Abstract

A vibrational probe based on isonitrile (NC)-derivatized alanine 1 (Ac-Ala(NC)-NHMe) was synthesized and its structure and vibrational dynamics of its NC stretch mode were examined utilizing FTIR and femtosecond IR pump–probe spectroscopy. It has been found that the probe is characterized by very high sensitivity to the hydrogen bonding environment and in comparison to nitrile (CN) the NC stretch mode possesses larger dipole strength when attached to the aliphatic group. Its vibrational lifetime is several times longer than that of azido (N3) stretch mode in azido-derivatized IR probes and it was determined to be 5.52 ps and 5.53 ps in D2O and DMF, respectively. Furthermore, to understand the phenomenon of the vibrational solvatochromism of the new IR probe quantum chemistry calculations of methyl isocyanide in water clusters were carried out and the distributed site model for vibrational solvatochromism was applied.

Results – experimental data

FTIR

Polarization controlled IR pump–probe spectroscopy

Results – computational data

Interpretation and conclusions:

- Isonitrile group − highly sensitive reporter of H-bonding (Fig. 4):
  - Increase of H-bonding strength − blueshift of the NC frequency.
  - In hydrogen-bonding solvents − peak broadening (CH3CN, D2O or splitting (MeOH, CF3CH2OH).
  - The frequency shift of amide I band − possible perturbation the backbone conformation of alanine after introduction of isonitrile or nitrite group (Fig. 4a and Table 1). A single symmetric peak − the backbone conformation or solvation has no notable heterogeneity.

- A large dipole strength (1.82 ± 0.21 × 104 D) of new probe 1 − 5–40 times larger than CN stretching modes and about 2–3 times smaller than N3 stretching mode.

- PP spectra − heating effect observed and eliminated (Fig. 5).

- Vibrational lifetimes of the NC stretching mode − 5.5 ± 0.2 ps in both D2O and DMF (several times longer than N3 mode) − relaxation processes mainly determined by intramolecular vibrational relaxation (Fig. 6b, Fig. 7b and Table 1).

- The orientational relaxation time constants of the NC stretching mode − 0.52 ± 0.2 ps and 10.33 ± 0.2 ps in D2O (besticopitual decay analysed using the wobbling-in-a-cone model) and 7.28 ± 0.94 ps in DMF (Fig. 6c and Table 1).

- From solvatochromic model (Fig. 8):
  - For MeNC-water clusters mainly blueshift of the NC stretching band.
  - For non-linear H-bonding geometries (θ > 70°) − redshift (Fig. 10).
  - Direction of Δμ opposite for MeCN and MeNC.

- Isonitrile stretch mode − potentially an excellent IR probe for studying the structure and dynamics of proteins and to probe the local electrostatic potential.