SUGGESTED SOLUTION (ODD)

CHAPTER 20

20-1. From the attached gas spectra, what spectral resolution would be required to:

A. Resolve the individual lines of the hydrogen chloride MWIR band?

B. Discriminate between n-butanol and ethyl acetate in the LWIR atmospheric window (nominally 8 to 12 μm)?

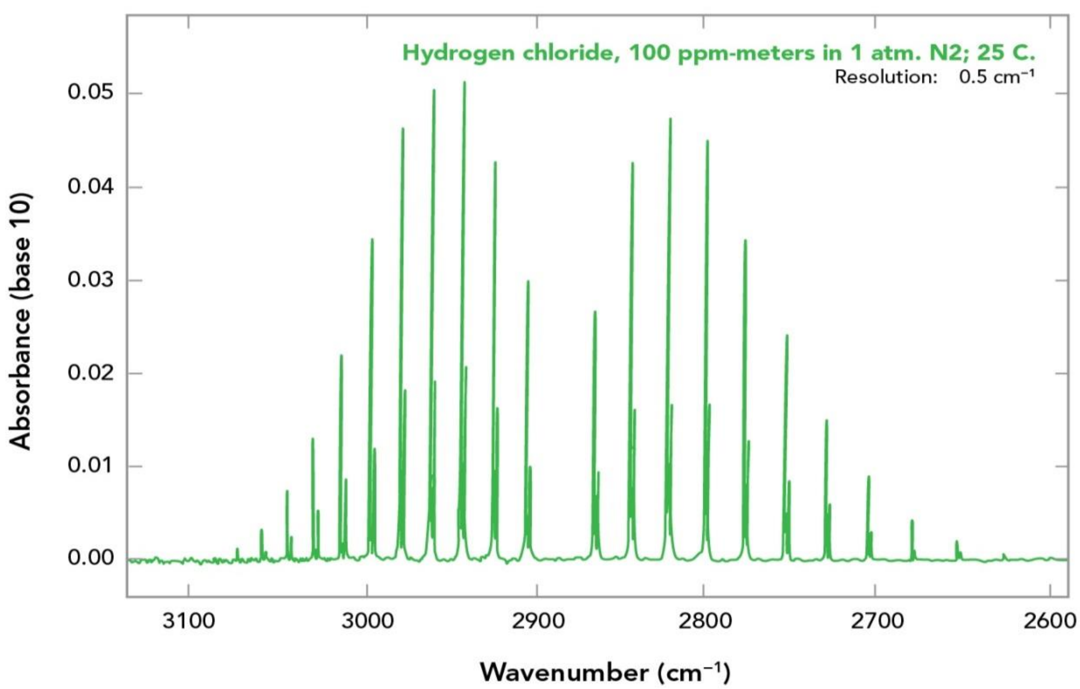
C. Discriminate between n-butanol and ethyl acetate in the MWIR atmospheric window (nominally 3.4 to 4.2 and 4.5 to 5.0 μm)?

THERE ARE NO UNIQUE ANSWERS TO THIS PROBLEM.

ANSWERS IN CM-1 ARE PERFECTLY ACCEPTABLE.

SUGGESTED SOLUTION:

A) HCl

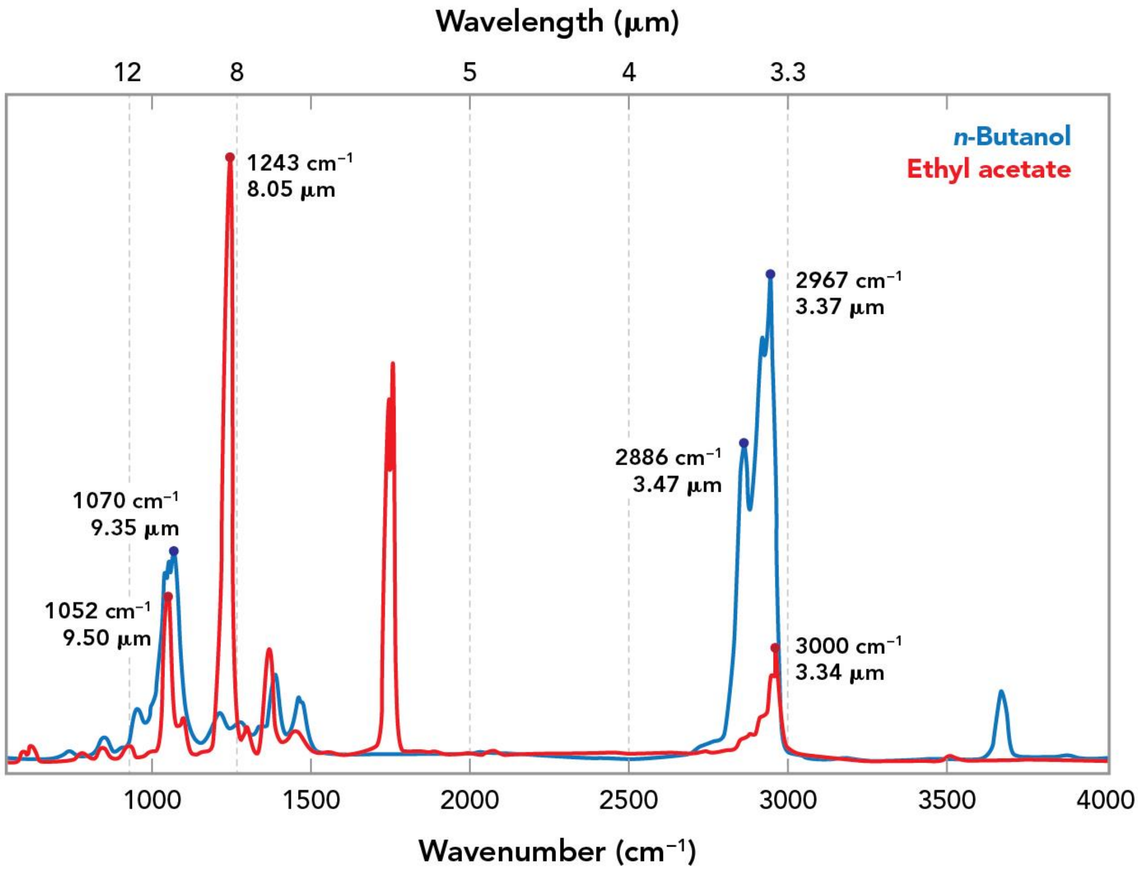


Between 2900 and 3000 cm^{-1} (3.33 and 3.45 μm) there are 5 spectral lines. To resolve them, 10 bands are needed (one on each line and one in between each line).

$$\Delta\upsilon_{MIN} \leq 10 \text{ cm}^{-1} \text{ OR } \Delta\lambda_{MIN} \leq 12 \text{ nm}$$

(Note: SEBASS might have just enough resolution at 3.4μm. Also note that the small side lobes to the right of each of the lines in the spectrum are those of a less abundant isotope of chlorine in HCl, that is HCl(37) versus HCl(35))

B) n-butanol vs ethyl acetate in the LWIR (8-12μm or 830 – 1250 cm^{-1})



Possible features

n-butanol - 1100 cm^{-1}

ethyl acetate - 1100 cm^{-1}, 1250 cm^{-1} (?)

If 1250 feature is visible, (70 cm^{-1} or $\Delta\lambda_{MIN} \leq$ 0.8μm) is good enough

If not, spectra are not shown in enough detail

$$\Delta\upsilon_{MIN} \leq 10\ cm^{-1} \text{ OR } \Delta\lambda_{MIN} \leq 500\ nm$$

C) n-butanol vs ethyl acetate in the MWIR (3.0 – 5.0μm or 2000 – 3333 cm^{-1})

Possible features

n-butanol - 2970 cm^{-1}

ethyl acetate - 2990 cm^{-1}

$$\Delta\upsilon_{MIN} \leq 10\ cm^{-1} \text{ OR } \Delta\lambda \leq 10\ nm \ \ (16.5\ cm^{-1}, 16.5\ nm)$$

(Note that the graphs presented do not have sufficient resolution to show the individual lines that make up the various bands of n-butanol and ethyl chloride.)

20-3

A. If a carbon dioxide gas laser emitting radiation at 10.6 μm is used as part of a DIAL lidar, which from the following list of gases (and the location of their absorption features) could be detected?

Carbon dioxide CO_2	4.3, 12 to 15 μm
Hydrogen chloride (HCl)	3.47
Ammonia (NH_3)	8, 13
Carbon monoxide (CO)	4.67
Octane fumes (C_8H_{18})	3.5, 6.8
Toluene fumes (C_7H_8)	3.3, 13.5, 14.3
Sulfur dioxide (SO_2)	7.3
Sodium clouds in upper atmosphere (Na)	0.589

B. If the same laser were used as part of a Raman scattering lidar, now which gas(es) from the above list could be detected?

C. Now suppose a solid-state neodymium-YAG laser emitting radiation at 1.06 μm is used as part of a DIAL lidar, which gas(es) from the above list gases could be detected?

D. If the same laser in part c) is used as a part of a Raman scattering lidar, now which gas(es) from the above list could be detected?

SUGGESTED SOLUTIONS

A. DIAL lidars are designed to detect one type of gas. That gas is the one which has a wavelength exactly equal to the wavelength of one of the lasers used. In this case, CO2 would seem to be a possibility, but the CO2 absorption transition probability is extremely low.

B. Raman scattering lasers can be used to detect any gas having spectral band, or line, at a wavelength longer than the wavelength of the laser used. In this case, ammonia, toluene fumes, and carbon dioxide.

C. DIAL lidars are designed to detect one type of gas. That gas is the one which has a wavelength exactly equal to the wavelength of one of the lasers used. In this case, none of the gases on the list.

D. Raman scattering lasers can be used to detect any gas having a spectral band, or line, at a wavelength longer than the wavelength of the laser used. In this case, all the gases on the list, except for the sodium clouds.