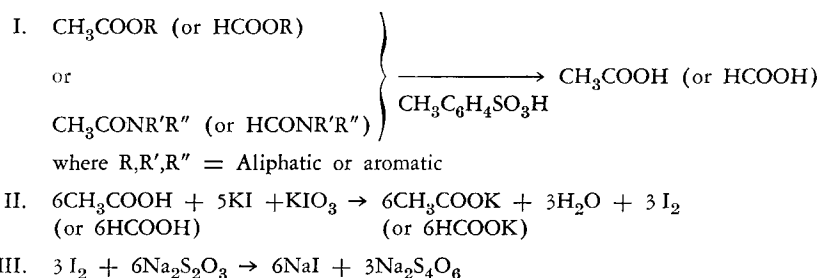
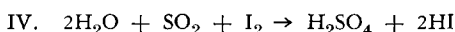


## Microdetermination of Acyl Groups (Acetyl and Formyl)

The determination of acetyl or formyl groups attached to either oxygen or to nitrogen (as in esters, amides, etc.) is carried out according to the method of Elek and Harte.<sup>2,19,44</sup> It is based on the hydrolysis of the compound by means of *p*-toluenesulfonic acid and treatment of the resulting acetic or formic acid with an excess of potassium iodide and iodate. The liberated iodine (proportional to the acetic or formic acid) is determined by titration with standard thiosulfate. The reactions are shown by the following:



During the course of the hydrolysis, small amounts of sulfur dioxide are often formed. This reacts with iodine, according to the following equation, so that correction for it must be made.



The presence of *labile* fluorine interferes with the determination. The same applies to any other acidic grouping present, or formed as a result of decomposition during the hydrolysis, that would steam distill at reduced pressure, *other than* chlorine, bromine, and iodine (which do *not* interfere since they are retained in the reaction mixture as the silver halides).

### Reagents

#### SILVER SULFATE POWDER

Reagent grade of silver sulfate powder is used in the reaction flask to trap any halogens present either in the sample or as an impurity in the *p*-toluenesulfonic acid.

***p*-TOLUENESULFONIC ACID<sup>18</sup>**

A 25% solution in water is prepared from a pure grade of *p*-toluenesulfonic acid.

**IODINE SOLUTION, 0.01N**

This solution is prepared according to the directions given in Chapter 5. It does not need to be standardized—this is used in the receiving flask.

**POTASSIUM IODIDE CRYSTALS**

Reagent grade of potassium iodide crystals are used along with the 0.01N iodine in the receiving flask.

**POTASSIUM IODATE SOLUTION, 4%**

A 4% solution of reagent grade of potassium iodate is prepared using freshly boiled distilled water. It is stored in a ground glass-stoppered bottle.

**STANDARD SODIUM THIOSULFATE SOLUTION, 0.01N**

This is prepared and standardized as described in Chapter 5.

**STARCH INDICATOR**

This is prepared as described in Chapter 5.

**Apparatus**<sup>19,33,34,40,44</sup>**ACYL APPARATUS**

The apparatus shown in Fig. 183 consists of a reaction flask, *a*, an introduction funnel, *b*, condenser, *c*, and receiving flask, *d*. A side arm with a Kjeldahl-type trap is attached to the neck of the reaction flask. Flow of liquid through the introduction funnel is controlled by means of a stopcock (water seal). The delivery end of the condenser tube has a sealed-in sintered glass plate for providing efficient absorption of the distillate in the receiving flask solution. A side arm with stopcock is attached to the receiving flask, *d*, through which the system may be evacuated. The reaction flask and funnel are joined by means of a ground joint using a water seal. Likewise, the side arm of the flask and the top tube of the condenser are connected by means of a ground joint (water seal), the male member of which is on the flask and the delivery tube extends beyond the male member grinding so that no loss of distillate will occur at this point. (The flask and condenser may also be joined by means of rubber tubing, effecting a glass-to-glass connection but the above-mentioned method is better.) The reaction flask is provided with a constant level type of water bath and the receiving flask with an ice bath.

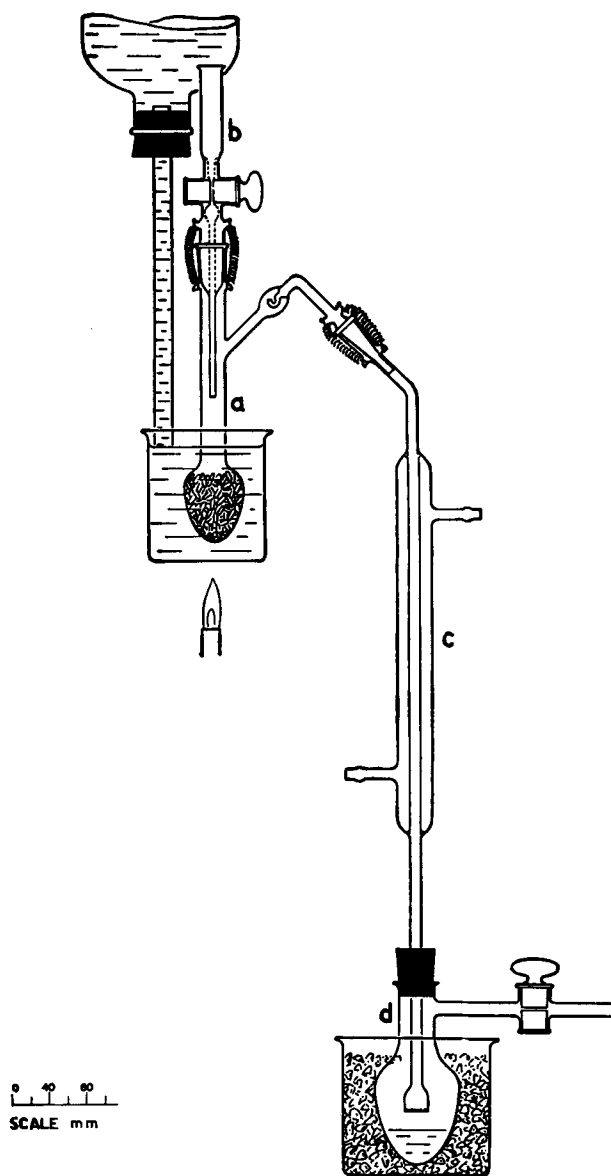


FIG. 183. Diagram of acyl apparatus, showing some details of construction.

### SOURCE OF VACUUM

A vacuum pump attached to a trap and a manometer is used as a source of vacuum. The trap should be provided with a "bleeder"\* of some type so that a pressure of 50–60 mm. of mercury may be maintained in the setup.

### BURETTES

Two automatic burettes of the type shown in Fig. 69 or 70, Chapter 5, are needed, one each for the 0.01*N* iodine and the 0.01*N* thiosulfate.

### PYREX GLASS ROD<sup>16</sup>

Small fire-polished Pyrex glass rods (about 2 × 5 mm.) are used in the reaction flask. These must be Pyrex and must have fire-polished edges or low results are obtained due to their becoming porous.

### ASCARITE-FILLED DRYING TUBE

Any type of drying tube is filled with Ascarite<sup>50</sup> and equipped with a one-hole stopper that fits the neck of the receiver flask.

## Procedure<sup>19,33,34,44</sup>

A weighed sample is transferred to the reaction flask, *a*. (The size of the sample is governed by the amount of acetyl or formyl present. Enough should be taken so as to require at least 4 ml. of 0.01*N* thiosulfate in the titration.) Onto the sample is added enough dry sections of Pyrex glass rod to three-quarter fill the bulb of the flask. This is followed by 10 to 15 mg. of silver sulfate powder onto the sections of glass rod. The introduction funnel, *b*, is inserted into the flask, *a*, which in turn is attached to the condenser, *c*, using water to lubricate the stopcock on the funnel and to seal the two ground joints (between the funnel and the flask, and between the flask and the condenser). Cold water is run through the condenser. Into the receiving flask, *d*, is placed 1.5 grams of potassium iodide crystals and 5.00 ml. of 0.01*N* iodine. This flask, *d*, is attached immediately to the condenser, by means of the rubber stopper, with the sintered glass plate on the end of the delivery tube about one cm. above the liquid. Adjustment of the height above the liquid is made easy by wetting the outer wall of the delivery tube and the rubber stopper, after which the latter can be slid up or down to any desired position. The stopcock on the receiving flask is closed and the flask cooled by packing cracked ice all around it.

\* An all-metal needle valve <sup>3,44-46,50</sup> (Fig. 92, Chapter 7) is most satisfactory for this purpose.

Two ml. of 25% *p*-toluenesulfonic acid solution is placed in the introduction funnel, the stopcock on it opened and the liquid allowed to flow into the flask. (If the solution does not drain down due to airlock in the closed system, the funnel is momentarily raised to separate the two members of the ground joint. Then after drainage is complete the water seal between the funnel and flask is remade.) The stopcock on the funnel is closed and the *funnel filled with water*.\* The water bath surrounding the reaction flask is heated to boiling and maintained so for one hour if the acyl is linked to oxygen and for 3 hours if it is linked to nitrogen.

The boiling water in the bath surrounding the reaction flask is then replaced with cold water. The stopcock on the receiving flask is opened and connection made to the vacuum system. The pressure is adjusted then to 50–60 mm. of mercury. A little water, for lubrication, is placed on top of the rubber stopper holding the receiving flask to the condenser. The receiving flask and stopper are then slid up on the delivery tube until the sintered plate on the tip rests at the bottom of the liquid. No bubbles should escape through the liquid if the system is air-tight. If bubbles do escape, water should be sprayed on the stopcock and on the two ground joints to effect water seals. The water bath surrounding the reaction flask, *a*, is heated to boiling and maintained thusly during the entire subsequent vacuum distillation. (Note: As the temperature of the bath rises, bubbles will escape through the liquid in the receiving flask for a short time until equilibrium is reached again and then cease). After the liquid has distilled from the reaction flask, *a*, and a dry residue remains, 1–2 ml. of water is carefully added through the stopcock on the introduction funnel. (If the addition is too rapid, some *p*-toluenesulfonic acid solution may be mechanically carried from the flask into the condenser and subsequently the receiver, spoiling the determination.) Vacuum distillation is continued again until a dry residue remains in the flask. This procedure is repeated about five times to effect a complete transfer of the acetic or formic acid from the reaction flask to the receiver. Each time that the contents of the reaction flask go to dryness, liquid rises from the receiver in the delivery tube well up into the water-cooled portion of the condenser. Addition of water to the reaction flask each time causes the solution to return to the receiver flask. After the fifth portion of water has been distilled out of the flask, *a*, the receiving flask, *d*, and rubber stopper are slid down so that the sintered plate is several centimeters above the liquid. Air is carefully admitted *through the stopcock on the introduction funnel* and the vacuum source then removed from the receiver flask. The reaction flask is disconnected from the condenser and several 1- to 2-ml. portions of water added to the top of the condenser and allowed to drain into the receiver.

\* This insures a water seal during the subsequent vacuum distillation.

The receiver flask is disconnected from the condenser and the iodine solution titrated with standard 0.01N thiosulfate to the end point using two drops of starch indicator. (Note: The starch is not added until the solution is light yellow in color.) A faint pink coloration is considered to be the end point. The above is known as the *first titration* and the volume of thiosulfate required is accurately recorded. Without delay, 2 ml. of 4% potassium iodate is added to the almost colorless contents of the receiver flask (after the first titration). Immediately, the receiver is stoppered with an Ascarite tube (stopcock on the side arm also closed) and then placed in a water bath at 35° C. for 20 minutes. After this period, the intensely blue iodine solution (caused by Equation II, p. 444) is titrated with standard 0.01N sodium thiosulfate to the end point. This is known as the *second titration*.

In order to correct for the effect of the sulfur dioxide formed (Equation IV, p. 444), the following titration must be made. Into a 125-ml. Erlenmeyer flask is placed 1.5 grams of potassium iodide crystals, 5.00 ml. of the same 0.01N iodine used above, and one drop of dilute acetic acid (containing about 2 mg. of CH<sub>3</sub>COOH per drop). The mixture is allowed to stand for at least 5 minutes and then titrated to the end point with 0.01N sodium thiosulfate using starch indicator. This is known as the *third titration*. If sulfur dioxide does form in the reaction, the volume of thiosulfate required for the third titration is greater than that for the first, since some of the iodine is converted already to hydriodic acid by the sulfur dioxide (Equation IV, p. 444). If the difference is more than 0.05 ml. the analysis should be repeated.<sup>19</sup> The difference, multiplied by two, to account for the dibasicity of the sulfuric acid formed, is deducted from the second titration as a correction for the acid introduced as sulfur dioxide.

*Calculation:*

*Factors:*

1 ml. of 0.01N sodium thiosulfate is equivalent to 0.4305 mg. of acetyl (CH<sub>3</sub>CO) or 0.2902 mg. of formyl (HCO)

$$\therefore \frac{\text{ml. of 0.01N Na}_2\text{S}_2\text{O}_3 \text{ (corr.)} \times 0.4305 \times 100}{\text{Wt. sample}} = \% \text{ CH}_3\text{CO}$$

or

$$\frac{\text{ml. of 0.01N Na}_2\text{S}_2\text{O}_3 \text{ (corr.)} \times 0.2902 \times 100}{\text{Wt. sample}} = \% \text{ HCO}$$

*Examples:*

a. A 5.694-mg. sample containing an acetyl group required,

5.05 ml. of 0.01N Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> for the first titration

4.80 ml. of 0.01N Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> for the second titration

5.10 ml. of 0.01N Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> for the third titration

(third titration — first titration) × 2 = correction for SO<sub>2</sub>

$$\begin{aligned} \therefore (5.10 - 5.05) \times 2 &= 0.10 \text{ ml. of } 0.01N \text{ Na}_2\text{S}_2\text{O}_3 = \text{correction for SO}_2 \\ \therefore 4.80 - 0.10 &= 4.70 \text{ ml. of } 0.01N \text{ Na}_2\text{S}_2\text{O}_3 \text{ actually used for the sample} \\ \therefore \frac{4.70 \times 0.4305 \times 100}{5.694} &= 35.53\% \text{ CH}_3\text{CO} \end{aligned}$$

- b. A 6.317-mg. sample containing a formyl group required,
- 5.00 ml. of 0.01N Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> for the first titration
  - 6.15 ml. of 0.01N Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> for the second titration
  - 5.05 ml. of 0.01N Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> for the third titration
  - (third titration — first titration) × 2 = correction for SO<sub>2</sub>
- $$\begin{aligned} \therefore (5.05 - 5.00) \times 2 &= 0.10 \text{ ml. of } 0.01N \text{ Na}_2\text{S}_2\text{O}_3 = \text{correction for SO}_2 \\ \therefore 6.15 - 0.10 &= 6.05 \text{ ml. of } 0.01N \text{ Na}_2\text{S}_2\text{O}_3 \text{ actually used for the sample} \\ \therefore \frac{6.05 \times 0.2902 \times 100}{6.317} &= 27.79\% \text{ HCO} \end{aligned}$$

The accuracy of the determination is  $\pm 0.3$ – $0.5\%$ .

TABLE 29

## ADDITIONAL INFORMATION ON REFERENCES\* RELATED TO CHAPTER 17

In addition to the procedure presented in the preceding pages of this chapter, the author wishes to call to the attention of the reader the references listed in Table 29. (See statement at top of Table 4 of Chapter 1, regarding completeness of this material.)

<b>Books</b>	<b>Apparatus (Cont.)</b>
Belcher and Godbert, 5, 6	Chaney and Wolfrom, 10
Clark, E. P., 13	Elek and Harte, 19
Clark, S. J., 14	Kainz, 24
Grant, 20, 21	Kuhn and Roth, 25
Milton and Waters, 30, 31	Niederl and Niederl, 33, 34
Niederl and Niederl, 33, 34	Roth, 35–38
Roth, 35–38	Schöniger, Lieb, and El Din Ibrahim, 39
Siggia, 41	Steyermark, 44
Steyermark, 44	Wiesenberger, 51–53
<b>Review</b>	<b>General, miscellaneous</b>
Hall and Shaefer, 22	Inglis, 23
<b>Collaborative study</b>	Matchett and Levine, 27
Steyermark and Loeschauer, 47	Mázor and Meisel, 28
	Sudo, Shimoe, and Tsujii, 48
<b>Apparatus</b>	<b>O-Acetyl compounds</b>
British Standards Institution, 8	Alicino, 1
Buděšínský, 9	Chaney and Wolfrom, 10

\* The numbers which appear after each entry in this table refer to the literature citations in the reference list at the end of the chapter.

TABLE 29 (Continued)

<b>O-Acetyl compounds (Cont.)</b>	<b>Distillation (Cont.)</b>
Clark, 13	Mizukami, Ieki, and Koyama, 32
Cramer, Gardner, and Purves, 17	Schöniger, Lieb, and El Din Ibrahim, 39
Elek and Harte, 19	Steiermark, 44
Kunz and Hudson, 26	Sudo, Shimoe, and Tsujii, 48
Mázor and Meisel, 28	
Steiermark, 44	
Wolfrom, Konigsberg, and Soltzberg, 54	
<b>N-Acetyl compounds</b>	<b>Iodometric procedures</b>
Chaney and Wolfrom, 10	Bradbury, 7
Clark, 13	Elek and Harte, 19
Elek and Harte, 19	Inglis, 23
Steiermark, 44	Mizukami, Ieki, and Koyama, 32
	Steiermark, 44
<b>Formyl groups</b>	<b>Titration with alkali</b>
Alicino, 2	Alicino, 1
Spingler and Markert, 43	Clarke and Christensen, 15
Steiermark, 44	Inglis, 23
	Kuhn and Roth, 25
	Mázor and Meisel, 28
	Niederl and Niederl, 33, 34
	Roth, 35-38
	Schöniger, Lieb, and El Din Ibrahim, 39
<b>Benzoyl groups</b>	<b>Spectrophotometric, colorimetric methods</b>
Grant, 20, 21	Bayer and Reuther, 4
Roth, 35-38	McComb and McCready, 29
Tani and Nara, 49	
<b>Types of compounds which interfere</b>	<b>Gas-chromatographic method</b>
Clark, E. P., 13	Spingler and Markert, 43
Späth and Gruber, 42	
<b>Distillation</b>	<b>Cation-exchange</b>
Buděšínský, 9	Tani and Nara, 49
Clark, 11-13	
Elek and Harte, 19	
Matchett and Levine, 27	

## REFERENCES

1. Alicino, J., *Anal. Chem.*, **20**, 590 (1948).
2. Alicino, J. F., *Ind. Eng. Chem., Anal. Ed.*, **15**, 764 (1943).
3. American Society for Testing Materials, *ASTM Designations*, E 148-59T.
4. Bayer, E., and Reuther, K. H., *Ber.*, **89**, 254 (1956).
5. Belcher, R., and Godbert, A. L., "Semi-Micro Quantitative Organic Analysis," Longmans, Green, London, New York, and Toronto, 1945.
6. Belcher, R., and Godbert, A. L., "Semi-Micro Quantitative Organic Analysis," 2nd ed., Longmans, Green, London, 1954.
7. Bradbury, R. B., *Anal. Chem.*, **21**, 1139 (1949).
8. British Standards Institution, *Brit. Standards*, **1428**, Pt. C2 (1954).



9. Buděšínský, B., *Chem. listy*, **50**, 1936 (1956).
10. Chaney, A., and Wolfrom, M. L., *Anal. Chem.*, **28**, 1614 (1956).
11. Clark, E. P., *Ind. Eng. Chem., Anal. Ed.*, **8**, 487 (1936).
12. Clark, E. P., *Ind. Eng. Chem., Anal. Ed.*, **9**, 539 (1937).
13. Clark, E. P., "Semimicro Quantitative Organic Analysis," Academic Press, New York, 1943.
14. Clark, S. J., "Quantitative Methods of Organic Microanalysis," Butterworths, London, 1956.
15. Clarke, R., and Christensen, B. E., *Ind. Eng. Chem., Anal. Ed.*, **17**, 334 (1945).
16. Corning Glass Works, Corning, New York.
17. Cramer, F. B., Gardner, T. S., and Purves, C. B., *Ind. Eng. Chem., Anal. Ed.*, **15**, 319 (1943).
18. Eastman Kodak Company, Rochester, New York.
19. Elek, A., and Harte, R. A., *Ind. Eng. Chem., Anal. Ed.*, **8**, 267 (1936).
20. Grant, J., "Quantitative Organic Microanalysis, Based on the Methods of Fritz Pregl," 4th ed., Blakiston, Philadelphia, Pennsylvania, 1946.
21. Grant, J., "Quantitative Organic Microanalysis," 5th ed., Blakiston, Philadelphia, Pennsylvania, 1951.
22. Hall, R. T., and Shaefar, W. E., in "Organic Analysis" (J. Mitchell, Jr., I. M. Kolthoff, E. S. Proskauer, and A. Weissberger, eds.), Vol. II, p. 19, Interscience, New York, 1954.
23. Inglis, A. S., *Mikrochim. Acta*, p. 228 (1958).
24. Kainz, G., *Mikrochemie ver. Mikrochim. Acta*, **35**, 89 (1950).
25. Kuhn, R., and Roth, H., *Ber.*, **66**, 1274 (1933).
26. Kunz, A., and Hudson, C. S., *J. Am. Chem. Soc.*, **48**, 1982 (1926).
27. Matchett, J. R., and Levine, J., *Ind. Eng. Chem., Anal. Ed.*, **13**, 98 (1941).
28. Mázor, L., and Meisel, T., *Anal. Chim. Acta*, **20**, 130 (1959).
29. McComb, E. A., and McCready, R. M., *Anal. Chem.*, **29**, 819 (1957).
30. Milton, R. F., and Waters, W. A., "Methods of Quantitative Microanalysis," Longmans, Green, New York, and Arnold, London, 1949.
31. Milton, R. F., and Waters, W. A., "Methods of Quantitative Microanalysis," 2nd ed., Arnold, London, 1955.
32. Mizukami, S., Ieki, T., and Koyama, C., *Yakugaku Zasshi*, **76**, 465 (1956).
33. Niederl, J. B., and Niederl, V., "Micromethods of Quantitative Organic Elementary Analysis," Wiley, New York, 1938.
34. Niederl, J. B., and Niederl, V., "Micromethods of Quantitative Organic Analysis," 2nd ed., Wiley, New York, 1942.
35. Roth, H., "Die quantitative organische Mikroanalyse von Fritz Pregl," 4th ed., Springer, Berlin, 1935.
36. Roth, H., "F. Pregl quantitative organische Mikroanalyse," 5th ed., Springer, Wien, 1947.
37. Roth, H., "Pregl-Roth quantitative organische Mikroanalyse," 7th ed., Springer, Wien, 1958.
38. Roth, H., "Quantitative Organic Microanalysis of Fritz Pregl," 3rd ed. (E. B. Daw, trans., 4th German ed.), Blakiston, Philadelphia, Pennsylvania, 1937.
39. Schöniger, W., Lieb, H., and El Din Ibrahim, M. G., *Mikrochim. Acta*, p. 96 (1954).
40. Scientific Glass Apparatus Company, Bloomfield, New Jersey.
41. Siggia, S., "Quantitative Organic Analysis via Functional Groups," 2nd ed., Wiley, New York, and Chapman & Hall, London, 1954.

42. Späth, E., and Gruber, W., *Ber.*, **71**, 106 (1938).
43. Spingler, H., and Markert, F., *Mikrochim. Acta*, p. 122 (1959).
44. Steyermark, Al, "Quantitative Organic Microanalysis," Blakiston, Philadelphia, Pennsylvania, 1951.
45. Steyermark, Al, Alber, H. K., Aluise, V. A., Huffman, E. W. D., Kuck, J. A., Moran, J. J., and Willits, C. O., *Anal. Chem.*, **21**, 1283 (1949).
46. Steyermark, Al, Alber, H. K., Aluise, V. A., Huffman, E. W. D., Kuck, J. A., Moran, J. J., and Willits, C. O., *Anal. Chem.*, **21**, 1555 (1949).
47. Steyermark, Al, and Loeschauer, E. E., *J. Assoc. Offic. Agr. Chemists*, **37**, 433 (1954).
48. Sudo, T., Shimoe, D., and Tsujii, T., *Bunseki Kagaku*, **6**, 494 (1957).
49. Tani, H., and Nara, A., *Yakugaku Zasshi*, **74**, 1399 (1954).
50. Thomas, Arthur H., Company, Philadelphia, Pennsylvania.
51. Wiesenberger, E., *Mikrochemie ver. Mikrochim. Acta*, **30**, 241 (1942).
52. Wiesenberger, E., *Mikrochemie ver. Mikrochim. Acta*, **33**, 51 (1948).
53. Wiesenberger, E., *Mikrochim. Acta*, p. 127 (1954).
54. Wolfrom, M. L., Konigsberg, M., and Soltzberg, S., *J. Am. Chem. Soc.*, **58**, 490 (1936).