Ultraviolet spectrum-based molecular precision detection

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Abstract. This research discusses the role of modern instrumental technology in accurate molecular detection, with emphasis on UV spectroscopy. At the beginning, the research puts the accent on the importance of molecular precision detection in scientific and industrial applications, highlighting how advanced instruments can help us better understand the molecular structure and interactions. Then the article points out that UV spectrum is a technology to measure the absorption characteristics of molecules in UV spectrum. In particular, its applications in biomedical research, environmental monitoring, food safety and other fields were elaborated, showing its versatility and effectiveness in detecting low concentration substances and providing rapid analysis. At the same time, the challenges and potential innovations of UV spectroscopy in sensitivity, resolution, sample preparation and data analysis are also analyzed. Finally, the article looks forward to the continuous development of UV spectroscopy will make a significant contribution to the progress of scientific research and the improvement of the quality of life.

Keywords: Molecular precision detection; Ultraviolet spectroscopy; Biochemical analysis; Modern instrument technologies; Environmental monitoring.

1. Introduction

Molecular precision detection is of great significance in the scientific development of society. By deeply understanding the molecular structure of substances, scientists can reveal the properties, mechanisms and potential risks of compounds. By continuously promoting the development of technology, molecular precision detection provides a powerful tool for social development and promotes innovation and progress in various fields.

The development of modern instrument technology has brought great convenience and possibility for scientific research and industrial application, and promoted technological progress and social development. Advanced instruments and equipment not only provide high-precision and high-sensitivity measurement means, but also expands our understanding of nature and the material world. In the field of scientific research, nuclear magnetic resonance, mass spectrometer, electron microscope and other instruments are widely used. It enables scientists to deeply study the micro world and reveal the structure and interaction at the molecular level. At the same time, these instruments also provide powerful tools for drug research and development, material chemistry and other fields. In industrial application, modern instrument technology plays a key role in production, quality control and process monitoring. In the production process, sensors, spectrometers and other instruments improve the production efficiency, but also ensure the quality of products. The continuous innovation of instrument technology can also make the industrial field more energy-saving and environmental protection, and promote sustainable development.

Molecular precision detection is a highly sophisticated science and technology. Through the use of advanced instruments and technical means to measure the absorption, emission or scattering of molecules to specific energy of light, so as to infer the molecular characteristics in the sample [1]. This detection method can reveal the structure, composition and interaction of molecules, and provide key information for scientific research, medicine, chemistry and environmental science. Molecular precision detection plays an important role in the application of different fields, which can promote the development of research and industry, and provide an indispensable means for improving health, protecting the environment and innovating science and technology. In the medical field, molecular precision detection is applied to disease diagnosis, treatment and drug development. For example, nuclear magnetic resonance (NMR) and mass spectrometry can be used to analyze biomarkers, help

doctors identify early signs of disease. At the same time, some spectroscopy technologies also play a key role in drug research and development to ensure the purity and efficacy of drugs [2]. In chemical research, molecular precision detection is used to analyze the structure of compounds, understand the reaction mechanism and optimize the synthesis process. For example, ultraviolet visible spectroscopy, infrared spectroscopy and other technologies are widely used to analyze chemical bonds, functional groups and other properties, therefore, it can further provide key information for the design of new materials and chemicals. In the application of environmental science, molecular precision detection is used to monitor pollutants in air, water and soil. For example, mass spectrometry can be used to analyze volatile organic compounds in the atmosphere, while molecular spectroscopy technology can detect chemical substances in water, which is helpful to protect the ecosystem and public health. In the food industry related to our diet, molecular precision detection can help detect harmful substances, additives and microorganisms in food. Nuclear magnetic resonance and mass spectrometry can be used to verify the tested components and detect whether there are potential risks to ensure product quality and consumer safety.

Due to the wide application and diversification of science and technology, modern instrument technology can be classified into several aspects according to the detection principle and application field. These technologies have their own unique advantages and application scope, and together constitute an indispensable technical foundation in modern scientific research and industrial application. Spectroscopic methods, such as ultraviolet visible spectroscopy, infrared spectroscopy, nuclear magnetic resonance spectroscopy and mass spectrometry, it is due to the interaction between matter and light to recognize molecules. Ultraviolet visible spectroscopy is used to measure the absorption characteristics of molecules in the UV-vis region; Infrared spectroscopy is to determine the molecular structure by analyzing the absorption of infrared light; NMR spectroscopy is the use of nuclear magnetic resonance phenomenon to study the chemical environment and structure of molecules; Mass spectrometry is used to determine the mass and chemical structure of molecules. Chromatographic methods, including liquid and gas chromatography, are analyzed by separating the components in the mixture. Liquid chromatography is the separation and identification of molecules through the interaction difference between different molecules in the liquid phase and the stationary phase; Gas chromatography is suitable for the separation and analysis of volatile and gaseous molecules. The main application of electrochemical detection method is to use electrochemical sensors, which use the electrochemical principle to detect the concentration or existence of molecules. Biochemical methods, such as ELISA and fluorescence in situ hybridization, are mainly used to identify biomarkers. The former uses antigen antibody specific binding for molecular detection. The latter uses fluorescent labeled probes to detect specific nucleic acid sequences. Molecular biology techniques, such as PCR and gene sequencing, focus on the detection and analysis of genetic material.

The above contents are a summary and classification of modern instrument technology in molecular precision detection. Each of these technologies and methods is essential for scientific and social progress. The importance of molecular precision detection in scientific and industrial applications is emphasized, and how advanced instruments can help us better understand the molecular structure and interactions is highlighted. Next, the article will carefully introduce UV spectrum, a technology to measure the absorption characteristics of molecules in UV-Vis spectrum.

2. UV spectrum detection technology

UV spectrum detection is a technology commonly used for precise molecular detection, which can obtain information about molecular structure and concentration by measuring the absorption characteristics of samples to UV light. Molecules absorb light of a specific wavelength in the ultraviolet region and produce absorption peaks. The position and intensity of the absorption peak can be used to determine the chemical bond, structure and concentration of molecules. UV detection is widely used in biochemistry, drug research and development, environmental monitoring and other fields.

2.1. Principle of UV spectrum detection

UV spectrum detection is an analytical method based on the absorption characteristics of some substance molecules in the ultraviolet and visible spectral region. This molecular absorption spectrum is mainly produced by the transition of valence electrons in the outer layer of the molecule from the ground state to the excited state between the electronic energy levels. When a molecule absorbs ultraviolet light at a specific wavelength, its internal electrons will transition from low energy level to high energy level. Different molecules or different functional groups within molecules have specific absorption characteristics for specific wavelength of ultraviolet light. In the UV spectrometer, the ultraviolet light emitted by the light source passes through the sample, the molecules absorb part of the light energy, and the rest of the light energy reaches the detector. By measuring the light intensity passing through the sample, the absorption of the sample to different wavelengths of light can be obtained, and the absorption spectrum can be drawn. By comparing the absorption spectrum of the test sample with the standard spectrum of the known substances, the qualitative analysis of substances can be carried out. The quantitative analysis is based on Lambert Beer's law, that is, the absorbance is proportional to the concentration of analytes in the sample. By measuring the absorbance, the concentration of specific molecules in the sample can be calculated.

2.2. Characteristics of UV spectrum

As an important analytical technology, UV spectral detection has four most important advantages. The first is high sensitivity and high selectivity. It can detect very low concentrations of substances, which is particularly important in trace analysis and pollutant monitoring. For example, in environmental monitoring, UV spectrometry is often used to detect trace organic pollutants in water. Secondly, it is fast and easy to operate, because most UV spectral analysis can be completed in a few minutes, which is especially suitable for rapid detection and real-time monitoring. There is also a wide range of applications, which is reflected in the fact that UV spectroscopy technology can be widely used in many fields, such as chemistry, environmental science, pharmacy, food safety and so on. For example, in the field of food safety, UV spectroscopy is used to detect whether food is adulterated and analyze food ingredients. The last point is that it can be combined with other technologies to improve the resolution and accuracy of analysis.

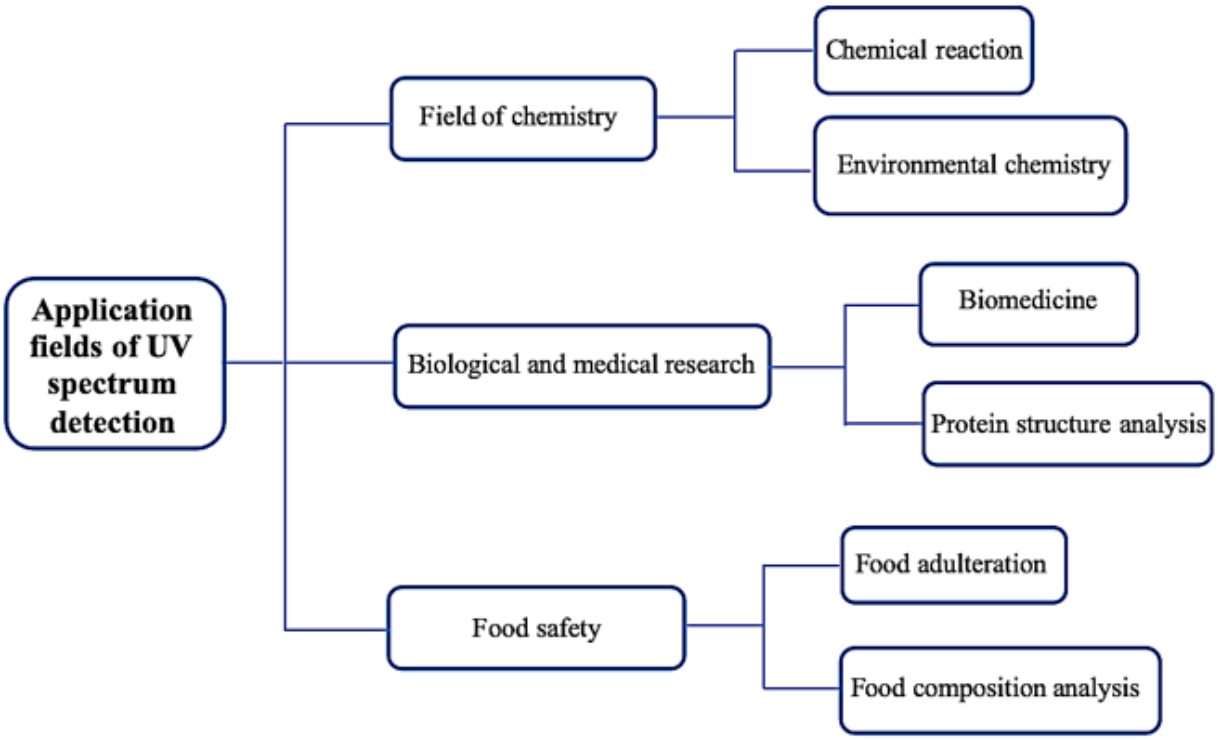


Fig 1. UV spectrum application.

3. Application of UV spectrum in molecular precision detection

3.1. Biological and medical research

As shown in Fig. 1, the application of UV spectroscopy technology has become one of the key tools for life science research, especially in the field of protein structure analysis and drug research and development. The application of this technology in biological and medical research shows its powerful function and potential, but also has a positive impact. This must be attributed to the accuracy and sensitivity of UV spectrum detection.

3.1.1. Protein structure analysis and interaction with other substances

Protein structure analysis is one of the cores of biomedical research. The application of UV spectral analysis in this field is mainly reflected in the identification of secondary and tertiary structures of proteins. Because aromatic amino acids in proteins, such as tryptophan, tyrosine and phenylalanine, can absorb ultraviolet light. By measuring the absorbance of these amino acids at a specific wavelength, it can infer the structural information of proteins. At the same time, UV spectroscopy technology is also very important in studying the interaction between proteins and small molecules or other biological macromolecules. Researchers can infer the binding site, binding affinity and binding mechanism by analyzing the changes of UV spectra of proteins before and after binding with small molecules.

Zhang et al. proposed a machine learning protocol for protein far ultraviolet spectroscopy [1], which utilizes the characteristics of UV absorption spectroscopy commonly used to characterize the overall structure of proteins, and the theoretical interpretation of UV spectroscopy is hindered by a large number of expensive excited states spanning a huge conformational space. This protocol can predict the far ultraviolet spectrum of protein with the same accuracy as that calculated by density functional theory, but the computational cost is reduced by 3-4 orders of magnitude. It also shows excellent predictive ability and transferability, and can be used to detect structural mutations and protein folding pathways. This method can further improve the importance of UV spectroscopy in protein structure analysis.

Amadeo et al. found that due to the presence of tryptophan, tyrosine, and phenylalanine residues [2], when proteins absorb ultraviolet light, their maximum absorbance values are at 280, 275, and 258 nm, respectively. Therefore, the absorbance of three wavelengths was linked to obtain a universally useful and sensitive protein "folding" probe. After experiments, it was found that the probe can be used to study unfolding, refolding, disulfide bond, stability, buffer excipients, and even protein-protein and protein ligand interactions.

In the development of modern science, the study of protein-protein interaction, especially in high concentration solution, has become more and more important. However, the analytical methods used to study protein interactions mainly rely on the detection of non-ideality in relatively diluted solutions. Thakkar et al. introduced the application of variable path length UV-Vis absorption spectroscopy [3], in order to better examine and understand this interaction using several representative proteins in a wide concentration range. Absorbance can be used to monitor the change of UV absorption, and it is the difference between the absorbance measured in a wide range of protein concentrations and the corresponding theoretical absorbance. After light scattering correction, three model proteins (bovine serum albumin, lysozyme, and monoclonal antibody) were found to have different levels of absorbance. The absorbance increased with the increase of protein concentration. This absorbance measurement is an alternative method to monitor and evaluate interactions in high concentration protein solutions.

3.1.2. Biomedicine

The applications of UV spectroscopy in biomedicine and pharmaceutical analysis, such as disease diagnosis, pharmaceutical composition analysis and new technology development, emphasize the practicability and innovation of UV spectroscopy in these fields.

Visceral leishmaniasis is a zoonotic disease caused by juvenile Leishmania, and people think that dogs are the main urban hosts of disease transmission in the future. Therefore, the first and most effective control measure to prevent the spread of disease is to determine the infected animals as soon as possible and then treat them. Although there are various diagnostic tests for visceral leishmaniasis in dogs, rapid and accurate diagnosis is essential. Coelho et al. tried to use ultraviolet visible spectroscopy as an alternative diagnostic method for visceral leishmaniasis diagnosis [4], using the antigen antibody interaction in dog serum and the principle of machine learning algorithm. It is found that there are nine electron absorption bands in the main UV spectrum in the range of 220~280 nm, but there is no significant difference between the positive and negative groups. Then principal component analysis and cross validation and external validation were carried out on the prediction model, and the overall accuracy reached 75%.

Absorbance subtraction, spectral subtraction, bivariate and ratio difference methods can be used to solve the Overlapping UV spectra of ciprofloxacin and metronidazole combined drug formulations. These methods have been verified by the International Conference on pharmaceutical chemistry standards, and their accuracy, repeatability, robustness and accuracy are all at an acceptable level. These four methods belong to the application methods of UV spectroscopy technology, which are developed on the basis of UV spectral analysis. They are used to process and analyze UV spectral data, especially when dealing with complex samples with overlapping spectral characteristics. Each method has its unique processing and analysis principle, but their common point is that they all rely on UV spectroscopy technology to obtain the spectral data of samples. While Carneiro et al. combined UV spectroscopy with optical removal technology to induce new tissue windows [5], and then evaluate the efficiency and study the diffusion characteristics of the reagent and distinguish cancer.

3.2. The field of chemistry

UV spectroscopy can be used for quantitative and qualitative analysis of various chemical substances in the field of chemistry. By measuring the UV absorption characteristics of samples, UV spectroscopy provides a simple, rapid and highly sensitive analytical method for chemists, and also provides important technical support for chemical research and environmental monitoring.

3.2.1. Chemical reaction analysis

In the determination of solution concentration, UV spectrum is a very important technology. According to beer Lambert law, there is a direct relationship between the concentration of solute in solution and the intensity of light absorbed at a specific wavelength. The concentration of solute can be accurately calculated by measuring the absorbance of solution at a specific wavelength. This method is widely used in the concentration measurement of inorganic, organic compounds and biological molecules, such as protein, DNA, drug molecules and so on. UV spectroscopy also has important applications in chemical reaction monitoring. It can track the consumption of reactants and the formation of products in real time, so as to help chemists understand the reaction kinetics and mechanism. When studying the efficiency of catalyst or optimizing reaction conditions, UV spectrum can provide a convenient monitoring means. In addition, UV spectra can also be used to identify and verify synthetic compounds. Many organic compounds show specific absorption peaks under UV light, which can be used to confirm the structure and purity of compounds. When combined with chromatographic techniques, UV spectroscopy can become an important tool for identifying and purifying synthetic products.

3.2.2. Environmental chemistry

UV spectrum can be used to monitor pollutants in water and air in environmental science. In the early days, the detection of COD in water by UV Vis spectrometry was completed by a single spectral source. With the rapid development of economy, water pollution is becoming more and more serious, and a single wavelength is difficult to adapt to the more complex water quality environment. Researchers began to use multi wavelength analysis and detection, and finally developed to full

spectrum detection. This can ensure a good detection accuracy in the water environment with unstable water quality and complex pollutants.

Norio et al. obtained the UV absorbance curve of common water bodies such as rivers, lakes, seas and rain [6]. At the same time, they also pointed out that the content of organic matter in water can be measured with a wavelength of about 250 nm. UV spectrophotometry can be used to determine the COD value of water samples, and selected the wavelength of 254 nm, and preliminarily analyzed the influence of turbidity on the determination results [7]. Yamaoto et al. detected the absorbance of different organic substances in river water and found that COD value was correlated with the absorbance of water at 260 nm wavelength [8]. The accuracy of single wavelength and 440 nm and 560 nm dual wavelength detection were used when detecting COD by spectroscopy, and the dual wavelength detection accuracy was higher [9]. The absorbance COD model at 254 nm can be used, with ideal accuracy and correlation coefficient of 0.9866 [10]. Li et al. analyzed three spectral interval selection algorithms combined with PLS modeling and compared them with full spectral PLS modeling [11], and found that spectral interval selection algorithm combined with PLS modeling can get a better COD model, among which the effect of collaborative interval partial least squares is the best. The relationship curve between COD and absorbance under multiple wavelengths was analyzed [12], and a linear exponential piecewise regression model was developed. For the piecewise modeling of high and low concentrations of COD, the root mean square error of prediction was only 5.6647. Qi et al. used the embedded particle swarm optimization genetic algorithm (epso-ga) to select the optimal wavelength [13], combined with PLS algorithm to establish the COD prediction model, and the model R2 reached 0.9993. Zheng et al. used pso-pls algorithm to establish COD model [14], and the correlation coefficient of the model reached 0.99998. With the continuous innovation of science and technology, the technology of detecting COD by UV-vis spectroscopy is becoming more and more mature. It detects COD from a single wavelength to a certain band of full spectrum detection, and uses different wavelengths to extract effective information in water, making the detection accurate, efficient, simple and pollution-free.

In terms of air pollutant detection, Davenport et al. described a method for the detection of formaldehyde using low resolution non-dispersive UV absorption spectroscopy [15]. By developing a dual channel sensor, the strong absorption peak at 339 nm and the adjacent region with negligible absorption at 336 nm are used as reference. A simple detection system for formaldehyde was constructed, and formaldehyde was successfully detected.

3.3. Food safety

3.3.1. Food adulteration inspection

Food adulteration is a serious problem, UV spectroscopy technology is just used in authenticity, adulteration, origin identification and content determination of effective ingredients, which can be used to identify whether illegal or unmarked ingredients are added to food. Due to the diversity of sources of traditional Chinese medicine, it is difficult to identify the authenticity, while precious traditional Chinese medicine is rare. In the traditional Chinese medicine market, there are often adverse situations of using inferior quality as superior and using false as true, which cause chaos in the traditional Chinese medicine market and seriously affect its safety and effectiveness. The composition, content and structure of substances in traditional Chinese medicine can be analyzed, determined and inferred by using the characteristics of differences in ultraviolet spectrum and absorption degree caused by ultraviolet absorption of different components of traditional Chinese medicine molecules or ions. The method has the advantages of simple principle, convenient operation, high sensitivity, high accuracy, no pollution, good reproducibility and strong practicability.

Single UV spectral line method, UV spectral group method, derivative spectrum method and other UV spectral methods can be used to identify the authenticity of traditional Chinese medicine. Zuo et al. used the similarity of UV fingerprint to carry out the adulteration test [16]. UV scanning was carried out on the test solution of six different varieties of tartary buckwheat powder. Firstly, it was confirmed that there were some differences in the UV absorption spectra of six varieties of tartary

buckwheat powder, and the precision of its UV spectrophotometer met the test requirements, which was feasible for the adulteration identification of tartary buckwheat samples. Secondly, the team carried out the experiment of adding barley powder into 10 batches of the same variety of tartary buckwheat powder. Through the UV absorption spectra, it was found that there were significant differences between the UV absorption spectra of barley powder and wheat powder mixed with different proportions and between them and normal tartary buckwheat powder. The UV fingerprint of traditional Chinese medicine was used in the experiment, which showed that the UV fingerprint could reflect the difference of components in tartary buckwheat powder to a certain extent, and could be used as a rapid and simple method to identify the quality stability of tartary buckwheat powder.

The method of identifying the authenticity of traditional Chinese medicine by UV spectroscopy is also reflected in another group of typical examples. The traditional Chinese medicine water Pinellia ternata has similar antitussive and expectorant effects with Pinellia ternata, but water Pinellia ternata is different from Pinellia ternata in the antiemetic effect. Due to the large clinical consumption of Pinellia ternata and the continuous reduction of wild resources, it is very common to use water Pinellia ternata instead of Pinellia ternata in the market. Li et al. have found that there are differences in the UV spectra and first derivative spectra of Pinellia ternata koji and water Pinellia ternata Koji [17], where they successfully used UV spectroscopy to identify Pinellia ternata koji and water Pinellia ternata koji.

3.3.2. Analysis of food composition

UV spectroscopy is also effective in analyzing food ingredients. It can not only accurately determine the content of effective ingredients in food, but also reveal the relationship between these ingredients and food sources. It is an important tool for analyzing food ingredients. This analysis, which is attributed to the high sensitivity, accuracy and reproducibility of UV spectrometry in quantitative analysis, is essential to ensure the accuracy of food nutrition labels and monitor food quality. Therefore, it is widely used in the determination of the content of effective ingredients in food. Platycodon grandiflorum polysaccharide, one of the active components of Platycodon grandiflorum, has antioxidant and anticancer activities. Liu et al. used phenol sulfuric acid staining UV detection method to determine the polysaccharide content in Platycodon grandiflorum from different production areas in Chongqing [18]. It was found that the polysaccharide content of Platycodon grandiflorum was 13.06% - 58.70%. According to principal component analysis, the best quality Platycodon grandiflorum has the highest sugar content. And there was a significant correlation between the content of total polysaccharides, total flavonoids and total saponins of Platycodon grandiflorum. Wang et al. used UV fingerprint technology to study Panax notoginseng samples from 10 different origins in Yunnan [19]. They used UV fingerprint combined with PLS-DA method to analyze the samples of Panax notoginseng from different origins, and found that the main components of Panax notoginseng had low correlation with the origin, while the content difference had correlation with the origin.

4. Challenges and prospects

4.1. Challenges

Although UV spectroscopy has a wide range of applications in the field of molecular detection, it still faces several challenges and limitations.

For sensitivity, the main challenges in the sensitivity of UV spectral detection technology are the detection limit of trace substances and the complexity of sample matrix. For low concentration samples, especially those substances with weak absorption in the UV region, UV spectroscopy may be difficult to provide sufficient sensitivity for effective detection. In addition, other components present in the sample may produce interference signals, causing difficulties for microanalysis. This effect can lead to the increase of the background signal, thus masking or distorting the signal of the target analyte, affecting the sensitivity and accuracy of detection.

For resolution, when a sample contains a variety of components, especially those with absorption peaks at similar wavelengths, the spectra of these components may overlap, making it difficult to distinguish individual components. Because UV spectrum provides the overall absorption characteristics rather than the details of specific molecules, its resolution may be insufficient when distinguishing substances with similar structures or similar spectral characteristics.

For sample processing and preparation, samples usually need to undergo specific treatments before analysis, such as dilution, pH adjustment or other chemical treatments, to ensure that they are suitable for UV spectral analysis. In addition, for some types of samples, such as solid, turbid liquid or samples containing a large number of impurities, additional pretreatment steps, such as filtration or centrifugation, may be required to obtain a clear solution suitable for spectral analysis. These additional steps increase the time and complexity of the analysis and may introduce new variables or potential sources of contamination.

For equipment and operation requirements, UV spectral analysis usually requires high-quality and high-performance spectrometers, which are often costly and require good maintenance and calibration to maintain their accuracy. In addition, the operator needs to have certain professional knowledge and skills to carry out UV spectral analysis, including skilled operation of spectrometer, correct sample processing and data analysis ability. Incorrect operation or improper treatment of equipment may lead to the decline of data quality and affect the reliability of analysis results.

For data analysis and processing, the data generated by UV spectrum usually contain a lot of information, and extracting meaningful conclusions from these data often requires in-depth understanding and professional analysis skills. This includes distinguishing the attribution of absorption peaks, identifying the characteristics of overlapping peaks, and dealing with noise and interference that may be caused by the instrument settings or the sample itself. In addition, especially when dealing with complex samples or conducting multicomponent analysis, data analysis may need to rely on advanced computer algorithms and chemometric methods. These analyses usually require operators not only to have a solid background in chemistry and spectroscopy, but also to master relevant knowledge of data processing and statistical analysis.

4.2. Possible improvement and innovation directions

In view of the challenges faced by UV spectroscopy in molecular precision detection, improvements and innovations can be made in the future. It will not only help overcome the limitations of existing technologies, but also promote the wider application of UV spectroscopy in the field of molecular precision detection.

For enhanced sensitivity, the sensitivity can be enhanced by improving the sensitivity of detectors, developing more efficient light sources and improving sample preparation methods. Using more sensitive detectors can improve the ability to capture weak signals. With stronger light source, the light intensity passing through the sample can be increased. Improving the sample preparation method can increase the concentration of target analytes in the sample and make it easier to detect. These improvements and innovations not only improve the sensitivity of UV spectroscopy technology, but also expand its application in various fields, making it a more powerful and flexible analysis tool.

For improve resolution, the spectral resolution of the system can be improved by improving the optical elements. The use of advanced data processing technology helps to more accurately analyze and distinguish the close absorption peaks, thus improving the resolution. In addition, combining with other spectral technologies, such as mass spectrometry or fluorescence spectroscopy, can provide complementary information and further improve the ability to distinguish components in complex mixtures.

For simplify sample handling, it mainly focuses on developing more efficient and automated sample processing methods and introducing new sample processing technologies to reduce some preparations. This includes the use of microfluidic technology to achieve automated sample processing. This method can complete the mixing, reaction and separation of samples on a tiny chip, greatly reducing the complexity and time of sample preparation. In addition, efforts have been made

to avoid or minimize sample pretreatment, which can directly analyze the original samples without complex pretreatment steps. These improvements and innovations not only help to simplify the sample processing process of UV spectral analysis, but also make this technology easier to apply to various environments, including on-site rapid detection and high-throughput screening.

For portable and on-site detection equipment, researchers can try to make the device more miniaturized, flexible and easy to use, so as to facilitate rapid and accurate detection in non-laboratory environment. For example, develop smaller, low-power spectrometers and detectors, make them small enough to carry, and simplify the operation interface. At the same time, we can try to make these devices develop towards higher automation and intelligence, so as to quickly analyze and display the results. In addition, the integration of wireless communication technologies, such as Bluetooth or Wi Fi connection, allows these portable devices to rapidly dock with smart phones to achieve data sharing and remote analysis.

For innovation in data processing and analysis, more advanced calculation methods and algorithms can be introduced to improve the accuracy and efficiency of data analysis. These methods can automatically extract and autonomously learn from complex spectral data, thereby improving the accuracy of analysis and prediction ability. In addition, research can also focus on developing real-time data processing software, which can analyze spectral data in real time and provide fast feedback, especially suitable for on-site detection applications that need rapid decision-making.

5. Conclusion

In the wide field of molecular precision detection, the importance of modern instrument technology cannot be underestimated. As one of the key technologies in this field, the application scope and far-reaching impact of UV spectrum detection show the core position of advanced instrument technology in modern scientific research. UV spectroscopy has become an indispensable analytical tool in biomedicine, chemistry, environmental science, food safety and other fields due to its non-invasive, high sensitivity and rapid response characteristics. In the future, further research and development of UV spectroscopy technology will focus on improving sensitivity, resolution, sample processing simplification and data processing ability. With the integration and application of nanotechnology, machine learning and artificial intelligence, it is hoped that a more efficient, accurate and intelligent UV spectrum detection system will appear. These innovations are expected to solve the challenges faced by current technologies and expand the application boundaries of UV spectroscopy technology. In the field of molecular precision detection, UV spectroscopy technology will continue to play its unique role, not only promoting the in-depth development of scientific research, but also helping to achieve more efficient industrial processes and stricter environmental regulation. With the continuous progress of technology, it is expected that UV spectral detection technology will play a greater role in improving the quality of human life and environmental protection.

References

[1] Zhang J, Ye S, Zhong K, et al. A machine-learning protocol for ultraviolet protein-backbone absorption spectroscopy under environmental fluctuations. The Journal of Physical Chemistry B, 2021, 125(23): 6171-6178.

[2] Biter A B, Pollet J, Chen W H, et al. A method to probe protein structure from UV absorbance spectra. Analytical biochemistry, 2019, 587: 113450.

[3] Thakkar S V, Allegre K M, Joshi S B, et al. An application of ultraviolet spectroscopy to study interactions in proteins solutions at high concentrations. Journal of Pharmaceutical Sciences, 2012, 101(9): 3051-3061.

[4] Coelho M L, França T, Mateus N L F, et al. Canine visceral leishmaniasis diagnosis by UV spectroscopy of blood serum and machine learning algorithms. Photodiagnosis and Photodynamic Therapy, 2023, 42: 103575.

[5] Carneiro I, Carvalho S, Henrique R, et al. Enhanced ultraviolet spectroscopy by optical clearing for biomedical applications. IEEE Journal of Selected Topics in Quantum Electronics, 2020, 27(4): 1-8.

[6] Ogura N. Ultraviolet absorbing materials in natural water. Nippon Kagaku Zasshi, 1965, 86(12): 1286-1288.

[7] Ding Z. Determination of chemical oxygen demand in water samples by UV spectrophotometry. Industrial water treatment, 1990, 10 (05): 40-41.

[8] Katuhiro Y. Trial of an organic composition examination in natural water by UV spectra. Kagaku to kyoiku, 1999, 47(5): 338-341.

[9] Jiang R, Chai X, Zhang C, et al. A dual wavelength spectral method for detecting low concentration chemical oxygen demand. Spectroscopy and spectral analysis, 2011, 31(7): 2007-2010.

[10] Wu G, Bi W, Lv J, et al. Study on Determination of chemical oxygen demand in water by near infrared transmission and ultraviolet spectrophotometry. Spectroscopy and spectral analysis, 2011, 31(6): 1486-1489.

[11] Li J, Tong Y, Guan L, et al. Optimization of COD determination by UV–vis spectroscopy using PLS chemometrics algorithms. Optik, 2018, 174: 591-599.

[12] Tian G, Xu G, Tian Q. A linear exponential piecewise mathematical model for measuring COD in water by UV spectroscopy. Spectroscopy and spectral analysis, 2020, 40(6): 1741-1746.

[13] Qi W, Feng P, Wei B, et al. Characteristic wavelength optimization algorithm for water quality cod detection based on embedded particle swarm optimization genetic algorithm. Spectroscopy and spectral analysis, 2021, 41(1): 194-200.

[14] Zheng P, Zhao W, Wang J, et al. Study on UV absorption spectrum detection of COD in water based on pso-pls hybrid algorithm. Spectroscopy and spectral analysis, 2021, 41(1): 136-140.

[15] Davenport J J, Hodgkinson J, Saffell J R, et al. non-dispersive ultra-violet spectroscopic detection of formaldehyde gas for indoor environments. IEEE Sensors Journal, 2018, 18(6): 2218-2228.

[16] Zuo X, Huang Y, Yang Z, et al. Application of UV fingerprint in identification of adulteration of tartary buckwheat powder. Food industry, 2014, 35 (2): 92-94.

[17] Li J, Xu R, Wang P, et al. Identification of Pinellia ternata koji and its counterfeit water Pinellia koji. Research and practice of modern Chinese medicine, 2016, 3: 16-20.

[18] Liu C, Zhang B. Research Progress on identification and quality evaluation methods of Platycodon grandiflorum. Chinese pharmacy, 2021 (11): 1403-1408.

[19] Wang Y, Zhong G, Zhang J, et al. Identification of Panax notoginseng from different habitats by UV fingerprint combined with chemometrics. Spectroscopy and spectral analysis, 2016, 6: 1789-1793.