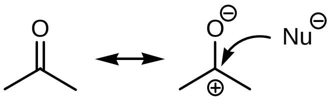
5. Gruppe: Carbonylverbindungen

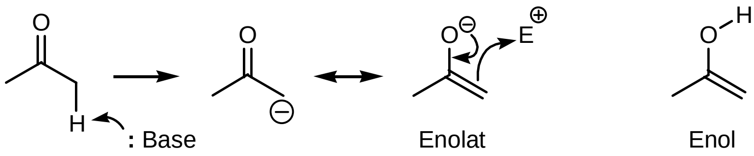
1) Darstellung von Aldehyden und Ketonen

1.1. Reaktivität der Carbonylgruppe:

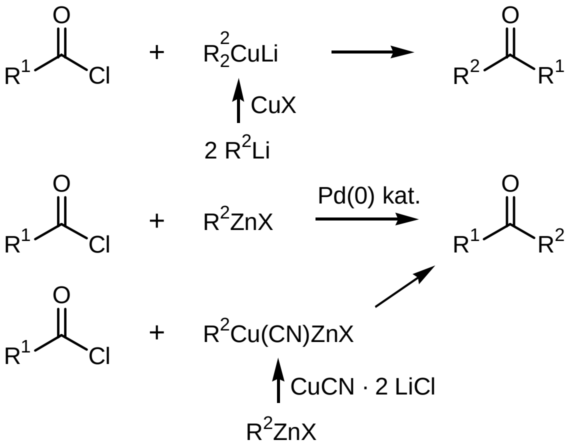


C═C : 146 kcal/mol

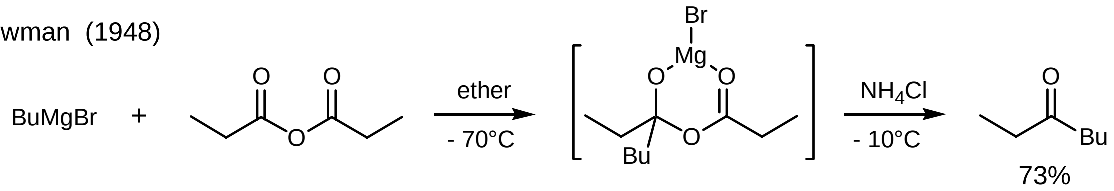
C═O : 175 kcal/mol



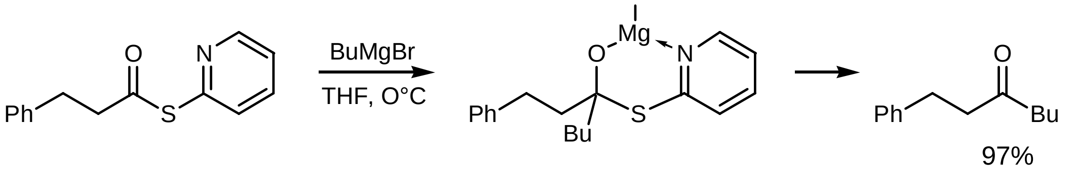
1.2. Metallorganische Synthese

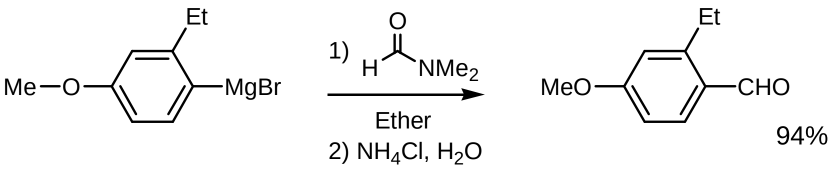


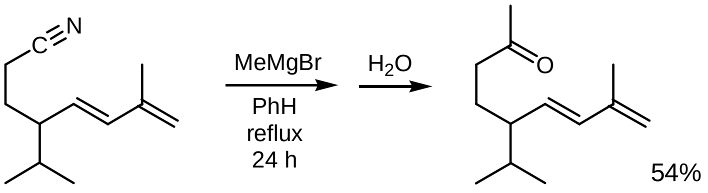
Newman (1948)

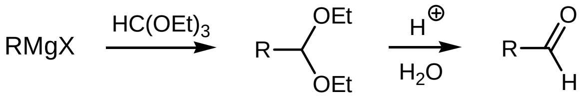


Mukaiyama (1973)



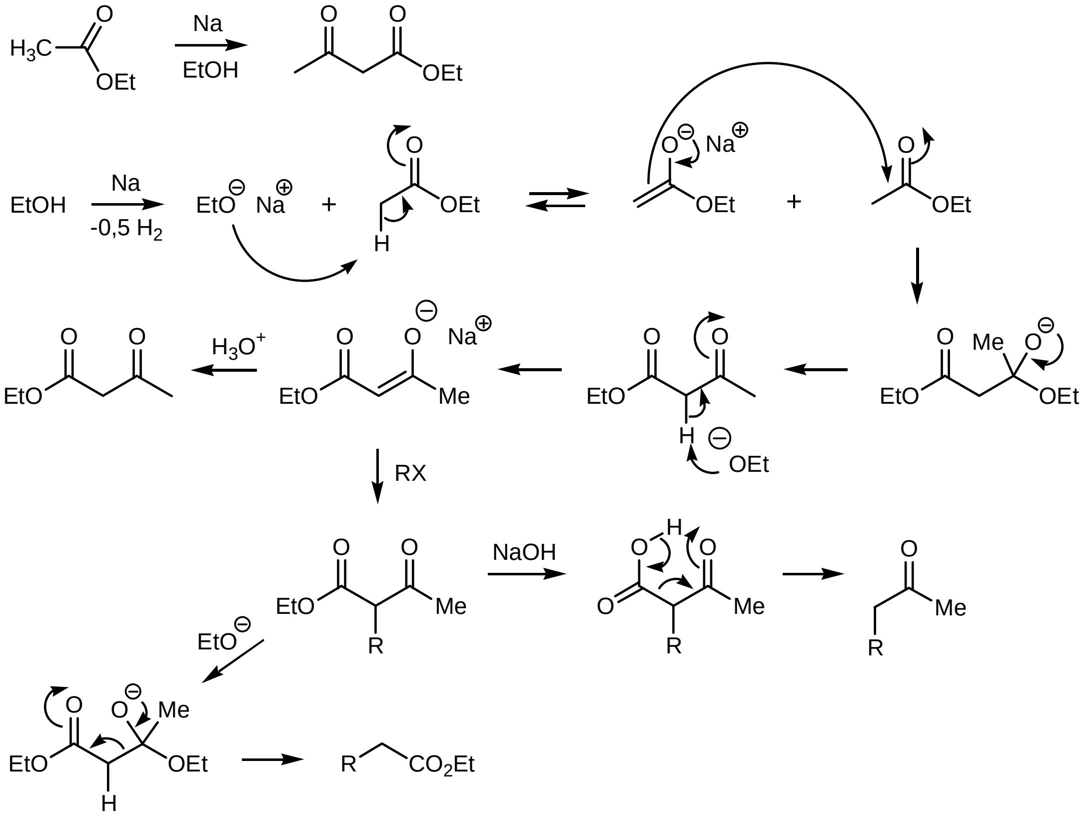




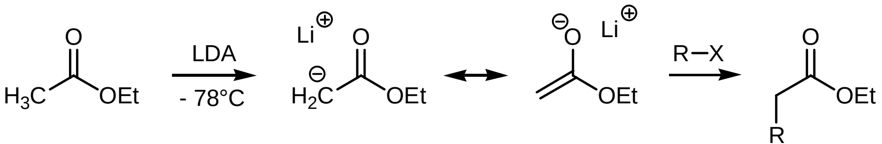


1.3. Enolat-Chemie

Claisen-Kondensation



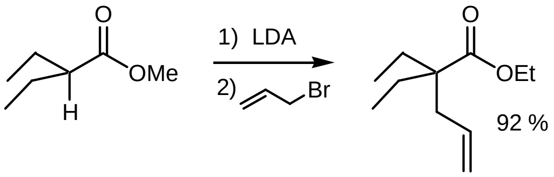
Moderne Methode: Stöchiometische Bildung des Lithium-Enolats



LDA: Lithiumdisopropylamid

5. Gruppe: Carbonylverbindungen

LDA: Lithiumdiisopropylamid



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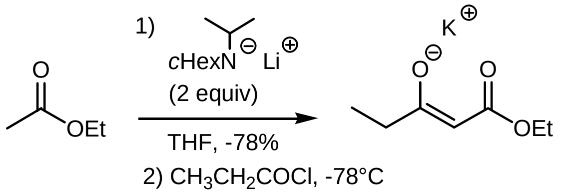
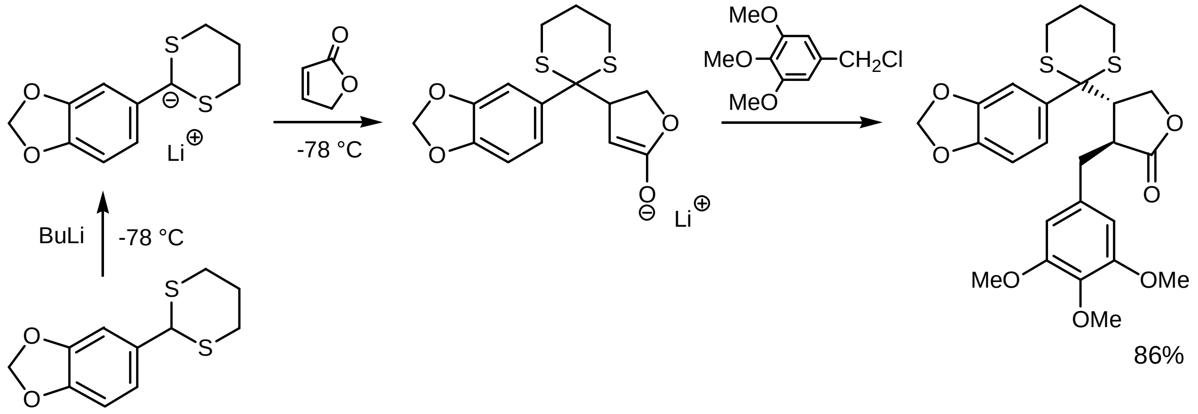
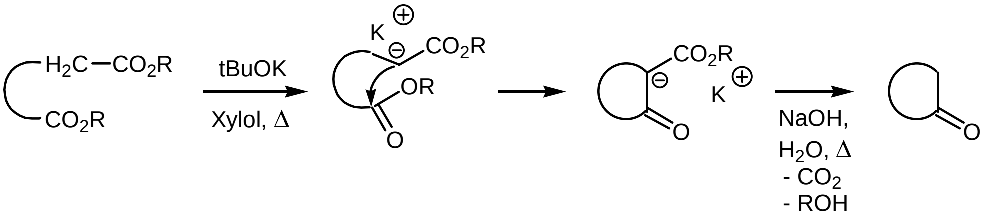
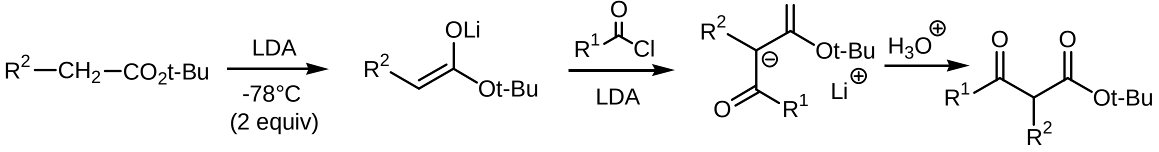




Intramoleculare Dieckmann-Kondensation



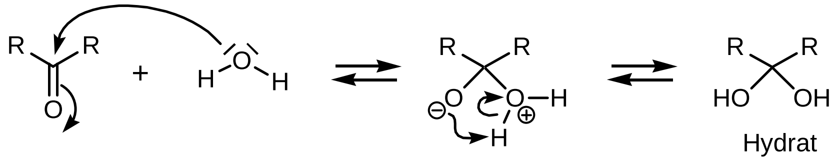
Gekreuzte Esterkondensation

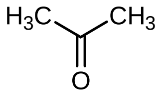


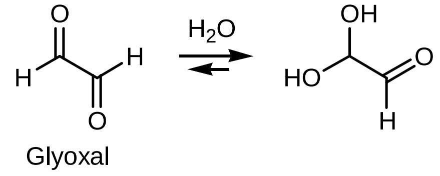
2) Reaktionen der Carbonylverbindungen

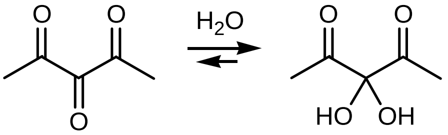
2.1. Addition nucleophiler Verbindungen

2.1.1. Addition von Wasser



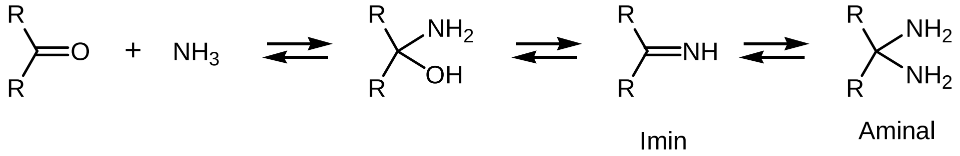
Verbindung	% Hydrat in H_2O
$H_2C{=}O$	> 98
CH_3CHO	64
CCl_3CHO	100
	0.1



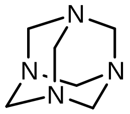


2.1.2. Addition von Aminen

Ammoniak:

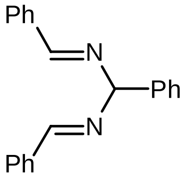


6 CH_2O + NH_3 ⟶



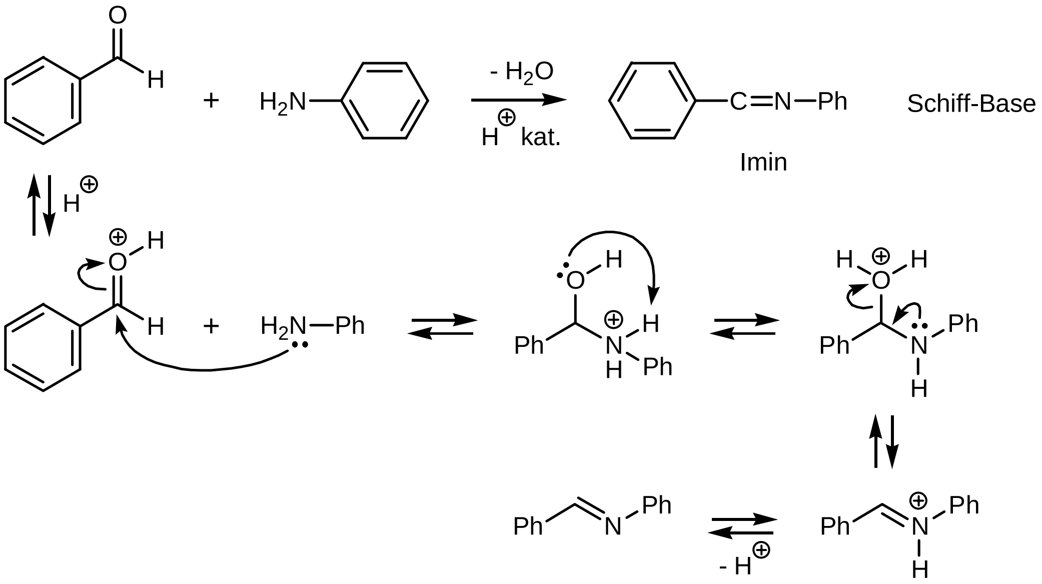
Urotropin

PhCHO + NH_3 ⟶

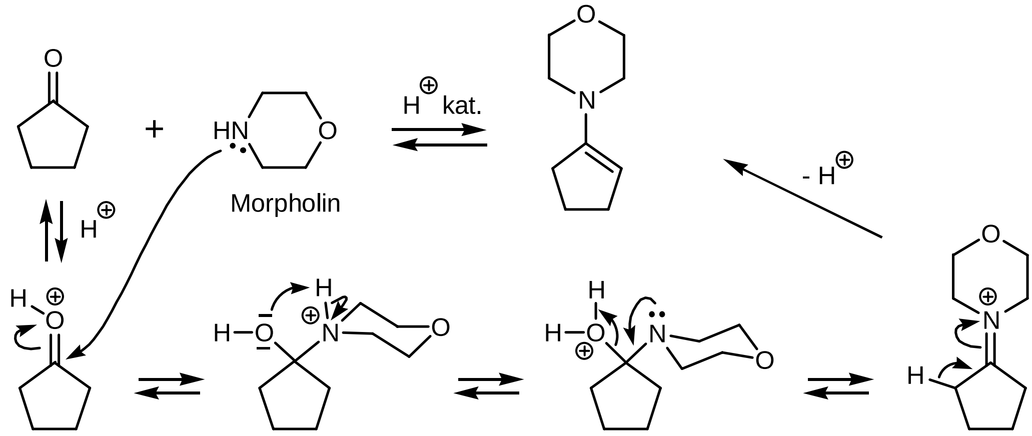


5. Gruppe: Carbonylverbindungen

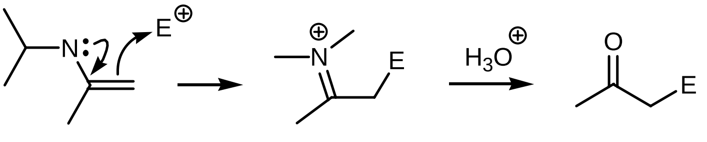
Primäre Amine

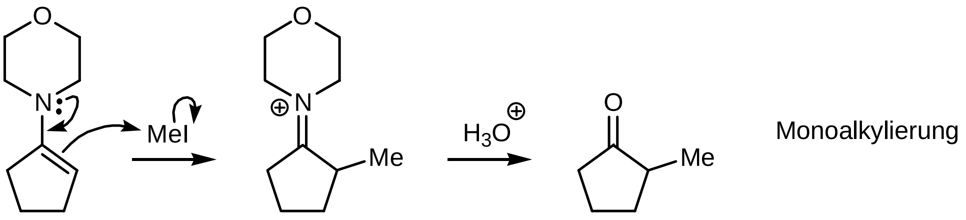


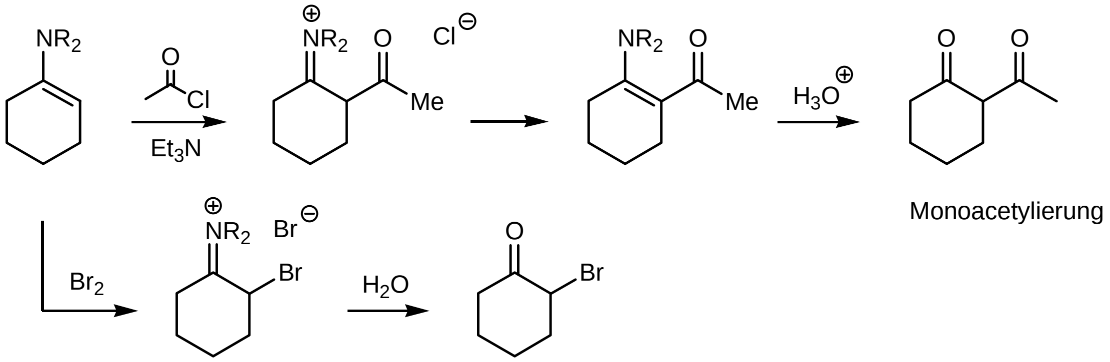
Sekundäre Amine



Reaktivität von Enaminen

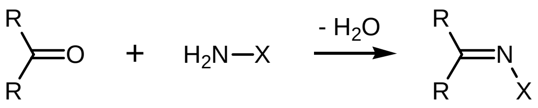






Monoacetylierung

Hydroxylamin- und Hydrazin-Addition



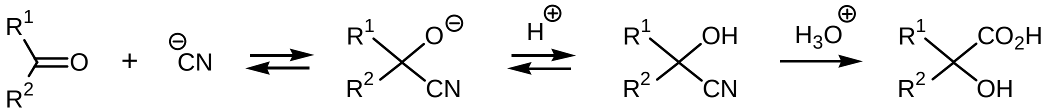
X = OH : Oxim

$X = NHR^1$: Hydrazon

$X = NH\text{-}CONH_2$: Semicarbazon

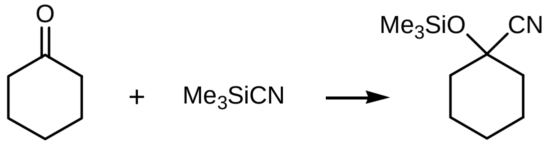
2.1.3. Addition von HCN

$HCN + Base \longrightarrow \overset{\ominus}{CN} + \overset{\oplus}{BH}$



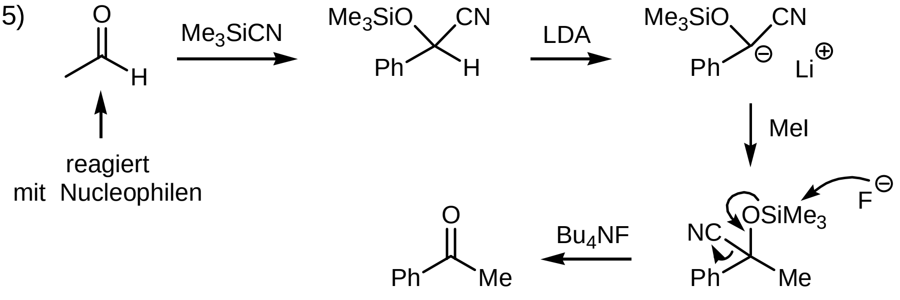
Cyanhydrin

α-Hydroxy-Carbonsäure

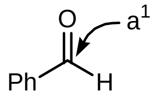


Umpolung der Reaktivität

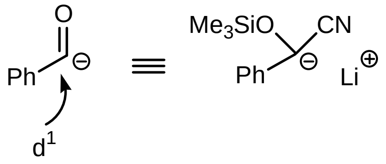
Hünig (1975)



Normale Reaktivität :

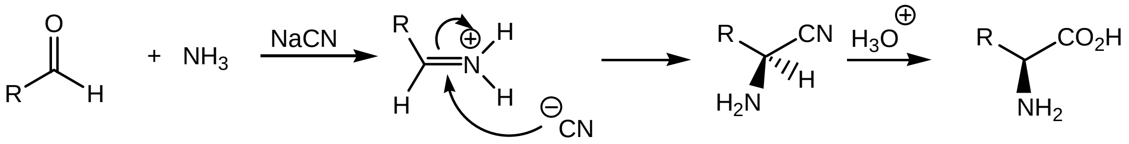


Umpolung :



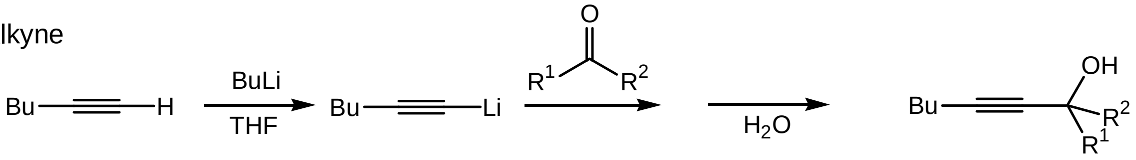
5. Gruppe: Carbonylverbindungen

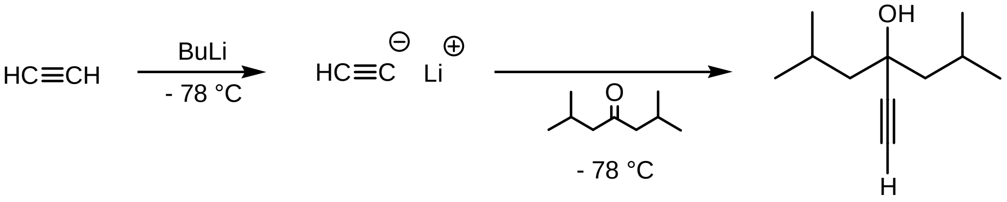
Strecker-Synthese von α-Aminosäuren



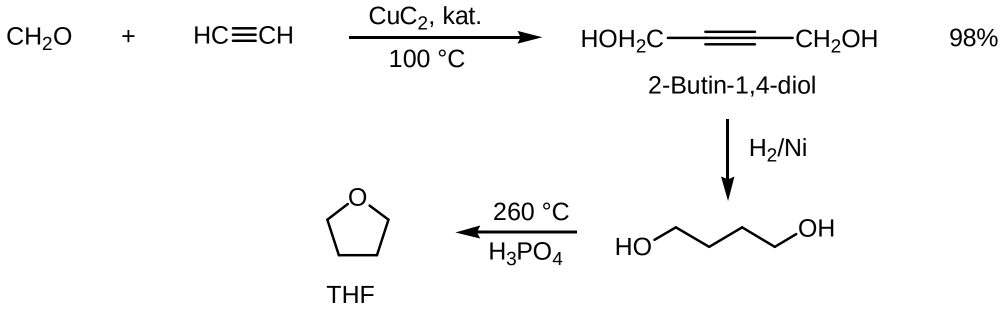
2.1.4. Addition von metallorganischen Reagenzien

Alkyne

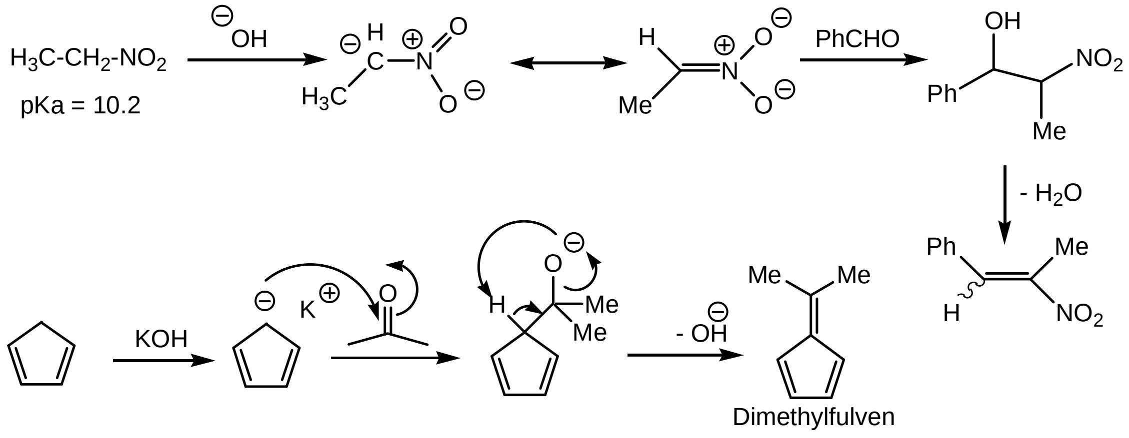




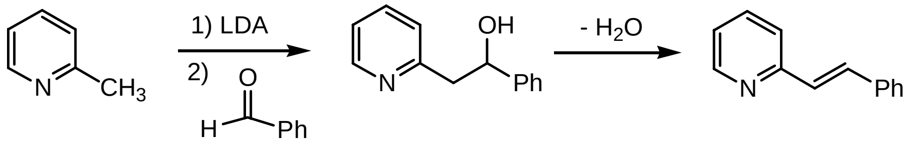
Reppe - Synthese (BASF)



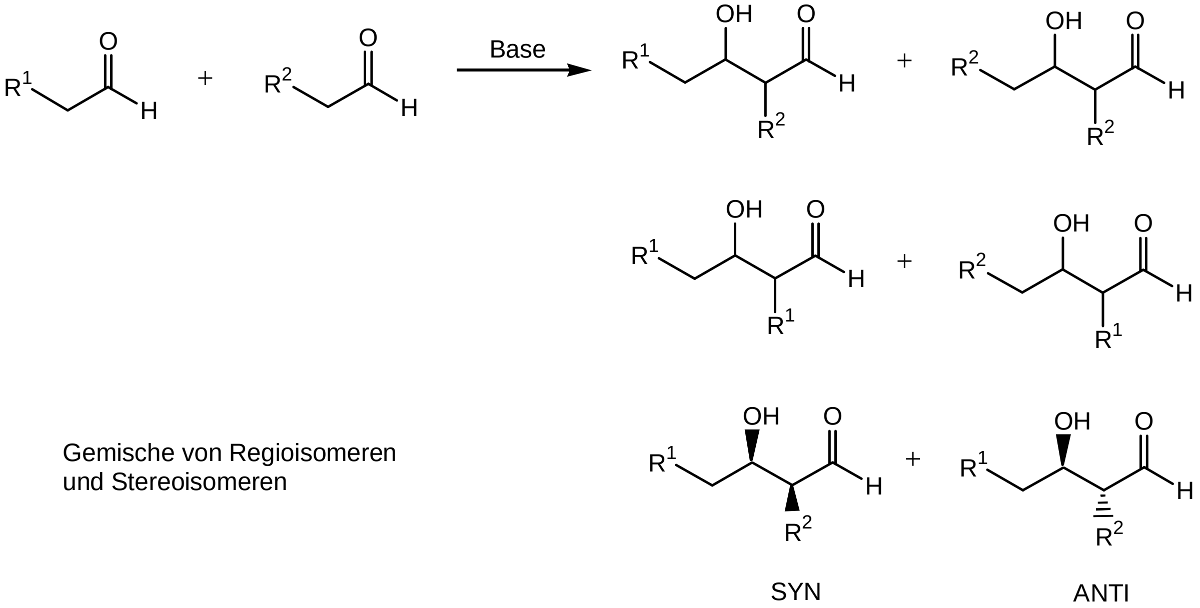
Addition von Nitroalkenen (Henry-Reaktion)



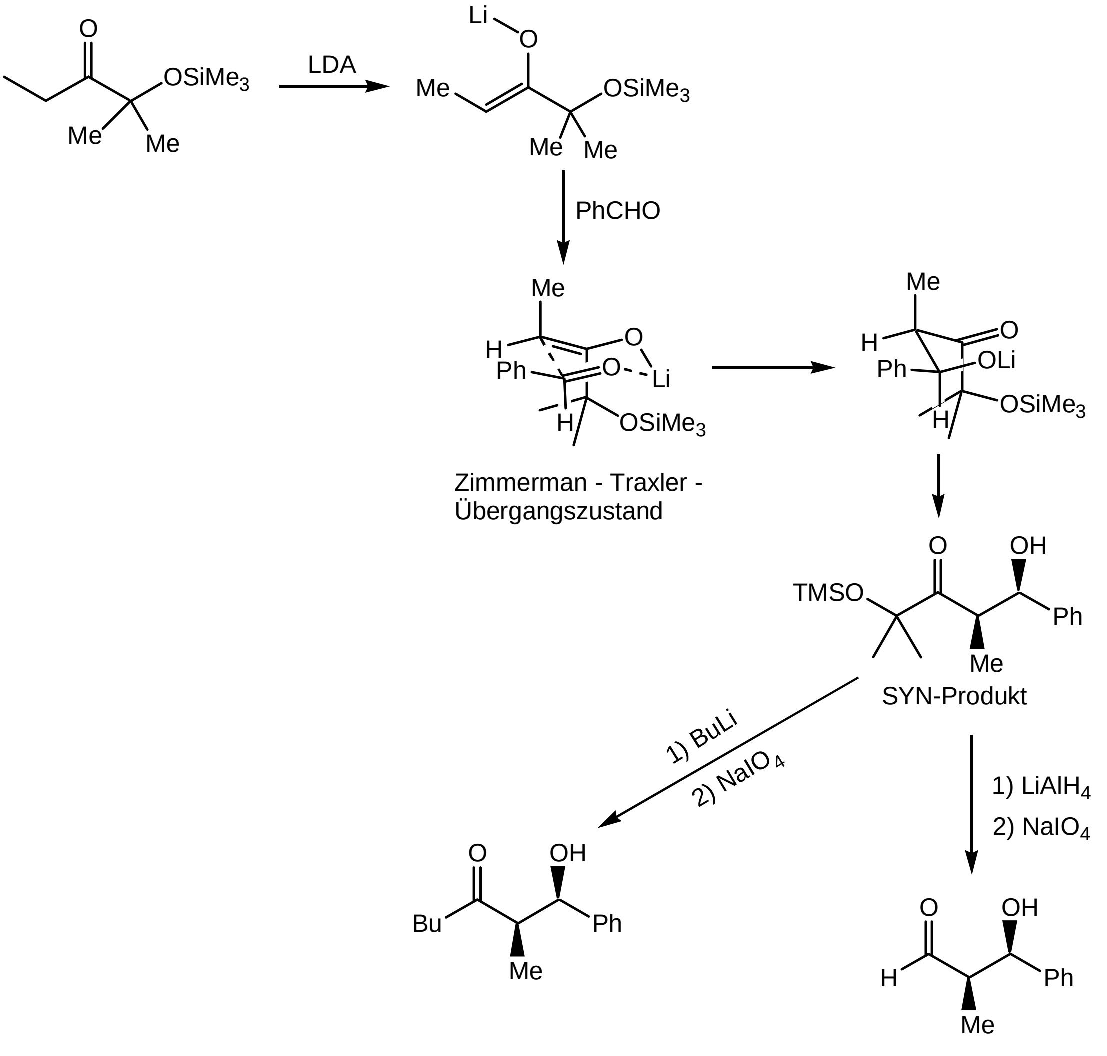
Picolin



2.2. Die Aldol - Reaktion

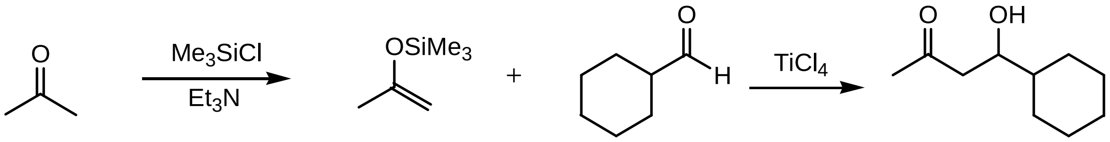


Gemische von Regioisomeren
und Stereoisomeren

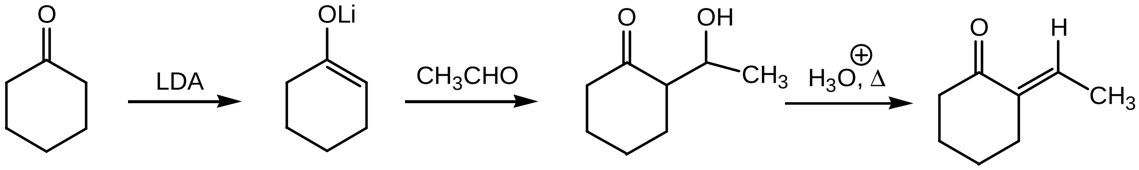


5. Gruppe: Carbonylverbindungen

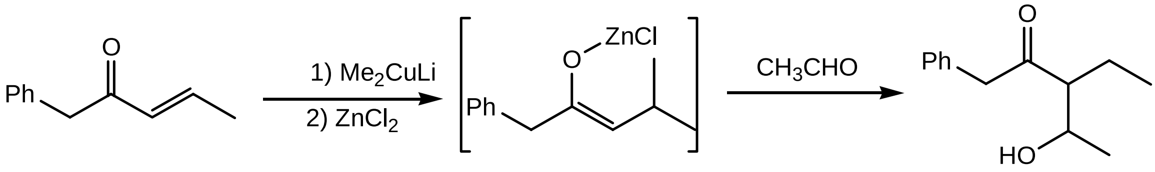
Mukaiyama - Methode



Aldol - Kondensation

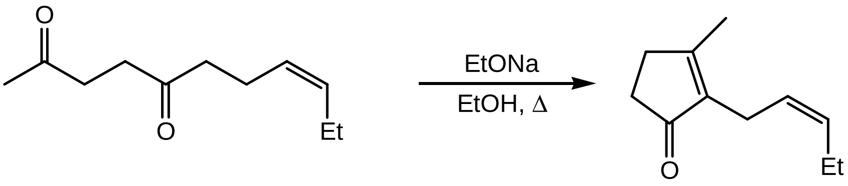


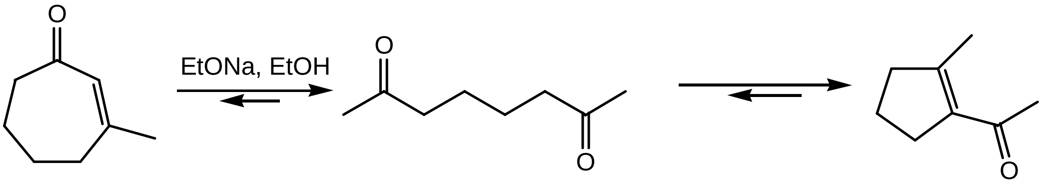
Selektivität der Aldol - Reaktion



91%

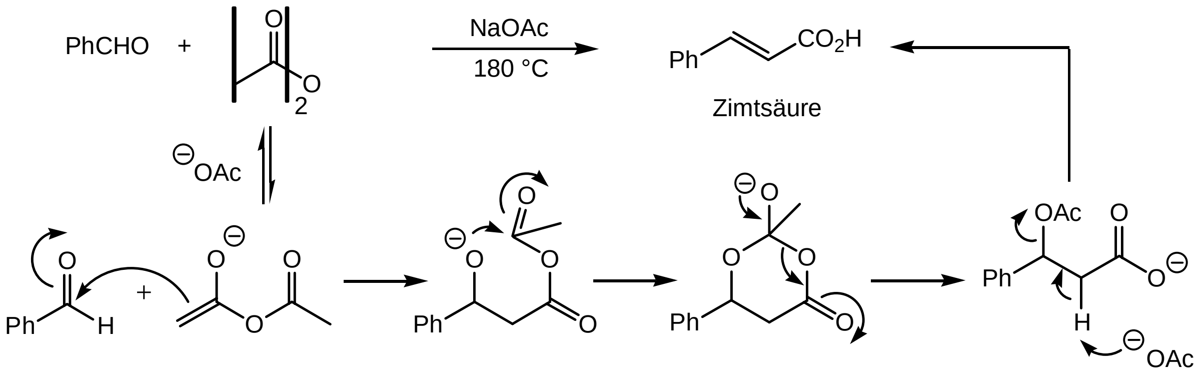
Cyclopentanone werden bevorzugt gebildet



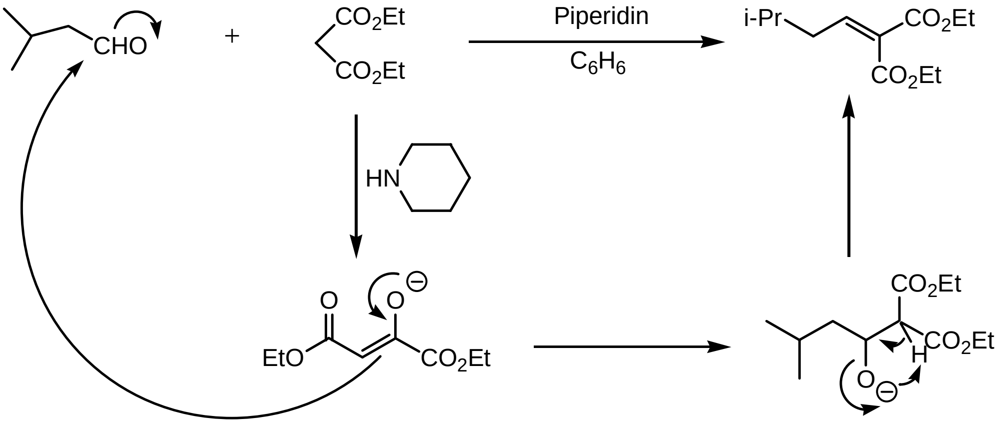


80%

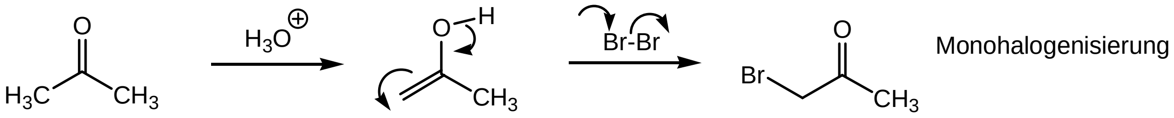
2.3. Die Perkin - Reaktion



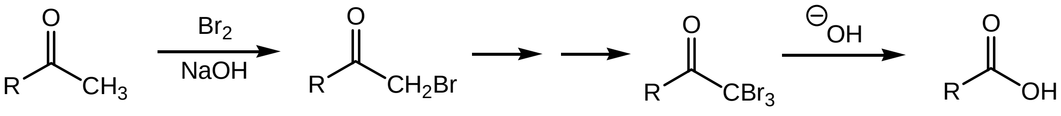
2.4. Die Knoevenagel - Kondensation



2.5. α-Halogenierung von Aldehyden und Ketonen



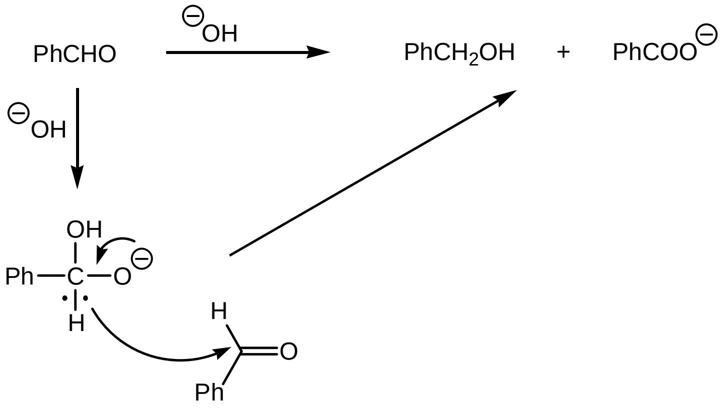
Geschw. = k[Aceton][$H_3O^{\oplus}$]. In basischen Medien wird eine Polybromierung beobachtet.



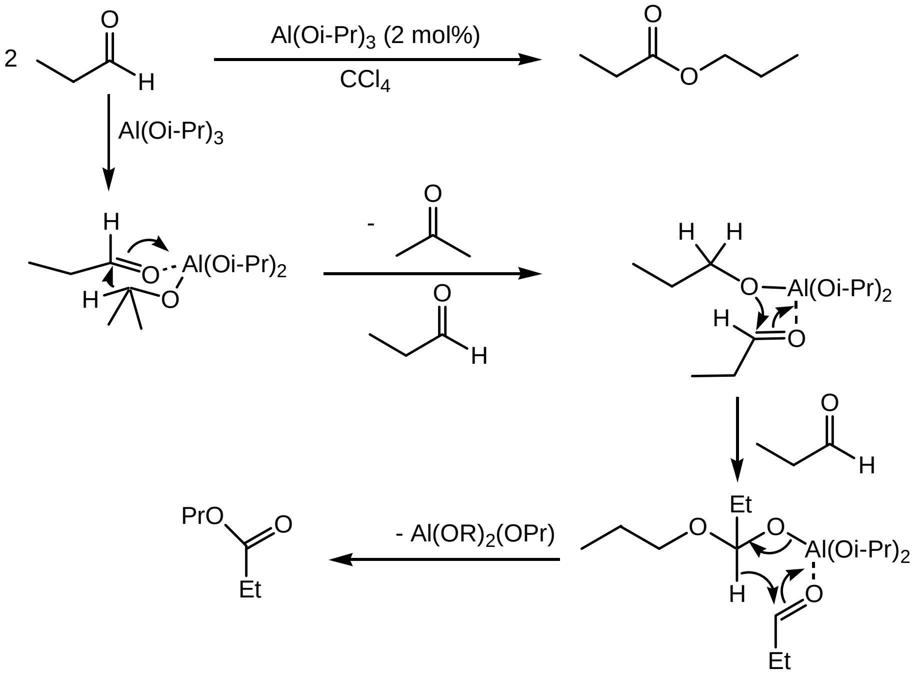
Haloform-Reaktion

5. Gruppe: Carbonylverbindungen

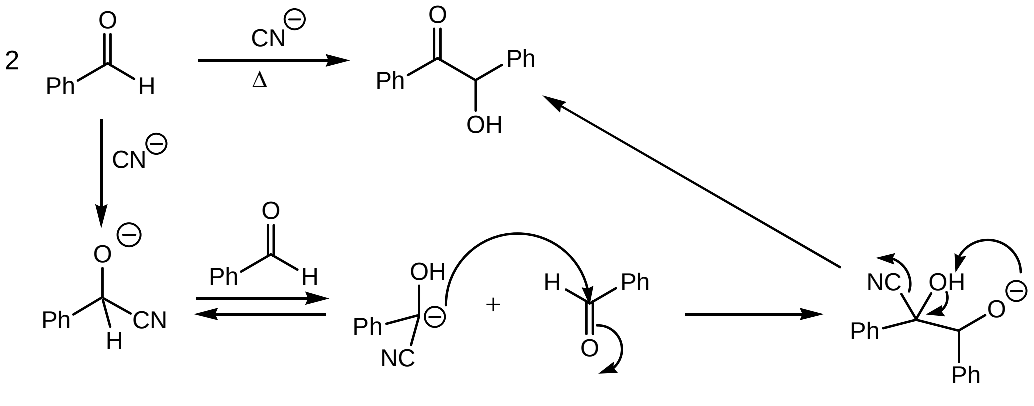
2.6. Cannizzaro - Reaktion



Tischtschenko - Claisen - Reaktion



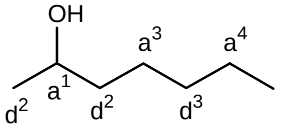
Die Benzoin - Kondensation



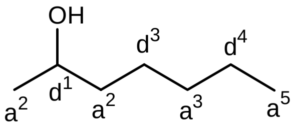
Umpolung der Reaktivität

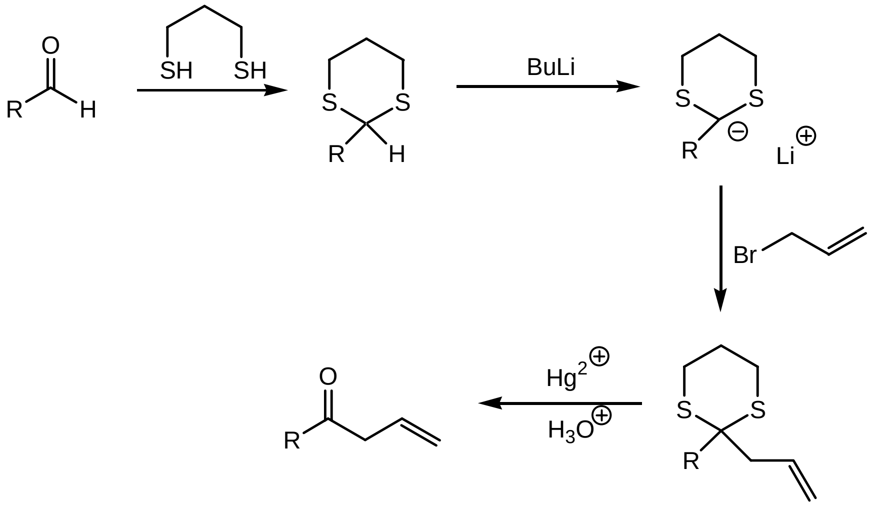
5. Gruppe: Carbonylverbindungen

Normale Reaktivität

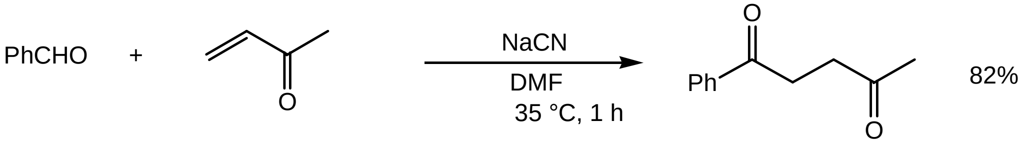


Umpolung der Reaktivität

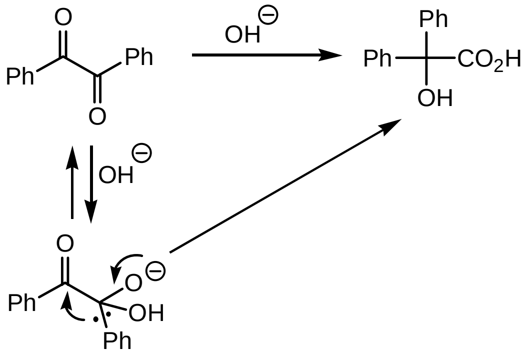


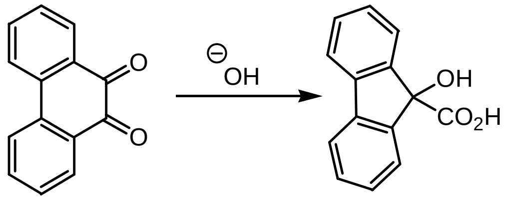


Stetter-Reaktion:



2.7. Die Benzilsäure - Umlagerung





2.8. Reaktionen mit metallorganischen Verbindungen

2.8.1. Einführung

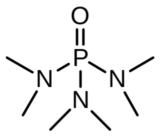
$\overset{-\delta}{\text{R}}\text{-}\overset{+\delta}{\text{Met}}$ Reaktivität RLi > RMgX > RZnX > R-Sn

Je elektropositiver das Metall, desto reaktiver ist die entsprechende metallorganische Spezies.
Die Reaktivität steigt auch nach erhöhtem p - Charakter:

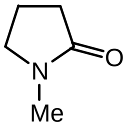
$$Csp < Csp^2 < Csp^3\ (prim.) < Csp^3\ (sek.) < Csp^3\ (tert.)$$

5. Gruppe: Carbonylverbindungen

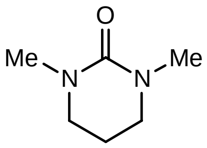
Metallorganische Verbindungen sind meistens reaktiver in THF als in Ether und reaktiver in Ether als in Hexan. Die Verwendung eines polaren Lösungsmittels wie HMPT oder NMP beschleunigt viele metallorganische Reaktionen. (DMPU ist auch gut geeignet)



HMPT

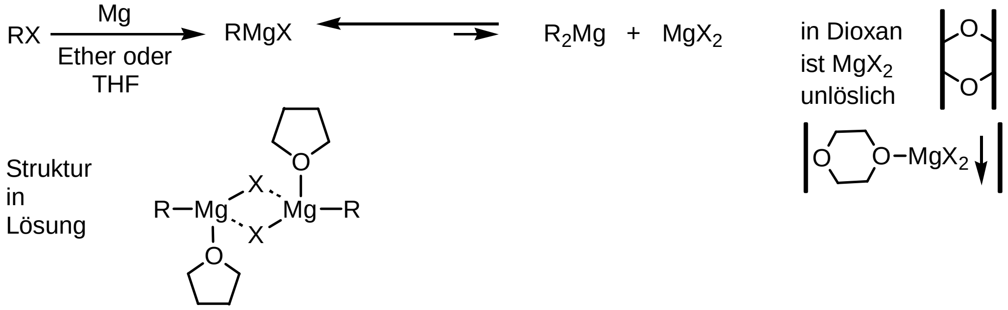


NMP

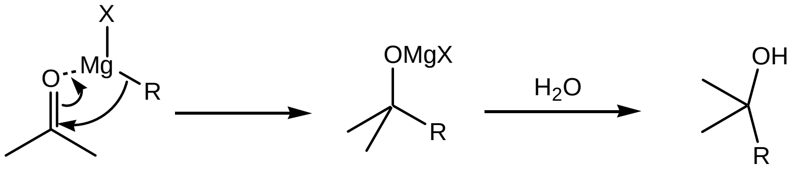


DMPU

2.8.2 Reaktionen von Grignard - Verbindungen:



Reaktion mit Carbonylverbindungen:



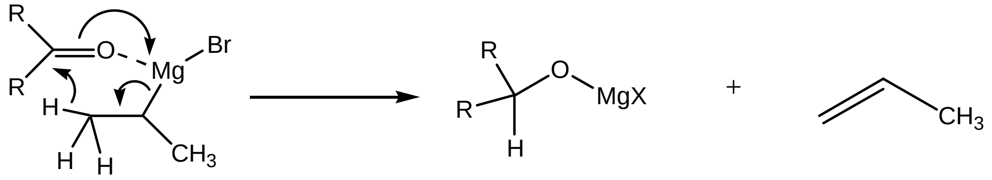
Aldehyde → sek. Alkohole

Ketone → tert. Alkohole

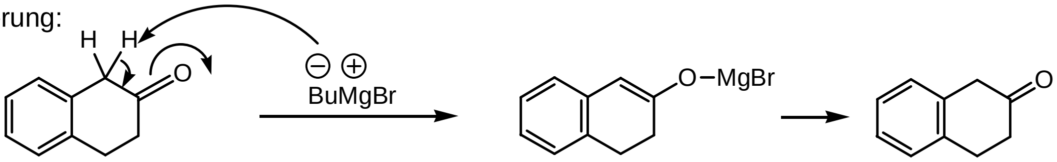
CH_2O → prim. Alkohole

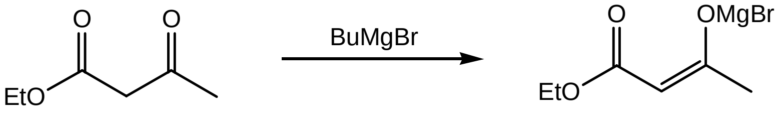
Nebenreaktionen:

Reduktion:



Enolisierung:



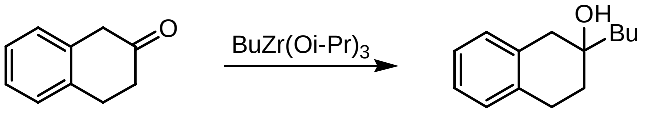


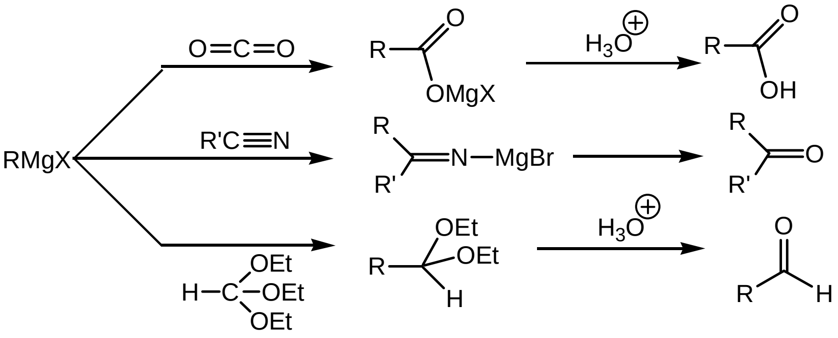
5. Gruppe: Carbonylverbindungen

Lösung des Problems: Ummetallierung

Imamoto: $BuMgBr \xrightarrow{CeCl_3} BuCeCl_2$

Reetz - Seebach: $BuMgBr \xrightarrow[ClTi(Oi\text{-}Pr)_3]{} BuTi(Oi\text{-}Pr)_3$





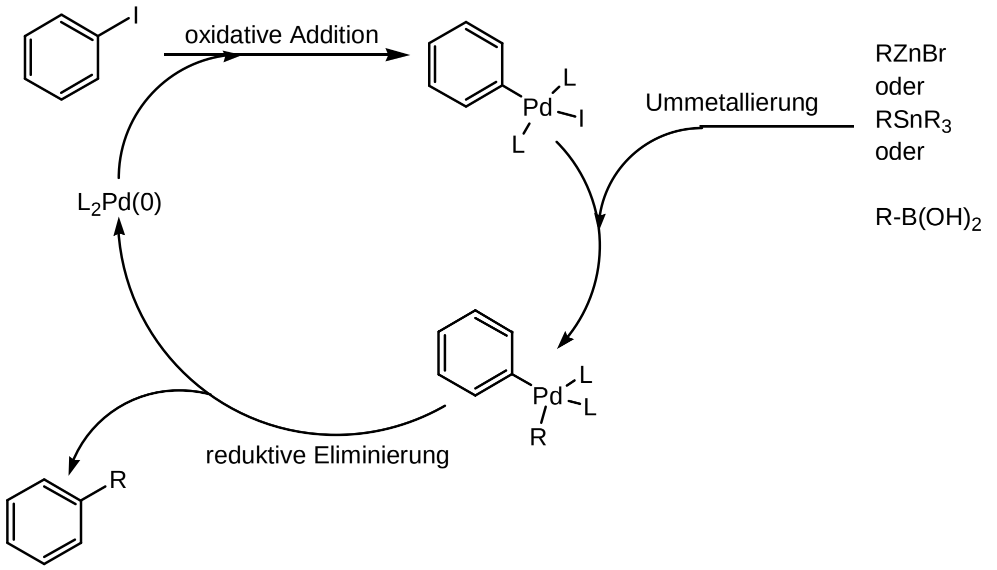
Substitutionsreaktionen:

$RMgX \xrightarrow{CuI} RCu \xrightarrow{ICH_2R'} RCH_2R'$

$RMgX \xrightarrow{ZnBr_2} RZnBr \xrightarrow[Pd(0)kat.]{PhI} RPh$

$RMgX \xrightarrow[2)\ H_2O]{1)\ B(OMe)_3} RB(OH)_2 \xrightarrow[Cs_2CO_3,\ \Delta]{PhI,\ Pd(0)kat.} RPh$

Substitution an $C_{sp}{}^{2}$ - Zentren:



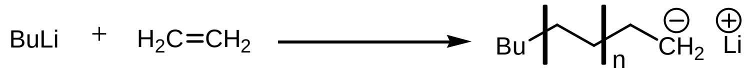
2.8.3 Reaktionen und Synthesen von Lithium - Verbindungen:

Herstellungsmethode 1: Oxidative Addition

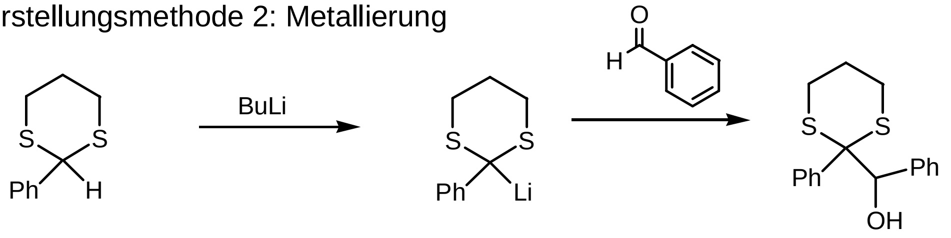
$$BuCl + 2\,Li \xrightarrow[-LiCl]{} BuLi$$

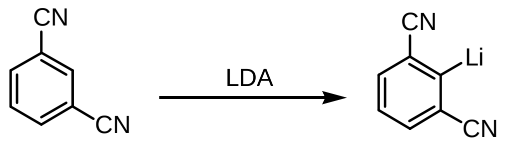
BuLi ist reaktiver als BuMgBr

Bsp.:

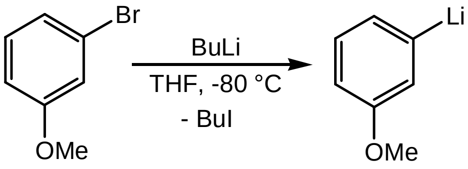


Herstellungsmethode 2: Metallierung

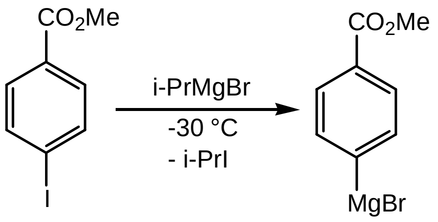


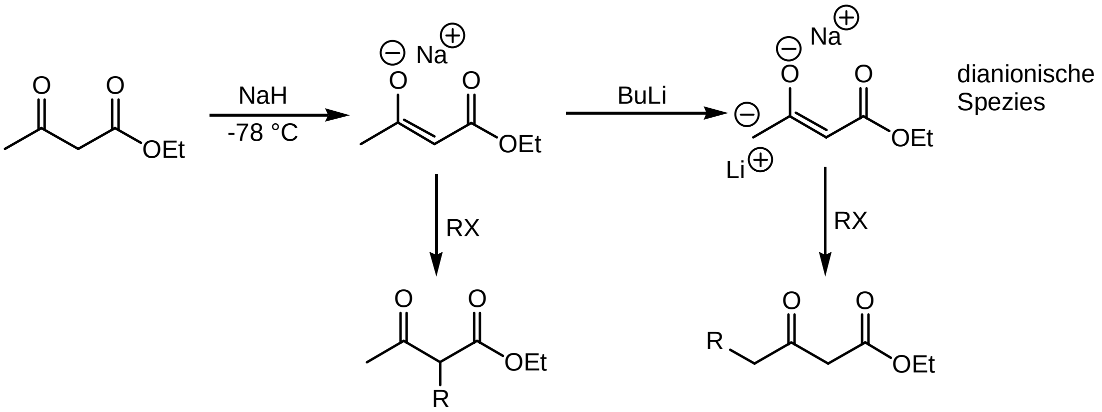


Herstellungsmethode 3: Halogen - Lithium - Austausch

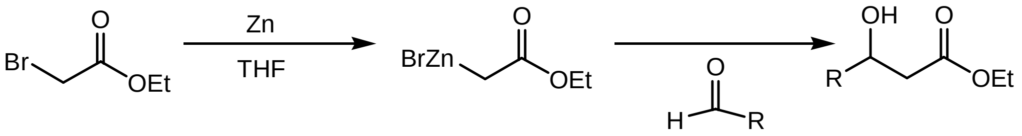


vgl.

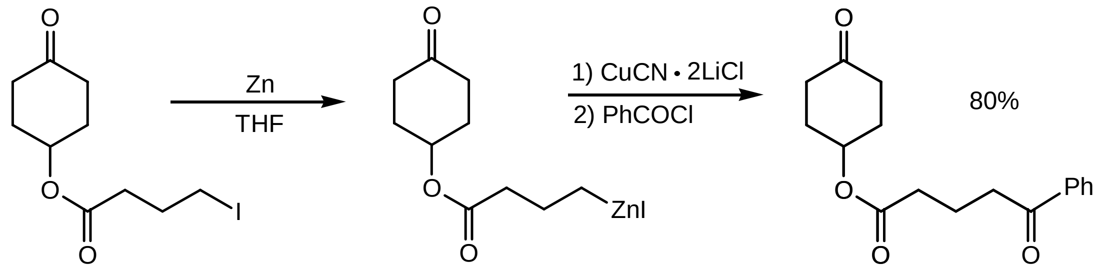




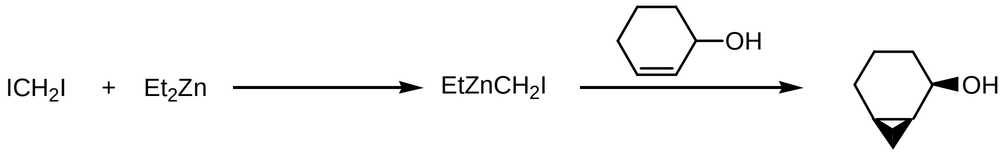
2.8.4 Zinkorganische Verbindungen:



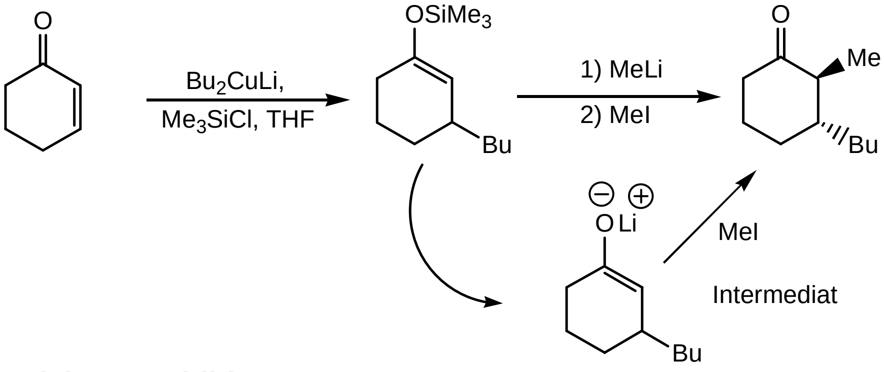
5. Gruppe: Carbonylverbindungen



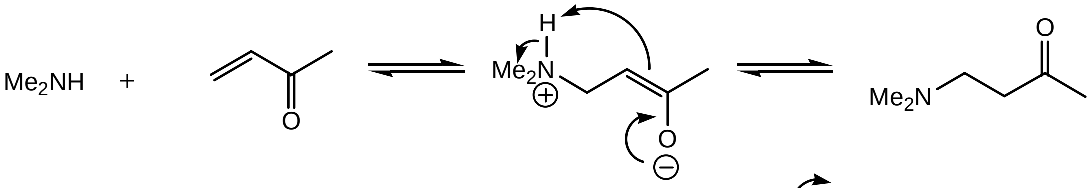
Simmons - Smith - Reaktion: Cyclopropansynthese

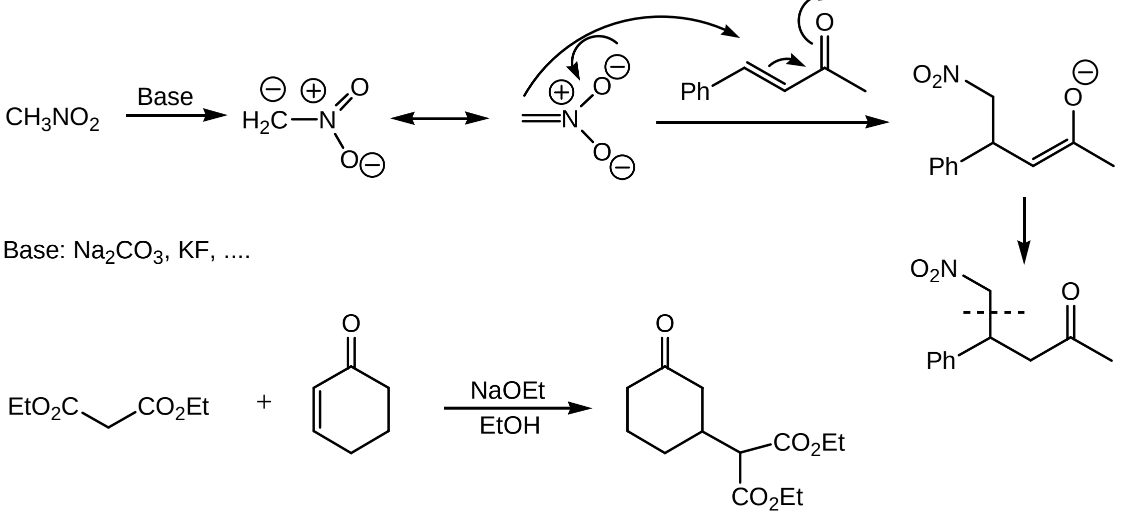


2. 8. 5. Kupferorganische Verbindungen:



2. 9 Die Michael - Addition:

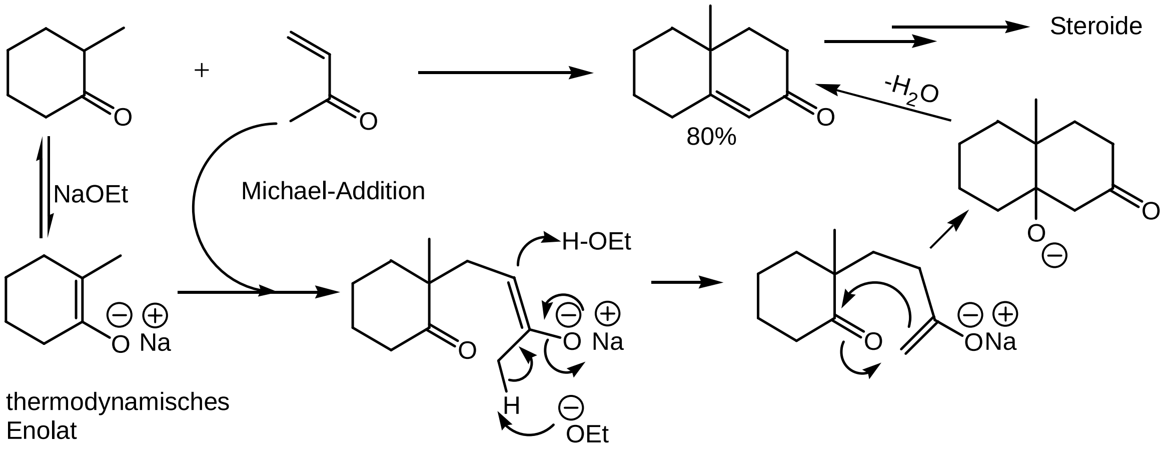




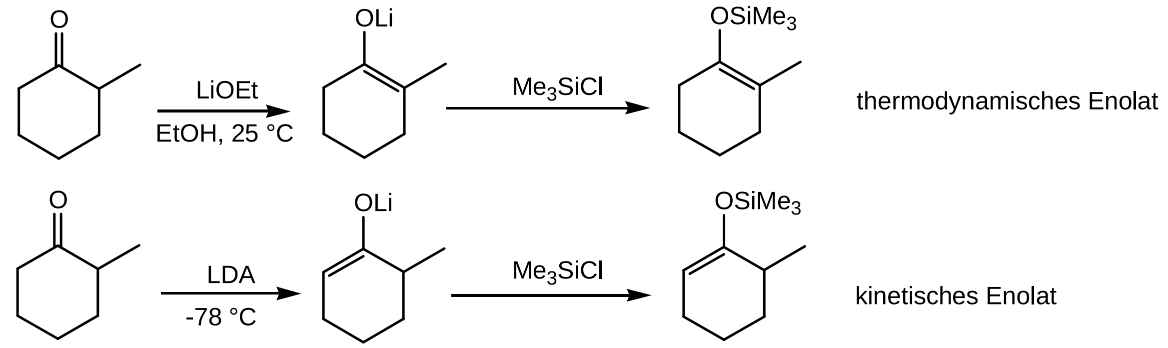
Base: Na_2CO_3, KF, ...

5. Gruppe: Carbonylverbindungen

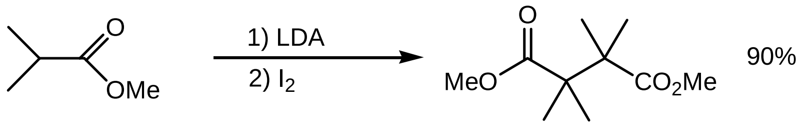
Robinson - Anellierung



Das kinetische Enolat kann unter Nicht - equilibrierungsbedingungen hergestellt werden
z.B.: mit LDA

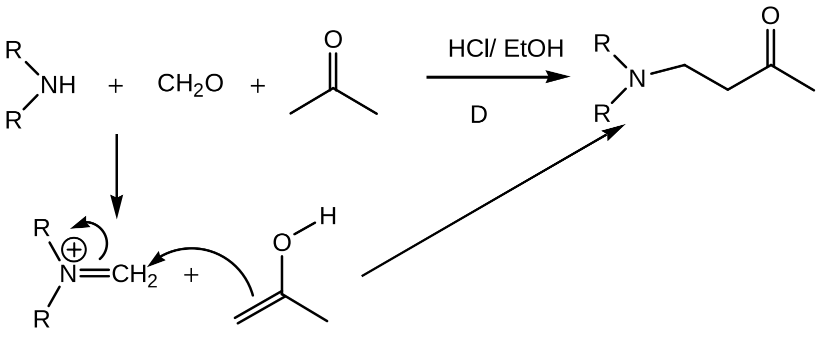


Dimerisierung von Enolaten



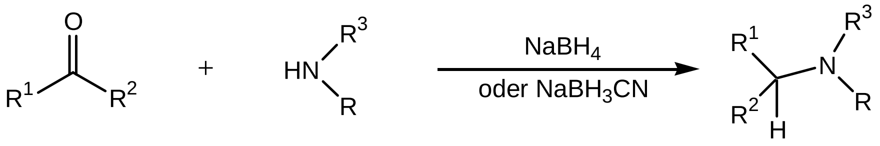
2. 10 Die Mannich - Reaktion:

wichtige Reaktion in der Alkaloid - Synthese

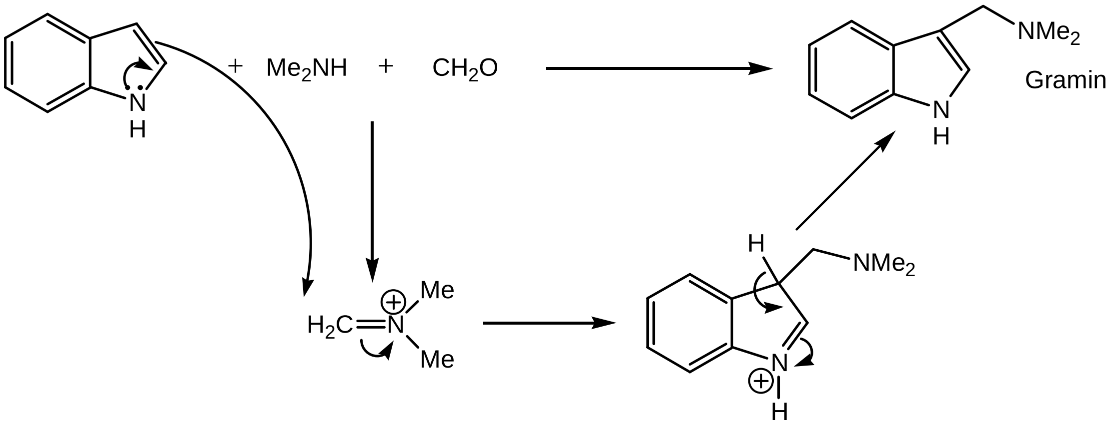


5. Gruppe: Carbonylverbindungen

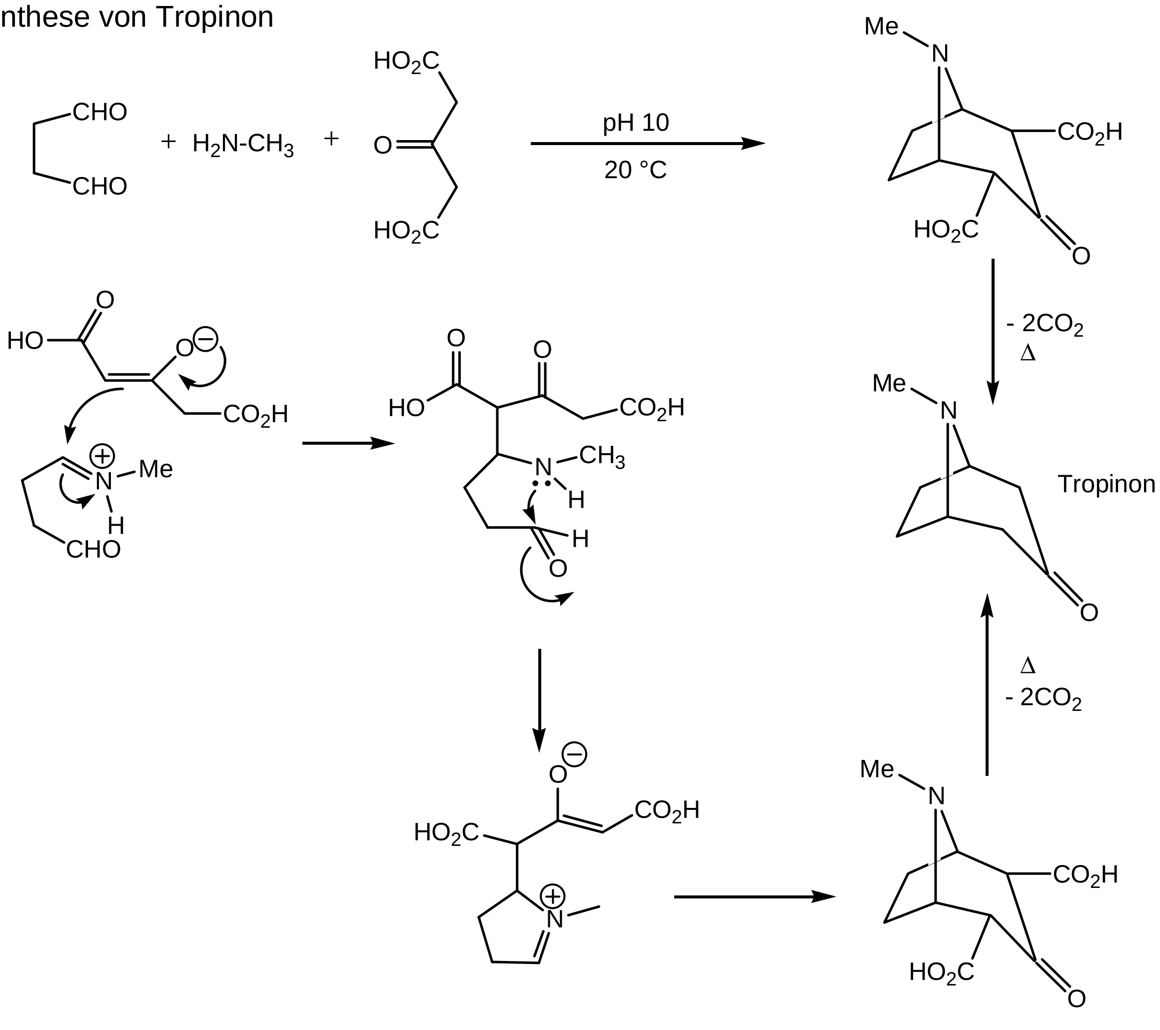
Vgl. mit der reduktiven Aminierung von Carbonyl - Verbindungen



Synthese von Gramin

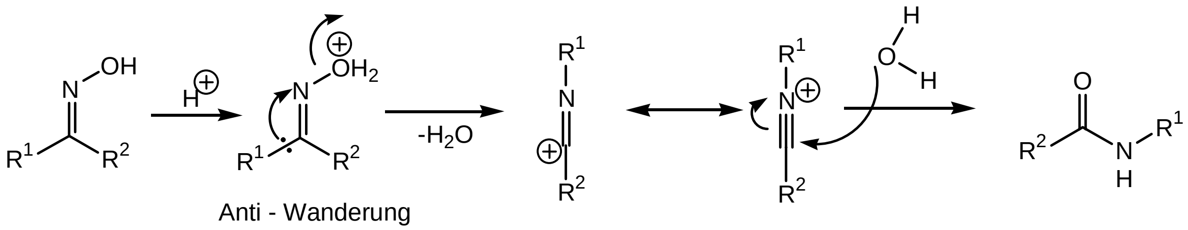


Synthese von Tropinon

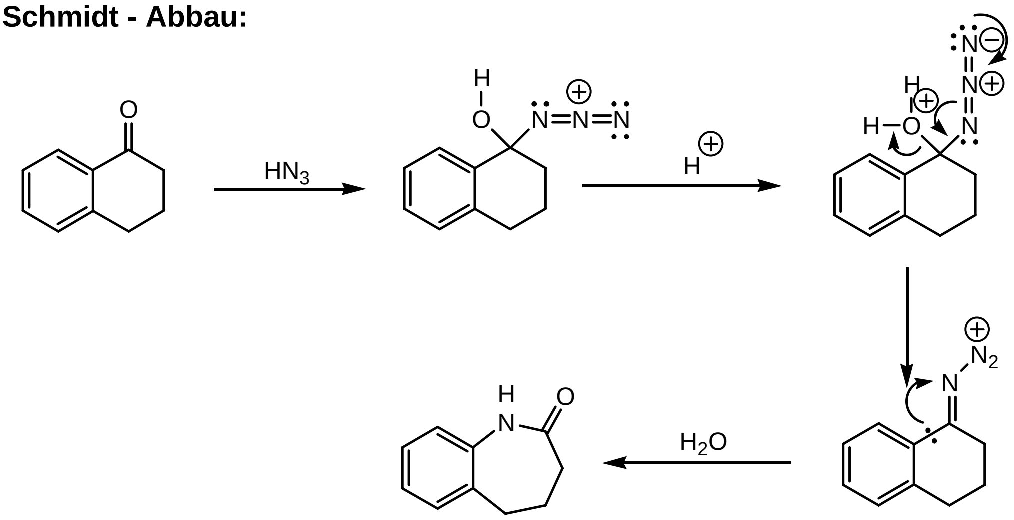


3. Umlagerungsreaktionen

3.1 Die Beckmann - Umlagerung

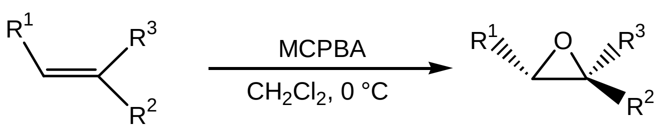


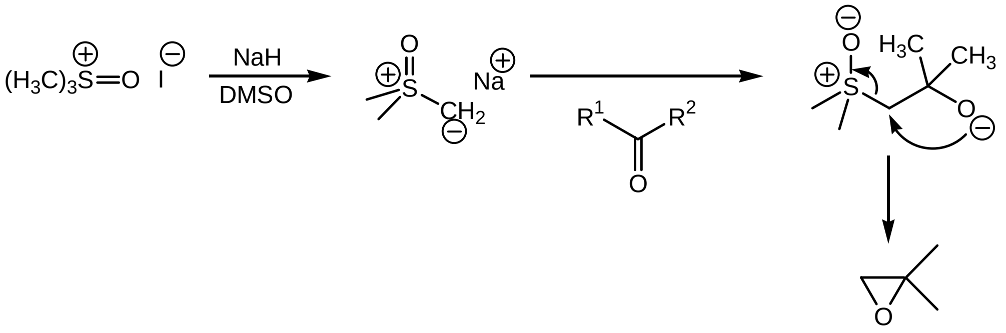
3.2 Schmidt - Abbau:

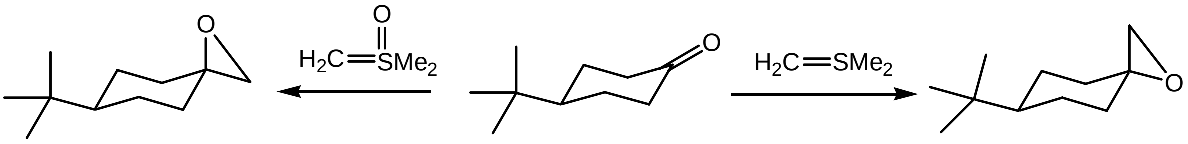


4. Synthese ausgewählter Heterocyclen:

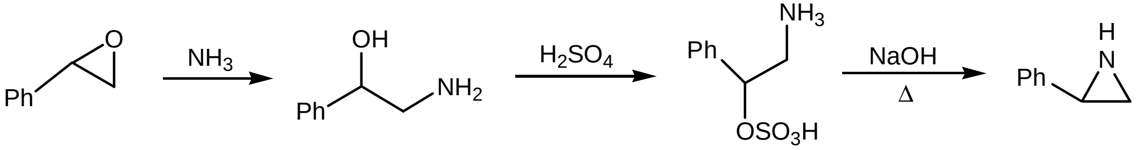
4. 1 Oxirane:



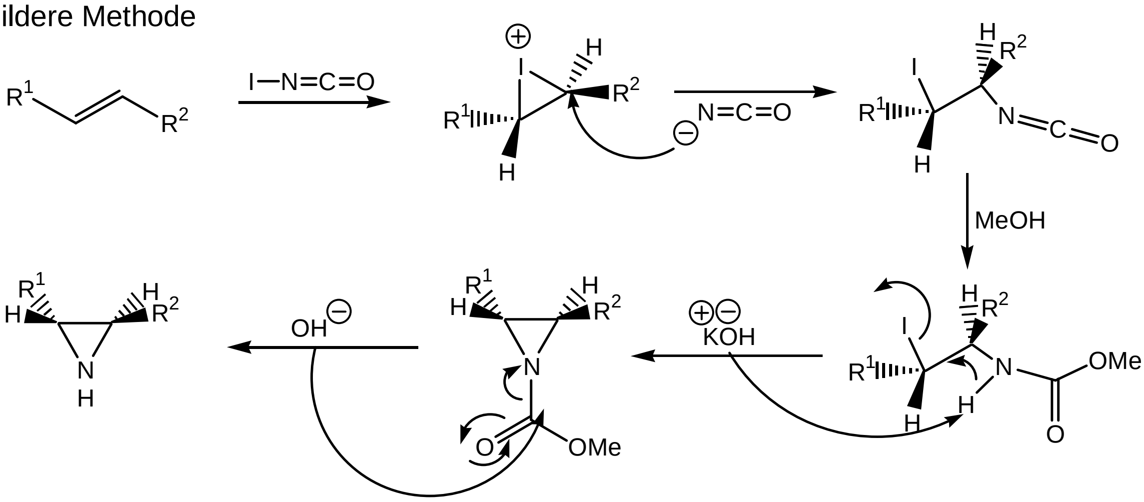




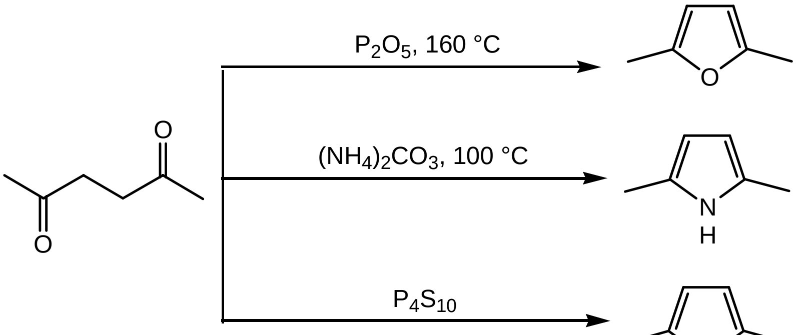
4. 2 Aziridin - Synthese:



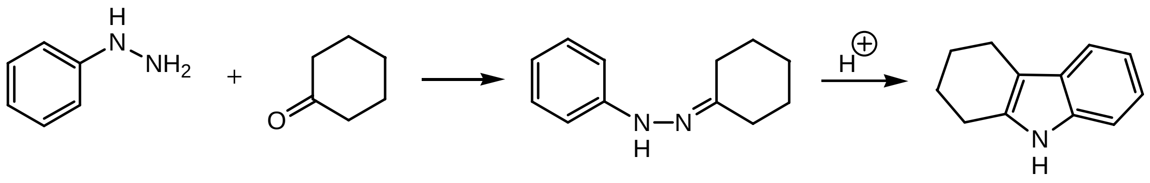
mildere Methode

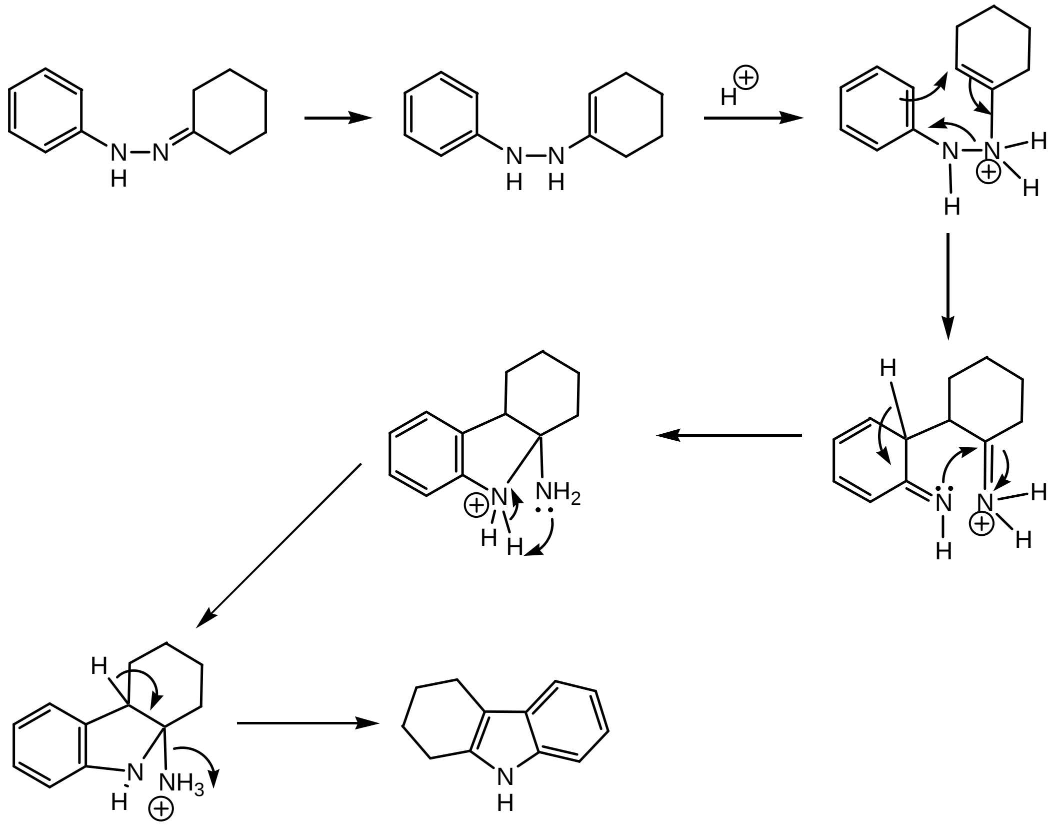


4. 3 Furane, Pyrrole und Thiophene:



4. 4 Fischer - Indolsynthese:





4. 5 Hantzsch - Pyridinsynthese: