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ABSTRACT

This publication is part of the Oxford/Council of Europe Study for the Evaluation of the Curriculum and Examinations (OCESCE) Study, and is concerned with aims, objectives, program content, teaching methods, evaluation, and assessment and future trends in the development of curricula for the gifted student at the upper academic secondary level. Included in the booklet is a discussion on the aims of teaching chemistry, data and discussion relevant to the percentage of students studying chemistry, and time devoted to chemistry teaching. The determination of a syllabus, its content, and the evaluation of syllabus changes are discussed. One chapter presents data representative of teaching methods used, teaching aids, textbooks, and the liaison with industry that is present. Appendices include a list of aims of chemistry teaching, a bibliography for publications, chemistry syllabi of selected countries, and a taxonomy of educational objectives in chemistry. (EB)

FOREWORD

The Council of Europe, working through the Committee for General and Technical Education of the Council for Cultural Co-operation, has in recent years become increasingly interested in the field of curriculum development. One manifestation of this interest is the continuing support it has given to what has become known as the OCESCE Study (Oxford/Council of Europe Study for the Evaluation of the Curriculum and Examinations) of which this present study of chemistry forms part. Thus several publications of the results of the Study, in mathematics, Latin and modern languages have already been published either under the auspices of the Council for Cultural Co-operation or commercially (1). The OCESCE Study, which is also partially financed through the generosity of the Gulbenkian Foundation, of course represents no more than the opinions of those specialists engaged in it : any judgments made are theirs, and do not commit the responsibility of the Council of Europe in any way. At the same time, as the one appointed to direct the Study, I should like to express gratitude to the Council of Europe for the help and encouragement it continues, through its Secretariat, to give us.

The OCESCE Study, which is carried out at Oxford in the University Department of Educational Studies, aims at being European - rather than national-oriented - and is concerned with the aims and objectives, the programme content, teaching methods, evaluation and assessment and future trends in the development of curricula for the gifted at the upper academic secondary level. Through a study of the official and semi-official publications of the member countries of the Council of Europe it has arrived at an overall evaluation which represents the state of a number of subjects about the beginning of the new decade. It shows a clear tendency towards increasing rigour in the delimitation of curriculum goals, the subject matter taught and in the use of assessment techniques.

From the Study is emerging valuable data concerning curriculum theory in the member countries, which should be useful in arriving at pedagogical agreements on equivalences between the various European countries. To some extent this is a function of what might be termed

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(1) W.D. Halls and D. Humphreys, European Curriculum Studies No. 1 : Mathematics, Council for Cultural Co-operation, Strasbourg, 1968

P. Story, European Curriculum Studies No. 2 : Latin, Council for Cultural Co-operation, Strasbourg, 1969

W.D. Halls, Modern Languages and Education in Western Europe, George Harrap, London, 1970 the congruence problem : How far do terminal school courses in one country "fit" with initial courses in higher education in another ? What the Study seeks to provide is the raw material upon which pedagogical decisions made by educational experts at international conferences could be based.

The present publication in chemistry exemplifies the wide diversity that still exists in teaching programmes in this subject at the upper secondary level. On the other hand, current trends towards the harmonising if not the unification, of programmes can be discerned.

Further studies which are in the press include those on biology and physics. One on the teaching of economics is in preparation. The series will be completed by comparative studies of the mother tongue, civic and social education, history and geography. It is hoped that by 1972 the main subjects of the academic secondary curriculum will have been covered in this way. A synthesis of the whole series of subject studies will then be made in relation to such questions as the overall balance of the curriculum, the various alternatives to traditionalexaminations that are emerging and the increasingly blurred distinction between general and vocational education, as well as other related issues.

OXFORD W.D. HALLS

PREFACE

This book represents an attempt to survey the field of chemical education at the most specialised level of the academic secondary school, i.e. at the immediately pre-university stage, on behalf of the Council of Europe for its member States. It includes an investigation into the aims, organisation, syllabuses, teaching methods, examinations and teachers of chemistry, through consultation with experts from the countries represented, analysis of questionnaires answerd by them and reference to official publications available to us. I would like to acknowledge with gratitude the help given in this work by Peter Figueroa with the review of the official publications, and by Julia Marshall with the analysis of the chemistry syllabuses. It is inevitable in a study of this nature that errors will have inadvertently been included, and the author apologises in advance for them. It is also unfortunate that in so rapidly a changing field as chemical education some of the material will be out of date by the time this book reaches publication. It is hoped that member governments and individuals will send in their amendments for correction in any subsequent edition or further study.

Finally I would like to thank my chemistry colleagues throughout Europe, and Denis Driscoll of Melbourne, Australia, in particular, for most stimulating correspondence and discussion in connection with this work.

OXFORD. J.J. THOMPSON

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ABBREVIATIONS

The following abbreviations have been used throughout the text for each of the countries represented :

A	Austria
B	Belgium
CY	Cyprus
DK	Denmark
D	Federal Republic of Germany
F	France
EIR	Ireland
I	Italy
IS	Iceland
L	Luxembourg
M	Malta
NL	Netherlands
N	Norway
S	Sweden
SL	Scotland
E	Spain
CH	Switzerland
TR	Turkey
GB	England and Wales

CHAPTER I

AIMS OF CHEMICAL EDUCATION

The declared aims of chemical education at the immediately pre-university level for each of the countries participating in the study were examined by two methods. The first method used was to examine the official publications of the governments, examining bodies and national science teachers' organisations involved, whilst the second method sampled the opinions of the experts from each of the countries concerned using a short questionnaire.

The results of the first method are set out in some detail in Appendix I, and the bibliography of the publications used are contained in Appendix II. The selection of material for this purpose was not always straightforward, and inevitably the list of publications is far from comprehensive. The situation is made more difficult by, for example, the wide diversity of examining boards in England, and the different Länder in the Federal Republic of Germany. In such cases the best judgment of experts from the countries involved has been drawn upon for this, and all relevant material which will subsequently appear in this report.

A reading of the synopses of the aims shows that whereas most countries subscribe to the same set of general aims, each country places its own emphasis on particular aims. This is hardly surprising in view of the different educational systems represented. Table I is an attempt to summarise the emphasis placed by each country on the several aims of teaching chemistry, but it must be pointed out that the absence of a mark in any column does not necessarily mean that the country concerned does not include a particular item among its aims.

An inspection of Table I shows that all the countries concerned subscribe to the view that a factual knowledge of chemical laws and phenomena is an important aim. In the same way all are in agreement that knowledge of, and training in, chemical experimentation is of primary importance. This may seem obvious for a subject like chemistry which is based firmly on empirical evidence, but it has not been universal practice to encourage the development of manipulative skills in the individual pupils until relatively recently. As will be shown later, the more recent teaching syllabuses and methods of assessment have put an increasing emphasis on the achievement of practical expertise in the individual pupils. Nearly all countries agree that an understanding of the "scientific method" should be gained by the time the pupils leave secondary education for university work, and that they should be in a position to derive a theory from empirical evidence, devise a method of testing the theory, and assess the possibilities and limitations of any model set up as a result. Again, nearly all are agreed that a realisation of the importance of applied chemistry and the part played by technology should be appreciated by this stage in the pupils'

Table I - General Summary of Chemistry Aims

	A	B	DK	D	F	EIR	I	L	M	NL	N	SL	E	CH	GB
<u>Philosophical</u>	x			x						x					x
Introduction to the reflective method				x											
Epistemological questions	x			x							x				
Moral, social, political questions				x											x
- Problems of values				x											
- Social and moral problems concerning technological applications of chemistry	x	x		x											
<u>Discipline centred</u>															
Understanding of, and training in, science :							x								
Disinterested pursuit of knowledge (incl.interest in knowledge in general ; desire for truth)				x											x
Comprehensive view of nature, understanding of nature				x	x										
Acquisition of the scientific spirit					x										x
Development of the objective attitude (Subjekt-Objekt Haltung)				x	x										
An understanding of the scientific way of thinking as a search for causes, for explanations				x	x										
A grasp of the scientific method (interplay of theory and empirical evidence) (use of hypotheses ; use of models)	x	x	x	x		x		x		x	x				x
Appreciation of the limitations of science, of scientists - and of chemistry (incl. a realisation of the tentative nature of scientific theories)				x											x

	A	B	DK	D	F	EIR	I	L	M	NL	N	SL	E	CH	GB
Understanding of, and training in chemistry :															
Coherence of chemistry and other disciplines	x		x	x	x	x	x			x					x
Knowledge of chemical laws and phenomena	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
A deepened understanding of chemistry (incl. a grasp of the chemical way of inquiry ; a grasp of the fundamental theoretical framework of chemistry)	x			x	x		x	x	x	x	x	x	x	x	x
Some knowledge of, and training in, the carrying out of (chemical) experiments	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
History of chemistry	x			x	x		x								x
Humanist elements of history of chemistry (chemists)				x	x										
Contemporary discoveries, advances and problems in chemistry (and in science)	x			x			x	x	x			x		x	x
Technological applications and importance of chemistry	x	x	x	x	x		x	x	x	x	x	x	x	x	x
Pupil centred												x			
Preparation for one's career					x										
Preparation for further education and for independent chemical/scientific research				x	x		x	x		x		x		x	x
A full (general, liberal) education				x	x					x		x			x
Preparation for life in modern technological society				x							x	x			x
An intellectual training		x		x	x										x
Exact observation and measurement	x			x	x			x	x						x
Sense of order ; orderly procedure				x				x							x
Logical and clear thinking, induction and deduction	x			x	x				x						x

	A	B	DK	D	F	EIR	I	L	M	NL	N	SL	E	CH	GB
Correct and clear expression	x			x				x							
Critical spirit				x	x						x				x
Development of judgment ; ability to form own considered opinion					x			x							x
Development of imagination					x			x							
Development of memory					x										
Character and moral training				x	x										x
- Development of certain attitudes and values					x										
- Spirit of co-operation				x											
- Independence				x											
- Will-power				x											
- Honesty				x											
- Initiative, creativeness															x
- Aesthetic sense				x											
- Sense of social responsibility				x											
<u>Society centred</u>															
To prepare the scientists needed by society															x

scientific career, and many would add to this a knowledge of contemporary discoveries and advances in the chemical fields. It is most encouraging to note the importance that is placed on the coherence of chemistry and the other disciplines, and this is finding expression in some countries in combined science courses not only at the lower secondary level but also at the pre-university level. The Nuffield Physical Science Course in the United Kingdom is one example. So far as the pupil-centred aims are concerned, the most popular is that of preparing the pupil for further education, and at the same time (for many) providing a full and liberal education. Whilst these two aims are not incompatible, their realisation in terms of syllabus content and teaching method is by no means a simple one, and this subject will be returned to in a later chapter.

If it is interesting to note the points of agreement concerning the general aims of teaching chemistry, it is equally interesting to note those aims which are shared by only a few of the countries concerned. In this respect the Federal Republic of Germany, together with Austria to a lesser degree, would lay greater emphasis on the philosophical aspects of the subject than most, and the reader should consult Appendix I to find out to what extent this is shared by the different Länder concerned. The history of chemists and chemistry does not feature very greatly, and the author feels that this may be because the historical aspects of the subject are considered not so much as primary aims in themselves but as possible teaching methods for some parts of the subject. For example, one might wish to develop the atomic theory through a historical approach and hence demonstrate the contributions made by many outstanding scientists, without these contributions being the fundamental aim involved. Most of the rest of the aims shared by only a few countries appear in the latter part of the table which is concerned with moral and intellectual attitudes, and understandably there is a diversity of emphasis for such aims. It is quite obvious that specific goals, which may operate on a short-term basis, can be more easily identified and agreed upon than the longer-term, more philosophical, goals.

The second method by which the aims of chemistry teaching were assessed involved a short questionnaire which simply asked the experts consulted to indicate the extent to which they agreed with a list of statements concerning the objectives of chemistry teaching. The results of this survey are summarised in Tables II to VI inclusive, and each statement on the left-hand side should be preceded by :
"The chemistry course in my country has been designed with the intent that at the end of his secondary schooling, a chemistry student will, as a result of his chemistry studies,..........".

The code letters A to E used in these Tables indicate the following agreement with the aim :

A : agree strongly B : agree mildly C : uncertain

D : disagree mildly E : disagree strongly

Table II - Further Education and Employment
Table III - Society/Social based
Table IV - Industry based
Table V - Nature of Science and the Scientific Method
Table VI - Chemical Analysis

The Tables only include replies received from countries at the date of compiling the report.

Table II - Further Education and Employment

		D	EIR	I	L	CH	TR	GB
(i)	be qualified to proceed to further study in chemistry at the tertiary level :	B	A	E	A	A	A	A
(ii)	be able to study other science and technological subjects at the tertiary level :	B	A	D	A	A	B	A
(iii)	be in a position to take employment as a worker in a scientific or technological situation with very little further scientific training :	E	B	C	C	E	E	B

Table III - Society/Social based

		D	EIR	I	L	CH	TR	GB
(i)	have an informed and critical interest in scientific matters in general :	A	B	C	A	A	B	C
(ii)	Have an informed and critical interest in social issues such as environmental pollution, conservation of national resources etc :	A	D	D	B	A	C	C
(iii)	be able to detect unjustified assumptions and illogicalities in un-scientific areas such as advertising and political propaganda :	C	D	C	C	A	E	D

Table IV - Industry based

		D	EIR	I	L	CH	TR	GB
(i)	understand the scientific principles underlying the major chemical industries :	B	D	B	D	B	B	A
(ii)	have an appreciation of the interaction of economics, availability of materials, politics and chemistry, that exists in the chemical industry :	B	D	C	C	E	C	B

Table V - Nature of Science and the Scientific Method

		D	EIR	I	L	CH	TR	GB
(i)	see the progress of science as an orderly and logical development, with major advances being made essentially by the application of the scientific method :	A	B	B	C	B	C	A
(ii)	see the progress of science as involving, to a considerable extent, the controlled use of the imagination :	A	B	C	C	B	B	A

Table VI - Chemical Analysis

		D	EIR	I	L	CH	TR	GB
(i)	have a grounding in systematic qualitative chemical analysis :	E	B	D	E	E	E	A
(ii)	have a grounding in systematic quantitative chemical analysis :	E	C	D	E	B	D	A

Table II, concerning the objectives of chemistry teaching for further education and employment, shows that nearly all the countries represented rate the provision of a course leading to a further study of chemistry or a related science at the tertiary level as a high priority. Italy can be seen to be an exception to this, and as the other Tables reveal, the emphasis for this country lies elsewhere. It is interesting to note that all the countries (again with the exception of Italy) rate the preparation of the pupils for further scientific education higher than preparation for direct employment as a scientific or technological worker. From Table III it can be seen that most countries have included in their course objectives the development of an informed and critical interest in general scientific matters, and three out of the seven rate this as the highest priority. There is not such a high premium on the application of these attitudes to social issues such as conservation of natural resources, and the response is more varied, but here again it should be noted that the newer courses are recognising this objective to a greater degree (the institution in Italy of a scheme for the study of air pollution, jointly carried out by the schools and a National Laboratory, for example). Lowest placed of the society-based objectives is that of the application of scientific training to non-scientific areas such as advertising and political propaganda. It must be pointed out that of the countries represented here,Switzerland gives the highest rating to all of the aims expressed in Table III. Table IV, which seeks to assess the aim of chemistry courses concerning industry, shows that whereas most countries would expect an understanding of the scientific principles underlying the major chemical industries to be achieved, in general this would not lead to a deeper appreciation of the interaction of economics, resources, and politics, relevant to the chemical industry. Table V indicates that all the chemistry courses seek to demonstrate the nature of scientific progress as an orderly and logical development involving the controlled use of the imagination. It is hardly surprising, in view of the earlier assessment (see Table I), that the Federal Republic of Germany rates these aims amongst their highest priorities. Table VI represents an attempt to assess the attitudes of member countries to the importance of chemical analysis in their courses. Such objectives receive the lowest grading of those assessed by this second method, with the exception of the United Kingdom, and possibly Ireland. In both of these countries, however, the newer courses in chemistry at this level have not placed such great emphasis on systematic chemical analysis as suggested by Table VI.

The first method of assessment tried to sample the aims of chemistry teaching over a wide spectrum, whereas the second method was restricted to narrower limits but attempted to grade the aims in importance. Inspection of both methods and their results reveals that a consensus can be reached on a substantial number of aims and of their relative importance, which, in itself, is a most satisfactory state of affairs when cognisance is taken of the different educational systems represented. In particular it is felt that it would be desirable to draw up a list of aims to which all could subscribe, not because it represents a poor compromise between the existing systems but rather because it constitutes the primary and fundamental goals in the teaching of the subject. The author has attempted to do this, but the list is inevitably a short one, and it is given below.

The aims of the teaching of chemistry

1. To give the pupil such a knowledge of the framework of the subject as to enable him to understand the structure and changing of matter, under conditions which we call chemical.

2. To make clear to the pupil the possibilities and limitations of such a knowledge, and to create in him an awareness of the impact and influence this knowledge has on society, so preparing him for life in a technological age.

3. To inculcate in the pupil a critical attitude with theoretical speculation based on experimental facts and liable to change, together with the ability for precise formulation of thought.

4. To develop in the pupil those manipulative and experimental skills necessary to make him competent and confident in the investigation of the materials around him.

Although not in itself an aim, all the representatives consulted considered it of the utmost importance that every pupil should, at some stage in the secondary school, follow a course of chemistry which embodies the aims listed above.

When one has arrived at a taxonomy of aims, however, the task of curriculum reform has only just begun. The major part of the work must then be concerned with the ways in which these aims can be made operational and this will mean the ways in which they are realised through the syllabus content, teaching method and assessment techniques for the chemistry course. The bulk of this report will therefore be concerned with an examination of the extent to which the content and methods of chemical education reflect the aims outlined in this chapter.

CHAPTER II

CHEMISTRY IN THE SECONDARY CURRICULUM

During the past twenty-five years most of the European countries have seen a substantial reorganisation of their secondary school system, many of which have been redeveloped along comrehensive lines. This reorganisation has had an effect on the place in the school curriculum of science subjects no less than any other, and together with the need for an increasing number of scientists and, particularly, technologists, to meet the demands of present-day society, changes in the extent to which science subjects occupy a part of the students' basic education are currently taking place. A fairly detailed review of the organisation of science teaching within the secondary school system has already been given in this series of curriculum studies, and it is not the intention to repeat that here. Rather, this chapter will be concerned with a short appraisal of the place of chemistry in the secondary curriculum, and will thus serve as a background against which the material in the remainder of this report can be seen.

Chemistry and other sciences

Many countries offer a wide variety of science subjects which may be studied in the final two years of the secondary school, and chemistry features largely in most of the combinations which are chosen. This, in part, will be due to the fact that for some countries there is a free choice not between all the sciences separately, but only between certain combinations of sciences. This probably arises due to the entrance requirements of the universities or to the limits imposed in the time-tabling of the many combinations of science subjects possible. The three most popular combinations which involve chemistry are shown in Table VII.

Table VII - Combinations of Science Subjects Involving Chemistry

	A	B	CY	F	D	IS	EIR	I	L	M	NL	N	S	E	CH	TR	GB
Maths; Chem; Biol; Phys;	::	::	::	::		::	✓	::		2	::	::	::	::	::	::	2
Chem; Maths; Phys;					::		✓		::	1							1
Phys; Chem;							✓										✓

Key : ✓ Combination possible, but no priority given

:: Compulsory combination

1,2 Order of priority

It will readily be seen that the combination of chemistry with physics and biology is the most common one for those who are potential university scientists. In most cases this combination is a compulsory one, although very often more subjects are added (again compulsorily) such as mathematics or geography, or in some countries both, along with astronomy in a few cases. The combination of physics and chemistry for the Federal Republic of Germany arises through the option which students have to study <u>either</u> chemistry <u>or</u> biology with compulsory physics. Where one of several options is available (as in the United Kingdom), the order of preference among students is shown - thus the combination of mathematics with physics and chemistry is more common than biology with physics and chemistry in Malta and the United Kingdom. The provision of integrated science courses at the upper end of the secondary school is not at all common, although many countries are increasingly expressing the desirability for the establishment of such courses. The most advanced project of this type is the Nuffield Advanced Level Physical Science course which is currently under trial in the United Kingdom. This course is, in effect, a study of the structure and properties of matter, and includes many of the fundamental concepts in both the physics and chemistry syllabuses at this level. The inclusion of a course such as physical science in the school curriculum will ultimately mean that students will be able to study mathematics, biology and physical science as a combination, so achieving a much broader range of scientific experience than is very often possible at present in that country.

Percentage of students studying chemistry

From information available, the percentage of students who study chemistry in their final academic year at secondary school has been estimated, and the results are given in Table VIII.

Table VIII - Percentage of Students Studying Chemistry in the Final Year

Country	%	Country	%
A	7	*I	100
B	100	L	100
CY	100	M	45
F	20	NL	53
D	62	S	44
IS	65	E	80
EIR	18	GB	28

* Figure for penultimate year.

The figure for Italy refers to the penultimate year in school as no chemistry at all is taught during the final year. The figures in Table VIII are only estimates and should be treated with caution, but they are included at this point to indicate the extent of chemistry teaching at this level. A wide variation can be seen, which in view of the different organisation of science courses in the different countries is not surprising.

The age at which chemistry is taught

The beginnings of the teaching of chemistry sometimes take place as part of an integrated course of general science which preceeds the teaching of the separate sciences in the secondary school. Although only approximately half of the countries represented in the present survey have adopted such courses they usually last for a minimum of two years and persist for up to four years. The extent of general science courses in the individual countries is shown in Table IX, but the inclusion of general science for any particular country does not necessarily imply that it is compulsory or even extensively adopted - merely that it is sufficiently frequent for it to be considered a significant contribution to the teaching of science. From Table IX it can be seen that by the age of fifteen years most students will be studying chemistry as a separate subject. Often the age at which this study begins will be even earlier, especially for those countries where chemistry can be offered alongside general science as an option in the lower part of the secondary school (the United Kingdom, for example). Only in a few cases will the study of chemistry as an individual subject be delayed until the age of sixteen years or over. For only one country (Iceland) is the chemistry course a non-continuous one, where no chemistry is taught in the penultimate year. For Italy, however, chemistry is studied for one year only, which is the penultimate year of the secondary school.

Time devoted to the teaching of chemistry

Inspection of Table IX shows that the length of the chemistry course varies from country to country, the shortest one being that in Italy which lasts for only one year, whilst the longest courses are of five years (or even more where general science is replaced by chemistry in the lower part of the school) and this happens in several countries. However, more important than the number of years for which the chemistry course lasts is the time devoted to the subject in each year it is taught. Table X indicates the number of hours of chemistry taught in any given year of the course (the figures for Switzerland and Turkey are not available at the time of compilation).

Table IX - The age of students studying general science and chemistry

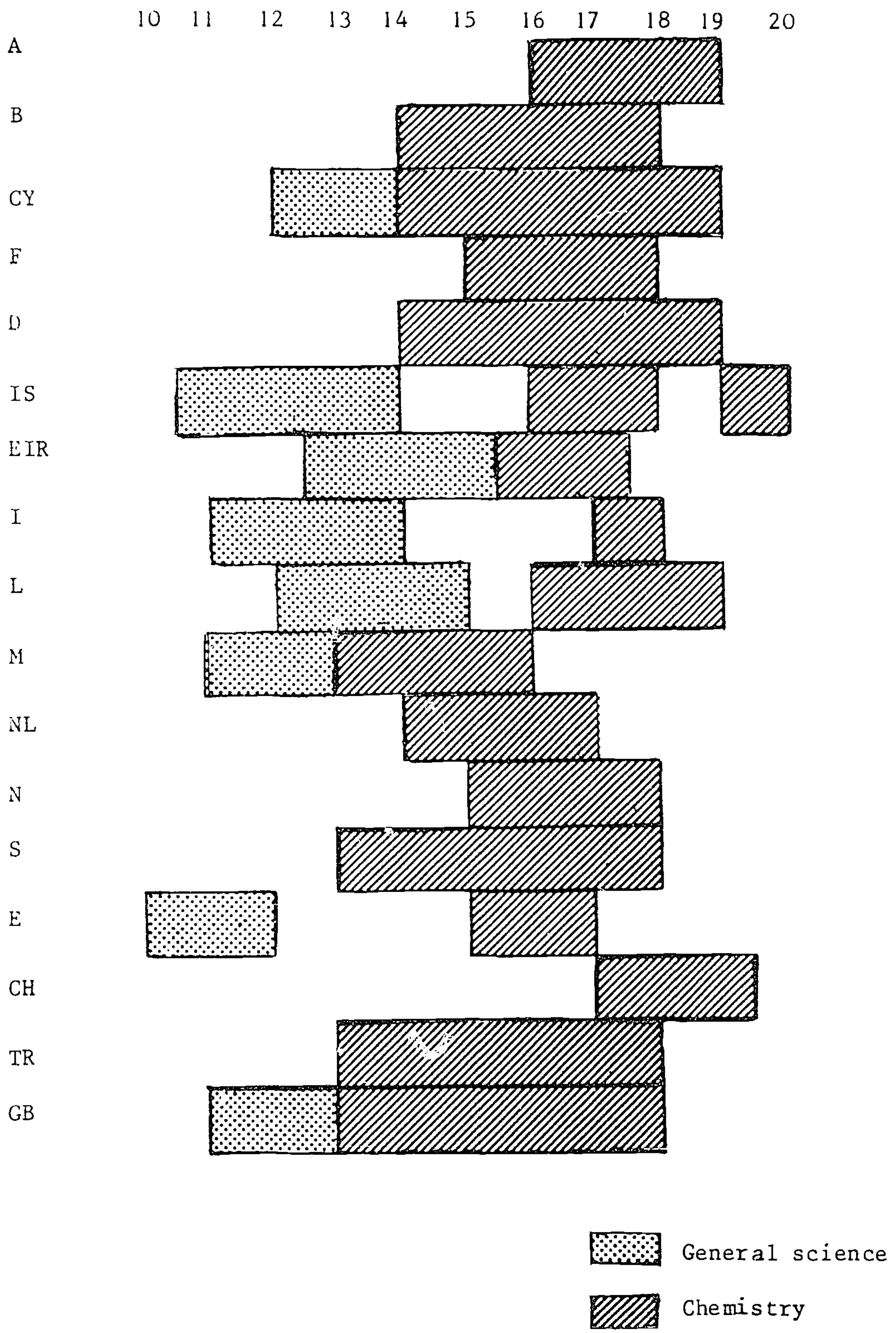


Table X - Number of Hours of Chemistry Teaching in Each Year of the Secondary School

	11	12	13	14	15	16	17	18	19	20
A						120	120	120		
B				30	60	60	60			
CY				30	30	70	90	90		
F					30	30	30			
D				60	60	60	90	90		
IS						75/100	75/125	0	50	
EIR					90	90				
I							90			
L						60	90	90		
M			90	90	90					
NL				50	100	100				
N					87	87	87			
S			48	48	60	60	48			
E					91	91				
GB			50	68	91	160	160			

As would be expected, a wide variation is evident, but it is fairly common for a chemistry student in his last year of secondary school to be spending at least ninety hours per year on this subject alone. The total length of time given to the teaching of chemistry shows an even greater variation, the shortest course being that of Italy, as already noted, which is of ninety hours' duration. The longest courses are in excess of three hundred hours, and, in the case of the United Kingdom, even in excess of five hundred hours. This variation must inevitably reflect a different level of achievement at the immediate pre-university stage, and the extent to which this is identified in the depth of treatment or overall subject matter covered will be examined in the subsequent part of this report.

Chemistry for the non-science specialists

A substantial number of countries do not demand specialisation into "science" and "non-science" streams before the end of the secondary phase of education, and for such countries the question of chemistry courses for "non-specialists" naturally does not arise. There are, however, some countries which do feature specialisation as a part of their system, and for those students who have opted out of the main science stream (for example the "language line" or "classical line") provision is sometimes made for a continued study of chemistry (either as a separate subject or as a part of a "science" study) on a more limited time schedule. It is rare that the length of time devoted to a course of this kind is longer than one hour per week.

In some cases, for example in Germany, the language stream will study a science course which in subject matter is the same as that in the specialist chemistry course, the depth of treatment being the same also. In other cases a more limited treatment is adopted - for example in the Belgian schools there would be no practical work in such courses, nor would organic chemistry be included. In Cyprus there would be no attempt at quantitative work with such non-specialists, whilst in the United Kingdom the depth of treatment of the subject matter would be very much less and wider in scope than that in the specialist course. In Turkey the literature stream take a chemistry course which is completely different from that of the specialist course, but which occupies as much as twenty per cent of the total school time.

Perhaps in this area as much as in any other is there the greatest variation in attitude and approach to the subject. Most countries who include such courses in their curriculum emphasize that they provide an opportunity for relating chemical principles more directly to industrial and social aspects, for which there is often little time in the specialist courses.

CHAPTER III

THE CHEMISTRY SYLLABUS

The Determination of the Syllabus

The most general way in which the chemistry syllabus is determined for the academic secondary school is through the central authority responsible for the organisation of secondary education - which in most cases is the Ministry of Education. This is usually carried out through the work of Government Inspectors, or through a specially-constituted national body, or commission, whose sole purpose is to determine and evaluate syllabus changes. However, although this may represent the general pattern, it is by no means the exclusive method by which syllabus content is determined. In the Federal Republic of Germany, for example, a much more local organisation of education leads to each Land being responsible for such reform, and this is similar to the situation in Switzerland where each Canton has its own department of education, and where a great deal of freedom exists even for the individual schools in deciding syllabus content. The situation in England is quite distinct from either of these two methods briefly described. There the syllabus is determined by each of the eight examination boards quite independently and to a large degree the schools are free to adopt the syllabus (and therefore the examination) of any board they wish. Although the boards are independent of each other their syllabuses do not differ widely either in content or approach, and any changes must be approved by the Government Department of Education and Science.

Whatever the actual method of syllabus determination a most encouraging feature of almost every country is the increasing part being played by the school teachers themselves in such activity. Either through their own national professional body, through meetings organised by Universities and Ministry Departments, or through conversation with Government inspectors on visits to schools, the school teachers (along with the University teachers and Inspectors) are playing an important role in the setting-up of the syllabus.

The average "lifetime" of a syllabus varies from country to country depending on the mechanism of syllabus reform, and many representatives point out that syllabus reform is a continuous process, changes being made wherever and whenever necessary, but indications are that syllabuses have an average lifetime of five to seven years, subject to the relatively minor changes made from year to year.

Syllabus content

One method by which syllabus content could be assessed would be through a detailed inspection of the publications of the countries concerned from their Ministries of Education or Examination Boards. A selection of such syllabuses is given in Appendix III. A reading of these syllabuses shows immediately that a comparison of content based on such material alone would be a very difficult proposition, since they differ so widely in the method of presentation and degree of specification. It was therefore decided to solicit the opinions of specialist representatives from each of the countries involved for an item analysis of their chemistry syllabuses. Over five hundred items were contained in the analysis, but shortage of space prevents the complete analysis being reproduced here. Three assessments were taken for each of the items in the analysis ; these being

a - the approximate time spent on the item during the teaching of the subject in the last two years of secondary school,

b - the relative importance of the item, so far as the terminal examination or final assessment was concerned, and

c - the extent of practical work which was carried out in connection with that item.

It was impossible for the representatives taking part in the survey to reach any agreement at all on a suitable list of common categories which could adequately describe the syllabus in each of the countries concerned. Any classification will be arbitrary, and will be inadequate in the sense that the different categories will almost certainly overlap in some way or other, and the fewer categories there are the more this will tend to happen. Of course, the more overlap there is in the actual teaching situation the better this is, for that is what is meant by a coherent framework of chemical knowledge. At one extreme all of the items would need to be assessed separately (which is unpracticable as stated above), whilst at the other the syllabus would simply break down into the traditional subdivisions of physical/theoretical, inorganic and organic chemistry. Although the latter method of subdividing the subject is a traditional categorisation still in wide usage, it is increasingly being abandoned both as a syllabus structure and, more important, as a teaching pattern. Physical and theoretical principles are being used increasingly as a basis for the teaching of inorganic and organic chemistry and it would therefore be difficult to place many items exclusively in one category or the other. In general, however, representatives felt that they were able to place, in order of emphasis, the importance of

a - physical/theoretical chemistry,

b - inorganic chemistry,

c - organic chemistry, and

d - industrial chemistry (industrial processes and reactions), for the chemistry syllabuses in their countries.

The results are given in Table XI.

Order of importance : 1 most important
4 least important
= of equal importance

Table XI - The relative importance of the broad categories of chemistry in the syllabus

Country	Physical/ Theoretical	Inorganic	Organic	Industrial
A	3	1	2	4
B	1	2	3	4
CY	1	2	3	4
F	=	=	=	4
D	2	1	3	4
IS	1	2	3	4
EIR	1	2	3	4
I	1	=	=	=
L	1	2	3	4
M	1	2	3	4
NL	1	2	3	4
N	4	1	2	3
S	1	=	=	4
E	1	2	3	4
CH	1	3	2	4
TR	4	1	2	3
GB	1	2	3	4

No doubt because of the applicability and relevance to the other categories, physical and theoretical chemistry features in greatest importance in most countries, inorganic chemistry being the next in importance, followed by organic chemistry and, finally, industrial chemistry.

The results of the detailed item analysis are given in Table XII, the categories used being eventually determined by the author. The classification is based on a modification of the Universal Decimal Classification System, and the information is displayed as follows : for each country the estimation of the time (in minutes) spent on each topic is indicated by the figure in the top half of the appropriate square. The importance of practical work in the topic (see Chapter IV) is given in the bottom left hand side of the square by a letter in accordance with the following scale :

A : great deal of practical work done

B : limited practical work

C : non pupil practical work

D : demonstration by teacher

The relative importance of each topic for the terminal examination or final assessment prior to entrance to higher education is given by a letter in the bottom right hand side of the square, on the following scheme :

E : very important

F : moderately important

G : of relatively little importance

Table XII - Syllabus analysis

	A	B	CY	F	D	IS	EIR	I	L	M	NL	N	S	E	CH	TR	GB
540 HISTORY .1 Early theories (e.g. alchemy)	2 C G	Optional course on history of science	–	–	45 C G	–		–	60 C G	x D G	–	90 C G	–	–	–	–	
.2 Dalton's atomic theory	10 C G		x C E	120 A E	45 C F	10 C G	120	20 C G	60 C G	x D F	50 D F	15 C G	5 C G	30 C E	40 C F	45 C/DF	x E
.3 Molecular theory (Avogadro, Gay-Lussac)	5 C G		x C E	60 ?	45 C E	100 C E		90 C E	60 C G	x D E	50 D E	90 C F	10 C F	60 C E	40 C F	45 C/DE	x ? E
541 THEORETICAL AND PHYSICAL CHEMISTRY .2 Theoretical															Referred to through-out course		
.22 Molecular structure .221 Structural formulae	40 C F	20 D G	x B/DE	180 C E	90 C F	45 C E	x 600	60 C F	120 D F	x B E	150 D E	– –	140 E F	60 C/DE		130 C/DF	x E
.222 Molecular weights determination	10 C F	30 D G	x D G	210 C F	40 C F	45 A F		80 D F	40 D G	x B E	– –	225 D F	120 C E	30 C F	–	20 C F	300 B/CF
.224 Molecular bonds valencies	65 C/DF	270 B/DG	x C/DE	255 C E	225 C E	130 C E		250 C F	360 D E	x C E	230 D E	110 ?	320 A/BE	130 C E	620 C/DE	180 C E	x E
.225 Structural variations	28 C/DG	30 C F	x C/DF	150 C E	90 C F	65 C E	600	65 C G	210 D E	x B E	160 D E	200 B F	255 B/DE	120 D E	240 B/CE	80 C/EF	930 B/DF
.226 Intermolecular forces	2 C G	–	–	15 C F		45 C E		–	80 C E	x A/BE	20 D E	10 ?	40 D E	20 C E	40 C F	–	60 C E
.24 Atomic structure	31 C/DF	120 E F	x C E	255 B/DF	135 C F	45 C F	x	110 C E	360 DE/F	x B F	150 C E	105 ?	160 C E	80 C/DF	80 C F	60 C F	380 C E
.243 Spatial atomic arrangements	31 C/DF	100 D E	x C F	280 C E	215 C E	75 C E	360	65 CE/F	200 D E	x B E	260 D E	55 ? F	140 B E	150 C E	180 C F	225 C F	150 C/DE
.25 Kinetic theory of gases	5 C/DF	x	x C E	60 C E	45 C E	150 C E		20 C E	40 D E	x ? E	–	45 C F	40 C E	60 C E	(x)	–	45 C E
.26 Stoichiometry	34 C/DF	50 D E	x C E	180 C/EF	290 C E	400 C E	360	240 C E	180 CF/G	x ? E	350 B/DE	295 B/DF	580 C/DE	120 C E	(x)	210 C/DF	x C E
.28 Quantum chemistry	35 C F	60 D E	x C E	120 C E	215 C F	175 C E	600	130 CF/G	240 CE/F	x ? E	300 D E	–	250 C/DF	210 C/DE	200 CE/F	120 C E	300 C F
.3 Physical chemistry																	
.32 Gas laws	21 C F	? x	x C E	210 B E	155 C F	115 C E		115 D E	–	–	–	–	440 BE/F	110 C E	–	60 C/DE	275 C E

	A	B	CY	F	D	IS	EIR	I	L	M	NL	N	S	E	CH	TR	GB
541.34 Solutions .341 Properties	20 C/DF	(x)	x C F	240 A F	210 C E	60 B E	480	100 DE/F	80 D F	x C E	100 D F	180 D F	380 B/DE	125 C E	(x)	45 C E	840 B/DE
.342 Solubility	10 C/DF	(x)	x C/DF	120 C F	170 E/F	280 A E		85 E F	115 B E	x C F	50 D E	–	80 B/DF	105 C E	(x)	140 C/DE	x A/BE
.345 Colloids	6 C G	120 B/DE	–	–	45 F	–		–	45 D F	x C F	100 B/DE	45 ?	80 D F	40 B F	(x)	–	300 B/CF
.349 Partition law	–	–	x C F	–	(x)	–		–	10 D F	x C F	–	–	80 A E	10 B G	–	–	180 B E
.36 Thermochemistry Thermodynamics	5 C/DF	50 C G	x B/DF	480 A F	300 CE/F	185 B G	360	130 D F	300 B/DF	x C F	250 D E	–	460 A/C E/F	230 A E	200 C F	100 C/DF	100 B/CE
.37 Electrochemistry	96 C/DF	350 B/DE	x B/DE	1280 A/DE	785 C E	715 AE/F	360	670 (A) E	360 B/DF	x C E	2200 B/DE	1330 A/DE	2400 A/DE	515 B/CE	940 A/DE	410 C/DE	1530 A/BE
.38 Radiochemistry	66 C/DF	20 C G	Physics	325 DE/F	270 CE/F	90 CE/F	180	160 C G	300 F/G	x C F	250 C E	330 C F		340 C E	–	225 C E	150 ?
.392 Chemical equilibrium	60 B/DE	130 D E	x C E	195 DE/F	315 C E	195 B E	360	270 C F	250 B/DE	x C E	900 D E	380 BE/F	1100 A/DE	145 C E	300 B/DF	70 C F	800 B/DE
.394 Reaction rates ; factors affecting	10 C/DF	20 D F	x C E	60 D E	60 F	100 E F		30 C F	130 C F	x B F	150 B/DE	90 C F	340 D E	75 C E	140 B/CF	90 C/DF	700 B/D E/F
.901 Periodicity	64 C/DF	200 C E	x C F	120 C E	255 C F	150 C F	720	85 C F	180 C F	x C F	350 DE/F	290 ? E	240 C F	105 CE/F	80 C/DE	60 C F	300 B E
544 <u>QUALITATIVE ANALYTICAL CHEMISTRY</u>																	
.1 Systematic separations identification	180 C E	–	x A E	–	Prac work	45 A E	120	–	120 D F	x B F	450 B/DE	1525 A E	–	–	–	–	2000 A E
.6 Spectroscopic analysis	30 C/DG	–	(x) D G	135 A/DF	40 C G	–	180	–	330 B/DF	x B F	150 B/DE	–	400 A/DE	20 C G	(x)	–	540 B F
545 <u>QUANTITATIVE ANALYSIS</u>	10 C/DF		x		–	30 E	360	–		x B F							
.1 Gravimetric	–	–	x A E	30 ?	–			–	60 B/DG	x C F	–		120 A E	–	–	–	–
.2 Volumetric	10 C/DF	180 B/DF	x A E	360 A E	–	60 A E			300 A/DF	x C F	600 B/DF	405 B/DE	360 A E	140 A/CF	(x)	240 C/DF	3000 A E
.3 Electroanalysis (conductiometric)	–	–	–	–	–	–	–	–	30 D G		–	–	100 A E		(x)	–	(x)

		A	B	CY	F	D	IS	EIR	I	L	M	NL	N	S	E	CH	TR	GB
546	INORGANIC CHEMISTRY							1800										
.1	General principles	600 C/DE	400 B/DE	x B/DE	285 A/D E/F	285 E	110 E/F		310 (A) E	360 B/DE	x B E	100 D E	360 A F	580 D E	240 B/CE	280 A/DF	60 C/DF	x A E
.2	Hydrogen and compounds	375 C/DE	130 E	x B E	390 A/DE	405 E	75 E		125 (A) F	480 B/DE	x B F	220 B/DE	260 AF/E	800	150 C E	320 C/DF	240 C/DF	x A E
.3	Metals and their compounds	825 C/DE	80 B/DE	x A/DE	395 A/DE	285 E	185 E		105 F	210 B/DF	x B F	420 B E	290 B F		140 B/CF	200 B/DF	200 C/DE	450 A/BE
.38	Group IA Alkali metals	170 C/DE	100 D E	x A E	30 F	145 F	45 E		40 F	20 D G	x B F	50 B E	145 D F		-	40 D F	70 C/DE	180 B E
.39	Group IIA alkaline earths	180 C/DE	200 D E	x A E	30 F	180 E	100 E		35 ?	20 D G	x B F	100 B E	135 D F		10 C G	40 C/DG	110 C/DF	90 B E
.5	Groups IVA, VA, VIA, VIIA	10 C G	200 B/DE	-	-	-	-		45 F	20 G	x B F	190 B E	90 B F		-	-	20 C/DG	(180) (A) (F)
.6	Group VIII	210 C/DF	80 -E	x A F	-	75 F	85 E		75 F	110 D F	x B F	60 B E	405 C F		80 C F	40 C G	170 C/DF	120 B E
.66	Group IIB	16 D F	-	x B F	-	30 F	30 F		25 F	50 B/DF	x B F	50 B E	135 C F		-	-	70 C/DF	90 B E
.67	Group IIIB	12 D F	50 D E	x B F	-	45 E	20 F		20 F	50 B/DF	x B F	160 B E	145 C F		40 C F	-	100 C/DF	60 B F
.68	Group IVB	20 D E	60 D E	x B F	-	195 E	35 F		80 F	60 B/DF	x B F	150 B E	270 C F		40 C E	80 C F	115 C/DF	90 B E
.71	Group VB	10 C E	200 B/DE	x C/DE	-	90 E	20 E		60 F	80 D F	x B F	100 B E	270 A/DF		60 C F	-	75 C/DF	90 B E
.72	Group VIB	200 C/DE	120 D E	x A E	30 ?	180 E	20 E		45 F	300 B/DE	x B F	100 B E	225 B E		80 A/CE	80 C/DE	135 C/DF	90 B E
.73	Group VIIB	210 D E	40 D E	x B F	30 B E	225 E	60 E		90 F	200 B/DE	x A E	100 B E	450 B/DF		90 B/CF		90 C/DF	150 A E
.75	Rare gases	10 G	30 E	(x)	30 E	30 F	25 E		10 F	20 G	x B F	50 C E	135 ? E		10 C F			90 C E
.91	Extraction of metals (general methods)	-	150 F	x B/DE	1130 B/DE	315 E/F	105 E F			240 DF/G	x B E	-	690 C F		165 C/DE	60 ?	370 C/DF	725 C E
.93	Compounds of special interest (industrial)	545 D E	220 D F	x B/DE	1275 A/DE	815 E/F	125 F	-		600 B/D E/F	x B E	440 DE/F	1150 B E		445 A/C E/F	160 C F	615 C/DF	1075 B/CF

	A	B	CY	F	D	IS	EIR	I	L	M	NL	N	S	E	CH	TR	GB
547 <u>ORGANIC CHEMISTRY</u>																	
.1 Physical and theoretical organic	230 C/D E/F	100 C F	x C/DE	535 A/DE	245 CE/F	145 C E	780		360 CF/G	x B E	230 D E	75 ?	260 A/DE	230 C E	440 A/CE	220 C/DF	770 B/DE
.12 Purification techniques	55 C F	-	x B/DF	345 A/DF	75 CF/G	15 C F	240		180 B/DF	x B E	50 B/DF	-	210 A E	160 DE/F	x A G	45 C/DF	1200 B E
.13 Reaction mechanisms	-	-	(x) (D)(F)	-	135 C F	-	240		60 C F	x C F	150 D E	-	-	25 C G	60 C/DF	-	-
.132 Types of reaction	160 C F	-	x C/DF	75 G	270 C F	60 C G			360 CF/G	x C F	500 D E	-	190 C F	35 C G	640 A/D E/F	275 C/DF	-
.2 Synthesis and named reactions	570 D E	80 D F	x C/DF	345 A/DE	410 CE/F	175	-		600	x B F	450 D E	20	230 C F	270 CE/F	140 AF/G	210 C/DF	x B/CE
.3 Analysis	-	-	x A/DE	150 A G	90 C E	-	x		120 D G	x BE/F	100 D E	-	-	60 C G	90 A G	95 CD/F	180 B E
.4 <u>Aliphatic compounds</u>																	
.41 Hydrocarbons	70 C F	220 D E	x C/DE	180 A/DE	195 CE/F	45 C E	720		120 B/DF	x B F	50 D E	180 D F	120 A/CE	120 C E	80 B F	50 C/DF	200 B E
.412 Olefins	15 C F	100 D E	x C/DE	120 A/DE	65 C E	30 C E			150 B/DF	x C F	50 D E	45 D F		55 C E		40 C/DE	300 B/D E
.4131 Acetylene	5 C F	20 D E	x B/DE	120 A/DE	45 C F	-			90 B/DE	x C F		90 B F		20 C E		20 C/DE	300 B/DE
.44 <u>Hydrocarbon derivatives</u>																	
.442 Halogen derivatives	40 CE/F	-	x B/DE	45 A/DF	140 C E	30 C F	300		300 D G	x B E	50 D E	90 B F	40 C E	50 C E		65 C/DF	600 B E
.4431 Alcohols	80 C F	60 D E	x B E	150 A/DE	95 C E	30 C E			150 B/DE	x C F	100 D E	90 C F	40 A/CE	30 C E	160 A F	60 C/DF	400 A/DE
.44315 Polyhydroxyalcohols	30 C F	20 D F	x ?	-	40 C F	10 C F			90 B/DE	x C F	50 D E	45 C F	40 C E	25 C E		20 C/DF	40 B E
.4435 Ethers	10 C E	-	x C/DE	-	30 C F	10 C E			60 D E	x C F	50 D E	20 C G	10 C F	20 C E	20 A F	30 C/DF	150 B E
.4436 Aldehydes and ketones	60 C F	30 C E	x B/DE	-	230 C E	25 C E			240 B F	x B F	50 D E	180 B F	50 C E	40 C E	80 A F	45 C/DF	720 A/BE

	A	B	CY	F	D	IS	EIR	I	L	M	NL	N	S	E	CH	TR	GB
.4437 Acids	20 C E	20 B E	x C E	120 A/DE	105 C E	20 C E			95 A/DF	x C F	50 D E	45 D F	40 C E	55 C E	80 A/DF	45 C/DF	240 A/BE
.44373 Derivatives R.CO.X.	-	-	x D E	-	35 C G	15 C F			195 B E	x B F	-	45 D F	-	35 CE/F	(x)	60 C/DF	360 B E
.44374 Derivatives R. COOH	100 C/DE	10 C G	x D E	15 C F	100 C E	15 C F			105 B E	x B F	50 D E	180 B E	40 C F	40 C E	(x)	65 C/DF	180 C F
.44375 Dibasic acids	25 C F	-	x B/DF	-	90 CF/G	10 C F			60 D G	x C F	50 D E	45 B F	15 C F	40 C E	(x) A F	45 C/DF	480 C E
.4438 Esters	30 D F	50 B/DE	x B/DE	60 C F	75 C E	10 C F			30 D G	x B F	50 D E	180 A E	60 A E	80 A E	40 A F	25 C/DF	180 B E
.4442 Aliphatic amines	10 D F	-	x B/DE	-	10 C F	15 C F			-	x BF/G	50 D E	-	20 C F	20 C F	-	20 C/DF	270 B E
.445 Metallic compounds	10 C F	-	x B E	-	30 C F	10 C G			-	x B E	-	-	-	25 C E	(x)	15 C E	-
.6 Aromatic compounds																	
.61 Hydrocarbons	70 C/DE	(x)	x C F	-	45 C F	25 C F	360		45 D F	x B F	50 D E	45 C E	70 C F	85 C E	(x)	45 C/DF	120 B E
.62 Halogen derivatives	10 C F	-		15 C F	(x)	5 G			5 C G	x B F	50 D E	40 C E	70 B/DE	20 C E	(x)	90 C/DF	40 CE/F
.63 Hydroxy derivatives	40 C F	-	x C G	-	40 F	5 G			60 B/DE	x B F		20 C E	60 ?	20 CE/F	(x)		150 CE/F
.636 Benzaldehyde	30 D E	-	x C E	-	45 C F	-			20 D E	x B F		-		-	(x)		80 B E
.6371 Benzoic acid	40 C F	-	x C F	-	10 C F	10 C G			30 C G	x B F		10 ?		10 C F	(x)	45 C/DF	180 B E
.638 Esters	20 D F	-	x C G	-	45 ?	-			10 C G	x C F	10 D E	-			(x)	25 C F	260 B E
.6411 Nitrobenzene .6412 Dinitrobenzene	15 C F	-	x C F	15 C F	45 C E	5 C G			35 B E	x B F	40 D E	90 B F	15 C F	10 C E	(x)	45 C/DF	150 B E
.642 Aniline	20 C F	-	x C/DE	-	x	5 C G			30 D E	x C F	50 D E	-	20 A E	10 C E	(x)	-	240 A/BE
.6431 Benzene diazonium chloride	10 C F	-	-	-	-	-	-		-	x C F	-	-	-	-	-	-	(120) B G

		A	B	CY	F	D	IS	EIR	I	L	M	NL	N	S	E	CH	TR	GB
.7	Natural products	1520 D E	120 E F	x B/DE	120 C F	730 CE/F	90 C F	–		660 A E	x C F	200 D E	855 B F	135 A/CF	295 C E	600 C/DF	230 C/DF	300
.8	Synthetic polymers	150 D E	–	x C G	120 D E	120 C F	20 C F	120		120 A E	x B F	200 D E	65 C G	80 B E	60 C E	80 C/DE	60 C F	
.86	Dyes	100 D E	–	x D G	–	–	–	–		160 B/DF	x B F	–	–	–	–	(x)	–	
.87	Detergents	100 D E	–	x D G	–	20 C F	–	–		160 D F	x	–	–	20 B E	10 C E	(x)	–	

In addition to the key explained above, the following should be noted. Where no specific time has been given but the topic is taught an 'X' has been placed in the appropriate position (note that (X) implies the topic only has a very short mention in the syllabus as a whole). It will also be seen that in some cases the combination 'AF' or 'AG' appear - these are not self-contradictory but indicate that although the topic as a whole is not so important, one or two aspects of the topic might be examined in detail and quite a lot of practical work carried out on them.

The following points are worthy of note for each of the countries represented.

AUSTRIA :

The programme given is for the Allgemeinbildende Höhere Schule, which is at present a two year course but will shortly become one of three years. There is very little practical work carried out by the pupils themselves, often due to lack of equipment and suitable buildings. Optional practicals do take place in a very few schools.

The treatment of metals is such that most will be dealt with but each in little detail.

A heavy emphasis on inorganic chemistry, but not so much on detailed organic, although there is a fairly detailed study of the majority of natural products.

BELGIUM .

Historical aspects of chemistry are usually included in the optional 'History of Science' course rather than in the main subject chemistry. Some of the topics listed are taught in the physics course rather than the chemistry course and these include the kinetic theory of gases, electrolysis, Faraday's Law, and radiochemistry. Thermochemistry and thermodynamics are taught at the discretion of the teacher.

Of the inorganic chemistry only the following elements and their compounds are studied : copper, aluminium, carbon, silicon, nitrogen, phosphorus, oxygen and sulphur.

Organic chemistry is restricted to aliphatic compounds, and then to specific examples rather than functional group types.

CYPRUS .

No times were given at all for this country. Here again, some of the topics listed are covered by the physics course rather than the chemistry course and these include thermodynamics, radiochemistry and colloids (which also appear in the biology syllabus).

Most items are indicated as being included in the syllabus (except for mechanistic organic chemistry) and of being fairly important, which must inevitably mean a fairly superficial study.

FRANCE :

Data given is for the last three years of secondary education, and the total time in the Table exceeds the figure given in Table X since some of the topics (unspecified) are included in the physics course.

The treatment of organic chemistry is restricted mainly to aliphatic compounds and mechanistic interpretations are not included. There is a comprehensive treatment of the principles of inorganic chemistry rather than a detailed study of many elements and their compounds, and systematic qualitative analysis is not attempted.

FEDERAL REPUBLIC OF GERMANY .

Fairly extensive coverage of most of the items listed in the Table but with little pupil practical work apart from voluntary classes in systematic inorganic analysis. Emphasis is on inorganic chemistry primarily, and some topics (thermodynamics, Faraday's Laws) are taught in physics.

ICELAND .

Fairly complete coverage of the material, but no mechanistic approach to organic chemistry. Little practical work by the pupils themselves.

IRELAND :

Very little data given. No indications of practical work or relative importance of the different items. Of the transition elements only platinum, copper and silver are studied, along with only aluminium in Group IIIB and carbon and silicon in Group IVB.

ITALY :

The entire course is only ninety hours (see Table X), and most of the work is covered by lectures and demonstrations from the teacher. Where practical work is indicated in parentheses, e.g. (A), this refers to a pilot scheme currently under trial in about ten per cent of the schools, whose object is to give greater emphasis to pupil experimental work.

The method adopted is to select certain areas of the syllabus and to examine these in detail, rather than attempt a more superficial study of a much broader syllabus, and these are shown in the Table. Organic chemistry accounts for only ten per cent of the syllabus, and because of this limited time available it is not possible to attribute definitive times to the organic items. Teachers vary in the amount of time they spend on any given class of organic compound.

LUXEMBOURG .

Broad coverage of the items listed in the Table, but with limited opportunity for pupil practical work.

MALTA :

The syllabus is based on the Oxford University Local Examination Board's Advanced Level Examination, and is therefore determined by the requirements of that Board. Fairly extensive coverage of the items listed, with more than the average amount of time spent on qualitative inorganic analysis.

NETHERLANDS .

Almost complete coverage of the syllabus, except in one or two isolated areas as indicated. Some mechanistic organic chemistry is being attempted.

NORWAY .

Information given is for Naturfaglinje, the Science line of the Gymnasium.

Inorganic chemistry receives the greatest attention, along with systematic inorganic analysis where appreciable pupil experimental work is carried out. The organic chemistry topics are heavily balanced on the side of aliphatic rather than aromatic compounds, with quite a lot of time spent on natural products.

SWEDEN :

Fairly complete coverage, with no systematic qualitative analysis of anions and cations although some quantitative analysis is attempted. The choice of elements and compounds to be studied in the inorganic section is left largely to the teacher, and it is therefore difficult to allot separate times to each item. Radiochemistry is dealt with in the physics course.

SPAIN :

Extensive coverage of nearly all the items, but with limited opportunity for pupil practical work.

SWITZERLAND .

Since there is no centralised system the answers have been given for the Kantonale Oberrealschule, Winterthur.

Some of the topics are treated in physics (for example, kinetic theory of gases and radiochemistry). No systematic qualitative or quantitative analysis carried out, and the study of Group VIII is limited to iron only, and that of Group IVB to carbon and silicon. A general approach to organic chemistry is adopted, leaning heavily towards aliphatic compounds, and very little rote learning is expected.

TURKEY .

Coverage of inorganic and organic items is extensive, but there is very little practical work carried out due to the widespread lack of facilities. Some of the topics are covered in the physics syllabus rather than the chemistry one, and these include intermolecular forces, kinetic theory of gases, thermodynamics and Faraday's Laws.

ENGLAND AND WALES .

More than the average amount of practical work is being carried out in connection with most items in the list. An extensive coverage is realised, possible due to the relatively high amount of time devoted to the subject at this level (see Table X). Some of the items in the list would have been covered in the lower part of the secondary school (stoichiometry, atomic and molecular theories) whilst others would be covered in the physics course (kinetic theory of gases and radiochemistry).

A substantial proportion of the practical time is spent on qualitative and quantitative analysis (a requirement of many Examining Boards), and schools are increasingly using a mechanistic approach to the organic chemistry, although this is not required for the Advanced Level Examination

Note .

Most national representatives found difficulty in answering the item analysis accurately, principally because at present many countries are reviewing their chemistry syllabuses and pilot schemes are under trial, or because many topics appear in physics and biology syllabuses at this level also. Obviously additional difficulty was experienced by those representatives from countries where no overall, centralised, syllabus policy is adopted.

Evaluation of syllabus changes

In very few countries is there a well-established body whose function it is to evaluate syllabus changes. The most common method of assessing any effects of syllabus changes is by the feedback from the schools themselves, given by the teachers to Inspectors or national professional science teacher organisations. In some cases assessment is based on the performance in the terminal leaving examination, and in others by comments from University authorities on the quality of entrant from the schools. In too many cases representatives reported either a complete lack of such a body, or the inadequate and ineffective way the work was being done by those methods at present in existence.

CHAPTER IV

TEACHING METHOD AND MATERIALS

Teaching Method

Very few countries seek to stipulate a given method of teaching chemistry which must be followed by all schools, and in this respect therefore, teachers throughout Europe are free to determine their own method of presentation. In practice other factors will limit the style of teaching which will be adopted, obvious ones being terminal examination requirements, the availability of well-equipped laboratories and technical assistance, the size of the classes and the availability of ancillary aids. Table XIII shows the average pupil/teacher ratio at this level, along with the proportion of boys to girls taking the subject.

Table XIII - Pupil : teacher ratio and boys : girls ratio for chemistry at the upper secondary school

Country	Pupil : Teacher	Boys : Girls
A	14 : 1	1.4 : 1
B	33 : 1	
CY	*40 : 1	10 : 1
F	35 : 1	3 : 1
D	25 : 1	1.5 : 1
IS	100 : 1	4 : 1
EIR	20 : 1	1 : 1
I	32 : 1	1.5 : 1
L	20 : 1	3 : 1
M	40 : 1	3 : 1
NL	20 : 1	1 : 1
N	25 : 1	4 : 1
S	30 : 1	2 : 1
E	40 : 1	1.6 : 1
CH	25 : 1	10 : 1
GB	12 : 1	4 : 1

* 20 : 1 for practical classes

The fairly high pupil/teacher ratios would seem to militate against extensive individual pupil practical work, and the figures in Table XII confirmed this for many countries. The most popular way in which

Table XIV - Demonstration experiments by the teacher

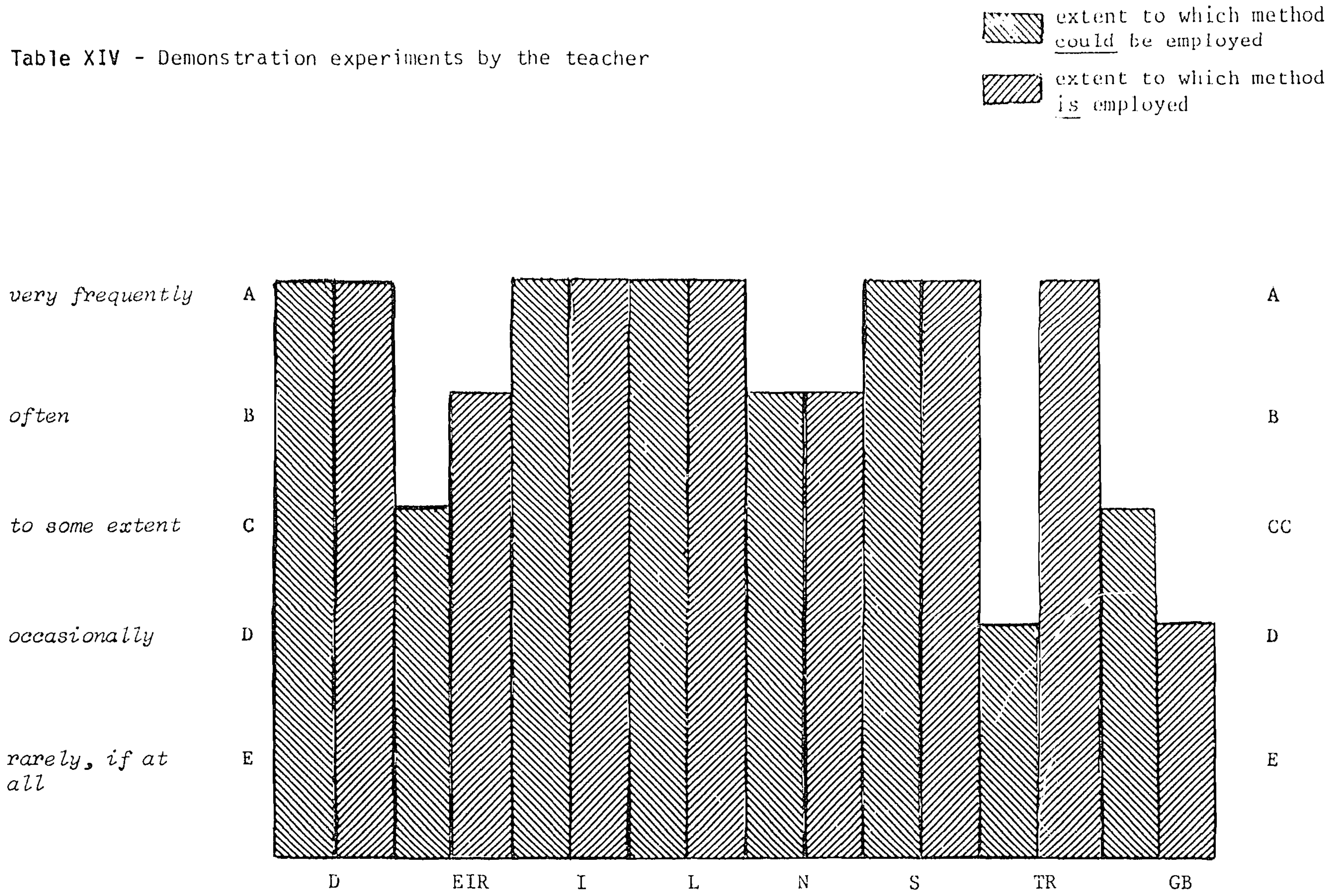


Table XV - Teaching method : Teacher lecture plus pupil note-taking

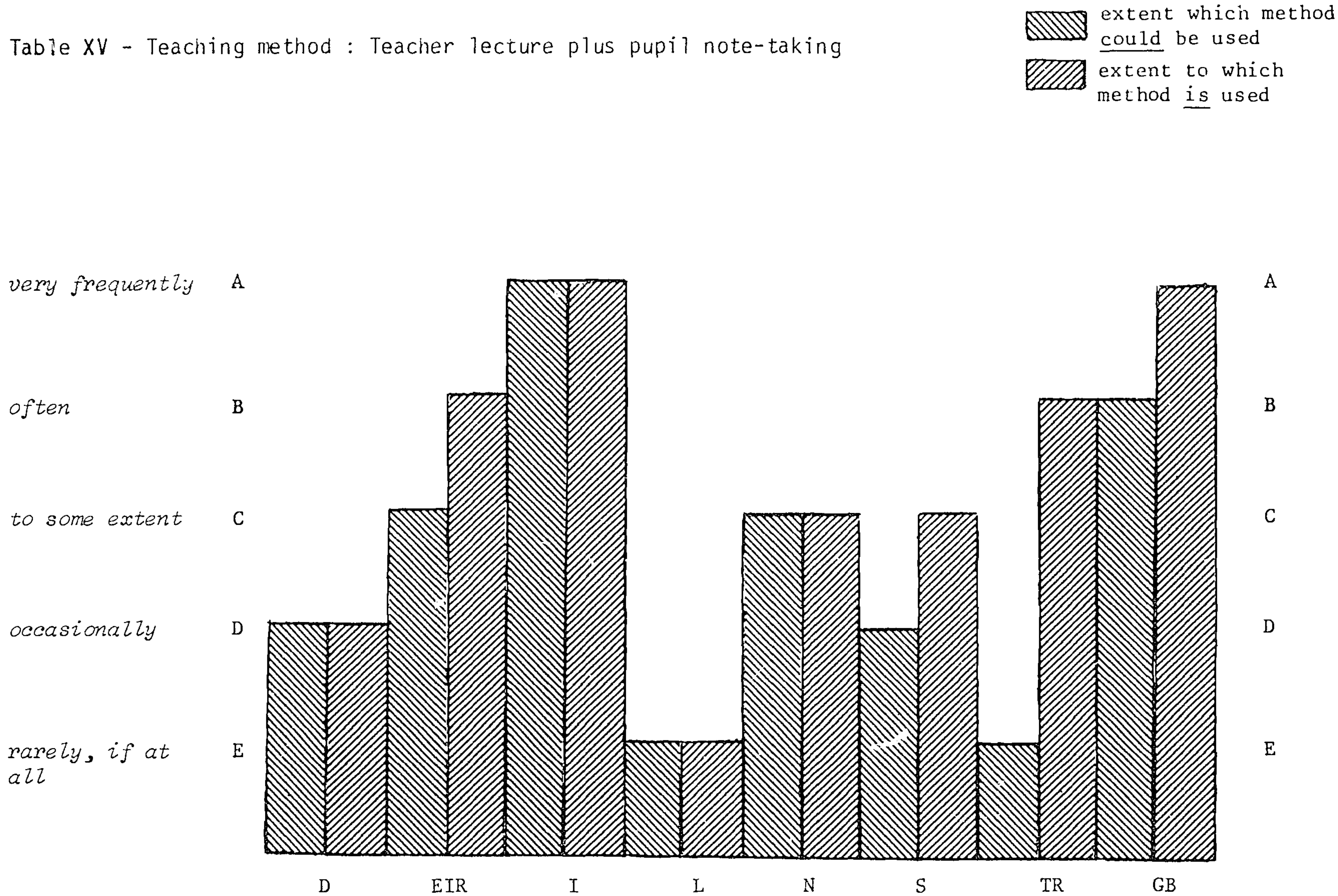
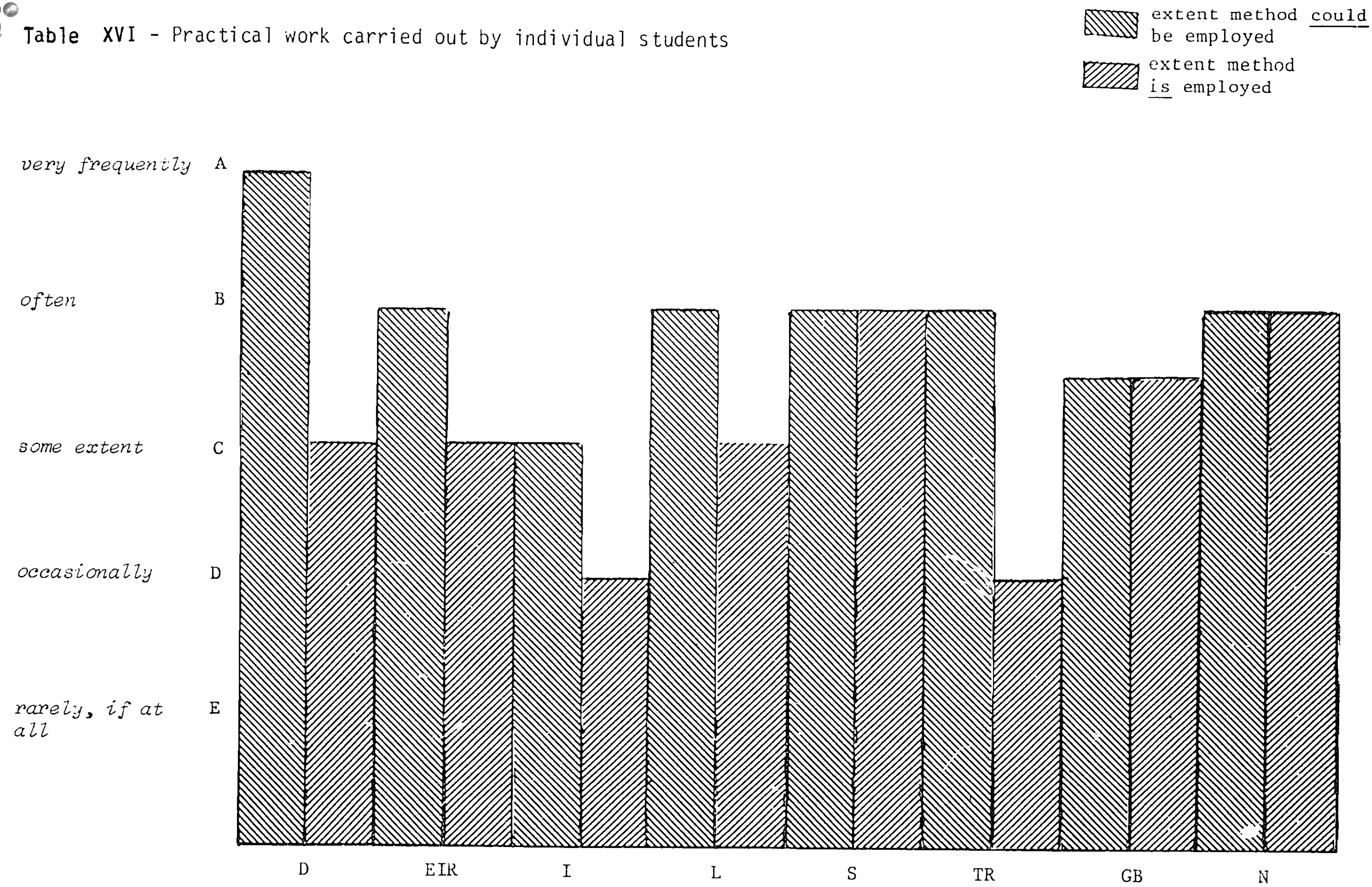


Table XVI - Practical work carried out by individual students



experimental work is carried out is by demonstration from the teacher, as shown in Table XIV (which compares the extent to which this method could be employed in any particular country to the extent to which it is being employed for selected countries only). Here it can be seen that by and large the demonstration experiment is being used as fully as possible, although in Turkey it is being used more than is thought to be desirable, and in the United Kingdom is not being used quite enough. The extent to which the more formal "lecture" method is being used can be seen in Table XV (selected countries only). This method is not used so often as the last, although it is inevitable that the most common method will, in fact, be a mixture of the two, i. e. a lecture-demonstration method. The amount of practical work being carried out by the pupils themselves varies from country to country, but Table XVI indicates that most countries would like to do more if they could. It is not necessarily always the lack of a laboratory which prevents more practical work being carried out. Table XVII shows the response to the question 'how much teaching of chemistry takes place in a well-equipped laboratory ?'

Table XVII - Percentage of time for chemistry teaching in a well-equipped laboratory

Country	Percentage of time	Country	Percentage of time
A	0	L	100
B	100	M	100
CY	50	NL	80
F	100	N	100
D	some	S	100
IS	10	E	12
EIR	most	CH	33
⁜ I	0	GB	100

⁜ 30 % in 'pilot'schools

In fact, the amount of practical work being carried out in the schools would seem to be rather higher than the impression one gains from Table XII. Delegates were asked to estimate what proportion of the course time a pupil would spend on practical work during his last two years in the school, and these results are given in Table XVIII.

Certainly most delegates expressed the hope that the proportion of practical work carried out by the pupils themselves would increase in the next few years. Possibly the major influence in the growth of practical work is the interest currently being shown in the 'enquiry' approach to the teaching of chemistry, a scheme which is essentially

Table XVIII - Percentage of course time spent on pupil practical work during last two years of secondary school

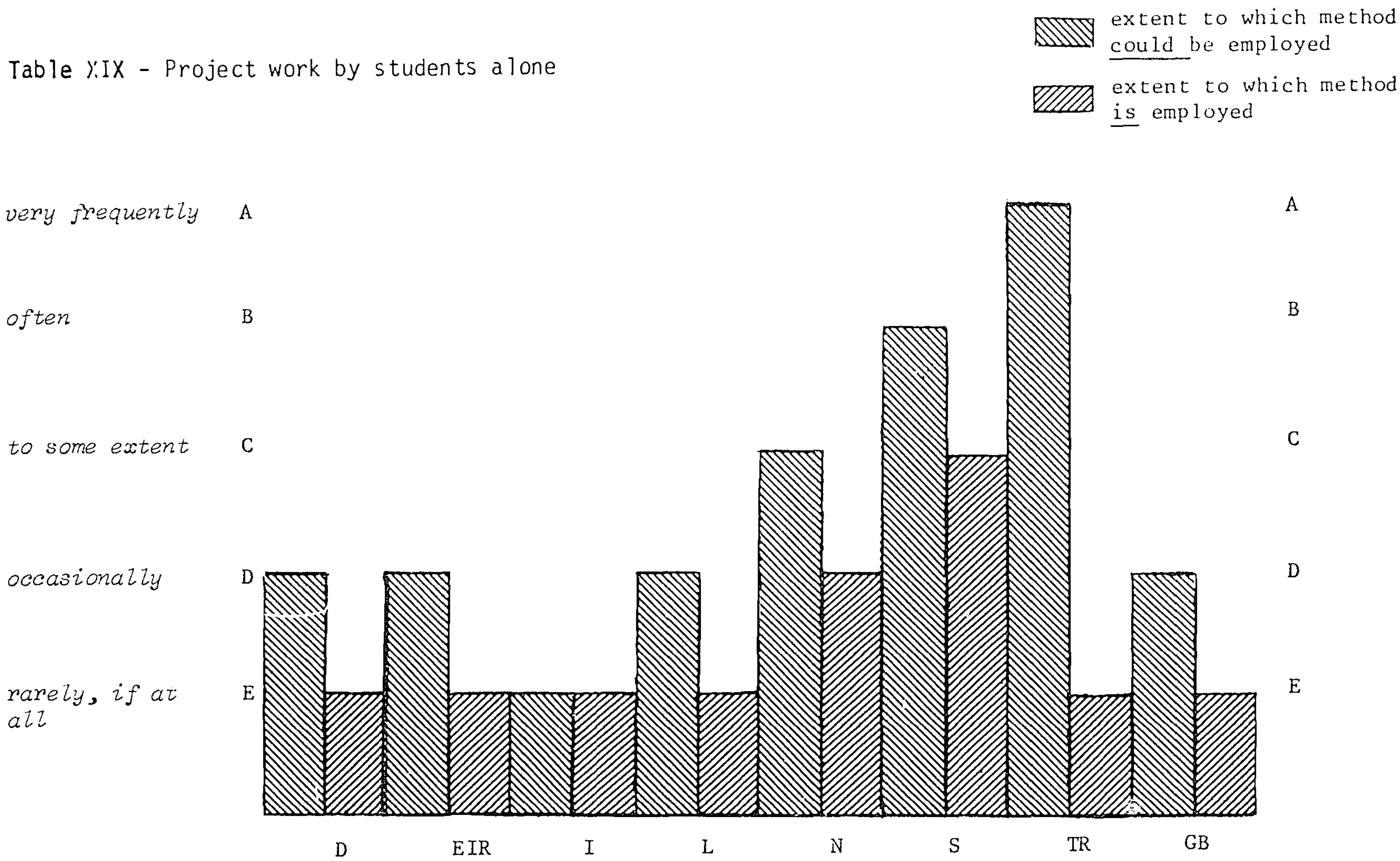
Country	% course time on pupil practical	Country	% course time on pupil practical
A	0	M	33
B	20	NL	20
CY	50	N	12
F	40	S	20
D	12	E	12
IS	5	CH	33
EIR	33	TR	very small
I	⁕ 0	GB	40
L	25		

⁕ 30 % in 'pilot' schools

laboratory-based and experimentally-orientated. Nearly all countries represented in this survey have pilot schemes and trial courses in which the heuristic method features largely, and all owe a great deal to the work carried out in the United States of America particularly by the CBA and Chem. Study bodies. However, none of these courses are yet well enough established nor extensive enough to have been included in the present report.

One of the ways in which pupil practical work is being increased is through the introduction of "project" work into the schools. Project work involves the pupil carrying out an investigation, a series of experiments or the construction of a piece of apparatus, for example, over a period of some weeks during which time his work is not closely supervised by the class teacher. It is thought that an activity such as this relates most closely to the sort of activity which the potential research worker or industrial worker will be involved in, and it is increasing in popularity. In the United Kingdom it is already established as a requirement in the final assessment of at least one course to Advanced Level. Table XIX shows the present position with respect to project work in eight selected countries.

Table XIX - Project work by students alone



Technical assistance

Well over half the delegates questioned reported that technical assistance from a laboratory assistant was not available at all for teachers of chemistry in their country. For those who did possess such assistance it was often by a non-trained person for a part of the course time, a full time assistant only being obtained for every thirty hours of course time (and in one case fifty hours of course time). Often the assistant was a pupil at the same school who was being paid to carry out the most routine tasks after school hours. In France and Holland the assistants will have experienced professional training during a two years course and have passed a national examination. The situation is very similar in Luxembourg where full-time assistants are available who have gained the diploma of the école d'artisans. In Italy the assistants will have carried out a course at the Technical High School, whereas in Ireland as soon as the size of class exceeds twenty four pupils an extra fully qualified teacher is assigned to help with the practicals. In the United Kingdom many schools will have laboratory assistants in chemistry who will in some cases be qualified technicians with special training for the job, but who are more often likely to be non-qualified helpers. In most cases the maintenance and ordering of equipment and reagents, the cleaning of the laboratory and the preparation of stock solutions are carried out, but very little development work can be attempted.

Teaching Aids

Probably one of the largest expanding fields in education at the present time is that of educational aids, and this is true in science teaching no less than any other subject. Although television and radio are not used very often films are used quite widely and an increasing interest is being shown in the use of 8 mm. film loops of three or four minutes duration for the teaching of single concepts. Table XX attempts to summarise the attitude of selected countries to the use of movie films in chemistry teaching. Quite clearly in some cases it is felt that not enough films of the right type are being shown. This is also true of the attitude of teachers to the use of the overhead projector, where not only printed and written material can be projected but also apparatus and even experiments. Table XXI indicates that the overhead projector is likely to be developed as a useful aid for the chemistry teacher in the near future.

Programmed learning instruction techniques are being rarely used by any of the countries, if at all, and the opinion of representatives was that there would be little room for such aids in their chemistry courses.

The general attitude towards aids of all types was that they served a very useful purpose in specific areas, but that their use should be limited, and they should at no time be substitutes for personal practical work or experience.

Table XX - Use of movie films in Chemistry teaching

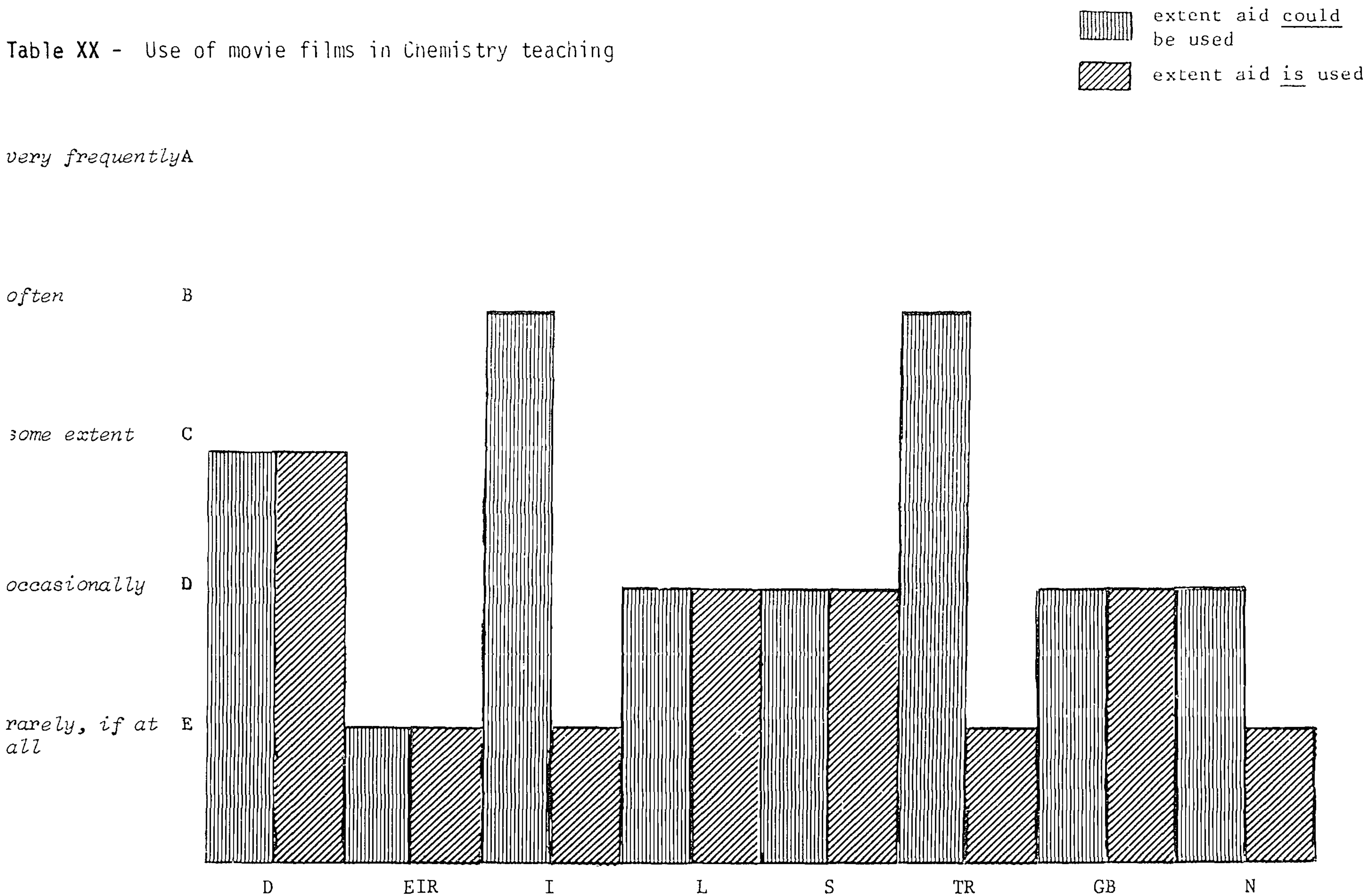
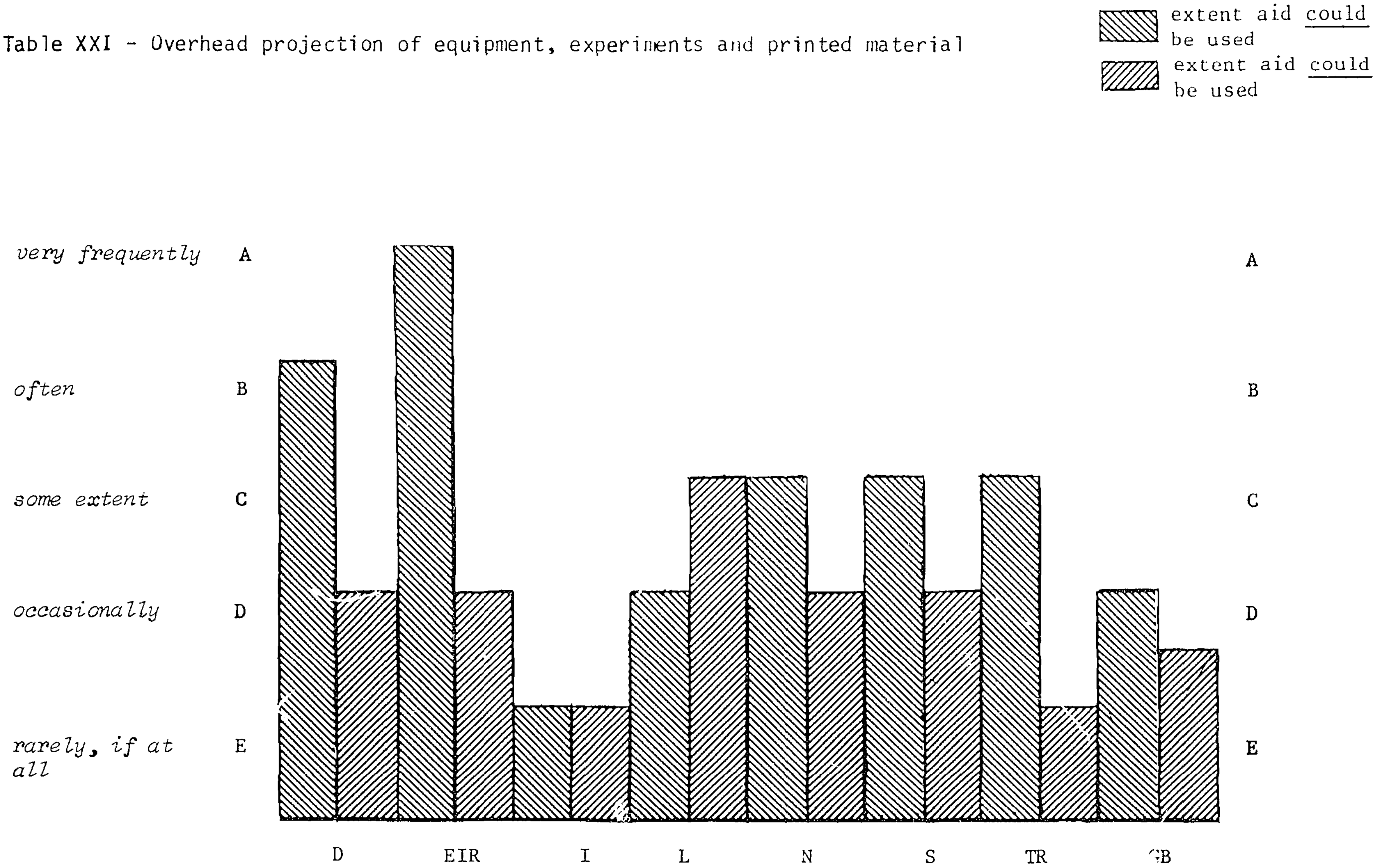


Table XXI - Overhead projection of equipment, experiments and printed material



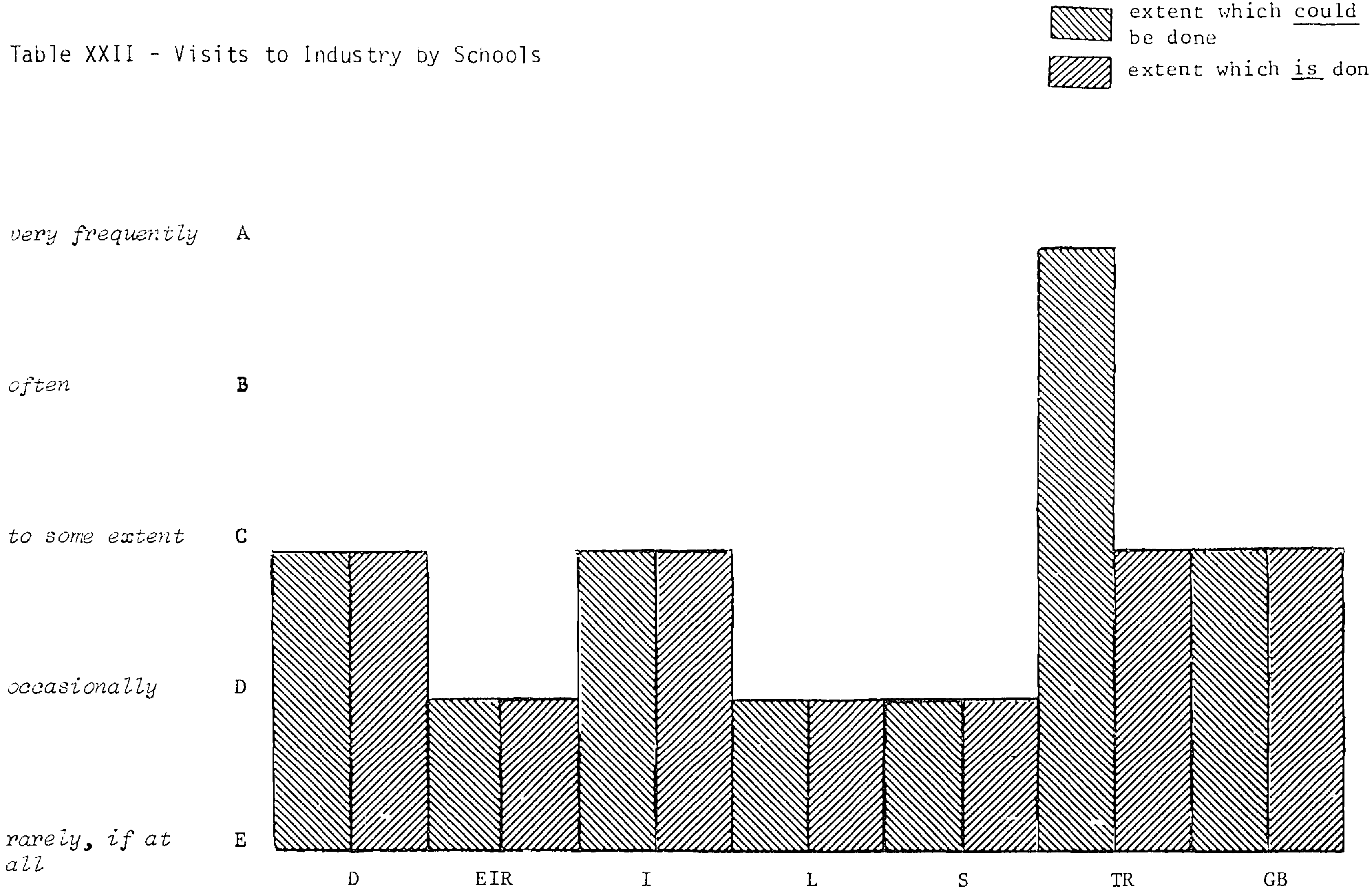
Textbooks

In the large majority of countries represented the teachers in the schools have complete freedom of choice with regard to the textbooks used in the chemistry courses. In only a few cases is a list of textbooks rigorously prescribed by a central body, and in the case of Luxembourg, which falls into this category, every lycee has a representative on the textbook committee. In some cases textbook committees do exist in an advisory capacity, but no compulsion is brought to bear in accepting their recommendations, and the committees are usually composed of school and university teachers together with inspectors.

Liaison with Industry

Links between industry and schools are not so firmly established as those between industry and universities in all countries. In fact, for many countries there hardly exists any liaison at all between the larger industrial companies and the secondary schools. However, in the Federal Republic of Germany strong links have been made, and industry is giving help to the schools by way of organising visits to plant processes, holding conferences for teachers and pupils, providing apparatus and materials where possible on request by the schools, and even by giving financial incentives for chemistry graduates to join the teaching profession. The situation is very similar in Switzerland where the chemical companies particularly are keen to help teachers and pupils alike. In the United Kingdom some of the larger companies have also made a contribution through the provision of teaching aids, films, booklets, film loops and specimen materials, and in some cases in the building of new laboratories, especially for the independent schools. A conscious effort is being made at present by British industry to concern itself with the ways in which it can most effectively help secondary schools, and one idea currently being tried out is the so-called 'Link-scheme' in which selected individuals act as link-men between their company and a particular school, giving help and advice in any area where it is required. It is being gradually realised that industry can play a much larger role in science education at the secondary level than had been originally anticipated, which extends beyond the established school visits to local industry (see Table XXII).

Table XXII - Visits to Industry by Schools



CHAPTER V

EVALUATION AND ASSESSMENT

A detailed account of the general methods of assessment and evaluation in member countries of the Council of Europe has already been given elsewhere, and it is not the present intention to repeat, or develop, that here. Therefore, this chapter will be concerned with an investigation of the methods of assessment as applied specifically to chemistry, but it is worthwhile noting that in the case of Sweden there is no final leaving examination as such, and the teachers conduct a continuous assessment throughout the course, often involving written papers supplied by the National Board of Education and standardised by them. For the rest, two general methods of assessment are used. The first is that of a wholly or partially centralised system, where the papers are set by an external authority (often inspectors, or an examining board) and marked either by the teachers themselves with external moderation, or by the external authority itself (for example France, the United Kingdom and the Netherlands). The second is that of an internal examination set by (very often) the individual schools themselves, marked by the class teachers, with very little external influence brought to bear (for example Federal Republic of Germany, Switzerland and Belgium). Both systems have their advantages and disadvantages ; in the case of the centralised system the standards can clearly be more easily maintained from year to year, and objectivity may be more readily attained, but it suffers from the fact that in such systems the examination syllabus tends to restrict the teacher with regard to the degree of freedom he has in determining his own teaching method. The 'internal' method makes the comparative assessment of students' achievement more difficult for prospective employers or higher education but it does permit a much larger degree of flexibility in course content and teaching method than would otherwise be possible.

The written examination

Of the methods of assessment the written examination is by far the most popular. The relative importance of the written paper compared to the practical examination or oral examination is given in Table XXIII, which shows that in the case of seven of the countries represented it is the only form of assessment at the secondary leaving stage. Next in importance comes the oral examination, which, in the case of Austria, Federal Republic of Germany and Italy, is the only examination given, and finally the practical examination held by only four countries.

Table XXIII - Relative importance of written, practical and oral tests in the final assessment

Country	Written	Practical	Oral
A	0	0	1
B	1	0	0
CY	1	0	0
F	1	0	0
D	0	0	1
IS	5	∗1	0
EIR	1	0	0
I	0	0	1
L	1	0	0
M	2	1	0
NL	1	0	1
N	0	1	2
S	-	-	-
E	1	0	0
CH	1	0	1
TR	1	0	0
GB	4	1	0

∗ No practical examination is held ; the practical mark is arrived at by continuous assessment

Table XXIV - The written examination in chemistry

Country	Number of written papers set	Length of papers (hours)	Number of questions per paper	Freedom of choice
A	-	-	-	-
B	1	1-2	varies from 4-10	no choice
CY	1	2	5	attempt 3
F	1	3	varies as few as 1	no choice
D	-	-	-	-
IS	1	4	varies 10-20	no choice
EIR	1	2 1/2	10	attempt 6
I	-	-	-	-
L	1	2	3	no choice
M	2	3	12	attempt 6
NL	1	3	12	no choice
N	-	-	-	-
S	-	-	-	-
E	1	2	2	no choice
CH	1	3	9	attempt 6
TR	1	3	10	no choice
GB	2	2 1/2 to 3	9 or 10	attempt 5 or 6

Table XXV - The oral examination in chemistry

Country	Is there an oral examination?	Duration of oral (mins)	Examiner	Number present at oral	Previous preparation by candidate
A	Yes	30-45	School teacher	pupil + teacher	20 mins
:: B	Yes	15-20	chemistry teacher	pupil + teacher	15 mins
CY	No	-	-	-	-
+ F	Yes, for borderline candidates	10-15	"jury" teacher	pupil + examiner	10-20 mins
D	Yes	15-20	teacher + inspector	pupil, teacher, inspector	not specified
IS	No	-	-	-	-
EIR	No	-	-	-	-
I	Yes	15	class teacher	pupil + 2 teachers	none
+ L	Yes, for borderline candidates	30	class teacher	pupil + 2 teachers	5 mins
M	No	-	-	-	-
NL	Yes	20	school teacher + univ. teacher	pupil + school and univ. teachers	none
N	Yes	30	teacher + appointed censor	pupil + teacher + censor	none
S	No	-	-	-	-
E	No	-	-	-	-
CH	Yes	15	class teacher	4 pupils + teacher	occasionally
TR	No	-	-	-	-
GB	No	-	-	-	-

Note p. 53.

Note :* In Belgium the oral examination is used as an assessment for the "non-specialists" in the penultimate year ; there is no oral examination for the specialist chemists.

+ As indicated, the oral examination is used for those candidates on the borderline between pass and fail.

Table XXIV sets out the features of the written examination in a little more detail. Most countries set only one written paper lasting usually between two and three hours. In a fairly high proportion of these there is no choice of questions, the candidate having to attempt the whole of the paper. Short-answer questions are generally popular as a quick method of estimating factual knowledge and (to a lesser extent) understanding. 'Essay' questions (in which the candidate is expected to write a short account of some aspect of chemistry, lasting about thirty minutes each) are commonly used, as are 'problem' questions in which the candidate is presented with chemical data and required to exercise his understanding of the principles of chemistry in solving some associated problem. Cyprus set specific questions in which the candidate is tested on his ability to apply mathematics to chemistry, but quantitative aspects of the subject appear in all the papers of the countries represented. The scripts are usually marked on behalf of the external authority by university and school teachers, (together with inspectors in some cases) appointed by the authority. In the case of the internal examination the marking is carried out by the class teacher himself. In the centralised system standardisation is achieved by the use of previously drawn-up mark schemes, and the meeting together of the examiners on one or more occasions for the purposes of coordination.

The oral examination

The oral examination, as already indicated, is used quite frequently in the final assessment, and Table XXV sets out some of the details of this type of examining in the countries concerned. In the case of France and Luxembourg the oral examination is only given to those candidates who have not given a satisfactory performance in their written paper, and in the case of Belgium it is used exclusively for the assessment of non-specialists in the penultimate year at school. Therefore for these countries no reference to the oral examination was made in Table XXIII. The length of the oral examination varies from as little as ten minutes to forty-five minutes. It is most usually conducted by the candidates' class teacher often in the presence of either a second teacher or an external representative (either an inspector or a jury' teacher). In some countries it is the practice to give the candidates a short time in which to prepare their answers to the questions they are to be asked, the time varying from five to twenty minutes. The types of questions asked in the oral examination are on topics concerned directly with the chemistry syllabus but which may not have been covered in the written paper, and an opportunity is given for the candidate to be questioned about his practical work and any project work he may have carried out. It is not common practice to question the candidate on his deficiencies revealed by the written paper, nor is it usual to present the candidate with materials and apparatus for comment or demonstration. No attempt is made to devise a mark scheme or to moderate the oral assessment, which is arrived at by impression' entirely.

The practical examination

Very few countries set a practical examination as part of the final assessment, and those which do so (Malta, Norway and the United Kingdom) set one paper of three hours duration. The materials for the examination are normally prepared by the class teacher, and this examination is supervised by him also. The scripts are marked by the external examiners for the written paper. The examination usually includes a quantitative exercise involving volumetric analysis, together with a qualitative exercise on the chemistry of a range of chemical compounds, the identity of which is not disclosed to the candidates.

Little or no provision is made at present in any of the countries for theoretical or practical work during the course to be taken into account in the final assessment in chemistry. The practical mark in Iceland is derived from the work carried out over the period of the course, but this appears to be the only case. The position of Sweden in this respect has already been noted. Very little use is also being made of multiple choice questions.

It is of interest at a time when an increasing emphasis is being placed on the value of practical work in the chemistry curriculum, and there is a growing enthusiasm for the 'discovery' approach in the teaching of chemistry, that so few countries are prepared to attempt an assessment of practical ability and manipulative skill in their students. If practical work has any value at all in the study of chemistry then it is the author's conviction that this ability ought to be evaluated for the final assessment. This may not necessarily be achieved through formal practical examinations as described (indeed, there is some evidence from those countries possessing such examinations that they may not be the best method of evaluating practical skill) and experiments are currently in progress to devise more effective methods. These include the assessment of project work (a sustained practical investigation by the individual pupil over a period of time) and a variety of continuous assessment procedures. Much work remains to be done in this area.

Percentage pass rate in final examination

The percentage of students passing the final examination in chemistry is given, for a few selected countries from which information was available, in Table XXVI. It very often happens that the final examination is used to rank students for the purposes of university entrance or as an aid for employers in the selection of appropriate employees. It is certainly perceived as such by the majority of students. Naturally an examination designed specifically for these ends would be a very different one from that designed with the express intention of measuring chemical 'maturity' in whichever way that may be defined (see chapter I on 'Aims'). It is therefore of the utmost importance that before the examination is constructed the objectives are clearly defined. However, any question set in an examination is bound to test the pupil in two ways. In the first case each question will test a certain ability, and at the same time it will necessarily test a certain subject area. This demands that for any examination we shall require two sets of information. One describes the subject matter from which the material is to be drawn, and will be the syllabus for the subject. The other describes the abilities which the examination sets out to measure, and a convenient classification of these abilities in chemistry is given in Appendix IV which is intended to serve as a guide for those teachers whose responsibility it is to devise chemistry examinations for their students.

Table XXVI - Average percentage pass rate for the final assessment in chemistry (figures for 1966-67)

	A	F	IS	EIR	I	NL	N	E	CH	TR	GB
Percentage pass (%)	90	65	99	85	65	85	100	70	100	75	69

CHAPTER VI

THE CHEMISTRY TEACHER

Important as syllabuses and examinations are in the study of chemistry in the upper secondary school, possibly the most important feature of the process of chemical education is the teacher, whose responsibility it is to put the aims into practice through his teaching method and style.

A majority of the countries represented in this survey report a shortfall of specialist chemistry teachers at this level.

Table XXVII - Shortfall of chemistry teachers (1968)

	B	CY	F	D	IS	EIR	I	L
Shortfall-percentage of teachers required	none (excess)	Shortage but figure not stated	none	7 %	50 %	Shortage, figure not stated	20 %	5 %

	M	NL	N	S	E	CH	TR	GB
Shortfall-percentage of teachers required	35 %	20 %	none	slight	none	Shortage but figure not stated	Short age figure not stated	slight

The extent of this shortfall varies from five per cent (in the case of Luxembourg) to as high as twenty per cent (in the Netherlands and Italy). Some of the smaller countries (Ireland and Malta) report even larger shortfalls, but this is due to their relatively small size of population and is hardly comparable with the countries with larger populations. By no means all countries are experiencing a heavy shortfall however, and in the case of the United Kingdom and Sweden the position is balanced so far as numbers are concerned, i.e. the number of chemistry teachers available is just about equal to the number of posts requiring them. Sweden anticipates that in the next few years she will be overproducing chemistry teachers, a state of affairs already in existence in Belgium and France. All countries, however, report a shortage of well-qualified and effective teachers of chemistry. The most quoted reason for the lack of well-qualified entrants to the profession is the more attractive salaries and facilities offered to chemists by industry, other professions and the universities. In some cases there is a lack of places at universities for students of chemistry and therefore the supply of prospective teachers of chemistry is inadequate. The measures being taken by the different countries vary according to the size of the problem. In the Federal Republic of Germany incentives are given to teachers of chemistry by the chemical industry in the form of industrial scholarships, whilst Sweden has in the past few years made many more university places available through the creation of new universities. In Italy special government allowances are obtainable for intending chemistry teachers and in the United Kingdom an extensive advertising campaign has been carried out in the press. It would seem that in general not enough university students are aware of the challenge and opportunities that exist in the teaching profession, and it seems that many are afraid that if they embark on a teaching career they will lose contact with modern developments and their job will be repetitive and monotonous. Even a vast improvement in the salary structure for chemistry teachers will not altogether solve the problem of the shortfall in such cases. It will only be through the type of curriculum reform and changes mentioned in the earlier part of this report that the profession will be made attractive to the most highly qualified chemists.

The proportion of women to men teaching chemistry at the upper secondary level is given in Table XXVIII.

Table XXVIII - Proportion of women to men teachers of chemistry at the immediate pre-university stage (selected countries)

	B	F	IS	EIR	I	L	M	NL	N	S	E	CH	TR	GB
% women	50	50	10	50	70	40	30	10	10	40	30	5	65	20
% men	50	50	90	50	30	60	70	90	90	60	70	95	35	80

For nearly all countries concerned the proportion of chemistry teachers who are graduates of a university is very high, usually ninety-five per cent or more. However, not all graduates will have followed a pedagogic course of training before entering the teaching profession. Table XXIX shows the position for a few selected countries.

Table XXIX - Qualifications of chemistry teachers in selected countries

	D	EIR	I	L	N	S	TR
% chemistry teachers whose study taken in UNIVERSITY	100	95	100	100	95	100	32
% chemistry teachers whose study taken in COLLEGE OF EDUCATION etc.	-	5	-	-	5	-	68
% chemistry teachers who have taken a pedagogic course of one year (or more)	100	95	0	100	-	50	89
% chemistry teachers who have taken a pedagogic course of less than one year	-	5	0	-	100	50	11

It would be almost universally true that all chemistry teachers at this level will have studied chemistry at university or some similar tertiary level institution. (In the case of Ireland and Turkey it is reported that up to ten per cent of the teachers of chemistry do not fall into this category, and in Cyprus where an overproduction of biologists means that these people often teach chemistry a similar situation probably exists). As will be seen, at present in Italy there is no special training course, the graduate entering the school straight after the university chemistry course. The different methods of teacher training in each of the countries concerned has been dealt with elsewhere, and, since the chemists follow essentially the same type of course as for all teachers, it will not be repeated here.

The facilities which are available to teachers for refresher courses or in-service training are an important feature of any branch of the profession, but perhaps even more so for chemistry teachers on whom great demands are made to keep abreast of modern developments not only in teaching technique but also in the discovery of new processes and materials. Nearly all countries provide facilities of this kind in some form or other. In all cases (with the exception of Turkey) the courses or periods of in-service training are voluntary, and do not lead directly to further qualification or promotion in the profession (although the teachers attending are often the keenest and most able, and in time fill the highest posts). In Turkey the courses are compulsory and a requirement of further promotion. In the case of Ireland the classes taught by teachers attending refresher courses would become eligible for grants from the government for new equipment and teaching aids. The refresher courses usually last for a period of one to three days, and are most often held either in a university department or by an industrial company. Sponsorship for the courses is usually by the government, although in the Federal Republic of Germany and in Switzerland the chemical industry directly organises and financially supports such courses for their teachers. In the Federal Republic of Germany and the United Kingdom the National Science Teachers' body is also very active in the organisation of in-service courses. In some countries teachers' centres are developing (United Kingdom and Cyprus for example) where discussion between chemistry teachers can take place on a local, rather than national, basis. Longer courses of one to two weeks are often held by many countries during the school holidays, and in the Netherlands evening courses also exist. In the case of Iceland, after ten years' service the teacher is released for one year on full salary, and a similar situation exists in Switzerland where after a similar period of service the teacher is allowed to take six months leave of absence on full salary. Table XXX indicates the proportion of teachers who take advantage of this kind of in-service training (figures available for a few countries only).

Table XXX - Percentage of chemistry teachers attending in-service training courses during the past five years

Country	Duration of course		
	1 day	1 week	1 term
D	50	10	-
EIR	20	50	-
I	-	10	10
L	-	35	-
N	very few	very few	-
S	100	100	-
TR	-	-	100

The aims of the in-service training courses are shown in Table XXXI, again in the case of a few selected countries.

Clearly there remains much to be done in this area, but from the evidence available there is every indication that increasing importance is being attached to the establishment of a variety of in-service courses and refresher facilities for chemistry teachers in every country. Economic considerations cannot be lightly discounted, but it is in the interests of every nation to ensure that the best possible education is available for its citizens, and in a technological age this must surely include a sound scientific education, brought about through the provision of the finest equipment and supporting facilities for students and teachers alike.

Table XXXI - Aims of in-service training courses

Country	Updating of scientific knowledge	Improvement of teaching methods	More general educational objectives
D	1	2	3
EIR	1	2	3
I	2	1	3
L	=	=	3
N	1	2	3
S	2	1	3
TR	2	1	3
GB	=	=	3

1, 2, 3, : order of importance

= : of equal importance

APPENDIX I

AIMS OF CHEMISTRY TEACHING

A more detailed illustration of the aims of chemistry teaching in some of the countries taking part in the study. The numbers in parentheses refer to the bibliography in Appendix II, which constitutes a list of some of the publications available on the aims of chemistry teaching, and from which the material in this appendix has been drawn.

AUSTRIA :

In Austria (2, pp. 134 and 138 ff.) the aims of chemistry teaching in the Oberstufe are : to awaken an understanding of chemical processes in nature, in everyday life and in technology ; and, on the basis of experiments, to put across a knowledge of chemical laws and of the more important types of reactions. Atomic theories are to be included. Technology is to be limited to examples of importance for the economy and of which the chemistry can easily be understood. The cultural significance of chemistry and its place among the natural sciences should be treated. The history of chemistry may also be dealt with.

"The pupil shall be offered, on an experimental basis, an insight into the structure (Aufbau) of matter and into the prevailing regularities". (2, p. 138). "In the Realistisches Gymnasium and in the Mathematisches Realgymnasium the pupil should, as appropriate, be made familiar with modern views about atomic structure, the bond theory and some of the simplest atomic reactions". (2, p. 139). The material covered should form an organic whole.

"Modern methods of analytical chemistry (e.g. chromatography and spectrographic analysis) and the use of radioactive and stable isotopes should be discussed". (2, p. 139). Practical work, in which the experiments also include simple analyses and syntheses, should have a prominent place, so that the pupil can obtain an idea of the methods used by chemists.

"All opportunities (Möglichkeiten) for bringing the pupils to independent scientific thought should be made use of. In particular, value should be placed on exact observation, a thorough analysis of the tests, logical conclusions and clarity of language". (2, p. 139). Connections with other subjects - physics, natural history, geography, mathematics, philosophy ... - are to be pointed out, and, as occasion arises, the teacher should draw attention to the limits of knowledge.

BELGIUM : (Catholic)

The National Federation for Secondary Catholic Education in Belgium states that, "The teaching of science in the humanities has as its aim first of all to provide the pupils with an initiation into this particular domain of human knowledge and next to that to give them a certain preparation for further education". (3, p. 29).

Science familiarises the pupil with the inductive method. "It is not at all an amassing of bookish knowledge that the teacher will propose to inculcate in his pupils ; but rather the scientific method, or better the scientific spirit". (3, p. 29). The aim of the humanities, in science as in the other branches, is not to fill the mind but rather to open and broaden its powers.

"The teaching of science is essentially experimental. Observation must be the point of departure and the basis of the reasoning." (3, p. 29). The experiments will have a problem-solution orientation. "Each experiment is a question put to nature". (3, p. 29). The experiences of modern, everyday life should be exploited as far as possible in the teaching.

The results of the experiments must be carefully analysed. The pupils must learn to make judgments with "... that critical spirit which is part of the true scientific spirit". (3, p. 30). By their constant demand of objectivity the scientific disciplines contribute to a love of truth. The pupil must also be able to express himself precisely, briefly and with clarity.

The pupils must be familiarised with a way of thought, of observing, of reasoning ; with a method of work. They must obtain the outlook proper to the observational sciences.

"The teacher must always keep the general education (Formation générale) of his pupils in mind", bringing to their attention the points of contact with the other branches of learning (3, p. 30).

The history of scientists and of their discoveries would bring out the fact that it takes the contribution of many researchers to bring about the development of science. Underlining the role in science of human thought, ever" ... seeking and creative, always in search of truth and beauty" (3, p. 30), the historical approach avoids an exaggerated utilitarian conception of science. The admirable examples of the true men of science will teach the pupils "... to appreciate disinterested work, intellectual integrity, courage ; tenacity, love of truth, team spirit, ... modesty, honesty (the spirit of) self-sacrifice ..." (3, p. 30).

The philosophy of science should also be touched on, showing the relative and tentative nature of scientific theory. The pupils must understand that science does not explain everything - indeed, it gives rise to an increasing number of problems in need of solution. "This conviction will awake in them the sense of mystery which penetrates the whole of nature". (3, p. 31). "Finally, conscious of his role in the framework of the formative mission of Catholic education, the teacher will be concerned with drawing the attention of his pupils to the digitus Dei which shows itself everywhere in nature". (3, p. 31).

In dealing specifically with chemistry, the Belgian Catholic directives state the aim is not to produce skill in the use of apparatus nor the memory of all the properties of an element.

Because of recent theoretical advances chemistry today can be presented more directly and more logically. "The principal aim of chemistry is the study of the changes which take place in nature ; these changes are only the manifestations, on a large scale, of deeper changes which take place at the microscopic level ". (3, p. 34).

Thus in chemistry there are really two worlds : that of observable phenomena and that of phenomena at the atomic level. "... it is by observing the first that the pupil must learn to 'live' in the second.." (3, p. 34). The pupil must acquire gradually, but quite quickly, this atomic imagination or "vision".

The internal structure of the atom will form the basis of the degré supérieur.

The pupil must arrive at the theoretical concepts by a process of reasoning based on experimental data. Descriptive aspects must be secondary to general and theoretical concepts.

BELGIUM : (State)

"The descriptive elements and the synthetic elements have been separated.

The latter shall be taught as soon as possible, but in relation with the study of the appropriate descriptive and experimental elements.

The concepts which the pupils are required to know shall rest, as far as possible, on facts and experiments. This is why, for instance, the study of industrial preparations will only be undertaken en première, by which time the pupils will have a sufficient knowledge of chemistry to be able to understand the social and human dimensions and to profit intellectually from this study". (4, p. 23).

These directives can be seen against the background of two statements made in the section on the less advanced stages : "The aim of secondary education is the intellectual formation of the pupils ; it seeks much less to impart numerous items of knowledge". (4, p. 10).

"Neither should the teacher forget the present influence of science and of technical advances on human life and thought ; the should show the connection between the practical aspects (caractère utilitaire) of the different techinques and their value as agents of civilisation". (4, p. 11).

DENMARK :

In the Mathematics Line in Denmark "The objects of the course are to give the pupils knowledge of chemical method, phenomena and laws, and to give some conception of the application and significance of chemistry in technology". (6, p. 15).

"The course in chemistry shall be based on experiment, and to as great an extent as possible the pupils should gain a firm knowledge of the substances and their reactions by their own experience in working with them. Both demonstrations and exercises by the pupils must form part of the course.

The properties of the elements should be compared with their position in the periodic table, and general laws and theories should always be illustrated and utilised in teaching.

As a whole, the subject should be studied qualitatively ... quantitative treatment should be given, however, ... (to topics such as stoichiometry, and the calculation of pH in solutions including buffer equilibrium).

...

Use should be made of any opportunities to visit, occasionally, the industrial and other plants in order to stimulate the pupils' interest in the practical application of chemistry.

... The teacher himself must decide the order he considers appropriate on pedagogical and methodological grounds, including collaboration with the courses in physics and biology (for dealing with the items on the syllabus)". (5, p. 28 - 1st Gymnasium Class and the Mathematics-Physics and the Natural Science Branches).

FEDERAL REPUBLIC OF GERMANY :

Baden-Württemberg (10, pp. 107 ff. ; 12, p. 184) stresses the laws of chemical behaviour as the focus, and the experiment as the basis, of the teaching. Chemical concepts and laws should be exactly formulated and the teaching should not get lost in a welter of separate items of information. There should be early and thorough practice of symbols. The pupil should have his part in the planning, carrying out and interpreting of the experiment. Also he should be trained in giving an exact report on it.

Few but important examples from technology should be used. Visits to nearly chemical works would be a means of showing :

1) how scientific knowledge is utilised and,
2) of permitting valuable scientific and social insights.

The concepts and laws that have to be learnt include those concerned in the kinetics of reversible and irreversible chemical reactions, relativity and the macromolecules and colloids of inorganic chemistry. Also a certain number of substances have to be mastered, such as calcium, iron, silicon.

The general aims laid down for science teaching in Berlin (14, pp. 60-61, 68-70) are that the young person should gain an understanding of nature and should obtain a sufficient if simplified picture of scientific research. The main characteristics of the scientific mode of thought is that it seeks after causes : the value and range of causal thought must therefore be made clear to the pupil (p. 60).

The science lesson has four main tasks (pp. 60-61). The first has to do with knowledge ("erkenntnismässig"). Above all is the understanding of the posing of a problem. The pupil must learn to make unbiased and exact observations, to think clearly and logically and to express himself to the point and without being wordy. The experiment should be at the centre of the lesson. The class should participate freely in the posing of questions, the thinking up of solutions and the evaluation of results.

Practical work ("Ubungsbetrieb") in particular contributes towards the formation of character : "Patient painstaking trains one's will-power, reliability in making measurements indicates a love of truth, working in groups promotes the spirit of comradeship" (p. 60). The science lesson is also the opportunity for setting right the popular notions of the pupil.

The second task is the philosophical one. "Today a deepened general education is no longer possible without some knowledge and understanding of science" (p. 61). Concepts such as time, space, substance, causality, etc. cannot be fully understood without science. General problems from the sciences can awaken philosophical reflection and show the value of objective, critical thought. Although it is not the job of the science lesson to develop any specific world-view, the connection between science and the thought of a period should be pointed out, for science makes an essential contribution to the ways the world is seen in any given age.

The third task is the historical one, giving cross-sections of historical problems as fitting. Similarly, the paths, detours and dead-ends of research and the lives of the great scientists can be illustrated by passing examples. This can help towards the formation of character.

Lastly, there is the practical task, that is, concerning applications of science of individual, social and economic importance - and the underlying laws involved. The fact that technical achievements can be both advantageous and disadvantageous leads to the consideration of ethical problems and of philosophical problems concerning civilisation ("kulturphilosophisch").

Concerned as it is with meaningful classifications of natural phenomena, with painstaking conceptual work, with the precise understanding of the laws of nature and with the contribution of science to the modern view of the world, the science lesson" ... has a formative effect on the higher dimensions of the make-up ('geistige Struktur') of the growing person and so serves a humanistic purpose : the development of the personality" (p. 61).

Dealing with chemistry specifically, the Berlin Entwurf says that chemistry is necessary for a scientific view of the world, for it deals with an area which concerns the foundation of our being, that is with the problematic nature of matter and with its different formations ("Umwandlungen").

Through hypotheses and theories he will learn about the laws that govern the natural world. The constant interaction of thought and fact will, among other things, be brought out by a historical treatment. The methods and modes of thought characteristic of modern chemistry will illustrate analysis and synthesis and how order and clarity are introduced into chaos.

The pupil must become familiar with the most important elements, their properties and structures. Especially in relation to the Periodical System and to crystallography, chemistry brings out the importance, for an understanding of the properties of matter, of the arrangement of the basic particles - not only, unlike Physics, of their number and size. As far as possible physical chemistry must also be treated, leading right up to the notion of the equivalence of matter and energy.

The treatment of the most important processes of the chemical industry and their underlying scientific basis will bring the pupil to appreciate the chemical industry for what it is : ingenious applications of scientific knowledge. "By means of examples from the chemical industry he can realise that modern life, which is governed by technology, is a complicated structure with a dynamic equilibrium" (p. 69).

Induction and deduction will be used in the teaching, the point of departure being essentially experience. The qualitative experiment will usually be used. The quantitative will sometimes be necessary, however - for instance, as the basis of a hypothesis or to demonstrate a law. Here mathematics will be called upon. Chemical symbols and formulae should be introduced as early as possible.

The pupil must not be given just facts, but a knowledge of the problems and of the approaches to their solutions. Thus the Chemistry lesson can be of a great formative value and can permit a critical judgment of chemical knowledge and an appreciation of its limitations. Chemistry lessons with a sound subject-matter basis, but also having a wider orientation" ... will not only help to form the pupil's intellect and to develop his personality, but will also produce in him respect for the great researchers in science and technology as also a reverential fear for the Creator of all things" (p. 69).

Hessen (80, pp. 5-11 ; 17, pp. 17-20 ; 18, pp. 9-12) points out that typical of sciences is the subject-object attitude. Science thus requires certain concepts and methods : causality, probability, finality ; questioning, observing, hypotheses, controlled experiments. Science simply asks questions and poses problems about quality, quantity and form : it does not pretend to arrive at the essence of things nor to be a world-view. It is the task of the science lesson to develop in the pupil this subject-object attitude. Above all it should spark the desire for truth and promote the striving towards clarity which can only be achieved in disciplined, critical thought. Experimentation and theory go together, not pure thought and not undirected experimentation.

Philosophical, aesthetic, sociological and ethical questions should not be avoided, especially in the Oberstufe. This is contrary to the earlier accent on a value- free natural science. It should be made clear that research and responsibility are inseparable. The scientist is often not sufficiently aware of the interrelatedness of rapid scientific and technological progress with structural changes in society. The technological appplications of scientific knowledge both free and limit man. The great danger in the sciences of absolutising the scientific approach and its result must be avoided. One must not produce just narrowly specialised engineers but men of high technical, moral and intellectual qualities, men who can be leaders.

Thus Hessen is fully aware of the social responsibilities of the scientist and of the implications of a technological age. "The age of worldwide industrialisation sets new goals for the educational system of any nation" (18, p. 12). The extent to which each nation takes part as a pioneer and helper in this industrialisation will determine its place in a peaceful world far more than the most modern military machinery would. The pupil should be shown that the natural sciences are universal, are the task and achievement of all mankind.

However, the school should not try to force an out-dated romantic view of the beauty of nature on to the pupil. He will also arrive, on the basis of his more objective experience of nature, following the strict path of investigation and discovery, at a reverential fear of his creator.

Another aim not within the field of chemistry as such expressed in the official Hessen publications is the putting across of the precise use of words. The natural science lesson is suitable for this because scientific language is economical and clear.

However, the Hessen publications are of course also concerned with the acquisition of a deepened knowledge of chemistry and of the skills involved in chemical research. The foundations for further scientific studies must be laid. There will be a deepened treatment of the periodic law. The chemistry of carbon compounds will be dealt with. The pupil must obtain a knowledge of the specific approach of chemistry, of the methods of chemical inquiry. The pupil will be led to work on his own. In the last two years he should arrive at a state of knowledge which permits him an opening on to the new tenets of the natural sciences.

An appreciation of the interrelatedness of chemistry and the other natural sciences is also important. The pupil should be given the opportunity of seeing the common objectives of the three natural sciences and also the differences in their approaches and methods.

One might summarise the aims expressed in the Hessen publications somewhat as follows. The pupil must acquire a sound basis in chemical knowledge and in the scientific approach. He must have the right attitude towards his work. He must be well prepared for further scientific training and research. He must know the origins and the fundamental contents of our world, so that he can decide freely and responsibly for its demands. He should see the interrelations of chemistry with the other natural sciences and with technology. He must have a keen social consciousness and a sense of reponsibility and must appreciate the wider moral and philosophical implications of the sciences and of industrialisation. He must be prepared scientifically and fully to play his role in the world of tomorrow.

The aims of chemistry teaching in Niedersachsen (20, pp. 47 ff.) cover the following ground : an acquisition of chemical knowledge and methods, based on experiments ; a grasp of theoretical thinking ; an understanding of the relation of chemistry with other disciplines ; and an appreciation of the importance of chemistry today.

The pupil must be familiarised with matter, its properties, changes of state as well as with laws of action and reaction. There is a new basis to thinking in chemistry now. He should learn the structure of nature, think in terms of structure, draw up models for understanding reality. The structure of matter has educational value - in the study of crystals, for instance, the pupil sees the order and symmetry of nature. The use of models is now characteristic of all understanding. It gives the pupil an important insight into the extent and limitations of the subject and an experience of strict mental discipline.

Besides the static elements (structure), there is also the dynamic element (laws of change of state), the understanding of reaction and chemical equilibrium.

Through observation and evaluation of chemical reactions the pupil begins to understand the basis laws, hypotheses and definitions and to complete the process from observation to theory and vice versa. Exact observation is important. It involves the ability to describe observed phenomena exactly andto draw logical conclusions. Thus the chemical method teaches pupils self-criticism and honesty.

In chemistry the inductive and deductive methods are both important. Through constant interchange of these thought processes, through observation and experiment, through use of models, through analysing and synthesising, independent logical modes of thinking are encouraged.

Chemistry must not be taught without experiments. Demonstrations by the teacher and practical work by the pupil are both important, but the pupil's own work should have precedence. From his observations the pupil poses questions and should find a way of answering his questions experimentally. Abstract language should be practised with experiments : the pupil should learn to find laws by experiment and to apply these laws sensibly to other examples.

Achievements of chemical research should be brought to the pupil's notice. The history of chemistry will help him to understand the possibilities and limits of the subject.

Industrial and technical applications of chemistry should be illustrated. Industrial films, visits, etc. all help the understanding of chemical methods in industry. The student should recognise that only a responsible application of chemical knowledge serves mankind.

Modern civilisation is inextricably bound up with chemistry - nutrition, food preservatives, medicines. There are also the undesirable effects of chemistry on mankind : air and river pollution, radioactivity, unwanted consequences of artificial fertilisation and of pest killers on the plant and animal world.

The connection of chemistry with physics, biology, geography and social problems should be pointed out. For instance, there should be a class discussion of ground common to physics and chemistry with both physics and chemistry teachers present.

Niedersachsen makes specific reference to the important concept of exemplarisches Lernen. The chemical world is far too large for the pupil to study in its entirety. Thus typical and fitting topics and examples should be chosen as points at which the study goes into depth, so as to exemplify chemical knowledge and bring across the general laws and concepts.

Nordrhein-Westfalen (21, pp. 1, 10, 20) lays down two general aims :

1) to help the maturing men and women to lead their lives responsibly and with an awareness of reality, and

2) to lay a basis for higher education and of scientific formation.

There should be a broadening and deepening of the pupil's knowledge of organic and physical chemistry. The pupil should gain a familiarity with the more important elements and an understanding of the sorts of laws that are typical in chemistry. He must obtain an insight into the nature of chemical problems and into their relationship to each other. Finally, questions of the theory of knowledge and of problems of values should be raised.

To sum up briefly, in the Federal Republic of Germany chemical laws and the atomic structure of matter are stressed as the focus, and the experiment as the basis, of the teaching. It is important for the pupil to gain an understanding of the scientific method. The coherence of chemistry and other disciplines is underlined. The pupil should also appreciate the technological and industrial implications of chemistry for modern civilisation. Above all, he should be brought to a sense of social responsibility. Indeed, science and the way it is taught can make a large contribution to character formation. Moral and philosophical issues should be raised.

The pupil is to get a wide but at the same time a deepened view of chemistry. The exemplarische method of teaching is one of the main means recommended towards the attaining of this end.

One criticism which could be made is that there seems to be a very strong assumption of transfer of training, especially as regards moral and character formation. It would also be interesting to see to what extent what actually happens if the classroom measures up to the expressed ideals.

FRANCE :

France (24, especially pp. 9-24 ; 27, pp. 21-25, 28-29) stresses the formation of the person. The general aims of science teaching is not simply to impart the knowledge necessary for an understanding of the modern world, it is not just to pass on a certain body of knowledge. Rather it is above all to develop certain intellectual, and even moral, qualitites : it is to contribute to the formation of the man of today. The adult must be capable of forming a considered opinion on the problems he will have to face. The important thing is to see the natural sciences as contributing, in union with the other disciplines, to a general education. "... a consciousness of spiritual values in the widest sense - of those which assure the maintenance of the superior civilisations and most especially the consciousness of the pre-eminence of man and of his endeavours over the world - must be awakened and developed". (24, p. 16). Above all, rather than being given knowledge, the pupil must be made capable of acquiring knowledge for himself.

He must acquire a certain number of intellectual mechanisms : straight thinking, the spirit of observation and of seeing analogies and of generalisation. The different forms of the memory must be developed as also imagination and the power of judgment. Although the art disciplines are more suited to developing the spiritual values, physics and chemistry, especially industrial chemistry, are also amenable to this task.

Indeed, one of the first objectives in teaching the physical sciences is to reveal to the pupil the complexity of reality. We must show him that nothing is simple and we must create in him an objective attitude towards facts (24, p. 18).

However, the programme in the terminal classes permits a certain synthesising of the pupil's knowledge, both theoretically and with regard to the technical applications of science. Central notions on which these syntheses could focus would be those of energy and of the structure of matter and of the industrial production and utilisation of energy. It is not bad to touch on contemporary questions of interest to the pupils who might "... be able to acquire, along with a sense of the open question, the pride which man feels in looking at what he has accomplished, and the will to pursue the exciting and hazardous exchange with nature in which the very destiny of Humanity is at stake" (27, p. 25).

The Instructions list, with regard to approach, the following aspects of scientific work as contributing towards a general formation : objective and precise observation orientated towards finding explanations ; the thinking up and carrying out of experiments and the interpreting of the results - involving as this does the use of logic and mathematics in the "structuring" of the data ; and a critical study of existing theories (27, p. 21).

The historical approach is stressed as useful in the formation of the pupils if past discoveries are replaced, as they should be, into the climate of thought, the state of knowledge and the controversies in which they occurred. But past discoveries should not simply be presented with a ready-made verification. Rather a method of "rediscovery" should be used, systematically considering all the possible factors (27, p. 22). It is not necessary to follow the exact course of history, but a general historical-type approach is useful, tracing the general movement from fact to law to theory. The natural sciences have an important role to play in the formation of the scientific spirit of the pupil.

Lazerges points out that the pupils must be initiated in the experimental procedures. We must convince them that pure logic alone is not the only means of arriving at the truth. He also stresses teaching by what he calls the natural method, that is to say, going from the known to the unknown, and from the concrete to the abstract, and, in general, starting from the situation, experience and language of the pupil and not from that of the adult (24, pp. 21, 24 ff.).

Also chemistry must not be taught as a narrow specialisation, rather it should be tied up with other subjects, thus bringing out the problems of raw materials and eliciting interest in the history of technology and the advances of industry and showing the importance of different industries and the conquest of man in the world.

Although the stress is on the value of chemistry as contributing towards the general education of the person, this does not, of course, mean that more specific objectives are disregarded. For instance, Lazerges says that naturally the pupils will be expected to retain a certain body of knowledge ; that it is also legitimate for them to be concerned with examinations and to be aiming at a place in an institute of higher education ; and that it is only good and right for them to be also career orientated (24, p. 23).

In the Instructions one of the specific objectives mentioned for the Classe de première is the obtaining, by a study of certain elements and their derivatives, of a notion of the periodic classification of the elements, as this is the basis of all modern theories of the structure of matter. Another specific objective is the introduction of the fundamental notion of ionisation to show that the properties of a salt are the properties of its ions. In the Classes terminales the gradual development of the use of symbols in chemistry will be treated : from their use in the representing of the chemical properties of matter to the determination of the very structure of molecules. Also there will be the study of organic chemistry and the consolidation of the pupils' knowledge by means of the notions of general chemistry.

The main emphasis seems to be on a pupil-centred orientation, that is, on the intellectual and moral formation of the person. However, the person seems to be conceived of basically as an individual and hardly at all as a member of society with social responsibilities. Moreover, although great stress is placed on the valeurs spirituelles, one is given little indication of what values are actually intended, yet this phrase would not mean the same to a fascist as to a liberal.

LUXEMBOURG : *

The general objectives of teaching chemistry in the terminal stage of secondary education in Luxembourg are : by confronting the pupil with scientific work, to show him the aims and methods, and to give him a true appreciation, of this kind of work ; and to prepare him for further education at the University level (36).

Or as Mr. Gust Altzinger (32) put it : "Generally speaking, in the scientific subjects, the pupils are familiarised with the problems of modern science, its working methods, its way of thinking and its achievements".

The course of chemistry considers these aims by providing them with a living panoramic view of the constitution of matter, its properties and its changes.

* It might be noted that Luxembourg is at present in a period of major transformation regarding its secondary school curricula.

In sub-sections A and B it will suffice that the pupils get a general view ... they will (also) be able to realise the import of chemistry on the development of our civilisation.

In sub-sections B and C (mathematics, natural sciences) the teaching of chemistry will be far more advanced. The electronic structure of the atom with its consequences is an indispensable basis for the organisation of the course and the interpretation of chemical changes. ... chemistry as an experimental science is based on experimenting in order to develop the pupil's own ability to observe. But the aim of the course is not to make the pupils acquire numerous isolated scientific facts ; on the contrary the modern teaching of chemistry has to limit to a minimum the descriptive chapters in order to become more and more an explicative discipline so that the different chapters are linked together logically. To this end the course of chemistry has to offer the pupils a rational and coherent view of the chemical world and of scientific thinking and has to allow them to explain, even to foresee the evolution of chemical changes.

In order to reach this aim, the curriculum has to insist on the following chapters : atomic structure, atomic models, periodic system, chemical bond (covalent, ionic, metallic), relations between structure and properties of matter, oxidation-reduction reactions, acid-base reactions, reactions of complexes, energetic considerations in chemical changes, fundamental concepts of thermodynamics and chemical kinetics. Organic chemistry has to be based upon the electronic theory and could not do without treating the analysis of the mechanism of its reactions.

...

(The specialised programme in chemistry aims not only at furnishing the pupils with the necessary knowledge required to start university studies, but ..."will also contribute to develop their faculties of imagination and judgment") (32).

NORWAY :

In Norway the aims for the teaching of chemistry in the naturfag line is to give the pupils : "(1) Further knowledge of the three main branches of chemistry : inorganic chemistry, physical chemistry and organic chemistry. The section on organic chemistry is to include the chemistry needed for the teaching of psychology.(2) A more thorough knowledge of, and experience in, work in a chemistry laboratory" (42, Kj 1).

The pupils are to be given an understanding of the topics covered by the syllabus partly through the use of demonstrations in the teaching and partly by themselves carrying out experiments. "The practicals ... must increasingly be made the centre of the teaching". (42, Kj 3). Work which had been started at a lower level must be continued so as to reveal laws. "During the oral examination in chemistry in the natural sciences line one is to test the candidate's knowledge of the principal theories in chemistry and his knowledge of laws, reactions and chemicals ... Furthermore, one is to test the candidate's knowledge of and practice in practical laboratory work. The main emphasis is to be put on the candidate's understanding of the subject, less weight on the amount of detail he has acquired". (42, Kj 6).

"From an early stage in school the pupils have been trained to appreciate that it is our sense-perceptions which give us our understanding of Nature. This approach must be continued in the chemistry lessons ... The pupils must also be able to see examples of how science tries to use our experiences to postulate beyond our experiences. They must participate in putting forward some theories, and participate in erecting some accurate expressions for chemical reactions (equations). The pupils ought to be subjected to the idea that the methodology of science is not limited to science alone, but that we must use the same methodology in our daily lives. Commonly we must rely on sense-perception to build a solid foundation for our work, but we often find our experience is too limited for final conclusions". (42, Kj 3).

SPAIN

The pupils are to acquire the habit of interpreting chemical phenomena on the basis of general chemical laws and theories. Above all, therefore, they must learn the theories about the structure of the atom and the nature of the chemical bond and about thermodynamic and kinetic aspects of chemical reactions. It is the electronic structure of the atoms that determines the nature of the chemical bonds and permits a general interpretation of the more important properties of the chemical elements and compounds. Structural models, graphs and the tables of the numeric values of the properties should be used to bring out the more intuitive aspects of these theories (85, p. 307).

The study of the general theories should be applied to "... chemical substances or reactions that are characteristic and of practical importance." (85, p. 308).

Demonstrations and practical work are essential so that the pupil may have first hand knowledge of the phenomena to be interpreted.

"... the fundamental objective ... is that the pupil should be initiated in the mode of thought proper to present day chemistry. To this end the theoretical and descriptive aspects of chemistry must be presented in such close relationship (to each other) that they form a single whole" (85, p. 308).

SWEDEN :

The general aims of the gymnasium in Sweden (46) are roughly : to prepare the pupils for further education and for the labour market ; to further their personal development, above all encouraging in them an independent and critical attitude ; and to give them the necessary social training. These should be seen as the background to the following aims of the chemistry teaching (46, pp. 13 ff.).

"The purpose of the teaching in chemistry is : to convey the main features of atomic structure and the nature of the chemical bond ; to give knowledge of the more important inorganic and organic groups of compounds ; to give some knowledge of experimental methods of investigation ; and also to give a certain understanding of the use of important chemical methods, compounds and groups of compounds in industry and society" (46, p. 307).

"... the teaching ought first of all to reveal chemical relationships and processes" (46, p. 309). "The theory of structure and the physico-chemical laws and principles should form the basis of the teaching" (46, p. 309). The contemporary conception of the atom should be presented as soon as possible.

Those topics should be chosen for treatment which can be used to demonstrate some general law or principle, or which are particularly important for another subject, or are of general interest. A few main points of interest to the pupils and the teacher should be studied more intensively - not, indeed, so as to accumulate a mass of details, but to lead to new concepts and to an increased knowledge of chemical relationships.

"... the learning of facts must not be an end in itself" (40, p. 319). Nor should the pupils experience chemical phenomena as some form of magic following arbitraty rules. Rather they "... should see them as a result of atomic reactions which it is possible in some form or another to illustrate by a model" (46, p. 309).

Emphasis should be placed on mathematical treatment. This helps to consolidate the pupils' knowledge and to create a complete understanding of quantitative relationships. The pupils should also get used to equations.

"Experiments and their analysis ought to have a central place" in the teaching which should also be amply illustrated by examples, facts and models from inorganic and organic chemistry (46, p. 309). Sometimes theoretical discussions with deductive argumentation are also useful. Indeed, "The teaching (e.g. when dealing with current views of atomic structure) will often, out of necessity, take the form of theoretical presentation without experiments or references" (46, p. 320). In such cases support must be sought in physical data from textbooks and the like.

Finally, "It is convenient to review ... some of the more recent advances in chemistry and the possible fields of research. Thus the pupils can gain increased understanding of the role of chemistry in progress and economic growth" (46, p. 309). "It is also desirable that the pupils be informed about some of the experiments through which science has arrived at its present views" (46, p. 320).

ENGLAND AND WALES : *

It is on the whole agreed that a two-fold objective must be met : the training of chemistry specialists and a "full education".** The first objective is dealt with at length and itself involves other more or less tacit assumptions or goals. The second tends to remain somewhat general and vague.

The training of chemistry specialists means not simply the memorisation of a mass of facts, but rather a deepened and real understanding of the principles and theory of chemistry and of the scientific method (cf. also 53, p. 183). The central theoretical framework in chemistry is to be found in the atomic theory of matter. "It will be among the principle functions of the advanced course in chemistry to study the erection of this grand edifice (built up on the atomic theory), to appreciate the mechanics which endows the whole design with strength and rigidity, and to become familiar with the foundation of fact upon which it rests" (56, p. 121). The Science Masters also stress theory, but with a somewhat different emphasis : "... it is a major aim of the (advanced chemistry) course to examine critically the logical foundations for the theoretical structure which attempts to create a rational unity from the diversity of nature" (69, P. 607).

The pupil should also acquire the habits of thought and the other skills involved in the scientific method and in carrying out independent, scientific research. "Sixth Form work should be an experience of, and an exercise in, the methods of intellectual exploration as much as an occasion for acquiring information and techniques" (69, p. 5, cf. 56, pp. 101, 120 f., 126).

No concepts should be presented to the pupil which are not grounded in experience for him and about which he is not in a position to think critically. He must appreciate that the scientific method is essentially a "circular" one : the starting point is experience, but this is then understood and organised by means of a theory or hypothesis, which is in its turn empirically testable or at least gives rise to testable hypotheses.

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* This section on the United Kingdom is based mainly on : (88), chapter 25 (56) especially pp. 1 ff., 69 ff., 96 ff., 120 ff. and 157 ff. ; (65) pp. 7, 12-13 and 15- 17 ; (68) and (69).

** (56), pp. 1-2, 111, 157-159 ; (68) ; and (69), p. 1. See also (65), pp. 12 and 16.

The limitations of chemistry must be appreciated. First of all there are no absolute truths in science, but only more or less probable statements with more or less supporting evidence. The Nuffield (O Level) Chemistry Handbook for Teachers underlines the tentative and changing nature of scientific knowledge. It stresses that chemistry is not a "body of received doctrine", but "a dynamic interplay between observation ... and speculation" (62, p. 5). Secondly chemistry is interdependent on other disciplines and in particular on physics, to which it must be related for the pupil. This can be seen in the atomic theory of matter which is the backbone of chemical theory.

The historical approach is also useful, for it gives the pupil an insight into how scientific discoveries have been made and into the meaning of chemistry as a form of man's response to the world around him. The pupil should have an appreciation of the technological implications of science, and, in this sense, of the place of science in modern life.

In the objective of training chemistry specialists one can see two further goals involved. On the one hand is the notion of society's needs. The country must be supplied with well trained scientists. Pupils must therefore be prepared for university and for research. On the other hand there is the goal of knowledge for itself.

This leads us to a further discussion of the second, rather broad objective. Today's pupils must be given a full education and one that is appropriate to a modern technological age - which includes a scientific formation. Thus the Science Masters argue in their Policy Statement that given the effects of science on human life and thought, to be properly educated and truly cultural one must have an understanding of science (68). The Nuffield Foundation Progress Report 1965 says : "New sixth-form science courses should provide a good preparation for life in an increasingly technological age as well as a solid foundation for higher education" (65, p. 16). However, an unduly narrow scientific formation would be a disservice even to science itself. The scientist and the technologist must also be capable of making all types of judgments, including value and moral judgments.

And, indeed, chemistry - along with the sciences in general - has its part to play in the liberal education of the pupil. The Science Masters want science to be recognised and taught as a major human activity. It is a subjective quest for truth. It should be presented as part of our cultural and humanistic heritage, in harmony with the various arts subjects (68). Properly taught, chemistry can help to develop many desirable qualities of thought and of character. In chemistry one must be exact and must respect the facts. One must proceed in an orderly way and weigh up different alternatives. One must accept the limitations of science and of the individual scientist. One must think clearly and critically. One must have initiative.

The Science Masters (68) put forward the suggestion of two science courses at the Sixth Form Level, Course "A" for all pupils and Course "B" for the science specialists. Course "A" would cover : the philosophy, linguistics and history of science ; some of the social, technological and intellectual applications and implications ; the origins and development of some of the major live issues in science today ; major themes such as, matter and energy, cosmology, the relations between science and religion and, maybe, an introduction to psychology and to the social sciences ; applications to health and food supply and to manufacturing industries ; and a close study of a few sequences of scientific discovery and some personal experience of scientific investigation. This last named item would " ... lead to a conscious examination of the ways in which scientists work and of the values and limitations of the methods they use" (68). Course "B" would include the examination of the place of the specialised work in relation to other areas of human thought and endeavour, and a going into greater intellectual depth, though not over-much factual detail (68).

To conclude, the expressed aims and objectives of chemistry teaching in the United Kingdom seem to combine (albeit often rather without the implications being really developed) a discipline,a child - and a society - centredness. Chemistry is to be taught in such a way that its inner and essential structures can be grasped. The child is to be led to full development and is to be taught in a way both interes ing and appropriate to him. The needs and demands of society - social and technological - are to be met.

A criticism which could be made is that transfer of skills seems sometimes to be assumed. For instance, it seems to be felt that the capacity to make a sound chemical judgment is unquestionably similar in kind to that of making a right moral or a suitable value judgment. It seems also to be somehow implied that the acceptance of the limitations of science and of the probalistic nature of its statements will preserve the scientist from man's totalitarian tendencies. It must be granted, however, that it was implied that these desirable results would not necessarily spring automatically from the teaching of chemistry, but that chemistry was a good occasion for developing the qualities mentioned.

APPENDIX II

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Skriftserie") ("Background Information on Secondary School Reform") DAS/EID/65.83, restricted, Paris, November 1965.

TURKEY :

87. BILMEN, M. Sitki, The Turkish Lycée, its Stable Characteristics and Curriculum, Ankara, Maarif Basimevi, 1960.

ENGLAND AND WALES :

88. MINISTRY OF EDUCATION, 15 to 18 - A Report of the Central Advisory Council for Education (England), ("The Crowther Report"), Vol. I, especially Part Five, London, Her Majesty's Stationery Office,1959.

APPENDIX III

CHEMISTRY SYLLABUSES OF SELECTED COUNTRIES

Belgium : Class II (2 hours)

A. DESCRIPTIVE CHEMISTRY

I. Inorganic

1. Nitrogen, ammonia, ammonium compounds, nitric acid, nitrates
2. Phosphorus, phosphoric acid, phosphates
3. Carbon, oxides of carbon, carbonic acid, carbonates
4. Silicon, silica, silicates (very elementary notions)

II. Organic

1. Introduction : cyclic and heterocyclic chains
2. Methane, petroleum, distillation, fractionation, ethylene, acetylene
3. Ethyl alcohol. Fermentation
4. Carbohydrates
5. Acetic acid. Vinegar.
6. Esterification. Saponification
7. Acetamides and urea. Proteins
8. Amino acids
9. Benzine (tar, coal-tar, coke-gas)
10. Phenol, aniline

B. THEORETICAL NOTIONS

1. Revision of laws of gaseous combinations and of the Avogadro-Ampere law. Consequences of the Avogadro-Ampere law.
   a) composition of a molecule of a gaseous element
   b) determination of molecular weights by density of gas or vapour
   c) molecular volume ; Avogadro number
   d) determination of the formula of a substance
2. Electrolysis : ionic theory. Ionic equations. Electrovalency

Class I (1 hour)

A. DESCRIPTIVE CHEMISTRY

1. Study of metals

Metallurgy : general notions. Study of principal chemical and physical properties of metals. Among others the following will be studied in the laboratory :

Sodium and potassium
Copper and silver
Magnesium and calcium
Zinc
Mercury
Aluminium
Lead
Iron

2. Chemical analysis

a) Qualitative

Students are expected to evolve their own simple analytical tables (under the guidance of the teacher) by a study of positive and negative radicals in solution.

b) Quantitative

Simple volumetric analysis with acids and alkalis.

B. THEORETICAL NOTIONS

1. Revision of periodic classification of elements. Bohr's atomic model.

2. Oxidation and reduction seen as variations of valence.

3. Idea of chemical equilibrium. Applications : pH hydrolysis, amphoteric hydroxides.

4. Radioactive disintegrations.

Denmark : The mathematical line

A. 1ST GYMNASIUM CLASS AND THE MATHEMATICS-PHYSICS AND THE NATURAL SCIENCE BRANCHES

I. List of subjects

1. General chemistry :

Atoms, molecules and ions. The periodic table. Chemical bonds. Isomerism. Properties of dilute solutions. Reaction kinematics and chemical equilibrium. Acid-base reaction. Reduction-oxidation reaction.

2. Inorganic chemistry :

   The most important elements and some of their compounds. Special attention shall be paid to such substances as are important for technology or in daily life, and to such as may serve to illustrate general laws and theories.

3. Organic chemistry :

   Aliphatic compounds, including hydrocarbons, halogen derivatives, alcohols, aldehydes, ketones, carboxylic acids, esters, amines, amino-acids. Cyclic compounds, including aliphatic compounds, hydroxyl compounds, carboxylic acids, amines : natural substances (carbohydrates, fats, proteins) and synthetic polymers.

   Demonstrations and experiments form part of the course.

II. Comment

The course in chemistry shall be based on experiment, and to as great an extent as possible the pupils should gain a firm knowledge of the substances and their reactions by their own experience in working with them. Both demonstrations and exercises by the pupils must form part of the course.

The properties of the elements should be compared with their position in the periodic table, and general laws and theories should always be illustrated and utilised in teaching.

As a whole, the subject should be studied qualitatively. As examples of topics where a quantitative treatment should be given, however, the following are suggested : stoichiometry and the calculation of pH in solutions (including buffer equilibrium).

England : Joint Matriculation Board (1968) Advanced Level

(Two papers(I and II) each of three hours and a practical examination consisting of one paper (III) of three hours will be set at Advanced Level).

Chemistry may not be offered at the same sitting of the examination as either physics-with-chemistry or general science I or II.

The examiner will assume that candidates possess a knowledge of the topics included in the Ordinary syllabus in Chemistry and also a knowledge of elementary physics and will be at liberty to set questions which involve such knowledge. The standard of the papers will be such as a candidate might reasonably be expected to attain in two years after reaching the Ordinary Level.

The principles and reactions involved in the syllabus for the practical examination may be tested in the written papers.

In all sections of the papers, questions will be set which test the candidate's knowledge of general principles and the examiners will assume that candidates are familiar with test-tube reactions.

Each paper will consist of three sections. In section (1) the questions will be mainly of a general and physico-chemical character ; in section (2) questions will be set on inorganic chemistry ; in section (3) questions will be set on organic chemistry.

Each section will contain five questions, two unstarred which will contain only "basic" material (i.e. excluding those "supplementary" topics which are shown in brackets below) and three starred which may contain material from both the basic and the supplementary parts of the syllabus. Candidates will be required to answer two questions, including at least one starred question, from each section. It will be possible for a candidate to satisfy the examiners on "basic" material alone.

1. Atomic theory, including a simple introduction to atomic structure ; atomic numbers ; stable isotopes. The periodic classification of the elements treated from the point of view of atomic structure.

(Nuclear reactions ; unstable nuclei ; radioactivity of light and heavy elements, all treated qualitatively. The history of the development of the present atomic theory ; Dalton, Gay-Lussac, Avogadro, Cannizzaro).

2. The empirical laws of chemical combination. Chemical equivalents and atomic weights and their determination. The concept of valency.

(The limitations of the law of constant competition : non-stoichiometric (non-Daltonian, Berthollide) compounds).

3. The means by which separate atoms unite to form individual molecules or three-dimensional structures as represented by the extreme types of :

   a) electron sharing, e.g. CCl_4 and diamond

   b) the co-ordinate or dative bond ;

   c) electron transfer, e.g. K^+Cl^-

(Intermediate types of bonding, e.g. in gaseous HCl ; the crystal structure of CsCl as compared with that of KCl).

4. A simple treatment of electrolytic dissociation. The complete dissociation of strong electrolytes : strong and weak acids and bases ; Ostwald's dilution law ; hydrogen ion concentration ; pH ; neutralisation ; choice of suitable indicators in acid and alkali titration. Salt hydrolysis treated qualitatively.

(The approximate relative sizes of a few simple atoms and ions. The effect of cationic size and valency on salt hydrolysis. Complex ions).

5. Metals in equilibrium with aqueous solutions of their ions ; the Electrochemical Series treated qualitatively.

(Electrode potentials as a quantitative expression of this series).

6. A simple treatment of oxidation-reduction processes in terms of electron-transfer and electron sharing.

(The comparison between the Electrochemical Series and Redox potentials of other systems).

7. The movement of ions in solution in an electric field and their discharge at electrodes. Ionic conductance treated qualitatively only. Faraday's laws of electrolysis : explanations of the reactions occurring at the electrodes during the electrolysis of aqueous solutions.

(Elementary quantitative treatment of specific and equivalent and molar conductances and their use for estimating degree of ionic dissociation).

8. Qualitative treatment of the kinetic theory of gases. Kinetic concepts of evaporation of liquids and solids and of the melting of solids. The effects of temperature and pressure on a gas, limited to the equation pv = RT. Thermal dissociation.

(Deviations of the behaviour of a gas from the equation pv = RT considered qualitatively. The role of attractive forces between neutral molecules (van der Waals) in the formation of liquids. Gaseous diffusion and Graham's law).

9. The determination of the molecular weight of a volatile liquid by the method of Victor Meyer.

(Molecular weight determination by the methods of Dumas and Regnault. The method of limiting density is not included).

10. Physical equilibria in two-phase and one or two component systems involving solid-liquid and liquid-vapour equilibria, and the effects of temperature and pressure.

(Numerical calculations will not be set). (The distribution of an unassociated, associated or dissociated solute between two immiscible solvents, including simple numerical examples).

11. Chemical equilibria in two-phase systems involving

   a) solubility products treated as an equilibrium between a sparingly soluble solid and its dissolved ions ;

   b) the dissociation of calcium carbonate and the action of steam and iron.

(The vapour pressure of water over salt hydrates in equilibrium at a constant temperature (the phase-rule treatment is excluded). Arithmetical problems may be set on solubility products).

12. Properties of solutions which are related to concentration ; vapour pressure, freezing-point, boiling-point, osmotic pressure. The concepts of volume concentration and molfraction. The determination of freezing-point depression, boiling-point elevation, vapour pressure lowering as methods of molecular weight determination in dilute solutions of simple non-volatile non-electrolyte solutions.

(Practical details will be required only for freezing-point depression and boiling-point elevation).

(The treatment should include molecular weight determination by these means of electrolytes and of associated and non-associated non-electrolytes. The colloidal state. Differences between colloidal dispersions and true solutions. Simple methods of preparing colloidal suspensions such as those of starch, gelatine, arsenious sulphide, ferric hydroxide).

13. (Elementary thermochemistry : heats of reaction, formation and neutralisation, Hess's Law of Constant Heat Summation. Heat changes associated with the process of solution are included. (Questions will not be set upon the experimental methods and, in view of varying practice, data given in Question will specify whether heat transferred is to be regarded as heat given out by the reaction (ΔH is negative) or as heat taken in (ΔH is positive).

14. The law of mass action. Reaction velocity ; the effects on the velocity of reaction of temperature and of concentration of reactants : simple qualitative kinetic interpretation of these effects. Catalysis.

15. Reversible reactions. Chemical equilibria and the effects of changes in temperature and pressure on the equilibrium position of a reversible reaction. (Qualitative treatment only).

(Simple quantitative examples of equilibria in homogeneous systems).

16. The chemistry of the elements, named below, based on the extended Periodic Table, copies of which will be provided for examination use.

The noble (inert) gases : isolation and structure

Hydrogen

Sodium : the properties of the metal ; the chemistry of its oxides, hydroxide, chloride, hypochlorite, chlorate, carbonate, bicarbonate sulphates, thiosulphates, sulphites, nitrate, nitrite.

(Sodium hydride, cyanide, amide. The comparison of sodium with other alkaline metals).

Magnesium and calcium : the properties of the metals ; the chemistry of their oxides, hydroxides, chlorides, carbonates, bicarbonates, sulphates; magnesium nitride.

(Calcium hydride, calcium cyanamide ; a comparison of the chemistry of magnesium with that of zinc and that of the alkaline earth metals).

Aluminium : the properties of the metal ; the chemistry of its oxide, hydroxide, chloride, sulphate; alums.

Carbon : its allotropic modifications ; the chemistry of carbon monoxide, carbon dioxide, carbonic acid and its salts.

(A comparison of the chemistry of carbon with that of silicon and lead ; carbon disulphide, carbon tetrachloride).

(Silica, silicic acid, simple silicates).

Nitrogen : ammonia and ammonium salts ; nitrous oxide, nitric oxide ; nitrogen dioxide ; dinitrogen tetroxide ; nitrous and nitric acids and their salts.

(Tin : its allotropic modifications ; the chemistry of its oxides, sulphides, chlorides).

(A comparison of the chemistry of nitrogen with that of phosphorus and arsenic).

Phosphorus : its allotropic modifications ; the chemistry of its trihydride, oxides, chlorides, orthophosphoric acid and its salts.

(Metaphosphoric acid, pyrophosphoric acid, and their salts).

Oxygen : water, hydrogen peroxide, ozone ; classification and general properties of oxides.

Sulphur : its allotropic modifications ; the chemistry of hydrogen sulphide and metal sulphides, sulphur dioxide, sulfur trioxide, sulphuric acid, sulphurous acid and their common salts.

(Sulphamic acid).

Chlorine, bromine, iodine : the chemistry of the elements and of their compounds with hydrogen, including the salts of the hydracids.

(The preparation of fluorine and the comparison of its chemistry with that of the other halogens).

(Iron and copper considered as typical transition elements ; the chemistry of their oxides, chlorides, sulphates).

17. General methods available for the production of the metals (e.g. chemical reactions and essential conditions) as exemplified by the following : sodium, magnesium, zinc, aluminium, iron, lead.

(The production of steel from cast iron).

18. The chemistry (i.e. chemical reactions and essential conditions but excluding details of any industrial plant) involved in the large-scale production of the following : hydrogen, producer gas, water gas, ammonia, hydrochloric acid, sulphuric acid, nitric acid, sodium hydroxide, sodium hydrogen carbonate, phosphorus, chlorine, bromine, iodine.

19. A knowledge of the reactions of the cations and anions as involved in quantitative and qualitative analysis and as specified in the syllabus for the practical examination.

20. (A simple consideration of the three-dimensional structure of crystalline solids in terms of molecular crystals (e.g. sulphur, naphthalene), macromolecular crystals (e.g. ice, diamond), ionic crystals (e.g. sodium chloride, magnesium oxide)).

21. Classical structure theory in organic chemistry. Principles underlying the determination of empirical molecular and structural formulae. Homologous series. Structural isomerism.

(Simple stereochemistry of carbon ; optical isomerism (lactic acid) and geometric isomerism (maleic and fumaric acids)).

22. The detection of the elements nitrogen, sulphur, chlorine, bromine, and iodine in organic compounds.

23. The processes of ether extraction, crystallisation, drying and distillation (including a simple qualitative treatment of steam distillation) as used in the purification of organic compounds. The determination of melting point and boiling point as tests of purity.

24. General methods of preparation and characteristic properties of simple paraffin hydrocarbons. Saturated compounds and substitution.

25. Organic chemistry as the chemistry of characteristic groups. The methods of introduction into a compound, the detection, the characteristic reactions and the variations of chemical behaviour of the following groups as shown by a study of the classes of compounds mentioned.

$-OH$ (monohydric alcohols, phenol, acids)

Halogen (alkyl, aryl and acyl halides)

$>C=O$ (aldehydes and ketones)

$-COOH$ (monocarboxylic acids ; esters)

$-NH_2 > NH > N-$ (primary, secondary and tertiary amines ; quaternary ammonium compounds ; amides).

$-CN$ (nitriles)

$>C=C<$, $-C\equiv C-$ (Olefins, acetylenes).

(The behaviour of characteristic groups in bifunctional compounds, illustrated by a simple consideration of vinyl compounds, hydroxy-acids, dicarboxylic acids and amino acids).

26. The properties of benzene and a very elementary consideration of its structure. Substitution reactions of the nucleus (halogenation, nitration, sulphonation) and the properties and transformations of the products. The chemical behaviour of the groups listed in paragraph 25 when in the nucleus or the side chain of aromatic compounds. (Di-substituted compounds and directive effects are not included).

    (The formation and reactions of simple diazonium compounds).

27. A knowledge or the essential experimental details of the laboratory preparation and purification of the following organic compounds will be required : ethyl bromide, ethyl benzoate, nitrobenzene, m-dinitrobenzene, aniline, acetanilide.

(Benzoyl chloride and benzamide ; the Hofman hypobromite reaction of acetamide ; glycine ; phenylazo - β - naphthol ; acetaldehyde (in aqueous solution)).

28. (Elementary indication of the nature of the following biological important materials : carbohydrates, fats, polypeptides, proteins urea).

29. (The simple structure of linear polymers ; illustrated by polythene, polyvinyl compounds, nylon, Terylene. (The mechanism of polymerisation is excluded)).

30. (Petroleum, coal tar and acetylene processes as large-scale sources of organic compounds. Fermentation processes).

Practical Examination (three hours)

Books and laboratory notebooks may be used during the Practical Examination. In all problems set in the Practical Examination sufficient working details will be given. If any problems are set which are not clearly within the limits defined by the practical syllabus, sufficient information will be given in the question paper to bring the problems within these limits.

1. Candidates will be required to be familiar with the use of the balance and to be able to prepare solutions of known concentration from materials provided. No restriction is placed on the type of balance used, whether the older free-swinging type with removable weights or the newer aperiodic types with built-in weights. The exercise set will always be such that, provided the weight of material measured out by the candidate is within ± 10 milligrammes of its true weight the answer to the exercise will not be displaced for this reason by an amount, which would lead to loss of marks.

Gravimetric analysis, that is the weighing of precipitates, is excluded from the practical syllabus.

A knowledge of the following volumetric processes will be required : the estimation of

a) strong and weak acids and alkalis,

b) ferrous iron, oxalic acid and oxalates by potassium permanganate,

c) iodine by sodium thiosulphate, and hence those oxidising agents capable of liberating iodine from potassium iodide,

d) halides in neutral solution by silver nitrate.

The weighing test and volumetric exercise may be extended by requiring candidates either to perform simple stated tests on the materials provided or to identify these materials. In such an event there will be a corresponding reduction in the requirements of the qualitative exercise.

2. Qualitative analysis of simple salts or mixture of salts containing in all not more than four radicals. The radicals included will be limited to the following :
Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Ba^{2+}, Cr^{3+}, Mn^{2+}, Fe^{2+}, Fe^{3+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Ag^{+}, Zn^{2+}, Cd^{2+}, Hg^{2+}, Hg_2^{2+}, Al^{3+}, Sn^{2+}, Sn^{4+}, Pb^{2+}, Sb^{3+}, Bi^{3+}, NH_4^{+}, S^{2-}, Cl^{-}, Br^{-}, I^{-}, CO_3^{2-}, NO_3^{-}, PO_4^{3-}, SO_3^{2-}, SO_4^{2-}.

Where mixtures are set they will not contain more than one metal in any given group as classified in standard analytical tables. For this purpose lead is to be taken as occurring both in Group I (Hydrochloric acid precipitations) and in Group II (Hydrogen sulphide precipitation). So called "phosphate separations" will not be required.

Joint Matriculation Board,
General Certificate of Education
Regulations and Syllabuses 1968

France : Classe de seconde

Water. Air. Oxygen. Hydrogen.

Structure of matter : atoms, molecules, ions, electrons.

Chemical notations : symbols, formulae, Avogadro's number. Representation of a chemical reaction by an equation.

Sodium chloride ; electrolyses : sodium and chloride ions ; electronic interpretation of the formation of ions from atoms ; standard electrode potentials.

Hydrochloric acid, hydrogen ion.

Sodium hydroxide, hydroxide ion.

Acids, bases.

Chlorine ; notion of oxidation-reduction.

Transformation of sulphur into sulphur dioxide and trioxide. Chemical properties of sulphuric acid ; sulphate ion.

Ammonia ; synthesis of ammonia as an example of reversibility and chemical equilibrium ; ammonia in solution, ammonium ion.

Chemical properties of nitric acid ; nitrate ion.

Allotropic varieties of carbon ; combustion of carbon. Carbon dioxide ; acidity of its solution, carbonate ion.

Classe de première (Section C - 1 hour + 1 hour practical)

Properties of methane and ethylene. Properties and preparation of acetylene. Knowledge of petrols and natural gases.

Properties of monoethylamine.

Properties of ethyl oxide.

Properties of acetamide. Properties of urea.

Properties of glycerol ; principle of its industrial preparation.

Properties of glucose.

Classe terminale (Section D - 1 hour + 1 1/2 hours practical).

Atoms and chemical notations

Structure of the atom ; nucleus, electrons. Composition of atomic nucleus ; number of charge and number of mass ; atomic number, isotopes. Atomic models.

Molecular bodies

The molecule. Covalency.

Physical laws relative to gases and diluted solutions concerning molar masses ; Avogadro-Ampere law. Determination of molecular weights by vapour density and freezing point methods.

Structure of some molecules (hydrogen, hydrogen chloride, carbon dioxide, water, ammonia, ethane, acetylene, benzene) ; and their application to organic reactions (e.g. substitution, addition, polymerisation).

Functional groups in organic chemistry ; the OH group as an alcoholic function, in esterification and in hydrolysis of esters.

Acids, bases, salts in water solutions

Ionisation of water ($H^+ \times OH^- =$ constant) ; definition of pH ; use of coloured indicators ; acid or base characteristic of saline solutions. (Any calculations concerning pH are strictly outside the syllabus ; the same goes for the study of neutralisation curves).

Oxidation/reduction

Electronic interpretation of oxidation/reduction limited to the following examples : reduction of a metallic ion and of the hydrogen ion by a metal, qualitative study of Daniell cell ; Hydroxyl ion ; permanganate ion in acid solution ; ferrous ion ; sulphur dioxide in water solution.

Source - Le second cycle long conduisant au baccalauréat.

Institut Pédagogique National, Paris, 1967.

Ireland :

Rules and Programme for Secondary Schools

Leaving Certificate

Pass Course

1. The properties of gases, liquids and solids ; elements compounds and mixtures.

2. Atomic theory : the structure of the atom, electrons, protons, neutrons, atomic number, isotopes.

3. Structure of simple molecules ; covalent, electrovalent and metallic bonds ; crystal structure as exemplified by the sodium chloride lattice ; electronegativity.

4. The structure and valence of elements as exemplified by the first twenty elements of the Periodic Table.

5. The Kinetic Theory of Gases : its use in explaining the Gas Laws, Diffusion. Application of the Gas Laws ; osmotic pressure and its application.

6. Determination of equivalent, atomic and molecular weights. Vapour density. Simple volumetric and gravimetric analysis. Formulae and equations.

7. a) Study of the following elements and compounds :

   Hydrogen , oxygen, water ;

   Nitrogen, ammonia, ammonium salts, nitrogen oxides, nitric acid, nitrates ;

Carbon, carbon dioxide, carbonates, hydrogen carbonates, carbon monoxide ;

Sulphur, hydrogen sulphide, sulphur dioxide, sulphurous acid, sulphur trioxide, sulphuric acid, sulphates ;

The halogens, halogen hydrides ;

Phosphorus, phosphorus oxides, phosphoric acids.

b) Study of the following elements and their more important compounds :

Sodium, potassium, copper, silver, magnesium, calcium, zinc, aluminium, lead, iron.

Suitable reference should be made to the Electrochemical Series and the Periodic Table in dealing with the above elements and compounds.

8. Study of the chemistry of methane, ethylene, acetylene, ethyl alcohol, acetaldehyde, acetic acid, benzene, nitrobenzene.

9. Heats of formation and heats of reaction.

10. Modern concepts of acid-base reactions, oxidation-reduction processes.

Honours Course

As for the Leaving Certificate Pass Course and in addition :

11. Concepts of energy levels, ionisation potential and electron affinity.

12. The shape of simple symmetrical molecules (organic and inorganic ; tetrahedral, planar and linear), reference to orbitals and hybridisation.

13. The Periodic Table in relation to Atomic Structure.

14. Study of the chemistry of methyl alcohol, ethylene (polymerisation of), chloroform, diethyl ether, glycerol, formaldehyde, formic acid, lactic acid (optical isomerism), fumaric and maleic acids (geometrical isomerism), ethyl acetate, acetone, glucose, cane sugar, aniline.

15. First Law of Thermodynamics.

16. The Law of Mass Action and electrolyte solutions ; strong and weak acids, hydrolysis of salts ; pH and indicators.

17. Oxidation and reduction as electron transfer. Oxidation number.

18. The study of the following reactions as examples of reaction mechanisms : chlorine and hydrogen, chlorine and methane, bromine and ethylene, sodium hydroxide and ethyl bromide. Catalysis.

19. Radioactive isotopes and their uses (elementary treatment only).

20. The identification of the ions of the chief salts of the metals in par. 7 (b) by micro or semi-micro methods. Volumetric analysis using silver nitrate, potassium permanganate.

(Rules and Programme for Secondary Schools. The Stationery Office, Dublin).

Luxembourg : 2nd Class (1 1/2 hours)

Nature of chemical phenomena. Mixtures and pure substances. Chemical elements. Stoichiometry and valency. Elements and compounds. Atomic and molecular structure. - Oxygen. - Chemical functions. - Hydrogen. Chlorine. Hydrogen chloride and hydrochloric acid. Sodium hydroxide. - Electrolytes. Ionisation - Electronic configuration of the atom. Periodic classification of elements. Electronic theory of the chemical bond. Sulphur. Hydrogen sulphide. Sulphurous and sulphuric acids. - Oxidation and reduction. Electronic interpretation of redox phenomena. Oxidation number. - Acid-base reactions. Concept of pH. - Nitrogen. Ammonia. Nitric acid. Chemical equilibrium. Influence of pressure and temperature on chemical equilibrium. Catalysts. Carbon monoxide and carbon dioxide. - Principles of metallurgy. Study of iron : natural state, properties, metallurgy.

Textbook : R. Faucher, Chemistry, Classe de Seconde CM et Classe de Première CM, Hatier, Paris, 1958.

Practical : (1 hour every fortnight for pupils in sous-sections latines B and C)

Work with glass. Current techniques in the chemistry laboratory : dissolution, crystallisation, precipitation, filtration, distillation. Natural water and de-ionised water. Properties and preparation of oxygen, chlorine, iodine. Hydrogen chloride and hydrochloric acid. Acidimetry and alkalimetry. Iodometric titrations, sulphur. Hydrogen sulphide. Sulphur dioxide. Sodium sulphite and thiosulphate. Ammonia. Nitric acid.

Students should write up reports when object of the work demands it.

1st Class (1 1/2 hours)

Oxidation. Outline of the principles of oxidising agents. Anodic oxidation. Reduction. Outline of the principles of oxidising agents. Cathodic reduction.

Atomic structure and chemical reactions. Chemical isotopes and elements. Ionic, covalent, semi-polar bonds. Secondary bonds.

Chemical properties of methane. Alkanes : nomenclature and isomerism. - Preparation and properties of acetylene. - Ethanol : preparation and chemical properties. Alcohol function. Ethanal : preparation and chemical properties. Carbohydrates. - Acetic acid : chemical properties. Carboxylic acid function. - Lipides : constitution, hydrolysis, saponification.

The syllabus includes the study of the following chapters : Classes de mathematiques et de sciences expérimentales, 15-18, 52-53, 77-80, 104-114, 120-128, 130-138, 140-149, 151-157, 161-162 bis, 174-177.

Textbook : Same as for 2nd Class.

Practical : (1 hour every fortnight for students in sous-sections latines B and C)

Hydrogen peroxide. Study of redox character of compounds of chromium and manganese. Manganimetric titrations. Experimental study of the electrochemical series of metals. Carbon monoxide and dioxide. Separation of a mixture by paper chromatography. Analysis by ion exchange. Alcoholic fermentation ; distillation and properties of ethanol. Acetic acid. Properties of glucose and starch. Characteristic reactions of lipides and proteins.

Students should write up reports when object of the work demands it.

Norway :

Chemistry syllabus (1)

(The Gymnas, Natural science branch)

Teaching plan and syllabus

Chemical change. Physical change. Mechanical mixtures. Chemical bonding. Affinity.

Atomic and molecular theory. Avogadro's hypothesis. Chemical symbolism. Valency. Equivalent weight. Chemical reaction schemes and chemical equations. Chemical calculation. Energy status during chemical processes. Thermochemical equations.

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(1) Taken from Undervisningsplaner for realskolen og gymnaset, 1964, Kj 5GN

The law of conservation of matter. The law of constant composition of chemical combinations. The law of multiple proportions.

The ionic hypothesis. Dissociation constant. Chemical bonding : ionic bonds, atomic bonds (covalent bonds). Complex ions. Dipoles.

Redox processes.

Electromotive series.

Reaction velocity. Chemical equilibrium. The law of mass action. Le Chatelier's principle. Catalysis.

The hydrogen ion concentration measured as pH. Buffer solutions. Theories of indicators. Solution products. Near-complete chemical reactions.

The structure of atoms. The periodic table. Radioactivity. Isotopes and their uses.

Mono- and multi-atomic gases. Mol-volume. Loschmidt's number. Measurement of molecular weight by several methods : specific weight, vapour volume, boiling-point elevation, freezing-point depression.

Osmotic pressures and osmotic laws. True solutions. Colloids. Solubility of gases.

Molarity and normality.

The following elements should be included : Hydrogen. Lithium, sodium, potassium, caesium. Magnesium, calcium, barium, and radium. Boron and aluminium.

Carbon, silicon, tin and lead. Nitrogen, phosphorus, and arsenic. Oxygen, sulphur, and selenium. Fluorine, chlorine, bromine, and iodine. The inert gases. Iron, cobalt, nickel, and platinum. Copper, silver, and gold. Zinc, cadmium, and mercury.

Chromium, molybdenum, wolfram, and uranium. Manganese.

Some of these elements need only be discussed briefly. The elements are here quoted according to their position in the Periodic Table. In teaching one has to divert somewhat from this order.

One should only include those chemical reactions and chemical compounds from inorganic chemistry which are of special interest for educational, practical, or theoretical reasons. As far as possible one should avoid matters which have little value apart from the mere memorising of them. Particular emphasis must be put on the treatment of acid, bases, salts, and redox-processes. The pupils must become familiar with the acid-base hypothesis of Bronstedt.

To be included are : a theoretical and practical course in titration analysis : acidimetry, alkalimetry, iodine titrations, manganese titration, and precipitation analysis. Also to be included : a theoretical and practical course in qualitative analysis. Here one will use a simplified analytical table.

The simplest main features in crystallography are to be included and brief attention is to be given to the most important properties used for the determination of crystals : shape, colour, lustre, hardness, streak, specific gravity. The pupils should get to know the commonest or most important minerals and rocks, e.g. those of importance to Norwegian industry.

From organic chemistry the following should be included : Petroleum, Coal-gas. The flame. Alcohols. Ethers. Aldehydes. Ketones. Carbonic acids. Esters. Lipids. Soap. Amino acids. Proteins. Alkaloids. Carbohydrates : glucose, lactose, sucrose, maltose, starch, glycogen, cellulose. Lactic acid.

Benzene. Aniline. Phenol. Benzoic acid. Salicylic acid. Tannic acid (tanning).Naphthalene. Anthracene.Turpentine.

The following should also be mentioned under organic chemistry ; isomerism, stereoisomerism, optically active and inactive compounds. Furthermore, the transformation of energy through chemical processes in nature, and the carbon, nitrogen, and phosphorus cycle in nature.

The necessary chemical background for the teaching of biological topics should also be given under organic chemistry : carbon dioxide-assimilation, fermentation, digestion, breathing and excretion.

Also to be included in organic chemistry : Nutrients, their chemistry and energy content. Vitamins. The food requirement. Protective foods. Drinking water.

From the chemical industry one should include : the nitrogen industry, the fabrication of coal-gas, pulp, cellulose, paper, synthetic silk, plastics, calcium carbide, carborundum, cement, iron and steel, aluminium, copper, zinc, cadmium, tar products. When treating the production of metals, the flotation process should be mentioned.

Aspects of the history of chemistry should be covered.

At the end of each of the three school years the pupils taking the natural sciences stream should have a practical laboratory examination. They shall then be tested in one of the practicals they have done previously. At the end of the last but one year one may choose the experiment from those done over the last two years. At the end of the final year the experiment for the common laboratory practical and examination test may be chosen from the forty-five practicals presented by the pupils. For the practical laboratory examination one does not always have to choose a practical identical to one of the practicals done by the pupils earlier. It may differ somewhat. This applies to titration and qualitative analysis (choice of chemical to be tested).

The practical laboratory examination must not take more than three periods, and there ought not to be more than fifteen pupils in the group. The teacher must feel free to make his own arrangement for this examination. The pupils work separately. During the practical, the pupils make notes as instructed initially, and - where appropriate - make the necessary calculations. On the basis of the written description, notes (and calculation), and the proficiency shown in laboratory work, the teacher gives a grade for the practical laboratory examination. This grade should be given much weight when the grade for the year or the predetermined grade is decided.

The total syllabus in chemistry must not be made longer than steady and thorough work facilitates.

Spain :

Outline

1. Atomic molecular theory.

2. States of matter.

3. Properties of solutions.

4. Structure of the atom.

5. Periodic classification of chemical elements.

6. Types of chemical bond.

7. Non-metallic chemical elements. Study of hydrogen, halogens, oxygen and nitrogen.

8. Metallic bond. Metallic chemical elements. Study of iron and aluminium.

9. Chemical equilibrium. Law of mass action .

10. Acid-base reactions.

11. Precipitation reactions.

12. Oxidation-reduction reactions.

13 More important catalytic reactions in industrial processes.

14. Nuclear reactions and atomic energy.

15. A study of bonding in carbon compounds.

16. Concept of isomerism.

17. Knowledge of organic functions with examples of different functions.

18. Chemistry of petroleum.

19. Principal natural organic products. Glucose, lipids and proteins.

20. Macromolecules.

Programme content

Lesson 1 - Atomic molecular theory

Homogenous and heterogeneous systems. Pure chemical substances. Elements and compounds. Symbols and formulae. Chemical reactions. General laws of chemical combination ; gravimetric and volumetric analysis ; atomic molecular theory. Atoms and molecules. Avogadro's law Avogadro number. Atomic and molecular weights. Gram atom and gram molecular weight. Molar volume. Concept of chemical valence. Chemical equivalence.

Lesson 2 - State of Matter

General properties of gases. Equation of state : variables and functions of state. Law of ideal gases. Normal conditions. Dependence of the volume of a gas on pressure ; dependence of volume of a gas on temperature. Scale of absolute temperatures. Kinetic theory of gases. Gaseous diffusion ; real diffusion. Real gases. Van der Waal's equation. Properties of solids and liquids. Crystalline state. Diffraction of X-rays by crystals. Fusion. Sublimation : vapour pressure of crystal hydrates. Properties of liquids. Evaporation and boiling ; kinetic interpretation. Vapour pressure of liquids. Viscosity. Vitreous state ; structural characteristics.

Lesson 3 - Properties of solutions

Solutions ; classes. Solution of solids, liquids ; forms of expressing concentration. Saturated solutions ; solubility curves. Super saturation. Kinetic theory of solution. Vapour pressure of solutions ; Raoult's law. Vapour density and freezing point methods. Osmosis and osmotic pressure. Colloidal state. Liquid solutions. Solutions of gases in liquids. Henry's law. Diffusion of gases. Dalton's law of Partial Pressures.

Lesson 4 - Structure of the atom

Electric charge in gases. Radioactive phenomena. Characteristics of the proton, neutron and electron. Structure of the atom according to Rutherford. Atomic nucleus. Atomic number. Moseley's law. Isotopes. Electronic structure of atoms. Atomic spectra. Formulation of the theory of Planck's numbers. Bohr's theory. Structure of the hydrogen atom. Distribution of electrons in energy levels. Pauli's principle.

Lesson 5 - Periodic classification of chemical elements

Electronic structure of chemical elements and situation in the Periodic Table. Relation of electronic structure and properties.

Lesson 6 - Types of chemical bond

Ionic bond. General properties of ionic compounds. Covalent bond. General properties of covalent compounds.

Lesson 7 - Non-metallic chemical elements

Hydrogen : isotopes. Properties. Halogens : variation of the properties in a group. Oxygen and nitrogen ; energy of dissociation and chemical behaviour.

Lesson 8 - Metallic bond. Metallic elements

Metallic bond and crystal structure of metals. General properties of metals. Metal alloys. Iron and aluminium. Metallurgy.

Lesson 9 - Chemical equilibrium. Law of Mass Action

Heat and work in chemical reactions. Velocity of reaction. Factors which influence velocity of reaction. Chemical equilibrium. Law of Mass Action. Influence of changes of temperature and pressure on equilibrium : Le Chatelier's Principle. Equilibria in heterogeneous systems. Electrolytic dissociation. Faraday's laws. Degree of dissociation.

Lesson 10 - Acid-base reactions

Acids. Strength of acids. Ionisation constant of water. Concentration of hydrogen and hydroxyl ions ; pH scale. Indicators. Hydrolysis. Volumetric analysis of acids and bases.

Lesson 11 - Precipitation reactions

Factors which influence the solubility of ionic compounds. Solubility product ; applications. Ionic change ; applications.

Lesson 12 - Oxidation-reduction reactions

Electric energy in chemical processes ; voltaic pile. Nernst theory of electrolytic solution pressures. Ionic reactions. Standard potentials. Determination of pH for measuring potentials. Accumulators.

Lesson 13 - The more important catalytic reactions in industrial processes

Production of water gas and producer gas. Sulphuric acid. Obtained by contact method ; properties. Ammonia : synthesis and properties ; applications. Nitric acid : synthesis and properties ; applications.

Lesson 14 - Nuclear reactions and atomic energy

Spontaneous disintegration. Radioactive isotopes. Russell-Soddy displacement law. Artificial disintegration. Nuclear stability. Bond energy of nuclear particles. Nuclear fission and fusion. Preparations and applications of radioactive isotopes.

Lesson 15 - A study of bonding in carbon compounds

Carbon bonds. Length and angle of bonds ; covalent radius. Representation of organic molecules ; molecule models.

Lesson 16 - Isomerism

Strucutral isomerism : chain and position varieties. Geometrical isomerism : cis-trans ; molecule assymetry ; optical isomerism.

Lesson 17 - Knowledge of organic functions with examples of different functions

Classes of functions. Homologous theory. Nomenclature in organic chemistry. Hydrocarbons ; distinct classes of hydrocarbons. Oil ; its uses. Place of oxygen and nitrogen in organic compounds.

Lesson 18 - Chemistry of Petroleum

Origin of petroleum. Composition of petroleum. Products of distillation of petroleum. Cracking : petroleum by-products.

Lesson 19 - Natural products

Glucose. Photosynthesis. Alcoholic fermentation. Muscular contraction. Lipids. Fats and soaps. Amino acids. Proteins.

Lesson 20 - Macromolecules

Plastics. Polymerisation reactions. Rubber. Silicones.

Turkey :

Chemistry

(in the Branch of Science in the Lycee)

1st Year (Three hours)

1. Definition of Chemistry

2. Matter (definition of matter and pure substances : physical and chemical characteristics of matter)

3. Physical and chemical changes in matter

4. Elements (definition of elements ; symbols of elements ; classification of elements ; physical and chemical characteristics of metals and metalloids)

5. Compounds

6. Mixtures

7. Comparison of compounds and mixtures

8. Energy, its conservation and conservation of matter, related laws

9. Oxygen (occurrence ; preparation : from analysis of potassium chlorate, from mercury oxide, electrolysis of water, from liquefaction of air ; brief information about catalisation ; physical and chemical characteristics of oxygen ; oxidation : fast oxidation, slow oxidation, burning, ignition, putrefy and decomposition against decomposition and rust ; use of oxygen)

10. Ozone (allotropy ; allotropic forms of oxygen ; occurrence of ozone ; preparation of ozone ; physical and chemical characteristics of and use of ozone)

11. Hydrogen (occurrence, preparation : from electrolysis of water, from effects of some metals on water, effect of hot coke on steam, from acids ; physical and chemical characteristics ; reduction ; use of)

12. Water (importance of water ; occurrence of water ; physical characteristics ; chemical characteristics ; consistency, effects of metals, electrolysis of water, effects on metal oxides, effects on metalloid oxides ; purification of water, characteristics of drinking water, distillation of water)

13. Analysis and synthesis

14. Solutions (definition of solutions, solvents ; solute suspension and emulsion ; types of solutions : dilute, concentrated, unsaturated, saturated, supersaturated solutions ; solubility, effect of heat and pressure ; facilitating of dissolution ; comparison between solutions and suspensions)

15. Crystals and brief information about crystallisation

16. Hydrogen peroxide (composition ; obtaining ; characteristics ; use) Atoms, molecules, formulae and chemical equations

17. Atomic theory of Dalton : (Law of Conservation of Mass ; rates of definite weights law ; Law of Definite Composition, Law of Multiple Proportions ; atom, atomic weight, molecular weight, formulae, valence, positive and negative valences, formula writing)

18. Equations (writing of equations ; balancing of equations ; types of chemical reactions)

19. Brief information about modern atomic theory

20. Ions - brief information about ions and electrolysis. Oxides acids, bases and salts.

21. Oxides (definition ; important oxides ; anhydrides, preparation of oxides ; naming of oxide)

22. Acids (definition ; characteristics ; preparation ; important acids ; naming of acids)

23. Bases (definition ; characteristics ; preparation ; important bases ; naming of bases)

24. Salts (definition ; preparation ; characteristics ; types of salts ; naming of salts).
Halogens : their general characteristics ; order of activities.

25. Chlorine (occurrence ; preparation through : salt acids and manganese dioxides, electrolysis of salt solution ; physical and chemical characteristics of chlorine ; its effect as a bleach use)

26. Hydrochloric acid (occurrence : obtaining through combination of chlorine and hydrogen, effect of sulphuric acid on salt ; obtaining physical and chemical characteristics, use ; important chlorates)

27. Bromide (characteristics ; use ; hydrogen bromide)

28. Iodine (characteristics ; use; hydrogen iodide)

29. Fluorine (characteristics ; use ; hydrogen fluoride)

30. Air (definition ; explanation of its composition ; importance ; liquid air)

31. Nitrogen (characteristics ; use)
Nitrogen compounds

32. Ammonia : occurrence ; preparation ; physical and chemical characteristics ; use

33. Nitrogen Oxides

a) Dinitrogen oxide

b) Nitrogen monoxide

c) Nitrogen dioxide

d) Dinitrogen trioxide

e) Dinitrogen pentoxide

34. Nitric acid : preparation ; physical and chemical characteristics ; use ; important nitrates

35. Nitrogen fixation : fixation of nitrogen by nature and man ; the cycle of nitrogen in nature

36. Phosphorus :

a) Occurrence, preparation

b) White and red phosphorus and characteristics

c) Use of ; match making ; match production in Turkey

d) Phosphoric acids and important phosphates

2nd Year (three hours)

<u>Sulphur and sulphur compounds</u>

1. Sulphur :

a) Occurrence

b) Preparation

c) Sulphur industry in Turkey

d) Allotropic forms

e) Physical and chemical characteristics

f) Use

2. Hydrogen sulphide :

   a) Occurrence

   b) Preparation

   c) Physical and chemical characteristics, use

3. Sulphur dioxide :

   a) Occurrence

   b) Preparation

   c) Physical and chemical characteristics

   d) Use

4. Sulphur trioxide :

   a) Preparation

   b) characteristics

5. Sulphuric acid :

   a) Preparation

   b) Sulphuric acid industry in Turkey, physical and chemical characteristics, use, important sulphates

6. Artificial dung (dung made by nitrates and phosphates)

7. Carbon :

   a) Importance

   b) Occurrence

   c) Allotropic forms

   d) Crystal carbons :

      1 - Diamond,
      2 - Graphite

   e) amorphous carbons ; coke, charcoal, bone charcoal, active charcoal, soot

8. Carbon oxides :

   a) Carbon dioxide, occurrence, source of carbon dioxide in the air, preparation, physical and chemical characteristics, the cycle of carbon in nature, use, carbon dioxide as an extinguisher, carbonic acid and major carbonates

   b) Carbon monoxide :

      1 - Occurrence
      2 - Physical, physiological and chemical characteristics
      3 - Comparison between carbon monoxide and carbon dioxide

9. Carbides :

   a) Calcium carbide ; preparation, characteristics, calcium cynamide

   b) Silicon carbide

   c) Carbon disulphide

10. Silcon dioxide :

   a) Characteristics

   b) Silicic acid and silicates

   c) Glass : characteristics, kinds, preparation

11. Metals :

   a) Comparison between metals and ametals

   b) order of activeness of metals

   c) mixture of metals and important mixtures

12. Alkali metals group :

13. Sodium :

   a) Characteristics

   b) Preparation

14. Sodium hydroxide :

   a) Preparation, sodium hydroxide production in Turkey, characteristics, use

15. Sodium carbonate, "soda" :

   a) Characteristics

   b) Preparation

   c) Use

16. Important sodium compounds :

   a) Sodium chloride, salt production and salt beds in Turkey

   b) Sodium nitrate

   c) Sodium bicarbonate

17. Potassium and its compounds

   Alkaline earth metals :

18. Calcium :

   a) Occurrence

b) Physical and chemical characteristics

c) Biological importance of calcium

19. Calcium compounds :

a) Calcium oxide "burning lime"

b) Calcium hydroxide "slaking lime"

c) Lime water

d) Milk of lime

e) Calcium carbonate

1 - Limestone
2 - Marble
3 - Chalk

f) Calcium chloride

g) Other calcium salts

1 - Calcium phosphate
2 - Calcium fluoride
3 - Calcium hypochlorite

20. Hardness of water and softening of water

21. Anhydrite and gypsum

22. Magnesium :

a) Occurrence

b) Physical and chemical characteristics

c) Magnesium compounds

Earth metals :

23. Aluminium and its compounds :

a) Occurrence

b) Preparation

c) Physical and chemical characteristics

d) Use

e) Mixtures

f) Thermite

g) Aluminium oxide

h) Aluminium hydroxide and aluminates

24. Earthenware :

a) Clay

b) Porcelain and faience

c) Rock, tile

d) Earthenware industry in Turkey

25. Cement :

a) Preparation of cement

b) Kinds of cement

c) Cement, mortar and concrete

d) Cement industry in Turkey

26. Iron :

a) Occurrence and ore of iron

b) Preparation and blast furnace

c) iron and steel industry in Turkey

d) Pig, grey and white pigs

e) Preparation of steel : Siemens Martin, Bessemer, Thomas & Electro steels

f) Alloyed steel : manganic steel, chromic steel, molybdenum and vanadium steel, alycium steel

g) Importance of iron and steel industry and life

27. Iron compounds :

a) Iron oxides

b) Ferric sulphate

c) Ferric chloride

d) Reduction and oxidation of iron compounds

28. Copper and its compounds :

a) Occurrence

b) Preparation

c) Copper industry in Turkey

d) Characteristics of copper

e) Mixtures of copper

1 - Bronze
2 - Brass

f) Use

g) Copper compounds :

1 - Oxides and hydroxides of copper
2 - Copper sulphate

29. Zinc and its compounds :

    a) Occurrence and preparation of zinc

    b) Zinc oxide and zinc hydroxide

    c) Use

30. Lead and its compounds :

    a) Occurrence and preparation

    b) Physical and chemical characteristics

    c) Use

    d) Oxides of lead

    e) Compounds of lead : lead sulphate, lead nitrate, lead acetate, lead carbonate, "ceruse", lead sulphur

31. Other metals :

    Arsenic, antimony, bismuth, nickel, cobalt, manganese, chromium, tin, mercury, silver, "principles of photography", gold and platinum, their characteristics and use.

32. Periodic system of elements and radioactivity

3rd Year (Three hours)

1. Fundamentals of organic chemistry

2. Organic elements and organic compounds, and their classification

    Aliphatic Hydrocarbons :

    Hydrocarbons and their classification :

3. Rubber :

    a) Natural rubber

    b) Synthetic rubber

    c) Importance and vulcanising of rubber

4. Combustibles :

    a) Definition of combustibles

    b) Solid combustibles

        1 - Natural combustibles : wood, turp lignite, coal, anthracite

        2 - Artificial combustibles : charcoal, semicoke, coke, briquette, combustibles industry in Turkey

c) Liquid combustibles :

1 - Natural combustibles : oil and derivative products
2 - Artificial combustibles : derivatives obtained from cracking, hydrogenation and catalysis

d) Gas combustibles :

1 - Natural combustibles : earth gases
2 - Artificial combustibles : gas, generator gas water gas, combines gas.

5. Flame :

a) Characteristic of flame

b) Colour of flame

c) Bunsen burner and zones of Bunsen flame

d) Parts of candle flame

6. Alcohols :

a) Methyl alcohol

b) Ethyl alcohol and alcoholic fermentation, spirits, preparation, alcohol industry in Turkey

c) Alcoholic liquor and liquor industry

d) Isomerism

e) Polyvalent alcohols

1 - Glycol
2 - Glycerin

7. Ether :

a) Preparation of ether

b) Vinyl ether : use and characteristics

8. Aldehydes and ketones :

a) Formaldehyde

b) Acetaldehyde

c) Acetone

Organic acids (alicyclic compounds) :

9. Univalent organic acids :

a) Formic acid

b) Acetic acid

c) Butyric acid, palmitic acid, stearic acid

10. Bivalent organic acids : oxalic acid

11. Univalent and polyvalent acids : :

    a) Carbonic acid
    b) Urea
    c) Lactic acid
    d) Optical activity and isomerism
    e) Malic acid
    f) Tartaric acid
    g) Citric acid

12. Esters :

    a) General information about esters
    b) Esters of organic acids : ethyl acetate, isoamylacetate, honeywax
    c) Ester of nitric acid : glycerine trinitrate, nitroglycerine, dynamite

13. Oils :

    a) Vegetable and animal oils
    b) Composition of oils
    c) Characteristics and feeding value of oils
    d) Margarines
    e) Waxes

14. Soap and soap industry in Turkey

15. Dry oils, oil paints and varnishes

16. Carbohydrates : general information about carbohydrates

17. Monosaccharides :

    a) Glucose
    b) Levulose

18. Disaccharides :

    a) Saccharose
    b) Sugar industry in Turkey
    c) Lactose
    d) Maltose
    e) Cellulose

19. Polysaccharides :

a) Starch :

1 - Characteristics
2 - Preparation
3 - Assimilation and uses
4 - Dextrin of starch
5 - Glycogen
6 - Feeding value of starch

b) Cellulose :

1 - Occurrence
2 - Preparation

c) Paper and paper industry in Turkey

d) Artificial materials obtained from cellulose :

1 - Cellulose trinitrate
2 - Celluloid
3 - Nitrolic
4 - Cellophane
5 - Cotton, thread
6 - Vulcanised fibre
7 - Artificial skin
8 - Cellon

e) Synthetic silk :

1 - Silk of cellulose nitrate
2 - Silk of cellulose acetate
3 - Silk of viscose

f) Synthetic silk industry in Turkey

g) Nylon

19. Polysaccharides :

20. Amino acids

21. Proteins

22. Aromatic hydrocarbons

23. Distillation of coal tar

24. Benzene, benzol :

a) Preparation

b) Characteristics and use

c) Benzene compounds

d) Other aromatic hydrocarbons :

1 - Toluene
2 - Xylene
3 - Naphthalene

25. Aromatic nitro and amino compounds

    a) Nitro benzene, trinitrotoluene

    b) Nitroaniline

26. Phenols : univalent phenols :

    a) Phenol

    b) Creosols

    c) Picric acid

    d) Bivalent and polyvalent phenols

27. Aromatic alcohols, aldehydes and acids :

    a) Benzyl alcohol

    b) Benzaldehyde

    c) Benzoic acid

    d) Salicylic acid

    e) Gallic acid

    f) Tannin and its use

28. Plastics :

    a) Phenol resin (bakelite)

    b) Casein resin (galatite)

    c) Urea resin

    d) Vinyl compounds

Note : All chemistry classes are held in the laboratory

APPENDIX IV

A TAXONOMY OF EDUCATIONAL OBJECTIVES IN CHEMISTRY

(Adapted from B.S. Bloom (ed.), Taxonomy of Educational Objectives - the Classification of Education Goals, Handbook I, Cognitive Domain, Longmans, Green and Co. Ltd., London 1956 (Reprinted 1964))

Abilities

1. Knowledge

The abilities tested in this category involve simple recall. The questions testing this ability must be presented to the pupil in a word form very similar to the one he has met before, and he therefore has only to recall the associated response to answer correctly.

1.1.1 Knowledge of chemical terminology

The language of the subject. Knowledge of the significance of symbols, terms and words.

1.1.2 Knowledge of specific facts

Knowledge of physical and chemical properties of common elements and their compounds.

1.2.1 Knowledge of conventions

Knowledge of the style and conventions used in scientific prose.

1.2.2 Knowledge of trends and sequences

1.2.3 Knowledge of classifications and categories

Knowledge of the classes and groups which are fundamental to chemistry.

1.2.4 Knowledge of criteria

Criteria of judgment. The methods used for the appraisal of techniques and their accuracy ; theories and their reliability.

1.2.5 Knowledge of methodology

Methodology includes both experimental procedure and ways of thinking. Knowledge of methods of enquiry, techniques and procedures. Emphasis on the candidate's knowledge of the method rather than his ability to use it.

1.3.1 Knowledge of principles and generalisations

1.3.2 Knowledge of theories and structures

The inter-relations of chemical principles and theories. Emphasis on a body of principles.

1.4 Knowledge of everyday applications of chemical experience

It is essential under this category to use familiar applications, for presenting the student with an unusual application will test his understanding in an entirely different way.

2. Manipulative skills

The abilities tested here involve the use of apparatus. The following is an attempt to define those manipulative skills which it is necessary and important to test, and which cannot be tested without apparatus.

2.1 Skill in using and reading the common tools of chemistry

Here the student would be required to read a preset instrument, e.g. thermometer, manometer, or to use an instrument for a measurement, e.g. weighing out a fixed quantity of material.

2.2 Skill in assessing the accuracy of a given piece of apparatus

Ability to be tested with the apparatus at hand.

2.3 Skill in making accurate observations

'Observations' here are mainly qualitative, e.g. the observations of changes during a chemical reaction.

2.4 Skill in assembling standard apparatus to perform a particular function

Ability to use common apparatus to carry out familiar processes, e.g. assembling apparatus for a fractional distillation.

2.5 Skill in adapting apparatus to a novel function

The ability to use common apparatus in new situations.

3. Comprehension

The abilities tested under this category are varied, but they have in common the handling of given information. No value judgements are called for, and the operations are fairly routine.

3.1 The ability to translate information from one form to another

A question in this category would ask a student to read a graph, and express its information in words, or vice versa. The rephrasing of an idea, and the ability to translate a problem into concrete or less abstract phraseology.

3.2 Ability to summarise a set of data, and to apply known laws and principles to a routine problem

3.3 Ability to understand contemporary commentaries on recent advances in chemical knowledge and thought

'Recent advances' is included to give a means of maintaining an up-to-date syllabus.

3.4. Ability to apply accepted knowledge to novel problems

4. Synthesis

This category involves the putting together of elements and parts to form a whole, and the manipulation of the several parts to construct a pattern not clearly present originally. Inevitably this must involve a piece of work which is essentially new to the student.

4.1 Ability to construct a plan with which to investigate a particular problem or question

4.2 Ability to construct a hypothesis or theory from a set of experimental data, and then to use it to make predictions

5. Evaluation

Abilities in this category call for value judgements. Judgements about the value of material and methods for given purposes. Quantitative and qualitative judgements about the extent to which material and methods satisfy criteria. Use of a standard of appraisal.

5.1 Ability to identify central issues, underlying assumptions, ambiguities, mistakes and misconceptions, and the relevant and irrelevant factors in a given communication

5.2 Ability to estimate the degree of uncertainty, ambiguity, error or emotive expression in a communication, and hence discriminate between two conflicting hypotheses

5.3 Ability to evaluate the relative claims of scientific considerations and other social or philosophical factors.

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