1. Determine the number of peaks you would expect in the $^1$H NMR of the following compounds. For each type of peak, determine the multiplicity.

(a)

1. a: red peak: singlet
   b: blue peak: doublet
   c: green peak: doublet

(b)

2. a: red peak: doublet
   b: blue peak: none (9)
   c: green peak: quartet
   d: pink peak: triplet (or quartet if OH shows up)
   e: black peak: no peak or lump

(c)

3. a: red peak: doublet
   b: blue peak: sextet (6)
   c: green peak: septet
   d: pink peak: pentet (or septet if OH shows up)
   e: purple peak: doublet
   f: black peak: no peak or lump

2. Define the following pairs of protons as homotopic, enantiotopic, or diastereotopic. Would you expect them to have the same or different chemical shift?
3. The NMR spectra for compounds containing 10 hydrogens are shown below. For each, determine how many different types of hydrogens there are, and how many of each type there are (only the portions of the spectra containing peaks are shown).
It may be difficult for you to determine whether the peak(s) just below 3 is one or two peaks. If it’s one peak, the ratio is $2H:3H:4H$. If it’s two peaks, the ratio is $2H:3H:2H:2H$.

(It is actually two separate peaks)

Since the two peaks around 1 have very distinct shapes from one another, they probably represent two separate peaks, so there are three different peaks. The ratio is 1:2:2. To make it equal 10H, the ratio becomes:

$2H:4H:4H$

There are seven different peaks, with a ratio of 1:2:1:2:2:1:1.
4. Assign the peaks of each $^1$H NMR spectrum to the structure that accompanies it.

a.

![NMR spectrum of butanoic acid](image)

b.

![NMR spectrum of ethylbenzene](image)
c.

2-methyl-2-butanol

(d) (no peaks below 6 ppm)

2,4-dichlorobenzaldehyde
5. The following two partial spectra belong to 4-bromophenol and 3-bromophenol. Which spectrum belongs to which compound?

3-bromophenol has four different types of protons (a singlet, two doublets, and a triplet, each 1H).
4-bromophenol has two different types of protons (two doublets, each 2H)
Therefore, the spectrum on the left is 3-bromophenol, while the one on the right is 4-bromophenol (some of the peaks in 3-bromophenol overlap, so there are not four distinct peaks, but the spectrum on the right is obviously two equal area doublets.)

6. The following spectra belong to the three structures shown below. Which spectrum belongs to which compound? (only the portion of the spectra containing peaks is shown)

One way to solve the problem is to look at all the peaks expected for each compound, and match it to the corresponding spectrum. However, a faster method would be to just look
at the hydrogens on the carbon attached to the oxygen, which appear at a distinct area of the spectrum than the rest of the protons, and simply match these up.

This spectrum has no peaks in the 3-4 ppm range, so it is:

![Chemical Structure](image1)

This spectrum has a peak just above 4 ppm that is 2H, triplet, so it is:

![Chemical Structure](image2)

This spectrum has a peak at 3.8 ppm that is 2H, doublet, so it is:

![Chemical Structure](image3)