Pure & Appl. Chem., Vol. 50. pp.575-577. 0033-4545/78/0601-0575 $02.00/0
Pergamon Press Ltd. 1978. Printed in Great Britain.

ANALYTICAL CHEMISTRY IN UNDERGRADUATE LABORATORIES

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Abstract - Analytical Chemistry can be defined as "the use of techniques to solve problems related to materials", and as such, can be labelled as a "relevant" branch of science as distinct from some more theoretical or "elitist" sections of Chemistry. It overlaps the boundaries of the classical division of the subject into Inorganic, Organic and Physical Chemistry. Only small changes in syllabus are necessary to give a balanced introduction to Analytical Chemistry to undergraduates, and to lead into graduate programmes at the M.Sc. level.

INTRODUCTION

In my view Analytical Chemistry is a specialisation in its own right and the need for graduates with professional training in this area is unlikely to diminish for some time to come. It requires a full measure of practical skill, a broad scientific background and a tolerance to routine, and offers in return the reward of using chemistry to solve problems of importance in all walks of society. Many have presented views on the teaching of Analytical Chemistry and some of these will be shown as examples together with other papers and books in my poster session.

As Analytical Chemists, we have had to struggle for survival against the now-established pattern of Inorganic, Organic and Physical Chemistry although all, including interdisciplinary Biochemistry, Geochemistry and Materials Science need it to collect their data. Perhaps the time has come to speak up for the "Renaissance of Analytical Chemistry". I am not sure how Educational Science would regard its value in teaching: from the little that I have read it seems that their discipline borders on a Social Science and cannot be exact in all parts. I hope they will forgive me for suggesting that their views can be regarded to an approximation as somewhere between the extremes of, on the one hand, the Elitist who says that "University education should develop the best minds in the community to the utmost and has the responsibility to undertake fundamental research aimed at extending the frontiers of knowledge" and on the other there is the Relevantist who maintains that "University education should train a Nation's youth to take responsibility for Society, and for management in Industry, including the development of the new processes needed to improve our living standards". Both are honourable but it is the latter view that one chooses in order to defend the inclusion of some practical Analytical Chemistry in undergraduate courses. Indeed this line might even support the view that theory has grown too far at the expense of practical skills generally in University teaching. It could be that because of this there are signs that in England some graduates are having difficulties in competing for their first jobs with industry-based students who have studied part-time at Colleges of Technology since leaving school.

Against this rather grim background, we can build up, on a more optimistic note, and show how, with relatively small changes of syllabus, one can try to give a balanced introduction to Analytical Chemistry at undergraduate level, and how this can be extended for some who want to, by continuing post-graduate and part-time studies, to the Master's degree level. I know that patterns of this kind are going on in several places elsewhere, and in subsequent discussion it will be valuable to know what common ground exists between the different Universities and Technical Colleges represented at this important UNESCO Conference.

I define Analytical Chemistry more exactly as "the use of Techniques to solve Problems related to Materials", as this emphasises the three areas which need to be brought together in a unified approach for its teaching, and I will discuss these in more detail.

On the techniques used, one needs to give systematic attention to the steps or unit processes that are involved in the complete procedure of analysis, thus:

Sampling $\longrightarrow$ Separation + Determination $\longrightarrow$ Calculation (Action)

The undergraduates will need to know how to take representative samples of gases, liquids and solids from outside the laboratory. They need to have practical experience of a reasonable selection of separation techniques in common use. These will range from simple "clean-up" procedures such as the solvent extraction of trace metals from polluted water or wet-ashing of a food for the same purpose to the complete resolution of organic constituents by TLC and GLC (demonstration only). The determination step that follows will fall into the categories of either Chemical or Instrumental Methods. It is wrong to think that industry has discarded the former, and there are usually good reasons for retaining many of these low cost methods to cover a range of "one-off" analyses. Also the ability to use balances and volumetric glassware with precision and accuracy to better than $\pm$ 0.2% is implied in the use of most instrumental methods which have confidence levels of $\pm$ 1 to 2%. The determination of chemical oxygen demand and Winkler's method for dissolved oxygen in natural waters are typical examples of this type of analysis. On the other hand, it is true that Instrumental techniques, especially where they can be operated automatically, are used increasingly for low cost routine work. The principles behind these methods (Opticometric, Electrometric and others) are usually well-covered by lectures in Physical Chemistry. However, one needs to consider the way in which Analytical Chemists rate these in terms not only of cost effectiveness, but also of sensitivity, selectivity, limit of detection, linear range and so on. Perhaps most important of all is that undergraduates should learn to test their instruments by careful calibration and standardisation using authenticated chemical standards. The final step of calculation is as important as any of the others and it is here that the largest errors can occur.

Turning now to the problems concerning the real materials that Analytical Chemists are asked to investigate, one sees that these are very wide-ranging and can offer the young graduate many types of scientific "adventure". This is because he needs to read up and become a "bit knowledgeable" about the background of many subjects in order to make a wise choice of the techniques that will be most useful in solving particular problems. Their good scientific background, and ability to study by themselves, is of course the justification for using graduate labour in analytical chemistry, rather than technicians. At present I have an M.Sc. student from Nigeria considering quicker methods for E.coli counts of potable waters there and an M.Phil. who is surveying the levels of the birth pill steroid residues in water resources in England. Both topics should appeal to the Relevantist. Such questions as these raise legal and social problems also, and the undergraduate needs to be aware that he must be prepared to work as part of a team in solving such problems when he leaves the University.

For the final part of my paper, I turn now to consider patterns of teaching analytical chemistry in a unified way in order to see how much an undergraduate syllabus might need to be changed. I have said already that these need not be large changes, based on our experience at Chelsea College. A good deal depends on how well practical chemistry is taught from the schools onwards, and I do think that more basic work (the "bread and butter stuff") should be taught there between 16 and 18, to at least the standard achieved by industry, presumably with the less able school leavers. It is worth noting incidentally that many of our most senior analytical chemists in England "came up the hard way" by part-time education. For undergraduates who come full-time to us, we use a small part of their final year, about a sixth, in order to give a unification of the basis of Analytical Chemistry in much the way that I have described it and as they will meet it in their future employment. We have them for one whole day a week, 10 a.m. to 5 p.m., for the thirteen weeks of the first semester of their third year. They have twenty-five lectures and about fifty hours practical work. In the practical sessions there are about thirty-five students. They are divided into groups of seven for demonstrations including the use of atomic absorption, gas-liquid chromatography, infra-red spectroscopy, ion-selective electrodes and differential pulsed polarography. But for most of the time the students do their own practical work in pairs and start real development projects, for example, to measure the uptake of fluoride by germinating seeds, the testing of detergents to specification, the determination of strontium levels across a mineral deposit, solvent extraction and the polarographic determination of a known drug metabolite, the determination of chromium in River Thames water, the use of attenuated total reflection to record the infra-red spectra of polymer forms, and so on. There is one member of academic staff in charge of this course with assistance from two postgraduates who are doing research in Analytical Chemistry for Ph.D./M.Phil. degrees and two experienced technicians. The practical course ends with each pair giving a ten to fifteen minute talk on their achievements before their fellows and a certain amount of celebration usually follows this meeting! At present the three hour theory paper on the lectures carries more weight towards the course assessment than the report on the practical work in keeping with general practice in the Department.

From this brief undergraduate course, one does not claim to have made a practising analytical chemist but it does make them aware of the specialisation, has the advantage of not causing too much disturbance to the rest of our B.Sc. syllabus and does not force it upon those (elitists) who do not want it. For the more professional training of Analytical Chemists, we strongly favour the M.Sc. level course and personally I prefer to have mature students with three years' industrial experience of analysis - but perhaps that is another story!