CIHM Microfiche Series (Monographs)

ICMH Collection de microfiches (monographies)

> Th Ce



Canadian Institute for Historical Microreproductions / Institut canadien de microreproductions historiques



Technical and Bibliographic Notes / Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

oriques

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sent peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

	12X	16X		20×	-	24X	287		
				1					
10×	14X		18X		22 X	26 X		30 x	
Ce docum	ent est filmé au taux	de réduction	iecked belo 1 indiqué ci	w/ -dessous.					•
This item i	is filmed at the redu	stion setion 1	and the state						
Com	mentaires suppléme	intaires:							
	itional commenter/						1 uo io ii		
						Générique (pério	diques) de la li	vraison	
pas	ete filmees.					Matthead			
mais	s, lorsque cela était ;	possible, ces p	bages n'ont		L	Titre de départ d	e la livraison		
lors	d'une restauration a	pparaissent d	lans le texte	a,		Caption of issue	,		
ll se	peut que certaines	pages blanche	s ajoutées		L	Page de titre de l	a livraison		
with	in the text. Whene	ver possible, 1	these have			Title page of issu	ie/		
Blar	k leaves added duri	ng restoration	n may appe	ar			ere provient:		
						Le titre de l'en-	aken from:/		
La r dist	orsion le long de la s	iuser de l'omi marge intérier	bre ou de la ure			Tiele or too t			
alor	ng interior margin/				L	Comprend un (d	es) index		
Tigh	ht binding may caus	e shadows or	distortion			Includes index(e	s)/		
nei	e evec u autres doci	anten 15			L	Pagination conti	nue		
Bou	ind with other mate	rial/				Continuous pagi	nation/		
							e i mpression		
Plar	nches et/ou illustrati	ions en coulei	ur			Qualité inécale c	varies/ le l'impression		
Col	oured plates and/or	illustrations/			· · · · ·	Duality of asta	united (
End End	cre de couleur (i.e. a	utre que bleu	e ou noire)		V	Transparence			
V Col	oured ink (i.e. other	than blue or	black)/			Showthrough/			
						LI Tayes Getachees			
Car	tes sécoraphiques el	n couleur				Pages detached/			
Le	titre de couverture i	manque			V	Pages décolorée	s, tachetées ou	piquées	
Con	ver title missing/					Pages discolour	e A ro benista be	aved/	
	uverture restauree en	t/ou penicule	e		L	Pages restaurées	et/ou palliculi	es	
Co	vers restored and/or	laminated/				Pages restored a	nd/or laminate	d/	
						- · ages endomma	ideez		
Co	uverture endommag	ée				Pages damaged/	néer		
	vore domanad/								
	uverture de couleur					Pages de couleu	, Ir		
Co	loured covers/						,		

The copy filmed here has been reproduced thanks to the generosity of:

National Library of Canada

The images appearing here are the best quality possible considering the condition and legibility of the original copy and in keeping with the filming contract specifications.

Original copies in printed paper covers are filmed beginning with the front cover and ending on the last page with a printed or illustrated impression, or the back cover when appropriate. All other original copies are filmed beginning on the first page with a printed or illustrated impression, and ending on the last page with a printed or illustrated impression.

The last recorded frame on each microfiche shall contain the symbol → (meaning "CON-TINUED"), or the symbol ▼ (meaning "END"), whichever applies.

Maps, plates, charts, etc., may be filmed at different reduction ratios. Those too large to be entirely included in one exposure are filmed beginning in the upper left hand corner, left to right and top to bottom, as many frames as required. The following diagrams illustrate the method: L'exemplaire filmé fut reproduit grâce à la générosité de:

Bibliothèque nationale du Canada

Les images suivantes ont été reproduites avec le plus grand soin, compte tenu de la condition et de la netteté de l'exemplaire filmé, et en conformité avec les conditions du contrat de filmage.

Les exemplaires originaux dont la couverture en papier est imprimée sont filmés en commençant par le premier plat et en terminant soit par la dernière page qui comporte une empreinte d'impression ou d'illustration, soit par le second plat, selon le cas. Tous les autres exemplaires originaux sont filmés en commençant par la première page qui comporte une empreinte d'impression ou d'illustration et en terminant par la dernière page qui comporte une telle empreinte.

Un des symboles suivants apparaîtra sur la dernière image de chaque microfiche, selon le cas: le symbole → signifie "A SUIVRE", le symbole ▼ signifie "FIN".

Les cartes, planches, tableaux, etc., peuvent être filmés à des taux de réduction différents. Lorsque le document est trop grand pour être reproduit en un seul cliché, il est filmé à partir de l'angle supérieur gauche, de gauche à droite, et de haut en bes, en prenant le nombre d'images nécessaire. Les diagrammes suivants illustrent la méthode.





1	2	3
4	5	6

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPL IMAGE IED Inc

1653 Eost Moin Street Rochester, New York 14609 USA (716) 482 - 0300 - Phone (716) 288 - 5989 - Fax



Lopy deposited h-11940.



A HAND-BOOK FOR

TEACHERS OF CHEMISTRY

IN

SECONDARY SCHOOLS

BY

J. A. GIFFIN, B.A., LL.B.,

COLLEGIATE INSTITUTE, ST. CATHARINES, ONT.

TORONTO WILLIAM BRIGGS 1900

QI41 : G5

Entered according to Act of the Parliament of Canada, in the year one thousand nine bundred, by JAMES A. GIFFIN, at the Department of

> ŝ ŧ t] I r

PREFACE

This little book has been prepared for the use of teachers of Chemistry in our secondary schools, in the hope that it may be helpful in presenting a difficult subject. It is a cause for regret that many teachers are obliged to give instruction in Chemistry with very limited apparatus, and, what is even worse, to perform experiments in laboratories which are not properly equipped with draft cupboards. To add to these difficulties, text-books often give very imperfect directions for performing many important experiments, and if those experiments are attempted by large classes, as directed in the text-books, they become a source of danger to the health of both students and teachers. This is particularly the case in studying the properties of gases. We cannot hope for a remedy for this state of affairs until we have more stringent school regulations in regard to general health, as school boards are very often unwilling to supply even the most necessary, to say nothing of efficient, appliances for teaching the subject. It is to aid in overcoming these difficulties by means of inexpensive apparatus, that these hints and suggestions are submitted for the consideration of Science teachers.

The methods employed, and the experiments and modifica-

3

, in the year one he Department of

PREFACE.

tions of experiments, are for the most part original. introduction to the chemical equation is based on the recommendation of one of our foremost teachers of Chemistry, that in teaching the science the principles should be introduced as early as possible. But the plan of teaching the equation, and the method of handling noxious gases in the laboratory by large classes, and the method of gas analysis, are entirely This is also true of the modifications of experiments, except where otherwise stated. It might be added, however, that the plan of handling noxious gases is based on a method which is sometimes used in qualitative analysis. All except two of the experiments to illustrate the Law of Definite Proportions, and many of the suggestions in the chapter of General Hints, are collected from various sources. tion on Graphic Formulæ is taken from Bailey's "Tutorial The sec-Chemistry."

I may not have presented the best way of performing these experiments in every case, but if this little book proves helpful to any of my fellow-teachers in overcoming their difficulties, or if it should induce others to present their plans of work for the consideration of their fellow-teachers, I will feel amply repaid for the time spent in working out the details of the methods and of the experiments which have proved so successful in my own classes.

ST. CATHARINES,

J. A. GIFFIN.

October 4th, 1900.

iv

CONTENTS.

CHAPTER I.

THE CHEMICAL EQUATION : HOW TO TEACH IT.

										PAGE
§ 1.	Introductory Work	•								7
§ 2.	Some Experiments to	Illus	strate	the	Law	\mathbf{of}	Defini	te 1	Pro-	
	portions .		•	•	•					11
§ 3.	How to Represent Mo	leculo	es and	l the	ir Ro	act	ions uj	pon	one	
	another		•	•			•			16
§ 4.	The Formulæ of Compo	mids	•		•		•			2 0
§ 5.	The Place of Mendeleje	ff's C	las	icatio	m		•			22
§ 6.	Valence	•								24
§ 7.	An Explanation of the	Law	s of 1	Multi	ple P	rop	ortion	s, D	efi-	
	nite Proportions an	d Av	ogadı	o's L	aw					27
§ 8.	Molecular Volume and	Atom	ie W	eight						31
§ 9.	What is an Element ?									34
§ 10.	The Chemical Equation									36
§ 11.	Graphic Formule									40

CHAPTER II.

NOXIOUS GASES : HOW TO HANDLE THEM.

§ 1. Sulphuretted Hydrogen in Qualitative Analysis .		43
§ 2. Nitrogen Monoxide		45
§ 3. Nitrie Oxide, Carbon Dioxide, Olefiant Gas, etc		46
§ 4. Carbon Monoxide when prepared from Oxalic Acid		47
§ 5. Chlorine : Its Preparation and Properties		48
§ 6. Hydrogen Sulphide : Its Preparation and Properties		50
§ 7. Sulphur Dioxide: Its Properties		52
•		-

ost part original. The is based on the recomhers of Chemistry, that should be introduced teaching the equation, ases in the laboratory analysis, are entirely tions of experiments, t be added, however, s based on a method nalysis. All except e Law of Definite s in the chapter of sources. The sec-Bailey's "Tutorial

ay of performing little book proves overcoming their 'esent their plans v-teachers, I will 'orking out the nts which have

4. GIFFIN.

CONTENTS.

Ð

66

74

CHAPTER III.

HINTS ON APPARATUS.

Simple Apparatus to Illustrate the tar			
§ 1. Combustion			PAGE
§ 2. How to Fill the Eudiometer			54
§ 3. The Decomposition of Water and Hud	•		56
§ 4. Boyle's Law			58
§ 5. The Law of Charles	•		60
§ 6. The Percentage of Oxygen in Air	•		62
7. The Diffusion of Liquids and Gases	•	•	63
8. The Solubility of Air and Ammonia Gas in W	•	•	64
and the transmit water			65

CHAPTER IV.

GAS ANALYSIS.

A New and Simple Method .

ş

81 M

CHAPTER V.

GENERAL HINTS.

S 1.	Many General Suggestions						
§ 2.	Cements	•	٠	•	•		72
§ 3.	How to Remove Stains	•	•	•	•		73
	short frams						

vi

C

TUS.

I.

•	•	•	•		54
•	•	•			56
troe	hlorie	Acid	•		58
•	·	·	•		60
·	·	•	•	•	62
•	•	•	•	•	63
÷.,		•	•		64
is in	Wate	r			65

PAGE

66

72

73

74

A HAND-BOOK OF CHEMISTRY.

CHAPTER I.

THE CHEMICAL EQUATION : HOW TO TEACH IT.

§1. INTRODUCTORY WORK.

A TEACHER of Elementary Chemistry finds many difficulties in his work, and one of the greatest he encounters is in teaching junior students to write a chemical equation, and to have a proper understanding of what it denotes. The reason for this is quite apparent. To successfully express a chemical fact it is necessary to have a comprehensive idea of the theory of the constitution of matter, without which a beginner will not make much progress in his work.

Among the many plans suggested for teaching equations, by writers of text-books, none are satisfactory. The introductory work is not always arranged in logical order, nor with a view to giving the student a clear conception of the atomic theory. Many points are omitted which give considerable trouble, and the teacher is left to work out his own plan to overcome these difficulties. It may be argued that this is not within the province of an elementary text-book, but surely anything which will aid the student in getting a better grasp of the subject should have a place in such a work.

One important reason why the beginner has so much diffi-

culty in writing an equation is because he does not use the gift of imagination, nor does the teacher always encourage him in its use. By imagination is not meant mere fancy, which creates unreal and impossible images, but the power of making pictures to the mind of that which exists, though it is invisible to us. It is well known, for example, that oxygen and hydrogen combine to form water, and that this may be expressed by an equation. But it is better still to have a mental picture of the atems clasping each other, and combining so as to form a new substance, and to feel how wonderful are the forces which bring about such a change. "No one loves dry facts; we must clothe them with real meaning and love the truths they tell, if we wish to enjoy science." If we as teachers fail in using this gift, it is not astonishing that our students look upon chemistry as drudgery, and study it because they find it necessary to pass some examination, and not because they enjoy learning more about nature and discovering its secrets.

Another reason is that inaccuracies occur in some textbooks, which lead to misconceptions, and many important facts which aid in explaining the atomic theory are not introduced until the student has almost completed his study of inorganic chemistry. He learns early that two or more elements may combine to form a number of different compounds, but is not given a rational reason why one compound should be formed rather than another, and facts are not placed before him which will enable him to predict what may take place when he performs an experiment, or to confirm his results after he has done his work. Sometimes statements are made which have long been discarded by chemists, and the beginner is asked to learn many things which might be much better acquired by introducing facts in harmony with the most modern discoveries. For example,

CHEMISTRY.

HOW TO TEACH THE CHEMICAL EQUATION.

9

is better still to have a g each other, and combinnd to feel how wonderful such a change. "No one m with real meaning and to enjoy science." If we it is not astonishing that s drudgery, and study it s some examination, and e about nature and dis-

ies occur in some text-, and many important nic theory are not introcompleted his study of ly that two or more mber of different comson why one compound er, and facts are not him to predict what experiment, or to conhis work. Sometimes g been discarded by to learn many things by introducing facts overies. For example,

ecause he does not use the the old method of classifying the elements into monads, teacher always encourage diads, triads, etc., has been retained in some text-books, so is not meant mere fancy, that the students may be enabled to write the compounds of e images, but the power of the elements. It is worth while asking if this is not only at which exists, though it unnecessary but misleading. Would it not be one hundred , for example, that oxygen times better to give the same information by means of Mener, and that this may be delejeff's classification? Why should we leave the introduction of such an important law until we have studied the more important elements and their compounds? From the table the formulæ of the different oxides may be seen at a glance, and then how easy it is to write the sulphides, sulphates and carbonates. The classification further indicates the way in which the other elements combine with hydrogen, and when we know how hydrogen combines with oxygen, it is not difficult to determine how many atoms of hydrogen the metals displace in the hydrogen compounds, and how the metals and metalloids form their chlorides, bromides, hydrates, nitrates, Thus we have a simple and rational method of writing etc. out the more important compounds of the elements, and at the same time we may draw attention to many other features of one of the greatest discoveries of chemical science.

It has long been the opinion of the best teachers of Chemistry that the principles underlying the subject should be introduced as early as possible. For that reason, in the plan here submitted, the Law of Constants, the Law of Definite Proportions, the Law of Multiple Proportions, some features of the Periodic Law and Avogadro's Law have been introduced at the very beginning of the work, and in practice the result has been exceedingly satisfactory. Experience has shown that in carrying out this or any other plan, the aim should be to give the student experimentally, and as quickly as possible, a comprehensive notion of the atomic theory. In so doing, care should be taken not to make use of experi-

ments which would be confusing, or which would become burden to the memory. Hence the beginner should perform or see performed, only such experiments as would have som practical value in illustrating the principles underlying the subject.

In the suggestions that follow, it has been assumed that the student has a knowledge of elementary physics, or in other words, is familiar with the physical properties of liquids and gases, and hence that he has acquired some facts which would aid in introducing the atomic theory.

First, by means of experiments, the beginner should obtain a knowledge of a physical change, a chemical change, the conditions that promote a chemical change, and the difference between a mixture and a compound, etc. Attention might also be drawn to the great number and variety of chemical compounds. Then the question naturally arises, are the substances which enter into a combination themselves compounds? This introduces the elements, their number, their symbols and what the symbols denote, the fact that the elements have not been decomposed, and that they may be divided, in a general way, into metals and non-metals; and further, it brings up the important question, how do elements combine to form compounds? Such a question may most easily be answered by the analysis and synthesis of water, or the analysis and synthesis of hydrochloric acid. In these experiments the student sees that the gases oxygen and hydrogen, and hydrogen and chlorine, unite in definite proportions by volume, and that they must of necessity unite in definite proportions by weight. Then, very naturally, come the important questions, Are compounds constant in composition, and is it a fixed law that other gases unite in definite proportions by volume to form compounds? Do other elements unite in definite proportions by weight? Manifestly the

CHEMISTRY.

it has been assumed that

thesis of water, or the

c acid. In these experi-

es oxygen and hydrogen,

definite proportions by

essity unite in definite

naturally, come the im-

onstant in composition,

unite in definite propor-

s? Do other elements

Manifestly the

 $ext{ight}?$

HOW TO TEACH THE CHEMICAL EQUATION.

11

; or which would become a answer may be obtained by means of some good experiments he beginner should perform to illustrate the Law of Constants and the Law of Definite ments as would have some Proportions. We will now consider a few such experiments.

§ 2. Some Experiments to Illustrate the Law of Constants and the Law of Definite Proportions.

elementary physics, or in (*Note.*—An easy method of filling the eudiometer, to which hysical properties of liquids special attention is directed, is described in Chap. III.) acquired some facts which Ex. I. Decompose water with an electric ensurement and the special end of t

acquired some facts which Ex. 1. Decompose water with an electric current, collecting c theory. Ex. 1. Decompose water with an electric current, collecting the gases in separate test-tubes, so as to compare their volumes and to study their properties by igniting. (A good form of apparatus for this purpose is described in Chap. III., § 3.) change, and the difference of, etc. Attention might is not satisfied that moisture is formed, it will be necessary to prepare dry hydrogen and burn it in air or oxygen, collecting turally arises, are the sub- the product in a cold dry bottle.

on themselves compounds? Ex. 2. Pass some pure dry hydrogen and oxygen into a r number, their symbols eucliometer over mercury. Take care that the gases are at the the elements have the same temperature. Measure the volume of each gas and ey may be divided, in a explode. Repeat the experiment until the student is conmetals; and further, it now do elements combine ion may most easily he from these two experiments it will be seen (1) that mathematical source of the same temperature over mercury. Take care that the gases are at the same temperature. Measure the volume of each gas and explode. Repeat the experiment until the student is conmatter what volume of each gas may be present. From these two experiments it will be seen (1) that mathematical second

From these two experiments it will be seen (1) that water is constant in composition, (2) that water is a compound, (3) that a definite volume, and hence a definite weight, of hydrogen unites with a definite volume and weight of oxygen to form aqueous vapor.

Let us now consider the question, Do other gases unite in definite proportions by volume? To obtain a satisfactory answer, use dry hydrogen chloride. There are two very important advantages in using this gas to demonstrate these facts. In the first place, only inexpensive apparatus, which is to be found in almost any laboratory, is necessary to per-

form the experiments, and for this reason, the laws may be demonstrated, in this way, by any teacher, while more elaborate and expensive apparatus, such as an induction coil, a battery, and a delicate pair of balances are required for other experiments of this kind. Secondly, the experiments may be used for the purpose of showing that molecules of hydrogen and chlorine each contain two atoms, but at a later stage in the work. The next experiment is taken from Reynolds' "Chemistry."

Ex. 3. (a) Open the stopcock (Fig. 1), and pass a current of hydrogen chloride gas through the \cup tube for some time,



then quickly close the stopcock and pour mercury into the \cup tube to close the bend, and half fill the open arm. Open the stopcock slightly, and allow the gas to escape until the mercury stands nearly the same height in both arms. Mark the height of the mercury in the closed arm. Next drop into the open arm sodium amalgam, and fill to the top with mercury; close the open end with the thumb and pass the gas backward and forward a number of times through the mercury by tilting the tube. Finally hold the tube erect, raise the thumb and allow air to enter the open arm. Pour in or remove mercury until it is the same height in both. The gas in the closed arm should now occupy half the volume that it did at first. Tilt the tube so that the mercury will press on the gas in the closed arm, cautiously open the stopcock and hold

the nozzle to the flame. (See also experiment 7, and the chapter on the analysis of gases.)

(b) A modification of the same experiment may be performed as follows: Into a bent tube (Fig. 2), filled with mercury conduct dry hydrochloric acid gas, and then intro-

HOW TO TEACH THE CHEMICAL EQUATION.

e laws may be nile more elabonduction coil, a uired for other riments may be es of hydrogen t a later stage from Reynolds'

l pass a current for some time, d pour mercury and half fill the htly, and allow y stands nearly fark the height Next drop into d fill to the top with the thumb cward a number tilting the tube. the thumb and

Pour in or reheight in both. now occupy half Tilt the tube so the gas in the opcock and hold ment 7, and the

nt may be per-2), filled with and then introduce in the bend of the upper part a little piece of dry metallic sodium. On heating the latter with a lamp, the hydrochloric acid is decomposed, the

chlorine combines with the sodium to form a sodium chloride while hydrogen is set free. Upon measuring the residual hydrogen, it will be found that its volume is exactly half of the HCl introduced.



In preparing the gases for the next experiment use apparatus described in Chap. III., § 2, Fig. 14, and Chap. III., § 3, Fig. 15.

Ex. 4. Pass equal volumes of pure dry hydrogen gas and chlorine gas into a graduated tube or cudiometer, over mer-

cury, as in Fig. 3 About 6 c.cm. of each will be sufficient. Place the graduated tube in a very dim light while mixing the gases. When the tube is ready, place in the sunlight, or burn magnesium ribbon near it, and chemical union will ensue. If a eudiometer is used, an electric spark from an induction coil may be passed through it. Some water may be passed into the tube by means of a pipette, if considered



F1G. 3.

advisable, when the hydrochloric acid gas will be dissolved.

An instructor in chemistry may find it an advantage to demonstrate that the laws hold true when solids, or a solid and a gas combine. The three following experiments are recommended, but must not be attempted unless with a delicate balance.

Ex. 5. (a) Into a hard glass tube, which has been weighed (Fig. 4), introduce a weighed quantity of copper oxide. About one gram is a convenient amount. Pass dry hydrogen through this tube, and, after all air is expelled, heat the tube

and contained oxide to redness. Weigh the tube and contents, and find the weight of the remaining copper. Calculate the combining weights of oxygen and copper. It is best to have a piece of rubber tubing on the end of the glass tubing,



so as to drive off moisture without igniting the surplus gas.

(b) Heat the copper that is left in the tube in a current of air, and find the weight of CuO that is formed. This may best be done by

e

b

d

a

to

at

b

of

to

attaching an aspirator, or a rubber bulb with valve similar to those used in a rubber syringe.

Ex. 6. The following very simple and inexpensive experiment was designed by the writer to illustrate this law, by burning magnesium ribbon (Fig. 5). Take a clear sheet of



mica about eight inches long, and four or five inches wide, roll in the form of a cylinder, having the ends overlap about one inch. Firmly fasten the ends together with any good cement. Around the cylinder place a couple of fine rubber bands, to hold it securely. Take two small pieces of mica, to place on top and bottom of the cylinder. These need not be secured.

Through a small aperture, made with a fine needle in the centre of one, place a piece of platinum wire about one and a half inches long, and fastened at one end to close the

HOW TO TEACH THE CHEMICAL EQUATION.

15

te tube and conopper. Calculate r. It is best to the glass tubing, o as to drive of

noisture without gniting the surdus gas.

(b) Heat the opper that is left in the tube in a urrent of air, and and the weight if CuO that is ormed. This may nest be done by a valve similar to

xpensive experiate this law, by a clear sheet of ong, and four or the form of a verlap about one e ends together round the cylinrubber bands, to o small pieces of d bottom of the not be secured. a needle in the about one and ad to close the

aperture. On the other end of the wire make a small hook. Weigh the apparatus, including the cylinder, two pieces of mica, and platinum wire. Now weigh a piece of magnesium ribbon, about two inches long, hang it very loosely on the hook, and place it through the upright cylinder. Do not let the lower end of the ribbon extend below the lower aperture of the cylinder. Now ignite the magnesium ribbon, and instratly place on the piece of mica. Press on the upper surface of the apparatus, so as not to allow any of the fumes to escape. This is very important. It is best to place the apparatus on a piece of glass or porcelain while burning the magnesium, as the mica becomes quite hot. Weigh the apparatus when cool, and calculate the combining weights of O and Mg. The accuracy of the experiment largely depends upon weighing before and after ignition, at about the same temperature and with the same weight of air present in each case. It may be repeated a number of times without trouble, since it is necessary to shake off only the loose powder hefore repeating. With a little practice and a delicate balance, this experiment can be quickly and easily done.

Ex. 7. The following experiment is also simple and easily performed. The apparatus is similar to Fig. 1, used in the analysis of hydrochloric acid, and, still more important, may be used in the analysis of gases. The reader's attention is directed to the chapter on this subject.

The piece of apparatus described here is sometimes used as a eudiometer.

Take a \cup tube similar to Fig. 1, with one arm drawn out to a point, so that a piece of rubber and clamp may be attached, or better, having a stopcock. It is best to have the base of this arm nearly level, as in the diagram, and the base of the second arm rounded. It would also be an advantage to have the arm graduated, but this is not necessary. One

Y.

arm of the tube must not hold less than 75 or 80 c.cm. Close the stopcock. Pour in distilled water, and by tilting completely fill the closed arm, and have the water rise a few inches in the open arm. Now earefully weigh out from .150 to .200 gms. of zine, and drop it into the open arm, and cause it to rest on the level b. se under the closed arm. A few scraps of platinum might be added. Now pour some strong sulphurie acid into the open arm, and let the gas collect in the closed arm. If the tube is not graduated, place it in a tank of water, and over it a graduate filled with water, and allow the gas to pass into the graduate, so that it can be measured. Bring the water to the same level both inside and outside the graduate. In calculating allow for the tension of the aqueous vapor, the temperature and atmospheric pressure, and determine the weight of H displaced by Zn in $H_{o}SO_{4}$.

Other methods of performing the same experiment will be found in Reynolds' "Chemistry," Chap. X., page 95, Experiment 54; also Remsen's "Chemistry" (Advanced), page 754, which it might be well to consult.

Ex. 8. A method of determining the amount of oxygen in a weighed quantity of potassic chlorate is described in Remsen's "Advanced Chemistry," page 745.

§ 3. How to Represent Molecules and their Reactions upon One Another.

From our experiments we have learned that two or more elements may combine to form a compound. For example, O and H unite to form water, and H and Cl combine to form hydrochloric acid. Now, the smallest particle of any compound or element which can exist by itself, or in a free state, and which still retains the properties of that substance, is called a molecule. Hence it follows that a molecule of water must contain at least two parts, or combining units of hydro-

HOW TO TEACH THE CHEMICAL EQUATION.

17

5 or 80 c.em. Close and by tilting comter rise a few inches n out from .150 to en arm, and cause it arm. A few scraps ome strong sulphuric collect in the closed ice it in a tank of water, and allow the t can be measured. side and outside the nsion of the aqueous pressure, and deter-

H₂SO₄. experiment will be X., page 95, Experidvanced), page 754,

mount of oxygen in described in Rem-

ES AND THEIR THER.

d that two or more ind. For example, Cl combine to form article of any comf, or in a free state. that substance, is a molecule of water ing units of hydro-

gen, and one part, or combining unit of oxygen ; and a molecule of HCl must contain at least one part, or combining unit of hydrogen, and one part or combining unit of chlorine. Each particle of hydrogen, oxygen or chlorine which enters into the composition of the molecule, is called an atom. A molecule of water, then, must contain at least two atoms of hydrogen and one atom of oxygen ; a molecule of hydrochloric acid must contain at least one atom of hydrogen and one atom of chlorine; and a molecule of cupric oxide must contain at least one atom of copper and one atom of oxygen. Molecules of these compounds are usually written H2O, HCl, CuO, etc., but it is best also to represent them by diagrams, somewhat as follows :

0 H H Cl Cu 0 Mg 0 By means of these the beginner may form a mental picture of

H

how the atoms are held together in the molecules.

Just at this stage in the work the student should learn what the symbols of chemical notation, such as Cl, H, O, etc., denote; what is indicated by the formula of a compound, as, H₂O, CuO, MgO, etc.; and further, that the electropositive element stands first in the formula. This should be followed by the preparation of hydrogen gas from the acids and such metals as zinc, magnesium, etc. ; also from water by using potassium and sodium, as these experiments will best serve the purpose we have in view.

Having performed these experiments, it will be an advantage to make diagrammatic representations of the molecules of substances used and formed, when these chemical changes took place. For example, potassium hydrate, K 0 H sodium hydrate, Na H , and other formulæ not in the 0 2

STRY.

previous paragraph, might be written out. The transmutations in these experiments might now be represented somewhat in this way :

(1) When potassium is thrown on water, hydrogen and potassium hydrate are formed.



(2) When sodium is thrown on water, hydrogen and sodium hydrate are formed.

This may be represented by a diagram similar to the action of potassium on water (1). For a representation of this see \S 10 of this chapter, page 37.

(3) When hydrochloric acid is poured on zinc, hydrogen and zinc chloride are formed.



а

g

HOW TO TEACH THE CHEMICAL EQUATION. 19

t. The transmuta-

ater, hydrogen and



STRY.



ydrogen and sodium

imilar to the action entation of this see

on zinc, hydrogen



(4) When copper is heated in a current of air, oxide of copper is formed.



(5) When hydrogen is passed over CuO, water and copper are produced.

For a diagram of this reaction see § 10 of this chapter, page 38.

(6) When magnesium is heated in air, oxide of magnesium is formed.

This may be represented by a diagram similar to the action of oxygen on copper (4).

(7) The synthesis of hydrochloric acid may be represented :



(8) The analysis of hydrochloric acid may be demonstrated as in diagram, § 10 of this chapter, page 36.

(9) The synthesis of water may be represented as in diagram, $\S10$ of this chapter, page 37.

(10) The analysis of water may be represented :



Many other illustrations might be added, such as the action of sulphuric acid on zinc, and on magnesium; the heating of potassic chlorate, mercuric oxide, etc., but enough have been used to indicate the method.

In the preparation of hydrogen, and in many other introductory experiments, the more important acids have been used, and the beginner will be familiar with their common names. These may be used to good advantage to introduce the formulæ of compounds.

§ 4. THE FORMULÆ OF COMPOUNDS.

Like water, the acids are compounds of hydrogen, or con tain displaceable hydrogen, as shown in the preparation of hydrogen gas; and such compounds of hydrogen may be written somewhat as follows:

 H_2O , HOH, HCl, HI, HBr, HNO₃, H_2S , H_2SO_4 , H_2CO_3 , H_3PO_4 , etc.

Besides the common names, water, hydrochloric acid, nitric acid, etc., these compounds are called hydrogen oxide, hydrogen chloride, etc.

When potassium was thrown on water, an atom of K took the place of one atom of H, and formed KOH. If another atom of K were to take the place of the atom of hydrogen,

HOW TO TEACH THE CHEMICAL EQUATION. 21

EMISTRY.

represented :



lded, such as the action nesium ; the heating of but enough have been

in many other introtant acids have been r with their common dvantage to introduce

MPOUNDS.

of hydrogen, or con in the preparation of of hydrogen may be

NO3, H2S, H2SO4,

drochloric acid, nitric ydrogen oxide, hydro-

, an atom of K took KOH. If another atom of hydrogen, we would have K_2O , the oxide of potassium. Other compounds of potassium may be formed by displacing the hydrogen of the acids with K, one atom of K taking the place of one atom of hydrogen. In this way we may write down the compounds of potassium corresponding to those of hydrogen : KCl, KI, KNO₃, KBr, K_2S , K_2SO_4 , K_2CO_3 , K_3PO_4 , etc. In the same way the compounds of sodium may be written out.

Now let us look at magnesium. The oxide is written out. MgO. Then an atom of Mg just takes the place of two atoms of hydrogen, as the oxide of hydrogen is written H_2O . Hence the sulphate of magnesium will be MgSO₄, its sulphide MgS, and its carbonate MgCO₃. Since one atom of hydrogen combines with one atom of chlorine to form HCl, an atom of magnesium will combine with two atoms of chlorine to form magnesium chloride, MgCl₂. Then its other compounds will be written Mg(OH)₂, MgI₂, MgBr₂, MgNO₃, etc.

The table, as it appears on the blackboard, will be:

o		····, ··	
Oxides.	Hydrates.	Chlorides.	Bromides.
$H_{2}O$	HO.H	HCl	HBr
K ₂ O	КОН	KCl	KBr
Na_2O	NaOH	NaCl	NaBr
MgO	$Mg(OH)_2$	$Mg(Cl)_2$	Mg(Br) ₂
Iodides.	Nitrates.	Sulphides.	Sulphatos
HI	HNO ₃	H	H _o SO.
KI	KNO ₃	K.S	K-SO
NaI	NaNO _a	Nas	Na SO
$Mg(I)_2$	$Mg(NO_3)_2$	MgS	MgSO.

Zinc and copper might be added to this list as practice for the student, but before writing out any more compounds it will be necessary to get a clear idea of how the elements combine with one another, and this can be done by a study of Mendelejeff's classification.

	h					TAT	- BO	OK	OF	СН	EM	list	RY.		
		- 'III/	R0,	.				Co 58.4	Cu 63.1	Rh 102.2	Ag 107.12)		Ir 191.5 Au 195.7	
		-	[55.6	58.3	100.9	105.8		0 00	93.33	
	-							Fe	Ï	$\mathbf{R}\mathbf{u}$	Ρd		ě	L T	
			R ₂ 0,	Hy		F 18.9	Cl 35.19	Mn 54.5	Br 79.36		1 104 01	1 125.90			
TTTTT			, RO.			0 15.85	S 31.82	Cr 51.8	Se 78.5	do 95.3	Te 194.4		. 100.0	193.0	237.6
	A.		RH3 RH3	-	;	N 13.95	P 30.8	V 50.8	As 74.5	Nb 93.2 1	Sb 119.0		a 181 1	Bi 207.3	n
	IV.	RO	RH,		011	16'11 O	2.82. IC	21.47.8	Ge 71.9	Zr 90.0	Sn 117.2			Pb 205.4	h 230.7
	III.	$ m R_2O_3$			B 10.8	Al 96.0	12 42 6	Co 60.0	0.60	00.0	In 113.0	a 137.5	165.0	TI 202.7	-
	II.	RO			Be 9.0	Mg 23.8	Ca 39.7 S	Zn 64.8	Sr 87.0 V	Cdino	7111 00	Ba 136.4 La	B	Hg198.8	
	i	K20		Н 1.	Li 7.0	Na 22.87	K 38.84	Cu 63.	Rb 34.8	Ag 108.	0 001 0	1 0.261 80			

§ 5. MENDELEJEFF'S TARLE

22

1-4

- 40

A HAND-BOOK OF

HOW TO TEACH THE CHEMICAL EQUATION. 23

In studying this table with the class it is best to have a large chart made, showing the elements with their atomic weights, and have it hung in a conspicuous place. The elements are arranged, in the classification here presented, in eight vertical columns, representing eight groups ; while successive series are presented in horizontal lines. (These may be made to incline slightly, so that on rolling the table Na will immediately succeed F, K will succeed Cl, and so on, in a spiral line. See Shepherd's "Chemistry," page 221.) The first eight present very marked individual characteristics. The teacher should not draw attention to too many facts at first, but only give such information as will be useful in illustrating the way in which elements unite to form compounds. If too much is attempted it may lead to confusion, and the teacher must use his own judgment as to what is necessary. The following might be made clear:

1. The elements are in the order of their atomic weights.

2. The meaning of RO, R_2O , R_2O_3 , etc., RH_4 , RH_3 , RH_2 , RH, etc.

3. The elements of cach group have a series of compounds corresponding to the oxides.

4. One atom of Cl, Br, etc., unites with one atom of H, and hence with one atom of each element in Group I. The other groups form similar compounds.

5. The position of the metallic and non-metallic elements in the table.

The next step in the work is quite plain. The student should write out a series of compounds, or at least one element in each group, similar to those of H, Na, etc., already given, but it should be made plain that many of these have compounds corresponding to the elements in other groups, and that the elements of each group should be memorized. In connection with this study the subject of valence, and the

CHEMISTRY.

u 100.9 Rh 102.2 d 105.8 Ag 107.12		180.9 +	t 193.33 Au 195.7	
1 19% 00	06.071 -			
Te 124.4		. tot W	0.601	U 237.6
Sb 119.0		Ta 181.1	Bi 207.3	
Sn 117.2			Pb 205.4	Th 230.7
113.0	137.5	165.0	202.7	
Ч	1.8	Er	E	
Cd 111.2	130.4		Hg 198.8	
Ag 108. Cs 132.0				

meaning of univalent, bivalent, trivalent elements, etc. should be considered. This introduces chemical nomencla ture and the principles upon which the names of compounds in inorganic chemistry are based.

The following explanation of valency, which is condensed from two or three different text-books of chemistry, indicates a line which may be followed in considering the subject. All

§ 6. VALENCE.

Our study of Mendelejeff's table has demonstrated clearly that "elements or radicals have the property of combining with or replacing other elements or radicals in definite and constant proportion. The degree of this property is commonly indicated by the number of atoms of hydrogen with which the atom or radical can combine or which it can replace. The combining capacity of hydrogen is taken as the unit, hence hydrogen is said to have a valence of one." Thus it will be seen that the valency may be ascertained from the composition of the hydride; where no such compound exists then the most stable oxide or chloride may be used. hydrides in Mendelejeff's table are represented : The

RH₄, RH₃, RH₂,

By writing down the hydrides of the different elements and their atomic weights we learn that, "in each group the affinity of the elements for hydrogen diminishes step by step with the increasing atomic weight; nevertheless, the number of hydrogen atoms which combine with one atom of each of the other elements is constant for each group." This is what is called valence or atomicity, and may be defined as "the function of affinity of an element in its relation to hydrogen," or referred to the combining power of hydrogen as a unit. To determine, then, the valency of the more important elements, let

CHEMISTRY.

E.

has demonstrated clearly e property of combining radicals in definite and f this property is comatoms of hydrogen with bine or which it can reydrogen is taken as the valence of one." Thus e ascertained from the such compound exists le may be used. The resented :

RH.

different elements and each group the affinity step by step with the the number of hydroof each of the other his is what is called l as "the function of drogen," or referred a unit. To deterportant elements, let

HOW TO TEACH THE CHEMICAL EQUATION.

 $\mathbf{25}$

trivalent elements, etc., as examine their hydrides or chlorides. One atom of hydrooduces chemical nomencla gen unites with one atom of each element of the chlorine the names of compounds group. Hence the halogens possess one affinity unit and are

monovalent. Sulphur and oxygen each unite with two atoms lency, which is condensed of hydrogen or chlorine, and since they possess two affinity ks of chemistry, indicates units they are divalent, i.e., an element which will not comsidering the subject. All bine with more than two atoms of hydrogen or chlorine, or will not displace more than two atoms of hydrogen is divalent. For similar reasons nitrogen and arsenic are trivalent, and carbon and silicon tetravalent. "Nor can one atom of chlorine, sulphur, nitrogen or carbon be made to combine with more than one, two, three and four atoms of hydrogen respectively, to form stable and definite compounds. They are satisfied, or saturated, and these compounds are termed saturated compounds,"

"Chemical affinity, however, must not be confused with valency. Valency is quite independent of affinity, and peculiar to individual elements." Carbon combines with four atoms of chlorine, sulphur with two, and hydrogen with one atom to form saturated compounds, but this does not indicate that carbon has a greater affinity for chlorine than sulphur or hydrogen. Very often the opposite is the case. "Those elements which have the greatest chemical affinity have often the lowest valency, and inert bodies, such as those of Group IV. and Group VIII., have often the highest valency."

A study of the equivalent weights of the elements will also aid in determining their atomicity. It has been found by actual experiment that 23 grams of sodium liberate from water l gram of hydrogen; 24 grams of magnesium or 65 grams of and displace 2 grams of hydrogen from the hydrogen compounds, and 27 grams of aluminium liberate 3 grams of hydrogen ; also 12 grams of magnesium displace 108 grams of silver from silver nitrate. The weight obtained in each case is

known as the equivalent weight when referred to hydroge as unity. In the case of sodium and the other elements Group I., the equivalent weights are identical with the atom weights. The equivalent weights of magnesium and the other elements of Group II. are proportional to half the atomi weights; and those of aluminium and Group III. to one-third Since the equivalent weights of sodium and the other elements of Group I. are identical with the atomic weights, they are monovalent. The equivalent weights of magnesium and zinc are respectively 12 and 32.5, and the atomic weight is in each case double the equivalent weight; hence these and other elements of Group II. are divalent. In the case of aluminium, the atomic weight is three times the equivalent weight; therefore aluminium and the other elements of Group III. are trivalent.

From what has been pointed out it will be seen that there is a "periodic relation between valency and atomic weights." In general the members of Group I. are monovalent, Group II. are divalent, Group III. are trivalent, Group IV. are tetravalent, Group V. are pentavalent or trivalent, Group VI. are hexavalent or divalent, Group VII. are heptavalent or monovalent, Group VIII. are octovalent or divalent. . It must be remembered, however, that there are compounds which prove exceptions to this general statement, and to obtain a full appreciation of the subject we must study the "constitution of the chemical compounds." In order to do this chemists have adopted a symbolic method of representing the formulæ, "which serves to give expression not only to the proportion in which the elements combine, but also to the distribution of the atoms within the molecule, and their mode of attachment to one another." It is the opinion of the writer that it is not best to introduce graphic formulæ until the students have learned to write a chemical equation.

26

17 A -- 2 "

F CHEMISTRY.

are identical with the atomic of magnesium and the other uivalent weights of sodium I. are identical with the t. The equivalent weights vely 12 and 32.5, and the ble the equivalent weight; Group II. are divalent. ic weight is three times uminium and the other

t will be seen that there cy and atomic weights." are monovalent, Group ivalent, Group IV. are ent or trivalent, Group p VII. are heptavalent valent or divalent. . It there are compounds cal statement, and to bject we must study pounds." In order to polic method of repregive expression not lements combine, but hin the molecule, and " It is the opinion luce graphic formulæ a chemical equation.

HOW TO TEACH THE CHEMICAL EQUATION.

when referred to hydrogen 7. AN EXPLANATION OF THE LAW OF MULTIPLE PROPOR-TIONS, THE LAW OF DEFINITE PROPORTIONS, AND AVO-GADRO'S LAW.

we are now in a position to consider a multiplication of the prod Group III to be atomic Proportions, which forms an essential amplification of the Law of Definite Proportions; and perhaps the Law of Multiple Proportions can best be explained by calling attention to the oxides of nitrogen.

A study of this law leads us to a consideration of the most important principles of chemistry. Dalton made the great discovery that "elements unite in definite proportions by weight," and applied to his discovery the atomic theory. This grew out of a crude analysis of matter, which proved to his mind, at least, that the same substance always had precisely the same composition, as Proust and other investigators had already written on the "constancy of the relations by weight of the component parts of bodies." We now know this fact as the Law of Constants, namely, that "matter is constant in composition," or in other words, that "all compounds are definite, and contain only certain determinate proportions of their constituents." Gay Lussac then discovered that gases unite in definite proportions by volume ; and finally Avogrado made a distinction between atoms and molecules, and from these facts built his great hypothesis. This made a revolution in chemical science, and nothing is clearer than that the student should think out for himself the reasons which led to such conclusions. No other statement or apology is necessary why an epitome of these facts, which are fully explained in Richter's and other text-books, with some of the writer's own observations, should be given in the next few paragraphs. The question now assumes the form, What is the best explanation of these great principles?

"The Law of Constant or Definite Proportions finds its

best explanation in the hypothesis of the existence of atom which Dalton first applied to explain this law. It was during his investigations on marsh gas and olefiant gas that the atomic theory first suggested itself to Dalton. He calculate that if the weight of carbon in each of these compounds we reckoned to be the same, then marsh gas contained twic the weight of hydrogen present in olefiant gas. He furthe observed that the quantity of oxygen in carbonic acid ga (CO_2) was twice as much as carbonic oxide gas (CO). These and similar facts he conceived, might be explained by assuming that matter consists of extremely small particles which cannot be further divided, either chemically or mechanically; or, in other words, that matter consists of atoms possessing definite weights, the ratios of which could be denoted by numbers, the weight of an atom of hydrogen being taken as unity. Further, he conceived that the atoms of different elements possess different weights, and all atoms of one element have the same absolute weight and are like each other. The combination of these atoms with one another would account, then, for the definite propertion in which the elements united, and the weight of the smallest particle or molecule of a compound might therefore be obtained by adding together the weights of its constituent atoms. On such a basis we see that the constituents of compounds should

"The consideration of the Law of Multiple Proportions brings out the fact that the halogens unite with hydrogen in only one proportion, and when we compare the proportions in which these elements combine, with their densities, we are forced to the conclusion that in equal volumes of these elementary gases there is contained an equal number of atoms, or combining units. If in one volume of hydrogen, for example, there are 1000 atoms, which equal 1000 weight units,

17 1-8

F CHEMISTRY.

in olefiant gas. He further sygen in carbonic acid gas nic oxide gas (CO). These, ht be explained by assumnely small particles which nemically or mechanically; nsists of atoms possessing ich could be denoted by hydrogen being taken as : the atoms of different and all atoms of one eight and are like each toms with one another propertion in which the the smallest particle or erefore be obtained by constituent atoms. On its of compounds should

Multiple Proportions unite with hydrogen in pare the proportions in heir densities, we are l volumes of these eleual number of atoms, f hydrogen, for exam-1 1000 weight units,

HOW TO TEACH THE CHEMICAL EQUATION.

is of the existence of atoms, and in a like volume of chlorine there are 1000 atoms of lain this law. It was during chlorine, which = 1000×35.45 weight units, then it is evident and olefiant gas that the that the relation between the atomic weights and that bef to Dalton. He calculated tween the densities must be the same, or one volume of ch of these compounds were hydrogen = 1000×1 , and one volume of chlorine = 1000×1 35.45. Hence the atomic weights of the halogen elements are proportional, or equal to their densities if referred to the same unit.

We arrive at a perfectly similar, but much more general, conclusion, by the consideration of the physical properties of gases or vapors. According to the law of Mariotte and Boyle, "the volume of a gas at constant temperature varies inversely as the pressure," and from the law of Charles and Gay Lussac we learn that, "the volume of a given gas at a constant pressure varies directly as the absolute temperature," From this we infer that when we have the smallest etc. particles which can exist in a free state, and the gas expands from an increase of temperature, the particles do not increase in number, nor do they increase in size, but the spaces between the particles must become larger. In other words, when heat or energy is transferred to a volume of gas, the temperature increases, and each particle receives the same amount of energy. Hence, according to the kinetic theory of gases, they are driven apart, or affected, to the same extent, so that the spaces between the particles must increase to the same extent. Now, it necessarily follows that if equal volumes of different gases change to the same extent when subjected to equal alterations in temperature and pressure, "there must be an equal number of particles contained in equal volumes." From this it is inferred that their relative weights are proportional to their volume weights, or gas densities.

Now we can appreciate the historical order of these dis-
coveries, and the important question again arises, How gases combine by volume? The analysis and synthesis hydrochloric acid and water make this point plain.

From these experiments we learn the following :

1 volume of H + 1 volume of Cl = 2 volumes of HCl; also, 2 volumes of H + 1 volume of O = 2 volumes of H_2O .

As a confirmation of our experiments, we are aware the Gay Lussac discovered (1) that gases unite according to sim ple volume ratios, and (2) that the volume of the resultin body bears a simple ratio to the volumes of the constituents Dalton discovered that the quantities by weight of the combining elements also bear a simple ratio to one another. If we grant the atomic or molecular constitution of matter Avogadro's hypothesis follows, namely, "that equal volumes of gases under the same conditions of temperature and pressure contain the same number of particles or molecules."

Having proved the truth of these laws we may infer concerning hydrochloric acid, that since, according to Avogadro's law, "equal volumes of gases under the same conditions of temperature and pressure contain the same number of molecules,"

Then 1 molecule of hydrogen + 1 molecule of chlorine = 2 molecules of HCl;

Hence $\frac{1}{2}$ a molecule of $H + \frac{1}{2}$ a molecule of Cl = 1 molecule of HCl;

Therefore a molecule of Cl and a molecule of H each contain at least two atoms.

A similar inference may be drawn from the analysis and synthesis of water.

2 molecules of hydrogen + 1 molecule of oxygen = 2 molecules of water vapor;

Therefore 1 molecule of hydrogen $+\frac{1}{2}$ a molecule of oxygen = 1 molecule of water vapor;

Hence we infer that a molecule of oxygen is divided into 2 parts, or contains at least 2 atoms.

estion again arises, How de e analysis and synthesis o e this point plain.

Irn the following :

f Cl = 2 volumes of HCl; of O = 2 volumes of $H_{a}O$. eriments, we are aware that ases unite according to sin he volume of the resulting olumes of the constituents ities by weight of the com ratio to one another. ar constitution of matter, articles or molecules." ese laws we may infer cone, according to Avogadro's he same conditions of temme number of molecules," l molecule of chlorine = 2

olecule of Cl = 1 molecule molecule of H each conn from the analysis and cule of oxygen = 2 mole-¹ a molecule of oxygen oxygen is divided into

HOW TO TEACH THE CHEMICAL EQUATION.

§ 8. MOLECULAR VOLUME AND ATOMIC WEIGHT.

We have already pointed out that ihe relative weights of gases are proportionate to their densities, and in determining their densities that hydrogen is taken as a unit. In other words, to obtain the density of any gas, we divide the weight a certain volume by the weight of an equal volume of hydrogen at the same temperature and pressure. It will be manifest, therefore, from Avogadro's hypothesis, that if we divide the weight of a certain number of molecules by the weight of an equal number of molecules of hydrogen, we also get the lensity; and, further, we arrive at the same result by dividing the weight of one molecule of the gas by the weight of a mely, "that equal volumes may obtain the weight of a molecule of any gas by multiplynolecule of hydrogen. It is quite apparent, then, that we ng the density of the gas by the weight of a molecule of ydrogen. The reverse of this is also true; we may obtain the density from the molecular weight, which is very important to the beginner in studying the properties of gases.

To determine the weight of a molecule, however, we must now the number of atoms in a molecule and the weight of an atom. It is certain, then, that the student will need to have a clear conception of "molecular volume" and "atomic weight," and it must be made plain that the molecule exists only in theory, but that the assumption of its existence serves, at present, as the best means of explaining chemical phenomena. We are ignorant of both the form and character of the molecule, and any measurements which have been made of its volume are approximations. To say that a molecule is invisible to the highest powers of the microscope does not by any means give an idea of its volume. Sir W. Thompson estimated the diameter to be about one ten-millionth of a millimeter; but it would take a considerable stretch of the imagination to even conceive of a particle of such

minute dimensions. Such measurements are interesting, l ever, as they tend to support the view that ultimate part of matter, though extremely small, have a definite size. will be quite apparent, then, that the weight of an a cannot be actually determined, but the weight of an ator hydrogen has been adopted as unity, and all measureme have been made relatively to its weight. Since, ther molecule of hydrogen contains two atoms, and an atom hydrogen weighs one, its molecular weight is two, and molecular weight of any gas is equal to the density of the in its relation to hydrogen multiplied by two. Then, too must be apparent that if we take a volume of hydrog which weighs two (its molecular weight), an equal volume any other gas at the same temperature and pressure m weigh i.s molecular weight. Therefore, if a volume of hyd gen weighs two pounds, grams or ounces, an equal volume any gas at the same temperature and pressure will weigh number of pounds, grams or ounces corresponding to molecular weight.

We might very properly at this point discuss the metho of determining the atomic weight of an element, but it w be sufficient for our purpose to state that in determining the atomic weight of any element we must (1) find the molecula weight of all compounds containing the element by the method already indicated, and then (2) from an analysis of its com pounds calculate the smallest amount of the element in the molecular weight of each of its compounds. This will giv the atomic weight, which may be defined as "the smalle weight of that element which enters into a molecule of i compounds."

Now we are in a position to appreciate a simple method determining the molecular weight of any gas. 22.4 litres hydrogen at 0° C. and 760^{mm} barometric pressure weigh 2 gran

HOW TO TEACH THE CHEMICAL EQUATION.

33

surements are interesting, house 2 is the molecular weight of hydrogen, and since by Avohe view that ultimate particladro's law, "equal volumes of gases under the same condions of temperature contain the same number of molecules," that the weight of an atom follows that 22.4 litres of any gas at 0° C. and 760mm barobut the weight of an atom metric pressure must weigh its molecular weight in grams. unity, and all measuremen 2.4 litres of chlorine at 0° C. and 760mm weigh 71 grams, Since, then, herefore 71 is its molecular weight; 22.4 litres of ammonia two atoms, and an atom at the same temperature and pressure weigh 17 grams, and cular weight is two, and t_{17} is the molecular weight of ammonia. On the other hand, equal to the density of the gif we know the number of atoms in a molecule, and the tiplied by two. Then, too, weight of each atom, we can calculate the weight of 22.4 take a volume of hydrog litres of the gas at standard temperature and pressure. In r weight), an equal volume ammonia, for example, there are three atoms of hydrogen and perature and pressure muone atom of nitrogen; an atom of hydrogen weighs 1 and an erefore, if a volume of hydratom of nitrogen weighs 14, therefore the molecular weight is r ounces, an equal volume 2+14=17. Hence it follows, from what has been said, that re and pressure will weigh 2.4 litres of ammonia gas at standard temperature (0° C.)

ounces corresponding to and pressure (760mm B. P.) weigh 17 grams. For the same reason 22.4 litres of marsh gas (CH_4) at standard temperais point discuss the methodene and pressure weigh 12 + 4 = 16 grams. t of an element, but it w For the above reasons, it will be important to know the

ate that in determining toumber of atoms in a molecule of the different elements. must (1) find the molecule There are two atoms in a molecule of each of the more comng the element by the methonon gases, such as H, Cl, O, etc. Potassium, sodium, zinc from an analysis of its containd mercury have one atom in a molecule, and recent invesount of the element in the gations on the new gases, argon and helium, indicate that compounds. This will givenere is but one atom in a molecule of each of these elements. be defined as "the smallent is interesting here to note that recent investigations ters into a molecule of indicate that arsenic is not an element, but a compound of

phosphorus.

preciate a simple method of any gas. 22.4 litres etric pressure weigh 2 gram

The following table is interesting, and should be stuby the class.

$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $						
Hydrogen 1.0 1 2 2 H. Nitrogen 14 14 2 28 Ng Oxygen 16 16 2 32 02 Chlorine 35.4 35.4 2 70.8 Cl Sodium 11.5 23 1 23 Na Potassium 11.5 23 1 23 Na Sodium 19.5 39 1 39 K Zine 32.5 65 1 65 Zn Cadmium 55.8 111.7 1 111.7 Cd Mercury 100 200 1 200 Hg Iodine at 450° C. 126.5 126.5 2 253.0 I2 Sulphur at 500° C. 96 32 6 192 Se Sulphur at 1000° C. 32 32 2 64 S2 Dzone 24 16 3 48 03 Phosphorus 159.8 74.0 4 124 P4 </th <th>Hydrogen 1.0 1 2 2 H Nitrogen 14 14 14 2 28 N₂ Oxygen 16 16 16 2 32 O₂ Chlorine 35.4 35.4 23 1 23 Na Sodium 11.5 23 1 23 Na Potassium 11.5 23 1 23 Na Zinc 32.5 65 1 65 Zn Cadmium 55.8 111.7 1 111.7 Cd Mercury 100 200 1 200 Hg Iodine at 450° C. 126.5 126.5 2 253.0 I₂ Iodine at 1500° C. 63.3 126.5 1 126.5 I Sulphur at 500° C. 96 32 6 192 Se Sulphur at 1000° C. 32 32 2 64 S₂ Dzone 24 16 3 48 O₃ Phosphorus 62.0</th> <th>-<u>-</u></th> <th>V_{apor} Density (H = 1).</th> <th>Atomic Weight.</th> <th>Number of Atoms in a Molecule.</th> <th>Molecular Weight.</th> <th>Molecular</th>	Hydrogen 1.0 1 2 2 H Nitrogen 14 14 14 2 28 N ₂ Oxygen 16 16 16 2 32 O ₂ Chlorine 35.4 35.4 23 1 23 Na Sodium 11.5 23 1 23 Na Potassium 11.5 23 1 23 Na Zinc 32.5 65 1 65 Zn Cadmium 55.8 111.7 1 111.7 Cd Mercury 100 200 1 200 Hg Iodine at 450° C. 126.5 126.5 2 253.0 I ₂ Iodine at 1500° C. 63.3 126.5 1 126.5 I Sulphur at 500° C. 96 32 6 192 Se Sulphur at 1000° C. 32 32 2 64 S ₂ Dzone 24 16 3 48 O ₃ Phosphorus 62.0	- <u>-</u>	V_{apor} Density (H = 1).	Atomic Weight.	Number of Atoms in a Molecule.	Molecular Weight.	Molecular
	150.5 74.9 4 299.6 As ₄	Hydrogen	$\begin{array}{c} 1.0\\ 14\\ 16\\ 35.4\\ 11.5\\ 19.5\\ 32.5\\ 55.8\\ 100\\ 126.5\\ 63.3\\ 96\\ 32\\ 24\\ 62.0\\ 159.8 \end{array}$	1 14 16 35.4 23 39 65 111.7 200 126.5 126.5 32 32 16 31.0 7.4 0	2 2 2 2 1 1 1 1 1 2 1 6 2 3 4	2 28 32 70.8 23 39 65 1111.7 200 253.0 126.5 192 6.1 48 124	H N ₂ O ₂ Cl ₂ Na K Zn Cd Hg I ₂ I S ₆ S ₂ O ₃ P ₄

§ 9. WHAT IS AN ELEMENT?

During all this time the student has been studying element and compounds, but it is certain he will not be able to te why hydrogen, iron or calcium, for example, are classified a elements. This is something which should be settled at once

What reasons, then, have we for believing that hydroge is an element? The following are some reasons, but any on of them must not be regarded as a reason in itself.

HOW TO TEACH THE CHEMICAL EQUATION.

resting, and should be studia. Hydrogen has a characteristic spectrum, as in the case f other elements.

2. Its atomic weight has been determined by a number of ifferent methods, and has been found to be constant.

Formula 3. Chemists have never been able to obtain anything from but hydrogen. It has never been decomposed.

4. All its compounds are constant in composition ; it unites definite proportions by weight with other elements, and it hows the Law of Multiple Proportions in forming its comounds, as for example, H_2O and H_2O_8 .

5. Hydrogen occupies a definite position in Mendelejeff's assification, and its atomic weight is such as to lead us to dieve that it is an element, from its relation to other atomic eights in that classification.

6. It forms a series of compounds similar to those of Group of Mendelejeff's classification, and it may be displaced in uose compounds by many other substances which we believe be elements; and both hydrogen and its compounds have operties similar to those we would expect an element and compounds to have which would occupy the position it oes in the table.

For similar reasons other substances are classified as ements.

While studying the relation of hydrogen to other elements, ue other point should be made clear. Is hydrogen a metal

a non-metal? The answer we get will aid very materially has been studying elemena understanding its compounds, and their relation to the he will not be able to teompounds of other elements. For the following and other example, are classified ansons, it is believed to be a gaseous metal at ordinary h should be settled at oncomperatures.

r believing that hydroge 1. Hydrogen is absorbed by the metal palladium, and the some reasons, but any orompound conducts itself like an alloy of two metals, being reason in itself.

Weight.	Number of Atoms in Molecule	Molecular Weight.	Molecular
1	2	2	н
14	2	28	N
16	2	32	0
35.4	2	70.8	CI
23	1	23	N
39	1	39	K
15	1	65	Zn
1.7	1	111.7	Cd
0	1	200	Hg
6.5	2	253.0	I ₂
6.5	1	126.5	I
2	6	192	S.
2	3	64	S2
3	3	48 ′	0,
.0	4	124	P ₄
.9	4	299.6	As,

ELEMENT ?

metallic in appearance, and having the power of conducti heat and electricity.

2. When water is decomposed hydrogen appears at t electro-negative pole, as other metals when their salts a decomposed.

3. It possesses the power (in marked degree for a gas) conducting heat and electricity.

4. Hydrogen is absorbed by the metals potassium an sodium, forming alloys, in which the density of H is .62.

5. Liquid hydrogen is said to have a metallic appear ance, etc.

6. The element displays the character of a metal in it chemical deportment.

§ 10. THE CHEMICAL EQUATION.

We are now in a position to write and understand what i denoted by a chemical equation. Let us begin by writin out what took place in the analysis and synthesis of hydr chloric acid, as we had evidence in those experiments that molecule of H and a molecule of Cl each contained two atom (At this point the signs should be fully explained.)

(1) When hydrochloric acid is decomposed, hydrogen an chlorine are formed.



This may be expressed : $2HCl = Cl_2 + H_2$.

ing the power of conducting

d hydrogen appears at the netals when their salts ar

arked degree for a gas)

the metals potassium and the density of H is .62.

have a metallic appear

haracter of a metal in it

L EQUATION.

fully explained.)

decomposed, hydrogen an



(2) When hydrogen and chlorine combine, hydrochloric cid is formed

HOW TO TEACH THE CHEMICAL EQUATION.

For a diagram of this reaction see § 3 of this chapter, p. 19. This may be written : $H_2 + Cl_2 = 2HCl$.

(3) Now represent what takes place with water. When and H combine H₂O is formed.



This may be represented : $2H_2 + O_2 = 2H_2O$.

The student writes out the molecular equation, and does ite and understand what i not need to write the equation in the atomic form, to which Let us begin by writin so many chemists seriously object. Further, he is able to is and synthesis of hydr understand everything that is denoted by the equation, and n those experiments that it should be fully explained that what is represented by the each contained two aton: equation is true both by weight and by volume.

(4) When sodium is thrown on water, hydrogen is formed.



This is expressed : $2Na + 2H_2O = H_2 + 2NaOH$.



 $\mathbf{H}_{2} + \mathbf{H}_{2}$

(5) When hydrogen is passed over copper oxide it ma represented :



 $2CuO + 2H_2 = 2H_2O + 2Cu.$

All the student will need now is some practice in writi out a few simple equations in this way. Then he will need little practice in balancing an equation, after he has writt down the formulæ of substances used and produced. It w be surprising how quickly he gets over the difficulty. The plan has never been found to fail.

This section would be incomplete without answering the question, What chemical information does a typical equation convey?

It will be observed, by way of introduction, that the sub stances which react upon one ar ther to produce a chemica change, are always placed at the left-hand side of the equa tion, and the compounds produced are placed to the right The sign + indicates that the substances are brought togethe under such conditions that they react upon one another, and the sign = means that they "give" or "produce" the sub stances on the right-hand side of the equation. The number placed to the left of each molecular formula denotes the nun ber of molecules, and the numbers placed at the base of eac



$2H_2O + 2Cu$.

HOW TO TEACH THE CHEMICAL EQUATION.

39

d over copper oxide it may symbol denote the number of atoms of that particular element in a molecule; thus, $2H_2O$ denotes that there are two molecules of water, and each molecule contains two atoms of hydrogen and one atom of oxygen; $KClO_3$ indicates that there is one molecule of potassic chlorate, which contains one atom of potassium, one atom of chlorine, and three atoms of oxygen. Further, $KClO_3$ indicates that a molecule of potassic chlorate weighs $(39 + 35.4 + 3 \times 15.96)$ or 122.28, which is the sum of the weights of the atoms; 2KClO $_3$ would be twice this amount.

Let it not be forgotten that an equation is based on the indestructibility of matter; in other words, matter may be transforme, but cannot be destroyed. The total weight of

the substances reacting on one another must be equal to the v is some practice in writin sum of the weights of the substances produced, and to obtain is way. Then he will need such a result the number of atoms on one side of the equation quation, after he has writte must be equal to the atoms on the other. Further, when used and produced. It will be elements and compounds used and produced are in the ets over the difficulty. The aseous state, the numbers indicating the molecules used will

indicate the proportions by volume in which the gases complete without answering the bine, and the numbers denoting the molecules produced will tion does a typical equatic indicate the volumes produced when in the gaseous state.

For example, introduction, that the sub

 $2H_2 + O_2 = 2H_2O.$

ther to produce a chemica This expresses what we learned by experiment :

left-hand side of the equal 1. That 2 volumes of hydrogen + 1 volume of oxygen proed are placed to the right duces 2 volumes of water vapor, calculated at the same temtances are brought togethe perature and pressure. The water must be in the gaseous eact upon one another, an state. ve" or "produce" the sul

2. Hence, from Avogadro's law 2 molecules of hydrogen + 1 he equation. The number molecule of oxygen produces 2 molecules of water vapor at r formula denotes the num the same temperature and pressure.

placed at the base of each 3. 4 by weight of hydrogen $(2 \times 2) + 31.92$ (2×15.96) by weight of oxygen produces 35.92 by weight of water vapor. This proportion holds, no matter in what denomination weights are expressed—pounds, ounces, or grams.

The proportions by volume do not hold true unless substances are in the gaseous state.

This should be followed by the consideration of a problems in chemical arithmetic.

§ 11. GRAPHIC FORMULÆ OF VOLATILE COMPOUNDS.*

It will now be in order to study the graphic formulae compounds. The valency is indicated by means of lines proximity to the symbol, and may be drawn in any convenie position.

The'molecule of hydrogen is H-H, the atom H-



* From Bailey's "Tutorial Chemistry."

er in what denomination therer, in which valency is not exercised to the full extent; ounces, or grams.

ate.

the consideration of a few comes of hydrogen, and in acetylene with one.

VOLATILE COMPOUNDS.*

udy the graphic formulæ d dicated by means of lines i y be drawn in any convenier

Carbon dioxide. Ammonia ΗH

Ń

 \mathbf{H}

toxide. D

Ň

have already considered certain compounds, how

al Chemistry."

ese are termed unsaturated compounds. For example, in do not hold true unless the arsh gas carbon is associated with four atoms of hydrogen, hile in ethylene each atom of carbon is associated with two Thus:

H-C-H	C-H
$\mathbf{H} = \mathbf{C} = \mathbf{H}$	∭ C—H
Ethylene.	Acetylene.

It is assumed in such cases that certain valencies are suppressed or latent. Carbon monoxide and nitric oxide are also examples of latent valency.

=C=0

-N=0

Carbon monoxide. Nitric oxide.

Such bodies are usually characterized by the ease with hich they enter into further combination with elements groups of elements to form saturated compounds. Ethyene in the presence of chlorine gas forms ethylene dichloride, $_{2}H_{4}Cl_{2}$, commonly known as "Dutch liquid," and chlorine nites directly with carbon monoxide to form $(COCl_2)$ phosene gas; nitric oxide unites readily with ferrous salts, and with chlorine; in the former case it is used as a test for nitric

exide, and in the latter it forms nitrosyl chloride (NOCl).

There is another problem which every teacher must have Why, for example, does the body A react upon the met. body B, and produce the bodies C and D? Few students have not asked the questions, How can I predict when A will react upon B? and, If the bodies A and B react upon one nother, what substances will be produced? The answer lies t the very foundation of analytical chemistry, and it may be long time before we can say to the beginner, "This reaction vill take place, because," etc. Nevertheless, every teacher hould become familiar with the developments in physical chemistry throwing light upon this interesting question.

CHAPTER II.

HOW TO HANDLE NOXIOUS GASES IN THE OPEN LABORATORY.

THIS is a very important question, as the health of experimenter often depends upon the judicious handling noxious gases produced in his work. No student or teac can retain his health in an atmosphere which is vitiated w sulphuretted hydrogen, chlorine, nitric oxide, or with fumes of strong acids which are constantly used in the labo When the general health of a class in practical che tory. istry is imperilled, it becomes a very serious question. So instructors may not be willing to admit it, but it is, new theless, a fact, that any teacher who attempts to handle, permits his pupils to study, noxious gases by following t methods described in our ordinary text-books, takes a su course of destroying his own health and that of the studen he has under his charge. Since this is the case, it is n surprising to find that many contend that practical wo should not be attempted in a laboratory which is not su plied with suitable draught cupboards; and I am inclined think that is the proper position to take, if other means ca not be found to overcome the difficulty. Having had son experience in such a laboratory, I set about to devise a simp method of overcoming the difficulty, and happily succeeded so far as it is possible to succeed without incurring very grea expense, as the following plan will show.

ER II.

KIOUS GASES IN THE ORATORY.

uestion, as the health of t on the judicious handling

sphere which is vitiated with e, nitric oxide, or with the constantly used in the labor of a class in practical cher very serious question. Son (L) o admit it, but it is, neve who attempts to handle, d tious gases by following the ary text-books, takes a sur Ith and that of the student e this is the case, it is no ontend that practical worl boratory which is not sup

HOW TO HANDLE NOXIOUS GASES.

§ 1. SULPHURETTED HYDROGEN IN QUALITATIVE ANALYSIS.

Sulphuretted hydrogen, for example, is used so extensively in analytical work, that it becomes absolutely necessary to ave a convenient method of disposing of the surplus gas. this is the end I have had in view in all experiments described n this chapter. To overcome the difficulty, I have found it bsolutely necessary to use rubber tubing and rubber stoppers. It may not always be easy to make the tubing and corks to fit; but some hints are given at the end of the book which will aid in this respect.

Take a large glass jar, and fit it with a double perforated rubber stopper, or what is better, use a Wolff bottle, with work. No student or teach two necks, which will hold one or two quarts. Place in the



necks of the bottle (Fig. 6, a), perforated rubber stoppers (b) and (c). Through one (b) pass a glass tube (d), which fits tightly in the stopper, and which passes to the

pards; and I am inclined the (a). Through the other stopper pass a short glass rod, to take, if other means ca and connect this rod by a rubber tube (e) about twelve inches ifficulty. Having had son long to a test-tube or bottle (h), in which the solution to be set about to devise a simp precipitated is placed. In the mouth of this test-tube or ilty, and happily succeeded bottle place a double perforated stopper. Through one perwithout incurring very greatoration pass a long glass tube (g), which reaches nearly to the bottom of the test-tube, and through the other perfora-

tion a piece of tubing (f), long enough to connect with tubing (e) of the Wolff bottle. Connect the longer glass (g) with the flask or test-tube (k, fitted with a performander of the stopper <math>(l) and glass tube), in which the gas is mathematical. See that all stoppers are air-tight.

Now fill the jar (a) with water, and place in a tank deep plate, to gather water which flows from the tube Place the solution to be tested in the test-tube (h), and go rate the gas in the test-tube or Florence flask (k). The passes through the solution in (λ) , and the surplus gas pass into the jar (a), forcing the water up through (d). It is h to have the tube (g) so that it can be pulled up and do easily through the stopper. When the solution has be tested remove the test-tube (h), and put an empty test-tu or one containing a little water, in its place, so as to wash any solid formed on the glass rod.

For a test-tube rack, a couple of quinine bottles, or tin ca about six inches deep, with cotton batting in the bottom, a very convenient to keep the test-tubes in place.

Sulphuretted Hydrogen Water.—To manufacture hydrog sulphide water, place a quinine bottle fitted with a doul perforated rubber stopper in place of the tube (h). Fill with water, and let the gas bubble up through it as long desired.

Chlorine water, ammonium sulphide and hydrogen iodi may be manufactured in the same way.

If the stoppers fit tightly it is possible to handle any g without allowing it to escape into the room.

From what has been stated, it will be observed that st dents may study many gases with a modified form of th apparatus, as shown in Fig. 7. This is the case with hydr gen, oxygen, nitrogen, monoxide, etc.; but to make a succe of chlorine, hydrogen sulphide and sulphur dioxide, apparatu similar to that described in Fig. 6 must be used. Each pair

vater, and place in a tank of hich flows from the tube (d) in the test-tube (h), and gen

§ 2. NITROGEN MONOXIDE.

r Florence flask (k). The gap Place the ammonium nitrate in the test-tube or Florence

), and the surplus gas pass flask (a), Fig. 7, which is er up through (d). It is befitted with a perforated can be pulled up and dowrubber stopper and short When the solution has been ass tube, and connected , and put an empty test-tubby a rubber tube (c) to the in its place, so as to wash cominine bottle (e), fitted d. with a rubber stopper, and

of quinine bottles, or tin casone short and one long on batting in the bottom, appece of glass tubing. Fill tubes in place. the bottle (e) with water

.-To manufacture hydroge The gas will pass through bottle fitted with a double), and force the water ace of the tube (h). Fill up through the tube (f).

uphide and hydrogen iodid e way.

is possible to handle any ge the room.

it will be observed that st ith a modified form of th This is the case with hydr etc.; but to make a succe d sulphur dioxide, apparatu 6 must be used. Each pai

ng enough to connect with the students should have test-tubes, quinine bottles and a large Connect the longer glass tubes jar, fitted as in Fig. 6; also an extra stopper, to attach to (k, fitted with a perforate surplus jar, as in Fig. 9, and test-tubes fitted, as in Fig. 8. be), in which the gas is many experience has shown that it is best to use quinine bottles in

HOW TO HANDLE NOXIOUS GASES.

ace of (h) Fig. 6, when studying the properties of chlorine, lphur dioxide or hydrogen sulphide.



le up through it as long and it is desired to wash the gas with ferrous sulphate and sustic potash, test-tubes may be used for wash bottles, and



FIG. 8.

connected as in Fig. 8. When one bottle is full q remove the stopper, cover the bottle with moist mica or and insert the stopper in another bottle full of water many bottles as required may be prepared in this way. reaction ceases, it will be an advantage to remove the st (b) from the test-tube, place the thumb over the apert the stopper and quickly drop it into a bottle of water. will prevent the air from mingling with the prepared A little water may be left in one of the bottles, and sh up with the gas, to show its solubility in cold water. Ob that air bubbles back through the tube (f).

§ 3. NITRIC OXIDE, CARBON DIOXIDE, OLEFIANT Gas, etc.

Use apparatus similar to that in Fig. 7. The copper, w water and nitric acid may be placed in the test-tube (a), the gas collected in the bottle (o), as in the case of nitro monoxide. A little water may be left in one of the bot and shaken up with gas, so that it may be tested with lit paper, both before and after air is allowed to mingle with gas. When a bottle is filled, or when reaction ceases, proc



46

as in the case of nitrogen monoxide. further experiments see any pract text-book. It is best to have a jar Wolff bottle ready, with tube and co attached, as in Fig. 9, so that when flask is disconnected the surplus gas m be passed into the Wolff bottle if to reaction has not ceased. If care

FIG. 9.

taken nitric oxide may be prepared wi out allowing any of the gas to escape into the room.

Carbon dioxide, carbon monoxide, marsh gas, olefiant g and acetylene may be handled in the same way. It is som

HOW TO HANDLE NOXIOUS GASES.

When one bottle is full quickles desirable to show how marsh gas and olefant gas act bottle with moist mica or glason chlorine. In the case of marsh gas, it is best to parnother bottle full of water. Ally fill a bottle or jar with the gas. Then remove the be prepared in this way. Wheoper from the generating flask and place in a test-tube in advantage to remove the stopphich chlorine is generated, and fill the bottle by forcing the thumb over the aperture at the rest of the water. Quickly attach the generating it into a bottle of water. Thak to surplus jar (Fig. 9). In the case of ethylene, it is ingling with the prepared gist to have the olefant gas and the chlorine prepared in one of the bottles, and shakeparate bottles, using apparatus Fig. 7.

the tube (f).

BON DIOXIDE, OLEFIANT ETC.

t in Fig. 7. The copper, wapey are equal in placed in the test-tube (a), aolume is to pre-(a), as in the case of nitrogate a quinine be left in one of the bottottle full of the t it may be tested with litmases, as in Fig. ' is allowed to mingle with thand insert a t when reaction ceases, proceedible perforatuse of nitrogen monoxide. For rubber stopperiments see any practice. Through one It is best to have a jar certure pass a e ready, with tube and corunel (with a s in Fig. 9, so that when the pcock if possiponnected the surplus gas me), and through

§ 4. CARBON MONOXIDE, WHEN PREPARED FROM OXALIC ACID.

When carbon monoxide is prepared from oxalic acid, it is ixed with carbon dioxide. A good method of showing that



into the Wolff bottle if the other aperture pass a short glass tube, and attach with s not ceased. If care tuber tubing to a wash bottle (test-tube) containing KOH, oxide may be prepared with then to another quinine bottle filled with water, and cape into the room. ranged as in Fig. 10. Pour mercury into the funnel, and tide, marsh gas, olefiant give the gas slowly through the caustic potash into the the same way. It is someond bottle (b). Take the precaution to determine the

volume of the bottles (a) and (b) when filled with wat means of a graduate. The quantity of water remaining may be measured after the gas has been washed, if the b are not equal in size. A still better method of perfor this experiment would be to fit up apparatus as describ the chapter on Gas Analysis.

§ 5. CHLORINE, ITS PREPARATION AND PROPERTIES.

In handling this gas it is best to use apparatus Fig. 6. however, only one bottle is required, it may be prepared apparatus Fig. 7, and then attach the generating flas surplus jar Fig. 9, but experience has shown that stud are not likely to prepare more than one bottle without aling the gas to escape when using apparatus Fig. 7. For reason it becomes a necessity to use apparatus Fig. 6. experiments with chlorine may be divided into two series.

In the first series of experiments use a test-tube or qui bottle in place of (h) Fig. 6. Fill the large jar (a)water. Prepare the gas by placing manganese dioxide hydrochloric acid in the test-tube (k). Let the gas through the empty test-tube (h), or better, have a little w in the bottom of the test-tube or bottle, but not enoug! have the gas bubble through it, and permit the surplus ga pass into the jar (a). Quickly remove the test-tube, place thumb over the mouth, and shake up with the cold wa and quickly insert a test-tube or bottle full of water in place, and let the gas bubble through this for some ti (When showing that the gas is soluble, without removing thumb invert the test-tube and drop it into a bottle of wat After the water in the second test-tube is saturated rem it, and put test-tubes containing solutions of logwood indigo in its place, to show the bleaching properties of gas. Into a fourth test-tube place a piece of printed pap

 $\mathbf{48}$

ARATION AND PROPERTIES.

HOW TO HANDLE NOXIOUS GASES,

(b) when filled with water, lich has been moistened, and on which words are written antity of water remaining in the lead pencil and ink; let the gas pass over this for some s has been washed, if the botte. Another test-tube might be filled, to show the action l better method of perform he gas on a piece of blotting paper soaked in turpentine. it up apparatus as described the chlorine water may now be used to show its action

oon the oxides of lead, what happens when it is placed in night and when it is mixed with a solution of sodic hydrate id evaporated.

st to use apparatus Fig. 6. To prepare some dry gas, use apparatus Fig. 8. Place the uired, it may be prepared uphuric acid in one test-tube. The dry chlorine will pass ttach the generating flask to the second test-tube. Into this test-tube put a piece of ence has shown that studelico, and let the gas pass over it for some time. Quickly than one bottle without allmove the calico, moisten it, and replace in the dry chlorine. ig apparatus Fig. 7. For (at any time during this experiment the gas ceases to come to use apparatus Fig. 6. I from the generator, pinch or clamp the rubber tubing be divided into two series. tween the test-tube and the surplus jar, so as not to allow ents use a test-tube or quine gas to become moist, from the water in the receiver. Fill the large jar (a) which is very important.

acing manganese dioxide In the second series of experiments use a quinine bottle in Let the gas peplace of test-tube (h), and force the air into the surplus , or better, have a little was jar. Quickly remove the bottle when full, cover it with or bottle, but not enough nece of moist mica or invert it on a sheet of moist paper,

and permit the surplus gas remove the test-tube, place ake up with the cold way r bottle full of water in through this for some ti oluble, without removing lrop it into a bottle of wat est-tube is saturated rem ng solutions of logwood bleaching properties of ace a piece of printed paper. 11.

and put an empty bottle in its place. Test bottles of the gas prepared in this way, by shaking into it powdered arsenic, and by lowering into it a piece of glowing charcoal and a lighted taper.

It cannot be too often impressed upon the student that he must put a test-tube or bottle in the place of (h) as soon as it is removed. If this precaution is taken, the gas can be handled without allowing any of it to escape.

To show the action of sunlight upon chlorine water, invert a test-tube full of the solution in an

evaporating dish, or use a tube scaled at one end, similar Fig. 11. Fill with chlorine water and place in sunligh This experiment, which is recommended in some text-books is more interesting because it illustrates an important principle in physics.

Hydrochloric Acid Gas.—To prepare this gas use apparatu Fig. 6, and as in chlorine, use the test-tube (k) as a generato Fill as many bottles as required, by placing empty bottles is place of (h). To neutralize caustic soda place the solution is the test-tube or bottle (h), and let the gas pass through it for some time, allowing the surplus gas to pass into the receive

For further experiments see any Practical Chemistry.

Potassic Chloride and Potassic Chlorate.—When preparin KCl and $KClO_3$ use apparatus Fig. 6. Place the hot or co caustic potash in the test-tube (h), and let chlorine gas par through it as long as desired. It will be observed that the potash may be kept hot while the gas is passing through it.

Bleaching Powder may also be prepared by using the same apparatus, Fig. 6. Cover the inside of the bottle (h) will slaked lime, and pass chlorine gas through it as long as nece sary, collecting the surplus gas in the receiver (a).

§ 6. Hydrogen Sulphide, its Preparation and Properties.

The Preparation of the Gas.—It is sometimes difficult a prepare hydrogen sulphide quickly and in small quantitibut the chief difficulty, no doubt, arises from the sulphide iron. The following is a simple method which I saw appla recently, for the first time. Take some powdered sulphide iron, and prepare the gas in the ordinary way, or pour so water upon it and let it stand for a time—a few hours, possible. Then pour off the surplus water, just leaving a sulphide covered. Now add a few drops of sulphuric act

HOW TO HANDLE NOXIOUS GASES.

CHEMISTRY.

aled at one end, similar and, without heating, the gas instantly comes off. When ter and place in sunlighthe action has ceased, pour off the surplus solution, and pour hended in some text-bookinto the test-tube a quantity of clean water, and let it stand instrates an important primaril next required. Now pour off the surplus water and add

and. This is an excellent plan where the gas is frequently epare this gas use apparaturquired and in small quantities. It not only saves the test-tube (k) as a generatorouble of heating, but always ensures success. It may be by placing empty bottles increasing to prepare the gas by heating the first time; after e soda place the solution that, wash and keep the sulphide covered with clean water, the gas pass through it fand no trouble will be found.

as to pass into the receive The Properties of the Gas.—In handling this gas always use y Practical Chemistry. apparatus Fig. 6. Prepare the gas in the test-tube (k). Fill Chlorate.—When preparitive receiver (a) with water, and use test-tubes or quinine ig. 6. Place the hot or cooottles in place of (h). Quinine bottles are in many respects), and let chlorine gas proster than test-tubes. Into the test-tube (h) place a small It will be observed that trunnity of water, but not enough to have the gas bubble gas is passing through it. Hrough it. Now fill the test-tube with gas, by forcing the prepared by using the same into the receiver (a). Remove this test-tube, put the haside of the bottle (h) withomb over the mouth, and quickly put another test-tube in through it as long as neces place. Shake up the gas in the first test-tube, to show its the receiver (a).

ITS PREPARATION AND IES.

abe and drop it into a bottle of water. Dip some pieces of thite paper into a solution of lead acetate, and place one of

Its. here into another test-tube. Now remove the second test-It is sometimes difficult use of gas, and put the one containing the paper soaked in ally and in small quantiticetate in its place. Bring the second test-tube as quickly as the arises from the sulphideossible to the flame of the gas jet. When the hydrogen nethod which I saw applulphide ignites place over the burning test-tube a dry quinine e some powdered sulphideottle, and observe that moisture and sulphur dioxide are ordinary way, or pour sormed. Remove the third test-tube and put in its place a for a time—a few hours, st tube full of water, and let the gas pass through it for a plus water, just leaving me. Now remove the sulphuretted hydrogen water, and ew drops of sulphuric acut in its place solutions of copper sulphate, mercuric chloride,

lead acetate, etc. Replace the generating flask with one gena erating chlorine, and pass some chlorine into the receiver, and through a solution of H_2S . Let a drop of the solution h fall on a silver coin, and use some of it to precipitate acid and alkaline solutions of different metals. Some ammonium sulphide might also be prepared by passing the gas through ammonium hydrate. Do not forget to replace one test-tube by another as quickly as possible; upon this will depend your success in handling the gas. Tight-fitting rubber stoppers must be used in these experiments. Never leave the apparatus open for an instant.

n

re

b

b

§ 7. SULPHUR DIOXIDE : ITS PROPERTIES.

The same apparatus must be used in handling this gas as in hydrogen sulphide and chlorine (Fig. 6). Use test-tube or quinine bottle in place of (i). Fill the receiver (a) with Heat copper clippings and sulphuric acid in the testwater. tube (k), and proceed as in other gases. Place about half an inch of cold water in the test-tube (h), and force the air into the receiver, without allowing the sulphur dioxide to bubble through the water. Quickly remove the test-tube, placing the thumb over the mouth, and put a second test-tube in its place. Shake up the first test-tube, to show the acidity and solubility of the gas. Replace the second test-tube with one containing a highly colored flower. Test for the inflammability of the gas. Remove the third test-tube containing the flower, and put in pure air. Quickly replace this test-tube with solutions of logwood, indigo and potassium permanganate in succession. Now pass the gas through a test-tube full of water, and when it is saturated replace it with an empty test-tube. Test for the properties of sulphurous acid.

This gas is much easier to handle than hydrogen sulphide, and for that reason it is best to study its properties before

HOW TO HANDLE NOXIOUS GASES.

MISTRY.

ing flask with one genine into the receiver, a drop of the solution to precipitate acid and Some ammonium sulsing the gas through o replace one test-tube a this will depend your tting rubber stoppers ever leave the appara-

PROPERTIES.

in handling this gas as 6). Use test-tube or the receiver (a) with phuric acid in the test-

Place about half an and force the air into ohur dioxide to bubble the test-tube, placing econd test-tube in its o show the acidity and nd test-tube with one est for the inflammaest-tube containing the replace this test-tube potassium permanganhrough a test-tube full place it with an empty lphurous acid.

n hydrogen sulphide, its properties before attempting to prepare sulphuretted hydrogen. The student needs some practice before studying gases like chlorine and hydrogen sulphide. If only one bottle of sulphur dioxide is required, it may be prepared by using a test-tube and a bottle arranged as in Fig. 7.

Other gases may be studied in the same way. Enough has been given to show the plan.

CHAPTER III. HINTS ON APPARATUS.

§ 1. APPARATUS TO ILLUSTRATE COMBUSTION.

It is very important to have good experiments to sho that combustion is a chemical action, in which at least tw substances are equally concerned, but the descriptions of suc experiments are not always satis⁶actory. I have found th following method, which I devised, to work exceptionall well.

For this purpose use Wolff bottles (α) and (c), Fig. 1. One jar should hold about one and a half or two quarts, and



the other about one quart. Fit the necks of the larger jar and one neck of the smaller jar with perforated rubber stopper. Through one neck of the larger jar (a), place a funnel with stop cock (b). To the other neck at tach rubber tubing of good length and a glass rod eighteen inche long drawn out to a fine point (d)

Through one neck of the smaller jar place a wide glass tub (e)—a part of a medium-sized test-tube does very well. Fi it tightly, by placing around it some adhesive plaster. This is to prevent the bottle breaking when the gas is burning.

If you wish to burn oxygen in coal gas, connect the neck (f) of the jar (c) with the gas supply, and when the air is

R III. PARATUS.

STRATE COMBUSTION.

ien the gas is burning.

HINTS ON APPARATUS.

riven out, ignite the gas at the tube (e). Fill, or partly fill, the Wolff bottle or jar (a) by forcing out the water, as in Figs. and 7. Pour water into the funnel (b), and force the gas brough the tube (d). Slowly lower it through the tube (e), aking care that it ignites as it is passed down. To reverse the experiment, connect the tube (d) with the gas supply, nd when ignited lower into the jar of oxygen (c).

A much more difficult experiment is to burn chlorine in bydrogen. Arrange the apparatus as in Fig. 13. Fill the good experiments to sho per (a) with chlorine by displac-

ction, in which at least twing the water, and arrange the but the descriptions of suc tunnel (b), the rubber tubing "actory. I have found the and the glass tubing (d) as in sed, to work exceptional the figure. Connect the second jar (c) by means of a perforated ottles (a) and (c), Fig. 1: topper and glass tubing with d a half or two quarts, an Florence flask, in which hydroher about one quart. Firmen is generated. Invert as in cks of the larger jar and c). When all the air is driven (A) eck of the smaller ja out ignite the hydrogen gas at erforated rubber stopper the mouth of the wide glass tube. h one neck of the large Now force the chlorine very slowplace a funnel with stop y out of (a)—the smaller the



). To the other neck at stream of gas the better-and slowly pass it through the wide bber tubing of good length class tube in the neck of (c), but be careful to see that it glass rod eighteen inche gnites. Do not let the chlorine mingle with the hydrogen wn out to a fine point (d) onless it is ignited. When the gas burns in (c) increase the r place a wide glass tub force in the funnel (b). It is possible to burn chlorine in the tube does very well. Fi far (c) without having it connected with the flask in which ne adhesive plaster. This the hydrogen is generated, but it is not satisfactory. Air may be burned in coal gas in the same way, with a little coal gas, connect the neck practice. The advantage of this method is that you can oly, and when the air is regulate the supply.

§ 2. How TO FILL THE EUDIOMETER.

The eudiometer commonly used in our schools consists of straight graduated tube closed at one end, and it is not convenient to pass into it a fixed volume of gas. For example if a fixed volume of chlorine has been placed in the eudiometer, it is not easy to pass into it an equal volume of hydrogen In most cases the gas may be passed through the wash bottle and drying tube and into the eudiometer from the flask in



FIG. 14a.

which it is generated. Arrange apparatus as in Fig. 14*a*. As in the diagram, attach to the drying tube (*a*) a rubber tube, in the middle of which is a rubber bulb (*b*), with or without valves, which may be purchased from any druggist. If necessary, attach the other end to the surplus gas jar, and let the gas pass through the apparatus until you are absolutely certain that the tube and bulb are filled with pure dry gas. Then disconnect, and insert a short piece of glass tubing in the end of the rubber tube, and put it into the dish contain ing the eudiometer. Close the stopcock (*c*). When the rubber bulb is full of gas, press gently, so as to drive out any giv in the glass tubing. Then insert the tube under the mouth of the eudiometer, and press on the bulb. Even the smallest volume of gas may be passed into the eudiometer in this way.

CHEMISTRY.

E EUDIOMETER.

in our schools consists of diometer from the flask is



HINTS ON APPARATUS.

This is the case even if the generator has ceased to give off ras. Be careful to see that the stopcock is closed before one end, and it is not cor pressing on the bulb. After forcing out the gas pinch the me of gas. For example ubber at the end nearest the eudiometer, so as not to allow een placed in the eudiom, the mercury to flow back into the bulb; if the generator has equal volume of hydrogen ceased to act, pour water or acid into the funnel, so as to fill d through the wash bottle the bulb with gas. Even a gas like chlorine may be passed nto the eudiometer in this way. When it is desired to repeat he experiment a number of times, fill a

uinine or other wide-mouthed bottle (Fig. 4b) with gas. To do this, insert a rubber topper with three perforations. Through ne pass a funnel. Into the second perforaion put a long glass tube, reaching nearly the bottom of the bottle, and into the hird place the drying tube, to which is ttached the rubber bulb. The long tube nay be connected with the generator, and Il the air driven out of the apparatus. apparatus as in Fig. 14a if this is not satisfactory, fill the bottle



drying tube (a) a rubber with water or mercury. Attach the rubber tube with bulb rubber bulb (b), with or to the wash bottles of the generator, and force out the liquid chased from any druggist through the long tube. Now disconnect the rubber with the to the surplus gas jar, and pulb from the generator, and insert in the dish containing us until you are absolutely the eucliometer. Place a short piece of rubber over the long e filled with pure dry gas. ube, and clamp it. Pour mercury into the funnel, open the piece of glass tubing in topcock, and let some of it drop into the bottle. When the t it into the dish contain rubber bulb is full of gas, close the stopcock and insert the ock (c). When the rubber under the mouth of the endiometer. Press gently on as to drive out any ir in the bulb. While the hand is still on the bulb, pinch the tube under the mouth of rubber near the eudiometer, so as not to allow the mercury to ulb. Even the smallest low back; pour more mercury into the funnel, so as to force e eudiometer in this way, he gas into the bulb. The reason for using a rubber cork

with three perforations is because it is difficult to insert the funnel without allowing air into the bottle after it has bee filled with gas.

When passing air into the eudiometer it might be convenient to have a bulb with valves, but it is not absolute necessary. Use a drying tube and a rubber tubing with bul-Place the finger over one aperture of the drying tube, an force the air out through the other end by pressing on thbulb. Pinch the rubber tubing near the end, and let the air pass in through the drying tube. If valves are used on thbulb, they may be arranged as in an ordinary atomizer.

§ 3. Apparatus to Illustrate the Decomposition of Water and Hydrochloric Acid.

The apparatus usually sold for the decomposition of wate gets out of repair very easily. Fig. 15 shows a piece of apparatus, designed by the writer, which may be used for th purpose. Take a piece of glass tubing about the size of



test-tube or dryin tube, and have mad as in Fig. 15. Leav tubes (a), (b), (c) and (d) open. Have fitted into (b) and (c) two uniform test-tubes of equal size which will slip up and down easily, without per

mitting water to escape when the apparatus is filled. Use pieces of electric-light carbons, about one inch long, for electrodes, to place in the tubes (a) and (d). Make a groove if the earbons, to attach the copper wire, and insulate the wirwith sealing wax. Have air-tight stoppers, through which the conductors pass at the opening of the tubes (a) and (d)

HINTS ON APPARATUS.

CHEMISTRY.

an ordinary atomizer.

TE THE DECOMPOSITION OCHLORIC ACID.

as in Fig. 15. LeaverFig. 15).

 $\eta(D)$

slip up and dow The apparatus can-

easily, without period be used without apparatus is filled. Use stand. Figs. 16 ut one inch long, for elecand 17 show convend (d). Make a groove interest and s for this wire, and insulate the wireurpose. Take two stoppers, through which locks of wood of g of the tubes (a) and (d)

it is difficult to insert the When making the gases (in the dark, if necessary) invert the he bottle after it has bee test-tube in (c), so that the sealed end will come down nearly

to the carbons. Now incline the apparatus, and the mixed adiometer it might be compass will pass up (b). Attach a drying tube, rubber tubing es, but it is not absolute and bulb (as in Fig. 14a), and pass the gases into the eudiomea rubber tubing with bul ter and explode. Thus it will be seen that the analysis and are of the drying tube, an evothesis of a compound may be shown in one experiment. her end by pressing on the this cannot be done unless the gases come off in the proper ear the end, and let the air roportions. When decomposing hydro hloric acid, some If valves are used on the ext-books recommend mixing one volum of concentrated hydrochloric acid with ten volumes of a sabarated solution of common salt. This is not satisfactory, unless the current passes through the mixture until it becomes thoroughly saturted with chlorine, which takes considerable time. In most the decomposition of wate eases it will be found more convenient to prepare the gases Fig. 15 shows a piece exparately, and pass into the eudiometer.

which may be used for the The best method of filling the apparatus is to put a stopper ubing about the size of $\frac{1}{10}$ the aperture (a), put the test-tubes into place; pour the test-tube or dryin plution into (b), slightly tilting, until completely full. Then tube, and have made lowly slip the electrodes into position, as in the diagram

tubes (a), (b), (c) and Should the apparatus be used to decompose salts, fuse (d) open. Have fittle necess of platinum, one inch long and half an inch wide, to into (b) and (c) two opper wire, and insulate the wire. Place the platinum tips uniform test-tubes (a) the apertures (a) and (d). This apparatus can be cheaply equal size which winade by any glass-blower. It prevents leakage, etc.



FIG. 16.

similar size, and cut grooves in them, as in the diagram that the apparatus will be held in place when the blocks brought together. They may be held in place by two driven into one side, and holes placed opposite in the o



The apparatus stand will then it the appearance Fig. 17. It will observed that a ratus Fig. 15 can used for the dec position of water of hydrochloric a electrolysis of sa

and to show there is a back current when disconnected fr the battery and attached to the galvanometer.

§ 4. APPARATUS TO ILLUSTRATE BOYLE'S LAW.

The apparatus now recommended for this experiment to take a tube about 25 cm. in length, and closed with a sto cock. Connect this with a rubber tube not less than .50 c long and a glass tube about 50 cm. long. Place on a grad ated support, etc. Take the reading of the barometer.

I have constructed a modified form of this apparatus which is much easier to make, as it does away with the graduate support. Take a uniform tube sealed at one end, about 30 cm long, or use a thistle tube with stopcock. Connect this is means of a heavy rubber tube about 30 inches long with long glass tube about 70 cm. in length. Take narrow strip of paper and graduate with the centimeter scale. Place the strips on the tubes with starch paste or fish glue. The apparatus will now appear as in Fig. 18.

Wrap the joints firmly with string. As it is necessary to



galvanometer.

STRATE BOYLE'S LAW.

ength, and closed with a store required amount of air in (b). er tube not less than 50 cm Let us suppose we have 10 c.cm. when

Fig. 18.

HINTS ON APPARATUS.

n them, as in the diagrams, we the tube with pure dry air, attach a rubber bulb and dry-d in place when the blocks any tube, as in Fig. 14, to the longer tube, and force the dry be held in place by two per through it and the rubber tube until you are sure the s placed opposite in the other paratus is filled with dry air. Now close the stopcock in

The apparatus and. If the tube (b) is sealed at the end stand will then have will be necessary to fill the longer glass the appearance where and rubber with air before attaching Fig. 17. It will be tube (b). Now fill the tube (b) with observed that approver and attach the rubber tube. ratus Fig. 15 can Firmly wrap the joint with a string. used for the decomput some mercury into (a), but in doing position of water and do not allow the air in the room to of hydrochloric actiongle with the dry air in the tube. electrolysis of salutace the tube (b) on the floor. Hold (a)rent when disconnected from right and gently raise the tube (b) and then the rubber tube alternately until the required amount of air is in (b). When toing this lift the rubber about the ended for this experiment intre. In this way it will be easy to get

m. long. Place on a grade mercury is the same level in (a) and (b), and that the rometer stands at 75 cm. Pour about 50 c.cm. into (a). form of this apparatus which adually lower the tube (b) until the volume of the enclosed bes away with the graduater is 5 c.cm. The apparatus will now be as in Fig. 19. aled at one end, about 30 currents the level of the mercury in (b) on the rubber tubing at stopcock. Connect this line point (c), Fig. 19. Now raise the tube (b), and with it about 30 inches long with masure the distance from (c) on the rubber to (o) on the length. Take narrow strippinger tube (a), which we will suppose is 30 cm. This would entimeter scale. Place thanks the difference of level 75 cm., which should be the paste or fish glue. Theme as the barometer.

Now lower the tube (a) as in Fig. 20. Observe the differing. As it is necessary there in the level of the mercury in (a) and (b) when the



volume is 20 c.cm. This should be 37.5 cm. Use the t(a) as a graduate for measuring the difference in the level.When made in this way the apparatus need not cost m

than 30 or 40 cents, and can be made any teacher. I think it is much hand than with the stand.



§ 5. Apparatus to Illustrate the Law of Charles.

For this purpose use apparatus similar to Fig. 19. The tube (b) need not be graduated and may be much shorter Fill the tubes with dry air as in apparatus to illustrate Boyle law, and pour enough of mercury in (a) to bring it above the level of the rubber. Fit a rubber stopper, with three performances to the tube of the tube of the tube. Through one aperture pass the tube (b). Through the other performances the tube (b).

I think it is much handien it is level with that in (b). stand.



be 37.5 cm. Use the tubess short glass rods, one to allow steam to pass in, and the the difference in the level. oner for the steam to pass out, as in Fig. 21. Place (c) apparatus need not cost more a retort stand and attach (a) to another retort stand.) cents, and can be made berround (b) with snow and raise (a) until the mercury The gas

now under a pressure of one atmos Remove the melting snow by bere. connecting with a Florence flask of boilwater and pour mercury into (a)raise it if sufficient mercury is already the tube until the mercury in (b) ands at the same level as when the air as surrounded with snow. Observe the difference in the level of the mercury and calculate the increase in volume for each tegree of increase in temperature. For example, if the atmospheric pressure was



10 cm. and the tube (a) was raised 25.64 cm., the increase is volume would have been $\frac{2.5 \cdot 6.4}{70}$ had the gas been allowed co expand without increasing the pressure, because the volume of a gas varies inversely as the pressure

NOTE.—If the retort stands are not heavy enough at the se they may be clamped to the table.

§ 6. THE PERCENTAGE OF OXYGEN IN AIR.

E THE LAW OF CHARLES. In showing the composition of the atmosphere it is often is similar to Fig. 19. The ommended to invert a cylindrical jar over a jet of burning and may be much short-bydrogen, so that the mouth of the cylinder will be under paratus to illustrate Boyle ter in the dish. This may best be done by filling a jar or in (a) to bring it above the olff bottle with hydrogen. (A large bottle with a rubber stopper, with three performerk with two perforations does very well.) Put the perforouthed bottle. Through on ed corks with funnel having a stopcock and the connecting ough the other perforation ober tube in place. Pour water into the funnel and force

out the gas and ignite. Having placed the tube in positive lower the cylindrical jar over the jet, Fig. 22. The instathe flame goes out turn the stopcock in the funnel. The will ensure success as the gas can be regulated when burning



which cannot be done if comes from a flask when t gas is being generated. If Florence flask is used to ge erate the gas, have in t stopper a funnel with a sto cock. When the gas ju ceases to come off pour wat into the funnel and ignit Arrange as in Fig. 22. T gas may then be regulated

with a Wolff bottle. It also saves the trouble of filling a extra bottle. After the water has ceased to rise in the cyli der, slip a cover glass or mica cover under the jar and tu mouth upwards. The capacity of the cylinder and the amount of water in it may be measured with a graduate.

§ 7. The Diffusion of Liquids and Gases.

To show the diffusion of liquids through a membrane (osmose) it is sometimes difficult to tie a piece of parchmer paper or animal membrane over a funnel or thistle tub This may be conveniently done by tying on the membran as tightly as possible with twine. Then take a piece sealing wax and place it in boiling water until it becom plastic. While in this state remove it from the water an quickly place around the funnel at the point desired, the sealing the membrane to the glass so as to make it reasonab air-tight.

The same difficulty is sometimes experienced in fitting

which cannot be done if into the battery cell. omes from a flask when t as is being generated. If THE SOLUBILITY OF AIR AND AMMONIA GAS IN WATER. rrange as in Fig. 22. The experiment. sured with a graduate.

IQUIDS AND GASES.

so as to make it reasonab

s experienced in fitting

HINTS ON APPARATUS.

65

placed the tube in position forated stopper into a porous battery cell to show the he jet, Fig. 22. The instantification of gases. It is best to have a rubber stopper for ppcock in the funnel. Thesis purpose, but if one cannot be obtained an ordinary cork be regulated when burning be made air-tight with plastic sealing wax, and fitted

lorence flask is used to ge Ammonia Gas is Soluble in Water.-When working with rate the gas, have in the arge class, the simplest method of illustrating this is to topper a funnel with a storage some aqua ammonia in a test tube and over it place ock. When the gas just inverted empty test-tube. Heat the liquid until une eases to come off pour water pty tribe is full of gas. Remove it, and drop it mouth nto the funnel and ignin wnwards into a bottle of water. Have each student do

as may then be regulated *Air is Soluble in Water.*—In class work one of the best es the trouble of filling withods is to half fill an evaporating dish or mortar with s ceased to rise in the cylinter and into it place an inverted test-tube full of water in er under the jar and turnich no air is visible. Let the test-tube project over the of the cylinder and the e of the dish. Gently heat the test-tube above the edge of dish until the water is converted into steam and descends the test-tube. Now take away the lamp and allow the ter to rise. Repeat two or three times and allow the s through a membrane (e ter to cool. A bubble of air will be found at the top of b tie a piece of parchment test-tube. a funnel or thistle tub Surface Tension.—To cause a drop of oil to float in a mix-

y tying on the membran e of alcohol and water, half fill a test-tube with water, e. Then take a piece at put into it one or two drops of oil. Now pour in a little ng water until it become phol. The drop. of oil floats out into the mixture of the ove it from the water are ne density as itself where its form may be studied. at the point desired, the ometimes used as an illustration of surface tension. This
CHAPTER IV.

A SIMPLE METHOD OF GAS ANALYSIS.

PERHAPS the simplest and most complete method of galaxies is the one originated by Prof. Hemphill, but the teacher of chemistry in a secondary school very often do not receive sufficient grant from a school board to purchat the most necessary apparatus, and although there are man times in his work when he would like to determine the different gases in a mixture which comes under his notic he has not the means at his disposal of satisfying h curiosity. If he wishes to overcome the difficulty, he mu either work with inferior apparatus of his own construction and be satisfied with unsatisfactory results, or he must purchase rather costly appliances such as Prof. Hemphill at his own expense, and this is something very often his ill able to afford.

This is the only excuse for submitting the followin simple and original method of gas analysis, as th apparatus employed is such that most teachers have a their disposal, or that can be purchased at a small cos

Take two \cup tubes used for drying gases with calciu chloride. The shape of the tubes is immaterial, but it woul be convenient to have one of their similar to (b) Fig. 2: having the neck between the bulbs aarrow so that the ga will not pass through it when their washed. It is best to have the other tube with a steppoek in one arm similar to F CHEMISTRY.

ER IV.

F GAS ANALYSIS.

A SIMPLE METHOD OF GAS ANALYSIS,

67

that used for the analysis of hydrochloric acid, Fig. 1, or of be size and shape recommended for the determination of drogen in sulphuric acid, Ex. 7, § 2. One arm of each tube may be drawn out to a point so that the rubber tubing

ay be slipped over them onveniently. If the arms of the tubes are not drawn out to a point and one of them does not possess a stop-

ost complete method of g cock, they may by Prof. Hemphill, but the connected dary school very often do by rubber stopa school board to purchapers and a d although there are manual piece of ould like to determine thubing with a ch comes under his noticelimp placed disposal of satisfying how ween them ome the difficulty, he mu which us of his own construction purpose ctory results, or he mugnite well. s such as Prof. Hemphill The size of the tubes will

of gas analysis, as urchased at a small cost venient form. rying gases with calcius is immaterial, but it would eur similar to (b) Fig. 23 aurrow so that the ga ing washed. It is best to ck in one arm similar t



something very often largend upon the quantity of

serves

to be analyzed, but a tube submitting the following ich holds 75 or 80 c.cm. and theying stopcocks and graduated most teachers have a in Fig. 23 would be the most

Fill the tube (a) Fig. 23, with mixture to be analyzed. is may be done by connecting tube with a generator or gas

and letting the gas pass through it until all the air driven out. Pour water or mercury into the open arm.

FIG. 23.

A HAND-BOOK OF CHEMISTRY,

Then disconnect from the generator and allow the liquid become level in the two arms and close the stopcock.

Another method would be to close the stopcock and b tilting fill the closed arm with mercury or water so that will rise to the point (d) in the open arm. Then conne with the gas jar and open the stopcock. The liquid used wi come to a level in both arms. By regulating the quantity liquid with the stopcock or by removing some with a pipet from the open arm, the volume of gas desired will be obtained in the closed arm. Connect the tube (b) to (a) and by tiltin fill the closed arm with the solution to be used in washin until it reaches the point (c) in the open arm. Now open the stopcock and pour liquid into the open arm of (a) until all t gas has passed into (b). The solution will slowly rise in t open arm of (b). If all the gas does not pass over readil remove some of the solution from the open arm of (b) with pipette. When the gas is in (b), the tube should be lar enough so that the bulb of the closed arm will cutain sor solution. Place the thumb over, or put a rubber stopper in the open arm of (b) and by tilting wash the gas thorough Close the stopcock in (a) and remove the solution from t open arm until it stands at (d).

Now open the stopcock and pour some of the solution us in washing into the open arm of (b). By regulating t quantity of liquid in the open arm the gas will pass back in (a). If it is desired to accurately determine the volume gas remaining and (a) is not graduated, the gas may passed into a graduate and measured, making allowance f the tension of the aqueous vapor, temperature and pressure

The solution for washing the gas may now be removed an another solution put in its place for determining the next g in the mixture.

By having pieces of platinum wire fused into the graduate

A SIMPLE METHOD OF GAS ANALYSIS.

CHEMISTRY.

close the stopcock,

gas desired will be obtaine woorst, London. on to be used in washin on gases: open arm. Now open th pen arm of (a) until all t tion will slowly rise in t oes not pass over readiland $C_2 H_2$. the open arm of (b) with Sulphuric acid dissolves ammonia gas. put a rubber stopper in Ferrous sulphate (concentrated) dissolves NO. wash the gas thorough Cold water or alcohol dissolves N_2O .

some of the solution us sonlight.

tor and allow the liquid the be (a), it may be used as a eudiometer to explode marsh close the stopcock and be stop

69

nercury or water so that we only intended as an aid to those with limited apparatus. open arm. Then connectall information on the subject will be found in Hemphill's cock. The liquid used with Analysis, translated by Dennis and published by Macregulating the quantity millan & Co. ; also, Winkler's Hand-book of Technical Gas noving some with a pipet Analysis, translated by Lunge and published by John Van

ibe (b) to (a) and by tilting The following may be used in determining the more com-

A solution of pyrogallate of potash dissolves oxygen.

. 11 " caustic potash CO... An ammoniacal solution of cuprous chloride dissolves CO

the tube should be large Ammoniacal solution of silver nitrate dissolves C_2H_2 . sed arm will ϵ . tain sor the gas is also very soluble in water.

ove the solution from to Oxygen may also be determined by placing a piece of P in the tube containing the gas and setting the apparatus in the

(b). By regulating t Hydrogen is absorbed by palladium asbestos. Some of the the gas will pass back in \mathbf{n} betances may be put into a \cup tube of fine bore and placed determine the volume is a beaker of water kept at 100° C. while the gas is passing duated, the gas may grough the tube. Place this tube between the tubes deed, making allowance for the analysis of gases, in this chapter, and make emperature and pressure connections with short pieces of rubber tubing. Force may now be removed as gas slowly backwards and forwards over the palladium determining the next geneestos three or four times.

Marsh Gas (CH_4) has no absorbent and is determined by e fused into the graduate mbustion. 100 volumes of incombustible gas are taken for

A HAND-BOOK OF CHEMISTRY.

25 to 37 volumes of methane and oxygen to prevent t combustion of nitrogen.

Ethylene (C_2H_4) is absorbed by bromine water or 1 fuming sulphuric acid. The acid must be so concentrate that when the temperature is lowered crystals of pyrosulphur acid will separate.

Sulphuretted Hydrogen (H_2S) is determined by lease acetate, also by drawing the gas through iodine water, an potassium iodide with starch in it. The operation is stoppe as soon as the liquid becomes colorless.

Nitrous Acid (HNO₂) is determined with concentrat H_2SO_4 , or a solution of potassium permanganate acidulat with H_2SO_4 .

Sulphur dioxide (SO₂) is determined with KOH, or solution of iodine.

Bromine, hydrochloric acid and chlorine are also absorb by KOH.

Nitrogen has no absorbent.

A solution of KOH for testing is usually made by mixi one part of caustic potash and two parts of water.

An ammoniacal solution of silver nitrate is made by d solving some crystals of silver nitrate in distilled water an adding just enough aqua ammonia to redissolve the preciptate formed.

An ammoniacal or acid solution of cuprous chloride may made as follows: Cover the bottom of a bottle of two litre capacity with a layer of copper oxide three eighths of an ine deep. Place in beliefte a number of pieces of rather stor copper wire reacting from top to bottom. The bundle should be one inch in diameter. Fill the bot with common hydrichloric acid of 1.10 sp. gr. The bottle is occasionally shake and when the solution is colorless or nearly so, it is poured in smaller bottles containing copper wire. Care should be take

A SIMPLE METHOD OF GAS ANALYSIS.

F CHEMISTRY.

rless.

n permanganate acidulat

ermined with KOH, or

chlorine are also absorb

is usually made by mixi o parts of water.

er nitrate is made by d rate in distilled water an a to redissolve the precip

of cuprous chloride may om of a bottle of two litre ide three eighths of an ind er of pieces of rather stor pottom. The bundle shoul bot 9 with common hydr ottle is occasionally shake r nearly so, it is poured in vire. Care should be take

and oxygen to prevent the at the copper wire does not become entirely dissolved, and at the stopper is greased to keep out the air, as it turns the by bromine water or location brown and weakens it. To make ammoniacal cupd must be so concentrate mus chloride, treat the acid chloride with ammonia until a red crystals of pyrosulphur font odor of ammonia is perceptible. Copper should be kept it as in the acid solution.

5) is determined by let For a number of reasons the alkaline solution is preferable through iodine water, at the acid solution in determining CO.

. The operation is stoppe Pyrogallate of Potash.-Weigh out 5 grams of the solid and (pyrogallic). Place it in a reagent bottle, and pour upon ermined with concentrat it 100 c.cm. of potassium hydrate, made as al eady described.

A HAND-BOOK OF CHEMISTRY.

CHAPTER V.

GENERAL HINTS.

§ 1. MANY GENERAL SUGGESTIONS.

To perforate a rubber stopper, take an ordinary cork bore used for perforating cork stoppers, and heat it in the lam flame until it becomes quite hot. The stopper may then be easily and quickly perforated. A much better method is to use a solution of caustic potash as a lubricant on the borer.

It is sometimes difficult to attach a piece of rubber tubin to glass tubing. This may be done by wetting the glas tubing with water. The rubber will then slip over the glas quite easily.

When a piece of rubber tubing is larger than the gla tubing it is best to first place a short piece of rubber tubin half an inch long over the glass tubing. The first piece of rubber should be about the same size as the glass tubing. Then place the larger rubber tubing over the smaller piece This will make the joint quite air-tight.

Adhesive or surgeon's plaster will be found very valuable in the laboratory. It may be used to tighten stoppers is builtes or to make a piece of glass tubing air-tight in stopper. There are many ways in which it will be foun useful in fitting up apparatus, but it cannot be used whe heat is applied to the glass vessel.

In filling a narrow glass tube closed at one end witas mercury or any other liquid, i will often be found convenieur CHEMISTRY.

GENERAL HINTS. connect a thistle tube or funnel to the glass tube by means

RV.

INTS.

SUGGESTIONS.

of a piece of rubber tubing. When the narrow tube becomes obgged with the liquid and the air cannot force its way up, as to allow the liquid to descend, shove into the tube a bent piece of iron or copper wire of a zigzag outline. The more regular the undulations of the wire the better. Run the wire up and down quickly a few times. The liquid will descend quite rapidly and the tube may be filled in a short space of time.

Most noxious gases, such as carbon dioxide, freely dissolve ke an ordinary cork bore in cold water. That is why a room which is much occupied, and heat it in the lam such as a school-room or a bedroom, may be almost completely The stopper may then bearated by having a pail of cold water left in it over night. much better method is there the same reason the apparatus described in another lubricant on the borer. chapter for handling noxious gases may be constantly used a piece of rubber tubin without having any gas escape.

ne by wetting the glas To toughen glassware, lamp chimneys, etc., immerse them Il then slip over the glasin cold water to which some common salt has been added.

t piece of rubber tubin A burette or bottle, which is wet with water, may be dried

n which it will be foun it cannot be used whe

Boil the water well and cool slowly. Glass treated in this g is larger than the glasway will resist any sudden change of temperature.

The first pierby rinsing with alcohol, and then with ether, and blowing a e size as the glass tubin ourrent of air through or into it. Sometimes alcohol is all ng over the smaller piecethet is necessary if the glass is allowed to stand for a few unites after rinsing.

be found very valuable Sealing wax may be made plastic by placing it in boiling d to tighten stoppers in ter. When in this state it may be used for many purposes ass tubing air-tight in a fitting up apparatus and making it air-tight.

§ 2. CEMENTS.

Cement Proof Against Acids.-Take some India rubber closed at one end with melt it. Add about 6 or 8 per cent. by weight of acid often be found convenier keep stirred. Next day add lime until it becomes a soft

A HAND-BOOK OF CHEMISTRY.

paste and, lastly, add enough red lead to make it dry an harden.

A Fire-proof Cement for China and Glassware.—Into thick solution of gum arabic stir plaster-of-Paris until becomes the consistency of cream. Apply with a brush t both edges. In about three days it cannot be broken. Th cement is very white.

§ 3. TO REMOVE STAINS.

The teacher of science is so frequently asked for method of removing stains from clothing that the following which have been collected from various sources are given here.

Silver nitrate stains may be removed from the hands of from goods by washing in a strong solution of potassiu iodide or ammonia. Potassium cyanide is sometimes use but it is a violent poison and its use is attended with dange

The most obstinate stains of iodine may be removed b soaking them for some time in cold water and then soakin them over night in starch paste and rubbed. They may als be removed by a strong solution of sodium bicarbonate.

Stains caused by sulphuric acid and hydrochloric acid mabe removed by treating them with dilute ammonia or bicar bonate of soda to neutralize the acid, and then sponge with chloroform to restore the color. This will not do for nitriacid. Ammonia or bicarbonate of soda sets the stain. When intric acid falls on cloth theroughly sponge it, as quickly possible, with water and then with a little chloroform. If nitric acid stain is already formed there seems to be no wo of restoring the color.

Cream of Tartar and alcohol will remove grass stains fro the daintiest goods, as it never stains the most delicate shad

A strong solution of borax will remove oil stains free cotton and linen.

CHEMISTRY.

lead to make it dry an

and Glassware.—Into plaster-of-Paris until i Apply with a brush t cannot be broken. Th

STAINS.

uently asked for method hat the following which inces are given here. hoved from the hands of ig solution of potassiun anide is sometimes used is attended with dange ine may be removed b water and then soaking rubbed. They may also odium bicarbonate.

nd hydrochloric acid ma lilute ammonia or bica d, and then sponge with s will not do for nitri da sets the stain. Whe sponge it, as quickly a little chloroform. If there seems to be no we

remove grass stains from the most delicate shad remove oil stains from

GENERAL HINTS.

Boiling water poured through a cloth for some time will emove tea stains, cherry and many other fruit stains. If his does not succeed, turpentine will remove obstinate stains. Stains of iron rust may be removed by placing on them first some common salt and then some lemon juice. Wash at nee with cold water.

Ink, fruit and mildew stains may be removed by putting them first in cold water and then in half a pint of water to which a teaspoonful of lemon juice and half a teaspoonful of oxalic acid have been added. Afterwards wash with clear water.

Sulpharous acid will whiten undyed goods, straw, etc.

Goods dyed with aniline dyes and faded from exposure to the sun should be sponged with chloroform.

