or labile molecules such as peptides, proteins, polymers, dendrimers, and fullerenes

## Sample Requirements

Low levels of some salts, buffers, and detergents can be tolerated as well as less than 2% of glycerol. Water, acetonitrile, methanol, THF, and other organic solvents can be used. DMSO and DMF cannot be used.

Sample size depends on molecular weight, the higher the molecular weight the less the sample that is needed. Samples are dissolved in a suitable solvent. Proteins and peptides are usually dissolved in H<sub>2</sub>O with 0.1% TFA. 1-10 pmol/microliter is needed for MW 1000, 5-10 pmol/microliter for MW 20,000, and 1 pmol/microliter is needed for MW 60-100,000. In some cases as little as 250 fmole of sample is needed on the target. The upper mass limit for MALDI is about 350,000 amu. MALDI is useful for mixtures such as tryptic digests since the technique produces predominantly (M+H)<sup>+</sup> species for lower molecular weight compounds. Samples should be submitted in small Eppendorf-type tubes.

MALDI can handle mixtures. As a quick rule of thumb, 1 mg is always enough.

## Sample Preparation

There should be no excess salts in the sample. Buffers such as phosphate and HEPES are fatal to these techniques. Weigh out your sample into a small screw-top vial. For very small amounts of sample, a Reacti-Vial is best. This is especially true for oils. Oil smeared around the inside of a regular vial is very difficult to get out. For high molecular weight biomolecules, such as peptides, an Eppendorf-like tube is required. Use an inert cap liner, such as aluminum foil or Teflon, for screw-top vials since we may use a solvent which will leach plasticizers out of the caps. Solvent is always used for FD, FAB, ESI, MALDI, GC/MS, and LC/MS. Accurate weighing is mandatory for FD, FAB, GC/MS, and LC/MS and is important for other techniques. Sample size 250 fmole - 500 pmole

## Detection Limits

Sample size 250 fmole - 500 pmole.

## Accuracy

Mass accuracy depends on mass, but typically +/- 0.1 amu

## Typical Interferences

The mass spectrum of a mixture is a confusing jumble of molecular ions and fragments from each component. Also, the signal for any one component will be weaker than if it were pure. To make matters worse, the spectra of some components may be totally suppressed by the others

### Facility

Mass spectrometry facility in CHM Division

### Contacts

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### Key Words

Mass spectrometry, proteins, large organic molecule characterization

### Analytical Tool

HP 1100 quat pump liquid chromatograph diode array detector with Thermoquest/Finnigan LCQ ion trap mass spectrometer

### Description

The Thermoquest LCQ mass spectrometer is equipped with a Hewlett LC1100 liquid chromatograph and photo diode array (UV) detector and an ion trap mass analyzer with a m/z limit of 4000 da. Even though this instrument has a limited m/z range, it has the capability to determine masses of significantly larger molecules as described and illustrated below. The LC instrument equipped with atmospheric ionization (API) and electrospray ionization (ESI) ion sources. ESI is achieved by supplying a solution through a fine needle held at a high potential (1-5 kV) in close proximity to a much lower counter electrode. The high electrostatic field produces an aerosol when the electrostatic forces exceed the cohesive forces of the solution. Ionization is achieved by ion evaporation from the aerosol particles and is characterized by multiple charging of the analyte. Multiple charging produces analytes with several to many charges dependent on chemical properties of the analyte. Since MS measures the mass to charge (m/z) ratio of analytes, multiple charging can essentially extend the effective mass range of a mass spectrometer.

### Typical Uses

Analysis of nonvolatile polar organic, high molecular weight compounds and inorganic compounds in matrices.

### Sample Requirements

Nanograms of material

### Sample Preparation

Samples are in solvents and injected into liquid chromatograph for separation, detected by diode array detector, and sent through an interface to the mass spectrometer. An autosampler can handle up to 100 samples unattended. A variety of LC columns are available, from reversed phase (C18) to size exclusion columns.

### Detection Limits

Parts-per-million to parts-per-billion depending on sample analyzed

### Accuracy

Mass accuracy of 1 amu.

### Typical Interferences

none

### Facility

Mass Spectrometry unit

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### Key Words

Mass spectrometry, chromatography



### Analytical Tool

300 MHz Varian NMR

### Description

300 MHz Varian NMR for solutions  
Equipped with a broadband Probe

### Typical Uses

Routine structural elucidation of organic chemicals  
Proton, Carbon, and Phosphorus Shift determinations  
The NMR is in a radiological controlled area and can be used with samples that contain radioactive materials

### Sample Requirements

Ideally 50 milligrams or more.

### Sample Preparation

Dissolve sample into 0.75 ml of appropriate deuterated solvent

### Detection Limits

Millimolar concentrations

### Accuracy

Usually within a few percent when measuring concentration versus a standard

### Typical Interferences

Paramagnetic nuclei

### Facility

Chemistry Division, Argonne National Laboratory, Heavy Elements and Separation Science groups

### Contacts

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### Key Words

NMR, Proton, Carbon, Phosphorus, Broadband NMR, Structural elucidation, Radioactive Sample

### Analytical Tool

Kratos MS50 High Resolution Mass Spectrometer

### Description

The MS 50 is a three sector mass spectrometer that can routinely perform at 20,000 to 40,000 resolution.

### Typical Uses

Analysis of organic compounds, even in complex mixtures

### Sample Requirements

Samples have to be organic liquids or solids.

### Sample Preparation

Samples should be free of water.

### Detection Limits

The working detection limit is between part per million and part per billion.

### Accuracy

The mass accuracy is 1 in 10,000.

### Typical Interferences

none

### Facility

Mass Spectrometry Unit

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### Key Words

High resolution  
Mass spectrometer  
Organic analysis

## Analytical Tool

### Atom Trap Trace Analysis

#### Description

Atoms are trapped in a magneto-optic trap (MOT) using laser cooling techniques. The process of cooling and trapping atoms has extraordinary isotopic selectivity, better than a part-per-trillion. For example, a single atom of  $^{81}\text{Kr}$  can be detected amongst a sea of  $10^{12}$  Kr atoms of other isotopes.

#### Typical Uses

Since isotopes of alkali, alkaline earth and rare gases have all been trapped using laser techniques – isotopic trace analysis using these atoms would be possible with selectivity in the part-per-trillion range. One application of interest for counter-terrorism would be the detection of  $^{85}\text{Kr}$  using atmospheric samples as a monitor of fission activity near suspected sites.\_

#### Sample Requirements

Differs for different elements due to the different operation of the source. For  $^{85}\text{Kr}$ , a sample of 0.1 cc STP is sufficient for a 10% measurement which would take 15 min.

#### Sample Preparation

Elements must be made into an effusive atomic beam. Various sources have been investigated over the course of the past 60 years – see, e.g. Norman Ramsay's classic book "Molecular Beams". Depending upon the application, the source would be designed to optimize the pure atomic beam while minimizing the consumption rate. For the krypton isotopes, we found that a rf discharge source enhanced the flux by a factor of ten over the standard DC discharge source.

Detection Limits: Can detect a single atom of a particular isotope.

Accuracy: Depends upon the counting time. A typical count rate for  $^{85}\text{Kr}$  is 420 counts/hr.

Typical Interferences: None yet observed.

Facility: Individual investigator laboratory (No national facility.)

#### Contacts

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#### Key Words

Atom trap, single atom detection

## Analytical Tool

### Laser-Induced Fluorescence Analysis of Heavy Element Ions

#### Description

Highly sensitive technique based on laser excitation of characteristic f-electron states of heavy element ions in condensed phases followed by time- and wavelength-resolution of the resulting luminescence from the excited ion. This technique achieves count rates that range from hundreds to more than a million times higher than those achieved using nuclear counting methods for the same quantity of a radioactive heavy element isotope. In the case of liquid phase samples, the standard addition method is used to quantify the concentration of a particular heavy element ion that is present.

#### Typical Uses

Determination of heavy element ions in solids and liquids.

#### Sample Requirements

The heavy element fraction of a sample material is recovered by chemical separation using ion exchange followed by elution or ion chromatography to achieve a degree elemental separation.

#### Sample Preparation

The material to be analyzed must be processed to render its heavy element content soluble in aqueous solution.

#### Detection Limits

Range from a few hundred heavy element ions to a few billion heavy element ions, depending on the heavy element, its oxidation state, and the presence of interfering ions.

#### Accuracy

Relative standard deviations of typically  $\pm 2\%$ , in comparison with a standard sample, are achieved.

#### Typical Interferences

Transition metal elements, such as iron, cobalt, and nickel, can interfere if they are only partially removed during chemical separation processing. Determining a low abundance heavy element ion in the presence of high concentrations of other heavy element ions may require additional sample processing to improve the degree of elemental separation achieved.

#### Facility

Analyses are carried out in a laser-induced fluorescence laboratory that is approved for use with trace to macroscopic amounts of radionuclides.

#### Contacts

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#### Key Words

Fluorescence of transition metal elements

## Analytical Tool

### Electron Paramagnetic Resonance (EPR) Spectroscopy

#### Description

The information obtained from EPR spectra includes both the electronic structure of the unpaired electron, i.e. where the electron is located in the system of study, and the dynamics of the electron, i.e. movement of the electron. EPR spectroscopy provides a relatively fast way to both detect and identify paramagnetic species as well as monitor the time-dependent formation of radical species under different conditions.

#### Typical Uses

EPR spectroscopic techniques are widely used in many fields of study, including chemistry, biology, physics, environmental sciences, and material science. EPR spectroscopy has been applied to study both the structure and dynamics in a variety of systems including: metalloproteins, nanocomposites, biopolymers, semiconductors, inorganic and organic complexes, and cathode and anode materials.

#### Sample Requirements

EPR signals will be observed only for samples having unpaired electrons. Samples can be analyzed as solids or liquids. Sample volumes range from 1- 100 microliters dependent on the frequency (9, 35, or 140 GHz) of measurement.

#### Sample Preparation

No special sample preparation is needed. Samples are placed directly in EPR tube for measurement.

#### Detection Limit

EPR is a very sensitive technique. Specific detection limits depend on the frequency (9, 35, or 140 GHz) of measurement and the type of radical species. At X-band high spin ferric ions can be detected at ppm concentrations.

#### Accuracy

Observed EPR spectra are sample specific.

#### Typical Interferences

None

#### Facility

Advanced EPR Facility

#### Contacts

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#### Key words

EPR, magnetic resonance, radicals, unpaired electrons

## **Other Facilities**

### Argonne Premium Coal Sample Facility

The purpose of the Argonne Premium Coal Sample Program is to supply highly uniform, premium (unexposed to oxygen) coal samples to researchers investigating coal structure, properties and behavior, and to maintain accessible databases of published reports describing work carried out with Argonne Premium Coal Samples. The facility is designed to carry out processing of up to 1 ton of material in an inert atmosphere.

## Scientific Glass Blowing Facility

The Chemistry Division at Argonne National Laboratory operates a state-of-the-art scientific glassblowing facility. We are very fortunate to have fourth generation Master Scientific Glassblower, Joseph Gregar on the Chemistry staff. Joe is a world-renowned craftsman and has taught scientific glassblowing all over the country and has mentored many freshman scientific glassblowers. Joe has 36 years of industrial and research glassblowing experience and is continuously attending and instructing at national and local scientific glassblowing conferences to keep up to date with the latest technologies and advances. He also updates the facility with the latest equipment and technology to insure that all requests can be met.

The unique aspect of the Chemistry Division's scientific glassblowing facility is the complete full service treatment received by the researchers. Some shops specialize in optical cell fabrication and others in basic or specialty laboratory glassware. The Chemistry Division glass shop has the experience and talent to do it all. The large scope of our glassblower's experience allows researchers to get very specialized custom optical cells to hold samples with very tiny optical flats incorporated into the cell. Some of these are so small that they have to be fabricated under magnification. On the other end of the spectrum the shop has the talents to fabricate apparatus and vessels as large as 18" in diameter. Also under the same guidance is the ability to construct and design all of the apparatus from different types of glass ranging from soft glass to the Borosilicate glasses to Quartz fabrication. Joe has spent many years dedicated to producing the highest quality Quartz glasswork available in the industry.

The Chemistry Division is very proud of the equipment that outfits the glass shop. Some of these include various glass lathes to accommodate glass fabrication of many different sizes and specialty annealing ovens including one to anneal Quartz products. We are also very proud to have a very special vertical glass lathe for jobs that cannot be fabricated in the conventional horizontal manner. The shop also has up-to date cutting and grinding equipment using high quality diamond cutting wheels and diamond core drilling equipment. For the more demanding drilling the glass shop boasts of its ultrasonic drilling instrument. This is capable of drilling holes of infinite varying shapes and holes down to 0.004" in diameter. The glass shop also has flat wheel grinding and polishing tables to facilitate the fabrication of very intricate parts and flats. All this equipment is maintained by our glassblower to insure everything is in first class working condition.

The glass shop also maintains an extensive inventory of the latest products and supplies to ensure quick response to researcher requests. The glass shop can accommodate a magnitude of jobs from the sophisticated one of a kind prototype to mid-scale production runs. The glass shop seldom sends work outside to be fabricated. By doing this the glass shop is solely in control of the quality assurance of its products. The researchers that utilize the talents of the Chemistry glass shop are pleased and accustomed to receiving only the highest quality glassware available.

## Laser Facilities

The Chemistry Division has approximately 90 research grade lasers including excimer, Nd:YAG, CO<sub>2</sub>, and ps/fs dye. The radiation chemistry group maintains a high powered laser system capable of any wavelength up to 1 Joule in a femtosecond pulse. A terawatt pulsed laser system is now coming on line for pulse radiolysis and x-ray work.