

3. The vapor pressure of water adsorbed on zinc oxide *ex* oxalate has been measured at 300–400°.

4. The heat of adsorption of water vapor, probably of the activated form, on zinc oxide *ex* oxalate is approximately 30,000 calories.

5. Evidence for the activated adsorption of water on zinc oxide *ex* oxalate has been obtained.

6. An explanation of the low dehydration–dehydrogenation ratio of zinc oxide has been given.

7. The velocity of the adsorption of hydrogen by zinc oxide *ex* oxalate has been measured in the temperature interval 0–306°, and isotherms have been obtained at –191 and –78.5°.

8. Two types of adsorption of hydrogen by zinc oxide *ex* oxalate have been distinguished, their heats of adsorption determined, and the activation energy for the activated type has been measured over a wide range.

9. The theory of activated adsorption has been developed mathematically, leading to expressions for the temperature of maximum adsorption, and methods of calculating the activation energy and heat of adsorption in difficult cases have been presented.

10. Except in the initial stages, the theoretical equations reproduce the course of the activated adsorption of hydrogen on zinc oxide with great fidelity.

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FURTHER RESEARCH ON ELEMENT 87

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Detection of element 87 in pollucite and lepidolite was announced by Allison and Murphy.¹ They employed the magneto-optic method² which was developed in this Laboratory.

In continuing this research, a more extended study was made to determine whether the minima attributed to compounds of 87 might be due to some other substance and a search was made for other sources of 87.

In this work, water solutions of the substances studied were prepared. Soluble salts were simply dissolved; insoluble ones were extracted with acid or aqua regia. The desired anion was obtained by adding the appropriate acid or sodium hydroxide and the solution was then examined by the magneto-optic method. Every substance was examined both as

¹ Allison and Murphy, *Phys. Rev.*, **35**, 285 (1930).

² Allison, *ibid.*, **30**, 66 (1927); Allison and Murphy, *THIS JOURNAL*, **52**, 3796 (1930).

the chloride and sulfate; some also as the nitrate and hydroxide. Readings were made visually and the more important ones were checked with a photo-electric cell.

The characteristic minima attributed to 87 are located on our scale as shown in Table I.

TABLE I
SCALE READINGS OF COMPOUNDS OF ELEMENT 87

87Cl	87NO ₃	87SO ₄	87OH
44.01	11.48	30.48	22.08
44.62	11.66	30.85	22.40
45.11	11.98	31.35	22.82
46.22	12.28	32.02	23.18
46.42	12.67	32.32	23.66
47.80	12.94	32.71	24.06

Examination of the table of scale readings of other elements² shows that these minima must be produced by the compounds of a cation whose equivalent weight is greater than Tl⁺. This limits us to element 87 and complex ions.

Ammonia complex ions are eliminated at once as they do not exist in acid solution. SnCl₃⁺ and ReCl⁺ have been suggested.³ To test these possibilities, nitric acid solutions of pollucite and lepidolite, free from chloride, were prepared. The minima of 87 nitrate were present. Sulfuric acid was added and the minima of 87 sulfate were obtained. Therefore, the minima attributed to 87 cannot be due to any complex chloride.

To prove this point further, a careful examination of stannic chloride solutions was made and showed not only the regular eleven minima at 19.94, 20.02, 20.06, 20.15, 20.23, 20.28, 20.34, 20.40, 20.45, 20.51 and 20.55 but also four minima at 44.18, 44.40, 44.98 and 46.06. It will be seen that these do not coincide with any of the six 87 chloride minima and can be accurately distinguished from them. Furthermore, these four minima disappear after reduction with sulfur dioxide or conversion into the stannate by the addition of excess sodium hydroxide, whereas 87 chloride minima persist after each of these treatments.

Similarly rhenous chloride solutions were examined. In addition to the regular minima at 32.55 and 32.65, two were found, one at 45.93 and one at 47.54. These were not destroyed by the addition of nitric acid but did disappear on the addition of perchloric acid, whereas 87 minima persisted after the addition of an excess of perchloric acid.

Since we have found nothing else which might give the minima attributed to compounds of 87 and since these minima persist after treatment with acids, bases, oxidizing and reducing agents, we conclude, as previously announced, that these minima are due to element 87.

³ Papish and Wainer, THIS JOURNAL, 53, 3818 (1931).

The six minima indicate the probable existence of six isotopes.⁴ The long distance covered on the scale suggests considerable difference in weight, possibly transition products in a radioactive transformation.

In addition to pollucite and lepidolite, previously reported, we have found element 87 in sea water, Searles Lake (California) brine, kainite (Stassfurt), crude cesium chloride, monazite sand (Brazilian and North Carolinian) and samarskite⁵ (Brazilian, Norwegian and several American samples).

Although the tin and rhenium minima were usually present in samples that contained 87, they were easily distinguished from each other on the scale; they occur in different relative amounts as shown in Table II; furthermore, the tin and rhenium minima were destroyed by the chemical treatment indicated above while 87 minima persisted.

TABLE II

APPROXIMATE CONCENTRATION IN GRAMS OF SAMPLE PER CUBIC CENTIMETER OF SOLUTION AT WHICH MINIMA FROM 44 TO 48 ON THE SCALE APPEAR

The scale readings of these minima are not such as could be attributed to the chlorides of Sn⁺⁺⁺⁺ and Re⁺⁺. Moreover, the minima due to the chlorides of Sn⁺⁺⁺⁺ and Re⁺⁺ persist on dilution after the above minima have disappeared.

Sample	SnCl ₄	ReCl ₂	87Cl
Crude cesium chloride (prepared from pollucite)	2/10 ⁵	2/10 ⁴	2/10 ⁴
Monazite (Brazilian)	2/10 ⁵	2/10 ⁴	2/10 ²
Kainite (Stassfurt)	[not present at 2/10 ²]	2/10 ³	2/10 ²
Samarskite (Brazilian)	2/10 ⁵	2/10 ⁴	2/10 ³
Samarskite (N. C.)	2/10 ⁵	2/10 ⁴	2/10 ⁴

Since the apparatus detects a few parts in 10¹², the above samples would contain approximately one part in 10⁸, 10¹⁰, 10¹⁰, 10⁹ and 10⁸, respectively, of element 87. The concentration of this element in all substances examined is very low, ranging from a few parts in 10¹² to 10⁸.

We suggest the name virginium and the symbol Va for element 87.

Summary

Characteristic minima, as previously announced, have been obtained for the chloride, nitrate, sulfate and hydroxide of a cation whose equivalent weight is greater than Tl⁺. It has been shown that these minima cannot be due to SnCl₃⁺ or ReCl⁺. They are attributed to element 87.

The characteristic minima of element 87 are not affected by acids, bases, oxidizing or reducing agents.

Element 87 appears to have six isotopes.

Several sources of element 87 were found but the concentration in each is very low.

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⁴ Allison and Murphy, *Phys. Rev.*, **36**, 1097 (1930); Allison, *Ind. Eng. Chem.*, in press.

⁵ The detection of 87 in samarskite by x-ray spectra has been reported by Papish and Wainer.³