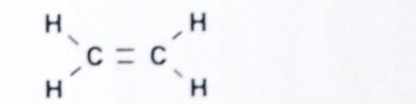
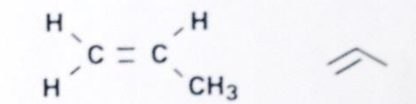
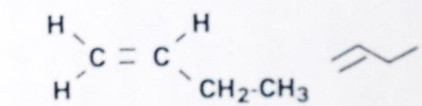
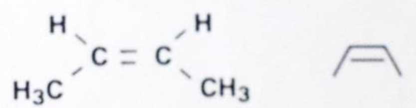
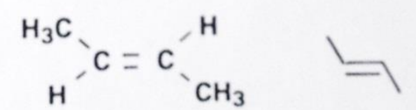
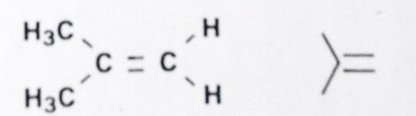
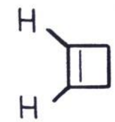
# 4 Ungesättigte Kohlenwasserstoffe - Alkene

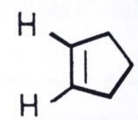
## 4.1 Reihe der Alkene (Olefine)

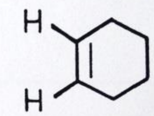
Alkene: $C_nH_{2n}$

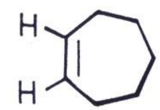
| Summenformel | Konstitutionsformel / Kurzformel | Bezeichnung |
|---|---|---|
| $C_2H_4$ |  | Ethen bzw. Ethylen |
| $C_3H_6$ |  | Propen bzw. Propylen |
| $C_4H_8$ |  | 1-Buten |
| $C_4H_8$ |  | cis-2-Buten bzw. Z-2-Buten |
| $C_4H_8$ |  | trans-2-Buten bzw. E-2-Buten |
| $C_4H_8$ |  | 2-Methylpropen bzw. Isobuten |
| $C_nH_{2n}$ | | Alken |

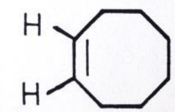

Cyclopropen

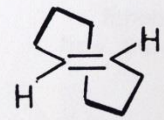

Cyclobuten

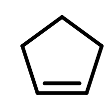

Cyclopenten

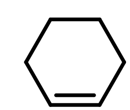

Cyclohexen

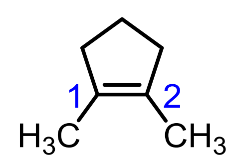

Cyclohepten


cis - Cyclocten

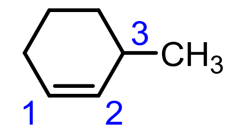

trans - Cycloocten


Cyclopenten


Cyclohexen



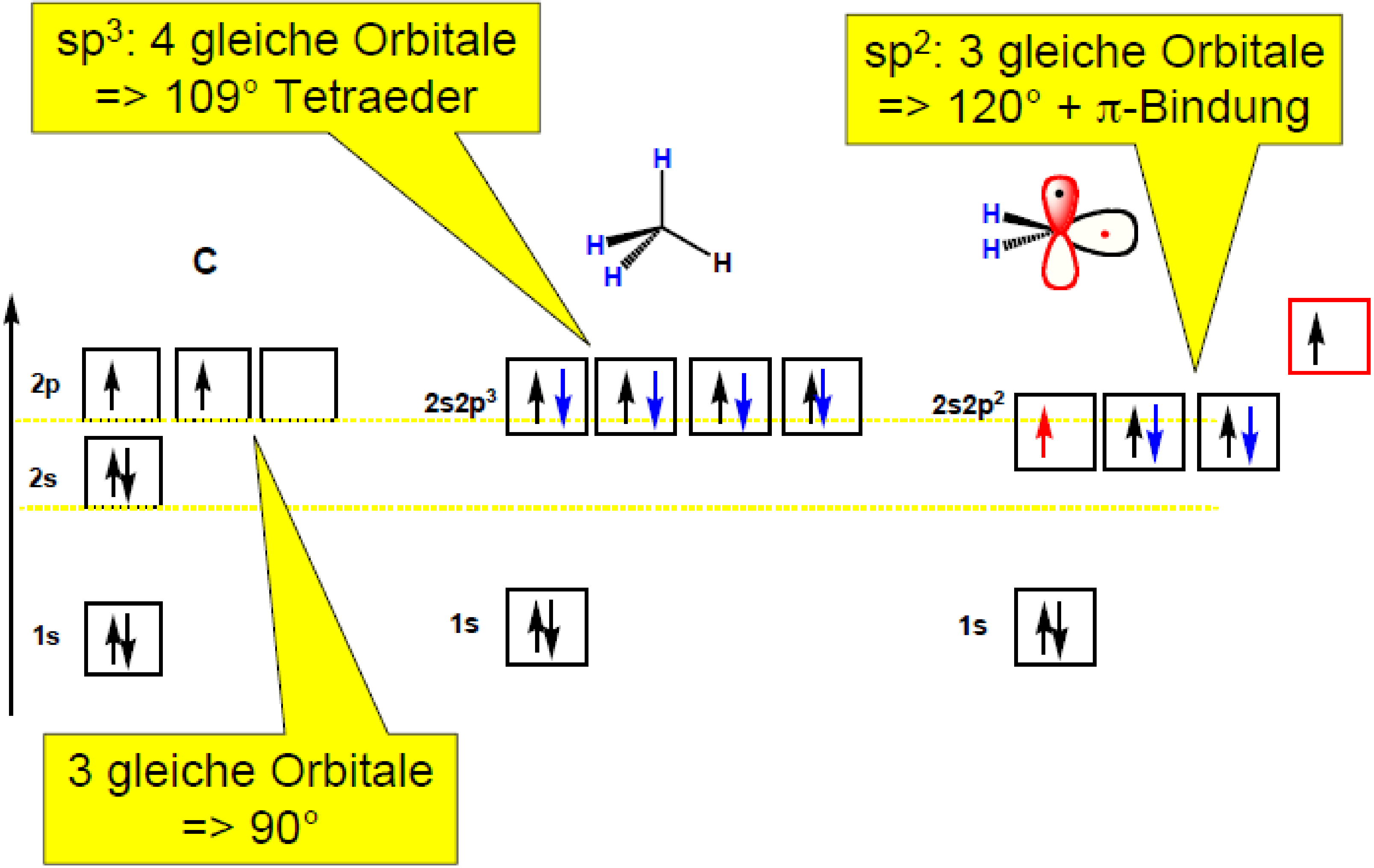
1,2-Dimethylcyclopenten



3-Methylcyclohexen

# $sp^3$ vs. $sp^2$ Hybridisierung

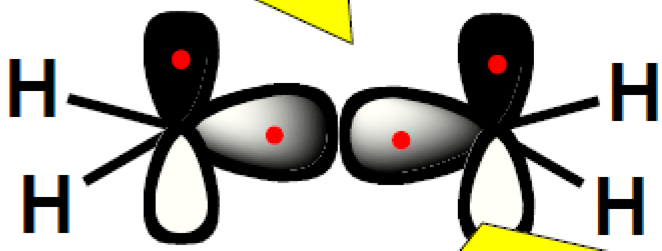
Wiederholung: Hybridisierung des „C“



# Bessere Bindung der Alkene

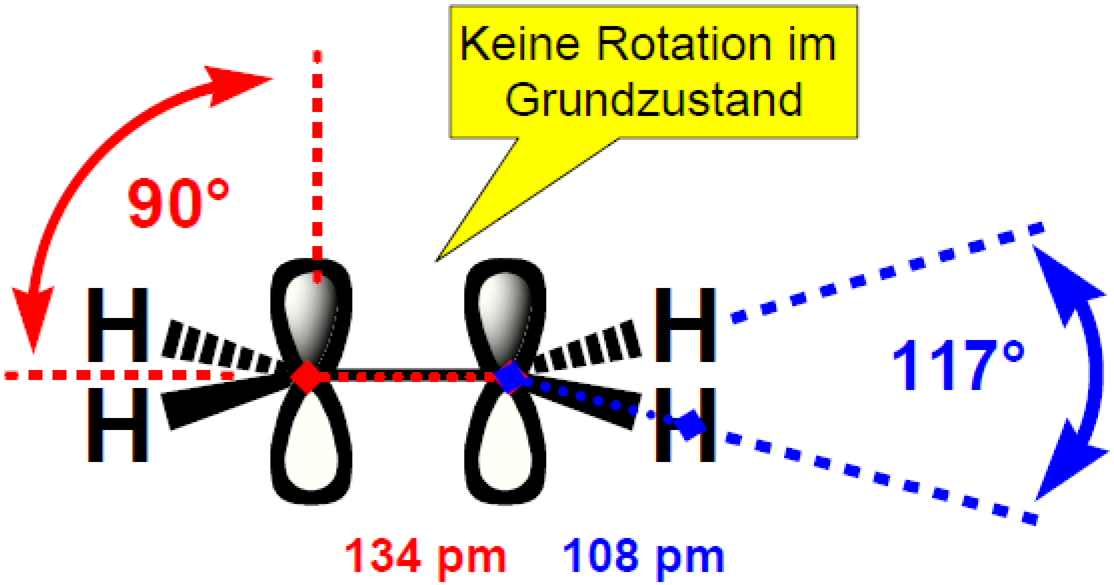
- 4x 1s Orbitale der 4 H-Atome, je 1 e
- 2x $2s2p^2$ Hybride der 2 C-Atome, je 3 e
- 2x 2p Orbitale der 2 C-Atome, je 1 e
- => 12 e => 6 Bindungen

Starke lineare $\sigma_{2s2p^2-2s2p^2}$ Bindung




Senkrecht zur $\sigma$: schwache $\pi_{2p-2p}$ Bindung

# Ethen



## 4 Ungesättigte Kohlenwasserstoffe - Alkene

### 4.1.1 Nomenklatur: Besonderheiten bei Alkenen

1. Die längste Kette enthält die **Doppelbindung** (**DB**)

2. Die Position der **DB** erhält eine Nummer und die Nummerierung der Kette beginnt am Ende, das der **DB** am nächsten ist

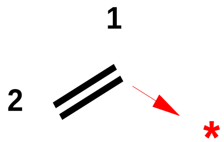
3. *cis/trans*-Isomere sind möglich, auch als E/Z-Isomere bezeichnet

4. Verschiedene funktionelle Gruppen im Molekül: Priorität z.B. Alkohol > Alken

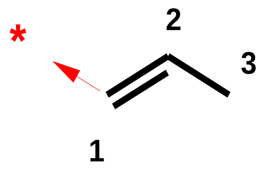
5. Substituenten mit **DB** werden als Alkenyl bezeichnet

# 4 Ungesättigte Kohlenwasserstoffe - Alkene

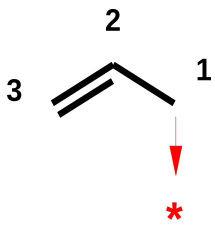
## 4.1.1 Nomenklatur: Bezeichnung ungesättigter Alkylgruppen - Alkenyl



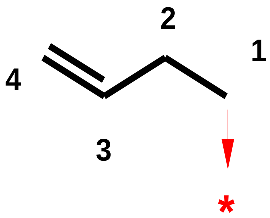

**Ethenyl (Vinyl)**



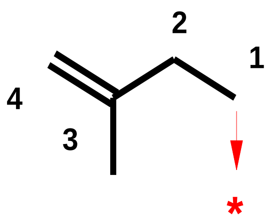

**1-Propenyl**



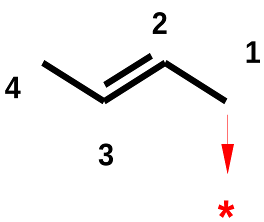

**2-Propenyl (Allyl)**



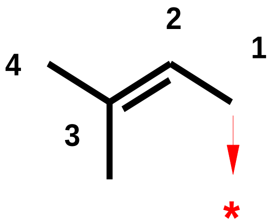

**3-Butenyl**



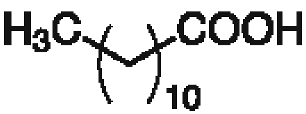
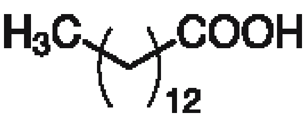
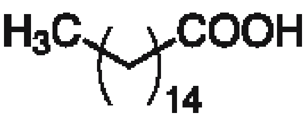
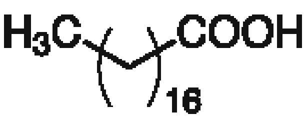
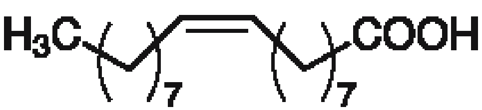
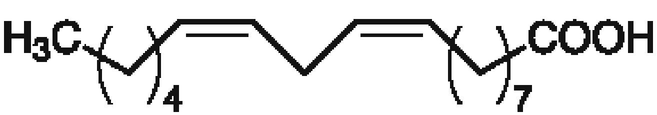

**3-Methyl-3-butenyl (Isopentenyl)**




**2-Butenyl**

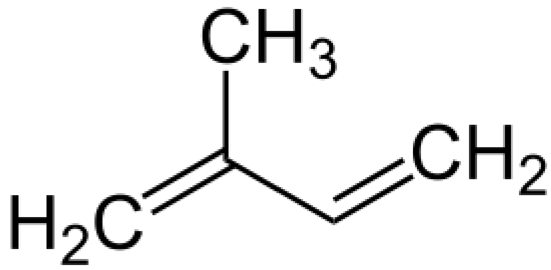



**3-Methyl-2-butenyl (3,3-Dimethylallyl)**

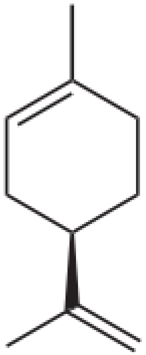
| Konstitution | Trivialname | Anzahl der C-Atome |
|---|---|---|
|  | Laurinsäure | 12 |
|  | Myristinsäure | 14 |
|  | Palmitinsäure | 16 |
|  | Stearinsäure | 18 |
|  | Ölsäure | 18 |
|  | Linolsäure | 18 |

# Terpene

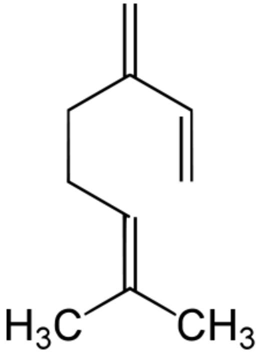
- Vielfalt von Naturstoffen, abgeleitet vom Isopren
- Mehr als 20000 Terpene bekannt
- Oft starker Geruch (vgl. Limonen)
- Auch Pheromone, Insektizide, antimikrobielle Eigenschaften,…




**Isopren**
(2-Methylbuta-1,3-dien)



**(R)-Limonen**
(1-Methyl-4-prop-1-en-2-yl-cyclohexen)

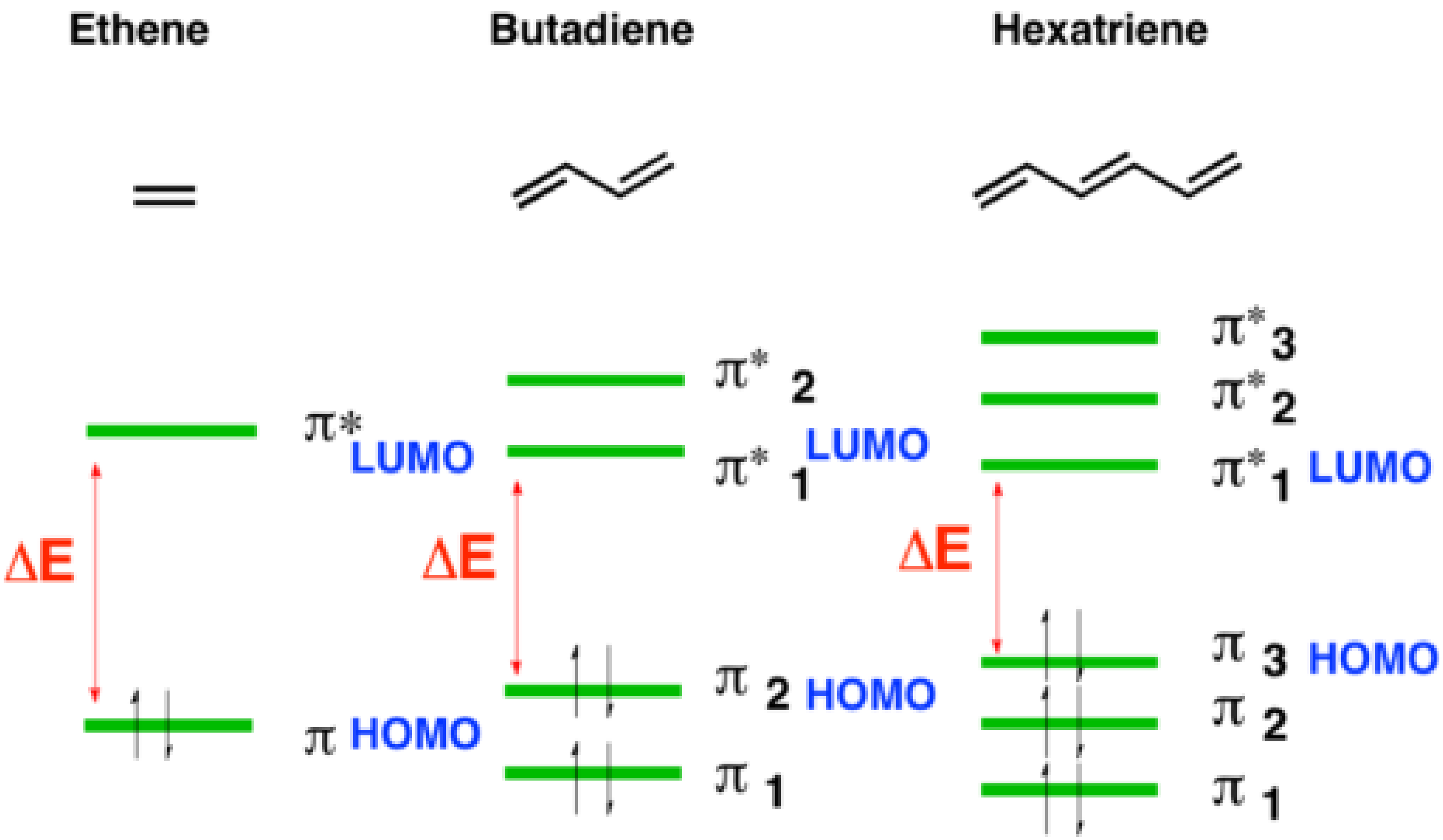



**Myrcen**
(7-Methyl-3-methylen-1,6-octadien)

& viele weitere Oligomere

Monoterpene („10 C-Atome“)
Cyclisch, nicht cyclisch,
auch Heteroatome: Terpenoide

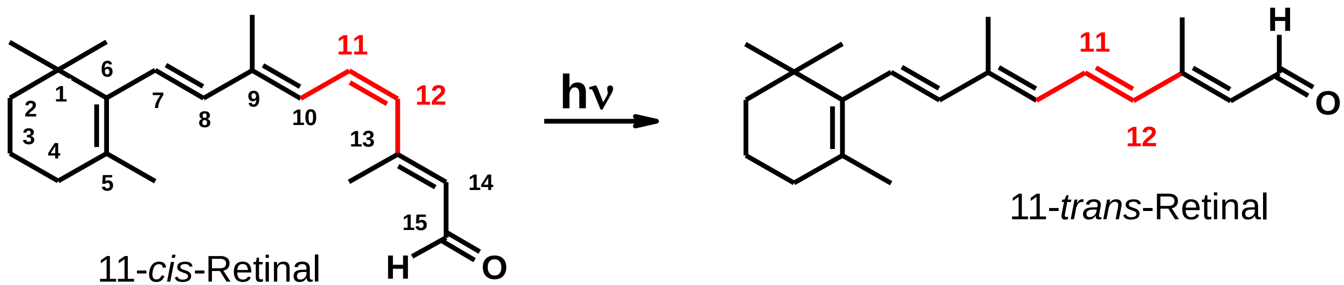
# Molekülorbitale Olefine

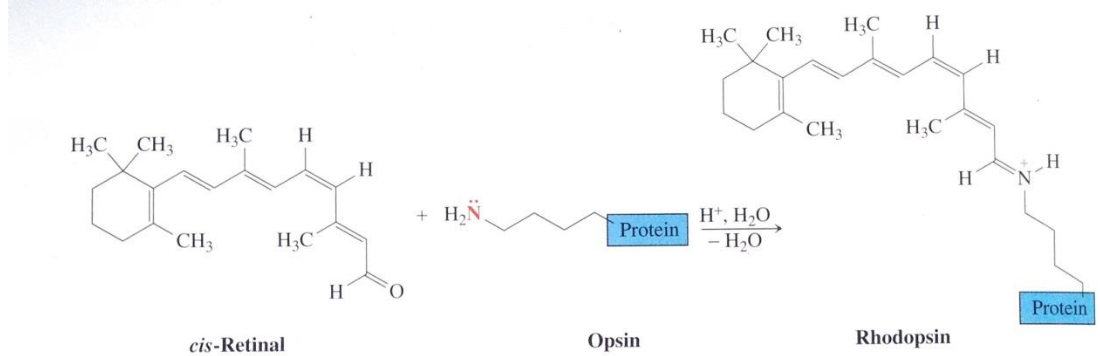


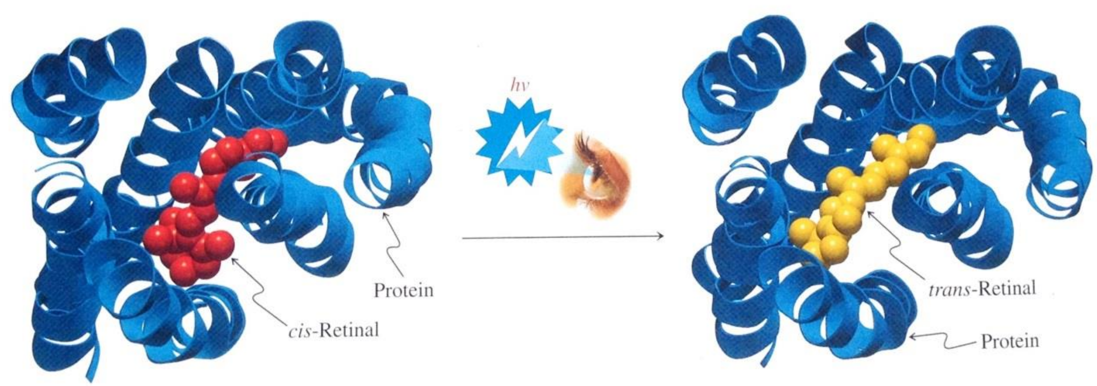

**Beachte:** Energiedifferenz ΔE („HOMO-LUMO-gap“) wird kleiner, je ausgedehnter das konjugierte π-System wird. *(vgl. Farbigkeit)*

# 4 Ungesättigte Kohlenwasserstoffe - Alkene

**Einschub**: Lichtinduzierte *cis-trans*-Isomerisierung beim Sehvorgang



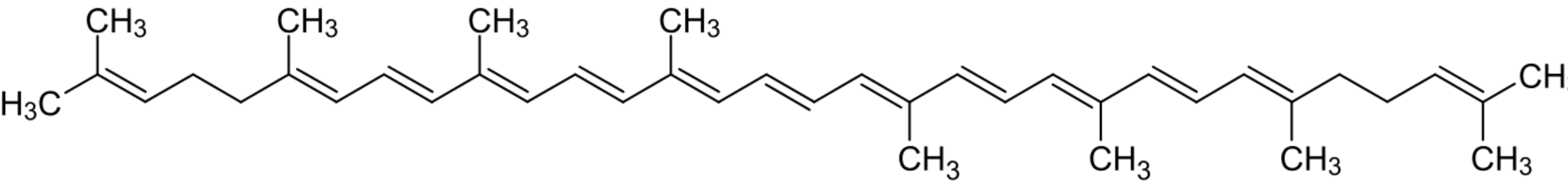




**Rhodopsin vor Absorption eines Photons**

**Rhodopsin nach Absorption eines Photons**

# Naturstoffe: Alkene

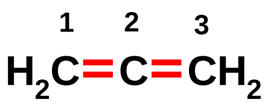
**Lycopin:** roter Farbstoff in Tomaten



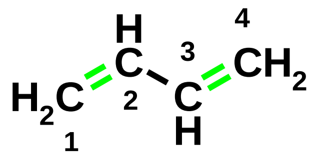
(6*E*,8*E*,10*E*,12*E*,14*E*,16*E*,18*E*,20*E*,22*E*,24*E*,26*E*)-2,6,10,14,19,23,27,31-octamethyl-dotriaconta-2,6,8,10,12,14,16,18,20,22,24,26,30-tridecaen

# 4 Ungesättigte Kohlenwasserstoffe - Alkene

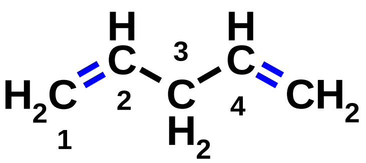
## Mehrfach ungesättigte Alkene und Cycloalkene



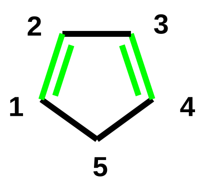
**1,2-Propadien (Allen)**



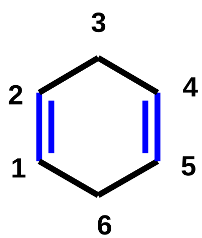
**1,3-Butadien**



**1,4-Pentadien**



**(1,3-) Cyclopentadien**



**1,4-Cyclohexadien**

**kumuliert**

**konjugiert**

**isoliert**

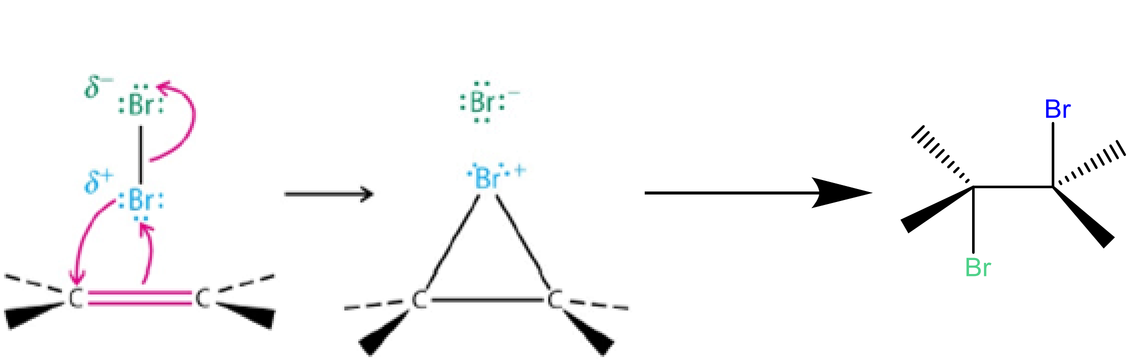
# 4 Ungesättigte Kohlenwasserstoffe - Alkene

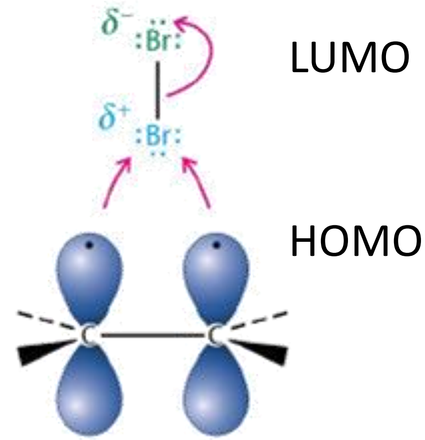
## 4.1.6 Reaktionen der Alkene: Elektrophile Addition ($A_E$)

$$H_2C{=}CH_2 \;+\; X - Y \;\longrightarrow\; X - CH_2 - CH_2 - Y$$

| Reagens | Produkt | allgemein |
|---|---|---|
| H - Hal<br>(HCl, HBr, HI) | Halogenethan | Halogenalkan |
| Hal - Hal<br>($Cl_2$, $Br_2$, $I_2$) | 1,2-Dihalogenethan | 1,2-Dihalogenalkan |
| HO - Cl | 2-Chlorethanol | 2-Chloralkanol |
| H - H<br>(Pd od. Pt als Kat.) | Ethan | Alkan |
| H - $BR_2$ | Ethylboran<br>(bei $BH_3$: Triethylboran<br>Hydroborierung) | Alkylboran |
| H - OH / $H^+$ | Ethanol | Alkohol |
| H - $OSO_3H$ | Monoethylsulfat<br>(Schwefelsäure-<br>monoethylester)<br>(Weiterreaktion zu<br>Diethylsulfat) | Monoalkylsulfat<br>(Schwefelsäure-<br>monoalkylester)<br>(Weiterreaktion zu<br>Dialkylsulfat) |

# Bromierung von Alkenen




Elektrophile Addition an C=C ($A_E$)

Mechanismus:

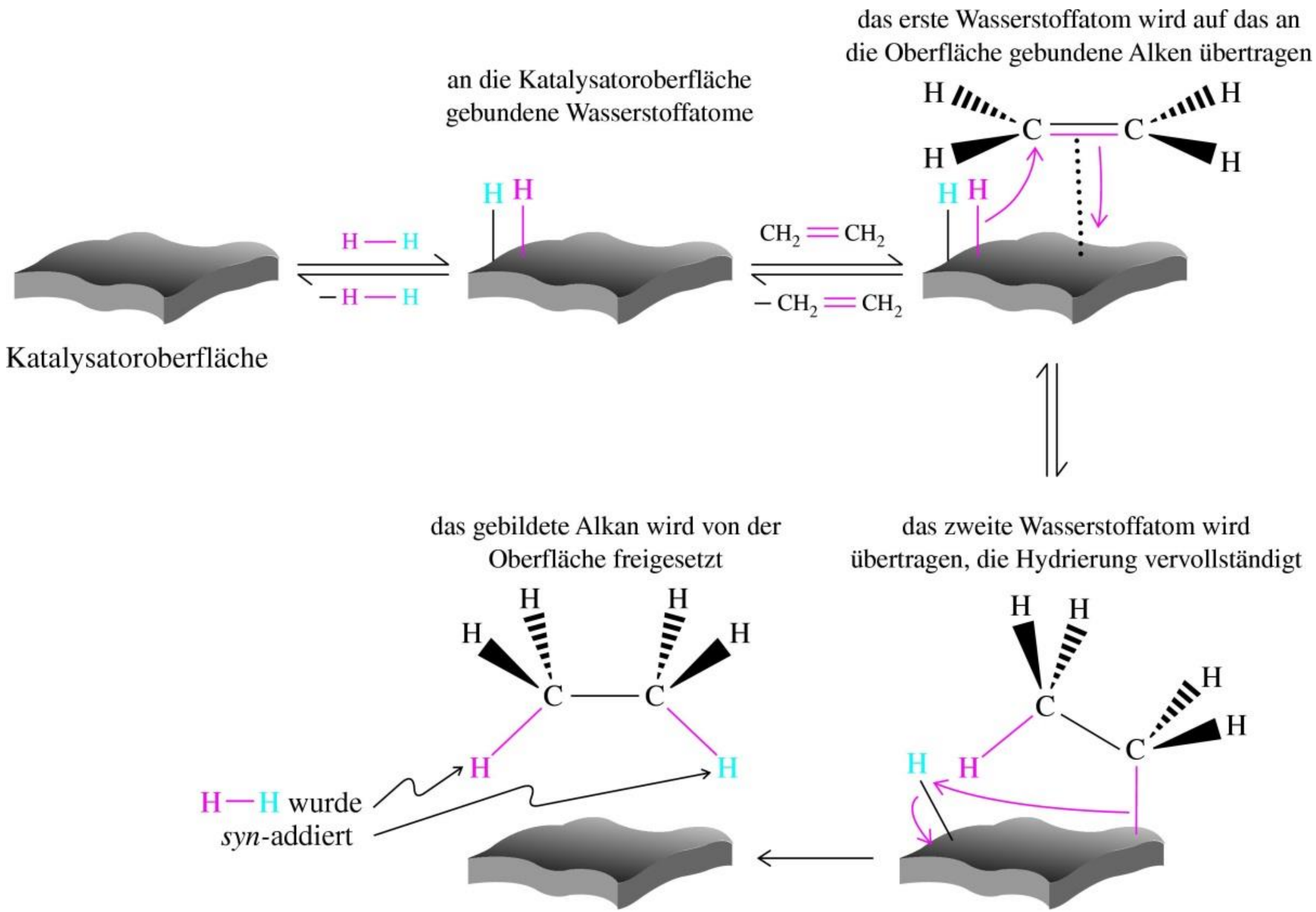
1.) nukleophiler Angriff von HOMO der C=C im LUMO der Br-Br-Bindung (antibindend)

2.) Ausbildung eines cycl. Bromoniumions

3.) nukleophiler Angriff des $Br^-$ öffnet Bromoniumion

# 4 Ungesättigte Kohlenwasserstoffe - Alkene

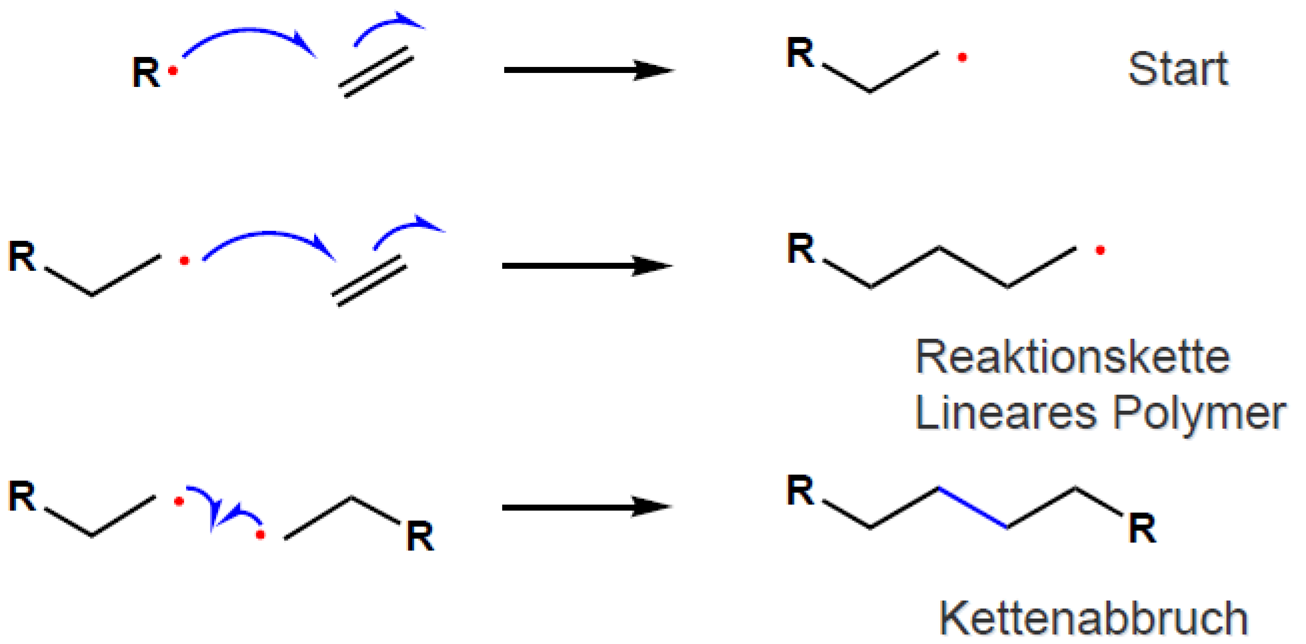
## Katalytische Hydrierung an Katalysator-Oberflächen



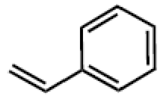
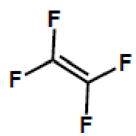


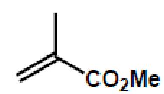
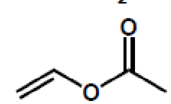
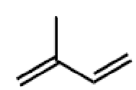
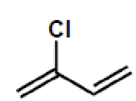
Vollhardt - Organische Chemie
ISBN: 9783527327546 Abb. 12-001

# Radikalische Polymerisation: Ethen



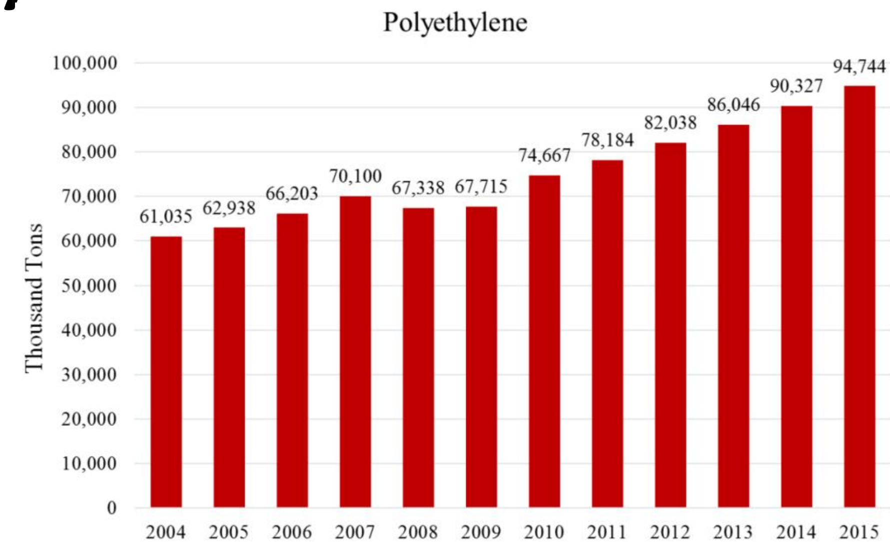

Triebkraft: C=C $\pi$–Anteil 240 kJ/mol => C-C 346 kJ/mol

| Polymer | Monomer | Verwendung |
|---|---|---|
| Polyethen |  | Plastiktüten |
| Polypropen |  | Eppendorfs |
| Polystyrol |  | Styropor |
| Polyvinylchlorid |  | Rohre, Kabelisolierung |
| Polyacrylnitril |  | Handschuhe |
| Teflon |  | Pfannen Reaktoren |

| Polymer | Monomer | Verwendung |
|---|---|---|
| Polymethylmethacrylat |  | Plexiglas Zahnfüllungen |
| Polyvinylacetat |  | Klebstoff Kaugummi |
| Isopren |  | Gummi |
| Neopren |  | |

# Polyolefin-Produktion

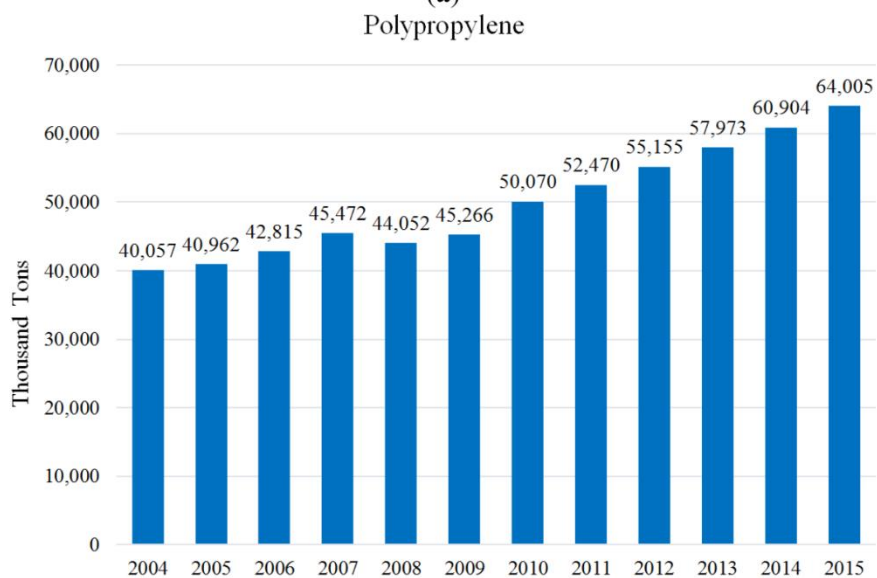
HD-PE



**(a)**

LD-PE

PP



**(b)**

Süddeutsche Zeitung

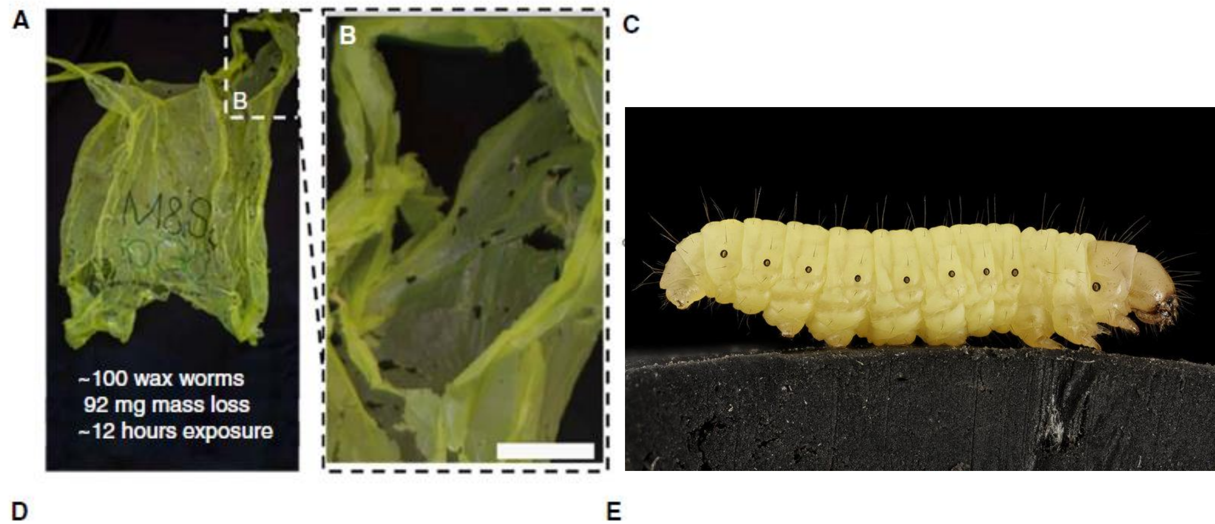
# Der Plastik-Planet

Current Biology
Magazine

Correspondence

# Polyethylene bio-degradation by caterpillars of the wax moth *Galleria mellonella*

Paolo Bombelli[1],
Christopher J. Howe[1,*],
and Federica Bertocchini[2,3,*]




Larven der Wachsmotte können PE abbauen.

Current Biology 27, R283–R293, April 24, 2017

# Alkine: Nomenklatur

Homologe Reihe Alkine: $C_nH_{2n-2}$

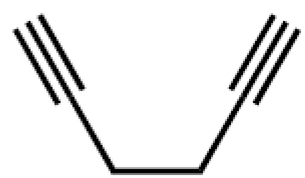

Ethin

Acetylen


Propin


1-Butin

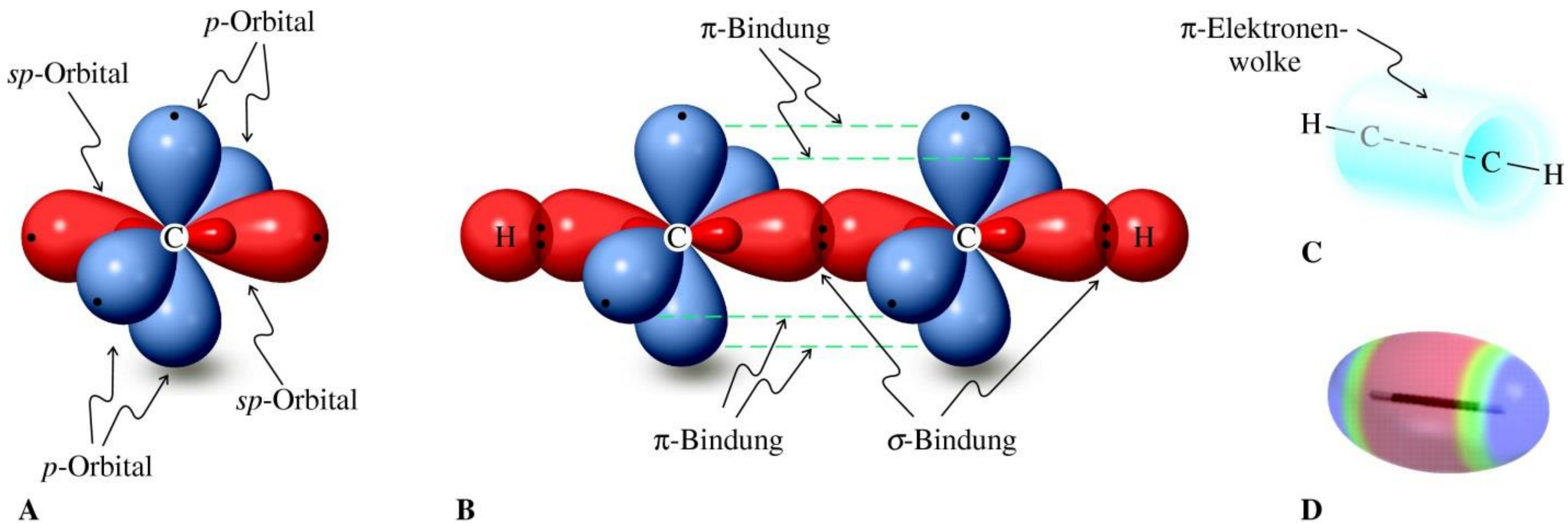
2-Butin



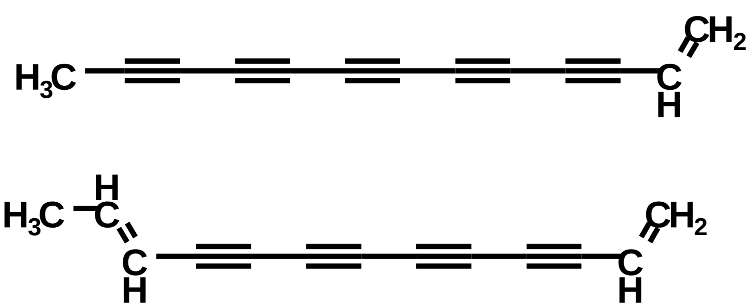
1,5-Hexadiin

# 4 Ungesättigte Kohlenwasserstoffe - Alkene

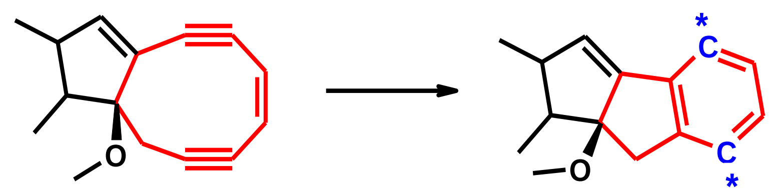
## 4.3 Alkine: sp-Hybridisierung




### Natürlich vorkommende Alkine




In Pflanzen: Molluskizide, Fungizide




Antitumor-Wirkung
vgl. Calicheamicin, Esperamicin

# Alkine: Reaktivität

- Elektrophile Addition an Alkine