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The Role of MACTLAC Departments in the Preparation of High School Science Teachers

The Chairman ~~and Resource Person~~ presented much information indicating the continued low level of preparation of science teachers in elementary and secondary schools. Less than ten percent of the high school science teachers in Minnesota meet the modest minimum recommendations of the Garrett Committee Report of fifteen years ago. Statistics also showed that liberal arts colleges are producing a distressingly low number of science teachers (only about 10% of those employed in Wisconsin).

The state departments of education are slow to adopt higher requirements for certification. Because of inadequate undergraduate preparation in their science majors, high school teachers tend to do their advanced work in Education. As a consequence, high school students are ill-prepared when they enter college and the chemistry department, receiving a mediocre product from high school Chemistry, faces the problem of producing in four years a teacher who is properly qualified.

The colleges can establish the minimum requirements for the major in Chemistry, but high school teachers can be assigned to teach in fields in which they have not majored. A scarcity of qualified teachers of high school Chemistry encourages the latter situation. The colleges should seek to encourage more students to prepare for teaching Chemistry in the high schools.

But students with bright minds should be encouraged to go to graduate school. Industry, with better salaries, offers competition. As a consequence, the number of Chemistry majors who can be recruited for high school teaching is reduced. It was generally agreed that a student of average ability and who is well prepared in the field could be a good high school teacher. Personality and an ability to communicate with students were recognized as important and necessary characteristics of a good high school teacher.

In conclusion, the group concurred in stating that the college graduates in Chemistry who are to teach in the high schools should meet the minimum recommendations of the Garrett Committee. Physical Chemistry was considered to be more important than Organic Chemistry because of the Chemical Bond Approach. The student must have sufficient background so that he is able to show the impact of Chemistry upon our life and upon the age in which we live. It was also emphasized that an adequate undergraduate preparation in chemistry would permit the teacher to pursue graduate work in the discipline rather than in education.

RESEARCH SEMINAR IN COORDINATION CHEMISTRY

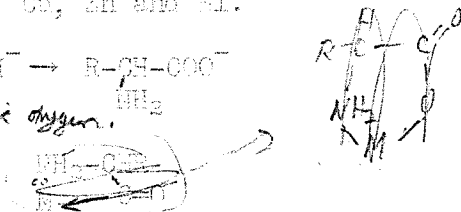
I. Infrared spectra of metal complexes of amino acids

Sister M. Kennelly, Mundelein College

Amino acids studied were $\text{CH}_3\text{CH}_2\text{CH}(\text{NH}_3^+)\text{COO}^-$, $\text{CH}_3\text{C}(\text{OH})(\text{NH}_3^+)\text{COO}^-$, $\text{HOCH}_2\text{C}(\text{OH})(\text{NH}_3^+)\text{COO}^-$, $\text{H}_2\text{N}-\text{CH}_2-\text{C}(\text{OH})(\text{H})\text{COO}^-$,

and these were complexed with the metals, Pt, Cu, Zn and Ni.

In slightly basic solutions, amino acid + $\text{OH}^- \rightarrow \text{R}-\text{CH}(\text{NH}_2)\text{COO}^-$
 which then complexes ~~in the following manner~~ *through the nitrogen and acidic oxygen.*



Study of the NH_2 stretching frequency shows that it appears at lower frequencies as the amino acid is complexed. The standard used is the sodium salt of the amino acid.

~~In acid solution, the amino acid will be $\text{R}-\text{CH}(\text{NH}_3^+)\text{COOH}$.~~ In studies of the $\text{C}=\text{O}$ stretching

frequencies, the hydrochloride was used as a standard. The following results were obtained.

NH_2 stretch (cm^{-1})

	Na	Pt	Cu	Ni(blue)	Ni(green)	Zn
α -n-butyric acid	3390	3213	3311	3333	3333	3322
β -i-butyric acid	3356	3256	3268	3279	3300	3300
Serine	3356	3279	3311	3333	3333	3344
β -alanine	3356	3236	3300	3333	3333	3322

$\text{C}=\text{O}$ stretch (cm^{-1})

	HCl	Pt	Cu	Ni(blue)	Ni(green)	Zn	Na
α -n-butyric acid	1745	1658	1629	1600	1590	1603	1600

A Perkin Elmer 21 was used to obtain the spectra, using solid NBr disks. Some were checked using NaCl mulls. X-ray structure study of the copper complex showed it to be trans planar with H_2O above and below the plane. Studies by Nakamoto in solution showed the same general relationship.

II.

Dr. T. Donovan, Knox College

X will be used to represent $\text{Na}_3[\text{Co}(\text{CO}_3)_3] \cdot 3\text{H}_2\text{O}$.

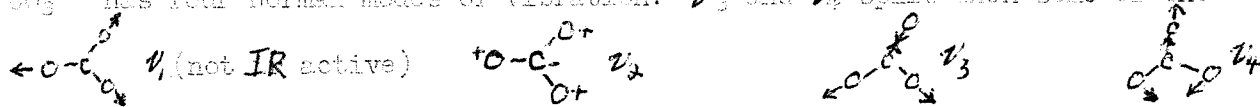
It is found that (1) $\text{X} + 3 \text{en} \cdot 3\text{HCl} \rightarrow [\text{Co}(\text{en})_3]\text{Cl}_3 + 3\text{CO}_2 + 3\text{NaCl} + 6 \text{H}_2\text{O}$

(2) $\text{X} + 3 \text{acac} + 3\text{HNO}_3 \rightarrow \text{tris-acac Co(III) complex}$

(3) $\text{X} + \text{HSCCH}_2\text{CH}_2\text{SH} \rightarrow \text{Na}_3[\text{Co}(\text{SCH}_2\text{CH}_2\text{S})_3] + 3\text{CO}_2 + 6\text{H}_2\text{O}$

X can be prepared by mixing NaHCO_3 , CoCl_2 and H_2O_2 to obtain a green solid. The formula and structure are uncertain. Possibilities are $\text{Na}_3[\text{Co}(\text{HCO}_3)_3(\text{OH})_3]$ where the bicarbonate is a unidentate ligand, or $\text{Na}_3[\text{Co}(\text{CO}_3)_3(\text{H}_2\text{O})_3]$, where CO_3^{--} is a bidentate ligand.

CO_3^{--} has four normal modes of vibration. ν_2 and ν_4 split when some of the O's are



coordinated. The following frequencies are observed and calculated for various cases of unidentate ligands and bidentate ligands, and are compared with those for compound X.

$[\text{Co}(\text{NH}_3)_5\text{CO}_3]\text{Br}$ (observed)	Calculated (unidentate)	$[\text{Co}(\text{NH}_3)_4\text{CO}_3]\text{Cl}$ Observed)	Calculated (bidentate)	Observed for X
1453	1482	1593 (vs)	1595	1455
1373	1376	1265	1282	1380
1070	1069	1030	1038	1075
756	772	760	771	760
678	676	430	429	690
362	303	395	370	

This information seems to indicate that it is monodentate. The very strong line near 1600 cm^{-1} does not appear for the compound X. A large band in the $3000\text{-}3500 \text{ cm}^{-1}$ region was unresolved. Inter- and intra-molecular H-bonding could possibly account for this.

III. Stability Constants

Dr. D. Tarr, St. Olaf College

The stability constant for a 1:1 complex of Fe(III) and benzohydroxyacetic acid was studied. Actually, several complexes can form, depending on the pH of the solution. The 1-1 complex forms a red-purple solution, the 2-1 complex an orange solution and the 3-1 complex a dark crystalline solid.

$$K = \frac{[\text{FeL}][\text{H}^+]}{[\text{Fe}^{+3}][\text{HL}]} \quad \text{and} \quad \frac{[\text{Fe}^{+3}]_t [\text{HL}]_t}{A} = \frac{1}{a} \left([\text{Fe}^{+3}]_t + [\text{HL}]_t \frac{-A}{a} \right) + \frac{[\text{H}^+]}{aK}$$

where A is absorbance and a is molar absorptivity, and L stands for the ligand. The following are representative values.

[H ⁺]	K	a
0.012	2.2	2000
0.116	106	1750
0.351	130	1500
0.17	100	1000

The procedure used was to choose a value for K , which would then give a value for $[Fe^{II}]$. This in turn gave a value of A_{calc} , which can be compared with A_{exp} . The sum of the squares of the differences was taken. Another value for K was then used. This gives a value of the sharpness, which is defined as $\frac{\text{variance} - \text{best variance}}{\text{best variance}}$, $\frac{1/0}{10}$

A sharpness of 20-30 was obtained, which indicated good data. However, the solution was probably a mixture of the complexes previously indicated.

- IV. R. Rich of Bethel College reported the preparation of a very stable complex of copper, prepared from diacetyl pyridine, copper acetate and 1,3-dioxinopropane in DMF. The complex is diamagnetic as a solid and paramagnetic in solution. A similar nickel salt was prepared.

#4

MACTLAC MEETING, Lawrence University

October 15, 1965

Discussion group topic: The Combined Introductory Course in Chemistry and Physics.

In an opening statement Dr. Child of Carleton College called attention to the reasons for the combined introductory chemistry-physics courses and posed the following questions:

1. Do students understand and appreciate the reasons for the course?
2. What is the role of the course in respect to non-science students?

He then asked Dr. Ralph Deal of Kalamazoo College and Dr. Edward Fuller of Beloit College to describe the combined programs in their respective schools. Their reports served as a basis for the ensuing discussion which, at first, consisted largely of questions to them and their answers. By the end of the meeting several more or less well defined ideas and impressions were apparent, and we summarize them in outline form.

AIMS - the combined programs seek to:

1. take advantage of the basic principles, normally first taught in physics courses, which are useful to chemistry,
2. show the underlying unity of chemistry and physics,
3. avoid duplication of material.

ADVANTAGES AND GAINS of the combined program are:

1. there is a definite saving of time,
2. chemistry students come earlier to understand the basic physical-chemical concepts and relations (for example, energy),
3. the student generally is more knowledgeable and better prepared for subsequent courses.

DISADVANTAGES AND PROBLEMS result from:

1. a lack of suitable textbooks,
2. a lack of teachers who have training in both chemistry and physics. As a result the courses usually are broken up into periods taught alternately by chemistry and physics teachers and hence lose some of the desired unity.

3. the difference in terminology and symbols as used by physicists and chemists.

OUTLOOK:

1. More suitable textbooks are forthcoming.
2. The number of properly qualified teachers will probably remain small.
3. The place of the non-science student in the program remains unclear.
4. Combined programs at the higher levels can be expected.

Submitted by,

Harold W. Fenrick
Paul L. Splitstone

Group V. INSTRUMENTATION REQUIREMENTS IN THE UNDERGRADUATE CHEMISTRY CURRICULUM.

Leader: R. Bayer, Carroll College. and John Zimmerman, Wabash College

The discussion began with a report of an informal survey conducted by the group leader. Of the 22 schools comprising the survey:

1. All schools had gas chromatographic, UV and IR instrumentation.
2. Most schools had at least two recorders.
3. Two schools had an NMR and four had a Cary 15 or a Beckman DK spectrophotometer.
4. Thirteen of the 22 schools surveyed were seriously interested in NMR.

The ensuing discussion developed around the criteria involved in the addition of instrumentation to a department's curriculum. Cost did not appear to be the decisive factor. The group noted an increasing willingness of college administrations to purchase costly instrumentation. This observation was especially true when matching fund arrangements could be made.

The next criterion to be considered was the question, "How much instrumentation is essential to the undergraduate curriculum?" The main point of contention was the advisability of purchasing an NMR. This led to a discussion of the effectiveness of an elementary organic course with a spectroscopic emphasis, but without direct student contact with the instruments in question. The group was equally divided on this point. Concern was expressed for an overemphasis ^{on} ~~of~~ instruments at the expense of principles demonstrated by more classical approaches.

The group consensus was that the small liberal arts college could not hope to purchase and maintain an up to date holding in all the diverse areas of chemical instrumentation. However, the chemistry major should be exposed in depth to at least one of the more sophisticated instruments -- IR, X-ray, etc. Student experience with the maintenance, stability and calibration problems inherent in complex instrumentation was considered to be an important complement ^{the} to/use of instrumental data to help answer chemical questions.

Several participants pointed out the common oversight of maintenance costs as

a factor in instrument selection. The mechanical and electronics ability necessary to maintain instruments in an optimum operating condition was a missing factor in most of the departments represented. An informal show of hands indicated approximately half (20) of those present were interested in obtaining formalized electronics instruction. Several noted ^{that} ~~the~~ heavy demand for such instruction has made it difficult to gain admittance to the various concentrated programs of instruction based on the Heathkit adaptation of the Malmstadt-Enke modular electronics approach.

#6
MACTLAC Meeting - Lawrence University, October 15, 1965

Discussion Group - ACS Approval of Undergraduate Chemistry Departments

Chairman - Dr. S. F. Darling, Lawrence University

Resource Person
Discussion Leader - Dr. E. L. Haenisch, Wabash College

~~18 people were present in the group.~~

Dr. Haenisch indicated that at the present time there are over 330 approved departments and 20-25 requests for approval of new departments each year. This constitutes a preposterous working load if each approved institution is to be visited once every five years. The Committee on Professional Training is much concerned with the quality of both undergraduate and new Ph.D. programs.

At the National ACS meeting held in Atlantic City in September, 1965, the Committee met with department heads from approved institutions and discussed various proposed changes in the minimum standards. A new edition of the Minimum Standards booklet should be out some time in December, 1965. The changes will not be very great. Many of the proposals made in Atlantic City will not be put into effect. As the Committee has stressed repeatedly in the past, it is willing to consider special proposals with an open mind.

Questions and answers indicated the following:

1. Biochemistry if offered should have as a prerequisite, one year of organic and some preparation in thermodynamics and kinetics.
2. Some concern has been indicated about the 180 hours of organic laboratory. These may be reduced.
3. Qualitative organic seems to be coming integrated more and more with general organic chemistry. There is nothing wrong, however, with qualitative organic as an advanced course.
4. There will probably always be four semesters of advanced courses required, but one may be in physics or mathematics. As of now, inorganic and analytical courses with a physical chemistry prerequisite are required.
5. There may be some adjustment of the 225 hours now required in advanced laboratory. This may be moved up and 180 hours of organic laboratory may come down.
6. There seems to be a desire to abolish requirements in terms of course titles and express requirements in terms of required topics.

7. A reading knowledge of German and evidence of the use of it in the study of chemistry is still required. Very likely Russian will be permitted as an alternate language, but it would then have to be used in advanced chemistry courses.
8. When an institution is under consideration, the Committee will probably ask to see copies of examinations, laboratory reports, research reports, etc.
9. After a request for an evaluation visit has been sent to the Committee, it may be six months or a year before the school is visited.
10. Requests for copies of the Minimum Standards booklet should be sent to:

Mr. J. H. Howard, Secretary
Committee on Professional Training
343 State Street
Rochester, New York 14650

Respectfully submitted,

Kenneth L. Hamm

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Kenosha, Wisconsin

James C. Nichol
James C. Nichol
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MACTIAC MEETING - OCTOBER 15-16, 1965

Lawrence University

Appleton, Wisconsin

Discussion Group #7.

Applications of Nuclear Magnetic Resonance (~~N-M-R~~) in
Organic Chemistry.

Chairman: Dr. John McFarland, De Pauw University

Panelists: Dr. Addison Ault, Cornell College.

Dr. Howard Burkett, De Pauw University.

Dr. Luther Erickson, Grinnell College

~~October 15-20~~

Dr. McFarland introduced the panelists and proposed that the principles and application of N M R in teaching and research be considered and discussed. He pointed out that while large universities have complete instrumentation and sufficient funds for maintenance, the liberal arts college finds acquisition of instruments such as N M R or the mass spectrometer difficult, if not impossible.

Dr. McFarland stated that the graduate schools are beginning to insist on a working knowledge of the principles and applications of N M R. In order that his students will not be deficient in this field, he offers an introduction to the principles and applications although his school has no N M R spectrometer. Furthermore, several elementary organic textbooks include discussions of N M R applications, so that even the undergraduate student must be acquainted with this valuable technique, even though the student may never see an N M R machine until he goes to graduate school.

Dr. Erickson summarized the principles of NMR and discussed in detail three parameters which are present in high resolution NMR spectra. These are: 1) the chemical shift; 2) spin-spin coupling, and 3) relaxation times.

Dr. Erickson described undergraduate research work which he is supervising at Grinnell. In this work the student runs the NMR spectrometer and thus gains first hand knowledge of instrumental techniques. ~~This work involved conformational analysis~~

→ This work involved conformational analysis studies on substituted succinic acids and anhydrides where the dihedral angle between vicinal protons varied. The variation of the spin-spin coupling constant (J) with the variation of the dihedral angle was studied. For symmetrical vicinal dihalosuccinic anhydrides, the protons are equivalent except when one was attached to C^{13} nucleus (spin = $\frac{1}{2}$). High resolution techniques are required for observation of the C^{13} - H^1 splitting, which yields proton-proton spin coupling constants. There was a variation of J when vicinal dibromo anhydride was dissolved in various solvents, but no variation for the similar dichloro compound in the same solvents. This difference in behavior was not explained.†

† This work involved the determination of the C^{13} - H^1 splitting. There was a variation of J when vicinal dibromo anhydride was dissolved in various solvents, but no variation for the similar dichloro compound in the same solvents. This difference in behavior was not explained.

Other experiments included investigations into the metal ion (~~Co~~ in D_2O) complexes of biologically significant amino acids, including histidine and glycine.

Dr. Auld qualitatively defined and described saturation, spin-spin decoupling, relaxation and the effect of nitrogen on proton signals. Saturation was described as excitation of the nuclei (protons) so that the population of those nuclei in the excited state precisely equals the population of the nuclei in

the unexcited state. When this occurs, there can be no net absorption of energy by transitions between the two states, and therefore the signal ~~states begins to fade~~ will fade to zero. ~~will occur.~~

Relaxation is the process of emission of the excess energy into the other energy-state nuclei. ~~The methods of relaxation~~

Replace 2. by "There are two general mechanisms of relaxation: spontaneous emission (a minor factor) and emission stimulated by fluctuating magnetic fields. The fluctuating magnetic fields may be due to other magnetic nuclei (most common), to dissolved oxygen or to other paramagnetic species in solution."

~~and a of collision.~~

Factors affecting fluctuating magnetic fields were briefly described. ~~These include a) viscous solutions which lead to~~ saturation, b) ~~the~~ dilution of the solution, the intensity of of the sample.*

Spin-spin decoupling was described as a method which is very useful in determining the structure of complex molecules. By irradiation of the sample with a selected radio frequency, which

Replace 4. by "transitions between states of nuclei with the corresponding chemical shift will become very frequent. Under these conditions, neighboring nuclei which ordinarily would be split by these nuclei will now all experience an average field from them and therefore will not exhibit any splitting due to them."

Replace 5. by "Dr. Ault also cited some examples to illustrate the different possible appearances of the N.M.R. signal due to protons bonded to nitrogen. The two factors involved are the rate of exchange

of the protons bonded to nitrogen and the rate of relaxation of the nitrogen nucleus which can be rapid due to its nuclear quadrupole moment."

Ammonium nitrate in concentrated hydrochloric acid has three peaks whereas an aqueous solution of ammonia has only one absorption peak due to the increase in chemical exchange reactions.

Splitting patterns for different nuclei were described but are too detailed for inclusion in this report.

Dr. Kayser presented a discussion of an undergraduate research problem concerned with detection of restricted rotation due to hindered conformation. N,N-dimethylformamide has a limited rotation about the C-N bond in the ionic species. This decreased rotation leads to two separate peaks due to the two different environments for the non-identical methyl protons. Upon application of heat, the equilibrium is shifted to the non-ionic species and only one peak becomes apparent.

Other experiments included student research on the decarboxylation of 2,4,6-trimethoxybenzaldehyde in 70% H_2SO_4 and 64.6% D_2SO_4 in order to determine the position of initial attack by the acid.

Dr. Burkett showed a series of spectra of compounds related to 3,3,3-trichloro-1-nitropropene. Variations included the 1- and 2-methyl and ethyl substituted alkenes and the corresponding alkanes.

A round table discussion of teaching N M R at the undergraduate level followed. It was the consensus of the group that it should be taught and in fact, a majority of the schools represented presently teach N M R. There was no general agreement as to the best time for teaching this course during a student's undergraduate career. The time of introduction varied from sophomore year Elementary Organic Chemistry (using Roberts and Caserio's Organic Chemistry) to mid-year junior Physical Chemistry to senior year Advanced Organic or Inorganic Chemistry. There was one case of

teaching this material together with infrared, ultraviolet and mass spectrometry during the third term of the sophomore year when Advanced (Qualitative Organic) Analysis was offered, at a school on the three term-three course system. (~~school and name available from FBI~~).

The problem of justification of the purchase of an N M R machine is perhaps the main reason why most schools have no plans for acquiring an instrument at present. The initial purchase price -- about \$30,000, for Coe College's A-60A -- is the main factor. However maintenance, presumed by many to be high, has proven to be surprisingly low at Grinnell, according to Dr. Erickson. *He suggested that it does, however, require that one staff member assume responsibility for maintenance.*

It was concluded that N M R is a very valuable tool in teaching as well as research. Whether or not a school has an instrument, the theory and applications of N M R should be thoroughly covered. Most students will learn the subject matter better when there is an instrument available.

The attached bibliography was submitted by the panel.

If any further information is desired concerning any aspects of this report, please correspond directly with the person (s) concerned.

Respectfully submitted

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Group 8 - Role of Analytical Chemistry in the Undergraduate Curriculum

Chairman: Dr. Stanley Watkins, Coe College

Resource Persons: Dr. W. Stratton, Earlham College

Dr. J. Bixler, Lake Forest College

Dr. R. Ramette, Carleton College

Dr. Watkins posed as the question for discussion how to integrate analytical chemistry into the total chemistry curriculum. In the sense that it requires a knowledge of organic and physical chemistry it is already integrated. Content is currently being handled in several ways. It may be integrated into other courses and eliminated as a separate course, or introduced in general chemistry to be followed by a more rigorous treatment in junior or senior year as a separate course. He called on the resource persons to describe their solutions to this problem.

1) Dr. Stratton; Earlham College

In the Earlham curriculum (discussed in detail in an AC₃ report) quantitative methods and analytical techniques have been integrated into courses as needed--e.g., ionic equilibria in the course on "Ions", instrumental analytical techniques in the course on "Energy". The buret is used as a tool in freshman chemistry. Second year students prepare compounds and analyze their own preps. Organic qual comes in the junior year. Further synthesis and analysis of compounds, with methods taken mostly from the literature, is done in the senior year.

Dr. Stratton also indicated that the University of Illinois eliminates the quant course for chemistry majors. The lab work is part of the general chemistry course. Dr. Stratton feels that students are not ready for the theory at this point. There must be a significant lecture component and carefully designed laboratory work.

2) Dr. Bixler; Lake Forest College

Expressed more of the traditional view. He feels sufficient and specific time must be devoted to analytical chemistry as a separate course. At Lake Forest qualitative analysis is taken in the junior year in the form of a rigorous course in solution equilibria. The qual scheme is an excellent way to get in descriptive chemistry. Second year students take a term of quantitative analysis with special emphasis on titration curves, introduction to absorption spectrophotometry, and the analysis of real substances and mixtures.

3) Dr. Ramette; Carleton College

All chemistry demands analysis. The declining emphasis on analytical chemistry will lead to a shortage of good analytical chemists and teachers. The Carleton curriculum includes quantitative methods at all levels of instruction. A student should develop a feeling for comparative values of several methods of analysis. In the senior year analytical chemistry is presented with a professional outlook.

In the ensuing discussion the following questions were raised and answered:

How can one deal adequately with all the different and complex equilibria encountered in qualitative analysis?

This cannot be done in the freshman year. Do much with outside reading and individual student conferences.

What "significant lecture components" should accompany quant experiments?

The theory of indicators, end-point detection, titration curves, comparative methods.

What is the solution to the shortage of analytical chemists?

ACS should put the analytical course back into the minimum standards requirements.

In the semester plan, where would be a good place for the analytical course?

It was suggested that quant be put in the first term of the sophomore year; organic in the second term; physical chemistry in the first term of the junior year, and both physical chemistry and quant courses in the second term.

How can the "cook-book" aspect of qualitative analysis be eliminated?

Assign simple salts at the end of the course, to be analyzed without notes or texts.

Give an unknown ion not included in the qual scheme.

Do not allow lab manuals in the lab at any time - directions are restricted to what the student can put on a 3x5 card.

Is the difficulty in analytical courses merely one of nomenclature? Have we changed course names but not the content?

It is wrong to equate elementary quantitative analysis to analytical chemistry. New course names are more descriptive and include analytical techniques where needed.

Is there replication of samples if quantitative analysis is done in freshman year?

Both "yes" and "no" answers were given.

What are the advantages of including quantitative experiments in freshman year?

You may show that different experiments need different degrees of precision, a concept not always easy to show with the conventional quant course.

What inorganic preparations have been used for subsequent analysis?

BaCl_2 (the Ba^{++} interferes with Mohr titration for chloride); hexammine cobalt complexes (Kjeldahl for NH_3 , iodometry for Co^{++}); $\text{K}_2\text{Cu}(\text{C}_2\text{O}_4)_2$; (gravimetric for K^+ , COPPER by spectrophotometry, oxalate by redox).

What is left to be taught in advanced courses?

Rigorous theory of chromatography; polarography; solvent extraction; advanced equilibria. Content will depend on the particular curriculum of the department.

What is the place for "Electronics for Scientists" in the chemistry curriculum?

It is a difficult course to teach! Maybe taught by the physics department and encourage chemistry majors to take it.

If instruments are used at the freshman level, are they just "black boxes"?

For the most part yes. However, at some time in the curriculum these instruments should be explained in theory.

What about NMR and mass spectrometry?

NMR and mass spectrometers are not necessary instruments in the undergraduate college. Mass spectrometry is useful only with a high precision instrument. The basic ideas of NMR can be given and spectra from other sources can be handled and analyzed by the students.

Respectfully submitted,

Sister M. Emilius, OSF (Alverno)
Sister John Mark, OP (Rosary)