

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of
Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

THE EXPERIMENTAL BASIS OF CHEMISTRY

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of
Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

THE EXPERIMENTAL BASIS OF CHEMISTRY

SUGGESTIONS FOR A SERIES OF
EXPERIMENTS ILLUSTRATIVE OF
THE FUNDAMENTAL PRINCIPLES
OF CHEMISTRY

BY

IDA FREUND

SOMETIME STAFF LECTURER AND ASSOCIATE OF
NEWNHAM COLLEGE, CAMBRIDGE

EDITED BY

A. HUTCHINSON, M.A.

FELLOW OF PEMBROKE COLLEGE,
UNIVERSITY DEMONSTRATOR OF MINERALOGY

AND

M. BEATRICE THOMAS

LECTURER IN CHEMISTRY, GIRTON COLLEGE, CAMBRIDGE

CAMBRIDGE
AT THE UNIVERSITY PRESS
1920

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org

Information on this title: www.cambridge.org/9781107511552

© Cambridge University Press 1920

This publication is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First published 1920

First paperback edition 2015

A catalogue record for this publication is available from the British Library

ISBN 978-1-107-51155-2 Paperback

Cambridge University Press has no responsibility for the persistence or accuracy of URLs for external or third-party internet websites referred to in this publication, and does not guarantee that any content on such websites is, or will remain, accurate or appropriate.

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

PREFACE

IDA FREUND had been for many years before her death a naturalised British subject, but was Austrian by birth. Left an orphan while still quite young, she was brought up by her grandparents in Vienna, and received her early education at a Bürgerschule in that city. Afterwards she took the diploma of a State Training College for teachers, and the experience there gained in the study of continental methods broadened her outlook and was possibly the origin of the interest in the profession of teaching and sympathy with teachers which were to become marked characteristics of her later career. She then came to England to make her home with her uncle, the violinist Ludwig Straus, well known to music lovers as a member of the Joachim quartet. Her uncle sent her to Cambridge, where as a student of Girton College she took the complete honours course in Natural Sciences, and in 1886 was placed in the first class of the second part of the Natural Sciences Tripos for her knowledge of chemistry.

In the following year she began her life's work as a teacher at Newnham College where she laboured till her retirement in 1912. At that time women students were not admitted to the University Chemical Laboratory until they had passed Part I of the Tripos, and thus Miss Freund was entirely responsible for the laboratory training of the majority of her students, many of whom came up to College with little or no knowledge of chemistry.

Triumphing over disabilities due to physical infirmities and indifferent health such as would have daunted a less intrepid spirit, she devised and elaborated for her first year students a course of practical work supplemented by short lectures, demonstration experiments and discussions, and

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

these form the basis on which this book rests. In 1904 she published a considerable work entitled *The Study of Chemical Composition*, which carried her influence as a teacher far beyond the limits of her own laboratory. The orderly arrangement of the book, the fulness of its historical references, and the quotations often of considerable length from the original papers in which the fundamental laws of chemistry were enunciated and established by their discoverers give it permanent value as a students' "source book" of chemical theory, and secured for it a favourable reception. This encouraged Miss Freund to attempt to bring to the notice of other teachers her views as to the manner in which students might be helped to realise that chemistry is a science based on experiment and that the logical interpretation of experiment leads directly to the generalisations known as the laws of chemistry. Miss Freund had a dread of thoughtless experimenting and slipshod thinking. She felt strongly that much that passes for training in science has little relation to scientific method and is of small educational value. The scheme of practical work which she arranged for her students was designed to include not only the performance of many of the experiments usually found in an elementary course, but also the repetition in a simple form of experiments historically interesting and of fundamental importance to the theory of chemistry, and such that the manipulative difficulties involved were not too great to allow of the attainment of a reasonable degree of accuracy in the hands of beginners. By directing special attention to the sources of error inherent in the methods employed, by distinguishing carefully between what was taken for granted and what was really proved, and by getting her students to compare the accuracy attained in their illustrative experiments with that of the most trustworthy work on the subject, she was able to arouse the critical faculty and to give some insight into the methods and aims of the science. To quote her own words, "I aimed at giving by means of class teaching not only a common ground of knowledge, but also a common standard concerning the nature of scientific proof and the meaning of real accuracy

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)*Preface*

vii

to a number of students differing greatly in knowledge of chemical facts and manipulative experience. As was to be expected, I find that in order to make a connected and fairly proportioned book, gaps have to be filled in between the experiments, and a connecting story has to be supplied so as to make it clear where and how the experiments fit in to the fabric of the science and to establish a sequence ; as a matter of fact I have to write what I used to give in every demonstration as a half hour's introductory lecture. This connecting story has turned out very long in the chapters already written ...but I have got to feel convinced that this is a necessity, and even to think it possible that it may prove an advantage, raising the book above the scope of a mere laboratory manual."

After her retirement from active teaching she began to arrange the material collected in her laboratory note books and students' records with a view to describing a series of illustrative experiments such as she had found specially suited to her needs. The Syndics of the Cambridge University Press, the publishers of her first book, having expressed their willingness to bring out a second work from her pen, an agreement was signed in November 1913, and almost up to the time of her death, which followed an operation in May 1914, Miss Freund was busily engaged in preparing the manuscript for the Press. The book was planned to consist of twenty chapters; the first ten are those which appear here, the rest were to have dealt with the detailed study of water, oxygen and hydrogen, and with the consideration of acids, bases and the classification of oxides, and were to have included a discussion of the law of mass action, of oxidation and reduction and of the conditions which modify chemical change.

The first ten chapters were left by Miss Freund almost ready for the Press. They would have formed the larger part of the book and the part in which she was most interested, and are not only complete in themselves but also give a clear idea of her views and aims. Further they exhibit many and characteristic differences from the ordinary text book of experimental chemistry. For these reasons it was decided to

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

viii

Preface

proceed with the printing of this section, and to us as personal friends of Miss Freund of long standing, and well acquainted with her ideas, was entrusted the duty of seeing the book through the Press. As editors our task has been a light one; we have corrected a few obvious slips, made a few verbal changes, and here and there slightly altered the construction of a sentence, where we deemed that by so doing Miss Freund's meaning would be more clearly expressed. We have scrupulously refrained from making any omission, addition or alteration which should in any way conflict with or obscure her intentions. To Mr Peace, the University Printer, and to his staff, we desire to express our best thanks for the patient kindness with which they have endeavoured to carry out our views as to the way in which justice should be done to the somewhat complicated system of headings and sub-headings indicated in the manuscript, and for the care which they have devoted to the reproduction and arrangement of the diagrams.

All teachers worthy of the name strike out lines of their own and devise their own schemes, and it is unlikely that many will feel inclined to conduct their students through the whole of the work here detailed. But feeling as we do that Miss Freund's criticisms of methods still current are just and that many valuable suggestions are to be found in the following pages, we commend them to students and teachers alike, in the belief that much may be learnt by examining methods which have stood the test of practical experience in the laboratory of a teacher richly endowed with the critical faculty, keenly sensitive to fallacious reasoning, and quick to detect an unwarrantable assumption.

A. HUTCHINSON.
M. B. THOMAS.

August 1920.

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

TABLE OF CONTENTS

INTRODUCTORY

The figures in black type refer to pages

- I. Method of treatment indicated by title. 1. "Suggestions," 1. 2. Illustrative experiments, 2.
- II. Fundamental differences between students' illustrative experiments and research work, 9.
- III. Error of experimental measurements, 24. 1. Nature and evaluation of experimental error, 24. 2. Application of knowledge concerning magnitude of the experimental error to the theoretical interpretation of experimental results, 27. 3. Conditions which determine degree of accuracy to be aimed at in measurements, 35.
- APPENDIX. Determination of the density of a gas soluble in water, 41.

CHAPTER I

THE NATURE AND RECOGNITION OF CHEMICAL CHANGE

- I. Desirability of describing and circumscribing subject-matter of chemistry, 48. 1. Difficulties inherent in the classification of the sciences, 48. 2. Utility of classification, 49. 3. Place of chemistry in the scheme of classification of the sciences, 51.
- II. Nature of chemical change, 53. 1. Typical cases to show the existence of two kinds of change that substances can undergo, 53. 2. Current definitions which bring out the accepted division between physics and chemistry, 58.
- III. Criteria for the occurrence of a chemical change, 59. 1. Theoretical aspect of the problem, 59. 2. Practical work to be done in the solution of the problem, 62. 3. Examples of the manner of dealing with such problems, 65.
- IV. Historically interesting and debatable cases, 76. 1. Classical researches in which the point at issue was the establishment of the occurrence or non-occurrence of chemical change, 77. 2. Debatable cases, 78.

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

CHAPTER II

THE CLASSIFICATION OF SUBSTANCES INTO COMPLEX AND SIMPLE (ELEMENTS)

- I. The importance of quantitative methods, **82**.
- II. The study of the changes in weight which accompany chemical change, **83**.
- III. The results of the quantitative aspect of chemical change used for the purposes of classification, **103**.
- IV. The conception of 'element,' **103**.
- V. Criteria for recognising a substance as complex or elementary, **107**.
- VI. Classical researches in this province, **108**. 1. The isolation of elements from substances previously recognised as complex, **108**. 2. Recognition of the elementary nature of substances previously considered complex, **109**.

CHAPTER III

CLASSIFICATION OF COMPLEX SUBSTANCES INTO MIXTURES AND COMPOUNDS

- I. Recognition of the characteristics of the two types of complex substances, **111**. 1. Method of obtaining the data used in the subdivision of complex substances, **112**. 2. Use of the data obtained to subdivide complex substances into mixtures and compounds, **121**.
- II. Method followed and practical work required in recognising an unknown substance as a mixture or a compound, **123**.
- III. Classical researches undertaken with the object of recognising whether a special substance is a mixture or a pure substance, **132**. 1. The resolution of didymium, **132**. 2. The discovery of neon, krypton and xenon, **133**. 3. Establishment of the homogeneous nature of helium, **136**. 4. Establishment of the homogeneous nature of tellurium, **137**.
- IV. Recent developments in the technique of the purification of gases, **139**.

CHAPTER IV

THE PART WHICH AIR PLAYS IN COMBUSTION

- I. Historical, **142**. 1. Sequence in the discovery and the establishment of facts, **143**. 2. Explanations of the cause and nature of combustion, **146**. 3. Lavoisier's work, **149**.
- II. The various phenomena observed in the study of combustion, illustrated by the special case of (1) phosphorus, (2) iron, **151**. 1. Certain substances when heated in air are permanently changed, giving rise to new kinds of matter, **152**. 2. The so-called 'burnt substance'

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)*Contents*

xi

- weighs more than the original substance, 155. 3. The effects obtained in 1 and 2 require the presence of air, 156. 4. The increase in the weight of the substance burnt is equal to the decrease in the weight of the air participating in the reaction, 157. 5. The air decreases in volume, and does so to the same extent for (1) phosphorus and (2) iron, 163. 6. The residual gas obtained in 5 is inactive towards both the solids experimented with, 166. 7. The properties of the gases left after the action on moist air of (1) phosphorus, (2) iron are the same, but differ from those of the original air, 168. 8. The increase in the weight of the burnt substance and the decrease in weight and volume of the air are due to the combination of the burning substance with a constituent of the air; air is made up of two constituents, one of which is Priestley's 'dephlogisticated air' (Scheele's 'fire-air,' our oxygen), and the other the gas whose properties have been investigated under 7, 175.
- III. Interpretation of the various phenomena observed in the study of combustion and illustrated by the experiments dealt with in the preceding section, 177.
- APPENDIX. Gaseous density: what it is and how it is measured, 184.

CHAPTER V

THE CONSERVATION OF MASS

- I. Historical, 192. 1. Indestructibility of matter assumed axiomatically from the earliest times, 192. 2. The indestructibility of matter becomes a scientific principle, 194.
- II. The experimental basis of the law, and its accuracy, 195. 1. The correct results of analyses making use of equations based on this principle, 195. 2. The results of complete syntheses and analyses, in which C , the actually determined weight of the compound, is compared with $(A + B)$, the sum of the actually determined weights of the constituents, 197. 3. Experiments specially devised and intended to test the accuracy of the law of conservation of mass, 202.
- III. Students' Illustrative Experiments, 206. 1. A reaction is made to occur in a closed system which is weighed before and after, 206. 2. Measurement of the loss of weight in one part and the gain in weight in another part of a system within which a reaction occurs, 210. 3. Complete syntheses of silver sulphide and silver iodide, 217.

CHAPTER VI

THE LAW OF FIXED RATIOS

- I. Nature and Scope of the Law, 225.
- II. Historical, 227.
- III. Establishment of the Law as exact, 230.

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

- IV. Students' Illustrative Experiments, **233**. 1. The combining ratios of substances interacting in solution are independent of the concentration, **233**. 2. The composition of substances is independent of the mode of preparation (material used and physical conditions), **235**. 3. The composition of the compound is independent of the relative amounts of the constituents present at its formation, **245**. 4. The composition of substances is independent of the differences in the conditions operative in their natural and artificial formation, **249**.

CHAPTER VII

THE LAW OF MULTIPLE RATIOS

- I. Nature and Scope of the Law, **253**. 1. Existence of more than one compound of the same constituents *A* and *B*, and characteristics of such substances *C*₁, *C*₂, *C*₃, **253**. 2. Simple numerical relation between, $\frac{A_1}{100 - A_1}$, $\frac{A_2}{100 - A_2}$, $\frac{A_3}{100 - A_3}$, the ratios of the same constituents *A* and *B* present in the different compounds *C*₁, *C*₂, *C*₃, **267**.
- II. Historical, **268**. 1. Dalton, **268**. 2. Wollaston, **269**. 3. Berzelius, **269**.
- III. Classification of the Law as exact, **271**.
- IV. Students' Illustrative Experiments, **272**.

CHAPTER VIII

THE LAW OF PERMANENT RATIOS

- I. Nature and Scope of the Law, **284**.
- II. Historical: discovery and establishment of the law, **288**. 1. Cavendish, **288**. 2. Richter, **289**. 3. Berzelius, **292**.
- III. Deductive application of Richter's Law, **294**. 1. Cavendish, **294**. 2. Richter, **294**. 3. Berzelius, **295**.
- IV. Is the Law exact? **295**.
- V. Students' Illustrative Experiments, **299**. 1. To show that the quantities *A* and *B* equivalent in one reaction are so in all reactions, **299**. 2. To show that the ratio *A* : *B* is the same in the binary compound *AB* as in the ternary compound *ABC*, **309**. 3. To show that the ratio *A* : *B* is the same in the combinations *AC*, *BC*, and *AB*, i.e. that the quantities of *A* and *B* which are equivalent in the power of combination with a third substance *C* are also the quantities which will combine together and vice versa, **309**.

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)*Contents*

xiii

CHAPTER IX

COMBINING OR EQUIVALENT WEIGHTS

- I. The conception of the Combining Weight, **314**.
- II. Consideration of the general formula $mA + nB + pC + qD + \dots$, which represents the quantitative composition of any compound M , **315**.
 1. Choice of a standard, **315**. 2. Direct and indirect reference to the standard, **316**. 3. Operation of the Law of Multiple Ratios, **318**.
- III. Symbolic Notation, **318**.
- IV. The experimental determination of the Combining or Equivalent Weight, and the choice of the Atomic Weight, **324**.
 1. Selection of the Atomic Weight, **326**. 2. The experimental determination of the Combining Weight, **328**. 3. The fundamental ratios, **336**.
- V. Students' Illustrative Experiments, **340**.
 1. Utilisation for the purpose of combining weight measurements of data primarily obtained with a different object in view, **340**. 2. Provision of additional data for the purpose of combining weight measurements by means of experiments done with this definite object, **348**.

APPENDIX. The relation between the Combining Weight and the Atomic Weight, **360**.

CHAPTER X

THE LAW OF COMBINING VOLUMES

- I. Historical, **380**.
 - II. Nature and Scope of the Law, **381**.
 - III. Experimental basis and verification of the law, **382**.
 - IV. Is the Law exact? **384**.
 - V. Application of the Law, **384**.
 - VI. Students' Illustrative Experiments, **386**.
 1. Water, **386**. 2. Carbon dioxide. 3. Methane. 4. Hydrogen Chloride, **389**. 5. Ammonia, **395**.
- INDEX, **403**.

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

LIST OF EXPERIMENTS

- I. Determination of experimental error in measuring vessels, **38**.
- II. Investigation of effect of heat on (i) platinum, (ii) zinc oxide, (iii) lead nitrate or manganese carbonate, (iv) copper-calcium acetate or lead-potassium iodide, **53**.
- III. Investigation of effect of heat on (i) magnesium, (ii) iron, (iii) cuprous oxide, **54**.
- IV. Investigation of effect on iodine of (i) carbon bisulphide, (ii) a solution of ammonium sulphite, **56**.
- V. Investigation of effect of heat on ammonium chloride, **65**.
- VI. Investigation of effect of heat on calcium nitrate, **70**.
- VII. Investigation of effect on iron of (i) a magnet, (ii) dilute sulphuric acid, **75**.
- VIII. The heating in air of (i) iron, (ii) magnesium, (iii) copper, **86**.
- IX. The action of heat on potassium chlorate and perchlorate, **90**.
- X. The action of silver on nitric acid followed by that of hydrochloric acid, **96**.
- XI. The comparative study of (i) iron, (ii) sulphur, (iii) iron and sulphur intimately mixed, (iv) iron and sulphur intimately mixed and heated, **112**.
- XII. The comparative study of (i) oxygen, (ii) sulphurous anhydride, (iii) a mixture of these two gases, (iv) the same mixture after it has been passed over platinised asbestos and collected in a vessel surrounded by a freezing mixture, **114**.
- XIII. The action of bromine on different types of organic compounds, **124**.
- XIV. The differential decomposition of nitrates by means of heat, **129**.
- XV. Fractional distillation and fractional crystallisation, **129**.
- XVI. The burning of phosphorus in air, **154**.
- XVII. To show that burnt phosphorus weighs more than the original substance, **156**.
- XVIII. Investigation of change in weight produced in iron when heated (i) *in vacuo*, (ii) in air, **157**.
- XIX. The burning of phosphorus in a closed flask, **160**.
- XX. Measurement of volume change produced in air by (i) the smouldering of phosphorus, (ii) the rusting of iron, **163**.

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)*List of Experiments*

xv

- XXI. Measurement of volume change produced by iron on the gas remaining after the burning of phosphorus in air, and of volume change produced by phosphorus on the gas remaining after the rusting of iron in air, **168**.
- XXII. Examination of the properties of (a) air and (b) the gases residual after the action on air of (1) phosphorus, (2) iron, **169**.
- XXIII. The preparation of oxygen from air by the use of litharge, **177**.
- XXIV. Investigation of change of weight produced when solutions interact in a closed system, **207**.
- XXV. The action of hydrochloric acid on marble and the absorption of the gas formed, **210**.
- XXVI. The complete synthesis of silver iodide, **217**.
- XXVII. The synthesis and various modes of decomposition of mercury bromide, **226**.
- XXVIII. To show that when a neutral salt is produced, the ratio of the weights acid : alkali is independent of the concentration of the solutions used, **233**.
- XXIX. The gravimetric synthesis of silver chloride, **235**.
- XXX. To find the ratio between the weight of potassium chloride and of silver nitrate required for the complete precipitation of the chloride. Preparation of materials required, **238**.
- XXXI. Continuation of the previous experiment, **241**.
- XXXII. To find the volume of gaseous hydrogen combining with 1 of oxygen in the formation of water, **245**.
- XXXIII. Determination of the weight of calcium carbonate obtained by precipitating a solution of a known weight of Iceland spar with ammonium carbonate, **249**.
- XXXIV. Synthesis of the two iodides of mercury, **254**.
- XXXV. Synthesis of the two chlorides of copper, **254**.
- XXXVI. Synthesis of carbon dioxide from carbon monoxide and oxygen, **256**.
- XXXVII. Analysis of the two carbonates of potassium, **261**.
- XXXVIII. Analysis of the two sulphates of potassium, **263**.
- XXXIX. The relationship between potassium chlorate and potassium perchlorate, **263**.
- XL. Determination of the ratio between the quantities of carbon dioxide combined with the same weight of potash in the two carbonates of potassium, **272**.
- XLI. Determination of the ratio between the quantities of potash combined with the same amount of oxalic acid in the three oxalates of potassium, **277**.

Cambridge University Press

978-1-107-51155-2 - The Experimental Basis of Chemistry: Suggestions for a Series of Experiments Illustrative of the Fundamental Principles of Chemistry

A. Hutchinson and M. Beatrice Thomas

Frontmatter

[More information](#)

List of Experiments

- XLII. Determination of the ratio between the weights of copper combined with the same amount of chlorine in the two chlorides of copper, **280**.
- XLIII. Preparation and properties of some simple compounds of lead and silver, **285**.
- XLIV. Comparison of the ratio between the weights of sulphuric and hydrochloric acids which neutralise equal amounts of different alkalis, **299**.
- XLV. To find the quantities of hydrogen expelled by 1 gram of magnesium from (i) hydrochloric acid, (ii) sulphuric acid, **303**.
- XLVI. To find the ratio between the weight of metal combining with unit weight of oxygen and that evolving unit weight of hydrogen for (a) magnesium, (b) zinc, (c) tin, **309**.
- XLVII. Oxidation of lead sulphide to lead sulphate, **309**.
- XLVIII. Determination of the volumetric combining ratios for the substances marsh gas, carbon dioxide, and water, **309**.
- XLIX. Determination of the ratio hydrogen chloride : silver chloride, **353**.
 - L. To find the combining weight of calcium from the determination of the ratio calcium carbonate : carbonic acid anhydride, **356**.
 - LI. To find the combining weight of nitrogen from the determination of the ratio potassium nitrate : nitric anhydride, **358**.
 - LII. To find the volume of hydrogen liberated from a known volume of dry hydrogen chloride, **389**.
 - LIII. To find the volume of nitrogen liberated from excess of ammonia by a known volume of chlorine, **396**.