LECTURE 3

(e) *Ipso*-Substitution

Ipso-substitution usually occurs either with tert – alkyl substituents which can form stable carbocations after attack by the electrophile or in reversible electrophilic substitution reactions such as sulphonation:

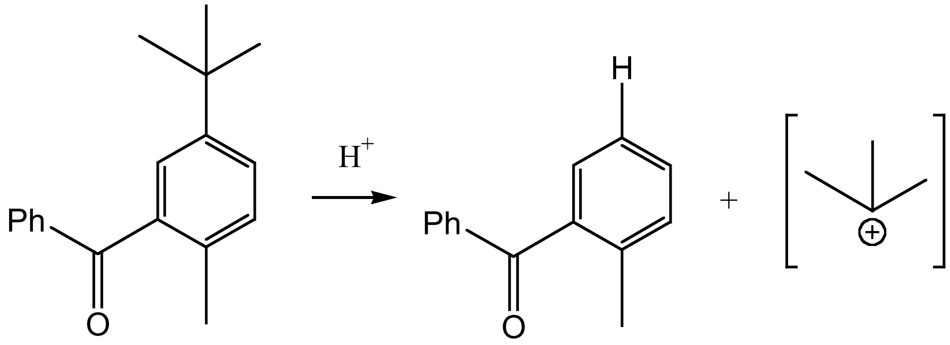


Fig. 1

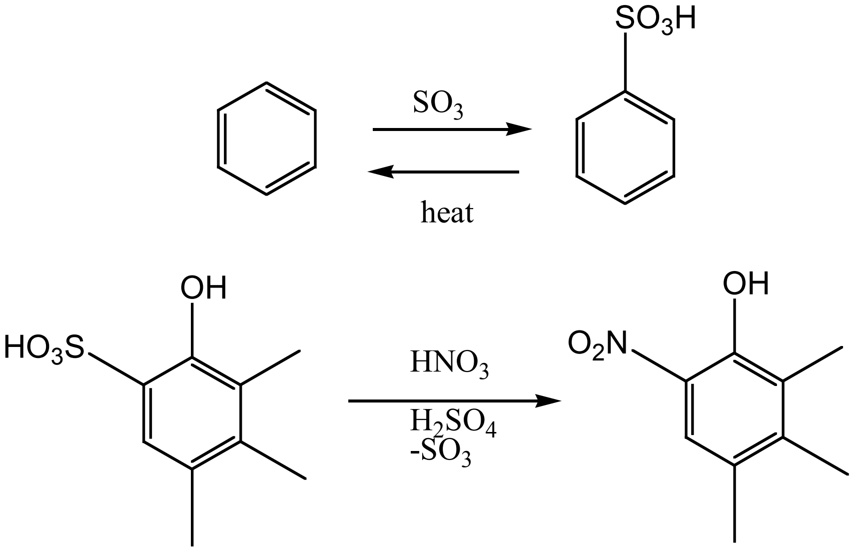


Fig. 2

(f) Reversible sulphonation: thermodynamic *versus* kinetic control

When we have a reversible attack on a substituted benzene the prediction of the final position of the electrophile is more complicated. To illustrate this we will look at the sulphonation of naphthalene:

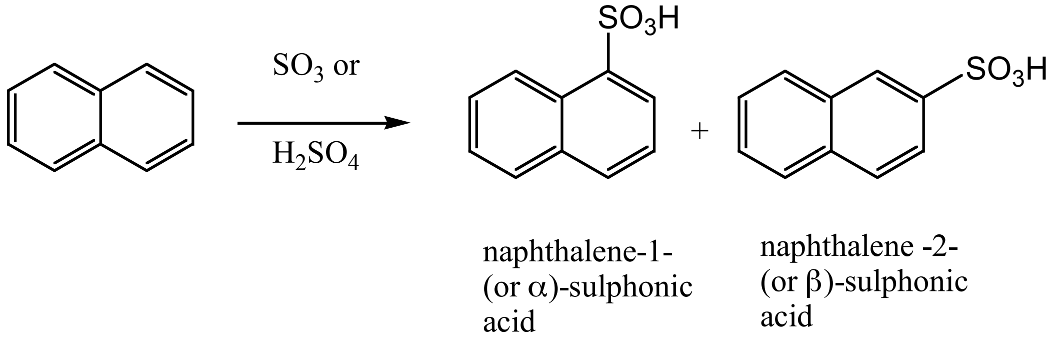


Fig. 3

The two isomeric sulphonic acids are formed under different conditions, with the 1-sulphonic acid predominating at lower temperature and the 2-sulphonic acid predominating at higher temperature. Moreover the 1-sulphonic acid is converted into the 2-sulphonic acid at the higher temperature. The 1-sulphonic acid is, therefore, called the **kinetic** product (or the product of kinetic control) since it is formed faster at lower temperatures whereas the 2-sulphonic acid is called the **thermodynamic** product (or the product of thermodynamic control) since it is more stable at higher temperatures:

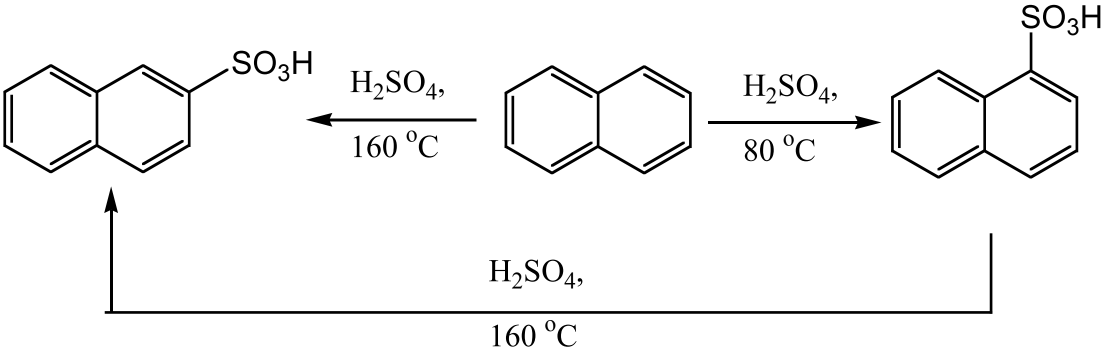
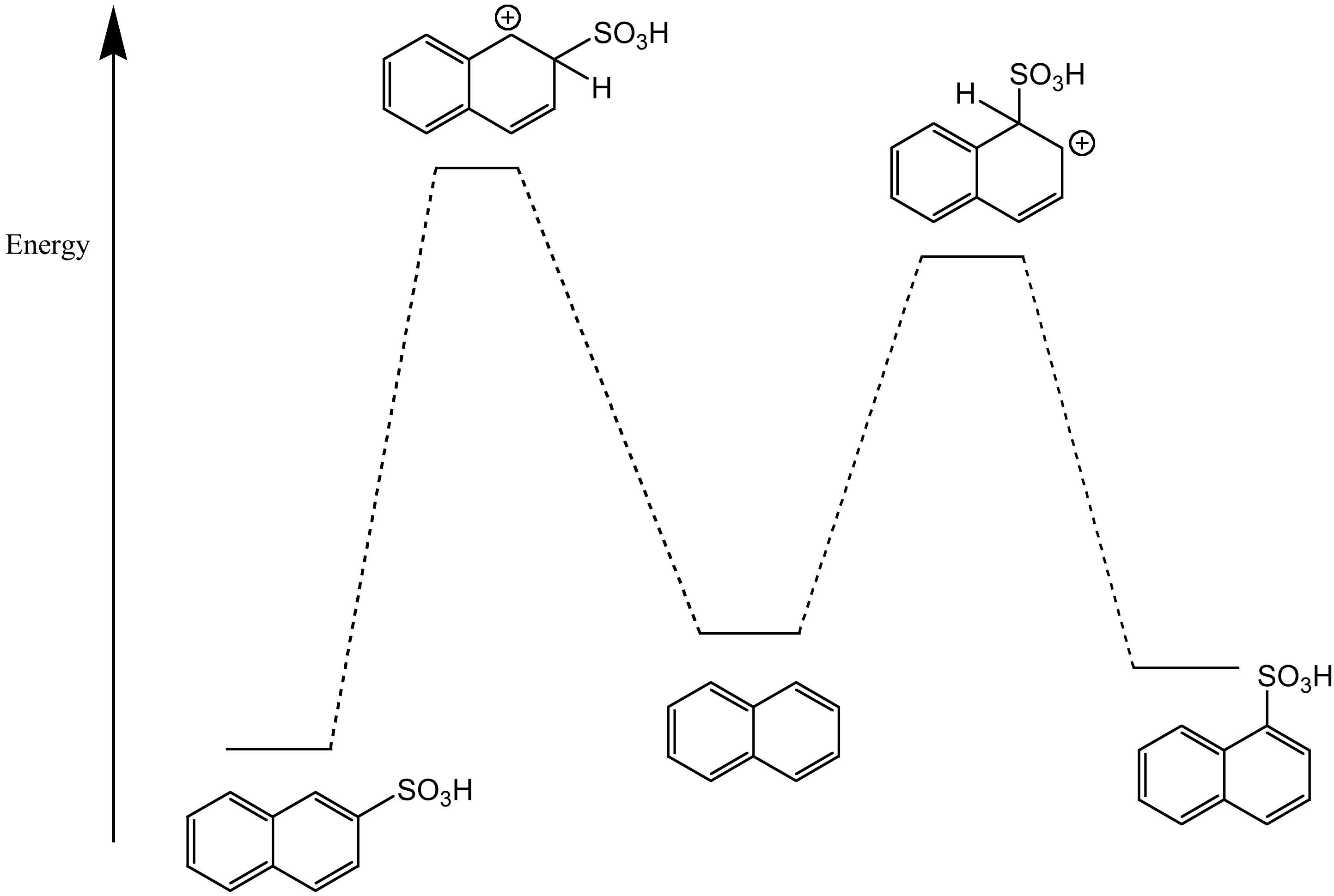


Fig. 4

We can understand this behaviour if we look at an energy level diagram for the reaction:

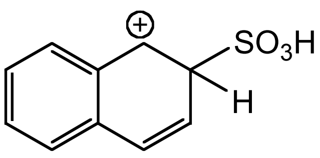


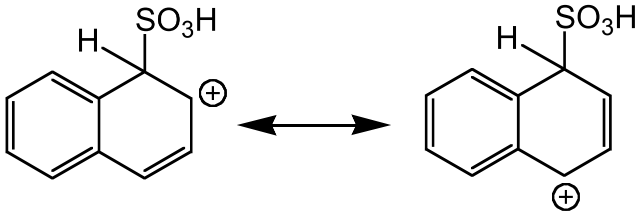
First, we notice that the 2-sulphonic acid is lower in energy than the 1-sulphonic acid i.e. the 2-sulphonic acid is the more stable (thermodynamic) product, as noted above.
Second, the Wheland intermediate to the 1-sulphonic acid is lower in energy than that to the 2-sulphonic acid i.e. there is a lower activation energy to the former than to the latter leading to faster production of the former i.e. the 1-sulphonic acid is the kinetic product, again as noted above.
Finally, the reaction is reversible so that the 1-sulphonic acid can revert to naphthalene and at higher temperatures the system will have enough energy to get over the activation barrier to the 2-sulphonic acid again as the experiment shows.

Thus the experimental results are explained by this diagram but we still need to answer two questions viz.:

- Why is the Wheland intermediate to the 1-sulphonic acid lower in energy than that to the 2-sulphonic acid?
- Why is the 2-sulphonic acid product lower in energy than the 1-sulphonic acid product?

The answer to the first question is that the Wheland intermediate to





the 1-sulphonic acid has two contributing resonance forms whereas that to the 2-sulphonic acid has only one and therefore the Wheland intermediate (and hence the transition state) to the 1-sulphonic acid is more stable:

Fig. 5

The answer to the second question is that the 1-sulphonic acid is destabilised by a repulsive force between the sulphonic acid group and a hydrogen on the so-called peri-position. This interaction is absent in the 2-sulphonic acid making this acid more stable:

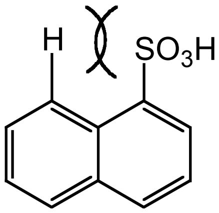


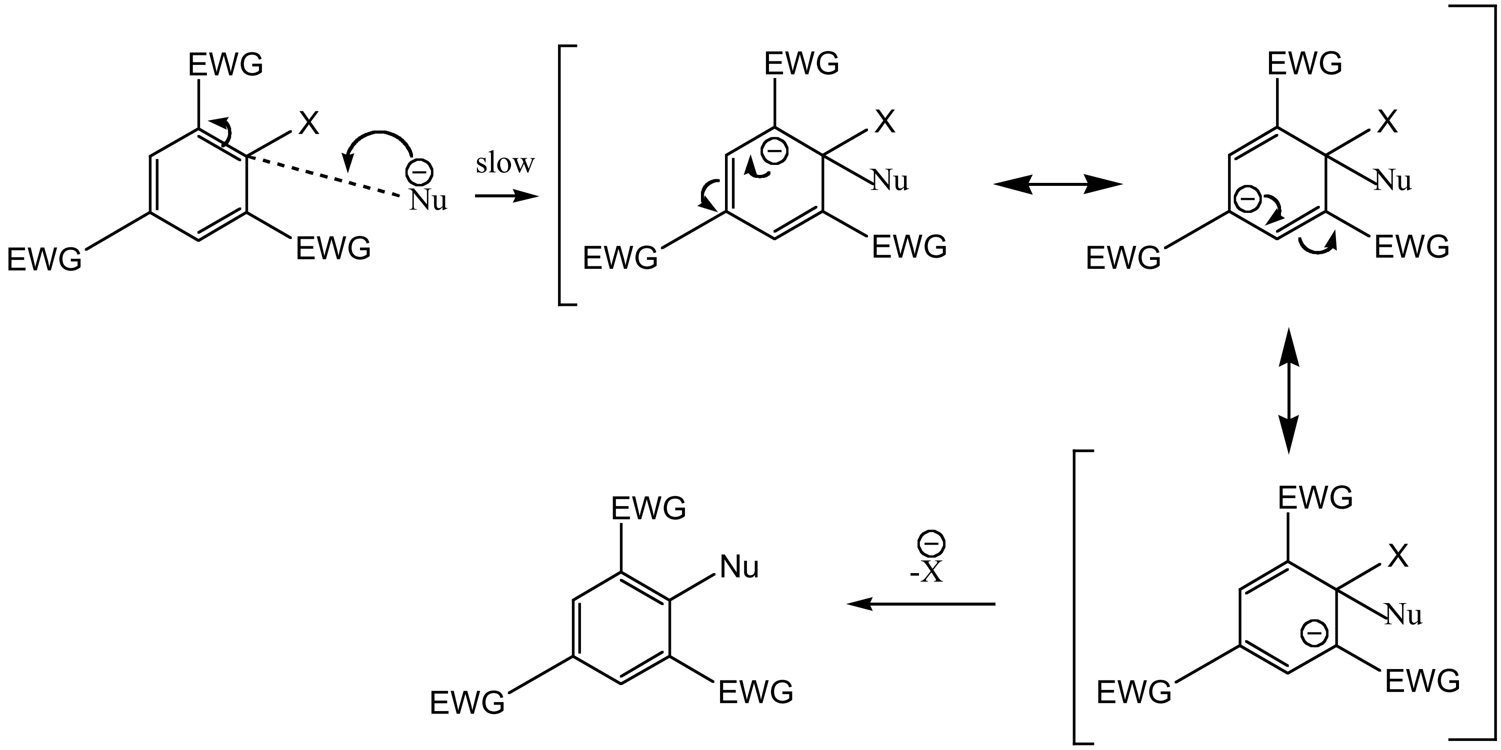
Fig. 6

4. Reactions: Nucleophilic Substitution

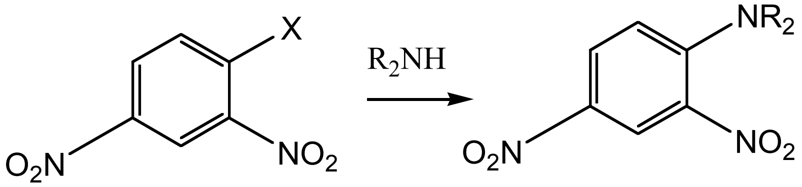
This is much rarer than electrophilic substitution because the aromatic ring is relatively electron rich and will therefore tend to repel the electron rich nucleophilic reagent. Two mechanisms are possible, the S_NAr mechanism and the Benzyne mechanism.

(a) The S_NAr Mechanism

This occurs in those aromatic rings which bear powerfully electron-withdrawing groups which can (i) attract the nucleophile by withdrawing electron density from the ring and (ii) stabilise the intermediate (which looks like the anionic equivalent of the Wheland intermediate):



An example of this is the displacement of halide from 2,4-dinitro – halobenzenes:



X = Halide

Fig. 7

The most convincing evidence for this mechanism comes from the isolation by Meisenheimer in 1902 of one example of the intermediate which was sufficiently stable to have its structure confirmed by X-ray analysis. Subsequently a number of these “Meisenheimer complexes” have been isolated or detected.

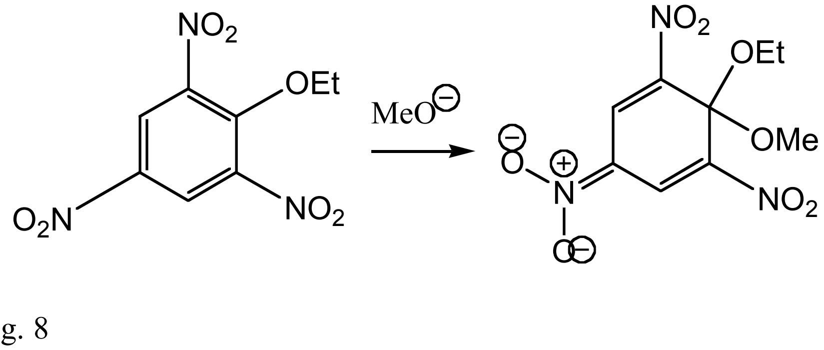


Fig. 8