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UV-Vis Spectrophotometer UV-1900i Plus

Application News

High-Speed Spectral Analysis of Samples that Change over Time —Using the UV-1900i Plus Ultra High-Speed Scan—

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User Benefits

- The UV-1900i Plus ultra high-speed scan(Survey scan) rapidly captures complete spectral profiles.
- The UV-1900i Plus Survey scan allows users to follow short-time spectral changes associated with chemical reactions.

■ Introduction

Spectral analysis is essential for evaluating chemical reactions that involve color changes. But rapid chemical reactions, such as the aggregation of metal nanoparticles after the addition of an alkaline solution or the Belousov–Zhabotinsky (BZ) reaction between a metal salt and carboxylic acid catalyzed by bromide ions, cause very fast color changes that cannot be captured by normal methods, so they require high-speed spectral measurements.

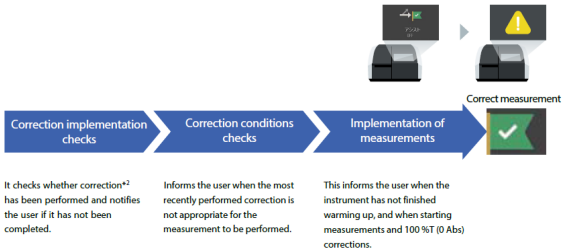
This Application News describes using the ultra high-speed scan(Survey scan) of the newly developed UV-1900i Plus UV-Vis spectrophotometer, which has a scanning speed of approximately 29,000 nm/min, to observe the changes that occurred when an alkaline solution was added to gold nanoparticles and the short-time changes that occurred during a BZ reaction.

■ Instrument Overview

To enable smoother system operations, the new UV-1900i Plus (Fig. 1) is equipped with new CPU that doubles the response speed of the control panel compared to the previous model. Other new user-friendly standalone functions include a startup validation function (Fig. 2) that couples validation when the instrument is turned ON, an assist function (Fig. 3) that guides the user through the analysis process, a shutdown function (Fig. 4) that automatically places the system into sleep mode at a preset time, and a wake-up function (Fig. 5) that automatically wakes the system from sleep mode at a specified time.

Fig. 1 UV-1900i Plus

Fig. 2 Startup Validation Function



* This function is applied to baseline corrections, auto-zero correction, and cell blank corrections.

Fig. 3 Assistant Feature

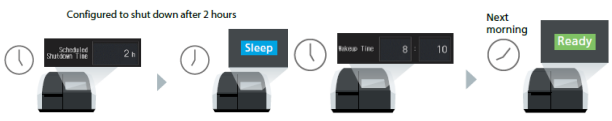


Fig. 4 Shutdown Function

Fig. 5 Wake-up Function

■ Analysis of Gold Nanoparticles

Commercially sourced gold nanoparticles with nominal particle sizes of 15, 30, 60, and 100 nm were analyzed under the conditions shown in Table 1 and the resulting absorbance spectra are shown in Fig. 6. In the Survey scan mode and the conditions shown in Table 1, a complete absorbance spectrum of the entire wavelength range was captured in approximately 6 seconds. This compares to approximately 30 seconds in high-speed, 90 seconds in medium-speed, and 200 seconds in the low-speed scan speed.

Table 1 Measurement Conditions

Instrument:	UV-1900i Plus
Wavelength Range:	350 to 800 nm
Data Interval:	1.0 nm
Scan Speed:	Ultra high-speed (Survey)
Slit Width:	1.0 nm

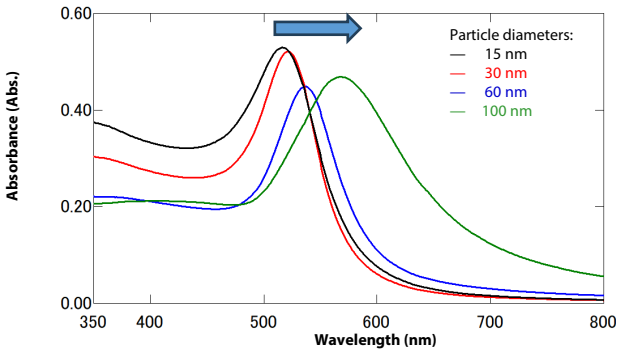


Fig. 6 Absorption Spectra of Gold Nanoparticles of Various Sizes

Survey scan mode quickly captures sufficiently accurate absorption spectra from samples with absorbance readings between 0.2 and 1 Abs. Fig. 6 shows how the absorption peak shifts to longer wavelengths for larger gold nanoparticles, a phenomenon caused by surface plasmon resonance.

■ Spectral Evaluation of Gold Nanoparticle Aggregation

3 mL of a solution of 30 nm gold nanoparticles was added to a quartz cell and kept at 22 °C with a thermoelectrically temperature-controlled cell holder (TCC-100). An alkaline solution consisting of 500 µL of aqueous NaCl solution was prepared and added while the gold nanoparticle solution was agitated with a stirrer. The repeat measurement feature was used to observe how the absorption spectrum changed at 10-second intervals before and after the solution was added under the conditions shown in Table 2.

Table 2 Measurement Conditions

Instrument:	UV-1900i Plus, TCC-100 (with stirrer)
Wavelength Range:	350 to 1,100 nm
Data Interval:	1.0 nm
Scan Speed:	Survey
Slit Width:	1.0 nm

The resulting absorption spectra are superimposed in Fig. 7. The absorption spectra showed that adding NaCl solution to the gold nanoparticle solution reduced the intensity of the peak near 520 nm and simultaneously created a new peak near 700 nm, which gradually shifted to 800 nm while increasing in intensity for approximately 5 minutes before the intensity began to decline.

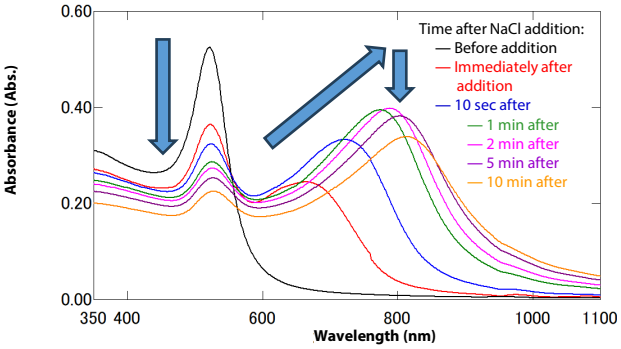


Fig. 7 Absorption Spectra of Gold Nanoparticles (30 nm) Plus NaCl Solution

Fig. 8 is an xy chromaticity diagram prepared using the spectra in Fig. 7. (The images in the top right corner of Fig. 8 show the color of the sample before and after adding the NaCl solution.) The solution was reddish, but after the NaCl solution was added, it changed to an achromatic gray within 10 minutes. The diagram provides a quantitative visual representation of color-related parameters (hue and saturation).

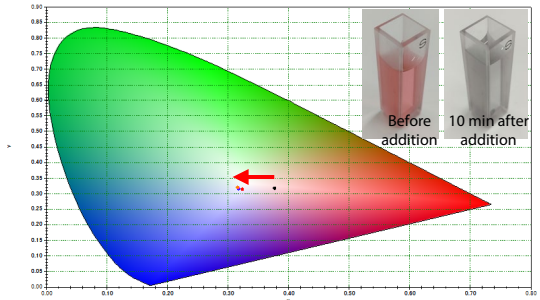


Fig. 8 Color Values of Gold Nanoparticles (30 nm) Plus NaCl Solution (xy Chromaticity Diagram)

■ Spectral Evaluation of BZ Reaction

700 µL of sodium bromate solution, sodium bromide solution, malonic acid, and sulfuric acid were combined in a quart cell,[1] kept at 24 °C with a thermoelectrically temperature-controlled cell holder (TCC-100), and reacted together while being agitated with a stirrer.

After the reaction solution changed from yellow to transparent, 700 µL of ferroin solution was added to the mixture, and the repeat measurement feature was used to record the absorption spectrum every 10 seconds under the conditions shown in Table 3.

Table 3 Measurement Conditions

Instrument:	UV-1900i Plus, TCC-100 (with stirrer)
Wavelength Range:	350 to 800 nm
Data Interval:	1.0 nm
Scan Speed:	Survey
Slit Width:	1.0 nm

The resulting absorption spectra are superimposed in Fig. 9. The absorption spectra peaked near 510 nm. The peak disappeared 3 minutes and 10 seconds after the ferroin solution was added. It reappeared 10 seconds later, disappeared again after 40 seconds, before reappearing 10 seconds later. This was caused by a cyclical oxidation-reduction reaction, where bromate ions acted as an oxidizing agent and bromide ions acted as a reducing agent on the ferroin.

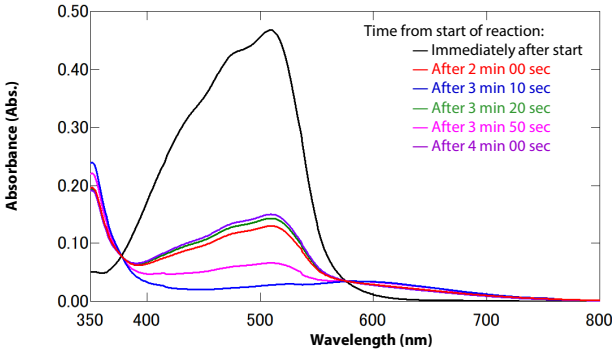


Fig. 9 Absorption Spectra of BZ Reaction

Fig. 10 is an xy chromaticity diagram prepared using the spectra in Fig. 9. It shows how the cyclical disappearance and reappearance of the 510 nm peak also caused the color of the reaction solution to change cyclically.

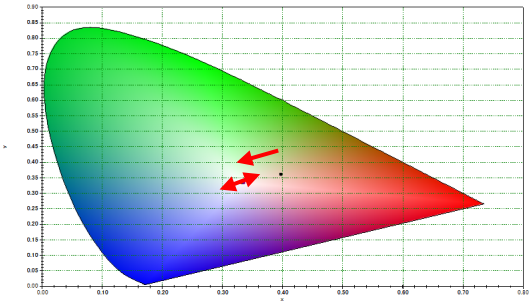


Fig. 10 Color Value of BZ Reaction (xy Chromaticity Diagram)

The intensity of the absorbance peak near 510 nm was also measured over time. The results are shown in Fig. 11.

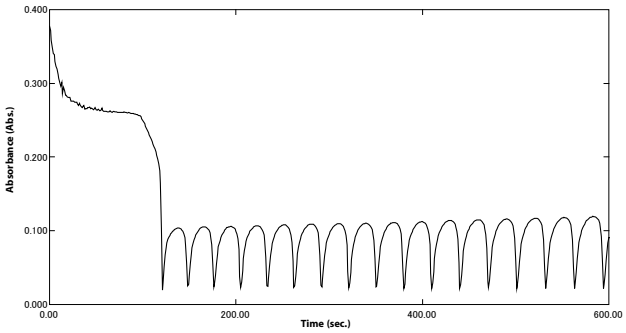


Fig. 11 Absorbance of 510 nm Peak Measured over Time

Fig. 11 also shows the cyclical disappearance and reappearance of the absorption peak.

■ Conclusion

The ultra high-speed scan(Survey scan) of the UV-1900i Plus UV-Vis spectrophotometer was used to measure the aggregation of gold nanoparticles after an alkaline solution was added and the rapid color changes of the reaction solution during the BZ reaction. The experiment demonstrated that it can rapidly capture absorption spectra, enabling users to accurately monitor the sort of changes described above.

<Related Application News Articles>

1. Evaluating Chromotropism with a Spectrophotometer: Solvatochromism and Thermochromism
   Application News No. 01-00673-EN

<References>

1) NeoAlchemist No.294 BZ Reaction
https://www.ut-kgb.hmc5.com/NeoAlchemist/294/04/

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