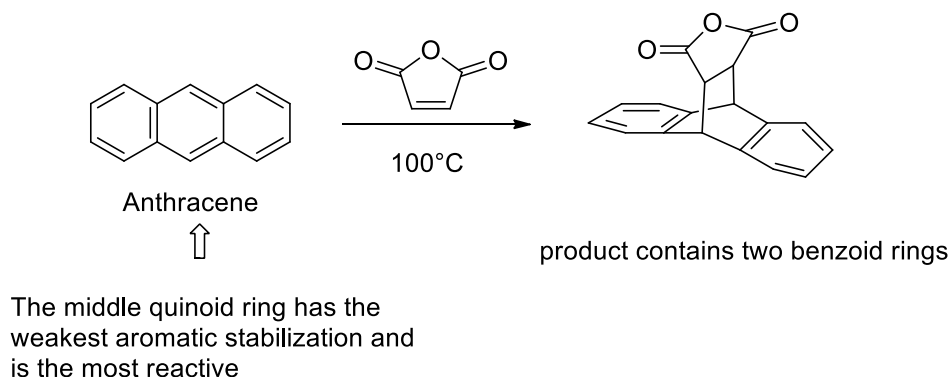


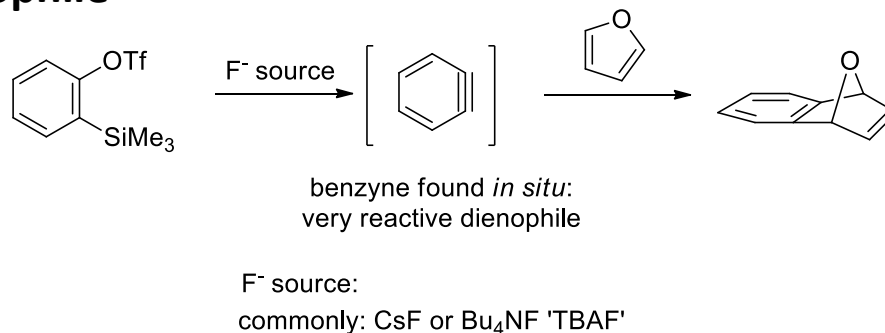
3.3. Additional examples of Diels-Alder cycloaddition

3.3.1. Extended polycyclic aromatics as diene component

Polycyclic arenes can react as diene-components in Diels-alder cycloaddition

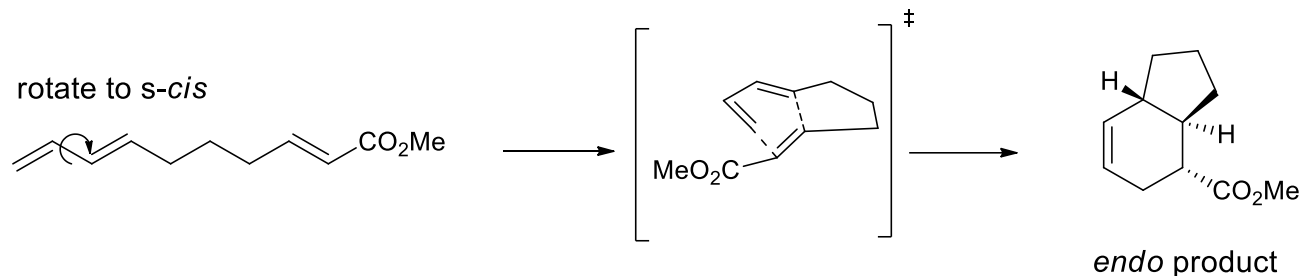


3.3.2. Benzyne as dienophile



3.3. Additional examples of Diels-Alder cycloaddition

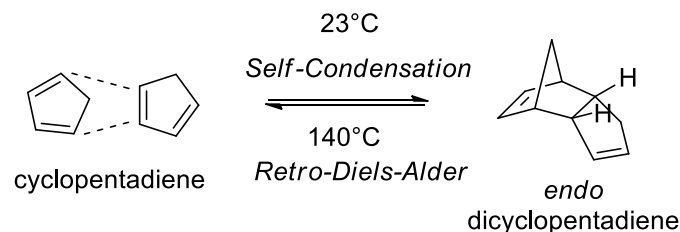
3.3.3. Intramolecular Diels-Alder reactions



➡ In intramolecular Diels-Alder reactions, even not very favorable Diene/Dienophile combinations which are unreactive for intermolecular Diels-alder reactions react.

3.3.4. Self condensation and Retro-Diels-Alder reaction

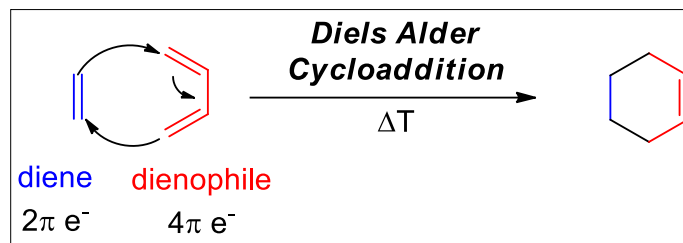
Cyclopentadiene self-condenses at ambient temperature. The reaction is reversible above 140°C



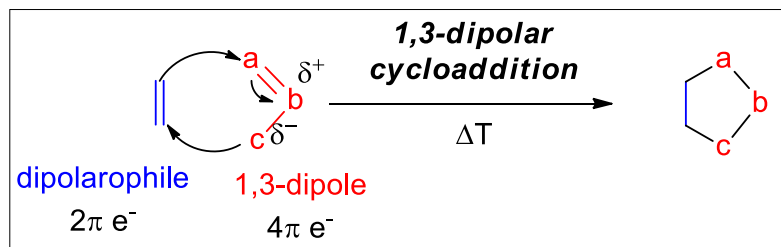
➡ All Diels-Alder cycloadditions are principally reversible at a high enough temperature (>350°C) as the entropy increases (2 molecules v.s. 1 molecule)

4.1.1. 1,3-dipolar cycloaddition

- Recap of the Diels-Alder cycloaddition:



- Analogy for 1,3-dipolar cycloaddition:



Types and Classification of 1,3-Dipoles

Two Types of Dipoles:

(1) Allyl anion



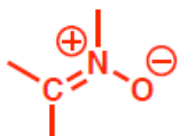
- Bent
- Y = N, O, S

(2) Propargyl/allenyl anion

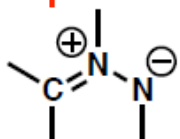


- Linear
- Y = Nitrogen

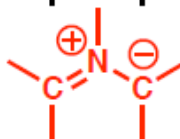
Classification of the Allyl Anion Type 1,3-Dipoles



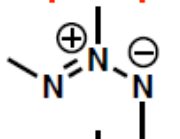
Nitrones



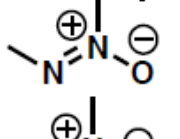
Azomethine Imines



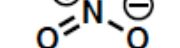
Azomethine Ylides



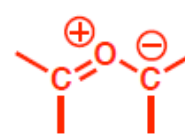
Azimes



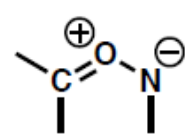
Azoxy Compounds



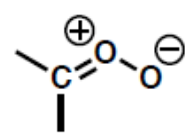
Nitro Compounds



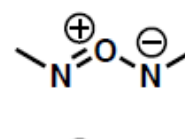
Carbonyl Ylide



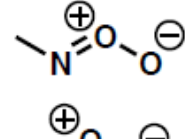
Carbonyl Imines



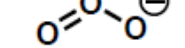
Carbonyl Oxides



Nitrosimines



Nitrosooxides

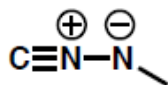


Ozone

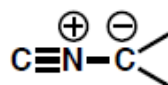
Classification of the Propargyl/Allenyl Anion Type 1,3-Dipoles



Nitrile Oxides



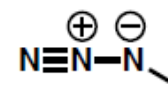
Nitrile Imines



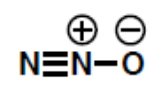
Nitrile Ylides



Diazoalkanes



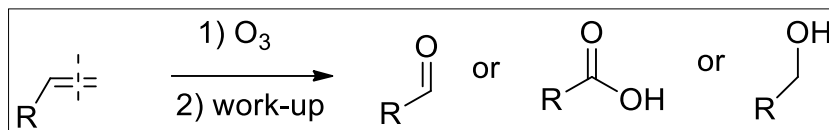
Azides



Nitrous Oxide

4.1.1. Ozonolysis

- Ozonolysis is a synthetically very important reaction converting olefins into alcohols, aldehydes, or carboxylic acids.

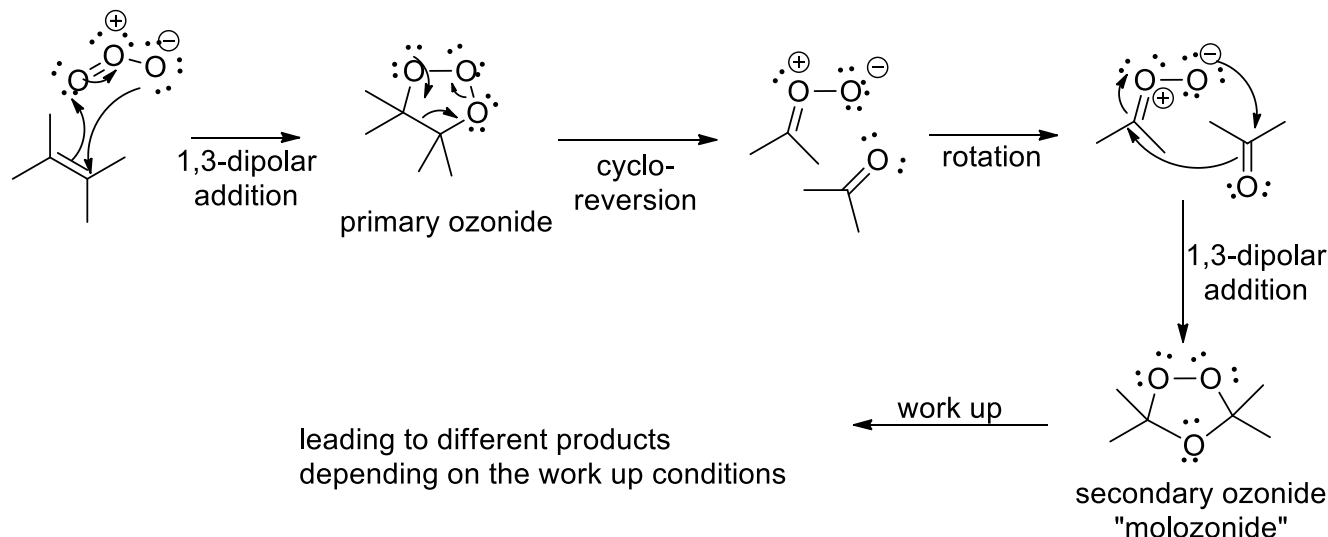


- Ozone O_3 is generated from O_2 (dry) by silent discharge: $\text{O}_2 \xrightarrow{\text{silent discharge}} 1 \text{ to } 5\% \text{ O}_3 \text{ in } \text{O}_2$

Ozone has a blue color in solution, allowing to follow the progress of a reaction with it. When the reaction mixture turns light blue, it means that ozone is not consumed anymore and that the reaction is complete.

Careful: it is explosive in pure solution

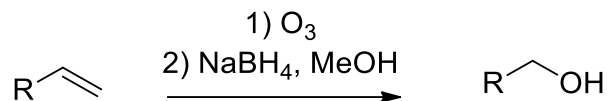
- Mechanism:



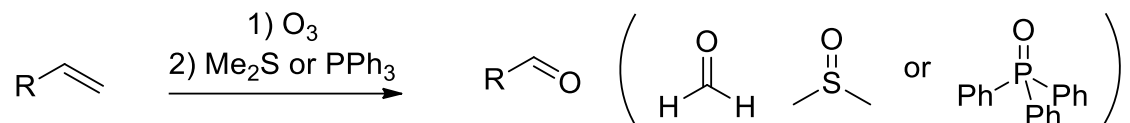
4.1.1. Ozonolysis

Different work-up strategies:

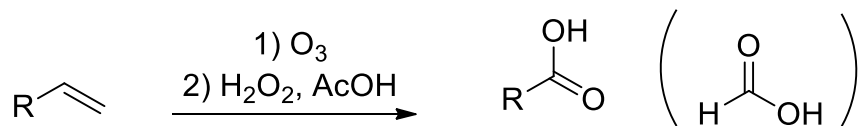
- Reductive work up with $\text{NaBH}_4 + \text{MeOH}$: formation of alcohols



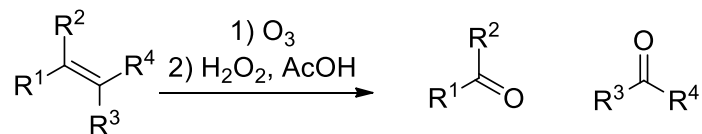
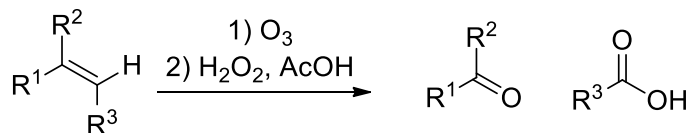
- Mildly reductive work up with Me_2S or PPh_3 : formation of aldehydes or ketones



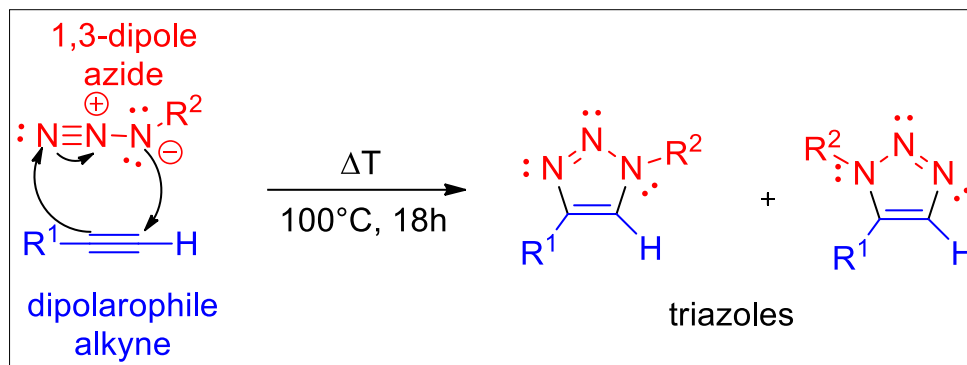
- Oxidative work-up with $\text{H}_2\text{O}_2 + \text{acetic acid}$: formation of carboxylic acids or ketones



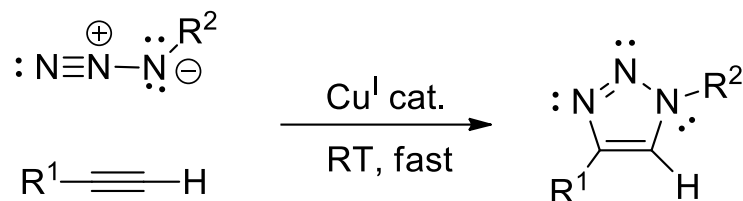
Careful with tri- or tetra-substituted alkenes:



4.1.1. Huisgen azide-alkyne cycloadditions, Click chemistry



When catalyzed by copper(I), it is known as “Click chemistry” :



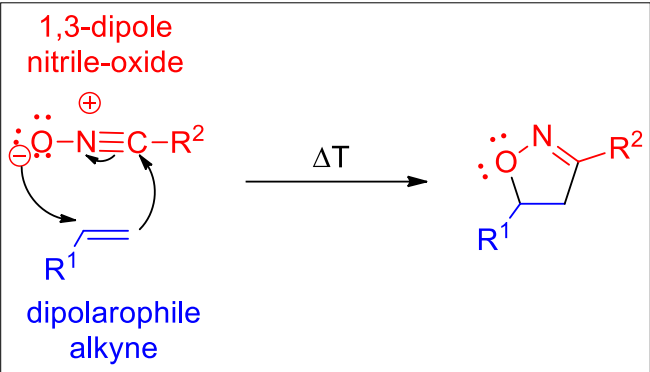
It is no longer a concerted mechanism but a stepwise metal-catalyzed process.

Usually: $\text{Cu}^{\text{II}}(\text{OAc})_2 + \text{NaAscorbate} \longrightarrow \text{Cu}^{\text{I}}$ source
reductant

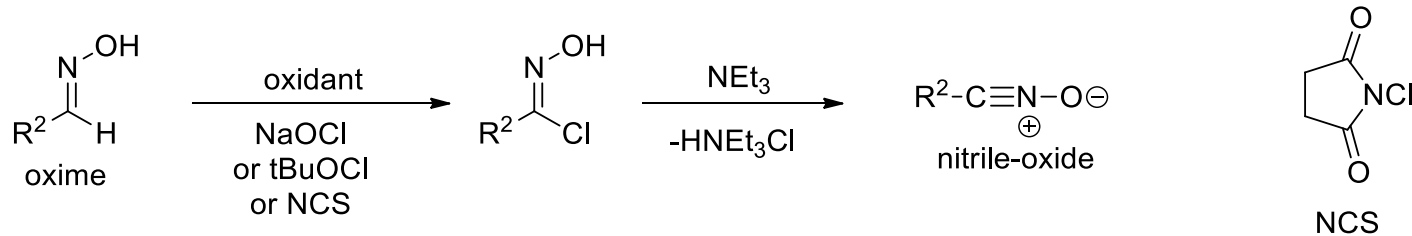
The reaction is very fast even at room temperature and it is proceeding in water as well.

It has found widespread applications in chemistry, chemical biology, material science, etc.

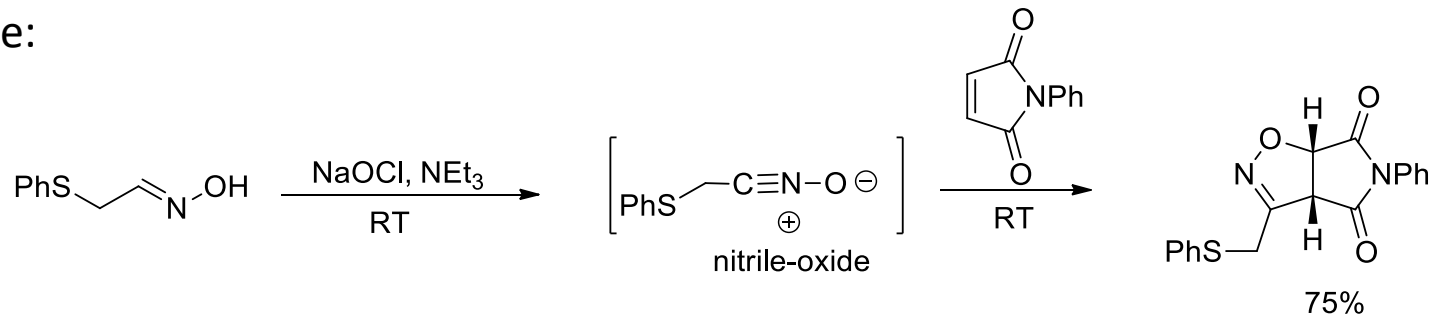
4.1.1. Nitrile-oxide cycloaddition



The nitrile-oxide dipole is not isolable, it needs to be generated in situ:



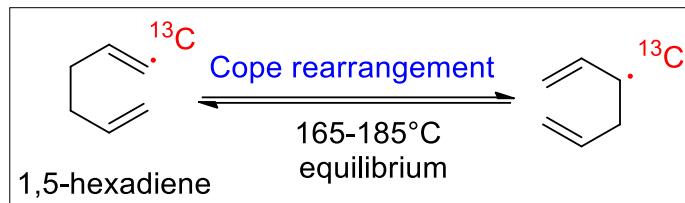
Example:



4.2.1. Cope rearrangement

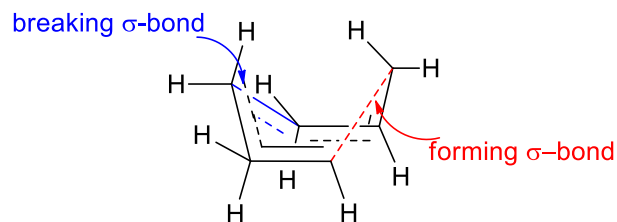
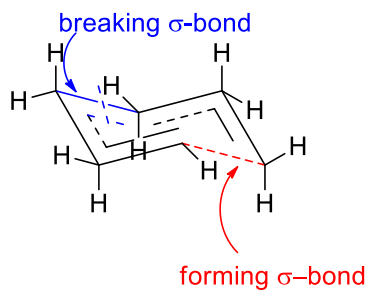
Diels Alder and 1,3-cycloadditions: $4\pi e^- + 2\pi e^-$

Now, concerted molecular rearrangements: $4\pi e^- + 2\sigma$ bonds



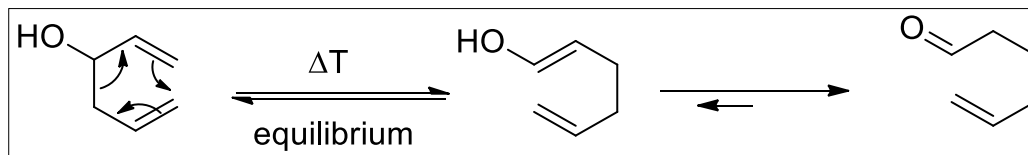
The equilibrium is thermally induced.

The reaction proceeds via a chair or boat transition state:



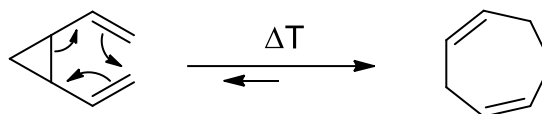
4.2.1. Cope rearrangement

- Driving the equilibrium to one side:
- oxy-Cope rearrangement: driving force = aldehyde formation

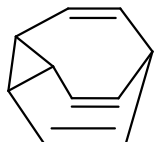


The carbonyl tautomer is more stable, removing the enol from the equilibrium.

- Divinylcyclopropane rearrangement: driving force = release of the ring strain of cyclopropane



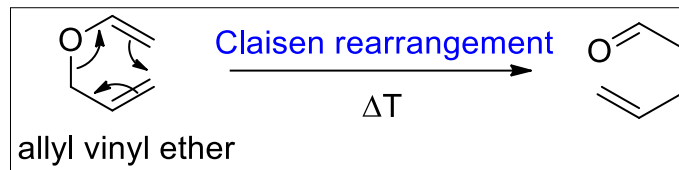
Example: bullvalene



bullvalene

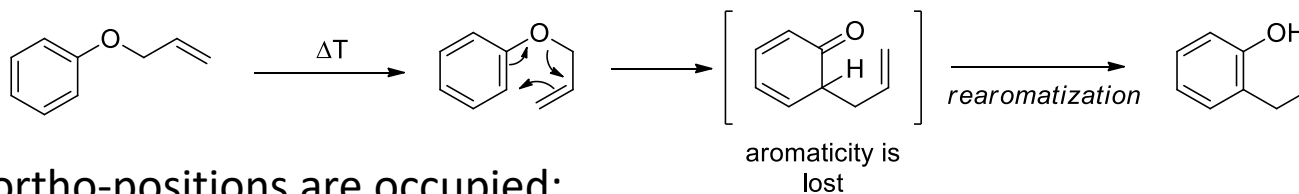
fluxional molecule: degenerated Cope rearrangements lead to different (1'209'600) valence tautomers

4.2.2. Claisen rearrangement



driving force of the reaction = carbonyl group formation

- Aromatic Claisen rearrangement:



When the ortho-positions are occupied:

