Chemical Ionization Mass Spectrometry Utilizing an Isotopically Labeled Reagent Gas

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The use of a mixture of 5% ammonia in methane, where the ammonia is 50% ^{15}N -labeled, provides a very useful reagent gas for chemical ionization mass spectrometry. We find that this combination gives spectra very much like pure ammonia reagent gas except that all of the adduct ions are clearly labeled. (*J Am Soc Mass Spectrom* 1994, 5, 596-598)

It is widely recognized that isotopic labeling of reagent gas can provide additional information when operating in chemical ionization (CI) mode. For example, Lin and Smith [1] reported the use of ND_3 as a reagent gas. Carroll et al. [2] reported use of isobutane mixed with pyridine and pyridine- d_5 in an equimolar mixture. In addition Stillwell et al. [3] used mixtures of $(\text{CH}_3)_4\text{Si}/(\text{CD}_3)_4\text{Si}$ to identify adduct ions that contain the trimethylsilyl ion. Each of these reagent gases provides unambiguous information regarding adduct formation. However, ND_3 has exchangeable protons that may interfere with interpretation, and neither pyridine nor $(\text{CH}_3)_4\text{Si}$ is a typical reagent gas. We have considered the use of $^{15}\text{NH}_3$ to more easily interpret ammonia spectra. Mixtures consisting of $^{15}\text{NH}_3$ and $^{14}\text{NH}_3$ in approximately equal quantities are potentially very useful for providing doublets for every ion that contains the elements of the reagent gas. However, $^{15}\text{NH}_3$ is quite expensive and can be used only intermittently.

Rudewicz and Munson [4] have shown that 1% ammonia in methane provides a reagent gas that gives an ammonia-like spectrum and may also give enhanced sensitivity. Our examination of 1% ammonia in methane utilizing a JEOL (Peabody, MA) SX-102 high resolution magnetic mass spectrometer produced spectra that were more nearly like methane spectra. If we increased the reagent gas pressure so that the value measured above the diffusion pump was 1.2×10^{-4} torr and reduced the accelerating voltage from 10 to 3 keV, we were able to observe spectra similar to those reported by Rudewicz and Munson [4]. Rather than operate under compromised conditions, we sought to find a level of ammonia in methane that would give

the desired results. A level of 5% was found to give adequate results with a pressure above the diffusion pump of 2.5 to 3×10^{-5} torr, which is well within normal operating conditions.

Therefore, a custom gas mixture consisting of 2 L of 50% ammonia- ^{14}N and 50% ammonia- ^{15}N v/v (lot CC 331) was obtained from Cambridge Isotope Laboratories (Woburn, MA). Within a vacuum manifold, 1.61 g of this gas mixture was cryogenically transferred into a 500-mL stainless steel cylinder. Ultra high purity methane (99.97%) (Matheson Inc., Bridgeport, NJ) was used to pressurize the cylinder such that the final weight of methane in the cylinder was 28.85 g. The final concentration of ammonia in the cylinder was thus 4.9%. We estimate that the reagent gas mixture would last three years if used every day for 8 h per day. The ultimate cost therefore is no more than a few cents per gas chromatography-mass spectrometry run.

The reagent gas mass spectrum is provided in Figure 1. The spectrum is generally as reported previously, where $(\text{NH}_4)^+$, $(\text{C}_2\text{H}_5)^+$, $(\text{C}_3\text{H}_5)^+$, and $(\text{C}_3\text{H}_4 + \text{NH}_4)^+$ are the major ions. The ion at m/z 58 is identified easily as $(\text{C}_3\text{H}_4\text{NH}_4)^+$ from the pair of ions of equal abundance at m/z 58 and m/z 59.

CI mass spectra utilizing ammonia as the reagent gas are characterized by ions that acquire a proton $[\text{M} + \text{H}]^+$, acquire ammonia $[\text{M} + \text{NH}_4]^+$, acquire ammonia and lose a neutral fragment $[\text{M} + \text{NH}_4 - \text{X}]^+$, or acquire ammonia and lose a radical $[\text{M} + \text{NH}_4 - \text{Y}]^+$. Other ions may arise from radical or neutral losses from the $[\text{M} + \text{H}]^+$ ion. The difficulty in interpretation arises because both addition of NH_4 and/or addition of a proton can and often do occur. Although high resolution measurements and/or metastable studies can be used to resolve these difficulties, both of these methods require more work and may not be readily available. A second run with a different reagent gas may also resolve the difficulty, but is time consuming.

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Figure 1. Reagent gas mass spectrum for 5% ammonia (50% ^{15}N) in methane.

Utilizing a labeled reagent gas, the problem is greatly simplified. For example, consider the spectrum of hexyl acetate provided in Figure 2. At the top of the figure is the pure ammonia mass spectrum and at the bottom is the labeled ammonia-methane mass spec-

Figure 2. Chemical ionization mass spectrum of hexyl acetate (a) with ammonia and (b) with 5% ammonia (50% ^{15}N) in methane as the reagent gas.

trum. The ammonia spectrum shows a large ion at m/z 162. Clearly, if this large ion were an unknown, it would not be possible to tell if it was a protonated molecular ion or an adduct with ammonia. However, by using the labeled reagent gas we obtain both an $[\text{M} + \text{H}]^+$ ion (m/z 145) that shows no labeling and a clearly labeled adduct ion at m/z 162.

Figure 3 provides the ammonia and labeled ammonia-methane spectrum for 1-adamantanol. In this case we have a difficult situation in which the molecule loses water. Observation of the unlabeled spectrum indicates that the ion at m/z 170 may be an $[\text{M} + \text{H}]^+$ ion or it may be an $[\text{M} + \text{NH}_4]^+$ ion. Also the m/z 152 ion may be an $[\text{M} - \text{H}_2\text{O}]^+$ or an $[\text{M} + \text{NH}_4 - \text{H}_2\text{O}]^+$ ion. The use of labeled reagent gas clearly indicates that both m/z 152 and 170 contain nitrogen and therefore m/z 170 is $[\text{M} + \text{NH}_4]^+$ and m/z 152 is $[\text{M} + \text{NH}_4 - \text{H}_2\text{O}]^+$; m/z 135 consists of $[\text{M} + \text{H} - \text{H}_2\text{O}]^+$. This spectrum also has been studied by using linked scans [5], which agree with this assignment.

Figure 3. Top: Chemical ionization mass spectrum of 1-adamantanol (a) with ammonia and (b) with 5% ammonia (50% ^{15}N) in methane as the reagent gas.

When comparing labeled and unlabeled spectra, it is important to remember that we must compare the sum of the labeled ions versus the sum of the unlabeled ions. For example, in Figure 2 we find that if we take the sum of 162/163 and compare it with the sum of 145/146 for each of the two spectra, then the relative amount of m/z 145 is found to be quite similar. However in Figure 3, if we compare the sum of 170/171 with the sum of 135/136, we find that m/z 135 is approximately a factor of 2 higher. This enhancement is presumably due to the presence of CH_4 .

Some molecules do not produce adducts at all and as a result do not show any labeling. Most amines fall into this category. Also the degree of adduct formation ($[\text{M} + \text{NH}_4]^+$) generally increases with decreasing source temperature and increasing source pressure.

Some molecules show small adducts for $[\text{M} + \text{C}_2\text{H}_5]^+$ and $[\text{M} + \text{C}_3\text{H}_5]^+$. We find this gas can be 2 to 3 times more sensitive than ammonia alone, which is in good agreement with ref 4.

References

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