**Interpreting NMR Spectra from your Wittig Reaction**

When you first look at the spectrum obtained from your reaction it might seem a little messy, but there are a few steps that can clarify things a bit and hone in on the important data.

- If your product or any expected impurities have a known NMR spectrum, look them up so you can check if the required peaks are present. To do this, you can

    o Check chemical suppliers such as SigmaAldrich to find spectra for commercially available compounds.

    o Check the Spectral Database for Organic Compounds (SDBS) website for your compounds. (Google SDBS)

    o Use the spectra prediction functionality available in ChemDoodle to estimate where peaks should appear.

- Does any starting material (SM) remain? You should be able to look up the peaks for your starting material and determine if there is any left. If no, the reaction went to 100% conversion. Even the smallest amount of SM will still give a peak (albeit very small).
    o Look at the aldehyde region for leftover starting material; this should be a pretty decipherable peak.

- Next, find characteristic peaks for your *E* and *Z* isomers and calculate your *E/Z* ratio.
    o Perhaps the most useful data on the spectrum are the alkene peaks from your products. They are usually downfield, between 5.5 and 7.5 ppm, just upfield of the aromatic region, but this may vary according to your compound. Assuming there are two alkene protons on your molecule, each alkene isomer will result in a set of peaks.

    o The alkene protons of th*e E* and *Z* isomers can be differentiated based on their coupling constants. You may recall learning that these are typically slightly larger for the *E* isomer than the *Z*. Although we are not calculating the exact values of coupling constants, you should be able to use a ruler to determine which set of peaks has the larger coupling constant.
    (Some of you may see that some alkene peaks are shifted into the aromatic region and difficult to detect due to overlap with other peaks, but based on coupling constants, you can probably pick them out even in the mess of peaks. Think about why they may shift downfield.)

    o The *E/Z* ratio is based on the ratio from the integration of these two peaks. Normalize the ratio so that the sum of each adds up to 100.

    o Note: For class consistency, report the *E* isomer first regardless of which is the major product.

- Calculate your conversion based on the aldehyde starting material.
    o Do this by finding representative peaks for SM, *E*, and *Z* isomers. If possible, you should be looking at the same functional group for each of the molecules (SM, *E* and *Z*).

        ▪ For example, maybe you used *p*-methyl benzaldehyde. All three molecules (SM, *E*, and *Z*) will contain a singlet corresponding to the CH_3 group on the aromatic ring. Comparing the ratio of the three singlets allows you to calculate the conversion.

- If you cannot use the same functional group for your conversion calculation, then use the *E* and *Z* peaks you identified and the aldehyde H peak.

  o Figure the ratio of SM:*E*:*Z*. Sum the integral values for *E* and *Z*. Divide that number by the sum of SM, *E*, and *Z*. This is your conversion. Express it as a percent.

  o More accurate results can be obtained if there are multiple regions that will allow you to perform this analysis. Average the calculations to obtain a better result. (From the example above maybe your conversion was 84% when looking at the aromatic methyl group. Doing the same calculation with the alkene/aldehyde H's might give 86%. The average would then be reported as 85%)

  o *Note: For this experiment, the % conversion is calculated based on aldehyde, not phosphonium ylide. Why?*

- The aromatic region will be pretty hard to interpret. As you may recall, the byproduct of this reaction that is difficult to avoid without purification steps is triphenylphosphine oxide. Each molecule of triphenylphosphine oxide will have 15 aromatic protons that show up in this region. Try to avoid getting spending too much time interpreting this region unless the only peaks that can determine the E/Z selectivity fall here.

Example: *p*-chlorobenzaldehyde and (*t*-butoxycarbonylmethyl)triphenyl phosphonium chloride using KOH (spectra of product are on the next page):
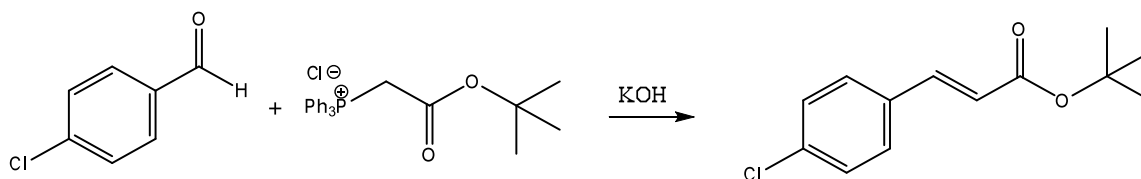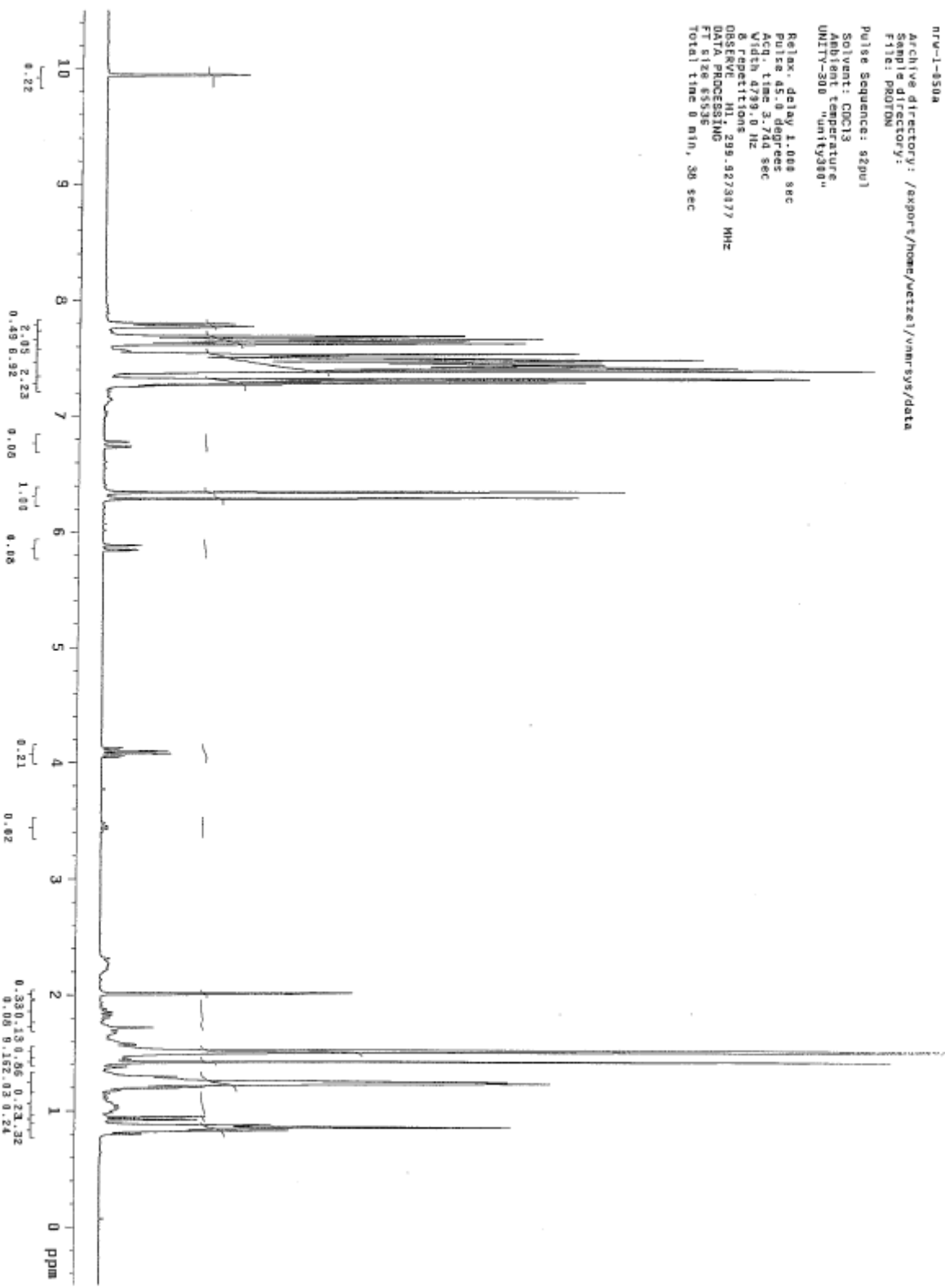

- On the NMR spectrum, first notice that there is a singlet at about 10 ppm corresponding to the aldehyde. You should notice that there are peaks in this spectrum that do not fit with the expected spectrum for the SM or the products. Needless to say, starting material remains, the product is impure, and the conversion is not 100%.

- Calculating the *E/Z* ratio: First, look in the alkene region (5.5-7.5 ppm). There are doublets that correspond to the vinyl protons on each isomer. At about 5.85 ppm there is a small doublet and to its left at about 6.35 ppm there is a larger doublet. The integration of the smaller doublet comes out to 0.08 (representing a vinyl proton on the minor isomer) and the larger is 1.00 (major isomer). A little bit farther downfield there is another doublet that integrates to 0.08 representing the other vinyl proton on the minor isomer. You should expect to have another large doublet downfield to correspond to the other alkene proton, but this is in the aromatic region, so for now don't worry about it. Notice also that the coupling constant for the larger doublet is greater than that of the small doublet. This means that the major product (from the larger doublet) corresponds to the *E* isomer. Taking this information, the ratio of the integrals of the smaller doublet to the larger is 12.5:1, and this is the *E/Z* ratio. Normalize this to 100 by doing it as a mole fraction…thus 12.5:1 is the same as 93:7. Look upfield and see large singlets that are from the *t*-butyl group (other peaks in this region are likely from solvent impurities i.e. hexanes). You should expect this peak to integrate to 9 if it were the *t*-butyl group on the major isomer. The minor isomer *t*-butyl group would be smaller (0.08 x 9 = 0.72). There is a singlet at 1.5 ppm that integrates to 9.16 (major isomer) and another singlet at 1.45 ppm integrating to 0.86 (minor isomer). The ratio of these two peaks also corresponds to the *E/Z* ratio already determined. In this case it is 10.7:1 or 91:9, slightly smaller than what was calculated previously and likely different due to error associated with the integration and/or overlapping impurities. These numbers can be averaged to give a reportable *E/Z* ratio of 11.6:1 or 92:8. Report your data in normalized form with the E isomer first.

- Calculating % Conversion: To calculate the conversion, pick three related peaks that correspond to SM, *E* and *Z*. Since the aromatic region is a mess, it will be difficult to analyze peaks there. For this spectrum, what makes the most sense is to compare the aldehyde H (integral=0.22) to the alkene H's (integral= 1.00 and 0.08). Conversion is taken by dividing (1.00 + 0.08)/(1.00 + 0.08 + 0.22) = 0.83 or 83% conversion. When calculating % conversion it is always important to find 3 peaks without interfering impurities that are as close to each other on the spectrum as possible.

- Full Spectrum for the product mixture resulting from the reaction of *p*-chlorobenzaldehyde and (*t*-butoxycarbonylmethyl)triphenyl phosphonium chloride using KOH

1

nrv-1-050a

Archive directory: /export/home/wetzel/vnmrsys/data
Sample directory:
File: PROTON

Pulse Sequence: s2pul

Solvent: CDCl3
Ambient temperature
UNITY-300 "unity300"

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 3.744 sec
Width 4799.0 Hz
8 repetitions
OBSERVE H1, 299.9273477 MHz
DATA PROCESSING
FT size 65536
Total time 0 min, 38 sec

Expansion of downfield region

mrw-1-050a
Archive directory: /export/home/wetzel/vnmrsys/data
Sample directory:
File: PROTON

Pulse Sequence: s2pul

Solvent: CDCl3
Ambient temperature
UNITY-300 "unity300"

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 3.744 sec
Width 4799.0 Hz
8 repetitions
OBSERVE H1, 299.9273077 MHz
DATA PROCESSING
FT size 65536
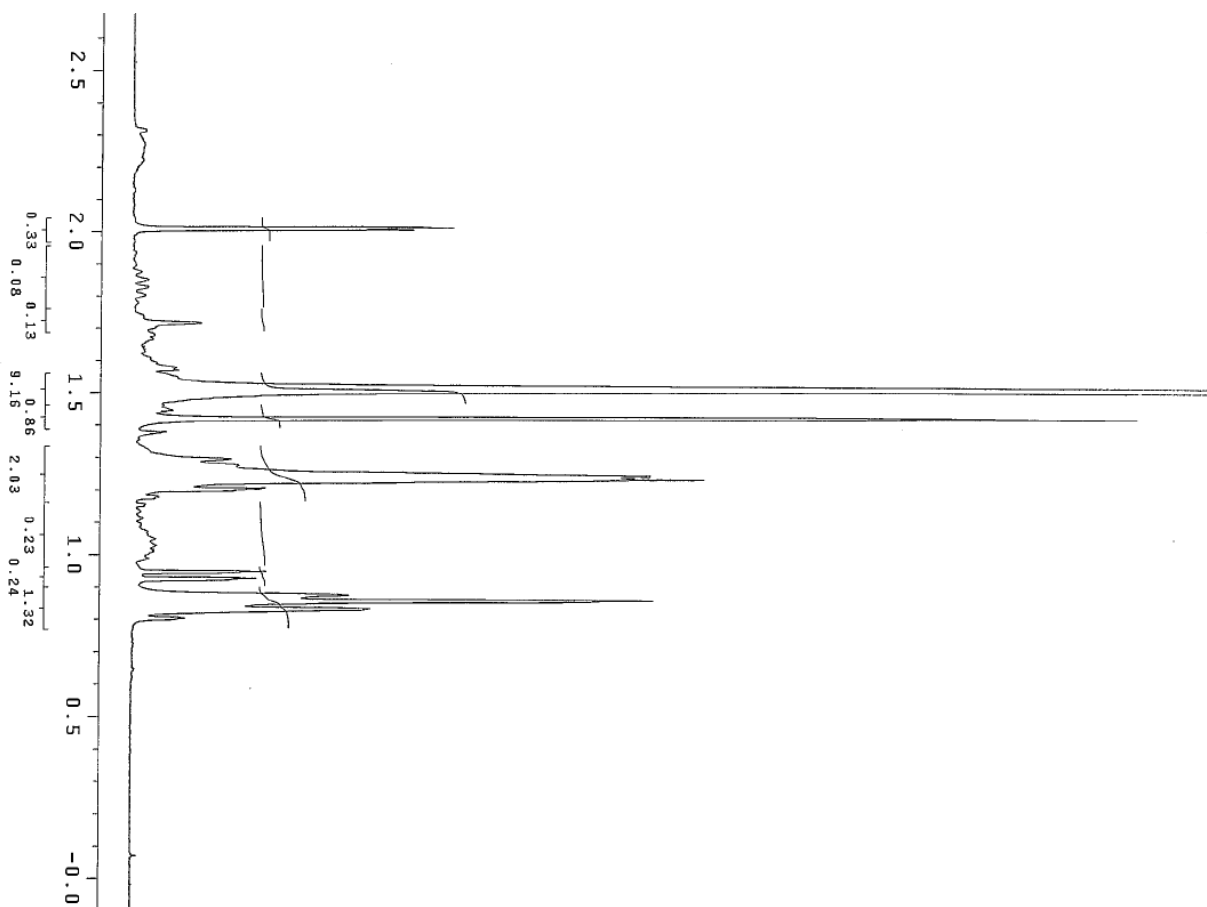Total time 0 min, 38 sec
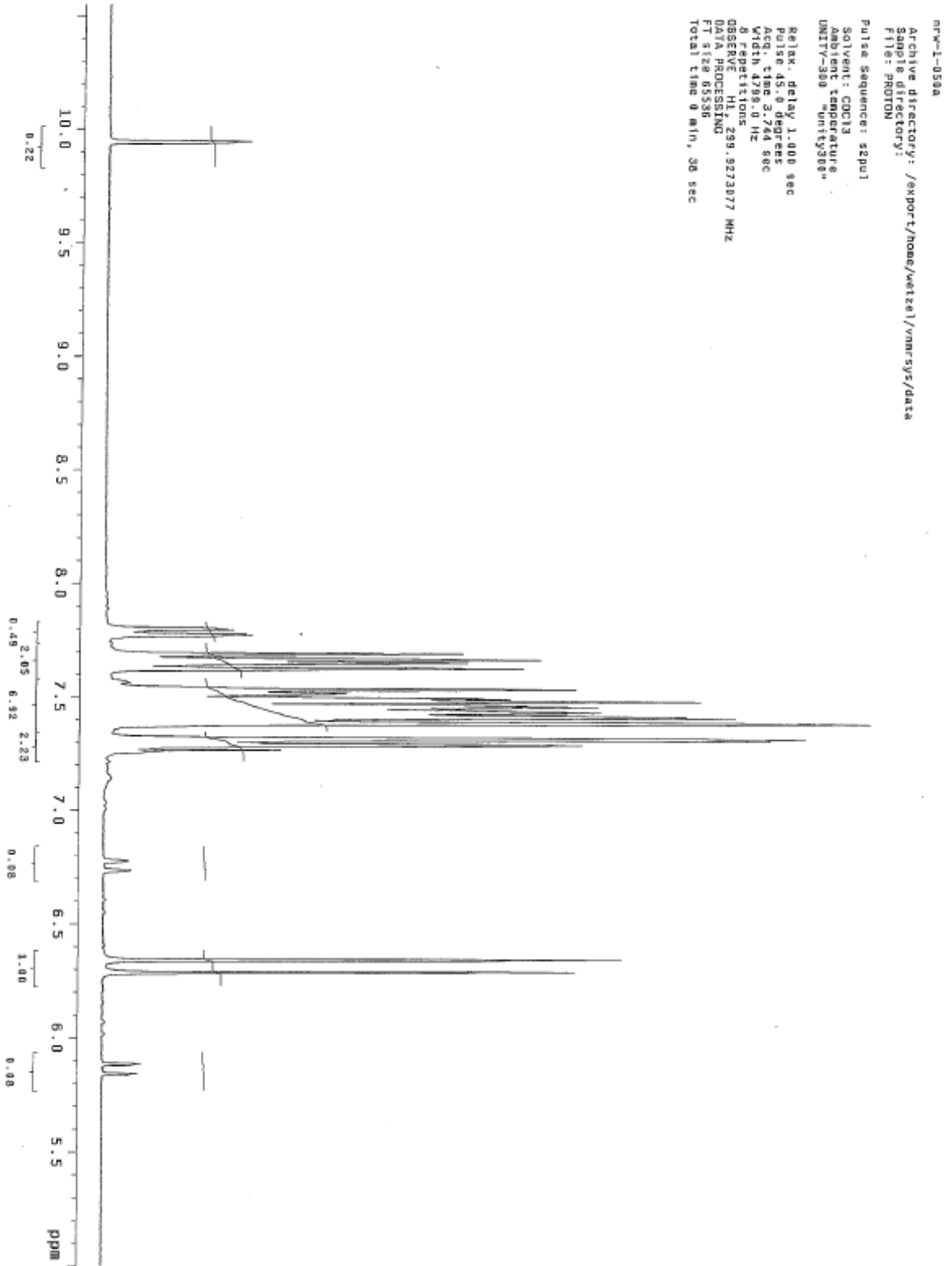
Expansion of Upfield region

For practice, an additional set of spectra taken on our 60 MHz instrument is provided. You should be able to identify the peaks corresponding to
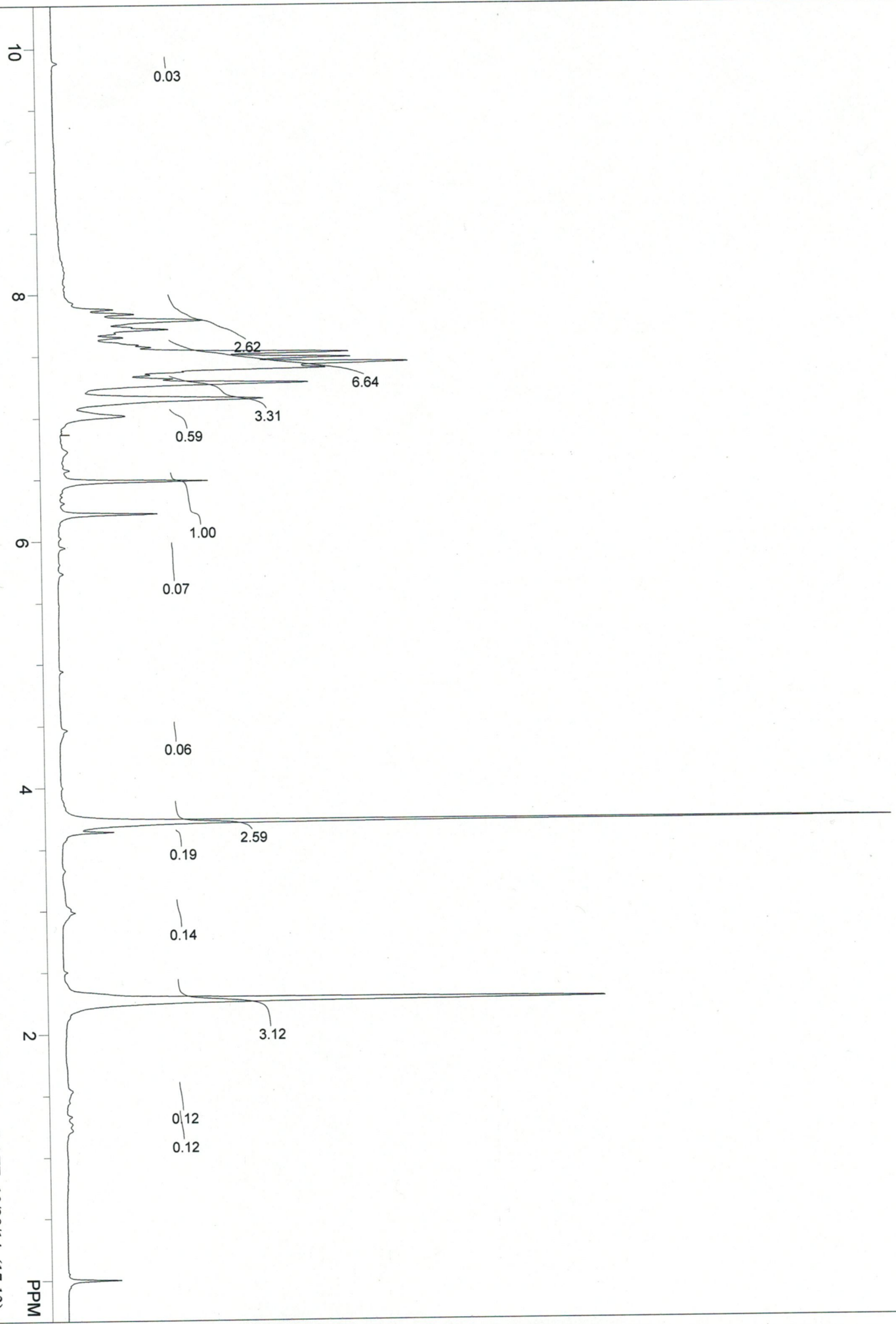
- The *E* isomer
- The *Z* isomer
- The remaining aldehyde

Hint: The visual separation between the two peaks of any doublet on our instrument is wider than on an instrument with a larger magnet.

Practice calculating conversion and *E/Z* ratios.

PMe MeO

EX: c:\eft\H1\ZG.ppg

F1: 60.133

SW1: 1000

PW: 14.9 us

PD: 3.0 sec

OF1: 413.0

NA: 32

PTS1d: 8192

USER: -- DATE: 10/28/14 (17:13)

Nuts - temp

LB: 0.0

10   8   6   4   2   PPM

0.03

2.62

6.64

3.31

0.59

1.00

0.07

0.06

2.59

0.19

0.14

3.12

0.12
0.12