1) Which of the following molecules, drawn using the Newman projection formulas, is/are chiral? Label all stereogenic centers as (R) or (S).

The first compound is iso-butyl bromide, and because it does not have 4 different groups attached to any given carbon, can not be chiral. The second compound is 2,3-dimethylbutane and is also not chiral The third compound, 3-methylhexane, is chiral, and is of the (S) configuration. The last compound, 3-chloro-2-butanol, is also chiral (in fact, has two chiral centers!) The one we are examining is C-3, and is of the (R) configuration. (We have not been asked about the other center; were we to have been, it is of the (S) configuration.)

2) Draw all possible stereoisomers for the following molecule.

Here we are only asked to draw all possible stereoisomers. There are 3 chiral centers (indicated by an “*”), so we should find and draw 8 stereoisomers.
Here are the 8 stereoisomers:

3) How many stereoisomers of the following compound are possible?
Here there are also three stereogenic areas: two for enantiomers, and one for cis/trans. (Marked as “*” and “c/t” respectively.) Therefore, there are 8 stereoisomers possible.

Even though it's shown as trans, it can do cis/trans.

4) A 5.0 g sample of optically pure (+)-2-bromooctane was dissolved in 40 mL of CCl₄. The observed rotation was +2.7°, measured in a 10-cm polarimeter tube.
   a) Calculate the specific rotation, \([\alpha]_D\) of (+)-2-bromooctane

   We can find that \([\alpha]_D = \frac{\alpha}{cl}\) (\(c\) in grams/mL, and \(l\) in decimeters (dm)). Doing our calculations, we find \(c = 0.125\) g/mL, and \(l = 1\) dm (recall 10 cm = 1 dm). Substituting, we get: \([\alpha]_D = \frac{\alpha}{cl} = \frac{+2.7}{(0.125)(1)} = +21.6^°\)

   b) Based on the result of the measurement, is it possible to determine whether an (R) or an (S) enantiomer was present? Explain.

   No, it is not. Absolute configuration and optical rotation do not run hand-in-hand i.e. an (R) enantiomer can be either (+) or (-), and the same for an (S) enantiomer.

5) The following two compounds served as starting materials for the construction of the carbon skeleton of the natural product phorbol, which has tumor-promoting properties.
a) What is the relationship of the two (diastereomers, enantiomers, identical, or constitutional isomers)?

Because the cyclopropyl ring must be fused cis, and the methyl group on the cyclohexenyl ring is above the plane in both molecules, I would say that these molecules represent diastereomers, as they are clearly isomers, and are non-superimposable, non-mirror images. The geometry on the five-membered ring is different.

b) If the two are mixed and the mixture is subjected to $^{13}$C-NMR analysis, how many signals would we expect to see in the spectrum?

Remember that diastereomers are different compounds, so will have different properties. Each diastereomer has 19 different carbons (the three methyls on the silicon, gratefully, are identical) so we should expect to see 38 signals in the $^{13}$C-NMR spectrum. (We might see fewer; arguably, the trimethylsilyl groups could be sufficiently similar to occur together.)