

Quantitative Surface Enhanced Raman of Nicotine at PPB Concentrations



Introduction

Surface Enhanced Raman Spectroscopy (SERS) is an effect in which nanoscale silver and gold can be used to amplify the intensity of Raman spectra. Resonance Raman can be used in conjunction with SERS to yield enhancement by Surface Enhanced Resonance Raman Spectroscopy (SERRS). Enhancement factors of 10^7 are routine for SER(R)S, and materials at femtomol concentrations can be routinely analyzed. For further information on the theory of SER(R)S please see our SER(R)S technical note.

Nicotine is commonly used in smoking cessation therapies. These typically take the form of patches, chewing gum or lozenges. These products are effective drug delivery devices for a potent and potentially toxic API, so the ability to make quantitative measurements of nicotine concentrations is important.

As shown in Figure 1, nicotine is based on a substituted heterocyclic (pyridine) ring. The nitrogen in the ring is in a sterically unhindered position and is ideal for binding to a SERS surface in much the same way as the pyridine parent compound, which is well known to be SERS active.

Author

Andrew Dennis BSc, Ph.D.
 PerkinElmer
 1 Chlorine Gardens
 Belfast, N. Ireland
 BT9 5DJ

Dr. Steven Bell
 Dr. S. Surimutu
 School of Chemistry
 and Chemical Engineering
 Queen's University
 Belfast BT9 5AG, N. Ireland

Quantitative analysis using SERS is difficult, because slight differences in SERS surface preparation can dramatically alter enhancement factors. In addition, the absolute SERS intensity depends on simple experimental parameters such as sample focus.

A good way to work around this variability is to use an internal standard and to measure peak intensities relative to the intensity of the standard rather than absolute values.

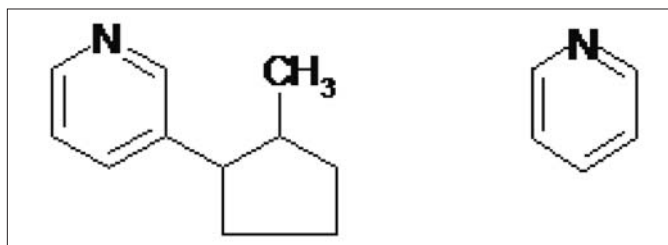


Figure 1. Chemical structures of nicotine and pyridine.

Choosing an internal standard is not a simple matter of selecting a species whose bands do not overlap with the analyte. In SERS, the enhancement is only observed from materials which are adsorbed onto the SERS surface, so it is important to find a standard which does not compete for surface sites and preferably one which adsorbs in a similar manner to the analyte of interest.

Since nicotine has a pyridine-like core it would be obvious to use pyridine as an internal standard. However, there is some overlap between the pyridine ring breathing mode at ca. 1000 cm⁻¹, and the strongest nicotine band which arises from the equivalent breathing mode of the substituted pyridine ring in nicotine. This problem can be circumvented by use of deuterated pyridine as an internal standard since deuteration gives a useful downshift in this ring breathing band. This is a cost-effective solution since deuterated pyridine is widely available due to its use as a solvent for NMR studies.

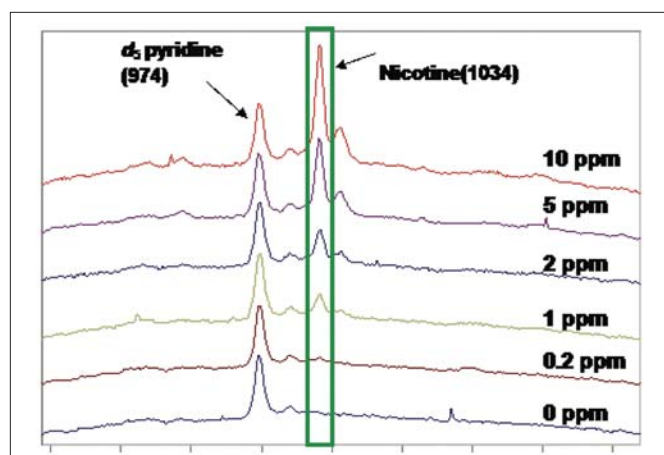


Figure 2. SERS spectra of nicotine at various concentrations relative to fixed concentration of d₅ pyridine.

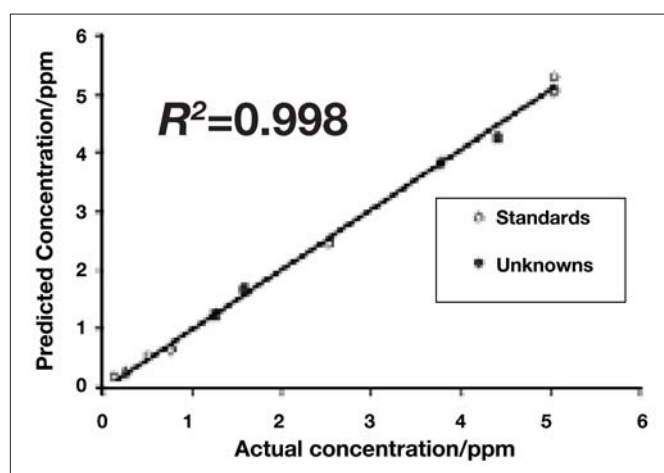


Figure 3. Linear calibration graph of nicotine concentration derived from peak intensities shown in Figure 2.