Talanta 51 (2000) 1125–1147
Talanta
www.elsevier.com/locate/talanta

How to succeed in analytical chemistry: a bibliography of resources from the literature

Charles A. Lucy *

Department of Chemistry, University of Alberta, Edmonton, Alta, Canada T6G 2G2

Received 30 July 1999; received in revised form 9 December 1999; accepted 13 December 1999

Abstract

Technical excellence is necessary to succeed in a career in analytical chemistry. However there are many other skills necessary for success for which analysts receive no formal training. Talanta has had a tradition of publishing articles on practical aspects of our profession, such as how to write a paper in spectrophotometry or on ion selective electrodes. This article culls the literature for advice on how to purchase equipment, how (and when) to write a manuscript, how to review an article, how to give oral, poster and computer presentations, and how to get a job in analytical chemistry.

Keywords: Analytical chemistry; Bibliography; Literature; Career

1. Introduction

Probably the best place to start a discussion of how to succeed in analytical chemistry is to describe what analytical chemistry is. However, this is not an easy task. The late Professor Charles N. Reilley of the University of North Carolina at Chapel Hill glibbly stated that [1,2]:

> *Analytical chemistry is what analytical chemists do.*

A more detailed definition is provided by the Division of Analytical Chemistry of the American Chemical Society [3]:

> *Analytical Chemistry seeks ever improved means of measuring the chemical composition of natural and artificial materials. The techniques of this science are used to identify the substances which may be present in a material and to determine the exact amounts of the identified substances.*

They then go on to define the duties of an analytical chemist as:

> *Analytical chemists work to improve the reliability of existing techniques to meet the demands for better chemical measurements which arise constantly in our society. They adapt proven methodologies to new kinds of materials or to answer new questions about their composition.*

* Corresponding author. Fax: + 1-780-4928231.
E-mail address: charles.lucy@ualberta.ca (C.A. Lucy)

0039-9140/00/$ - see front matter
PII: S0039-9140(00)00284-8

They carry out research to discover completely new principles of measurement and are at the forefront of the utilization of major discoveries such as lasers and microchip devices for practical purposes. They make important contributions to many other fields as diverse as forensic chemistry, archaeology, and space science.

Finally, in 1992 the Federation of European Chemical Societies held a paper competition to define 'what is analytical chemistry?'. The winning entry by K. Cammann of the University of Münster (Germany) stated [4]:

Analytical Chemistry provides the methods and tools needed for insight into our material world…The Analytical Chemist is specialized in providing reliable tools for answering four basic questions about a material sample: What? Where? How much? What arrangement, structure or form?

Regardless of the precise definition, it is obvious that analytical chemistry is a wide-ranging and interdisciplinary subject, such as is reflected in each issue of Talanta. As such, it is difficult for any one individual to possess all, or even most, of the skills necessary to succeed in this field. Given this, it is not surprising that basic skills necessary to a career in analytical chemistry, as opposed to the science of analytical chemistry, are often overlooked.

In the 1970's a series of landmark papers were published in Talanta. These papers did not report novel and significant advances in analytical chemistry. Rather they discussed what information should be included in a manuscript describing a new spectrophotometric, gravimetric, or titrimetric method. As such they were unique within the analytical chemistry literature. Essentially all of the scholarly literature in analytical chemistry describes the science and application of analytical chemistry. Little discussion is devoted to practical issues such as what career opportunities exist for analytical chemists, how to communicate your results, or how to purchase an instrument. Yet these issues are critical to the success of every analytical chemist's career.

The objective of this paper is to provide a listing of the information and advice relevant to analytical chemists which exists in the literature. The purpose is not to exhaustively detail this advice, but rather to bring these resources to the attention of the reader so that they may make use of them. It is also hoped that this article will catalyze a revival of Talanta's publication of professional aspects of analytical chemistry.

2. A career in analytical chemistry

2.1. Advice for scientists in general

There are a number of books that provide practical advice about how to succeed in a career in science [5–8]. These are summarized in Table 1. The briefest of these books, and in many ways the most readable, is 'A Ph.D. is Not Enough' by Peter J. Feibelman [7]. The philosophy of this book is best summarized by the quotation in the last chapter: "Experience is the best teacher (but only when the experience isn't fatal)". The book covers topics primarily of interest to individuals starting their careers in science.

A more cynical and calculating book of advice for a career in science is Carl J. Sindermann's 'Winning the Games Scientists Play' [5]. This book answers the most essential questions for success. A subsequent book by Sindermann is 'Survival Strategies for New Scientists' [6]. This book is aimed at the younger scientist. Indeed, W.S. Lyon of the Analytical Chemistry Division of Oak Ridge National Laboratory states that this book

…should be required reading for graduate students and young professionals who aspire to partake successfully in The Joy of Science.

There are also a number of Web sites devoted to issues related to success in a career in science. These include Science's Next Wave from the American Association for the Advancement of

Table 1
Practical advice on a career in science

A Ph.D. is Not Enough [7]
How to choose a thesis advisor and a post-doctoral position.
How to give talks.
How to write papers ('Publishing without perishing').
A comparison of the merits of jobs in academia, industry, and government laboratories.
What happens in a job interview and what you may be asked.
How to prepare a successful grant proposal.
How to establish a successful research program.
Winning the Games Scientists Play [5]
How to overcome bureaucracy and bureaucrats.
How to get on the fast track.
How to organize a meeting and attract top people.
How to publish papers.
How to act at a meeting.
How to get and use power.
How to review a paper.
How to write a review.
How to prepare a talk.
How to organize a symposium or conference.
Survival Strategies for New Scientists [6]
What happens at conferences.
Issues to consider in choosing a thesis supervisor.
Issues associated with recruitment.
How to prepare notes for a lecture.
What are the characteristics of the scientific workplace.
What is the appropriate etiquette for a junior scientist.
Getting What You Came For [12]
Do you need to go?
Choosing a School: The Thesis Adviser and Secondary Aspects.
Application and Admission.
Master's and Doctorate: The Hurdles
Managing Yourself
Choosing and Managing Your Thesis Committee
The Thesis
Dealing with Stress and Depression
Bringing It All Together: The Job
To Boldly Go [8]
Career planning.
How to explore the job market.
How to network.
Review of books on careers in science (including those above).
Listing of Web sites (some of which are listed below) which advertise jobs and give practical advice for the job search.
CV versus resume, there *is* a difference.
How to construct your resume to be scanned[a].
Case studies of how to tailor one's resume for a particular job application.
The interview.
How to negotiate an offer.
Science's Next Wave [9]
Career transitions.
Alternative science careers.
Career and job-hunting news.
Family and career issues.
Women in science.
Science's big debates.

[a] Many larger companies and agencies will scan resumes, and then use computer programs to search for desirable employees.

Science [9], the Career Planning Center sponsored by the National Academy of Sciences [10], and ChemCenter of the American Society of Chemistry [11]. Science's Next Wave is a weekly online publication that covers scientific training, career development, and the science job market. Agencies in Canada, China, Germany, New Zealand, the United Kingdom and Japan support country-wide access to the Next Wave for scientists at universities, research institutions, and government agencies. In the United States, many universities, research establishments, and government agencies have subscribed to the web page. The Next Wave web page has a listing of these universities and agencies. Alternatively, individuals can also subscribe.

2.2. Graduate school

There are numerous steps involved in a career in analytical chemistry. The book 'Getting What You Came For' [12] by Robert L. Peters provides excellent advice for students who are considering or who have just started graduate school. Peters' experiences during his "eight long, painful years" getting his doctorate in fish biology provides poignant and useful advice to students considering analytical chemistry. The chapters in this book are summarized in Table 1. Some of the advice is surprising ("it is important to find a good thesis adviser *before* you choose the university", and "don't concentrate too much on teaching") and some anecdotes are alarming (a physics professor at MIT *compromised* and reduced a student's lab time to 95 h a week). However, the discussion is merely meant to open undergraduates eyes as to what is entailed in graduate school. In that regard, it does a very good job. Dermer [13] gives a briefer discussion of choosing a graduate advisor and a research project. I give this article to all prospective graduate students that visit my lab, and they always find it thought-provoking.

Another excellent discussion of choosing a thesis advisor is Sindermann's chapter entitled 'Have You Hugged Your Major Professor Today?' in 'Survival Strategies for New Scientists' [14]. In this chapter Sindermann gives an extensive discussion of the importance of the advisor–student relationship, and even provides a checklist of questions to consider when choosing a thesis advisor.

2.3. Post doctoral

A post doctoral position is an important stepping-stone in a career in analytical chemistry [15]. In Chapter 2 of 'A Ph.D. is Not Enough!' [7] Feibelman discusses the selection of both the Ph.D. supervisor and post-doctoral position. He stresses that there are three important tasks to accomplish in your post-doctoral years: to decide in what area of science to make your name; to *finish* at least one significant project; and to establish your identity in the research community sufficiently to land an assistant professorship or a junior position in an industrial or government laboratory. These imply that you do not want a position where your field of research is undefined (you want to get to work on a significant project upon arrival or shortly afterwards), and you do not want to get involved in a project where the chances of producing results in time for your job search are low. Further if you are changing fields, you want to start reading and learning *before* you arrive at the post-doc site. This will again help to ensure quick results.

A number of articles on issues related to post doctoral positions are available on the Web at *Science*'s Next Wave site [9]. These identify a number of characteristics for 'good' post doctoral positions [16]: a flexible advisor and project. These allow the post doc to best approximate the real world of research science by allowing one to develop new areas of research and seek out sources of funding; a decent salary and benefits; many good colleagues and good facilities; and prestige. However, Jensen [17] asserts that the quality of the science should be the overriding priority. He advises one to check out recent papers from the lab, ask opinions of colleagues and faculty about the principle investigator, and talk to recent lab graduates. Further, the project should force the post doc to aquire new skills. This rounds out your knowledge and experience, allowing you to come out from under your Ph.D. advisor's shadow and establish your independent research program.

But how do you get a post-doctoral position? A key is for a Ph.D. graduate to have proven productivity in the lab, and be an interested and involved member of their local scientific community. The former is obvious, and involves publications on your graduate work. The latter point is not as obvious. Interacting within your scientific community will have the obvious benefits of increasing your knowledge and exposure, and help you establish your network. These points are important because your letters of reference are a critical ingredient to getting a post doc position [18]. Obviously, one letter of recommendation must come from your thesis supervisor, and your productivity will have a significant impact on this letter. However, it is equally important to have strong letters from others. Name recognition and reputation are important factors, but only when coupled with some years of positive interaction with the recommender. The recommender should be enthusiastic about you, and have followed your career with interest. Such interest is more likely to come about if you have actively interacted with your colleagues.

You should start your search for a post doc a year and a half before you graduate. Once you have selected a few labs, based on the criterion described above, you should write to the principle investigator expressing your wishes. The letter should be specific to the lab, not a form letter. It should describe your experience and interests briefly, and should reflect a knowledge of the current work in the laboratory. Your CV and publications should also be included. It can also be useful to have your thesis supervisor contact your potential post doc advisor on your behalf. After a few weeks follow up your letter with a phone call or e-mail.

2.4. A 'real' job

General discussions of careers in science are given in books mentioned at the beginning of this article. Feibelman [19] and Sindermann [20] discuss the pluses and minuses of jobs in academia, government, and industry. Fiske [8] focuses primarily on how to get a non-traditional science job (see below). In addition to discussing writing resumes and CV's, interviewing skills, and how to negotiate an offer, he offers unique advice on how to research job opportunities beforehand. Similar advice is also available on the Web at the Next Wave site [9], which has articles discussing managing first impressions at an interview, how to present your weaknesses at an interview, dressing for success, and how to network.

The Career Planning Center [10] provides electronic bulletin boards on: graduate schools, post doctorals, careers and teaching; an advice service which will match you with an on-line mentor (professionals can also volunteer to act as mentors); and provides job postings.

ChemCenter provides a listing of jobs advertised in Chemical & Engineering News. This service is only available to members of the American Chemical Society (ACS). ACS members can also post their personal employment profile, which can be searched by potential employers. The site also provides a limited array of articles on topics such as networking, job-hunting in mid-career, and searching for jobs using the net.

A recent article details the resources available from the American Chemical Society Career Services [21]. They provide a number of publications. 'Careers for Chemists: A World Outside the Lab' illustrates possible chemistry careers by profiling more than eighty chemists in more than twenty fields. 'Tips on Résumé Preparation', 'The Interview Handbook', and 'Targeting the Job Market' review the basics for getting a job. 'Career Transitions for Chemists' covers personal assessment, salaries, résumés, and networking for laboratory jobs and other careers. It also discusses other services offered such as: workshops; the ACS Professional Data Bank; and the job bank (available only to ACS members) [11]. In addition to technical competence, Marasco stresses that a number of other competencies are important to a career in chemistry. These include: communication skills — you need good oral and written skills, as well as an ability to listen; interpersonal skills — you must be able to approach people you do not know to discuss career options and directions, and in the workplace you need to be comfortable talking to diverse groups of people both inside and outside the company; and initiative — in searching for a job, do not mail out resumes and then passively wait for the telephone to ring. Be self-motivated, assertive and self-starting. These are the qualities that employers are looking for, and so they should be reflected in your job search.

Stu Borman provided an interesting, if somewhat dated, comparison of analytical chemistry careers in academia or industry [15]. A more recent description is offered in an article on training analytical chemists for industry [22]. Industrial analytical chemistry is characterized as focussing on real world problems (often several at once) quickly with the resources at hand and involving collaboration with teams of chemists and engineers who may be located throughout the world. The projects will be diverse. Therefore the analyst must be flexible and willing to approach each problem as a unique challenge. Generally the analytical chemist must make use of the tools available in or around the lab. An elegant answer too late is useless. Finally, industry values analytical chemists for their problem solving ability.

Sindermann [23] characterizes industrial research in a variety of settings from large industrial research laboratories to small entrepreneurial ventures. He provides advice for young scientists in industrial settings: establish an early reputation as a good team player; charge ahead, but give others appropriate credit; be mindful of patent possibilities for processes or equipment that you develop. Applying for patents will increase your visibility within the company; if a project is going nowhere, or headed by an unassertive team leader, take the first opportunity to move to another project. But do not do this too many times, or it will appear that you cannot complete an assignment; and if you have science management as a career goal, begin early to acquire training. Take advantage of company policies on released time and tuition payment. Again, the Web site Next Wave has a number of articles discussing industrial jobs [24], as well as alternative careers [25] such as technology transfer, patent law, and science journalism. Finally, Newman [26] provides case studies of six analytical chemistry professor's activities as entrepreneurs.

With regard to applying to government agencies, Sindermann [20] provides useful advice. He stresses that it is important to write the initial letter to a *person*, and not just to an *office*. You should be prepared to be ignored, and then send a follow-up letter, followed in turn by a phone call to the *appropriate level* — too high and you irritate, too low and you get nowhere. The key in such initial contacts is to be aggressive, but polite. Emphasis your particular talents or expertise. Seek internships or temporary positions, as they will allow you to study this complex system from within, so as to place you in an advantageous position when a permanent job does develop.

Table 2
Do's and Don'ts for being an independent consultant

Do's

Do define the consulting services you intend to provide.
Do study your target market, to find out who needs your services, and who is providing such services and how you will compete.
Do maintain and expand your contact network. Most of your initial work comes from word of mouth
Do develop a support network. Find others whose skills and expertise complement your own so as to better serve your clients.
Do develop an office infrastructure (word processing, courier services, internet provider, etc.)

Don'ts

Don't try to stay attached to the company you left. Expand your client market.
Don't let your clients down.
Don't hesitate to get help, both legal and technical.

Many scientists now find themselves seeking 'non-traditional science jobs'. The book 'To Boldly Go' by Peter S. Fiske [8] is based on seminars from the Stanford University Career Planning and Placement Center, and provides a wealth of advice for such individuals, as well as anyone seeking a job in science. It emphasizes that training in science develops a number of skills that are important in a variety of careers. However, the book stresses that simply having such skills will not land you a job. It emphasizes that career planning does not start with looking for a job. Rather career planning is a host of professional and personal actions undertaken to educate oneself and the outside world about your unique talents, gifts, and capabilities.

An expanding area in industrial jobs is consulting. A series of short articles were recently published in Canadian Chemical News [27–29] and give advice on careers in consulting. The book 'Inside the Technical Consulting Business' [30] by Harvey Kaye provides a more detailed and comprehensive discussions of issues relating to starting and succeeding as a consultant. Some of the Do's and Don'ts that arise from these discussions are summarized in Table 2.

3. Communicating your science

A first question that arises in writing a manuscript is what constitutes publishable material? The Aims and Scope of Talanta [61] states that the journal "provides a forum for publication...in all branches of pure and applied analytical chemistry...[with] papers on fundamental studies and novel instrumentation development...especially encouraged." Professor R.A. Chalmers, former Editor-in-Chief of Talanta, stresses that novelty alone is not sufficient to justify publication of a new method [37]. Rather the method should also represent a significant improvement over competently performed conventional methods. Numerous others express similar emphasis on the need for the novel technique to provide superior performance [31,44]. Further, the novel method should have useful applications [32,44]. As early as 1933 Lundell [32] stressed the

Table 3
Statistical analysis of analytical chemistry journal articles

Journal	Number of words			Turn-around	Citation
	10%	Mean	90%	Days	Impact factor[a]
Anal. Chim. Acta	2514	4308	6101	264	1.778
Analyst[b]	3270	5731	8192	135[c]	1.614
Anal. Chem.[d]	2737	5147	7557	222	4.743
Anal. Sci.[b]	1705	3279	4853	134	0.892
Elec. Acta[e]	1717	4163	6609	186	1.522
Fresenius Z. Anal. Chem.[f]	1773	3484	5195	277	1.398
J. Electroanal. Chem.[g]	3267	4968	6669	215	1.590
J. Amer. Soc. Mass Spec.[h]	1980	4983	7985	225	2.855
J. Chromatography A[i]	2411	3842	5273	203	2.697
Talanta[j]	2118	3760	5402	322	1.149

[a] 1997 Science citation impact factor.
[b] Based on a random sample of ten articles from the March 1999 issue.
[c] From January 1999 Analyst editorial, based on last six issues of 1998.
[d] Based on a random sample of 25 articles from the February 01, 1999 issue. Accelerated Articles were excluded.
[e] Based on a random sample of ten articles from volume 44 (17), April 15, 1999.
[f] Based on a random sample of eight articles from volume 363.
[g] Based on a random sample of ten articles from volume 465 (2), April 29, 1999.
[h] Based on a random sample of eight full articles from the April 1999 issue.
[i] Based on a random sample of ten full articles from volume 837, April 2, 1999.
[j] Based on a random sample of 25 articles from the March 1999 issue.

need for new methods to be applicable to "real samples".

A more cynical view of what constitutes publishable material is the concept of 'least publishable unit'; a euphemism for fragmentation of work to the smallest unit that is still publishable [33]. Additionally, Sindermann [34] proposes the concepts of 'optimal publishable unit' and 'maximum publishable unit'. The optimum publishable unit includes "an amount of data that can be comfortably encompassed in a reasonable paper of five to eight printed pages of text, with no artificial subdivisions, with conclusions that are few and crisp, and with discussion that is sharply focused and relevant". Additionally, Sindermann [34] states that the characteristics of the maximum publishable unit include: an overly long methodology section with too much subdivision; difficulty in maintaining continuity in the discussion section; and more than six conclusions. Further, exceeding the maximum publishable unit may result in important results and ideas within the paper being lost in the sea of discussion.

However since pagination differs between journals, it is difficult to translate Sindermann's "five to eight printed pages" definition of the 'optimal publishable unit'. To better define these publishable units a sampling of recent analytical chemistry journals was made. This yielded the statistics listed in Table 3. It can be presumed that the optimum publishable unit for a journal would be the average length of articles in that journal. Similarly, the least publishable unit and maximum publishable unit could then be estimated as the 10 and 90% limits of the distribution.

3.1. When to write a manuscript

While there is a great deal of advice as to how to write manuscripts (see below), there is little discussion of when one should write a manuscript [35]. Ramírez-Muñoz [36] states that "Writers should not write just for pleasure, but to satisfy other people's needs, and to help their colleagues… offering them clear information, well-tested results, and reproducible working procedures." Scientists must guard against writing up the work too early. This will result in fragmentary discussion of the topic, incomplete studies and potentially erroneous conclusions. These characteristics invariably lead to long lists of corrections from reviewers, having to return to the bench for more experiments, and ultimately long delays in publication, if not outright rejection. Sindermann [48] states that "The science on which the manuscript is based must be impeccable; inadequate or sloppily planned research seldom results in data that can be massaged or manipulated into anything but a paper that transmits the deficiencies... Quality is always enhanced by more-than-adequate data and by at least a few days of quiet contemplation of the research results before the word processor keyboard is approached."

Similarly, scientists must avoid unduly delaying writing manuscripts due to fear of publishing an error or because of 'writer's block'. Feibelman [35] suggests that research should be planned as a series of short, complete projects leading towards your overall long-term goal. Each project is then written as an independent piece of work describing a new kernel of knowledge, placed in the context of the long-term goal in the Introduction. Such a plan ensures a regular publication record, establishes scientific priority, and helps prevent having to write overly long and complex articles that tend to cause writer's block. It also better satisfies the short time schedules of job reviews and granting agencies.

Another advantage of planning research as a series of short projects is that it makes it clearer when a significant body of work is complete, and it is time to write. Certainly one of the best pieces of advice that I received early in my career is that "A scientist should spend an hour a day working on the manuscript *closest* to completion." It is easy to get distracted by the many exciting results and projects going on in your lab. Sometimes so much so that many papers are partially written, but never brought to completion. Focussing attention on the manuscript closest to completion facilitates getting your manuscripts out, thereby shrinking the number of balls in the air.

3.2. Where to submit the manuscript

An important question is where to submit your manuscript. The obvious answer to this question is Talanta. But more seriously, there are a number of factors to consider. These include whether the journal is appropriate for your article, whether the journal will give your work the audience that you want, and the timeliness of publication (important for job reviews or grant applications). Table 3 includes statistics on the time between submission and publication and the citation impact factor for a number of analytical journals. The citation impact factor is one indicator of the attention that a journal receives. However, citation impact factors primarily reflect the attention that an article receives within academia. In an applied field such as analytical chemistry many papers are widely read and their methodologies widely used in analytical laboratories, without receiving citation. Also experience has shown that always publishing in the same journal limits the audience for your work. Occasionally submitting articles to other journals increases the overall exposure of your work within the scientific community.

The first- and most important- step in choosing an appropriate journal for your manuscript is to *read* the journal on a regular basis. This reinforces the Aims and Scopes of each journal, which also should be read carefully. Reading the journal also makes one aware of its special areas of emphasis, such as sensors in Talanta. One useful technique for choosing a journal is to review the references cited in your manuscript. If there is a preponderance of references from a particular journal, then that is probably the most appropriate journal to which to submit the article.

3.3. Content and paper style

Table 4 lists references dealing with writing scientific papers in general, and analytical chemistry papers in particular. The references in the 'General' section describe structural and grammatical aspects of writing scientific manuscripts. The 'Specific' section lists a series of papers that appeared in Talanta in the 1970s. These papers

Table 4
Writing a paper on chemical analysis

Topic	Reference
General	
Scientific writing	C. Potera, J. Chem. Educ. 61 (1984) 246. T. Spector, J. Chem. Educ. 71 (1994) 47. J.S. Dodd, Ed, The ACS Style Guide, 2nd ed., American Chemical Society, Washington, DC, 1997. M. Alley, The Craft of Scientific Writing, 3rd ed., Springer, New York, 1996. C.J. Sindermann, Survival Strategies for New Scientists, Plenum Press, New York, 1987. Ch. 6 Writing Guidelines for Engineering and Science Students, http://fbox.vt.edu:10021/eng/mech/writing/.
Analytical papers	R.A. Chalmers, CRC Crit. Rev. Anal. Chem. 1 (1970) 217. Idem, In Essays on Analytical Chemistry; Wänninen, E., Ed.; Pergamon Press; Oxford, U.K., 1977. p. 551–7. Idem, Talanta 40 (1993) 121.
Specific	
Gravimetry	L. Erdey, L. Pólos, R.A. Chalmers, Talanta, 17 (1970) 1143. IUPAC, Pure Appl. Chem., 53 (1981) 2303.
Titrimetry	A. Berka, J. Ševcík, R.A. Chalmers, Talanta, 19 (1972) 747.
Spectrophotometry	G.F. Kirkbright, Talanta, 13 (1966) 1. IUPAC, Pure Appl. Chem., 50 (1978) 237.
Polarography	L. Meites, B.H. Campbell, P. Zuman, Talanta, 24 (1977) 709.
Ion selective electrodes	G.J. Moody, J.D.R. Thomas, Talanta, 19 (1972) 623. IUPAC, Pure Appl. Chem., 53 (1981) 1907.
Atomic absorption spectrophotometry	J. Ramírez-Muñoz, Talanta, 20 (1973) 705.
Ion-exchange (chromatography)	J. Inczédy, Talanta, 27 (1980) 143. IUPAC, Pure Appl. Chem., 52 (1980) 2553.
Kinetic methods	H.B. Mark, Jr., Talanta, 20 (1973) 257.
Solvent extraction	Y. Marcus, Talanta, 23 (1976) 203.
Stability constants	H.S. Rossotti, Talanta, 21 (1974) 809. IUPAC, Pure Appl. Chem., 61 (1989) 1161.
Surface analysis techniques	IUPAC, Pure Appl. Chem., 51 (1979) 2243.
Chromatography	J. Chromatography A, Instructions to Authors, Append. 1 (http://www.elsevier.nl/inca/publications/store/5/0/6/8/8/502688.pub.istaut.shtml).

present advice on the development and presentation of manuscripts on specific analytical methodologies such as spectrophotometry, titrimetry, gravimetry, polarography and many other techniques. These papers are unprecedented in that they discuss the factors that need to be considered in developing a new analytical method and explicitly state what information is considered essential in a manuscript to provide maximum utility to others in the field. Further they included explanations as to why this information was regarded as important. As such, they are extremely valuable to a neophyte in the field, and serve as useful checklists for more experienced practitioners.

Robert Chalmers, former editor of Talanta, has written a number of articles on writing, reviewing, and editing in analytical chemistry [37–39]. These articles discuss concerns about potential sources of error, use of statistics, basic chemical knowledge, and reference accuracy.

3.4. Format

The format of a scientific paper (Introduction, Experimental, Results and Discussion) has remained essentially unchanged since scientific journals first appeared in the 1660s. Each of these sections will be discussed individually below. In writing an analytical chemistry paper, Ramírez-Muñoz [36] recommends the use of a climactic order in the general presentation of the paper. That is, the order of the information presented should keep the reader in crescendo through the paper. Further, experimental and results sections should be written in a passive voice, but the introduction and discussion should be written in the more succinct active voice.

3.5. Review papers

Ramírez-Muñoz [36] provides some sound advice on writing review papers. Readers generally look to review articles "to save them the trouble of going to the library to look for details of a general subject or of a definite field of that subject". Meanwhile, writers must balance being exhaustive with the space limitations imposed by the journal. However, the writer must also guard against unintentional biases within the references cited. Such biases can result from: (a) *topic*. The author's own personal interests are emphasized, leaving other areas untouched; (b) *language*. Many interesting papers are ignored because they are written in a language the author cannot read. The reader may not have that same limitation; (c) *commercial literature*. Potential reference articles should be judged on their informative and formative value, not on whether the journal is profit-oriented or not; (d) *country of origin*. Valuable contributions may come from any country, regardless of whether that country's research is considered 'state-of-the-art' or not; and (e) *accessibility*. The writer should not pre-impose their own limitations to the literature upon the readers. If information was not available to the writer when the manuscript was being prepared, they should nonetheless mention the unavailable reference accompanied by the Chemical Abstracts index number.

To overcome the restrictions to references listed above, and yet provide more than a 'single sentence' description is a formidable task. Ramírez-Muñoz [36] notes that often the most appreciated reviews are those restricted to selected fields, such as instrumentation, trace analysis, environmental analysis, etc. This allows the writer to keep the information lively and focused. Also, the writer is more capable of being a specialist in the area discussed, and so is more able to provide as much of the information available without rejecting or ignoring too many papers. In writing focused reviews, some care must be taken in the introduction to help the reader make the transition from a known area to a new one.

3.6. Specialty papers

Mark [40] states that any manuscript describing a new analytical method must cover:

Accuracy and precision – It is essential that a statistical analysis of repetitive analyses be given. Statistical evidence in support of the optimal conditions should also be given. Justification of conditions simply through theoretical arguments are generally not sufficient as they often neglect unsuspected effects.

Applications – At least brief discussion should be included regarding procedures suitable for alternative sample matrices. If the method is potentially unsuitable for a sample matrix, this should be pointed out.

Justification – The value of a method must be realistically compared with other methods for the same species. Key criteria are speed, accuracy, selectivity, and cost.

Ramírez-Muñoz [36] divides specialty papers into three groups. The first group of papers focuses on instrumentation. These should present information such that the reader is able to construct any homebuilt instrumentation or accessories described, or to judge the real value of any commercial instrument described. The second group of papers describes the determination of specific analytes. The key measure of whether a paper of this kind is well written is whether the reader can reproduce the work, even with different instrumentation. The third group of papers describes specific sample applications. In this type of paper the author should try to prepare the paper so that the reader may replicate the sample preparation and instrumental procedures, with only the minor adjustments necessary for differences in the instrumentation.

3.7. Title

Most scientists rely on browsing or abstracting services to keep abreast of the literature. Such services generally provide only the title. Thus, the title must draw the reader's attention just as a newspaper headline does [41]. Ideally it should attract attention by providing a succinct description of what is noteworthy in the paper. Furthermore, while short it nonetheless should include all keywords potentially used in database searches. Thus it is important that authors think carefully about their choice of title.

Murray [42] has identified and commented on six styles of titles. *Snappy titles* attempt to invent a phrase or label to describe a new technique or subject. These can be successful if the subject is genuinely new, but more often they simply generate confusion and so should be used infrequently and only with discretion. *Announcement titles*, such as 'Ion chromatography of complex surfactants', provide a topical description of the work. Care must be taken to not make such titles too brief (e.g., 'Determination of lead'), in which case they are uninformative. Furthermore, such titles give no indication of the results or conclusions of the work. *Assertion titles* state a central conclusion of the paper. An example is 'Chemically modified tips enable selective atomic force nanoanalysis'. The aggressive nature of such titles can be effective in capturing the reader's interest. *Acronym titles* contain excessive abbreviations, and are most common with hyphenated methods. The effectiveness of such titles is limited to those readers already intimately familiar with the subject. *Buzzword titles* incorporate trendy topics or prefixes to capture the reader's interest. An example is the increased use of 'nano-' rather than 'micro-'. *Series titles* primarily convey that the author has studied the field for a while. Sindermann [48] and Feibelman [41] also identify the *cutesy title*, for example 'Stable environments for seahorses'. Such titles should be avoided.

3.8. Abstract

Ramírez-Muñoz's [36] rule for abstract preparation is to consider that the reader may read the abstract instead of reading the paper itself. Thus, like the title, the abstract must provide the key information from the paper, while hopefully enticing the reader to read the rest of the paper. It is best to not repeat the article title in the abstract, and to keep it short (50–150 words, with a maximum of 250). Such a limit should be followed even if the journal allows longer. A short concise abstract has a better chance of being read.

For experimental papers, abstracts should list the analytes studied and/or samples tested. Significant working conditions and procedure characteristics (sensitivity, accuracy, and precision) should be mentioned [36]. No mention of future work or the work of others should be made in the abstract.

In industry and government laboratories, it is also necessary to write an executive summary for the upper management. Like an abstract, the executive summary should concisely summarize the essence of the work and emphasize its importance. Unlike a journal abstract however, the executive summary must minimize the use of jargon.

3.9. Keywords [36]

An author can best determine the appropriate keywords by placing themselves in the position of needing to search for the information contained within the paper. They should then include all words that they would consult in searching the journal's index. Words contained in the title should be included. In fact, some journals do not explicitly list keywords, in which case relevant keywords should be included in the title and abstract. Analytes, samples, instrumental method, sample preparation, and words related to the main steps of the experimental procedure should be included.

3.10. Introduction

The Introduction must provide a discussion of what the paper is about, why it is important and what approach is taken. Sufficient details from the literature must be included to allow the reader to compare the work being reported with the prior literature. The Introduction is not the place for exhaustive literature reviews [39,48]. Ramírez-Muñoz [36] recommends that papers discussing instrumental aspects of a technique devote roughly 1/9 of the paper to the Introduction while papers dealing with analysis of specific analyte or samples devote roughly 2/9 of the paper to the Introduction

The Introduction should define the problem and/or approach taken. Ramírez-Muñoz [36] states that in a paper focussing on instrumentation, the advantages of the instrument or accessory should not be presented in the Introduction. This should be left until later, once enough data has been presented to allow discussion. This allows the paper to build to a climax. Feibelman [41], on the other hand, argues that many readers skim articles by reading only the Introduction and Conclusions. He therefore argues that the important results must be highlighted in the Introduction to catch the reader's attention.

Feibelman [41] also offers interesting advice regarding how to draft the Introduction. Imagine being on the telephone with a scientist friend with whom you have not spoken for awhile. The friend asks, "What have you been doing lately?" Your imagined response is the outline of your Introduction.

3.11. Experimental

Regardless of whether a paper focuses on instrumentation or the determination of a particular analyte, this section along with the Results and Discussion makes up the bulk of the paper. Ramírez-Muñoz [36] states that these sections should comprise about 2/3 of the body of the paper. As to what should be included, it is here that the papers published in Talanta on writing papers for specific areas of analytical chemistry are particularly valuable. These articles are listed in Table 4. In particular, Berka et al.'s [43] discussion of the development of a new titrimetric methods are highly informative, and strongly recommended to anyone teaching quantitative analysis.

The overriding consideration in the Experimental Section is "No matter how precious space in journals is or becomes, it makes no sense to publish data without giving the reader enough information to enable him to interpret or reproduce them." [44].

In the Apparatus section, descriptions of apparatus must provide sufficient detail for the reader to assess its performance and reliability. For commercial instruments, this simply requires identification of the manufacturer and make. For home-built instruments, greater detail will be required.

The Materials and Reagents section should contain a full characterization of the chemicals and reagents used [44]. Systematic (IUPAC) names of the compounds studied should be provided. If trivial names or abbreviations are used, the correct name should be given in parentheses upon first usage. The purity of the chemicals should also be given, although statements such as "of the highest available purity" are meaningless. Defined purity grades such as "analytical reagent grade" are acceptable.

The composition of the solvent and purity should be given. For water the methods of purification (distillation or ion exchange) and storage should be stated. For non-aqueous solvents, the water content and how it was measured should be indicated. For mixed solvents, it is important to indicate the proportions, and whether these are weight or volume based. If volume based proportions are used, whether the proportions were measured before or after mixing should be stated.

In methodologies as diverse as polarography [44] and gravimetry [45], a factorial experiment design has been recommended. Such an approach considerably reduces the development time and greatly increases the amount of useful information obtained. The tolerances on the various experimental conditions should be stated along with evidence regarding how they were determined.

3.12. Results and discussion

A key here is to use a logical order, rather than a chronological history of the experiments performed. Headings can help organize the order and flow of the text. The significance of any tables and figures should be explained, rather than forcing the readers to extract the information for themselves.

In discussing the Results, what constitutes 'good' reliability can vary greatly depending on the system studied and the available standards and alternative methods. However, sufficient replicate analyses should be performed to enable the reader to form a fair estimate of the precision of the procedure, and whether and how that precision depends on the nature of the sample [44]. Also, the accuracy is best demonstrated by comparison with the analytical results of an alternative procedure, if a suitable procedure exists. There must be adequate validation of results, supported by statistical analysis.

Even accurate and precise methods can prove unreliable because critical conditions or points of technique have been omitted in the manuscript. The best method of avoiding such omissions is to give the manuscript and a few representative samples to a colleague or technician (preferably one who was not involved with the procedure development), and request that the procedure be used to analyze the samples [44]. If the results are consistent with the claims made of the procedure, the manuscript is ready for submission.

3.13. Conclusions

It is in this section that there is probably the greatest variability in the format of different analytical journals. Analytical Chemistry states that the Conclusion section should only be used for interpretation, not for summarizing data already presented in the Abstract or text. In contrast, in his article in Talanta, Ramírez-Muñoz [36] recommended a long (2/9 of the paper) closing for papers that discussed instrumentation. The conclusions for such a paper should clearly state the significance and new information offered by the paper. Information which should be included are the capabilities of the instrument (sensitivity, accuracy, precision, speed handling, versatility and reliability), how the instrument/accessory resolves present problems, and what advantages it offers over similar existing instruments. The conclusions should also indicate what additional work is required, and where future developments may lie.

For papers discussing the determination of a particular analyte, Ramírez-Muñoz [36] recommends a shorter conclusion section (1/9 of paper). In this type of paper the conclusions should briefly summarize the achievements and applicability of the proposed conditions. If the paper focuses on the determination of an analyte in a particular matrix, Ramírez-Muñoz states that this section should be brief, and focus on the usefulness of the method and its validation with other methods and collaborative studies.

3.14. References

Authors are expected to cite literature that deals with issues closely related to the contributed work. In a recent editorial, Royce Murray, editor of Analytical Chemistry, comments that "the overwhelming majority of authors fully understand the need to provide proper literature citations" [46]. However, in some instances important references are not included in manuscripts. Murray's comments on this are instructional [46]:

> *Why do authors fail to cite relevant literature...? I believe that the vast majority of such cases are simple, honest mistakes. In spite of powerful literature-searching technology, the literature is vast, and important work can be missed… A few occurrences are less obviously mistakes. Sometimes a failure of referencing appears to be based on genuine disagreement between authors as to the significance or priority of previous publications, and one author chooses to ignore the existence of another. This is a disservice to the reader and borders on the unethical. Finally, a small number of cases do appear to cross onto unethical grounds, and the Editor pays special attention, with sometimes special actions, to these. These include not referencing a similar paper in press elsewhere (duplicate publication) and obviously and repeatedly ignoring a competitor. These often are pointedly brought to light by reviewers.*

Obviously, our ability to search the vast literature is critical. But what resources are available for searches? Jane Henley's article entitled "The Analytical Chemist: Online" is an excellent place to start [47]. Although somewhat specific to the United Kingdom and dated by the explosion of information on the Web, this article still provides a wealth of practical advice for performing searches of relevance to analytical chemists. It stresses that careful pre-search preparation and knowledge of the types of source material available in the database are essential for a successful search. Common reasons for disappointing searches are [47]:

- making the search too broad
- using the wrong search terms
- forgetting synonyms and variations of spelling, and
- using inappropriate databases.

Henley then proceeds to make recommendations as to the most appropriate databases for various categories of searches that an analytical chemist may wish to conduct. However, it should be noted that these recommendations are pre-Web, and so other options are now available.

In addition to citing a reference, it is necessary to ensure the accuracy of the citation. In a survey of 23 manuscripts in 1991 [37], there were 55 errors in authors' names, three in journal names, two in year of publication, five in volume number and five in page number! Two more references were so completely wrong, it was impossible to determine what they should have been.

3.15. Acknowledgments

A general rule is for authors to extend 'reasonable generosity' [36,48,49]. All who have contributed to the research or manuscript beyond their job description should be acknowledged. Such acknowledgments do not detract from the recognition of the authors, yet are greatly appreciated by the recipient. Acknowledgments should be direct and sincere. Reviewers acknowledged should be provided a disclaimer, and must have provided prior approval to include their name.

Any assistant who performed a significant portion of the practical work should be considered as a co-author.

3.16. Supporting information

An often-overlooked part of a manuscript is Supporting Information [50]. Supporting Information can be used to present additional documentation of relevant experimental details, experimental responses and numerical data, fuller details of data analysis and computations, computer code, figures in color, and even rotatable three-dimensional figures. As such, the use of Supporting Information enables the writing of shorter, more concise and more readable descriptions of research without compromising the detail of the discussion.

It is essential however that the printed research paper be a self-contained and coherent story. The Supporting Information must remain an adjunct to the presentation in the printed paper. Essentially, the Supporting Information should be information that would be desired by an interested specialist, but not essential to the primary story.

4. Presentations

A number of references discuss how to give effective oral and poster presentations. Advice from these is summarized below. In addition, Jeff Radel of the Kansas University Medical Center provides an excellent on-line tutorial on Effective Presentations [51].

One of the best summaries of how to prepare and deliver an oral presentation is the article by Vince Giardina [52], which Pittcon provides to its speakers. It concisely presents some commonsense rules for giving effective presentations. The ingredients of a good presentation are: good science to present; careful organization; preparation; and a forceful delivery. Also, important is a realization that you are speaking to present information on your topic, and to achieve understanding on the part of the audience. Many speakers overlook the latter goal.

A good presentation starts with careful planning. Know your goal, and how to reach it. Assemble your material in a logical fashion. This will enable the audience to follow the steps in your work and appreciate the conclusions. Winn

[53] states that a key step in planning a talk is to prepare a single declarative sentence which summarizes the central idea of the talk. Doing so focuses the speaker's thoughts, such that the rest of the speech preparation comes easily. The next step is to identify the three or four most important points (no more!) of the central idea (the single-sentence summary). The arrangement of these points can then take on one of a number of designs. For scientific presentations, the most common designs are:

Categorical — some topics fall naturally into categories. For example: offense and defense; pros and cons; basic research and applications.

Sequential — a sequential design follows a time order. (e.g., the steps in an analytical procedure or the main stages in the development of an instrument) However, a chronological history of experiments tried is not a good design to use.

Spatial — some topics break down naturally into physical parts. For instance, you might move through an instrument schematic from left to right, or alternatively move through a pie chart in a clockwise fashion.

Comparison–contrast — start with the similarities and then describe the differences. This can lead to discussion of the problems that result from failing to recognize the differences or the opportunities that exist in exploiting the differences.

Simple-to-complex — gradually build from say a simple model or schematic towards a more complete model or diagram. This allows the audience to follow the logic of the argument. This pattern works especially well with technical topics.

Problem–solution — this design is best when the audience is likely to be resistant to your solution. People are more likely to agree on the problem than on the solution. Thus, examine the problem first. This allows you to demonstrate sound logic and build credibility with your audience before presenting the more controversial part of your talk.

Residual — when the audience agrees upon the problem, you can use the process of elimination. Examine possible solutions and logically eliminate them one at a time, until you finish with a defense of the recommended solution.

Winn [53] describes other designs for presentations, but these are better suited to motivational or marketing presentations.

As to the actual presentation, the Giardina article [52] presents a series of 'Do's and Don'ts' for oral presentations:

DO tell your story briefly and in a conversational style.

DO develop good speech habits. Don't speak too quickly or softly.

DO use graphics such as charts, slides, pictures, etc. But keep them simple. Include no more detail than is necessary to make your point.

DO use good speaking posture.

DO practice your talk. This will allow you to memorize the outline of the talk and to develop an expressive speaking voice. It will also give you a sense of the timing of the talk.

DO NOT read your paper in full. You should use only an outline of the talk. This will enable you to speak more extemporaneously.

DO NOT waste your time on something that is not part of your paper.

DO NOT stare vacantly at the audience. Select a few individuals distributed throughout the audience and speak to them in a direct and conversational manner.

DO NOT walk aimlessly about the podium or make unconscious gestures such as playing with the pointer, or pulling on your ear. Movements such as walking or gesturing with your hands should only be used to emphasize and clarify points.

DO NOT let your story run down. Keep up the interest and your voice until you come to the end – and then stop! Include a brief summary and then finish with a good concluding statement.

DO NOT overrun your time! Overrunning time leaves the impression of poor preparation and does not leave any time for discussion.

Winn further suggests that the following attributes will help you hold the audience's attention:

Sentence variety – A succession of sentences of the same type and length sedates the audience.

Concrete language – Saying "A 30 kV CE power supply can throw a 6'2" man twelve feet across a room." better conveys the need for caution with a capillary electrophoresis instrument than "You will be injured if you do not exercise caution."

Figurative language – Occasional similes, metaphors and other figures of speech perk the listener's attention and help emphasize points. Overuse however can make the talk 'cutesy', and turn the audience off. Similarly, Sindermann [54] states that humor in talks should appear spontaneous, or should be very clever without being 'cute'. Humor is an art form that must be handled delicately and with finesse. Otherwise it should be avoided.

Over-and-above all the designing and calculation that has been discussed above is a simple rule. Enjoy yourself! Controlled but obvious enthusiasm for your topic is infectious, and will cause your audience to overlook minor 'technical' flaws in your presentation.

4.1. Visual aids

Visual aids, whether they are overhead transparencies, 35-mm slides or computer projections, are an essential part of any scientific presentation. Winn [53] provides some simple rules to ensure effective visuals.

Rule of six – It should be possible to read an unprojected transparency from 6 feet away. There should not be more than six words on a line. There should not be more that six lines on a page.

Color – Color accelerates learning and recall by over 55% and comprehension by 70%. However Winn cautions against overuse of color. As a rule, use only two colors on a slide. Use additional colors only for accent. Bright colors should only be used as accents, not as the primary colors.

Gradually build complexity – If it is necessary to present a complex figure or graph, it is best to start with a simple version, and then gradually on successive slides increase the complexity. This is particularly effective using computer projection programs such as PowerPoint.

Is it necessary? – Do not include anything on a transparency that you do not intend to discuss.

Visual aids must look professional – Nothing detracts from a presentation more than poorly prepared unreadable visual aids. Modern presentation programs such as Freelance Graphics, Harvard Graphics, or Microsoft PowerPoint make generation of professional visual aids straightforward and easy, and are strongly recommended.

4.2. Computer projection

Direct projection of computer screens is becoming much more common in scientific talks. Recently, Smith provided a detailed discussion of the use of multimedia in scientific presentations [55]. In general, the considerations for preparing such presentations are much the same as for transparencies and slides as discussed above. Programs such as Harvard Graphics, Freelance Graphics, PowerPoint, and Corel can be used, with the latter two being most popular. These programs make a wide array of visual and audio effects available for a presentation. Below are some considerations, as discussed by Smith [55].

- As with any presentation, a graph almost always conveys information to the audience better than a table.
- As stated above, it can be effective to start with a simple graph or schematic and then gradually, over subsequent slides, build the complexity of the visual. This works particularly effectively in computer-projected presentations.
- Again, as stated above, colors can enhance a presentation. However, with computer projected presentations there is a greater tendency to use a colored background. In such cases it is essential to maintain a high contrast between the text and the background color.

A particularly effective use of color is when a series of lines of text is being discussed. Individual lines can appear sequentially. As each new line appears it is presented in bold text, and the previous lines remain on the screen but are dimmed.

This draws the listener's attention to the information being discussed, while allowing them to refer back to previous items.

- Cartoons and photographs can both be included with ease. However, such figures can be overly complex for the audience, and may detract from the talk. Thus, care must be taken. Also, scanned figures can generate large files that may load slowly during a talk. Thus, figures should be scanned at the minimum resolution that will provide a sharp image when presented.
- Sound can be used to highlight or emphasize particular events during a talk such as introducing a new element to a figure. However, sound should be used sparingly, as it may be perceived as 'cute'. Also, computer generated sounds may not be heard by the audience in larger lecture rooms where microphones are necessary.
- Many of the presentation programs allow text to 'fly in'. These features should be used with caution. Some are subtle and work well, but many are too 'glitzy' for science presentations.
- Drawings of a figure may be allowed to move through a series of steps to illustrate phenomenon such as electroosmotic flow in capillary electrophoresis. Alternatively, video clips can be used to illustrate phenomenon such as the movement of DNA through a sieving gel. Both of these can be extremely effective in presentations. If a VCR is used for video clips, the tape should be cued to the start of the clip before the presentation. Also, speakers should familiarize themselves with the VCR before the presentation. If a computer is used to play a clip or animation, consideration should be made of the speed of the computer. What appears as a short illustrative clip on your office computer may become a long tedious clip if a slower microcomputer is used during the presentation. Therefore, either one should use one's own computer for the presentation or inquire beforehand regarding the facilities available for the presentation.
- The more complex the presentation, the more things that can go wrong. Thus, from personal experience, one should prepare for failure. It is recommended that the presenter have a backup version of the talk are available on overhead transparencies.

4.3. Poster presentations

Poster sessions are a ubiquitous part of scientific conferences. Yet very few discussions of how to prepare and present a good poster are available in the literature. One exception is the chapter by Barbara Schowen in 'The ACS Style Guide' [56]. A first consideration is 'When is a poster most appropriate?' Schowen feels that a poster is ideal for reporting a contained body of work, a single experiment (or related set of experiments), or something with a straight-forward question posed and a clear and clean-cut conclusion. Posters do not work well for instruction, persuasion, development of arguments, evaluation (of conflicting data or theories, for example), for critical literature review, or for reporting on a number of loosely related experiments. Such topics are better suited to oral presentations.

To be successful, a poster must do two things. Firstly, it must attract a conferencee's attention and interest. Secondly, it must effectively convey your scientific message. To accomplish the former task, the poster must be pleasing to the eye — use a minimum number of words and panels, use a readable font, and be well laid out. Indeed, the entire poster should be easily read from a distance of at least 3–4 feet. Schowen recommends that font size and style for text be uniform across the poster. Type should be 3/8 inch high, with Times New Roman 24 point boldface being the absolute minimum for text. Headings should be of larger type and should have blank lines above and below them. Figures should be of similar size throughout the poster. Finally, Schowen recommends personalizing or 'spicing-up' the poster by adding an eye-catcher such as a molecular model glued onto a colored piece of paper, a photo of your apparatus or of computer generated graphics or models, an actual piece of equipment, or a vial of brightly colored or crystalline compound. However, she stresses that one of these accessories is probably sufficient.

To effectively convey your scientific message with a poster is not as simple task as it sounds. Visitors will seldom have more than five minutes to devote to your poster. Therefore, the poster must deliver your message quickly and efficiently. Thus, the poster must use a minimum of words and panels. Each panel should be designed such that it can be understood and appreciated in less than a minute. For instance, the Introduction should be summarized in a paragraph or less on a single sheet of paper. Likewise the purpose or statement of the problem should be expressed in one or two succinct sentences, again on a separate sheet of paper. The length of the Experimental or Theoretical section will be highly variable, depending on the topic. Regardless of the length however, only the essentials should be given, not all the details as would appear in the same section in a paper. For presenting data, the same rules should be used as for transparencies or slides. That is, graphs better convey information than numerical tabulations. Similarly, chemical structures should be used rather than names wherever possible. Key spectral and chromatographic peaks should be labeled. Each figure, graph, or spectrum should be completely labeled so that it can stand on its own. Interpretation should be concise. Use short numbered or bulleted phrases wherever possible. Conclusions should be no longer than two sentences.

In presenting the poster, you want to hang the panels at a height that can easily be read. That is, below eye level and above hip height. Plan to be at the poster for the entire time designated in the schedule. You should stand next to the poster but not obscure it. Have your nametag clearly visible so that a visitor can easily identify you as the presenter. Avoid socializing with friends or neighbors during the poster session, as visitors will be reluctant to interrupt.

You should also prepare a short (5 min max.) summary of the main points (purpose, results, conclusions) of your poster, as some visitors will ask you to 'tell' them about your poster. Likewise you should prepare a brief oral explanation of important features of the poster such as tables, figures, chromatograms, etc. Finally, it is effective to have copies of a one-page handout on your poster. This should include your name, poster title, affiliation, meeting date, and addresses (including e-mail), along with a summary of your poster including the key aspects of your poster. These should be placed in an envelope at the end of your poster along with a note saying, 'Take one'. An alternative approach is to hang up an envelope into which interested visitors can place their business card to receive a copy of the poster. (Students who do not have a business card should prepare copies of a small note containing their name and address along with a statement such as "I am very interested in your poster, and would appreciate receiving a copy.")

5. Reviewing

> ...The accuracy of our publications lies at the very heart of our system of communicating scientific progress. The reviewer community provides an enormous service in preserving it. [46]

Thus, reviewing of scientific manuscripts has an important role within science. Yet, it is a task for which most scientists receive no formal training, and little guidance. Chalmers, a former Editor of Talanta, provides an overview of the entire publishing process, including the role and responsibility of the reviewer [38]. Royce Murray, Editor of Analytical Chemistry, provides a short discussion of his expectations of reviewers [57]. Sindermann also provides detailed advice regarding reviewing scientific manuscripts [58,59]. Chong has written an excellent discussion of reviewing and editing manuscripts for agricultural journals, which is nonetheless highly relevant to analytical chemistry publications [60]. These discussions can be summarized into the following guidelines.

- The reviewer first and foremost should have a genuine competence in the subject matter of the manuscript. In instances where competence is lacking, the reviewer should return the manuscript to the editor as soon as possible without reviewing. A decline to review is better than a cursory or inadequate review.

- The reviewer should consider the manuscript with respect to the scope of the journal and any instructions for reviewers from the journal. Talanta's Aims and Scope have been clearly stated by the editors [61], and instructions are on the back page of each issue.
- A reviewer will have to invest a significant amount of time to review a manuscript properly. The same care, diligence, and thoroughness should be used in reviewing a manuscript as when writing one. It has been estimated that reviewers spend 6 h per manuscript on rejected papers and 6.25 h on accepted papers [62].
- The reviewer must ask: is the work novel?; does it represent a significant improvement over competently performed conventional methods? [37].
- A reviewer should not be harsh or belittling. Good reviews are constructive in nature. Always highlight and emphasize the positive aspects of a paper. Authors appreciate reviewers who make an effort to improve the manuscript. However such comments will be best received if they are written in a humble and caring tone.
- A reviewer must make gentle but firm and clear statements of deficiencies in the manuscript. Most reviews give a short paragraph or two of general comments including: a statement of the research problem; an indication as to how well the paper achieved its objectives; and what changes are required to improve the manuscript or make it acceptable for publication. The general comments are usually followed by more specific comments listed by page and line number.
- A reviewer should make due allowance for limitations in the author's command of the language.
- Finally, sometimes a paper is rejected. In such cases, the reasons for rejection should be clearly stated. Recommendations as to what changes are necessary to make the work publishable should also be included.

Ideally, the review process offers a learning opportunity for both the reviewer and author. However, the success of the review exercise lies not only with the reviewer. Authors must consider the reviewers' comments seriously. The author should revise the manuscript according to those comments that improve the manuscript. In instances where the comment reflects a misunderstanding, the author should consider whether the text adequately expresses the point. If not, the text warrants revision. However, the author does not need to accept every comment. If major comments by the reviewer are not accepted, the author should write to the editor explaining clearly and completely why the comment is not accepted. However, if the rebuttal is long or elaborate, it may be better if the discussion were added to the original text. Finally, it must be appreciated that if an error or misconception is not caught during the review process, it cannot be corrected once the paper is in print. Thus, the author must appreciate that a review, even a negative one, is a *gift* of the reviewer's time and experience.

6. Economics of analytical chemistry

6.1. Purchasing equipment

Analytical chemistry has become increasingly dependent on complex and expensive instrumentation. As such, one of the most pivotal and stressful events in an analyst's career is the purchase of a new instrument. 'Olson's Four Tenets of Instrument Purchasing' (E.C. Olson, Upjohn, Kalamazoo, Michigan) provide some homespun wisdom for purchasing equipment [63]:

1. Make sure it's necessary. The instrument should fulfill an important need, not just be a 'nice' addition.
2. Specify hardware that will minimize personnel costs, because, in the long run, people are usually far more expensive than instruments.
3. Don't buy serial number one of anything.
4. Don't buy the last serial number of anything.

However, once you are satisfied that Olson's tenets are fulfilled, how do you proceed? Numerous tabulations of vendor instrumentation specifications have been reported for a wide range of instrumentation. Table 5 summarizes some such reports. Further instrument comparisons can be

Table 5
Surveys of commercial analytical instrumentation[a]

Instrument	Citation
Electrochemistry	
Potentiostats	Anal. Chem., 69 (1997) 369A
Mass spectroscopy	
Electrospray MS	Anal. Chem., 69 (1997) 427A
Electrospray TOFMS	Anal. Chem., 71 (1999) 197A
MALDI-TOFMS	Anal. Chem., 70 (1998) 733A
MS/MS	Anal. Chem., 67 (1995) 265A
Secondary Ion MS	Anal. Chem., 68 (1996) 683A
FAB-MS	Anal. Chem., 69 (1997) 625A
Quadrupole ion trap MS	Anal. Chem., 70 (1998) 533A
Isotope ratio MS	Anal. Chem., 68 (1996) 373A
Separations	
Gas chromatography	Anal. Chem., 71 (1999) 271A
Used GC's	LC-GC, 17 (1999) 1113
GC-MS	Anal. Chem., 71 (1999) 401A
Portable GC and GC/MS	Anal. Chem., 69 (1997) 195A
GC/FT-IR	Anal. Chem., 70 (1998) 801A
Thermionic NPD	Anal. Chem., 70 (1998) 599A
Electron capture detector for GC	Anal. Chem., 67 (1995) 439A
Electrochemical detectors for LC	Anal. Chem., 66 (1994) 601A
Evaporative light scattering detector	Anal. Chem., 69 (1997) 561A
Ion chromatography	Anal. Chem., 71 (1999) 465A
Size exclusion chromatography	Anal. Chem., 68 (1996) 431A
Supercritical fluid chromatography	Anal. Chem., 69 (1997) 683A
Supercritical fluid extraction	Anal. Chem., 70 (1998) 333A
Capillary electrophoresis	Anal. Chem., 68 (1996) 747A
Chromatography data stations	Anal. Chem., 71 (1999) 333A
Spectroscopy	
Circular dichroism	Anal. Chem., 71 (1999) 545A
FT-IR spectroscopy	Anal. Chem., 70 (1998) 273A
FT-IR photoacoustic spectroscopy	Anal. Chem., 66 (1994) 757A
Near-IR spectroscopy	Anal. Chem., 71 (1999) 625A
Open path IR	Anal. Chem., 69 (1997) 43A
Raman spectrometers	Anal. Chem., 69 (1997) 309A
Graphite furnace AAS	Anal. Chem., 67 (1995) 51A
ICP-AES	Anal. Chem., 70 (1998) 211A
ICP-MS	Anal. Chem., 68 (1996) 46A
X-ray photoelectron spectroscopy	Anal. Chem., 67 (1995) 675A
X-ray fluorescence	Anal. Chem., 69 (1997) 493A
CCD camera	Anal. Chem., 70 (1998) 663A
Surface analysis	
Atomic force microscopes	Anal. Chem., 68 (1996) 267A
Scanning electron microscopy	Anal. Chem., 69 (1997) 749A
Miscellaneous	
Automatic protein sequencers	Anal. Chem., 70 (1998) 401A
Thermal analyzers	Anal. Chem., 71 (1999) 689A
DNA sequencers	Anal. Chem., 68 (1996) 493A
Dynamic and static light scattering	Anal. Chem., 70 (1998) 59A
Electron paramagnetic resonance	Anal. Chem., 68 (1996) 323A
Flow cytometry	Anal. Chem., 71 (1999) 755A
Flow injection analysis	Anal. Chem., 68 (1996) 203A
Laboratory robotics and workstations	Anal. Chem., 69 (1997) 255A
Microplate fluorometer	Anal. Chem., 71 (1999) 39A
Microwave digestion	Anal. Chem., 70 (1998) 467A
Quartz crystal microbalance	Anal. Chem., 68 (1996) 625A
Solid-state NMR	Anal. Chem., 68 (1996) 559A

[a] Product reviews from Anal. Chem. published after September 1997 (Anal. Chem. 69 (1997) 561A) are available on the world wide web at http://pubs.acs.org/journals/ancham/index.html.

found in the Product Review column of Analytical Chemistry.

But how do you use these specifications to help select the appropriate instrument for your needs? One can take the cynical view as stated by the late Tomas Hirschfield and "Take all manufacturer's specifications and divide by two." Alternatively, the Analytical Methods Committee of the Royal Society of Chemistry has devised a more detailed and systematic approach. They have developed tables of instrument features that should be considered, along with the reasons why those features should be considered, and some guidance for assessment of each feature. Table 6 lists the instruments for which these evaluation tables have been developed. The objective of these evaluation tables is not to recommend particular features, but rather to prompt the purchaser to *explicitly* consider the importance of each feature for their application.

The Analytical Methods Committee of The Royal Society of Chemistry further stress that the first step in selecting an instrument is to determine the range of determinations that it will be expected to perform [64]. These requirements should not be specified too narrowly, as they will change with time, but must also avoid being too broad, as this will make the selection criteria too detailed. Based on these needs and the available budget, the choice of instruments can often quickly be reduced to a few instruments. At this point the detailed guidelines developed by the Analytical Methods Committee become useful.

An additional criterion that can be used in the purchase of an instrument is a 'suitability test'. To develop a suitability test, determine what is the critical analysis that the instrument must perform. Then ask the vendor to demonstrate the candidate instrument's capability to perform this analysis [65]. Such a condition may even be incorporated within the purchase contract as a term of acceptance [63].

6.2. Patents

The invention and refinement of instrumentation is an integral part of analytical chemistry. However if one is to profit from this invention a patent is necessary. The rationale for patenting an invention is the monopoly that it obtains. This monopoly reduces the economic risk of bringing the invention before the public, it gives the inventor a chance to establish their brand without competition, and it increases access to investment capital. Mitscher et al. [66] provide a summary of the most important points in the patent process designed for the patent novice. A second article by Murphy and Svensson [67] also discusses patents with respect to chemistry, but is more directed to the patenting of pharmaceutical products.

The essential features necessary for an invention to be patentable are novelty, utility and non-obviousness. Patents can be issued for an analytical method or assay if the method is novel and non-obvious. Additionally if the assay requires a novel or non-obvious apparatus or device to carry out the analysis, it may be possible to patent the apparatus. Generally obtaining a patent takes 1.5–3 years.

Table 6
Instrument evaluation tables developed by the Royal Society of Chemistry[a]

Instrument	Reference
Flame atomic absorption spectrometer	Analyst 123 (1998) 1407
Electrothermal atomic absorption spectrometer	Analyst 123 (1998) 1415
Polychromator for inductively coupled plasma atomic emission spectrometer	Anal. Proc. 23 (1986) 109
Monochromator for inductively coupled plasma atomic emission spectrometer	Anal. Proc. 24 (1987) 3
Plasma sources for inductively coupled plasma atomic emission spectrometer	Anal. Proc. 24 (1987) 266
Inductively coupled plasma mass spectrometer	Analyst 122 (1997) 393
Wavelength dispersive X-Ray spectrometer	Anal. Proc. 27 (1990) 324
Energy dispersive X-ray spectrometer	Anal. Proc. 28 (1991) 312
Gas–liquid chromatography	Anal. Proc. 30 (1993) 296
High performance liquid chromatography	Analyst 122 (1997) 387

[a] Analytical Methods Committee, The Royal Society of Chemistry, Burlington House, Piccadilly, London, UK W1V 0BN.

6.3. Expert witness

Analytical chemists have expertise in making precise and accurate measurements that are often used to solve complex and intricate problems. As such the analytical chemist may find themselves called as an expert witness in a court of law. Simpson [68] provides a highly readable description of the expectations and duties of an expert witness illustrated with her own experiences from the British judicial system.

Acknowledgements

The Natural Science and Engineering Research Council of Canada have supported this work. Also, my graduate students past and present are thanked. Their dedication and enthusiasm made me want to be as effective a mentor as I possibly could, which lead to this collection of advice from the literature. Finally, I thank Julian Tyson for his enlightening discussion of 'What is analytical chemistry?'.

References

[1] R.W. Murray, Anal. Chem. 66 (1994) 682A.
[2] J. de Haseth, Spectroscopy 5 (1990) 20.
[3] http://nexus.chemistry.duq.edu/analytical/whatisanalyticalchem.html.
[4] K. Cammann, Fres. J. Anal. Chem. 343 (1992) 812.
[5] C.J. Sindermann, Winning the Games Scientists Play, Plenum Press, New York, 1982.
[6] C.J. Sindermann, Survival Strategies for New Scientists, Plenum Press, New York, 1987.
[7] P.J. Feibelman, A Ph.D. is Not Enough!, Addison Wesley, Reading, MA, 1993.
[8] P. Fiske, To Boldly Go…A Practical Career Guide for Scientists, American Geophysical Union, 1996 (http://earth.agu.org/careerguide/).
[9] Science's Next Wave: Resources for the Next Generation of Scientists, American Association for the Advancement of Science (http://nextwave.sciencemag.org/).
[10] Career Planning Center, National Academy of Sciences (http://www4.nas.edu/osep/cpc.nsf).
[11] http://www.chemcenter.org/careers.html.
[12] R.L. Peters, Getting What You Came For: The Smart Students Guide to Earning a Master's or Ph.D, Farrar, Straus & Giroux, 1992.
[13] M.L. Dermer, J. Chem. Ed. 70 (1993) 303.
[14] C.J. Sindermann, Winning the Games Scientists Play, Plenum Press, New York, 1982 (Chapter 3).
[15] S.A. Borman, Anal. Chem. 57 (1985) 526A.
[16] P. Fiske, Pick a Peck of Postdocs Trends (http://nextwave.sciencemag.org/cgi/content/full/1998/03/29/150).
[17] M.A. Jensen, A Beginner's Guide to Finding and Choosing Postdoc Positions (http://nextwave.sciencemag.org/features/academic_career_issues.dtl).
[18] M.A. Jensen, A Beginner's Guide to Finding and Choosing Postdoc Positions: Part II—The All-Important Funding (http://nextwave.sciencemag.org/features/academic–career_issues.dtl).
[19] P.J. Feibelman, A Ph.D. is Not Enough!, Addison Wesley, Reading, MA, 1993 (Chapter 5).
[20] C.J. Sindermann, Winning the Games Scientists Play, Plenum Press, New York, 1982 (Chapter 9).
[21] C.A. Marasco, Today's Chemist at Work, (1997) 12.
[22] T.M. Thorpe, A.H. Ullman, Anal. Chem. 68 (1996) 477A.
[23] C.J. Sindermann, Winning the Games Scientists Play, Plenum Press, New York, 1982 (Chapter 13).
[24] http://nextwave.org/features/industry_job_topics.dtl.
[25] http://nextwave.org/features/alternative_careers.dtl.
[26] A. Newman, Anal. Chem. 68 (1996) 311A.
[27] C.W. Bowman, Can. Chem. News (1997) 10.
[28] D.M. Wiles, Can. Chem. News (1997) 12.
[29] M. Nisbet, Can. Chem. News (1997) 13.
[30] H. Kaye, Inside the Technical Consulting Business, 3rd edn, Wiley, New York, 1998.
[31] G.F. Kirkbright, Talanta 13 (1966) 1.
[32] G.E.F. Lundell, Ind. Eng. Chem. Anal. Ed. 5 (1933) 221.
[33] W.J. Broad, Science 211 (1981) 1137.
[34] C.J. Sindermann, Winning the Games Scientists Play, Plenum Press, New York, 1982, p. 33.
[35] P.J. Feibelman, A Ph.D. is Not Enough!, Addison Wesley, Reading, MA, 1993, pp. 40–42.
[36] J. Ramírez-Muñoz, Talanta 20 (1973) 705.
[37] R.A. Chalmers, Talanta 40 (1993) 121.
[38] R.A. Chalmers, CRC Crit. Rev. Anal. Chem. 1 (1970) 217.
[39] R.A. Chalmers, Talanta 33 (1986) 7–10.
[40] H.B. Mark Jr, Talanta 20 (1973) 257.
[41] P.J. Feibelman, A Ph.D. is Not Enough!, Addison Wesley, Reading, MA, 1993 (Chapter 4).
[42] R.W. Murray, Anal. Chem. 67 (1995) 583A.
[43] A. Berka, J. Ševcík, R.A. Chalmers, Talanta 19 (1972) 747.
[44] L. Meites, B.H. Campbell, P. Zuman, Talanta 24 (1977) 709.
[45] L. Erdey, L. Pólos, R.A. Chalmers, Talanta 17 (1970) 1143.
[46] R.W. Murray, Anal. Chem. 67 (1995) 161A.
[47] J. Henley, Chem. Ind. Oct. 01 (1990) 609.
[48] C.J. Sindermann, Survival Strategies for New Scientists, Plenum Press, New York, 1987, pp. 122–131.

[49] C.J. Sindermann, Winning the Games Scientists Play, Plenum Press, New York, 1982, p. 17.
[50] R.M. Murray, Anal. Chem. 67 (1995) 521A.
[51] http://www.kumc.edu/SAH/OTEd/jradel/effective.html.
[52] V. Giardina, AIAA Stud. J. 19 (1981) 46.
[53] L.J. Winn, The ACS Style Guide, second edn, in: J.S. Dodd (Ed.) American Chemical Society, Washington, DC, 1997 (Chapter 12).
[54] C.J. Sindermann, Winning the Games Scientists Play, Plenum Press, New York, 1982 (Chapter 2).
[55] D.L. Smith, Can. J. Plant Sci. 78 (1998) 371.
[56] K.B. Schowen, The ACS Style Guide, second edn, in: J.S. Dodd (Ed.) American Chemical Society, Washington, DC, 1997 (Chapter 2).
[57] R.W. Murray, The ACS Style Guide, second edn, in: J.S. Dodd (Ed.) American Chemical Society, Washington, DC, 1997, pp. 326–327.
[58] C.J. Sindermann, *Survival Strategies for New Scientists*, Plenum Press, New York, 1987, pp. 132–135.
[59] C.J. Sindermann, Winning the Games Scientists Play, Plenum Press, New York, 1982, pp. 25–29.
[60] C. Chong, Can. J. Plant Sci. 78 (1998) 377.
[61] G.D. Christian, J.-M. Kauffmann, Talanta 47 (1998) 1.
[62] D.W. King, D.D. McDonald, N.K. Roderer, Scientific Journals in the United States: Their Production, Use and Economics, Hutchinson Ross, Stroudsberg, PA, 1981, p. 112.
[63] S.A. Borman, Anal. Chem. 57 (1985) 1484A.
[64] Analytical Methods Committee, Analyst 122 (1997) 393.
[65] Analytical Methods Committee, Analyst 122 (1997) 387.
[66] L.A. Mitscher, S.R. Crowley, J.J. Plattner, Anal. Chem. 66 (1994) 575A.
[67] G.M. Murphy, Jr, L.R. Svensson, Chem. Tech. (1990) 146.
[68] D. Simpson, Trends Anal. Chem. 15 (1996) 494.