

DETERMINATION OF Fe, Mn, Cu, Cr AND Ni IN SOME MINERALS FROM THE ALŠAR MINE BY ATOMIC ABSORPTION SPECTROMETRY

Anna Lazaru and Trajče Stafilov

Institute of Chemistry, Faculty of Science, University "St. Kiril and metodij", POB 162, 91000 Skopje, Macedonia

Abstract: In this paper, the methods for determination by atomic absorption spectrometry of iron, manganese, copper, chromium and nickel in arsenic (realgar and orpiment), antimony (stibnite) and iron (marcasite, except Fe) sulfide minerals and dolomite and results are presented. The investigation of the interferences show that it is possible to determine manganese and iron directly from the obtained solutions by flame, and copper, chromium and nickel, and manganese and iron in some minerals, by electrothermal atomic absorption spectrometry. Using these methods, iron, manganese, copper, chromium and nickel were determined in some mineral samples from the Alšar deposit, Macedonia.

Key words: Determination, iron, manganese, copper, chromium, nickel, atomic absorption spectrometry, sulphide minerals, realgar, orpiment, stibnite, lorandite, marcasite, dolomite

INTRODUCTION

The LOREX project is based on the idea that the mineral lorandite ($TlAsS_2$) from Alšar deposit (Macedonia) could be used as a solar neutrino detector (Freedman et al., 1976). The aim of this project is to determine the content of ^{205}Pb accumulated in the thallium minerals from Alšar, especially in lorandite, which is produced in the nuclear reaction between solar neutrinos and ^{205}Tl :



Therefore, it is necessary to determine exactly the lead content in the thallium or other minerals (Todt, W., 1988, Palme et al. 1988, Stafilov et al., 1990a, 1990b, 1990c, 1993), the content of thallium in nonthallium minerals (Stafilov et al. 1993b), but it is also necessary to determine the content of the other elements in these minerals present in Alšar deposit, such as: realgar (As_4S_4), orpiment (As_2S_3), stibnite (Sb_2S_3), marcasite (FeS_2), dolomite ($CaMg(CO_3)_2$) etc.

For the application of this experiment it is very important to determine the content of the other elements, such as: Fe, Mn, Cu, Cr, Ni, Bi, U, Th, Hg ect., especially those which are involved in background

reactions which produce ^{205}Pb . Also, detection of these elements and their concentrations in the ore and mineral samples helps to establish the conditions in which these elements have been formed, e.g., it helps to broaden the known geology of the Alšar mine. Until now, there have been very few recorded assessments of such analyses (Palme et al., 1988).

There are a number of investigations concerning the determination of elements investigated in similar geological samples by atomic absorption spectrometry (ETAAS). Some authors have investigated the possibility of the determination of these elements directly from the sample solutions, by flame AAS (Beccaluva and Venturelli, 1971, Rubeska and Miksovsky, 1974, Srivastava, 1977, Bichova and Kherebenko, 1978, Alvin and Gardner, 1986, Zorkin and Zubova, 1990), or by ETAAS (Schweizer, 1975, Zelentzova and Yudelevich, 1983, Taddia and Lanza, 1984, Nakamura et al., 1988). However, in most cases, the influence of interfering elements was of particular interest: in the flame AAS determination (Otaway et al., 1970, Sundberg, 1973, Hannaker and Hughes, 1977, Robinson, 1980, Marabini et al., 1982, Wang, 1980, Eidecker and Jackwerth, 1988) or in the ETAAS

determination (Matsusaki et al., 1981, Zelentzova and Yudelevich, 1983, Tominaga and Umezaki, 1983, Danz and Jackwerth, 1986, Subramanian, 1988). To overcome such interferences, the addition of different matrix modifiers was suggested in flame (Otaway et al., 1970, Robinson, 1980), or in ETAAS determination (Williams et al., 1986, Burba and Willmer, 1987), or the separation and concentration of these elements from the matrix and their determination by flame AAS (Hannaker and Hughes, 1977, Robinson, 1980,

Marabini et al., 1982, Wang, 1980, Eidecker and Jackwerth, 1988, Danz and Jackwerth, 1986, Williams et al., 1986, Burba and Willmer, 1987, Donaldson, 1989) or by ETAAS (Subramanian, 1988, Isshiki et al., 1989)

In this work we propose a method for the Fe, Mn, Cu, Cr and Ni determination by atomic absorption spectrometry. It was suggested that it is possible to determine these elements directly from the obtained solution of the investigated minerals.

EXPERIMENTAL

Instrumentation

A Perkin-Elmer 703 and 303 atomic absorption spectrophotometer and an HGA-400 and HGA-72 and M56 recorder were used. A hollow cathode lamp was used as a source. Operating conditions for the determination of Fe, Mn, Cu, Cr and Ni are given in Table I.

Table 1

Instrumental parameters for determination of Fe, Mn, Cu, Cr and Ni by ETAAS

| Parameters | Fe | Mn | Cr | Cu | Ni |
|------------------|-------------------------|-------|-------|-------|-------|
| Wavelength, nm | 279.5 | 279.5 | 358.0 | 324.7 | 232.0 |
| Slit, nm | 0.2 | 0.2 | 0.7 | 0.7 | 0.7 |
| Lamp current, mA | 20 | 10 | 25 | 15 | 25 |
| Calibration mode | Absorbance, peak height | | | | |
| DRY | | | | | |
| Temperature, °C | 120 | 120 | 120 | 120 | 120 |
| Time, s | 30 | 30 | 30 | 30 | 30 |
| Ramp time, s | 2 | 2 | 2 | 2 | 2 |
| CHAR | | | | | |
| Temperature, °C | 1100 | 1100 | 1300 | 1200 | 900 |
| Time, s | 30 | 30 | 30 | 30 | 30 |
| Ramp time, s | 1 | 1 | 1 | 1 | 1 |
| ATOMIZE | | | | | |
| Temperature, °C | 2400 | 2400 | 2500 | 2500 | 2400 |
| Time, s | 5 | 5 | 5 | 5 | 5 |
| Ramp time, s | 0 | 0 | 0 | 0 | 0 |
| CLEAN | | | | | |
| Temperature, °C | 2700 | 2700 | 2700 | 2700 | 2700 |
| Time, s | 3 | 3 | 3 | 3 | 3 |
| Ramp time, s | 1 | 1 | 1 | 1 | 1 |
| GAS | Argon | | | | |

Procedure

1. Realgar and orpiment

0.1 to 1.0 g of powdered samples of realgar or orpiment were dissolved in 5 cm³ concentrated HNO₃. The solution was evaporated to dryness, and then the residue was dissolved in 10 cm³ of concentrated HCl and a few drops of H₂O₂ with a minimum of boiling. The solution was transferred to a volumetric flask of 25 (50) cm³. From this solution a volume of 20 mm³ was introduced to a graphite furnace.

2. Stibnite and dolomite

0.1 to 1.0 g of powdered mineral samples were dissolved in 5 cm³ concentrated HCl, 1 cm³ concentrated HNO₃ and a few drops of H₂O₂. The solution was evaporated to dryness, and then the residue was taken up in 10 cm³ of concentrated HCl.

3. Marcasite

0.1 to 1.0 g of powdered mineral samples were dissolved in 5 cm³ concentrated HCl, 5 cm³ concentrated HNO₃ and a few drops of H₂O₂. The solution was evaporated to dryness, and then the residue was taken up in 10 cm³ of concentrated HCl.

4. Lorandite

0.1 to 1.0 g of powdered mineral samples were dissolved in 15 cm³ concentrated HCl, 3 cm³ concentrated HNO₃ and a few drops of H₂O₂. The solution was evaporated to dryness, and then the residue was taken up in 15 cm³ of concentrated HCl.

Table II

Results from the matrix interferences investigation in the determination of Fe and Mn by flame atomic absorption spectrometry

| No. | mM/mg | cm/mg cm ⁻³ | Mass ratio mMn(Fe):mM | A _{Mn} | A/A _{cM} =0·100 | A _{Fe} | A/A _{cM} =0·100 |
|--------|-------|---------------------------|--------------------------|-----------------|--------------------------|-----------------|--------------------------|
| M = As | | | | | | | |
| 1 | 0 | 0 | 1:00 | 0.1475 | 100.0 | 0.0419 | 100.0 |
| 2 | 50 | 1 | 1:200 | 0.1480 | 100.3 | 0.0428 | 102.1 |
| 3 | 100 | 2 | 1:400 | 0.1475 | 100.0 | 0.0425 | 101.4 |
| 4 | 150 | 3 | 1:600 | 0.1475 | 100.0 | 0.0429 | 102.3 |
| 5 | 200 | 4 | 1:800 | 0.1463 | 99.2 | 0.0444 | 106.0 |
| 6 | 300 | 6 | 1:1200 | 0.1475 | 100.0 | 0.0444 | 106.0 |
| M = Sb | | | | | | | |
| 1 | 0 | 0 | 1:0 | 0.1475 | 100.0 | 0.068 | 100.0 |
| 2 | 50 | 1 | 1:200 | 0.1475 | 100.0 | 0.0663 | 97.5 |
| 3 | 100 | 2 | 1:400 | 0.1463 | 99.2 | 0.0671 | 98.7 |
| 4 | 150 | 3 | 1:600 | 0.1463 | 99.2 | 0.0671 | 97.8 |
| 5 | 200 | 4 | 1:800 | 0.1463 | 99.1 | | |
| 6 | 300 | 6 | 1:1200 | 0.1475 | 100.0 | | |
| M = Mg | | | | | | | |
| 1 | 0 | 0 | 1:0 | 0.0657 | 100.0 | 0.0391 | 100.0 |
| 4 | 10 | 0.2 | 1:200 | 0.0662 | 100.8 | 0.0391 | 100.0 |
| 5 | 35 | 0.6 | 1:600 | 0.0665 | 101.2 | 0.0391 | 100.0 |
| 6 | 50 | 1.0 | 1:100 | 0.0651 | 99.1 | 0.0391 | 100.0 |
| 7 | 60 | 1.2 | 1:1200 | 0.0639 | 97.3 | 0.0391 | 100.0 |
| M = Ca | | | | | | | |
| 1 | 0 | 0 | 1:0 | 0.0400 | 100.0 | 0.0657 | 100.0 |
| 2 | 10 | 0.2 | 1:200 | 0.0400 | 100.0 | 0.0651 | 99.1 |
| 3 | 30 | 0.6 | 1:600 | 0.0400 | 100.0 | 0.0656 | 99.7 |
| 4 | 60 | 1.2 | 1:1200 | 0.0400 | 100.0 | 0.0659 | 100.3 |
| M = Fe | | | | | | | |
| 1 | 0 | 0 | 1:0 | 0.1574 | 100.0 | | |
| 3 | 50 | 1 | 1:200 | 0.1574 | 99.1 | | |
| 4 | 100 | 2 | 1:400 | 0.1574 | 100.0 | | |
| 5 | 150 | 3 | 1:1200 | 0.1574 | 100.0 | | |
| M = Tl | | | | | | | |
| 1 | 0 | 0 | 1:0 | 0.1624 | 100.0 | 0.0605 | 100.0 |
| 2 | 10 | 0.2 | 1:40 | 0.1624 | 100.0 | 0.0595 | 98.3 |
| 3 | 20 | 0.4 | 1:80 | 0.1612 | 99.2 | 0.0665 | 101.0 |
| 4 | 50 | 1 | 1:200 | 0.15999 | 98.4 | 0.0615 | 101.6 |
| 5 | 100 | 2 | 1:400 | 0.1624 | 100.0 | 0.0635 | 104.9 |
| 6 | 200 | 4 | 1:800 | 0.1624 | 100.0 | 0.0615 | 101.0 |
| 7 | 300 | 6 | 1:1200 | 0.1624 | 100.0 | | |

Table III

Influence of As, Sb, Fe, Ca and Mg on the determination of Cu, Cr and Ni by ETAAS

| No. | mm/mg | mm:mm | Δ_{Cu} | $\Delta_{Cu}/\Delta_0 \cdot 100$ | Δ_{Cr} | $\Delta_{Cr}/\Delta_0 \cdot 100$ | Δ_{Ni} | $\Delta_{Ni}/\Delta_0 \cdot 100$ |
|---------------|-------|---------|---------------|----------------------------------|---------------|----------------------------------|---------------|----------------------------------|
| M = As | | | | | | | | |
| 1 | 0 | 1:0 | 0.0750 | - | 0.1819 | - | 0.0595 | - |
| 2 | 1000 | 1:4000 | 0.0810 | 108.0 | 0.1823 | 100.2 | 0.0540 | 90.76 |
| 3 | 200 | 1:8000 | 0.0786 | 104.8 | 0.1832 | 100.7 | 0.0573 | 96.30 |
| 4 | 350 | 1:14000 | 0.0786 | 104.8 | 0.1847 | 101.5 | 0.0540 | 90.76 |
| 5 | 600 | 1:24000 | 0.0713 | 95.1 | 0.1761 | 98.6 | 0.0577 | 95.29 |
| 6 | 700 | 1:28000 | 0.0630 | 84.0 | 0.1668 | 91.7 | 0.0547 | 91.93 |
| M = Sb | | | | | | | | |
| 1 | | | | | | | | |
| 2 | 100 | 1:4000 | 0.0812 | 100.5 | 0.1647 | 99.00 | 0.0441 | 100.68 |
| 3 | 200 | 1:8000 | 0.0786 | 97.7 | 0.1668 | 100.2 | 0.0451 | 102.96 |
| 4 | 350 | 1:14000 | 0.863 | 106.8 | 0.1692 | 101.7 | 0.0452 | 103.19 |
| 5 | 700 | 1:28000 | 0.867 | 107.3 | 0.1684 | 101.2 | 0.0564 | 128.76 |
| M = Fe | | | | | | | | |
| 1 | 0 | 1:0 | 0.0778 | - | 0.1810 | - | 0.1339 | - |
| 2 | 50 | 1:2000 | 0.0722 | 92.8 | 0.1763 | 97.4 | 0.1304 | 97.38 |
| 3 | 100 | 1:4000 | 0.0741 | 95.2 | 0.1741 | 96.2 | 0.1379 | 102.98 |
| 4 | 200 | 1:8000 | 0.0710 | 91.2 | 0.1772 | 97.9 | 0.1326 | 99.02 |
| 5 | 250 | 1:10000 | 0.0692 | 88.9 | 0.1708 | 97.3 | 0.0349 | 100.74 |
| M = Ca | | | | | | | | |
| 1 | 0 | 1:0 | 0.0750 | - | 0.1582 | - | 0.0345 | - |
| 3 | 50 | 1:2000 | 0.0705 | 94.0 | 0.1574 | 99.5 | 0.0344 | 99.71 |
| 4 | 100 | 1:4000 | 0.0726 | 96.8 | 0.1524 | 96.3 | 0.0284 | 82.29 |
| 5 | 200 | 1:8000 | 0.0603 | 80.4 | 0.1381 | 87.3 | 0.0289 | 86.38 |
| M = Mg | | | | | | | | |
| 1 | 0 | 1:0 | 0.0750 | - | 0.1958 | - | 0.0345 | - |
| 2 | 50 | 1:2000 | 0.0756 | 100.8 | 0.1967 | 100.4 | 0.0345 | 100.00 |
| 3 | 100 | 1:4000 | 0.0720 | 96.0 | 0.1941 | 99.1 | 0.0345 | 100.00 |
| 4 | 200 | 1:8000 | | | 0.1942 | 99.1 | 0.0355 | 102.89 |

Table IV

Influence of As, Sb, Fe, Ca, Mg and Tl on the determination of Fe and Mn

| No. | mm/mg | mFe,Mn:MM | A _{Fe} | A/AcM=0·100 | A _{Mn} | A/AcM=0·100 |
|--------|-------|-----------|-----------------|-------------|-----------------|-------------|
| M = As | | | | | | |
| 1 | 0 | 1:0 | 0.0419 | 100.0 | 0.1101 | - |
| 2 | 50 | 1:200 | 0.0428 | 102.1 | 0.1071 | 97.27 |
| 3 | 100 | 1:400 | 0.0425 | 101.4 | | |
| 4 | 150 | 1:600 | 0.0429 | 102.3 | 0.1024 | 93.01 |
| 5 | 200 | 1:800 | 0.0444 | 106.0 | 0.1104 | 100.27 |
| 6 | 300 | 1:1200 | 0.0444 | 106.0 | | 91.7 |
| M = Sb | | | | | | |
| 1 | 0 | 1:0 | 0.0680 | 100.0 | 0.1792 | - |
| 2 | 20 | 1:80 | 0.0696 | 102.3 | | |
| 3 | 50 | 1:200 | 0.0663 | 97.5 | | |
| 4 | 100 | 1:400 | 0.0671 | 98.7 | | |
| 5 | 150 | 1:600 | 0.0671 | 98.7 | | |
| 6 | 200 | 1:800 | | | 0.1792 | 100.00 |
| 7 | 300 | 1:1200 | | | 0.1936 | 108.03 |
| M = Mg | | | | | | |
| 1 | 0 | 1:0 | 0.0657 | 100.0 | | |
| 2 | 10 | 1:200 | 0.0662 | 100.8 | | |
| 3 | 35 | 1:600 | 0.0665 | 101.2 | | |
| 4 | 50 | 1:1000 | 0.0651 | 99.1 | | |
| M = Ca | | | | | | |
| 1 | 0 | 1:0 | 0.0657 | 100.0 | | |
| 2 | 10 | 1:200 | 0.0651 | 99.1 | | |
| 3 | 35 | 1:600 | 0.0655 | 99.7 | | |
| 4 | 50 | 1:1000 | 0.0659 | 100.3 | | |
| M = Tl | | | | | | |
| 1 | 0 | 1:0 | 0.0605 | 100.0 | 0.1314 | - |
| 3 | 20 | 1:80 | 0.0665 | 101.0 | 0.1373 | 104.49 |
| 4 | 50 | 1:200 | 0.0615 | 101.6 | 0.1335 | 101.6099.1 |
| 5 | 100 | 1:400 | 0.0635 | 104.9 | 0.1841 | 140.10 |
| 6 | 200 | 1:800 | 0.0615 | 101.0 | 0.0888 | 67.60 |

Table V

The results of determination of Fe, Mn, Cr, Cu and Ni in lorandite, realgar, orpiment, stibnite and dolomite.

| Mineral | m _{mineral} /g | w/ $\mu\text{g}\cdot\text{g}^{-1}$ | | | | |
|---------------|-------------------------|------------------------------------|--------|--------|---------|--------|
| | | Fe | Mn | Cr | Cu | Ni |
| Lorandite | | | | | | |
| pure | 0.0620 | 645.2 | | <1.0 | | <1.0 |
| nonpure | 0.2500 | 6760.0 | 58.6 | <1.0 | 63.73 | 6.2 |
| Ref. 10 | | 205-2100 | 2-74 | 0.5-10 | 200-360 | <10 |
| Orpiment | | | | | | |
| x-800-1 | 0.250 | 96.0 | 5.0 | <1.0 | 9.1 | <1.0 |
| x-800-2 | 0.250 | 192.0 | 9.4 | <1.0 | 4.4 | <1.0 |
| x-800-3 | 0.250 | 490.0 | 14.4 | 32.6 | 7.4 | 41.0.0 |
| x-800-4 | 0.250150 | 620.0 | 28.3 | <1.0 | 6.5 | 115.1 |
| Ref. 10 | | <200 | 100 | <100 | <300 | <30 |
| Realgar | | | | | | |
| x-800-1 | 0.1935 | 365.6 | 70.4 | <1.0 | <1.0 | <1.0 |
| x-800-2 | 0.1461 | 1410.0 | 307.2 | <1.0 | <1.0 | 6.9 |
| x-800-3 | 0.1374 | 3400 | 954.9 | <1.0 | <1.0 | 7.4 |
| from orpiment | 0.0292 | - | - | <1.0 | <1.0 | <1.0 |
| P-21-1 | 0.2500 | 3900 | 48.6 | <1.0 | 4.7 | 3.4 |
| P-21-2 | 0.2500 | 36500.0 | 561.2 | <1.0 | <1.0 | 6.4 |
| P-21-3 | 0.2500 | 33500.0 | 1034.8 | <1.0 | <1.0 | 6.4 |
| P-21-4 | 0.2500 | 5550.0 | 1887.0 | <1.0 | <1.0 | 1.9 |
| Ref. 10 | | | | <10 | <1200 | <30 |
| Stibnite | | | | | | |
| 1 | 1.0000 | - | - | 4.0 | 1.8 | 9.6 |
| Dolomite | | | | | | |
| x-800-1 | 0.21340 | 287.4 | 216.3 | <1.0 | <1.0 | 16.2 |
| x-800-2 | 0.2610 | 386.6 | 385.3 | <1.0 | <1.0 | 17.6 |
| x-800-3 | 0.2008 | 450.7 | 431.6 | <1.0 | <1.0 | 13.4 |
| Marcasite | | | | | | |
| 1 | 1.0000 | - | - | 1.2 | - | - |
| 2 | 0.2146 | - | - | 4.9 | 30.2 | 84.3 |

RESULTS AND DISCUSSION

In most papers on the determination of investigated elements by ETAAS in different geological samples, acid digestion is suggested for sample dissolution. However, these solutions contain different ions of elements dissolved from the sample matrix, which may interfere with the determinations. Therefore, it is necessary to investigate this possible cause if interference.

The interferences of matrix elements of the minerals studied (As, Sb, Tl, Fe, Ca and Mg) on the determination of Fe, Mn, Cu, Cr and Ni, were investigated by preparing a series of solutions with the same concentration of investigated elements and different concentrations of interfering elements with concentrations similar to the concentrations in the sample solutions. Because of the higher concentration of iron and manganese in realgar, orpiment, lorandite, stibnite and dolomite, it was possible to determine these elements by flame AAS. In the case of copper, chromium and nickel it was necessary to use electrothermal AAS. The results of this interferences in the determination of iron and manganese by flame AAS are presented in Table II. The results of this interference in the determination by electrothermal AAS, of copper, chromium and nickel are presented in Table III, and for iron and manganese in Table IV.

As can be seen from Table II, there is very little interference from As, Sb, Ca and Fe on the determination of Fe and Mn by flame AAS up to the

mass ratio which corresponds to the mass of 0.5 g of investigated minerals, so that it is not necessary to separate these elements from the matrix if we take this mass of minerals. From the results given in the Tables III and IV it can be seen that all the investigated elements can be determined from arsenic minerals, stibnite and marcasite when 1 g of mass is used, and in the case of dolomite 500 mg and for lorandite not more than 250 mg.

Using these procedures, samples of lorandite, realgar, orpiment, stibnite and dolomite (without and with standard additions) were dissolved, extracted and Fe, Mn, Cu, Cr and Ni were determined. The results are given in Table V. It can be seen from these results that the content of iron has high values probably from the presence of marcasite and pyrite as impurities. These values are especially high in realgar. Manganese is also present as a high content in realgar. The content of copper, chromium and nickel is usually low, and in most case it is below $10 \mu\text{g} \cdot \text{g}^{-1}$, or precisely below $1 \mu\text{g} \cdot \text{g}^{-1}$. The obtained values for the content of these elements in the investigated minerals compared with those of Palme et al. (1988) are many precise and in more cases they are in the same range.

The methods were checked by the method of standard addition for all elements and minerals and values of the recovery in a range of 95.5 - 103.8 % were obtained.

CONCLUSION

Iron, manganese, copper, chromium and nickel can be determined by atomic absorption spectrometry in some minerals (realgar, orpiment, lorandite, stibnite, marcasite and dolomite) from the Alšar mine, Macedonia. Iron and manganese can be analyzed by flame, and copper, chromium and nickel by

electrothermal atomic absorption spectrometry. The content of these element in the investigated minerals varies from below 1 ppm for copper, nickel and chromium, to some percent for iron in some samples of nonpure realgar.

REFERENCES

- Alvin, J. F., Gardner, F. R. (1986): Determination of Cu, Fe, Pb and Zn in complex sulfide materials by flame atomic absorption spectrometry.- *Analyst*, **111**: 897-9.
- Beccalova, L., Venturelli, G. (1971): Nickel, chromium and strontium determination in some silicate rock.- *At. Absorpt. Newslett.*, **10**: 50-52.
- Bichova, L. V., Kherebenko, A. V. (1978): Atomic absorption determination of impurities in natural calcite.- *Prikl. Teor. Fiz.*, **1978**: 175-179.
- Burba, P., Willmer, P. G. (1987): Multielement preconcentration for atomic spectroscopy by sorption of dithiocarbamate-metal complexes (HMDC) on cellulose collectors.- *Fresenius Z. Anal. Chem.*, **329**: 539-545.
- Danz, J. H., Jackwerth, E. (1986): Multielement preconcentration for trace analysis of lead-antimony alloys.- *Fresenius Z. Anal. Chem.*, **325**: 157-62.
- Donaldson, E. M. (1989): Determination of cobalt, nickel, lead, bismuth, and indium in ores, soils, and related materials by atomic absorption spectrometry after separation by xanthate extraction.- *Talanta*, **36**: 543-548.
- Eidecker, E., Jackwerth, E. (1988): Multielement preconcentration from pure iron and iron compounds.- *Fresenius Z. Anal. Chem.*, **331**: 401-7.
- Freedman, M. S., Stevens, C. M., Honwitz, E. P., Fuchs, L. H., Sherner, J., Goodman, L. S., Childs, W. J. (1976): Solar neutrinos: Proposal for a new test.- *Science*, **193**: 1117-1118.

- Hannaker, P., Hughes, T. C. (1977): Multielement trace analysis of geological materials with solvent extraction and flame atomic absorption spectrometry.- *Anal. Chem.*, **49**: 1485-8.
- Isshiki, K., Sohrin, Y., Karatani, H., Nakayama, E. (1989): Preconcentration of chromium(III) and chromium(VI) in seawater by complexation with quinolin-8-ol and adsorption macroporous resin.- *Anal. Chim. Acta*, **224**: 55-64.
- Marabini, A., Barbaro, M., Passarillo, B. (1982): Determination of manganese in ore by atomic absorption spectrophotometry.- *At. Spectrosc.*, **3**: 140-142.
- Matsusaki, K., Yoshino, T., Yamamoto, Y. (1981): Removal of chloride interferences in the determination of chromium by atomic absorption spectrometry with electrothermal atomization.- *Anal. Chim. Acta*, **124**: 163-8.
- Nakamura, T., Okubo, K., Sato, J. (1988): Atomic absorption spectrometric determination of copper in calcium carbonate scale and carbonate rocks by direct atomization of solid samples.- *Anal. Chim. Acta*, **209**: 287-92.
- Otaway, J. M., Coker, D. T., Rowston, W. B., Bhattarai, D. R. (1970): Interferences of cobalt, nickel, and copper in the determination of iron by atomic-absorption spectrometry in an air-acetylene flame.- *Analyst*, **95**: 567-573.
- Palme, H., Pavičević, M., Spetel, B. (1988): Major and trace elements in some minerals and ore from Crven Dol, Allchar.- *Nucl. Instr. Meth. Phys. Res.*, **A271**: 314-319.
- Robinson, P. (1980): Determination of calcium, magnesium, manganese, strontium, sodium and iron in the carbonate fraction of limestones and dolomites.- *Chem. Geol.* **28**: 135-146.
- Rubeska, I., Miksovsky, M. (1974): Analysis of sulfatic minerals by atomic absorption spectrometry.- *Czech. Chem. Commun.*, **39**: 3485-93.
- Schweizer, V. B. (1975): Determination of cobalt, chromium, copper, molybdenum, nickel, and vanadium in carbonate rocks with the HGA-70 graphite furnace.- *At. Absorpt. Newsl.*, **14**: 137-141.
- Srivastava, R. K. (1977): A comprehensive atomic absorption and spectrophotometric scheme for the determination of major and trace elements in rocks and minerals.- *Neues Jarhb. Mineral., Monatsh.*, **9**: 425-432.
- Stafilov, T., Jordanovska, V., Aleksovska, S. (1990a): Determination of lead in antimonite by electrothermal atomic absorption spectrometry.- *Vest. Slov. Kem. Drust.*, **37**: 141-148.
- Stafilov, T., Jordanovska, V., Aleksovska, S. (1990b): Matrix interferences in the determination of lead in As-Sb-Tl ores by electrothermal atomic absorption spectrometry.- *Bull. Chem. Technol. Macedonia*, **8**: 93-98.
- Stafilov, T., Jordanovska, V., Aleksovska, S. (1990c): Determination of lead in arsenic minerals from Alshar by atomic absorption spectrometry.- *Bull. Chem. Technol. Macedonia*, **9**: 159-166.
- Stafilov, T., Aleksovska, S., Jordanovska, V. (1993): Determination of lead in lorandite and marcasite by electrothermal atomic absorption spectrometry.- *Neues Jbr. Miner.*, in press.
- Stafilov, T., Lazaru, A., Pernicka, E. (1993a): Determination of thallium in sulfide minerals by Zeeman electrothermal atomic absorption spectrometry.- *Acta Chim. Slo.*, **41**: 37-46.
- Subramanian, K. S. (1988): Determination of chromium(III) and chromium(VI) by ammonium pyroolidinecarbamate-methylisobutyl ketone - furnace atomic absorption spectrometry.- *Anal. Chem.*, **60**: 11-15.
- Sundberg, L. L. (1973): Interferences in Ni determinations by AAS.- *Anal. Chem.*, **45**: 1460-4.
- Taddia, M., Lanza, P. (1984): Determination of chromium in gallium arsenide by electrothermal atomic absorption spectrometry.- *Anal. Chim. Acta*, **159**: 375-80.
- Todt, W. (1988): Isotope dilution measurements of Pb, U and Th concentration in lorandite from Allchar.- *Nucl. Instr. Meth. Phys. Res.*, **A271**: 251-252.
- Tominaga, M., Umezaki, Y. (1983): Evaluation of interference suppressors in electrothermal atomic absorption spectrometry.- *Anal. Chim. Acta*, **148**: 285-291.
- Wang, W.-I. (1980): Determination of trace chromium(VI) as a thiosemicarbazide complex by solvent extraction and atomic absorption spectrometry.- *Anal. Chim. Acta*, **119**: 157-60.
- Williams, M. C., Edward, E. J., Niemezyk, T. M. (1986): Masking, chelation and solvent extraction for the determination of sub-per-million levels of trace elements in high iron and salt matrixes.- *Anal. Chem.*, **58**: 1541-7.
- Zelentzova, L. V., Yudelevich, I. G. (1983): Atomic absorption analysis of high purity arsenic.- *Zh. Anal. Khim.*, **38**: 1404-1407.
- Zorkin, I. D., Zubova, O. D. (1990): Determination of lithium, rubidium, cesium, strontium, copper, zinc, lead, cobalt, nickel, and chromium in silicate rock by atomic spectroscopy.- *Zh. Anal. Khim.*, **45**: 1858-1860.