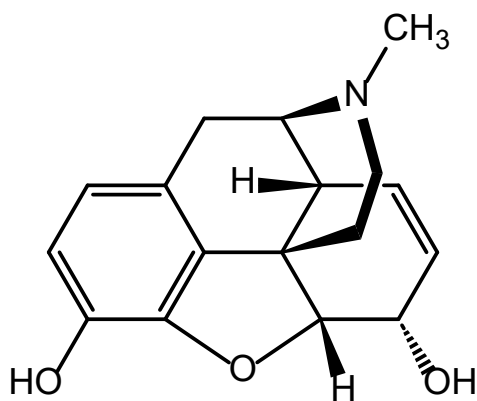


Name: \_\_\_\_\_ Last \_\_\_\_\_ First \_\_\_\_\_  
(print legibly) Last \_\_\_\_\_ First \_\_\_\_\_ Last 4 Digits of Student ID Number: \_\_\_\_\_

**Read all directions very carefully.** Write your answer legibly in the designated spaces. Total number of points is 200. This exam is supposed to have six (6) pages, with the last page intentionally left blank.

1. Morphine is a non-synthetic narcotic with a high potential for abuse and is derived from opium. It is used for the treatment of pain. How many chiral centers are there in the molecule of morphine, shown below? Clearly mark all the chiral centers. Then assign their configurations as (*R*) or (*S*). 40 points

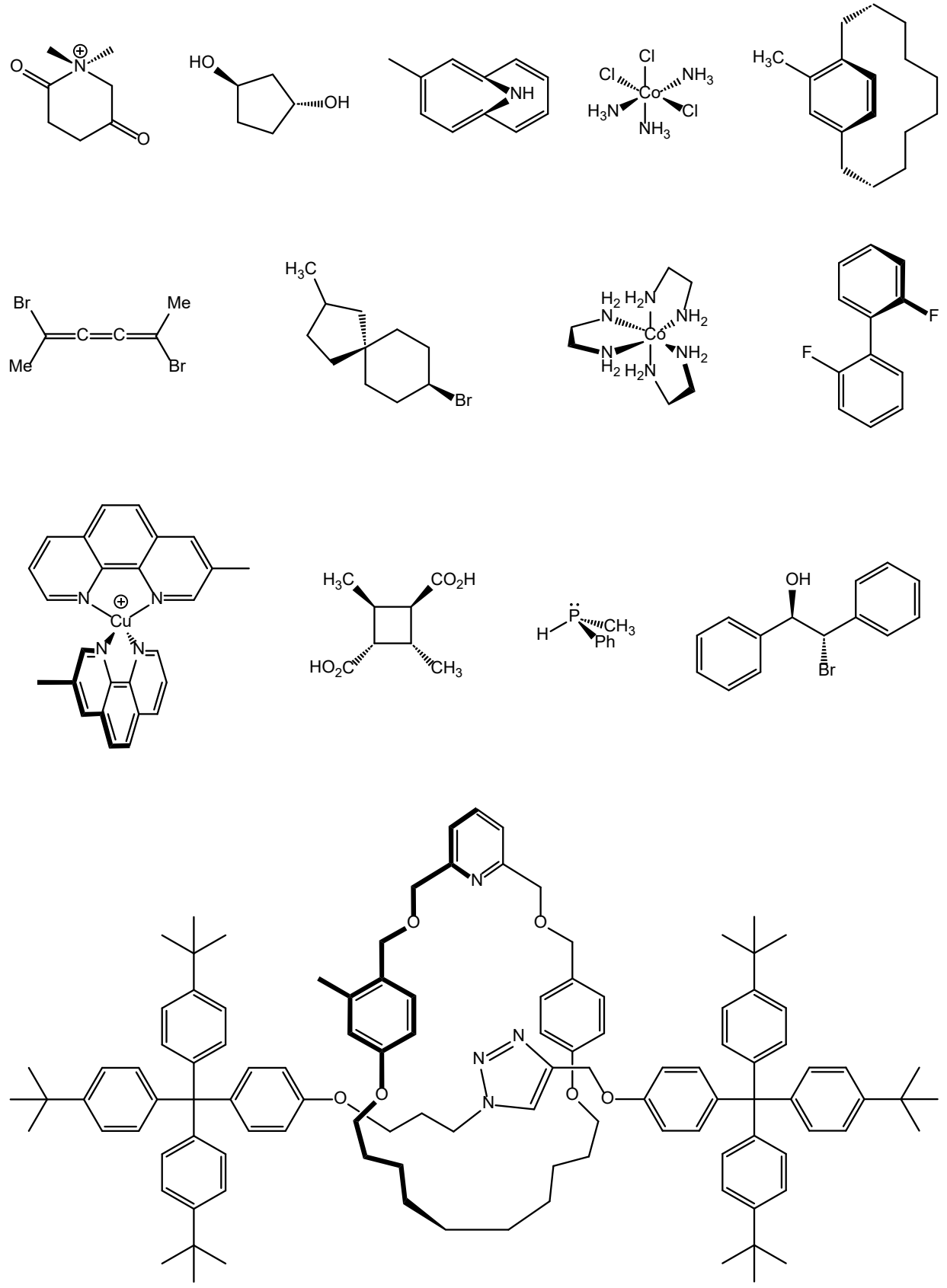


*morphine*

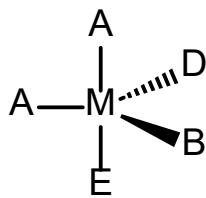
DO NOT WRITE  
IN THIS SPACE

**FINAL SCORE**

2. Circle all chiral molecules. For each chiral molecule, assign the configuration of its chiral elements with appropriate *R/S*, *A/C*, *M/P*, or  $\Delta/\Lambda$  designators. 60 points



3. Draw all the possible isomers of a hypothetical  $MA_2BDE$  complex, which has trigonal bipyramidal symmetry on the central atom  $M$ . Circle the chiral ones, assuming that substituents  $A$ ,  $B$ ,  $D$ , and  $E$  have different chemical identities. Shown below is one of the possible isomers. *40 points*



4. Define, in your own words, the following terms. Be succinct but precise, and feel free to use chemical structures to illustrate your definitions. 4 × 5 = 20 points

**Conformation**

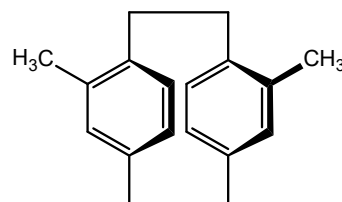
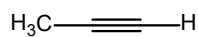
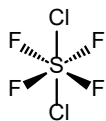
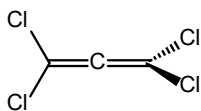
**Atropisomerism**

**Stereogenic center**

**Topological chirality**

5. Which point groups do the following molecules belong to?

40 points



# Chart for the Determination of Point Groups

