^{13}C Sensitivity for Mass Limited Samples
Nano Probe *vs* 3mm $^{13}C\{^{1}H\}$

Our recent equipment upgrade has lead to questions concerning sensitivity and measurement of probe performance for mass limited samples. Our current probe inventory includes two probes that maximize mass sensitivity for carbon-13 NMR, a 3mm $^{13}C\{^{1}H\}$ standard high resolution probe for the KECK 750 instrument and a 4mm $^{13}C\{^{1}H\}$ Nano-Probe tuned for UI500WB. The question is: Which is the better probe for acquiring a carbon spectrum of a mass limited sample?

For the comparison we start with available data, signal to noise ratios (S/N) for 40% dioxane in C_6D_6. The 3mm probe gives a S/N of about 220:1 compared to 80:1 for the Nano probe. This data must be adjusted to account for the differences in sample size. The total sample volumes are 200uL for the 3mm and 40uL for the Nano probe. The much larger sample volume for the 3mm sample is due the fact that the sample extends beyond the coil or observe region of the probe. This is necessary to avoid irregularities due to magnetic field inhomogeneities at the ends of the sample. The Nano probe design allows the entire sample to be contained in the probe coil. When this factor of 5 difference in sample volumes (i.e. total amount of analyte) is considered the Nano probe is favored, giving an adjusted S/N of 400:1.

The above comparison is for a sample in the 3mm probe that is approximately three times the probe's coil length or about 4.5 to 5 cm long. In this configuration only about one third of the sample is detected. Reducing the sample volume will increase the concentration of analyte, the amount of analyte observed and hence the signal. We have been able to achieve comparable lineshape with samples as small as 110 uL with the 3mm probe. If the volume is reduced to110µL the volume factor is reduced to 2.75 and the Nano probe and 3mm give comparable mass sensitivities.

With a 110 µL sample in the 3mm tube only about 50% of the analyte is within the observe region of the probe. Susceptibility matched plugs, Shegemi tubes and spherical sample cells, are all designed to restrict the sample to the observe region of the probe with a minimum of line broadening due to field inhomogeneity. If the analyte is restricted to the observe region of the 3mm probe, without a notable degradation of lineshape, the mass sensitivity should increase by about a factor of two from the 110µL sample. At best this will give the 3mm probe a 2:1 advantage over the Nano probe. A 2:1 increase is about what would be expected due to the increase in field strength. Our experience with these is limited and lineshape may or may not be an issue.

In the comparison of the Nano and 3mm probes, lineshape may be a factor as well. Both probes are capable of lineshape values narrower than that of the 3.7 Hz line broadened, benzene triplet used to determine S/N. Routinely achievable lineshape values are 0.2/3/4 for the 3mm and 0.4/7/8 for the Nano probe (50%/0.55%/0.11% linewidth of the proton decoupled dioxane peak, no line broadening applied). This difference in homogeneity between the two probes results in lines of different widths for the C_6D_6 triplet, thus for lines of comparable width, the homogeneity differences are included in the measured S/N values. However, most research samples give

narrower linewidths. As the linewidth narrows, (assuming minimal line broadening is applied and magnetic field homogeneity, shimming, is good) the 3mm probe's advantage increases.

There are other practical considerations as well. The 3mm probe is a standard probe and as such requires a minimum of additional user training, changing samples is routine and sample tubes are available from standard suppliers. The Nano probe is a "high resolution" slow spinning MAS probe. As such, more user training is involved, sample changing is less routine and sample tubes are currently available only from Varian for a price greater than most 3mm tubes.

All things considered the 3mm probe for the KECK750 is generally the better choice for maximum ^{13}C sensitivity of normal liquid samples. The S/N is comparable for sample volumes of 110μL in the 3mm probe and likely better depending on lineshape. The advantage could be as high as 2:1 if it is possible to use one of the techniques mentioned above for restricting the sample to the observe region. The Nano probe's performance is still very good and it is the only choice for its intended use, that of molecules tethered to solid supports.