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# DETERMINATION OF ALKALI METAL AND ALKALINE-EARTH ELEMENTS BY FLAME PHOTOMETRY: A BIBLIOGRAPHY

Jeanne R. French

October 31, 1955

ANALYTICAL CHEMISTRY DIVISION

M. T. Kelley, Director
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## ABSTRACT

The literature, for the period 1935 through 1954, was reviewed for information pertaining to the determination of the alkali metal and alkaline-earth elements by flame photometric methods with particular emphasis on interference studies related to the determination of various combinations of these elements. Over a hundred references are given in the bibliography.

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# DETERMINATION OF ALKALI METAL AND ALKALINE EARTH ELEMENTS BY FLAME PHOTOMETRY: A BIBLIOGRAPHY

## INTRODUCTION

The literature, for the period 1935 through 1954, was reviewed for information pertaining to the determination of the alkali metal and alkaline-earth elements by flame photometric methods. Those references, in which studies were presented of the interference of one or more of these elements on the flame photometry of another cation of the alkali metal or alkaline earth groups, were of particular interest.

The bibliography, which is composed of the pertinent references that were reviewed, is arranged in chronological order.

## BIBLIOGRAPHY


### Prior to 1940

1. The Proper Procedure and Significance of Quantitative Spectrum Analysis, Gerlach, W., Z. anorg. u. allgem. chem., 142, 383-98, (1925).

An internal standard method for the flame photometric determination of calcium is discussed.

### 1940 Through 1945

2. The Substitution of Illuminating Gas for Acetylene in the Determination of Potassium With the Flame Photometer, Herrmann, R. and Lederle, P., Bodenkunde u. Pflanzernahr., 30, 189-96 (1942).

Various features of flame photometry are discussed. The apparatus used in the flame photometric determination of potassium is described.

3. The Routine Determination of Potash Available in Plants by the Method of Egner and a Special Flame Photometer, Riehm, H., Bodenkunde u. Pflanzernahr., 28, 246-56 (1942).

Construction details of a special flame photometer are described.

4. Experiences With the Flame Photometer of Schuhknecht-Waihel, Romlehner, Lazlo, Mezogazdosagi Kutatasok, 17, 51-7 (1944).

Practical advice is given for the use of the flame photometer.

5. Flame Photometry, a Rapid Analytical Procedure, Barnes, R. B., Richardson, D., Berry, J. W., and Hood, R. L., Ind. and Eng. Chem., Anal. Ed., 17, 605-11 (1945).

A new flame photometer is described by means of which results with an error of only ± 3 per cent can be obtained. The flame photometric determination of alkali metals and alkaline earth elements is discussed.

6. Determination of Potassium in Lactate Extracts With the Flame Photometer Without Precipitation of Calcium, Riehm, H., Bodenkunde u. Pflanzernahr., 36, 109-20 (1945).

An instrument is described in which illuminating gas is used. The flame obtained with illuminating gas was not hot enough to stimulate very many calcium lines.

1946 Through 1949

7. Determination of Exchangeable Potassium and Sodium, Attoe, O. J., and Truog, E., Soil Sci. Soc. Am. Proc., 11, 221, (1946).

Interference studies on the flame photometry of potassium and sodium are discussed in this article.

8. Improved Method of Flame Photometry, Berry, J. W., Chappell, D. G., and Barnes, R. B., Ind. Eng. Chem., Anal. Ed., 18, 19-24 (1946).

A new instrument which makes use of an internal standard is described. An error of ± 1 per cent is reported. Interference studies on sodium and potassium are included. Studies of the viscosity and of the surface tension of solutions are, also, given. It was reported that inorganic acids and salts produce a depressing effect on the flame photometry of sodium and potassium. The unknown is diluted to eliminate the interference of inorganic acids and salts.

9. Flame Photometer for the Measurement of Sodium and Potassium in Biological Materials, Hold, P. M., J. Biol. Chem., 167, 499-510 (1947).

In this article, the results of interference studies on the flame photometry of potassium and sodium are discussed.

10. Sodium and Potassium Determination in Health and Disease, Marinis, T. P., Murihead, E. E., Jones, F., and Hill, J. M., J. Lab. Clin. Med., 32, 1208 (1947).

The application of the Perkin-Elmer Instrument to the flame photometric determination of sodium and potassium was discussed.

11. The Flame Photometer in Soil and Plant Analysis, Myers, A. T., Dyal, R. S., and Borland, J. W., Soil Sci. Soc. Am. Proc., 12, 127-30 (1947).

It was reported in this article that the flame photometer is used directly for the determination of potassium in ammonium acetate leachates of the soil. While the organic matter that is present in the soil does not need to be destroyed, the average amounts of calcium and magnesium in the soil and plants should be included in the standards used to calibrate the instrument.

12. Sodium, Potassium and Chloride Concentrations in Erythrocytes of the Malarious Monkey, Overman, R. R., and Davis, A. K., J. Biol. Chem., 168, 641 (1947).

The flame photometric determination of sodium and potassium by means of the Perkin-Elmer Instrument was described.

13. Flame Excitation Methods for Quantitative Chemical Analysis, Stace, H. C. T., Australian Chem. Int. J. and Proc., 14, 144-50 (1947).

The principle of flame photometry is outlined, and two techniques (Lundegardh and Ramage Methods) for flame excitation are described.

14. The Flame Photometer, Barnes, R. B., Berry, J. W., and Hill, W. B., Eng. Mining J., 149, No. 9, 92-4 (1948).

The application of flame photometry to the analysis of (1) solutions of sodium, potassium, lithium and calcium, (2) potash ores for sodium and potassium, (3) clays and feldspar and (4) magnesite for calcium was described. The possibility of applying this method to other analyses was, also, discussed.

15. Mineral Composition of Leaf and Root of Sugar Beet Analysis, Bartstra, E. A. C., and Verburgt, J. W., Inst. Rationeele Suikerproduct, 17, 111-22 (1948).

The internal standard method for the determination of sodium and potassium was described.

16. Determination of Calcium and Magnesium in Leaves, Brown, J. G., Lilliland, O., and Jackson, R. K., Proc. Am. Soc. Hart, Sci., 52, 1-6 (1948).

This article includes a study of the effect of inorganic acids and salts on the flame photometric determination of sodium and potassium.

17. Errors in the Use of a Model 18 Perkin-Elmer Flame Photometer for the Determination of Alkali Metals, Parks, T. D., Johnson, H. O., and Lykken, L., Anal. Chem., 20, 822-25 (1948).

Interference studies of the common metals, acids, and solvents on the determination of sodium and potassium are presented. Very large negative errors were observed when phosphate, borate, oxalate, and mineral acids were present. Negative errors were also observed in the presence of ammonium, alkali metals and alkaline earth elements. Although compensating errors, similar to correction factors, were used in some instances, it was recommended that interfering substances be removed from complex samples of unknown composition.

18. Determination of Sodium, Potassium, and Calcium in the Flame Photometer by the Method of Riehm-Lange, Riehm, H., Z. Anal. Chem., 128, 249-64 (1948).

The apparatus of Riehm and Lange was used for the flame photometric determination of sodium, potassium and calcium. When interference was caused by sodium and calcium, a filter of Schott and Gen. was used. The interference of potassium was eliminated by means of a filter RG 8 of Schott and Gen.

19. Determination of Eight Mineral Elements in Plant Tissue, Toth, S. J., Prince, A. L., Wallace, A., and Milckelsen, D. S., Soil Sci., 66, 459-66, (1948).

The internal standard method for the flame photometric determination of calcium was described.

20. Reduction of Error in Flame Photometry, Bills, C. E., McDonald, F. G., Niedermeier, W., and Schwartz, M. C., Anal. Chem., 21, 1076-80 (1949).

The Perkin Elmer and a newly designed amplifier circuit were proposed to eliminate mutual interference in the flame photometric method. When the concentration of a solution is decreased, it was observed that the interference also decreases even though the ratio of the two constituents remains constant. The presence of organic solutes was reported to either enhance or depress the flame determination depending on the characteristics of the solute.

21. Flame Photometer for the Determination of Sodium Oxide and Potassium Oxide in Portland Cement, Eubank, W. R., and Bogue, R. H., J. Research Natl. Bur. Standards, 43, 173-82 (1949).

The use of lithium as an internal standard in the Perkin-Elmer instrument was recommended. The determination of sodium and potassium in portland cement by this method was satisfactory.

22. Flame Photometric Determination of Potassium and Sodium in Biological Fluids, Hollman, N., and Leppanen, V., Suomen Kemistilehti, 22B, No. 11, 55-60 (1949).

When a Wallace flame photometer was used with lithium as the internal standard, sodium and potassium were determined in serum with a limit of error of 2 per cent.

23. Improvement of Sensitivity of Determination of Elements in Flame Test, Ivanov, D. N., Zavadskaya Lab., 14, 1136-8 (1949).

When a high-voltage a.c. is discharged through an acetylene-air flame along the height of the flame, with 18-20 cm electrode spacing, the intensity of the spectral lines is improved. This improvement is caused by an increase in the temperature of the flame.

24. Use of Flame Photometry for the Determination of Sodium and Potassium Plasma and Urine, Mosher, R. E., Boyle, A. J., Bird, E. J., Jacobson, S. D., Batchelor, T. M., Iseri, L. T., and Myers, G. B., Am. J. Clin. Pathol., 19, 461-70 (1949).

The results of studies that were made to determine the interference of inorganic acid, salts and organic solutes on the flame photometry of sodium and potassium are presented and discussed.

25. Use of Interference Filters in the Reduction of Error Due to Calcium in the Flame Photometric Determination of Lithium, Pratt, P. F., and Larson, W. E., Anal. Chem., 21, 1296 (1949).

A Baird interference filter was used with the Perkin-Elmer instrument in order to eliminate the interference of sodium on the flame photometric determination of calcium.

26. Use of the Flame Photometer in Rapid Soil Tests for Potassium and Calcium, Stanford, G., and English, L., Argon J., 41, 446-7 (1949).

It was reported in this article that the high concentration of sodium in the soil did not interfere with the determination of potassium and calcium.

27. Estimation of Cation-Exchange Capacity and Exchangeable Calcium, Potassium and Sodium Contents of Soils by Flame Photometry, Toth, S. J. and Prince, A. L., Soil Sci., 67, 439-45 (1949).

A flame photometric method in which an internal standard is used for the determination of calcium, was discussed in this article.

28. A New Method of Flame Photometry, Weichselbaum, T. E., and Varney, P. L., Proc. Soc. Exptl. Biol. Med., 71, 570-2 (1949).

A new type of atomizer-burner system is described for a flame photometer. With this system, consistent and accurate results are obtained for sodium, potassium and other cations.

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29. Sodium and Potassium Determination in Refractory Materials Using a Flame Photometer, Biffen, F. M., Anal. Chem., 22, 1014-17 (1950).

In this article a method is described for the analysis of refractory materials. The materials are sintered with calcium carbonate and then extracted with water. Sodium and potassium are then determined in the water extract. A Perkin-Elmer instrument in which lithium is used as the internal standard, is recommended for the determination of sodium and potassium. The effect of calcium is eliminated by adding calcium to the standard solutions.

30. Flame Determination in Plant Tissues, Brown, J. C., Lilliland, O., and Jackson, R. K., Proc. Am. Soc. Hort. Sci., 56, 12-22 (1950).

The authors discuss the flame photometric determination of sodium, potassium, magnesium and calcium in plant tissues.

31. Flame Photometer Techniques, Conrad, A. L., and Johnson, W. C., Anal. Chem., 22, 1530-3 (1950).

A flame photometric method for the determination of alkali metals and alkaline earth elements in lubricating oils, which permits atomization of samples in organic media, is described. The article includes studies of the viscosity and of the interference of anions and cations.

32. Beckman Flame Spectrophotometer, Gilbert, P. T., Jr., Hawes, R. C., and Beckman, A. O., Anal. Chem., 22, 772-80 (1950).

The first Beckman flame spectrophotometer is described. Interference effects and methods of circumventing them are discussed. Flame spectra and detection limits are given for a number of elements.

33. Determination of Milk Minerals by Flame Photometry, Keirs, R. J., and Speck, S. J., J. Dairy Sci., 33, 413-23 (1950).

The determination of calcium, sodium, and potassium by flame photometry is discussed. Various techniques for the elimination of interferences are suggested.

34. Flame Photometric Determination of Calcium in Brucite and Magnesite, Mosher, R. E., Bird, E. J., and Boyle, A. J., Anal. Chem., 22, 715-7 (1950).

A Beckman flame photometer was used in combination with a narrow slit and a didymium filter to increase the sensitivity for the determination of calcium in the presence of sodium. It was recommended that the standard be of approximately the same composition as that of the unknown solution. It was reported that titanium, manganese and chromium do not interfere with the determination of calcium but that aluminum, magnesium and iron do interfere. The emissivity of calcium is decreased in the presence of aluminum, magnesium and iron. This phenomena, which is more pronounced in the high temperature zone of the flame, may be due to the absorption of the emission energy of calcium by aluminum. The fact that the emission of calcium is decreased in the presence of aluminum has been used as an indirect quantitative method for the determination of aluminum.

35. Routine Use of the Perkin-Elmer Flame Photometer in the Clinical Laboratory, Natelson, S., Am. J. Clin. Path., 20, 463-72 (1950).

It is reported that sodium and potassium are determined with an error of 2.5 per cent when the Perkin-Elmer flame photometer is used for this analysis. It is recommended that the analysis be made by comparing the unknown with a standard rather than using a calibration curve.

36. Calcium Determination in Serum, Urine, and Other Fluids, Severinghaus, J. W., and Ferrebee, J. W., J. Biol. Chem., 187, 621-30 (1950).

In this article, empirical correction factors are used for the determination of calcium. Studies of the viscosity and of the interference of inorganic acids and salts are also included in this article.

37. Emission Spectrography, Sherman, J., in "Physical Methods in Chemical Analysis," edited by W. G. Berl, pp. 330-331, New York, Academic Press, Inc., 1950.

The effect of sulfates on the determination of sodium by flame photometry was studied. It was reported that sulfate ions have a pronounced effect on the flame photometry of sodium.

38. Spectrochemical Values of Sodium, Potassium, Iron, Magnesium and Calcium in Normal Human Plasma, Smith, R. G., Craig, P., Bird, E. J., Boyle, A. J., Iseri, L. T., Jacobson, S. D., and Myers, G. B., Am. J. Clin. Pathol., 20, 263 (1950).

A discussion of the flame photometric determination of sodium and potassium is given in this article.

39. Application of Flame Spectrophotometry to Water Analysis; Determination of Sodium, Potassium, and Calcium, West, P. W., Folse, Patricia, and Montgomery, D., Anal. Chem., 22, 667-70 (1950).

The use of "radiation buffers" to prevent the interference of diverse ions on the flame photometry of sodium, potassium and calcium was described. A Beckman flame photometer was used in these studies. The error produced by the diverse ions was reported to be positive or negative depending on the concentration and identity of the metals involved. It was reported that sodium, potassium and calcium enhance the emissivity of each other, that is, the intensity of an alkali metal is increased if another alkali metal is present. These errors were eliminated when "radiation buffers" were used.

40. Flame Photometric Determination of Lithium, Wilberg, Z., Anal. Chem., 131, 405-9 (1950).

In a recent article, (C. A. 42, 5795 h), Riehm described his method for the determination of potassium, sodium, and calcium. In this reference the determination of lithium with 0.04 - 0.20 milli-equivalent of lithium in 100 ml is discussed. Excellent results were obtained in 25 experiments. It was reported that potassium and lithium can be determined in a mixture of these cations by first finding the sum of the lithium plus potassium in the solution and then comparing this value with the calibration curves for pure solutions of lithium and potassium. Details of the apparatus and procedure are given.

41. Flame Photometry - Round Table Discussion, Anal. Chem., 22, 1202-03 (1950).

The flame photometry of calcium and magnesium were of particular interest. Various factors influencing the functioning of the instrument and the reproducibility of the results were discussed. Calibration techniques and sample preparation were also included in the discussion.

42. Quantitative Spectrochemical Analysis of Rubidium in Lepidolite, Ahrens, L. H., and Gorfinkle, L. G., Am. J. Sci., 249, 451-6 (1951).

In the spectrochemical determination of rubidium in lepidolite, potassium was used as the internal standard. The lepidolite is diluted with standard albite and mixed with rubidium chloride in an albite matrix. In one of the methods, potassium is assumed to be constant while in the other method an allowance is made for any possible variation in the concentration of potassium.

43. Flame Photometers: A Description of Two Instruments, Brealey, L., and Ross, R. E., Analyst, 76, 334-339 (1951).

Two flame photometers are described; a simple one for the determination of sodium and potassium and a more versatile general-purpose instrument for the determination of a variety of cations. Data are given to show the influence of other ions present on the flame photometry of various cations.

44. Flame Spectrophotometry for Determination of Sodium, Potassium, and Lithium in Glass, Broderick, E. J., and Zack, P. G., Anal. Chem., 23. 1455 (1951).

An accurate flame spectrophotometric method was presented for the determination of the alkali metals in glass and similar refractory materials. The results were equal to or better than those secured by the classical gravimetric methods. Interferences are also given.

45. The Effect of Organic Solvents on the Flame Photometric Emission of Certain Elements, Curtis, G. W., Knauer, H. E., and Hunter, L. E., Am. Soc. Testing Materials, Symposium on Flame Photometry, Spec. Tech. Publ. No. 116, 67-74 (1951).

The effect of organic solvents on the flame photometry of alkali metal and alkaline earth metallo-organic compounds was described.

46. Flame Photometry of Alkalies and Alkaline Earths, Diamond, J. J., and Bean, B., Am. Soc. Testing Materials, Preprint 128 (1951).

In this article, flame photometric methods for the determination of the alkali metal and the alkaline earth elements are discussed.

47. Control of Interferences Caused by Acids and Salts in the Flame Photometric Determination of Sodium and Potassium, Eggertsen, F. T., Wyld, G., and Lykken, L., Am. Soc. Testing Materials, Symposium on Flame Photometry, Spec. Tech. Publ. No. 116, 52-65 (1951).

As a result of tests that were made to determine the effect of acids and salts on the flame photometry of sodium and potassium, it was reported that negative errors are produced by moderate concentrations of the common acids and salts when the operation of the instrument is dependent upon a mist produced in a spray chamber. This same phenomena is also observed when an internal standard is not used. These errors were reported to be caused by differences in the rate of evaporation of the mist droplets. When a high concentration of the salt or acid was added, as a buffer, to the test solution and to the standard, negative errors were eliminated.

48. Serum Sodium and Potassium Values Determined by the Beckman Flame Photometer, Elliott, H. C., Jr., and Holley, H. L., Am. J. Clin. Pathol., 21, 831 (1951).

The flame photometry of sodium and potassium is discussed in this reference.

49. Stable Internal Flame Photometer for Potassium and Sodium Analyses, Fox, C. D., Jr., Anal. Chem., 23, 137-42 (1951).

A new flame photometer is described in which an accuracy of ± 1 per cent is reported for the determination of sodium and potassium. The internal standard used is lithium. A viscosity study is also included in this article.

50. Determination of Alkalies in Portland Cement, Gilliland, J. L., Am. Soc. Testing Materials, Preprint 129 (1951).

The flame photometry of the alkali metals and alkaline earth elements is discussed.

51. Instrument for Internal Standard Flame Photometry: Aplication to Determination of Calcium in Rare Earths, Heidel, R. H., and Fassel, V. A., Anal. Chem., 23, 784-8 (1951).

A flame photometer, in which manganese is used as the internal standard, is described for the determination of calcium in rare earths.

52. Flame Photometric Determination of Sodium and Potassium, Hunter, F. R., J. Biol. Chem., 192, 701 (1951).

The use of a Perkin-Elmer flame photometer for the determination of sodium and potassium is described.

53. Determination of Sodium and Potassium in Lithium Metal by a Flame Photometer, Inman, W. R., Rogers, R. A., and Fournier, J. A., Anal. Chem., 23, 482-3 (1951).

In this reference a method is described, in which the Perkin-Elmer model 52A flame photometer is used, for the flame photometric determination of sodium and potassium in lithium metal. It is reported that as little as 0.001 per cent of sodium and potassium can be determined in lithium metal. Separation of these elements was unnecessary because the small error caused by the presence of lithium can be eliminated by means of correction curves. Since the standard curves were not straight and since the departure from linearity was greater at higher concentrations of sodium and potassium, it is necessary that sufficient data be obtained to establish accurate working curves. While it is possible to adjust the instrument so that the emissivity of 2 ppm of either sodium or potassium will be 100, it was recommended that the instrument be adjusted so that the emission of 2 ppm will

be 80 in the 0 to 2 ppm range for sodium and potassium. With this setting of the instrument, small adjustments that are necessary during the course of several analyses can be made.

It was reported that sodium and potassium in the order of 0.01 per cent can be determined in lithium metal with an accuracy of within 10 per cent. The error in all cases is positive. Since the limit of detection by the flame photometer for both Na and K is about 0.02 ppm, the relative error will increase with diminishing amounts of the element being determined.

Complete recovery of sodium and potassium in the 0 to 2 ppm range was achieved. In the higher concentration ranges, a decrease in emissivity of about 10 per cent for K and 7 per cent for Na, was experienced. The emissivity was essentially constant above 6000 ppm of lithium and 25 ppm of potassium and sodium. The construction and use of correction curves was recommended. These curves could be used to adjust the emissivity as determined by the flame photometer. This procedure should yield results that are accurate to 2 per cent of the amount of sodium or potassium that is present.

54. A Modified Recording Flame Photometer, King, W. H., Jr., and Priestley, W., Jr., Am. Soc. Testing Materials, Symposium on Flame Photometry, Spec. Tech. Publ., No. 116, 97-103 (1951).

The modification of the Beckman Flame Photometer, for use as a recording insturment, is described in this article.

55. Flame Photometry, Knickmann, E., Z. Pflanzenernahr. Dung. Bodenk., 54, 117-24 (1951).

In this article, a condensation of an address on flame photometry is given. The development, sensitivity, and selectivity of interference and of color filters suitable for the determination of sodium, potassium and calcium by flame photometry is discussed.

56. Mineral Analysis With the Flame Photometer, Knight, S. B., Mathis, W. C., and Graham, J. R., Anal. Chem., 23, 1704-6 (1951).

A method in which an internal standard is used, for the flame photometric determination of calcium is discussed.

57. A New Flame Photometer, Lange, B., Dechema Monograph, 17, 149-59 (1951).

The history of flame photometers is reviewed. A new instrument is also described.

58. Improved Flame Photometry, Leyton, L., Analyst, 76, 723-8 (1951).

The performance and reliability of a new flame photometer is described and discussed. The selectivity of the instrument is increased by the use of interference filters.

59. A Review on Flame Photometry, Meloche, V. W., Am. Soc. Testing Materials, Symposium on Flame Photometry, Spec. Tech. Publ. No. 116, 3-12 (1951).

Forty references pertaining to flame photometry are given.

60. The Determination of Calcium in Lubricating Oil by Flame Spectrophotometer, Moberg, M. L., Waithman, V. B., Ellis, W. H., and DeBois, H. D., Anal. Chem., 23, 1053 (1951).

In this article, the use of a Beckman flame photometer for the determination of calcium in lubricating oil was discussed. It was reported that sodium, sulfur, zinc, lead and phosphors do not interfere.

61. Rapid Determination of Sodium and Potassium in Rocks and Minerals by Flame Photometry, Osborn, G. H., and Johns, H., Analyst, 76, 410-15 (1951).

It was reported in this reference that sodium and potassium can be determined in rocks and minerals by flame photometry. The intensity of the emission of sodium and potassium was such that an analysis could be made by the direct addition method. Although most of the rocks were decomposed by mineral acid, it was necessary to heat samples of tourmaline, beryl, biotite, or topaz with calcium carbonate and ammonium chloride before extraction with a dilute acid. An aliquot of the acid solutions was taken for analysis. If ammonium phosphate is added, the excess calcium does not interfere. If more than 0.5 per cent sodium is present, as little as 50 mg of sample is sufficient. The results obtained with the flame spectrophotometer agree well with those obtained by the J. L. Smith method.

62. The Flame Photometer in the Analysis of Water and Water-Formed Deposits, Scott, R. K., Marcy, V. M., and Hronas, J. J., Am. Soc. Testing Materials, Symposium on Flame Photometry, Spec. Tech. Publ. No. 116, 105-14 (1951).

The results secured for the alkali metal and alkaline earth elements by means of the Beckman and Perkin-Elmer flame photometers were essentially the same as those secured by the gravimetric method.

63. Elimination of Calcium Interference in the Photometric Determination of Sodium in Soils and Plants, Seay, W. A., Attoe, O. J. and Truog, E., Soil Sci., 71, 83-90 (1951).

The effect of calcium on the flame photometric determination of sodium in soils is eliminated by decreasing the sodium results 7 pounds for each 1000 pounds of calcium that is present. This interference can, also, be eliminated by precipitating calcium as the oxalate.

64. Flame Photometric Determination of Sodium and Potassium in Blood, Smit, J., and Alkemade, C. T. J., Biochim. Biophys. Acta, 6, 508 (1951).

Sodium and potassium were determined in blood by means of the Perkin-Elmer flame photometer.

65. Uses and Abuses of the Flame Photometer, Sommer, A. J., Am. J. Med. Technol., 17, 276-82 (1951).

The effect of gas pressure and the purity of distilled water were discussed in connection with the use of the flame photometer.

66. Flame Photometers for Alkali Determination, Zoellner, H., Glas-Email-Keramo-Tech, 2, 290-4 (1951).

Two flame photometers that were produced in Germany were compared and discussed. In these instruments, the Schott glass filters were replaced with Schott-Schwandorf interference filters.

67. Factors Influencing the Accuracy of Flame Photometric Alkali Determinations, Zoellner, H., Glas-Emil-Keramo-Tech, 2, 378-81 (1951).

Factors influencing the accuracy of flame photometric methods for the determination of the alkali metals were discussed. It was reported that if the admixed alkali (e.g. potassium) is less than 3 times the concentration of sodium that the error is negligible but when the ratio of potassium to sodium is increased to 4, a correction of $\pm$ 2.2 per cent must be applied. For a 10-fold increase in the concentration of potassium, a correction of $\pm$ 9.2 per cent must be applied. The acidity or basicity of standards and samples must be the same. The use of sulfate should be avoided. An internal standard of lithium is used for greater accuracy.

68. Symposia on Flame Photometry, Anal. Chem., 23, 1053-4 (1951).

69. ASTM Method for Cement by Flame Photometry, Am. Soc. Testing Materials, Philadelphia, "ASTM Standards on Cement (With Related Information)," Designation C 228-49 T, p. 57-61 (April 1952).

70. A Further Contribution to the Development of the Flame Photometric Determination of Sodium and Potassium in Blood Serum, Alkemade, C. T. J., Smit, J., and Verschure, J. C. M., Biochem. et Biophys. Acta, 8, 562-70 (1952).

A new flame photometer is described. A flame of lower temperature is used to avoid interference in the flame photometric determination of sodium and potassium in blood serum.

71. Flame Photometry, Bauserman, H. M., and Cerney, R. R., Jr., Proc. Am. Soc. Sugar Beet Technol, 681-7 (1952).

In this article on flame photometry, it is reported that the standard must contain the same impurities as the sample.

72. Adaption of Photomultiplier Photometer to a Beckman DU Spectrophotometer, Collier, H. B., and Barschell, R. P., Anal. Chem., 24, 1030-1 (1952).

It is reported in this reference that when the Beckman DU Spectrophotometer is modified, the sensitivity increases and the slit width is decreased.

73. Flame Photometry, Domange, L., Ann. fals. et fraudes., 45, 276-88 (1952).

In this article a discussion of theory, equipment and uses of flame photometry is presented.

74. Experiences With the Flame Photometer of Riehm-Lange, Fischer, J., and Zettler, H., Chem.-Ing.-Tech., 24, 146-8 (1952).

In this article a study of the use of the flame photometer is given. Pertinent data is discussed and recommendations are made.

75. Effect of Organic Solvents on the Emission Spectra of Sodium and Potassium, Kingsley, G. R., and Schaffert, R. R., Science, 116, 359 (1952).

The flame photometric determination of sodium and potassium in serum and aqueous solutions is discussed.

76. Flame Photometric Determination of Sodium in Salts of Organic Acids, Knight, S. B., and Peterson, M. H., Anal. Chem., 24, 1514-17 (1952).

A Perkin-Elmer instrument was used with lithium as the internal standard for the flame photometric determination of sodium.

77. Determination of Calcium in Serum by a Flame Photometer, Kohnlein, J., and Lucke, K. E., Z. Pflanzenernahr. Dung. Bodenk, 57, 114 (1952).

Errors in the flame photometric method for the determination of calcium in serum are discussed.

78. A Simple and Accurate Flame Photometer for the Determination of Blood Alkali Metals, Leppanen, L., Krusius, F. E., and Mettinen, T., Ann. Med. Exptl. et Biol. Fenniae, 30, 305-26 (1952).

A flame photometer, in which an internal standard is used, was constructed for the determination of sodium and potassium.

79. Flame Photometry, a Survey, Lundgren, Per, Svensk. Farm Tid., 56, 433-44, 457-71 (1952).

In this article a review that includes mechanical construction of instruments, operation, and limiting factors of flame photometry is presented.

80. Report on Potassium Analysis by Means of Flame Photometer Methods, Mehlich, A., and Monroe, R. J., J. Assoc. Offic. Agr. Chemists, 35, 588-92 (1952).

Errors in the flame photometry of potassium are discussed with respect to the concentration of potassium, different analysts, and different extractions of soil.

81. The Use of Flame Photometers in Continuous Laboratory Analysis, Safir, K., Chemie, 8, 230-4 (1952).

The results of experiments with sodium and potassium are included in this article on flame photometry.

82. Effect of Flame Photometry on Line Intensity, Schafer, Kl., and Staab, K., Naturwissenschaften, 39, 375-6 (1952).

The interference of sodium on the flame photometry of potassium is discussed in this reference.

83. Flame Photometry, Seger, A. J., Van Loon, E. J., and Likins, M. R., Am. J. Med. Technol., 18, 281-9 (1952).

The use of the Barclay Flame for the flame photometric determination of sodium and potassium is described. An internal standard of lithium sulfate is recommended. Sources of error in this method are discussed.

84. Physical Principles of Flame Photometry, Smit, J. A., Chem. Weekblad, 48, 697-9 (1952).

In this article, a survey that includes the principle of flame photometric analysis as well as a description of the flame photometer is given.

85. A Flame Photometer for Routine Biochemical Use, Warren, R. L., J. Sci. Instr., 29, 284-6 (1952).

A flame photometer is described, which makes use of an oxygen-butane flame, for the determination of sodium and potassium.

86. Precision of a Simple Flame Photometer, White, J. U., Anal. Chem., 24, 394-99 (1952).

A simple flame photometer is described, in which lithium is used as the internal standard, for the determination of sodium and potassium.

87. Use of the Flame Photometer, Zwetsch, A., Sprechsaal, 85, 91-3 (1952).

Details are given for the determination of sodium oxide and potassium oxide by means of flame photometry.

88. Flame Spectrophotometric Determination of Sodium and Potassium in Viscous Solutions or Plant Extracts, Bauserman, H. M., Cerney, R. R., Jr., Anal. Chem., 25, 1821-4 (1953).

A Beckman DU-10300 flame photometer was used for the determination of sodium and potassium. In solutions that contain an unknown amount of organic material, the accurate determination of sodium and potassium presents a problem because the rates at which the samples are introduced into the flame are different. This problem is overcome by the addition of a known amount of lithium to the solution. The correction factor called the "concentration correction factor," in this reference, is calculated as a ratio between the actual ppm of lithium that was added and the ppm of lithium that was found, experimentally.

89. Determination of Calcium in Biological Material by Flame Photometry, Chem, P. S., Jr. and Toribara, T. Y., Anal. Chem., 25, 1642-4 (1953).

It was reported that in the flame photometry of calcium the emission of calcium is decreased in the presence of phosphate but that protein in the sample inhibits the effect of phosphate. When a Weichselbaum-Varney flame was used, the emission of calcium was increased in the presence of sodium or potassium. For this reason, the concentration of sodium was kept constant at 5 meq per L and a correction factor was used to eliminate the effect of potassium. An error of $\pm$ 3 to 4 per cent was reported for the flame photometric determination of calcium.

90. Improvements in Flame Photometric Determination of Sodium in Portland Cement, Diamond, J. L., and Bean, L., Anal. Chem., 25, 1825-30 (1953).

In the flame photometric determination of sodium in Portland Cement it is reported that the emissivity of calcium is decreased by silicon dioxide in the region of the spectrum that is used for the determination of sodium, 589 mμ. When the emissivity of calcium is decreased in this manner, an error is introduced in the determination of sodium. The error may be decreased by either removing the silicon dioxide or by narrowing the effective band width of the instrument. The band width can be decreased by the addition of a multilayer interference filter to the optical system of the flame photometer.

91. Flame Photometric Determination of Calcium, Strontium, and Barium in a Mixture, Hinsvark, O. N., Wittwer, S. H., and Sell, H. M., Anal. Chem., 25, 320-2 (1953).

The effect of calcium, strontium and barium on the flame photometry of each of these cations was discussed in this article. It was reported that when the carbonates of the alkaline earth elements are dissolved in perchloric acid that calcium interferes with barium and strontium interferes with calcium at the wavelengths used. It is possible to obtain accurate results without separations, however, if a correction factor is used. Data obtained by means of a Beckman DU flame spectrophotometer indicates that the emission of the alkaline earth elements is higher in solutions of perchloric acid than in solutions of nitric or hydrochloric acid. The relationship between concentration and emission was reported to be linear at lower concentrations of calcium, strontium and barium but deviations from linearity were noted at higher concentrations of these cations. In general, neither calcium nor barium interfere with the determination of strontium, although, strontium does interfere with the determination of calcium. Calcium was reported as interfering in the flame photometry of barium. Since these interferences increase linearly with increased concentrations of the interfering ions, the use of a correction factor is recommended.

92. Flame Photometric Measurements by Means of a Monochromator in Connection With a Secondary-Electron Amplifier With a Photo-Cathode, Kick, H., Z. Pflanzanernahr. Dung. Bodenk, 60, 163-7 (1953).

The use of a prism monochromator to secure narrower spectral bands was discussed in this article. It was reported that sodium, potassium, lithium, calcium, barium, strontium, manganese and, in larger amounts, magnesium can be determined without noticeable interferences.

93. Direct Microdetermination of Sodium, Potassium, and Calcium in a Single Biological Specimen, Kingsley, G. R., and Schaffert, R. R., Anal. Chem., 25, 1738-40 (1953).

The method described, for the determination of sodium, potassium and calcium, avoids the usual errors and difficulties of flame photometry by the use of a photomultiplier tube and a narrow slit width to eliminate the spectral interference of other constituents that may be present in biological samples. A Beckman DU spectrophotometer was used to determine sodium in the concentration range of 0 to 100 meq, and for potassium and calcium in the range of 100 to 200 meq.

94. A Flame Photometer Which Can be Constructed in the Laboratory, Polit, I., and Garcia-Llaurado, J., Boichem. Z., 323, 418-23 (1953).

A flame photometer that can be assembled in the laboratory is described.

95. Exclusion of Air-Borne Contamination in Flame Photometry, Sims, E. A., and Kaplow, L., J. Lab. Clin. Med., 41, 303-61 (1953).

A device is described which eliminates dust contamination in flame photometry.

96. Determination of Lithium in a Magnesium Alloy by the Flame Photometer, Strange, E. E., Anal. Chem., 25, 650-1 (1953).

In this article, a method is described in which a Beckman-10300 flame photometer is used to determine lithium in an alloy of magnesium. It is reported that small amounts of sodium and potassium do not interfere, but high concentrations of magnesium and aluminum decrease the emissivity of lithium. This interference can be eliminated by the addition of magnesium and aluminum to the standards in the same concentration as found in samples.

97. Flame Analysis in the Clinical Laboratory, Zak, B., Mosher, R. E., and Boyle, A. W., Am. J. Clin. Pathol., 23, 61 (1953).

The flame photometric determination of sodium and potassium is discussed.

98. Effects of Anions on Calcium Flame Emission in Flame Photometry, Baker, G. H., and Johnson, L. H., Anal. Chem., 26, 465-8 (1954).

The effect of perchlorate, phosphate, sulfate, and dichromate ions on the flame photometry of calcium was discussed. It was suggested that pyro-ions of phosphorus or sulfur may be responsible for the flame anomalies since perchlorate ions intensify the flame, whereas, mixtures that contain sulfate or phosphate ions in addition to perchlorate ions may show lower values than those that contain sulfate or phosphate alone.

99. Flame Photometric Determination of Calcium in Wet-Process Phosphoric Acid, Brabson, J. A., and Wilhide, W. D., Anal. Chem., 26, 1060-1 (1954).

The use of a Perkin-Elmer flame photometer to determine calcium in phosphoric acid was discussed. It was noted that iron, fluoride, and sulfur in their usual proportions did not interfere but in the presence of aluminum the emission of calcium was decreased. If the concentration of sodium is greater than 4 g/liter, it must be removed prior to the flame photometric determination of calcium.

100. Determination of Lithium in Spodumene by Flame Photometry, Brumbaugh, R. J., and Fanus, W. E., Anal. Chem., 26, 463-5 (1954).

The flame photometry of lithium in spodumene was investigated by means of a Beckman DU spectrophotometer with the flame attachment of the Perkin-Elmer. Small amounts of iron, calcium, and magnesium do not interfere and as much as 6 per cent sodium oxide and 12 per cent potassium oxide can be tolerated. The interference caused by aluminum or the acidity of the solutions is eliminated by appropriate additions to the standard solutions. In solutions that contain 10 to 50 ppm of lithium and 0 to 600 ppm of potassium, the potassium does not interfere. The emissivity of lithium is decreased when sodium in excess of 100 ppm is present in solutions that contain 100 ppm of lithium. Sodium interferes only above 200 ppm when the concentration of lithium is 20 ppm. The maximum permissible concentration of sulfuric acid is 0.7 N. When calcium is present in excess of 70 ppm, the emissivity of lithium, 0 to 30 ppm, is increased.

101. Some Interferences in Flame Photometry, Caton, R. D., Jr., and Bremner, R. W., Anal. Chem., 26, 805-13 (1954).

In this article, the results of studies to find viscosity correction factors or otherwise correlate the effects of viscosities on flame photometry, are discussed. Other effects, dependent upon the particular viscosity-regulating additive used, were found to play an important role in changing the flame intensity. Particle size, which is one of these effects, is studied by means of photomicrographs.

102. Some Errors in the Determination of Calcium in Aged Blood Serum Eliminated by Flame Photometry, Chem, P. S., Jr., and Toribara, T. Y., Anal. Chem., 26, 1967-68 (1954).

The calcium is precipitated with oxalate and dissolved in acid to free it from contaminants, prior to the flame photometric determination of calcium.

103. Flame Photometric Determination of Sodium and Potassium in Zinc Cadmium Sulfate Phosphors, Deal, S. B., Anal. Chem., 26, 598-99 (1954).

The use of a Perkin-Elmer flame photometer for the determination of sodium and potassium in zinc cadmium sulfate phosphors was described. Interference studies were not included in this article.

104. Determination of Sodium and Potassium Oxides by Flame Photometry in Portland Cement Raw Materials and Mixtures and Similar Silicates, Ford, C. L., Anal. Chem., 26, 1578-81 (1954).

A method is described whereby acid-insoluble silicates, such as are used in the manufacture of portland cement, can be dissolved rapidly for the determination of sodium and potassium oxides by the flame photometric techniques that are commonly used for the analysis of cement. The dissolution of these materials was accomplished by sintering and extracting the material by the classical J. L. Smith method. The calcium in the extract is removed and a known amount of calcium (plus hydrochloric acid) is added to approximate that found in the standard solutions which were prepared from standard samples of Portland Cement.

105. Flame Photometric Determination of Alkali and Alkaline Earth Elements in Cast Iron, Kuemmel, D. F., and Karl, H. L., Anal. Chem., 26, 386-91 (1954).

A Beckman DU and Model 9200 flame attachment were used for the determination of the alkali metals and alkaline earth elements in cast iron. It was reported that sodium, calcium and magnesium in the quantities expected in the experimental cast iron would not cause significant interference with one another. Also, small amounts of lithium would not interfere with the determination of low concentrations of sodium, calcium and magnesium. Small quantities of sodium, calcium and magnesium, furthermore, do not interfere with the determination of small quantities of lithium.

106. Determination of Small Concentrations of Sodium, Mazzamara, P., and Tatoian, G., Anal. Chem., 26, 1512-13 (1954).

In this article, the use of a Barclay flame photometer for the determination of small amounts of sodium was described. It was reported that distilled water is free from sodium and that contact with glass or polyethylene at room temperature did not seem to contaminate the distilled water over a period of a week or two. A sodium concentration of $6 \times 10^{-7}$ gram equivalents per liter can be determined with ease and accuracy.

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