

Composti aromatici

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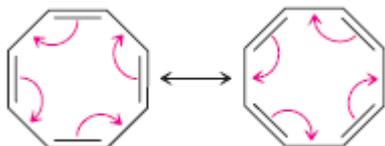
francesca.scaramuzzo@uniroma1.it

L'aromaticità



Ciclobutadiene:
instabile

Benzene:
aromatico



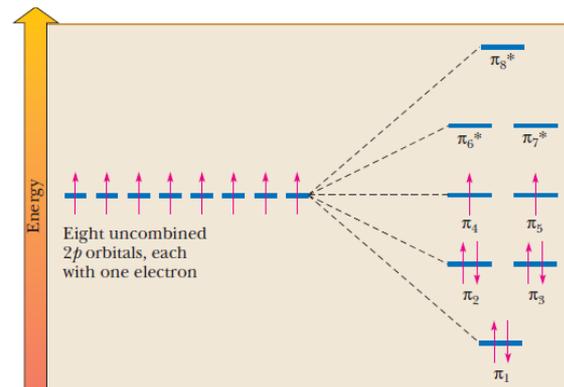
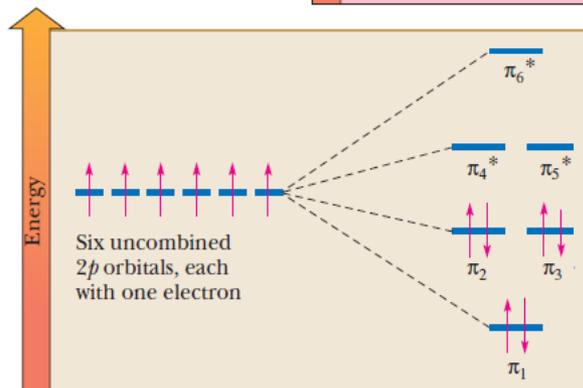
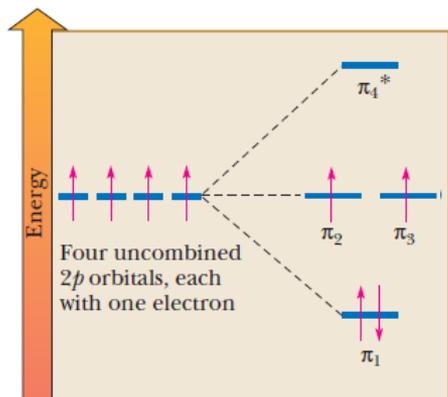
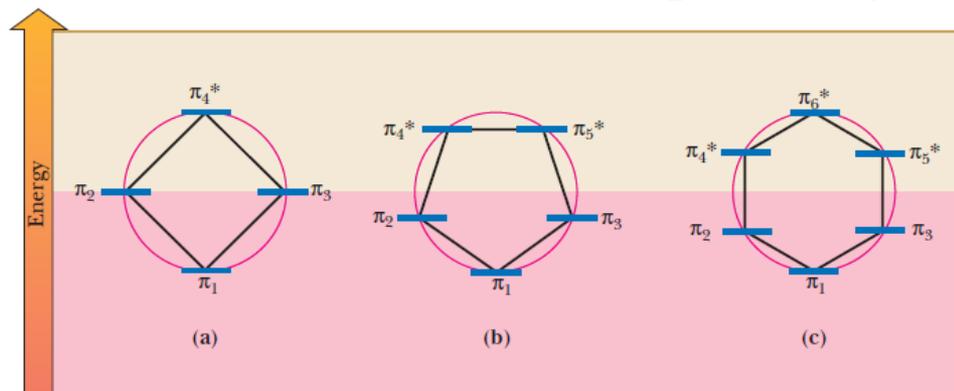
Cicloottatetraene:
alchene

Criterio di aromaticità di Hückel:

- Essere ciclico
- Avere un orbitale p su ciascun C dell'anello
- Essere planare o quasi planare
- Avere $4n + 2$ elettroni π nella distribuzione ciclica degli orbitali p

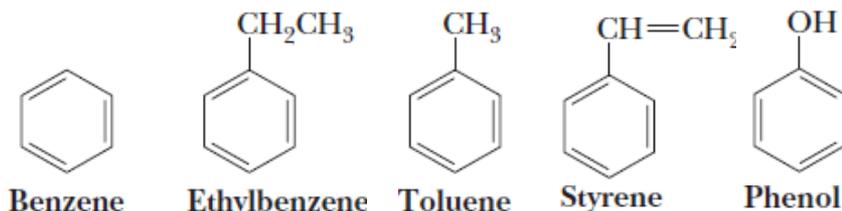
Composto antiaromatico: composto che soddisfa i primi 3 criteri dell'aromaticità di Hückel, ma ha $4n$ elettroni π nella distribuzione ciclica degli orbitali p

Circonferenza di Frost: modo grafico per determinare le energie relative degli orbitali molecolari π per composti planari, completamente coniugati e monociclici

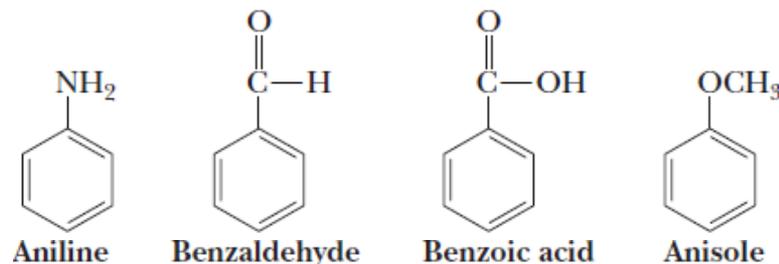


Nomenclatura

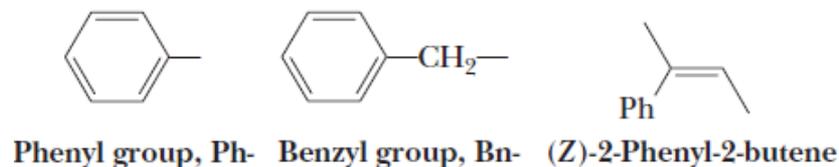
- **Alchilbenzeni monosostituiti:** denominati come derivati del benzene
- La IUPAC mantiene i nomi comuni per alchilbenzeni monosostituiti semplici



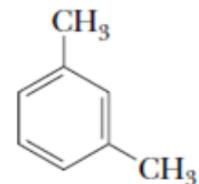
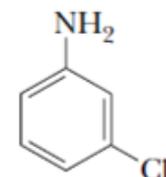
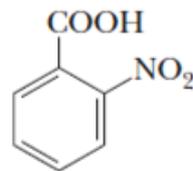
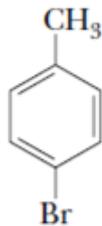
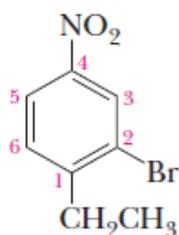
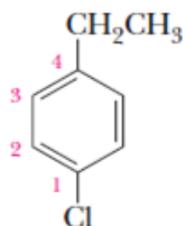
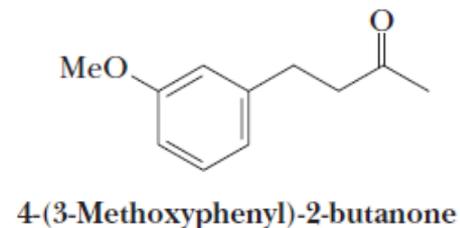
- **Gruppo fenile (-Ph):** gruppo arilico derivato togliendo -H dal benzene
- **Gruppo benzile (-Bn):** gruppo derivato dal toluene togliendo un -H dal suo gruppo metilico
- In presenza di altri gruppi funzionali, il gruppo -Ph è considerato un sostituito



- **Benzeni disostituiti:** posizione sostituenti definita da numeri o con termini orto (1,2), meta (1,3), para (1,4)



- **Benzeni polisostituiti:** posizione sostituenti definita da numeri
- Se uno dei sostituenti conferisce alla molecola un nome particolare, il composto viene denominato come un derivato della molecola con nome particolare



1-Chloro-4-ethylbenzene
(*p*-Chloroethylbenzene)

2-Bromo-1-ethyl-4-nitrobenzene

4-Bromotoluene
(*p*-Bromotoluene)

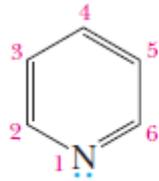
2-Nitrobenzoic acid
(*o*-Nitrobenzoic acid)

3-Chloroaniline
(*m*-Chloroaniline)

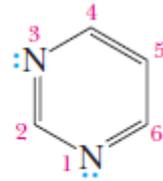
m-Xylene

Nomenclatura

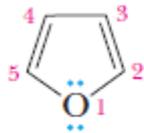
- Composti eteroaromatici:** composti aromatici in cui almeno uno dei vertici è occupato da un eteroatomo



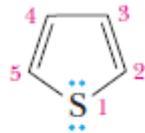
Pyridine



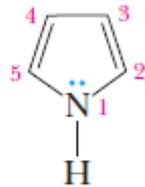
Pyrimidine



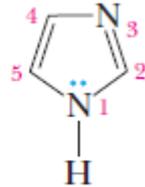
Furan



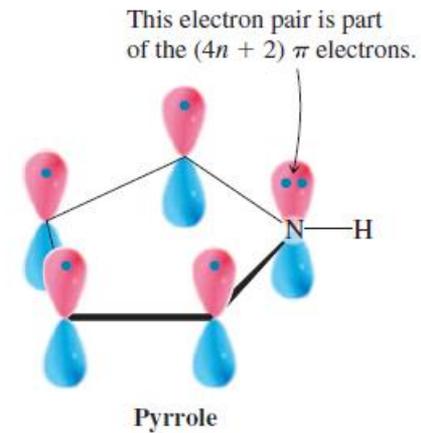
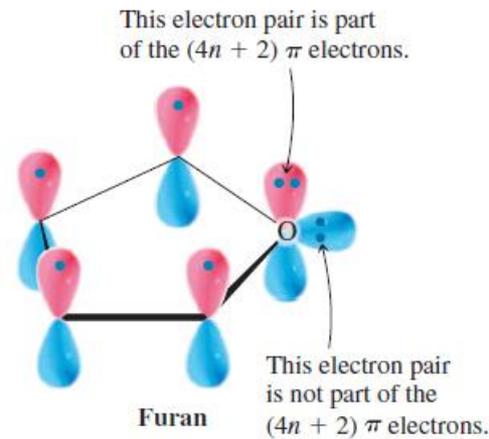
Thiophene



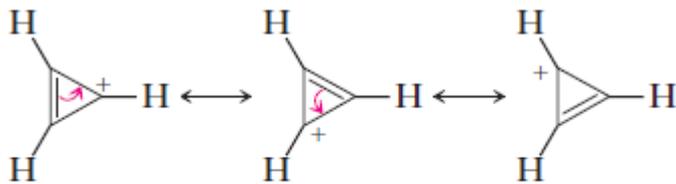
Pyrrole



Imidazole

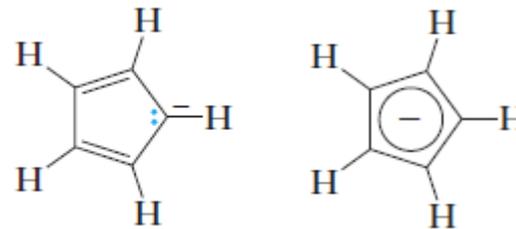


- Ioni aromatici**

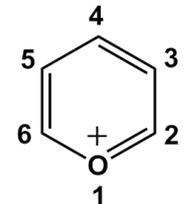


Cyclopropenyl cation

(a hybrid of three equivalent contributing structures)



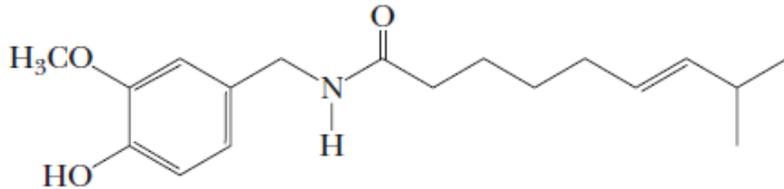
Cyclopentadienyl anion



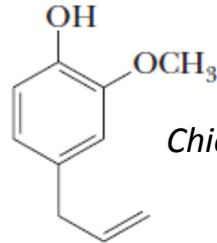
Pyrylium cation

I composti aromatici in natura e in chimica farmaceutica

Metaboliti vegetali

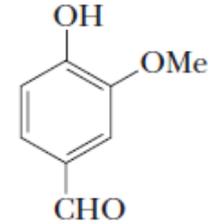


Capsaicin
(from various types of peppers)



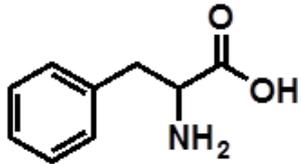
Eugenol

*Chiodi di garofano
analgesico*

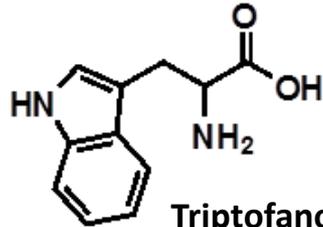


**4-Hydroxy-3-methoxybenzaldehyde
(Vanillin)**

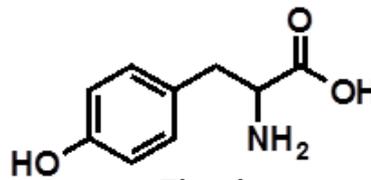
Amminoacidi



Fenilalanina

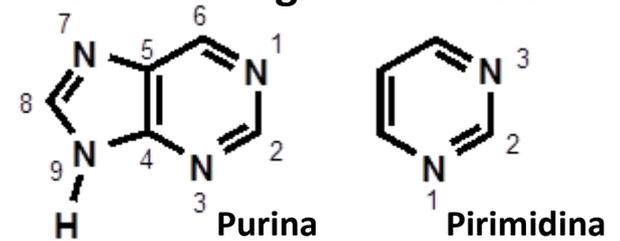


Triptofano



Tirosina

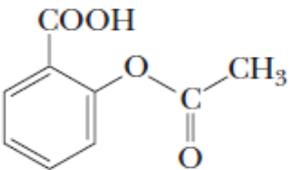
Basi azotate degli acidi nucleici



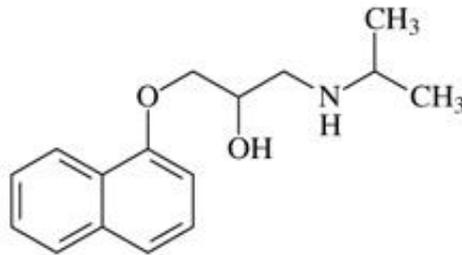
Purina

Pirimidina

Farmaci

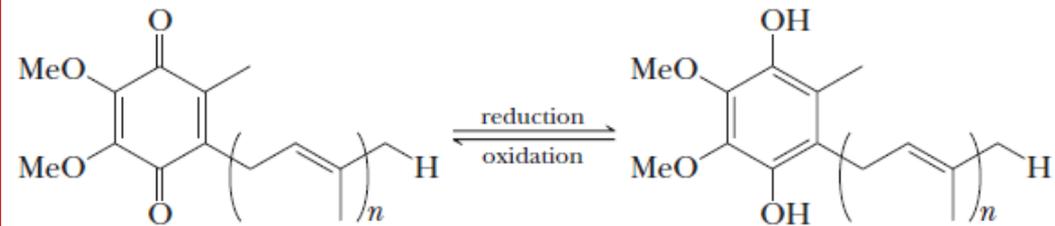


**Acetylsalicylic
acid
(Aspirin)**



Propranololo

Trasportatori di elettroni

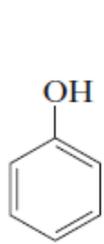


**Coenzyme Q
(oxidized form)**

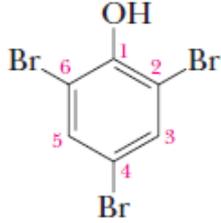
**Coenzyme Q
(reduced form)**

Fenoli

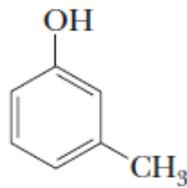
Fenolo: composto che contiene un gruppo –OH legato a un anello aromatico



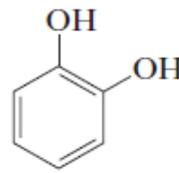
Phenol



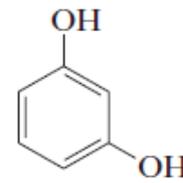
2,4,6-Tribromophenol



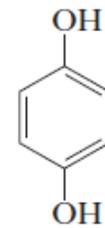
3-Methylphenol
(*m*-Cresol)



1,2-Benzenediol
(Catechol)

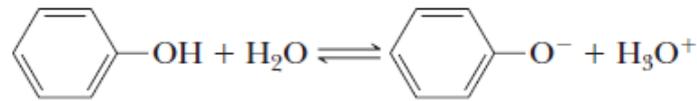


1,3-Benzenediol
(Resorcinol)



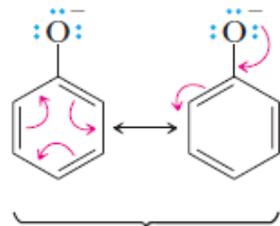
1,4-Benzenediol
(Hydroquinone)

Acidità dei fenoli

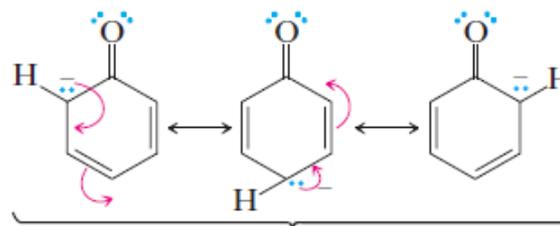


- Effetto induttivo elettrone-attrattore di C sp²

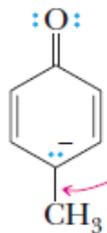
- Delocalizzazione di carica



These two Kekulé structures are equivalent

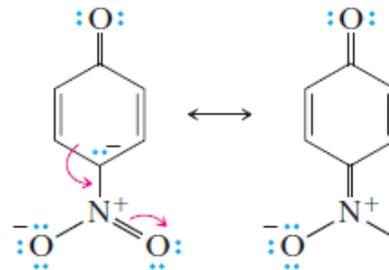


These three contributing structures delocalize the negative charge onto carbon atoms of the ring



Polarization of this C—C bond by the electron-releasing inductive effect of the sp³ carbon of the methyl group destabilizes this contributing structure

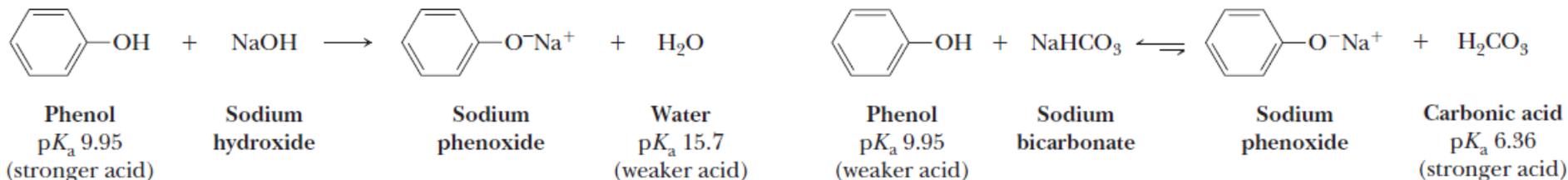
pK_a 10.17



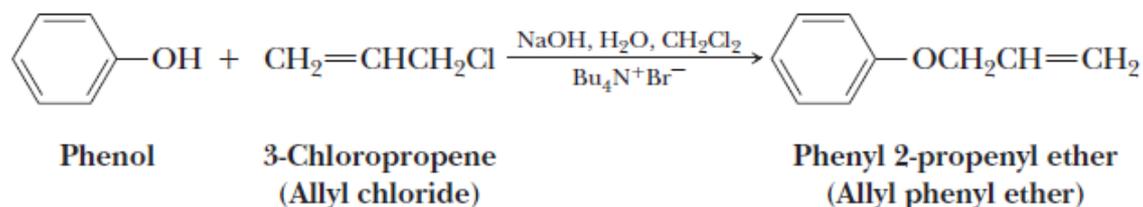
Delocalization of negative charge onto oxygen further increases the resonance stabilization of phenoxide ion

pK_a 7.15

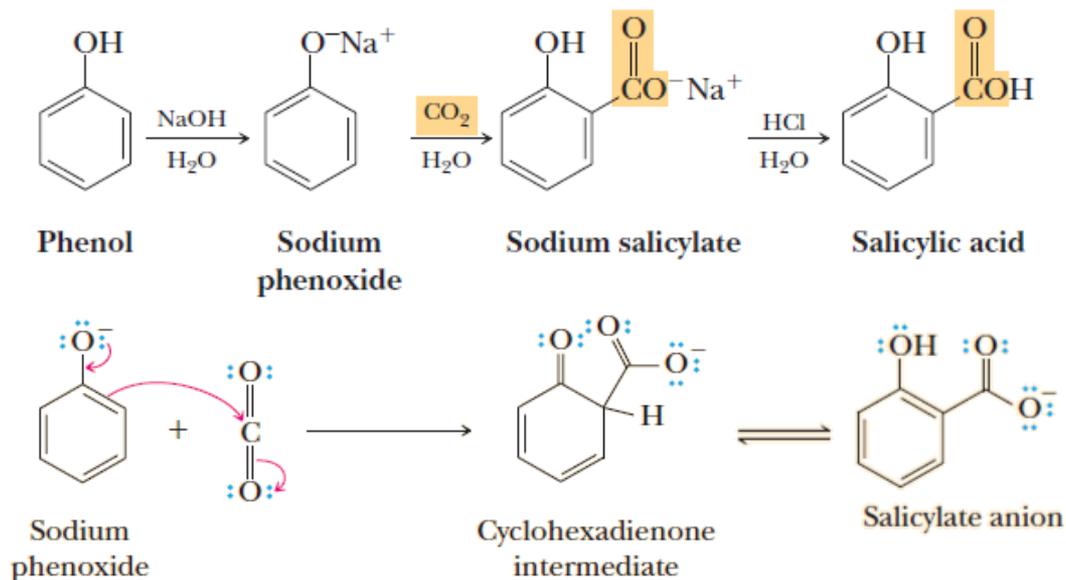
Reazioni acido-base dei fenoli



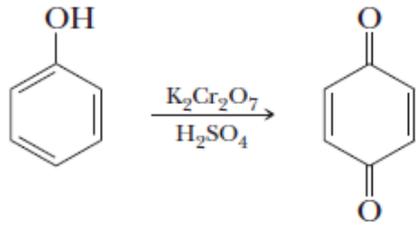
Preparazione di eteri alchil-arilici



Carbossilazione di Kolbe

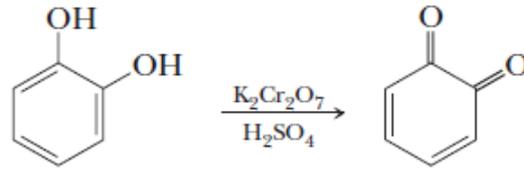


Ossidazione a chinoni



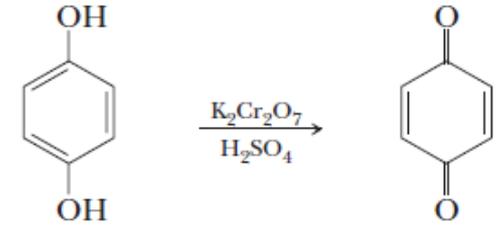
Phenol

1,4-Benzoquinone
(*p*-Quinone)



1,2-Benzenediol
(Catechol)

1,2-Benzoquinone
(*o*-Quinone)

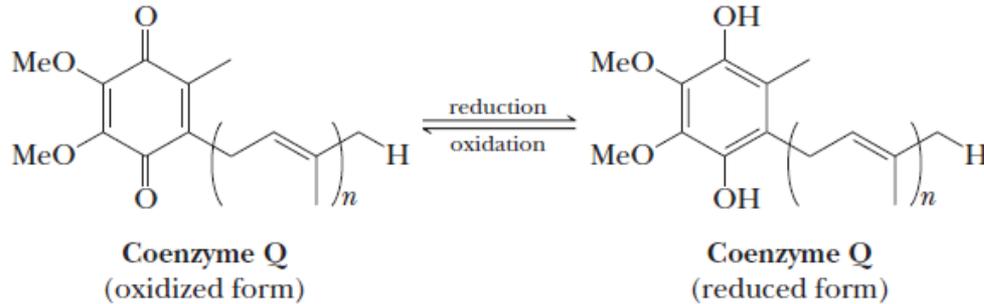


1,4-Benzenediol
(Hydroquinone)

1,4-Benzoquinone
(*p*-Quinone)

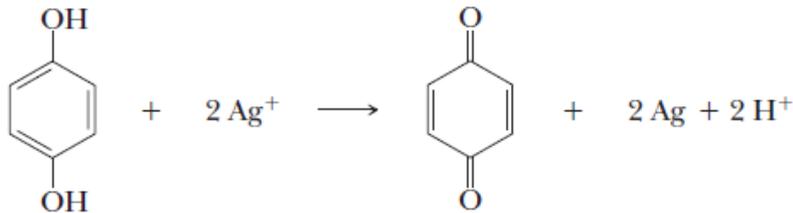
$$6 < n < 10$$

- Ancorato nella membrana mitocondriale interna
- Trasportatore di e^- nella catena respiratoria



Coenzyme Q
(oxidized form)

Coenzyme Q
(reduced form)

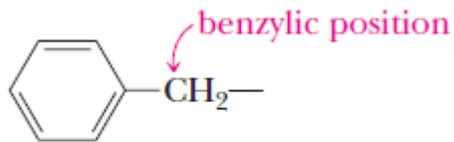


1,4-Benzenediol
(Hydroquinone)

1,4-Benzoquinone
(*p*-Quinone)

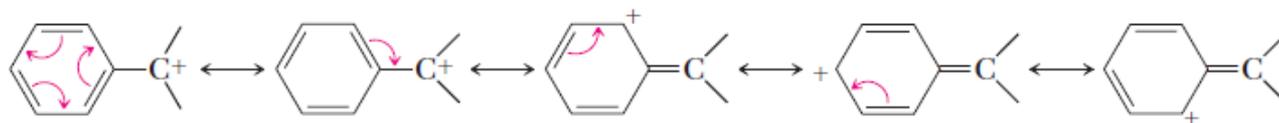
- Reazione utilizzata per sviluppare fotografie b/n

Reazioni in posizione benzilica

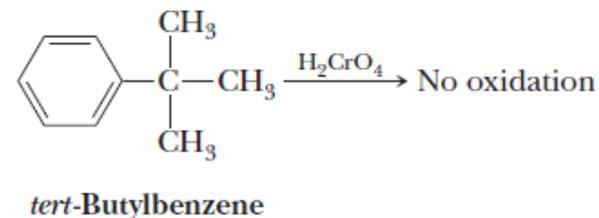
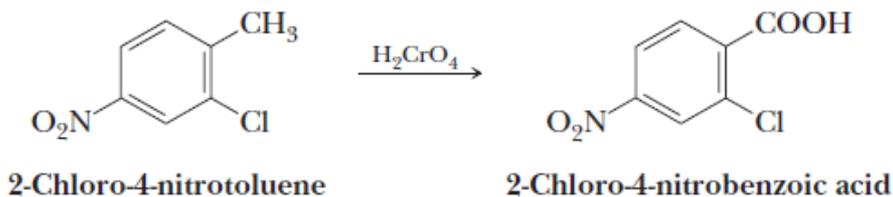


Benzyl group

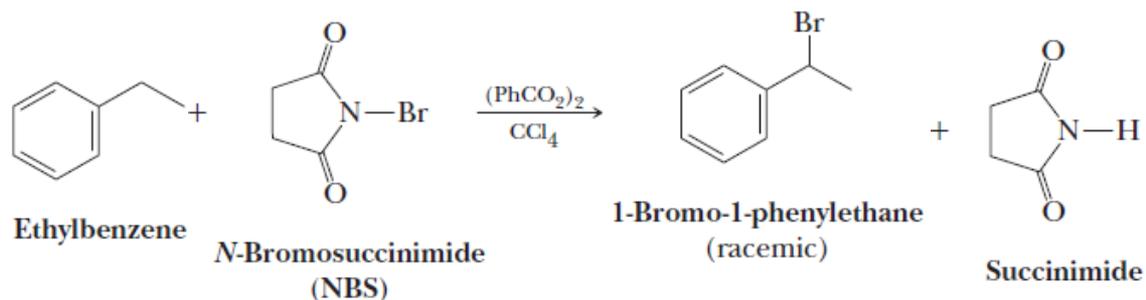
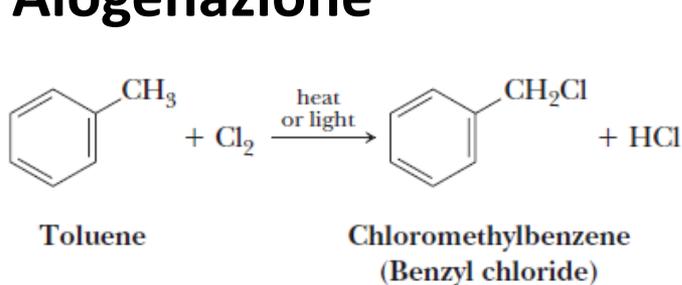
C benzilico: C sp³ legato a un anello benzenico



Ossidazione

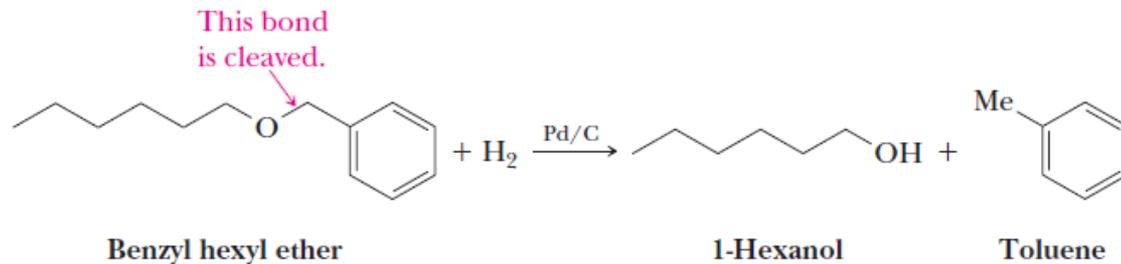


Alogenazione



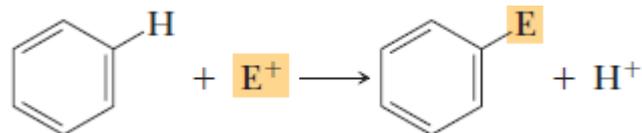
Reazione regioselettiva

Idrogenolisi di eteri benzilici

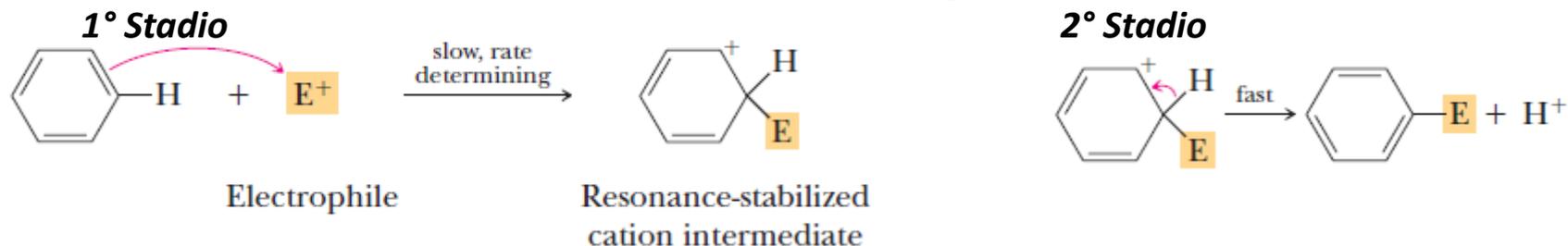


Sostituzione elettrofila aromatica

Reazione su un anello aromatico nella quale un -H viene sostituito da un elettrofilo

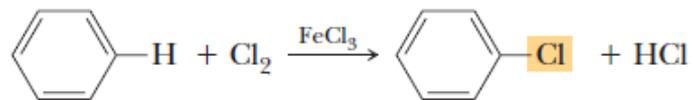


Meccanismo generale



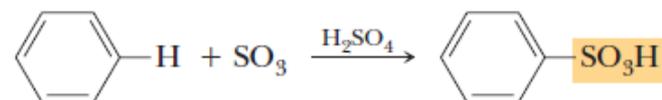
Esempi

Halogenation:



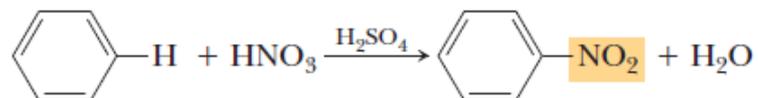
Chlorobenzene

Sulfonation:



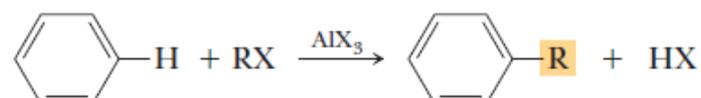
Benzenesulfonic acid

Nitration:



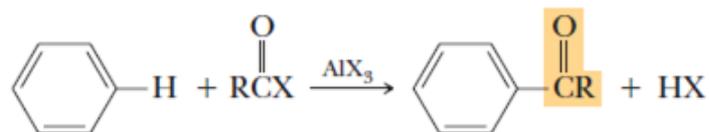
Nitrobenzene

Alkylation:



An alkylbenzene

Acylation:

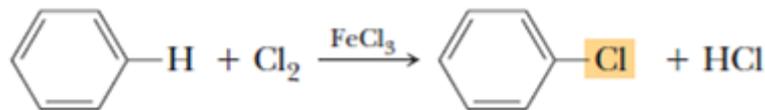


An acylbenzene

Sostituzione elettrofila aromatica

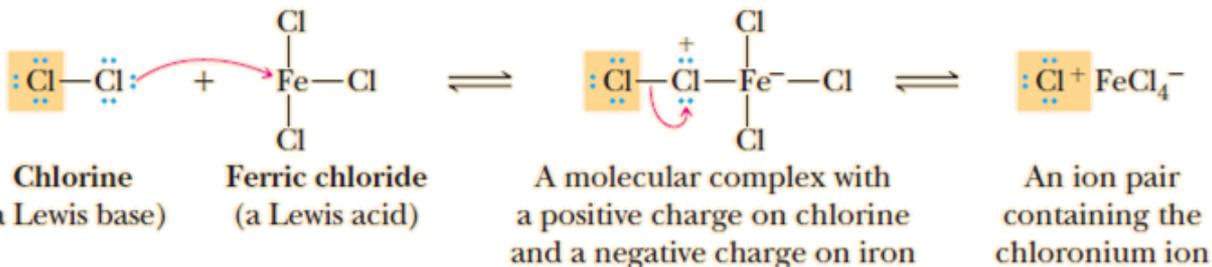
Reazione su un anello aromatico nella quale un -H viene sostituito da un elettrofilo

Clorurazione

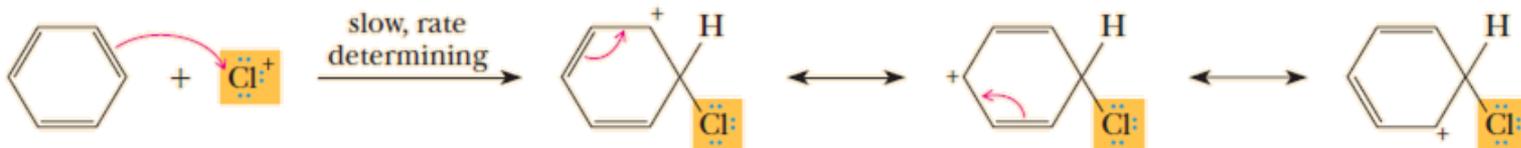


Chlorobenzene

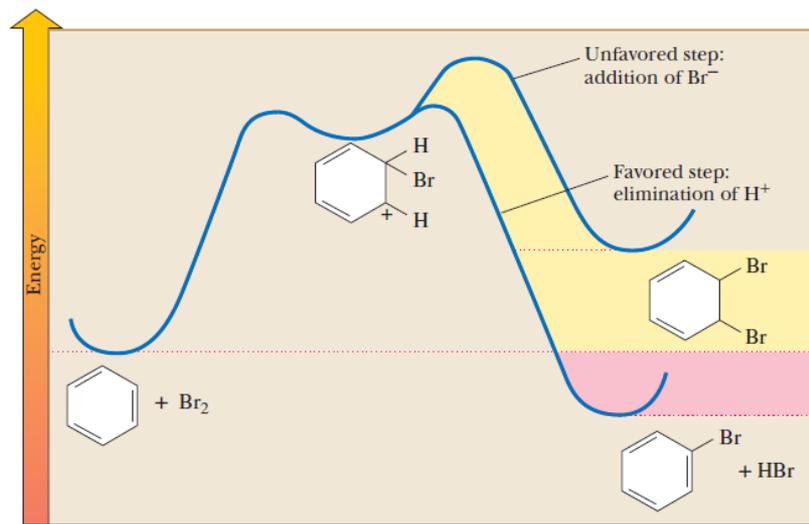
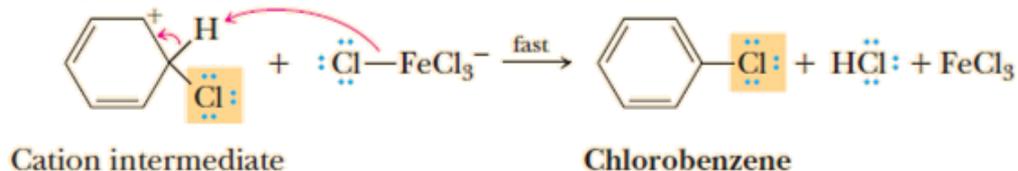
1° Stadio



2° Stadio



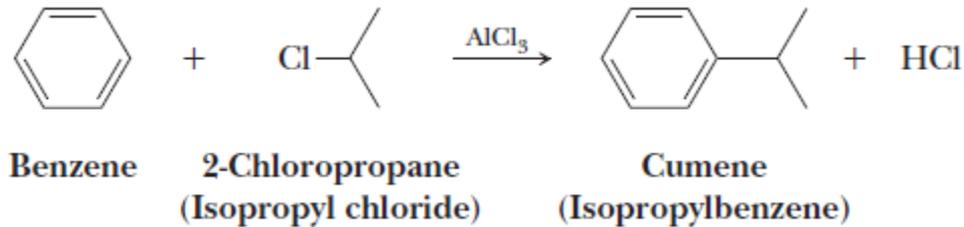
3° Stadio



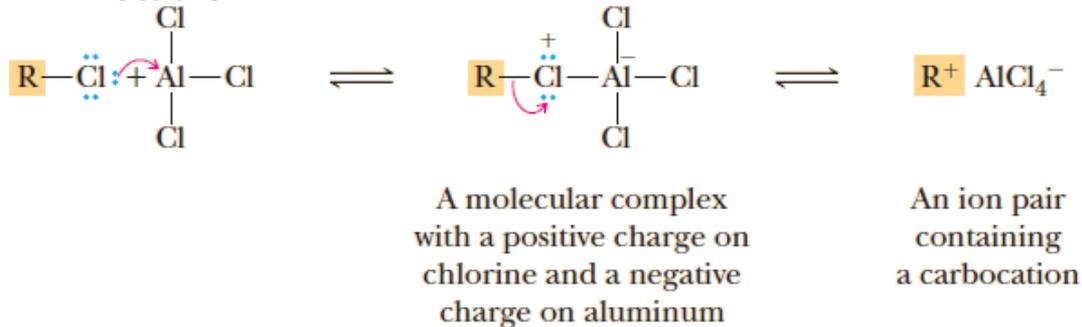
Sostituzione elettrofila aromatica

Reazione su un anello aromatico nella quale un -H viene sostituito da un elettrofilo

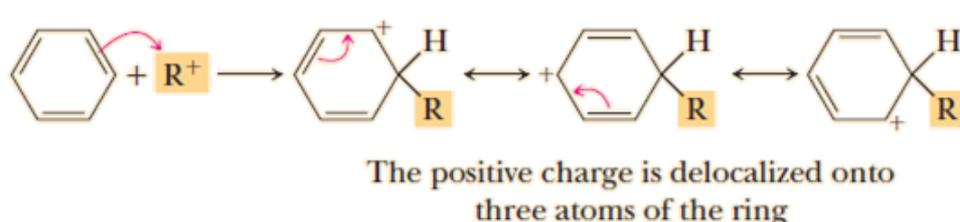
Alchilazione di Friedel-Crafts



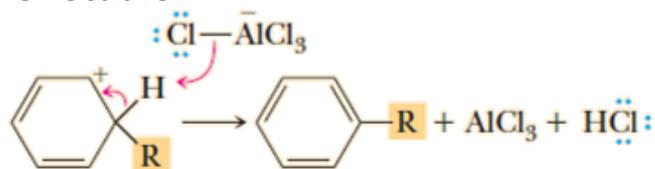
1° Stadio



2° Stadio



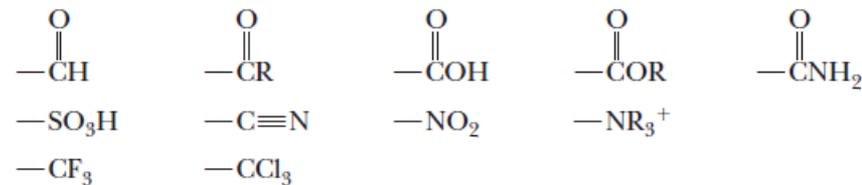
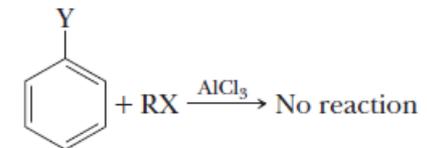
3° Stadio



- Sono possibili riarrangiamenti

La reazione non è fattibile in presenza di:

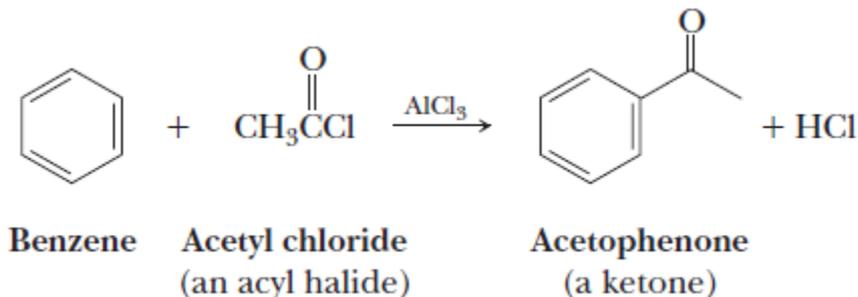
- alogenuri vinilici e arilici
- sostituenti elettron-attrattori sull'anello



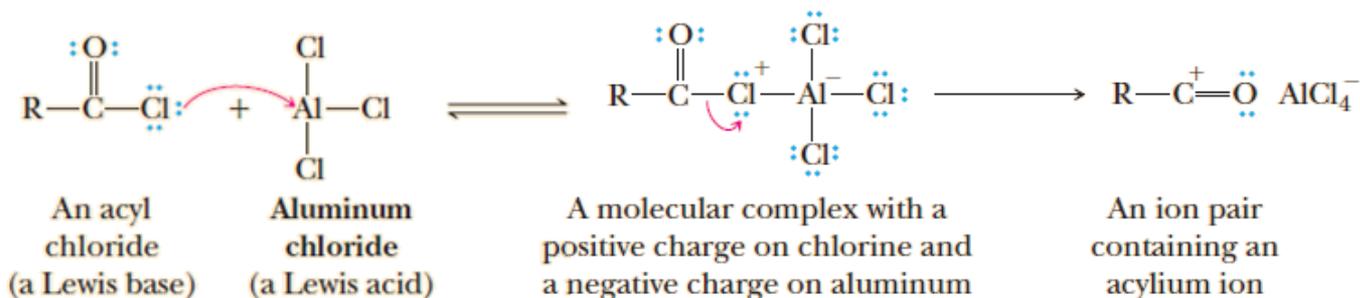
Sostituzione elettrofila aromatica

Reazione su un anello aromatico nella quale un -H viene sostituito da un elettrofilo

Acilazione di Friedel-Crafts

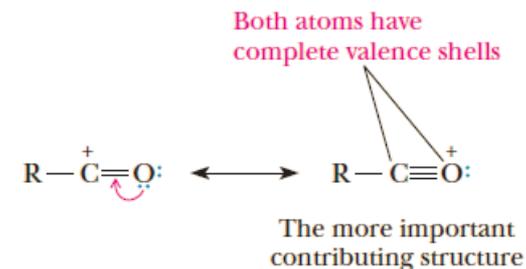


1° Stadio



2° e 3° stadio sono simili all'alchilazione

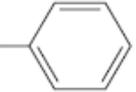
Ione acilonio: catione stabilizzato per risonanza con struttura $[\text{RC}=\text{O}]^+$ o $[\text{ArC}=\text{O}]^+$



L'acilazione non ha le limitazioni dell'alchilazione

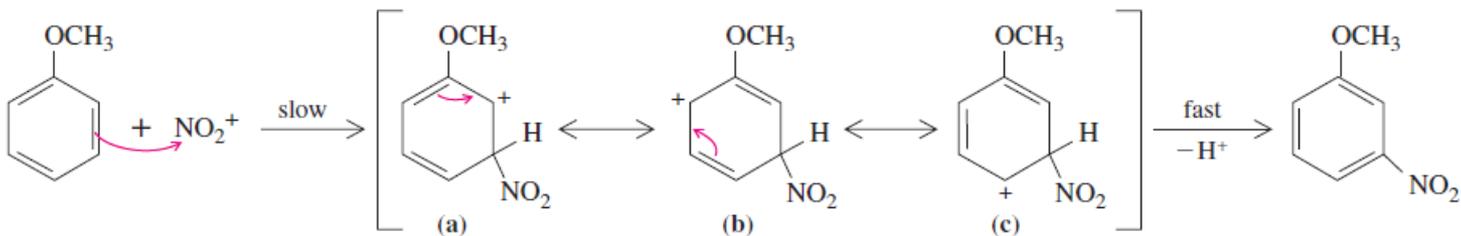
Polisostituzioni

- La sostituzione elettrofila aromatica su un benzene monosostituito può portare al prodotto orto, meta o para sostituito
- I sostituenti influenzano l'orientazione dei nuovi gruppi
 - Sostituenti orto-para orientanti
 - Sostituenti meta orientanti
- I sostituenti influenzano la velocità delle ulteriori sostituzioni
 - Sostituenti attivanti
 - Sostituenti disattivanti

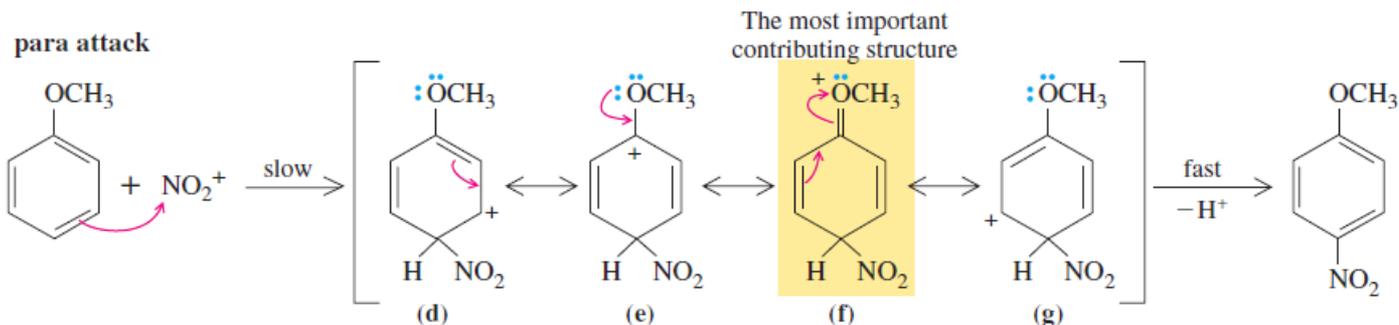
Ortho-Para Directing	Strongly activating	$-\ddot{\text{N}}\text{H}_2$	$-\ddot{\text{N}}\text{HR}$	$-\ddot{\text{N}}\text{R}_2$	$-\ddot{\text{O}}\text{H}$	$-\ddot{\text{O}}\text{R}$	Relative importance in directing further substitution 		
	Moderately activating	$-\ddot{\text{N}}\text{H}\overset{\text{O}}{\parallel}\text{CR}$	$-\ddot{\text{N}}\text{H}\overset{\text{O}}{\parallel}\text{CAr}$	$-\ddot{\text{O}}\overset{\text{O}}{\parallel}\text{CR}$	$-\ddot{\text{O}}\overset{\text{O}}{\parallel}\text{CAr}$				
	Weakly activating	$-\text{R}$							
	Weakly deactivating	$-\ddot{\text{F}}:$	$-\ddot{\text{Cl}}:$	$-\ddot{\text{Br}}:$	$-\ddot{\text{I}}:$				
Meta Directing	Moderately deactivating	$-\overset{\text{O}}{\parallel}\text{CH}$	$-\overset{\text{O}}{\parallel}\text{CR}$	$-\overset{\text{O}}{\parallel}\text{COH}$	$-\overset{\text{O}}{\parallel}\text{COR}$	$-\overset{\text{O}}{\parallel}\text{CNH}_2$		$-\overset{\text{O}}{\parallel}\text{SOH}$	$-\text{C}\equiv\text{N}$
	Strongly deactivating	$-\text{NO}_2$	$-\text{NH}_3^+$	$-\text{CF}_3$	$-\text{CCl}_3$				

Polisostituzioni

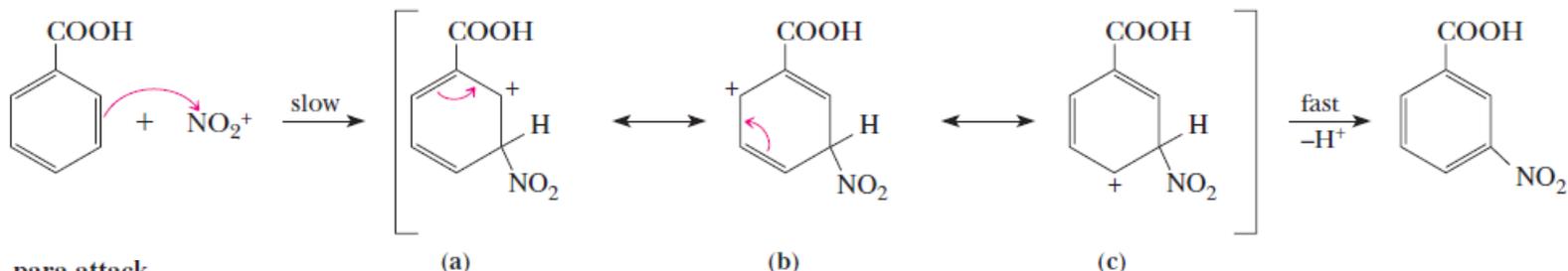
meta attack



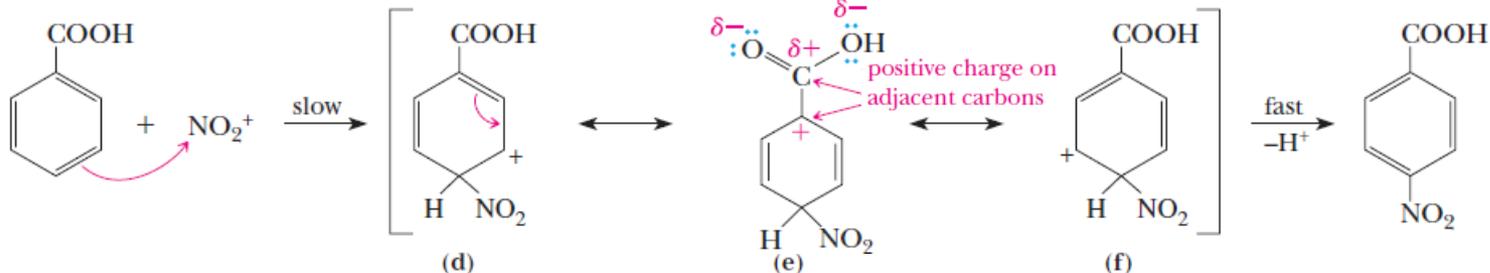
para attack



meta attack



para attack

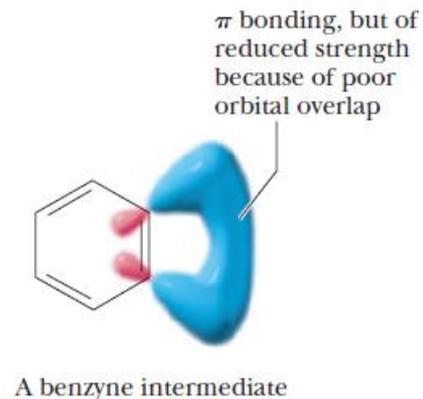
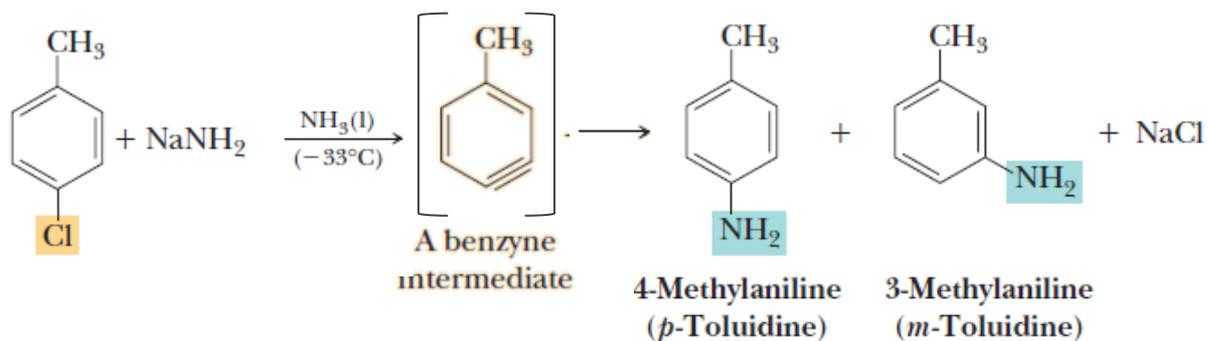


The most disfavored
contributing structure

Sostituzione nucleofila aromatica

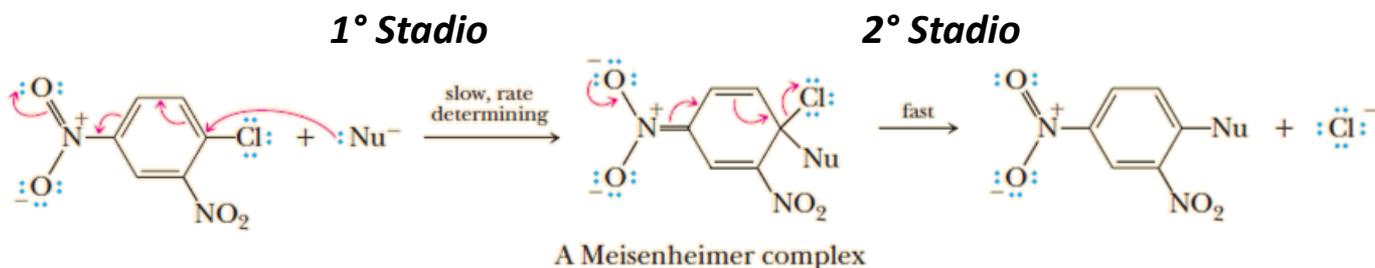
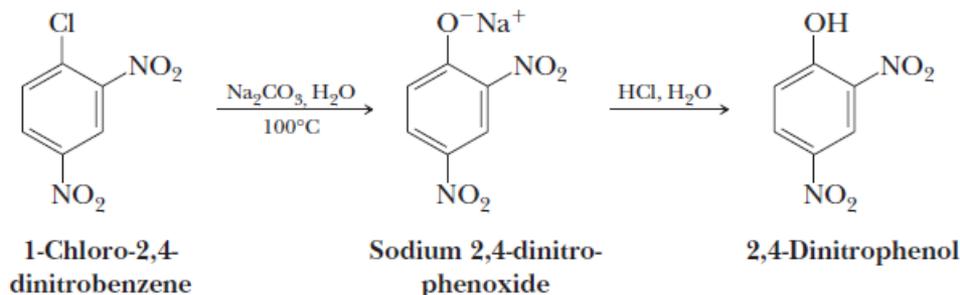
Reazione nella quale un nucleofilo legato ad un anello aromatico viene sostituito da un altro nucleofilo

Sostituzione nucleofila via intermedio benzino



Sostituzione nucleofila mediante addizione-eliminazione

In presenza di gruppi nitro in orto o in para rispetto all'alogeno



Esercizi riassuntivi

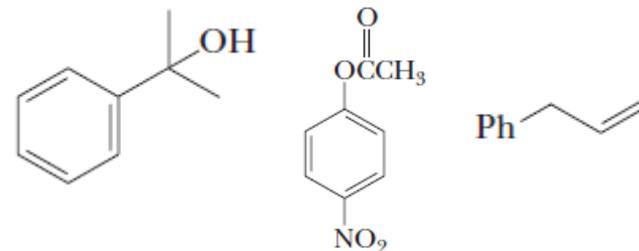
Esercizio

Scrivere le formule di struttura dei seguenti composti:

- a) 3,4-dimetossibenzaldeide
- b) etil-4-amminobenzoato

Esercizio

Scrivere i nomi dei seguenti composti

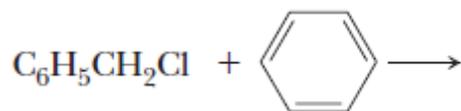


Esercizio

Scrivere le formule di struttura dei seguenti composti: fenolo, 2,4-dinitrofenolo, alcol benzilico. Disporre i 3 composti in ordine di acidità crescente e giustificare la risposta.

Esercizio

Completare la seguente alchilazione di Friedel Crafts e scrivere i nomi di reagenti e prodotto



Esercizio

Quale prodotto si ottiene per vigorosa ossidazione dell'1,4-dimetilbenzene (p-xilene) in acido cromico? Scrivere le formule di struttura di reagenti e prodotti.

Esercizio

Completare le seguenti reazioni di sostituzione elettrofila aromatica e scrivere i nomi di reagenti e prodotto/i

