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ABSTRACT

This manual will be useful to superintendents, chemical technology teachers, and students in a high school which is planning or already offering a chemical technology program. Designed to prepare students for entry-level employment as chemical technicians or further post-secondary training, these instructional materials include: (1) a discussion of the school industry relationship, (2) a job description which details advancement opportunities and working conditions, (3) job qualifications, (4) a description of a chemical technology instructor, (5) extensive job and task analyses, (6) lists of laboratory equipment, (7) an occupational competency examination for job placement purposes, and (8) teaching outlines for courses in general analytical chemistry and introductory physics, giving general and specific course objectives and suggested teaching procedures in a 3-column format. This document was developed as part of a federally funded project by educators in vocational education and leaders in chemical industries in New Jersey. (AG)

THE CHEMICAL TECHNOLOGY PROGRAM

State of New Jersey
Department of Education
Division of Vocational Education
Curriculum Laboratory

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Department of Education
Division of Vocational Education

THE CHEMICAL TECHNOLOGY PROGRAM

ITS INAUGURATION, OPERATION, AND EVALUATION

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PREFACE

This manual is meant to assist, in several ways, a school which is planning or already offering a chemical technology program.

The superintendent who is investigating the advantages and disadvantages associated with such a program will find the introduction, the student description, the teacher description, and the section dealing with equipment and facilities to be informative sections. Each of these sections contains information he will wish to consider.

The chemical technology teacher will find the entire document to be useful for a variety of purposes. He will already be familiar with most of the content, but the availability of the material in printed form will be useful in planning, as documentary information to support requests, and as material to help orient students to their occupation.

The student will be interested in Chapters 1 and 2. This material will be useful to him as guidance information. It can also be used in pre-selection guidance procedures.

Chapter 7, the occupational competency examination, as rudimentary as it is, will join the limited store of validated performance examinations. Present societal pressures must surely lead to the acceptance of performance examinations, and the rejection of evaluation based upon written examinations.

INTRODUCTION

After reviewing the information obtained from testing a cross-section of technicians, it became evident that an open-ended summary, directed to both the school and the industry, was needed. Personal reactions gleaned from supervisors, personnel men, and the technicians themselves added much to the detailed features of a problem.

Thomas Edison is credited as the first to hire scientific technicians in the United States. Few other employers followed Edison's lead in the differentiated use of staff until World War II, when a sudden growth of the scientific industry in this country required unavailable professional manpower. Then industry adopted the use of technicians to meet the emergency. Edison seems to have had a desire to use any skill that came his way. The war-time industry just needed hands that could speed up scientific development. Scientific technicians were defined as semi-professionals who assisted the professional staff. The label, general duties, and most hiring and promotion practices have stuck, but in the ensuing years the laboratory has changed completely. Now what is a checmical technician? There is no definite accepted answer because of the apparent variability of the problem, except as a semi-professional who assists the professional scientist. The technician title may cover anyone from a test-tube washer to a semi-professional who routinely uses equipment employing principles practically unknown in 1940 and math which requires a computer to get an answer in one lifetime. The initiative involved ranges from rote repetition to re-designing of the procedure for each trial. All, mind you, at a semi-professional level.

As the writer had long suspected, testing indicated that most scientific technicians presently perform relatively uniform and relatively basic duties. These duties have to do with measurement skills and manipulative skills. The duties also commonly require a knowledge of certain basic instruments by all, and of specialized instruments by a few. "Good" technicians also exhibited pride in workmanship along with a rugged sense of integrity in relation to their work.

Technicians were easily divded into three groups upon the basis of the test scores: a small group of inexperienced and untrained technicians who exhibited few of the needed skills; a large group of technicians who showed moderate skill, but little initiative or knowledge of special instruments; and another small group of elite technicians who could perform all skills on the test and much more. Yet technicians from each group were actually working at all pay levels. Most of the high-school trained technicians were working at the top levels, but a few were at the very lowest level. The pay levels of technicians in the other two groups showed little correlation with performance ability. The technicians did not show any score difference due to different kinds of assignments, including biological assignments.

This description does not fit the image stated by the supervisors and personnel men. These people usually stated requirements of much greater specialty and skill. They also thought in terms of four or five levels of skill. They select and promote technicians on the basis of college credits because they believe this attracts competent technicians. The testing would indicate that this was not the case. The personnel men were also puzzled by a big turnover and the limited number of people seeking technician jobs. Finally, industry noted that good technicians are promoted to supervisory status in six to eight years. This is significant to a school because it implies the need to prepare the student for degree admission.

The juxtaposition of realities must be noted by the school if not by the industry. Putting it bluntly, this failure to watch realities is dynamite to the school. *The industry requests two years of training for fully qualified technicians, but will only assign them to duties which can be acquired in sixty to ninety days of serious instruction.* Once the fully qualified technician is hired, he is encouraged to continue his education. In a few months he is bored by his work and by the time he makes it to top-technician duties, he is also over-qualified for and bored by them.

If the school is to succeed it must have a working relationship with industry. Such an arrangement allows the school to plan its graduation with companies who will quickly promote their graduates to the highest technician level that they can handle. The school must also prepare the student for college entrance, because under present practice the student will be foreced to get a degree to avoid a dead-end job.

Industry has a much bigger problem. It must recognize that technical work has evolved rapidly and that it is continuing to do so. There must be a choice. The choice is either to hire unqualified technicians and give them a limited degree of training, or to hire fully qualified technicians and expand the job descriptions. For companies which require only rudimentary control and quality control procedures, the first choice would be adequate and less expensive. For research and pharmaceutical laboratories the latter alternative must at least be considered. Somehow the chemical technician slot must be converted to an end in itself, rather than a stepping stone to better things. This will require an evaluation of the concept of chemical technician, but it must be that or watch the chemical industry invest more in professional manpower to do semi-professional work. Surely now professional and semi-professional job descriptions can expand with the progress of the industry for greater profit and to help to make men happy at their work.

CHEMICAL-LABORATORY TECHNICIAN
(profess. & kin.) 022.281

Conducts chemical and physical laboratory tests and makes qualitative and quantitative analyses of materials for purposes such as development of new products, materials, and processing methods, and for maintenance of health and safety standards, working under direction of BIOCHEMIST, CHEMICAL-LABORATORY CHIEF; CHEMIST, ANALYTICAL; CHEMIST, INORGANIC; CHEMIST, ORGANIC; or CHEMIST, PHYSICAL: Sets up laboratory equipment and instruments, such as ovens, leaching drums, gas cylinders, kilns, vacuum chambers, autoclaves, pyrometers, and gas analyzers. Analyzes products, such as food, drugs, plastics, dyes, and paints, to determine strength, purity, and other characteristics of chemical content. Tests ores, minerals, gases, and other materials for presence and percentage of elements and substances, such as carbon, tungsten, nitrogen, iron, gold or nickel. Prepares chemical solutions for use in processing materials, such as textiles, detergents, paper, felt, and fertilizers, following standard formulas.

ACKNOWLEDGEMENTS

Several organizations and people have assisted in the conceptualization and testing of this information.

Dr. Morton Margules and Mr. Benjamin Shapiro must be singled out for providing the initial encouragement for the project, primarily because they recognize the need to develop a variety of approaches to curriculum construction. The characteristic which makes this a different project is the method of selecting items to be used in the technology outline. Three highly experienced technician consultants were first asked to prepare a list of skills required of chemical technicians, as in the traditional approach to curriculum development. That list of skills was then converted into a performance test and the test was administered to a random sample of practicing chemical technicians. Thus, the technology outline consists of proven, validated items, not items someone just believes might be needed.

Grateful appreciation is extended to the following for their assistance:

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CHAPTER I

INTRODUCTION TO CHEMICAL TECHNOLOGY

WHAT DOES THE CHEMICAL TECHNICIAN DO?

The specific daily duties of chemical technicians are almost unbelievably variable. At some point in its manufacture or growth, nearly every product on the market requires the services of a chemical laboratory, and these are supplied by chemical technicians. It is the very product range that insures variety in a chemical technician's duties. These duties may vary to include a complex determination of the atomic arrangement of the molecule of a compound on one extreme, and on the same day this same technician may hand-wrap hundreds of samples of a product just to see how people react to the product's appearance in that wrap. Every product requires several tests, and at least one of these tests is likely to be unique to that product.

In some cases the chemical technician must have a second training to perform his duties. The testing of food products may require the ability to cook. The testing of fabrics may require the skills of a tailor. The testing of electronics products may require a second skill in electronics. Subjective testing may even require skill in public relations duties.

Within all of this job variety there is a certain amount of order and uniformity which shows as a form of standard classification. Production companies will usually fit their chemical technicians into one of three categories: control-laboratory technician, pilot-plant technician, or quality-control technician. Research laboratories are more likely to categorize their chemical technicians into a combination of specialization fields and major product areas. The choices available in research work will be detailed in the job choice section.

The control laboratory is used to control the manufacturing process. To accomplish this, samples are submitted to the laboratory for analysis at various critical or progressive stages of manufacture. The results are used as a basis for continuing or altering the manufacturing process. The same laboratory may control a number of products simultaneously.

The nature of the control laboratory demands a chemical technician who can obtain reasonably rapid and reasonably accurate results with a variety of tests. Either delayed or wrong results could cost the employer thousands of dollars in wages and materials. This type of performance is facilitated by making the tests standard and routine. All tests are carefully worked out in a research laboratory and written up in a standard procedure. When the sample arrives for analysis, the control technician can read the standard procedure and if he knows how to operate the instruments, he will know how to do the test quickly. Such procedures are also checked to be sure that when followed, the procedure followed will yield results which are accurate enough for the control decisions to be made.

A pilot-plant technician also makes use of procedures worked out in a research laboratory, but the similarity in jobs ends there. The purpose of the pilot plant is to take the research laboratory's newest product idea and try to produce it on a pilot scale. Many ideas which work well in a test tube cannot be put into production. Therefore, each new research product is "scaled up" from the test tube to semi-production by the pilot plant. The chemical technicians and the chemical engineer routinely solve new sets of problems to make a commercial product possible. If the problems cannot be solved, the potentially valuable product must be dropped. When a potential product makes it through the pilot plant, the plant continues to make enough product for market research and development. If the market is favorable, a multi-million dollar plant will be built to produce the product.

The pilot-plant technician, like the control technician, runs chemical tests, but he is also instrumental in working out the procedures for those tests. The pilot plant technician must also be mechanically inclined, as much of his work involves the rearranging of equipment and controls, frequently under trying conditions. This technician should have a "feel" for the potential of the equipment he operates. Ideally, when a process fails because of equipment limitations, he knows why and can suggest an alternate for the engineer to work out. Thus, in pilot-plant operation, the satisfaction of accomplishing the routine well is replaced with the adventure of the constantly new situation.

The quality control operation is somewhat different, for here rests the company's reputation. Finished batches are sampled and then await quality control approval before they are shipped. The quality control technician carefully employs standard procedures to be sure the company's product meets the company's established product standards. When a batch is approved by quality control, the only judge remaining is the consumer.

The quality control technician must always employ a standard testing procedure without variation. The precision of his work is very important, but there is no rush. If he has any doubts about a result he can run another sample, for seldom will any harm be done by another hour of delay in the results.

The research laboratory does not really provide a great variety of duties. All chemical technicians do pretty much the same work, that is, take measurements and manipulate laboratory equipment. Of course, the natures of various types of measurements are so different as to obscure the point that the principles of accurate measurement do not change from test to test. The natural phenomena used in the various instruments do vary considerably and research work frequently requires a degree of expertise with a given instrument which comes only with much usage. This is the prime reason for organizing research laboratories by testing categories. A good research chemical technician is usually able to find a way to conduct some difficult test a chemist needs – if the test is at all possible. Research laboratories are also product oriented for the same reason. Familiarity with a product may lead to a use which no one who wasn't highly familiar with the product could anticipate.

THE CHEMICAL TECHNICIAN'S WORKING CONDITIONS

The chemical technician's working conditions, like his duties, will vary to some extent with the product his company makes. If the processing of the product is smelly or dirty, then the laboratory will likewise be smelly or dirty. This is a factor to consider before employment. A technician looking for employment should always request a tour of the area where he will be working. There are many jobs that are not smelly and dirty.

The potential chemical technician will do well to remember that he is considering indoor work. A chemical technician usually works in a moderately crowded, air-conditioned laboratory. There are few non-air-conditioned laboratories today because of the types of electronic equipment in use which demand air-conditioning. But the laboratory is indoors and the background odors are usually chemicals and not the scent of pine trees or the odors of construction work.

The appearances of laboratories tend to vary. A modern research laboratory is likely to be a place of beauty and comfort. Since everyone likes the atmosphere, the employer can usually hire help at a slightly lower wage. A pilot plant resembles the boiler room of a factory or ship. Everything in the pilot plant is built for easy changing, and much of the work requires tanks of up to 500 gallons capacity. Many pilot plants use hazardous solvents and must be made explosion-proof. Control laboratories are seldom fancy, unless they are used for visitor tours. The control laboratory is built in one or more rooms somewhere in the manufacturing building. The technician usually has to walk through the manufacturing area to get to his job and he frequently has to go out on the floor to pick up samples. Thus, the appearance of the laboratory structure is again determined by the product, but in most cases the laboratory itself is quite clean.

The chemical technician enjoys moderately indirect supervision. A typical pattern is one in which the technician is assigned a series of tests and then remains unsupervised until he submits the results. In a control laboratory, where the process dictates the workload, and shiftwork is common, the technician may not receive any direct supervision for days at a time.

Most companies provide their technicians with white or pastel colored uniforms. The uniform colors frequently serve as a cue to the plant supervisors in keeping unauthorized people out of certain areas. Since the laboratory technician usually has to get into all areas, the color white is commonly used. The benefit enjoyed by the technician is the saving of personal clothing. The production technician need not buy work clothing. The research laboratory usually provides only a white coat which goes over the technician's own clothing.

Most beginning chemical technicians will have to work shift work. This may be a fixed shift or a rotating shift. A rotating shift is used when the process is continued over the weekend. As chemical processing equipment is quite expensive, the company cannot afford to let it sit idle sixteen hours a day. In some cases the process itself takes one or two days to complete and an interruption might ruin the product. Control laboratory and pilot plant technicians are usually organized in at least two and sometimes three or four shifts. If a laboratory needs three technicians to handle the work load and it works around the clock, seven days a week, the company has to hire twelve technicians just to staff that laboratory. That is why most beginning technicians have to work shift work – the greatest number of technicians are needed for shift work.

JOB CHOICES AND ADVANCEMENT

The key word in this introduction has been variety, and the potential job choices are no exception. The variety is in so many directions that it will be necessary to make some basic decisions before job hunting. For the student starting his preparation such considerations now may allow more choice later.

The first choice will be one of intentions. If chemical technology is only to be a "stepping-stone," the choices will be different from "lifetime" career decisions. Many girls enter the field as a nice occupation until marriage and motherhood. A young man who cannot afford college may enter the field for the paid college benefits offered by many companies. There are also other good reasons to look upon chemical technology as a temporary occupation.

As a general rule, "short termers" will probably be better off to look for a research job. The young girl will appreciate the atmosphere and the opportunity to meet eligible young men with similar interests. The part-time college student will not be able to work swing shifts or second shifts, so the research laboratory is a prime choice. If the girl cannot get a research job, her next choice should probably be a pharmaceutical or other "ethical" industry. She will probably still be looking for a pleasant atmosphere and a chance to wear nice clothing. She definitely is not interested in second shift work, as that eliminates dating. The part-time college student who misses the research job would do well to look for a company which does not work weekends. If he cannot find a day shift job, he may be able to find a third shift job. If he can sleep days he is better off than the day worker, for he has access to day and evening classes.

The life-long career technician must decide whether he is good enough to make the top category in a limited number of years. If he thinks he is, he should definitely consider a control laboratory or a pilot plant. If he thinks not, he should look for a job that he really likes because he is not likely to move often.

The control laboratory, or in some cases the pilot plant, has several advantages for the career technician who hopes to "make it to the top." Shift work offers good differential pay to attract workers to the undesired shifts. Working a holiday weekend once a year brings in an extra week's pay. More important, however, is the abundant opportunity. There is an opportunity to get experience on many different instruments much sooner than would be possible on the day shift. There is the opportunity to get to know the supervisors and for them to get to know you. This is a big advantage when new openings occur because they then know more of what you can do, even if you have not had a similar assignment in the past. The opportunity to show your real ability is much greater in all areas, because the other technicians with experience and seniority tend to prefer the day shift. The last opportunity is indirect, but just as important. As a control technician you get to know the entire operation. When you are ready for the responsibility you have a good chance of getting a supervisory position because of your knowledge of the jobs to be supervised.

The good technician who wishes to move up must be alert to his promotion potential. He must move up even if this means changing jobs. The first promotion should take place no later than one year on the job. If the promotion does not come, he must find opportunities elsewhere. The second promotion should also come with no more than two and one half years of experience. The promotions must come by then because after this period of time the technician should look for a permanent day or third shift job.

After no more than three years of experience the technician *must* get back to school. It will take a college degree to reap the full benefits of the experience and training already gained. A college degree and supervisory status will take at least six and probably eight years to earn going to school part-time. By then you will be ready to fill the position, probably making the step from senior technician at about age thirty.

If a technician's ambitions are not quite so high, the shift work route is still probably best. That work will allow the technician to find which instruments he likes best. He will also get the experience he will need to change over to research work and be respected for his expertise.

The career technician will not look for better working conditions until he has something outstanding to offer the prospective employer. Then he can compete and have an edge in a crowded job market-place.

THE FUTURE OF CHEMICAL TECHNOLOGY

The chemical industry is so very central to today's life that the industry must continue with an expanding future to fit our population growth. Most chemicals do not show on the retail markets. We are aware only of the medicines, agricultural chemicals and a few other chemicals such as food additives. The largest portion of chemicals is consumed as necessary incidentals and ingredients in other manufacturing processes. An example is the metals industry, which cannot function without acids, paints, and alloying additives. Another example is the building industry, with about forty per cent of all materials coming out of a chemical factory.

It is difficult to predict which portions of the industry will grow or recede over a period of years. The push on environmental pollution could well upset traditional approaches to such estimates. If pressed, there is more likelihood an industry will alter its manufacturing process than there is of the industry's discontinuing the product. Thus, because more chemical technicians are needed to develop the changes, the number of chemical technicians needed is likely to increase throughout the next twenty-five years.

CHAPTER II

WHO SHOULD STUDY CHEMICAL TECHNOLOGY

The chemical technician works in a world of science and technology, where his assignment is to accomplish a part of the technological work. There is a great difference between science and technology and the technician should understand the difference.

The word *science* comes from the latin word *scio,* meaning "I know." Knowledge for the sake of knowledge is the domain of science. The pure scientist is primarily interested in learning *why* things are what they are. He has little interest in practical applications. The pure scientist is usually a "thinker" who requires someone else to make his thoughts functional. There is also the applied or developmental scientist who possesses a different realm of knowledge. His realm of knowledge includes an extensive knowledge of how things happen, as well as the abstract theory. The *how* combined with the *why* is the technology. Note, however, this second kind of scientist specializes in the knowledge of technology and not in the performance of technological duties. An example of such a scientist would be an automotive engineer. He is perfectly capable of designing an engine, but does not normally assemble or service an engine and might not even be able to do so. Science deals with abstractions and ideas.

Technology is the application of science. Technology combines the ideas of science, matter, and a knowledge of how to form things that are useful and functional. As you have seen, technology employs scientists to develop the plans for the "things" of technology. These scientists work in conjunction with technicians to turn the plans into the actual operational "things."

The creation of useful "things" is only a small part of technology.The larger part of technology involves the operation of the useful things. The operation is done by "hands-on" workers. These workers are technicians and operators.

Technicians are used in situation which require a degree of knowledge as to *why* and *how* the job is being done. If the job can be reduced to following a set of instructions without regard for *what* is happening, it can be relegated to an operator.

The reader can see that the technician's role involves both science and technology with the emphasis on technology. The chemical technician has to know just enough science to appreciate what his scientist supervisor is trying to accomplish and to understand the basic principles of his equipment and tests. On the other hand he must function in the field of technology to a very high degree. This function is difficult to describe in exact words because much of the function borders upon being an art. In fact, if the supervisor could reduce the technician's duties to a standard description, he could turn the work over to an operator. The chemical technician is a "hands-on" worker who understands what he is doing to the point that he knows when a reaction or test is going well; when, and how to make changes; and when to report malfunctions because correction is undesirable or beyond the capabilities of the equipment.

The technician is also likely to be unable to specify his future life goals because, in fact, he enjoys any and all types of technological challenge. He is comfortable with the challenge of the uncertain because he "knows" he will somehow make the situation work.

NEEDED PERSONAL CHARACTERISTICS

Before all else, the chemical technician must feel comfortable when working with equipment and machinery. If he feels nervous instead of confident in such an environment, he will never do well as a technician.

Going a step further, a potential chemical technician should be a person who looks forward to an opportunity to work with any equipment which is new to him. The successful technician has a built-in desire to master almost any kind of mechanical device he encounters. With such a desire, mastery and rapport quickly develop between the equipment and the technician. The term *rapport* is appropriate here even though the equipment is inanimate. An experienced technician can and must use his equipment with as much agility as most people use their own fingers.

The chemical technician need not be a mathematician, but should be reasonably good at general mathematics and simple algebraic equations. Nearly all actual calculations will be done with calculators, so there is little need for computational ability, but almost all of a technician's work involves measurement and thus numbers. The successful technician must also develop a sense of precision which is based upon a facility with numbers.

A third characteristic important to success in chemical technology is everyday mechanical aptitude. Chemical technicians frequently assemble, adjust, and operate: glassware, motors, pumps, shafts, grinders, etc. Much time is spent doing tasks which require everyday mechanical aptitude.

A fourth trait necessary for a successful chemical technician is persistence. Young men and women spend much time discussing the variety in a potential job, but the fact is all jobs are highly repetitive. A good chemical technician must obtain the same precision on a given test whether it is the first, the one hundred first, or the one thousand first sample. Research projects can run for months or years, and without uniformity in testing, all the effort and cost is wasted. Remember, it is the technician who must turn the scientist's ideas into fact. Unless the fact is persistent it does not meet the needs of technology.

At least average intelligence is also needed for success in this occupation. The many technical facts to be learned in the program require at least average intelligence to master. There is an adequate range of jobs in the occupation to allow for a broad range of intellect, though individuals of average intelligence can do very well if they apply themselves.

PERSONAL INTERESTS

The potential chemical technician should understand that this is indoor work. The chemical technician does not get to enjoy much sunlight while he is working. There is a definite feeling of being cut off from the out-of-doors. This is very much like school, without the long vacation.

The work is relatively clean. The individual can go for days without really getting his clothing or hands dirty. Upon occasion, some assignments, such as pilot plant work, may be somewhat dirty, but this is a small part of the total career for most individuals.

The working atmosphere is usually relaxed and in most ways quite similar to high school laboratories. If a student likes those courses he will probably like working as a chemical technician.

A potential technician should understand that he will have to develop orderly work habits. If there is an aversion to the idea of keeping everything neat, this may be a negative factor in consideration of this career. A positive feeling toward orderliness is, of course, helpful.

Along the same line, a chemical technician candidate should realize that at times he will have to work quite closely with his supervisor and/or other technicians. A "hot head" will not last at such work. On the other hand, if a technician can hold his temper during the few trying times, he will find that the greatest portion of his work is done without direct supervision. As a result, he should also be capable of working without someone to check on him.

Last but far from least, the chemical technician gets to share a feeling of discovery as part of his career. Seldom does a week go by without some kind of discovery, even in production work. Production work also offers the chance to accomplish something each and every day.

CHAPTER III

DESCRIPTION OF A CHEMICAL TECHNOLOGY INSTRUCTOR

The educational truism which says the teacher is the most important part of the educational process is even more true in vocational-technical education. If the right teacher is selected, and given reasonable administrative support, the program will rapidly develop strength. Conversely, if the wrong teacher is selected, no amount of administrative support will make the program viable. What is the description of the "right" Chemical Technology teacher?

EXPERIENCE AND TECHNICAL TRAINING

The first consideration is related industrial experience and technical training. The technical training and industrial experience should be considered together. College education cannot be a substitute for practical experience, because the college education does not include many knowledges needed to run a successful chemical technology program. Practical experience can be a substitute for formal training, but must be examined carefully, as described below.

When considering an applicant's experience, examine the application for length of experience, balance, and variety. It is not possible to say that an applicant needs a fixed number of years of experience, because the quality of the experience can be quite variable. An applicant should have at least one year of experience where he knew that he had to do this work to earn a living. Certification rules will usually allow a summation of summer experiences, but a summer experience is not the same as full time experience. The summer worker is not under the same pressure to hold his job; therefore, he does not experience many of the subtleties of the occupation and cannot advise or prepare his students for these matters.

Variety of experience is critical. Ideally, an applicant should have at least a few months experience on each of the major instruments and on the wet chemistry bench. If the candidate had experience in each major type of work, that is, production work, pilot plant work, and research work, this would also be helpful. However, if the ideal applicant does not apply, the candidate chosen should have experience on at least three different kinds of assignments which involve different major instruments. A teacher who has a lesser variety of experience will have difficulty overcoming this handicap. Such an applicant will probably have a total of at least three or four years of experience.

If an applicant does not have a great variety of experience, the balance becomes important. What types of duties did the experience include? Did the applicant have to supervise others, or have to plan his own work, or did he just follow the instructions of someone else? Did he have to order supplies and equipment and be responsible for the condition of his laboratory? Did his limited sphere of experience include precise work, or was it all rough and ready work? All of these factors must be balanced against the amount of experience.

The ideal technical training would be that of a high school science teacher with a major in Chemistry. This training should include 8 to 12 semester hours of Physics; 8 to 12 semester hours of Biology, including elementary Microbiology; and 30 semester hours of Chemistry. If the applicant has another 18 or more semester hours of education courses, it will save him extra certification effort during the first few years of teaching.

Again, as with the experience, alternatives are acceptable. Many chemical technicians have an Associate Degree in Chemical Technology which usually includes at least half the science courses suggested above. A well-balanced experience record should provide the additional knowledge of science needed to teach in this field. It is also possible for a research technician with little formal education beyond high school to be highly competent in the area of science because of his daily association with top scientists. His exposure could be even better than that which any university could offer. However, the total record must be examined to make sure the teacher applicant is technically competent. Remember that your program will rest on this competence and that your school is not equipped to help the teacher enrich his technical shortcomings.

PERSONAL QUALIFICATIONS

Conducting a vocational-technical shop course tends to be more strenuous and exasperating than conducing a regular classroom situation. A vocational program requires many extra services and a variety of special equipment. There is much more opportunity for things to "go wrong" and they will. This extra burden requires an extra commitment on the part of the teacher. Fortunately, if you are alert to the difference, many applicants will be seen to have this commitment.

The tip-off is in the reason why the applicant wishes to become a teacher. If he has been successful in his technical career, the applicant is likely to be sincere in his desire to teach — sincere enough to change occupations despite the temptations of success in his present technical occupation. An applicant with limited success as a chemical technician, or a supervisor who is frustrated because of his own personality is likely to be looking for an easier path to success. Such a candidate is unlikely to be happy with the demanding teaching load required for a successful chemical technology program.

A vocational-technical teacher should be interested in teaching the student, not the subject. This sounds like a trite old statement, but it is really an essential characteristic for successful vocational-technical teaching. Whether we like to admit it or not, the student who is willing to study for the sake of knowledge or conformity is in the college preparatory track.

The student who is most suited to study in a high school technical program usually enters as an underachiever. The vocational-technical teacher must organize this program to break the underachieving pattern. This is usually done by organizing individual instruction and using projects in place of talk to pass on the subject matter. The teacher has to get to know each student well enough to know when the student needs to build his confidence and when the student is overconfident. The teacher has to be willing to discover each student's learning style and cater to it until the style can be improved. All of this calls for a great deal of empathy for the student and a willingness to put the student's personal development ahead of the need to master a body of knowledge. A teacher who places knowledge and a formal classroom atmosphere first will never get a technical program off the ground. You are looking for a teacher who has enough faith in people to know that they will rise above their shortcomings if given adequate opportunity and encouragement and that they will master the required subject matter.

PROFESSIONAL PREPARATION

If possible, hire a teacher who meets all the above requirements and is a fully certified teacher. Do not be surprised, though, if a fully qualified applicant does not apply. Most applicants who meet the technical and personal requirements will have little or no preparation as professional educators. The great majority of vocational-technical teachers start with emergency certificates and must complete up to 42 semester hours of general and professional education before they can be certified.

This problem is alleviated in most states by the presence of college programs designed to facilitate the certification of vocational-technical teachers. These programs usually include supervised teaching and basic methods courses early in the program.

The school should anticipate the need for close supervision for the first two years. The new teacher frequently requires some assistance in learning to organize long range instruction and to execute daily lesson techniques. Fortunately, your school is probably prepared to offer such assistance.

CHAPTER IV

CHEMICAL TECHNICIAN JOB ANALYSIS

The job analysis included here is a combined job analysis produced by a committee of three consultants and the writer. The committee was carefully selected to be representative of all Chemical Technician employers.

Consideration was given both to type of laboratory and type of operation. Three major companies were chosen because, combined, they conducted every major type of work performed by chemical technicians. In each case a company official was asked to select the person he considered to be the most experienced and capable chemical technician on his staff. Since the people named were experienced they also had some experience gained from previous employers. The reader may be surprised to learn that two of the consultants so named were women. Women have done as well as men in this field.

Each committee member was first asked to perform a chemical technician job analysis without any assistance from the other members. They were encouraged to seek assistance from their colleagues at work.

When all individual analyses were submitted, the members met as a committee. The analyses were then compared and combined. It was immediately evident that most duties were universal for all the companies with just a few special tasks in each case.

The initial task listings were quite specific because of their tie-in with product lines. The committee quickly agreed on changing the specifics to equivalent general terms. When this was done the universal nature of the work evidenced itself.

Some readers may question the generalizations about the operation of a variety of electrical appliances. After some discussion, the committee was of the opinion that the same basic knowledges and skills were used in each case, despite a wide variety of seemingly unrelated applications.

Each of the consultants contributed a few tasks which were not present at another consultant's company. In each case the other consultants recognized the tasks and usually had performed a similar task, but rarely or at another job years before.

COMBINED JOB ANALYSIS

The following list of complex tasks are those identified by the three consultants as tasks which highly competent Chemical Technicians should be capable of performing. There are many other specialty tasks which are required only of Chemical Technicians working with certain products. However, those specialty tasks require only break-in practice, not new basic abilities or behaviors.

1. Select, assemble and operate standard and automatic burettes for titrations.
2. Use a variety of pH meters to determine the hydrogen ion concentration (pH reading) to the appropriate number of decimal places.
3. Keep an accurate laboratory notebook with day-to-day log of observations.
4. Synthesize and purify organic and inorganic compounds using a chemist's general instructions.
5. Use a refractometer to obtain the index of refraction of liquids, dissolved solids, and some solid materials.
6. Assemble, adjust, and supervise the operation of motors and stirrers and other related types of equipment.
7. Select, assemble, and operate filtration apparatus.
8. Connect, adjust, and read electrical controllers.
9. Connect and read ammeters and voltmeters in various current and voltage applications.
10. Operate all types of balances in fashion that yields results with precision appropriate to the balance, without excess wear and tear.
11. Select, install, and care for thermometers.
12. Assemble, select, and recognize the nomenclature of standard glass apparatus.
13. Install, read, and adjust gas, vacuum, and pressure gages, regulators, and meters.
14. Use hydrometers or density columns to determine densities of materials.
15. Load and operate centrifuges.
16. Use microscopes to view magnified samples.
17. Use the various instruments which measure transmittance and absorbance values in the visible, ultra-violet, and infra-red range. This use includes taking readings for gaseous, liquid, and solid samples as well as flame photometry for the analysis of metallic solutions.

18. Use column, paper, or gas chromatography to separate, and/or identify mixtures, compounds, or elements.

19. Assemble and operate fractionating apparatus including columns, heads, and receivers.

20. Operate and obtain viscosities from four viscosimeters (Saybolt, Fenske, Brookfield, and Bubble Tube).

21. Assemble and operate melting point apparatus to determine a range of melting points from near room temperature up to 400°C.

22. Connect, adjust, and read the charts of various recorders.

23. Always record all readings and determinations in a systematic fashion.

CHAPTER V

BEHAVIORAL ANALYSIS – CHEMICAL TECHNICIAN

The behavioral analysis, sometimes called a structural analysis, is a process which breaks the job analysis into a learning blueprint. This blueprint can be just as useful when building an educational program as a building blueprint is in building a school structure. As with the structure, we can get along without the blueprint if we are willing to accept a chance product.

Each performance ability described in the job analysis is subdivided in terms of immediate prerequisite abilities needed to accomplish the described ability. Each of the prerequisite abilities is then divided, in turn, into its immediate prerequisite abilities. The subdivision process is repeated until the prerequisite abilities are those assumed to be present in an untrained person, or a beginning chemical technology student. The resulting product is a series of chains emanating from each performance ability described in the job analysis.

As stated, the structural analysis is a blueprint, not a teaching outline. This blueprint can be used in many ways to build an effective educational program. In each case where a question arises, the analysis becomes the specification which must be met or exceeded. The tasks can become examination items to be used for any type of evaluation. After the program is put into operation, such examination can even be used to evaluate the validity of the assumed learning sequence itself through the keeping of records of accomplishment at each level. The teaching outline is of primary importance in any educational endeavor, and the analysis permits construction of a clean-cut outline which follows the learning sequence. This analysis also provides a framework to assess adequacy of teaching materials and equipment.

The following behavioral analysis was derived from the job analysis presented in Chapter IV. This analysis has not been experimentally validated. A school may wish to conduct such an evaluation. Some resequencing of items may be indicated by such a validation. All materials developed will still be valid when used in the new sequence. The difference will be revealed as increased student accomplishment with no increase in teaching effort.

1A Selects, assembles and operates standard and automatic burettes for titrations

- **1B1** Selects and assembles a clean burette which holds enough titrant to complete the run
- **1B2** Selects, assembles, and fills an automatic burette where many titrations are made with the same titrants
  - 1C1
  - 1C2
  - 1C3
  - 1C4
- **1B3** Uses an accurately standardized titrant and titrates to an end point

1C1 Selects a clean burette or cleans one

1C2 Selects a burette which holds enough titrant to finish the run

1C3 Assembles the burette without stop-cock leaks

1C4 Rinses the burette with solution from 1C6

1C5 Fills the reservoir with the standardized titrant from 1C6

1C6 Prepares a standardized titrant according to the procedure instruction or uses prepared titrant

1C7 Accurately measures one or more samples of the sample as instructed

1C8 Adds the indicator or assembles the conductimetric apparatus as instructed

1C9 Fills the burette and titrates the sample to and beyond the end point

1C10 Cleans the apparatus at end of titration or runs another sample

1D1 Fills burette with distilled water and allows it to empty

1D2 Watches for droplets of water clinging to sides of burette

1D3 Rejects glassware with clinging drops or cleans in the approved manner

1D4 Checks instructions for an estimated volume of titrant

1D5 If no information is given, a rough ratio of sample to titrant is determined with a graduate cylinder

1D6 Checks stopcock for free rotation

1D7 Checks stopcock seal for leaks and reseals if necessary

1D8 Checks ground glass fitting for cleanliness before insertion of male fitting

1D9 Fills reservoir nearly full

1D10 Rinses reservoir with solution from 1C6

1D11 Records titration volume in log book and on form accompanying sample (to two decimals)

1D12 Subtracts first reading from second reading to obtain results (volume of titration)

1D13 Mixes reactants constantly by hand or magnetic stirrer

1D14 Titrates to and beyond end point

1D15 Fills the burette until the meniscus is on scale near zero

1E1 Does further calculations if instructed to do so

1E2 Does not use results if burette must be refilled before end point is reached

1E3 Reads volume in burette at end point (reads at all intervals for conductimetric unless instructed otherwise)

1E4 Titrates one to three drops at a time until end point is reached after 1E5, and then beyond until assured end point has been passed (may be instructed otherwise for conductimetric titrations)

1E5 Uses uniform small amounts of titrant until end point is approached

3A Records all readings and determinations in a systematic fashion

- 3B3 Records all readings in a log book when it is provided
- 3B2 Records all readings in a systematic fashion until the results are complete if a log book is not provided
- 3B1 Records automatic instrument readings and calculations on a log sheet provided and writes log numbers on the corresponding trace

2A Is able to use pH meters to determine the pH reading of samples

- 2B4 Takes meter reading estimating last decimal place
- 2B3 Rinses electrodes in distilled water before and after each use
- 2B2 Uses buffer solution to calibrate the meter before first use of the day and as instructed during the day
- 2B1 Turns on meter and allows it to warm until there is no needle drift

- **4A** Uses mixes and reacts compounds and elements in solids, liquid or gaseous forms as directed without endangering himself or others in the lab
  - **4B7** Avoids mixing strong acids and alkalis in concentrated form
  - **4B6** Pours more dense liquids into less dense liquids when diluting or mixing chemicals
    - **4C6** Pours slowly while mixing
    - **4C5** Allows any heat buildup to dissipate
  - **4B5** Avoids splashing corrosive materials
    - **4C4** Washes down any splashes that do occur
    - **4C3** Uses a mild neutralizing agent when appropriate
  - **4B4** Wears safety goggles when handling corrosive materials
  - **4B3** Does not mix materials without instructions unless the results are known to be safe
  - **4B2** Works in hood when using or generating poisonous, choking or odiferous gases
  - **4B1** Uses extreme care in the use of flammable or explosive gases
    - **4C2** Avoids sparks and open flames
    - **4C1** Maintains ventilation to prevent a dangerous buildup of gas

6A Assembles, adjusts, and supervises the operation of motors, stirrers and related equipment

- **6B3** Disassembles, cleans, and replaces equipment in the case of routine stoppages
  - **6C3** Can tell by observation when adjustments are needed
- **6B2** Adjusts motor speeds and other related equipment, as instructed, to maintain desired conditions
  - **6C2** Can convert instructions into operating conditions — speed, time, etc. — and maintain them
- **6B1** Assembles stands and associated equipment for stirrers, mixers, rotaters, etc.
  - **6C1** Is familiar and at ease with mechanical adjustment and simple tools

5A Uses a refractometer to obtain the index of refraction of liquids and some solid materials, also to determine total dissolved solids

- **5B4** Takes instrument readings and records them as a 5 digit four-decimal number
- **5B3** Adjusts instrument for the sharpest reading and best light
- **5B2** Converts index of refraction readings with the use of tables or conversion factors
- **5B1** Cleans and dries the optical surfaces with distilled water and lens tissue

7A Selects, assembles, and operates filtration apparatus, both from standard instructions and on own initiative to perform work from more general instructions

- 7B1 For general work selects the correct grade of paper for the fastest filtration consistent with particle size to be filtered and completes the filtration
  - 7C1 Uses aspirator or vacuum with sintered glass filter
  - 7C2 Uses gravity or aspirator with paper
- 7B2 For special filtration selects and assembles the correct type of filter and completes the filtration
  - 7C3 General filtration with build-up of residue, uses the correct grade of paper
    - 7D1 Discards paper with traces of residue or all of residue as there is generally no concern for amount lost on paper
  - 7C4 Large volume pilot plant, uses a commercial cartridge type filter
    - 7D2 Pumps liquid to be filtered and filters it under pressure
  - 7C5 500 ml up to several liters, no build-up of residue, selects and uses an in-line filter
    - 7D3 Installs in-line filter and uses vacuum on receiver
  - 7C6 Analytical work-selects the correct grade of ash-free filter paper
    - 7D4 Uses aspirator flask to speed filtration, or uses a longer neck funnel
    - 7D5 Selects coarsest grade of paper consistent with particle size of residue

- 9A Connects and reads ammeters in various current applications
  - 9B3 Reads meter with correct precision
    - 9C4 Looks straight at needle to avoid parallax
    - 9C3 Reads appropriate number of decimals estimating only one
  - 9B2 Connects the ammeter in series with the circuit
  - 9B1 Selects an ammeter with a mid scale range at the desired current for the application

- 8A Connects and adjusts electrical controllers
  - 8B2 Adjusts the controller to fulfill instructions
  - 8B1 Connects the electrical controller in series with the controlled motor or other application

- 10A Is able to operate a wide range of balances with appropriate precision and without excess wear and tear, including the selection of an appropriate balance for the job
  - 10B3 Protects the knife edges from impact shock
    - 10C11 Is able to read any balance including estimation of the final decimal
      - 10D4 Reads vernier for fourth decimal
      - 10D5 Converts scale position to third decimal
      - 10D6 Operates weight levers or dials to load balance beam
    - 10C10 Converts reading to a decimal number when recording readings
  - 10B4 Reads the balance scale to the final decimal and records the correct reading
    - 10C9 Does not place more than .01g on the analytic balance with the pans down -.001g for some
    - 10C8 Loads balance with the pan supports up
  - 10B2 Operates the balance without unnecessary banging and vibration and keeps it clean
    - 10C7 Cleans a dusty balance and places load on a tare sheet or container
      - 10D1 Uses tare sheet when weighing
      - 10D2 Checks zero after cleaning and re-adjusts if needed
      - 10D3 Removes dust with a fine brush
    - 10C6 Places load on the balance without dropping it
    - 10C5 Avoids banging and rattling of balances
  - 10B1 Recognizes the degree of precision and the maximum load of a variety of balances
    - 10C4 Uses pan balances for rough weighing to the nearest gram
    - 10C3 Uses torsion balances to weight loads between 100-500g with second decimal precision
    - 10C2 Uses a general analytical balance for 0-100g with four decimal place precision
    - 10C1 Uses special analytical balances for great precision

11A Selects, installs, reads and cares for thermometers

- **11B4** Cleans and returns thermometer to case or drawer immediately after each use
- **11B3** Installs the thermometer in the correct position for the application
  - **11C8** Inserts the thermometer to the correct depth if the temperature of a liquid is to be determined
  - **11C7** Inserts the bulb in the center of the gas flow if the temperature of a gas flow is being monitered
  - **11C6** Uses a conductor block if the temperature of a solid is to be determined
- **11B2** Selects a thermometer with the desired scale marking for the accuracy (precision) requirement of the application
  - **11C5** Checks instructions to find the degree of precision needed
  - **11C4** Selects a scale range which has the precision needed by estimating the last decimal
  - **11C3** Checks the length of the thermometer so that the desired portion of the scale is not covered or blocked
- **11B1** Selects a thermometer with the desired temperature scale and range
  - **11C2** Reads the abbreviation to select between Farenheit, Centigrade and Kelvin scales
  - **11C1** Selects a temperature range that places the anticipated reading midscale

- **12A Selects and assembles standard glass apparatus when instructed by standard nomenclature**
  - 12B1 Recognizes the names of common laboratory glassware
    - 12C1 Selects the correct measuring glassware to meet instructions
    - 12C2 Selects the correct size and taper of ground-glass pieces as instructed
    - 12C3 Selects the correct piece of special but standard glassware as instructed
    - 12C4 Selects the correct piece of general containing glassware as instructed
  - 12B2 Constructs a neat, functional apparatus from glass, or glass-connected components
    - 12C5 Connects fittings and supports so that final apparatus is stable and firm
    - 12C6 Uses rubber fittings to make approved type fittings if all-glass fittings are not available
      - 12D1 Butts pieces of tubing to expose minimum amount of rubber at connections
      - 12D2 Fits stoppers to glassware with a snug leak-tight connection
    - 12C7 Is able to bend regular glass tubing to get a fit
    - 12C8 Uses all-glass fittings if possible
    - 12C9 Follows instructions in building glass laboratory apparatus from components

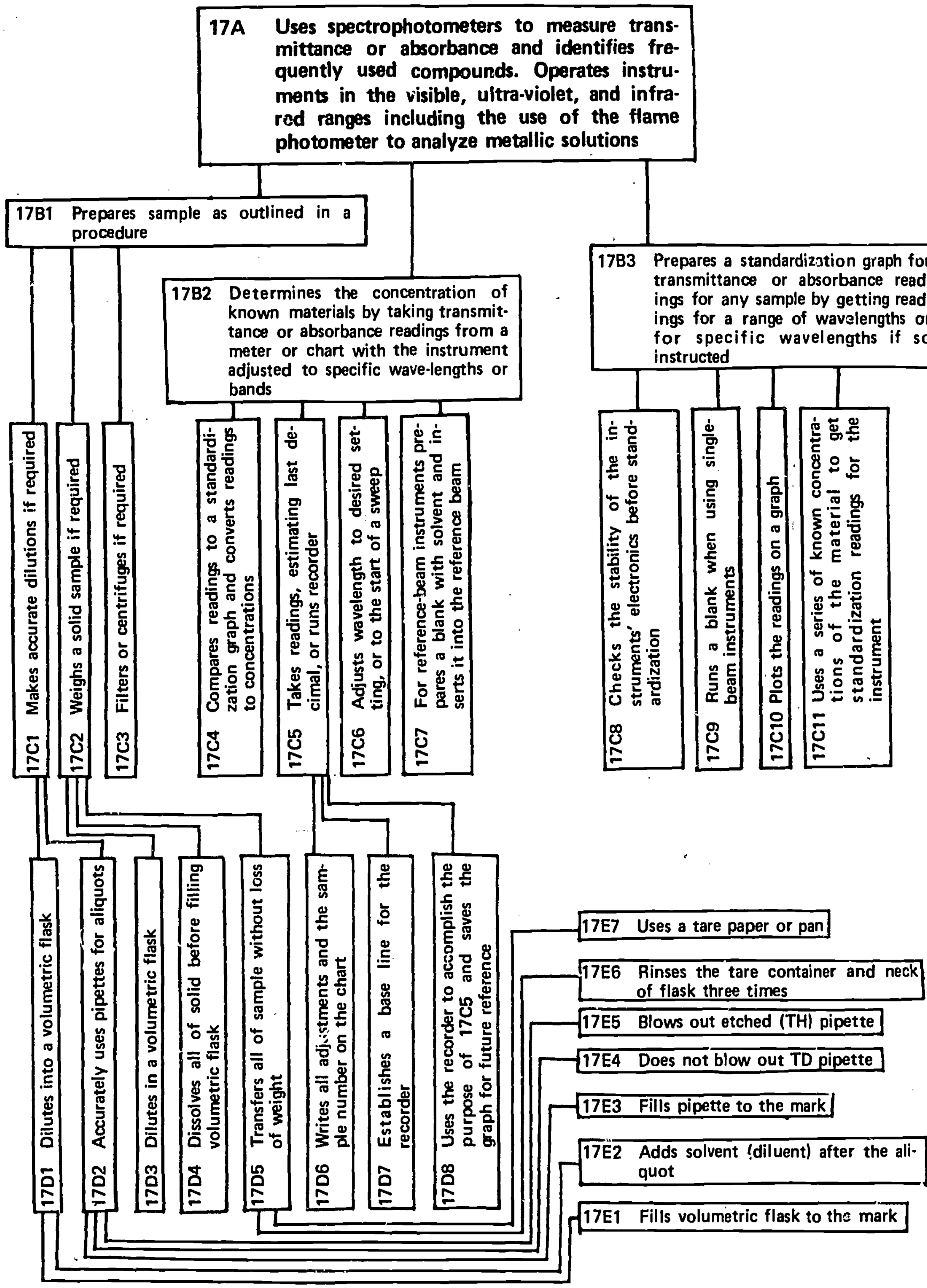
- **13A** Selects, installs, and reads gauges, manometers, and flow meters, and adjusts valves or controllers to control flow and pressure
  - **13B1** Selects and installs appropriate gage or manometer to determine the systems pressure
    - 13C1 Installs gage without crossing or stripping threads but with no leaks
      - 13D1 Checks fittings with soap solution if leaks are dangerous or important
      - 13D2 Tightens gage firmly with wrench, but does not strain
      - 13D3 Checks threads for crossing by finger starting connections
    - 13C2 Selects correct gage thread for gas pressure reducer meters
      - 13D4 Checks cylinder thread and picks identical meter thread
    - 13C3 Selects a manometer for accurate low pressure or high vacuum readings
    - 13C4 Selects a gage with desired pressure near mid-scale or at least on scale
  - **13B2** Selects and installs flow meter according to flow range to be used
    - 13C5 Installs flow meter with flow upward
    - 13C6 Selects flow meter with correct range
  - **13B3** Reads the gage or flow meter as needed or at specified intervals as instructed
    - 13C7 Reads manometers as inches of liquid between tops of columns
    - 13C8 Reads gages or flowmeters from face of gage
  - **13B4** Adjusts valves or pressure controls to vary flow or pressure as desired
    - 13C9 Makes adjustments to maintain conditions as instructed
    - 13C10 Makes adjustments while watching gages

- **14A Selects and uses hydrometer, density columns or other means to determine densities**
  - 14B3 Fills a container of known volume and uses weight to determine densities of powders
    - 14C10 Fills a container of known volume with powder
    - 14C9 Weighs sample and subtracts tare of container
    - 14C8 Calculates weight per unit volume to find density
  - 14B2 Uses a density column to determine specific gravity of solids of indeterminate volume
    - 14C7 Prepares the column according to instructions – including temperature control
    - 14C6 Inserts calibration beads
    - 14C5 Prepares a calibration chart from the bead readings
    - 14C4 Drops individual samples in column and takes readings when they come to rest
  - 14B1 Selects hydrometers for liquids and determines the specific gravity
    - 14C3 Uses a wide-range hydrometer to get the approximate density
    - 14C2 Selects a narrow-range hydrometer if more precise readings are desired
    - 14C1 Reads scale at surface of liquid

15A Loads and operates centrifuges

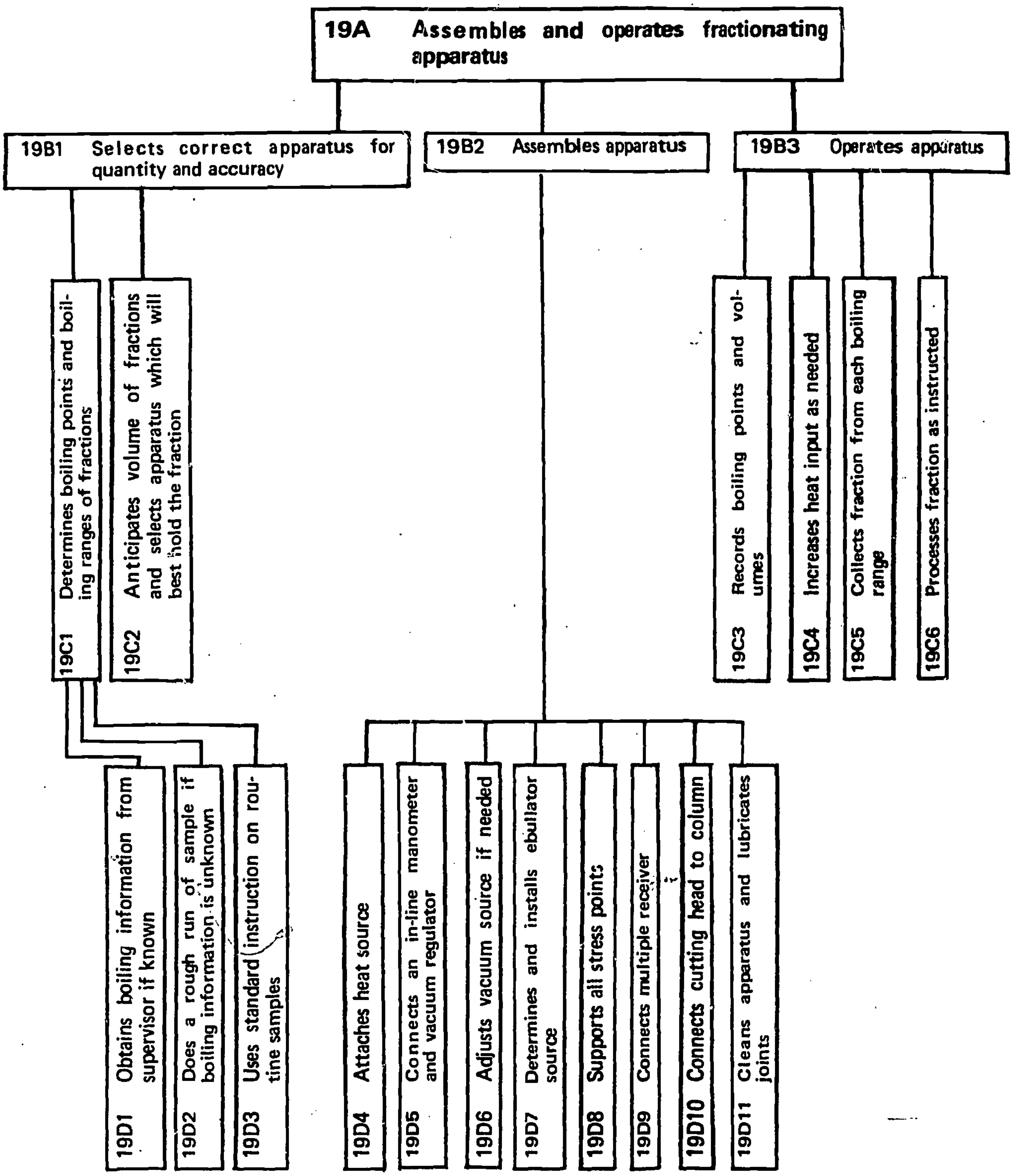
- **15B1** Carefully balances the centrifuge when loading it
  - **15C1** Closes lid before turning centrifuge on
  - **15C2** Uses a tube with water if there is an odd number of samples
  - **15C3** Equalizes the balance in loading various sample cups
  - **15C4** Checks centrifuge cups for cleanliness and cleans them if they are dirty
- **15B2** Runs centrifuge for a specified r.p.m. and times, or (if no instructions) until solids are separated, and stops it
  - **15C5** Allows centrifuge to come to rest without jarring—if brake is used it is released as centrifuge slows to a near stop
  - **15C6** In absence of specific instructions sample is checked for clarity and separation
  - **15C7** Checks instructions and sets centrifuge for correct r.p.m.s if centrifuge speed is variable
  - **15C8** Turns centrifuge off at specified time interval to maintain uniform samples
    - **15D1** Is at centrifuge waiting a few seconds before time
    - **15D2** Checks instructions for spin time

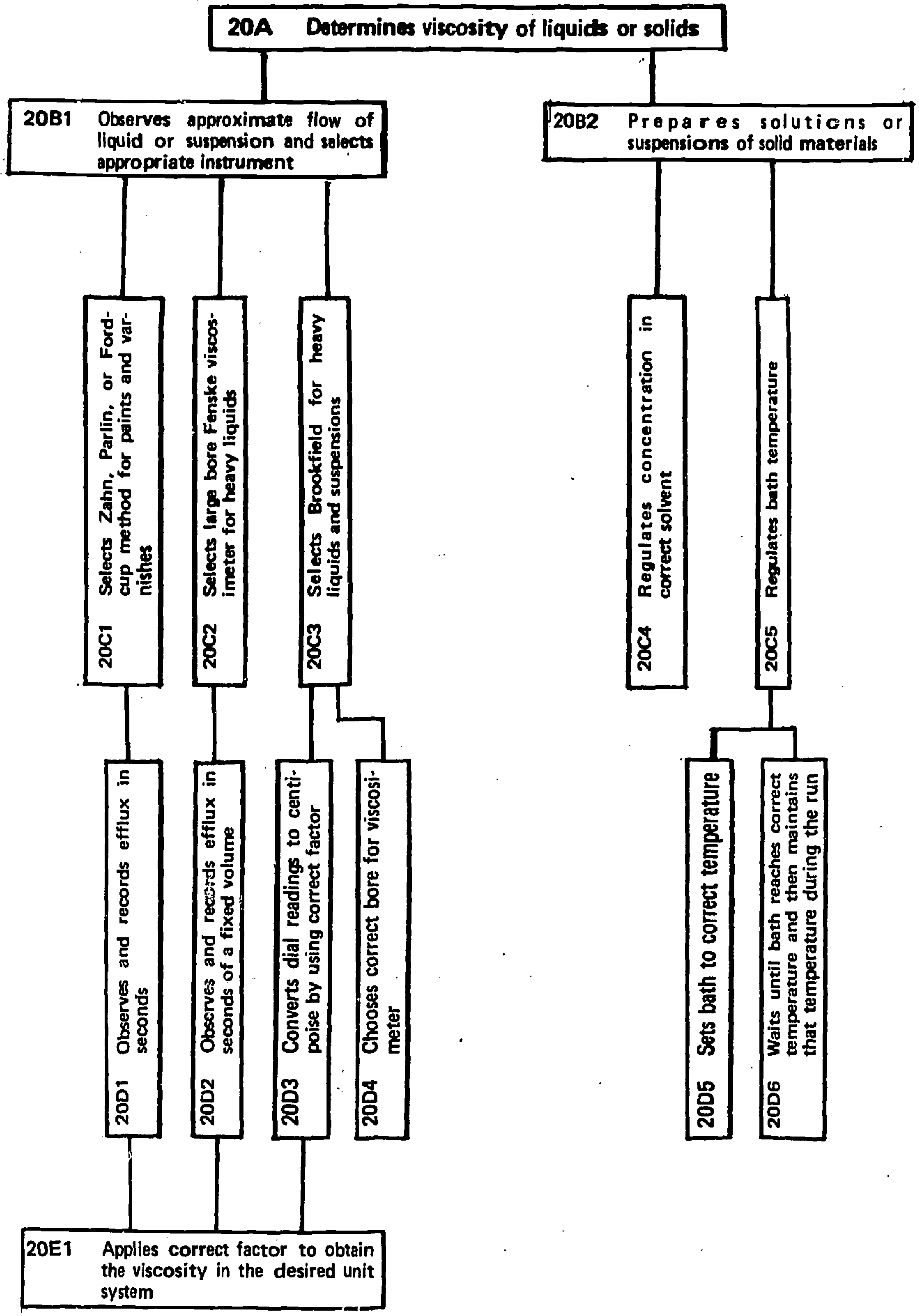
- 16A Uses microscopes to view a variety of magnified samples not easily seen with the naked eye
  - 16B3 Prepares samples for viewing
    - 16C9 In absence of instructions prepares sample in a slice thin enough to transmit light, if possible
    - 16C8 Prepares samples as directed
    - 16C7 Places sample on a glass slide with a cover glass, if possible
  - 16B2 Selects the correct objective for viewing the sample
    - 16C6 Centers sample in field with lowest power objective
    - 16C5 Adjusts focus with low power objective
    - 16C4 Switches to other objective as needed
  - 16B1 Arranges light source according to materials to be viewed
    - 16C3 Shines light through transparent samples
    - 16C2 Reflects light from opaque samples
    - 16C1 Shines light from below crystal structures for outlines


17A Uses spectrophotometers to measure transmittance or absorbance and identifies frequently used compounds. Operates instruments in the visible, ultra-violet, and infrared ranges including the use of the flame photometer to analyze metallic solutions
17B1 Prepares sample as outlined in a procedure
17B2 Determines the concentration of known materials by taking transmittance or absorbance readings from a meter or chart with the instrument adjusted to specific wave-lengths or bands
17B3 Prepares a standardization graph for transmittance or absorbance readings for any sample by getting readings for a range of wavelengths or for specific wavelengths if so instructed
17C1 Makes accurate dilutions if required
17C2 Weighs a solid sample if required
17C3 Filters or centrifuges if required
17C4 Compares readings to a standardization graph and converts readings to concentrations
17C5 Takes readings, estimating last decimal, or runs recorder
17C6 Adjusts wavelength to desired setting, or to the start of a sweep
17C7 For reference-beam instruments prepares a blank with solvent and inserts it into the reference beam
17C8 Checks the stability of the instruments' electronics before standardization
17C9 Runs a blank when using single-beam instruments
17C10 Plots the readings on a graph
17C11 Uses a series of known concentrations of the material to get standardization readings for the instrument
17D1 Dilutes into a volumetric flask
17D2 Accurately uses pipettes for aliquots
17D3 Dilutes in a volumetric flask
17D4 Dissolves all of solid before filling volumetric flask
17D5 Transfers all of sample without loss of weight
17D6 Writes all adjustments and the sample number on the chart
17D7 Establishes a base line for the recorder
17D8 Uses the recorder to accomplish the purpose of 17C5 and saves the graph for future reference
17E7 Uses a tare paper or pan
17E6 Rinses the tare container and neck of flask three times
17E5 Blows out etched (TH) pipette
17E4 Does not blow out TD pipette
17E3 Fills pipette to the mark
17E2 Adds solvent (diluent) after the aliquot
17E1 Fills volumetric flask to the mark

18A Uses four methods of chomatography to separate and/or identify components of mixtures

- **18B1** Uses paper chromatography to separate mixtures and identify parts of mixtures when a procedure is provided
  - **18C1** Spots chromatogram paper with sample
    - **18D6** Marks sample with sample identification and spotting point
    - **18D7** Places spot of sample
  - **18C2** Selects or assembles jar with chemicals according to instructions
  - **18C3** Places paper into jar suspended, with spot end dipped into mobile-phase solvent
  - **18C4** Removes paper before lead front goes off the far end
    - **18D1** Watches front movement and removes paper as instructed
    - **18D2** Marks fronts while they are still wet
  - **18C5** Calculates factors or cuts paper for further processing according to instructions
    - **18D3** Measures front distances from spotting point
    - **18D4** Calculates RF factor from front distances
    - **18D5** Submits paper portions for further analysis unless otherwise instructed
- **18B2** Uses thin-layer chromatography to separate mixtures and identify parts of mixtures when a procedure is provided
  - Same as 18C1 thru 18C5
- **18B3** Uses column chromatography to separate mixtures and identify parts of mixtures when a procedure is provided
  - **18C6** Subjects material to further tests as instructed or notes colors
  - **18C7** Elutes or removes materials absorbed on resin or resins as instructed
  - **18C8** Ajusts pH on resins as instructed
  - **18C9** Assembles column as instructed
- **18B4** Uses gas chromatography to separate mixtures and identify parts of mixtures when a procedure is provided
  - **18C10** Selects columns as instructed and installs them
  - **18C11** Prepares instrument for run
    - **18D8** Turns on carrier gas and adjusts flow
    - **18D9** Turns on the power and allows instrument to reach temperature
    - **18D10** Adjusts sensitivity as instructed
    - **18D11** Prepares recorder for run
  - **18C12** Injects sample and waits for graph to be completed
  - **18C13** Injects standard or uses previous standard as instructed
  - **18C14** Identifies sample and calculates concentration


19A Assembles and operates fractionating apparatus
19B1 Selects correct apparatus for quantity and accuracy
19B2 Assembles apparatus
19B3 Operates apparatus
19C1 Determines boiling points and boiling ranges of fractions
19C2 Anticipates volume of fractions and selects apparatus which will best hold the fraction
19C3 Records boiling points and volumes
19C4 Increases heat input as needed
19C5 Collects fraction from each boiling range
19C6 Processes fraction as instructed
19D1 Obtains boiling information from supervisor if known
19D2 Does a rough run of sample if boiling information is unknown
19D3 Uses standard instruction on routine samples
19D4 Attaches heat source
19D5 Connects an in-line manometer and vacuum regulator
19D6 Adjusts vacuum source if needed
19D7 Determines and installs ebullator source
19D8 Supports all stress points
19D9 Connects multiple receiver
19D10 Connects cutting head to column
19D11 Cleans apparatus and lubricates joints


20A Determines viscosity of liquids or solids
20B1 Observes approximate flow of liquid or suspension and selects appropriate instrument
20B2 Prepares solutions or suspensions of solid materials
20C1 Selects Zahn, Parlin, or Ford-cup method for paints and varnishes
20C2 Selects large bore Fenske viscosimeter for heavy liquids
20C3 Selects Brookfield for heavy liquids and suspensions
20C4 Regulates concentration in correct solvent
20C5 Regulates bath temperature
20D1 Observes and records efflux in seconds
20D2 Observes and records efflux in seconds of a fixed volume
20D3 Converts dial readings to centipoise by using correct factor
20D4 Chooses correct bore for viscosimeter
20D5 Sets bath to correct temperature
20D6 Waits until bath reaches correct temperature and then maintains that temperature during the run
20E1 Applies correct factor to obtain the viscosity in the desired unit system

- **21A** Selects and operates an appropriate apparatus to determine melting points between room temperature and 400°C
  - **21B1** Anticipates the melting range and selects an instrument which can slowly raise the temperature through that range
    - **21C1** Arranges material in holder of apparatus
    - **21C2** Determines approximate melting point from a handbook or supervisor
  - **21B2** Inserts sample and operates the instrument
    - **21C3** Adjusts instrument to a temperature below the anticipated melting point and allows instrument to reach that temperature
    - **21C4** Inserts the sample
    - **21C5** Observes and records shrink point, wet point, and final melt point
      - **21D1** Observes shrink point
      - **21D2** Observes wet point
      - **21D3** Observes final melting point
    - **21C6** Determines purity of sample from melting range

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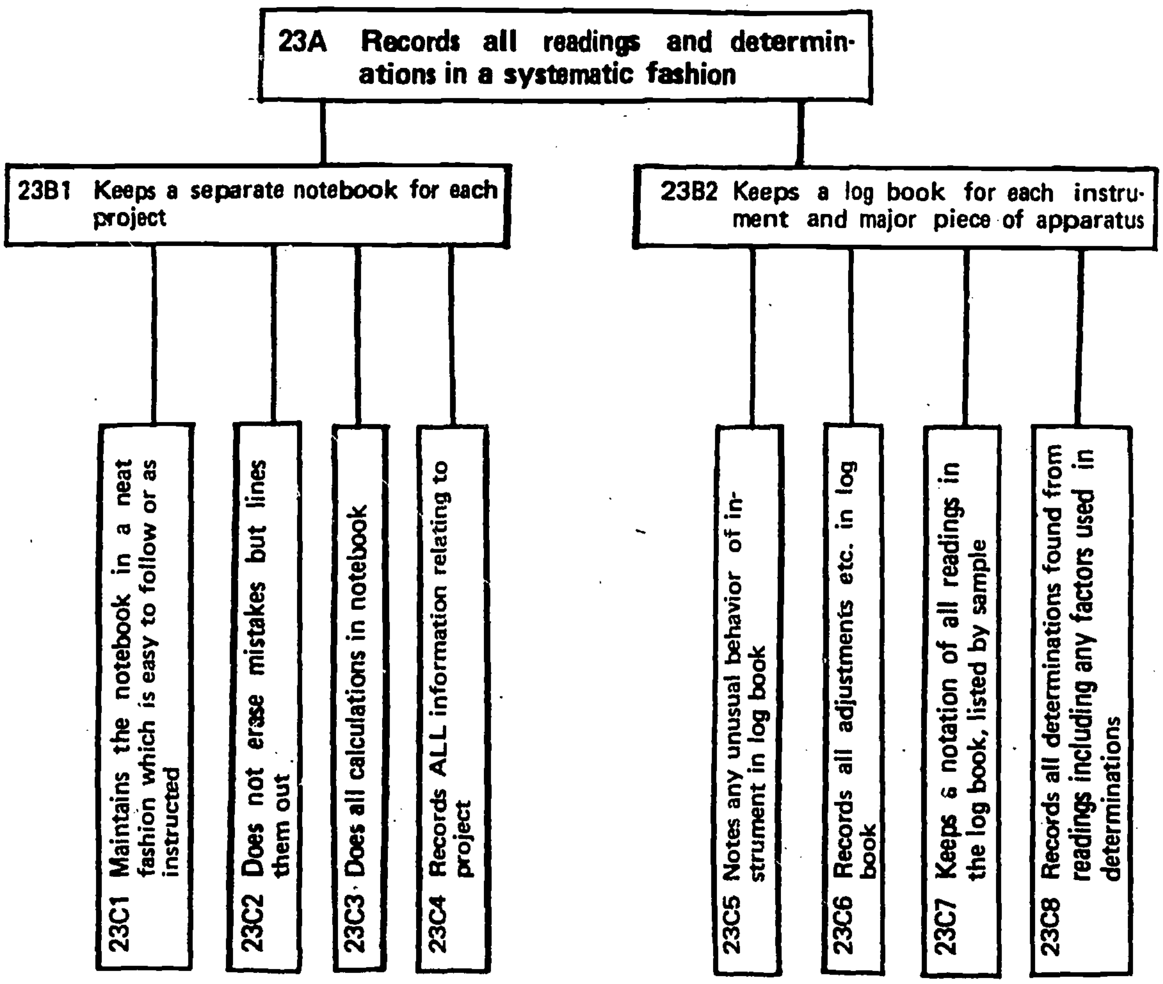
- **22A** Selects and inserts charts, adjusts scribes, and reads charts of various recorders
  - **22B1** Selects the correct chart for the application and inserts it in the recorder
    - **22C1** Determines the type of recording to be used, linear, log, or polar
    - **22C2** Determines the length of recording to be sure the chart paper will record the entire sequence
    - **22C3** Inserts chart, engaging drive teeth, and orients chart if necessary
  - **22B2** Zero-adjusts recorder and sets scribes at the correct drive at the time of installation
    - **22C4** Checks and adjusts zero of instrument to calibrate zero setting
    - **22C5** Makes sure of correct reading if a continuous recorder is being used
    - **22C6** Checks and services pen to assure a clear trace
    - **22C7** Sets chart drive speed as instructed or for best results when not instructed
  - **22B3** Reads charts and records or reports readings as instructed
    - **22C8** Assures correct input range and setting
    - **22C9** Prepares calibration curve as per 17B3
    - **22C10** Records all settings, sample numbers, etc. on chart
    - **22C11** Takes readings from the trace
      - **22D1** Recognizes the type of recording from the trace pattern
      - **22D2** Applies standard procedures to measure the trace
    - **22C12** Records readings or converts them to concentrations as instructed
    - **22C13** Submits charts and readings to supervisor


23A Records all readings and determinations in a systematic fashion
23B1 Keeps a separate notebook for each project
23B2 Keeps a log book for each instrument and major piece of apparatus
23C1 Maintains the notebook in a neat fashion which is easy to follow or as instructed
23C2 Does not erase mistakes but lines them out
23C3 Does all calculations in notebook
23C4 Records ALL information relating to project
23C5 Notes any unusual behavior of instrument in log book
23C6 Records all adjustments etc. in log book
23C7 Keeps a notation of all readings in the log book, listed by sample
23C8 Records all determinations found from readings including any factors used in determinations

CHAPTER VI

THE LABORATORY AND ITS EQUIPMENT

Reference to the subject matter outline will show that the major units of study can be considered to be Introductory and Analytical Chemistry, Laboratory Instrumentation, Technical Physics, and Organic Chemistry. This requires a total of at least 120 student drawers with locks. Twenty drawers will hold common hardware items, such as burners, that can be shared by all. In addition, many more spaces will be needed for general storage and special set-ups. Because each student will be working on his/her own, it is desirable to spread the general work area as far apart as possible. The floor plan suggests a perimeter arrangement. Since the laboratory must be air-conditioned, a dual purpose roof unit can be used. This almost doubles the bench footage which can be put in the room because there will be no heating units to interfere with perimeter use.

The instrumentation equipment has been deliberately spread about in this plan, to allow adequate access by 20 students. Certain types of equipment are sandwiched among student perimeter tables. This should present no problem, as two students will seldom need the same spot. Upon rare occasion the student with the lowest priority requirements may need to show courtesy to the other student.

The floor plan shown here is a convenient arrangement which allows maximum flexibility and quite adequate working space. If necessary the floor space could be reduced up to thirty per cent and still permit operation of a full program. Local conditions might also call for other table layouts. In all such cases consider the working and movement pattern of twenty students.

The General and Analytical Chemistry equipment list provides typical equipment for each student registered in this course. It is suggested that a fully equipped two-drawer set-up be provided for each student. The traditional plan of sharing by two students costs more in the long run because of increased breakage. In this plan, inevitably the dominant student takes over and the submissive student gets short-changed. Also, remember that a technician needs to learn self reliance and technique in the laboratory more than he needs to learn subject matter.

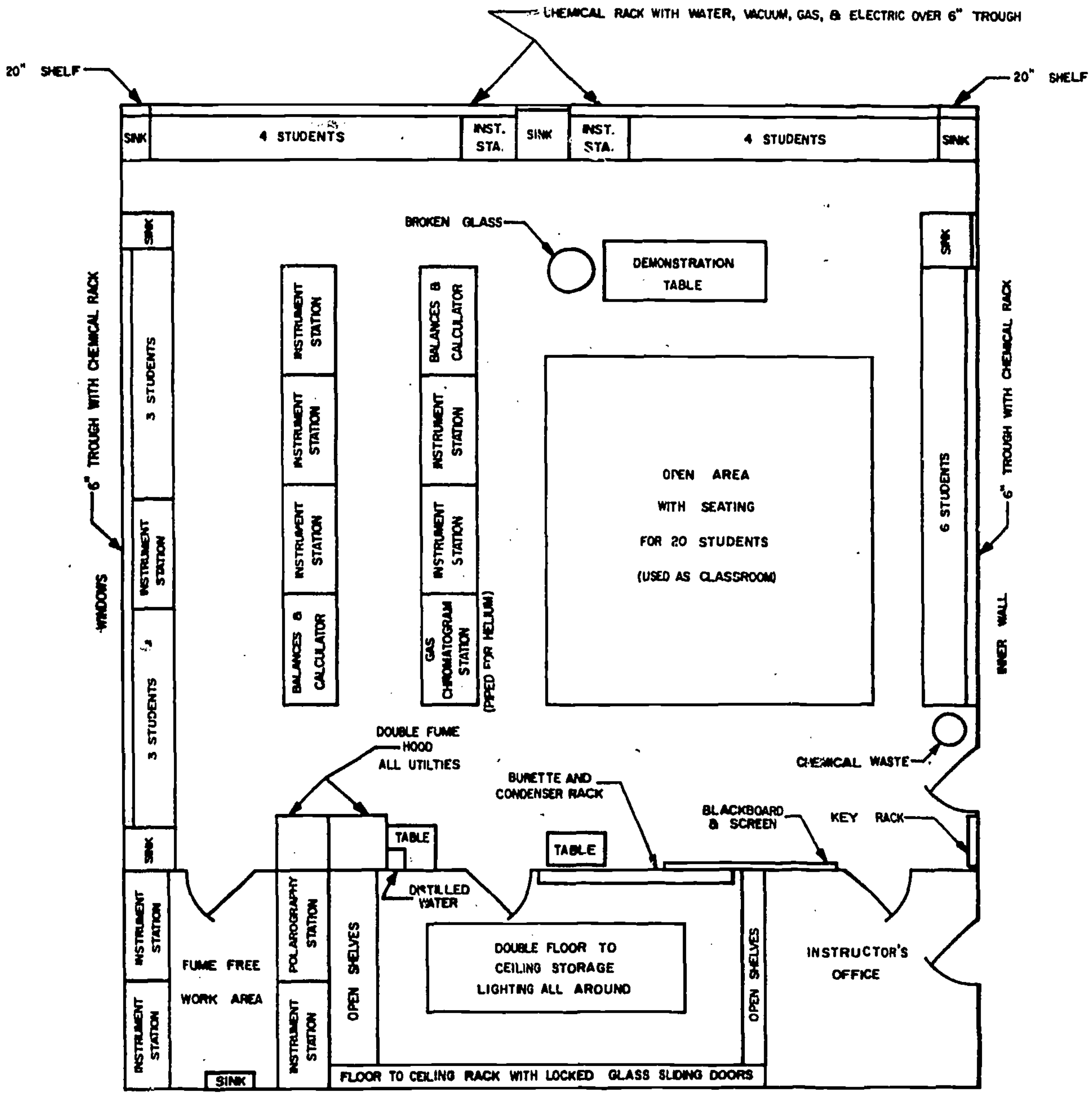
Other equipment will be needed, but it can be carried in the stockroom and used on a sign-out basis. A teacher with a special interest may wish to supplement the list presented here to support that interest.

ALL WORK SURFACES APPROXIMATELY 30" HIGH, WITH 4 LOCKING DRAWERS APPROXIMATELY 20" WIDE.

INSTRUMENT BENCHES ALL WITH ELECTRICITY AND STUBBED DRAINS; OTHER UTILITIES STUBBED, TO BE INSTALLED AS NEEDED.

FULL AREA TO BE AIR CONDITIONED.

FUME-FREE ROOM TO BE HUMIDITY CONTROLLED.



GENERAL AND ANALYTICAL CHEMISTRY EQUIPMENT LIST
PER STUDENT

Glassware

Beakers	
50 ml	4 ea.
100 ml	4 ea.
250 ml	4 ea.
400 ml	4 ea.
Flasks, Erlenmeyer	
50 ml	2 ea.
100 ml	2 ea.
250 ml	2 ea.
400 ml	2 ea.
Flasks, Florence	
125 ml	2 ea.
250 ml	2 ea.
500 ml	2 ea.
Flasks, Filtering	
250 ml	2 ea.
Flask, Volumetric	
100 ml w/stopper	2 ea.
Funnels	
Short stem 65mm	2 ea.
Long stem 65mm	2 ea.
Thistle Tube	1 ea.
Graduate Cylinder	
10 ml	1 ea.
100 ml	1 ea.
Thermometer	
-20° to 110°C	1 ea.
-10° to 200°C	1 ea.
Bottles, 8 oz. Small Mouth w/screw cap	4 ea.
Bottle, Wash	
8 oz. plastic	1 ea.
Drying tube, plastic	2 ea.
Crucible w/cap No. 1	2 ea.
Evaporating Dish	
Size 00 No. 4	2 ea.
Filter Paper 12.5 cm	1 box
Filtering Cone 63 mm	1 ea.
pH Paper Hydrion Disp	1 ea.
Microscope slides	4 ea.
Watch Glass	
65 mm	2 ea.
100 mm	2 ea.
Mortar w/pestle Size 0	1 ea.
Pipette, Volumetric	
25 ml	1 ea.
10 ml	2 ea.
5 ml	2 ea.
2 ml	2 ea.
1 ml	5 ea.
Test Tubes	
10 X 75 mm	10 ea.
13 X 100 mm	10 ea.
20 X 150 mm	2 ea.
Condenser w/sealed tube	1 ea.
Pneumatic trough, plastic	1 ea.
Eyedropper	2 ea.
Policeman, Rubber	2 ea.
Tubing, Rubber	Assortment

Hardware

Forceps, Chemical	1 ea.
File, triangular	1 ea.
Burette clamp	1 ea.
Deflagrating spoon	1 ea.
Test tube holder	1 ea.
Test tube clamp	2 ea.
Rubber tubing clamp	2 ea.
Spatula, metal	1 ea.
Condenser clamp	2 ea.
Triangle, porcelain	2 ea.
Wire gauze	2 ea.
Marking pencil (grease)	1 ea.
Crucible tongs	1 ea.
Brushes, test tube	3 ea.

In Common Drawer For All Courses

Fisher burner	1 ea.
Ring stand	1 ea.
Funnel stand	1 ea.

The Organic Chemistry equipment list duplicates much of the glassware used in the previous list. However, much of this glassware is inexpensive or would be needed for replacement anyway. The more expensive items require the care of the person running the tests as part of the training. A realistic assessment of certain habits requires that the student be the only person to use certain pieces of equipment. For these reasons the following lists of equipment should be provided for each student in locked drawers which have sufficient space for safe storage. This list have to be modified to meet the needs of any special project desired to provide skills needed by a local industry.

ORGANIC CHEMISTRY EQUIPMENT LIST
PER STUDENT

2 Adapters, bent $\mathbf{\$}$ 24/40
3 Beakers, 100 ml
3 Beakers, 250 ml
3 Beakers, 400 ml
3 Beakers, 600 ml
3 Bottles, gas
3 Bottles, reagent, 68 ml
6 Bottles, sample
1 Bottle, wash
1 Brush, test tube
1 Burner, Fisher
4 Clamps, condenser
4 Clamps, extension
1 Clamp, pinchcock
1 Clamp, screw
2 Clamps, test tube
1 Clamp, thermometer
8 Clamps, holder
2 Condensers $\mathbf{\$}$ 24/40
1 Cylinder, graduated 100 ml
1 Cylinder, graduated 10 ml
1 Dish, evaporating No. 00
1 Dish, evaporating No. 4
1 Distilling column $\mathbf{\$}$ 24/40
2 Droppers, medicine
1 File, round
1 File, triangular
2 Flasks, distilling, $\mathbf{\$}$ 50 ml
2 Flasks, distilling $\mathbf{\$}$ 125 or 250 ml
2 Flasks, distilling $\mathbf{\$}$ 500 or 1000 ml
4 Flasks, Erlermeyer, 250 ml
1 Flask, filtering, 250 ml
1 Flask, Florence 500 ml
1 Flask, round bottom 200 or 300 ml
1 Flask, Volumetric, 100 ml
1 Funnel, 65 mm
1 Funnel, Buchner, No. 0
1 Funnel, separatory, 60 ml
1 Funnel, separatory, 125 or 250 ml
2 Gauzes, wire
2 Glass plates
1 pH paper Hydrion
2 Rings, extension
2 Rings, flask
2 Scoopulas
1 Support, test tube
10 Test Tubes, soft, 6"
4 Test tubes, pyrex, 6"
1 Test tube, pyrex, 8"
2 Thermometers, 100°C
2 Thermometers, 360°C
1 Tongs, crucible
1 Tube, drying
1 Tube, "T"
8 Tubbings, rubber 3'
2 Tubings, vacuum

The following list provides individual materials needed to run a modified physics program. Since the teaching of a physics course requires many other items of specialized equipment, the school may desire to teach this course in the regular physics room. In that case, not all of this separate equipment would be needed.

STUDENT EQUIPMENT – PHYSICS

Physical Measurements and Mechanics

1 vernier caliper
1 micrometer caliper
1 metric ruler
1 student pycnometer
3 dial-type spring balances
1 protracter
1 compass
3 clamps, meter stick, support and knife edge
1 simple form truss
2 pulleys single sheave
2 pulleys double sheave
1 pulley triple sheave
1 set wooden density rods (can be made by wood shop)
1 set friction blocks (can be made by wood shop)
1 thermometer -10°C to 110°C.

Light and Optics (per student)

1 lens convex 10 cm
1 lens convex 20 cm
1 lens concave 10 cm
1 screen approximately 5" by 5"
1 wire mesh approximately 5" by 5"
4 holders to fasten above items on a meter stick
1 plastic diffraction grating
1 plane mirror

Electricity and Magnetism (Stockroom items which may not be available in physics room. These items could be made by the first class if necessary)

8 multimeters
4 power-supply demonstrator kits
4 amplifier demonstrator kits
4 time-constant demonstrator kits
4 photo-electric demonstrator kits

INSTRUMENTATION – STUDENT SET–UPS

The instrumentation set-ups are best handled as a combination arrangement. Each student should be assigned a single drawer for equipment and sample storage. The student equipment to be kept in the drawer should be limited to a few beakers, some flasks, a spatula, and half dozen test tubes of each commonly used size. A few other small items can be taken from stock, as needed, during the first year of operation and then a permanent list can be made to meet the local need.

Each instrument will need one or more drawers of associated equipment available on a daily operation basis. It is suggested that, as each instrument is procured, consideration be given to the modes of operation desired for the instrument. Auxiliary equipment should then be ordered to fulfill those needs. Since such equipment is frequently back-ordered it is wise to order extras wherever possible. The extra equipment can then be kept in a separate locked drawer near the equipment. Students should have access to the daily use drawers, but only the instructor should transfer items from the stock (extras) drawers.

A list of basic instruments follows. This list gives a fairly representative sample of all laboratory instrumentation in use. These are "batch" type instruments. Some of the basic processes used in "on line" instruments are not available in this instrument selection. However, it is usually considered impractical to use "on line" instruments as they require a production unit before they can be operational. In addition, the local advisory committee may suggest other special equipment. Such equipment is definitely needed if it is heavily used in the manufacture of a specialty product produced in the locality. For instance, a school in Oklahoma would be justified in considering several instruments which are used only in petroleum processing.

A school may choose to price the equipment in this list when it constructs its budget and plans the purchase of other major instruments in successive years. Such a plan might also permit the actual purchase of equipment to be delayed until an instructor is hired, so he can review the local needs.

Balances– A selection of single-pan analytical balances and torsion balances is needed. A minimum of two analytical balances will do for the class if there is at least one torsion balance which is accurate to the second decimal place for every four students. If torsion balances are not used, one analytical balance for every five students is recommended. If possible each balance should be of a different brand or type.

Centrifuges– Two or three centrifuges are needed. These should be a small model centrifuge with rubber feet, a fixed angle head, a closable cover, and a speed regulator.

Colorimeter– One colored-filter type photoelectric colorimeter with adequate filters to cover the visible range.

Spectrophotometers– One visible-range refracting type electronic spectrophotometer, such as the Bausch and Lomb "Spectronic 20" or the "Coleman Junior." One recording-type spectrophotometer which covers both the visible and ultra-violet range. This should be one of the standard, major brand instruments. One infra-red spectrophotometer including a selection of standards for each classification of organic compound to be tested.

Gas Chromatographer– One dual column, recording gas chromatographer with temperature control. At least two different matched sets of columns are needed for this instrument. The recorder for this instrument should include an integrator or have an integrator attachment.

Conductimetric Titrations– One conductimetric bridge with a conductivity cell. One resistance bridge (low priced) with an electric eye for end-point determination. One conductivity cell attachment for a pH meter.

pH Meter– One pH meter accurate to the second decimal with parameters for potentiometric and conductimetric titrations. This purchase should include appropriate extra cells and buffers.

Muffle Furnace– One muffle furnace with an approximately 4" by 4" by 8" chamber.

Melt Point Apparatus– One capillary tube melting-point apparatus. One alternate form of melting-point apparatus. If the budget allows, this second type of apparatus might be a combination melting-point, boiling-point apparatus.

Pipetting Machine– One automatic pipetting machine with a capacity of up to 10 ml per aliquot.

Refractometer– One Abbe refractometer. Auxiliary to this instrument, but necessary to its full operation, is a constant-temperature bath and at least two different indexes of refraction calibration standards.

Polarimeter– One half-shade type polarimeter with some source of monochromatic light. If the school determines that local industry makes heavy use of this instrument, a water bath and jacketed sample tubes will be needed.

Polarograph– One recording polarograph including a dropping electrode mercury cell and a rotating electrode cell. The inexpensive "Heath" polarograph is quite adequate for student work. It may be readily used with the "Heath" recorder or any standard recorder. The "Heath" polarograph has the advantage of being convenient for use in several exercises when teaching basic instrumentation.

Viscosimeter– One viscosity bath with temperature control. This viscosity bath should be capable of holding several types of viscosity tubes including Saybolt and Cannon-Fenske. Up to a half dozen of each type of tube should be purchased with the instrument. One shear type viscosimeter with at least three rotating bobs of different ranges. A power driven instrument is preferable.

Other– A variety of scientific fractional horsepower motors, controllers, shafts, etc., should be purchased for use by students. The facility gained in using these devices is needed even though the school lab could easily by-pass the need for such instruments to complete any tests.

STOCKROOM SUPPLIES AND EQUIPMENT

It is very difficult to provide specific and useful information about the kinds of items needed in the stockroom. In general, the stockroom will require the same kinds of chemicals and glassware needed in a regular high school chemistry laboratory. In addition to this, several special chemicals will be needed for the instrumentation phase of the program. A first duty of the new instructor will be to review the exercises planned for that work and then order the needed chemicals. Increased student working time will require up to four times the amount of chemicals usually consumed by a single student in high school chemistry. The glassware items will also be similar but in many cases should be of greater precision than usual. Many items will require $ fittings instead of stopper fittings. A number of special glassware items not normally found in a high school laboratory will be needed, but can be added as the need is established.

A stock of individual student glassware items is needed to maintain the laboratory. A standard stock of 25% should prove adequate. In many instances case lot prices will suggest larger spare supplies of specific items to permit the school long-term savings.

CHAPTER VII

OCCUPATIONAL COMPETENCY PRE–PLACEMENT EXAMINATION FOR CHEMICAL TECHNICIANS

TESTING MANUAL

Use Of The Examination

The chemical technician occupational competency examination was primarily designed as a selection and placement device. It can be useful to the employer as a screening and placement device. Schools offering chemical technology programs may find the examination of value as a pre-placement device. The examination may also be of value for teacher selection and certification purposes.

If the examination is used for teacher selection or certification purposes,it is suggested that successful candidates should score in the same range as the successful top-level technicians. Such practice would assure that the teacher candidate has sufficient occupational competence in his subject field.

When the examination is used by schools as a pre-placement device it is suggested that the examination be administered just prior to graduation. The student should not receive any kind of special preparation for the examination. The examination should be administered in a fashion that prohibits the other students from observing the examinees while they work. No scores should be announced until all students have completed the examination. The examiner should also avoid discussing any information on the rating checklist. Following these precautions avoids invalidating the examination scores. Unless scores have been announced, there is no danger in having students discuss the examination before they take it. The only way a student can improve his score is to improve his competence. There is some likelihood of such improvement, since a discussion of the judgments involved could lead a student to improve his judgment, especially if he has not previously considered his work in terms of decision making.

The student scores could be made a part of the credentials offered to the prospective employer. If this is done, an insert containing the pertinent validation information should also be included. Many employers would have to provide the validation information to the United States Office of Economic Opportunity before they could accept the examination as a selection device.

When the examination is used by the employer as a selection and placement device, it is suggested that the testing be done by the supervisor who will be supervising the selected candidate. The supervisor does not need any special training. He will need to read this manual, the test, and the checklist before he administers the examination for the first time. Should this suggestion be impractical for any given employer, a qualified personnel department professional employee can administer the examination. If this is to be the practice, it is further suggested that the designated employee assist a laboratory supervisor in the administration of the examination at least once and then have the laboratory supervisor assist him at least once before he attempts to administer the examination on his own.

There are at least two advantages to the initial suggestion. Observation of the candidate during the examination will give a good review of where the candidate has strengths and weaknesses. This could be valuable information for in-service training of the selected candidate. Possibly more important than the score is the candidate's working personality. Administration of the examination will probably take between 35 and 60 minutes. During this time the supervisor can make a good evaluation of the candidate's working personality. Since the supervisor would usually wish to interview the candidate anyway, there is little loss of time to gain this information.

The personnel department should review the pay level schemes presented in this manual and make policy decisions which are consistent with local needs. It should be noted, however, that only the three-level scheme provides a seemingly natural break in scores that give reasonable assurance of pay levels which fit individual competency.

Since the examination requires the use of many pieces of minor equipment and a few pieces of common major equipment, it is suggested that the testing always take place in the same laboratory. If a laboratory which has the large items is selected, the company need only tie up one cabinet space and about 80 dollars' worth of equipment. Other activity can take place in the laboratory during the examination unless the company wishes to retest the other technicians for advancement purposes. A laboratory is suggested instead of an office because running water, distilled water, and several electrical outlets are needed during the examination. The laboratory environment also adds to the realism.

Administration Of The Examination

Administration of the examination requires approximately one hour. Less capable candidates will usually require less time and some very capable candidates will require as much as an hour and a quarter because they will need 15 to 20 minutes to interpret the graphs which are part of the examination.

To prepare for the examination, gather the equipment and supplies listed on the attached sheet. Assemble them in a laboratory which has running water and at least 20 square feet of bench top. Five 110-volt outlets will also be needed. If the laboratory already has an analytical balance, a calculator, and a pH meter, the bench space can be reduced. Organize the glassware as shown on the diagram (page 62), on the second page of the equipment list. If the space is limited and a different arrangement is needed, make sure all the volumetric glassware is neat, together, and in plain sight. The pH meter should have a probe which is assembled and in operating order, but if possible, the power should be turned off. Other people may work in the laboratory during the examination, but they should not talk to the candidate, or about the test, nor should they be allowed to disturb the equipment.

When the candidate arrives, allow him to read the examination tasks he is to perform. After he has read the tasks, take two to three minutes to show him the location of everything he will need. A friendly, relaxed atmosphere is desirable, but do not discuss the rating checklist or how to perform any item. If the candidate asks how to do something, tell him he is to use his best judgment.

The exact wording to be used follows: *Mr. (or Miss) _____: The* (Name of firm) *requires chemical technician candidates to take a performance test. This test will probably take 30 to 60 minutes to complete. You may not be able to do some tasks. Do not worry, just skip them.* Give the candidate his examination sheet and allow him to read it. Say: *You are to perform all the tasks to the best of your ability and according to your best judgment.* Then point out the various pieces of equipment. Allow the candidate to ask any questions he has and allow him to start.

To rate the candidate, watch his performance of the tasks and check those behaviors he demonstrates. If the candidate performs the task somewhat differently, decide whether or not he has performed the equivalent of what is described in the checklist and rate him accordingly. If the candidate questions something, such as the dirty burette, remain neutral and respond with some comment such as — *"Yes, I see it is somewhat dirty,"* but tell him to go ahead and work with it since it would take too long to clean it. The appropriate items which are indicated by the questioning would, of course, be checked.

Validation Information

This is a brief summary of the pertinent validation information. More detailed information is available from the examination publisher.

Mean Score of the Standardization Sample	= 52.3
Number of Subjects in the Sample	= 61
Standard Deviation of Scores	= 15.9
Range of Scores for the Standardization Sample	= 12 to 90
Split-Half Reliability Coefficient	= .94
Inter-Rater Reliability Coefficient	
Laboratory Supervisor	= .98
Personnel Specialist	= .98

Score Interpretation

Since virtually all companies hiring chemical technicians follow a practice of saving the top technician pay level for employees of long and successful tenure, that pay level does not have to be considered for selective purposes. This leaves two selection sequences. Those companies which recognize four pay levels have need for three selection levels, while the companies with five pay levels have need for four selection levels.

The scores show a natural three-level breakdown. If the mean score for the total standardization sample (52.3) is chosen as the midpoint for the second pay level score range, we need only subtract one standard deviation to obtain the midpoint for the level 1 score range (36.4) and add one standard deviation to obtain the midpoint for the level 3 score range (68.2). Each of these midpoints lies very close to the corresponding standardization group mean. Scores of 28 to 44 would be used to select pay-level-1 technicians. Scores of 45 to 60 would be used to select pay-level-2 technicians. Scores of 61 and above would be used to select pay-level-3 technicians.

The only difference between this proposed three-level score interpretation and present practice is that it would be harder to become a level-3 technician. Present level 3's do not score as well as present level 4's. However, in the suggested selection scheme, level 3 and 4 technicians are assumed to have the same ability. The only way to fully meet present practice is to use the same score range (45-60) for the selection of pay levels 2 and 3. This matches present practice. The mean of pay level 3 of the standardization sample was 1.6 score points more than the mean of pay level 2 of the standardization sample.

Those companies which use five pay levels need four selection ranges. They could use a score range of 28 to 44 to select pay-level-1 technicians. A score range of 45–60 could be used to select technicians for pay levels 2 and 3. A score range of 61 and above could be used to select pay levels 3 and 4. Such practice would parallel the competencies obtained by present selection practices.

If a company desires a higher competency at each pay level, the examination could be used to assign such levels. By adding one-half standard deviation to the standardization sample mean, a score of 60 is obtained. This could be the midpoint of pay level 3. If the remaining midpoints are separated by three-fourths of a standard deviation the following midpoint values are obtained: pay level 1 = 36, pay level 2 = 48, pay level 3 = 60, and pay level 4 = 72. The score ranges for each level would be 30 to 42, 43 to 54, 55 to 66, and 67 or above respectively.

Suggested Score Ranges

Three Level			Four Level			
Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 4
28 to 44	45 to 60	60 & up	30 to 42	43 to 54	55 to 66	67 & up

CHEMICAL TECHNICIAN

OCCUPATIONAL COMPETENCY EXAMINATION

Rating Checksheet

Starting Time ________________ Subject No.__________

1. Weigh out approximately 1 gram of sodium hydroxide pellets to be used to make a standardization solution.

_____ Selects an analytical balance accurate to at least four decimal places.

_____ Obtains a tare sheet (a small piece of clean paper).

_____ Takes the bottle of NaOH pellets to the balance.

_____ Turns on the balance and checks the zero point before weighing.

_____ Estimates weight of tare sheet (reads two to three decimals).

_____ Keeps the pan support raised except during readings, especially when adding more than a few grains of powder (raised for pellets).

_____ Operates weight dials to obtain weight range.

_____ Immediately replaces bottle cap after use, before taking final balance reading. (In this case, as in many, atmospheric moisture will ruin the contents.)

_____ Reads major scale accurately (nearest division).

_____ Reads vernier to ±one division, or rounds off last figure to nearest whole division.

_____ Transfers balance readings to a digited, decimal figure, accurately.

_____ Writes first full readings on paper. (Does not trust memory.)

_____ Writes tare readings on paper (after step 2).

_____ Enters net weight on answer sheet.

2. Dissolve the pellets of NaOH in 100.0 ml of distilled water.

_____ Selects a 100 ml volumetric flask (only practical instrument available with the correct degree of precision).

_____ Transfers pellets to bottle without touching them. (Correct procedure is to make a funnel with tare paper and pour them.)

_____ Washes neck of flask with water.

_____ Fills flask to a convenient level, less than 3/4 full.

_____ Completely dissolves pellets by swirling.

_____ AFTER ALL PELLETS ARE DISSOLVED, fills flask until the bottom of the meniscus and the graduation circle are sighted as one.

_____ Assures complete mixing by ample agitation, using air bubbles as mixer.

3. Use the calculator and determine the normality of the sodium hydroxide solution. Use the equation printed immediately below. Insert the numbers in the spaces provided.

_____ Obtains correct answer from calculator (between .200 and .300).

*_____ Enters results on sheet to three decimals. (The 4.00 was inserted to test interpretation on errors of significant figures and to make four decimal place weighing realistic.)

_____ Does not have to start any part of the calculation twice because of any type of error. (Subject may have been taught to run entire problem twice to check.)

* If subject uses less accurate number, ask why; if he refers to hygroscopic nature of NaOH check both blanks as correct.

4. Using the approximately .1N hydrochloric acid as a titrant and phenolthalein as an indicator, determine the normality of the approximately .1N hydrochloric acid. Use two 10.0 ml aliquots of the sodium hydroxide. Titrate duplicates and average the results. Record the results in the blanks. Use the equation provided for your calculations. Use the magnetic stirrer to mix the reactants.

_____ Use a 10 ml pipet to obtain aliquots. (The best of three poor choices. Tell subject to avoid getting this liquid in his mouth, after he reaches for pipet. This concentration is only slightly harmful if not rinsed with water.)

_____ Fills pipet so that the bottom of the meniscus and the calibration mark are even.

_____ Allows pipet to run empty. (Does not blow out the last of the liquid.)

_____ Touches end of pipet to side of flask to remove last drop.

_____ Selects a small Erlenmeyer flask as a titration container.

_____ Takes and records initial buret reading.

_____ Uses 1 to 3 drops of phenolthalein.

_____ Rounds buret reading to nearest .05 ml.

_____ Adjusts magnetic stirrer for a swirl.

_____ Titrates, using a number of approximately equal volumes until the end-point is approached.

_____ Near end point, titrates at a rate such that individual drops can be counted.

_____ Checks for cleanliness of buret. (Looks for clinging drops.)

_____ Inserts plastic magnet.

_____ Assembles buret-stand – upright – and buret clamp so that the buret tip is somewhat below the mouth of the flask when the flask is on the stirrer.

_____ Fills buret so that liquid is off scale and somewhat above the zero.

_____ Slowly opens the valve and allows the liquid to displace all air.

_____ Allows liquid to drop into a spare container until meniscus is on scale, or if necessary refills buret.

_____ Compares the volume of acid in buret with result, to avoid refilling buret during a titration.

_____ Averages readings and does other calculations as instructed.

_____ Does not exceed end point by more than two drops.

_____ Takes and records final reading.

_____ Enters difference in readings on answer sheet.

_____ Exhibits reasonable dexterity during the above operations.

5. Combine the two titrated aliquots in a beaker and take pH reading.

_____ Combines the two aliquots in a small beaker.

_____ Turns on pH meter.

_____ Allows pH meter to warm until there is no drifting of needle.

_____ Accurately adjusts pH meter with buffer as a standard.

_____ Rinses meter probes.

_____ Takes reading, rounding off the last digit to a realistic extent (depends upon meter scale).

_____ Records the reading accurately.

_____ Rinses the probes with distilled water.

6. Mix about 20 ml each of solutions A and B. Centrifuge three tubes of the product.

_____ Mixes the solutions.

_____ Fills each centrifuge tube with an equal amount.

_____ Inserts the tubes in centrifuge opposite each other.

_____ Uses a fourth tube filled to same level with water as a counterbalance.

_____ Measures solution with a graduate cylinder.

_____ Closes lid, if any, before running centrifuge.

_____ Allows centrifuge to run a few minutes.

_____ Turns off centrifuge and allows it to coast to a stop (no sudden jarring).

_____ Checks separation of one tube, to see if further centrifuging is needed.

7. Identify what instrument the chart for item 7 was run on. Assume that the standard solution contains 120 grams per liter of a product. Find the amount of the product in each of the two samples. You are to use the two sheets of paper inserted after the chart, item 7, for your work.

_____ Identifies instrument as auto-analyzer or like equipment.

_____ Attempts to prepare a standardization graph.

_____ Plots concentration on one axis and readings on the other.

_____ Chooses and draws a straight line that runs through the approximate center of the plotted points.

_____ Plots the points on the standardization on the graph.

_____ Gets a value between 64 and 70 grams per liter as a value for sample No. 1.

_____ Gets a value between 49 and 54 grams per liter for sample No. 2.

_____ Records values where instructed.

8. What type of instrument were the charts for item 8 run on? Give the formulas of the two samples or whatever part of the formulas you can. Place your responses on the sheet of paper inserted after the charts.

_____ Identifies instrument as a spectrophotometer (ignore any model or brand information).

Two types of reading are:

_____ absorption

_____ transmittance.

Instrument is commonly used without a chart by:

_____ reading the meter at specified wavelength.

9. What type of instrument were the charts for item 9 run on? Give the formulas of the two samples or whatever part of the formulas you can. Give the amount of each of the two samples. Approximate this figure within 10-15%. Place your responses on the sheet of paper inserted after the charts.

_____ Identifies the gas chromatogram.

_____ Gives C_2H_6 as formula for unknown No. 1.

_____ Gives $C_4H_?$ as formula for unknown No. 2.

_____ Gives between 4.3 and 5.8 microliters as a response to unknown No. 1.

_____ Gives between 6.8 and 9.2 microliters as a response to unknown No. 2.

_____ Records responses as instructed.

10. Using the equipment provided, set up a reflux condenser. Assume that the reactants and a heating mantle will be added later, after the set-up is approved.

_____ Chooses a condenser.

_____ Chooses a flask.

_____ Chooses no other glassware.

_____ Inserts condenser into flask and clamps both upright with at least 3 clamps.

_____ Fastens rubber tubing.

11. Using the equipment provided, dilute the solution labeled C in distilled water to produce a solution containing 1 ml. in 125 ml, 1:125.

_____ Places a little of C into a clean beaker.

_____ Takes exactly two ml with a pipette.

_____ Places 2 ml in a 250-ml volumetric flask.

_____ Fills flask to mark.

_____ Agitates, using air bubble to mix contents.

Finishing time _______________ Working time _______________

AN OCCUPATIONAL COMPETENCY EXAMINATION
FOR
CHEMICAL TECHNICIANS

1. Weigh out approximately 1 gram of sodium hydroxide pellets to be used to make a standardization solution.

   Weight of NaOH____________ grams

2. Dissolve the pellets in 100.0 ml of distilled water.

3. Use the calculator and determine the normality of the sodium hydroxide solution. Use the equation immediately below. Insert the numbers in the spaces provided.

   Calculations:

   $$\frac{\text{Wt. in Grams}}{4.00} = \text{Normality of Sol.} = \frac{\_\_\_\_\_\_\text{ g}}{4.00} = \_\_\_\_\_\_\text{ N NaOH}$$

4. Using the approximately .1N hydrochloric acid as a titrant and phenolthalein as an indicator, determine the normality of the approximately .1N hydrochloric acid. Use two 10.0 ml aliquots of the sodium hydroxide. Titrate duplicates and average the results. Record the results in the blanks. Use the equation provided for your calculations. Use the magnetic stirrer to mix the reactants.

   Aliquot No. 1______________ ml of HCl

   Aliquot No. 2______________ ml of HCl

   Average______________ ml of HCl

   Calculations:

   $$\frac{\text{N of NaOH x 10}}{\text{Avg. ml HCl}} = \text{N of HCl} \qquad \frac{\_\_\_\_\_\_\text{ N NaOH x 10}}{\_\_\_\_\_\_\text{ ml HCl}} = \quad \text{N HCl}$$

   The normality of the HCl is______________

5. Combine the two titrated aliquots in a beaker and take pH reading.

   pH__________

6. Mix about 20 ml each of solutions A and B. Centrifuge three tubes of the product.

7. Identify what instrument the chart for item 7 was run on. Assume that the standard solution contained 120 grams per liter of a product. Find the amount of the product in each of the two samples. You are to use the two sheets of paper inserted after the chart, item 7, for your work.

8. What type of instrument was the chart for item 8 run on? What two types of readings can be taken with this instrument? Could you use the instrument without a chart? How? Use the sheet of paper inserted after the chart, item 8, for your responses.

9. What type of instruments were the charts for item 9 run on? Give the formulas of the two samples or whatever part of the formulas you can. Give the amount of each of the two samples. Approximate this figure within 10-15%. Place your responses on the sheet of paper inserted after the charts.

10. Using the equipment provided, set up a reflux condenser. Assume that the reactants and a heating mantle will be added later, after the set-up is approved.

11. Using the equipment provided, dilute the solution labeled C in distilled water to produce a solution containing 1 ml. in 125 ml, 1:125.

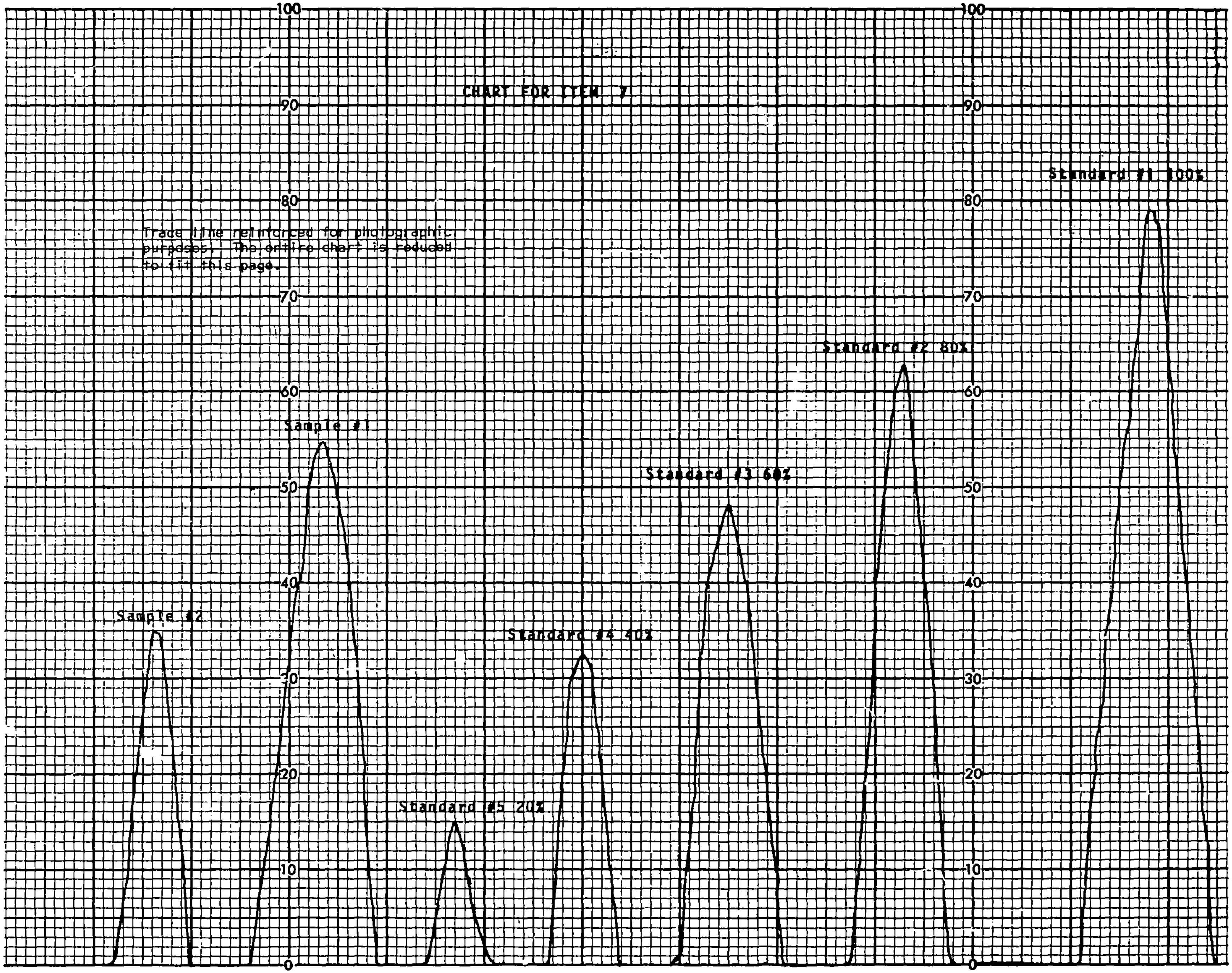
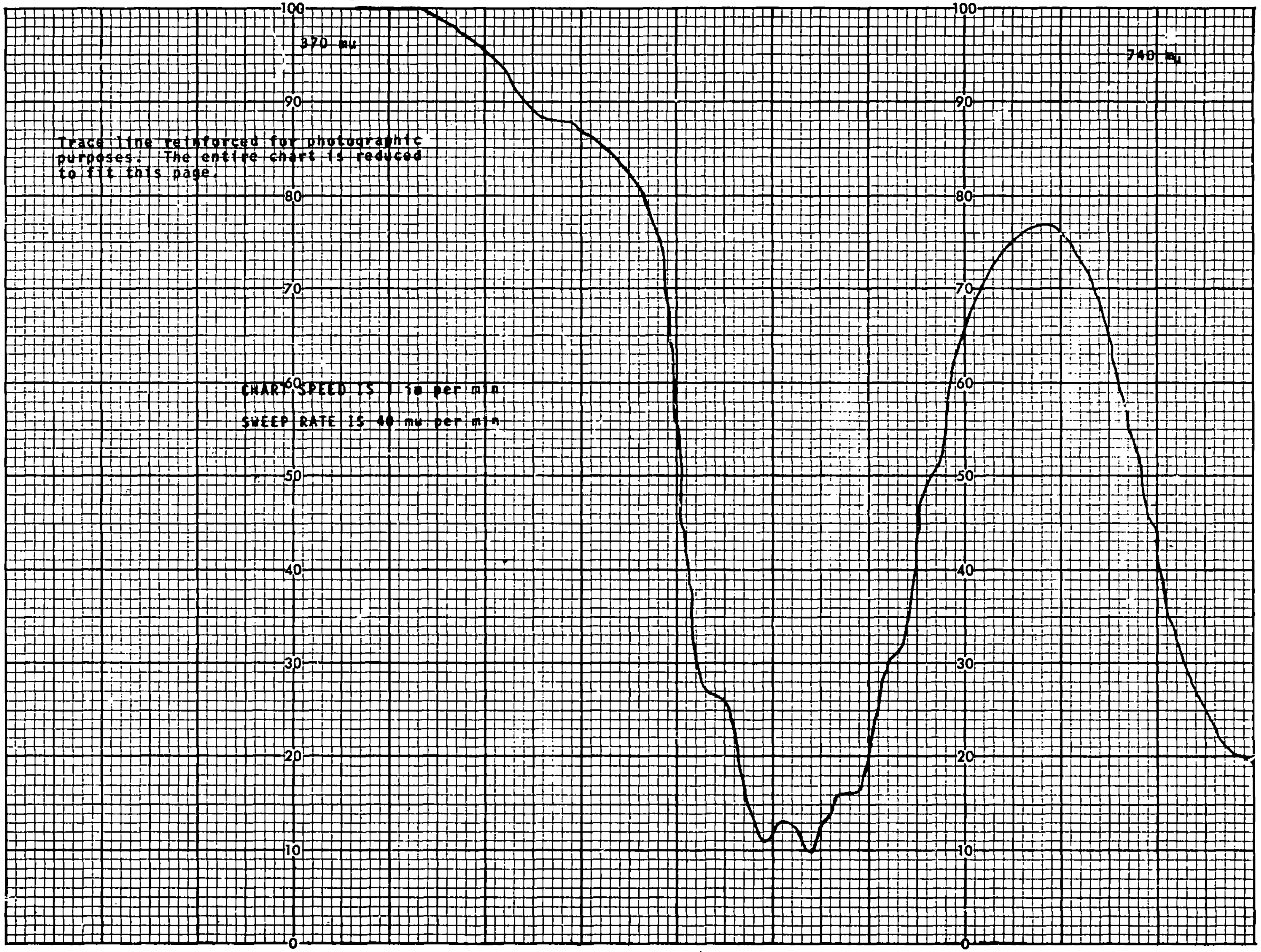
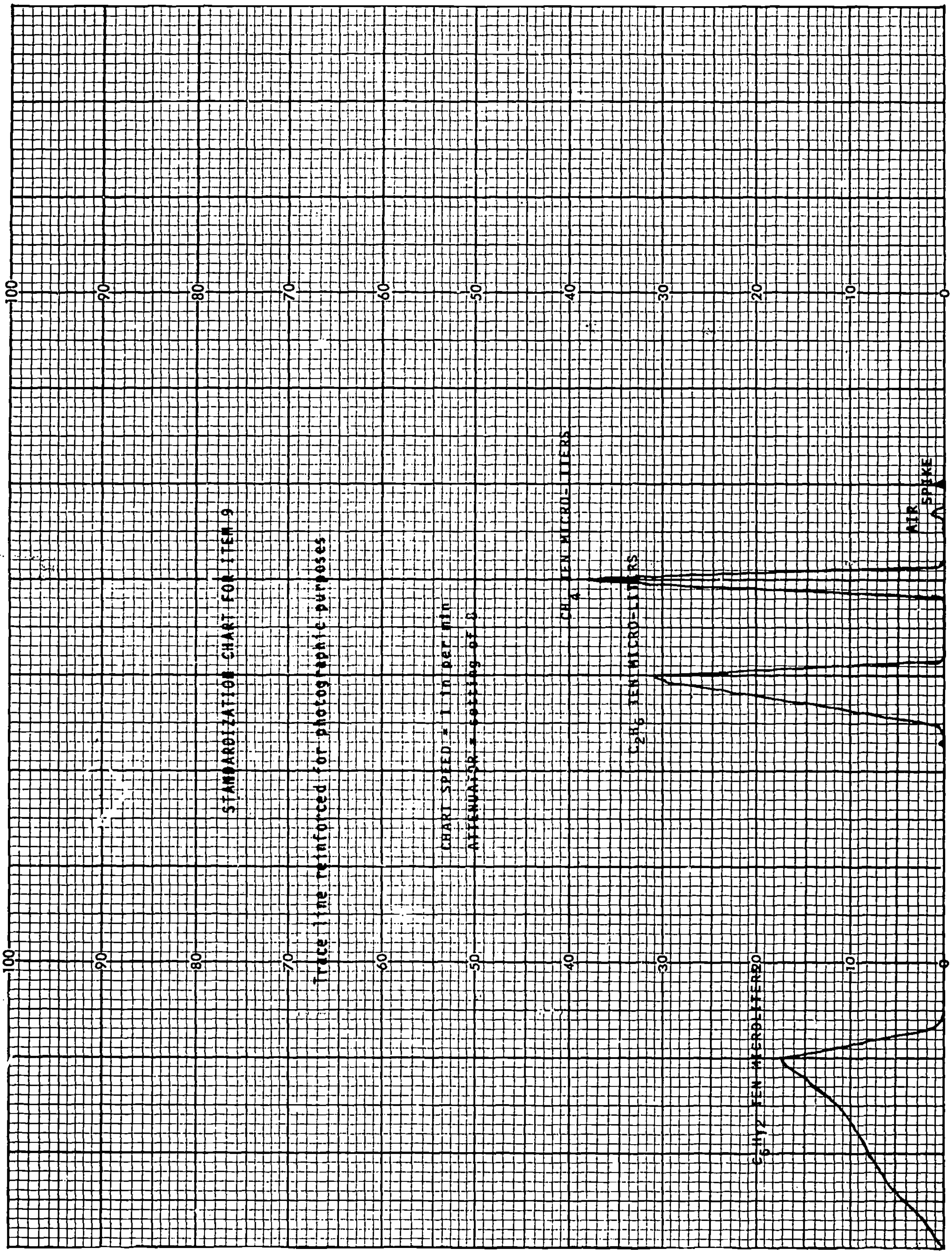


CHART FOR ITEM 7
Trace line reinforced for photographic purposes. The entire chart is reduced to fit this page.
Standard #1 100%
Standard #2 80%
Standard #3 60%
Standard #4 40%
Standard #5 20%
Sample #1
Sample #2

CHART FOR ITEM 8




STANDARDIZATION CHART FOR ITEM 9
Trace line reinforced for photographic purposes
CHART SPEED = 1 in per min
ATTENUATOR = setting of
CH_4 TEN MICRO-LITERS
C_2H_6 TEN MICRO-LITERS
C_6H_{12} TEN MICROLITERS
AIR SPIKE

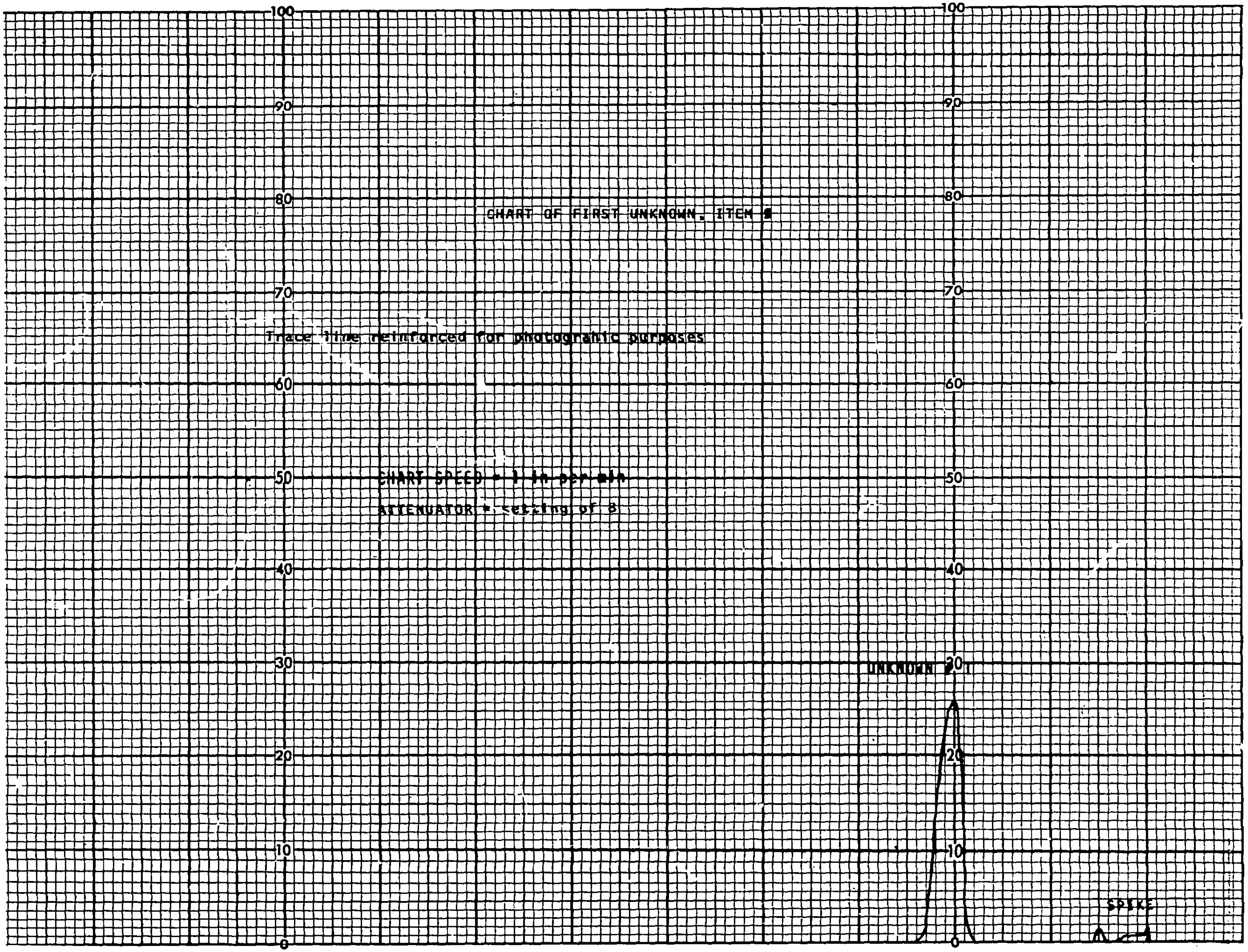


CHART OF FIRST UNKNOWN, ITEM
Trace line reinforced for photographic purposes
CHART SPEED = 1 in per min
ATTENUATOR = setting of 8
UNKNOWN #1
SPIKE
100
90
80
70
60
50
40
30
20
10
0

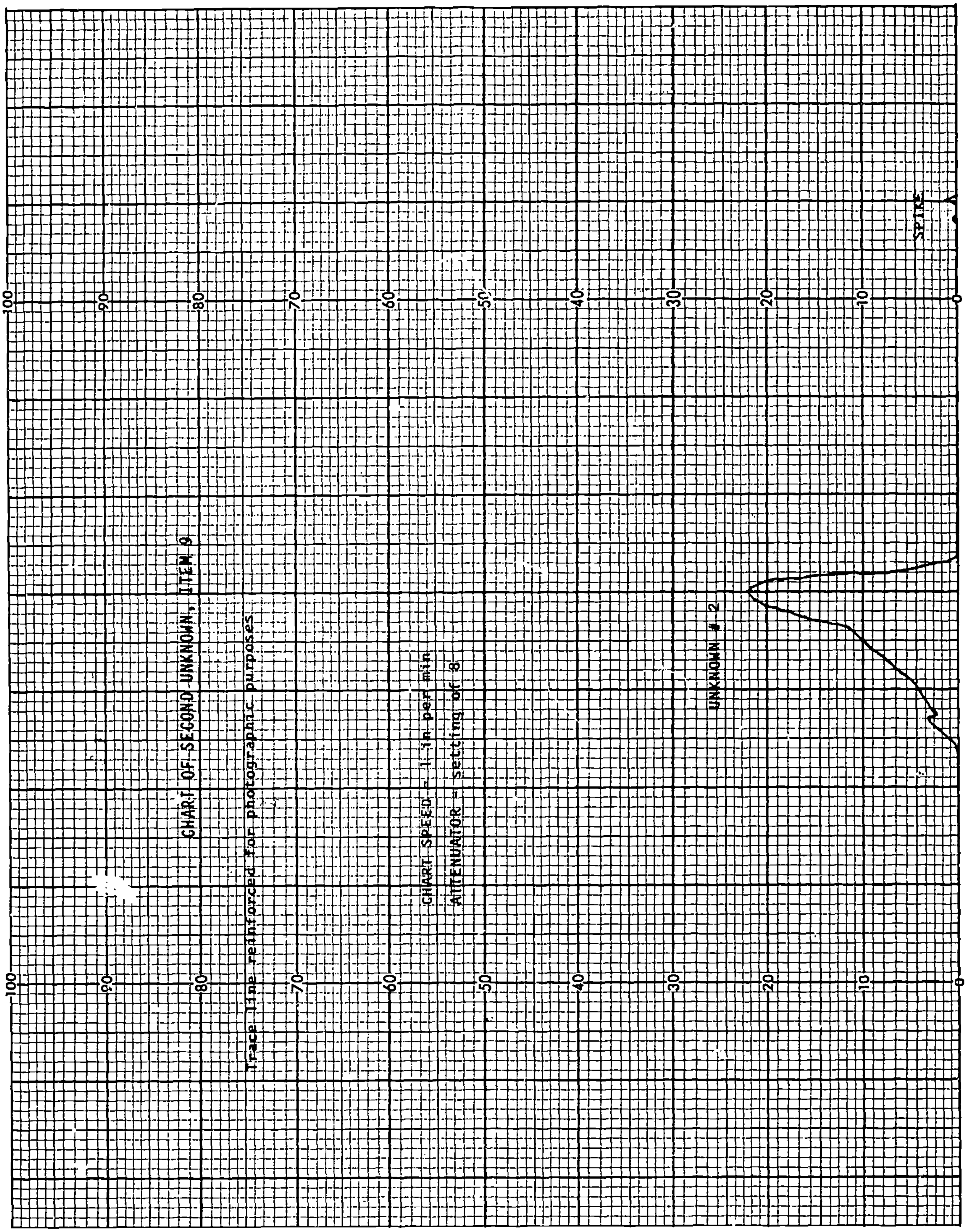


CHART OF SECOND UNKNOWN, ITEM 9
Trace line reinforced for photographic purposes
CHART SPEED = 1 in per min
ATTENUATOR = setting of 8
UNKNOWN # 2
SPIKE
100
90
80
70
60
50
40
30
20
10
0

EQUIPMENT USED FOR ADMINISTRATION OF THE EXAMINATION

The following list includes all of the equipment used for the administration of the examination. The equipment is listed in the most probable order of use. Items may be listed at the end of a previous sequence when two sequences of items are needed to perform the same task.

1. Sodium Hydroxide Pellets(1 pound dry)
2. Spatula
3. Glassine Tare Sheets
4. Analytical Balance (to fourth decimal)
5. Calculator
6. Wash Bottle
7. Volumetric Flasks
   50 ml
   100 ml
   150 ml
   250 ml
8. Burette - clean, 1
9. Burette - slightly dirty, 1
10. Burette Clamp
11. Burette Stand
12. Flasks Erlenmeyer
    4 - 125 ml
    4 - 250 ml
    4 - 500 ml
13. Flasks Florence
    2 - 150 ml
    2 - 250 ml
    2 - 500 ml
14. Magnetic Stirrer
15. Stirrer Magnets – 2
16. Distilled Water (on tap)
17. Phenolthalein Indicator Solution
18. Hydrochloric Acid Sol .1N
19. Beakers
    2 - 150 ml
    4 - 250 ml
    2 - 500 ml
20. Sodium Chloride Sol A Approx. .1N
21. Silver Nitrate Sol B Approx. .1N
22. Centrifuge
23. Centrifuge Tubes – 6
24. pH Meter with 7.0 buffer
25. Graduate Cylinder 100 ml
26. Copper Sulfate Sol C Approx. .1N
27. Pipette TD
    1 - 1 ml
    1 - 2 ml
    1 - 5 ml
    1 - 10 ml
28. Ring Stand
29. Distilling Apparatus, Simple
    1 flask any size $\mathfrak{T}$ to fit
    1 condenser tube $\mathfrak{T}$ to fit
    1 adapter $\mathfrak{T}$ to fit
    1 receiver, right angle $\mathfrak{T}$ to fit
    2 pieces rubber tubing to fit condenser

The following diagram is a suggested layout of equipment. This layout was used for standardization study. Minor shifts of item positions may be needed to fit your laboratory benches. Large items may be used where they now exist if they are in the same room. The positions of items are indicated by the item numbers used above.

ITEM ARRANGEMENT DIAGRAM

		19	13	12		25	7	27	18	26	21	20	1
				14			8, 9		10, 11	17			2
	22, 23										28, 29		
4.	24				6		16						5
3.													

CHAPTER VIII

TEACHING OUTLINE

When this outline is followed every student in the class who shows a reasonable level of mastery should accomplish two major objectives. He should possess all the basic skills necessary to be a successful chemical technician and he should know enough basic chemistry to continue with a college education. The second is considered to be a prerequisite for top technicians. The class "Top Technicians" must be promotable. As has been stated before, there is room for the less successful, but we should recognize the limited advancement potential of that student and help him avoid getting in over his head on the first job.

The teacher will immediately note a sharp departure from the typical high school chemistry course. There is no attempt at a liberal education as such. Descriptive chemistry and in-depth theoretical chemistry not essential to the present program are discarded. Not because it is believed that these are inappropriate, but because no one course can successfully be all things to all people. The commitment here is to the shaping of a chemical technician, not a chemist, nor a consumer. The emphasis is on individual participation and performance from the very beginning. It is assumed that this student believes in doing, not just knowing. Supplementary reference materials of a general nature might serve some of the more advanced students to good advantage in learning traditional chemistry. There is a question, however, if the teacher has a right to include this in the evaluation.

Some of the suggested teaching alternatives are "make work" in nature. This is done because mastery of certain objectives is paramount to technician training, yet only a production set-up provides the need to run repetitive samples through certain tests. In such cases the outline unabashedly suggests artificial tasks to accomplish the desired objectives.

GENERAL ANALYTICAL CHEMISTRY

Theoretical Objective	Technical Objective	Some Suggested Teaching Alternatives
To Learn That:	To:	
I. all measurements contain a certain degree of uncertainty.	I. demonstrate the correct use of significant figures	I. A.
		1. Have each student measure a table surface or large block, using a meter stick and a vernier scale. The students should then compare the results.
		2. Do the same with a small block, but use the vernier jaws and a micrometer.
		3. Do the same with a volume of water, using the range of liquid volume measuring instruments available.
		B.
		1. Give the students a handout which presents the rules for significant figures, including examples.
		2. Check each student's work and insist upon constant use of significant figures for all future work.
		C. Give a textbook reference for the presentation of significant figures.

To learn that:	To:	
II. chemistry is an experimental science and that as such all generalizations are interpretations of collections of data.	II. initiate the habit of neatly recording all measurements and observations as data in a notebook. (See Behavior 23, page 36.)	II. A. 1. Distribute notebooks and a handout describing how the book is to be kept. 2. Spotcheck all notebooks frequently at first, then as needed to maintain good habits. 3. Keep a logbook at each instrument. The first page should contain directions for maintaining the logbook. B. 1. Tell some anecdote which shows the value of good notes and the habit of being alert for any observation of what happened. 2. Suggest a few library books which use this concept as a major part of their theme.
III. all matter can be classified as compounds, elements, or mixtures. a. To learn the definition of a mixture. b. To learn the definition of a compound. c. To learn the definition of an element.	III. correctly identify materials as mixtures, compounds, or elements.	III. A. Prepare handouts defining these terms. B. Give a textbook reference for these definitions.

To learn that:	To:	
IV. a. some elements combine with other elements to form compounds. b. some elements replace other elements to form compounds. c. compounds can be separated into elements with differing degrees of difficulty.	IV. safely manipulate glassware and other equipment according to instructions to bring about chemical reactions and to collect samples. (See Behavior 4, page 19.) (See Behavior 12, page 25.)	IV. A. Prepare detailed handouts which give complete instructions on how to carry out several combination, replacement, and decomposition reactions. The handouts should include set-up instructions and what to look for at each step. These handouts should include basic safety, glass bending, and basic nomenclature of common laboratory items. No. prior knowledge is assumed here except significant figures. It is suggested that checksheets be made for all mastery items. Each item can then be checked off as the student progresses, and the teacher will have a record of what may be assumed in more advanced lessons and what must be taught.
V. one can predict which elements will combine to form compounds and how readily.	V. use charts and tables in the process of following instructions. (See Behavior 12, page 25.)	V. A. Use a textbook reference to introduce the Mendeleyev Chart. B. Use a textbook reference to introduce the first two quantum numbers and the concept of the stable octet. C. Use a handout to describe the stable octet. This should emphasize the first two quantum numbers and the concept of energy level. The same handout should introduce the valence table.

To learn that:	To:	
		V. D. Assign an exercise in which the students are instructed to attempt to combine different elements and report the results. This exercise should tell the students what to do and what to look for, but manipulations covered in previous lessons should not be described again. The student will then be forced to seek information he has not learned. Be alert to safety habits.
VI. in a given sample of an element the *average* weight of the atoms never varies. a. the concept of gram atomic weight (Avegadre's number) b. isotopes c. gram atomic weights can always be found on the chart or in tables.		VI. A. Use a textbook reference to present this series of concepts. B. Prepare a handout to present this series of concepts and include examples which present isotopes of common elements. C. Use a film to present these concepts. (Several are available thru the AEC.)
VII. elements always combine in definite whole-number proportions: a. the concept of a definite chemical formula for each compound b. the smallest ratio for the formula c. rules for naming compounds	VII. correctly use balances. (See Behavior 10, page 23.) correctly use centrifuges. (See Behavior 15, page 28.) correctly use laboratory filtration apparatus. (See Behavior 7, page 21.)	VII. A. Use a series of student exercises which are worked up as handouts. The exercises should start with a known weight of an element, react it with a second element or compound, and separate, dry, and weigh the product. The handouts should include instructions for the empirical determination of the chemical formula, with examples. All new procedures or techniques should be described. Old procedures or techniques should be assumed, but available upon inquiry.

To learn that:	To:	
		Suggestions: Oxides are easy to form by heating metals in air. Sulfides can be formed by roasting in sulfur or by reaction with H_2S. Chlorides can be formed by replacement, or in a chlorine generator. Salts are readily formed by double replacement, but only the advanced student will be able to follow the calculations.
		B. Use a textbook reference for the presentation of the method of calculating the empirical formula.
		C. Use a Chem Study film which presents this material.
VIII. chemical equations are used to predict what will happen in a reaction. The equation later serves as a blueprint for all calculations, including amounts of ingredients needed.	VIII. a. balance equations using the valences. b. write a balanced equation in the notebook before undertaking any reaction.	VIII. A. Use a textbook reference to present the material -- avoiding electron theory at this time. B. Use a one- or two-page practice sheet and a textbook reference for valences C. Have the student write balanced equations for all reactions described in his notebook.
IX. the gram formula weight is known as a mole.	IX. include the water of hydration in any of the gram formula weight calculations.	IX. A. The student should randomly select ten chemicals from the shelf and calculate the gram formula weight for each, using the formula on the label. This can be compared with the formula weight listed on the label.

To learn that:	To:	
X. solutions are made up as a. molar, b. molal, c. normal.	X. a. include the dissolved chemical in the volume for molar solutions (that is, dissolve and bring to volume).	X. A. Have each student prepare 250 ml quantities of several chemicals in concentrations between .1M and .3M. The M and the N can be marked on the label and the solutions can be used below. They should also prepare molal solutions to compare the units.
	b. add the desired volume of solvent for molal solutions.	B. Use a textbook reference to present the discussion of these terms to the students.
	c. divide the formula weight by the valence for normal solutions and to add the solvent to bring it to volume (same as molar.)	C. Make a point of quizzing each student on his knowledge of these three units of measure.
XI. the amount of one chemical which reacts with another chemical to replace or neutralize it is called an equivalent weight with respect to the other.	XI. a. use volumetric glassware to accurately measure reactants.	XI. A. Prepare handouts describing several procedures in which the student determines the concentration of the solutions prepared above. The instructor will have to prepare or purchase a primary standard.
a. normal solutions are by definition, equivalent to each other.	b. use prepared directions to perform calculations.	B. Have each student react appropriate combinations of the chemicals above to determine the milliequivalents of each. They can verify the accuracy of XI. A.
b. the concept of milli-equivalents is convenient for everyday calculations.	(See Behavior 4, page 19.)	
XII. there is a type of reaction characterized by the term *redox*		XII. A. Use a text reference to present the definitions.
a. definition of redox		B. Use a handout to present the definitions and include classic as well as modern examples.
b. definition of reduction		
c. the balanced electron equation		C. Have each student conduct several redox reactions.

To learn that:	To:	
XIII. the chemical bond is caused by electron path distortion or complete electron exchange, depending upon the amount of energy involved. a. electrovalent bonding b. covalent bonding c. coordinate covalent		XIII. A. Use textbook references to present the concept. B. Provide opportunity for small group discussions of this concept. C. Prepare a handout with examples of each type of compound.
XIV. all chemical reactions involve energy exchange (usually heat.)	XIV. use a thermometer accurately. (See Behavior 11, page 24.)	XIV. A. Have each student carry out some strongly exothermic reactions. B. Have each student carry out some moderately exothermic reactions in a calorimeter and measure the heat gain per mole of product. (It may be necessary to start with warm water, or some other device, to get the reaction started.) C. Have the students construct an exercise that they can use to calculate the heat needed for an endothermic reaction.
XV. reactions must take place in a fluid to allow molecular collision. a. gases b. liquids		XV. A. Use an exercise and handout which describes the conditions needed for reaction and suggest some methods of obtaining them. The exercise should require each student to produce both reactive and non-reactive conditions, with all reactants present in both cases. (For instance, just the water for solution missing.) B. Use a textbook reference which describes reaction conditions.

To learn that:	To:	
		XV. C. Use the Chem Study film *Reaction Equilibrium.*
XVI. when compounds go into solution, the molecules separate to some degree to form free ions.	XVI. use conductivity apparatus to measure purity and end points of titrations.	XVI. A. Use textbook references to present the terms: *ionization, dissociation, equilibrium constant.*
a. the degree of separation is called the ionization constant.		B. Have each student perform an exercise in which he compares the strength of compounds and their conductivity.
b. the constant varies with the solvent and the temperature.		
c. strong compounds have a high degree of separation.		C. Have each student do a titration which uses both an indicator and conductivity. The instructions should include a discussion of what took place.
d. weak compounds have a lesser degree of separation.		
XVII. one mole of any gas occupies 22.4 liters at S.T.P.	XVII. practice in the use of previously introduced equipment	XVII. A. Have each student manufacture a gas quantitatively and verify this concept. (Do not neglect the solubility of the gas.)
a. Charles' Law		
b. Boyle's Law		B. Make reading assignments to increase each student's exposure to the gas laws and the concept of the molar volume of a gas.
XVIII. different compounds are soluble to different degrees, and the solubility varies with the solvent and temperature.	XVIII. learn to facilitate the solution process by:	XVIII. A. Have each student experience the solution factors by conducting an exercise in which each of the factors is varied and the solution time measured.
	a. changing the temperature,	
	b. increasing the surface area of the solute,	B. The student should realize that there is an energy exchange in the solution process and that the amount of energy can be related to the strength of the solute (not
	c. stirring,	
	d. changing the solvent.	

To learn that:	To:	
		concentration). A very convincing proof of this is to have the student hold a volume of anhydrous copper sulfate, equal to a match-head, in the palm of the hand and add two drops of water. (SAFETY – do not increase the volume greatly.)
		C. Use text assignments to amplify the principles involved.
XIX. there are three classes of compounds – acids, bases, and salts. a. Define acids. b. Define bases. c. Define salts.		XIX. A. Conduct a discussion relating to the classification of inorganic compounds. B. Use a standard lab manual exercise to manufacture acids and bases from anhydrides.
XX. nearly all compounds cause water to become somewhat acid or somewhat basic upon dissolving.		XX. A. Use a text reference to teach the students that the dissolving compound usually ties up more of the one water ion than the other; that is, more of the H or of the OH. Thus the solution becomes acid or basic. B. Demonstrate this principle on the chalkboard.
XXI. there is a scale used to measure the degree of acidity and it is called the pH scale.	XXI. a. learn to use pH indicators. b. learn to use a pH meter.	XXI. A. Present the concept with a text reference. B. Follow up with a class discussion which emphasizes the meaning of the scale and that the scale is logarithmic (that each succeeding number indicates a factor of 10):

To learn that:	To:	
		C. Have each student test the pH of several compounds using a variety of indicators and a pH meter.
XXII. there is a similarity between vertical groups of elements on the Mendeleyev chart, leading to the term *families*.	XXII. gain familiarity with a number of elements and families.	XXII. A. Have each student read a standard chemistry text to gain familiarity with at least three chemical families.
		B. Have each student perform the experiments relating to the families selected in A, which may be found in a standard high school lab manual.
		C. Have each student submit a paper describing the chemical families, or a series of papers describing each family.
XXIII. there are several standard schemes of qualitative analysis.	XXIII. a. gain practice in the skills used during qualitative analysis: 1. separation, 2. precipitation, 3. pH adjustment, 4. etc.	XXIII. Use the scheme of analysis available in any chemical handbook. Have each student run one or more samples with all the ions and then at least 2 unknowns which have 1 to 3 ions present.
	b. recognize that such procedures are seldom used today, except as a quick check, because of modern instrumentation.	

To learn that:	To:	
XXIV. ions or compounds can be measured quantitatively with wet chemistry if due care is taken.	XXIV. a. gain practice in skills used during quantitative analysis: 1. weighing, 2. transferring, 3. dissolving, 4. titrations, 5. calculations, 6. following instructions, 7. using factors, 8. using a variety of equipment. b. recognize that most determinations are now done with instrumentation because it is more efficient and quicker, except in research where individual tests may be run and not justify instrument set-up.	XXIV. Use a standard quantitative chemistry text and assign several determinations of different unknowns to each student. Three to six determinations should be quite sufficient. The student should, wherever possible, carry out the determinations without assistance. Advice as to technique being used should facilitate further learning.

INTRODUCTORY ORGANIC CHEMISTRY

Theoretical Objective	Technical Objective	Some Suggested Teaching Alternatives
To learn that:	To:	
I. carbon is an exceptional element which readily shares its four bonds with other carbon atoms and other elements to form chains.		I. A. Use a text reference to present this concept. B. Reinforce the text assignment with a chalk talk. C. Introduce the *organic* concept in a class discussion.
II. carbon and hydrogen atoms combine to form an infinite variety of straight chains. III. there is an accepted system used in naming straight-chain compounds.		II. and III. A. Use a chemical handbook as a reference to introduce the system of nomenclature. B. Have several class drills on straight-chain nomenclature. C. Use a spelling bee type of contest to quiz the students.
IV. other elements can be used to replace hydrogen atoms or carbon bonds to form different classes of compounds.	IV. recognize that in some cases we can only break down a natural material.	IV. A. Discuss the use of reagents to facilitate reactions. B. Have each student carry out one or two of the simpler replacement reactions.

To learn that:

V. there are many classes of organic compounds:

a. alkanes
b. alkenes
c. alkynes
d. aldehydes
e. alcohols
f. acids
g. ethers
h. esters
i. ketones
j. sugars
k. ring structures

To:

V. a. gain experience in the reaction of organic compounds.

b. gain experience in the use of condensers and boiling apparatus.

c. gain experience in identification of organic compounds with the use of a melting point apparatus.

d. gain experience with T glassware.

e. gain experience in the purification of organic compounds.

f. appreciate the need for further methods of accurate identification of organic compounds.

V. It is suggested that a selection of experiments be taken from standard Organic Chemistry lab manuals and modified as a series of handouts for this purpose. The selections should require the students to manufacture and purify as many classes of organic compounds as practical in the local circumstance. When modifying the experiments remember that the purpose of this instruction is to increase student manipulative techniques and to have the student gain a working vocabulary. There is no desire to have the student become an organic chemist and therefore no desire to have him learn theoretical details. The keynote is exposure, not mastery. As with Inorganic Chemistry, some students will become interested in learning Organic Chemistry itself and this is fine, but do not let a spirit of competition develop which may undermine the feeling of individual success of the other students.

INSTRUMENTATION

The purpose of the instrumentation course is to introduce the students to each of the major instruments which are in wide use and to have them become familiar with the instruments' usual parameters and common applications. Instruments such as emission spectroscopes and NMR are omitted because of high costs and limited application; that is, limited numbers of technicians presently needed for the work.

This course, as recommended, uses two textbooks for most instruments and leaves the selection of references for a few instruments to the instructor. The first recommended text, *Instrumental Methods of Analysis,* is by Willar, Merrit, and Dean, 4th Edition, D. Van Nostrand. This book contains both background information and practical exercises termed experiments. It is suggested that the teacher modify the suggested experiments to meet local needs and distribute them as handouts. The second book, a paperback, gives excellent supporting practical and theoretical information. The second book is *Quantitative Analytical Chemistry, Volume I,* Flaschka, Barnard, and Sturrock, Barnes and Noble. It is suggested that a half dozen of each be purchased and supplemented by other specific references for each instrument.

Behavior	Practice and Information
2. Is able to use pH meters to determine the pH reading of samples and to do conductimetric titrations.	2. Willard pages 582-613. Experiments 22–1 p. 609 22–2 p. 609 22–3 p. 610 Flaschka pages 272-284.
5. Uses a refractometer to obtain the index of refraction of liquids and some solid materials. Also to determine total dissolved solids and molar concentration when provided with factors.	5. Willard pages 396-411. Experiment – Handout, operating instructions p. 409.
6. Uses spectrophotometers to measure transmittance or absorbance and identifies commonly used compounds. Is also capable of quantitative determinations when provided with standards and instructed as to the correct wavelength.	6. Willard pages 32-159. Flaschka pages 423-455.

a. Uses filter spectrophotometer.	Experiment 4-1 page 104. 4-8 page 107.
b. Can do visible light scanning spectrophotometer. (e.g. Spec 20)	Experiments 3-1 page 70. 3-2 page 71. 4-1 page 104.
c. Uses ultra-violet, visible light spectrophotometer.	Laboratory work page 153. Also handouts with analysis to be run.
d. Uses infra-red spectrophotometer.	Laboratory work page 153. Also handouts with analysis to be run.
18. Uses four methods of chromatography.	18. Willard pages 478-529. Flaschka pages 515-522.
a. paper chromatography	A handout experiment must be selected from any of several common texts.
b. column chromatography	Select an appropriate resin system and have each student work separations of a mixture and determine the components quantitatively.
c. thin layer chromatography	Repeat the paper chromatography experiment with a thin layer system and make comparisons.
d. gas chromatography	Experiment 19-1 Willard page 523. 19-2 page 523. 19-4 page 524. 19-5 page 524.
20. Determines the viscosity of liquids or solids (Newtonian)	20. A separate reference will have to be obtained for this topic. Individual experiments can be adapted from the A.S.T.M. standards and/or from local industry, along with sample materials.

21. Selects and operates appropriate apparatus to determine the melting points between room temperature and 400° C.	21. Select a separate reference for this instrument. Nearly any textbook dealing with the separation and identification of organic compounds should be adequate.
*Uses a polarograph to identify ions, and to make quantitative determinations.	Willard pps. 672-700. Flaschka pps. 365-389. Experiments 25-1 p. 698. 25-2 p. 698. 25-5 p. 699.
*Uses a polarimeter to measure the optical rotation of optically active materials, both for identification and qualification.	Willard pps. 412-427. Experiments 15-1 p 426. 15-2 p 426.

*Optional, not in behavioral analysis because many companies have only a very few technicians who operate these instruments. However, if the Heath polarograph is used, both instruments can be offered with little budgetary consideration.

INTRODUCTORY PHYSICS

Theoretical Objective	Technical Objective	Some Suggested Teaching Alternatives
To Learn That:	To:	
I. simple machines can be used to make work more convenient, but not to multiply work.	I. a. recognize that nearly all instruments and equipment controls and drives use simple machines.	I. A. Use a text assignment to introduce this material.
a. Work = Force thru a Distance W = F x S	b. recognize that scientific equipment would not be practical without the use of simple machines to vary speeds.	B. Hold a class discussion about the uses of machines (levers).
b. First class levers can be used to multiply either distance or force.		C. Prepare a handout exercise which has each student use a meterstick lever, pulleys, and spring scales in a great variety of arrangements. The exercise should include the measurement of force, distance, work, and mechanical advantage for each of the arrangements. This exercise will probably extend over a two or three day period.
c. Second class levers can be used to multiply force.		
d. Third class levers can be used to multiply distance.		
e. There is a variety of machines which can be used to accomplish special jobs.		D. Review this work with a film.
II. power is work divided by time.		II. A. Have the students use a stopwatch and a stairway to measure their work and compute their maximum horsepower as they run the stairs.
		B. Have each student review the horsepower formula.

To learn that:	To:	
III. gravity exerts a force.		III. A. Use a pendulum to measure the force of gravity.
		B. Use a reading assignment to have the students write a report on the force of gravity.
		C. One of several good films may be used to review this topic.
IV. density equals mass divided by volume. $D = \frac{M}{V}$	IV. (See Behavior 14, page 27.)	IV. A. Use a text reference to introduce density and specific gravity.
		B. Have each student use a commercial hydrometer and then make a stick hydrometer to measure the specific gravity of several liquids.
		C. Have the class construct a density column and measure the density of several solids.
V. when more than one force acts upon the same body, the angle between them affects the total (resultant) force.		V. A. Have each student use spring balances and a force board to experience the effect of vector quantities.
a. forces in the same direction are additive.		B. Have each student trace the direction of the forces using one side of each spring balance and measure it off to scale, according to the balance reading.
b. forces in opposite directions are subtractive.		
c. forces at other angles can be calculated by the Pythagorean theorem.		C. Have each student use the parallelogram method to solve several vector problems.

To learn that:	To:	
VI. rotary motion causes an outward component called centrifugal force.	VI. centrifugal force in centrifuges must be balanced.	VI. A. Have each student use a spool, string, and weights apparatus to experience centrifugal and centripetal forces. Have them check the effect of: 1. mass 2. speed 3. length of arm
VII. heat is a form of energy. a. heat "level" is measured in degrees with a thermometer. 1. Fahrenheit scale 2. centigrade scale 3. absolute scale b. amount of heat is measured in calories.		VII. A. Use a text reference to introduce the temperature scales. B. Have each student express at least ten different temperatures on all three scales. C. Use a text reference to present the calorie and use a handout to have each student calculate the heat exchange for a number of temperature changes in different quantities of water.
VIII. different materials absorb different amounts of heat per degree change.	(See Behavior 11, page 24.)	VIII. A. Use a handout or text reference to introduce the concept of specific heat. B. Have each student carry out an exercise using different metals and a calorimeter of water to calculate heat exchange and thus specific heat.

To learn that:	To:	
IX. it takes a relatively large amount of heat energy for a material to change phase.		IX. A. Have each student experimentally determine the heat needed to melt a gram of ice and to boil a gram of water.
X. materials expand and contract with any temperature change, and the amount per degree is constant for any given material.		X. A. Use a text reference to present the concept of expansion B. Have each student calculate the coefficient of linear expansion of several metals using a bar apparatus.
XI. heat can be transferred by a. conduction, b. convection, c. radiation.		XI. A. Use a handout to describe the three methods of heat transfer, including illustrations. B. Have the class use a Dewar flask set to measure heat transfer by each method. (This requires at least five hours.)
XII. static electricity is an excess or a shortage of electrons.		XII. and XIII.
XIII. voltage (E.M.F.) is a force caused by imbalance of electrical charge and is always the difference between two potentials.		A. Use a worksheet and static apparatus to introduce the effects of static electricity and the concept of voltage as a repelling or attractive force between electrons.
XIV. electrict current is a flow of electrons thru a conducting path. a. flow is directly proportional to voltage. b. flow is inversely proportional to resistance.	(See Behaviors 8 and 9, page 24.)	XIV. A. Use a worksheet to have each student use a resistance, a variable voltage supply and meters to verify Ohm's law. B. Use a library reading assignment to have the students gain perspective on Ohm's law.

To learn that:

XV. series resistances are additive and parallel resistances are reciprocally additive.

XV. A. Use an exercise with a parallel and series resistance hookup and a constant voltage power supply and measure the current under different configurations.

B. Use a text reference to present parallel - series resistance calculations. The student can then calculate the resistance in A.

C. Use an exercise to present the function of a fuse, a switch, and how to avoid circuit overload.

XVI. when magnetic lines of force are cut, they produce a current in a closed circuit. Likewise, a current always produces a magnetic field.

a. generator

b. transformer

c. motor

XVI. A. Demonstrate a simple generator with an electromagnet, a bar magnet, and a galvanometer.

B. Use an exercise with a St. Louis motor and a galvanometer to generate voltage and phase relationships.

C. Use an exercise with a simple transformer and a vibrator to generate A.C. voltage.

D. Use the transformer in C and a galvanometer to check phase relationships between the primary and the secondary of a transformer.

E. Use an auto coil, a switch and an oscilloscope to get a picture of the voltage pattern when a circuit is closed and opened. Repeat with a vibrator.

To learn that:	
	F. Use a text reference and a St. Louis motor to present motor action.
	G. Use an A.C. voltmeter and an electric motor to measure the back E.M.F. of the motor. An ammeter can also be used to show the corresponding current draw.
XVII. alternating currents do not obey D.C. Ohm's law when they pass thru a coil or a capacitor because the voltage and current are out of phase with each other. The relationship must be compared with vectors, as with any other non-parallel force.	XVII. A. Construct a series of exercises in which the students use A.C. meters and oscilloscopes to determine the phase relationships between voltage and current in various applications.
a. define inductive reactance.	B. Use a text reference to present the impedance formula, including the reactance principle.
b. define capacitive reactance.	
XVIII. by varying one or more of the factors in XVII, the remaining reactance factor can be controlled. All of our electronics instruments depend upon this.	XVIII. A. Use a circuit with variable inductance and capacitance, a frequency generator, and an oscilloscope in an exercise where the student varies each of the factors and determines the response of the circuit.
	B. Assign a reading report so the student will need to read about several applications of this circuitry.

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To learn that:

XIX. vacuum tubes or transistors can be used to

a. convert A.C. to D.C.

b. amplify voltages.

c. detect light energy.

XIX. A. Use the student power-supply kit and the oscilloscope in a handout exercise in which the student constructs a half-wave rectifier, a full wave rectifier, and a filtered power output. The exercise should include voltage measurements and background information.

B. Use the student one-tube amplifier and meters in an exercise designed to have the student become familiar with the functions of each part of the circuit.

C. Repeat B with a rectifier circuit.

D. Set up a demonstration radio so that the student will be introduced to detector circuits.

E. Use the Heath Polarimeter time constant circuit and oscilloscope and meters so that the students may witness what happens during a series of time periods.

F. Use a text assignment to represent time constant circuits.

G. Use a phototubecircuit exercise to present the photoelectric effect and the principle of wavelength selectivity of a detector.

To learn that:

XX. light is a form of energy related to heat and electricity.

- a. light may be absorbed to provide heat or electricity.
- b. the intensity of light varies inversely with the square of the distance.
- c. light travels in a straight line.

XX. A. Use a series of different reflectances (colors) on the outside of a container filled with water and measure the heat absorption.

B. Use a photocell to demonstrate the production of electricity by light. Use a related reference to introduce the photon.

C. Have each student complete an exercise in which he measures the intensity of a light at various whole-number multiple distances with a photometer and calculates a mathematical relationship.

D. Use a text reference to present the wave propagation theory, which explains why light travels in straight lines.

XXI. objects are seen by reflected light.

- a. virtual images and plane reflectors
- b. real images and curved reflectors

XXI. A. Use an exercise conducted either in a darkroom or on a stage. The exercise should show both need of reflected light for any vision and reflectance of specific colors for color vision.

B. Have each student complete one or more exercises with plane mirrors in which the student constructs the reflected image and derives the laws of plane reflection.

C. Using a parabolic reflector, have the student work with objects at distant points and at the principal focus. This exercise should include construction of rays on paper to verify the focus equation.

To learn that:

XXII. there is a direct relationship between object and image distances and the image size.	XXII. A. Repeat XXI. C. and make measurements. B. Make paper construction lines to prove this concept.
XXIII. because light obeys the laws of geometry, the focal length of a mirror or lens can be predicted from the object and image distances with the equation $\frac{1}{D^o}$ plus $\frac{1}{D^i}$ equals $\frac{1}{f}$	XXIII. A. Have each student draw upon his existing experience to design a proof with constructed rays on paper. B. Use a textbook reference to verify this concept.
XXIV. the path of light is always bent as it passes thru different transparent media, unless it enters on the principle axis. a. the bending is caused by a change in velocity. b. the different colors are bent different amounts. c. curved materials (non-parallel sides) can focus parallel rays.	XXIV. A. Use a textbook reference to present the principles of refraction. B. Have each student conduct an exercise in which he traces the image of a small object thru a parallel-sided glass plate, a parallel-sided plastic plate, a curved-glass lens, and a curved piece of plastic. C. Use a handout to emphasize the change of path due to color differences and the corrections thus needed in prism spectrophotometers which have a wide range.
XXV. light is a three-dimensional wave motion which can be reduced to two dimensions by a polarizer.	XXV. A. Use a standard college laboratory exercise in which the student becomes familiar with polarized light. B. Have each student write a report describing polarized light and detailing its many instrumental applications.

To learn that:

XXVI. white light is made up of all colors:

a. the visible spectrum,

b. the infra-red spectrum,

c. the ultra-violet spectrum.

XXVI. A. Use a text reference to detail the portions of the spectrum.

B. Use the spectrophotometers to demonstrate the presence of the ultra-violet and infra-red spectra.

C. Use the color filter spectrophotometer to demonstrate the presence and approximate amounts of the five colors (filters) in the white light produced by the instrument light source.

XXVII. white light can be separated into colors with a diffraction grating or a prism.

XXVII. A. Use a series of exercises in which each student is forced to become familiar with the principles of diffraction gratings and light passing through them.

B. Repeat the bending exercises of A with prisms.

C. Have each student write a report comparing prisms and diffraction gratings in instrumentation.