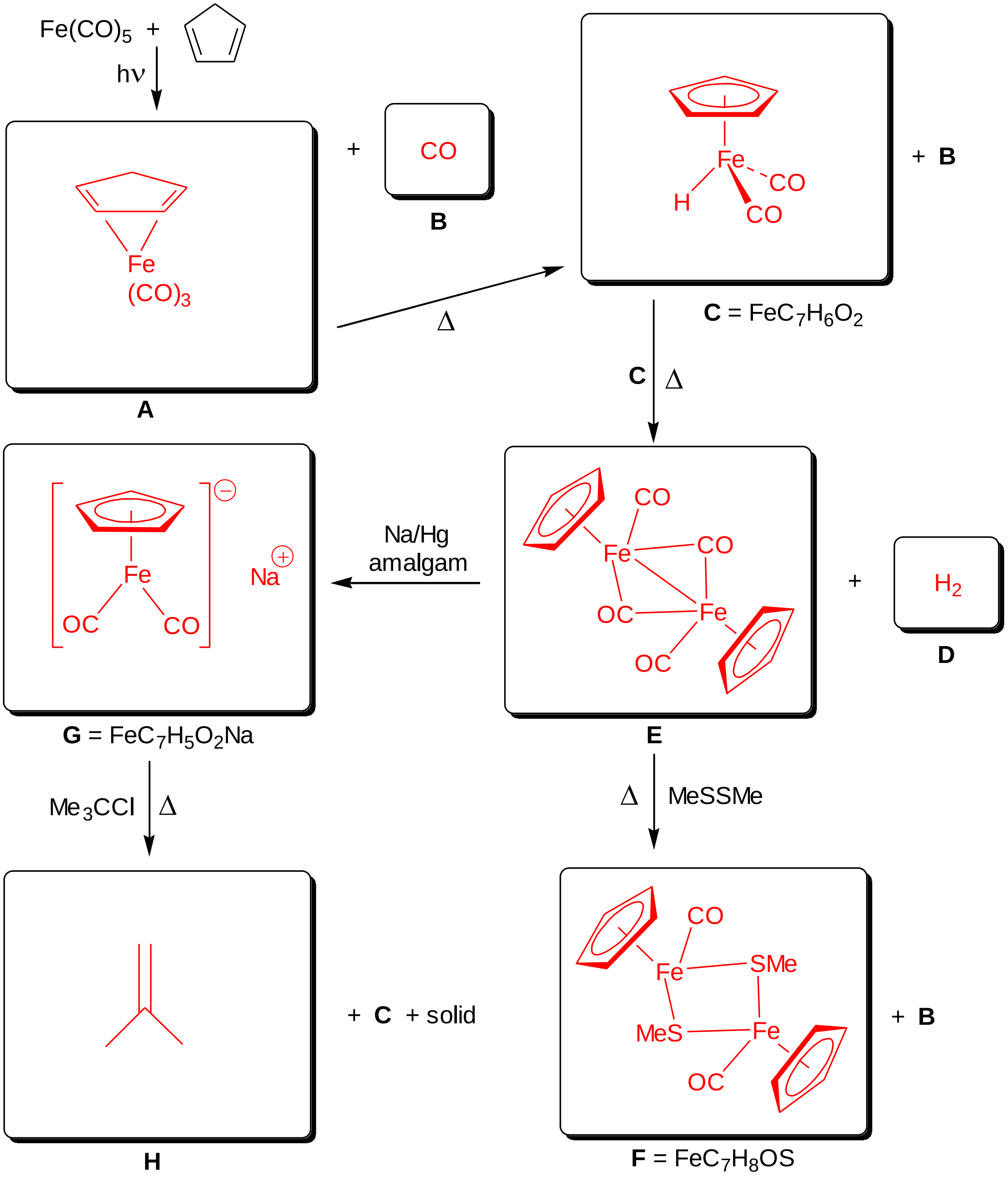
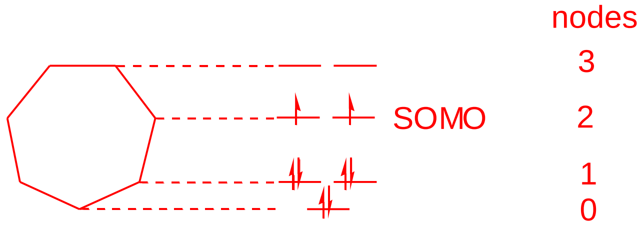
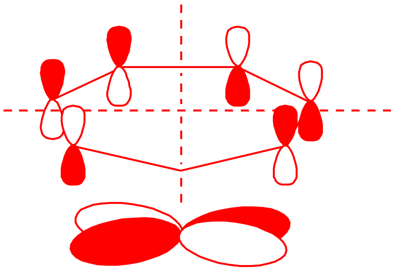
1. Irradiating $Fe(CO)_5$ with UV light in the presence of cyclopentadiene results in the formation of **A** and colourless gas **B**. **A** has four different ^1H NMR environments in a 2:2:1:1 ratio. Heating **A** further results in the release of more **B** to make **C**, having the formula $FeC_7H_6O_2$. Molecule **C** reacts rapidly with itself at room temperature to eliminate colourless gas **D**, forming solid **E**. Compound **E** has two strong IR bands, one near 1850 cm^{-1}, the other near 2000 cm^{-1}. Heating **E** with MeSSMe gives a product **F** that has an elemental analysis consistent with FeC_7H_8OS and with a single strong IR band near 2000 cm^{-1}. Treatment of **E** with Na metal generates solid **G** of empirical formula $FeC_7H_5O_2Na$. Reaction of **G** with Me_3CCl in a non-polar solvent produces **C**, **H** and a white precipitate. Draw structures for **A** to **H** in the appropriate boxes below.

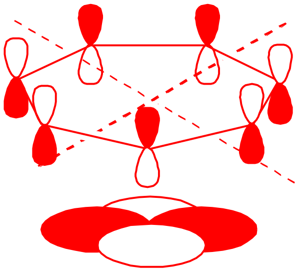


2. Draw the two singly occupied molecular orbitals of the cycloheptatrienyl anion, $[C_7H_7]^-$. Sketch alongside each of these singly occupied MOs the metal orbitals with the correct symmetry for a bonding interaction. Assume the *z*-axis runs through the metal centre and the centre of the ring of carbon atoms.



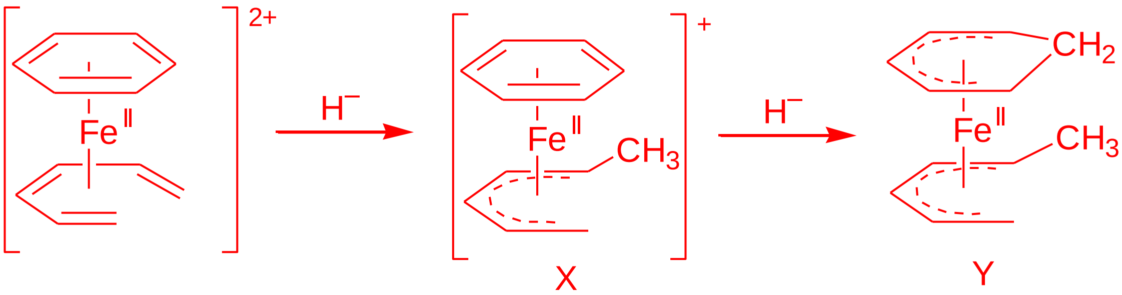


d_{xy}

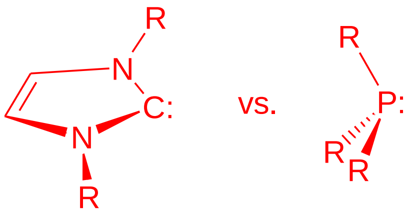


$d_{x^2-y^2}$

3. $[(\eta^6\text{-}C_6H_6)(\eta^6\text{-}C_6H_8)Fe]^{2+}$ is treated with one equivalent of H^- to produce **X**. **X** is treated with another equivalent of H^- to produce **Y**. Draw the probable structures of **X** and **Y**, and give the oxidation state of the metal for both products.

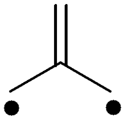


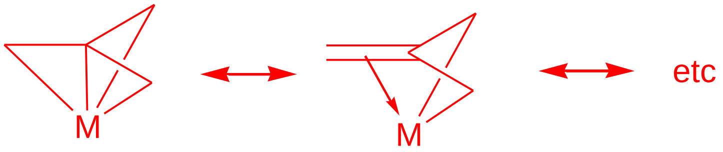
4. *N*-heterocyclic carbenes are very poor π-acceptors, and are less tunable both sterically and electronically than phosphines. Explain the reasons for these two facts.

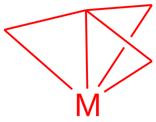


N's donate π electron density to C *p* orbital, reducing its ability to accept π electron density from metal. Modifiable R groups on NHC more remote from C, so electronic effect of changing them is reduced. NHCs are fan-shaped rather than cone-shaped, and can rotate to reduce steric repulsion.

5. Trimethylenemethane (below) is a planar diradical and very unstable in the free state. However, it is stable as a ligand for transition metals, and all four carbon atoms bind to the metal. Draw possible resonance forms for this ligand binding to a metal, and suggest how it might be distorted from planarity on binding. How many electrons does it donate to the metal? In an $M(CO)_3(\eta^4$-trimethylenemethane) complex, what is the oxidation state of M?







would improve overlap between p orbitals on outer C's and M

4e donor (LX_2) M(II)

6. Cobaltocene, Cp_2Co, is stable at room temperature, but the rhodium analogue dimerizes to give the compound $Rh_2C_{20}H_{20}$. Draw two possible structures for the product; both should obey the 18 electron rule.