Food and Beverage

Alcohol proof measures the amount of ethyl alcohol (ethanol) in an alcoholic beverage. Absolute alcohol is 200 proof, or 100 % pure ethanol, 100 proof is 50% alcohol by volume, 50 proof is 25 % alcohol, and soon on. We tested this proofing system with the Thermo Scientific™ picoSpin™ 45 NMR by measuring the proton (^{1}H) NMR spectrum of several beverages ranging in proof from 42 (21% alcohol) up to 100 (50% alcohol). In **Figure 1** individual, unnormalized spectra of 7 beverages are compiled: 42 and 55 proof; rum, 60 proof; schnapps, 70 and 80 proof; vodka, 94 proof; gin, and 100 proof; whiskey. Except for the 'walk' of the hydroxyl (-OH) signal centered near 4.7 ppm the spectra look very similar. To observe differences is alcohol content we expand two regions of this figure, the methyl ($-CH_3$) group region (**Figure 2**) and the -OH signal (**Figure 3**).

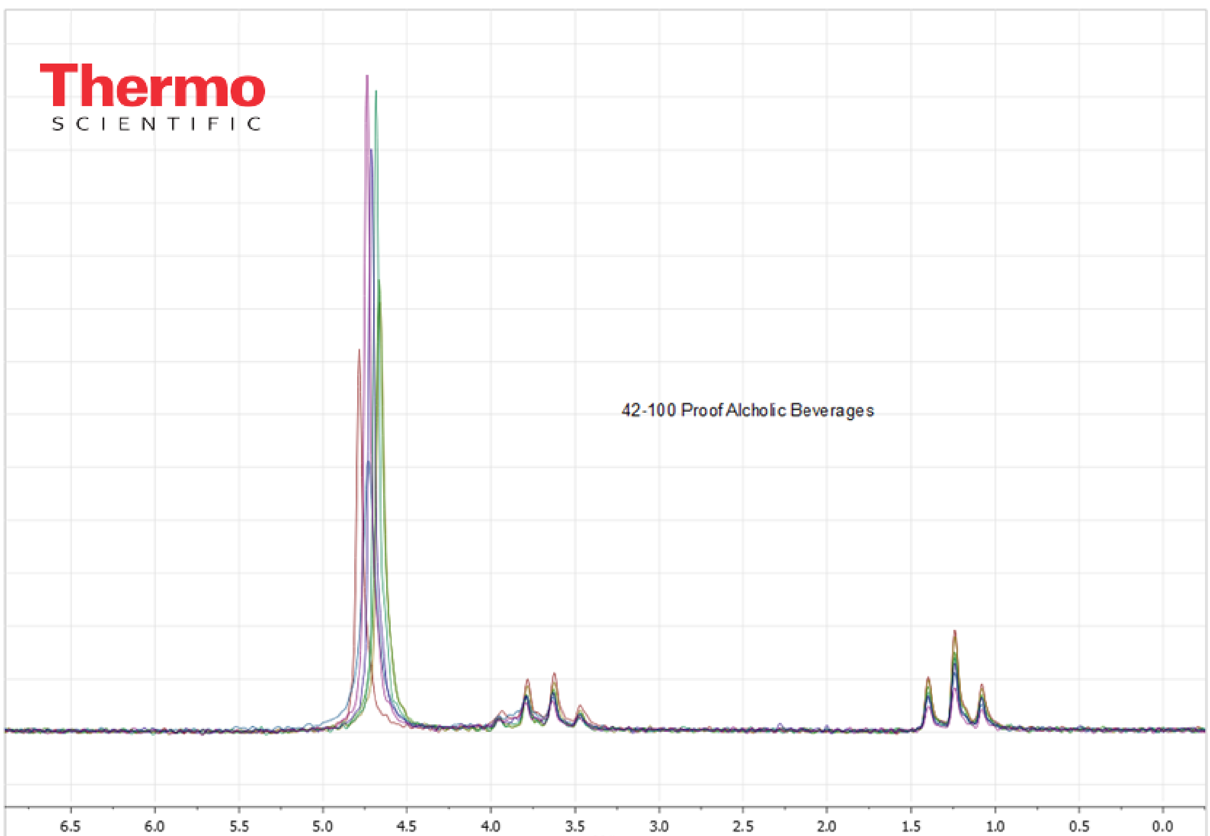

Figure 1. NMR Spectrum of a Variety of Alcoholic Beverages ranging from 42 to 100 Proof (24 scans).

In **Figure 2** the difference in percent alcohol content becomes evident. Our whiskey sample (100 proof) has the largest methyl signal due to the larger concentration of $-CH_3$ groups, while the 42-proof rum beverage has the lowest alcohol content and, hence, the weakest methyl signal. As the beverage proof increases from 42 to 100 in our tested samples we see the $-CH_3$ signal likewise increase. Only the 55-proof rum signal is out of order. This may be due to the coconut flavoring compound in our rum sample increasing the methyl signal, or the 60-proof schnapps alcohol content is not properly labeled. Based on the trend from 70 – 100 proof, it would appear the 55 proof signal is larger than it should be while the 60 proof signal is lower than expected.

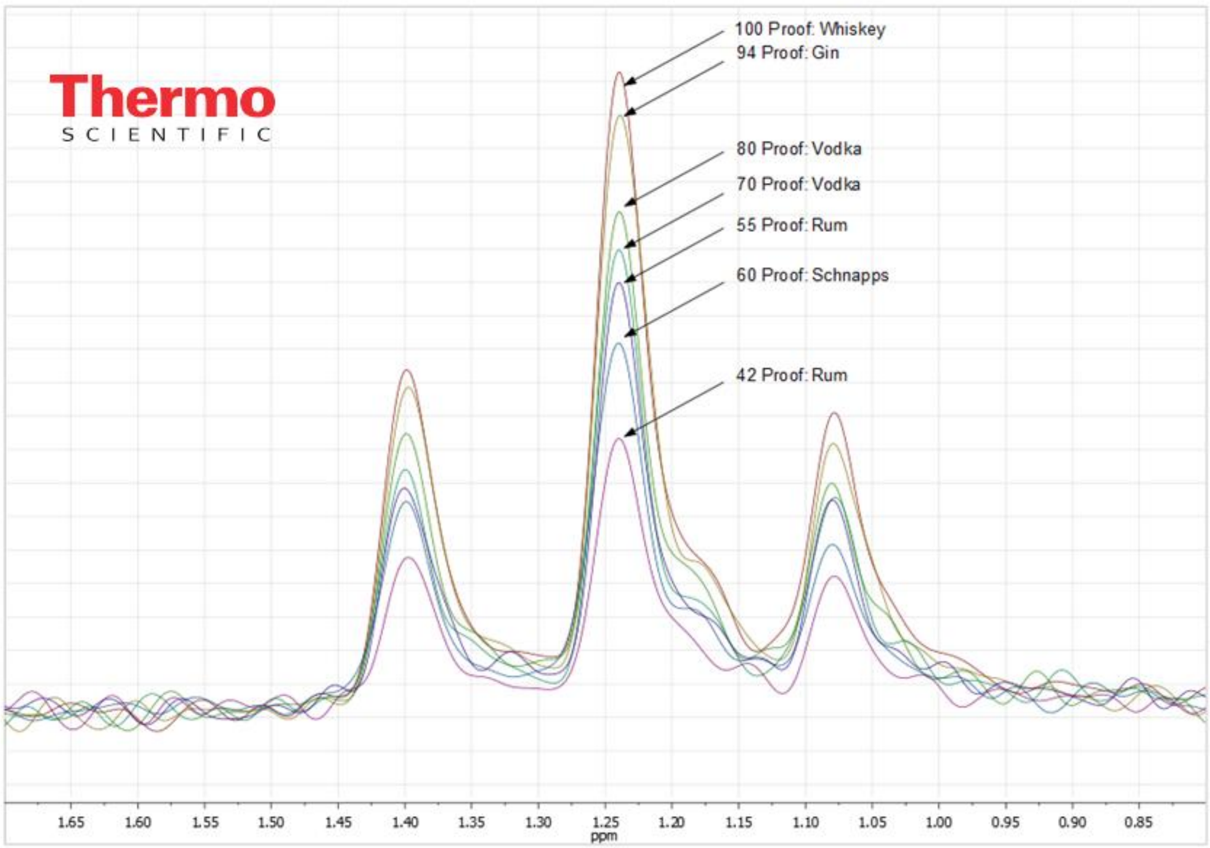

Figure 2. Expanded Spectrum of the Methyl Group Region.

What is apparent in **Figure 3**, is that the behavior of the -OH peak is different than that of the methyl group upon changing alcohol concentration. The chemical shift of the this signal is sensitive to the alcohol content in solution and appears to 'walk' as the alcohol/water ratio changes. There is also an inverse relationship in the $-CH_3$ to -OH signal, as the alcohol content increases the water content decreases. So as the $-CH_3$ signal increases there should be a commensurate decrease in -OH signal. The 100-proof whiskey sample saw the largest $-CH_3$ signal, and its -OH signal should be the smallest. Some of these beverage samples also contain sweeteners which cause broadening of the -OH signal. The beverages which contain sweeteners are the 42- and 55-proof rum, and 60-proof schnapps. The 60-proof schnapps beverage, which contains sugar sweeteners, shows considerable broadening in the -OH signal. There also is evidence of sugars in the methylene ($-CH_2-$) region (not shown) of the 60 proof spectrum.

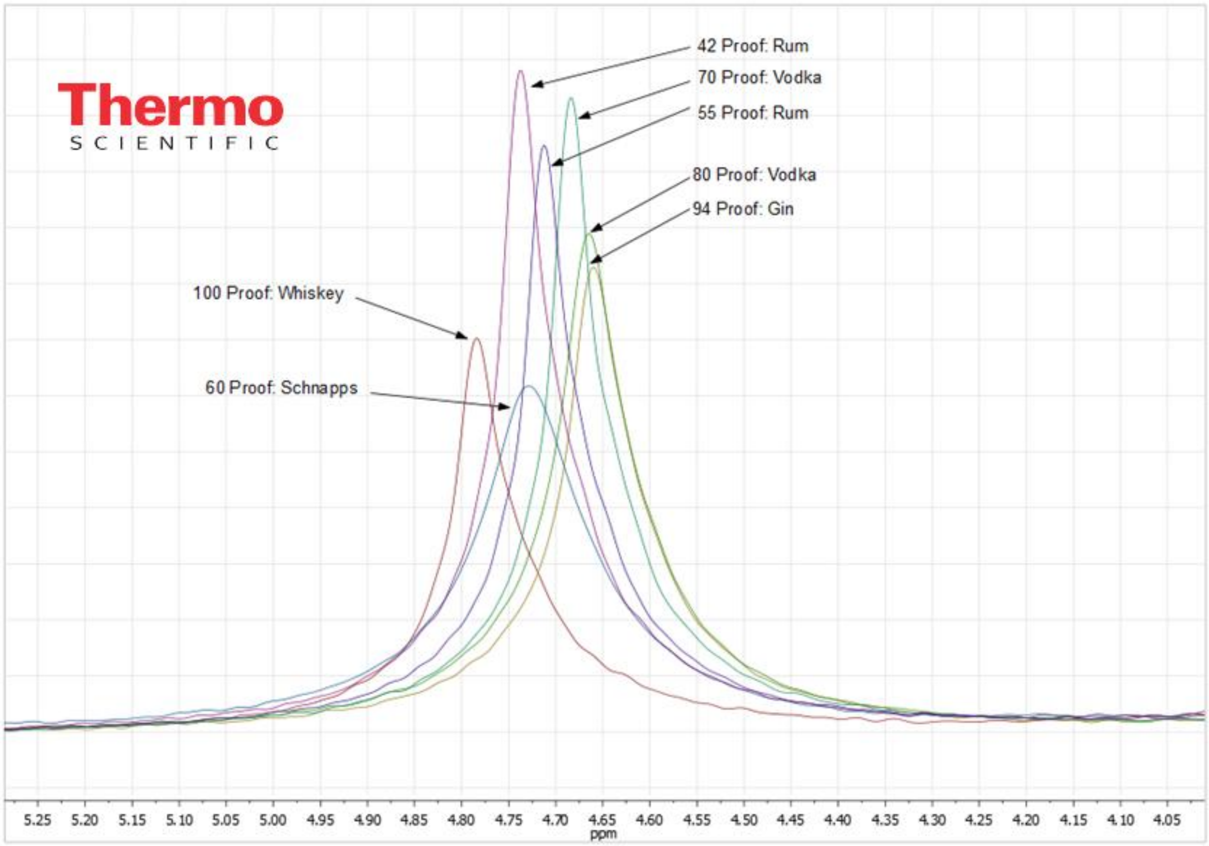

Figure 3. Expanded Spectrum of the Hydroxyl (-OH) Signal.

Tinctures are also alcoholic solutions. Their alcohol content is not subject to the same proof labeling regulations as alcoholic beverages, but their proof can be determined by simply doubling the stated percent alcohol content. A 50% alcohol tincture would be equivalent to a 100 proof beverage in ethanol content. We tested this by comparing a picoSpin ^1H NMR spectrum (**Figure 4** and **5**) of pure vanilla extract with a stated alcohol content of 35% (70 proof) to that of a vodka beverage of the same proof. Clearly the labeling of alcohol content in the vanilla tincture and vodka beverage is accurate since the -CH_3 signal from both samples have identical intensity.

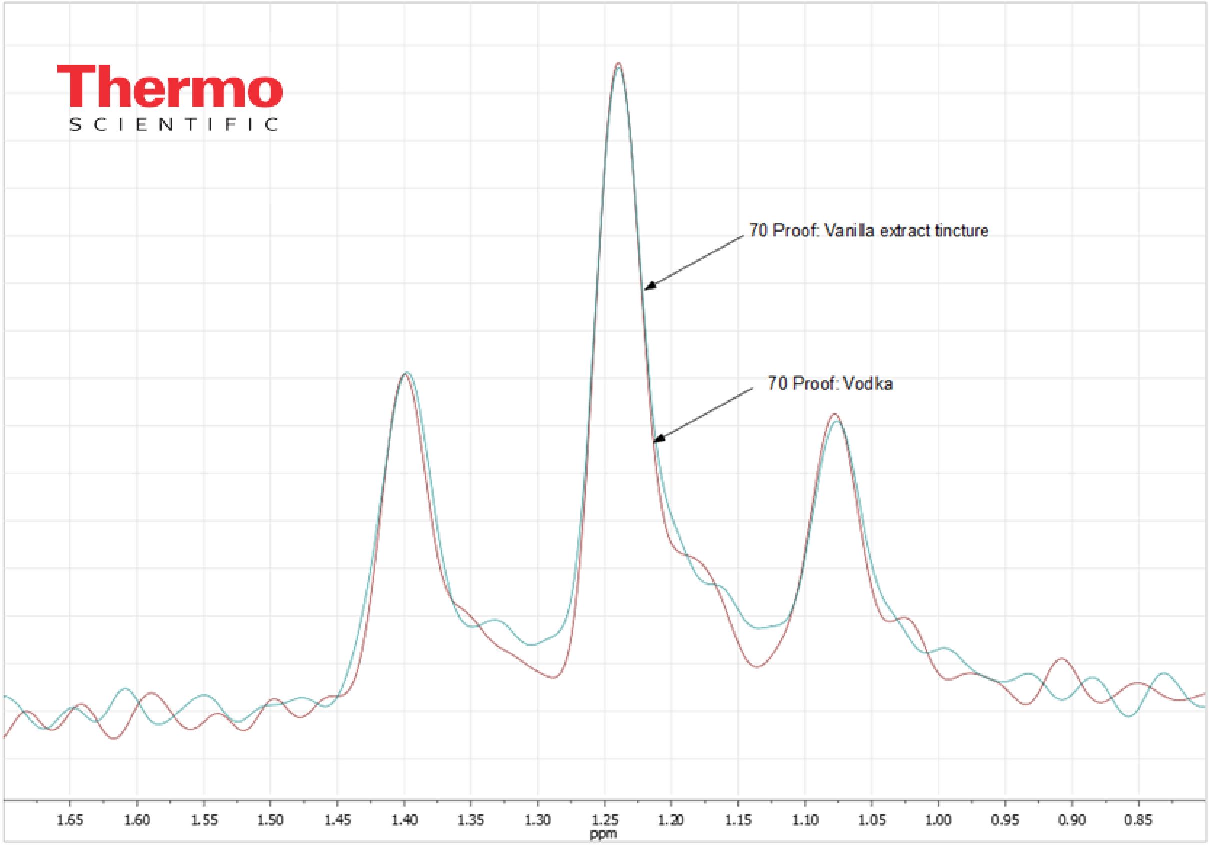

Figure 4. Expanded Spectrum of the Methyl Group Region – Comparison of 70-proof Vodka and 70-proof Vanilla Extract Tincture.

The -OH signal, again, depends on other factors such as sugar content. Thus, the vanilla extract tincture, which also contains sugar, produces a broad -OH signal. This is similar to the behavior of the -OH signal in the 60-proof schnapps sample seen in **Figure 3**.

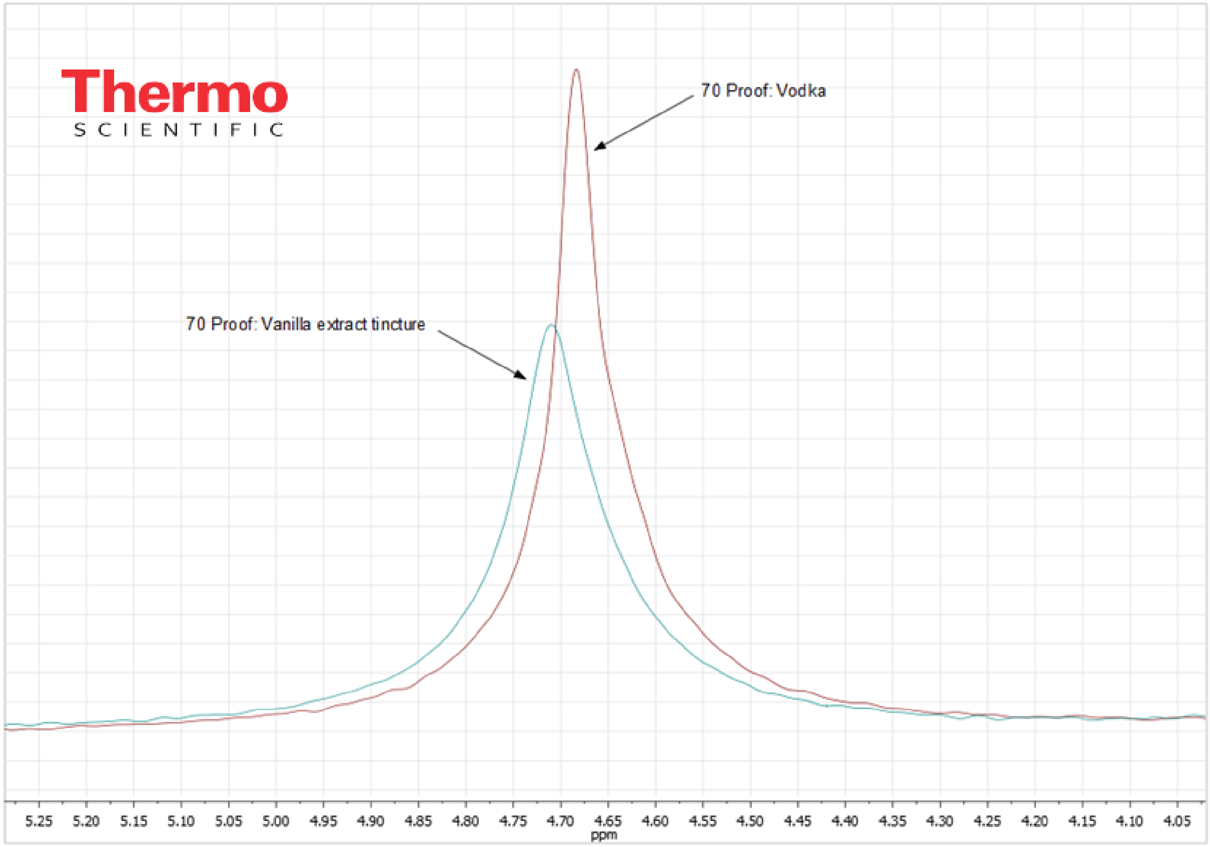

Figure 5. Expanded Spectrum of the Hydroxyl (-OH) Signal – Comparison of 70-proof Vodka and 70-proof Vanilla Extract Tincture.

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