

## 5. This question is about the metal osmium in organic reactions

In 2004 it was reported that a terrorist attack that planned to use osmium tetroxide ( $\text{OsO}_4$ ) had been foiled. However, although osmium tetroxide is highly toxic, it is unlikely to be used for such a purpose due to the high cost of this rare element (around £100 per gram of  $\text{OsO}_4$ ). Nonetheless, osmium compounds are used in certain organic reactions.

### NATURAL HISTORY OF OSMIUM.

THIS is another new metal discovered by Mr. Tennant. The name of osmium is given to it on account of the oxid of it being exceedingly volatile, and diffusing, on being volatilized, a peculiar pungent odour. This metal likewise exists in the black powder, mixt with the ore of platina.

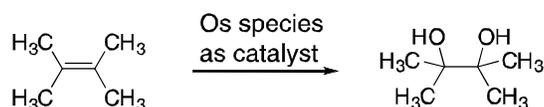
From "System of Theoretical and Practical Chemistry" by Fredrick Accum, 1808

In aqueous solution, osmium can exist as a number of species.

(a) Write down the oxidation number of the osmium atom in the following species:



An osmium species is able to catalyse the following transformation of an alkene into a diol where the two OH groups are on adjacent carbon atoms.

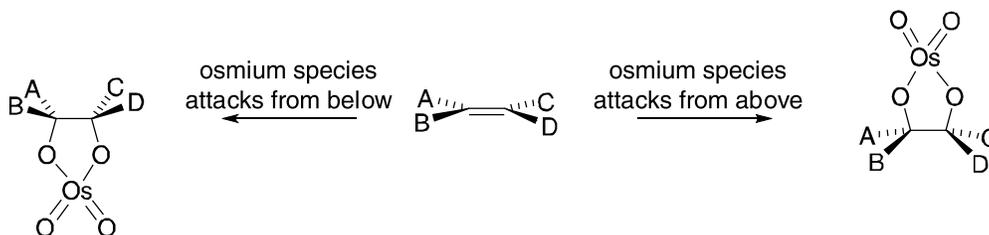


(b) How would you classify the reaction above? Circle the correct answer in the answer booklet.

Hydration    Dehydration    Oxidation    Reduction    Isomerisation

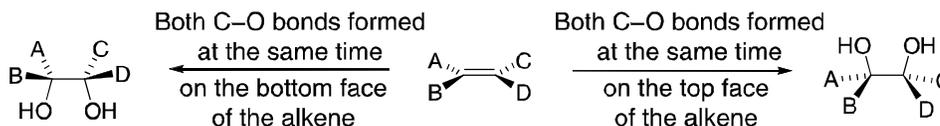
(c) Only one of the osmium species in part (a) is able to catalyse this reaction. Based on your classification of the reaction in part (b), which one of the osmium species do you think is used as the catalyst?

This reaction is very useful as there is a precise stereochemical outcome due to the way that the new C–O bonds are formed. Both new C–O bonds are formed simultaneously on the same face of the double bond. The first step is the formation of a cyclic compound where the osmium species can attack the double bond on either face.

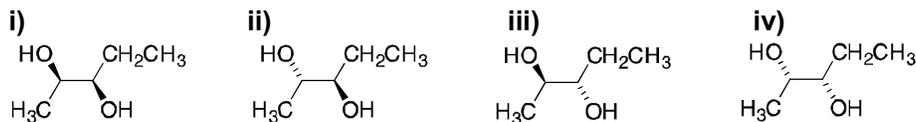


(d) What is the oxidation number of the osmium atom in the cyclic species?

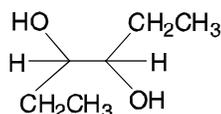
After hydrolysis, the new OH bonds end up either both on the top face, or both on the bottom face. This means that only certain stereoisomers can be formed.



- (e) The diol below can exist as four possible stereoisomers. For each one, draw the alkene that would need to be treated with the osmium species to form that stereoisomer.



- (f) i) How many stereoisomers are there for the following diol?

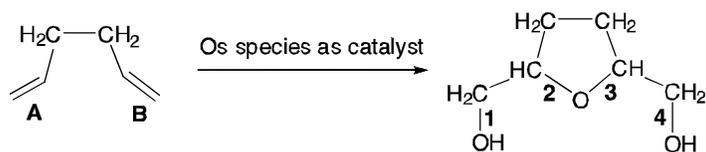


Circle in the answer booklet:

1      2      3      4

- ii) Draw the structure of each stereoisomer and the corresponding alkene needed to make it.

In certain molecules with two double bonds it is possible for one of the oxygens that is added to end up bonded to two carbon atoms, and in doing so form a ring. This reaction has a defined stereochemical outcome as well. Of the four new C-O bonds that are formed, bonds **1** and **2** are formed simultaneously on the same face of double bond **A**, and bonds **3** and **4** are formed simultaneously on the same face of double bond **B**.



- (g) The cyclic product from the reaction of the following molecule with the appropriate osmium species can exist as 16 stereoisomers. In the answer booklet write the numbers of the stereoisomers that can be formed from this reaction given the information above.

