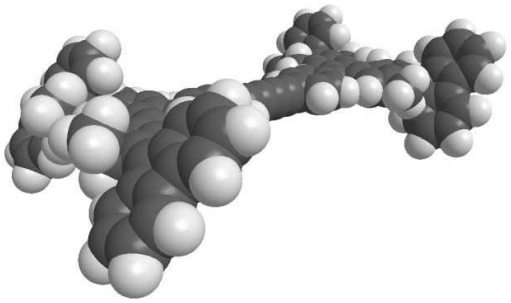
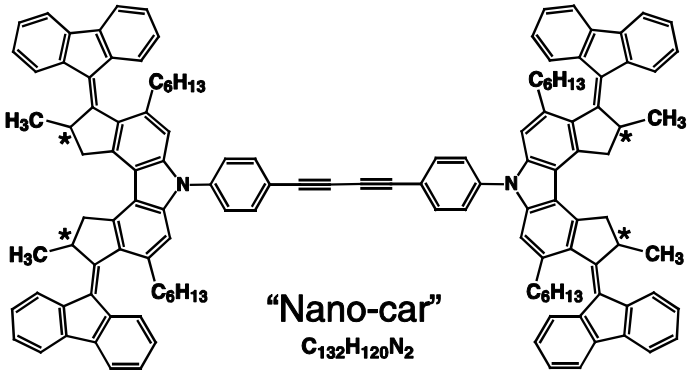
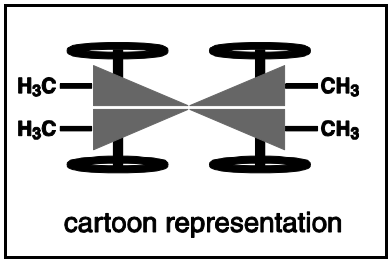
5. This question is about the world's smallest powered car



In November of 2011, the premier scientific journal Nature published an article titled "Electrically driven directional motion of a four-wheeled molecule on a metal surface". Essentially, this paper reported the synthesis and observations of the world's smallest powered car – the "Nano-car".





On completion of the synthesis, the sample was analysed using NMR and mass spectrometry. Not surprisingly, the group did <u>not</u> submit their precious material for combustion analysis!

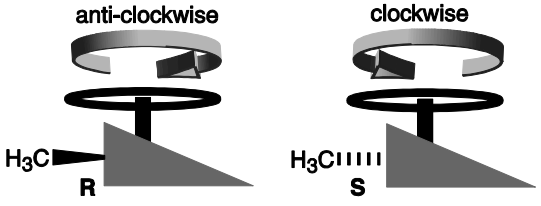
(a) i) Give an equation for the complete combustion of nano-car.

ii) Calculate the percentage by mass of carbon, hydrogen and nitrogen that would be predicted were the analysis to be performed. Give your answers to two decimal places.

Crucial in the design of the molecule are the hexyl and methyl groups shown explicitly in the structure above. It is because of these that the aromatic "wheels" of the car are actually arranged at an angle, straining the double bond that attaches them to the rest of the structure. This double bond can break, rotate and reform when sufficient electronic energy is provided using the tip of a scanning tunnelling microscope.

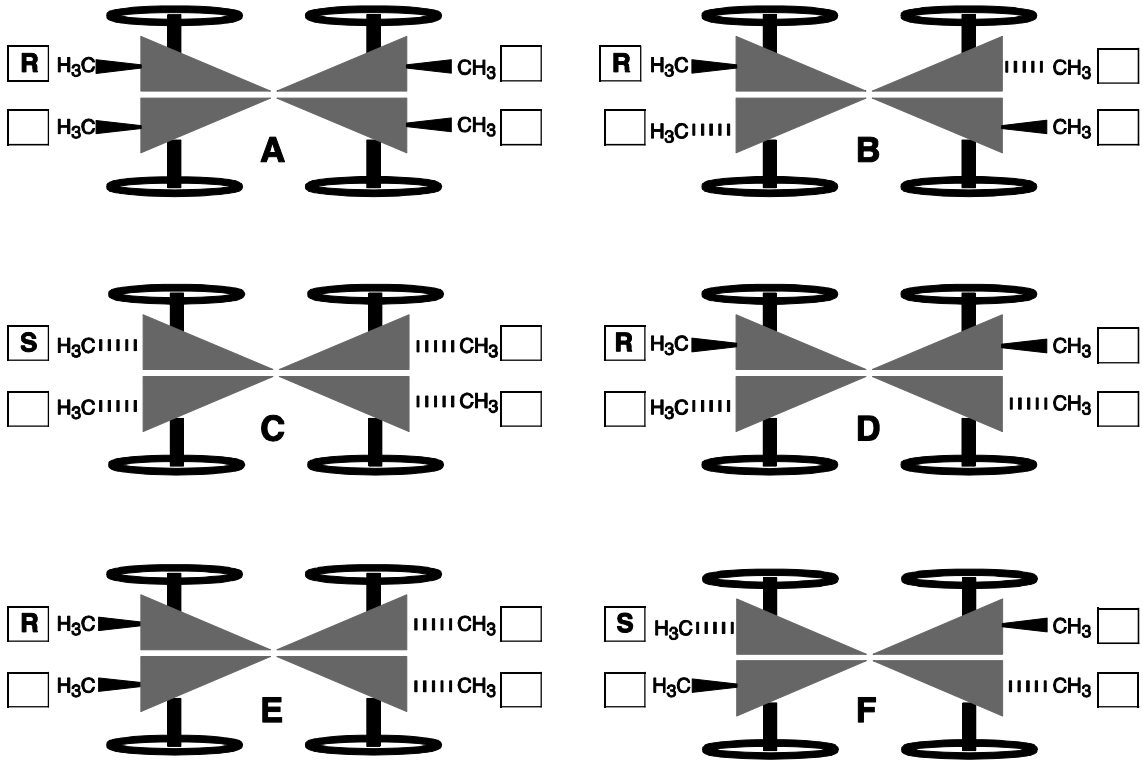
The carbon atoms to which the methyl groups are attached are chiral centres – each has four different groups attached to it. These are marked with an asterisk in the structure above.

The car is made up of four rotor units. A separate rotor unit exists as optical isomers – non-superimposable mirror images called enantiomers. Chemists distinguish between them with the labels "R" and "S" as shown on the right. The "wheels" on each enantiomer turn in opposite directions as shown (as viewed as if standing next to the car facing the wheel).



The bold wedge comes out of the paper; the hashed bond goes into the plane.

In the synthesis of the car, a number of different stereoisomers were formed. These are shown in cartoon form below, in the arrangements the chemists detected on a surface of copper atoms (as viewed from above).



(b) In your answer booklet, assign the label "R" or "S" to each rotor unit in the cars **A-F** in the boxes provided. The top left rotor in each car has already been assigned.

(c) Which of the <u>cars</u> **A-F** are optical isomers?

(d) Before being deposited on the copper surface, rotation is possible about the triple bonds linking the two halves of the car. Taking this into account, which of the cars **A-F** are the same molecule when free from the surface?

(e) By considering the directions of rotation for the four rotor units in each car, and assuming that all four rotors are active simultaneously, complete the table in the answer booklet, indicating whether each car will :

- spin round on the copper surface clockwise
- spin round on the copper surface anti-clockwise
- remain stationary on the copper surface
- move forwards over the copper surface.