Journal of Computer Science and Electrical Engineering
ISSN: 2663-1946
DOI: 10.61784/jcsee240119

APPLICATION PROGRESS OF INDUCTIVELY COUPLED PLASMA ATOMIC EMISSION SPECTROSCOPY TECHNOLOGY

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Abstract: This article introduces the application progress of inductively coupled plasma atomic emission spectrometry (ICP-AES) in different fields such as metallurgy, geology, environment, food, traditional Chinese medicine, biochemistry, petrochemical industry, etc. in recent years. Finally, the application progress of inductively coupled plasma atomic emission spectrometry is discussed. The development prospects of spectral analysis were prospected.
Keywords: ICP-AES; Metallurgical; Geological; Environment; Application progress

1 ICP-AES APPLICATION PROGRESS

Inductively coupled plasma atomic emission spectrometry (ICP-AES for short) not only has the advantages of simultaneous determination of multiple elements by atomic emission spectrometry (AES), but also has a wide linear range, and can simultaneously determine the composition of major, secondary, and trace elements, can be used for liquid and solid sample analysis. Since the 1960s, after half a century of development, ICP-AES has made great progress in sensitivity, accuracy, selectivity, automation, analysis speed, etc., and has become a routine method for analyzing inorganic elements and is ideal for laboratories. elemental analysis methods. ICP-AES is not only indispensable in the fields of metallurgy, geology, environment, etc., but also increasingly highlights its superiority in biochemical sample detection, food safety, etc., becoming the laboratory analysis method with the most superior analytical performance and practical value.

1.1 ICP-AES Detects Metal Materials in the Metallurgical Field

Metal materials can be divided into non-ferrous metals (such as copper, lead, zinc, aluminum and magnesium), ferrous metals (such as iron, manganese and chromium) and alloys. There are two main types of analysis of the chemical composition of metal materials. One is the analysis of elements in various metal or alloy materials, such as: Cu, Fe, Pb, Zn, Mn, Ni, Analysis of Al, Be, Cr and other elements; the other is the identification of various alloy brands based on the analysis results, such as aluminum-magnesium alloy, copper alloy, stainless steel, etc. In the past 10 years, there have been an increasing number of articles on the detection of metallic materials by inductively coupled plasma emission spectrometry in various domestic and foreign journals and magazines. According to statistics, from 2007 to 2011, there were about 2,200 related papers, and there were about 400 articles analyzing metal materials, accounting for 18%; but from 2012 to 2016, reports on the ICP-AES method were published in domestic journals. There are about 2,300 articles in large-scale domestic conferences, and about 500 articles on metal material analysis account for 20%. It can be seen that the total number of articles and the proportion of metal material application articles are on the rise. Due to the convenience, speed and accuracy of the ICP-AES method for detecting metal materials, it has long been included in national standards or industry standards. Examples: GB/T 20125 for determination of multiple elements in low alloy steel, GB/T 13748 for determination of magnesium and magnesium alloys, and GB/T 20975 for simultaneous analysis of multiple elements in aluminum and aluminum alloys, etc.

The standard method for palladium purity testing is powder emission spectrometry. This method is not only prone to contamination of Ca and Si, but also has poor analysis accuracy and precision. It also has a long analysis cycle and consumes a large amount of palladium matrix. Li Guangli et al.[1] used the ICP-AES method to determine 22 impurity elements in pure metal palladium. In order to reduce the detection limit, elements that have a large impact on the palladium matrix are measured using multivariate spectral fitting, and elements that have a small impact on the palladium matrix are measured using background interference correction. The relative standard deviation (RSD) and spike recovery rate of the method were 1.9%~8.3% and 85.3%~116.7% respectively. The measured elements include the impurity elements required for determination in palladium according to the national standard[GB/T 1420-2004]. The impurity elements in palladium with a purity of 99.90% to 99.99% can be measured at one time, meeting the qualification requirements of SM-Pd 99.99. At the same time, it can also meet the requirements of ASTMB 589-94 (2005) Grade 99.95 for the determination of impurity elements.

1.2 Application of ICP-AES in Geological Sample Analysis

Geological sample testing mainly includes analysis of rocks, minerals, soil, water system sediments, etc. The composition of the test object is complex, the content range of the measurement is wide, and the interference is large. Traditional analysis techniques mostly require separation and enrichment, which are cumbersome to operate, have long analysis processes, and are labor-intensive. They cannot meet the requirements for analysis of large quantities of geological and mineral samples. The ICP-AES method can directly measure more than 70 metal elements (special samples need to be separated and enriched). The detection content ranges from ng/g level to constant. It is widely used and has become an indispensable analysis in geological and mineral laboratories. testing method.

Phosphate rock is a non-renewable resource. Phosphate rock is the main raw material for the production of phosphate fertilizer. Harmful components such as FeMgO, Fe2O_3 , Al2O3, SiO_2, CaO, and MnO in phosphate rock will affect the quality of fertilizer. Therefore, it is possible to accurately detect the contents of P_2O_5 , MgO, Fe_2O_3, Al_2O_3 , SiO_2 , CaO, K_2O, Na_2O, TiO_2 , MnO, SrO, and S in phosphate rock. Provide reference for production process design. Feng Xiaojun et al.[2] selected a high-salt atomizer for sample injection and directly used the ICP-AES method to determine the above 12 indicators such as P2O5 in phosphate rock. They used lithium metaborate flux, added lithium bromide release agent, and lithium nitrate oxidant, and melted it on a high-frequency melting machine at 1050°C for 4 minutes. After acidification and extraction with nitric acid to a constant volume, the matrix matching method was used to prepare a calibration curve to eliminate the influence of the matrix effect. The detection limit of the method is 0.000 2~0.025 8 μg/g. The relative standard deviation RSD (n=11) of the results is 0.48% ~1.3%. The above-mentioned 12 indicators including P_2O_5 in 3 phosphate rock standard samples including GBW07210, GBW07211 and GBW07212 were measured according to the experimental method. The measured values were basically consistent with the certified values (or the measured values of the national standard method GB/T 1880-1995).

Bauxite is the main raw material for aluminum production. Its main component is Al_2O_3. In addition, it is often accompanied by other useful components, such as Li, Ga, V, Ti, Nb, Ta, etc. In the comprehensive analysis of bauxite, the above trace elements need to be analyzed for comprehensive evaluation and comprehensive recycling of bauxite; it can also be used to explore the mineralization and mineralization environment of bauxite. Lu Yeyou et al.[3] used a hydrochloric acid-nitric acid-hydrofluoric acid-perchloric acid dissolution system to treat samples, and established an ICP-AES method for the simultaneous determination of lithium and gallium in bauxite samples. Experiments show that when the mass concentrations of lithium and gallium are in the range of 0.001 1% ~ 2.400 0 μg/mL and 0.001 6 ~ 2.400 0 μg/mL respectively, their volume mass fraction has a linear relationship with the emission intensity. The linear correlation coefficient of the calibration curve is They are 0.999 9 and 0.999 8 respectively; the detection limits are 0.14 μg/g and 0.20 μg/g respectively. The method was applied to the determination of lithium and gallium in the bauxite composition analysis standard materials GBW 07177 and GBW0 7179 (the development unit is the National Geological Experimental Testing Center). The measurement results are consistent with the certified values. The relative standard deviation (DRS, n=11) is 0.68%~1.60%.

1.3 Application Progress of ICP-AES in Environmental Detection

At present, the country is making great efforts to solve the problem of environmental pollution. Among them, the more prominent heavy metal pollution includes lead, cadmium, arsenic, mercury, copper, manganese and other elements. They have low biodegradability and slow toxicity development. They enter the human body through soil, water, food, atmosphere, etc., and are contained in the organs of the human body. Slowly accumulating, causing chronic poisoning and endangering human health. For example, cadmium can accumulate in the kidneys, liver and other organs and tissues of the human body, causing tissue and organ damage; another example is the Minamata disease incident that shocked the world in Japan from 1953 to 1961, because the discharged wastewater contained inorganic mercury. Inorganic mercury is slowly converted into methylmercury after being eaten by aquatic organisms in the sea. It is ingested and accumulated by fish, and then biomagnified in the food chain. Local residents are poisoned after eating it.

Li Min et al.[4] compared the advantages and disadvantages of the ICP-AES and ICP-MS methods for the determination of heavy metal cadmium, and clarified the applicable scope of the two methods. After preprocessing the environmental samples, they used ICP-AES and ICP-MS methods to determine the cadmium content. The results showed that there was no significant difference between the measurement results. However, ICP-MS has a lower detection limit, high cost, and low penetration rate, and is mainly used in trace and ultra-trace analysis; ICP-AES has a higher penetration rate in grassroots laboratories, and ICP-AES is preferred for routine cadmium analysis. AES. Phosphorus-containing wastewater is extremely harmful to the environment. High concentrations of phosphorus will reduce dissolved oxygen in the water and cause abnormal plankton reproduction. Therefore, phosphorus is one of the important monitoring indicators for comprehensive wastewater discharge. Wang Xueping[5] treated water samples with nitric acid-hydrochloric acid-hydrofluoric acid mixed acid microwave digestion, used the ICP-AES method to determine the total phosphorus content in sewage, and established a method for determining the phosphorus content in sewage. Compared with the current national standard GB 11893 "Ammonium molybdate spectrophotometric method for determination of total phosphorus in water quality", this method does not require the preparation of multiple chromogenic reagent solutions in pre-treatment, has less interference from human uncertain factors, has a short detection cycle and high analysis efficiency. The waste liquid produced by the test has less environmental pollution.

Inductively coupled plasma atomic emission spectrometry is widely used to determine inorganic elements such as phosphorus, lead, copper, zinc, cadmium, chromium, beryllium, manganese and nickel in sewage, solid waste and soil. It has a short analysis process, high efficiency and low cost. The analytical data has high precision and accuracy, and can be used to evaluate the toxicity of solid waste and analyze the pollution status of harmful heavy metals in soil and sewage.

1.4 Progress in the Application of ICP-AES in Food Testing

The ICP-AES method is used to determine trace elements in black foods such as black beans, black rice, black sesame, fungus, seaweed and other foods; it is used to determine aluminum in foods. Compared with traditional spectrophotometry, the linear range is wide and The detection limit is low, simple and accurate.

The mineral elements Ca, Fe, Na, K, and Zn are the basic elements needed by the human body. The national standard method mainly uses flame atomic absorption spectrometry. This method is complex to operate and takes a long time. At the same time, due to its narrow linear range, especially when detecting the constant elements Ca and Na, it often requires multiple dilutions, causing inconvenience in operation. Qin Yilei et al.[6] used the ICP-AES method to determine the above five major elements in flour foods. Compared with the national standard testing method, the microwave digestion/ICP-AES method has more advantages in determining samples. The linear range of this method is 0.1~30 μg/mL, the detection limit is less than 0.01 μg/mL, and RSD $< 0.5\%$. Compared with the traditional acid decomposition method for processing samples, not only the test results are consistent, but also it has the advantages of faster, more efficient, less pollution, etc., which can fully meet the requirements of food analysis.

1.5 Progress in the Application of ICP-AES in the Detection of Chinese Medicinal Materials

Trace elements play an important role in human cell metabolism and biosynthesis, and are related to the occurrence of many diseases. If you consume too much or not enough, it can cause imbalance in the human body and cause disease. Li Lihua et al.[7] used wet digestion to process the samples, and the ICP-AES method simultaneously measured the contents of 10 elements in five qi-regulating Chinese medicinal materials (tangerine peel, bergamot, tooneem, costus, and cyperus). Research results show that the five kinds of traditional Chinese medicines that regulate qi contain trace elements beneficial to human health such as Ca, Mg, P, Zn, Fe, Mn and Cu. The most abundant elements are Ca, P and Mg, followed by Al and Fe. There are certain differences in the contents of different elements in the five qi-regulating traditional Chinese medicines. Among them, the contents of Mg, Fe, Mn, Cu, Al and Si in Bergamot are relatively high, the contents of P and Zn are relatively high in Melanium japonica, and the contents of Agarwood are relatively high. The Ca and Sr contents are relatively high. The standard recovery rate of the method is 97.4%~105.8%, and the DRS is $\leq 3.27\%$. It has good accuracy and precision and can meet the needs of actual sample analysis. Through the analysis and determination of trace element contents in five kinds of Qi-regulating Chinese medicinal materials, certain scientific data and reference basis are provided to clarify the relationship between the pharmacology and efficacy of Qi-regulating Chinese medicinal materials and the types and contents of the elements contained in them.

1.6 Application of ICP-AES in Biochemical Sample Detection

The use of ICP-AES to determine heavy metal elements in biological samples (such as blood, urine, hair, nails) has become a common method of analysis and testing. The composition of biological tissues is complex, and the elements that need to be measured, such as lead, arsenic, antimony, mercury, tin, selenium, cadmium, etc., have extremely low concentrations, exist in uncertain forms, and are easily volatile, so the collection and pre-processing of biological samples are difficult. Zhang Tinghong et al.[8] established a fast and stable method for the determination of heavy metal elements in trypsin: using inductively coupled plasma atomic emission spectrometry (ICP-AES) to determine lead (Pb), chromium (Cd), cadmium (Five elements: Cr), arsenic (As), and mercury (Hg). The result is that the wet method HNO3-H2O2 was used to digest the sample, and the contents of the five elements Pb, Cd, Cr, As, and Hg in trypsin were simultaneously measured. The detection limits were 0.010 2, 0.000 9, 0.001, 0.028, respectively. 0.004 mg/L, the element recovery rate is between 98.0% and 103.0%, and the DRS (n=10) is 0.5% and 1.6%. The accuracy and precision of the established elemental analysis method for detecting heavy metals in trypsin meet the requirements. The results of applying this method to the determination of actual samples are satisfactory. The ICP-AES method was also used to test the content of the preservative thimerosal in recombinant yeast hepatitis B vaccines.

1.7 Application of ICP-AES in Petrochemical Products

With the rapid economic development, the petrochemical industry has an increasing demand for platinum-containing catalysts. According to statistics, among thousands of products in the petrochemical industry, more than 85% of the product production processes rely on catalytic reactions, and more than 50% of the catalysts used are related to platinum group metals. my country's precious metal resources are poor and it mainly relies on the international market. The recycling of secondary resources containing precious metals is a major event in my country's resource regeneration. The comprehensive utilization of platinum group metal secondary resources has received more and more attention. Yu Fengshan et al.[9] studied the use of ICP-AES to determine the platinum content in spent petrochemical aluminum-silicon carrier catalysts. The sample uses sulfuric acid to dissolve the petrochemical aluminum-silicon carrier waste catalyst, and chlorine gas is used to oxidize the platinum complex into the solution. Under the condition of 2% (V/V) sulfuric acid, the Pt in the waste catalyst is measured using the standard curve method, which can accurately determine 0.100 %~0.800% content (mass fraction) of platinum, common impurity elements do not interfere with the determination. The results show that using low-concentration sulfuric acid as the medium and using the standard curve method for sample analysis, the detection limit of the method is 0.010 μg/mL, and the recovery rate of the sample is 97.2%~101.8%.

2 CONCLUSION

As a routine laboratory analysis method, inductively coupled plasma atomic emission spectrometry has the characteristics of simultaneous analysis of multiple elements, low detection limit, high sensitivity, and wide linear range of curves. It has been widely used in metallurgy, geology, environment, biochemistry, etc. Compositional analysis of solid and liquid samples in the field. The joint use of analytical instruments, the automation and intelligence of instruments, improving the efficiency of sample injection and atomization, or using new detectors to improve sensitivity are all good wishes of analysts and will promote the rapid development of ICP-AES testing technology.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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