100 lbs. 42° Bé. <i>Aqua Fortis</i> at 8½ c.	\$8.50
197 lbs. NaNO ₃ at 3.1 c.	6.11
313 lbs. water.	
Total 610 lbs. 36.5° Bé. mixture costing.	\$14.61
610 lbs. 36° Bé. <i>Aqua Fortis</i> at 7½ c. brings.	\$45.75
Minimum Margin to producer per 100 lbs. initial acid.	\$31.14
Minimum Excess (loss) paid by consumer per 100 lbs. purchased at 7½ c.	\$ 6.10
Minimum Excess at ante-bellum prices (3½ c.) per 100 lbs. purchased.	2.80

Cost of materials follows for the case where 40° HNO₃ was mixed with 12.62 parts Na₂SO₄ and 15.15 parts of water, giving a 40° Bé. solution.

100 lbs. 40° Bé. <i>Aqua Fortis</i> at 8¼ c.	\$ 8.25
12.62 lbs. Na ₂ SO ₄ at 0.7 c.	0.09
15.15 lbs. water.	
Total 127.77 lbs. 40° Bé. mixture costing.	\$ 8.34
127 lbs. 40° Bé. <i>Aqua Fortis</i> at 8 c. brings.	\$10.16
Minimum margin to producer per 100 lbs. initial acid.	\$ 1.82
Minimum Excess (loss) paid by consumer per 100 lbs. purchased at 8 c.	1.51
Minimum Excess at ante-bellum prices per 100 lbs. purchased at 4¼ c.	0.51

In the case where NaHSO₄ (nitre cake) was used the total matter added was much higher than in the case of sodium sulfate without lowering the gravity below 40° Bé. The margin to the producer would be greater, therefore, than with the normal sulfate and particularly so since nitre cake is a drug on the market at present with most acid makers and usually is with many of them.

DISCUSSION

With these quotations in mind it is evident that it would be profitable to buy 42° acid at the top price, 8½ or 5 cents in war or normal times, respectively, and add to it sodium nitrate or a strong nitrate of soda solution or either of the sulfates of soda in such a way as greatly to stretch the amount of acid on hand by diluting with water, and selling at even the lowest quotation for the particular specific gravity obtained.

Not as much salt and water need be present as in the extreme possible cases cited. The profit to the producer and the loss to the consumer can be of any size short of the maximum. It has been shown by the data given that even a casual boil-over of NaHSO₄ during distillation may entail an unnecessary loss to the consumer by unduly increasing the producers' yields at the expense of the consumer.

Even 1 cent per pound is a severe raise on the market in the case of 9 cent acid and may spell disaster to many operations.

It seems likely that no fraud was intended in the case which caused this investigation and, therefore, the name of the manufacturer has been withheld even in private conversation. Further deliveries, however, were refused. It would seem that the presence of the sulfuric radical in the nitrate separating from the acid shows either large amounts of sulfuric acid in the nitric acid or the results of a boil-over of nitre cake or "soup." The fact that the acid always arrived of the correct specific gravity does not signify intentional adulteration, for the final correction of the specific gravity might be made by an employee who had no knowledge that a boil-over had occurred.

The presence of SO₄ in reagent ("pure") HNO₃ has been long known though no commercial informa-

tion is published. In one case¹ the manufacturer suggested that it came from the "salt cake" used in making the bottles in which the acid was stored.

It is unlikely that adulteration of commercial acids is practiced to any extent. Obviously no reputable manufacturer would avail himself of the possibilities indicated in this paper. However, these possibilities must be kept in mind by consumers for even operating employees might at times fall to the temptation to better their yield record in this way.

The possibilities herein disclosed of varying amounts of contamination in commercial nitric acid are not of direct financial significance merely, though that phase is serious enough, for it is evident that the presence of salts in quantity may seriously impede processes as well as curtail yields of same. This last effect may be quite serious where the nitric acid failure even to the extent of a few per cent in one operation may cause a greatly magnified fall-off in the finished product, leaving all question of quality out of consideration.

It should be noticed by consumers of most commercial acids such as hydrochloric, sulfuric, and acetic, that similar possibilities exist in these cases. The solubility of salts in some of these is even greater than in the case of nitrates and with some of them little or no inspection is exercised other than specific gravity determinations. Obviously the determination of the acid radical in most cases would give little protection and titration is not satisfactory with some of them. An evaporation test for residual salt would be the only certain single test to eliminate the factor under discussion.

The author wishes to thank Messrs. F. R. Porter, W. J. Becker, H. Mersereau, S. L. Shenefield and T. A. Boyd for checking data by laboratory experiment at different times.

CONCLUSIONS

I—The strength of commercial nitric acid cannot be derived with safety from the specific gravity alone nor from the specific gravity and NO₃ content alone but titration will be necessary in addition provided always that sulfuric acid is found to be absent by qualitative tests. It seems desirable to combine a specific gravity or NO₃ determination with an evaporation test for residual salts.

II—Producers and consumers alike should inspect all commercial acids by an evaporation test.

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DETERMINATION OF THE EXPLOSIBILITY OF PYRITES AS WELL AS ITS AVAILABLE SULFUR AND THE SULFUR CONTENT OF ITS CINDERS

By C. R. GYZANDER
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In buying pyrites as a source of sulfur in sulfuric acid manufacture, high content of sulfur in the ore is not necessarily a guarantee for its fitness, since other characteristics have a bearing on the amount of sulfur available for the production of sulfur dioxide. Thus,

¹ Chem. News, 61, 289 and 301.

for example, the explosive property of some varieties of pyrites while rather an aid to high efficiency when the ore is burned as fines, is a great drawback when the ore is to be burned as lump, since the dust caused by explosion of the ore fills up the interstices between the lumps and thus prevents the free access of air, in consequence of which combustion is incomplete, the resulting cinders high in sulfur, and the available sulfur low.

Again, some ores consist of small crystals or particles of pyrites and sand or silica, loosely cemented together and readily broken up during the process of combustion, thus forming dust which may clog and render the material unsuitable as a lump ore.

These two qualities are easily exhibited by heating a lump of the ore on a clay triangle over the naked flame of a Bunsen burner while a screen of fine netting is placed over the lump to prevent the scattering of the small pieces of ore if it does explode.

The quantitative determination of its explosibility or crumbling quality is accomplished by heating the ore in a covered dish at a high temperature, until crumbling or explosibility has ceased, then cooling, screening and weighing the ore, originally selected to remain on a certain size screen while passing through a next larger size. Calling the total weight of the burnt ore a , and the portion that passes through the smaller screen b , the per cent explosibility or crumbling of the ore is $100 \times b/a$. By the use of graded sieves, the percentage of the various sizes resulting from the explosion may be determined.

Some authorities claim to destroy or minimize the explosive effect by a gradual preheating of the ore, but the writer's observations in this direction do not confirm that statement, possibly because the exact conditions of a successful preheating were unknown. Twenty-four hours' preheating at temperatures from 120 to 340° C. (at which temperature explosibility seems to commence) has no apparent effect in diminishing the explosive quality.

Some users of ore have offered as an explanation for the explosibility of a pyrites that its mass is subject to an unequal internal strain, but the fact that preheating seems to have no effect in annealing or equalizing this strain, even up to temperatures at which explosion begins, seems to speak against this theory.

Dr. Lunge suggests that the explosibility is due to pockets of CO₂ gas, the expansion of which, during the process of combustion, causes the breakage of the lump with more or less explosive violence. The correctness of this view seems to be borne out by the fact that the explosibility diminishes as the ore is crushed down in size, a process which naturally would tend to destroy any existing pockets through cleavage.

If actual values with reference to explosibility are sought the ore should be heated in the same size that it is to be used in the burners, *i. e.*, a definite weight of ore should be graded by screening and each portion tested separately, for explosibility. But this would involve the use of a cumbersome laboratory apparatus, while a relative explosibility, *i. e.*, the ex-

plosibility of the ore of a uniform but small size, would be equally as valuable as a means of comparison of two grades of ore, while the laboratory apparatus would be more manageable.

For a comparative test, therefore, the ore may be crushed to pass a 7/16 but remain on a 5/16 round hole screen, when, after heating, what passes through the 5/16 screen is explosive ore. This portion may now be graded to determine dust qualities.

As an example of the application of this explosive test the following cases are quoted.

The ores tested were Spanish "Perrunal" and Rio Tinto washed ore: 240 g., crushed to pass a 7/16 but to remain on a 5/16 round hole screen, were heated in a covered agate wash bowl, placed in a suitable ring tripod and heated with a large Méker burner for 1/2 hr., when all cracking had ceased. After cooling, the ore was sifted with the result given in Table I.

ORE:	SPANISH "PERRUNAL"		RIO TINTO WASHED	
	Lot No. 1	Lot No. 2	Lot No. 1	Lot No. 2
SCREEN ANALYSIS				
On 5/16 round-hole Screen...	232.5 g.	184.8 g.	209.5 g.	182.0 g.
On 10-mesh Sieve.....	3.8	20.8	9.2	40.0
On 20-mesh Sieve.....	0.2	4.7	1.0	1.0
Through 20-mesh Sieve....	0.2	7.9	3.1	3.0
TOTAL.....	236.7 g.	218.2 g.	222.8 g.	226.0 g.
CORRESPONDING PERCENTAGES				
Non-explosive Ore.....	98.22	84.69	94.03	80.6
Explosive Ore.....	1.78	15.31	5.97	19.4
TOTAL.....	100.00	100.00	100.00	100.0
EXPLOSIVE ORE CLASSIFIED				
On 10-mesh Sieve.....	1.60	9.53	4.12	17.7
On 20-mesh Sieve.....	0.09	2.15	0.44	0.4
Through 20-mesh Sieve....	0.09	3.63	1.41	1.3
TOTAL.....	1.78	15.31	5.97	19.4

This goes to show what a wide difference the same kind of ore does exhibit as to explosibility, and the same holds as to cinder tests which, with the "Perrunal" ore, vary from less than 1 per cent for a non-explosive ore up to 5 and 6 per cent for explosive ore, while the Rio Tinto cinders vary from 4 to 10 per cent, due to choking with dust; these cinder tests refer to the ores burnt as lump ore.

Though these explosive tests do not give absolute figures they indicate that one may reasonably look for a difference in the cinder values of such ores when burned as lump ore. What *exact* relation this relative explosion test bears to the cinder value is not known, since no systematic determinations have been carried out on separate lots, but, whatever relation does exist, it can be of only a local significance, since a lump burner with a large sectional area and shallow depth will be less affected by the dust than one of small sectional area and greater depth, as the chances are that the latter will retain more of the obstructive dust than the former. The figures in Table II may aid in judging the fitness of an ore for use in lump form in the production of SO₂. It might happen that the difference in sulfur content of the cinders of an explosive ore referred to burners of a certain construction, when compared with what should be the legitimate sulfur content of the same ore if it were non-explosive, would more than pay for the cost of crushing the lump into fines, the most effective form in which an explosive ore can be handled.

That the size of the lump does cause a difference in the explosive test will be seen from the figures in Table II, which were obtained with a specially selected explosive "Perrunal" ore. The explosibility dropped from 100 to 7.71 per cent by varying the size of the lump from that of a hen egg to that of coarse fines.

TABLE II

No.	SIZE OF ORE	EXPLODED
1	Lump, hen-egg size.....	100.00%
2	Passing 1 in., remaining on $\frac{3}{4}$ in. round hole Screen.....	89.01
3	Passing $\frac{7}{16}$ in., remaining on $\frac{5}{16}$ in. round hole Screen.....	37.42
4	Passing 6-mesh, remaining on 10-mesh Sieve.....	7.71

SCREEN ANALYSIS OF EXPLOSIVE PARTS OF ORE				
PERCENTAGES	No. 1	No. 2	No. 3	No. 4
On $\frac{5}{16}$ round-hole Screen.....	16.23	41.90		
On 10-mesh Sieve.....	49.23	22.87	26.63	
On 20-mesh Sieve.....	16.16	8.71	4.76	6.33
Through 20-mesh Sieve.....	18.38	15.53	6.03	1.38
TOTAL.....	100.00	89.01	37.42	8.71

But even though the ore is non-explosive or non-crumbling it still does not follow that it is economical as a source of sulfur, since its burning qualities may be poor, *i. e.*, the rate at which it gives up its sulfur, the rate of change of the ore, is low, or, as it is usually expressed, it burns more or less freely, and it is evident that, since the ore is subject to the process of burning, whatever it may be, for a definite length of time, the more freely burning ore will have less sulfur remaining unburnt in a given time, than the ore that burns more slowly, if such a quality does exist as an adjunct to a lot of pyrites.

Experience has proved that it does, and, therefore, the determination of the rate of change of combustion and its application to the determination of available sulfur as well as the sulfur content of the cinders will now be described.

METHOD PROPOSED

The method consists of burning a convenient amount of the ore, crushed to pass a 50-mesh sieve, in a standard size dish, under standard conditions of temperature, for various intervals of time, and determining the amount of unburnt sulfur in the resultant cinders, which furnishes the data necessary for the calculation of the rate of change of the ore.

Since the combustion of pyrites, like most other chemical reactions, is influenced by temperature, it is absolutely necessary to have the analytical temperature conditions constant at all times. Further, the ore which is used as a standard for comparison should be a fines ore, or, a non-explosive, non-crumbling lump ore, of which the sulfur value of its cinders is also known.

MANIPULATION

As a source of heat the author uses an electric furnace which attains a temperature of 1000° F. and heats 2 g. of ore, crushed to pass a 50-mesh sieve and accurately weighed, in small, thin-walled, electro-quartz dishes of uniform size and thickness. The ones the author uses hold 10 cc. and have a thickness of wall of $\frac{1}{32}$ in.

Three of them are placed, close together, in a sheet-iron rack (with handle) the exact size of the furnace and having holes which fit the respective dishes so that they touch the bottom of the oven when placed there. After 15-minute intervals of time, or longer if necessary, each dish is lifted, separately, out from

the furnace with crucible tongs, while an empty dish replaces it in the furnace, so as to insure that the circulation of heat remains constant as nearly as possible. The reaction is stopped by placing 5 g. Na_2CO_3 on top of the dish as soon as it comes out of the furnace, and the dish is left to cool.

There thus results three samples of cinders, having been exposed for known intervals of time, say for 15, 30 and 45 minutes, respectively. The sulfur content of each is determined by transferring the dish of cinders and Na_2CO_3 to a roomy platinum dish, breaking up the cake of cinders with a flattened, thick, glass rod, adding 5 g. NaNO_3 , mixing and fusing to oxidize the sulfur.

After cooling, it is lixiviated with water, filtered, the filtrate acidified with excess of HCl in a covered glass dish, CO_2 boiled off, the solution evaporated to dryness, the dry mass dissolved in water, acidified with HCl , filtered from SiO_2 , precipitated by BaCl_2 and this washed, dried, ignited, cooled and weighed. From these weights we ascertain the sulfur content which corresponds to $a - x$ in Equation (1) below. Whether we regard the combustion of the pyrites merely as a distillation of its sulfur content, or as an oxidation process or both, the reaction may be treated as one of the first order, since, even in the case of the oxidation, both in the analytical and practical operation, the burning ore is continually being treated with fresh quantities of air, in consequence of which the oxygen phase of the reaction is constant and hence only the sulfur is undergoing change. The rate of change is, therefore, expressed by the differential equation

$$(1) \quad \frac{dx}{dt} = K(a - x)$$

which when integrated for $x = 0$ and $t = 0$ becomes

$$(2) \quad \frac{1}{t} \log_e \frac{a}{a - x} = K.$$

Here a represents the amount of sulfur in the 2 g. of ore used.

From Equation (2) we see that, since the amount of action, or x , in a given time t , is proportional to a , other conditions being constant, m times as much ore, or ma g., would give m times as much action or mx in the time t ; hence the logarithmic factor of the equation becomes

$$\frac{ma}{ma - mx} = \frac{ma}{m(a - x)} = \frac{a}{a - x} \text{ or constant.}$$

Therefore, the value of K is independent of the value of a and so we may use the constant quantity 2 g. of ore, even if the samples do not always carry the same amount of sulfur. The value of K is still proportional to the velocity of the reaction, if the temperature conditions are constant, or any other conditions that may have an influence on the reaction are constant, like size and thickness of dishes used for the combustion.

As a sample for comparison the writer uses a non-explosive, non-crumbling variety of "Perrunal" ore which gave the tests noted below.

Sulfur in ore, 50.5%		Sulfur in cinders, 1.0%	
2 g. ore = $\frac{50.5}{100} \times 2 = 1.01$ g. sulfur = a			
t	$a - x$	K_{10}	
15	0.27163	0.38020	Av. K_{10} 0.03895
30	0.06351	0.04004	
45	0.01813	0.03879	

K_{10} represents the value of the velocity constant when referred to common logarithms in Equation (2). With reference to natural logs it is to be multiplied by 2.30259, hence $K = 2.30259 K_{10} = 0.089686$.

Since K is independent of the value of a , we may refer it to 100 g. of ore when determining available sulfur and cinder sulfur, in preference to using 2 g. or the analytical amount used in determining K .

The composition of the cinders is, in all probability, a mixture of Fe_2O_3 and Fe_3O_4 , but we will assume them to be Fe_2O_3 as sufficiently correct for our purpose.

The next question is, then, how long shall we have to burn 100 g. of the ore, under the same conditions of temperature and so on, as prevailed when determining K_e , in order that the cinders may contain 1 per cent sulfur?

If to do this, x g. of sulfur burn off, the cinders will be $100 - x + \frac{48}{128.24} x$, since for every 4 atoms of sulfur burnt off, 3 atoms of oxygen are taken up to form Fe_2O_3 , and we have the proportion

$$(100 - x + \frac{48x}{128.24}) : (50.5 - x) = 100 : 1$$

$$a - x = 0.69 \text{ per cent sulfur left in cinders}$$

$$x = 49.81 \text{ per cent available sulfur burnt off}$$

$$a = 50.50$$

Substituting these values in Equation 2 we have, when using common logs:

$$\frac{2.30259}{t} \log \frac{50.5}{0.69} = 0.089686, \text{ whence } t = 48 \text{ minutes}$$

That is to say, 48 minutes is the time to which we must refer the burning of all ores, so long as their rate of burning or the value of K_e has been determined in the electric furnace.

If for some reason this has to be given up, the value of K_e will have to be reestablished for the new con-

ditions, before we may make any computations as to cinder values or available sulfur.

Another lot of "Perrunal" ore tested as follows:

Sulfur in ore = 49.3 per cent Sulfur in cinder = 2.3 per cent

2 g. ore = $\frac{49.3}{100} \times 2 = 0.9860 = a$			
t	$a - x$	K_{10}	
15	0.37145	0.02826	Av. K_{10} 0.03239
30	0.10163	0.03296	
45	0.02373	0.03596	
$K_e = 2.30259 K_{10} = 0.07458$			

100 g. of this ore, burning as above for 48 minutes, would leave $a - x$ sulfur for cinders and we have

$$\frac{2.30259}{48} \log \frac{49.3}{a - x} = 0.074581$$

$$a - x = 1.37 \text{ g. sulfur left in cinders}$$

$$x = 47.93 \text{ g. available sulfur}$$

$$a = 49.30$$

$$100 - 47.93 + \frac{48}{128.24} \times 47.93 = 70.01 \text{ g. } Fe_2O_3 \text{ cinders}$$

$$\frac{1.37}{70.01} \times 100 = 2.0 \text{ per cent sulfur in cinders}$$

$$\text{Found} = 2.3 \text{ per cent sulfur in cinders}$$

The above value of K_{10} is not in very good agreement as a constant, but the calculations show that it is near enough for this case. Had the sulfur value of the cinders been required before burning the ore it would have been a safer practice to repeat the analytical operation with a view to obtaining better agreeing values of K .

Four analyses are compared with actual tests of the materials in Table III. The results on No. 4 show that burnt as fines, the ore would have left only 1.33 per cent sulfur in the cinders, but on account of the explosive dust and clogging this rose to 4.10 per cent.

In August of 1908, Carridad lump ore was burned at one set of burners, giving high cinder sulfur, while Eustis lump was being burned at another set of burners with normal sulfur test in the cinders. As it happened that men with less experience were engaged on the Carridad ore it was not unreasonable to suspect that the men, either from laziness or ignorance, had not given the attention to breaking and charging that they should, so the author tried the determination of the rate of change of the two ores, with the expectation that

1—A sample of Eustis fines		2—Another lot of Eustis fines		3—A Eustis lump ore		4—Another lot of explosive Eustis lump ore	
ACTUAL ANALYSIS		ACTUAL ANALYSIS		ACTUAL ANALYSIS		ACTUAL ANALYSIS	
A—Sulfur in ore.....	42.98%	A—Sulfur in ore.....	44.0 %	A—Sulfur in ore.....	41.92%	A—Sulfur in ore.....	43.24%
B—Sulfur in cinders.....	2.70%	B—Sulfur in cinders.....	2.70%	B—Sulfur in cinders.....	3.20%	B—Sulfur in cinders.....	4.10%
CALCULATION FROM A		CALCULATION FROM A		CALCULATION FROM A		CALCULATION FROM A	
$a = \frac{42.98}{100} \times 2 = 0.8596$		$a = \frac{44.6}{100} \times 2 = 0.8800$		$a = \frac{41.92}{100} \times 2 = 0.8384$		$a = \frac{43.24}{100} \times 2 = 0.8648$	
t	$a - x$	t	$a - x$	t	$a - x$	t	$a - x$
20	0.19164	15	0.35526	15	0.29676	15	0.28714
40	0.03952	30	0.15865	30	0.12453	30	0.02761
60	0.03468	45	0.04056	45	0.03663	45	0.03021
Average K_{10} 0.02975		Average K_{10} 0.02798		Average K_{10} 0.029296		Average K_{10} 0.03323	
$\therefore K_e = 2.30259 K_{10} = 0.06850$		$\therefore K_e = 2.30259 K_{10} = 0.06443$		$\therefore K_e = 2.30259 K_{10} = 0.0646$		$\therefore K_e = 2.30259 K_{10} = 0.07652$	
Burning to Fe_2O_3 cinders:		Burning 48 min. to Fe_2O_3 cinders		Burning 48 min. to Fe_2O_3 cinders		Burning 48 min. to Fe_2O_3 cinders	
$\frac{2.30259}{48} \log \frac{42.98}{a - x} = 0.06850$		$\frac{2.30259}{48} \log \frac{44}{a - x} = 0.06443$		$\frac{2.30259}{48} \log \frac{41.92}{a - x} = 0.06746$		$\frac{2.30259}{48} \log \frac{43.24}{a - x} = 0.07652$	
$a - x = 1.60$ Sulfur in cinders		$a - x = 2.00$ Sulfur in cinders		$a - x = 1.64$ Sulfur in cinders		$a - x = 1.09$ Sulfur in cinders	
$x = 41.38$ Available Sulfur		$x = 42.00$ Available Sulfur		$x = 40.28$ Available Sulfur		$x = 42.15$ Available Sulfur	
$a = 42.98$		$a = 44.00$		$a = 41.92$		$a = 43.24$	
$100 - 41.38 + (\frac{48}{128.24} \times 41.38)$		$100 - 42 + (\frac{48}{128.24} \times 42)$		$100 - 40.28 + (\frac{48}{128.24} \times 40.28)$		$100 - 42.15 + (\frac{48}{128.24} \times 42.15)$	
$= 74.06$ per cent Fe_2O_3 cinders		$= 73.84$ g. Fe_2O_3 cinders		$= 74.79$ g. Fe_2O_3 cinders		$= 73.94$ g. Fe_2O_3 cinders	
$\frac{1.60}{74.06} \times 100$		$\frac{2.00}{73.87} \times 100$		$\frac{1.64}{74.79} \times 100$		$\frac{1.09}{73.94} \times 100$	
$= 2.16$ per cent sulfur in cinders		$= 2.70$ per cent sulfur in cinders		$= 2.19$ per cent sulfur in cinders		$= 1.33$ per cent sulfur in cinders	

the suspicions regarding the men's guilt would be confirmed.

The results, however, entirely exonerated the men from all blame and showed the cause to be due to the poor burning quality of the ore itself. At that time I did not have the electric furnace, but made the determinations in one and the same dish placed on a tripod and heated with a small Méker burner, shielded from draughts by a sheet iron hood. The results were as given in Table IV.

EUSTIS LUMP ORE ACTUAL ANALYSIS			CARRIDAD ORE ACTUAL ANALYSIS		
A—Sulfur in ore.....	45.8%		A—Sulfur in ore.....	43.7%	
B—Sulfur in cinders.....	3.0%		B—Sulfur in cinders.....	9.7%	
CALCULATION FROM A			CALCULATION FROM A		
$a = \frac{45.8}{100} \times 2 = 0.9160$			$a = \frac{43.7}{100} \times 2 = 0.8740$		
<i>t</i>	<i>a</i> — <i>x</i>	<i>K</i> ₁₀	<i>t</i>	<i>a</i> — <i>x</i>	<i>K</i> ₁₀
15	0.3705	0.02620	15	0.5027	0.01601
30	0.1893	0.02282	30	0.3243	0.01435
45	0.0446	0.02916	45	0.1945	0.01450
Average <i>K</i> ₁₀ 0.02606			Average <i>K</i> ₁₀ 0.01495		
$\therefore K_e = 2.30259 K_{10} = 0.06001$			$\therefore K_e = 2.30259 K_{10} = 0.03442$		
$(100 - x + \frac{48}{128.24} x) : (45.8 - x)$			$\frac{2.30259}{51} \log \frac{43.7}{a-x} = 0.03442$		
$= 100 : 3$			$a - x = 7.55$ g. Sulfur in cinders		
$a - x = 2.18$ g. Sulfur in cinders			$x = 36.15$ Available Sulfur burnt off		
$x = 43.62$ g. Sulfur burnt off			$a = 43.70$		
$a = 45.80$			$100 - 36.15 + \frac{48}{128.24} \times 36.15$		
$\frac{2.30259}{t} \log \frac{45.8}{2.18} = 0.06001$			$= 76.91$ per cent cinder		
$t = 51$ minutes			$\frac{7.55}{76.91} \times 100$		
			$= 9.80$ per cent sulfur in cinders		

Again in November that same year some of this Carridad ore was burned as fines with such unusual low sulfur test in the cinders, compared with the lump ore, that now the suspicion arose as to the accuracy of the cinder samples or the cinder test. Again, the determination of the rate of change of the fines ore exonerated the parties concerned, and placed the explanation on the better burning qualities of the fines ore. As it was not any surety that the flame could be adjusted to the exact conditions prevailing when the test of the lump ores was made the preceding August, I chose for comparison a sample of Eustis fines ore burned the same month as the Carridad fines. The results are given in Table V.

EUSTIS FINES ORE ACTUAL ANALYSIS			CARRIDAD FINES ACTUAL ANALYSIS		
A—Sulfur in ore.....	46.1%		A—Sulfur in ore.....	42.2%	
B—Sulfur in cinders.....	2.6%		B—Sulfur in cinders.....	2.1%	
CALCULATION			CALCULATION		
$a = \frac{46.1}{100} \times 2 = 0.9220$			$a = \frac{42.2}{100} \times 2 = 0.8440$		
<i>t</i>	<i>a</i> — <i>x</i>	<i>K</i> ₁₀	<i>t</i>	<i>a</i> — <i>x</i>	<i>K</i> ₁₀
15	0.3962	0.0247	15	0.3628	0.0245
30	0.2120	0.0214	30	0.1941	0.0213
45	0.0675	0.0253	45	0.0621	0.0252
Average <i>K</i> ₁₀ 0.0238			Average <i>K</i> ₁₀ 0.0236		
$\therefore K_e = 2.30259 K_{10} = 0.0548$			$\therefore K_e = 2.30259 K_{10} = 0.0543$		
$(100 - x + \frac{48}{128.24} x) : (46.1 - x)$			$\frac{2.30259}{58} \log \frac{42.2}{a-x} = 0.0543$		
$= 100 : 2.6$			$a - x = 1.80$ g. Sulfur in cinders		
$x = 44.22$ g. Sulfur burnt off			$x = 40.40$ g. Available Sulfur burnt off		
$a - x = 1.88$ Available Sulfur left in cinders			$a = 42.20$		
$a = 46.10$			$100 - 40.4 + \frac{48}{128.24} \times 40.4$		
$\frac{2.30259}{t} \log \frac{46.1}{1.88} = 0.0548$			$= 74.72$ g. cinders		
$t = 58$ minutes			$\frac{1.80}{74.72} \times 100$		
			$= 2.40$ per cent sulfur in cinders		

CONCLUSION

It is well known that as regards available sulfur in pyrites no method has hitherto been presented that does at all agree with practice.

To account for the low yield of available sulfur it is the custom in some places at least, to determine such heavy metals as lead, copper and zinc and deduct from the total sulfur that equivalent to sulfates of these metals, but even so, there is usually no agreement with practical yields and as the sulfates of these heavy metals are all decomposable at a bright red heat, the temperature of the burners, it is evident that such a practice is faulty, even if it occasionally should seem to agree with practical results.

The only reliable method of arriving at the available sulfur content of a pyrites is, as has been shown, the determination of the rate of change of the ore, compared with some other ore that works normally and the available sulfur of which is known.

Furthermore, this determination serves as a check upon results already obtained and so helps to place the true explanation upon them instead of subjecting them to mere suspicions, which, though seemingly reasonable, may still be untrue.

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A CONVENIENT APPARATUS FOR ELECTROMETRIC TITRATION DEPENDING ON THE CHANGE OF OXIDATION POTENTIAL, AND ITS APPLICATION TO THE DETERMINATION OF SMALL QUANTITIES OF CHROMIUM IN STEEL

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THE APPARATUS

The apparatus for electrometric titration described by Hildebrand¹ and Forbes² and the modified form described by Kelley and Conant³ consisted of a number of separate parts, many of which were not well adapted to purposes to which they were put. In the present apparatus, which was made for us by Leeds and Northrup, the parts have been selected to give the greatest efficiency for such work and are combined as a unit in a single rugged instrument. The present instrument can be moved about the laboratory readily, requiring for its operation only the connection of a plug with an electric light socket. It is complete in that it carries a potentiometer system, a motor for the operation of the stirrer and the two burettes for the oxidizing and reducing solutions.

ILLUSTRATION

As will be seen in the illustration, the apparatus consists essentially of a wooden box with a metal upright carrying the motor, burettes and electrodes. In the box are two dry cells, an adjustable resistance and a Leeds and Northrup reflecting galvanometer of the form known as Type 2400. This galvanometer is sufficiently sensitive for the purpose and has the further advantage of a very short period. On the

¹ J. Am. Chem. Soc., **35** (1913), 869.

² Ibid., **35** (1913), 1527.

³ Ibid., **38** (1916), 341.