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GEOMETRICAL AND APPLIED OPTICS

The Influence of a Probe on the Optical Path of Atomic Absorption Spectrometer with a Graphite Tube Atomizer

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Abstract—We have studied the influence on the atomic absorption signal of the obscuring of the transmission beam by a probe for the two-stage atomization in a graphite tube atomizer. The following parameters were varied: the thickness of the probe (0.5–1.0 mm), its displacement from the optical axis of the spectrometer (up to 2 mm), the diameter of the transmission beam (1.3–4.0 mm), the slit width of the monochromator, and the shape of the intensity distribution over the cross section of the beam emitted either by a hollow cathode lamp, or a deuterium lamp, or an electrodeless lamp. We have shown that, using a probe with a thickness that is optimal for the two-stage atomization (1 mm), it is possible to register analytical absorption signals from 28 chemical elements out of 56 (except Hg), which can be determined in graphite atomizers, with a maximal sensitivity and with no optical interference. The remaining elements can be determined with a lower sensitivity because of the necessity to lower the temperature of the secondary atomization.

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INTRODUCTION

At present, atomic absorption spectrometry with a graphite tube atomizer of a sample is one of the most sensitive and wide-spread methods of spectral analysis of substances, which makes it possible to detect 57 chemical elements (mainly, metals) in the wavelength range of 180–853 nm at a level of 10^{-4}–10^{-8}% [1, 2] provided that elements are in single aqueous solutions. The sensitivity of direct analysis of samples with a complex composition (rocks, soils, biological tissues, etc.) significantly decreases because the main substance affects the analytical signal of the impurity. To eliminate these influences, a method of two-stage probe atomization has been proposed comparatively recently [3–5]. Initially, the substance to be analyzed is completely evaporated in an atomizer, and impurities to be determined are fractionally condensed onto a specially inserted tungsten probe. After that, this probe is introduced into an atomizer that is heated to a temperature of 1500–2500°C to evaporate the condensate and to measure the absorption signal. For a number of elements, the determination efficiency of the method is high; however, at the same time, the method has obvious instrumental restrictions, which are related to a large mass of corresponding probes. First, the probe obscures part of the transmission beam, thereby reducing the transmission of the spectrometer. Second, the probe is strongly heated and becomes a source of parasitic illumination of the photodetector, especially, upon an increase in the wavelength of the spectral line and temperature of the atomizer, which is dictated by the properties of the element to be determined. Potentially, these factors are sources of errors of photometric measurements of the absorbing layer of vapors and, in extreme cases, can prevent measurements from being made.

In this connection, to quantitatively estimate optical restrictions to the application of the probe atomization in the spectral analysis, we study in this work theoretically and experimentally how the obscuring of the transmission beam by the probe in the graphite atomizer affects the atomic absorption signal depending on the dimensions of the probe, the shape of the beam, the optical system of the spectrometer, and spectral and thermal properties of elements to be analyzed.

EXPERIMENTAL

Mathematically, the interaction of the probe with the transmission beam was simulated using the MATLAB software package.

Experiments were performed on the following three spectrometers: AAS-30 (Carl Zeiss Jena, Germany), which was equipped with an EA-3 longitudinally heated atomizer and a background corrector based on a deuterium lamp; MGA-915MD (Lumex, Russia), which was equipped with a similar atomizer and a background corrector based on the Zeeman effect; and SIMAA 6000 (PerkinElmer, United States), which was equipped with a THGA transversely heated atomizer and a background corrector