

APPLICATION NOTE

Online Water Measurements in Liquid Samples Using a ClearView® db Photometer

Introduction

Water concentration is a common measurement made using near-infrared (NIR) spectroscopy. This is due to its strong effect on product properties as well as chemical interactions that can occur during production. From an analytical perspective, water is easy to analyze due to its relatively strong signal compared to the hydrocarbon background. Moreover, because water is commonly analyzed with a single wavelength, photometers are the instrument of choice. The purpose of this application note is to show you how we arrive at recommending a photometer system with the proper wavelengths and a fiber optic probe with an appropriate sample pathlength.

Factors to Consider

These considerations affect the choice (and price) of the appropriate photometer and probe system.

- 1) background hydrocarbon spectral characteristics
- 2) concentration range of water and desired analytical precision
- 3) potential interference from hydroxyl
- 4) sample temperature variations
- 5) sample clarity

Analytical Goals

- 1) provide maximum sensitivity
- 2) select wavelength(s) to keep the absorbance below 1.2 Absorbance Units (AU)
- 3) minimize interferences due to background hydrocarbon variations and sample temperature changes
- 4) use an optical path of >1 mm in the fiber optic probe for ease of cleaning and minimal entrapment of bubbles and particles

Standard Guidelines

The 1900 nm region is generally used for <1% water. In a GUIDED WAVE™ ClearView® db Dual-Beam Photometer, a precision near ± 20 ppm can be achieved. The 1400 nm region is used for >1% water and a precision of near ± 100 ppm is attainable. For process analyzers, long-term (monthly) photometric drift is the most meaningful measure of “precision”. With our ClearView db this is typically <500 μ AU.

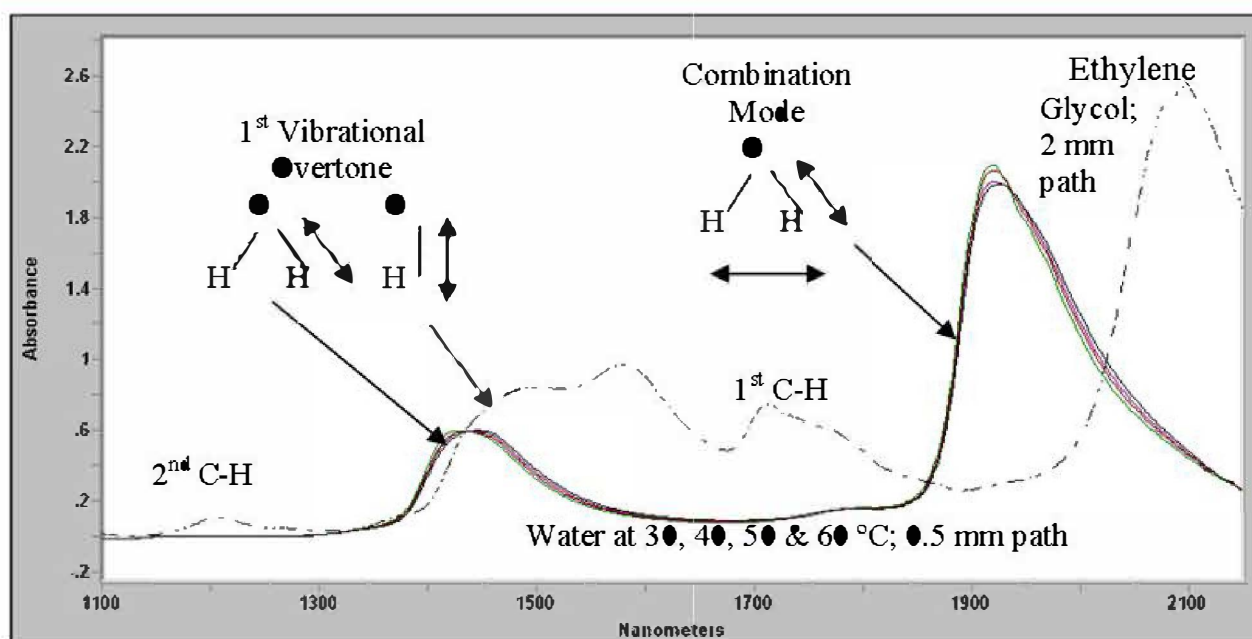


Figure 1

OH vs. H₂O

The 1400 nm region contains the 1st overtone of the O-H stretch in water and hydroxyl, as shown above for water and ethylene glycol. Mixtures of water and alcohols, therefore, have over-lapping features due to water and hydroxyl in this region. Water additionally has a unique peak near 1900 nm due to a combination of its O-H stretch and its H-O-H bending. The large peak near 2100 nm is a combination of O-H and C-H in the glycol. Notice that this pure glycol lacks an appreciable peak near 1900 nm where molecular water absorbs. With equivalent optical paths, you can see how much stronger water is compared to the C-H features.

Precision

The water peak at 1900 nm is about five times as large as its peak at 1430 nm. For example, 1 mAU in the 1900 nm region for n-propanol corresponds to about 20 ppm water for a 1 cm optical path, and about 90 ppm near 1430 nm. For water in methyl-isobutyl ketone (MIBK) or tetrahydrofuran (THF) these values are about 12 and 85 ppm/mAU, respectively. By doubling the optical path to 2 cm, if possible, the precision is also doubled. By taking a conservative 3 σ drift of 1.5 mAU for a ClearView db, and we arrive at ± 20 ppm at 1900 nm and ± 125 ppm at 1430 nm with a 1 cm probe.

Spectral Background and Pathlength

The absorbance from an organic liquid near 1900 nm is highly variable. CCl₄ has no appreciable absorbance in this region. Optical paths from 10 to 20 cm can be used to achieve <1 ppm precision. In contrast, many alcohols have significant absorbance. For example, ethylene glycol at 1900 nm has about 1.4 AU for a 1 cm optical path. Therefore, we could use a 5 mm optical path in a fiber optic probe to provide a 0.7 AU "baseline" absorbance in ethylene glycol. At 5 mm, the precision for water in ethylene glycol is about 24 ppm/mAU, so 1% water would add about 0.4 AU to the 0.7 AU resulting in an absorbance near 1.1 AU. You can see that adding >1% water to ethylene glycol, even in a 5 mm probe, would lead to an absorbance larger than our 1.2 AU desired limit. Thus, 2% water in ethylene glycol is measured with a shorter path, such as 2 or 3 mm, with some sacrifice in precision to achieve the greater concentration range.

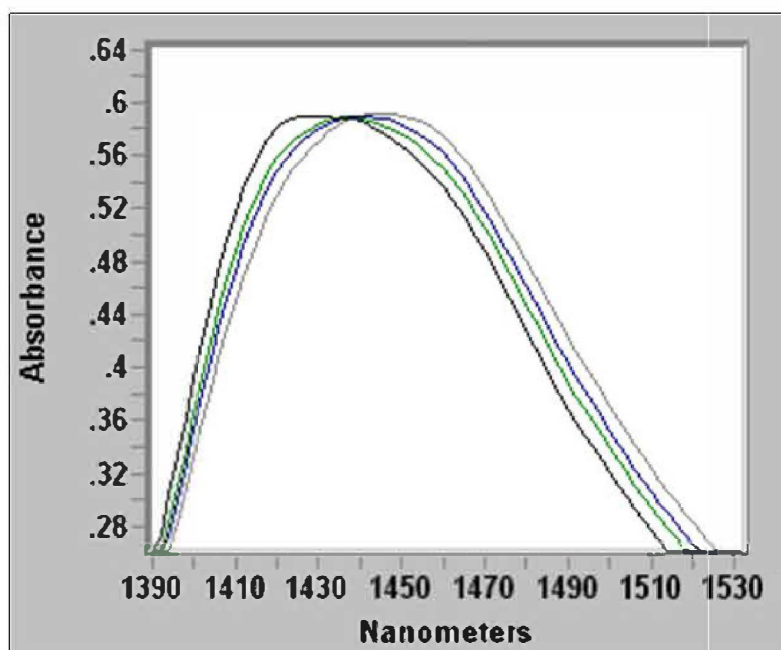


Figure 2

Temperature Effects

The top of the water peak near 1430 nm is shown in Figure 2. These spectra represent water at different temperatures from 30 to 60 °C. The peaks intersect at 1430 nm. There is an analogous intersection on the 1900 nm peak shown in Figure 1. This means that different temperatures have different calibration curves. In some of our studies of percent water in acids in the 1400 nm region, a 1 °C change can lead to a 0.1% (1000 ppm) change in the calculated water concentration. There are several methods to minimize sample temperature effects. The piping in a side stream can be heat traced or the wavelength at the spectral intersection point can be used for the calibration. Perhaps the most common solution is to measure the sample temperature with an RTD sensor or thermocouple near the probe and send the signal back to the ClearView db photometer. The software is equipped to correct water calibrations for sample temperature variations.

Sample Clarity

A photometer computes the absorbance between the water wavelength and a “reference” wavelength ($= -\log \text{Water/Reference}$) and converts that into water concentration. The “reference” wavelength is typically chosen in a “valley” which has little absorbance change, such as 1300 nm. The presence of light scattering entities entrained in the sample stream, such as bubbles, particles or immiscible phases, can “tilt” the entire spectrum between the water and “reference” wavelengths. Since we are already quantifying mAU changes at the water peak, it does not take much of a “tilt” to significantly impair a water calibration. The greater the wavelength difference, the more the effect, such as at 1900 nm. We can always choose a “reference” wavelength on either side of the 1900 nm water to minimize this effect, but it is still important to install particle filters and sample temperature control.

Conclusion

By considering the issues raised above, Process Insights can provide you with a cost-effective solution to obtain the desired sensitivity for water over the concentration range of interest in most organic liquids.

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Process Insights – The Americas

14400 Hollister Street, Suite 800-B, Houston, TX 77066, USA

☎ +1 713 947 9591

info.americas@process-insights.com

Process Insights – EMEAI

ATRICOM, Lyonerstrasse 15, 60528 Frankfurt, Germany

☎ +49 69 20436910

info.emeai@process-insights.com

Process Insights – CHINA

Wujiang Economic and Technology, Development Zone No. 258 Yi He Road
215200 Suzhou, Jiangsu Province, China

☎ +86 400 086 01

info.cn@process-insights.com

Process Insights – APAC

Premier@Kaki Bukit, 10 Kaki Bukit Ave 4, Blk 10 #05-65, Singapore 415874

☎ +65 6489 6612

info.apac@process-insights.com

