# National Institute of Standards & Technology

# Certificate

## Standard Reference Material® 2519

### Wavelength Reference Absorption Cell – Hydrogen Cyanide ($H^{13}C^{14}N$)

Serial No.

This Standard Reference Material (SRM) is intended for use in calibrating the wavelength scale of wavelength measuring equipment in the spectral region from 1528 nm to 1563 nm. SRM 2519 is an optical-fiber-coupled absorption cell containing hydrogen cyanide ($H^{13}C^{14}N$) gas. Hydrogen cyanide has more than 50 accurately measured absorption lines in the 1500 nm wavelength region.

**Certified Wavelength Values:** The vacuum wavelengths of absorption lines in the R and P branch of the $2\nu_3$ rotational-vibrational band of $H^{13}C^{14}N$ have been measured previously to high accuracy [1]. NIST has measured the line centers and pressure-induced shifts of 21 lines and certified their wavelengths with an expanded uncertainty (coverage factor $k = 2$) of ± 0.0006 nm. The remainder of the lines in the band are certified with an expanded uncertainty of ± 0.003 nm, where the uncertainty is dominated by the pressure shift uncertainty. Details of the measurement procedure and data analysis for the determination of the pressure shift can be found in reference [2]. A spectrum of the absorption band is shown in Figure 1 and certified wavelength values are given in Table 1. Figure 2 shows a higher resolution scan near lines P10 and P11.

**Expiration of Certification:** The certification of this SRM is indefinite within the measurement uncertainties specified, provided the SRM is handled, stored, and used in accordance with the instructions given in this certificate.

**Measurement Conditions and Procedure:** The long term stability of hydrogen cyanide and the use of fundamental molecular absorption lines render the SRM insensitive to changes in environmental conditions. The purpose of the certification procedure is to verify that the unit contains the correct pressure of $H^{13}C^{14}N$ gas and has no significant contaminants that produce additional absorption lines. Measurements were made using a 0.05 nm resolution optical spectrum analyzer. Spectra similar to those shown in Figures 1 and 2 were taken of each SRM unit and compared with measurements of reference absorption cells maintained at NIST. High resolution scans using a tunable laser and wavelength meter were made on at least one unit of each production run. These scans serve to verify the center wavelength of a selected line with an expanded uncertainty of less than ± 0.0006 nm.

**Storage and Handling:** The protective caps provided for the FC/PC fiber connectors should be replaced when the SRM is not in use. This SRM is intended to be used in a laboratory environment near ambient room temperature (22 °C ± 5 °C). Optical alignment is critical; the user should avoid exposing the unit to large temperature variations, temperature cycling, or mechanical shock, as these may cause the optical alignment to degrade. Optical misalignment affects the throughput of the SRM but will not shift the centers of the absorption lines. A more serious, but less likely problem, is cell breakage or leakage. The unit should be replaced if the linewidths or depths differ significantly from those shown in Figures 1 and 2 (when measured using comparable resolution).

Development of the SRM and supporting measurements were performed by S.L. Gilbert and W.C. Swann of the NIST Optoelectronics Division.

Statistical consultation was provided by C.M. Wang of the NIST Statistical Engineering Division.

The support aspects involved in the preparation, certification, and issuance of this SRM were coordinated through the Standard Reference Materials Program by J.W.L. Thomas.

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SRM 2519

Thomas E. Gills, Chief
Standard Reference Materials Program

Table 1. Certified Wavelengths for SRM 2519

The table lists the vacuum wavelengths of line centers in the $H^{13}C^{14}N$ $2\nu_3$ band for the 13.3 kPa (100 Torr) SRM cell pressure. The 21 lines that were measured at NIST are certified with an expanded uncertainty (coverage factor $k$ = 2) of ± 0.0006 nm. These lines are shown in the table with a (6) indicating the uncertainty in the last digit. The remaining line centers listed are the literature values from reference [1]. These values are certified with an expanded uncertainty of ± 0.003 nm, where the uncertainty is dominated by the pressure shift uncertainty.

| R Branch | Wavelength (nm) | P Branch | Wavelength (nm) |
|---|---|---|---|
| 25 | 1528.054 | 1 | 1543.1148(6) |
| 24 | 1528.4862(6) | 2 | 1543.809 |
| 23 | 1528.9271(6) | 3 | 1544.515 |
| 22 | 1529.376 | 4 | 1545.2314(6) |
| 21 | 1529.8376(6) | 5 | 1545.9563(6) |
| 20 | 1530.306 | 6 | 1546.690 |
| 19 | 1530.786 | 7 | 1547.435 |
| 18 | 1531.2764(6) | 8 | 1548.190 |
| 17 | 1531.774 | 9 | 1548.9554(6) |
| 16 | 1532.283 | 10 | 1549.7302(6) |
| 15 | 1532.8024(6) | 11 | 1550.5149(6) |
| 14 | 1533.329 | 12 | 1551.311 |
| 13 | 1533.867 | 13 | 1552.116 |
| 12 | 1534.4159(6) | 14 | 1552.931 |
| 11 | 1534.972 | 15 | 1553.756 |
| 10 | 1535.5401(6) | 16 | 1554.5892(6) |
| 9 | 1536.1170(6) | 17 | 1555.4346(6) |
| 8 | 1536.7034(6) | 18 | 1556.292 |
| 7 | 1537.2997(6) | 19 | 1557.157 |
| 6 | 1537.907 | 20 | 1558.033 |
| 5 | 1538.5224(6) | 21 | 1558.919 |
| 4 | 1539.149 | 22 | 1559.814 |
| 3 | 1539.786 | 23 | 1560.7185(6) |
| 2 | 1540.431 | 24 | 1561.6344(6) |
| 1 | 1541.087 | 25 | 1562.563 |
| 0 | 1541.753 | | |

## INSTRUCTIONS FOR USE

**General Considerations:** The SRM can be used to calibrate a wavelength measuring instrument in the 1530 nm to 1560 nm region. The wavelength calibration is vacuum wavelength; if the user requires the wavelength in air, the appropriate correction for the index of refraction of air must be applied (see reference [3]). Depending on the type of instrument being calibrated, a broadband source or a tunable narrowband source may be used.

**Use With a Broadband Source:** A broadband source in the 1500 nm region (such as a light emitting diode, white light, or amplified spontaneous emission source) is useful when calibrating a low resolution instrument such as a diffraction grating based optical spectrum analyzer or monochrometer. A schematic for this type of calibration is shown in Figure 3(a). Light from the broadband source is coupled into the SRM and the output (transmission through the SRM) is connected to the instrument that is being calibrated. The absorption lines of hydrogen cyanide appear as dips in the spectrum of the light source (see Figure 1).

**Use With a Narrowband Source:** The SRM can be used to calibrate the wavelength scale of a tunable narrowband source in this region (such as a diode laser or fiber laser). Alternatively, a tunable source and the SRM can be used to check the calibration of a wavelength meter, as shown in Figure 3(b). The laser is tuned over one or more of the hydrogen cyanide absorption lines. The transmission through the SRM is monitored by a detector; the transmitted power passes through a minimum at the center of an absorption line.

**Suggested Procedure for Low-Accuracy Requirements; Calibration Uncertainty ≥ 0.1 nm:** Connect the light source (either broadband or narrowband, as discussed above) to one of the fiber connectors on the SRM unit using a single-mode optical fiber terminated with a clean FC/PC connector. After identifying the absorption lines by comparing to the spectrum in Figure 1, find the center or the minimum point of a line listed in Table 1. If the instrument has variable resolution, it is best to use a resolution of ≤ 0.2 nm. For this level of accuracy, the procedure used to find the line center can be quite simple: setting a cursor to the line center or minimum by eye is sufficient. If using a tunable source, simply tune it to the transmission minimum of the line, using tuning steps of ≤ 0.01 nm. Calibrate the instrument to the wavelength of this line (from Table 1) using the calibration procedure specified by the instrument manufacturer. The instrument's linearity can be checked by repeating the procedure for a different absorption line and comparing it to the value listed in Table 1.

**Suggested Procedure for Moderate-Accuracy Requirements; Calibration Uncertainty in the Approximate Range of 0.01 nm to 0.1 nm:** Connect the light source (either broadband or narrowband, as discussed above) to one of the fiber connectors on the SRM unit using a single-mode optical fiber terminated with a clean FC/PC connector. If the source power varies significantly with wavelength, divide the SRM transmission spectrum by the source spectrum to obtain a normalized trace. After identifying the absorption lines by comparing to the spectrum in Figure 1, make a high resolution scan of a line listed in Table 1. If the instrument has variable resolution, it is best to use a resolution of ≤ 0.1 nm with a data point density of at least one point every 0.005 nm. Find the wavelength readings on both sides of the line where the absorption is 50 % of the maximum; the line center is half-way between these two wavelength readings. Repeat this procedure five times and take the average of the five measurements for the line center. Calibrate the instrument to the center wavelength of this line (from Table 1) using the calibration procedure specified by the instrument manufacturer. The instrument's linearity can be checked by repeating the procedure for a different absorption line and comparing it to the value listed in Table 1.

**Suggested Procedure for High-Accuracy Requirements; Calibration Uncertainty ≤ 0.01 nm:** *[Note: due to the presence of weak nearby lines and background slope, this SRM is not recommended for a calibration with an uncertainty of less than 0.001 nm.]* Connect the light source (either broadband or narrowband, as discussed above) to one of the fiber connectors on the SRM unit using a single-mode optical fiber terminated with a clean FC/PC connector. Divide the SRM transmission spectrum by the source spectrum to obtain a normalized trace. After identifying the absorption lines by comparing to the spectrum in Figure 1, make a high resolution scan of a line listed in Table 1. If the instrument has variable resolution, it is best to use a resolution of ≤ 0.1 nm with a data point density of at least one point every 0.001 nm. Using a fitting technique such as the least squares technique, fit the absorption data to the appropriate lineshape (Lorentzian if the line shape is dominated by the molecular absorption profile, Lorentzian convoluted with the instrument's filter characteristics if the instrument contributes significantly to the profile). Details of line fitting procedure and potential error sources can be found in reference [2]. Calibrate the instrument to the center wavelength of this line (from Table 1) using the calibration procedure specified by the instrument manufacturer. The instrument's linearity can be checked by repeating the procedure for a different absorption line and comparing it to the value listed in Table 1.

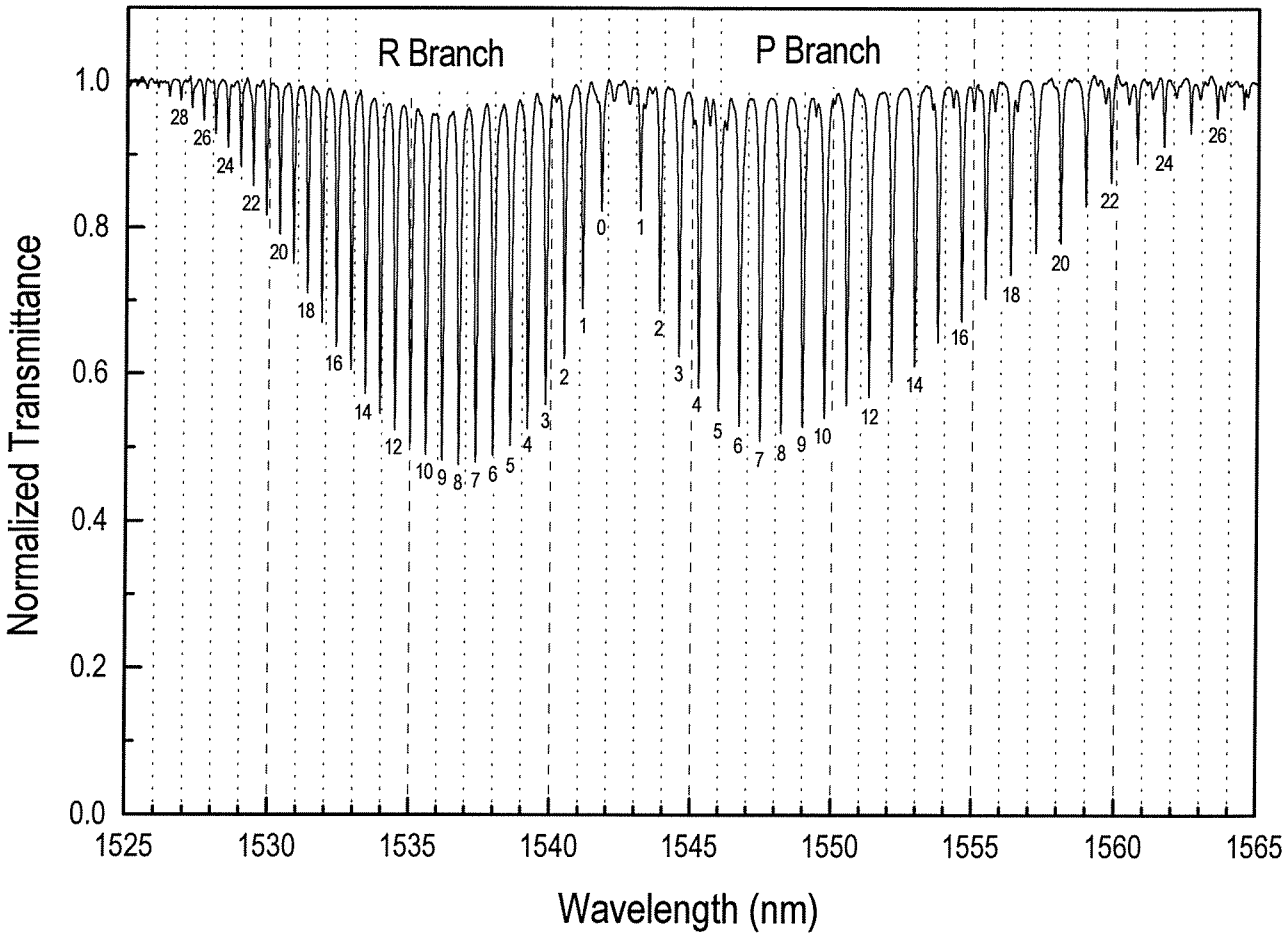


Figure 1. Hydrogen cyanide ($H^{13}C^{14}N$) spectrum taken by passing LED light through a SRM unit and recording the spectrum of the transmitted light using an optical spectrum analyzer with 0.05 nm resolution. The figure shows the recorded spectrum divided by the LED spectrum. The HCN gas pressure is 13 kPa and the optical path length through the gas is 22.5 cm.

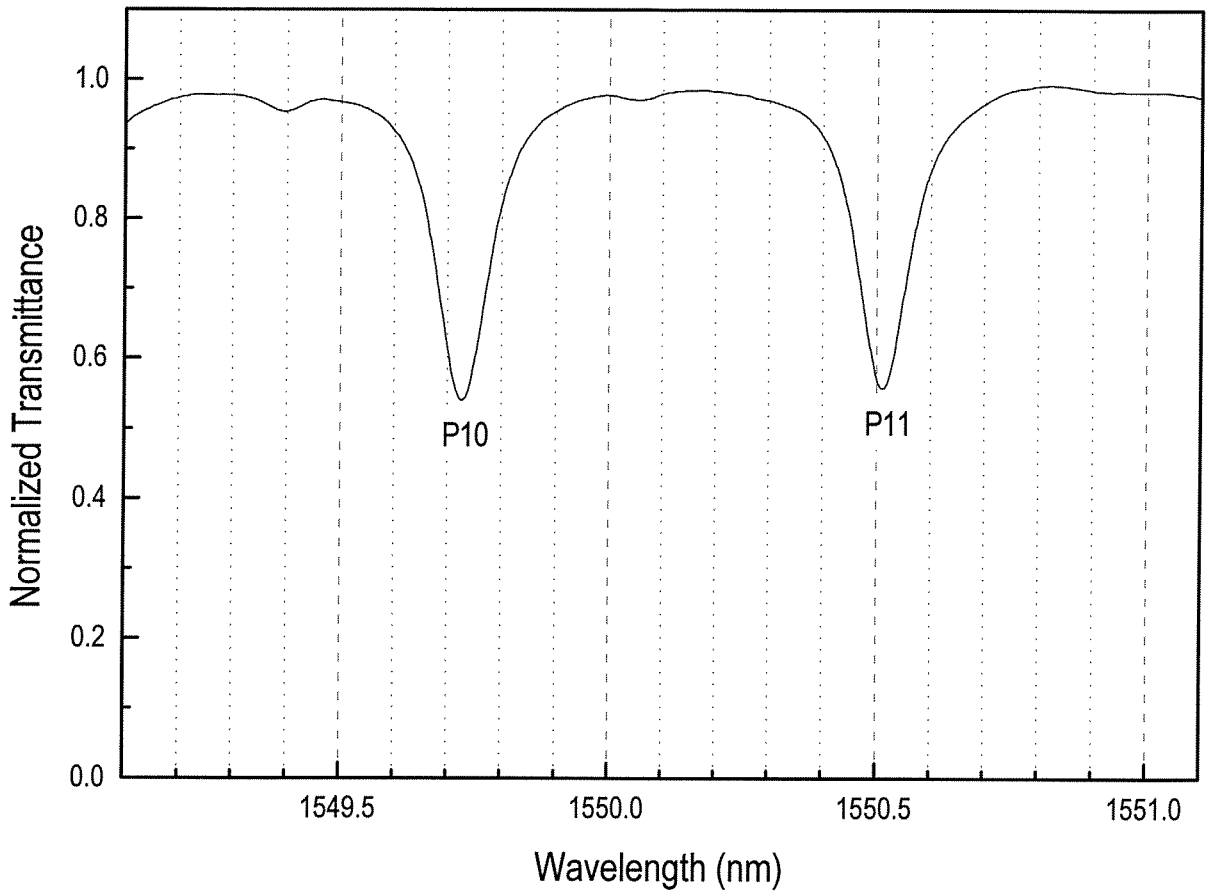


Figure 2. The P10 and P11 lines from Figure 1 on an expanded wavelength scale to show lineshape.

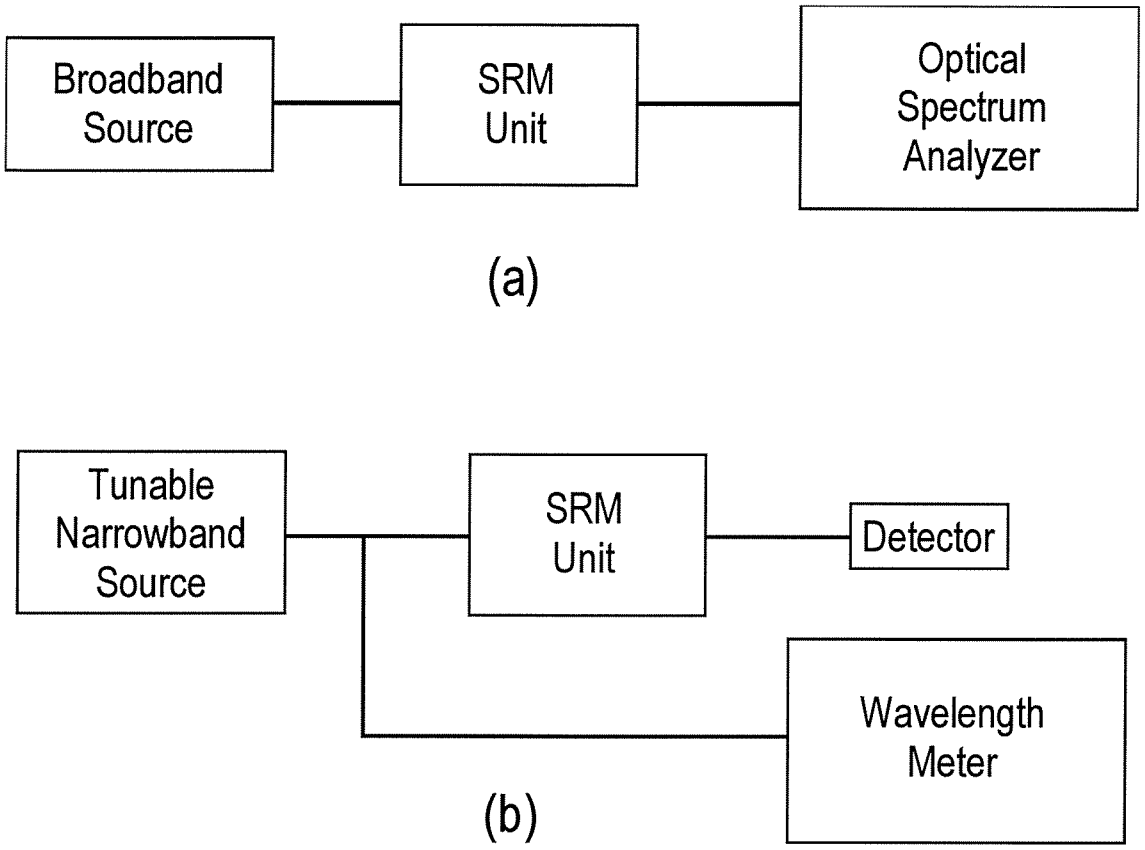


Figure 3. (a) Schematic of technique when using the SRM and a broadband source to calibrate an optical spectrum analyzer. (b) Schematic of technique when using the SRM and a narrowband source to calibrate a tunable laser or a wavelength meter. The wavelength meter is not required for a laser calibration.

## REFERENCES

[1] Sasada , H. and Yamada, K., "Calibration Lines of HCN in the 1.5-μm Region," Appl. Opt. **29**, pp. 3535-3547, (1990).

[2] Gilbert, S.L., Swann, W.C., and Wang, C.M., "Standard Reference Materials: Hydrogen Cyanide $H^{13}C^{14}N$ Absorption Reference for 1530-1560 nm Wavelength Calibration – SRM 2519," NIST Special Publication 260-137, (1998).

[3] Edlen, B., "The Refractive Index of Air," Metrologia, **2**, p. 12, (1966); CRC Handbook of Chemistry and Physics 77th Ed., pp. 10-266, (1996).

*Users of this SRM should ensure that the certificate in their possession is current. This can be accomplished by contacting the SRM Program at: Telephone (301) 975-6776 (select "Certificates"), Fax (301) 926-4751, e-mail srminfo@nist.gov, or via the Internet http://ts.nist.gov/srm.*