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Modern Methods of Studying the Microelement's Composition of Oil

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ABSTRACT

Information on the extended microelement composition of oil has practical significance and is of interest both for scientific research and for the development of technological processes for its processing. From the point of view of geochemistry, data on the features of the quantitative distribution of microelements in the composition of oil provide an opportunity to identify its genetic differences for oil exploration tasks. In the petrochemical industry, the results of determining the microelement composition make it possible to evaluate the composition of oil at the production stage and control the quality of the products obtained at different stages of its processing. The study of the microelement composition makes it possible to obtain additional information on the migration routes of an oil field. The development and application of instrumental methods for determining a wide range of microelements in oil are considered.

Keywords: Oil; Microelement composition; Resinous-asphaltene substances; Physicochemical methods of analysis; Spectral methods of analysis; Mass spectrometry with inductively coupled plasma

Introduction

The study of the microelement composition of oils is important for substantiating various theories of the origin of oil (including determining its age). It is known that the ratios of microelement concentrations in oil carry information about the genesis of hydrocarbons, so data on the distribution of elements can largely determine the strategy for searching for oil fields. Obtaining reliable data on the microelement composition will make it possible to compile geochemical passports of typical fields formed in various geodynamic settings and within individual oil and gas-bearing strata. At present, extensive experimental data on the microelement composition of oil have been accumulated[1], but it is mainly descriptive. In this article, we have attempted to summarize modern methods for studying the microelement composition of oil. It is known that the bulk of all microelements is concentrated in the highest-boiling fractions of oils, namely, in resinous-asphaltene substances (RAS)[1,2]. The most studied are vanadium and nickel compounds, since their content is relatively high; their compounds can be concentrated and purified. Thus, vanadium is completely concentrated in RAS and is practically absent in oil fractions. Nickel is also concentrated in the highest molecular weight part of oil, but is also present in small quantities in the oil part of heavy oil residues. It should be noted that studies of microelements in oils are extremely complicated by their endless variety and very small quantities[3].

Main Part

The most common methods used to determine the microelement composition of oil are chemical, physicochemical (instrumental) and physical methods of analysis. Methods of chemical analysis include titrimetric analysis (a method of quantitative chemical analysis based on measuring the volume of a reagent solution of known concentration spent on a reaction with a reagent solution of unknown concentration that needs to be determined). Titrimetric analysis uses chemical reactions of various types: neutralization, oxidation-reduction, precipitation and complexation. The analysis consists of titration being carried out to the equivalence point, which is determined using an indicator or instrumentally. As a rule, it is used to determine elements such as lead, barium, calcium and zinc.

The physicochemical (instrumental) methods of analysis are quantitative analytical methods of analysis that require electrochemical, optical, radiochemical and other equipment. These methods of analysis include: 1) electrochemical methods - potentiometry, polarography, conductometry, etc.; 2) methods based on the absorption and study of electromagnetic waves - emission spectral analysis, photometric methods, X-ray spectral analysis, etc.; 3) mass spectral analysis; 4) methods based on measuring radioactivity; 5) various methods of gas analysis.

Let us recall that potentiometry is based on measuring the potential of an electrode immersed in the analyzed solution, which changes as a result of a chemical reaction. The value of the electrode potential depends on the concentration of the corresponding ions in the solution under other constant measurement conditions. Potentials are measured using potentiometers. Polarography is based on measuring the current strength, which changes depending on the voltage during electrolysis, under conditions where one of the electrodes has a very small surface. In polarographic measurements, such an electrode is a drop of mercury flowing out of a very thin hole in a capillary tube, as well as platinum (rotating), graphite, silver and other electrodes. And, conductometry is based on measuring the electrical conductivity of the analyzed solutions, which changes as a result of chemical reactions and depends on the properties of the electrolyte, its temperature and the concentration of the dissolved substance.

It should be noted that the main physical and chemical method is photometry (these are optical methods of analyzing substances by absorption spectra in the wavelength range from ultraviolet to infrared rays), which is used in the analysis of petroleum products for lead, vanadium and arsenic.

Physical methods of analysis are also widely used in determining trace elements in petroleum products. These include flame photometry (an express method for the quantitative determination of certain trace elements in solutions by atomic and molecular spectra), spectral methods of analysis (atomic absorption spectrometry and atomic emission spectroscopy, atomic emission spectroscopy with inductively coupled plasma) and methods of X-ray structural analysis (X-ray spectral analysis, X-ray phase analysis and X-ray fluorescence analysis)[4].

Atomic emission spectral analysis is based on measuring the intensities of characteristic spectral lines of the elements that make up the analyzed substance. There is a proportional relationship between the intensity of the spectral lines of the element being determined and its concentration in the substance being studied: the higher the concentration of the element being determined, the greater the intensity of the spectral lines. The microelement composition of petroleum asphaltenes is determined by emission spectral analysis on a DFS-458 diffraction spectrograph. The main advantage of physical methods is that they can simultaneously determine a large number of different microelements in a wide range of their concentrations[5].

Radioactivation analysis

This is the most important nuclear-physical method, which has an exceptionally low detection limit; the method allows determining micro amounts of microelements in pure substances, geological samples and other objects. One of the advantages of this method is the ability to analyze without destroying the sample, without direct contact with it and in some cases - the rapidity of determinations. Depending on the radiation used for activation, there are neutron activation, gamma activation and other analyzes.

Neutron activation analysis (NAA) method

NAA is carried out using nuclear reactors or so-called neutron generators, which are cheaper and more accessible. Conventional measuring equipment is used to register radioactive radiation from the resulting radioisotopes, but semiconductor detectors (e.g., germanium-lithium) in combination with multichannel pulse analyzers play a special role in NAA. Semiconductor detectors have a high resolution, which makes it possible to analyze complex mixtures of radioisotopes. The NAA method was used to study the concentrations of microelements (ME) in RAS isolated from a number of typical Azerbaijani oils and their vacuum residues[2].

It was found that the studied RAS contain the elements in the highest concentrations in order of decreasing concentrations, most often forming the series: Fe> Ni> Cr> V> Co, as well as heavy halogens (iodine and bromine), present mainly in resinous substances. Fluorine is not found in Azerbaijani oils; during the distillation of oil, halogens are found in all fractions, with iodine concentrated in low-boiling fractions (80-170°C) and bromine in high-boiling fractions (above 300°C). Cr and Co are concentrated in the highest molecular weight fractions of petroleum asphaltenes. The presence of lanthanides (La, Eu, Ce, Yb), previously not determined experimentally, in the molecules of petroleum RAS were not revealed.

The data obtained by the NAA method indicate a significant influence of the chemical nature of ME on the features of their binding by resinous or asphaltene components of oils, in particular, on the preferential accumulation of the most common ME (Fe, Cr, Ni, Co, Ba, Zn) in asphaltenes and some ME in resins ((Ag, Se, Eu, Yb, Ta). That is, despite the reduced total concentration of ME, resinous substances, due to their high content in oils, retain in their composition the predominant amount of oil metal-containing compounds, in connection with which deasphalting using traditional extraction-precipitation methods does not provide the necessary depth of demetallization of oil feedstock.

It should be emphasized that during high-temperature vacuum distillation of oil, resins and asphaltenes, in most cases, are enriched with ME atoms (Fe, Ni, Co, Cr, Zn and Se) due to the assimilation of equipment corrosion products and lose a significant part of the atoms originally contained in them - V, Ba, Hg, Br and I. The results of the study of the ME composition of Azerbaijani oils showed that regardless of their location (onshore or at offshore), the compositions of the ME of oil and condensate are close and when passing from oil to condensate, the concentration of ME sharply decreases. Among the determined ME, Fe, Ni, Mn, Zn are dominant and the content of Mo and Cr is an order of magnitude lower.

In general, Azerbaijani oils (as indicated above) are characterized by a high content of the element Fe, which is mainly concentrated in younger weakly metamorphosed oils (which are Azerbaijani oils) at the initial moment of their formation. And then, as a result of oxidation reactions and when mixed with formation waters, partial leaching of iron from the oil occurs. We would like to note that the problem of determining a clear distribution of ME between the separated fractions (components) remains complex. It is difficult to predict due to the typical diversity of compounds and a significant predominance of any ME can lead to errors due to the existence of Compton background or interference. That is, today there is no single, established point of view on the source of ME in oils.

The study of the microelement composition of oils is also used to obtain geochemical information, since the geochemical and biogeochemical processes occurring in the biosphere determine the migration, dispersion and concentration of microelements in natural processes, influencing the geochemical situation that develops in individual regions of the planet. The microelement composition of oils also has important applied significance: S, Cu, V, Ni, Hg and other metals are extracted from them. In the USA, two-thirds of vanadium production is associated with its extraction from oil and in California, gold-bearing oils are exploited. The value of oils especially increases with the presence of Pt and Pd, which are used as effective catalysts in many hydrocarbons processing processes[6].

Method of neutron absorptiometry

This method is based on the weakening of the neutron flux in a substance containing elements whose nuclei have a high neutron capture cross-section. Using a polonium-beryllium source as a neutron supplier, we determine the content of boron, lithium, cadmium, gadolinium (only high concentrations of these elements - not lower than tenths or hundredths of a percent).

Inductively coupled plasma mass spectrometry

The inductively coupled plasma mass spectrometry method was used to determine the content of microelements in samples of petroleum asphaltenes, as well as in paraffin-naphthenic hydrocarbons, aromatic hydrocarbons and resins[7]. Based on the results of the analysis of Russian oil samples with different physicochemical properties (heavy high-viscosity and bituminous super viscous), the distribution of microelements in hydrocarbon groups was studied and it was found that both oils under study are enriched in microelements and belong to the "vanadium" type.

It was revealed that most of the elements being determined are contained in the oil samples at levels of more than 1.0 μg/g, 0.1 – 1.0 μg/g and less than 0.1 μg/g. The contents of the remaining elements are below the detection limits. The main trends in the distribution of microelements in hydrocarbon groups indicate their concentration in the composition of polar polycondensed structures (resins and asphaltenes).

Correlation analysis method

It should be especially noted that information on the extended microelement composition of oil has practical significance and is of interest both for scientific research and for the development of technological processes for its processing. From the point of view of geochemistry, data on the features of the quantitative distribution of microelements in the composition of oil provide an opportunity to identify its genetic differences for oil exploration tasks. In the petrochemical industry, the results of determining the microelement composition make it possible to evaluate the composition of oil at the production stage and control the quality of the resulting products at different stages of its processing.

It is the correlation analysis method that allows achieving high stability of comparison results, although, possibly, with a certain decrease in the sensitivity of the analysis. The presence of concentration values of a large number of elements allows calculating mutual correlations of the chemical composition of samples and comparing them both with each other and with the typical chemical composition of various georeservoirs, while the results of such comparisons are satisfactorily stable. Data are correlated not for individual characteristic elements, but for all elements detected in oils (or other natural formations). The calculation of the values of the correlation coefficients is carried out on a logarithmic scale, which allows taking into account data on elements with very low concentrations[8].

Thus, the article[9] discusses the results of calculations of the correlation coefficients of the microelement composition of samples with model chemical compositions of oils from various fields. Unlike the commonly used methods of comparing the content of individual elements and groups of elements, this method, based on the use of the entire set of data on the microelement composition, provides more accurate results. The basis of the analysis is a database compiled from a large number of analyses by different authors and including data on the microelement composition of oils from various fields. The results of calculations of the correlation coefficients at the quantitative level also confirm the previously made conclusions about the polygenic source of microelements in oils.

It should be especially emphasized that an important analytical task, primarily related to ecology and environmental protection, is the control of sulfur content in oil and oil products. The widespread use of various types of oil-based fuel (gasoline, kerosene, fuel oil, etc.) in automobile, marine and aviation transport, for the generation of electricity at thermal power plants leads to atmospheric pollution by combustion products, primarily sulfur dioxide, which leads to acid rain, which disrupts soil fertility and directly threatens human health.

If previously the sulfur content in fuel at the level of 100 - 150 mg/kg (0.01 - 0.015%) was considered quite acceptable, then the newly developed standards of leading countries provide for a reduction in the maximum permissible concentration of sulfur in gasoline and diesel fuel to 30 - 10 mg/kg and less. And in this case, the X-ray fluorescence method of analysis (using the universal X-ray fluorescence energy dispersive spectrometer BRA-135F) is the arbitration method for determining the mass fraction of sulfur in oil and various oil products, in particular, it will allow the analysis of diesel fuel, kerosene and motor fuel of all classes.

For example, this device is effectively used to determine chloride salts, chlorine and bromine in oil and liquid petroleum products, as well as to determine metals in oil and petroleum products. In the near future, due to the observed trend of depletion of ore deposits, oil may become a raw material for obtaining vanadium (V), nickel (Ni) and a number of other metals. Microelements contained in oil, primarily V, can have a significant impact on the technological processes of oil refining, causing poisoning of catalysts. The contents of the most common elements in oils - V and Ni vary greatly from fractions of g / t to 6 kg / t for V and up to 350 g / t for Ni.

These elements are determined by X-ray fluorescence analysis (XRF) with wave dispersion. XRF is one of the modern spectroscopic methods for studying a substance in order to obtain its elemental composition (elemental analysis). It can be used to detect various elements from beryllium (Be) to uranium (U). The XRF method is based on collecting and then analyzing the spectrum that occurs when the material being studied is irradiated with X-rays. Recently, software for X-ray fluorescence analysis of composition has appeared, based on the method of fundamental parameters. The essence of the method lies in solving a system of differential equations that relate the intensity of X-ray radiation at a certain wavelength to the concentration of an element in a sample (taking into account the influence of other elements). This method is suitable for quality control of samples with a previously known composition, since a standard with a similar composition is required to calibrate (graduate) the analyzer.

Rough calculations show that the BRA-135 device will allow determining V and Ni in oils and fuels with the required accuracy and detection limit of several g/t. By the way, the lightest hand-held X-ray fluorescence spectrometer in the world is currently the Thermo NITON XL5 Plus spectrometer. X-ray diffraction analysis is used to control the content of up to 29 chemical elements in liquid cracking catalysts. If necessary, additional elements can be added to the number of elements to be determined. Analysis of both fresh catalysts and those in operation and those already in operation is required to detect wear products. Regardless of the type of X-ray diffraction analysis, the standard provides for the analysis of both pressed and fused samples with borate flux. Note that an important area of application of X-ray structural analysis is the radiography of metals and their alloys.

We must always take into account that, that the use of metal-containing petroleum products as fuel results in the emission of their compounds into the atmosphere, which have a toxic effect. And their use as lubricating oils causes corrosion of active engine elements. All this points to the need to study the microelement composition of oil in the interests of a number of sectors of the national economy and also to improve existing methods for studying microelement composition.

Conclusions

The article examines and discusses various methods for studying the microelement composition of oils. Chemical, physicochemical (instrumental), physical and spectral methods of analysis are considered. All the methods considered have their pros and cons, but the correct choice of the method for studying the composition of microelements in oils and oil products will allow, in the future, to use it more rationally to determine and control the microelement composition of raw materials and products of organic and inorganic synthesis in the technological process, as well as to analyze both fresh catalysts containing microelements and working and already spent ones. From an environmental point of view, studying the microelement composition of oil is important for identifying sources of environmental pollution with oil, since microelements are present in all oil fractions, starting with gasoline and their amount, as a rule, increases with an increase in the boiling point of the fraction, reaching a maximum in the residues.

References

1. Punanova SA. Relationship between the microelement's composition of oils and the composition of the earth's crust as an indicator of the prospects of deep-seated deposits. Actual problems of oil and gas 2023;4(43):3-16.
2. Mirbabayev MF. High-molecular compounds of Azerbaijan oils. Chemistry and technology of fuels and oils 1998; 3:44-45.
3. Mirbabayev MF. Microelement's composition of Azerbaijan oils and their oil components - The XVII International Scientific Symposium 2021:257-259.
4. Mirbabayev MF. Methods of analytical control in metallurgical processes, Baku: Azerbaijan Technical University 2002.
5. Hajiev SN, Shpirt MY. Microelements in oils and their processed products 2012.
6. Marakushev AA. Parageneses of ore metals of hydrocarbon specificity. News of higher educational institutions. Geology and exploration 2007;6:33-40.
7. Kolodyazhny AV, Kovalchuk TN, Korovin YV, Antonovich VP. Determination of microelement's composition of oils and oil products. Status and problems (Review). Methods and objects of chemical analysis 2006;1(2):90-104.
8. Panyukova DI, Osipov K, Maryutina TA. Study of the distribution of microelements in oil hydrocarbon groups. Industrial laboratory. Diagnostics of materials 2024;90(1):26-33.
9. Rodkin MV. Patterns of microelement's composition of caustobiolites and carbonic fluids according to the results of correlation analyses. Actual problems of oil and gas 2023;3(42):97-117.