THE

Chemist's

DUPLEX SLIDE RULE

COMPLETE MANUAL

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Drawing Materials, Mathematical and Surveying Instruments, Measuring Tapes

The decimal point being fixed by inspection, we have:

$$
\begin{aligned}
(a) &= 24.6\% \\
(b) &= 12.3\% \\
(c) &= 5.3\% \\
(d) &= 33.3\% \\
(e) &= 16.6\% \\
(f) &= 7.9\% \\
& \overline{100.0\%}
\end{aligned}
$$

THE CHEMIST'S DUPLEX SLIDE RULE.

The simplest and perhaps the commonest stoichiometric problem coming to the chemist is to find the weight of one element, radical or compound, equivalent to a given weight of another element, radical or compound. To do this the particular reaction involved must be known. Take the reaction:

$$
\begin{matrix} HCl & + & NaOH & = & NaCl & + & H_2O \\ 36.47 & & 40.01 & & 58.46 & & 18.016 \end{matrix}
$$

it being desired to know the weight of hydrochloric acid (HCl) equivalent to 5.000 grams of sodium hydroxide (NaOH). As the ratio of the molecular weights of these substances is the same as that of their reacting weights in grams, we have

$$
\frac{\text{Mol. Wt. of HCl} \quad (a)}{\text{Mol. Wt. of NaOH} \ (b)} = \frac{\text{Wt. in gr. of HCl} \quad (X)}{\text{Wt. in gr. of NaOH} \ (c)}
$$

When conditions are such, as in this, that two ratios are equated, a proportion results. To solve the problem before us, we have

$$
\frac{a}{b} \times c = X \text{ or } \frac{HCl}{NaOH} \times 5.000 = 4.56 \text{ gr. HCl} \equiv 5.000 \text{ gr. NaOH}
$$

in which the expression $\frac{HCl}{NaOH}$ represents the fraction made up of the molecular weights of HCl and NaOH, viz., $\frac{36.47.}{40.01.}$ This problem is one of direct proportion, in which class is included the great majority of problems coming to the analytical chemist. A proportion involves four terms consisting of two pairs, each member of the pair being of similar units. The other pair consists of like units but of dissimilar kind to the first pair. In such a problem, one term is lacking, the missing term being the unknown, the remaining three terms being known. To solve a problem in direct proportion, being given three terms: *Make a fraction of the two terms in similar units, placing that term representing the magnitude sought over the line (making it the numerator), place the other term of the same kind of unit under the line (making it the denominator); multiply this fraction by the third term of the dissimilar unit.*

For problems in inverse proportion, reverse the position of the terms in the fraction.

The Chemist's Duplex Slide Rule (see figures 7 and 8) is provided on its upper half with a number of graduations that are identified by the chemical symbols opposite them. The left index of the rule is marked "Sought", the left index of the slide is marked "Given". In the problem under consideration, hydrochloric acid is Sought, while sodium hydroxide is Given. To solve by the Chemist's Duplex Slide Rule:

Sought	Set HCl	
Given	Set NaOH	
C		Under 5
D		Find 456

The answer is 4.56 grams of hydrochloric acid, the decimal point being easily fixed by inspection.

In order to facilitate the location of the symbols on the two upper scales on both sides of the rule, these have been placed according to the following system:

Salts - - - - - - - - - -	*Regular*	side	*Short*	graduation	marks.
Acids and Bases - - - -	"	"	*Long*	"	"
Oxides - - - - - - - - - -	*Inverted*	"	*Short*	"	"
Elements - - - - - - - -	"	"	*Long*	"	"

The chemist knows approximately the atomic and molecular weights of the common substances and so knows in what region of the scale to look.

Example: What weight of sulphuric acid (H_2SO_4) is equivalent to 3.000 grams of potassium hydroxide (KOH)? The reaction is

$$H_2SO_4 + 2KOH = K_2SO_4 + H_2O$$

This comes to

$$\frac{H_2SO_4}{2\,KOH} \times 3.000 = 2.622 \text{ gr. } H_2\,SO_4 = 3.000 \text{ gr. KOH}$$

The solution with the Chemist's Duplex Slide Rule is

Sought	Set H_2SO_4			
Given	On KOH			
C		R to 3	2 to R	Under index
D				Find 2622

The answer being 2.622 grams.

Example: What weight of lead (Pb) is contained in 2.500 grams of lead chromate ($PbCrO_4$)? As lead is an element it is found on the inverted side, while lead chromate being a salt, it is on the other side; consequently both sides of the rule must be employed to get the setting $\frac{Pb}{PbCrO_4}$

This is

$$\frac{Pb}{PbCrO_4} \times 2.500 = 1.602 \text{ gr. Pb}$$

By the Chemist's Duplex Slide Rule

Sought	Set R to Pb			
Given			On $PbCrO_4$	
CI		C		Under 25
D		D		Find 1602

The operation given graphically above is very simple of manipulation. On the Inverted side the runner is set to Pb, the rule turned over, $PbCrO_4$ being brought under the runner on the front of the rule. Under 25 on the front is found the answer 1.602, the decimal point being fixed by inspection. The runner served to hold the position of the Pb so that the $PbCrO_4$ on the opposite side of the rule could be brought into coincidence with it. By this method both sides of the rule are available for use with practically the same facility as though they were on the same side.

From the above examples the operation of the Chemist's Duplex Slide Rule is apparent. *To the mark of the symbol of the substance desired on the upper scale, inscribed "SOUGHT," bring the mark of the symbol of the substance given on the lower scale (the slide), marked "GIVEN"; using the runner when necessary. With this setting complete the solution of the equation using the Regular or Inverted scales according to which will require the fewest settings.*

To obtain a Chemical Factor. Set the mark corresponding to the symbol sought on the upper scale inscribed "Sought" to the mark of the symbol given on the slide inscribed "Given"; take into account the number of molecules involved, and multiply or divide accordingly. Under the index is the factor.

Example: What is the factor for the conversion of barium sulphate ($BaSO_4$) into equivalent sulphur trioxide (SO_3)? The factor is

$$\frac{SO_3}{BaSO_4} = .34300$$

To obtain by the Chemist's Duplex Slide Rule:

Sought	Set R to SO_3			
Given			Bring $BaSO_4$	
CI		C		Under index
D		D		Find factor=.343

Example What is the factor for the conversion of ferric oxide (Fe_2O_3) into iron (Fe)? As there are two atoms of iron in ferric oxide, the factor is;

$$\frac{2\,Fe}{Fe_2O_3} = .699$$

The setting on the Chemist's Duplex Slide Rule is

Sought	Set Fe		
Given	On Fe_2O_3		
CI		C	Under 2
D		D	Find factor = .699

To find the molecular weight of a substance not inscribed on the rule. Chemical symbols are so numerous that it would be impossible to inscribe all on the Rule. The Rule includes the most important of these to the average chemist, the symbols on the Rule having been selected with great care. Too many symbols on the Rule are undesirable, as they would confuse the operator, making them hard to locate.

Example: What is the molecular weight of barium sulphite ($BaSO_3$)? Barium sulphite may be regarded as made up of the basic oxide, barium oxide (BaO), and the acidic oxide, sulphur dioxide (SO_2), being $BaO.SO_2$. To find approximately the molecular weight of this compound on the Chemist's Slide Rule:

Sought	Set R to BaO	Set R to SO_2
Given		
CI		
D	Find mol. wt.=153.4	Find mol. wt. = 64.1

The sum of these, 153.4 + 64.1 = 217.5 is approximately the molecular weight of barium sulphite. Another method is

Sought	Set R to Ba	Set R to S	Set R to O		
Given					
CI				3 to R	Under Ind.
D	Find at. wt.=137.4	Find at. wt.=32.1			Find 48

The sum of these, 137.4 + 32.1 + 48 = 217.5, is approximately the molecular weight of barium sulphite. This method is not so rapid or convenient as the one first given but at times it may be the only method possible. The position of the decimal point is fixed by knowledge and inspection. The chemist knows approximately the atomic or molecular weight of a substance, at least to within the limit of a multiple of ten; so no difficulty need be apprehended as to the position of the decimal point.

To find the percentage composition of a compound.

Example: What is the percentage composition of silver nitrate ($AgNO_3$)? This amounts to

$$\frac{Ag}{AgNO_3} \times 100 = 63.50\ \%\ \text{silver}$$

$$\frac{N}{AgNO_3} \times 100 = 8.247\%\ \text{nitrogen}$$

$$\frac{3O}{AgNO_3} \times 100 = 28.25\ \%\ \text{oxygen}$$

$$\overline{99.997\%}$$

The percentage of the elements may be obtained by solving the above expressions in the ordinary manner already given. A more rapid and convenient method similar to the method for determining percentages given on pages 16 and 17 is:

First bring the indices into coincidence.

So't	R to $AgNO_3$								
Given					R to AG	R to N	R to O		
C		CI	Above R	L.ind.to 589				3 to R.	Und. index
D		D	Find recip'l of $AgNO_3$=589		Und.R find % Ag=63.5	Und.R find % N=8.25			Find % O=28.25

The decimal points being fixed by inspection we have

$$
\begin{aligned}
\text{Silver} &= 63.50\,\% \\
\text{Nitrogen} &= 8.25\,\% \\
\text{Oxygen} &= \underline{28.25\,\%} \\
& \quad 100.00\,\%
\end{aligned}
$$

Gravimetric Analysis. Direct gravimetric analysis is easily calculated. In general it consists in finding weight of the equivalent of the substance to be reported to the weight of the substance weighed, always taking into account the weight of substance taken.

Example: 2.000 grams of a substance yield .250 grams of barium sulphate ($BaSO_4$); what is the percentage of sulphuric anhydride (SO_3)? This comes to

$$\frac{SO_3}{BaSO_4} \times \frac{.250}{2.000} = 4.29\%\ SO_3.$$

With the Chemists' Slide Rule:

Sought	R to SO_3					
Given			$BaSO_4$ to R			
CI		C		R to 25	2 to R	Under index
D		D				Find 4.29

Volumetric Analysis.

Example; A solution of sodium hydroxide ($NaOH$) is equivalent to .004875 grams of sulphuric acid (H_2SO_4) per cubic centimeter. What is its equivalent per cubic centimeter in nitric acid (HNO_3)? As two nitric acid molecules are equivalent in acidity to one sulphuric acid molecule, we have

$$\frac{2\ HNO_3}{H_2SO_4} \times .004875 = .006264 \text{ gr. } HNO_3 \equiv 1 \text{ cc. NaOH sol.}$$

With the rule:

Sought	Set HNO_3				
Given	On H_2SO_4				
C		R to 2	CI	4875 to R	Under index
D			D		Find .00626

Example: It is found that 32.50 cubic centimeters of a solution of sodium hydroxide (NaOH) exactly neutralizes 30.00 cubic centimeters of a solution of sulphuric acid (H_2SO_4) known to contain .04902 grams per cubic centimeter. What is the strength of the sodium hydroxide solution per cubic centimeter? The expression to be solved is

$$\frac{2\ NaOH}{H_2SO_4} \times \frac{30.00}{32.50} \times .04902 = 03691 \text{ gr. per cc.}$$

By the Chemist's Slide Rule:

Sought	Set NaOH							
Given	On H_2SO_4							
C		R to 3	CI	49 to R	C	R to 2	325 to R	Under index
D			D		D			Find .0369

Volume of gas given by a known weight of substance.

Example: What volume of hydrogen, dry, under standard conditions of temperature and pressure will be liberated by 6.000 grams of iron when acted upon by sulphuric acid according to the equation

$$Fe + H_2SO_4 = FeSO_4 + H_2$$

The volume is obtained by solving

$$\frac{6}{Fe} \times 22.4 = 2.406 \text{ Liters}$$

Sought				
Given			Fe to R	
CI	Set 6	R to index		Under index
D	On 224			Find 2.406

Weight of substance requisite for the production of a given volume of gas.

Example: How many grams of calcium carbonate ($CaCO_3$) are required to produce 1700 cubic centimeters of carbon dioxide (CO_2) at 780 m. m. pressure and at 17° C.? The carbonate being completely decomposed

$$CaCO_3 \longrightarrow CO_2$$

The weight is obtained by solving

$$\frac{1.7}{22.4} \times \frac{780}{760} \times \frac{273}{290} \times CaCO_3 = 7.339 \text{ gr. } CaCO_3$$

This may be obtained on the rule:

So't											
Given									R to $CaCO_3$		
CI	Set 17	C	R to 273	760 to R	CI	R to 224	L. ind. to R	C		290 to R	Under ind.
D	Set 780	D			D			D			Find 734

The Slide Rule is not an instrument of absolute accuracy, but is dependent upon the degree of exactness with which the settings are made and results read off. The accuracy with which a setting may be made or a result read off is often dependent upon the degree of exactness in estimating between divisions. From 4 to 5, 5 to 6, etc. to the end of the rule, the smallest subdivisions are $\frac{1}{20}$ of the interval between 4 and 5, 5 and 6, etc. As the eye can estimate to within an accuracy of about one tenth, the error introduced is about $\pm .1$ From the construction of the rule it is seen that it may be relied upon to give three significant figures, with an average error of $\pm .5$ in the last figure. On a percentage basis, in the neighborhood of 4, the maximum apparent error is

$$\frac{.5}{400} \times 100 = .125\%$$

In the neighborhood of 9, we have

$$\frac{.5}{900} \times 100 = .055\%$$

On account of the close graduation in this region of the rule, settings may not be made with this accuracy. Suffice to say that the rule may be relied upon for three significant figures with an average maximum apparent error of one tenth. The error may be less than this; it should not be more.

This is quite within the limit of accuracy of the average operation of the analytical chemist. The rule does not attempt to completely replace logarithms, but is valuable in checking up results and may be used whenever rapid approximations to within a fair degree of certainty are desired. The rule is machine divided and the graduations may be relied upon in the symbols as well as in the logarithmic scales.

To those unfamiliar with the slide rule, it is strongly recommended that facility be first attained with the Regular scale and then with the Inverted scale. Either of these scales alone is capable of solving the problems of the type given under the discussion of the Regular scale. When facility is obtained in the manipulation of these scales separately, they may be used in conjunction, always endeavoring to solve a problem with the fewest number of settings.

The use of the symbols on the Chemist's Slide Rule should not be practiced till last. This Manual does not attempt to give instruction in Stoichiometry, For such instruction the reader is referred to text-books on the subject. It should be noted that the symbols on the Inverted side, both on the rule and on the slide, are graduated from the left index as on the front of the rule, consequently these graduations should not be used in the same way as graduations on the Inverted slide. The problems given are but types and do not exhaust the possibilities of the rule for the solution of chemical problems, as there are many other types of problems that might be given. The problems given are merely to illustrate the method of working the rule. In many cases the operator may solve a chemical problem directly with the rule, but when the problem is involved, it is better to write down the mathematical expression. The degree to which the operator may dispense with this procedure depends upon practice and the operator.

The following symbols are to be found on the slide rule:

Mannheim Side

Salts

Calcium carbonate
Sodium carbonate
Potassium Bromide
Magnesium sulphate
Aluminum phosphate
Calcium sulphate
Sodium sulphate
Silver chloride
Manganese sulphate
Cobalt sulphate
Potassium permanganate
Cuprous sulphate
Potassium iodide
Silver nitrate
Potassium sulphate
Strontium sulphate
Silver bromide
Barium carbonate
Barium chloride
Magnesium pyrophosphate
Mercurous sulphide
Barium sulphate
Silver iodide
Arsenious sulphide
Barium chromate
Manganese pyrophosphate
Potassium chromate
Lead sulphate
Zinc pyrophosphate
Arsenic sulphide
Magnesium pyroarsenate
Lead chromate
Antimony trisulphide
Paladium iodide
Lithium chloride
Ammonium platinic chloride
Bismuth trisulphide
Ammonium chloride
Sodium chloride
Potassium chloride
Calcium fluoride
Sodium bicarbonate
Sodium nitrate
Manganous sulphide
Oxalic acid
Zinc sulphide

Acids and Bases

Barium hydroxide
Hydro sulphuric acid
Ammonium hydroxide
Hydrochloric acid
Sodium hydroxide
Potassium hydroxide
Acetic acid
Nitric acid
Phosphoric acid
Sulphuric acid

Inverted Side

Elements

Hydrogen
Silver
Cadmium
Tin
Carbon
Antimony
Iodine
Barium
Nitrogen
Oxygen
Fluorine
Platinum
Gold
Mercury
Lead
Bismuth
Sodium
Magnesium
Aluminum
Silicon
Phosphorous
Sulphur
Chlorine
Potassium
Calcium
Titanium
Vanadium
Chromium
Manganese
Iron
Nickel
Cobalt
Copper
Zinc
Lithium
Arsenic
Bromine
Strontium
Molybdenum

Oxides

Aluminum oxide
Strontium oxide
Cadmium oxide
Phosphorous pentoxide
Molybdenum oxide
Stannic oxide
Chromic oxide
Barium oxide
Ferric oxide
Ammonia
Hydrogen oxide
Vanadium pentoxide
Ammonium
Arsenious oxide
Lead oxide
Arsenic oxide
Lead dioxide
Carbon monoxide
Antimony trioxide
Antimony suboxide
Magnesium oxide
Carbon dioxide
Nitrous oxide
Bismuth trioxide
Calcium oxide
Silicon dioxide
Sodium oxide
Sulphur dioxide
Boron trioxide
Ferrous oxide
Nickelous oxide
Cobaltous oxide
Nitrogen trioxide
Cupric oxide
Sulphur trioxide
Zinc oxide
Manganese dioxide
Potassium oxide