cpt Special Report
Committee on Professional Training

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SURVEY OF Ph.D. RECIPIENTS IN CHEMISTRY

PART 1. STATISTICAL ANALYSIS

Recently CPT has again become involved in studies of graduate education in chemistry in the United States. In 1996 a survey of Ph.D. chemistry programs was conducted with the aim of determining what the present practices were among the 190 Ph.D. programs in chemistry known to CPT. The results of this survey were published in a Special Report in the CPT Newsletter (Vol. II, No. 2, Spring 1997). A separate survey of master's degree programs was also conducted and the responses were described in a second Special Report (CPT Newsletter, Vol. II, No. 3, Spring 1998). These two surveys provided extremely interesting new information about the nature of graduate education in chemistry as it exists late in the twentieth century.

To gain even more insight into the question, CPT decided to seek the opinions and advice of those who have been students in US graduate programs. We chose to limit the survey to recipients of the Ph.D. degree and, because we wanted to detect any differences in attitudes and opinions between those who received the Ph.D. at different times, the questionnaires were mailed to two cohorts of equal size. These two groups were those 33-37 years of age in 1998 and those 43-47 years.

In mid-1998 the questionnaire was sent to 4000 randomly selected American Chemical Society members who have Ph.D. degrees. An equal number (2000) of members surveyed were in each cohort. The response was very gratifying and, after one follow-up mailing to those who had not yet responded, it was found that 2381 individuals (59.5%) had responded. Of these, 2336 individuals reported receiving the Ph.D. from a graduate institution in the United States, and it was their responses that were analyzed. The selection of the two groups according to age was necessitated by the fact that ACS does not have information about the year that members received the degree. It was this latter figure that was desired for selecting the two groups. Interestingly, the procedure resulted in the average year of receipt of the Ph.D. differing by almost exactly ten years between the two groups, 1990.8 for those in their thirties and 1981.3 for those in their forties.

Comments about response rate. The response rate of about 60% indicates strong interest in the survey by those who were polled. Even more encouraging was the fact that about one thousand respondents provided written comments concerning their experience in graduate education. An analysis of those written comments will be the subject of Part 2 of this Special Report.

In spite of the fact that six out of ten of those surveyed returned questionnaires to CPT, it is important to bear in mind that 40% did not respond and there is no way of knowing how their views would affect the average responses to be reported here. Nevertheless, it is believed that the numerical results that were obtained will be of significant interest in spite of the above reservation that the average results might not be representative of the whole group.

Questions included in the survey and the average responses. The questions in the survey are presented in Table 1 along with the average of the responses on each question, the standard deviation and (where relevant) the percentage of those responding "does not apply". Most but not all of the questions were constructed in such a way that a low numerical response (the range was 1 to 5) indicated a generally favorable impression of the particular aspect of graduate education embodied in the question. Thus a quick scan of the responses in Table 1 reveals many average responses in the range of 1.6 to 2.5, which gives the general impression that the Ph.D. recipients were favorably disposed toward their program of study.

Question 2 reveals that on the average the respondents felt that the courses taken in the program were appropriate and useful (mean response: 2.27). More courses outside chemistry were regarded as important (question 4, 2.13), but the respondents were more or less neutral when asked if more courses in chemistry would have been useful (question 3, 2.77). Seminars and colloquia (question 5, 2.04), formal presentations (question 6, 1.69), and original research proposals (question 7, 1.69) were features that were valued. Those for whom an original research proposal was not required (79%) were less certain of its value

Table 1. Responses to Survey of Ph.D. Recipients[a]

1. Was your Ph.D. institution U.S. or non-U.S.?	2% non-U.S.[b]		
	Mean	Standard Deviation	% "does not apply"
Questions 2 through 16 asked for a response from 1 (strongly agree) to 5 (strongly disagree) or "does not apply".			
2. The formal courses that I took in my Ph.D. program adequately prepared me for my present position.	2.27	0.97	2%
3. I would have benefited from additional courses in chemistry.	2.77	1.08	1%
4. I would have benefited from additional courses in disciplines other than chemistry.	2.13	0.98	1%
5. The seminars and colloquia that I attended during my Ph.D. studies contributed significantly to my education.	2.04	0.95	<1%
6. The formal presentations (exclusive of research group presentations and teaching) that I made during my graduate experience contributed significantly to my education.	1.69	0.80	3%
7. I was required to create and present/submit an original research proposal(s) and believe that this experience contributed significantly to my graduate education.	1.69	0.83	15%
8. An original research proposal(s) was not required, and I believe that I would have benefited from such an experience.	2.31	1.07	79%
9. My experience as a teaching assistant (or other teaching activities) has helped me in the performance of my job.	1.92	0.91	3%
10. Please respond to the ONE question (a, b or c) that best describes your experience with the interdisciplinary aspects of your graduate education.			
a. My graduate research involved a formal interdisciplinary program that included scientists from areas outside chemistry. This experience has proven to be beneficial to me in my professional career.	1.70	0.99	36%
b. My graduate research was interdisciplinary in nature but did not include formal interactions with scientists outside chemistry. I would have benefited from such interactions.	2.00	0.79	33%
c. My graduate research was focused within the traditionally defined boundaries of chemistry. This experience has adequately prepared me for my present position.	2.58	1.03	11%
11. The cumulative examinations that I took contributed significantly to my graduate education.	2.69	1.14	18%
12. The oral examination that I took prior to my thesis defense was beneficial.	2.17	0.93	13%
13. The comprehensive written examination was an important component of my graduate education.	2.55	1.02	58%
14. Facility in a foreign language is important in my position.	3.56	1.15	8%
15. The foreign language requirement in my Ph.D. program gave me a significant advantage in my professional career.	3.88	0.98	32%
16. The faculty advisory committee that monitored my progress toward the Ph.D. was constructive and helpful.	2.90	1.11	7%
Questions 17 through 21 asked for a response from 1 (excellent) to 5 (poor).			
17. Please rate the contributions of your research advisor to your graduate education in the following areas:			
a. Mentoring (e.g. role modeling, enthusiasm, work ethic, etc.)	1.95	1.13	
b. Career advisement	2.95	1.25	
c. Establishing appropriate standards (scientific, ethical)	1.76	0.97	
d. Establishing appropriate requirements (e.g. research reports, meeting deadlines, planning, etc.)	2.35	1.11	
e. Increasing your scientific knowledge (relevant, up-to-date)	1.86	0.94	
f. How would you rate the overall effectiveness of your graduate research advisor?	2.06	1.03	

	Mean	Standard Deviation	% "does not apply"
18. How would you rate the quality and quantity of the instrumentation facilities available to you during your graduate experience?	1.88	0.95	
19. How would you rate the quality and quantity of the library holdings at your graduate institution?	1.57	0.74	
20. How would you rate the quality and quantity of the chemistry physical plant (i.e. buildings and laboratories) at your graduate institution?	2.11	0.97	
21. How would you characterize the level of financial support (TA or RA stipend, fellowship, etc.) that you received as a graduate student?	2.23	1.06	
Questions 22 through 26 asked for a response from 1 (strongly agree) to 5 (strongly disagree) or "does not apply".			
22. Students in my graduate program participated in institutional governance (committee membership, etc.)	3.72	1.02	12%
23. Students in my graduate program were encouraged to develop computer skills.	2.66	1.12	4%
24. I was encouraged to attend and participate in professional meetings.	2.35	1.10	<1%
25. In graduate school, I developed a network of friends and associates that has benefited me significantly in my professional career.	2.80	1.14	<1%
26. The importance of teamwork was emphasized in my graduate program.	3.20	1.08	<1%

[a] Possible responses for questions 2-16 and 22-26 were: strongly agree (1), agree (2), neutral (3), disagree (4), strongly disagree (5) and "does not apply". For questions 17-21, a total of five choices was available ranging from 1 (excellent) to 5 (poor).

[b] Though those holding Ph.D. degrees from non-U.S. institutions were asked to return the survey form without responding to questions 2-26, it is thought that many did not do so and simply discarded the form. Thus 2% non-U.S. Ph.D. degrees is probably a lower limit for the group of ACS members that was surveyed.

(question 8, 2.31) than those who faced such a requirement. Experience as a teaching assistant was regarded as quite valuable (question 9, 1.92).

Question 10 attempts to elicit the respondents' attitudes about interdisciplinary study. Respondents were asked to respond to the single question (10a, 10b or 10c) most descriptive of the interdisciplinary nature of the Ph.D. research. Those who had taken part in a formal interdisciplinary program with participation by scientists outside chemistry were quite pleased with the result (question 10a, 1.70), and those whose interdisciplinary research did not involve such interactions with scientists outside chemistry generally felt that such interactions would have been useful (question 10b, 2.00). Those whose research was in one of the traditionally defined areas of chemistry were less pleased with this aspect of the Ph.D. program (question 10c, 2.58).

The respondents favorably recalled cumulative examinations (question 11, 2.69), oral examinations (question 12, 2.17) and comprehensive written examinations (question 13, 2.55). However, when asked if facility in a foreign language was important in their present position, the response was clearly on the negative side (question 14, 3.56), and the foreign language requirement was even less valuable (question 15, 3.88). It should be noted that only 32% indicated "does not apply" in question 15 which suggests that the removal of foreign language requirements from Ph.D. programs is a recent development that was not in place when the respondents were in school. (81% reported no foreign language requirement in 1996. See "Survey of Ph.D. Programs in Chemistry, CPT Special Report, Spring 1997.) The response concerning the value of the faculty advisory committee was close to neutral (question 16, 2.90).

Question 17 was designed to assess the performance of the research advisor, and the response was generally favorable (question 17f, 2.06) with strongest responses concerning mentoring (question 17a, 1.95), establishing appropriate standards (question 17c, 1.76), and imparting scientific knowledge (question 17e, 1.86). In the effectiveness of the research advisor in career advisement the response was almost neutral (question 17b, 2.95).

The remaining questions sought the respondents' impressions of the graduate institution and certain practices in the department. Instrumentation (question 18, 1.88), library (question 19, 1.57), physical plant (question 20, 2.11), and financial support (question 21, 2.23) were given good to very good marks. Few students participated in institutional governance (question 22, 3.72), but there was some encouragement to develop computer skills (question 23, 2.66) and participate in professional meetings (question 24, 2.35). The respondents reported that networking (question 25, 2.80) was not stressed, and that teamwork was not strongly emphasized (question 26, 3.20), the latter result perhaps reflecting the traditional practice of giving each Ph.D. student his or her own research project with little effort toward promoting teamwork.

Standard deviations. The standard deviations reported in Table 1 provide some idea of the range of responses for each question. The magnitude of the standard deviations falls between about 0.7 and 1.2. This statistical parameter provides a reminder that an average response of 2.00 (as in question 10b), for example, does not indicate a uniform response of "agree" (assigned a value of 2) from the respondents but rather a range of responses characterized by the standard deviation of 0.79. Table 2 provides a tabular view of the distribution for 10b and three other questions including one with a very low average response (question 6), a neutral response (question 17b), and a high average response (question 15). Thus, when considering the average

Table 2. Examples of distribution of responses.

Question	Average Response	Percent responding: Strongly Agree (1)	Agree (2)	Neutral (3)	Disagree (4)	Strongly Disagree (5)
10b	2.00	23.5	59.7	11.1	4.6	1.0
6	1.69	47.8	40.2	7.8	3.6	0.5
17b	2.95	12.8	27.3	26.8	18.3	14.8
15	3.88	1.7	8.4	18.7	42.2	28.9

responses discussed above, it is important to remember that the respondents actually held a wide range of opinions about each question.

Differences between responses given by different groups of respondents: "thirties group" and "forties group".

In examining the average responses from the two groups it was striking to see how similar they were. First of all, almost identical response rates were obtained for the "thirties group" (62%) and "forties group" (58%). To determine if the differences in the mean responses for the two groups were statistically significant, the t-test was applied. This statistical parameter allows one to say whether the two means are statistically different with a certain degree of probability. Using a 95% confidence level, it was found that responses of the two groups were significantly different for only 13 of the 33 questions and subquestions that were asked. These 13 were questions 3, 5, 6, 11, 14, 15, 16, 17d, 18, 22, 23, 24, and 25. In this analysis, a computed t-value greater than 1.96 indicates a statistically significant difference in the two means. One of the largest t-values was for question 3 ($t = 6.0$) where members of the "thirties group" were more likely to report that they would have benefited from more courses in chemistry. It is worth asking if this is a reflection of the rumored reduction of course requirements over the last two decades in our Ph.D. programs.

Another significant difference was found for question 6 ($t = 3.3$) where the "forties group" was more likely to value the role of formal presentations in the graduate program. On question 15, the "forties group" was more likely ($t = 3.6$) to report that the foreign language requirement was valuable. The "thirties group" had a stronger impression of the instrumentation available to them in their graduate work (question 18; $t = 6.7$). With respect to participation in institutional governance (question 22; $t = 4.3$), development of computer skills (question 23; $t = 6.1$), and networking (question 25; $t = 5.5$), the "forties group" reported significantly less involvement. The "thirties group" was more likely to report that they were encouraged to attend and participate in professional meetings (question 24; $t = 2.4$).

Differences between responses given by different groups of respondents: women and men. It was found that 24.0% of the total respondents were women. Again the average responses of the two groups (men and women) were very similar, with 12 of 33 questions showing a statistically significant (95% confidence) difference between the two means. Here, only three questions showed t-values above 3. They were question 2 ($t = 3.1$), where men were more pleased with the formal courses they took; question 5 ($t = 4.6$), where men were more likely to report satisfaction with seminars and colloquia; and question 11 ($t = 3.2$), where men were again more favorably impressed by the cumulative examinations than were the women. Mentoring by the research advisor was evaluated less favorably by women than men (question 17a) with a t-value of 2.6.

Differences between responses given by different groups of respondents: those employed in industry compared to those in academia. Among the groups compared, the differences between those Ph.D. recipients who are employed in industry (65%) versus those in academia (23%) were definitely the most pronounced (Figure 1). In this case, statistically significant differences in mean response were found for 27 of the 33 questions and subquestions. The questions that evoked statistically identical responses from the two groups were 10b, 11, 13, 15, 16, and 22. A brief scan of Figure 1 reveals that the industrial group had a less favorable opinion of their graduate education than the academic cohort on almost every question asked. Taken at face value, these results support the frequently expressed view that our Ph.D. programs are not preparing individuals for employment in industry as effectively as they should.

Some particularly significant differences will be highlighted. Compared to their academic colleagues, industrial chemists were less happy with the formal courses that they took (question 2; $t = 5.1$), and they were more likely to report that more courses outside chemistry would be beneficial (question 4; $t = 8.3$). Industrial chemists were less impressed by seminars and colloquia (question 5; $t = 4.4$) and by the formal presentations required in the program (question 6; $t = 4.6$). Those in industry found that experience as a teaching assistant was less valuable to them than did the academic group (question 9; $t = 8.3$), and for those whose research was in one of the traditionally defined fields of chemistry (question 10c; $t = 6.0$), industrial chemists were the less satisfied group.

Interestingly, those in industry were more likely to report that facility in a foreign language was important in their present job (question 14; $t = 4.9$), and the industrial group was less impressed with the career advisement they received from the research advisor (question 17b; $t = 8.1$). This latter result probably arises in large part from the lack of experience in industry that is characteristic of most professors. Ph.D. recipients employed in academia were more favorably impressed with the instrumentation available to them than were their industrial counterparts (question 18; $t = 5.9$), and the academic group was more likely to report that networking (question 25; $t = 9.4$) and teamwork (question 26; $t = 7.5$) were stressed in the graduate program.

Other characteristics of the respondents. Respondents were requested to provide additional information about themselves. Some of this data is of interest to the question of Ph.D. programs in chemistry because it reflects trends that are underway in our discipline.

As stated earlier, 24% of the total respondents were women. When the "thirties group" and "forties group" were compared, it was found that only 16.8% of the forties group (average com-

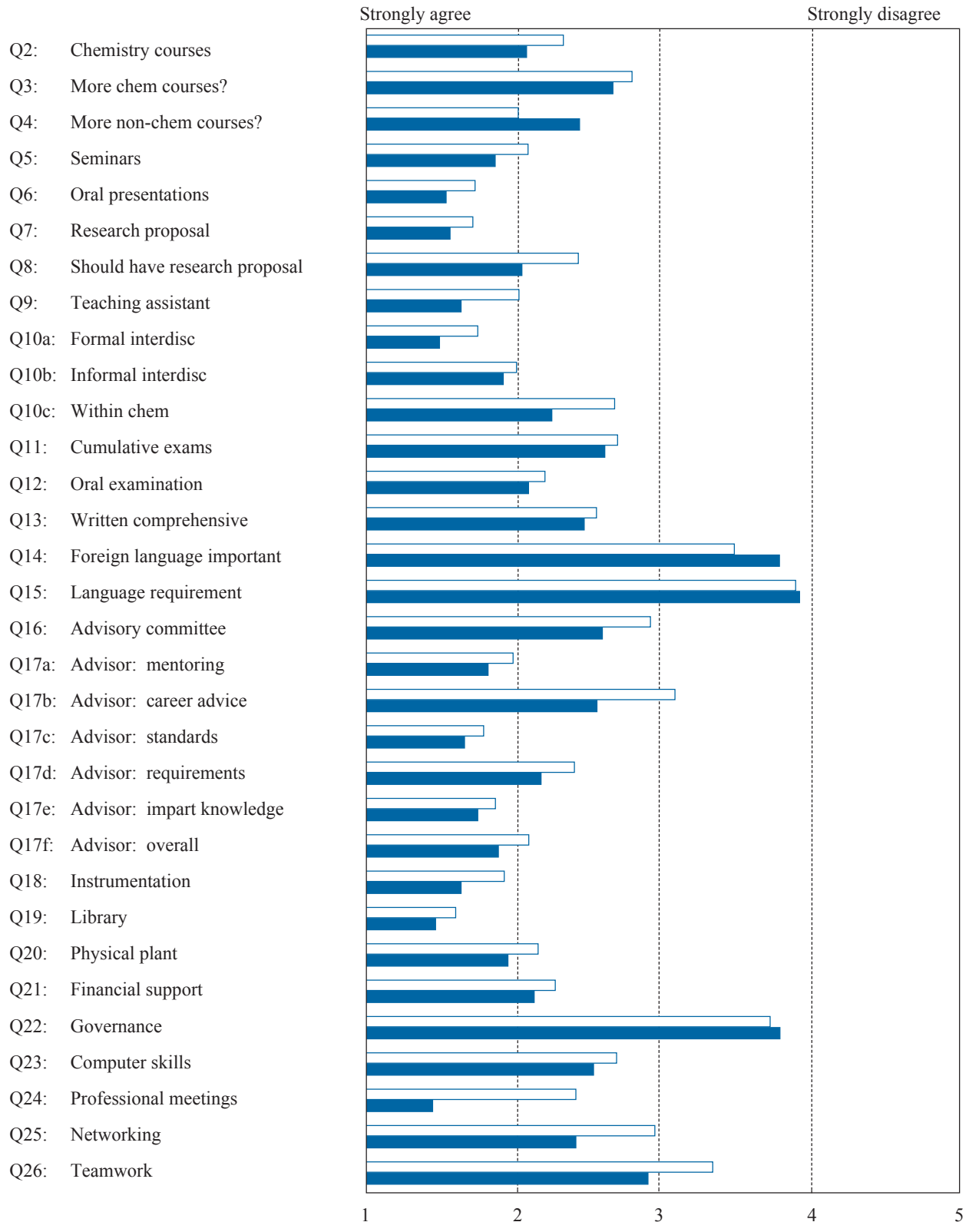

Figure 1. Mean responses of Ph.D. chemists employed in industry (open bars) compared to those in academia (filled bars).

pletion year 1981) were women, whereas the percentage had increased to 30.9% by the time the thirties group had completed the degree (average completion year 1991). This reflects the well-known increase over the last few decades in the number of women earning the Ph.D. in chemistry.

Sixty-eight percent of the respondents completed their Ph.D. program in a public institution, while the remainder received the Ph.D. from a private institution. By contrast, only 52% of the respondents attended a public institution as undergraduates while 48% attended private schools.

The average time required to complete the Ph.D. was 5.06 years for all respondents. For the various groups, the average was 5.08 years for the "thirties group", 5.04 years for the "forties group", 5.12 years for women, 5.04 years for men, 5.00 years for those in industry, and 5.11 years for those in academia.

Some students required significantly longer than average to complete the degree. Of those responding, 10.0% reported spending more than six years in graduate school (3.4% required more than seven years). When groups were compared, it was found that 8.0% of the "thirties group" spent more than six years (2.2% more than seven years), while 12.0% of the "forties group" required more than six years (4.7% more than seven years). For women, 9.8% required more than six years to complete the Ph.D. (3.1% more than seven years), and for men the percentages were 10.0% (more than six years) and 3.4% (more than seven years).

In terms of present employment, 65% reported industrial employment, 23% were in academic positions, 6% in government, 2.8% "other", 1.4% self-employed and 1.3% unemployed.

The respondents were asked to report the field in which they did graduate work and the specialty most closely related to their present employment. A summary of the results is given in Table 3.

Table 3. Distribution of Ph.D. Degrees and Present Employment by Field.

Field of Specialization	Percent Reporting Ph.D. in the Field	Percent Reporting Present Employment Most Closely Related to the Field
Organic Chemistry	36.3	24.7
Inorganic Chemistry	19.3	5.8
Physical Chemistry	14.4	6.6
Analytical Chemistry	12.4	16.6
Biochemistry	5.2	7.6
Other Chemical Science	3.2	3.5
Polymer Chemistry	2.9	8.6
Chemical Engineering	2.5	3.3
General Chemistry	1.3	3.8
Materials Science	0.9	4.9
Environmental Chemistry	0.6	2.4
Agricultural/Food Chemistry	0.4	1.6
Other Non-Chemistry	0.3	4.6
Computer Science	0.2	1.6
Business Administration	0.1	2.3
Clinical Chemistry	0.1	0.6
Law	0.0	1.6

The data in Table 1 indicate that the vast majority (88%) of Ph.D. degrees held by the respondents were in the traditional subdivisions of chemistry: organic, inorganic, physical, analytical, and biochemistry. When the fields most relevant to present employment are examined, it can be seen that some migration has occurred between receipt of the Ph.D. and employment in the years that have followed. Compared to the percentages receiving degrees in a given field, significant increases are seen in the fraction of Ph.D. chemists reporting the field most relevant to their employment to be analytical chemistry, biochemistry, polymer chemistry, and materials science, to name a few. These results emphasize the importance of a broadly based education for Ph.D. chemists so that they will be able to move into different areas as opportunities present themselves. Accomplishing this, while providing rigorous training in the area of specialization, is of course a difficult task.

Summary. A survey has been conducted of Ph.D. recipients from U.S. universities who are members of ACS. Two groups were surveyed. The first was a randomly selected group of 2000 chemists 33-37 years of age in 1998, and the second included 2000 Ph.D. recipients 43-47 years old. The results indicate a generally favorable view of the Ph.D. degree programs undertaken by the respondents. However, there were some areas of dissatisfaction noted. About 1000 respondents provided specific written comments, both critical and adulatory. An analysis of those comments will be provided in Part 2 of this Special Report.

Significant differences between the mean responses of the "thirties group" and the "forties group" were found on 13 of 33 questions, while differences between the responses of men and women were statistically significant in 12 cases. The most striking differences were found when comparison was made between Ph.D. chemists employed in industry and those in academia. Here, statistically significant differences were found on 27 questions, and on the average, the industrial group expressed a distinctly lower opinion of their graduate experience than did those in academia. It is recommended that serious consideration be given to these differences by graduate programs seeking to enhance the preparation of their Ph.D. graduates for careers in industry.