

★

152 592

★

INVENTORIES OF APPARATUS AND MATERIALS
FOR TEACHING SCIENCE. VOL. III. PART 2

INVENTORIES OF APPARATUS AND MATERIALS FOR TEACHING SCIENCE

VOLUME III
TECHNICAL COLLEGES
PART 2
PHYSICS AND CHEMICAL
ENGINEERING

UNESCO, PARIS

*Published by
United Nations Educational,
Scientific and Cultural Organization
Printed by Imprimerie Centrale de Lausanne
Copyright 1951 by Unesco, Paris
Unesco Publication 837*

Unesco Coupons may be used by institutions of learning and scientific research for the purchase of the major part of the items listed in these inventories, in countries participating in Unesco's Coupon Scheme for the purchase of scientific apparatus and material. For complete information on the Coupon Scheme write to:
Unesco, 19 avenue Kléber, Paris-16, France.

CONTENTS

	page
PREFACE	9
INTRODUCTION	11
FIRST PART: GENERAL AND INORGANIC CHEMISTRY, ORGANIC CHEMISTRY, ANALYTICAL CHEMISTRY.	
General and Inorganic Chemistry.	23
Syllabus	28
Practical work	28
Organic Chemistry.	29
Syllabus	32
Practical work	32
Analytical Chemistry.	34
Syllabus	41
Practical work	41
Equipment.	43
(1) Machines and material	43
(2) Measuring apparatus	44
(3) Resistances	44
(4) Instruments and apparatus	45
(5) Balances and weights	45
(6) Optics and accessories	45
(7) Photography and accessories	46
(8) Projection and cinema	46
(9) Heat, electricity, magnetism, etc.	46
(10) Laboratory instruments	47
(11) Tools	47
(12) Miscellaneous	47
Stocks of Materials, Chemicals, etc.	48
(1) Articles in precious metals	48
(2) Glassware	52
(3) Porcelain and earthenware	53
(4) Rubber articles	53
(5) Filter papers, etc.	53
(6) Articles in non-precious metals	53
(7) Various	53
(8) Chemicals	53
SECOND PART: PHYSICAL CHEMISTRY AND ELECTRO CHEMISTRY.	
Physical Chemistry.	67
Syllabus	67
Electro Chemistry.	71
Syllabus	72
Practical work	72
Equipment.	73
(1) Machines and material	73
(2) Transformers and rectifiers	73
(3) Accumulators	73
(4) General equipment	73
(5) Workshop and forge tools and accessories	74
(6) Measuring and metering equipment	74
(7) Resistances	74

	page
(8) Instruments and apparatus	74
(9) Balances and weights	75
(10) Optical apparatus and accessories	75
(11) Photography and accessories	76
(12) Projection and cinema	76
(13) Heat, electricity, magnetism, various	76
(14) Laboratory instruments	76
(15) Tools	77
Stocks of Materials, Chemicals, etc.	
(1) Articles in precious metals	77
(2) Glassware	77
(3) Porcelain and earthenware	77
(4) Rubber articles	77
(5) Articles in non-precious metals	77
(6) Miscellaneous	77
(7) Chemicals	77
(8) Experimental apparatus	77

THIRD PART: INDUSTRIAL CHEMISTRY.

Inorganic Industrial Chemistry.

Syllabus	81
--------------------	----

Organic Industrial Chemistry.

Syllabus	83
--------------------	----

Equipment.

(1) Machines and material	84
(2) Transformers	84
(3) Accumulators	85
(4) General equipment	85
(5) Workshop and forge machines and accessories	85
(6) Measuring instruments and apparatus	85
(7) Resistances	85
(8) Instruments and apparatus	86
(9) Balances and weights	86
(10) Optics and accessories	86
(11) Photography and accessories	87
(12) Projection and cinema	87
(13) Laboratory utensils	87
(14) Tools	88

Stocks of Materials, Chemicals, etc.

(1) Articles in precious metals	89
(2) Glassware	89
(3) Porcelain and earthenware	89
(4) Rubber articles	89
(5) Filters	89
(6) Articles in non-precious metals	89
(7) Various	90
(8) Chemicals	90

Demonstration Models and Material

90

FOURTH PART: PHYSICS.

General Physics.

Syllabus	93
--------------------	----

Optics (advanced).

Syllabus	99
--------------------	----

Electrodynamics (advanced).

Syllabus	100
--------------------	-----

Statistical Mechanics (advanced).

Syllabus	101
--------------------	-----

Practical work	102
--------------------------	-----

Equipment.	page
(1) Measuring apparatus	104
(2) Resistances	104
(3) Instruments and apparatus	105
(4) Balances and weights	106
(5) Optics and accessories	107
(6) Photography and accessories	108
(7) Projection and cinema	108
(8) Laboratory instruments	108
(9) Motors and dynamos	109
(10) Accumulators	109
(11) Transformers and rectifiers	109
(12) Tools	109
Stocks of Materials, Chemicals, etc.	
(1) Articles in precious metals	110
(2) Glassware, porcelain and earthenware, rubber, filters, chemicals, etc.	110
(3) Electrical equipment	110
(4) Apparatus of high value	110
APPENDIX I. Abbreviations	111
APPENDIX II. Conversion factors	112
The elements	113
APPENDIX III. Short list of suppliers of scientific instruments	114

P R E F A C E

EDUCATIONAL and cultural rehabilitation has been, and still is, one of the chief problems confronting the post-war world. Educational and cultural centres, such as schools, colleges, laboratories, libraries, museums, were either destroyed or looted on a large scale during the last war. The task of restoring them to their pre-war conditions has been vast and is far from being completed. In addition there has been an awakening to the urgent need for expanding all forms of education especially in under-developed regions.

Everywhere there is an increasing awareness that it is important to provide greater facilities for teaching science and technology. This trend is obviously due to the immense changes that science and technology have produced in man's ability to understand nature's mysteries and to control and utilize its forces for his purposes. It is not surprising therefore, that wherever peoples are confronted with low standards of life and try to improve them, they turn to science and technology.

To implement the plans that have been prepared for the adequate teaching of science in schools and colleges in the war-damaged and in the under-developed regions is admittedly a long-range enterprise. Any guidance towards improved techniques in this field of education would surely be of great help to the authorities concerned. For this reason Unesco is presenting, together with the corresponding curricula, a series of inventories of apparatus and materials for teaching science at all levels. It is hoped that these publications will be useful to educators as reference manuals for selecting essential equipment from the lists commonly used in some of the leading countries; for clarity the lists are related to corresponding curricula. To develop the information given in the inventories Unesco is now planning a series of 10 handbooks for science teachers in under-developed countries. By diffusing information of this comparative kind on the training of students, the inventories may well contribute also to bringing about equivalence of degrees and diplomas in science and engineering, irrespective of the universities and institutions where they are awarded.

Such an approach to the problem of scientific reconstruction was initiated by the Conference of Allied Ministers of Education which was first held in London in 1943. The Science Commission set up by that conference issued in 1945 a limited set of inventories of basic scientific equipment as an aide-memoire to the governments of occupied Europe, to assist them in rehabilitating scientific education.

Unesco inventories are being published in three volumes and in several languages: Volume I will group information bearing on Primary, Secondary and Vocational Schools; Volume II, on Universities; and Volume III, on Technical Colleges. While prices of items of equipment are mentioned in U.S. dollars whenever possible in the inventories, these should be taken more as indicative than exact, owing to the prevailing fluctuations both in the cost and in the quality of available apparatus. However, when a specific request arises for more detailed and up-to-date information for installing a school or a college laboratory, Unesco will attempt to furnish the answer.

The inventories have been compiled from reports submitted by experts from six countries generally considered to lead in the field of science education. Unesco expresses its thanks to Marcel Peschard, France; S. W. Tromp, the Netherlands;

Gunnar Hambræus, Sweden; Pierre Speziali, Switzerland; J. P. Stephenson and R. Thurlow, United Kingdom for submitting reports on short notice; and its appreciation to Norman R. D. Jones, President of the National Science Teachers' Association of the United States, for his generous permission to make use of the valuable information published by the Association on "Science course content and teaching apparatus used in schools and colleges of the United States".

INTRODUCTION

For reasons of convenience it seemed preferable to publish Volume III of the *Inventories of Apparatus and Materials for Teaching Science*, dealing, it should be remembered, with technical high schools, in separate parts. This, the second of such parts, covers schools for training engineers specializing in physical and chemical science.

The reader will find first an account of the organization of a certain number of technical schools of physics and chemistry in different countries, then the lists of apparatus, instruments and other equipment necessary for fitting out such schools. To illustrate these lists there is attached to each of them, as an example, a syllabus of the courses for which the equipment is necessary.

Aim.

It is rather difficult to give a definition of the chemical or physical engineer which would be valid for all schools of physics and chemistry. The training and qualifications of such specialists vary from one country to another and even from one school to another. It appears that the special departments called "Chemical Engineering" in the United States of America and in England and "Science of chemical engineering" or "Industrial Chemistry" in France have a different character in each country. This point has already been the subject of discussion. It was a question of knowing whether these special departments should be attached to engineering or chemistry.¹ To take sides on this question is outside our province. So the schools will here be defined simply by their essential aim which is the training of engineers who shall have a wide knowledge of physics and chemistry for employment especially in industry.

It is interesting to know how these engineers are trained. For this purpose the syllabuses of three different schools from three different countries will be outlined. These are:

The Federal Institute of Technology of Zürich (Switzerland), the École supérieure de Physique et de Chimie industrielles de la Ville de Paris (France), the Massachusetts Institute of Technology of Cambridge, Mass. (U.S.A.). The extracts published below are taken from official publications of these establishments. A comparison of these extracts and the syllabuses will enable the reader to form an idea of the different methods of training.

Federal Institute of Technology of Zürich (Switzerland).

This school includes among its various departments, a school of chemistry and a normal school of mathematical and physical sciences which grant diplomas as chemical engineer and master of mathematics and physics respectively.

To be admitted candidates must have attained the age of 18 years and either possess the federal certificate of maturity of a Swiss gymnasium (secondary school) or pass an examination of a corresponding standard. Studies at the school of chemistry last three and half years, at the school of mathematics and physics they last four years. The two first years are generally given up to mathematics, physics, chemistry, and natural sciences, in the last two years theoretical knowledge is applied in the technical sciences; students are introduced to the spirit and methods of scientific research and experiment. The technical and natural science courses include excursions.

The programmes of the two sections are shown in Tables 1 and 2.

École supérieure de Physique et de Chimie industrielles de la Ville de Paris (France).

By theoretical and practical teaching in the experimental sciences and their applications, the school trains physical or chemical engineers and research workers for teaching

¹ In this connexion, see the summary of a discussion held at Unesco House reported in the publication NS/SA/SR 3 (prov.).

and scientific or industrial research laboratories. The teaching given there is specially noted for the important part given to practical laboratory work. Since mathematics and mechanics are indispensable for the solution of problems in physics and chemistry, they are taught at the same time as the two latter subjects but are considered as subsidiary ones. Recruitment is by competition, candidates being between 16 and 21 years of age. Studies last four years. During the first three semesters pupils of the same year follow the same course and do the same practical work in physics, chemistry, mechanics, draughtsmanship, etc. At the end of the third semester they choose physics or chemistry the best students choosing first. They follow the same theoretical course in both subjects but for practical work separate into two groups to work in the laboratory of the chosen special subject. At the end of the sixth semester the students choose as before a sub-specialization namely, for chemistry: organic synthesis, physical and analytical chemistry, macromolecular chemistry; for physics: atomic physics and radioactivity, electronics and electro-magnetism, physical mechanics. During their fourth year the students only have lectures in applied science or technology. The major part of their time is spent in individual work in the laboratories of their sub-specialization.

The diplomas given are those of physical engineer and chemical engineer of the Institute of industrial physics and chemistry of the City of Paris.

The syllabus is shown in Table 3.

Massachusetts Institute of Technology (U.S.A.).

Amongst the various courses given at this institute is one which leads to the Diploma of "Bachelor of Science in Chemical Engineering" and another to that of "Bachelor of Science in Physics".

Chemists holding the first enter the chemical and petroleum industries. Their work will be to investigate new industrial processes, to develop and apply their discoveries, to manufacture new products and find outlets for them, and also to take the responsibilities of directors in highly technical enterprises. Preparation for such careers thus necessarily includes knowledge of the fundamental principles of both chemistry and engineering science.

For this reason students follow courses in general, inorganic, organic, analytical and physical chemistry, as well as in mathematics, physics, mechanics, electro-technics, and humanities which include history, English, German, French, and other non-professional subjects.

The physics course is intended to give to those who choose that subject a solid training, both theoretical and practical, in classical and modern physics. The syllabus is planned with a view to fitting physicists for an industrial career in some branch of applied physics, or for research in industrial or university laboratories.

The first year syllabus is the same as that of the chemists. In the fourth year more liberty is given to the student to choose a certain number of courses from those suggested.

The reader will find the chemistry and physics syllabuses of the Institute in Tables 4 and 5.

BRIEF BIBLIOGRAPHY.

Conference of the Allied Ministers of Education (Science Commission). *Standard Inventories of Basic Scientific Equipment for Teaching Purposes in the Schools, Universities and Technical Colleges of the Liberated Countries of Europe*. London, 1945, Part I.

Conseil fédéral suisse. *Règlement de l'École polytechnique fédérale (E. P. F.)* [*Regulations of the Federal Institute of Technology*]. Berne, April, 1924. 27 pp.

École polytechnique fédérale à Zurich. *Dispositions générales et plans d'études* [*General conditions and programmes of studies*]. Zurich, April, 1947. 56 pp.

Massachusetts Institute of Technology. *Massachusetts Institute of Technology Bulletin*. Cambridge, Mass., June, 1950. 208 pp.

Paris. Université. *Programme des conditions d'admission à l'École supérieure de Physique et de Chimie industrielles de la Ville de Paris* [*Outline of conditions of admission to the Institute of Industrial Physics and Chemistry of the City of Paris*]. Paris, 1950. 21 pp.

Paris, Ville. École municipale de physique et de chimie industrielles. *Cinquante années de science appliquée à l'industrie (1882-1932)* [*Fifty Years of Science Applied to Industry (1882-1932)*]. Paris, n.d. 369 pp.

The syllabuses of courses and practical work in chemistry are those of the Institute of Industrial Physics and Chemistry of the City of Paris. The syllabuses for physics are

those of the Federal Institute of Technology of Zürich. The lists given here are based on the equipment of the latter school. From the quantitative point of view, this equipment could serve for about 600 pupils in chemistry and 220 for physics. The list of chemicals was drawn up with the help of the publication of the Conference of Allied Ministers of Education in 1945. In view of the current market fluctuations, the prices accompanying the apparatus are only given as a guide.

We should like here to thank particularly the Federal Institute of Technology of Zürich through its President Mr. H. Pallmann, and the Institute of Industrial Physics and Chemistry of the City of Paris through its Director, Mr. R. Lucas, who kindly put at our disposal the material on which this publication is based.

TABLE I. PROGRAMME OF STUDIES AT THE "SCHOOL OF CHEMISTRY" OF THE FEDERAL INSTITUTE OF TECHNOLOGY, ZÜRICH (SWITZERLAND). (Duration of course: 7 semesters.)

	C	L	PW ¹		C	L	PW
Weekly Timetable							
FIRST YEAR							
<i>1st Semester.</i>				<i>2nd Semester.</i>			
Differential and integral calculus	5	—	2	Applied differential and integral calculus	2	—	—
Inorganic chemistry	5	1	—	Physics (electricity, magnetism, constitution of atoms)	4	1	—
Analytical chemistry laboratory	—	—	24	Organic chemistry I	5	—	—
General Mineralogy (crystallography)	3	—	—	Quantitative analysis	2	1	—
RECOMMENDED:				Analytical chemistry laboratory	—	—	24
General botany	4	—	—	Mechanics	2	—	1
				General Mineralogy II (crystal optics)	2	—	—
SECOND YEAR							
<i>3rd Semester.</i>				<i>4th Semester.</i>			
Organic chemistry II	2	—	—	Industrial chemistry laboratory	—	—	24
Inorganic chemical technology I (water, salts, acids)	2	—	—	General electrochemistry	2	—	—
Physical chemistry I	4	—	—	Inorganic chemical technology II (acids, alkalis, electrolysis)	3	—	—
Industrial chemistry laboratory	—	—	20	Machines II (Chemical industry)	2	—	1
Physics (mechanics, acoustics, optics)	4	—	1	RECOMMENDED:			
Elementary physics laboratory	—	—	4	Colloid chemistry	2	—	—
Machines I	2	—	2	Bacteriology and infectious diseases	2	—	—
General mineralogy III (crystallographic chemistry)	2	—	—	Practice in crystallography	—	—	1
RECOMMENDED:				Systematic botany II	2	—	—
General geology	4	—	—	Course in microscope technique I (starches, fibres, artificial fabrics, etc.)	—	—	3
Systematic botany I	2	—	—	Textile fibres (practice with the polarizing microscope)	—	—	1
				Constitution of modern Switzerland	1	—	—

¹ C = colloquia, L = lectures, PW = practical work.

THIRD YEAR

5th Semester.

Organic chemistry III . . .	4	—	—
Organic technology I (textile fibres, laundering, dyeing)	3	—	—
Organic technology II (fats, rubber, petrol) . . .	1	—	—
Inorganic chemical technology III (gas, nitrogenous compounds, fertilizers) . . .	2	—	—
Heat and fuels technology	2	—	—
Metallurgy . . .	2	—	—
Chemistry laboratory . . .	—	—	28
Industrial chemistry laboratory . . .	—	—	28
Physical chemistry laboratory	—	—	12
OPTIONAL COURSES (for diploma)			
Synthetic drugs I . . .	1	—	—
Physiological chemistry I . . .	1	—	—
Electrotechnics . . .	2	—	—

RECOMMENDED:

Dyeing (laboratory) . . .	—	—	2
Food chemistry and analysis	3	—	—
Food and nutrition . . .	1	—	—
Disposal and purification of waste waters (hygienic part) . . .	1	—	—
Physiology of work and works hygiene . . .	2	—	—
Bacteriology and hygiene (practical) I . . .	—	—	4
Methods of organic chemistry I . . .	1	—	3
Chemistry of colloids . . .	1	—	—
Electrometallurgy I . . .	1	—	—

6th Semester.

Mineral technology IV (glass, cement, ceramics) . . .	2	—	—
Organic technology III (explosives) . . .	1	—	—
Organic technology IV (organic synthetic dyestuffs) . . .	3	—	—
Organic technology V (hydrocarbons, fermentation) . . .	2	—	—
Physical chemistry II . . .	2	—	—
Mineral chemistry and analysis (selected topics) . . .	2	—	—
Organic chemistry laboratory . . .	—	—	28
Or Industrial chemistry laboratory . . .	—	—	28
Physical chemistry laboratory . . .	—	—	12

RECOMMENDED:

Synthetic drugs II . . .	1	—	—
Physiological chemistry II . . .	1	—	—
Methods of organic chemistry II . . .	1	—	3
Stereochemistry I . . .	1	—	—
Heating and ventilation hygiene . . .	2	—	—
Water supply service (hygienic part) . . .	1	—	—
Bacteriology II (practical) . . .	—	—	4
Gas analysis . . .	1	—	—
Electrometallurgy II . . .	1	—	—
Patent law . . .	1	—	—

FOURTH YEAR

7th Semester.

General chemistry laboratory	daily practical work
Industrial chemistry laboratory	daily practical work
Physical chemistry laboratory	— — 12

RECOMMENDED:

Stereochemistry II . . .	1	—	—
Political economy . . .	3	—	—
Law (introduction) . . .	3	—	—
Gas manufacture and coke ovens . . .	1	—	—

ADVANCED SEMESTERS.

Course on the methods involved in organic chemistry III and IV. Selected topics from organic chemistry I and II. Exercises in chemical thermodynamics.
Seminar on technology of organic chemistry. Seminar on industrial chemistry.
Seminar on organic chemistry.
Chemical laboratory work for advanced students in each laboratory.
Work in pharmaceutical chemistry for advanced students.
Individual work at the Institute of Mineralogy and Petrography for advanced students.

For analytical chemists, the following courses are advised:

Chemical toxicology. Toxicological analysis laboratory. Microscopy technique course II (spices, condiments, etc.). Elements of zoology for agronomists, foresters, and analytical chemists. Food chemistry I and II.

TABLE 2. PROGRAMME OF STUDIES AT THE "SCHOOL OF MATHEMATICAL AND PHYSICAL SCIENCES" OF THE FEDERAL INSTITUTE OF TECHNOLOGY OF ZÜRICH (SWITZERLAND) (duration of studies: 8 semesters).

	C	L	PW ¹		C	L	PW
Weekly Timetable							
FIRST YEAR							
<i>1st Semester.</i>				<i>2nd Semester.</i>			
Differential and integral calculus I	6	2	2	Differential and integral calculus II	6	2	2
Descriptive geometry I and vectorial geometry	4	1	4	Mechanics I	6	1	3
Analytical geometry and linear algebra I	3-4	—	—	Descriptive geometry II	2	—	3
Inorganic chemistry for physicists	2	1	—	Projective geometry	3	—	1
Chemistry laboratory for physicists	—	—	3	Analytical geometry and linear algebra II	2-3	—	—
RECOMMENDED:				RECOMMENDED:			
Photography I	2	—	—	Photographical laboratory	—	—	2
Photographical laboratory	—	—	2				
SECOND YEAR							
<i>3rd Semester.</i>				<i>4th Semester.</i>			
Applied mathematics	2	—	2	Physics II (electricity, magnetism, constitution of atoms)	4	1	—
Introduction to theory of functions	3	—	—	Physics laboratory for beginners	—	—	4-8
Elements of analysis	3	—	—	Theory of functions I	4	—	1
Mechanics II	4	1	3	Projective geometry	3	—	1
Physics I (mechanics, acoustics, optics)	4	—	2	Advanced course in mathematics and physics	—	—	—
Physics laboratory for beginners	—	—	4-8	Mathematical seminar	—	—	2
Calculation of probabilities and mathematical statistics (introduction)	2-3	—	—				
Linear algebra, selected topics	2	—	—				
Topology (introduction)	3	—	—				
Numerical methods	2	—	—				

5TH TO 8TH SEMESTERS. Selected courses, exercises, and laboratory work.

Differential geometry, topology. Non-euclidean geometry. Theory of functions II. Theory of numbers. Algebraic numbers. Algebra. Differential equations. Integral equations. Calculus of variations. Functions of real variables. Complete functions. Linear functional transformations. Theory of groups. Fourier

¹ C = colloquia, L = lectures, PW = practical work.

series. Theory of probabilities. Theory of potential. Graphical and numerical methods. Nomography; mathematical instruments. Mathematical seminar and discussion group.

Thermodynamics and kinetic theory of gases. Electrodynamics. Optics and electron theory. Theory of relativity and gravitation. Statistical mechanics and quantum theory. Wave mechanics. Molecular structure. Transformations of the atom. High frequency current technique I and II. Technical physics: illumination engineering, television, electronic engineering, electro-acoustical amplifiers and group filters. Ferromagnetism. Atomic and molecular spectra. X-rays. Physics laboratories. Scientific work in theoretical physics.

Advanced mechanics. Theory of potential. Aerodynamics. Astronomy. Astrophysics. Seminar in astronomy and geophysics. Topography. Advanced geodesy. Organic chemistry. Physical chemistry. Electrochemistry. Mineralogy, crystallography. Chemistry laboratory. Physical chemistry laboratory.

General didactics. Teaching of elementary mathematics. Fundamental problems of elementary mathematics. Geometrical constructions and theory of equations. Actuarial science. Pedagogy and philosophy. Pedagogical exercises. Constitution of modern Switzerland.

TABLE 3. PROGRAMME OF STUDIES AT THE "ÉCOLE SUPÉRIEURE DE PHYSIQUE ET DE CHIMIE INDUSTRIELLES DE LA VILLE DE PARIS" (FRANCE) (duration of studies: 8 semesters).

Weekly timetable of courses ¹

FIRST YEAR

1st Semester.

Analytical chemistry I	3
General chemistry	3
General physics	3
Mathematics	3
Drawing	1 1/2
Problems	1 1/2
Languages	1 1/2

2nd Semester.

General chemistry II	3
Organic chemistry I	3
General electricity I	3
Mathematics II	3
Graphical statics	(12)
Drawing	1 1/2
Problems	1 1/2
Languages	1 1/2

SECOND YEAR

3rd Semester.

Optics I	3
Organic chemistry II	3
General electricity II	3
Rational mechanics I	1 1/2
Mathematics III	1 1/2
Electrical measurements in the laboratory	(24)
Drawing	1 1/2
Problems	1 1/2
Languages	1 1/2

4th Semester.

Analytical chemistry II	3
Physical chemistry I	3
General physics II	3
Optics II	3
Rational mechanics II	1 1/2
Drawing	1 1/2
Problems	1 1/2
Languages	1 1/2

¹ The figures in brackets indicate the total number of hours in one semester.

THIRD YEAR

5th Semester.

Physical chemistry II . . .	3
Applied electricity I . . .	3
Physical mechanics I . . .	3
Rational mechanics III . . .	1 ½
Electrical measurements (industrial) . . .	(12)
Photography . . .	(12)
Electrochemistry . . .	(24)
Mathematical exercises . . .	(24)
Problems . . .	1 ½

6th Semester.

Applied electricity II . . .	3
Mineralogy I . . .	3
Physical mechanics II . . .	3
Rational mechanics IV . . .	1 ½
Macromolecular chemistry . . .	(24)
Electrotechnics . . .	(24)
Mathematical exercises . . .	(24)
Problems . . .	1 ½

FOURTH YEAR

7th Semester.

Chemists.

Organic synthesis . . .	(24)
Inorganic chemical industries . . .	(24)
Physical chemistry . . .	(24)
Analysis of reactions in solution . . .	(24)

Physicists.

Atomic and quantum physics . . .	(24)
Hydraulics . . .	(24)
Mechanics of vibrations . . .	(24)
Applications of short and ultra-short waves, study of manufacture of light bulbs . . .	(24)

Courses common to both

X-rays . . .	(24)
Heat cycles . . .	(6)
Photography, microphotometry . . .	(8)
Physical chemistry of radioelements . . .	(8)

8th Semester.

Chemists.

Biological chemistry . . .	(24)
Organic chemical industries . . .	(24)

Physicists.

Electro technology and electric measurements in industry . . .	(24)
Machine tools, servo-mechanisms . . .	(24)

Courses common to both

Metallurgy . . .	(24)
Construction of industrial chemical equipment . . .	(24)
Political economy . . .	(24)
Heat engines . . .	(24)

TIMETABLE OF PRACTICAL WORK PER SEMESTER. ¹*1st Semester.*

General chemistry . . .	5 weeks
Analytical chemistry . . .	5 weeks
General physics . . .	6 weeks

2nd Semester.

General physics . . .	3 weeks
General chemistry . . .	4 weeks
Analytical chemistry . . .	4 weeks
Organic chemistry . . .	5 weeks

¹ Each week includes about 20 hours' practical work.

3rd Semester.

General chemistry . . .	5 weeks
Analytical chemistry . . .	4 weeks
General electricity . . .	7 weeks

4th Semester.

Chemists.	
Organic chemistry . . .	6 weeks
General chemistry . . .	5 weeks
Optics . . .	5 weeks
Physicists.	
General physics . . .	7 weeks
General electricity . . .	4 weeks
Optics . . .	5 weeks

5th Semester.¹

Chemists.	
Organic chemistry . . .	10 weeks
Electrochemistry . . .	2 weeks
Optics . . .	2 weeks
Optics, electr. industry. . .	2 weeks
Physicists.	
Electricity, industry . . .	7 weeks
Optics . . .	5 weeks
Electrochemistry . . .	4 weeks

6th Semester.

Chemists.	
Analytical chemistry . . .	7 weeks
Electricity, industrial . . .	4 weeks
Electrochemistry . . .	5 weeks
Physicists.	
Electricity, industry . . .	10 weeks
Workshops . . .	2 weeks
General electricity . . .	4 weeks

7th Semester.

Chemists.	
Organic synthesis:	
Analytical chemistry . . .	8 weeks
Organic chemistry . . .	8 weeks
Physical and analytical chemistry:	
Physical chemistry . . .	16 weeks
Macromolecular chemistry:	
Industrial chemistry . . .	8 weeks
Analytical chemistry . . .	8 weeks
Physicists. :	
Atomic physics and radioactivity:	
General and applied electricity . . .	4 weeks
Physical mechanics . . .	4 weeks
General physics . . .	4 weeks
Electromagnetism and electronics:	
Physical mechanics . . .	4 weeks
General and applied electricity . . .	12 weeks
Physical mechanics:	
General and applied electricity . . .	4 weeks
Physical mechanics . . .	12 weeks

8th Semester.

Chemists.	
Organic synthesis:	
Organic chemistry . . .	8 weeks
Physical chemistry . . .	8 weeks
Physical and analytical chemistry:	
Analytical chemistry . . .	16 weeks
Macromolecular chemistry:	
Physical chemistry . . .	8 weeks
Industrial chemistry . . .	8 weeks
Physicists.	
Atomic physics and radioactivity:	
General and applied electricity . . .	8 weeks
General physics . . .	8 weeks
Electromagnetism and electronics:	
General and applied electricity . . .	12 weeks
General physics . . .	4 weeks
Physical mechanics:	
Physical mechanics . . .	8 weeks
General physics . . .	4 weeks
General and applied electricity . . .	4 weeks

¹ Students specialize as chemists or physicists at the end of the 3rd Semester. Higher specialization takes place in the 4th Year.

TABLE 4. CHEMISTRY SYLLABUS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AT BOSTON (U.S.A.) (duration of studies: 8 semesters) ¹

FIRST YEAR			
<i>1st Semester.</i>		<i>2nd Semester.</i>	
General chemistry . . .	7-4	General chemistry . . .	7-4
Physics	6-5	Physics	6-5
Engineering drawing . . .	6-0	Descriptive geometry . . .	6-0
English composition		English composition	
Humanities I	3-5	Humanities I	3-5
Calculus	3-6	Calculus	3-6
Military science	3-0	Military science	3-0
Athletic programme	2-0	Athletic programme	2-0
Quiz hour (calculus, chem., phys.)	1-0	Quiz hour (calculus, chem., phys.)	1-0
	31-20		31-20
SECOND YEAR			
<i>3rd Semester.</i>		<i>4th Semester.</i>	
Qualitative analysis . . .	7-3	Statics and dynamics . . .	3-5
Physics	5-5	Quantitative analysis . . .	7-3
History, Humanities II . . .	3-5	Physics	5-5
Calculus	3-6	History, Humanities II . . .	3-5
Military science	3-0	Differential equations . . .	3-6
Languages	3-5	Military science	3-0
	24-24		24-24
THIRD YEAR			
<i>5th Semester.</i>		<i>6th Semester.</i>	
Strength of materials . . .	3-6	Organic chemistry II . . .	4-4
Organic chemistry I . . .	4-4	Qualitative organic analysis	6-0
Organic preparations I . . .	6-0	Physical chemistry II . . .	4-4
Physical chemistry I . . .	4-4	Physical chemistry lab. II . .	2-0
Physical chemistry lab. I . .	2-0	Industrial chemistry . . .	3-4
Chemical engineering . . .	4-6	Chemical engineering . . .	4-6
Economic princ. humanities III	3-5	Humanities III	3-5
	26-25		26-23
FOURTH YEAR			
<i>7th Semester.</i>		<i>8th Semester.</i>	
Electrical eng., fund. . . .	4-6	Industrial chemistry . . .	3-6
Industrial chemistry . . .	3-6	Chemical engineering . . .	4-6
Industrial chemistry labora- tory	10-0	Thesis	12
or chemical engineering la- boratory	10-0	Humanities IV	3-5
Chemical engineering . . .	4-6	Elective subject	9
Thesis	3		48
Humanities IV	3-5		
	50		

¹ Each subject mentioned in the table is followed by two figures: the first representing the number of hours per week spent in classroom or laboratory, the second an estimation of the length of time an average student would have to give to preparatory work apart from the lectures and laboratory work. The normal timetable is thus about 50 hours per week, covering class and laboratory work and preparation.

Humanities: I. English composition; II. History; III. Economic principles; labour relations or introduction to psychology; IV. International relations; history of ideas, discussions in literature or introduction to music.

TABLE 5. PHYSICS SYLLABUS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AT BOSTON (U.S.A.) (duration of studies: 8 semesters)¹

FIRST YEAR			
Same syllabus as Table 4			
SECOND YEAR			
1st Semester.		2nd Semester.	
Physical chemistry	3-6	Elem. electrical circuit theory	4-8
Physics	5-5	Physics	5-5
History, humanities II. . . .	3-5	History, humanities II. . . .	3-5
Calculus	3-6	Differential equations	3-6
Military science	3-0	Military science	3-0
Languages	3-5	Languages	3-5
	20-27		21-29
THIRD YEAR			
3rd Semester.		4th Semester.	
Principles of electrical eng. . .	3-6	Electronics	4-5
Electrical measurements laboratory	3-3	Atomic structure laboratory	3-3
Atomic physics	4-6	Electronic devices laboratory	3-3
Experimental physics techniques	3-3	Advanced calculus for eng. . . .	3-6
Economic principles, humanities III	3-5	Humanities III	3-5
Advanced calculus for eng. . .	3-6	Elective subject	9
	19-29		47
FOURTH YEAR			
5th Semester.		6th Semester.	
Thermodynamics and statistical mechanics	4-5	Introduction to theoretical physics II	4-8
Experimental physics	8-4	Thesis	18
Introduction to theoretical physics I.	4-8	Humanities IV	3-5
Humanities IV	3-5	Elective subject	9
Elective subject	6		47
	47		
<i>Chosen subject.</i> Third Year: nuclear physics 4-6, or optics 3-6. Fourth Year: X-rays, nuclear physics, spectroscopy, electronics, optics, mathematics, chemistry, metallurgy or electrical engineering.			
<i>Humanities.</i> See Table 4.			

¹ For explanation of figures, see note to Table 4.

★

FIRST PART

GENERAL AND INORGANIC CHEMISTRY
ORGANIC CHEMISTRY
ANALYTICAL CHEMISTRY

★

GENERAL AND INORGANIC CHEMISTRY

SYLLABUS

(given only as an example to facilitate the use of the inventories)

INTRODUCTION TO THE STUDY OF INORGANIC CHEMISTRY.

Brief ideas about constitution of, and equilibrium in, chemical systems.

Chemical systems, pure substances. Compounds, simple substances or elements.

Molecular structure of matter.

Molecular agitation and statistical equilibria in gases. Molecular dimensions. Molecular heats. Discontinuities in the vibrational and rotational energies of molecules. Dissociation.

Approximate molecular weights of gases and vapours. Exact molecular weights of gases. Molecular volume.

Continuity of liquid and gaseous state. Continuity of crystalline and liquid state. Parachor.

Lattice structure of crystals. Diffraction of X-rays. Atomic crystals. Ionic crystals. Molecular crystals.

Constitution of atoms.

The atomic model of Rutherford. Bohr's hypothesis. Pauli's principle. Electronic structure of atoms and its relation to the periodic system of the elements.

Electronic theory of valency. Heitler and London's hypothesis. Very brief ideas about wave mechanics.

Constitution of complex compounds.

Werner's theory. Electronic theory of the structure of complexes.

Laws of equilibrium in chemical systems.

Phase rule. Displacement of equilibrium. Law of mass action.

Classification of chemical systems.

Study of phase diagrams.

Systems having one degree of freedom. PV diagram. Properties of tie lines.

PT diagram for water.

Principal binary systems.

Ternary systems. Properties of triangular diagrams. Method of residues.

Quaternary systems. Square diagrams. Application to the manufacture of potassium nitrate.

STUDY OF ELEMENTS AND OF THEIR PRINCIPLE COMPOUNDS.

Periodic classification of the elements.

Mendeleef's periodic table. Groups and periods. Normal and transition elements. Isotopes. Lothar Meyer's periodic law. Atomic number. Abundance of the elements in the terrestrial crust.

*Normal elements of the first group of the periodic table (alkali metals) : Lithium, sodium, potassium, rubidium and cesium.*¹

Preparation and properties of the alkali metals. Recent research on element No. 87. Compounds of the alkali metals.

Hydrides. Halides. Treatment of sylvinit: rectangular co-ordinate diagrams.

Treatment of carnallite, three-dimensional diagram for the system $\text{KCl}-\text{MgCl}_2-\text{H}_2\text{O}$. Oxides and hydroxides, sulphides and persulphides, nitrates, carbonates.

Ammoniacal salts.

Electronic structure of the ammonium ion, ammonium chloride, true vapour density, sulphides, carbonates.

Normal elements of the second group (alkaline earth metals) : Beryllium, magnesium, calcium, strontium, barium, radium.

Beryllium.

Nuclear reactions.

Magnesium.

Chloride, sulphate, isomorphous salts of the magnesium series, phosphates and carbonates.

Calcium, strontium, barium.

Oxides and hydroxides, thermal dissociation of barium peroxide. Calcium and barium chlorides. Calcium sulphate, theory of setting of plaster. Sulphates of strontium and barium. Calcium nitrate. Calcium phosphates, study of equilibria by means of Jolibois' tube. Calcium carbide. Calcium carbonate. Thermal dissociation.

Radium.

Theory of fractional crystallization of radium-bearing barium chlorides, scheme of fractional crystallization.

Normal elements of the third group excepting boron : Aluminium, gallium, indium, thallium.

Aluminium.

Electrochemical preparation. Chloride, alumina. Artificial jewels. Aluminates, sulphates, alums.

Gallium, indium, thallium.

Transition elements of the third group : Rare earth metals.

Electronic structure and maximum number of the rare earth metals. Classification and general properties. Trivalent, tetravalent and divalent compounds.

Cerium.

Antioxidation of cerous salts. Pyrophoric alloys.

Transition elements of the second group : Zinc, cadmium, mercury.

Zinc.

Chloride, oxide, sulphide, phosphorescence, complex compounds.

Cadmium.

Oxide, sulphide, sulphate.

Mercury.

Purifications of mercury. Amalgams, chlorides, iodides, oxides, sulphides, nitrates, basic salts, mercuri-ammonium compounds, theory of dimercurammonium.

¹ For each group of elements, the general properties, isotopic compositions and electronic structure of the atoms are first dealt with. Following this, for each important element and its principal compounds, the methods of preparation, the chemical principles underlying the main industrial processes, physical and chemical properties are studied. In this abridged programme only the list of substances studied and the most important special question are dealt with.

Transition elements of the first group : Copper, silver, gold.

Copper.

Halides, oxides, thermal dissociation of cuprous oxide. Cupric hydroxide, Schweitzer's solution. Sulphides, sulphates, carbonates. Basic salts. Cuprammonium salts.

Silver.

Treatment of argentiferous lead, Pattison's and Parkes' processes. Halides, photographic chemistry. Oxide, sulphate, nitrate.

Gold.

Treatment of auriferous sands by amalgamation and cyanidation. Colloidal gold. Chlorides. Oxides, aurates, meta-aurates. Sulphides. Auro and auri-cyanides.

Elements of the eighth group : Iron, cobalt, nickel, ruthenium, rhodium, palladium, osmium, iridium, platinum.

Iron.

Meteorites. Reactions and equilibria in the blast furnace. Allotropic modifications, Curie point. Corrosion of iron, theory of rust formation. Passivity of iron. Ferrous and ferric salts. Ferrous oxide, autoxidation of ferrous hydroxide, ferrous chloride and sulphate. Ferric oxide and hydroxide, ferrites. Ferric chloride and its hydrates. Ferric sulphate. Ferrates. Complexes, potassium ferro and ferricyanides, soluble and insoluble prussian blues. Thiocyanates.

Cobalt.

Oxides and hydroxides. Cobaltous chloride. Cobaltic sulphate, cobaltous aluminates. Cobalt-carbonyl. Cobalt-ammines, cobaltinitrites, cobalticyanides.

Nickel.

Metallurgy of nickel, Arford and Mond processes. Catalytic properties of reduced nickel, Roney nickel. Alloys, nickel steels. Oxides, chloride, nitrate, sulphate. Nickel-carbonyl.

Metals contained in the platinum ore.

Treatment of the crude platinum by the nitrite process.

Ruthenium and osmium.

Octovalent compounds. Osmiates.

Rhodium and iridium. Palladium and platinum.

Colloidal palladium. Palladium compounds. Platinous compounds. Platinic compounds. Hexachlor-platinites. Tetrachlor-dihydroxy-platinic acid.

Rare gases : Helium, neon, argon, krypton, xenon, radon.

Singular properties of liquid helium. Chemical inertia explained by the electronic structure of elements.

Hydrogen.

Preparation. Theory of the action of dilute acids on metals. Reversible reaction of iron on water vapour. Para hydrogen. Atomic hydrogen. Deuterium. Position of hydrogen in the periodic-classification.

Normal elements of the seventh group : Fluorine, chlorine, bromine, iodine.

Electronic structure of normal atoms and atoms of chlorine showing covalencies of 3, 5, and 7.

Fluorine.

Moissan's experiments: cause of their success. Analogies between fluorine and oxygen. Hydrofluoric acid.

Chlorine.

Deacon process. Photochemical chain reaction with hydrogen. Chlorine water-oxidising properties. Hydrochloric acid.

Bromine.

Hydrobromic acid.

Iodine.

Hydriodic acid. Reversible thermal dissociation, reaction velocity, equilibrium constants at different temperatures, heat of reaction, energy of activation of the molecules.

Normal elements of the sixth group: Oxygen, sulphur, selenium, tellurium, polonium.

Oxygen.

Mecanism of autoxidations. Ozone. Mechanism of reactions of formation and decomposition. Composition: Soret's experiments. Water. Preparation of chemically pure water. Structure of the water molecule and of liquid water. Salt hydrates. Heavy water. Hydrogen peroxide.

Oxygen compounds of the halogens.

Fluorine oxide. Action of the halogens on the alkali hydroxides. Hypochlorous acid and its anhydride. Chloride of lime. Hypochlorites. Iodine dioxide. Iodic acids and their anhydride. Periodic acid and the periodates. Chlorine dioxide. Chlorous acid. Chloric acid. Chlorates. Chlorine heptoxide. Perchloric acid and its anhydride.

Sulphur.

Equilibrium diagram of the crystalline varieties. Hydrogen sulphide. Action of acids on metallic sulphides. Persulphides. Sulphur dioxide. Sulphur trioxide. Contact process. Sulphuric acid. Theory of the Lead Chamber process. Chlorosulphonic acid. Persulphuric acids. Constitution. Hydrosulphurous acid. Constitution. Hydrosulphites. Hyposulphites: series of thionic acids.

Selenium.

Photo-conductivity. Hydrogen selenide. Selenium dioxide and selenous acid, Selenic acid.

Tellurium.

Hydrogen telluride. Dioxide. Telluric acids.

Polonium.

Chemical and radioactive properties.

Normal elements of the fifth group: Nitrogen, phosphorous, arsenic, antimony, bismuth.

Nitrogen.

Active nitrogen. Ammonia. Synthesis of ammonia. $N_2 + 3H_2 \rightleftharpoons 2NH_3$ equilibrium. Hydrazine. Hydrazoic acid. Hydroxyl amine. Reciprocal interactions of the nitrogen oxides. Nitric oxide and hyponitrous acid. Nitrous oxide. Nitrogen trioxide and nitrous acid. Nitrites. Nitrogen peroxide. Thermal dissociation. Nitric acid. Synthesis: (1) Arc process, equilibrium of the thermal reaction $N_2 + O_2 \rightleftharpoons 2NO$, mechanism of the reaction in the electric arc; (2) Catalytic oxidation of ammonia. Nitrogen pentoxide.

Atmospheric air.

Composition. Stratosphere. Liquid air.

Phosphorus.

Allotropic modifications. Phosphorescence, Semenov's theory. Radiophosphors. Hydrides. Chlorides. Phosphorus trioxide. Pentoxide. Hypophosphorous acid. Phosphorous acid. Hypophosphoric acid, ortho, meta, and pyrophosphoric acids.

Arsenic.

Trihydride. Trichloride. Arsenious oxide. Arsenic oxide and arsenic acid. Arsenates.

Antimony.

Trihydride. Chlorides. Antimonous oxide. Antimonic oxide, antimonic acid. Antimonites. Peroxide. Meta antimonates.

Bismuth.

Trichloride. Nitrate. Basic nitrates. Allan's equilibrium diagram.

Transition elements of the fifth group: Vanadium, niobium, tantalum, protactinium.

Vanadium.

Multiple valences. Hypovanadous salts, vanadous salts, vanadyl salts, vanadates. Vanadium pentoxide.

Niobium and tantalum.
Protactinium.

Boron.

Relations with elements of the third and fourth groups. Boranes and hydroboranes. Halogen compounds. Boric acid and its anhydride. Borates. Perborates. Boron nitride.

Normal elements of the fourth group : Carbon, silicon, germanium, tin, lead.

Carbon

Diamond. Crystalline structure from the X-ray diffraction patterns. Graphite, crystalline structure, fusion point. Amorphous carbon, various kinds. Micro-crystalline structure. Attempts at artificial production of diamonds. Carbon dioxide. Percarbonates. Carbon monoxide. Hydrogenation products. Thermal dissociation in the presence of iron. Reaction paths. Carbonyl chloride (phosgene). Metal carbonyls. Structure of the molecules CO and CO₂. Molecular resonance. Carbon disulphide. Cyanogen. Hydrocyanic acid and the cyanides. Cyanic acid and the cyanates. Thio-cyanates.

Silicon.

Carbon silicide. Silanes. Fluoride and fluosilicic acid. Silicon chlorides. Crystalline silica. Quartz, piezoelectricity. Tridymite, cristobalite. Silica glass. Hydrated silica and silicates. Silica gels. Structure of natural mineral silicates from X-ray diffraction studies. Metasilicates. Lamellar silicates. Feldspars. Zeolites. Permutites.

Germanium.

Tin.

Allotropic varieties. Chlorides. Stannic oxide. Stannic acids. Tin sulphides.

Lead.

Monoxide. Plumbites, plumbic salts, basic salts. Cerussite. Dioxide. Plumbates, red lead.

Transition elements of the fourth group : Titanium, zirconium, hafnium, thorium.

Titanium.

Tetrachloride. Dioxide. Titanates. Trichloride. Nitride.

Zirconium.

Zirconia. Chlorides.

Hafnium.

Discovery by X-ray spectra.

Transition elements of the seventh group : Manganese, technetium, rhenium.

Manganese.

Electronic structure of the ions. Heusler alloys. Oxide, hydroxides. Manganous chloride and sulphide, manganic salts, dioxide. Manganites, manganates and permanganates.

Technetium.

Radiotechnetium.

Rhenium.

Transition elements of the sixth group : Chromium, molybdenum, tungsten, uranium.

Chromium.

Chromous salts. Chromic oxide. Chromic chlorides, constitution of complexes. Sulphates, constitution of complex. Chromisulphuric acids. Chrome alum, chromates and polychromates. Chromium trioxide. Perchromic acid and chromyl chloride.

Molybdenum.

Molybdic oxide. Normal molybdates, paramolybdates, complex molybdates. Blue oxide of molybdenum.

Tungsten.

Manufacture of ductile tungsten. Halogen compounds. Tungstic oxide and tungstic acid. Normal tungstates, metatungstates, complex tungstates. Tungsten bronze.

Uranium.

Natural and artificial radioactivity (fission of the uranium nucleus). Oxides and hydroxides. Uranous salts. Uranyl salts. Uranates.

PRACTICAL WORK

FIRST YEAR

Work with cork and glass.

Erection of simple apparatus.

Exercises in filtration, pulverization, heating with coal, gas and electricity.

Preparation and properties of various inorganic substances.

Hydrogen.

Chlorine, bromine, iodine, hydrochloric acid, sodium iodate.

Oxygen, sulphur, sulphur dioxide.

Nitrogen, ammonia nitrous oxide, nitric oxide, nitric acid.

Phosphorous acid and phosphites. Phosphoric acids. Antimony. Bismuth.

Boric acid and borates.

Carbon monoxide. Sodium silicate.

Lead, lead dioxide, lead carbonate.

Stannous chloride.

Molybdic acid and molybdates. Tungstic acid and tungstates.

Monazite and cerium salts. Thoria and thorium salts.

SECOND YEAR

Treatment of minerals: carnallite, carnolite, emerald, gadolinite, garnierite, ilmenite, samarskite, thorite, zorgite.

Purification of the products obtained during the first year and new preparations: anhydrous chlorides of vanadium, tin, and titanium. Sodium nitrite via nitric oxide, oxygen and sodium carbonate, sodium sulphotitanate, potassium iodide free from iodate, pure potassium permanganate, cobaltammine and chromammine salts.

Catalytic reactions. Oxidation of SO_2 , NH_3 , H_2S . Deacon process. Preparation of urea from CO_2 and NH_3 . Cyclohexane by hydrogenation of benzene. Acetic aldehyde by hydration of acetylene.

Speed of reactions and equilibria. Kinetic study of the oxidation of iodides by the persulphates and of the esterification of acetic acid.

Solubility curves of sodium carbonate and of the mixture $\text{KCl} + \text{MgCl}_2$.

Equilibria in the system $\text{Na}_2\text{CO}_3 + \text{BaSO}_4$.

Application of the method of residues to the system BeSO_4 , K_2SO_4 , H_2O .

Thermal analysis of the systems KNO_3 , TlNO_3 and AgCl , LiCl .

Fractional distillation of crude amyl alcohol, of crude petrol, of a mixture of ethyl alcohol and benzene, preparation of absolute alcohol.

ORGANIC CHEMISTRY

SYLLABUS

(given only as an example to facilitate the use of the inventories)

GENERALITIES.

Definition of Organic Chemistry.
 Isomerism. Constitutional formulae. Polymerism.
 Nomenclature.
 Stereochemistry.
 Pasteur's principle.
 Application of Pasteur's principle to the chemistry of carbon.
 The Van't Hoff and Le Bel tetrahedral carbon atom.
 Asymmetric carbon atoms.
 Dissymmetry without asymmetric carbon atoms.
 Dissymmetry and chemical synthesis.
 The Walden inversion.
 Geometric isomerism of ethylenic compounds.
 Geometric isomerism of cyclic compounds.
 Other theories than that of the tetrahedron.
 Relations between the structure of molecules and their properties.
 Catalysis in organic chemistry.
 Division of the course.

FIRST PART. ACYCLIC SERIES.

Study of single type compounds.

Hydrocarbons.
 Saturated hydrocarbons. Generalities. Methane. Various natural hydrocarbons.
 Ethylenic hydrocarbons. Generalities. Ethylene, propylene.
 Acetylenic hydrocarbons. Generalities. Acetylene. Heptene-1.
 Diethylenic hydrocarbons. Allylenes. Hydrocarbons with conjugated double bonds.
 Polyethylenic hydrocarbons.
 Mono-substituted compounds.
 Generalities, isomerism.
 Monohalogen derivatives. Generalities. Chlorides, bromides and iodides of ethyl and methyl.
 Monohalogen ethylenic compounds, both of addition and substitution.
 Organometallic compounds. Generalities. Mixed organomagnesium compounds.
 Simple organo-zinc compounds. Mixed organo-zinc compounds.
 Alcohols: Generalities. Methyl alcohol, ethyl alcohol. Homologous alcohols.
 Ethylenic alcohols. Acetylenic alcohols.
 Ethers (alkyl oxides).
 Esters.
 Mercaptans.
 Thio-ethers (alkyl sulphides).

- Amines and ammonium derivatives.
- Phosphines.
- Arsines. Cacodyl group.
- Di-substituted compounds.
 - Compounds with two halogen atoms on the same C atom.
 - Aldehydes. Generalities. Formaldehyde. Acetaldehyde. Chloral. Ethylenic aldehydes. Acetylenic aldehydes.
 - Ketones. Generalities. Acetone. Ethylenic ketones. Ketenes. Acetylenic ketones. Oximes.
- Tri-substituted compounds.
 - Chloroform. Bromoform. Iodoform. Fluoroform.
 - Acids. Generalities. Formic acid. Acetic acid. Homologues. Monoethylenic acids. Polyethylenic acids. Acetylenic acids.
 - Acid chlorides. Acid anhydrides. Amides. Nitriles. Generalities.
 - Hydrocyanic acid. Carbylamines. Fulminic acid.
- Tetra-substituted compounds.
 - Generalities.
 - Derivatives of orthocarbonic acid. Carbon tetrahalides. Chloropicrin. Orthocarbonic esters.
 - Derivatives of metacarbonic acid. Phosgene. Chlorocarbonic esters. Carbonic esters.
 - Sulphides. Amides. Carbamyl chlorides.
 - Urethanes. Urea. Ureines. Ureides. Uric acid. Thiourea. Guanidine.
 - Brief ideas about natural and artificial derivatives of glyoxaline, pyrimidine, and purine.
 - General knowledge of the hypnotics derived from H_2CO_3 .
 - Nitrile derivatives and tautomers. Cyanogen derivatives. Isocyanic acids and esters. Thiocyanic acid and its esters. Mustard oils. Cyanamide.

Study of multiple type compounds.

- Double type compounds.
 - Glycols and internal oxides (ring ethers). Ethylene oxides. Diamines. Amino alcohols. Glyoxal. α and β -diketones. Acetylacetone. α -alcohol acids.
 - Glycollic acid. Lactic acid. β -alcohol acids. Hydracrylic acid. Lactones.
 - Aminoacids. Glycocoll. Homologues.
 - Brief ideas about the proteids (proteic substances). Glyoxylic acid. Pyruvic acid. β -ketonic acids. Acetyl acetic acid. Homologues.
 - Laevulic acid. Oxalic acid. Malonic acid and its derivatives.
 - Succinic acid and its derivatives.
 - Generalities concerning the other diacids. Ethylenic diacids. Maleic acid. Fumaric acid. Acetylene-dicarboxylic acid and carbon subnitride.
- Triple type compounds.
 - Glycerol. Principle esters.
 - Brief ideas about lipoids: fats, phosphatides (lecithins). Homologues.
 - Tartronic acid. Malic acid. Aspartic acid and asparagine. Glutamic acid and glutamine.
 - Mesoxalic acid.
- Compounds having more than three types.
 - Citric acid.
 - Polyols and the corresponding diacids. Generalities. Erythrites. Tartaric acids. Pentites. Hexites.
 - Glusides and aldonic acids. Generalities. Principal monoses. Stereochemistry. Holosides.
 - Heterosides.
 - Brief ideas about complex compounds based on carbohydrates.

SECOND PART. CYCLIC SERIES.

- Generalities.
- Subdivision of the subject matter.

Isocyclic series (carbocyclic).

Aromatic series.

Simple rings and compounds: benzenoid series.

Benzenoid hydrocarbons. Generalities. Benzene. Homologue.

Ethylenic hydrocarbons. Generalities. Styrolene.

Acetylenic hydrocarbons.

Nuclear substituted halogen derivatives.

Phenols. Generalities. Phenol. Homologues.

Diphenols. Generalities. Pyrocatechol. Resorcinol. Hydroquinone.

Polyphenols. Pyrogallol. Phloroglucinol. Oxyhydroquinone.

Phenols having ethylenic side chains. Thiophenols.

Sulphonic acids.

Nitro-derivatives. Generalities. Nitrobenzenes. Trinitrotoluene. Artificial muscs.

Nitrophenols: picric acid.

Nitroso derivatives. Hydroxylamines.

Aromatic amines. Generalities. Aniline. Toluidines.

Mixed amines, aromatic and aliphatic. Generalities. Methylanilines.

Polyarylamines. Diamines. Aminophenols. Nitrosamines.

Diazo compounds. Diazoamines.

Azo compounds. Azo dyes. Hydrazines.

Arsenicals.

Quinones. Generalities. Benzoquinone. Quinhydrone.

Iminoquinones. Indophenols. Indoanilines. Indamines.

Quinone-oxines. Polyquinyls and derivatives.

Brief ideas about quinoid dyes.

Compounds derived by side chain substitution. Methods of preparation and special characters of these compounds.

Condensed revision of the principle aromatic compounds containing different groups in the side chains. Brief review of their principle applications.

Diphenyl group.

Polyphenyl methane group.

Brief ideas about dyes related to this group.

Brief ideas about free radicals.

Multiple condensed ring compounds.

Naphthenic series: Special features of the production and properties of the naphthalenic group α and β -naphthols. α and β -naphthylamines. Azo compounds.

Naphthoquinones.

Anthracene series: Special features of the preparation and properties of the anthracene group.

Brief ideas about natural and artificial colouring matters based on the group. Alizarin.

Purpurin.

Phenanthrene series: Phenanthraquinone.

Alicyclic series.

Simple compounds and rings.

Generalities.

Cyclopentadiene. Brief ideas and the coloured hydrocarbons and the chromophoric groups.

Inositols.

Camphoric acids.

Special study of terpenes and their derivatives.

Acylic terpenes. Geraniol. Nerol. Linalol. Citronellol. Rhodinol. Citronellal. Ionones.

Monocyclic terpenes. Limonene terpeneols. Methols. Terpene and eucalyptol. Carvone-menthone.

Polycyclic terpenes. Pinene. Camphane. Bornylene. Borneols. Camphor.

Brief ideas about other terpenes: Their derivatives and related complex compounds.

Multiple condensed rings.

Indene and indenic resins.

Fluorene.

Sterols. Brief ideas about complex compounds related to sterols. Brief ideas about surface active compounds and on some of their applications (wetting, emulsification, frothing, detergency, flotation, etc.).

Heterocyclic series.

Five membered rings.

Generalities.

Furane group. Generalities. Furane Furfuryl alcohol. Furfural. Oxymethyl furfural.

Furoic acid. Benzofurane (coumarone) and coumarone resins.

Thiophene group. Thiophene.

Pyrrole group. Generalities. Pyrrole. Brief ideas about vegetable and animal pigments containing the pyrrole nucleus. Indole. Indoxyl. Oxindole. Indigo.

Brief ideas about the colouring matters of the indigo group. Indigotides and related substances. Isalin carbazole.

Six membered rings.

Pyrone group. Pyrones. Benzopyrane. Benzopyrones (coumarins and chromones). Xanthene. Xanthidrol.

Xanthone. Brief ideas about natural and artificial colouring matters related to benzopyrones.

Pyridine group. Generalities. Pyridine. Homologues. Hydropyridines. Piperidine. Coniine. Quinoline.

Isoquinoline. Acridine.

Complex heterocyclic substances: alkaloids.

Generalities. Brief ideas about their constitutions.

PRACTICAL WORK

GENERAL MANIPULATIONS.

First semester.

Each student performs one, and sometimes two manipulations in each of the following categories:

1. Nitration (example: o- and p-nitrophenol, p-nitraniline, nitronaphthalene, dinitrobenzene, etc.).
2. Sulphonation (sodium benzene-mono and di-sulphonate, p-toluene-sulphonate, sodium naphthol sulphonates, sulphuric acid).
3. Halogenation (bromides of ethyl and ethylene, bromo-benzene, o- and p-bromotoluene, bromonaphthalene, p-bromaniline, p-bromanisol).
4. Oxidation (cyclohexanone, anthraquinone, o-nitrobenzoic acid, benzaldehyde, mucic acid).
5. Reduction (aniline, azoxy-, azo-, hydroazobenzene, m-nitraniline, m-phenylene diamine, hydrocinnamic acid).
6. Pure solvents (absolute alcohol, thiophene-free benzene, anhydrous ether).
7. Acid chlorides (acetyl chloride, benzotyl chloride).
8. Conversion of chlorides into esters or amides.
9. Fusion of a sulphonic derivative with an alkali (prep. of phenol, cresols, resorcinol).
10. Esters (direct esterification).
11. Ethers (anisol, use of methyl sulphate).

12. Anilides (acetanilide, acetotoluidide).
13. Diazotation (prep. of a phenol, p-cresol, m-nitrophenol).
14. Diazotation (Sandmeyer or Gatterman's method: halogen derivatives of benzene and toluene, benzonitriles and tolunitriles).
15. Diazotation (various reactions: diazo-aminobenzene, aminoazobenzene, phenylhydrazine, etc.).

Second semester.

16. Condensation (Friedel and Crafts method; diphenyl-triphenyl methane, acetophenone, benzophenone, p-toluic aldehyde).
17. Condensation (various methods, ethyl benzene, salicylaldehyde, cinnamic acid, quinoline).
18. Grignard reaction (iodobenzene, benzyl alcohol, phenylacetic acid, triphenyl carbinol).
19. Extractive chemistry (quinine, rhamnetine and rhamnose, amygdaloside and emulsin, caffeine, piperin, tannin, etc.).
20. Treatment of an essential oil (geraniol, eugenol, cineol, citral, cinnamic aldehyde).

ELEMENTARY ORGANIC ANALYSIS.

Determinations by groups of two students (Dumas' method): (1) carbon and hydrogen; (2) nitrogen.

RECOGNITION OF PURE ORGANIC PRODUCTS OR MIXTURES.

These recognitions will be made by means of group properties, physical constants and the obtention of characteristic derivatives.

END OF YEAR WORK.

- (a) An exercise in systematic documentation concerning the modes of formation and the principle physical properties of an organic compound. Drawing up a bibliographic table.
- (b) Report based on this bibliography. Exposition of the principal methods from the original papers.
- (c) Experimental study of the preparation of a substance by several methods or even of several substances by methods drawn from the chemical literature by the student.
- (d) Writing up the work carried out in the laboratory.

ANALYTICAL CHEMISTRY

SYLLABUS

(given only as an example to facilitate the use of the inventories)

FIRST PART: CHEMICAL PROPERTIES OF IONS. QUALITATIVE ANALYSIS.

General properties.

Generalities.

The electron, ions, the proton. Bonds between atoms. Definition of complexes. Covalent and co-ordinate bonds. Electrovalence: exercises. Co-ordination number: exercises. Constitution of solutions. Recapitulation of law of mass action. Slow and irreversible reactions. Activity. Formulae for the activity coefficient (solely for practical purposes). The fundamental types of chemical reaction in solution. Exchanges between ions and electrons. (Generalized Bronsted theory).

Oxidizing and reducing agents. Electron transfer.

Definition, examples. Oxidation-reduction reactions. Reaction coefficients: exercises. Strength of oxidising and reducing agents. Oxidation-reduction (redox) potential. Aqueous solutions. Oxidation-reduction system of water. Expressions for the potential of oxidizing and reducing agents, buffer solutions, mixtures of two systems. Polyoxidizers, ampholytes. Dismutation. Some normal potentials: exercises.

Acids and protons. Proton transfer.

Definitions. Examples. Reactions between acids and bases. The acid-base system of water. Strength of acids and bases. pH-pK. Outline of reactions: exercises. Limitation of the acidity scale. Strong acids, strong bases. Simplified formulae for the pH of acids, bases, buffer solutions, mixtures of two systems. Polyacids. Ampholytes. Dismutation. Some constants: exercises. Flood's graphical method. Acidity potential.

Complexes. Ion transfer.

Definitions. Examples. Generalization of properties of acids and bases. Exchange reactions between ions. Aqueous solutions. Solvation. Strength of ion donors and acceptors. Stability of complexes. Characteristic concentration. Outline of reactions. Formulae. Buffer solutions. Mixtures of two systems. Polycomplexes. Ampholytes. Dismutation. Some constants. Complexes with normal ions. Very stable complexes. Internal complexes. Salts. Complexes with the ions of water. Dilution of complexes: exercises. Ion transfer potential.

Complexes and oxidation reduction. Ion and electron transfer.

Example. Normal potential of a complex system.

(1) Variation of oxidation-reduction properties by complex formation. Examples. Dismutation. Influence of complex formation on stability of valence.

(2) Displacement of the equilibrium of complexes by oxidation-reduction. Influence of valency on the stability of complexes. Examples and exercises.

Oxidation-reduction and acidity (proton and electron transfers).

Examples. Apparent normal potential. Variation of the oxidation-reduction properties as a function of pH.

Complexes and acidity. Ion and proton transfers.**Example.**

- (1) Influence of pH on the equilibrium of complexes. Complexes with NH_3 , S^{--} , and those involving an acid. Complexes with the ions of water.
- (2) Displacement of the acid-base equilibrium by the formation of complexes. Complex acids and bases: exercises.

Complexes with the ions of water.

Variation of oxidation-reduction properties with pH. Reaction coefficients. Dismutation. Influence of valency on the strength of acid-base systems. Existence of ions as a function of the valency and pH. Action of air and of water. Complexes with hydrogen peroxide.

Precipitation.**Properties of the precipitates.**

Adsorption. Colloids. Formation and development of precipitates. Growth of crystals. Variation of solubility during the development of a crystal. Impurities in precipitates. Applications.

Precipitation reactions.

Solubility product. Influence of ions on the solubility. Various types of precipitation reactions.

Precipitation and pH.

Solubility of hydroxides as a function of pH. Field of existence of hydroxides and of ions. Separations by pH control. Examples. Solubility of salts as a function of pH. Sulphides. Separations by pH control. Buffering effect of salts and of slightly soluble salts. Influence of precipitation on the acidity. Basic salts.

Precipitation and complexes.

Formation of a precipitate. Examples. Dissolution of a precipitate by formation of complexes. Examples. Precipitation of hydroxides in the complexes. Applications.

Precipitation and oxidation-reduction.

Precipitation of the elements. Dismutation. Reducing power of the elements. Variation of the oxidation-reduction properties as a function of pH during precipitation of the elements and of hydroxides. Dismutation. Existence of peroxides. Variation of oxidation-reduction properties during the precipitation of salts. Silver and mercury reducers. Oxidizability of the sulphides. Exercises.

Various examples.

Attack on metals by formation of complexes, etc.

Non aqueous solvents.

Active and inert solvents. Oxidation-reduction. Acidity. Complexes.

Reactions in the presence of a second solvent extraction.

Partition coefficient. Displacement of equilibrium in the presence of a second solvent. Extraction. Examples with organic reagents. Applications.

Indicators and reagents.

Definitions. Sensibility. Specificity. Quality of indicators. Indicators of pH, of redox potential, and of ionic concentration. Various types of indicators: those based on electron transfer, proton transfer, ion transfer, electron and proton, electron and ion, proton and ion transfers. Turbidimetric and adsorption indications.

Organic reagents.**Speed of reactions. Catalysis.**

- (1) Oxidation-reduction reactions. Slow reactions. Irreversible systems. Causes of variations in the speed of reactions. Catalysis.
- (2) Reactions of hydration. Examples.
- (3) Speed of extraction.
- (4) Induced reactions. Oxidation-reduction. Peptization and flocculation. Examples.

Recapitulation.

Comparable properties. Properties in the periodic classification.

Technique and conduct of analysis.

Microchemical technique. Semi-microchemical technique. Conduct of qualitative analysis. Classical method. The different groups.

Particular properties and the characterization of different ions.

For each valence of each element, the strength of the acid-base system, the solubility curve of the hydroxide as a function of pH, the list of slightly ionized compounds in their order of ionizability, the apparent redox potentials as a function of pH, and the characterizing reactions are given. The common properties are set out at the head of each group of elements. The student only learns the fundamental properties which are pointed out to him.

Alkali group.

General characters. Potassium. Ammonium. Sodium. Lithium.

Alkaline earth group.

General characters. Calcium. Strontium. Barium. Magnesium. Investigation of the alkaline earths and the alkalis.

Ammonia group.

General characters. Aluminium. Beryllium. Iron. Chromium. Rare earths. Cerium. Tetravalent elements. Titanium. Zirconium. (Thorium). (Niobium and tantalum). (Uranium). (Gallium, indium, thallium).

Zinc group.

General characters. Manganese. Nickel. Cobalt. Zinc. Cadmium. Copper.

Separation by pH control.

Precipitation of hydroxides and sulphides. Separation of the phosphate ions.

Lead. Bismuth. Mercury.

Arsenic group.

General characters. Arsenic. Antimony. Tin. (Germanium). Molybdenum. Tungsten. Vanadium.

Silver. Thallium.

Precious metals.

Gold. Platinum. Palladium (metals of the platinum mine).

Halogen ions.

Fluoride. Chloride. Bromide. Iodide.

Hydrogen.

Oxygen compounds.

Oxygen. Ozone. Water. Hydrogen peroxide.

Sulfur compounds.

Nitrogen compounds.

Phosphorous compounds.

Carbon compounds.

Silicon and boron compounds.

Conduct of analysis.

Investigation of anions and cations. Analysis of a solid. Some general remarks only: these operations are carried out in the laboratory.

Additional subjects.

Various methods. Chromatography, electrography, radio-active indicators, etc.

SECOND PART: THE METHODS OF QUANTITATIVE ANALYSIS.

General methods.

Generalities concerning volumetric work.

Different types of reaction. End of reactions logarithmic and rectilinear co-ordinates. "Quantitative" reactions.

Measuring instruments (the detailed instructions are given in the laboratory).

Cleaning, rinsing and drying receptacles. Measuring flasks. Pipettes, burettes. Utilization. Calibration. Precision and sources of error. Approximation of the results.

Reactions between acids and bases. Acidimetry.

Recapitulation of the concepts of acid and base. Constants and formulae. Usual buffer solutions. Variation of pH during neutralization [pH/(mls of base) curves].

1. Neutralization of a weak acid by a weak base. Precision of titration.

2. Neutralization of a strong acid by a strong base. Limitation of the acidity scale. Precision.

3. Neutralization of a weak acid by a strong base. Precision. General case. Exercises. Neutralization of polyacids and of mixtures of acid. Precision. Exercises. End of reactions. Different methods for detecting the end of a reaction. pH indicators. Acid-base indicators, causes of error. Indicators: mixed, complex, turbidimetric, adsorption, fluorescent. Determination of pH by means of coloured indicators. Colour scales. Colour standards. Indicator papers.

Standard solutions for titration.

Normal solutions. Principal standardizing substances. Hydrochloric acid titrated by sodium carbonate, and by borax. Strong bases titrated by biphthalate, and by oxalic acid.

Applications.

Various exercises. Important particular cases: carbonate + soda. Boric acid, borates, ammonium salts (formaldehyde method): exercises. Amino-acids. Varied methods. Influence of salts.

Reactions between oxidants and reducers. Oxidimetry.

Recapitulation of basic ideas. Formulae and constants. Variations of redox potential during titration [curves of $E = f(\text{mls of reducing solution})$]. Reversible systems. Accuracy. Titration of polyoxidants and oxidizing mixtures. Irreversible systems: exercises.

End points.

Different methods. Indicators: redox potential, oxidant-reducer, acid-base, complex, turbidimetric, fluorescent.

Standard solutions.

Normal solutions. Principal standards. Principal standard solutions. Their properties and standardization. Their applications; permanganate; ceric salts; dichromate; bromate; iodate; iodide; thiosulphate; arsenious acid; oxalic acid; divalent vanadium; divalent chromium; trivalent titanium. Relations between standard solutions.

Various oxidizing and reducing agents.

Perchloric acid. Properties. Applications. Periodic acid: bismuthate, persulphate, hydrogen peroxide, sulphurous acid. Reduction by metals; by zinc. Jones reductor, silver reductor. Devarda's alloy. Finely divided metals. Mercury and liquid amalgams.

Acidimetry during oxidation-reduction reactions.

Variation of redox potential during neutralization. Curve of $E = f(\text{mls of sodium hydroxide})$. Example: titration of oxidizers by acidimetry. Examples.

Titrimetry by complex formation.

Recapitulation of ideas. Formulae. (Generalization of what has been seen in acidimetry.) Variation of the concentration of an ion in the course of titration. Curves of $pX = f(\text{mls titrant ion})$.

- (1) Single very stable complex.
- (2) Several complexes. Accuracy. End-point. Different methods. Indicators and ionic concentrations. Applications. Determination of cyanide by silver salts. Cyanometry. Mercurimetry. Oxidation-reduction and complexes. Curves of $E = f(\text{mls complex ion})$. Complexes and pH.

Titrimetry by precipitation.

Recapitulation of ideas.

- (1) Precipitation of hydroxides. Variation of pH during precipitation. Curve of $pH = f(\text{mls of sodium hydroxide})$. Examples: aluminium hydroxide: acidimetric determination of silicofluoric acid.
- (2) Precipitation of the salts of strong acids.
 - (a) Variations in concentration during titration. Curve of $pX = f(\text{mls of } X^-)$. Accuracy. Fractional precipitation. Examples: $Cl^- + Br^- + I^-$.
 - (b) Variations of redox potential during titration. Curve of $E = f(\text{mls of } X^-)$. Determination of zinc by ferrocyanide, in presence of ferricyanide. Ferricyanide by iodometry I^- by Ag^+ in presence of iodine.
- (3) Precipitation of salts of weak acids. Variation of pH during precipitation.
 - (a) By addition of strong acid or base. Curve of $pH = f(\text{mls of NaOH})$. Examples: MnS , Ag_3PO_4 , $MgNH_4PO_4$.
 - (b) By addition of an acid or basic ion. Curve of $pH = f(\text{mls of } X^-)$. Pb^{++} by $C_2O_4^{--}$.

Precipitation and complexes.

Determination of the free acidity of salts by formation of complexes. Curve of $\text{pH} = f(\text{mls of OH}^-)$. Determination of cyanides by Ag^+ . Titration curve. Indicators: of precipitation reactions, of pH , redox, of ion concentration. Examples. Adsorption reagents. Properties. Determination of chlorides and fluorides. Argentometry. Standard solutions. Titration of Ag by thiocyanate; titration of Cl^- , Br^- , I^- . Mohr's method.

Acidimetry in non-aqueous solvents.

- (1) Properties of the solvent as acid and as base. Protolytic solvents: limitations of the acidity scale. Inert solvents. Examples. Applications.
- (2) Influence of the dielectric constant. Examples. Applications. Colour change in pH indicators; exercises. Complexes. Oxidation-reduction. Precipitation in non-aqueous solvents.

Reactions in presence of two solvents (inert solvent and water). Extraction.

Recapitulation. Partition coefficient.

- (1) Influence of the presence of a second solvent on the equilibria in water. Titration curve.
- (2) Extraction of a compound from an aqueous solution by means of an organic solvent. Accuracy. Influence of various factors. Example. Technique of extraction. Importance of extractive methods. Acidimetry in water in presence of a second solvent. Titration of oxine in presence of chloroform. Titration of alkaloid salts. Influence of pH on extraction. Extraction of aluminium oxinate with chloroform. Extraction of zinc dithionate.

Gravimetry.

Its role. Causes of error.

Apparatus and technique of analytic operations (detailed instruction is given in the laboratory).

Receptacles. Pyrex, porcelain, silica, platinum, silver, nickel, bakelite, their use and liability to attack. Heating apparatus. Filtration. Dessication. Decantation. Extraction. Comminution and sieving. Reagents. Calcination of precipitates. Sampling. Principles. Its importance. Examples. Metals, minerals.

The methods of physical analysis.

Importance of instrumentation in analysis. Analytic control. Automatic procedures. Documentation.

Optical methods.

Absorption spectrophotometry. Colorimetry.

Practical importance. Principle. The Lambert-Beer law: validity of Beer's law: pH ; complexes. Principal methods: (a) visual comparison: methods involving the use of a series of standards, and dilution, examples; principles of the Duboscq and Zeiss-Pulfrich colorimeters; (b) equipment using photoelectric cells: Jouan, Spekker, Coleman, Beckman (practical characteristics).

Accuracy: (a) visual methods; (b) photoelectric methods.

Sensitivity.

Perfecting a colorimetric determination. Control of the accuracy of an apparatus. Curve of absorption against wavelength. Determination of optimum sensitivity. Study of the validity of Beer's law. Determination of the best accuracy. Blank tests. Case of a mixture of several coloured substances. Elimination of interfering substances. Various methods. Examples.

Colorimetric titrations.

Various types of curves. Examples. Application to automatic determinations.

Spectrophotometry by infra-red absorption.

Field of application. Sensitivity. Accuracy. Examples.

Turbidimetry and nephelometry.

Principle. Accuracy. Sources of error. Field of use. Examples.

Fluorimetry.

Principle. Accuracy. Field of application. Examples.

Emission spectrophotometry.

Quantitative spectrography.

Principle. Field of application. Accuracy. Sensitivity. Advantages. Inconveniences. General indications about this method.

- (1) Obtention of the spectrum: spark, arc, alloy powders, solutions.

- (2) Dispersion and photography of the emitted radiations.
- (3) Study of spectra; use of comparison spectra, logarithmic sector.

Direct photometry of spectra.

Photometry and spectrophotometry of flames.

Applications.

Various methods.

Very rapid summary of quantitative analysis by X-rays, refractometry, polarimetry.

Electrical and electrochemical methods.

Potentiometric titration.

Principle utility.

Electrodes.

- (1) Inert, for redox potentials. Potentiometry by measurement of oxidation reduction potentials. Examples.
- (2) Metallic, for determining ionic concentrations.
 - (a) Metal—ion type.
 - (b) Metal—slightly soluble compound—ion.

Examples. Hydrogen electrode for pH determination. Utility. Electrodes of elements having slightly soluble hydroxides, for pH measurement: antimony electrode. Utility.

- (3) Electrometric indications. Examples. Quinhydrone, pH indicator; iodine-iodide, indicator of Ag^+ concentration; ferri-ferrocyanide, indicator of Zn^{++} concentration.
- (4) Solid wall electrodes. Glass electrode. pH-meters. Salt electrodes. Reference electrodes (very simplified).

Analytical apparatus.

Principle of determination. Particular apparatus.

- (1) Bimetallic electrodes.
- (2) Polarized electrodes.
- (3) Differential electro-titrations.
- (4) Multiple electrodes.

Electrolysis.

Field of use. Principle. Electrolysis potential and oxidation-reduction potential. Determination of ions reacting with the electrodes. Slow reactions exercises. Slow reactions. Overvoltage. Factors which affect the overvoltage. Calculation of the electrolysis p. d. Practical importance of overvoltage. Examples. Influence of pH and of the formation of complexes. Action of oxidizing agents and reducing agents. Variation of electrolysis potential during a separation. Separation by potential control; exercises. Apparatus and technique. Agitation. Rapid electrolysis. Micro and semimicroelectrolysis. Applications. Electrolysis with a mercury cathode. Applications.

"Internal Electrolysis."

Applications.

Electrography.

Examples.

Coulomb-metric analysis.

Examples.

Conductimetry.

Principle and examples. Sensitivity and accuracy. Influence of temperature.

Polarography.

Principle. Accuracy, sensitivity, advantages, inconveniences. Field of application. Maxima. Influence of oxygen. Influence of temperature. Influence of pH on the formation of complexes. Principles underlying the equipments. Polarographs. Use of platinum electrodes. Applications.

Polarographic titrations (polarometry).

Principle. Different types of curves. Applications.

Various methods.

Very rapid survey of dielectric constant, intensity of high frequency current, etc.

Various physical methods.

Chromatography.

Principle. Applications.

Capillary analysis.

Example.

Methods utilizing radioactive properties.

Principle. Accuracy and sensitivity.

(1) By direct measurement of radioactivity.

(2) Radioactive indicators: titrimetry.

(3) By rendering the element to be determined radio-active. Examples. Various methods.

Certain very simple remarks on mass-spectrometry. Raman spectra.

Organic reagents.

Compounds of organic reagents with inorganic ions. Internal complexes; solubility in organic solvents. Adsorption compounds. New possibilities. Cupferron, tannin, arsenic acids. Oxine. pH of precipitation and of extraction. Bromatometry. Examples. Applications. Dithizone. Extraction. Sensitivity. Examples of separation utilizing the pH of complexes, oxidation-reduction, extraction. Colorimetric determinations. Various reagents.

Properties of precipitates.

Complementary to the first year course. Applications of the phenomena of adsorption and of ageing of precipitates to quantitative analysis. Purity of precipitates. Examples. Use of surface active compounds.

The separations.

By precipitation.

The classical methods of separation are treated in this chapter.

(1) Of hydroxides. Action of pH. Examples. Buffering effect of hydroxides and of salts of weak acids. Examples. pH control by means of chemical reactions; iodate-iodide; nitrite, thiosulphate, etc. pH control by means of buffer solutions, acetate, hexamethylene tetramine. In alkaline media by sodium hydroxide, by persulphate, by sodium peroxide.

(2) Precipitation of salts. Action of pH. Classical precipitations of sulphates and phosphates.

(3) With complex formation. Separation with $(\text{NH}_3 \rightarrow \text{NH}_4^+)$. Examples. Separation in tartaric, citric, and oxalic acid solutions. Examples.

By extraction.

Separation of chlorides with ether. Examples.

By electrolysis.

By distillation.

Examples: AsCl_3 , CrO_2Cl_2 .

Determination of traces.

Importance of the subject. Methods and their sensitivity. Precautions. Reagents.

Separation of traces.

By precipitation. By entrainment. By chromatography. By zeolitic exchange. By extraction. By electrolysis.

Semi-micro and micro determinations.

Utility. Apparatus and technique.

Bringing into solution.

Attack by acids, alkalis. Formation of complexes. Examples. Dry methods of attack: Na_2CO_3 , NaOH , Na_2O , $\text{K}_2\text{S}_2\text{O}_7$, $\text{S} + \text{Na}_2\text{CO}_3$, borax. Examples.

Mineralization.

(1) By the dry way. Ignition in air and oxygen, bomb. Examples. Alkaline oxidative attack.

- (2) In the wet way, H_2SO_4 , $\text{H}_2\text{SO}_4 + \text{HNO}_3$, $\text{H}_2\text{SO}_4 + \text{CrO}_3$, HClO_4 , HNO_3 .
Examples.

Gas analysis.

Physical methods, thermal conductivity, conductivity after adsorption, etc. Automatic determinations. Chemical methods. Absorption of gases, the reagents. Bunte's burette. Orsat apparatus. Mercury reservoir.

Standardized methods. Types of sample. Documentation. Analytical calculations.

PRACTICAL WORK

FIRST YEAR.

Standardization of the spectroscope and wave length curve.

Dry procedure. Tests in open and closed tubes, on the charcoal block, beads of the principle metals, beads with microcosmic salt and copper oxide, fusion on platinum foil.

Reactions on hydrolysis and the repression of ionization, solubility products, stability of complexes.

Wet procedure. Characteristic of alkalis and alkaline earths. Separation of alkaline earths. Characteristics of the metals of the Cr-Fe-Ni-Co group, of V, U, etc. Separation of these metals:

- (1) From each other.
- (2) From neighbouring groups.
- (3) In presence of silicic acid, oxalic acid, phosphoric acid.

Characteristics of the metals of the copper group. Separation of these metals:

- (1) From neighbouring groups.
- (2) From each other.

Characteristics of the arsenic group metals.

- (1) Separation from each other.
- (2) Separation from neighbouring groups.

Characteristics of the silver group metals.

- (1) Separation from each other.
- (2) Separation from neighbouring groups.

Characteristics of the principal anions, their recognition.

Disaggregation of solid products.

- (1) Attack by acids.
- (2) Fusion with alkaline carbonates or with bisulphate, after elimination of metals with easily fusible oxides. Qualitative analysis bearing on the disaggregation and characterization of the ensemble of anions and cations.

SECOND YEAR.

- (1) Sensitivity of the balance. Calibration of the box of weights.
- (2) Calibration of the 10 cc pipette and the burette. Construction of the correction curve for the latter.

- (3) Determination of potassium and sodium in a mixture of chlorides by indirect means.
Determination of the total chloride in a mixture, by gravimetry and titrimetry. Conversion to sulphate and determination of total sulphuric acid.
- (4) Determination of magnesia as pyrophosphate (gravimetric), or as ammonium magnesium phosphate (titrimetric).
- (5) Determination of ammonia by distillation, preparation of $\frac{N}{2}$ hydrochloric acid using sodium carbonate (titrimetric).
- (6) Determination of calcium.
(a) Gravimetrically as CaO .
(b) Titrimetrically as oxalate with potassium permanganate, approx. N/10.
- (7) Iron-aluminium separation.
(a) With KOH .
(b) Determination of iron by potassium permanganate, by potassium dichromate and diphenyl amine (oxidation-reduction system) or by potassium iodide and hyposulphite.
- (8) Determination of zinc.
(a) Gravimetrically as oxide.
(b) Titrimetrically, ferrocyanide method with uranium nitrate or with diphenylamine as indicator (oxidation-reduction method).
- (9) Determination of manganese.
(a) Gravimetrically, as basic salt or pyrophosphate.
(b) Titrimetrically as permanganate.
- (10) Determination of copper.
(a) Gravimetrically as sulphide, Rose's method.
(b) Titrimetrically with potassium iodide and hyposulphite.
- (11) Determination of mercury.
(a) Gravimetrically as calomel.
(b) Titrimetrically by alkali titration.
- (12) Determination of lead.
Gravimetrically as sulphate.
- (13) Determination of tin.
Gravimetrically as SnO_2 .
- (14) Determination of arsenic.
(a) Gravimetrically as magnesium pyroarsenate.
(b) Titrimetrically as arsenious acid with iodine.
- (15) Separation of arsenic and antimony.
Gravimetrically; the arsenic is precipitated as ammonium-magnesium arsenate in tartaric acid solution and converted to pyrophosphate; the antimony is precipitated as sulphide and weighed in this form after ignition.
- (16) Determination of nitrogen in organic substances, Kjeldahl's method.
- (17) Determination of chlorine in organic substances, the lime method and that of Carius.
- (18) Determination of carbon dioxide by loss of weight.
- (19) Nickel-cobalt separation.
Either by Liebig method (cyanide) or as potassium cobaltinitrite. The students determine the nickel + cobalt electrolytically and then either the nickel or the cobalt alone in the same way, after separation by one of the two methods indicated.
- (20) Determination of phosphoric acid (Copaux' method).
- (21) Determination of nitrate.
(a) Reduction by ferrous sulphate (NO).
(b) Reduction in alkaline solution (NH_3).
- (22) Determination of sulphur in a pyrite or galena or a blende.
- (23) Analysis of an anti-friction alloy.
(a) Determination of antimony by titrimetry, bromate method.
(b) Determination of tin by titrimetry (iodide and bromate).
(c) Gravimetric determination of lead.
- (24) Analysis of various minerals involving: determination of silica, the principal anions and cations.
- (25) Rapid analysis of a water, by Wartha Pfeiffer's or Blacher's method.
- (26) Analysis of a coal: ash, volatile matter and sulphur.

EQUIPMENT

GROUP 1. MACHINES AND MATERIAL.

Quantity	Item	Total cost in dollars
82	Stirrers with electric motor	3,528.00
1	Copper alambic	390.00
1	Cailletet apparatus, complete	150.00
1	Combined extraction and distillation apparatus	2,221.00
1	Electrically heated still	500.00
1	Soxhlet extraction apparatus	343.00
1	Air humidification apparatus	59.00
8	Hydrogenators, with motor	924.00
14	Autoclaves, 0.5 to 2 l, with and without stirring gear	2,446.00
1	Copper steam bath	56.00
3	Shaking machines for vessels of 15, 25 and 35 l	112.00
2	Steam baths, 5 openings	413.00
1	Ice crusher	65.00
10	Centrifuges of various types	3,534.00
1	Copper extraction pan, complete	174.00
1	Vacuum pan in iron, 60 cm diam	100.00
1	Commutator, 24 V, 2 A	25.00
1	Air compressor	41.00
15	Transmission gears for stirrers, etc.	1,124.00
38	Accumulator units	580.00
11	Electric ovens, various	1,553.00
11	Steam ovens, various	6,950.00
1	Ice-chest	233.00
1	Molecular pump assembly	267.00
1	Hand-operated slicing machine	44.00
2	Refrigerators with 1/3 HP motor	902.00
1	Electric polishing machine, complete	90.00
80	Electric motors, various	2,270.00
1	Suspended motor, foot-operated	92.00
1	Universal electric power tool	80.00
1	Small electric pump, vertical	76.00
1	Special steam trap, 25 × 55 cm	135.00
45	Rotary vacuum pumps with motors	5,026.00
1	Centrifugal pump, with 1/4 HP motor	80.00
1	Recording potentiometer, 0-10 mV, writing speed 75 cm/h	793.00
1	Meat juice extractor	63.00
1	Centrifugal blower	51.00
1	Glass-working lathe, complete	133.00
14	Transformers, various kinds	1,548.00
1	Ventilator with extractor fan	13.00
Total		37,184.00

GROUP 2. MEASURING APPARATUS.

60	Ammeters	1,084.00
1	Apparatus for measurement of dipole moments	741.00
4	Chronographs	107.00
16	Stop watches	214.00
Carry forward		2,146.00

PHYSICS AND CHEMICAL ENGINEERING

Quantity	Item	Total cost in dollars
	Brought forward	2,146.00
1	Revolution counter	35.00
1	Laboratory gas-meter	68.00
17	Universal controllers	786.00
29	Galvanometers, both mirror and pointer	1,771.00
2	Galvanometer lamps on stands	70.00
2	Oxygen cylinder pressure gauges	11.00
4	Micro-ammeters	81.00
1	Micrometer reading to $\frac{1}{1000}$ mm	98.00
11	Milliammeters	347.00
18	Millivoltmeters	1,171.00
1	Nephelometer	269.00
8	pH meters	1,456.00
1	Kohlrausch bridge, complete	74.00
4	Optical pyrometers	516.00
1	Galvanometer relay	118.00
1	Vacuum thermocouple, 15 mA	16.00
1	Electronic voltmeter	151.00
36	Voltmeters	1,188.00
	Total	10,372.00

GROUP 3. RESISTANCES.

26	Precision decade resistance boxes	1,817.00
145	Rheostats, various	1,781.00
37	Fixed resistances, various	664.00
1	Precision Wheatstone bridge	54.00
8	Potentiometers, 0-100 mV	93.00
7	Potentiometers, with Weston standard cells	686.00
	Total	5,095.00

GROUP 4. INSTRUMENTS AND APPARATUS.

3	Magnetic stirrers	143.00
8 sets	Micro-analytic combustion apparatus	1,159.00
2 sets	Cryometric apparatus	84.00
1	Extractor, 8 l	125.00
1	Micro-electrolytic apparatus	39.00
2	Orsat apparatus	49.00
5	Ozonisers, complete	977.00
1	Apparatus for micro determination of molecular weight	70.00
17	Apparatus for melting point determination	522.00
2	Tesla coils (for leak detecting)	45.00
1	Densitometer	253.00
6	Nitrometers	37.00
5	Sublimation blocks, 400 W	299.00
1	Induction coil, 15 cm spark	63.00
3	Ruhmkorff coils, 1 cm spark	79.00
7	Colorimeters with accessories	1,693.00
1	Electronic commutator	164.00
2	Absorption cells, variable	38.00
4	Spark generators	1,186.00
1	Spark generator HF	70.00
1	Pointolite lamp	93.00
2	Hydrogen lamps with accessories	456.00
1	Vibratory mixer	99.00
6	Graticules, $\frac{1}{100}$ mm divisions	522.00
6	Complete microscope hot stages	818.00
	Carry forward	9,083.00

EQUIPMENT

Quantity	Item	Total cost in dollars
	Brought forward	9,083.00
5	LF oscillators	337.00
6	CR oscilloscopes	821.00
1	Gas pipette, 1 l capacity	8.00
2	Complete photometers	972.00
1	Oil diffusion pump	160.00
1	2-stage mercury diffusion pump	135.00
1	Electrically heated drier, in glass	20.00
4	Magnetic voltage stabilizers	384.00
4	Contact thermometers, with relay	117.00
4	Precision thermostats	360.00
2	Viscosimeters	200.00
	Total	12,597.00

GROUP 5. BALANCES AND WEIGHTS.

1	Automatic balance for analysis	557.00
108	Analytic balances	5,429.00
1	Automatic balance, 3 kg	241.00
10	Taring balances	142.00
33	Table balances	1,390.00
77	Sets of weights	1,070.00
	Total	8,829.00

GROUP 6. OPTICS AND ACCESSORIES.

2	Complete apparatus for micropolarimetry	1,844.00
10	Optical benches with various accessories	849.00
6	Photoelectric cells	94.00
6	Quartz cells, with two supports	158.00
3	Arc lamps, complete	173.00
3	Magnifiers	6.00
1	Magnifying glass	26.00
2	Microphotometers	1,752.00
4	Microscopes with accessories	921.00
1	UV microscope	278.00
2	Polarizing microscopes with accessories	225.00
2	Small microscopes	14.00
7	Refractometers with accessories	1,820.00
2	Spectrographs, optical systems in glass	4,400.00
2	Spectrographs, optical systems in quartz	3,488.00
1	Spectrophotometer with accessories	380.00
2	Prism spectroscopes	233.00
2	Pocket spectroscopes	61.00
2	Grating spectroscopes, complete	364.00
1	Spinthariscopes	7.00
1	Reading telescope	37.00
1	Ultramicroscope, with accessories	423.00
	Total	17,553.00

GROUP 7. PHOTOGRAPHY AND ACCESSORIES.

1	Enlarger	129.00
1	Recording camera	138.00
1	Microscope camera	63.00
1	Photographic attachment for spectroscope	171.00
1	Electric glazer	7.00
	Total	508.00

PHYSICS AND CHEMICAL ENGINEERING

GROUP 8. PROJECTION AND CINEMA.

Quantity	Item	Total cost in dollars
1	Optical bench for projection, complete with table	365.00
1	Epidiascope on stand	253.00
	Total	618.00

GROUP 9. HEAT, ELECTRICITY, MAGNETISM, ETC.

5	Ozonizers	20.00
1	Reactance coil, with variable air gap	21.00
4	Photoelectric cells	78.00
1	Comparator for plates 25 × 10 cm	148.00
2	Sodium vapour lamps	74.00
3	Delay switches (time relays)	130.00
5	AC relays	124.00
1	Hot air blower	8.00
	Total	603.00

GROUP 10. LABORATORY INSTRUMENTS.

1	Copper alambic	49.00
1	Alambic for water	18.00
56	Electrically heated stills, complete	64.00
3	Apparatus for alkaline fusion	14.00
38	Oil baths, electrically heated	827.00
228	Water baths	1,078.00
126	Water baths, electrically heated	4,905.00
8	Metal baths, electrically heated	114.00
1	Sand bath, electrically heated	14.00
113	Steam baths	648.00
1	Copper distillation flask	8.00
113	Burette stands, complete with 2 burettes	720.00
208	Steel gas cylinders and reducing valves	2,796.00
4	Ball mills	20.00
4	Tongs, with platinum points	34.00
1,000	Burners, various	1,263.00
14	Multiple burners	115.00
4	Centrifuges	59.00
29	Blow lamps for gas	374.00
14	Galvanized pans, 50 cm diam	229.00
3	Steam pans for distillation	49.00
2	Air compressors	19.00
1	Chromium plated steel tank, 19 × 14 × 9 cm	11.00
2	Water tanks, 50 l capacity	15.00
7	Oxygen reducing valves	129.00
27	Immersion heaters	169.00
4	Electrically heated funnels	61.00
6	Copper funnels	11.00
1	Decantation funnel, 50 l, steel	99.00
26	Funnels for hot filtration	78.00
98	Gas ovens	534.00
43	Combustion furnaces	1,624.00
14	Electric furnaces, various	1,320.00
9	Mercury vapour lamps, quartz	485.00
10	Magnifying glasses	25.00
13	Cork squeezers	14.00
1	Pressure gauge, 15 atm	4.00
85	Mercury manometers	438.00
	Carry forward	18,434.00

EQUIPMENT

Quantity	Item	Total cost in dollars
	Brought forward	18,434.00
1	Ice hammer	2.00
1	Micro-mill	109.00
17	Micro burners	25.00
1	Micro heating element, 50 W	7.00
8	Micro desiccators	18.00
114	Micro supports, various	359.00
1	Agate mortar and pestle, 12 cm	13.00
1	Mortar and pestle, hardened steel, 17 mm diam	4.00
3	Mortars, in cast iron	15.00
680	Objects, various, wooden	700.00
1	Fuel pump	3.00
2	Low pressure pumps	19.00
1	Rotary pump	7.00
2	Tablet presses	9.00
300	Hot plates, electric, various	5,281.00
2	Liquid air containers	40.00
8	Dry ice storage bins	339.00
1	Copper cooler for alcohol distillation	32.00
3	Alcohol storage vessels, 50 l each	42.00
1	Oil reservoir	11.00
1	Reservoir in sheet steel, 500 l capacity	276.00
5	Sets of sieves	29.00
1	High pressure blower	44.00
1	Anti-foaming valve	23.00
1,100	Metal supports, various, 4,000 bosses, 4,000 clamps, various	6,100.00
1	Superheater for steam	7.00
1	Vibrating drum, 1 l	15.00
2	Thermoregulators	18.00
515	Tripods, various	503.00
170	Water pumps	770.00
22	Water turbines	215.00
1	Vacuum meter	9.00
3	Ventilating fans	89.00
9	Iron vacuum flasks	79.00
	Total	33,646.00

GROUP 11. TOOLS.

Tools for laboratory assistants and for the laboratory	1,228.00
Total	1,228.00

GROUP 12. MISCELLANEOUS.

1 pair	Headphones	9.00
4	Trolleys	200.00
16	Extinguishers	444.00
3	Iron drums, 160 l	80.00
1	Water-hose nozzle, with tube, on trolley	37.00
4	Gas masks	16.00
1	Pump for emptying sumps	20.00
1	Extraction pump	455.00
3	Alarm clocks	18.00
2	Hooters	10.00
	Total	1,289.00

STOCKS OF MATERIALS, CHEMICALS, ETC.

(1) ARTICLES IN PRECIOUS METALS.

Quantity	Item	Total cost in dollars
	Platinum: Bottles, distillation apparatus, flasks, cooling tubes, tube, capillary, cupels, crucibles, electrodes, boats, ladles, spatulas, cones, bars, metal gauze, sheet, wire, thin foil, etc.	
	Silver: Cupels, crucibles.	
	Fine gold.	
	Mercury.	
	Total	8,250.00

(2) GLASSWARE (per student).

(a) Analytical chemistry.

1	Marsh apparatus	.22
	Glass rods	.11
1	Beaker, 50 cc	.16
1	Beaker, 100 cc	.18
2	Beakers, 150 cc	.40
1	Beaker, 250 cc	.25
1	Beaker, 400 cc	.36
1	Funnel, 6 cm diam	.24
1	Funnel, 7 cm diam	.25
1	Funnel, 8 cm diam	.28
1	Erlenmeyer, 100 cc	.16
2	Erlenmeyers, 200 cc	.43
1	Erlenmeyer, 300 cc	.25
1	Erlenmeyer, 500 cc	.32
1	Wash bottle, 1 l	.80
	Bottles, with white enamel contents label, ground stoppers:	
4	50 cc	.53
2	100 cc	.31
14	500 cc	10.90
2	Bottles, WM for solids, 100 cc	.53
1	Bottle, WM for solids, 500 cc	.33
12	Test tubes	.32
1	Glass tube for pptn of sulphides	.11
1	Piece of cobalt glass	.11
3	Watch glasses, 6 cm diam	.17
	Total	17.72

(b) Quantitative chemistry analysis.

	Glass rods, various sizes	.22
1	FB flask, 500 cc	.29
2	FB flasks, 1,000 cc	.95
1	Measuring flask, 25 cc	.64
1	Measuring flask, 50 cc	.66
1	Measuring flask, 100 cc	.86
1	Measuring flask, 250 cc	1.07
1	Measuring flask, 500 cc	1.44
1	Measuring flask, 1,000 cc	2.14
1	RB flask, wide neck, 500 cc	.39
2	RB flasks, wide neck, 1,000 cc	1.22
2	Beakers, 250 cc	.51
2	Beakers, 400 cc	.70
1	Beaker, 600 cc	.41
	Carry forward	11.50

Quantity	Item	Total cost in dollars
	Brought forward	11.50
1	Beaker, 800 cc	.53
1	Burette, white background, 50 cc	1.92
1	Burette, blue-line, 50 cc	2.66
1	Drop counter	.22
1	Vacuum desiccator, 16 cm	5.32
2	Funnels, 6 cm diam	.49
2	Funnels, 7 cm diam	.51
1	Funnel, 8 cm diam	.28
1	Graduated cylinder, 25 cc	.31
1	Graduated cylinder, 250 cc	.81
1	Graduated cylinder, 500 cc	1.00
2	Erlenmeyers, thin wall, 25 cc	.27
2	Erlenmeyers, thin wall, 50 cc	.27
1	Erlenmeyer, thin wall, 100 cc	.15
2	Erlenmeyers, thin wall, 200 cc	.42
1	Erlenmeyer, thin wall, 300 cc	.24
1	Erlenmeyer, thin wall, 500 cc	.27
1	Erlenmeyer, thin wall, 1,000 cc	.44
1	Erlenmeyer, thin wall, 2,000 cc	.66
1	Erlenmeyer, thick wall, 100 cc	.16
2	Erlenmeyers, thick wall, 250 cc	.44
1	Erlenmeyer, thick wall, 500 cc	.27
1	Erlenmeyer, thick wall, 1,000 cc	.44
1	Erlenmeyer, vacuum, 500 cc	1.09
1	Erlenmeyer, vacuum, with tap	1.77
1	Wash bottle, 1 l	.80
4	Clear glass bottles, ground stoppers, 100 cc	.62
4	Clear glass bottles, ground stoppers, 250 cc	.88
2	Clear glass bottles, ground stoppers, 500 cc	.62
2	Clear glass bottles, ground stoppers, 1,000 cc	1.06
1	Brown glass bottle, ground stoppers, 1,000 cc	.57
1	Brown glass bottle, ground stoppers, 2,000 cc	.88
1	Weighing bottle, 30/40 mm	.76
1	Weighing bottle, 20/40 mm	.38
2	WM bottles, 50 cc	.27
2	WM bottles, 250 cc	.49
1	Fresenius, 1 bulb, 250 cc	.84
1	Fresenius, 2 bulb, 500 cc	1.06
2	Sintered glass gooch crucibles (G ³ -G ⁴)	1.86
1	Matrass, 250 cc	.31
1	Phillips, 50 cc	.20
1	Phillips, 100 cc	.24
1	Phillips, 200 cc	1.29
1	Pipette, graduated, 1 cc	.38
1	Pipette, graduated, 5 cc	.51
1	Pipette, graduated, 10 cc	.64
1	Pipette, single mark, 5 cc	.28
1	Pipette, single mark, 10 cc	.33
1	Pipette, single mark, 20 cc	.53
3	Glass plates, 20 × 20 cm	.27
1	Straight condenser, 80 cm	1.77
1	Water pump	1.27
1	Baffle tube (dusarda)	.55
12	Test tubes	.32
	Glass tubes, various diam	.33
2	Watch glasses, 5 cm diam	.09
2	Watch glasses, 6 cm diam	.10
1	Watch glass, 8 cm diam	.07
1	Watch glass, 10 cm diam	.11
	Carry forward	53.12

PHYSICS AND CHEMICAL ENGINEERING

Quantity	Item	Total cost in dollars
	Brought forward	53.12
1	Watch glass, 12 cm diam	.18
1	Watch glass, 15 cm diam	.27
	Total	53.57

(c) Organic chemistry.

5	Absorbers	.72
1	Anschutz (adapter for condenser)	.29
	Glass rods, various sizes	.66
1	RB flask, 2 neck, 250 cc	.42
1	RB flask, 2 neck, 500 cc	.50
1	RB flask, 3 neck, 500 cc	1.38
1	RB flask, 3 neck, 1,000 cc	1.66
1	RB flask, 3 neck, 2,000 cc	2.20
1	Distilling flask, 10 cc	.14
1	Distilling flask, 25 cc	.17
1	Distilling flask, 50 cc	.20
1	Distilling flask, 100 cc	.28
1	Distilling flask, 250 cc	.39
1	Distilling flask, 500 cc	.61
1	Distilling flask, 1,000 cc	.66
1	Distilling flask, 3,000 cc	1.66
1	FB flask, 100 cc	.14
1	FB flask, 250 cc	.20
1	FB flask, 500 cc	.29
1	FB flask, 1,000 cc	.48
1	FB flask, 2,000 cc	.62
1	FB flask, 3,000 cc	.73
1	Measuring flask, 25 cc	.64
1	Measuring flask, 50 cc	.66
1	Measuring flask, 250 cc	1.06
1	Measuring flask, 500 cc	1.44
1	Measuring flask, 1,000 cc	2.14
1	Flask, RB, wide neck, 50 cc	.15
1	Flask, RB, wide neck, 100 cc	.16
1	Flask, RB, wide neck, 250 cc	.25
1	Flask, RB, wide neck, 500 cc	.39
1	Flask, RB, wide neck, 1,000 cc	.61
1	Flask, RB, wide neck, 2,000 cc	.94
1	Flask, RB, long neck, 50 cc	.14
1	Flask, RB, long neck, 100 cc	.16
1	Flask, RB, long neck, 500 cc	.33
1	Flasks, RB, vacuum, 50 cc	.40
3	Flasks, RB, vacuum, 100 cc	.46
1	Beaker, 50 cc	.16
1	Beaker, 100 cc	.18
1	Beaker, 300 cc	.29
1	Beaker, 400 cc	.35
1	Beaker, 600 cc	.41
1	Beaker, 800 cc	.53
1	Beaker, 1,000 cc	.55
1	Beaker, 2,000 cc	.77
1	Beaker, 3,000 cc	1.11
1	Beaker, 5,000 cc	1.33
2	Burettes, 50 cc	4.48
1	Flask, Claisen, 10 cc	.33
1	Flask, Claisen, 25 cc	.44
1	Flask, Claisen, 50 cc	.44
1	Flask, Claisen, 100 cc	.53
	Carry forward	36.23

Quantity	Item	Total cost in dollars
	Brought forward	36.23
1	Flask, Claisen, 250 cc	.68
1	Flask, Claisen, 500 cc	.75
1	Mercury reservoir	.77
1	Distillation fractions separator	.72
1	Fractionating column	.42
1	Bubble counter	.27
6	Drop counters	.80
2	Crystallizers, 4 cm diam	.40
2	Crystallizers, 6 cm diam	.49
2	Crystallizers, 10 cm diam	.88
1	Crystallizer, 15 cm diam	.66
1	Crystallizer, 20 cm diam	1.00
1	Crystallizer, 25 cm diam	1.33
2	Vacuum desiccators, 16 cm	10.66
1	Funnel, 4 cm diam	.11
1	Funnel, 6 cm diam	.24
1	Funnel, 8 cm diam	.28
1	Funnel, 12 cm diam	.31
1	Funnel, 15 cm diam	.33
1	Funnel, 20 cm diam	.55
1	Funnel, decanting, 250 cc	1.77
1	Funnel, decanting, 500 cc	3.33
1	Funnel, decanting, 1,000 cc	4.44
1	Funnel, decanting, 2,000 cc	5.44
1	Funnel, separating, 50 cc	1.22
1	Funnel, separating, 100 cc	1.44
1	Funnel, separating, 250 cc	1.88
12	Cylinders, normal	.32
6	Cylinders, squat	.13
1	Cylinder, graduated, 5 cc	.24
1	Cylinder, graduated, 10 cc	.27
1	Cylinder, graduated, 25 cc	.31
1	Cylinder, graduated, 50 cc	.44
1	Cylinder, graduated, 100 cc	.51
1	Cylinder, graduated, 500 cc	1.00
1	Cylinder, graduated, 1,000 cc	1.50
2	Cylinders, thin glass, 25 cc	.22
6	Cylinders, thin glass, 50 cc	.80
2	Cylinders, thin glass, 100 cc	.19
5	Cylinders, thin glass, 250 cc	.77
2	Cylinders, thin glass, 500 cc	.53
1	Cylinder, thin glass, 1,000 cc	.44
1	Cylinder, thin glass, 3,000 cc	.66
1	Cylinder, thick glass, 100 cc	.16
2	Cylinders, thick glass, 250 cc	.44
2	Cylinders, thick glass, 500 cc	.53
1	Cylinder, thick glass, 1,000 cc	.44
1	Cylinder, thick glass, 2,000 cc	.66
1	Cylinder, thick glass, 3,000 cc	.77
1	Cylinder, with ground stoppers, 100 cc	.61
2	Cylinders, with ground stoppers, 200 cc	.66
1	Cylinder, with ground stoppers, 300 cc	.83
5	Cylinders, vacuum	1.55
1	Wash bottle, 1 l	.80
1	Vacuum filter flask, conical, 50 cc	.33
1	Vacuum filter flask, conical, 150 cc	.44
2	Vacuum filter flasks, conical, 250 cc	1.33
2	Vacuum filter flasks, conical, 500 cc	2.18
1	Vacuum filter flask, conical, 1,000 cc	1.33
	Carry forward	98.79

PHYSICS AND CHEMICAL ENGINEERING

Quantity	Item	Total cost in dollars	
	Brought forward	98.79	
2	Bottles, clear glass, ground stoppers, 50 cc	.27	
5	Bottles, clear glass, ground stoppers, 100 cc	.77	
2	Bottles, clear glass, ground stoppers, 200 cc	.40	
2	Bottles, clear glass, ground stoppers, 250 cc	.44	
5	Bottles, clear glass, ground stoppers, 300 cc	1.28	
5	Bottles, clear glass, ground stoppers, 500 cc	1.55	
2	Bottles, clear glass, ground stoppers, 1,000 cc	1.06	
2	Bottles, wash, 250 cc	3.11	
2	Bottles, WM, 25 cc	.24	
2	Bottles, WM, 50 cc	.27	
2	Bottles, WM, 100 cc	.33	
2	Bottles, WM, 200 cc	.43	
5	Bottles, WM, 300 cc	1.33	
2	Bottles, WM, 500 cc	.66	
1	Bottle, WM, 1,000 cc	.39	
1	Marriotte bottle (aspirator), 2,000 cc	.88	
1	Woulff bottle, 3 tubulures with tap, 500 cc	1.66	
1	Air condenser, medium	.42	
1	Air condenser, small	.31	
1	Air condenser, 100 cc	.27	
1	Air condenser, 250 cc	.31	
1	Pipette, graduated, 1 cc	.38	
1	Pipette, graduated, 5 cc	.51	
1	Pipette, single mark, 10 cc	.33	
1	Pipette, single mark, 15 cc	.41	
1	Pipette, single mark, 20 cc	.53	
1	Pipette, single mark, 25 cc	.55	
2	Necked junction pieces	.22	
1	Condenser, straight, 30 cm	1.11	
1	Condenser, straight, 80 cm	1.77	
1	Condenser, with 4 bulbs	.88	
1	Condenser, with 8 bulbs	1.32	
1	Condenser, helical, 30 cm	2.00	
1	Drying tower	.77	
2	Carius tubes	1.11	
2	CaCl ₂ tubes	.53	
2	Combustion tubes	2.04	
10	Specimen tubes	.22	
1	T piece	.11	
	Glass tubes, various sizes	.66	
	Glass tubes, for capillaries	.70	
2	Watch glasses, 6 cm	.11	
2	Watch glasses, 8 cm	.16	
1	Watch glass, 10 cm	.11	
1	Watch glass, 12 cm	.18	
1	Watch glass, 15 cm	.27	
	Total	132.15	

(3) PORCELAIN AND EARTHENWARE (per student).

(a) Qualitative analytical chemistry.

1	Capsule, 7 cm diam	.11	
1	Capsule, 9 cm diam	.16	
1	Crucible	.22	
1	Mortar and pestle, 10 cm diam	.88	
	Total	1.37	

(b) *Quantitative analytical chemistry.*

Quantity	Item	Total cost in dollars
1	Blue capsule, 16 cm diam	1.11
1	Blue capsule, 7 cm diam	.11
1	Blue capsule, 9 cm diam	.16
1	Blue capsule, 12 cm diam	.24
2	Tiles, white, 15 × 15 cm	.22
1	Crucible	.22
1	Spoon	.22
1	Buchner funnel, 6 cm diam	1.44
1	Buchner funnel, 8 cm diam	1.77
1	Buchner funnel, 12 cm diam	2.55
1	Gooch crucible	.63
1	Mortar and pestle, 10 cm diam	.88
Total		9.55

(c) *Organic chemistry.*

2	Porous plates	.20
1	Capsule, 9 cm diam	.16
1	Capsule, 12 cm diam	.24
1	Capsule, 15 cm diam	.39
1	Capsule, 20 cm diam	.50
1	Capsule, 25 cm diam	.77
1	Buchner funnel, 6 cm diam	1.44
1	Buchner funnel, 8 cm diam	1.77
1	Buchner funnel, 12 cm diam	2.55
1	Buchner funnel, 20 cm diam	3.55
1	Buchner funnel, hot, 8 cm diam	.66
1	Buchner funnel, hot, 12 cm diam	1.11
1	Mortar and pestle, 10 cm	.88
2	Filter plates	.44
1	Spatula	.22
Total		14.88

(4) RUBBER ARTICLES.

Pliable tubing of different diameters, "policemen" (rubber teats) of different sizes, sheets, turbine belts, etc. 1,000.00

(5) FILTER PAPERS, ETC.

Filter paper, folded (fluted) and flat circular papers, extraction thimbles 375.00

(6) ARTICLES IN NON-PRECIOUS METALS.

Utensils, workshop essentials, electrical equipment . . . 1,250.00

(7) VARIOUS.

Towels and clothing, asbestos, corks, material for maintenance and sundries 2,000.00

Total 4,625.00

8. CHEMICALS (120 students).

Product	Unit	CG	Quantity ¹ CA	CP	CO
Acid, acetic, cryst	kg	14	14	2	14
Acid, arsenious, pure	kg	95	1	0	0.5
Acid, arsenic, pure	g	250	250	0	0

(a) *Inorganic substances.*

¹ CG = general chemistry, CA = analytical chemistry, CP = physical chemistry, CO = organic chemistry.

PHYSICS AND CHEMICAL ENGINEERING

Product	Unit	CG	Quantity CA	CP	CO
Acid, boric, powd, pure	g	500	500	500	500
Acid, boric, AR	kg	1	1	0.5	0.5
Acid, chromic, comml	kg	2	2	1	2
Acid, chromic, cryst, pure	kg	2	2	1	2
Acid, chromic, AR	kg	0.5	0.5	0.5	0.5
Acid, hydrofluosilicic	kg	0.5	0.5	0	0
Acid, hydriodic, comml	kg	0	0.5	0	1.5
Acid, hydriodic, AR	kg	0	0	0	1
Acid, hydrobromic	l	0	2	0	4
Acid, hydrochloric, conc, comml	l	16	18	10	16
Acid, hydrochloric, conc, pure	l	30	30	10	30
Acid, hydrochloric, conc, AR	l	6	8	0	6
Acid, hydrofluoric, 40%	kg	0	2	0	0
Acid, iodic	g	0	125	0	0
Acid, molybdic, anhyd, 40%	g	0	125	0	0
Acid, nitric, conc, comml	l	12	12	4	12
Acid, nitric, conc, fuming	kg	0	0	0	3
Acid, nitric, conc, pure	l	16	18	10	16
Acid, nitric, conc, AR	l	4	8	0	0
Acid, oxalic, cryst, pure	kg	2	2	0	1
Acid, oxalic, cryst, AR	kg	2	2	0	1
Acid, perchloric, 60-70%	kg	2	2.5	0	0.5
Acid, phosphomolybdic	g	0	250	0	0
Acid, phosphoric, syrupy	kg	0	2.5	0	2.5
Acid, phosphoric, syrupy, AR	kg	0	1	0	0
Acid, picric, cryst, pure	g	0	0	0	250
Acid, pyrogalllic, resublimed, pure	kg	1	0.5	0	1
Acid, sulphuric, conc, comml	l	12	12	4	12
Acid, sulphuric, conc, pure	l	24	24	8	24
Acid, sulphuric, conc, AR	l	8	8	0	8
Acid, sulphuric, conc, fuming	l	0	0	0	4
Acid, sulphurous, in siphons		3	3	0	2
Acid, tungstic (yellow)	g	0	125	0	0
Acid, vanadic, powd, anhyd	g	0	125	0	0
Aluminium, metal, fine powd	g	0	500	0	500
Aluminium, carbide	kg	0	0	0	1
Aluminium, nitrate, pure	g	750	750	0	0
Aluminium, oxide, activated, pure	kg	0	0	0	1
Aluminium, oxide, powd, pure	g	500	500	0	0
Aluminium, sulphate, cryst, pure	g	750	750	0	0
Ammonia, d = 0.880	l	14	16	8	12
Ammonia, d = 0.880, AR	l	6	6	2	6
Ammonium, bicarbonate, pure	kg	1	1.5	0.5	0
Ammonium, bicarbonate, cryst, pure	g	500	500	500	500
Ammonium, bromide, cryst, pure	g	500	500	0	0
Ammonium, carbonate, pure	kg	2	2	0	1
Ammonium, carbonate, AR	g	500	500	500	500
Ammonium, chloride, powd, comml	kg	5	5	1	3
Ammonium, chloride, pure	kg	2.5	2.5	0	1
Ammonium, chloride, AR	kg	0.5	1	0.5	0
Ammonium, molybdate	kg	1	1	0	0
Ammonium, nitrate, cryst, pure	kg	1	1	0	0
Ammonium, phosphate, cryst, pure	kg	0.5	0.5	0	0
Ammonium, sulphate, pure	kg	1.5	1.5	0	0.5
Ammonium, sulphide, soln	l	10	10	0	0
Ammonium, thiocyanate, cryst, pure	kg	0.5	0.5	0	0
Ammonium, thiocyanate, cryst, AR	g	250	250	0	0
Ammonium, tungstate, cryst, pure	g	250	250	0	0
Antimony, sulphide, pure	kg	1,250	1,250	0	0
Antimony, trichloride, cryst, pure	g	250	250	0	0
Asbestos, Gooch	kg	0.5	1	0.25	0.25

Product	Unit	CG	Quantity CA	CP	CO
Asbestos, wool	g	250	250	250	250
Silver, nitrate, sticks	g	0	0	250	250
Silver, nitrate, cryst, AR	kg	0.5	3.5	1	0
Arsenic, pentoxide, pure	kg	0	0.5	0	0.5
Barium, carbonate, pptd, pure	kg	0.5	1	0.25	0.25
Barium, chloride, cryst, pure	kg	1.5	2	1	0.5
Barium, chloride, cryst, AR	kg	1	2	1	0
Barium, hydroxide, cryst, pure	kg	1	4	1.5	0.5
Barium, hydroxide, cryst, AR	kg	1	1.5	0.5	0.5
Barium, nitrate, cryst, AR	g	500	500	0	0
Barium, nitrite, pure	g	500	500	0	0
Barium, sulphate, pptd, pure	g	250	500	0	250
Bismuth, bromide, pure	g	0	250	0	0
Bismuth, carbonate, pure	g	250	250	0	0
Bismuth, oxychloride, pure	g	0	500	0	0
Bismuth, iodide, red, pure	g	500	500	0	0
Bismuth, nitrate, cryst, pure	g	500	500	0	0
Bismuth, sulphate, pure	kg	0	1	0	0
Borax, powd	kg	1	2	0.5	0
Borax, powd, AR	kg	0.5	2	0.5	0
Bromine, pure	kg	0.5	0.5	0.5	7.5
Cadmium, bromide, cryst, pure	g	0	500	0	0
Cadmium, chloride, cryst, pure	kg	0.5	1	0.5	0
Cadmium, nitrate	g	250	375	0	0
Cadmium, oxide	g	500	500	0	0
Cadmium, sulphate, AR	g	0	250	250	0
Cadmium, sulphide, pure	g	375	375	0	0
Calcium, acetate, pure	kg	0	0	0	1
Calcium, bromide	g	0	250	250	0
Calcium, carbonate, pptd	g	500	500	500	500
Calcium, carbonate, iceland spar	kg	0	1.5	0.5	0
Calcium, chloride, comml	kg	14	7	3.5	3.5
Calcium, chloride, pure	kg	3.5	3.5	2.5	4.5
Calcium, carbide	kg	1	0	0	1
Calcium, cyanamide	kg	0	0	0	2.5
Calcium, fluoride, powd, pure	kg	0.5	1	0.5	0
Calcium, hypochlorite, powd, pure	kg	1	1	0.5	1
Calcium, nitrate, cryst, pure	g	0	250	250	0
Calcium, oxide, powd, pure	kg	0.5	0.5	0.5	0.5
Calcium, oxide, ex marble pieces	kg	1	1.5	0.5	0.5
Calcium, phosphide	kg	0.5	0.5	0	0
Calcium, sulphate, pptd, pure	kg	0.5	0.5	0.5	0.5
Carbon, disulphide, pure	l	2	2	2	2
Chromium, acetate, cryst, pure	kg	0	1	0	0
Chromium, alum	kg	0.5	1	0.5	0
Chromium, chloride, hydrated, pure	g	0	250	0	0
Chromium, sulphate, pure	g	500	500	0	0
Cerium, chloride, pure	g	0	125	0	0
Cerium, nitrate, pure	g	0	125	0	0
Charcoal, wood	g	250	500	250	0
Cobalt, bromide, pure	g	0	500	0	0
Cobalt, chloride, pure	g	0	250	250	0
Cobalt, nitrate, pure	kg	1	1.5	0.5	0.5
Copper, foil	g	500	500	750	750
Copper, chips	kg	1.5	2	1	0.5
Copper, acetate, pure	g	0	0	250	250
Copper, bromide, pure	g	0	500	0	0
Copper, carbonate, pure	g	0	250	0	250
Copper, chloride (ic), pure	g	0	250	0	0
Copper, chloride (ous), pure	kg	1.5	1.5	0.5	0
Copper, iodide (ous), pure	g	0	250	0	0

PHYSICS AND CHEMICAL ENGINEERING

Product	Unit	CG	Quantity CA	CP	CO
Copper, nitrate, pure	kg	0	0.5	0.5	1
Copper, oxide, powd, pure	g	250	250	250	250
Copper, sulphate, cryst, AR	kg	1.5	3	0.5	2
Copper, sulphate, cryst, pure	kg	6	5	2	1
Tin, metal, foil	g	250	250	0	500
Tin, metal, gran	kg	1.5	1.5	0.5	3.5
Tin, chloride (ous), pure	kg	3	4.5	1	2
Tin, sulphide (ic)	g	0	0	0	250
Hydrogen, peroxide, 100 vol	l	1	1	1	1
Iron, wire, 35 SWG.	rolls	6	6	0	0
Iron, alum	g	500	500	0	0
Iron, ammonium sulphate, cryst, AR	kg	0.5	1	0.5	0
Iron, ammonium sulphate, cryst, pure	kg	1.5	1.5	0.5	0
Iron, trichloride, pure	kg	1	1.5	0.5	0.5
Iron, oxide (ic), powd, pure	kg	1	1	0	0
Iron, phosphate (ic)	g	0	500	0	0
Iron, sulphate (ous), cryst, pure	kg	4.5	5	1	3.5
Hydrazine, hydrate, 52% soln	g	0	0	250	250
Hydrazine, sulphate, cryst, pure	g	0	125	125	250
Hydroxylamine, hydrochloride	g	250	500	250	1,000
8-Hydroxyquinoline	g	0	250	250	0
Iodine, comml	kg	0	0	0	5
Iodine, resubl, pure	kg	2	5	2	1.5
Iodine, resubl, AR	kg	0.5	2.5	0.5	0
Lithium, carbonate, pure	g	0	500	0	0
Lithium, sulphate, pure	g	0	500	0	0
Magnesium, ribbon	g	125	125	0	0
Magnesium, powd	g	250	250	250	250
Magnesium, chips	kg	0	0	0	5
Magnesium, bromide	g	0	250	0	0
Magnesium, carbonate, heavy	g	500	500	0	0
Magnesium, chloride, cryst, pure	kg	1	1	0	0
Magnesium, nitrate, pure	g	250	250	0	0
Magnesium, oxide, light	g	500	500	0	0
Magnesium, oxide, heavy	g	500	500	0	0
Magnesium, sulphate, cryst, pure	kg	0.5	1	0.5	0
Magnesium, sulphate, anhyd, pure	kg	0	0	0	1
Manganese, carbonate, pure	g	0	500	0	0
Manganese, chloride, pure	g	500	500	0	0
Manganese, dioxide, lump	kg	3.5	3.5	0	0
Manganese, dioxide, powd	kg	5	2	0	0
Manganese, sulphate, cryst	g	500	500	0	0
Marble, chips	kg	3.5	3.5	3.5	3.5
Mercury, metal	kg	0	3.5	21	3.5
Mercury, bromide (ic), pure	g	0	500	0	0
Mercury, chloride (ic), pure	kg	1	1	1	1
Mercury, chloride (ous), pure	kg	0.5	1	0.5	0
Mercury, cyanide (ic), pure	g	0	250	0	0
Mercury, iodide (ous), yellow, pure	g	0	500	0	0
Mercury, iodide (ic), red pure	g	500	500	0	0
Mercury, nitrate (ous), cryst, pure	kg	1	2	0.5	0
Mercury, oxide (ic), red	g	0	500	0	0
Mercury, oxide (ic), yellow	kg	1	1.5	0.5	0.5
Mercury, sulphate (ic)	g	250	500	0	250
Microcosmic, salt, pure	kg	0.5	1	0.5	0
Nickel, chloride, dry, pure	g	0	500	0	0
Nickel, nitrate, pure	g	0	500	0	0
Nickel, oxide, hydrated, pure	g	0	500	0	0
Nickel, sulphate, cryst, pure	g	250	1,250	250	250
Animal, charcoal	g	250	500	250	1,000
Gold, chloride, 2% soln	g	30	0	30	0

Product	Unit	CG	Quantity CA	CP	CO
Phosphorus, red, amorphous	g	0	250	250	1,500
Phosphorus, yellow, sticks	g	250	0	250	0
Phosphorus, pentoxide, pure	g	0	250	250	500
Platinum, wire, 0.3 mm diam	m	7	7	3	0
Platinum, foil, 0.025 mm thickness	cm ²	225	450	225	0
Platinum, chloride, solid	g	0	1	4	1
Lead, acetate, cryst, pure	kg	2	5	0.5	0.5
Lead, acetate, cryst, AR	kg	2	5	1	0
Lead, bromide, pure	g	0	500	0	0
Lead, carbonate, pptd, pure	g	500	500	500	500
Lead, chromate, powd, pure	g	500	500	0	0
Lead, dioxide, pure	g	0	0	0	500
Lead, nitrate, cryst, pure	kg	1	1.5	0.5	0.5
Lead, nitrate, cryst, AR	kg	1.5	1.5	0.5	0
Lead, oxide (litharge), pure	g	500	500	500	500
Lead, oxide (red lead), pure	kg	2	2	0.5	0.5
Pumice, pieces	kg	0	0.5	0.5	1
Pumice, gran	kg	0	1	0.5	0.5
Potassium, acetate, anhyd, pure	kg	0	0.5	0.5	1
Potassium, antimoniate, pyro	g	250	250	0	0
Potassium, arseniate, pure	g	250	250	0	0
Potassium, arsenite, pure	g	250	250	0	0
Potassium, bicarbonate, pure	kg	1	1	0	0
Potassium, dichromate, cryst, pure	kg	3.5	3.5	1.5	3.5
Potassium, dichromate, cryst, AR	kg	1.5	2	1.5	0
Potassium, bisulphate, pure	kg	0.5	0.5	0.5	0.5
Potassium, bitartrate, pure	kg	0	0	0	0.5
Potassium, bromate, cryst, pure	kg	1	1.5	1	0
Potassium, bromate, cryst, AR	kg	0	1	1	0
Potassium, bromide, cryst, pure	kg	1.5	4.5	1	3.5
Potassium, bromide, cryst, AR	kg	0	2.5	1	0
Potassium, carbonate, anhyd, pure	kg	0	0.5	0.5	2.5
Potassium, chlorate, cryst, pure	kg	0.5	5	1	3.5
Potassium, chloride, cryst, pure	kg	0	0.5	0.5	0
Potassium, chromate, cryst, pure	kg	1	2	0.25	0.25
Potassium, chromate, cryst, AR	kg	1.5	1.5	0.5	0
Potassium, cyanide, 90-95%	kg	1	1	0.5	1
Potassium, cyanide, AR	kg	0	1	1	0
Potassium, cyanide, double salt	kg	1	2	1	1
Potassium, ferricyanide, cryst, pure	kg	1.5	2	0	0.5
Potassium, ferricyanide, cryst, AR	kg	1	1	0	0
Potassium, ferrocyanide, cryst, pure	kg	1.5	2	0	0.5
Potassium, ferrocyanide, cryst, AR	kg	1	1	0	0
Potassium, fluoride, pure	kg	0.5	0.5	0	0
Potassium, phthalate, pure	g	250	500	250	0
Potassium, phthalate, AR	g	250	500	0	250
Potassium, hydroxide, pellets, pure	kg	2	6	3	3
Potassium, hydroxide, pellets, AR	kg	0	2.5	1	0
Potassium, iodate	g	0	375	375	0
Potassium, iodide, cryst, pure	kg	3.5	5	1	1
Potassium, iodide, cryst, AR	kg	1	2.5	0	0
Potassium, metabisulphite, powd, pure	kg	1.5	2	1.5	0
Potassium, nitrate, cryst, pure	kg	1	1	0	1.5
Potassium, nitrite, cryst, pure	kg	0.5	1.5	0	0
Potassium, periodate, AR	kg	0	0.5	0	0
Potassium, permanganate, pure	kg	3	5	2	2
Potassium, permanganate, AR	kg	1	2.5	0.5	0
Potassium, persulphate, pure	kg	0	0.5	0.5	0
Potassium, sulphate, cryst, pure	kg	0	0.5	0.5	0
Potassium, thiocyanate, cryst, pure	kg	1	1.5	0.5	0
Potassium, thiocyanate, cryst, AR	kg	1	1	0.5	0

PHYSICS AND CHEMICAL ENGINEERING

Product	Unit	CG	Quantity CA	CP	CO
Potassium, tungstate, ...	g	0	250	0	0
Potassium, uranate	g	0	250	0	0
Quinhydrone	g	0	0	250	0
Sand, silver	l	8	8	8	16
Selenium, metal, powd	g	0	250	250	0
Semicarbazide, hydrochloride	g	0	250	250	500
Silica, pptd, pure	g	500	500	500	0
Silica, gel, white	g	500	500	50	500
Silica, gel, indicator	kg	0	2	1	0.5
Soap, Wanklyn's solution	l	0	4	4	0
Sodium, metal, pure	kg	0	0.5	0.5	4
Sodium, acetate, cryst, pure	kg	1	2	1	1
Sodium, acetate, anhyd	kg	0	1	1	1.5
Sodium, arseniate, pure	kg	0.5	1	0	0
Sodium, arsenite, pure	kg	0.5	1	0	0
Sodium, diborate, pure	kg	1	1.5	0.5	0.5
Sodium, diborate, AR	kg	0.5	1	0.5	0
Sodium, bicarbonate, pure	kg	0.5	3	0.5	1
Sodium, bicarbonate, AR	kg	0.5	1	0.5	0
Sodium, dichromate, cryst, pure	kg	1	1	1	4
Sodium, bisulphate	kg	0	0.5	0	0.5
Sodium, bisulphite, pure	kg	2	3	0.5	5
Sodium, borate	g	250	500	250	0
Sodium, bromate, cryst	kg	0.5	2	1	0
Sodium, bromide	kg	0	0.5	0	0
Sodium, carbonate, cryst	kg	7	7	7	7
Sodium, carbonate, anhyd	kg	6	6	1	1
Sodium, carbonate, AR	kg	1	2	0.5	0
Sodium, chlorate, cryst, pure	g	0	0.5	0.5	1
Sodium, chloride, cryst, pure	kg	1.5	2.5	0.5	0.5
Sodium, chloride, cryst, AR	kg	0	1.5	0.5	0
Sodium, chromate, pure	kg	0.5	0.5	0	0
Sodium, cobaltinitrite, soln	l	2	2	0	0
Sodium, cobaltinitrite, solid	g	0	375	0	250
Sodium, cyanate, pure	g	0	0	0	250
Sodium, cyanide, pure	kg	0	0	0.5	1
Sodium, fluoride, pure	kg	0	0.5	0	0
Sodium, formate, pure	kg	0	0	0	1
Sodium, hydrosulphite	kg	0	1.5	0	3.5
Sodium, hydroxide, powd, comml	kg	4	6	3	10
Sodium, hydroxide, pellets, pure	kg	4	6	2	2
Sodium, hydroxide, pellets, AR	kg	2	6	3	3
Sodium, hypochlorite, soln	l	0	2	0	4
Sodium, iodate, pure	kg	1	2	0.5	0
Sodium, iodide	kg	0	1	0	0
Sodium, molybdate	g	0	250	0	0
Sodium, nitrate, cryst, pure	kg	1	1	1	0.5
Sodium, nitrate, cryst, AR	kg	0	1	0	0
Sodium, nitrite, cryst, pure	kg	4	5	2	3
Sodium, nitrite, cryst, AR	kg	0	1	0	0
Sodium, nitroprussiate, pure	g	0	125	0	125
Sodium, oxalate, AR	kg	2	2	0.5	0.5
Sodium, perchlorate, pure	kg	0	1	0	0
Sodium, potassium, tartrate	kg	0	0	1	2.5
Sodium, phosphate, acid	kg	1.5	2	0	0
Sodium, silicate, soln	kg	0	1	1	0
Sodium, succinate	g	0	0	0	250
Sodium, sulphate, cryst, pure	kg	0.5	1	0.5	0
Sodium, sulphate, anyd, pure	kg	0	1.5	1.5	4
Sodium, sulphide, cryst, pure	kg	1	2	1	1
Sodium, sulphite, cryst, pure	kg	2	2.5	1.5	1

Product	Unit	CG	Quantity CA	CP	CO
Sodium, thiosulphate, cryst, pure	kg	3.5	3.5	3.5	3.5
Sodium, thiosulphate, cryst, AR	kg	1.5	1.5	0.5	0
Sodium, tungstate, pure	g	0	250	0	0
Soda lime	kg	1.5	1.5	1.5	1.5
Strontium, carbonate, pptd, pure	kg	0.5	0.5	0	0
Strontium, nitrate, cryst, pure	kg	0.5	0.5	0	0
Sulphur, flowers	kg	1	0.5	0	0
Sulphur, sticks	kg	2	2	1	0
Sulphuryl, chloride	kg	0	0	0	1
Thallium, nitrate, pure	g	0	125	0	0
Thorium, nitrate, pure	g	250	250	0	0
Titanium, oxide, pure	g	0	250	0	0
Titanium, tetrachloride	kg	0	1	0	0
Tombac, leaf	book	4	2	0	0
Uranium, acetate, pure	g	0	250	0	0
Uranium, nitrate, pure	g	0	250	0	0
Uranium, oxide, yellow, pure	g	0	250	0	0
Vaseline, yellow	kg	1	1	1	0.5
Vaseline, white	kg	0.5	0.5	0.5	0.5
Wax, paraffin	kg	0	0	2	5
Zinc, metal, powd	kg	0.5	1	0.5	3
Zinc, metal, gran	kg	3.5	7	0	3.5
Zinc, metal, sticks	kg	0.5	2	1	0
Zinc, acetate, pure	kg	0	0.5	0.5	0
Zinc, bromide, pure	g	0	250	250	0
Zinc, carbonate, pure	kg	0.5	0.5	0	0
Zinc, chloride, sticks	kg	0	0.5	0	0
Zinc, nitrate, pure	kg	0	0.5	0	0
Zinc, oxide	kg	0.5	1	0	0
Zinc, sulphate, cryst, pure	kg	0.5	0.5	0.5	0.5
Zinc, sulphate, cryst, AR	kg	0	1	0	0

(b) Organic compounds.

Acid, acetic, anhyd, pure	kg	0	0	0	3.5
Acid, acetylsalicylic, pure	kg	0	0	0	0.5
Acid, adipic, pure	kg	0	0	0	1
Acid, aminoacetic	g	0	0	0	125
Acid, m-aminobenzoic	g	0	0	0	125
Acid, anisic, pure	g	0	0	0	250
Acid, anthranilic, comml	kg	0	0	0	1
Acid, anthranilic, pure	g	0	0	0	250
Acid, benzoic, synthetic, pure	kg	0	0	0.5	3
Acid, n-butyric, pure	g	0	0	0	250
Acid, carbolic, pure	kg	0	0	0	2
Acid, chloroacetic, pure	kg	0	0	0	3.5
Acid, chlorobenzoic, o-	g	0	0	0	30
Acid, chlorobenzoic, p-	g	0	0	0	30
Acid, chlorosulphonic	kg	0	0	0	1
Acid, cinnamic	kg	0	0	0	0.5
Acid, citric	g	0	0	250	750
Acid, crotonic	g	0	0	0	250
Acid, 3:5 dinitrobenzoic	kg	0	0	0	1
Acid, formic, d = 1.2	kg	0	0	0	2
Acid, fumaric, pure	kg	0	0	0	0.5
Acid, gallic	kg	0	0	0	0.5
Acid, lactic	kg	0	0	0	0.5
Acid, maleic	g	0	0	0	250
Acid, maleic, anhyd	kg	0	0	0	0.5
Acid, malonic	kg	0	0	0	0.5
Acid, naphthionic	g	0	0	0	250
Acid, nitrobenzoic	g	0	0	0	125

PHYSICS AND CHEMICAL ENGINEERING

Product	Unit	CG	Quantity CA	CP	CO
Acid, nitrobenzoic, m-	g	0	0	0	125
Acid, nitrobenzoic, p-	g	0	0	0	125
Acid, oleic, pure	kg	0	0	0	2.5
Acid, palmitic	g	0	0	0	250
Acid, phthalic, cryst	kg	0	0	0	0.5
Acid, phthalic, anhyd	kg	0	0	0	2
Acid, propionic	kg	0	0	0	0.5
Acid, propionic, anhyd	g	0	0	0	250
Acid, salicylic, synthetic, pure	kg	0	0	0.5	1.5
Acid, stearic, pure	kg	0	0	0.5	2
Acid, succinic, cryst, AR	g	0	0	0	250
Acid, sulphanilic, pure	g	0	0	0	250
Acid, tannic	kg	0	0	0	0.5
Acid, tartaric, cryst	kg	0.5	0.5	0.5	3.5
Acenaphthene	g	0	0	0	250
Acetal	g	0	0	0	250
Acetaldehyde, pure	kg	0	0	0	1
Acetamide, pure	kg	0	0	0	1
Acetic, ether, pure	kg	0	0	0	3.5
Acetone	l	4	2	4	30
Acetonitrile	g	0	0	0	250
Acetophenone	kg	0	0	0	1
Aceto-o-toluidine	g	0	0	0	250
Acto-p-toluidine	g	0	0	0	250
Acetyl, chloride, pure	kg	0	0	0	3
Alcohol, allyl	kg	0	0	0	1
Alcohol, isoamyl	l	0	0	0	2
Alcohol, tertiary, amyl	g	0	0	0	0.5
Alcohol, tertiary, amyl, pure	kg	0	0	0	250
Alcohol, benzyl	kg	0	0	0	0.5
Alcohol, butyl	l	0	0	0	2
Alcohol, butyl, secondary	kg	0	0	0	0.5
Alcohol, butyl, tertiary	l	0	0	0	2
Alcohol, diacetone	l	0	0	0	2
Alcohol, ethyl	l	8	8	16	88
Alcohol, ethyl, absolute	l	0	8	16	72
Alcohol, methyl	l	0	4	12	16
Alcohol, propyl, pure	kg	0	0	0	2
Alcohol, isopropyl	kg	0	0	0	2
Allyl, bromide	kg	0	0	0	0.5
Alumina	kg	0	0	0	0.5
Amalgam, sodium, 8%	kg	0	0	0	2
Aminoazobenzene	g	0	0	0	125
Amyl, acetate, pure	kg	0	0	0.5	0.5
Amyl, nitrite, pure	kg	0	0	0	0.5
Aniline, pure	l	0	0	0	6
Anisole	g	0	0	0	250
Anthracene, pure	kg	0	0	0	2.5
Anthraquinone, pure	kg	0	0	0	1.5
Benzene, hexachlor	kg	0	0	0	1
Benzaldehyde	l	0	0	0	2
Benzamide	kg	0	0	0	0.5
Benzanilide	g	0	0	0	250
Benzene, crystallizable	l	2	2	6	40
Benzene, for MW detn	l	0	0	3	3
Benzidine	kg	0	0	0	1
Benzidine, pure	kg	0	0	0	0.5
Benzonitrile	kg	0	0	0	0.5
Benzophenone	kg	0	0	0	0.5
Benzoylchloride	kg	0	0	0	3.5
Benzyl, acetate	kg	0	0	0	1

Product	Unit	CG	Quantity CA	CP	CO
Borneol	g	0	0	0	250
Bromacetanilide, p-	kg	0	0	0	0.5
Bromobenzene	kg	0	0	0.5	1.5
Bromophenacyl, p-, bromide	g	0	0	0	250
Butyl, bromide	kg	0	0	0	1
Butyl, benzoate	g	0	0	0	250
Butyl, phthalate	l	0	0	0	2
Camphor	kg	0	0	2	1.5
Carbanilide	g	0	0	0	250
Carbon, tetrachloride, pure	l	0	0	2	6
Chloral, hydrate	kg	0	0	0	0.5
Chloramine T	kg	0	0	0	0.5
Chlorobenzene	l	0	0	0	2
Chlorodinitrobenzene 1 : 2 : 4	kg	0	0	0	1
Chloroform	l	0	0	2	6
Chloronitrobenzene, o-	kg	0	0	0	0.5
Cinnamaldehyde	g	0	0	0	250
Collodion, acetone	kg	0.5	0.5	0.5	0.5
Cresol, o-	kg	0	0	0	0.5
Cresol, m-	kg	0	0	0	0.5
Cresol, p-	kg	0	0	0	0.5
Crotonaldehyde	kg	0	0	0	1
Cyclohexane, pure	l	0	0	0	2
Cyclohexane, pure	kg	0	0	0	0.5
Cyclohexanol	kg	0	0	0	5
Cyclohexanone	kg	0	0	0	3.5
Cymene, p-	kg	0	0	0	0.5
Dextrose, anhyd, powd	kg	0.5	0.5	0.5	1
Dichlorobenzene, o-, pure	kg	0	0	0	0.5
Dichlorobenzene, p-, pure	kg	0	0	0	0.5
Dichlorethylene	kg	0	0	0	2.5
Diethylamine, pure	g	0	0	0	250
Diethylaniline, pure	kg	0	0	0	2
Dimethylaniline	kg	0	0	0	2
Dimethylglyoxine	g	0	125	0	0
Dimethylsulphate	kg	0	0	0	3.5
Dinitrobenzene, m-	kg	0	0	0	1
Dinitrophenylhydrazine 2 : 4	g	0	0	0	250
Dioxane	kg	0	0	0	5
Diphenylamine	kg	0	0	0	0.5
Ether, d = 0.730	l	0	0	0	72
Ether, d = 0.720	l	0	0	0	48
Ethyl, acetate	kg	0	0	0	3.5
Ethyl, acetoacetate	kg	0	0	0	1
Ethyl, aniline, pure	kg	0	0	0	1
Ethyl, benzoate, pure	kg	0	0	0	1
Ethyl, bromide, pure	kg	0	0	0	2
Ethyl, iodide, pure	kg	0	0	0	3.5
Ethyl, malonate, pure	kg	0	0	0	1.5
Ethyl, oxalate, pure	kg	0	0	0	1
Ethyl, phthalate, pure	kg	0	0	0	1
Ethyl, succinate, pure	g	0	0	0	250
Ethylene, dibromide, pure	kg	0	0	0	2
Ethylene, dichloride, pure	kg	0	0	0	2
Ethylene, disulphate, pure	kg	0	0	0	1
Ethylene, glycol, pure	kg	0	0	0	2
Ethylene, oxide, pure	g	0	0	0	250
Formaldehyde	l	0	0	0	6
Furfural	kg	0	0	0	0.5
Gelatine, leaf	g	0	0	250	0
Glycerol	l	0	1	1	6

PHYSICS AND CHEMICAL ENGINEERING

Product	Unit	CG	Quantity CA	CP	CO
Glycine	g	0	0	0	250
Heptane, n-	kg	0	0	0	1
Hexamine	kg	0	0	0	0.5
Hydrazobenzene	g	0	0	0	125
Hydroquinone	kg	0.5	0.5	0.5	1.5
Inulin	g	0	0	0	125
Iodobenzene	g	0	0	0	250
Iodoform, cryst	g	0	0	0	125
Isatin	g	0	0	0	30
Kaolin	kg	2	0	0	2
Kieselguhr	kg	2	0	0	2
Lactose	kg	0	0	0	0.5
Laevulose	kg	0	0	0	0.5
Magenta	g	0	0	0	125
Maltose	kg	0	0	0	0.5
Mannitol	kg	0	0	0	0.5
Mesityl, oxide	kg	0	0	0	1
Metaldehyde	kg	0	0	0	2.5
Methyl, acetate	kg	0	0	0	0.5
Methyl, iodide	kg	0	0	0	3.5
Methyl p-nitrobenzoate	g	0	0	0	125
Methyl oxalate	kg	0	0	0	0.5
Methylamine, 33% soln	g	0	0	0	250
Methylaniline	kg	0	0	0	1
Methyl ethyl ketone	l	0	0	0	2
Methyl, salicylate	kg	0	0	0	0.5
Naphthalene	kg	0	0	0	3.5
Naphthol, α , pure	kg	0	0	0	2.5
Naphthol, β , pure	kg	0	0	0	2.5
Naphthylamine, α , pure	kg	0	0	0	1
Naphthylamine, β , pure	kg	0	0	0	1
Nitroaniline, o-, pure	kg	0	0	0	0.5
Nitroaniline, m-, pure	kg	0	0	0	0.5
Nitroaniline, p-, pure	kg	0	0	0	0.5
Nitrobenzaldehyde, o-, pure	g	0	0	0	250
Nitrobenzaldehyde, m-, pure	g	0	0	0	250
Nitrobenzaldehyde, p-, pure	g	0	0	0	125
Nitrobenzene, pure	l	0	0	0	6
Nitrotoluene, o-	kg	0	0	0	2
Nitrotoluene, m-	kg	0	0	0	0.5
Nitrotoluene, p-	kg	0	0	0	2
Oxamide	g	0	0	0	250
Paraffin, liquid	l	0	0	0	2
Paraffin, liquid, for melting points	l	0	0	0	12
Paraldehyde	l	0	0	0	4
Petrol, ether, b.p. 40-60° C	l	0	0	0	8
Petrol, ether, b.p. 60-80° C	l	0	0	0	16
Petrol, ether, b.p. 80-100° C	l	0	0	0	8
Petrol, ether, b.p. 100-120° C	l	0	0	0	8
Phenacyl, bromide	g	0	0	0	125
Phenetidine	g	0	0	0	125
Phenol	kg	0	0.5	1	8.5
Phenyl, benzoate	g	0	0	0	125
Phenylenediamine, m-, pure	g	0	0	0	250
Phenylenediamine, p-, pure	g	0	0	0	250
Phenylhydrazine	kg	0	0	0	1
Phenylhydrazine, hydrochloride	kg	0	0	0	1
Phthalimide	kg	0	0	0	0.5
Piperidine	g	0	0	0	125
Propionaldehyde	g	0	0	0	250
Propyl, bromide	kg	0	0	0	0.5

Product	Unit	CG	Quantity CA	CP	CO
Pyridine, pure	l	0	0	0	4
Pyrocatechol	g	0	0	0	250
Pyrogallol	kg	0.5	1.5	0.5	2.5
Quinoline	kg	0	0	0	0.5
Quinone	g	0	0	0	125
Resorcinol	kg	0	0	0	2
Salol	g	0	0	0	250
Scolamide	kg	0	0	0	1
Sodium benzene, sulphonate	kg	0	0	0	2.5
Sucrose	kg	0	0	3	0.5
Tetrachlorethane	kg	0	0	0	2.5
Tetrachlorethane, pure	kg	0	0	0	2.5
Tetrahydronaphthalene	kg	0	0	0	2.5
Tetrahydronaphthalene, dist	kg	0	0	0	1
Thionyl, chloride	kg	0	0	0	5
Toluidine, o-, pure	kg	0	0	0	2
Toluidine, m-, pure	kg	0	0	0	1
Toluidine, p-, pure	kg	0	0	0	2
Toluene	l	0	0	2	8
Trichlorethylene	kg	0	0	0	2.5
Trichlorethylene, pure	kg	0	0	0	1
Urea	kg	0	0	0.5	1.5
Urethane	g	0	0	0	250
Xylene	kg	0	0	0.5	1.5

(c) *Buffer Solutions.*

Citric, acid, AR	g	0	250	250	750
Potassium, acid, phosphate, AR	kg	0	1	0	0
Potassium, acid, phthalate, AR	g	0	750	250	0

(d) *Indicators.*

Acid, rosolic	g	10	30	10	0
Bromocresol green	g	0	2	0	0
Bromocresol purple	g	1	3	1	0
Bromophenol blue	g	10	10	20	0
Bromothymol	g	10	10	20	0
Chlorophenol red	g	0	15	0	0
Congo red	g	10	10	10	70
Cresol m-, purple	g	0	2	0	0
Cresol n-, purple	g	0	1	1	0
Cresol o-, red	g	1	3	1	0
Methyl orange	g	125	250	125	0
Methyl red	g	10	20	10	10
Phenolphthalein	g	60	60	60	60
Phenol red	g	1	3	1	0
Thymol blue	g	1	3	1	0

(e) *Liquefied or compressed gases in cylinders.*

Ammonia	3.5 kg	0	1	0	1
Nitrogen	1,000 l	0	0	1	1
Chlorine	1.75 kg	1	1	0	1
Carbon, dioxide	7 kg	1	0	1	0
Carbon, dioxide	14 kg	0	1	0	1
Sulphur, dioxide	1.75 kg	1	2	1	2
Hydrogen	1,000 l	1	1	1	1
Methyl, chloride	1 kg	0	0	1	1
Ethylene, oxide	1.75 kg	0	0	0	1
Oxygen	1,000 l	1	1	1	1
Phosgene	1.75 kg	0	0	0	1

Total 4,500.00

SECOND PART

PHYSICAL CHEMISTRY
ELECTRO CHEMISTRY

PHYSICAL CHEMISTRY

SYLLABUS

(given only as an example to facilitate the use of the inventories)

GENERALITIES CONCERNING THE APPLICATIONS OF THERMODYNAMICS TO CHEMISTRY.

Definition of chemical affinity; direction of reactions and equilibrium conditions. Revision of the principal thermodynamic functions and their variations with temperature and pressure or volume. Influence of composition; partial molar magnitudes.

Chemical potentials; fundamental properties. General conditions of physico-chemical equilibrium and direction of transformations. Examples of applications to changes of state. Gibbs-Duhem relation. Variations of chemical potentials with temperature, pressure, composition.

General equations of chemical equilibrium. Laws of equilibrium displacement. Phase rule.

First order transformation and Clapeyron's equations, crystalline allotropy, enantiotropy, monotropy; mesomorphous states. Second order transformations and Ehrenfest's equations.

CHEMICAL REACTIONS IN THE GASEOUS PHASE.

Law of mass action. Various equilibrium constants. Determination of equilibrium constants.

Chemical equilibria at high pressures and with imperfect gases. Idea of transience; its determination; Gillespie relation. Example of the synthesis of ammonia.

Influence of temperature on the equilibrium constants. Application to the calculation of heats of reaction. Integration constant and problem of the prediction of equilibrium constants.

REVISION OF THERMOCHEMISTRY.

Heats of reaction; influence of temperature and pressure. Determination of heats of reaction. Heat of formation. Binding energy.

Heat capacity of gases. Classical values of the translational and rotational terms; influence of temperature on the vibrational term; Einstein function. Review of the heat capacity of solids, Einstein and Debye functions.

Nernst theorem. Examples of its application to the study of equilibria in the condensed phase. Evaporation of a pure crystal and chemical constants. Calculation of the integration constant from chemical constants for chemical equilibria in a gaseous system.

Third law of thermodynamics; verifications. Calculation of equilibrium constants from entropies. Methods of approximation. Nernst formula of approximation.

Some examples of calculation of equilibria in the gaseous phase.

IDEAS OF STATISTICAL THERMODYNAMICS.

Relation between entropy and probability deduced from the expansion of perfect gases.

Maxwell-Boltzmann law of statistical distribution. Function of distribution or sum of states. Expressions for the principal thermodynamic functions. Boltzmann theorem. Bose-Einstein and Fermi-Dirac law of statistical distribution; classical limit.

Application to the case of perfect gases. Calculation of quantum levels of translation of the principal functions of thermodynamics. Sum of rotational states and terms of rotation for di-atomic molecules. Consideration of nuclear spins; ortho-hydrogen, parahydrogen. Sum of the state of vibration and vibrational terms.

Results of the application of statistical methods to liquids; strictly regular, perfect, ideal dilute solutions.

LIQUID MIXTURES, SOLUTIONS.

Interest of partial molar magnitudes. Partial molar volumes; their determination. Total and partial heats of solution.

Chemical potentials of the constituents of solutions. Ideal and non-ideal case. Concept of activity; activity co-efficients. Their variations with temperature and pressure; semi-ideal solutions. Entropy of mixture and regular solutions. Case of very dilute solutions.

Vapour pressure of constituents of a liquid mixture, and total vapour pressure. Perfect mixtures. Positive and negative deviations. Application to the determination of activity co-efficient. Justification of demixtion in the case of strictly regular solutions; critical solution temperatures. Theorem of the existence of a maximum and minimum when two phases in equilibrium have the same compositions. Thermodynamics of azeotropy; case of strictly regular solutions.

Boiling point of solvents; applications of ebullioscopy. Solubility of gases in liquids. Freezing of solvents; applications of cryoscopy. Solubility of solids in liquids; calculation of the eutectic temperature in the ideal case; regular solutions. Solutions of the same solute in two immiscible solvents.

Osmotic pressure; general thermodynamic expression; Van't Hoff's law. Applications.

General expression of the law of mass action in terms of activities. Influence of temperature and of dilution. Examples of chemical equilibria for reactions in the liquid phase.

SOLUTION OF ELECTROLYTES.

Degrees of ionization; their determination. Revision of classical methods; migration of ions and transport numbers weak electrolytes, strong electrolytes.

Activities of electrolytes, ionic activities, mean activity. Results of experimental determinations; concept of ionic strength. Calculation of ionic activity coefficients by the theory of Debye and Huckel.

Application of the law of mass action to ionic equilibria; ionization, acidity, basicity constants; variations of these constants with temperature, and heats of ionization. Acidity and basicity of solutions; effects of salts; hydrolysis of salts; buffer effect. Ampholytes; mixed ions; isoelectric point. Solubility product; application to the determination of activity coefficients.

APPLICATION OF MEASUREMENTS OF ELECTROMOTIVE FORCES TO THE STUDY OF EQUILIBRIA.

Electromotive force of reversible cells and free energy of reactions. Influence of temperature and concentrations. Application to the determination of activities of electrolytes.

Concentration cells without liquid junction. Concentration cells with liquid junction; application to the determination of transport numbers. Liquid junction potential.

Electrode potentials; so-called potentials of metals, of metalloids, of oxidation-reduction. Reference electrodes.

Determination of normal potentials of electrodes; relative entropies of ions. Oxidation-reduction in hydrogen-exchange systems, non ionized or ionized. Review of applications to chemistry and biology.

SURFACE PHENOMENA, CAPILLARY AND COLLOIDAL CHEMISTRY.

Properties of liquid surfaces. Surface tension, surface free energy. Vapour pressure over curved surfaces. Influence of temperature, parachor. Interfacial tension between liquids; work of adhesion and work of cohesion. Conditions for spreading.

Properties of insoluble surface films; surface pressure and potential. Different types of surface films.

Surface tensions of aqueous solutions; capillary active bodies. Gibb's theorem on adsorption; its quantitative variations. Foams, foaming agents. Emulsions, emulsifying agents; inversion of emulsions.

Properties of solid surfaces. Work of adhesion between solids and liquids; angles of contact. Wetting, wetting agents. Flotation, emulsification by powders.

Adsorption by solid surfaces; physical adsorption and chemisorption. Adsorption isotherms of gases; monomolecular layers and Langmuir formula; multimolecular layers and the theory of Brunauer, Emmett and Teller. Adsorption of dissolved substances; polar adsorption; exchange adsorption: film lubrication.

Suspensions; stability. Flocculation by electrolytes, valency rule.

COLLOIDS.

Definition and classification. Preparation of colloidal solutions. Dialysis, ultrafiltration. Optical properties of colloidal solutions. Electrical properties. Coagulation, peptization, protection, sensitization.

Macromolecular solutions; viscosity. Phenomena of swelling; coacervation. Determination of the size of particles or macromolecules.

CHEMICAL KINETICS.

Homogeneous reactions. Influence of concentrations. Order of reactions and methods of determination. Influence of temperature, Arrhenius equation, energy of activation. Bi-molecular reactions and the theory of activation by collision. Theory of activated complexes or transition states. Trimolecular reactions. Monomolecular reactions and Lindemann theory.

Mechanism of chemical reactions; overall reactions. Intermediate products; atoms and free radicals. Kinetic schemes.

Chain reactions; unbranched chains, and branched chains. Principal results of the theory of Semenov; influence of walls, of temperature, of degree of advance. Application to combustion reactions; regions of inflammability; anti-knocks. Polymerization reactions.

Homogeneous reactions in solutions.

Heterogeneous reactions; role of nuclei and diffusion. Dissolution of solids in liquids; corrosion of metals and chemical passivation.

Catalysis. Characteristics; modes of action of catalysts. Examples of homogeneous catalysis in the gaseous phase and in solution. Acid-base catalysis. Auto-oxidation and anti-oxidants. Heterogeneous catalysis and activated adsorption; active centres; promoters, inhibitors.

Photochemistry. Laws of photochemistry; quantum yield. Activation and dissociation of molecules by absorption of light. Examples of photochemical reactions. Chemiluminescence.

STRUCTURE OF MOLECULES AND OF CHEMICAL BONDS.

Review of state of knowledge of the structure of the atom. The Bohr-Sommerfeld atom; quantum numbers. The atom in wave mechanics, hydrogen atom, atoms with several electrons. s-electrons, p-electrons. Pauli's principle. Vectorial model of the atom and atomic states. Energy of ionization and electronic affinity. Volumes of atoms and ions.

Generalities concerning the chemical bond. Polar bonds and salts. Bond energies of molecules and ionic crystals. Co-ordination number of complex.

Non-polar bonds; covalency and co-ordination bonds. Exchange forces in wave mechanics. Method of electronic doublets; Heitler and London theory of the hydro-

gen molecule. Method of molecular orbits; τ -electrons, π -electrons; correlation diagrams. Pauling and Slater's generalization of the Heitler and London method; directed bonds; hybridization; the case of carbon. Mesomery, the case of carbon monoxide and benzene.

Methods of study of the structure of molecules. Review of the results of X-ray or electron diffractions. Spectral properties of molecules, rotation spectra, vibration-rotation spectra, electronic spectra. Electronic states of molecules and their symbolization. Raman effect. Applications of spectral studies; moments of inertia, form and dimensions of molecules; bond-angles; internal vibrations of molecules and their constitution. Continuous spectra; dissociation of molecules by vibration; energy of dissociation; pre-dissociation. Ideas on the absorption of light by liquids and solutions; ideas of chromophoric groups. Fluorescence, phosphorescence.

Electric properties of the atom and molecule. Electrical polarization and dipole moments. Atomic and molecular refraction.

Magnetic properties of atoms, molecules, and complex ions. Additivity of diamagnetism; paramagnetism. Ideas of magnetochemistry.

So-called Van der Waals intra and inter-molecular bonds. Effects of dipoles, induction, dispersion. Molecular associations in gases and liquids; solvation of ions. Molecular or ionic associations in solids; crystalline structure of non-polar compounds.

The metallic bond; relation with co-valency; ferromagnetism of transition elements.

ELECTRO CHEMISTRY

SYLLABUS

(given only as an example to facilitate the use of the inventories)

Conductivity of electrolytes in aqueous and non-aqueous solutions. Revision of generalities; measurements.

Conductimetric analysis.

Water purification: in the laboratory, in industry. Ion exchangers. Electro osmosis. Electro dialysis.

Relative velocities of ions. Transport number. Methods of measurement: Hitorf's moving boundary. Solvation of ions, hydration.

Revision of electronic theories of valency.

Electrochemical potential. Nernst formula.

Reversible electrodes, of the 1st and 2nd type.

Hydrogen, gas, quinhydrone electrodes.

Antimony electrode.

Dropping mercury electrode. Electrocapillary properties of mercury. Electro-capillary curve. Lippmann's electrometer.

Glass electrode.

Practical measurement of pH and rH.

Potentiometric analysis.

Theory of electrolysis.

Decomposition potentials. Over-voltage.

Over-voltage of H_2 , O_2 , and the other elements.

Theories of over-voltage.

Polarimetric analysis. Polarography.

Analysis by controlled potential. Electrolytic separations.

Rapid analysis.

Electrolytic hydrogen and oxygen. Industrial preparation.

Generalities about industrial electrolyzers. Electrolysis under pressure.

Batteries and accumulators.

Anodic behaviour of metals.

Passivity: anodic treatment of aluminium, electrolytic values; electrolytic condensers. Electrochemical protection of metals.

Corrosion; electrochemical theories of corrosion, protection against it.

Electrolytic polishing.

Electrochemical deposits. Generalities. Applications. Nickel plating. Chromium plating.

Electrometallurgy in an aqueous medium.

Generalities, principal examples.

Refinement of copper, zinc, etc.

Obtaining of metals directly from minerals.

Oxidation-reduction phenomena.

Electrochemical majorations and reductions, oxidations and hydrogenations.

Ozone, hydrogen peroxide. Persulphates, etc.

Hydrogenation of organic substances (nitrogen compounds).

Electrolytic chlorine and caustic soda.

Hypochlorites.

Chlorates and perchlorates.
Fusion electrolysis. Aluminium. Light metals.
Electrolytic recovery of ion. Electric furnaces.
Technical equipment. Direct current generators.
Rectifiers; mercury vapour, metal oxide, etc.

PRACTICAL WORK

Measurement of conductivity of electrolytes.
Application: titrimetry.
Equipotential lines.
Migration of ions: transport numbers.
Gravimetric and volumetric voltameters. Calibration of an ampere meter.
Electroplating: polishing, dipping, copper plating, silver plating, etc.
Standard electrodes: hydrogen, calomel, antimony, quinhydrone, glass.
Electrode potentials. Decomposition voltages and over-voltages.
Electrotitrimetry: determination of iodine, chlorine, etc.
Study of batteries and accumulators.
Electrometric and colorimetric measurements of pH. Acidimetry, alkalimetry, and buffer solutions.
Electrolysis in alternating currents.
Preparation of chlorine and caustic soda, bleaching compounds, chlorates and perchlorates.
Persulphates, iodoform, bromoform, and isopropyl alcohol.
Electrolytic reductions of nitrobenzene: nitrosobenzene, azoxybenzene, etc., aniline.
Ozone.

EQUIPMENT

GROUP 1. MACHINES AND MATERIAL.

Quantity	Item	Total cost in dollars
2	Centrifuges, with electric motors	192.00
1	Compressor, 1,000 atm	1,765.00
1	Compressor, for air cylinders	156.00
2 sets	Motor generator convertors, complete with distribution board	1,131.00
26	Electric motors, various	817.00
1	Block and tackle, 250 kg	23.00
2	Vacuum pumps, vane type	236.00
1	Overhead crane	50.00
Total		4,370.00

GROUP 2. TRANSFORMERS AND RECTIFIERS.

2	Autotransformers	54.00
2	Reactance coils, 5,000 V, 6 A	268.00
1	LT transformer, 30 kVA	250.00
1	HT transformer, 30 kVA	334.00
2	Transformers, various	133.00
2	Heavy duty transformers, 30 A	67.00
1	Transformer for 12,000 V	72.00
Total		1,178.00

GROUP 3. ACCUMULATORS.

1	96-element battery (<i>i.e.</i> for distributed LT supply)	3,413.00
34	Accumulator elements	324.00
Total		3,737.00

GROUP 4. GENERAL EQUIPMENT.

70	Distribution boards, various	3,570.00
1	Transmission	38.00
Total		3,608.00

GROUP 5. WORKSHOP AND FORGE TOOLS AND ACCESSORIES.

1	Apparatus for etching and dividing	57.00
1	Portable electric drill	48.00
1	Vertical electric drill	263.00
1	Autogenous welding set	140.00
1	Electric welding set	100.00
1	Circular saw, motor driven	73.00
1	Precision lathe, complete	842.00
1	Grindstone, electrically operated	75.00
Total		1,598.00

PHYSICS AND CHEMICAL ENGINEERING

GROUP 6. MEASURING AND METERING EQUIPMENT.

Quantity	Item	Total cost in dollars
49	Ammeters	991.00
1	Wheatstone bridge	38.00
1	Chronograph	5.00
4	Stop watches	50.00
1	Electricity meter	25.00
16	Universal controllers	793.00
12	Electrometers, various	349.00
31	Galvanometers	1,338.00
1	Interrupter	8.00
1	Flux meter	42.00
6	Manometers	66.00
7	Micro-ammeters and -voltmeters	145.00
5	Milliammeters	530.00
2	Millivoltmeters, recording	685.00
2	Weston standard cells	48.00
1	Slide wire bridge, instructional	13.00
2	Impedance bridges with LF generator	160.00
1	Kohlrausch bridge	41.00
1	Alarm clock	3.00
3	Tachometers	88.00
1	Contact thermometer, 0-50° C	22.00
1	Voltmeter, silver	14.00
1	Voltmeter, copper	10.00
41	Voltmeters	930.00
6	Lamp voltmeters	750.00
1	Precision wattmeter	150.00
Total		7,294.00

GROUP 7. RESISTANCES.

7	Precision decade resistance boxes	611.00
1	Standard 1 ohm resistance	14.00
21	Fixed resistances, various	668.00
84	Rheostats, various	1,546.00
Total		2,839.00

GROUP 8. INSTRUMENTS AND APPARATUS.

1	DC feed	143.00
1	LF amplifier	52.00
1	X ray analysis set	1,250.00
2	Metal distillation apparatus	83.00
1	Mercury distillation apparatus	20.00
1	Fusion point determination apparatus	19.00
1	CO determination apparatus	90.00
1	Water still	20.00
1	pH meter	351.00
1	Apparatus for measuring electrode potentials	120.00
1	Refrigerator	77.00
1	Autoclave with stirrer	156.00
1	Normal barometer	41.00
1	Induction coil, 10 cm spark	100.00
1	Ball mill	38.00
1	Bomb calorimeter, complete	63.00
2	Cathetometers	117.00
1	Collection of apparatus for Tesla expts	44.00
Carry forward		2,784.00

EQUIPMENT

Quantity	Item	Total cost in dollars
	Brought forward	2,784.00
3	Colorimeters	182.00
4	Electronic commutators	214.00
3	Laboratory gas-meters	279.00
1	Recording chronograph	183.00
3	Electric ovens	543.00
2	Gas ovens	73.00
1	Combustion furnace, 80 cm	27.00
8	Combustion furnaces, electric, various	397.00
2	LF generators	64.00
1	Short wave generator	21.00
1	Illumination installation with luminescent tubes	61.00
1	Interferometer for liquids and gases, complete	330.00
1	Heavy duty interrupter	75.00
2	Arc lamps	40.00
2	Incandescent lamps, 500 W with reflector	30.00
2	Mercury vapour lamps, in quartz	130.00
1	Sodium vapour lamp, complete	29.00
1	Extinction polarimeter, complete	314.00
3	Small induction coils	17.00
1	Complete polarograph	520.00
4	CR oscillographs	1,022.00
1	DC potentiometer	385.00
1	AC electronic potentiometer	300.00
1	Industrial potentiometer, complete	84.00
2	1,000 W projectors	59.00
1	Pyrometer, thermocouple	118.00
3	Pyrometers, optical, various	291.00
1	Spectrograph, quartz	219.00
1	Spectrophotometer	251.00
1	Spectroscope, prism	159.00
1	Spinthariscopes with screens	50.00
1	Thermopile	85.00
5	Precision water thermostats	832.00
	Total	10,168.00

GROUP 9. BALANCES AND WEIGHTS.

3	Analytic balances	231.00
1	Balance for determination of density	6.00
2	Precision balances	48.00
3	Precision balances, 1 kg capacity	50.00
1	Nernst micro-balance	25.00
3	Letter balance	8.00
8	Sets of weights	24.00
2	Sets of weights, 0.001 to 50 g, platinized	16.00
	Total	408.00

GROUP 10. OPTICAL APPARATUS AND ACCESSORIES.

4	Magnifiers	4.00
4	Reading telescopes	197.00
3	Micrometer objectives	7.00
1	Microscope with accessories	90.00
1	Microscope polarizing, complete	242.00
1	Abbe refractometer	189.00
	Carry forward	729.00

PHYSICS AND CHEMICAL ENGINEERING

Quantity	Item	Total cost in dollars
	Brought forward	729.00
1	Quartz spectrograph, with stand for spark	2,536.00
1	Pocket spectroscope	43.00
3	Reading telescopes	24.00
	Total	3,332.00

GROUP 11. PHOTOGRAPHY AND ACCESSORIES.

1	Microphotographic set-up	31.00
1	Photographic apparatus, 13 × 18 cm, complete	80.00
1	Reflex camera	91.00
1	Photocopying camera outfit	64.00
1	Photoelectrical cell	10.00
1	Fluorescent screen	16.00
1	Illumination projector	17.00
	Total	309.00

GROUP 12. PROJECTION AND CINEMA.

1	Universal projector	185.00
1	Screen	13.00
1	Epidiascope	125.00
	Total	323.00

GROUP 13. HEAT, ELECTRICITY, MAGNETISM, VARIOUS.

1	Box of condensers	44.00
5	Conjunctors-disjunctors	88.00
2	10 ohm headphones	12.00
1	Universal electrode	11.00
7	Slide wire bridges	217.00
4	Precision potentiometers	104.00
2	Platinum thermocouples	19.00
	Total	495.00

GROUP 14. LABORATORY INSTRUMENTS.

1	Electric shaking outfit for 48 flasks	50.00
50	Rings	40.00
1	Apparatus for measuring speed of depolarization	13.00
9	Water baths	44.00
3	Water baths, electric	132.00
1	Bucket, 200 l	6.00
1	Sterilizer	4.00
2	Steel bombs	89.00
12	Bottles of compressed gas	157.00
1	Cast iron mill	18.00
50	Burners	45.00
1	Gas burette	15.00
2	Gas torches	8.00
1	Heater	32.00
32	Reducing valves	294.00
8	Immersion heaters	41.00
1	Revolving rack	30.00
	Carry forward	1,018.00

EQUIPMENT

Quantity	Item	Total cost in dollars
	Brought forward	1,018.00
7	Gas ovens	30.00
3	Extinguishers	26.00
1	Branding iron	5.00
2	Gasometers	24.00
6	Large water baths	130.00
1	Set of sieves	5.00
1	Hefner candle	10.00
14	Individual assortments (1 Bunsen burner, 5 tongs, 5 rings, 5 nuts, 1 vice, 3 pr pliers, 1 metre rule, 1 box of gauges)	245.00
1	Casserole, 36 cm	5.00
4	Mortars, pestles, various	12.00
170	Bosses	75.00
120	Clamps	100.00
4	Clamps, crucible	8.00
8	Clamps, flexible	16.00
140	Iron stands	250.00
31	Hot plates	660.00
1	Electric press, for dry mounting	16.00
1	Gas regulator	16.00
2	Pressure regulators	17.00
25	Various stands, wooden	37.00
12	Tripods	5.00
	Total	2,710.00

GROUP 15. TOOLS.

Workshop: Hand-tools for 2 mechanics and accessories for the machine tools	184.00
Laboratory: Tools for maintenance men and laboratory assistants, and laboratory tools	149.00
Total	333.00

STOCKS OF MATERIALS, CHEMICALS, ETC.

(1) ARTICLES IN PRECIOUS METALS.

Platinum, gold, silver, mercury, rhodium 1,000.00

(2) GLASSWARE 875.00

(3) PORCELAIN AND EARTHENWARE 250.00

(4) RUBBER ARTICLES 125.00

(5) ARTICLES IN NON-PRECIOUS METALS.

Utensils, workshop essentials, electrical installations 1,000.00

(6) MISCELLANEOUS.

Filters, towels and clothing, asbestos, corks, maintenance
requisites and sundries 1,500.00

(7) CHEMICALS (see list p. 53) 250.00

(8) EXPERIMENTAL APPARATUS 1,250.00

Total 6,250.00

THIRD PART

INDUSTRIAL CHEMISTRY

INORGANIC INDUSTRIAL CHEMISTRY

SYLLABUS

(given only as an example to facilitate the use of the inventories)

GENERALITIES CONCERNING THE HEAVY CHEMICAL INDUSTRY.

Current world situation.

Sulphur industries.

Sulphur. Natural state. Extraction. Frasche process. Recovery of residual sulphur. Recovery of sulphur from coal gas and coke ovens. Purification and refining of sulphur. Carbon disulphide. Sulphur chlorides. Carbon tetrachloride.

Sulphur dioxide.

Sulphur ovens. Roasting of pyrites. Mechanical ovens. Rotating Frasch roasting ovens. Composition of gases. Dust removal. Purification of gases. Roasting of blends. Mechanical ovens. Roasting of other sulphides. Decomposition of alkaline earth sulphates. Liquid sulphur dioxide. Bisulphites. Hydrosulphite.

Sulphuric acid.

Generalities. Lead chamber process. Theory. Plant. Glover tower. Lead chambers, various types. Gay-Lussac tower. Suppression of lead chambers. Concentration of sulphur acid. Purification of sulphuric acid. Contact process. Principle. Theoretical yield. Actual yield. Platinum catalysts. Iron oxide catalysts. Vanadium oxide catalysts. Equipment: various converters. Absorption of sulphur trioxide: oleums.

Nitrogen industries.

Liquefaction of the air. Linde's apparatus. Claude's apparatus. Distillation of liquid air (Claude's process). Mathias-Frankl process.

Rare gases.

Neon and helium. Argon. Krypton and xenon.

Hydrogen.

Electrolysis of water. Steam-iron process. Manufacture of hydrogen from water gas. Method of manufacturing hydrogen from gaseous hydrocarbons.

Ammonia.

Ammonia from waste waters. Ammonia from coal, lignite, and peat. Calcium cyanamide; calcium carbide. Equipment for nitrogen fixation. Transformation of calcium cyanamide into ammonia, urea, cyanide. Ammonia from cyanides. Ammonia from nitriles.

Synthesis of ammonia.

Role of catalysts. Industrial realization. Haber process. Casale process. Fauser process. Mont-Cenis process. Description of plants.

Ammonium salts.

Ammonium sulphate: direct obtention and from gypsum. Nitrate. Chloride. Phosphate. Perchlorate.

Nitric acid.

Chili saltpetre. Nitric acid from nitrates. Synthesis of nitric acid: direct synthesis. Arc process. Various ovens. Absorption of nitrous vapours. Manufacture of nitrates and nitrites. Oxidation of ammonia. Various types of converters. Absorption of nitrous vapours. Concentration of nitric acid.

INDUSTRIES OF THE ALKALI METAL SALTS.

Sodium chloride.

Rock salt. Sea salt. Treatment of mother liquors.

Hydrochloric acid.

Sulphate ovens. Hargreaves and Robinson process. Hydrochloric acid by synthesis.

Action of chlorine on water vapour. Dissolution of hydrochloric acid.

Chlorine.

Early processes. Deacon process. Preparation from chlorides. Electrolysis of chlorides. Liquefaction of chlorine. Bleaching chlorides. Eau de Javel. Chloride of lime. Calcium hypochlorite.

Sodium carbonate.

Leblanc process. Solvay process. Equipment. Recovery. Modifications. Cauticization of sodium carbonate.

Potassium chloride.

Stassfurt deposits. Extraction of potassium chloride from carnallite. Alsace deposits.

Extraction of potassium chloride from sylvinite. Potassium sulphate. Various sources of potassium salts.

Bromine industry.

Calcium phosphates.

Phosphate from bones. Dephosphorization of slag. Mineral phosphates. Dicalcium phosphate. Superphosphates.

Manufacture of phosphorus and phosphoric acid.

Electric furnace process. Action of water vapour on phosphorus.

Compound fertilizers.

ORGANIC INDUSTRIAL CHEMISTRY

SYLLABUS

(given only as an example to facilitate the use of the inventories)

SOLID, LIQUID AND GASEOUS FUELS.

Solid fuels.

Coals: Generalities. Distillation of coal: (a) gas works; (b) coke ovens (high temperature carbonization, low temperature carbonization, utilization of gases, treatment of coal tars).

Lignites and peats.

Wood: Generalities. Distillation of wood, recovery of volatile products and their utilization.

Industries connexion with the distillation of wood: (a) acetic acid and its derivatives; (b) acetone; (c) methyl alcohol; (d) formaldehyde.

Liquid fuels.

Petrol. Bitumens and asphalts.

Gaseous fuel.

Natural.

Artificial. Coal gas, coke oven gas, wood gas, blast furnace gas, producer gas, low calorific gas, water. Gasification of lignites and peats in the presence of oxygen, underground gasification of coal.

The problem of motor fuels.

High octane fuels; substitute or auxiliary, and light synthetic motor fuels.

Cracking: (a) simple cracking, with or without catalyst; (b) hydrogenatic cracking.

Coal hydrogenation.

Cracking and hydrogenation of vegetable oils. Total synthesis.

DYES.

Generalities: history, terminology, classification, study of intermediates, study of dye groups.

Dyestuffs: nitrosic, nitrated, stilbene, azo, pyrazolone, thiazol.

Auramine group, triphenylmethane group.

Dyestuffs: xanthone, acridine, quinoline derivatives, polymethine, oxazine, thiazine, azine, sulphur, anthraquinone.

Indigo group, generalities concerning analysis and applications of dyestuffs.

EQUIPMENT

GROUP 1. MACHINES AND MATERIAL.

Quantity	Item	Total cost in dollars
16	Stirrers and shakers	742.00
1	Alternator	32.00
1	Apparatus for vacuum cooking, with oil bath	40.00
1	Apparatus for steam distillation	48.00
3	Crushers	201.00
3	Ball mills	388.00
1	Ice crusher	308.00
1	Centrifuge	1,263.00
9	Air compressors, various	3,861.00
1	Dye bath	150.00
1	Centrifugal drier	16.00
20	Ovens, electric or steam	5,900.00
4	Crucible furnaces	454.00
24	Gasometers	1,620.00
1	Electric steam raising plant	563.00
1	Ice box	19.00
2	Large water baths, 20 holes	464.00
9	Large heating plates on stands	311.00
3	Large screw presses	288.00
1	Converter set, motor-alternator, 40 HP complete	1,548.00
3	High pressure hydrogenators	620.00
3	Interruption	45.00
1	Machine for printing on fabric	250.00
1	Sieving machine	141.00
2	Mixers, kneading	736.00
1	Hot air motor	79.00
1	Compressed air turbine	40.00
173	Electric motors, various	5,595.00
15	Rotary vacuum pumps	1,930.00
7	Pumps for circulating liquids	1,074.00
1	Injection pump	63.00
1	Gantry with purchase	34.00
1	Hydraulic press, complete	413.00
1	Sodium press	16.00
4	Tablet presses	96.00
1	Electric refrigerator	198.00
3	Blowers	85.00
3	Electric instrument panels	110.00
5	Transmission sets, various	565.00
Total		30,306.00

GROUP 2. TRANSFORMERS.

1	Autotransformer, variable, 1 kVA	38.00
1	Installation of variable LT transformers	993.00
1	Rectifier	35.00
4	Transformers, 80 kVA, 6,000/500/380/220/190/110 V	5,000.00
1	Single phase transformer, 3 kVA	86.00
1	Variable transformer, 3 kVA	113.00
1	Three phase transformer, 7.5 kVA	44.00
Total		6,309.00

GROUP 3. ACCUMULATORS.

Quantity	Item	Total cost in dollars
17	Accumulator elements	293.00
	Total	293.00

GROUP 4. GENERAL EQUIPMENT.

1	Installation for compressed air and vacuum	2,125.00
1	Installation for evaporation	1,800.00
	Distribution boards, etc.	5,000.00
	Total	8,925.00

GROUP 5. WORKSHOP AND FORGE MACHINES AND ACCESSORIES.

2	Guillotines for sheet metal	600.00
1	Lever punch	24.00
1	Vice, 14 cm	18.00
1	Forge with anvil, hammers, tongs, etc.	165.00
1	Autogenous welding outfit	300.00
2	Flanging machines	146.00
1	Sanding machine	75.00
2	Mechanical grindstones	79.00
2	Electric drills	646.00
1	Sheet bender	39.00
1	Planing machine	600.00
4	Precision lathes	2,542.00
	Total	5,234.00

GROUP 6. MEASURING INSTRUMENTS AND APPARATUS.

70	Ammeters	711.00
2	Electric titrating apparatus	237.00
1	Mercury barometer	48.00
1	Recording barometer	47.00
3	Chronographs, $\frac{1}{10}$ s	119.00
32	Stop watches	304.00
26	Gas meters	2,000.00
1	Electricity meter	25.00
5	Universal controllers	392.00
1	HF vacuum controller	28.00
2	Galvanometers	47.00
1	Electric clock	9.00
1	Recording pressure gauge 0-500 atm	57.00
28	Metal pressure gauges	319.00
58	Millivoltmeters	2,707.00
1	Millivoltmeter, recording	148.00
1	CR oscillograph	325.00
1	pH meter	63.00
1	Hydraulic pump for pressure gauge calibrations	101.00
6	Measuring bridges	462.00
1	Electronic potentiometer	360.00
1	Abbe refractometer, complete	503.00
13	Temperature regulators	2,023.00
1	Delay switch, 10 A	36.00
13	Voltmeters	415.00
1	Electronic voltmeter	82.00
1	Tensimeter	150.00
	Total	11,718.00

PHYSICS AND CHEMICAL ENGINEERING

GROUP 7. RESISTANCES.

Quantity	Item	Total cost in dollars
49	Fixed resistances, various	1,334.00
106	Rheostats, various	2,253.00
	Total	3,587.00

GROUP 8. INSTRUMENTS AND APPARATUS.

2	Anemometers	23.00
1	Apparatus for hydrofluoric acid	71.00
1	Apparatus for distilling tar	35.00
1	Electrolysis apparatus	179.00
11	Orsat analysers	607.00
3	Apparatus for nitrogen determination	121.00
1	Apparatus for carbon determination	53.00
11	Apparatus for FP determination	258.00
2	Sublimation blocks	125.00
3	Induction coils	24.00
3	Bomb calorimeters	355.00
9	Calorimeters	453.00
1	Conductivity cell	10.00
1	Photoelectric colorimeter	530.00
2	Rayon spinners	70.00
1	Special refrigerating installation	2,200.00
1	Microtome	28.00
3	Water levels, in brass	15.00
1	LF oscillator	32.00
1	Polarograph	721.00
1	Injection pump	93.00
1	Centrifugal pump	13.00
7	Pyrometers, various	621.00
1	Telephone receiver	3.00
4	Temperature regulators for gas heating	104.00
1	Contact thermometer	8.00
2	Water thermostats	341.00
1	Höppler viscosimeter	115.00
	Total	7,208.00

GROUP 9. BALANCES AND WEIGHTS.

31	Analytic balances	1,908.00
1	Analytic balance, automatic	531.00
2	Gas balances	145.00
6	Hand balances	14.00
37	Taring balances	475.00
3	Steelyards, 100 kg	174.00
20	Precision balances, various	720.00
1	Weighing machine, 200 kg	56.00
51	Boxes of weights	265.00
	Total	4,288.00

GROUP 10. OPTICS AND ACCESSORIES.

1	Camera, 6 × 9 cm	4.00
4	Polarization apparatus with accessories	956.00
1	Apparatus for photographic reproduction	574.00
1	Optical bench with 4 riders	64.00
	Carry forward	1,598.00

EQUIPMENT

Quantity	Item	Total cost in dollars
	Brought forward	1,598.00
1	Chronometer	88.00
1	Condenser, 1.5 cm	36.00
1	Hematoscope	7.00
1	Interferometer for gases and liquids, with accessories	681.00
3	Darkroom lamps	32.00
4	Magnifying lenses	7.00
9	Microscopes with accessories	2,137.00
1	Photographic objective, 5 cm, f/3.5	16.00
1	Projection objective, 10 cm	18.00
1	Photometer	729.00
1	Mounting press, 30 × 40 cm	23.00
2	Polaristrometers	109.00
1	Disappearing filament pyrometer	181.00
1	Refractometer	25.00
1	Refractometer, sugar analysis	70.00
7	Spectroscopes	443.00
1	Spectroscope, grating with accessories	1,061.00
	Total	7,261.00

GROUP 11. PHOTOGRAPHY AND ACCESSORIES.

1	Enlarger	50.00
4	Drawing frames	21.00
1	Dark room lamp	13.00
	Total	84.00

GROUP 12. PROJECTION AND CINEMA.

1	Cine-camera	270.00
1	Cine-projector	191.00
1	Small format projector	58.00
1	Lantern slide projector	300.00
1	Epidiascope	210.00
	Total	1,029.00

GROUP 13. LABORATORY UTENSILS.

3	Stirrers	106.00
750	Rings	614.00
1	Apparatus for slow carbonization	24.00
1	Apparatus for micro-analysis (N)	221.00
1	Apparatus for micro-analysis (C and H)	214.00
38	Autoclaves, various	5,700.00
4	Reducing vats, ½ l, complete	300.00
7	Dye vats	57.00
10	Water baths, electric	116.00
95	Water baths, constant level	456.00
7	Oil baths, electric	37.00
9	Metal baths	11.00
1	Sand bath	38.00
6	Beakers, copper	18.00
200	Gloor blocks, cast iron	509.00
124	Bottles of compressed gases	1,858.00
122	Multiple burners	228.00
908	Ordinary burners	1,474.00
	Carry forward	11,981.00

PHYSICS AND CHEMICAL ENGINEERING

Quantity	Item	Total cost in dollars
	Brought forward	11,981.00
13	Animal cages	118.00
24	Capsules in enamelled iron	48.00
16	Gas torches	78.00
111	Heaters, various	722.00
1	Sodium knife	5.00
1	Wooden container, steam heated	48.00
48	Reducing valves	598.00
6	Disjunctors	107.00
9	Immersion heaters	84.00
19	Hot funnels	68.00
4	Sets of shelves, revolving	117.00
67	Gas ovens	1,089.00
26	Gas furnaces	811.00
2	Drums, for alcohol	30.00
24	Electric furnaces	2,390.00
6	Sets of sieves	250.00
10	Cork squeezers	14.00
8	Cork boring machines	40.00
2	Diamond mortars	3.00
8	Iron mortars	53.00
1,660	Bosses	1,000.00
1,000	Wooden objects (supports, stands, frames, etc.)	1,750.00
223	Stands, various	1,055.00
1,409	Clamps	1,528.00
2	Clamps, crucible	2.00
2	Spray guns	62.00
82	Hot plates	1,253.00
5	Alcohol stoves (primus stoves)	25.00
4	Speed reducers	51.00
5	Nickel condensers	8.00
1	Reflux condenser, pressure	10.00
1	High pressure valve, steel	10.00
1	Set of metal framework parts	285.00
17	Steam superheaters	127.00
785	Tripods	660.00
2	Water pumps	17.00
153	Turbines	980.00
1	Aluminium reaction vessel	38.00
1	Ventilator with fan	23.00
5	Vacuum flasks	38.00
7	Vacuum carboys	234.00
	Total	27,810.00

GROUP 14. TOOLS.

Workshop:

Hand tools for 3 mechanics and machine-tool accessories 2,370.00

Laboratories:

Tools for maintenance staff and laboratory assistants, and
laboratory tools 750.00
Total 3,120.00

STOCKS OF MATERIALS, CHEMICALS, ETC.

Quantity	Item	Total cost in dollars
1. ARTICLES IN PRECIOUS METALS.		
2,190 g	Platinum: Bottles, distillation apparatus, flasks, retorts, condenser, tubing, capillary tubing, cupels, crucibles, electrodes, boats, spoons, spatulas, cones, sieves, metal gauzes, sheet, wire, thin foil, etc.	4,500.00
180 g	Silver: Cupels, crucibles, etc.	20.00
4 g	Fine gold	4.00
	Palladium: Spiral	13.00
30 g	Mercury	175.00
	Various thermocouples	250.00
2. GLASSWARE.		
	Round-bottomed flasks, straight flasks, distillation flasks, sample vessels, bottles for solids and liquids, various condensers, crystallizing dishes, wash bottles, aspirators, small cylinders, measuring cylinders, pipettes and burettes, vacuum apparatus, vacuum distillation flasks, Kjeldahl flasks, test tubes, glass tubing, various thermometers, glass monometers on wooden stands, dewar flasks on wooden stands, flow indicators on wooden stands, containers for solid carbon dioxide with bag and padding, aerometers, etc.	2,500.00
	Reagent bottles (laboratory fixtures)	2,500.00
3. PORCELAIN AND EARTHENWARE.		
	Cupels, sample vessels, perforated funnels, crucibles, tubes, spatulas, rings, mortars, fusion crucibles, clay tiles, clay pipes, clay retorts, basins, pots, various utensils, etc.	3,000.00
4. RUBBER ARTICLES.		
	Pliable tubing of different diameters, stoppers, bungs of different sizes, diffusion discs, belts for turbines, etc.	500.00
5. FILTERS.		
	Filter paper, fluted and round filters, extraction thimbles	375.00
6. ARTICLES IN NON-PRECIOUS METALS (including workshop).		
	Iron cupels of different diameters, enamel cupels, copper cupels, copper flasks, sample vessels, funnels, shovels, various cans, water heaters, iron and nickel spatulas of various lengths, flat-nosed side-cutting pliers, sets of cork borers, enamelled or plain sample vessels, various files, screw clips, iron and copper wire, iron wire gauze, crucible tongs, tweezers, scissors, old parts of apparatus, instruments and machines, galvanized bottles.	
	Copper and brass: Wire, sheet, plates, rods, etc.	
	Steel and iron: Round, flat, etc.	
	Metal: Screws, nuts, bolts, nails, tacks, rivets, etc.	
	Lead: Blocks, plates, tubes, fittings, valves, taps, etc.	
	Electrical material: Interruptors, commutators, manipulators, circuit-breakers, tumbler switches, disjunctors, wire insulators, small transformers, incandescent lamps, tubes, rotary switch, files, etc.	
	Test installations subject to continual modifications	2,000.00
	Carry forward	15,837.00

PHYSICS AND CHEMICAL ENGINEERING

Quantity	Item	Total cost in dollars
7.	VARIOUS.	
	Brought forward	15,837.00
	Covers, towels, aprons, silk fabric, laboratory clothing, asbestos board and paper, stoppers, bungs and brushes of various sizes, horn spoons and spatulas, litmus paper, soaps, matches, various small utensils and crocks (test tube racks), trays and baskets, trestles, planks, tubs, driving belts, ropes, cardboard, paper, etc.	1,500.00
8.	CHEMICALS.	
	Various	4,000.00
	Total	21,337.00

DEMONSTRATION MODELS AND MATERIAL

2	Smoke analysis apparatus	23.00
1	Flash point determination apparatus	35.00
1	Apparatus for determining the densities of gases by effusion	10.00
1	Apparatus for determining the solidity of cements	5.00
4	Petroleum testing apparatus	112.00
2	Merccrizing apparatus	25.00
1	Apparatus for measuring the calorific value of illuminating gas	10.00
1	Standardizing flask for gas flow meters	6.00
1	Beckmann cryometer	10.00
1	Reeling machine	25.00
	Various demonstration models: bearings, gearings, mechanisms	50.00
1	Hardness tester	3.00
1	Eudiometer	13.00
1	Smoke determination apparatus	7.00
1	Davy safety lamp	2.00
1	Kneading machine	17.00
1	Power-hammer, 1.5 m	105.00
1	Lead pulverizor and 1 platinum pulverizor	26.00
1	Engler viscosimeter	17.00
	Total	501.00

FOURTH PART

PHYSICS

GENERAL PHYSICS

SYLLABUS

(given only as an example to facilitate the use of the inventories)

DYNAMICS OF A MATERIAL POINT AND A SOLID BODY.

Fundamental principles of movement.

Co-ordinates of position.

Velocity.

Acceleration.

Newton's principles.

Weight.

Harmonic vibrations.

Damped vibrations.

Forced vibrations and resonance.

Coupled vibrations.

Theorem of live forces.

Principle of conservation of energy.

Curvilinear motion.

Circular motion.

Duration of lunar revolution.

Pulley.

Mechanical systems of reference and d'Alembert's principle.

Centrifugal force.

Coriolis force.

D'Alembert's principle.

Poggendorff's balance.

Rotation motion of a solid body about a fixed axis.

Equation of rotational motion.

Compound pendulum.

Rotation impulsion or torsion theorem.

Free axes.

Rotational motion of a solid body about a fixed point. The spinning top.

Precession. Grindstone of edge-runner mill, bicycle wheel, monorail, gyroscopic compass, child's spinning top, precession of the earth's axis, nutation, free symmetrical gyroscope, general case.

HYDRO AND AERODYNAMICS.

Dynamics of incompressible frictionless fluids.

Continuity equation.

Bernouilli's equation.

Venturi tube.

Pitot tube.

Flow under the influence of pressure.

Flow under the influence of gravity.

Transition from frictionless flow to flow with interior friction.

PHYSICS AND CHEMICAL ENGINEERING

Internal friction of liquids.

Laminar flow in a tube. Poiseuille's formula.

Resistance to the progress of a sphere in a fluid in laminar flow with internal friction.

Stokes' formula.

Turbulence. Resistance due to eddy formation.

Reynolds number.

Dynamical similarity.

Turbulent flow in tubes.

Helmholtz's turbulence theorems.

Critical velocities and Reynolds critical number.

Dynamic thrust.

Magnus effect.

Relation between thrust and induced resistance.

STUDY OF ELASTICITY.

Elasticity of fluids.

Elasticity of isotropic solid bodies. Hooke's law.

Elastic modulus.

Lattice structure of crystals.

Transverse contraction.

Deformation by compression.

Shear modulus.

STUDY OF WAVES.

Mathematical study of a wave.

Velocity of propagation.

Establishment of the wave equation from the example of elastic longitudinal waves.

Sinusoidal wave.

Stationary waves.

Group velocity.

Acoustics.

Vibrations proper to systems of one, two, or three dimensions.

String.

Membrane.

Acoustics of halls.

Sound, tone quality, noise.

Intensity and pressure of sound.

The ear.

Scale of intensity in decibels.

The scale.

General properties of different kinds of waves.

Interferences.

Quincke's interference tube.

Mach's interferometer.

Interference field between two wave groups.

Refraction.

Total reflection and bent light rays.

Diffraction.

Diffraction through a slit.

Diffraction through a lattice.

Phenomena peculiar to light waves.

Polarization.

Brewster's law.

Nicol's prism.

Examination by polarized light.

Optical activity.

- Diffusion.
- Dispersion.
- Formation of images and power of resolution.
- Formation of images in the microscope.
- Experimental demonstration of Abbe's theory.
- Resolving power of a telescope.
- Measurement of radiation.
- Absorption.
- Study of colours.
 - The eye.
 - Fundamental principles of colour theory.
 - Additive mixing.
 - Young's and Helmholtz's theories.
 - Complementary colours.
 - Colour photography.
- The electromagnetic spectrum.
 - The infra-red.
 - Phosphorescence.
 - The ultra-violet.
 - Fluorescence.
- X-rays.
 - Determination of X-rays wavelengths.
 - Laue's method of crystal analysis.
 - Bragg's method of crystal analysis.
 - Powder method.
- α -rays.

THERMODYNAMICS.

- Introduction.
- Temperature scale. Temperature measurement.
 - Thermocouples.
 - Coefficient of thermal expansion.
- Quantity of heat.
- Equation of state of perfect gases.
- Van der Waal's equation.
- Surface tension.
- First law of thermodynamics.
- Thermal equation of state.
- Kinetic theory of gases.
 - Determination of molecular velocity.
 - Calculation of gas pressure.
 - Collision number and mean free path.
 - Brownian movement.
 - Distribution of molecular velocities.
 - Boltzmann's law of equi-partition.
- Specific heat of perfect gases.
- Specific heat of solids.
- Joule-Thomson effect.
- The Carnot cycle. Second law of thermodynamics.
- Vapour pressure. Clausius-Clapeyron equation.
- Entropy. Second expression of the second law.
 - Entropy of a perfect gas.
 - Relation between entropy of a state and its probability.
- Free energy. Helmholtz's equation.
- Propagation of heat.
 - Convection.
 - Conduction.
 - Radiation.
- Diffusion.

PHYSICS AND CHEMICAL ENGINEERING

RELATIVITY MECHANICS.

WAVE MECHANICS.

Two-fold nature of light.

Relation between wave and corpuscles.

ELECTRICITY.

Introduction.

Historical development.

Maxwell's theory.

Electromagnetic waves in space.

Two conceptions of electricity.

Characteristics of an electric current.

Establishment of a unit of current intensity.

Examples of intensity.

Characteristic of potential.

Establishment of a unit of potential.

Examples of potential.

Ohm's law and potential-current characteristic of a conductor.

Magnetic field of a current.

Magnetic field of a solenoid.

Magnetoscope.

Definition and unit of magnetic field.

Measurement of magnetic field.

The elementary law of Laplace (Biot-Savart).

Magnetic field of various conductors.

Magnetic field of an infinitely long rectilinear conductor.

Magnetic field inside an infinitely long solenoid.

Calculation of intensity of magnetic field from Maxwell's equations.

Magnetic properties of matter.

Formal description of magnetization.

Para, dia, and ferro-magnetic substances.

Magnetization curve (hysteresis curve).

Magnetization and elastic tensions.

Orientation of elementary magnets by elastic tension.

Magnetostriction.

Magnetoelastic remanance.

Curie point.

Magnetomechanical effects.

Induction phenomena.

Formulation of the law of induction.

Applications of the law of induction.

Second equation of Maxwell and the law of induction.

Measurement of induction constants μ_0 .

Self induction.

Phenomena connected with closing and opening of circuits showing self-induction.

Mutual induction of two coils.

Electrical energy and electrical work.

Experimental examples leading to the experimental theorem.

Forces exerted by a magnetic field on a conductor traversed by a current.

Density of energy of a magnetic field.

Electric charge.

Measurement of electric charge.

Capacity.

Discharge of a capacity through a resistance.

Concrete definition of potential.

Intensity of the electric field.

Electrical potential. Relation to intensity of the field.

- Unit of potential.
- Displacement density. Relation to intensity of the field.
- Determination of intensity of the field by displacement density.
- Measurement of constants of influence ϵ_0 (specific inductive capacity).
- Electric field of a charged condenser.
 - Potential and charge of a condenser.
 - Energy of the condenser.
 - Density of energy of the electric field.
 - Attractive force between the plates of a condenser.
 - Maxwell's stresses.
- Electric field of a charged sphere.
 - Intensity of the field at the surface of the sphere.
 - Field at a distance r .
- Coulomb's law.
- Dielectric properties of matter.
 - Formal description.
 - Explanation of dielectric constant from atomic theory.
 - Influence of polarization.
 - Elastic model of the atom.
 - Piezo-electric materials (Seignette salt).
- Alternating potential and alternating current.
- Resistance in alternating current.
 - Pure resistance.
 - Pure inductance.
 - Measurement of self-induction by the bridge method.
 - Pure capacitance.
- Electrical resonance.
 - Potential resonance.
 - Current resonance.
- Damped electrical oscillations.
 - Pendulum and oscillating circuit.
- Non-damped oscillations produced by reactive coupling.
 - Spark emitter.
- Effect of induction in the case of high frequency alternating currents.
 - Tesla transformer.
 - Impedance.
- Power in alternating current.
- Electrical conductivity.
 - Conductivity phenomena in the case of massive conductors.
 - Case of a divided conductor.
 - Ionic conductivity.
- Electrolytic conductivity.
- Transport of electricity by electrons in hard vacuum.
- Cathode rays.
 - Acceleration of cathode rays.
 - Deflection by an electric field.
 - Deflection by a magnetic field.
 - Determination of e/m by Busch's method.
 - Direct determination of the elementary charge.
- The cathode ray tube.
 - Grid-controlled cathode ray tube (triode).
 - Characteristic internal resistance and transconductance.
 - Amplifying function of the triode.
 - Production of stationary oscillations by the cathode ray tube.
- Metallic conduction.
- Permanent discharge in gases.
- Disruptive discharge in gases.
 - Paschen's law.
 - Canal rays.
 - Electric arc.
 - Rectifier.
 - Triode with gaseous atmosphere (thyatron).

ATOMIC STRUCTURE.

Radioactive rays and their detection.

Radioactive disintegration.

Rutherford's model of the atomic nucleus.

Establishment of Rutherford's dispersion formula.

The electronic envelope of the atom.

Quantum nature of light.

Energy levels of the atom. Spectra.

Wave mechanics of the electron.

Divergences from Rutherford's law of dispersion.

Nuclear reactions.

The neutron.

Nuclear reactions induced by artificially accelerated particles.

Equivalence of mass and energy. Formation of couples.

Construction of atomic nuclei.

Artificial radioactivity.

APPENDIX.

*

Some remarks on units and systems of measurement.

Absolute electromagnetic system.

Absolute electrostatic system.

International electrotechnical system.

Giorgi system of measurement (M.K.S.).

Conversion of units.

OPTICS

(advanced)

SYLLABUS

(given only as an example to facilitate the use of the inventories)

DIOPTRICS.

Fermat's principle.
Principles of Malus and of Huyghens. Laws of image formation.
Hamilton's theory.
 Special homogeneous form (isotropic bodies).
 More general homogeneous form (crystal optics).
 Non-homogeneous form.
Photometry.

THEORY OF INTERFERENCES AND DIFFRACTION.

General kinematics of waves.
 Oscillations.
 Waves.
Refraction, reflection, interferences.
Theory of diffraction.
 Kirchhoff's general solution.
 Diffraction according to Fraunhofer.
 Diffraction according to Fresnel.

MAXWELL'S THEORY.

Basis of the theory.
Non-absorbent media (Fresnel's formula).
Metal optics.
Stationary waves.

CRYSTAL OPTICS.

Equations of the normal to the wave.
Ray intensities.
Singular points.
Incidence and emergence in crystals.

MOLECULAR OPTICS.

Scattering of non-damped oscillators.
Scattering of damped oscillators.
Scattering of light.
 Principles of electrodynamics.
 Lorentz's theory.
 Scattering of X-rays.
Optical activity.
 Theory of the phenomenon.
 Kuhn's model.
Magnetic optics.
 Zeemann effect.
 Faraday effect.

ELECTRODYNAMICS

(advanced)

SYLLABUS

(given only as an example to facilitate the use of the inventories)

ELECTROSTATICS AND MAGNETO STATICS.

Coulomb's law.
 Field of point charges.
 Volume and surface charges.
 Energy of the electrostatic field.
 Example: spherically symmetrical distribution of charges.
 Demonstration of the equivalence of the electrostatic field equations and Coulomb's law.
 Dielectrics (study of the phenomenon).
 Significance of dielectric phenomena for electron theory.
 The problem of potential.
 Curvilinear co-ordinates.
 Examples of solutions of the problem of potential.
 Magnetostatics.
 Units and dimensions.

STATIONARY CURRENTS.

Theory of stationary currents.
 Magnetic fields of stationary currents.
 Equivalence of the magnetic field of closed currents and the field of distribution of dipoles.
 Gravitational forces.
 Reaction principle for electric and magnetic forces.
 Maxwell's stresses.

QUASI-STATIONARY FIELDS.

Faraday's induction law.
 Energy of current systems.
 Variation of current as a function of time.
 Laws of induction in moving conductors.

FIELDS HAVING RAPID VARIATIONS.

Maxwell's equations.
 Electromagnetic waves in vacuum.
 Energy and momentum theorem.
 Electromagnetic waves in material bodies.
 Radiation.
 (a) Electromagnetic potentials. Inhomogeneous wave equation.
 (b) First method of integration.
 (c) Discussion of the solution in the periodic case.
 General discussion in the wave zone.
 Dipole radiation in the wave zone.
 Hertzian oscillator.
 (d) Second method of integration.
 Field of a point charge in uniform motion.
 Damping of radiation.

STATISTICAL MECHANICS

(advanced)

SYLLABUS

(given only as an example to facilitate the use of the inventories)

CALCULATION OF THE NUMBER OF COLLISIONS.

Elementary ideas of gas kinetics.
 Laws of collisions.
 Variation of the partition function as a result of collisions.
 Stationary partition.
 Transfer phenomena.
 Temperature.
 Statistics of a perfect gas.

GENERAL STATISTICAL MECHANICS.

Phase space. Liouville's theorem.
 Microcanonical assemblies.
 Canonical assemblies.
 Thermodynamic equation of state.
 General partitions of density.
 Applications.
 Macrocanonical assemblies.

BROWNIAN MOVEMENT.

QUANTUM STATISTICS.

Radiation inside a black body.
 Theory of solid bodies.
 Adiabatic invariants.
 Vapour pressure. Third law.
 Theory of radiation in a black body according to Einstein.
 Quantum statistics for identical particles.

PRACTICAL WORK

MEASUREMENTS AND ERRORS IN MEASUREMENTS.

MECHANICS.

Balance and weighing.
Velocities of a pistol bullet.
Elasticity.
Moment of inertia.
Spinning top.
Transverse vibrations of a string.
Mechanical resonance.
Coupled pendulums.
Internal friction of liquids.
Model of a loaded wing.

HEAT.

Absolute zero of the temperature scale.
Vapour density and molecular weight (Meyer's method).
Universal constant of gases (Dumas' method).
Latent heat of vaporization.
Electrical equivalent of heat.

*

OPTICS.

Refractive index of a prism.
Refractive index of air (Jamin's interferometer).
Measurement of wavelength with the aid of a grating.
Interferences and diffraction of light.
Geometrical optics and its limits.
Power of resolution of prisms and gratings.
Rotation of the plane of polarisation of light.
Spectrophotometry.
Distribution of energy in the spectrum.
Pyrometry of radiation.
Spectral sensitivity of photoelectric cell.

ELECTRICITY.

Characteristics of electric conductors.
Determination of the Faraday number.
Conductivity of an electrolyte.
Discharge of a condenser.
Dielectric constant and refractive index of non-conducting liquids.
Induction.
Galvanometer.
Measurement of magnetic fields.
Hysteresis.

Alternating currents.
Electrical resonance.
Constant of influence ϵ_0 .
Induction coefficient μ_0 .
Cathode ray tubes.
Rectifiers.
Specific charge of the electron.
Radioactivity.

EQUIPMENT

GROUP 1. MEASURING APPARATUS.

Quantity	Item	Total cost in dollars
		3,406.00
155	Ammeters	50.00
1	Apparatus for studying crystal magnetism	491.00
5	Cotton balances	225.00
2	Curie balances	95.00
2	Kelvin balances	40.00
1	Wheatstone bridge	174.00
2	Wilson chambers	103.00
6	Chronographs	506.00
35	Stop watches with or without electrical contact	93.00
2	Revolution counters	200.00
3	Geiger counters	26.00
4	Telephonic counters	1,984.00
57	Universal controllers	38.00
1	Potential divider 100,000	13.00
1	Recorder, 2 adjustable rectangular co-ordinates	275.00
3	Secondary length standards	68.00
1	Fluxmeter	130.00
3	Frequency meters	400.00
11	Needle galvanometers	270.00
3	Moving magnet galvanometers	3,488.00
71	Moving coil galvanometers	172.00
3	Suspension galvanometers	179.00
5	Projection galvanometers	34.00
1	Vibration galvanometer	123.00
5	Galvanoscopes	39.00
1	Gaussmeter, pyrrhotine sphere	122.00
12	Micrometer gauges reading to 0.01 mm	141.00
15	Galvanometer lamps	135.00
2	Microradiometers	1,042.00
58	Milliammeters	647.00
21	Millivoltmeters	28.00
3	Slide calipers	33.00
11	Slide-wire bridges	521.00
6	Impedance bridges	110.00
2	Precision divided rules	414.00
15	Additional resistances	98.00
2	Spherometers	16.00
1	Bismuth spiral	88.00
2	Höpler viscosimeters	4,635.00
162	Voltmeters	126.00
4	Wattmeters	Total 20,778.00

GROUP 2. RESISTANCES.

149	Various fixed resistances	1,386.00
103	Precision and decade fixed resistances	3,349.00
203	Rheostats, various	3,926.00
	Total	8,661.00

GROUP 3. INSTRUMENTS AND APPARATUS.

Quantity	Item	Total cost in dollars
45	Magnets, various.	59.00
1	Supply for X-ray tubes	400.00
13	LF amplifiers	1,300.00
1	Clément and Desormes apparatus for the specific heat of gases	38.00
1	Apparatus for experiments on superficial water waves	44.00
2	Apparatus for calibration of thermometers	94.00
1	Apparatus for demonstrating the Magnus effect	12.00
2	Apparatus for measuring vapour densities	8.00
2	X-ray installations	588.00
1	Gravity balance (Cavendish)	78.00
1	Barograph	63.00
3	Aneroid barometers	106.00
7	Mercury barometers	426.00
5	Batteries of LT condensers	130.00
7	Sector feeding boxes	560.00
20	Various coils	544.00
1	Bomb calorimeter	138.00
1	Horizontal compass	56.00
18	Bottles of compressed gases	430.00
2	Calorimeters, Junkers	304.00
1	Telephone head-set	6.00
13	Cathetometers	1,864.00
5	Photoemissive cells	100.00
2	Photo voltaic cells	13.00
7	Debye-Scherrer chambers	400.00
3	Tuning fork chronographs	190.00
1	Chronometer for short time-intervals	34.00
1	Thomson oscillating circuit	56.00
1	Electronic commutator	164.00
1	Spark counter	7.00
5	Standard condensers	195.00
9	HT condensers	650.00
2	Oil condensers	33.00
2	Condensers for measuring the specific inductive capacity	250.00
1	Condenser, precision variable	26.00
2	Conjunctur-disjunctors 30 A	31.00
32	Gas reducing valves	710.00
3	Tuning forks with resonant chamber	29.00
8	Reading scales	184.00
6	Telephone earpieces	24.00
6	Luminescent screens	86.00
22	Electromagnets with 30-90 mm core	6,129.00
4	Electrodynamometers	276.00
9	Suspension electrometers	730.00
2	Lindemann electrometers	145.00
9	Quadrant electrometers	787.00
6	Golf-leaf electroscopes	184.00
4	Short wave emitters	1,020.00
2	Recorders	99.00
4	LF generators	512.00
2	HF generators	283.00
4	Large induction coils	718.00
2	Large variable condensers	90.00
2	Pump sets	651.00
1	Standard clock with pendulum enclosed in a low pressure chamber	838.00
3	Hygrometers	87.00
Carry forward		22,979.00

PHYSICS AND CHEMICAL ENGINEERING

Quantity	Item	Total cost in dollars
	Brought forward	22,979.00
2	Hypsometers	41.00
4	Sodium lamp installations	78.00
1	Delay switch	5.00
1	Rotary interrupter for heavy currents	73.00
1	Pointolite lamp	35.00
1	Lamp with concave mirror	8.00
1	Nernst lamp	5.00
5	Arc lamps	206.00
14	Mercury vapour lamps	757.00
54	Reading glasses	2,375.00
1	Dividing head, 65 cm	75.00
4	Wimshurst machines	600.00
1	Absolute manometer	35.00
3	Metal pressure gauges	38.00
1	Metronome	4.00
3	Micrometers, spark	54.00
1	Microphone condenser	45.00
1	Crystal microphone	19.00
2	Frequency modulators	104.00
3	Wavemeters	147.00
1	Poulsen oscillator	63.00
22	CR oscillographs	2,688.00
3	Electromagnetic oscillographs	265.00
1	Catskin	3.00
2	Hemholtz pendulums for measuring short time intervals	330.00
6	Small induction coils	16.00
1	Pick-up	15.00
1	Lambrecht polymeter	6.00
1	Oil diffusion pump	94.00
10	Mercury diffusion pumps, metal	821.00
12	Mercury diffusion pumps, glass	250.00
6	Cooling pumps for machine tools	274.00
24	Vacuum pumps, vane type	2,405.00
1	Capacity bridge	41.00
1	Electronic measuring bridge	40.00
1	Magnetic potentiometer	31.00
11	Potentiometers	1,529.00
1	Piezo electric quartz for 600 m	13.00
1	Wireless receiver	57.00
1	Relay for photoelectric cell	38.00
1	Moll thermal relay	101.00
1	Luminous quartz resonator for 499 m	25.00
1	X-ray spectrograph	250.00
1	Thermograph	56.00
4	Air thermometers	100.00
9	Thermopiles	260.00
1	Thermostat	37.00
2	Turntables	100.00
1	Tesla transformer	55.00
1	Vacuum-meter	25.00
1	Variometer	47.00
5	Silver voltameters	25.00
2	Water voltameters	18.00
	Total	37,761.00

GROUP 4. BALANCES AND WEIGHTS.

1	Automatic balance, 10 kg	96.00
13	High precision balances	1,389.00
	Carry forward	1,485.00

EQUIPMENT

Quantity	Item	Total cost in dollars
	Brought forward	1,485.00
6	Medium precision balances	127.00
6	Taring precision balances	68.00
2	Bascules	23.00
34	Boxes of weights, various	378.00
2	Micro balances	145.00
	Total	2,226.00

GROUP 5. OPTICS AND ACCESSORIES.

1	Abbe diffraction apparatus	9.00
1	Apparatus for projection of polarization phenomena	206.00
22	Optical benches with sliders and various holders	781.00
4	Photometry benches	458.00
3	Fresnel biprisms	87.00
1	Babinet compensator	9.00
3	Gas meters	394.00
25	Condensers with or without iris diaphragm	500.00
4	Grating copies	48.00
9	Absorption cells	96.00
8	Iris diaphragms	39.00
8	Variable slits	133.00
12	Filters	11.00
7	Wratten filters	25.00
1	Reflexion goniometer with two divided circles	179.00
3	Babinet goniometers	327.00
4	Goniometers for measuring the refractive indices of crystals	1,900.00
1	Large 6-prism spectrograph	3,000.00
2	Heliostats	410.00
1	Interferometer for measuring expansion coefficients	463.00
2	Jamin interferometers	288.00
1	Parallel quartz slice	8.00
4	Tourmaline slices	55.00
1	Lamp for spectrum analysis	25.00
1	Projection lamp with water cell	78.00
1	Hefner candle	8.00
9	Arc lamps for optical bench	185.00
3	Microscope lamps	83.00
29	Lenses	572.00
3	Cylindrical lenses	22.00
6	Biconvex lenses	32.00
2	Quartz lenses	30.00
28	Unmounted lenses	188.00
1	Rock-salt lens	47.00
25	Reading magnifiers	107.00
1	Pyrometer lens	38.00
1	Luxmeter	22.00
1	Recording microphotometer	2,326.00
8	Various microscopes with numerous accessories : condensers, objectives, oculars, micrometers, plates, illuminators	3,000.00
2	Rotating mirrors	110.00
1	Monochromator	188.00
3	Nicol prisms	91.00
18	Photographic or projection objectives	543.00
2	Ophthalmometers	253.00
1	Pair of achromatic prisms	9.00
3	Lippman photographs	20.00
1	Photometer	38.00
	Carry forward	17,441.00

PHYSICS AND CHEMICAL ENGINEERING

Quantity	Item	Total cost in dollars
	Brought forward	17,441.00
2	Polarization photometers	263.00
2	Plane parallel plates	15.00
11	Rock salt plates	74.00
1	Precision polarimeter	525.00
4	Polarimeters	128.00
3	Polaristrobometers	379.00
17	Prisms, various	492.00
6	Quartz prisms	151.00
9	Rock-salt prisms	276.00
1	Glass prism	45.00
2	Disappearing filament pyrometers	356.00
2	Wanner pyrometers	224.00
4	Refractometers	450.00
2	Rowland gratings	325.00
1	Glass grating	75.00
2	Iceland spar rhombohedra	38.00
1	Saccharimeter	115.00
1	Quartz spectrograph	568.00
1	Grating spectrograph	500.00
3	Spectrophotometers	396.00
6	Direct vision spectroscopes	500.00
2	Spinthariscopes	16.00
1	Turntable	47.00
1	Theodolite	138.00
2	Thermopiles	88.00
1	Wood's glass cell	5.00
2	View finders on stands	40.00
	Total	23,670.00

GROUP 6. PHOTOGRAPHY AND ACCESSORIES.

2	Enlargers	130.00
4	Cameras	222.00
3	Photocopying apparatus	84.00
1	Selenium cell	9.00
11	Frameworks, various	48.00
1	Guillotine	6.00
15	Dishes	18.00
1	Recorder, clockwork mechanism	150.00
3	Dark room lamps	22.00
	Total	689.00

GROUP 7. PROJECTION AND CINEMA.

2	Projectors	116.00
2	Optical benches for projection, with accessories	460.00
75	Boxes for lantern slides	209.00
4	Condensers for vertical projection	184.00
3	Epidiascopes	797.00
1	Projection lantern, small	922.00
6	Arc lamps	165.00
		2,853.00

GROUP 8. LABORATORY INSTRUMENTS.

1	Acetylene apparatus	27.00
1	Water bath, constant level	54.00
182	Bunsen burners	119.00
	Carry forward	200.00

EQUIPMENT

Quantity	Item	Total cost in dollars
	Brought forward	200.00
19	Electric boilers	189.00
1	Ice crusher	60.00
1	Centrifuge	25.00
11	Blow torches	24.00
1	Vacuum pan, 55 l capacity	40.00
2	Storage water heaters	111.00
6	Immersion heaters	28.00
25	Hand-vices	17.00
3	Ovens	44.00
1	Extinguisher	38.00
2	Electric crucible furnaces	60.00
14	Steam generators	140.00
48	Electric lamps on stands	123.00
1	Hydrogen liquefaction plant	100.00
2	Cork borer sets	10.00
220	Stands with 560 bosses and clamps	608.00
16	Burette stands	20.00
5	Dewar vessels, 2 l	102.00
3	Solid CO ₂ vessels	71.00
2	Refrigerators	210.00
1	Vacuum receiver	125.00
300	Wooden test tube holders	140.00
5	Blowers	32.00
3	Blowers for aerodynamic experiments	214.00
370	Stands, frameworks, etc., in wood	530.00
2	Vacuum flasks	13.00
	Total	3,274.00

GROUP 9. MOTORS AND DYNAMOS.

100	Motors and dynamos, different models	2,000.00
-----	--	----------

GROUP 10. ACCUMULATORS.

100	Accumulators, different models	5,000.00
-----	--	----------

GROUP 11. TRANSFORMERS AND RECTIFIERS.

100	Transformers and rectifiers, different models	17,500.00
-----	---	-----------

GROUP 12. TOOLS.

Workshop:

Hand-tools for 5 mechanics	580.00
General tools and machine tool accessories	1,700.00

Laboratory:

Tools for maintenance men and laboratory assistants and laboratory	300.00
Total	27,080.00

PHYSICS AND CHEMICAL ENGINEERING

STOCKS OF MATERIALS, CHEMICALS, ETC.

Quantity	Item	Total cost in dollars
(1) ARTICLES IN PRECIOUS METALS.		
	Platinum : wires (0.2 to 0.67 mm diam) foil, sheet, plates, small cylindrical rods, small tubes, cylindrical grids, crucibles (35 to 90 mm diam)	600.00
	Gold: Crucible (25 mm diam) wire, sheet, foil	50.00
	Silver: tube, small ingot	25.00
	Iridium	2.00
	Mercury	550.00
	Radium	11,000.00
	Total	12,227.00
(2) GLASSWARE, PORCELAIN AND EARTHENWARE, RUBBER, FILTERS, CHEMICALS, ETC.		
		2,200.00
(3) ELECTRICAL EQUIPMENT.		
	Commutators, coils, variable condensers, ebonite, fibre, gutta-percha, metal wire, cable, small mounting equip- ment	1,500.00
(4) APPARATUS OF HIGH VALUE (which it is hoped the College will possess).		
1	Cyclotron	150,000.00

APPENDIX I

ABBREVIATIONS

A	==	ampere	HT	==	high tension
AC	==	alternative current	kg	==	kilogram
AR	==	analytic reagent	kVA	==	kilovoltampere
anhyd	==	anhydrous	l	==	litre
atm	==	atmosphere	LF	==	low frequency
b.p.	==	boiling point	LT	==	low tension
C	==	degree centigrade	m	==	metre
CR	==	cathode ray	M	==	melting point
cc	==	cubic centimetre	mA	==	milliampere
cm ²	==	square centimetre	mm	==	millimetre
cm ³	==	cubic centimetre	mV	==	millivolt
comml	==	commercial	MW	==	molecular weight
conc	==	concentrated	p	==	pressure
cryst	==	crystallized	powd	==	powder
d	==	density	pptd	==	precipitated
DC	==	direct current	pr	==	pair
detn	==	determination	RB	==	round bottomed
diam	==	diameter	s	==	second
dist.	==	distilled	SWG	==	standard wire gauge
expts	==	experiments	synth	==	synthetic
f	==	focal distance	T	==	temperature
FB	==	flat bottomed	v	==	volume
FP	==	freezing point	V	==	volt
g	==	gram	W	==	watt
gran	==	granulated	WM	==	wide mouthed
HP	==	horse power			

APPENDIX II

CONVERSION FACTORS

Length

1 mm	=	0.03937 in	1 mil	=	1/1000 in
1 cm	=	0.3937 in		=	0,0254 mm
1 m	=	3.2808 ft	1 in	=	25,4 mm
	=	1.0936 yd	1 ft	=	12 in
1 km	=	0.6213 mile		=	30,48 cm
			1 yd	=	3 ft
				=	0,9144 m
			1 mile	=	1609,3 m
			1 line	=	1/12 in
				=	2,116 mm

Surface

1 mm ²	=	1973.5 circular mils	1 circular mil	=	0,0005067 mm ²
1 cm ²	=	0.155 in ²	1 in ²	=	6,4516 cm ²
1 m ²	=	10.7639 ft ²	1 ft ²	=	144 in ²
	=	1.1959 yd ²		=	0,0929 m ²
1 km ²	=	0.3861 mile ²	1 yd ²	=	9 ft ²
	=	247.11 acres		=	0,83613 m ²
1 hectare	=	2.4711 acres	1 acre	=	4046,9 m ²
			1 mile ²	=	1640 acres
				=	2,5899 km ²

Volume

1 ml	=	1 cm ³	=	0.06102 in ³	1 in ³	=	16,387 cm ³
1 l	=	1 dm ³	=	0.0353 cubic feet	1 ft ³	=	28,317 dm ³
	=	1 m ³	=	35.3156 ft ³	1 yd ³	=	0,76456 m ³
			=	1.3079 yd ³			

Capacity

1 l	=	35.196 British fluid ounces	1 British fluid ounce	=	0,0284 l
	=	1.75981 British pints	1 British pint	=	0,5682 l
	=	0.2199 British gallons	1 British imperial gallon	=	8 British pt
	=	33.8140 U.S. fluid ounces		=	4,5459 l
	=	2.1134 U.S. pints	1 U.S. fluid ounce	=	0,02957 l
	=	0.2642 U.S. gallons	1 U.S. pint	=	0,4732 l
			1 U.S. gallon	=	3,7854 l
			1 Winchester-quart	=	80 British fluid ounces = 2,2729

Weight

1 g	=	0.035 oz	1 oz	=	28,35 g
1 kg	=	35.273 oz	1 lb	=	453,5 g
	=	2.2046 lb	1 cwt	=	50,802 kg
			1 oz troy	=	31,103 g

Power

1 kW	=	1.341 HP	1 HP	=	0,7457 kW
------	---	----------	------	---	-----------

Pressure

1 kg/cm ²	=	14.223 lb/in ²	1 lb/in ²	=	0,070307 kg/cm ²
				=	95.760 pz

THE ELEMENTS¹

		Atomic Number	Atomic Mass			Atomic Number	Atomic Mass
Nn	Neutron	0	1.0088	Sn	Tin	50	118.70
H	Hydrogen	1	1.0080	Sb	Antimony	51	121.76
He	Helium	2	4.003	Te	Tellurium	52	127.61
Li	Lithium	3	6.940	I	Iodine	53	126.92
Be	Beryllium	4	9.02	Xe	Xenon	54	131.3
B	Boron	5	10.82	Cs	Caesium	55	132.91
C	Carbon	6	12.010	Ba	Barium	56	137.36
N	Nitrogen	7	14.008	La	Lanthanum	57	138.92
O	Oxygen	8	16	Ce	Cerium	58	140.13
F	Fluorine	9	19.00	Pr	Praseodymium	59	140.92
Ne	Neon	10	20.183	Nd	Neodymium	60	144.27
Na	Sodium	11	22.997	Pm	Promethium	61	147
Mg	Magnesium	12	24.32	Sm	Samarium	62	150.43
Al	Aluminium	13	26.97	Eu	Europium	63	152.0
Si	Silicon	14	28.06	Gd	Gadolinium	64	156.9
P	Phosphorus	15	30.974	Tb	Terbium	65	159.2
S	Sulphur	16	32.066	Dy	Dysprosium	66	162.46
Cl	Chlorine	17	35.457	Ho	Holmium	67	164.94
A	Argon	18	39.944	Er	Erbium	68	167.2
K	Potassium	19	39.096	Tm	Thulium	69	169.4
Ca	Calcium	20	40.08	Yb	Ytterbium	70	173.04
Sc	Scandium	21	45.10	Lu	Lutecium	71	175.0
Ti	Titanium	22	47.90	Hf	Hafnium	72	178.6
V	Vanadium	23	50.95	Ta	Tantalum	73	180.88
Cr	Chromium	24	52.01	W	Tungsten	74	183.92
Mn	Manganese	25	54.93	Re	Rhenium	75	186.31
Fe	Iron	26	55.85	Os	Osmium	76	190.2
Co	Cobalt	27	58.94	Ir	Iridium	77	193.1
Ni	Nickel	28	58.69	Pt	Platinum	78	195.23
Cu	Copper	29	63.542	Au	Gold	79	197.2
Zn	Zinc	30	65.377	Hg	Mercury	80	200.61
Ga	Gallium	31	69.72	Tl	Thallium	81	204.39
Ge	Germanium	32	72.60	Pb	Lead	82	207.21
As	Arsenic	33	74.91	Bi	Bismuth	83	209.00
Se	Selenium	34	78.96	Po	Polonium	84	210
Br	Bromine	35	79.916	At	Astatum	85	210
Kr	Krypton	36	83.7	Rn	Radon	86	222
Rb	Rubidium	37	85.48	Fr	Francium	87	221
Sr	Strontium	38	87.63	Ra	Radium	88	226.05
Y	Yttrium	39	88.92	Ac	Actinium	89	227
Zr	Zirconium	40	91.22	Th	Thorium	90	232.12
Nb	Niobium	41	92.91	Pa	Protactinium	91	231
Mo	Molybdenum	42	95.95	U	Uranium	92	238.07
Tc	Technetium	43	98.91	Np	Neptunium	93	237.07
Ru	Ruthenium	44	101.7	Pu	Plutonium	94	239.08
Rh	Rhodium	45	102.91	Am	Americium	95	243
Pd	Palladium	46	106.7	Cm	Curium	96	244
Ag	Silver	47	107.880	Bk	Berkelium	97	245
Cd	Cadmium	48	112.41	Cf	Californium	98	(246)
In	Indium	49	114.76			99	
				Ct	Centurium	100	(248)

¹ We are indebted to Mr. Grégoire of the *Institut du Radium* (Paris) who kindly gave us the latest data concerning atomic masses.

APPENDIX III

SHORT LIST OF SUPPLIERS OF SCIENTIFIC INSTRUMENTS

AUSTRALIA

Abacus Instrument Co.,
122 King St.,
Melbourne.

Dobbie Bros. (Thermometers),
80 Little Monsdale St.,
Melbourne.

BELGIUM

Fédération des Entreprises de l'Industrie des Fabrications Métalliques,
17 rue des Drapiers,
Brussels.

Société Belge d'Optique et d'Instruments de Précision,
110 rue de la Prairie,
Ghent.

DENMARK

Association of Scientific Instrument Manufacturers Industriraaet,
18 Vestre Boulevard,
Copenhagen 5.

H. Struers Chemiske Laboratorium,
38 Skindergade,
Copenhagen.

FRANCE

Association Interprofessionnelle des Constructeurs de Matériel d'Équipement Scientifique (AICMÉS)
(12 member federations comprising 165 firms),
61 rue de Malte,
Paris-11.

FOPEX
(group of 32 industrials),
61 rue de Malte,
Paris-11.

GREAT BRITAIN

Scientific Exports (Great Britain) Ltd. (SCIEX) (comprising 7 firms),
Buckingham House, Buckingham St.,
Adelphi, London, W.C.2.

Scientific Instrument Manufacturers' Association of Great Britain, Ltd.
SIMA (comprising 84 firms),
17 Princes Gate,
London, S.W.7.

ITALY

Antonio Vallardi,
22 Via Stelvio,
Milan.

NETHERLANDS

Vereeniging van Nederlandsche Instrumentfabrikanten,
73 Voorstraat,
Delft.

SWEDEN

Rudolph Grave Aktiebolaget,
48 C Malmskillnadsgatan,
Stockholm.
Norstedt & Söner,
17 Bryggaregatan,
Stockholm.

Axel Kistner,
20-22 Wallingatan,
Stockholm.

SWITZERLAND

Association Suisse des Construc-
teurs de Machines (V.S.M.),
4 General Wille Strasse,
Zürich 2.

UNITED STATES OF AMERICA

Scientific Apparatus Makers of
America (SAMA) (comprising
202 firms),
20 N. Wacker Drive,
Chicago 6,
Illinois.

U.S. Scientific Export Association Inc.,
50 Broadway,
New York, N.Y.

UNESCO SALES AGENTS

- ARGENTINA:** Editorial Sudamericana, S.A., Alsina 500, Buenos Aires.
- AUSTRALIA:** H. A. Goddard Ltd., 255a George Street, Sydney.
- AUSTRIA:** Wilhelm Frick Verlag, 27 Graben, Vienna, I.
- BARBADOS:** S.P.C.K. Bookshop (Regional Office Caribbean Area), Broad Street Bridgetown.
- BELGIUM:** Librairie Encyclopédique, 7 Rue du Luxembourg, Brussels IV.
- BRAZIL:** Livraria Agir Editora, Rua Mexico 98-B, Caixa postal 3291, Rio de Janeiro.
- BURMA:** Burma Educational Bookshop, 551-3 Merchant Street, P.O. Box 222, Rangoon.
- CANADA:** University of Toronto Press, Toronto.
- CEYLON:** Lake House Bookshop, The Associated Newspapers of Ceylon, Ltd., Colombo I.
- CHILE:** Libreria Lope de Vega, Moneda 924, Santiago de Chile.
- COLOMBIA:** Emilio Royo Martin, Carrera 9a, 1791, Bogota.
- CUBA:** La Casa Belga, René de Smedt, O'Reilly 455, Havana.
- CZECHOSLOVAKIA:** Orbis, Narodni 37, Prague I.
- DENMARK:** Einar Munksgaard, 6 Norregade, Copenhagen.
- ECUADOR:** Casa de la Cultura Ecuatoriana, Av. Mariano Aguilera 332, Casilla 67, Quito.
- EGYPT:** Librairie James Cattán, Fournisseur de la Cour, 118 Rue Emad el Dine, Cairo.
- FINLAND:** Akateeminen Kirjakauppa, 2 Keskuskatu, Helsinki.
- FRANCE:** Maison du Livre Français, 4 Rue Félibien, Paris (6^e). (Booksellers only.)
Unesco, Sales Service, 19 Avenue Kléber, Paris (16^e). (Individual sales.)
- GERMANY:** Florian Kupferberg Verlag, Eleonorenstrasse 6, Mainz-Kastel.
- GREECE:** Elefthéroudakís, Librairie Internationale, Athens.
- HUNGARY:** "Kultura", Akademia-u, 10, Budapest V.
- INDIA:** Oxford Book and Stationery Co., Scindia House, New Delhi.
- ISRAEL:** Leo Blumstein, Book and Art Shop, 35 Allenby Road, Tel Aviv.
- ITALY:** Messaggerie Italiane, Via Lomazzo 52, Milan.
- LEBANON AND SYRIA:** Librairie Universelle, Avenue des Français, Beirut, Lebanon.
- MALAYA AND SINGAPORE:** Peter Chong & Co., P.O. Box 135, Singapore.
- MEXICO:** Libreria Universitaria, Justo Sierra 16, México D. F.
- NETHERLANDS:** N. V. Martinus Nijhoff, Lange Voorhout 9, The Hague.
- NEW ZEALAND:** Whitcombe & Tombs, Ltd., G.P.O. Box 1526, Wellington, C.1.
- NIGERIA:** C. M. S. Bookshop, P.O. Box 174, Lagos.
- NORWAY:** A/S Bokhjornet, Stortingsplass 7, Oslo.
- PAKISTAN:** Thomas & Thomas, Fort Mansions, Frere Road, Karachi 3.
- PERU:** Libreria Internacional del Peru, S. A., Giron de la Union, Lima.
- PHILIPPINES:** Philippine Education Co., Inc., 1104 Castillejos, Quiapo, Manila.
- PORTUGAL:** Publicações Europa-America, Ltda, 4 Rua da Barroca, Lisbon.
- SWEDEN:** A.B. C.E. Fritzes Kungl, Hovbokhandel, Fredsgatan 2, Stockholm.
- SWITZERLAND:** French speaking cantons: Librairie de l'Université, 22-24 Rue de Romont, Fribourg.
German speaking cantons: Europa Verlag, 5 Rämistrasse, Zürich.
- TURKEY:** Librairie Hachette, 469 Istiklal caddesi, Beyoglu, Istanbul.
- UNION OF SOUTH AFRICA:** Van Schaik's Bookstore (Pty.), Ltd., P.O. Box 724, Pretoria.
- UNITED KINGDOM:** H.M. Stationery Office: York House, Kingsway, London (Retail Counter Service), or P.O. Box 569, London, S.E.1. (Orders by post.)
- UNITED STATES OF AMERICA:** Columbia University Press, 2960 Broadway, New York 27, N.Y.
- URUGUAY:** Centro de Cooperacion Cientifica para la America Latina, Unesco, Bulevar Artigas 1320, Montevideo.

SOME PUBLICATIONS OF UNESCO

"Problems in Education"

I. <i>War Handicapped Children</i> , by Dr. Thérèse Brosse. 1950	\$0.50	3/-	150 frs.
II. <i>Adult Education — Current Trends and Practices</i> . 1949	\$0.75	4/-	200 frs.
"Monographs on Fundamental Education"			
I. <i>Fundamental Education — Description and Programme</i> . 1949	\$0.25	1/-	75 frs.
II. <i>Co-operatives and Fundamental Education</i> , by Maurice Colombain. 1950	\$0.60	3/6	160 frs.
III. <i>The Mexican Cultural Mission Programme</i> , by Lloyd H. Hughes. 1950	\$0.45	2/6	125 frs.
<i>A Handbook for the Improvement of Textbooks and Teaching Materials as Aids to International Understanding</i> . 1949	\$0.45	2/6	125 frs.
<i>Inventories of Apparatus and Materials for Teaching Science</i> . — Vol. I. Primary, Secondary and Vocational Schools. 1950	\$1.00	6/-	300 frs.
Idem: Vol. II. Universities, 1950	\$2.00	12/3	600 frs.
Idem: Vol. III. Technical Colleges; Part I. Veterinary Sciences. 1950	\$1.20	7/-	350 frs.
<i>Directory of International Scientific Organizations</i> . 1950 ..	\$1.00	6/-	300 frs.
<i>Contemporary Political Science: A Survey of Methods, Research and Teaching</i> . 1950	\$5.00	25/-	1,200 frs.
<i>Press, Radio, Film</i> . I. 1947	\$1.20	6/-	300 frs.
<i>Press, Film, Radio</i> . II. 1948	\$1.20	6/-	300 frs.
<i>Press, Film, Radio</i> . III. 1949	\$1.20	7/-	350 frs.
<i>Press, Film, Radio</i> . Second Supplement. 1950	\$0.85	5/-	250 frs.
<i>Broadcasting to Schools</i> . 1949	\$1.00	6/-	300 frs.
<i>World Communications — Press, Radio, Film</i> . 1950 ...	\$1.20	7/-	350 frs.
<i>Films on Art</i> . A specialized study. An International Catalogue. Brussels and Paris. 1950	\$0.75	5/-	250 frs.
<i>Human Rights. Exhibition Album</i> . 1950	\$3.00	16/-	800 frs.
<i>Catalogue of Colour Reproductions of Paintings from 1860 to 1949</i> . Trilingual (English-French-Spanish). 1949	\$1.50	8/-	400 frs.
<i>Catalogue of Colour Reproductions of Paintings Prior to 1860</i> . Trilingual (English-French-Spanish). 1950	\$2.00	10/-	600 frs.
<i>Index Translationum</i> . International Bibliography of translations. New series I, 1948. Bilingual (English-French). 1949	\$3.00	18/6	900 frs.
<i>Monuments and Sites of History and Art and Archaeological Excavations</i> . Problems of today. Bilingual (English-French). 1950	\$1.50	6/-	300 frs.
Unesco Public Library Manuals:			
I. <i>Education for Librarianship</i> , by Periam Danton, 1949	\$0.65	4/-	200 frs.
II. <i>Public Library Extension</i> , by Lionel R. McColvin, 1950	\$0.65	4/-	200 frs.
III. <i>Adult Education Activities for Public Libraries</i> , by Carl Thomsen, Edward Sydney, Miriam D. Tompkins. 1950	\$0.65	4/-	200 frs.
<i>Study Abroad</i> . International Handbook. Fellowships, Scholarships, Educational Exchange. Vol. III. 1950-51. Paris 1950	\$1.25	5/-	250 frs.
<i>Suggestions for Science Teachers in Devastated Countries</i> , Prepared by J. P. Stephenson. 1948	\$0.80	4/-	200 frs.

Prices are in dollars, sterling and French francs.

