

LXXXIII.—*The Sulphonic Derivatives of Camphor.*

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THE substitution derivatives of camphor do not at present lend themselves to systematic classification or to prediction of the number of possible isomers. The preparation of any new derivative of camphor will, therefore, possess an interest of its own, apart from any question of the constitution of the compound. It will in all probability be necessary to prepare a large number of such compounds before we find our-

PLATE I.

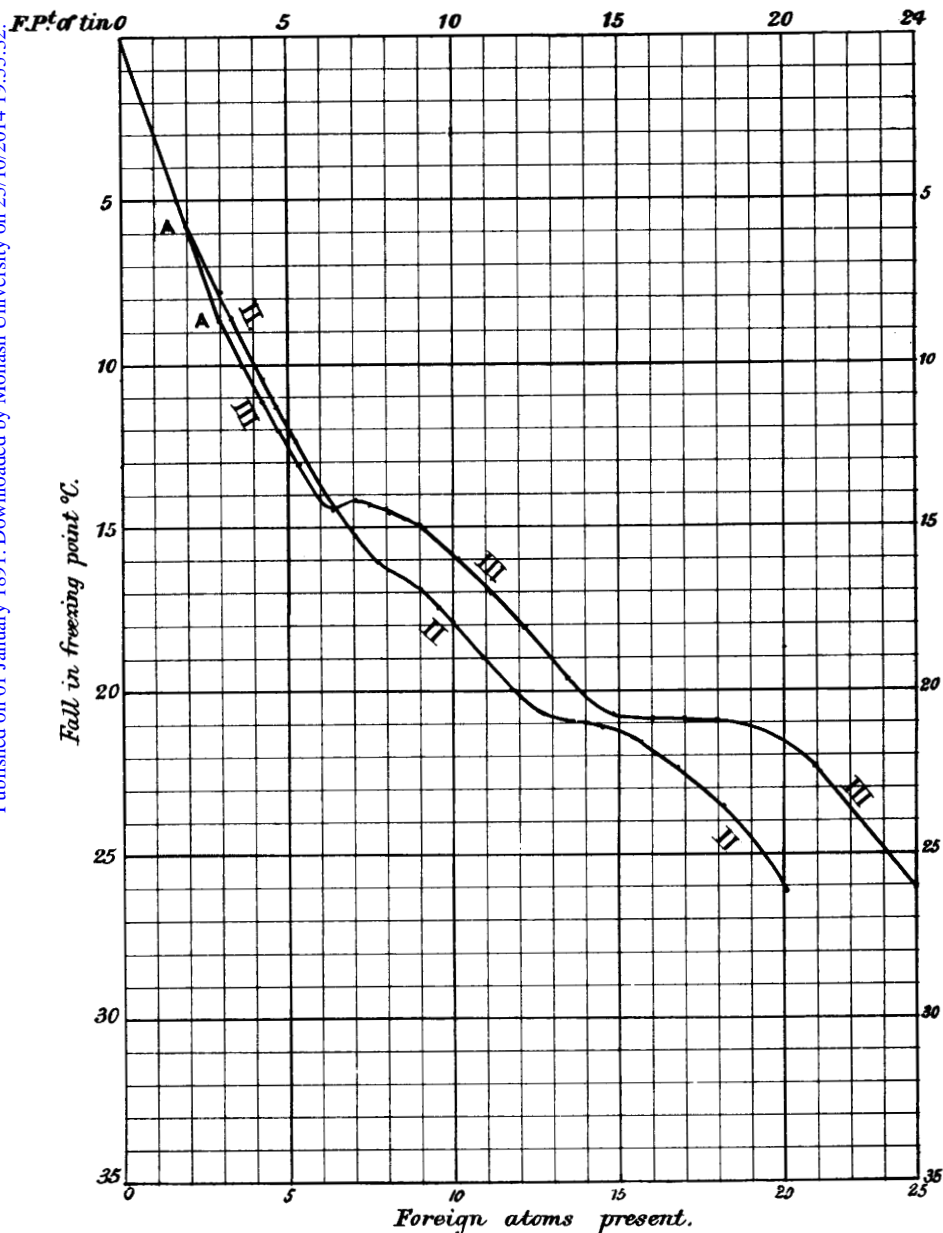
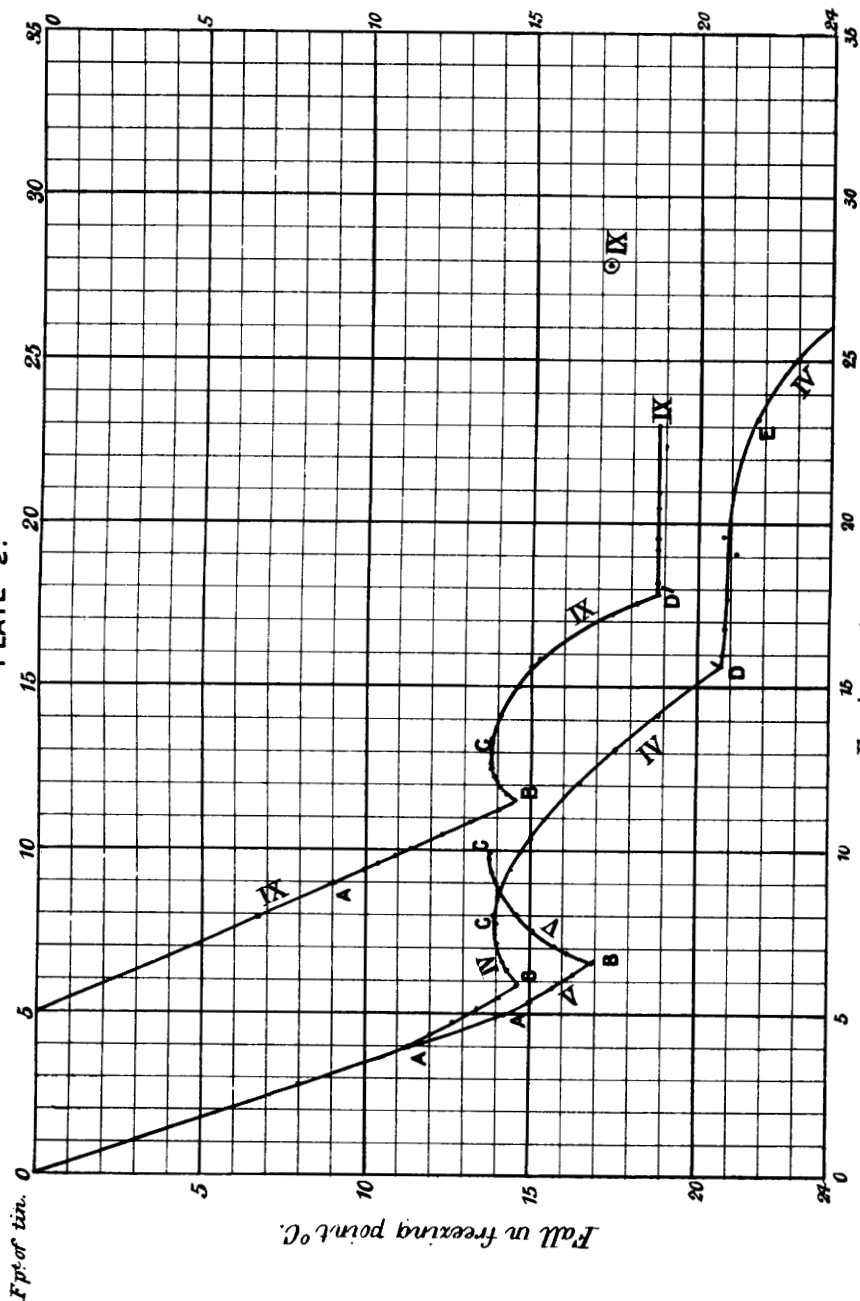


PLATE 2.



Foreign atoms present.
Roman numerals refer to the tables.

selves in a position to speculate with any confidence as to their atomic arrangements.

We have been acquainted for some time with chloro-, bromo-, and nitro-derivatives of camphor, but not with any compounds in which hydrogen is replaced by the sulphonic group SO_3H . The action of sulphuric acid on camphor did not yield either to Chautard (*Compt. rend.*, **44**, 66), to Schwanert (*Annalen*, **123**, 298), or to Kachler (*ibid.*, **164**, 90) any sulphonic acid, nor did Cazeuueve (*Compt. rend.*, **110**, 719) by the same reaction, or by that of sulphuric acid on the bromo- and chloro-camphors, observe any simple displacement of hydrogen by the sulphonic group, but rather compounds were formed which indicated a considerable and peculiar decomposition of the camphor nucleus.

Camphor we know does not yield directly a nitro-camphor, whereas bromo- and chloro-camphor, when treated with nitric acid, do give nitro-derivatives. Thus it seemed not improbable that, though camphor itself might be incapable of giving directly a sulphonic derivative, we should yet be able to obtain the corresponding compounds from the haloïd camphors. This we have in fact been able to do by employing chlorosulphonic acid, ClSO_3H , dissolved in chloroform for the sulphonation, instead of sulphuric acid. Camphor itself yields no sulphonic acid by this treatment. We have continued the work begun by one of us (*Trans.*, 1890, **57**, 828), and have prepared a number of derivatives of the sulphonic acids of the isomeric bromo- and chloro-camphors. These compounds we describe in the subsequent pages. At the same time, there are some remarks of a general character which we wish to make before entering into experimental detail.

In the first place, as to rotatory power, the sulphonic compounds have been found to rotate the plane of polarised light, a property hitherto observed in very few sulphur compounds, and not at all in any sulphonic acid. This optical activity affords an instance of the remarkably stable nature of the asymmetric carbon atom or atoms in the camphor nucleus, in striking contrast to their comparative instability in the case of other active substances. As another instance of this which has come under our observation, we have found that camphoric acid retains its optical activity unimpaired by the distillation of its anhydride through a red-hot tube, whereby a considerable part of it is decomposed; the recovered camphoric acid has, if anything, a higher rotation after this treatment than it possessed before.

Another point of interest is that the isomerism established between the respective chloro- and bromo-camphors, obtained by direct action of the halogen, is maintained in their sulphonic derivatives, and is characterised especially by the difference in rotatory power. This

difference corresponds with that between the bromo-camphors themselves; for example, the sulphonic compounds of the α -bromocamphor of sp. rot. $+135^\circ$ show a greater activity than those of the β -bromocamphor of sp. rot. $+30^\circ$.

Many of the sulphonic compounds are uncrystallisable, and, being also non-volatile, are difficult to purify. Some of the salts, however, crystallise well, and they have been studied in particular from two points of view, both as to their capability or not of crystallising, and as to their rotatory power. In neither case, however, could any general conclusion be drawn. It appeared at one time that the salts of metals of low atomic weight crystallised, whilst those of metals of high atomic weight did not, but from the impossibility of obtaining a crystalline lithium salt this view had to be abandoned. The rotatory power of these salts, as well as the salts of active acids generally, involves us in the vexed question of the nature of solution. If salts in dilute solution are completely dissociated into their ions, then the salts of an active acid should all have the same rotatory power, which would also be that of the acid itself, since the optically active ion would in every case be the same. Experiments are being continued in this laboratory to investigate this point further. So far, our own experiments, as well as those of Landolt on the tartrates, do not appear to support the dissociation theory. Landolt, in fact, obtained specific rotation values for the tartrates, of very various concentrations, it is true, lying between 20.64° , the value for sodium arsenyl tartrate, and 142.76° , the value for tartar emetic.

As to the chemical properties of the camphorsulphonic acids, fusion with potash of the α -bromo-acid splits off the sulphonic group which appears as sulphite, but nothing could be made of the compound or compounds formed; a profound decomposition appeared to have taken place. Nitric acid brings about a displacement of the sulphonic group, with production, in the case of the α -bromo-acid, of the ordinary nitrobromocamphor. In the case of the β -bromo-acid, a new isomeric nitrobromocamphor appeared to be formed, but it was not obtained sufficiently pure to merit a detailed description. Bromine-water produces a slight precipitation in a solution of the α -bromosulphonic acid in the cold, but we are unable at present to show whether or not the sulphonic group is replaceable by bromine.

Preparation of the Bromocamphors.

Camphor was brominated in alcoholic solution by the method already described (Trans., 1890, **57**, 828), and the two isomeric bromocamphors separated by fractional crystallisation from light petroleum. In the later experiments, the volatile products of the bromination

were led, by means of a bent tube, into a vessel containing water. A volatile oil was thus collected as a heavy layer beneath the hydrobromic acid, and was found to be pure ethyl bromide. Ethyl bromide may be obtained in considerable quantity in this way as a by-product.

By recrystallising the crude β -bromocamphor four times (an operation extending over many weeks) a product was obtained which gave for 2.1243 grams in 25 c.c. a value corresponding to

$$[\alpha]_D = +29.4^\circ.$$

The value previously found for the rotation of the β -isomer was $+34.9^\circ$.

This lower value is, therefore, more nearly the true rotation value for the new isomer, as any impurity, such as unaltered camphor or α -bromocamphor, would tend to increase the value observed.

The yield of pure α -bromocamphor obtained was about 50 per cent. of the theoretical; besides this, 20 per cent. of isobromocamphor was obtained and 20 per cent. of a mixture of the two isomerides.

A small amount of an oil, which solidifies in a freezing mixture, was also obtained, but the attempts to purify it were not successful. The probability is that it is a liquid dibromocamphor containing β -monobromocamphor. This oil reacts very violently with strong nitric acid in the cold, and, on distilling the product in steam, a yellow, semi-solid substance passes over, which, on analysis, proved to be dinitrodibromocamphor, a compound hitherto unknown.

Bromine Determination by Carius' Method.

- I. 0.2360 gram substance gave 0.2142 AgBr and 0.0023 Ag.
 II. 0.2400 gram of another specimen gave 0.2163 AgBr.

	Theory.	Found.	
		I.	II.
Br.	40.00 per cent.	39.34	40.8 per cent.

N Determination.

0.9460 gram substance gave 54.5 c.c. of moist N at 13° and 767 mm. b. p.

	Theory for $C_{10}H_{12}Br_2O(NO_2)_2$.	Found.
N	7.00 per cent.	6.77 per cent.

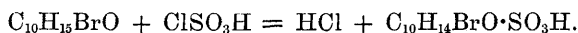
The two specimens of bromocamphor used in subsequent experiments had the following melting points and rotatory power:—

	M. p.	$[\alpha]_D$.
α -Bromocamphor	76°	$+132.0^\circ$
β -Bromocamphor	61	$+29.4$

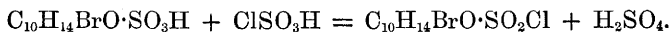
The α -compound was colourless and crystalline, and of a hard and brittle texture, whilst the β -compound was soft, yellowish, and of a camphorous consistency.

Sulphonation of α -Bromocamphor.

In the following experiments it was found that on treating 1 mol. of bromocamphor with 1 mol. of chlorosulphonic acid, only about 40 per cent. of the camphor was sulphonated :—



This equation, however, merely expresses the preliminary reaction, for the free sulphonic acid reacts with the excess of chlorosulphonic acid to produce the acid chloride and sulphuric acid, thus :—



By employing two equivalents of chlorosulphonic acid, the yield was more than doubled, and in one experiment as much as 95 per cent. of the theoretical amount of the barium salt of the α -bromosulphonic acid was obtained.

In the first experiments, a weighed quantity of bromocamphor, which had been dried for several days over sulphuric acid, was dissolved in the least amount of chloroform, previously freed from alcohol, and the chlorosulphonic acid added. The product always appeared rather charred and difficult to decolorise, but by using a much larger quantity of chloroform, preferably twice the weight of the bromocamphor taken, a much cleaner product was obtained, though the gross yield of sulphonate weighed as barium salt was not quite so great as when the more concentrated solutions were employed. The following is the description of a recent experiment :—

82 grams of pure, dry α -bromocamphor were placed in a round flask of 500 c.c. capacity, and 164 grams of chloroform, specially purified and dried, were added, when the bromocamphor was quickly dissolved. To ensure complete absence of moisture, the solution was shaken up with finely powdered calcium chloride, left for 24 hours, filtered, and the clear liquid put into a round flask fitted with a reflux condenser. The whole apparatus was placed on a water-bath in the draught chamber, although no heat was applied until it was required to hasten the reaction, and 82 grams of recently prepared chlorosulphonic acid was introduced by a tap funnel down the condenser. The liquid in the flask became perceptibly warm, although the action was not by any means violent.

A calcium chloride drying tube was now fitted to the top of the

condenser, and the flask gently heated on a water-bath, when a lively reaction set in, and torrents of hydrogen chloride were evolved. This evolution of hydrogen chloride ceased after 9 hours heating, but to ensure the completion of the reaction the heating was continued for 12 hours longer, at the end of which time the liquid had separated into two layers.

The whole mass was then poured into cold water, whereby an upper stratum of brownish-yellow solution and a heavy black oil were obtained. The latter was drawn off and dried with calcium chloride, and the chloroform evaporated, when the residue was found to be nearly all α -bromocamphorsulphonic chloride, together with an insignificant amount of unaltered bromocamphor.

The upper, aqueous solution took 115 grams of barium carbonate for complete neutralisation, and after filtering from the barium sulphate gave a brownish-yellow solution, which was evaporated to the consistency of a dense syrup on the water-bath; on treating this with methylated spirit, a small residue of barium carbonate and chloride was left undissolved, and the filtrate, on concentration, left a brown and dense syrup which we were unable to obtain crystalline. It was, therefore, dried at 115° in an air-bath, and after rapidly pulverising in a mortar, was quickly transferred to a stoppered bottle and employed as raw material for the preparation of the other derivatives of the α -bromocamphorsulphonic acid.

The extremely deliquescent nature of the salt renders it rather troublesome to deal with, but it is stable as compared with the potassium and lithium salts, which deliquesce so eagerly (when anhydrous) that when left in the open air they become liquid or pasty in less than a minute. The highly deliquescent nature of the lithium salt rendered it necessary to dehydrate it in a tube drawn out to a capillary point, which was sealed as soon as the salt was dry.

α -Bromocamphorsulphonic Acid and its Salts.

α -Bromocamphorsulphonic Acid, $C_{10}H_{14}Br \cdot SO_3H$.—To prepare the acid, 10 grams of the barium salt (see below) were dissolved in water, and dilute sulphuric acid run in until all the barium was precipitated. The filtrate was evaporated on the water-bath, extracted with absolute alcohol, and the alcoholic solution again evaporated. In this way a black, tarry mass was obtained which solidified on standing over sulphuric acid in a vacuum. It was soluble with great ease in water, producing a strongly acid liquid which evolved hydrogen when heated with zinc or magnesium.

Barium Salt, $(C_{10}H_{14}Br \cdot SO_3)_2Ba$.—This barium salt is soluble in water, and also in alcohol, but much more readily in the former. It

is practically insoluble in ether, benzene, chloroform, and carbon bisulphide.

The analysis gave the following results :—

- I. 0.4078 gram substance gave 0.1258 gram BaSO_4 .
 II. 0.4858 " " 0.1514 "
 III. 0.2880 gram was oxidised to 0.1718 "

	Found.			
	I.	II.	III.	Theory.
Ba	18.13	18.32	—	18.09
S	—	—	8.19	8.45

The aqueous solution of the salt was so dense that trustworthy values for the rotatory power were not obtainable. It was, however distinctly dextrorotatory.

The *potassium salt*, $\text{C}_{10}\text{H}_{14}\text{BrO}\cdot\text{SO}_3\text{K}$, is highly deliquescent, and readily becomes liquid in the open air.

A hot, alcoholic solution of the anhydrous salt on one occasion deposited a small crop of microscopic crystals on cooling; a few minutes exposure to the air, however, caused them to deliquesce, and to dissolve again in the mother liquor, showing the intense affinity of the anhydrous salt for water. The potassium salt was used for making the sulphonic chloride, and will be referred to again under that head.

The *Sodium Salt*, $\text{C}_{10}\text{H}_{14}\text{BrO}\cdot\text{SO}_3\text{Na}$.—This was prepared from the barium salt by dissolving 10 grams of it in hot water, and adding a solution of sodium carbonate as long as a precipitate of barium carbonate appeared. The solution was then concentrated by evaporation, and, on cooling, solidified to a crystalline mass. This was recrystallised from a very little boiling water, filtered, and dried on a porous tile. It was of a silky texture, and almost colourless. It melted to a colourless liquid at 52° .

Rotation of Sodium Salt in Aqueous Solution.

1.0762 grams in 25 c.c. at 15° gave for 20-decimetre tube $\alpha = +6.0^\circ$;

$$\therefore [\alpha]_D = +76.4^\circ.*$$

Analyses of Sodium Salt.

- I. 0.3442 gram substance lost 0.0602 gram water at 100° .
 0.3442 " " 0.0729 " " 135° .
 II. 0.2812 " " 0.0589 " " 135° .

* As the salt contained 5 mols. H_2O , $[\alpha]_D$ is referred to the anhydrous salt.

	Found.		Theory.
	I.	II.	
4H ₂ O.....	17.48	—	17.77
5H ₂ O.....	21.17	20.94	21.04
III. 0.3442 gram substance gave 0.0527 gram Na ₂ SO ₄ .			
IV. 0.2812 „ „ 0.0465 „ „			

	Found.		Theory.
	III.	IV.	
Na.....	4.96*	5.35	5.43

The *ammonium salt*, C₁₀H₁₄O·SO₃NH₄, was prepared as follows:—

10 grams of the barium salt were dissolved in hot water, and 3 grams of ammonium sulphate added. After filtering off the barium sulphate, the solution was evaporated on the water-bath and extracted with alcohol, which left a small quantity of ammonium sulphate undissolved. On evaporating the alcoholic solution, a semi-crystalline mass was obtained; this was dissolved in a few drops of hot water, and on cooling it became semi-solid. The white, silky needles were collected and recrystallised. On heating to 270°, the substance darkened, and melted with an almost explosive decomposition.

Rotation Determination.

1.1426 grams salt were dissolved in 25 c.c. of water.

$$l = 10; \alpha = +4^{\circ} 0'; \therefore [\alpha]_D = +87^{\circ}.$$

Sulphur Determination, Carius' Method.

I. 0.2112 gram substance gave 0.15045 gram BaSO ₄ .			
II. 0.3171 „ „ 0.2214 „ „			

	Found.		Theory.
	I.	II.	
Sulphur	9.78	9.89	9.75

Magnesium Salt.—This was first prepared by dissolving metallic magnesium in a dilute solution of the free sulphonic acid in water; hydrogen was thus freely given off, especially on warming. To ensure complete saturation of the acid, the solution was boiled with a little magnesia until quite neutral to litmus, and then filtered and evaporated. An almost colourless, crystalline product was thus obtained, which dried up over sulphuric acid to a crisp, dry powder.

* Slight loss by spirting.

Rotation Determination.

$T = 14^\circ$, Solvent H_2O , $l = 10$, $C = 1.1896$ in 25 c.c., $\alpha = 1^\circ 20''$;
 $\therefore [\alpha]_D = +27^\circ 9$.

The zinc salt is more deliquescent and less crystalline than the corresponding magnesium salt.

 α -Bromocamphorsulphonic Chloride, $C_{10}H_{14}OBr \cdot SO_2Cl$.

To prepare this, 20 grams of the dried potassium salt were mixed with the calculated weight of phosphorus pentachloride in a porcelain mortar, when an energetic reaction took place, and the mixture soon became liquid. After about five minutes, when the action appeared over, the brownish, viscid liquid was poured into a considerable volume of water; oily flakes were then thrown down which rapidly solidified. These were collected, dried as far as possible, and dissolved in chloroform; after drying the chloroform solution with powdered calcium chloride, it was evaporated on the water-bath, when it left a black, viscid oil. This smelt and tasted like an acid chloride, and, on standing over sulphuric acid in a vacuum, solidified to a black semicrystalline solid.

Analysis by Carius' Method.

0.3577 gram substance gave 0.4344 gram of mixed $AgCl$ and $AgBr$.

	Found.	Calculated.
Cl	10.70	10.77
Br.	24.11	24.27

This sulphonic chloride is remarkably stable towards water, and is not completely converted into acid, even after prolonged boiling with it. Dilute soda solution, however, rapidly decomposes it.

The action of strong aqueous ammonia on the sulphonic chloride produces a mixture of amide and ammonium salt; the latter being soluble in water is easily separable from the amide, which remains as a brown, viscid oil.

The chloride dissolves in alcoholic ammonia with a brown coloration and considerable production of heat. On evaporation, a sticky, brown tar is left, which eventually crystallises if left for two or three months.

Aniline reacts powerfully with the sulphonic chloride with production of an anilide. Like the amide, this is extremely difficult to purify, and has not yet been obtained definitely crystallised.

Sulphonation of β -Bromocamphor.

As sulphonation in a concentrated chloroform solution produced a considerable darkening in colour, and might be expected to effect a more or less extended conversion of the β -derivative into the corresponding α -modification, the operation was finally carried out in a fairly dilute solution. To compare and contrast the two isomers, equal quantities of α - and β -bromocamphor were similarly sulphonated under identical conditions.

In a comparative experiment, 82 grams of the respective bromocamphors, 164 grams of chloroform, and 82 grams of chlorosulphonic acid were employed, the chloroform solution being carefully dehydrated by powdered calcium chloride. A marked difference was noticed in the two reactions. The β -compound from the first reacted with a perceptible development of heat, and free evolution of hydrogen chloride; whilst the product of the sulphonation of the α derivative became black, that of the β -compound remained of a light-reddish tinge. The α -product required 115 grams of barium carbonate for complete neutralisation, whilst the β - took only 105 grams. About the same quantity of pure barium salt was obtained in each case, namely, 76 grams, the chloroform solution containing sulphonic chloride with a trace of the unaltered bromocamphor.

Barium β -Bromocamphorsulphonate, $(C_{10}H_{14}OBr\cdot SO_3)_2Ba$.—The barium salt was obtained as a thick, brown syrup on evaporating its aqueous solution on the water-bath, and required heating to a temperature of 125° to drive off the excess of water; a crisp, powdery solid was thus obtained having a great affinity for moisture. An analysis gave the following result:—

0.3450 gram substance gave 0.1067 gram $BaSO_4$.

	Found.	Theory.
Ba	18.10	18.09

Sodium β -Bromocamphorsulphonate, $C_{10}H_{14}OBr\cdot SO_3Na$.—5 grams of the barium salt were dissolved in water, and a solution of sodium sulphate added as long as a precipitate was formed. The filtrate was evaporated to a thick syrup on the water-bath, extracted with alcohol, filtered, and again evaporated down until fairly concentrated. The α -salt, under similar conditions, crystallised in silky, white needles. The β -salt absolutely refused to crystallise even when placed in a vacuum over sulphuric acid for a week. Under these circumstances, however, it solidified to a transparent, deliquescent mass, which, on heating at 120° , gave off water, and was obtained in

the anhydrous condition. It is of interest to note that, whilst the β -salt retains its 2 mols. of water of crystallisation at 100° , the α -salt loses 4 mols. H_2O at this temperature, and retains one only.

Rotation in Aqueous Solution 14° .

0.8555 gram anhydrous salt in 25 c.c.

$$l = 20, \alpha = + 0.50''; [\alpha]_D = + 12.2^\circ.$$

$$\alpha\text{-Salt}, [\alpha]_D = + 76.4.$$

Analyses of the β -Sodium Salt.

I. 0.5896 gram of the salt, dried at 100° and a vacuum over sulphuric acid, lost 0.0480 gram H_2O at 125° .

	Found.	Theory.
$2\text{H}_2\text{O}$	8.1	9.0

II. 0.5416 gram of the anhydrous salt gave 0.1152 gram of Na_2SO_4 .

	Found.	Theory.
Na	6.89	6.81

Ammonium Salt.—This was prepared in the same way as the α -salt previously described. The first crystalline product, on twice recrystallising gave an almost colourless, silky product, which was exactly similar to the α -salt in appearance.

The rotation in a 20-dec. tube for an aqueous solution was found to be $\alpha = 7^\circ 40''$.

$$\therefore [\alpha]_D = + 82^\circ; \text{ the } \alpha\text{-salt gave } [\alpha]_D = + 87^\circ.$$

Estimation of Sulphur by Carius' Method.

0.3171 gram substance gave 0.2324 gram BaSO_4 .

	Found.	Theory.
S.	10.06	9.75

From the rotation values, this salt appears to be practically identical with the α -salt.

The *potassium salt* of the β -acid was also prepared, but, owing to its deliquescent nature, was not fully examined.

Preparation of Chlorocamphor.

The two isomeric chlorocamphors of P. Cazeneuve (*Compt. rend.*, 95, 1358) were obtained by his method of chlorinating camphor in

alcoholic solution. His process may, however, be improved by distilling the product under diminished pressure before proceeding to separate the two isomers. In this way, the unaltered camphor was removed by heating the mixture at 130° under a pressure of 5 mm. for an hour, when 40 grams of unaltered camphor was recovered. The rest boiled at 135° , and nearly the whole distilled over between 135° and 140° . This fraction was then treated with spirit and fractionally crystallised in the same way as in the case of the corresponding bromo-derivatives.

The isomeric chlorocamphors are in every way analogous to the bromo-compounds, and two fairly pure specimens of the α - and β -isomers were ultimately obtained and employed in these researches.

An oil (as in the case of the bromo-derivatives) was also obtained; it is probably a crude di-substituted chlorocamphor containing some β -chlorocamphor in solution.

Sulphonation of α - and β -Chlorocamphor.

The sulphonation was carried out in exactly the same way as in the case of the bromo-compounds, and the crude barium salts were identical in appearance and properties.

The barium salt of the α -sulphonic acid, when treated with the calculated quantity of potassium carbonate, gave a syrupy product which was dehydrated at 120° . 25 grams of α -chlorocamphor gave 46 grams of the anhydrous potassium salt, which is equivalent to a yield of 90 per cent.

On analysis, the potassium salt gave the following results:—

- I. 0.3240 gram substance gave 0.0886 gram K_2SO_4 .
- II. 0.1820 gram substance gave 0.0858 gram $AgCl$ by Carius' method.

	Found.	Theory.
K	12.24	12.70
Cl.....	11.64	11.65

Ammonium α -Chlorocamphorsulphonate.—10 grams of the barium salt were treated with ammonium sulphate as previously described. A crop of delicate, moss-like aggregations of crystals was ultimately obtained which blackened and decomposed at 200° .

- I. 0.2112 gram substance gave 0.1367 gram $AgCl$ by Carius' method.

	Found.	Theory.
Cl.....	16.00	16.04

This agrees with the formula $C_{10}H_{14}ClO \cdot SO_3NH_4$.

α -Chlorocamphorsulphonic Chloride, $C_{10}H_{14}OCl \cdot SO_2Cl$.

The acid chloride was obtained by the action of phosphorus pentachloride on the anhydrous potassium salt. It was extracted with chloroform, and this solution when evaporated in a vacuum left a black, tarry residue which eventually solidified to a microcrystalline, black solid.

0.2096 gram substance gave 0.25565 gram $AgCl$.

	Found.	Theory.
Cl.....	24.52	24.91

It reacted with aniline, ammonia, alcoholic ammonia, ammonium carbonate (solid), and piperidine similarly to the chloride of α -bromocamphorsulphonic acid.

The piperidine derivative, on recrystallisation from alcohol, was obtained in delicate little needles of a reddish-brown tinge, but, owing to its great solubility, its purification was both difficult and tedious.

The β -chlorosulphonic derivatives are quite comparable with those of their β -bromo-congeners; for example, the barium and potassium salts are extremely deliquescent, non-crystallisable substances. Again the ammonium salt of the α -chlorinated acid is easily crystallisable from alcohol or water, the corresponding β -chloro-salt, however, like its analogue the β -bromo-salt of ammonium, is deliquescent and non-crystalline; it may be kept over sulphuric acid in a vacuum for weeks without becoming solid and dry.

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