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ABSTRACT

A questionnaire was mailed to 50 major chemistry departments, 112 smaller chemistry departments, and 25 chemical engineering (CE) departments. The survey (included in an appendix) consists of a series of questions on two broad subjects--the current inventory at the surveyed institutions and the needs for instrumentation. Responses were received from 32 major and 71 smaller chemistry departments, and 13 CE departments. (Due to the low response rate from the CE departments, data on these departments does not form part of this report.) Among the findings reported are those indicating that: (1) the median value of on-hand instrumentation at major institutions was $3.3 million while at smaller institutions the median was $104,000; (2) the instruments most commonly mentioned as being either on-hand or most needed are gas and liquid chromatographs, infrared and ultraviolet-visible spectrophotometers, and nuclear magnetic resonance (NMR), mass, and atomic absorption spectrometers; (3) 15 percent of the instrumentation is not fully operational at smaller chemistry departments and 9 percent at major ones; and (4) NMR instrumentation is needed by most of the chemistry departments. One recommendation noted is that funding agencies should enlarge support for instrumentation purchases, for both research and instruction. (JN)

# INSTRUMENTATION NEEDS OF ACADEMIC DEPARTMENTS OF CHEMISTRY

## A SURVEY STUDY

Report

of a joint

Task Force

of the

Committee on Science

and

Committee on Chemistry and Public Affairs

AMERICAN CHEMICAL SOCIETY

April 1984

# ACKNOWLEDGMENTS

The survey was initiated by a Task Force of the ACS Joint Board-Council Committee on Science consisting of Dr. I. Dwaine Eubanks, Dr. Herbert D. Kaesz, and Dr. Jordan J. Bloomfield, Chairman. The survey instrument was prepared, distributed, and the results compiled by Bob Jones and Harry Foxwell of the ACS Department of Professional Services. The survey data were analyzed by a joint Task Force of ComSci and CCPA consisting of Dr. Jordan J. Bloomfield, Dr. Robert T. Paine, Dr. Arthur F. Findeis, Dr. Herman L. Finkbeiner and Dr. Don I. Phillips. Stuart A. Borman, Associate Editor of ANALYTICAL CHEMISTRY, and L. N. McLeland of the ACS Department of Public Affairs, assisted in preparing the narrative report.

AMERICAN CHEMICAL SOCIETY

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## EXECUTIVE SUMMARY

There is almost [illegible] lack of information on the state of instrumentation at U.S. college[illegible]rsity chemistry and chemical engineering departments. In an effort [illegible] this situation, the ACS Committee on Science conducted this survey t[illegible] information on this important subject.

A questionnaire was ma[illegible] to 50 major chemistry departments, 112 smaller chemistry departments, and [illegible]emical engineering departments. The survey consisted of a series of questions on two broad subjects--the current inventory at the surveyed institutions, and the needs for instrumentation. Responses were received from 32 major and 71 smaller chemistry departments, and 13 chemical engineering departments.

Since only 13 chemical [illegible]ineering departments responded, 10% of the total number of departments accredited by the American Institute of Chemical Engineers, reliable statistical analysis of the data on chemical engineering departments was not possible and does not form part of this report.

The data indicated that the median value of on-hand instrumentation at major institutions was \$3.3 million, while at smaller institutions the median was \$104,000. The average age of the instrumentation was between eight and nine years, with the instrumentation at smaller institutions being the older on average.

The seven instruments most commonly mentioned as being either on-hand or most needed were the UV-visible spectrophotometer; gas chromatograph; nuclear magnetic resonance spectrometer; infrared spectrophotometer; mass spectrometer; liquid chromatograph; and atomic absorption spectrometer. These instruments constituted 54.6% of the major institutions' current inventory, and 72.2% of the smaller institutions' inventory.

Instrumentation is usually designated for either research training or undergraduate instruction and sometimes for these two combined. Larger institutions devote three times as much instrumentation for research training as for undergraduate instruction. Predominantly undergraduate institutions devote almost four times the instrumentation for undergraduate instruction as do the major institutions.

Regarding instrument condition, 15% of the instrumentation was not fully operational at smaller chemistry departments and 9% at major ones. Given that the instrumentation is between eight and nine years old, maintenance is a severe problem, particularly at smaller schools where trained technicians are all but nonexistent.

As instrumentation ages, obsolescence becomes more prevalant as well. The increased use of microprocessors, the development of totally new technologies, and the evolutionary improvement of old ones over the past decade have all combined to render instrumentation at the institutions surveyed generally obsolete.

In addition to a profile of the current inventory, an assessment of the respondents' needs for new instrumentation was made. Highlights include:

- a finding that the seven most common instruments make up 73% of the needs at smaller chemistry departments
- NMR instrumentation is needed most by the chemistry departments
- Major institutions plan to use needed instrumentation in roughly the same mix as currently held instrumentation, whereas smaller institutions want to use needed instrumentation for both research and instruction.

Regarding the cost of meeting instrumentation needs, the task force estimates that the 100 major U.S. chemistry departments would need $83.2 million for instrument purchases; the 470 smaller chemistry departments would need $65.5 million. When maintenance and other ancillary costs are included, a total of $500 million may be required.

Among the study recommendations:

- funding agencies should enlarge support for instrumentation purchases, for both research and instruction
- additional ways to finance instrumentation purchases should be explored
- grants for purchase of instrumentation should allow for maintenance costs

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# I. INTRODUCTION

During the past few years concern has grown in the science and engineering community about the increasing age and technical obsolescence of scientific instrumentation in U.S. colleges and universities. Without state-of-the-art instruments, scientific research efforts suffer and the quality of education provided to a new generation of scientists and engineers is placed in jeopardy. This would be particularly true in chemistry which has evolved in the last decades into a very instrument-intensive discipline. In response to these concerns, the Committee on Science of the American Chemical Society (ACS) conducted this survey study on instrumentation needs in academic departments of chemistry and chemical engineering.

## A. Objective of Survey

At the time this survey was initiated, there existed very little data on instrumentation used in chemistry and chemical engineering departments. A 1980 report[1] prepared by the Association of American Universities for the National Science Foundation contained selective information on the instrumentation needs in chemistry gathered through site visits at 16 major research universities. Another study[2] supported by the National Science Foundation to test the feasibility of developing indicators of instrumentation inventory, utilization, and needs in academic institutions was still under way at the time. It was expected to produce sample data representative of 38 academic institutions in four science and engineering subfields, including organic chemistry. Particularly lacking were data on instrumentation in smaller chemistry departments.

The objective of this survey study is to gather data across a broad sample of academic departments of chemistry and chemical engineering in order to obtain an indication of the status of the current inventory of instruments, and the magnitude of the needs for instruments at these departments.

## B. Survey Methodology

In the spring of 1982, the ACS Committee on Science sent a preliminary survey questionnaire to 15 chemistry departments and five chemical engineering departments. The schools surveyed included private and public universities and small colleges.

The survey questionnaire was modified based upon experience with the preliminary survey and comments received from responding departments. This revised questionnaire sought information on the age of the existing inventory, the funding source, condition and use of the inventory, and critical instrument

1 Association of American Universities, The Scientific Instrumentation Needs of Research Universities, Report to NSF, 1980

2 Westat Inc., Indicators of Scientific Research Instrumentation in Academic Institutions: A Feasibility Study, Report to NSF, 1982

needs for the next two to five years. It was sent (with a cover letter assuring that individual reponses will remain confidential) to the following sample of academic departments:

- chemistry departments at 50 major schools
- chemistry departments at 112 smaller schools
- chemical engineering departments at 25 major schools

A systematic sample was selected of one half of the 100 schools with largest R&D expenditures in chemistry, according to National Science Foundation statistics[3]. A systematic sample of 112 of the remaining (that is, not in the top 100) chemistry departments was taken from a mailing list prepared by the ACS Department of Professional Training. This list was sorted by ZIP Code, giving a sample which represented nearly all geographic regions within the U.S. The same NSF publication also lists U.S. colleges and universities ranked by 1979 R&D expenditures in engineering (not chemical engineering). A systematic sample of 25 of those schools with chemical engineering departments was selected.

The questionnaire and cover letter can be found in the Appendix.

## II. DEPARTMENT RESPONSE

### A. Response Rate

The response rate in both categories of chemistry departments was around 60%. The response rate for chemical engineering departments was slightly lower at 52%. The following table summarizes the data on department response rates:

TABLE 1. DEPARTMENT RESPONSE RATES

| | Responses | Number Surveyed | Total* Number | Response Rate | Percentage of Total |
|---|---|---|---|---|---|
| Large Schools | 32 | 50 | 100 | 64% | 32% |
| Small Schools | 71 | 112 | 470 | 63% | 15% |
| Chemical Engineering | 13 | 25 | 130 | 52% | 10% |

*Refers to total number of ACS-accredited departments in each category

[3] National Science Foundation, Academic Science: R&D Funds, FY 1979, 1980

The chemistry and chemical engineering departments responding to the survey are profiled in Table A of the Appendix. The table shows the types of degrees awarded by the departments, and the numbers of faculty, postdoctoral fellows, graduate and undergraduate students. The "small institution" category includes more than four-year colleges. Of the 71 small institutions responding 14 have Ph.D. programs and 13 have M.S. programs as the highest degree programs offered. Similarly, 6 of the small institutions have between 10 and 20 thousand students enrolled and 2 have more than 20,000. For the purpose of this survey, a school is considered "small" when it is not in the top 100 in total R&D expenditures in chemistry, according to figures published by the National Science Foundation.[4]

## B. Quality and Completeness of Data

A few respondents did not complete the questionnaire sections on instrument inventory and needs. They indicated that the task of filling out these sections was too burdensome and time-consuming. However, most respondents did provide data on instruments in the inventory and on instrument needs. Some respondents also noted that their returned questionnaires listed only the major instruments, and did not reflect the total scope of their inventories. It is reasonable to assume that, overall, the data obtained understates the instrument inventory in departments of chemistry and chemical engineering. Some departments also noted that they did not list instruments to which their investigators had access outside the departments, such as instruments in interdisciplinary institutes.

For the units of instrumentation in the inventory that were listed by respondents, there was almost no missing data on condition, funding source, use, operation, year of acquisition, and initial cost. However, a significant number of respondents listed multiple sources of funding for individual instruments. As no code numbers were provided for multiple sources of funding in the list accompanying the questionnaire, tabulation and data handling by computer could not be done without a great amount of additional work.

A few respondents provided data on their instrument inventory, but did not answer the section of the questionnaire dealing with instrument needs. Others indicated that the needs described in their returned questionnaires may change with faculty turnover.

Since only 13 chemical engineering departments responded, 10% of the total number of departments accredited by the American Institute of Chemical Engineers, reliable statistical analysis of the data on chemical engineering departments was not possible and does not form part of this report.

# III. INSTRUMENT INVENTORY

Survey respondents were asked to describe their department's instruments, excluding instruments "that would cost less than $5,000 at today's prices,"

[4] National Science Foundation, Academic Science: R&D Funds, FY 1979, 1980

and excluding computers and computer peripherals. Table B in the Appendix gives a profile of each type of department, in terms of inventory value, annual maintenance costs, and number of equipment personnel employed.

For instance, 25% of the responding chemistry departments at major institutions have instrument inventories of $1.660 million or less; 25% have inventories worth $5.8 million; and the median inventory for such departments is $3.3 million.

Tables C and D in the Appendix give a breakdown of the inventory reported by instrument type, condition, year of purchase, use, and department type. A glossary of instrumentation methods is included in the Appendix.

## A. Mean Age for All Instruments

The mean age of all instruments was computed from the data on year of purchase in Table C. For chemistry departments in smaller schools, the mean age of all instruments was 8.9 years, compared to 8.2 years at chemistry departments in major schools.

## B. Instrument Types

In the overall sample of all three types of departments, the seven instrument types reported most frequently in both the inventory and the list of needed instruments were:

1. Ultraviolet-Visible Spectrophotometer (UV-VIS)
2. Gas Chromatograph (GC)
3. Nuclear Magnetic Resonance (NMR)
4. Infrared Spectrophotometer (IR)
5. Mass Spectrometer (MS)
6. Liquid Chromatography (LC)
7. Atomic Absorption (AA)

For the purpose of this report, the above seven instruments will be referred to as "Seven Common Instruments." The other instruments for which code numbers were provided in the instructions accompanying the survey questionnaire will be identified as "Less Common Instruments." Finally, all instruments not assigned code numbers in the instructions will be referred to as "Other Instruments." Graph 1 shows for each type of department the distribution of the inventory between these three broad categories of instruments.

- The seven common instruments constitute 54.6% of the inventory of chemistry departments in major schools. As would be expected, these instruments make up a greater percentage (72.7%) of the inventory at smaller chemistry departments.

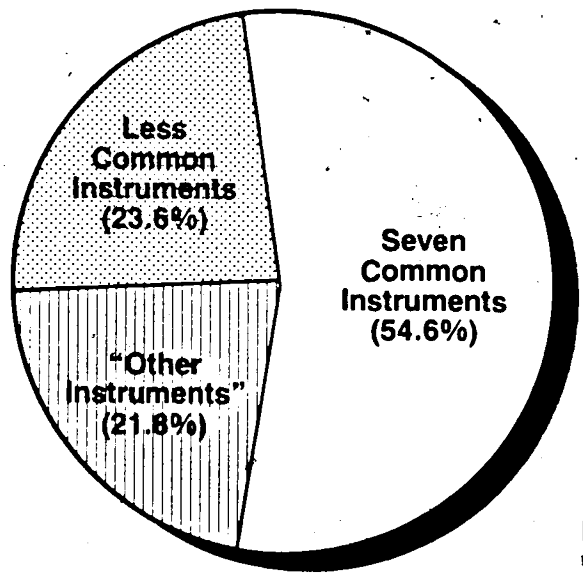
- A greater percentage (21.8%) of the inventory of major research chemistry departments falls in the category of "Other Instruments," compared to the percentage (6.9%) reported by smaller chemistry departments. This difference reflects the diversity of faculty research interests in the larger schools. For example, the "Other Instruments" category in major schools includes lasers and surface science instruments which are presently found less frequently in chemistry departments than the basic, key instruments.

Graph 2 shows the number of units of each of the seven common instruments, as a percentage of the total units of all instruments reported in the inventory.

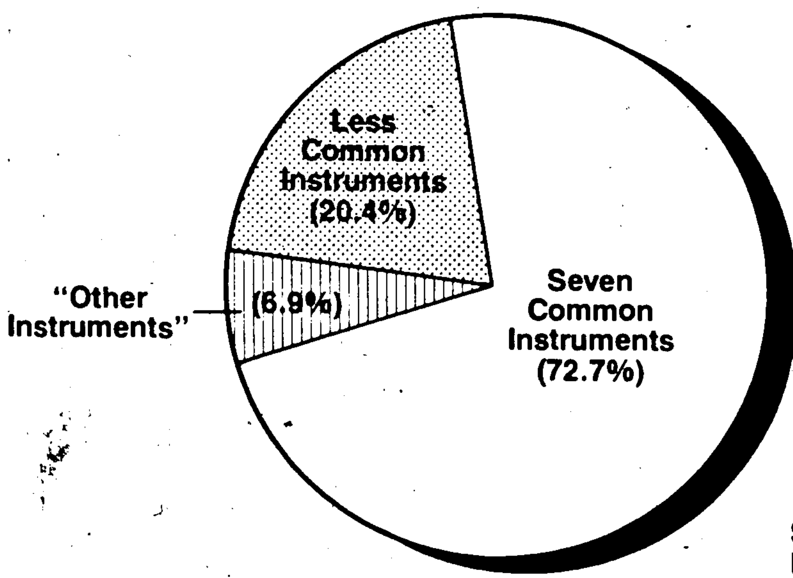
- UV-VIS, IR, GC, and AA instruments constitute a much greater percentage of the total inventory in the smaller chemistry departments, compared to chemistry departments at major institutions. This difference reflects the lower costs of these instruments and the perception that they constitute the minimum inventory needed for instruction purposes.

Graph 1

# **Instrument Inventory** (By Types)



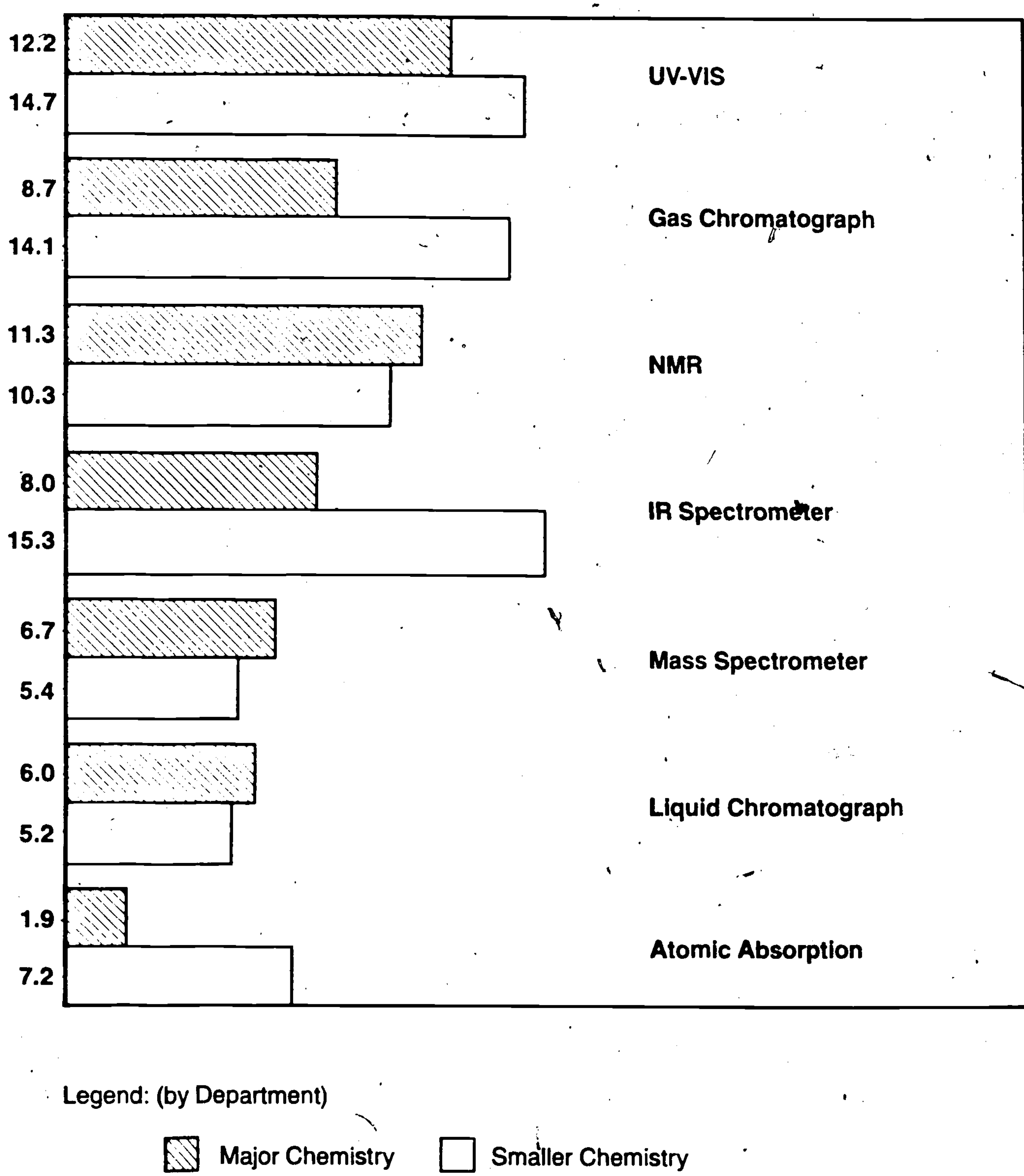

Major Research
Chemistry Departments




Smaller Chemistry
Departments

Graph 2

## Seven Common Instruments in Inventory
(as % of total inventory)



## C. Instrument Use

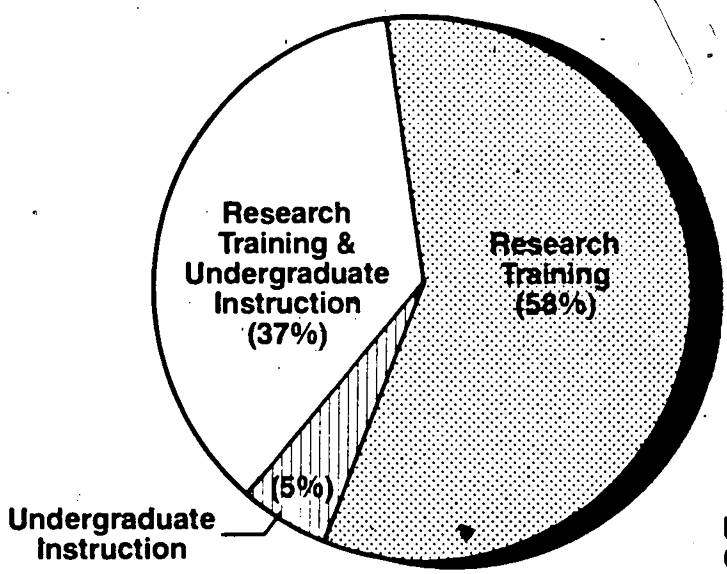
For purposes of brevity three categories of instrument use were designated. By "instruction only" we mean instrumentation in structured undergraduate laboratory instruction. By "research only" we mean training primarily of graduate and postgraduate students although undergraduate students also participate in research training on a selected basis. By "research and instruction" we mean a combination of the above uses. The percentages in Graph 3 relate instrument units in a particular category to all units in the inventory.

- The percentage of the inventory used primarily for undergraduate instruction in smaller chemistry departments (19%) is significantly greater than the corresponding percentage (5%) at major research chemistry departments.

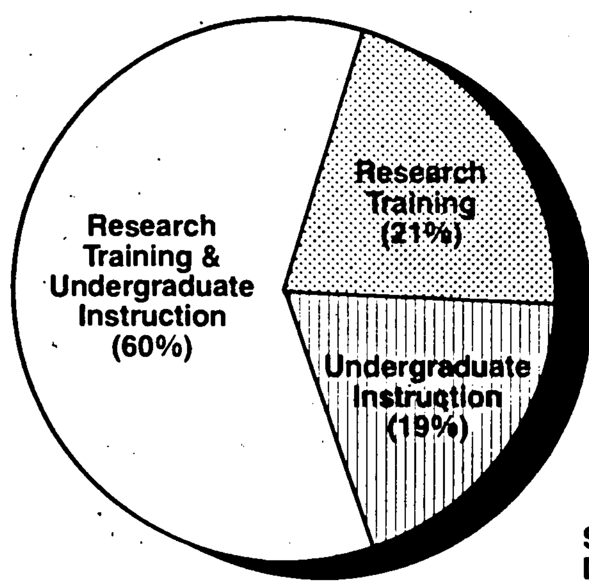
- Conversely, it is not surprising that close to three times as much of the instrumentation inventory at major chemistry departments is used in research training than the amount used in primarily undergraduate departments.

Graph 3

## **Instrument Inventory** (By Use)




Major Research
Chemistry Departments



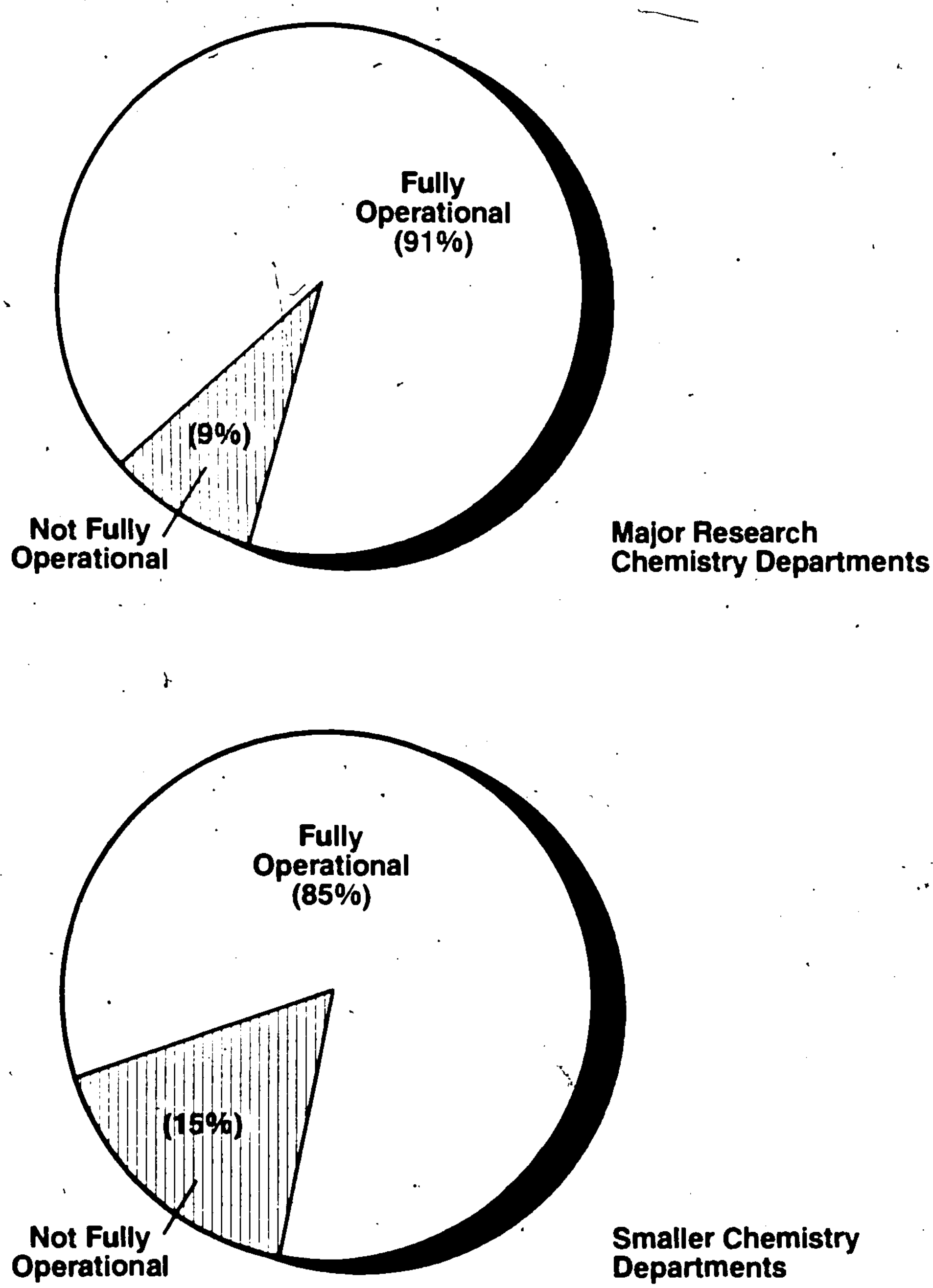

Smaller Chemistry
Departments

D. <u>Instrument Condition</u>

Graph 4 shows the condition of instrumentation currently on-hand at the three types of institutions surveyed.

Graph 4

**Instrument Inventory** (Condition)



## E. Assessment of Instrument Inventory

The mean age for all instrumentation in major research departments responding to the survey was 8.2 years. Instruments from smaller institutions were, on average, even older: 8.9 years for all instruments and over 10 years for the seven common instruments. By today's standards, the instrumentation inventory in departments of chemistry and chemical engineering in the U.S. is too old. A widely held estimate for the optimum useful life of a typical research instrument is about 7 or 8 years. In the experience of laboratory managers, retaining an instrument much beyond that life is unwise. First, maintenance problems are likely to grow rapidly after that period. Second, the instrument probably has become technologically obsolete.

### 1. Maintenance of Aging Instrumentation

The instrument maintenance budgets reported by responding departments were low in comparison to what is believed to be adequate maintenance expenditures, particularly in view of the age of the inventory. Annual maintenance expenditures at major chemistry departments in this survey were around 3% of the total value of the instrument inventory. The number of instrument maintenance personnel (Table B) also appears to be inadequate, especially in the smaller chemistry departments where these specialists are all but nonexistent.

Instrument service problems are evident at the smaller departments. For example, while 93% of the GCs in major departments are in good condition, this figure is only 85% at the smaller schools.

### 2. Technological Obsolescence

Maintaining instruments so that they remain in good working order is only one problem posed by an aging instrument inventory. Another question to be answered is: Does this aging inventory of instruments translate to obsolescence in the inventory? For chemical instrumentation the answer is "Definitely, Yes." The technology of chemical instrumentation has evolved rapidly in the last decade. Our concern is that decade-old instrumentation simply does not reflect the state-of-the-art.

Microprocessors. There are many causes for the rapid obsolescence rate in chemical instrumentation. In the last decade, spectrometers and chromatographs, the cornerstones of chemical instrumentation, have had incorporated in them the state-of-the-art electronics to a high degree, using all the new developments in this field. A series of rapid advances in microprocessor technology has made it possible for many scientists to reap the benefits provided by inexpensive, distributed intelligence in instrument control and in the acquisition, reduction (sorting out), and display of data. Much of this progress has been exhibited in a new breed of commercial instruments that incorporates embedded microcomputer systems. The microcomputer was first used to manipulate controls and perform mathematical treatments on data. More recently it has been used to perform certain logic functions such as comparing generated data to information stored in the memory of the equipment. In many cases, analysis time is reduced by 10- to 100-fold.

An effect of the instrument-computer marriage is that the changes in electronics technology have caused obsolescence in the instrument system. Fourier transform (FT) data reduction is a specific sample.

Fourier transform (FT) data reduction methods have revolutionized IR and NMR spectroscopy by making it possible to obtain spectra of very weak signals, such as IR spectra of planets and C-13 NMR spectra of very large organic molecules. The advent of Fourier transform data reduction in NMR also dramatically reduced the time required for obtaining a C-13 NMR spectra from several hours to a few minutes. FT-NMR spectrometers are also capable of a number of sophisticated multiple-pulse techniques that have opened up a wide range of new applications. A very recent advance in FT-NMR was the introduction of a FT-NMR spectrometer specifically designed for solid samples which would allow investigators to analyze such materials as coal, oil shale, catalysts, and biological specimens in their natural states. Also recently, a Fourier transform IR spectrometer was introduced which also had spectral search capability and contained a large data base of reference FT-IR spectra.

The advent of microprocessors has facilitated a new phenomenon: the interfacing of two instruments which are automated together as a single integrated unit via a hardware interface. The function of the hardware interface is to reconcile the often extremely contradictory output limitations of one instrument and input limitations of the other instrument. Interfacing a GC to a MS is now a very widespread practice. There is a unique compatibility between the two instruments: the GC separates the components of a mixture and delivers them one by one to the MS for spectral identification. This permits the identification of compounds present in quantities as low as $10^{-6}$ to $10^{-10}$ grams. Analyses that were previously impossible or lengthy and inaccurate now take half a day or less.

New Technologies. The last decade has seen the introduction of totally new technologies in chemical instrumentation. An example is supercritical fluid chromatography. Supercritical fluids are very dense gases kept above their critical temperatures (the temperature at which a gas can no longer be compressed to a liquid). Supercritical fluids dissolve compounds that cannot be separated by GC because they are nonvolatile. Their low viscosities and high solvent power also cause compounds to migrate 100 times faster in a chromatography column than liquids do, resulting in a higher resolution (better separation) between compounds. Thus, supercritical fluid chromatography is a separation technique which can be applied to heat-sensitive nonvolatile compounds, with 5 to 10 times the speed and 5 times the resolving power of high performance liquid chromatography (HPLC).

The inductively coupled plasma (ICP) mass spectrometer made its commercial debut recently. It combines the high ionization efficiency of the inductively coupled plasma torch with the sensitivity and selectivity of MS detection. The mass spectra obtained by this method are quite simple and free from the matrix interferences that often complicate traditional mass spectra.

There are now a host of new non-destructive techniques for the study of surfaces, which are going to play an important role in surface analysis and molecular design of catalytic phenomena.

Evolutionary Improvements. In addition to the incorporation of microprocessors, and the introduction of new technologies, there have been marked evolutionary improvements in the last decade in existing technologies. In mass spectrometry (MS), for instance, new sample-handling systems have been developed to extend the range of compounds that can be studied, and new ion sources have made it possible to study larger molecules than ever before, including many compounds of biological interest. Lasers and laser-based instruments will also figure prominently in future developments. The tunable dye laser holds the promise of expanding sensitivity, resolution, and selectivity in spectroscopy. Plotting spectra in the derivative mode or the wavelength modulation mode--all accomplished through electronic hardware--have increased the detectability of minor spectral features. Three dimensional plotting (of excitation wavelength, emission wavelength and emission intensity) is an innovation in fluoroescence spectroscopy which is especially useful for "fingerprinting" crude oils and other complex mixtures. Many areas of scientific research and chemical technology have been aided significantly by the availability of capillary GC and GC-MS which are particularly useful for the resolution of isomers, the analysis of complex mixtures and trace organic compounds, and chromatographic "fingerprinting" of samples.

## IV. INSTRUMENT NEEDS

In addition to a profile of the inventory, an assessment of the needs for new instrumentation at responding institutions also was made. Each department was asked to list instruments that were critically needed. A summary of the responses is shown in Table E of the Appendix.

### A. Instrument Types

Graph 5 shows for each type of department the distribution of the instrument needs between the three broad categories of instruments.

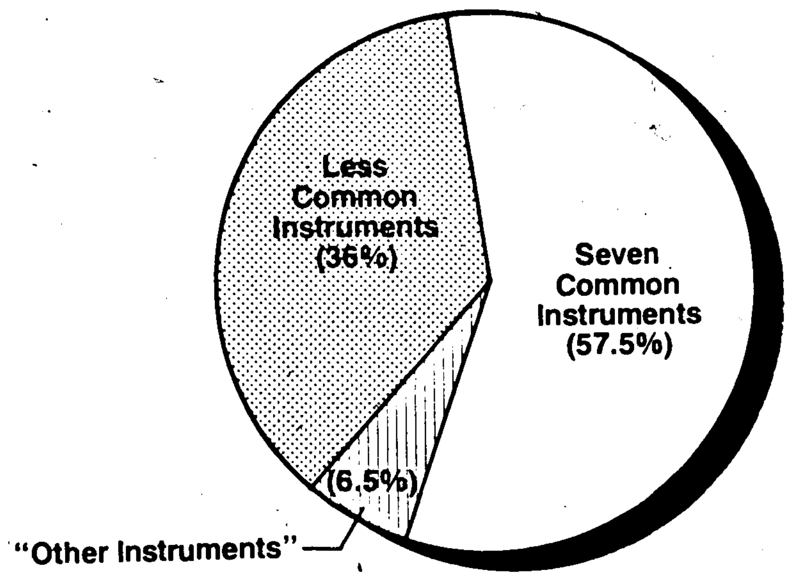
- The seven common instruments constitute 57.5% of the needs in chemistry departments at major schools. As would be expected, these instruments make up a greater percentage (73%) of the needs at smaller chemistry departments. These two percentages are very close to the percentages represented by the seven common instruments in the inventory.

Graph 6 shows the number of units of each of the seven common instruments, as a percentage of the total units of instrumentation needed.

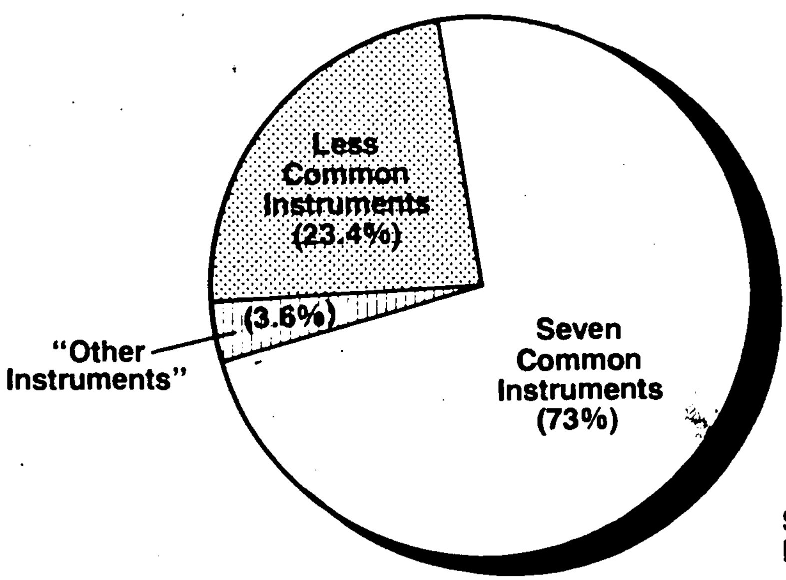
- NMR instruments dominate the needs list in both types of chemistry departments.

Graph 5

## Instrument Needs (By Types)



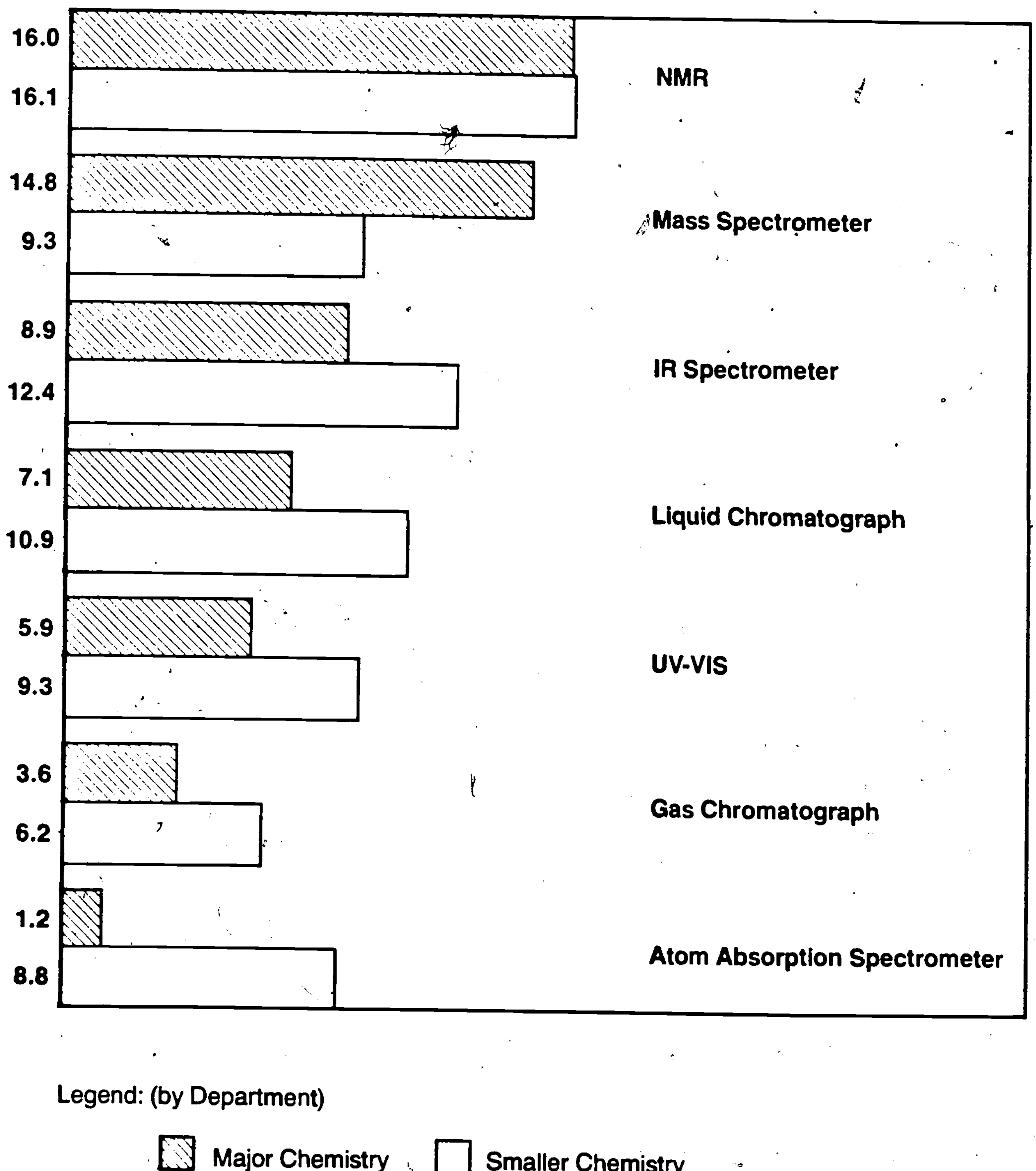

Major Chemistry Departments




Smaller Chemistry Departments

Graph 6

**Seven Common Instruments Needed**
**(as % of total needs)**



## B. Anticipated Instrument Use

Graph 7 shows the anticipated use of instruments needed by the three types of departments.

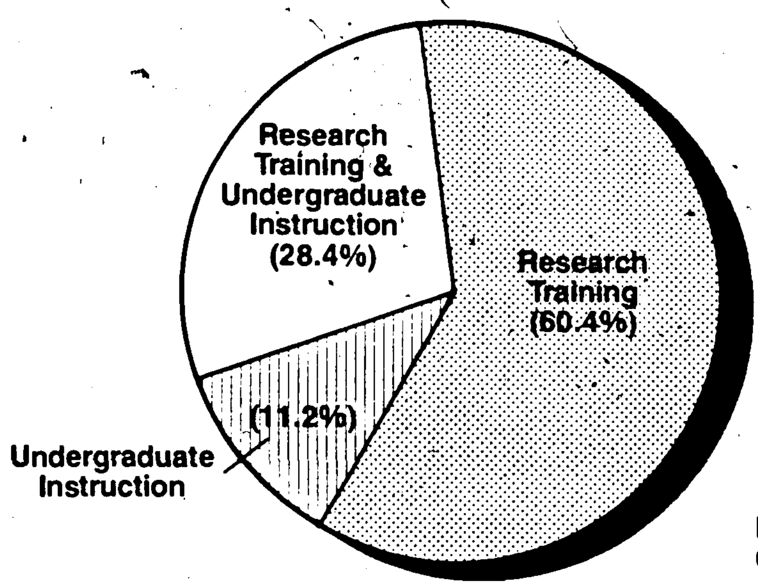
- Major chemistry departments apparently plan to use newly acquired instruments in roughly the same mix as they use currently on-hand equipment. Not surprisingly, they have indicated a need primarily for research training instruments, with only 11% of requests for instruments for undergraduate instruction.

- In contrast, smaller chemistry departments have the greatest need for instruments that can be used both in research training and undergraduate instruction. At these schools, 69% of new instrumentation will be devoted to these combined needs. Their need for instruments for research training is considerably less than for the major chemistry departments (22% vs. 60%).

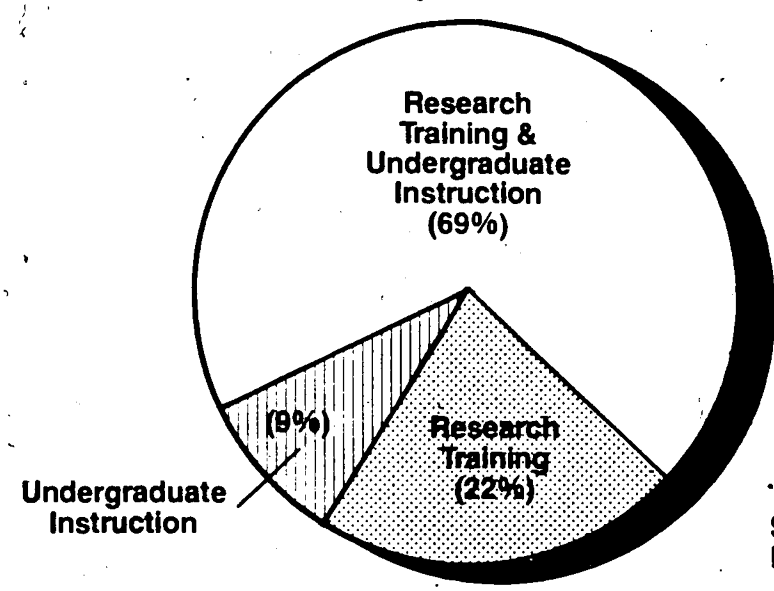
- The percentage of newly acquired instruments planned for undergraduate instruction is essentially the same at smaller chemistry departments (9%) and at larger chemistry departments (11%). This situation is quite different from the use of existing inventory where a much greater percentage is dedicated to undergraduate instruction at smaller chemistry departments than at major chemistry departments (19% vs. 5%).

Graph 7

# **Instrument Needs (By Anticipated Use)**




**Major Research Chemistry Departments**




**Smaller Chemistry Departments**

C. Assessment of Instrument Needs

A very important piece of information which is missing so far is the estimated cost of meeting the instrumentation needs of all departments of chemistry and chemical engineering in the U.S. The results of this survey provide one method for arriving at that overall cost figure.

Most of the departments which responded to the survey provided cost estimates for the specific instruments on their needs lists. In those few instances where these data were missing, an estimated cost was selected by the preparers of this report, taking into account the type of instrument involved and its anticipated use.

1. Major Chemistry Departments

Of the 32 chemistry departments at major institutions which responded to the survey, 28 provided estimates of the purchase price of each unit of needed instrumentation. The total of the cost estimates reported by the 28 schools was $23,292,460.

Extrapolating to 100 departments of chemistry gives us a cost estimate of approximately $83.2 million for meeting the instrumentation needs of the top 100 chemistry departments at major institutions.

2. Smaller Chemistry Departments

Sixty six chemistry departments at small schools provided cost estimates for their instrumentation needs, adding up to a total of $9,215,500. Extrapolating from this figure to the 470 ACS-accredited small schools gives a cost estimate of $65,625,530 (or $65.6 million) for meeting their instrumentation needs.

## V. CONCLUSIONS AND RECOMMENDATIONS

With rapid changes in technology taking place, instruments can become quickly outdated. A continuing program to update academic instrumentation is needed if we are to provide academic researchers with tools that are sophisticated enough to deal with today's complex scientific challenges, and provide an educational experience that is relevant to employment in industry or pursuit of breakthrough research.

To mount an attack on instrument obsolescence in academia, substantial expenditures will be needed. Where will resources of this magnitude emerge? Both private and governmental (state and federal) sources must be tapped if the problem of instrument obsolescence in academic departments is to be effectively addressed.

- The Federal Government, which is a major source of funds for purchase of instrumentation of chemistry research, should continue to support instrument purchases, not only for use in research training but also for undergraduate instruction.

- Additional mechanisms for financing the purchase of instrumentation should be explored further by academic institutions.
- Grants in support of research projects and instrumentation purchase should make allowance for the costs of maintaining instrumentation.

## APPENDIX

Table of Contents

Table A. Institutional profile of responding academic departments.

| | Chem. Depts. Major Institutions | Chem. Depts. Smaller Institutions | Chem. Eng. Depts., Major Institutions | All Institutions Surveyed |
|---|---|---|---|---|
| # of schools awarding as highest degree: | | | | |
| BS | 0 | 44 | 0 | 44 |
| MS | 0 | 13 | 1 | 14 |
| PhD | 32 | 14 | 12 | 58 |
| # of schools with undergrad. enrollment: | | | | |
| < 10,000 | 9 | 63 | 3 | 75 |
| 10,000 - 20,000 | 11 | 6 | 3 | 20 |
| > 20,000 | 12 | 2 | 7 | 21 |
| Median # of undergrad. seniors in dept., all schools | 30 | 8 | 70 | 15 |
| Median # of MS students in dept. at schools with highest degree: | | | | |
| BS and MS | - | 10 | 23 | 10 |
| PhD | 5 | 10 | 33 | 10 |
| Median # of PhD students in dept. at schools awarding PhD degree | 89 | 19 | 27 | 50 |
| Median # of postdoctoral fellows in dept. at schools awarding PhD degree | 20 | 4 | 4 | 11 |
| Median # of faculty members in dept., all schools | 28 | 6 | 16 | 10 |

Table B. Instrument inventory, maintenance expenditures, and support personnel at responding institutions.[1]

| | Chem. Depts. Major Institutions | Chem. Depts. Smaller Institutions | Chem. Eng. Depts., Major Institutions | All Institutions Surveyed |
|---|---|---|---|---|
| Total instrument inventory, dollars: | | | | |
| 25th percentile | $1,660,000 | $ 48,000 | $ 365,000 | $ 83,000 |
| 50th percentile | 3,300,000 | 104,000 | 700,000 | 325,000 |
| 75th percentile | 5,880,000 | 260,000 | 1,500,000 | 1,638,000 |
| Total annual instrument maintenance, dollars: | | | | |
| 25th percentile | $ 30,000 | $ 1,000 | $ 3,000 | $ 1,000 |
| 50th percentile | 70,000 | 2,000 | 12,000 | 5,000 |
| 75th percentile | 150,000 | 8,000 | 105,000 | 37,000 |
| Equipment personnel employed: | | | | |
| 25th percentile | 1 | 0 | 0 | 0 |
| 50th percentile | 5 | 0 | 1 | 1 |
| 75th percentile | 11 | 1 | 7 | 4 |

[1] For instance, 25% of chemistry departments at major institutions surveyed have instrument inventories of $1,660,000 or less; 25% have instrumentation worth $5,880,000 or more; and the median instrument inventory for such departments is $3,300,000.

Table C. Instrument Inventory at all responding departments (sorted by mean year of purchase)

| Instrument Type | Condition[a] | | | Year of Purchase | Use[b] | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | (mean) | 1 | 2 | 3 |
| Amino Acid Analyzer | 9 | 2 | 3 | 70.8 | 0 | 3 | 11 |
| ORD/CD | 18 | 5 | 1 | 70.9 | 2 | 7 | 15 |
| Optical Emission Spectrometer | 13 | 3 | 1 | 71.7 | 2 | 10 | 5 |
| Single-Crystal X-ray Diffractometer | 22 | 5 | 2 | 71.8 | 1 | 9 | 19 |
| Thermogravimetric Analyzer | 8 | 3 | 2 | 71.9 | 1 | 2 | 9 |
| ESR/EPR | 55 | 8 | 2 | 72.6 | 2 | 22 | 41 |
| Gamma Spectrometer | 13 | 3 | 1 | 72.8 | 3 | 4 | 10 |
| Differential Thermal Analyzer | 8 | 2 | 0 | 72.9 | 1 | 5 | 4 |
| X-Ray Diffractometer | 47 | 10 | 2 | 73.1 | 5 | 24 | 30 |
| ESCA | 10 | 1 | 1 | 73.3 | 0 | 1 | 11 |
| Infrared Spectrometer | 209 | 28 | 11 | 73.5 | 47 | 134 | 67 |
| Microscope | 11 | 0 | 0 | 73.5 | 0 | 5 | 6 |
| UV/VIS Spectrometer | 326 | 11 | 5 | 73.7 | 32 | 152 | 158 |
| Mass Spectrometer | 135 | 21 | 10 | 73.9 | 14 | 58 | 93 |
| Liquid Scintillation Spectrometer | 40 | 6 | 4 | 74.0 | 5 | 22 | 23 |
| Ultracentrifuge | 75 | 3 | 1 | 74.0 | 1 | 32 | 46 |
| Raman Spectrometer | 22 | 3 | 3 | 74.2 | 1 | 7 | 20 |
| Photoelectron Spectrometer | 7 | 2 | 0 | 74.4 | 1 | 4 | 4 |
| Gas Chromatograph | 264 | 23 | 8 | 74.6 | 24 | 155 | 115 |
| BET Surface Area | 3 | 1 | 0 | 74.8 | 0 | 0 | 4 |
| NMR Spectrometer | 224 | 23 | 12 | 75.2 | 30 | 134 | 95 |
| Atomic Absorption Spectrometer | 77 | 7 | 3 | 75.3 | 16 | 55 | 16 |
| Electron Microscope | 6 | 1 | 0 | 75.7 | 0 | 3 | 4 |
| Fluorimeter | 53 | 0 | 2 | 75.7 | 4 | 28 | 22 |
| Other Instruments | 404 | 7 | 3 | 75.7 | 23 | 92 | 298 |
| Differential Scanning Calorimeter | 21 | 0 | 0 | 76.0 | 0 | 7 | 14 |
| X-Ray Fluorescence Spectrometer | 8 | 0 | 0 | 76.0 | 0 | 4 | 4 |

Continued >>>>

Table C. Instrument Inventory at all responding departments (sorted by mean year of purchase), continued

| Instrument Type | Condition[a] 1 | Condition[a] 2 | Condition[a] 3 | Year of Purchase (mean) | Use[b] 1 | Use[b] 2 | Use[b] 3 |
|---|---|---|---|---|---|---|---|
| Quadrupole Mass Spectrometer | 16 | 0 | 0 | 76.1 | 0 | 1 | 15 |
| Liquid Chromatograph | 136 | 7 | 4 | 77.7 | 12 | 60 | 75 |
| Light Scattering Apparatus | 23 | 0 | 0 | 78.7 | 0 | 8 | 14 |
| EXAFS | 2 | 0 | 0 | 79.0 | 0 | 0 | 2 |
| Mercury Porosimeter | 1 | 0 | 0 | 79.0 | 0 | 1 | 0 |
| Mossbauer Spectrometer | 4 | 0 | 0 | 79.5 | 0 | 0 | 4 |
| Berty Reactor | 2 | 0 | 1 | 79.7 | 0 | 0 | 3 |
| ICP Spectrometer | 5 | 0 | 0 | 81.0 | 0 | 3 | 2 |
| Ion Chromatograph | 2 | 0 | 0 | 81.0 | 0 | 1 | 1 |

[a] 1 = Fully Operational, 2 = Partially Operational, 3 = Inoperative.
[b] 1 = Instruction Only, 2 = Instruction and Research, 3 = Research Only.

# Table D. Instrument Inventory (By Department Type)

**'TOP 50' CHEMISTRY DEPARTMENTS**

| INSTRUMENT TYPE | CONDITION -1- | -2- | -3- | YEAR PURCH (MEAN) | USE -1- | -2- | -3- | COUNT and % |
|---|---|---|---|---|---|---|---|---|
| AMINO ACID ANLZ | 7 | 1 | 2 | 70.1 | 0 | 3 | 7 | 10 |
| | 70 | 10 | 20 | | 0 | 30 | 70 | 0.6 |
| ATOM ABSOR SPEC | 28 | 1 | 0 | 75.0 | 5 | 14 | 10 | 29 |
| | 97 | 3 | 0 | | 17 | 48 | 34 | 1.9 |
| BET SURF AREA | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| BERTY REACTOR | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| DIFF THERM ANLZ | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| DIFF SCAN CALOR | 9 | 0 | 0 | 76.8 | 0 | 3 | 6 | 9 |
| | 100 | 0 | 0 | | 0 | 33 | 67 | 0.6 |
| ELECTR MICROSCP | 4 | 0 | 0 | 77.7 | 0 | 1 | 3 | 4 |
| | 100 | 0 | 0 | | 0 | 25 | 75 | 0.3 |
| ESCA | 10 | 1 | 1 | 73.3 | 0 | 1 | 11 | 12 |
| | 83 | 8 | 8 | | 0 | 8 | 92 | 0.8 |
| ESR/EPR | 41 | 7 | 1 | 72.7 | 2 | 16 | 31 | 49 |
| | 84 | 14 | 2 | | 4 | 33 | 63 | 3.1 |
| EXAFS | 2 | 0 | 0 | 79.0 | 0 | 0 | 2 | 2 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.1 |
| FLUORIMITER | 29 | 0 | 1 | 76.0 | 0 | 11 | 19 | 30 |
| | 97 | 0 | 3 | | 0 | 37 | 63 | 1.9 |
| GAMMA CTR/SPECT | 11 | 0 | 1 | 74.8 | 0 | 3 | 9 | 12 |
| | 92 | 0 | 8 | | 0 | 25 | 75 | 0.8 |
| GAS CHROMATOGPH | 127 | 8 | 1 | 75.4 | 2 | 81 | 53 | 136 |
| | 93 | 6 | 1 | | 1 | 60 | 39 | 8.7 |
| ICPE SPECTROMTR | 1 | 0 | 0 | 79.0 | 0 | 0 | 1 | 1 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.1 |
| IR SPECTROMTR | 106 | 15 | 4 | 74.1 | 20 | 50 | 55 | 125 |
| | 85 | 12 | 3 | | 16 | 40 | 44 | 8.0 |
| ION CHROMATOGPH | 1 | 0 | 0 | 82.0 | 0 | 1 | 0 | 1 |
| | 100 | 0 | 0 | | 0 | 100 | 0 | 0.1 |
| LIGHT SCATT APP | 16 | 0 | 0 | 78.7 | 0 | 7 | 8 | 16 |
| | 100 | 0 | 0 | | 0 | 47 | 53 | 1.0 |
| LIQ CHROMATOGPH | 88 | 5 | 1 | 77.7 | 2 | 44 | 48 | 94 |
| | 94 | 5 | 1 | | 2 | 47 | 51 | 6.0 |
| LIQ SCIN CTR | 25 | 4 | 1 | 73.6 | 1 | 13 | 16 | 30 |
| | 83 | 13 | 3 | | 3 | 43 | 53 | 1.9 |
| MERC POROSIMTR | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| MICROSCOPE | 6 | 0 | 0 | 77.0 | 0 | 2 | 4 | 6 |
| | 100 | 0 | 0 | | 0 | 33 | 67 | 0.4 |
| MASS SPECTROMTR | 79 | 18 | 8 | 73.6 | 6 | 40 | 59 | 105 |
| | 75 | 17 | 8 | | 6 | 38 | 56 | 6.7 |
| QUADRAPOLE MS | 10 | 0 | 0 | 75.1 | 0 | 0 | 10 | 10 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.6 |
| MOSSBAUER | 3 | 0 | 0 | 78.7 | 0 | 0 | 3 | 3 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.2 |
| NMR | 153 | 15 | 9 | 75.3 | 23 | 75 | 79 | 177 |
| | 86 | 8 | 5 | | 13 | 42 | 45 | 11.3 |
| OPT EMISS SPCTR | 6 | 1 | 0 | 71.4 | 0 | 4 | 3 | 7 |
| | 86 | 14 | 0 | | 0 | 57 | 43 | 0.4 |
| ORD/CD | 16 | 5 | 1 | 70.5 | 1 | 7 | 14 | 22 |
| | 73 | 23 | 5 | | 5 | 32 | 64 | 1.4 |
| PHOTOELEC SPCTR | 6 | 0 | 0 | 75.2 | 1 | 3 | 2 | 6 |
| | 100 | 0 | 0 | | 17 | 50 | 33 | 0.4 |
| RAMAN | 16 | 1 | 3 | 73.7 | 1 | 3 | 16 | 20 |
| | 80 | 5 | 15 | | 5 | 15 | 80 | 1.3 |
| SNGL CRYST XRAY | 15 | 3 | 0 | 73.2 | 1 | 3 | 14 | 18 |
| | 83 | 17 | 0 | | 6 | 17 | 78 | 1.1 |
| THRMGRAVMTR ANL | 3 | 0 | 0 | 75.3 | 1 | 0 | 2 | 3 |
| | 100 | 0 | 0 | | 33 | 0 | 67 | 0.2 |
| ULTRACENTRIFUGE | 57 | 3 | 0 | 74.3 | 0 | 25 | 35 | 60 |
| | 95 | 5 | 0 | | 0 | 42 | 58 | 3.8 |
| UV/VIS SPECTROM | 186 | 4 | 1 | 74.3 | 7 | 81 | 103 | 191 |
| | 97 | 2 | 1 | | 4 | 42 | 54 | 12.2 |
| XRAY FLUOR SPEC | 3 | 0 | 0 | 77.3 | 0 | 0 | 3 | 3 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.2 |
| XRAY DIFFRACT | 30 | 5 | 2 | 72.4 | 1 | 15 | 21 | 37 |
| | 81 | 14 | 5 | | 3 | 41 | 57 | 2.4 |
| OTHER INSTRUMNT | 333 | 3 | 2 | 75.7 | 8 | 70 | 259 | 338 |
| | 99 | 1 | 1 | | 2 | 21 | 77 | 21.6 |
| ALL INSTRUMENTS | 1427 | 100 | 39 | 74.9 | 82 | 576 | 906 | 1566 |
| | 91 | 6 | 2 | | 5 | 37 | 58 | 100.0% |

**'SMALLER' CHEMISTRY DEPARTMENTS**

| INSTRUMENT TYPE | CONDITION -1- | -2- | -3- | YEAR PURCH (MEAN) | USE -1- | -2- | -3- | COUNT and % |
|---|---|---|---|---|---|---|---|---|
| AMINO ACID ANLZ | 0 | 0 | 1 | 75.0 | 0 | 0 | 1 | 1 |
| | 0 | 0 | 100 | | 0 | 0 | 100 | 0.1 |
| ATOM ABSOR SPEC | 46 | 6 | 3 | 75.5 | 11 | 41 | 3 | 55 |
| | 84 | 11 | 5 | | 20 | 75 | 5 | 7.2 |
| BET SURF AREA | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| BERTY REACTOR | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| DIFF THERM ANLZ | 4 | 2 | 0 | 72.2 | 1 | 4 | 1 | 6 |
| | 67 | 33 | 0 | | 17 | 67 | 17 | 0.8 |
| DIFF SCAN CALOR | 7 | 0 | 0 | 73.5 | 0 | 4 | 3 | 7 |
| | 100 | 0 | 0 | | 0 | 57 | 43 | 0.9 |
| ELECTR MICROSCP | 0 | 1 | 0 | 82.0 | 0 | 1 | 0 | 1 |
| | 0 | 100 | 0 | | 0 | 100 | 0 | 0.1 |
| ESCA | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| ESR/EPR | 13 | 1 | 1 | 73.3 | 0 | 6 | 9 | 15 |
| | 87 | 7 | 7 | | 0 | 40 | 60 | 2.0 |
| EXAFS | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| FLUORIMITER | 23 | 0 | 1 | 75.6 | 4 | 17 | 2 | 24 |
| | 96 | 0 | 4 | | 17 | 74 | 9 | 3.1 |
| GAMMA CTR/SPECT | 2 | 3 | 0 | 66.5 | 3 | 1 | 1 | 5 |
| | 40 | 60 | 0 | | 60 | 20 | 20 | 0.7 |
| GAS CHROMATOGPH | 86 | 15 | 7 | 72.9 | 21 | 68 | 18 | 108 |
| | 80 | 14 | 6 | | 20 | 64 | 17 | 14.1 |
| ICPE SPECTROMTR | 4 | 0 | 0 | 81.5 | 0 | 3 | 1 | 4 |
| | 100 | 0 | 0 | | 0 | 75 | 25 | 0.5 |
| IR SPECTROMTR | 99 | 11 | 7 | 72.8 | 27 | 82 | 8 | 117 |
| | 85 | 9 | 6 | | 23 | 70 | 7 | 15.3 |
| ION CHROMATOGPH | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| LIGHT SCATT APP | 2 | 0 | 0 | 77.5 | 0 | 1 | 1 | 2 |
| | 100 | 0 | 0 | | 0 | 50 | 50 | 0.3 |
| LIQ CHROMATOGPH | 36 | 2 | 2 | 77.6 | 10 | 16 | 14 | 40 |
| | 90 | 5 | 5 | | 25 | 40 | 35 | 5.2 |
| LIQ SCIN CTR | 15 | 0 | 3 | 75.1 | 4 | 9 | 5 | 18 |
| | 83 | 0 | 17 | | 22 | 50 | 28 | 2.4 |
| MERC POROSIMTR | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| MICROSCOPE | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| MASS SPECTROMTR | 37 | 2 | 2 | 75.2 | 6 | 17 | 17 | 41 |
| | 90 | 5 | 5 | | 15 | 43 | 43 | 5.4 |
| QUADRAPOLE MS | 3 | 0 | 0 | 76.3 | 0 | 1 | 2 | 3 |
| | 100 | 0 | 0 | | 0 | 33 | 67 | 0.4 |
| MOSSBAUER | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| NMR | 68 | 8 | 3 | 75.4 | 7 | 59 | 13 | 79 |
| | 86 | 10 | 4 | | 9 | 75 | 16 | 10.3 |
| OPT EMISS SPCTR | 7 | 2 | 1 | 71.9 | 2 | 6 | 2 | 10 |
| | 70 | 20 | 10 | | 20 | 60 | 20 | 1.3 |
| ORD/CD | 2 | 0 | 0 | 75.0 | 1 | 0 | 1 | 2 |
| | 100 | 0 | 0 | | 50 | 0 | 50 | 0.3 |
| PHOTOELEC SPCTR | 1 | 2 | 0 | 73.0 | 0 | 1 | 2 | 3 |
| | 33 | 67 | 0 | | 0 | 33 | 67 | 0.4 |
| RAMAN | 4 | 2 | 0 | 74.5 | 0 | 4 | 2 | 6 |
| | 67 | 33 | 0 | | 0 | 67 | 33 | 0.8 |
| SNGL CRYST XRAY | 6 | 2 | 2 | 70.4 | 0 | 6 | 4 | 10 |
| | 60 | 20 | 20 | | 0 | 60 | 40 | 1.3 |
| THRMGRAVMTR ANL | 1 | 3 | 2 | 69.2 | 0 | 1 | 4 | 6 |
| | 17 | 50 | 33 | | 0 | 20 | 80 | 0.8 |
| ULTRACENTRIFUGE | 14 | 0 | 1 | 75.1 | 1 | 7 | 7 | 15 |
| | 93 | 0 | 7 | | 7 | 47 | 47 | 2.0 |
| UV/VIS SPECTROM | 101 | 7 | 4 | 72.7 | 25 | 70 | 17 | 112 |
| | 90 | 6 | 4 | | 22 | 63 | 15 | 14.7 |
| XRAY FLUOR SPEC | 5 | 0 | 0 | 75.2 | 0 | 4 | 1 | 5 |
| | 100 | 0 | 0 | | 0 | 80 | 20 | 0.7 |
| XRAY DIFFRACT | 11 | 4 | 0 | 75.0 | 4 | 9 | 2 | 15 |
| | 73 | 27 | 0 | | 27 | 60 | 13 | 2.0 |
| OTHER INSTRUMNT | 48 | 4 | 1 | 76.5 | 14 | 20 | 19 | 54 |
| | 91 | 8 | 2 | | 26 | 38 | 36 | 7.1 |
| ALL INSTRUMENTS | 645 | 77 | 41 | 74.2 | 141 | 458 | 160 | 764 |
| | 85 | 10 | 5 | | 19 | 60 | 21 | 100.0% |

**'TOP 50' CHEMICAL ENGINEERING DEPARTMENTS**

| INSTRUMENT TYPE | CONDITION -1- | -2- | -3- | YEAR PURCH (MEAN) | USE -1- | -2- | -3- | COUNT and % |
|---|---|---|---|---|---|---|---|---|
| AMINO ACID ANLZ | 2 | 1 | 0 | 72.5 | 0 | 0 | 3 | 3 |
| | 67 | 33 | 0 | | 0 | 0 | 100 | 1.4 |
| ATOM ABSOR SPEC | 3 | 0 | 0 | 75.0 | 0 | 0 | 3 | 3 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 1.4 |
| BET SURF AREA | 3 | 1 | 0 | 74.8 | 0 | 0 | 4 | 4 |
| | 75 | 25 | 0 | | 0 | 0 | 100 | 1.8 |
| BERTY REACTOR | 2 | 0 | 1 | 79.7 | 0 | 0 | 3 | 3 |
| | 67 | 0 | 33 | | 0 | 0 | 100 | 1.4 |
| DIFF THERM ANLZ | 4 | 0 | 0 | 74.0 | 0 | 1 | 3 | 4 |
| | 100 | 0 | 0 | | 0 | 25 | 75 | 1.8 |
| DIFF SCAN CALOR | 5 | 0 | 0 | 77.6 | 0 | 0 | 5 | 5 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 2.3 |
| ELECTR MICROSCP | 2 | 0 | 0 | 69.5 | 0 | 1 | 1 | 2 |
| | 100 | 0 | 0 | | 0 | 50 | 50 | 0.9 |
| ESCA | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| ESR/EPR | 1 | 0 | 0 | 62.0 | 0 | 0 | 1 | 1 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.5 |
| EXAFS | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| FLUORIMITER | 1 | 0 | 0 | 69.0 | 0 | 0 | 1 | 1 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.5 |
| GAMMA CTR/SPECT | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| GAS CHROMATOGPH | 51 | 0 | 0 | 76.0 | 1 | 6 | 44 | 51 |
| | 100 | 0 | 0 | | 2 | 12 | 86 | 23.5 |
| ICPE SPECTROMTR | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| IR SPECTROMTR | 4 | 2 | 0 | 71.4 | 0 | 2 | 4 | 6 |
| | 67 | 33 | 0 | | 0 | 33 | 67 | 2.8 |
| ION CHROMATOGPH | 1 | 0 | 0 | 80.0 | 0 | 0 | 1 | 1 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.5 |
| LIGHT SCATT APP | 5 | 0 | 0 | 79.4 | 0 | 0 | 5 | 5 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 2.3 |
| LIQ CHROMATOGPH | 12 | 0 | 1 | 77.6 | 0 | 0 | 13 | 13 |
| | 92 | 0 | 8 | | 0 | 0 | 100 | 6.0 |
| LIQ SCIN CTR | 0 | 2 | 0 | 71.5 | 0 | 0 | 2 | 2 |
| | 0 | 100 | 0 | | 0 | 0 | 100 | 0.9 |
| MERC POROSIMTR | 1 | 0 | 0 | 79.0 | 0 | 1 | 0 | 1 |
| | 100 | 0 | 0 | | 0 | 100 | 0 | 0.5 |
| MICROSCOPE | 5 | 0 | 0 | 70.0 | 0 | 3 | 2 | 5 |
| | 100 | 0 | 0 | | 0 | 60 | 40 | 2.3 |
| MASS SPECTROMTR | 19 | 1 | 0 | 72.8 | 2 | 1 | 17 | 20 |
| | 95 | 5 | 0 | | 10 | 5 | 85 | 9.2 |
| QUADRAPOLE MS | 3 | 0 | 0 | 79.0 | 0 | 0 | 3 | 3 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 1.4 |
| MOSSBAUER | 1 | 0 | 0 | 82.0 | 0 | 0 | 1 | 1 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.5 |
| NMR | 3 | 0 | 0 | 65.0 | 0 | 0 | 3 | 3 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 1.4 |
| OPT EMISS SPCTR | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| ORD/CD | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| PHOTOELEC SPCTR | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| RAMAN | 2 | 0 | 0 | 82.0 | 0 | 0 | 2 | 2 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.9 |
| SNGL CRYST XRAY | 1 | 0 | 0 | 60.0 | 0 | 0 | 1 | 1 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 0.5 |
| THRMGRAVMTR ANL | 4 | 0 | 0 | 73.5 | 0 | 1 | 3 | 4 |
| | 100 | 0 | 0 | | 0 | 25 | 75 | 1.8 |
| ULTRACENTRIFUGE | 4 | 0 | 0 | 66.5 | 0 | 0 | 4 | 4 |
| | 100 | 0 | 0 | | 0 | 0 | 100 | 1.8 |
| UV/VIS SPECTROM | 39 | 0 | 0 | 73.5 | 0 | 1 | 38 | 39 |
| | 100 | 0 | 0 | | 0 | 3 | 97 | 18.0 |
| XRAY FLUOR SPEC | 0 | 0 | 0 | — | 0 | 0 | 0 | 0 |
| | | | | | | | | 0.0 |
| XRAY DIFFRACT | 6 | 1 | 0 | 73.1 | 0 | 0 | 7 | 7 |
| | 86 | 14 | 0 | | 0 | 0 | 100 | 3.2 |
| OTHER INSTRUMNT | 23 | 0 | 0 | 73.4 | 1 | 2 | 20 | 23 |
| | 100 | 0 | 0 | | 4 | 9 | 87 | 10.6 |
| ALL INSTRUMENTS | 207 | 8 | 2 | 74.2 | 4 | 19 | 194 | 217 |
| | 95 | 4 | 1 | | 2 | 9 | 89 | 100.0% |

Table E. Instrumentation needs in chemistry instruction and research activities.

| Instrument Type | Major Research | | | | Smaller Departments | | | | Chemical Engineering | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Use[a] | | | Percent of Total | Use[a] | | | Percent of Total | Use[a] | | | Percent of Total |
| | 1 | 2 | 3 | | 1 | 2 | 3 | | 1 | 2 | 3 | |
| Amino Acid Analyzer | 0 | 0 | 1 | 0.6 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0.0 |
| Atomic Absorption Spectrometer | 0 | 2 | 0 | 1.2 | 2 | 14 | 1 | 8.8 | 0 | 0 | 1 | 2.1 |
| BET Surface Area | 0 | 0 | 0 | 0.0 | 0 | 0 | 2 | 1.0 | 1 | 0 | 0 | 2.1 |
| Berty Reactor | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 |
| Differential Thermal Analyzer | 0 | 1 | 0 | 0.6 | 0 | 2 | 0 | 1.0 | 1 | 0 | 1 | 4.3 |
| Differential Scanning Calorimeter | 0 | 1 | 0 | 0.6 | 0 | 2 | 1 | 1.6 | 1 | 1 | 0 | 4.3 |
| Electron Microscope | 0 | 0 | 1 | 0.6 | 0 | 0 | 0 | 0.0 | 0 | 0 | 1 | 2.1 |
| ESCA | 0 | 0 | 5 | 3.0 | 0 | 0 | 1 | 0.5 | 0 | 0 | 1 | 2.1 |
| ESR/EPR | 1 | 1 | 4 | 3.6 | 0 | 0 | 2 | 1.0 | 0 | 0 | 0 | 0.0 |
| EXAFS | 0 | 0 | 0 | 0.0 | 0 | 1 | 0 | 0.5 | 0 | 0 | 0 | 0.0 |
| Fluorimeter | 0 | 1 | 1 | 1.2 | 0 | 1 | 2 | 1.6 | 0 | 1 | 0 | 2.1 |
| Gamma Spectrometer | 0 | 0 | 2 | 1.2 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0.0 |
| Gas Chromatograph | 2 | 2 | 2 | 3.6 | 1 | 8 | 3 | 6.2 | 3 | 5 | 0 | 17.0 |
| ICP Spectrometer | 0 | 0 | 0 | 0.0 | 0 | 1 | 0 | 0.5 | 0 | 0 | 0 | 0.0 |
| Infrared Spectrometer | 3 | 5 | 7 | 8.9 | 4 | 15 | 5 | 12.4 | 0 | 1 | 1 | 4.3 |
| Ion Chromatograph | 0 | 0 | 0 | 0.0 | 0 | 2 | 0 | 1.0 | 0 | 0 | 0 | 0.0 |
| Light Scattering Apparatus | 0 | 1 | 1 | 1.2 | 0 | 1 | 0 | 0.5 | 0 | 0 | 0 | 0.0 |
| Liquid Chromatograph | 1 | 3 | 8 | 7.1 | 1 | 18 | 2 | 10.9 | 1 | 3 | 2 | 12.8 |
| Liquid Scintillation Spectrometer | 0 | 1 | 4 | 3.0 | 1 | 2 | 1 | 2.1 | 0 | 0 | 0 | 0.0 |
| Mercury Porosimeter | 0 | 0 | 0 | 0.0 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0.0 |
| Microscope | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 |
| Mass Spectrometer | 2 | 9 | 14 | 14.8 | 0 | 17 | 1 | 9.3 | 0 | 2 | 0 | 4.3 |
| Quadrupole Mass Spectrometer | 0 | 0 | 1 | 0.6 | 0 | 0 | 2 | 1.0 | 0 | 1 | 0 | 2.1 |
| Mossbauer Spectrometer | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 |
| NMR Spectrometer | 5 | 6 | 16 | 16.0 | 5 | 21 | 5 | 16.1 | 0 | 0 | 3 | 6.4 |
| Optical Emission Spectrometer | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 |
| ORD/CD | 0 | 1 | 5 | 3.6 | 0 | 2 | 0 | 1.0 | 0 | 1 | 0 | 2.1 |
| Photoelectron Spectrometer | 1 | 0 | 1 | 1.2 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 |
| Raman Spectrometer | 0 | 0 | 3 | 1.8 | 0 | 0 | 2 | 1.0 | 0 | 1 | 0 | 2.1 |

Continued >>>>

Table E. Instrumentation needs in chemistry instruction and research activities, continued.

| Instrument Type | Major Research Use[a] 1 | 2 | 3 | Percent of Total | Smaller Departments Use[a] 1 | 2 | 3 | Percent of Total | Chemical Engineering Use[a] 1 | 2 | 3 | Percent of Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Single Crystal X-Ray Diffractometer | 0 | 0 | 3 | 1.8 | 0 | 1 | 2 | 1.6 | 0 | 0 | 0 | 0.0 |
| Thermogravimetric Analyzer | 0 | 1 | 0 | 0.6 | 1 | 3 | 0 | 1.6 | 1 | 0 | 0 | 2.1 |
| Ultracentrifuge | 0 | 3 | 4 | 4.1 | 0 | 2 | 1 | 1.6 | 0 | 1 | 0 | 2.1 |
| UV/VIS Spectrometer | 2 | 5 | 3 | 5.9 | 2 | 11 | 5 | 9.3 | 1 | 0 | 1 | 4.3 |
| X-Ray Fluorescence Spectrometer | 0 | 0 | 0 | 0.0 | 0 | 3 | 0 | 1.6 | 0 | 0 | 0 | 0.0 |
| X-Ray Diffractometer | 1 | 4 | 7 | 7.1 | 0 | 1 | 1 | 1.0 | 0 | 0 | 0 | 0.0 |
| Other Instruments | 1 | 1 | 9 | 6.5 | 1 | 5 | 1 | 3.6 | 0 | 2 | 8 | 21.3 |
| All Instruments (Totals) | 19 | 48 | 102 | 100.0 | 17 | 133 | 43 | 100.0 | 9 | 19 | 19 | 100.0 |

[a] 1 = Instruction Only, 2 = Instruction and Research, 3 = Research Only.

American Chemical Society

OFFICE OF THE PRESIDENT

Robert W. Parry

1155 SIXTEENTH STREET, N.W.
WASHINGTON, D.C. 20036
Phone (202) 872-4600

July 14, 1982

Departments of Chemistry
Departments of Chemical Engineering

Dear Colleague:

The American Chemical Society's Committee on Science is urgently seeking information about the state of instrumentation used for teaching and research at U.S. universities. To obtain such information the committee has appointed a special task force, under the chairmanship of Dr. Jordan J. Bloomfield, to survey a sample of 200 chemistry and chemical engineering departments. The committee plans to use the task force's report to assist in the preparation of ACS testimony on the federal R&D budget.

The enclosed questionnaire asks you to describe your department and its major instrumentation. The ACS will report results only in such a way that no specific information can be attributed to your institution. Individual responses will remain confidential.

Please complete the questionnaire and return it in the enclosed envelope by July 31. All respondents will receive a copy of the ACS's report of the survey's findings.

Thank you for your cooperation.

Sincerely yours,

Robert W. Parry

Robert W. Parry

RWP/nb

Enclosure

A-6

ACS COMMITTEE ON SCIENCE

Survey of Major Instrumentation
At U.S. Colleges and Universities
July 1982

The ACS will use the label at the left to record that you have responded. Your individual responses will remain confidential.

## Part I - Institution

A. Field of your department:
   Chemistry . . . . . . . . . 1 [ ]
   Chemical Engineering . . 2 [ ]

B. Highest degree offered by your department:
   Bachelors . . . . . . . . . 1 [ ]
   Masters . . . . . . . . . . 2 [ ]
   Doctorate . . . . . . . . . 3 [ ]

C. Department size (full-time equivalent):

   Faculty members . . . . . . . . . . ______
   Post-doctoral fellows . . . . . . ______

   Students in Ph.D. program . . . . ______
   Students in masters program . . . ______
   Undergraduate seniors . . . . . ______

   Equipment personnel (total) . . . ______
     Persons (in FTE) responsible for:
       operating instruments . . ______
       maintaining instruments . ______
       designing instruments . . ______
       blowing glass . . . . . . ______
       performing other duties . ______

D. Campus size:
   Total number of undergraduate students (FTE):
   less than 500 . . . . . . . . . . 1 [ ]
   500 - 2,500 . . . . . . . . . . . 2 [ ]
   2,500 - 10,000 . . . . . . . . . . 3 [ ]
   10,000 - 20,000 . . . . . . . . . . 4 [ ]
   more than 20,000 . . . . . . . . . . 5 [ ]

E. Please estimate the TOTAL cost of all your department's instruments, using original purchase prices: $ __________

F. Please estimate your department's annual cost of maintaining these instruments (do not include amortization, depreciation, or set-aside funds): $ __________

Please complete and return this form by July 31, 1982.

Part II: Current Instruments

Please use the table below to describe your department's instruments. The enclosed page lists the codes that go into the first five columns.

<u>DO NOT INCLUDE</u>
-- Instruments that would cost less than $5,000 at today's prices
-- Computers and computer peripherals

Example: In 19<u>75</u> a hypothetical department spent $<u>50</u>,000 of <u>NSF funds</u> [2] to buy a <u>fluorine NMR</u> [253]. An <u>operator</u> [1] handles this instrument, which is <u>fully operational</u> [1] and is used for <u>research only</u> [3].

| | Instrument | Condition | Funding Source | Use | Operation | Year Acquired | Initial Cost ($1000) |
|---|---|---|---|---|---|---|---|
| Example | 253 | 1 | 2 | 3 | 1 | 75 | 50 |
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PART II (continued).

| Instrument | Condition | Funding Source | Use | Operation | Year Acquired | Initial Cost ($1000) |
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PLEASE TURN TO PART III.

## Part III: Instrument Needs

Please describe briefly your critical instrument needs for the next two to five years. The enclosed page lists the codes that go into the first two columns.

| Instrument | Use | Estimated Cost |
|---|---|---|
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Comments:

Please return to:
Committee on Science
Room 202
American Chemical Society
1155 16th Street NW
Washington, DC 20036

## INSTRUMENT

AMINO ACID ANALYZER . . . . . . . . . . 010

ATOMIC ABSORPTION SPECTROMETER . . . . 020

BET SURFACE AREA DEVICE . . . . . . . . 030

BERTY GRADIENTLESS REACTOR . . . . . . 040

DIFFERENTIAL THERMAL ANALYZER . . . . 050

DIFFERENTIAL SCANNING CALORIMETER
- Manual . . . . . . . . . . . . . . 061
- Computer Controlled . . . . . . . . 062

ELECTRON MICROSCOPE . . . . . . . . . . 070

ESCA
- UV Excitation . . . . . . . . . . . 081
- X-Ray and Electron Excitation . . . 082

ESR/EPR
- X-Band . . . . . . . . . . . . . . . 091
- Q-Band . . . . . . . . . . . . . . . 092
- ENDOR . . . . . . . . . . . . . . . 093
- Other . . . . . . . . . . . . . . . 094

EXAFS
- Synchrotron Radiation . . . . . . . 101
- Rotating Anode Generator . . . . . 102
- Sealed Tube Generator . . . . . . . 103
- Electron Microscope . . . . . . . . 104

FLUORIMETER . . . . . . . . . . . . . . 110

GAMMA COUNTER & SPECTROMETER . . . . . 120

GAS CHROMATOGRAPH
- Analytical . . . . . . . . . . . . . 131
- Preparative . . . . . . . . . . . . 132

INDUCTIVELY COUPLED PLASMA EMISSION SPECTROMETER . . . . . . . . 140

INFRARED SPECTROMETER
- IR-Prism . . . . . . . . . . . . . . 151
- IR-Grating . . . . . . . . . . . . . 152
- FTIR . . . . . . . . . . . . . . . . 153
- Far IR . . . . . . . . . . . . . . . 154
- Other . . . . . . . . . . . . . . . 155

ION CHROMATOGRAPH . . . . . . . . . . . 160

LIGHT SCATTERING APPARATUS
- Variable Angle . . . . . . . . . . . 171
- Low Angle Laser . . . . . . . . . . 172
- Solid State Laser . . . . . . . . . 173
- Quasi Elastic . . . . . . . . . . . 174

LIQUID CHROMATOGRAPH
- Analytical . . . . . . . . . . . . . 181
- Preparative . . . . . . . . . . . . 182

LIQUID SCINTILLATION COUNTER . . . . . 190

MERCURY POROSIMETER . . . . . . . . . . 200

MICROSCOPE
- Scanning . . . . . . . . . . . . . . 211
- Transmission . . . . . . . . . . . . 212
- Electron Microprobe . . . . . . . . 213

MASS SPECTROMETER
- High Resolution (1:20,000) . . . . 221
- Low Resolution (1:700) . . . . . . 222
- GC/MS . . . . . . . . . . . . . . . 223
- Other . . . . . . . . . . . . . . . 224

QUADRAPOLE MS . . . . . . . . . . . . . 230

MOSSBAUER . . . . . . . . . . . . . . . 240

NMR
- 60 MHz Proton . . . . . . . . . . . 251
- 90-100Mz Proton . . . . . . . . . . 252
- Fluorine . . . . . . . . . . . . . . 253
- Phosphorus . . . . . . . . . . . . . 254
- FT C/H . . . . . . . . . . . . . . . 255
- FT Multinuclei . . . . . . . . . . . 256
- FT Magic Angle Solids . . . . . . . 257
- Super Conducting Magnet . . . . . . 258
- Other . . . . . . . . . . . . . . . 259

OPTICAL EMISSION SPECTROMETER
- Direct Reading . . . . . . . . . . . 261
- Scanning . . . . . . . . . . . . . . 262

ORD/CD . . . . . . . . . . . . . . . . . 270

PHOTOELECTRON SPECTROSCOPE
- Ultraviolet . . . . . . . . . . . . 281
- X-Ray . . . . . . . . . . . . . . . . 282
- Dedicated Computer . . . . . . . . . 283

RAMAN
- Mercury . . . . . . . . . . . . . . 291
- Laser . . . . . . . . . . . . . . . 292

SINGLE CRYSTAL X-RAY
- Manual . . . . . . . . . . . . . . . 301
- Automatic . . . . . . . . . . . . . 302

THERMOGRAVIMETRIC ANALYZER . . . . . . 310

ULTRACENTRIFUGE
- Analytical . . . . . . . . . . . . . 321
- Preparative . . . . . . . . . . . . 322

UV/VISIBLE SPECTROMETERS
- Single Beam . . . . . . . . . . . . 331
- Double Beam . . . . . . . . . . . . 332
- Vacuum UV . . . . . . . . . . . . . 333
- Near IR . . . . . . . . . . . . . . 334
- Other . . . . . . . . . . . . . . . 335

X-RAY FLUORESCENCE SPECTROMETER . . . 340

X-RAY DIFFRACTOMETER
- Manual . . . . . . . . . . . . . . . 351
- Semi-automated . . . . . . . . . . . 352
- Computer Controlled . . . . . . . . 353

OTHER (Specify) ____________ 360

OTHER (Specify) ____________ 370

OTHER (Specify) ____________ 380

OTHER (Specify) ____________ 390

OTHER (Specify) ____________ 400

### CONDITION

Fully Operational . . 1
Partially Operational. 2
Inoperative . . . . . 3

### FUND SOURCE

Institutional . 1
Federal . . . 2
Industry . . . 3
Other . . . . . 4

### USE

Instruction Only . . . . . 1
Instruction and Research . 2
Research Only . . . . . . 3

### OPERATION

Operator performs required service for researcher . 1
Researcher or student operates equipment . . . . . 2

# INSTRUMENTATION METHODS

## Chromatography

A method of separating and analyzing mixtures of chemical substances. A flow of solvent or gas causes the components of a mixture to migrate differentially from a narrow starting zone in a special porous, insoluble, sorptive medium.

- Gas Chromatography uses a column in which volatile substances are made to percolate through a solid impregnated with a nonvolatile liquid solvent. The components of the substances are separated according to their migration rates.
- Liquid Chromatography uses a liquid mobile phase to separate mixtures moving through a specially packed stationary column.
- High Performance Liquid Chromatography (HPLC) uses columns of very small diameters and filled with very small particles of packing material.

## Spectroscopy

Spectroscopy is concerned with the production, measurement, and interpretation of electromagnetic spectra arising from either emission or absorption of radiant energy by various substances. The spectroscopic measurements of wavelengths and intensities of radiative energy are made using instruments called spectroscopes, spectrographs, spectrometers, or spectrophotometers. Interpretation of the spectra provides information concerning atomic and molecular energy levels, electronic configurations of atoms and ions, molecular geometries, and chemical bonds. Empirical correlations of the spectral characteristics with chemical and physical properties of matter provide a basis for qualitative and quantitative chemical analysis.

- Atomic Absorption Spectroscopy is based upon the ability of atoms in the vapor state to absorb radiation at certain well-defined characteristic wavelengths, the same phenomenon that is responsible for Fraunhofer lines in the solar spectrum. Its major use is in analysis for trace metal determinations.
- Infrared Spectroscopy measures the absorption of radiant energy in the infrared region of the electromagnetic spectra. The absorption spectra is related to the vibrational and rotational energies of molecules.
- Nuclear Magnetic Resonance Spectroscopy (NMR) is a form of absorption spectroscopy: radio-frequency radiation is absorbed by the nuclei of certain isotopes when they are in a magnetic field. The frequency of

radiation required for NMR absorption depends on the isotope and its chemical environment; the number of absorption peaks for magnetic nuclei in a given chemical environment is determined by the spatial positions of neighboring magnetic nuclei, and the intensity of the absorption peaks is proportional to the number of nuclei.

- Ultraviolet-Visible Spectroscopy measures the absorption of radiant energy in the ultraviolet-visible region of the electromagnetic spectra. The absorption spectra is related to electronic rearrangements in atoms or molecules.

X-Ray Photoelectron Spectroscopy
(or Electron Spectroscopy for Chemical Analysis)

This technique, referred to as either XPS or ESCA, involves the analysis of electrons ejected from matter by incident radiation. Only the surface region of solids can be probed by this technique.