These questions are based on the following article:

1. (1 point) Draw *cis*-decalin and *trans*-decalin (bond-line drawings, in 3D; i.e., use chair/boat conformations rather than a flat hexagon). Explicitly show the position of the hydrogens on the ring-fusion carbons.

2. (4 points) The synthesis, as laid out in this paper, has three main steps, as illustrated below.

The first step (A $\rightarrow$ B) is a Diels-Alder cycloaddition. Provide a detailed molecular orbital argument for this reaction. Illustrate your answers appropriately.
   a. Is this reaction photochemically or thermally allowed?
   b. Is this a suprafacial or antarafacial addition?

3. (2 points) The third stage in the synthesis (C $\rightarrow$ D) involves a Cope rearrangement. Propose a mechanism for this reaction, and explain why the *cis*-decalin is the final product.
4. (2 points) The stereochemistry of the cis-decalin products was confirmed by NOE spectroscopy.
   a. What does NOE stand for?
   b. Consider compound D in the illustration above. Propose two possible NOE experiments to verify its structure, and explain what you expect to observe in those experiments.

5. (1 point) Attached is the $^{1}$H NMR spectrum of compound B. Assign as many of the peaks as you can.

**Green Chemistry Question (2 points):**
The second stage in the synthesis (B $\rightarrow$ C) is an olefination. The authors use two different protocols to accomplish this transformation. One is a Wittig olefination (CH$_3$PPh$_3$Br, n-BuLi); the other utilizes Lombardo’s reagent (Zn, CH$_2$Br$_2$, TiCl$_4$). Compare and contrast these two methods from the perspective of green chemistry.