Development of Complex Curricula for Molecular Bionics and Infobionics Programs within a consortial* framework**

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**Molekuláris bionika és Infobionika Szakok tananyagának komplex fejlesztése konzorciumi keretben

***A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg.

WORLD OF MOLECULES

(Molekulák Világa)

Chemical reaction types, energy involvement; reactivity and stability

(A kémiai reakciók és típusaik, energiaviszonyaik; reaktivitás és stabilitás)

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Formatted by dr. Balázs Balogh

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Ad. 2.

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- Nucleophilic substitution
- Elimination
- Reduction
- Oxidation

Classification of reactions

Substitution reactions
Elimination reactions
Addition reactions

From a kinetical point of views - molecularity
bimolecular (polymolecular)
monomolecular (or unimolecular)
How many molecules construct the activated complex.

Kinetical order ≠ molecularity!
(although accidentally it *might be*)

According to the attacking agent:

nucleophile	N
electrophile	E
radical	R

Main types

Ad – addition
S – subtitution
E – elimination

N – nuclephilic
E – electophilic
cb – conjugate Base

1 – unimolecular
2 – bimolecular

Types: according to INGOLD

Substitution

S_N1 , S_N2 **S_E1 , S_E2**

Elimination

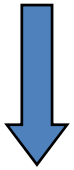
E1 , E2 , E1cb

Addition

electrophile (or electrophilic reagent) is a reagent
that forms a bond to its reaction partner (the nucleophile)
by accepting both bonding electrons from that reaction partner

Ad_N , Ad_E , Ad_R

X –Y formation of a new covalent bond



1. X: + Y nucleophile/electrophile
2. Y: + X nucleophile/electrophile
3. Y· + X· radical

An **electrophile** (or electrophilic reagent) is a reagent that forms a bond to its reaction partner (the nucleophile) by *accepting* both bonding electrons from that reaction partner

A **nucleophile** (or nucleophilic reagent) is a reagent that forms a bond to its reaction partner (the electrophile) by *donating* both bonding electrons.

Radical (or free radical) is a molecular entity possessing an *unpaired electron*. In a radical reaction, the reaction may occur between a radical and a non-radical, or between two radicals.

Electrophilic and nucleophilic reagents

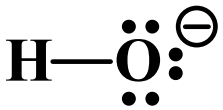
The most organic chemical reactions take place between an electron-rich and an electron-poor partner.

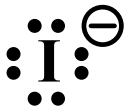
⇒ Nucleophile ⟶ Nucleophilic center
Electrophile ⟶ Electrophilic center

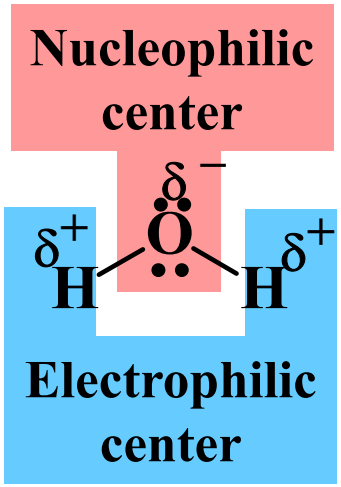
Reaction: nucleophilic - electrophilic centers

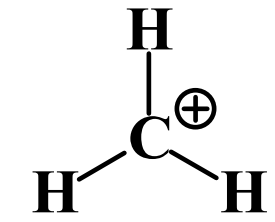
Mechanism:

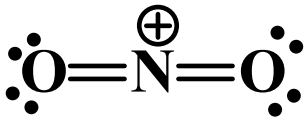
is dealing with the electrons taking part in the formation (or cleavage) of the bond. The story of the reaction.
Curved arrows are used for drawings.

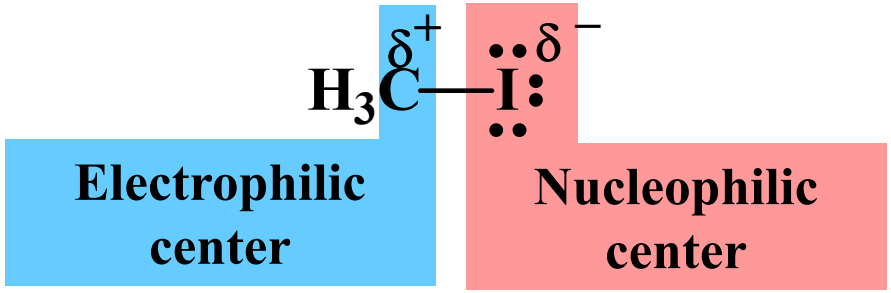





Nucleophilic center
δ −
δ+
O
δ+
H
H
Electrophilic center



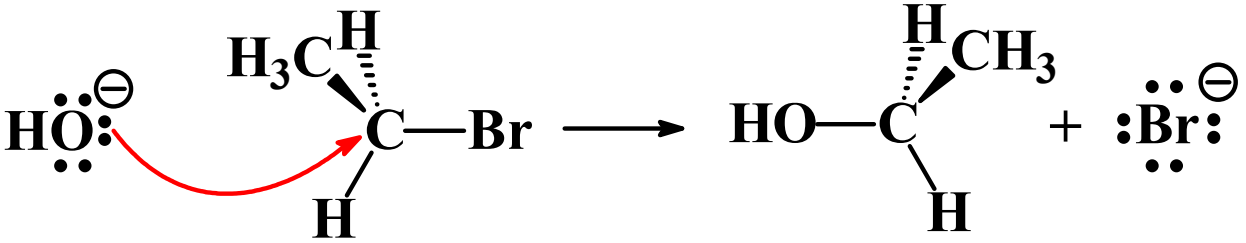


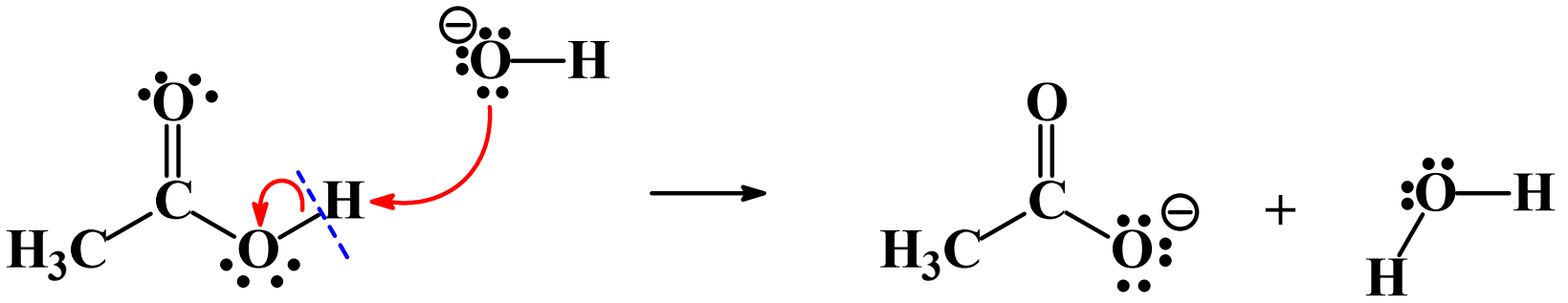

δ+
δ −
H3C—I
Electrophilic center
Nucleophilic center

$CH_3–CH_2–CH_3$

Drawing mechanism = curved arrow shows the electron movement starting on the electron source

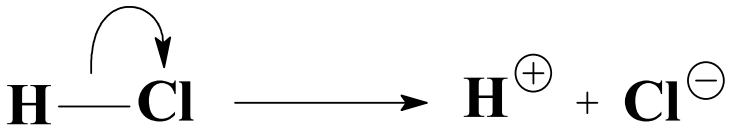
- pointing to the centre of the new bond (in case of bond formation)
- pointing to the corresponding atom (in case of lone electron pair formation)



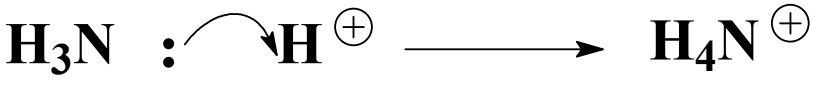


Curly arrows and fishhooks are the conventional ways of depicting electron movements for pairs of electrons and single electron respectively.

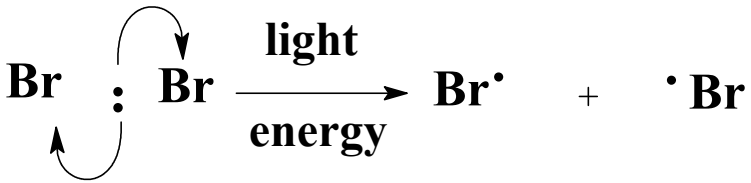
Examples: bond breaking



bond making



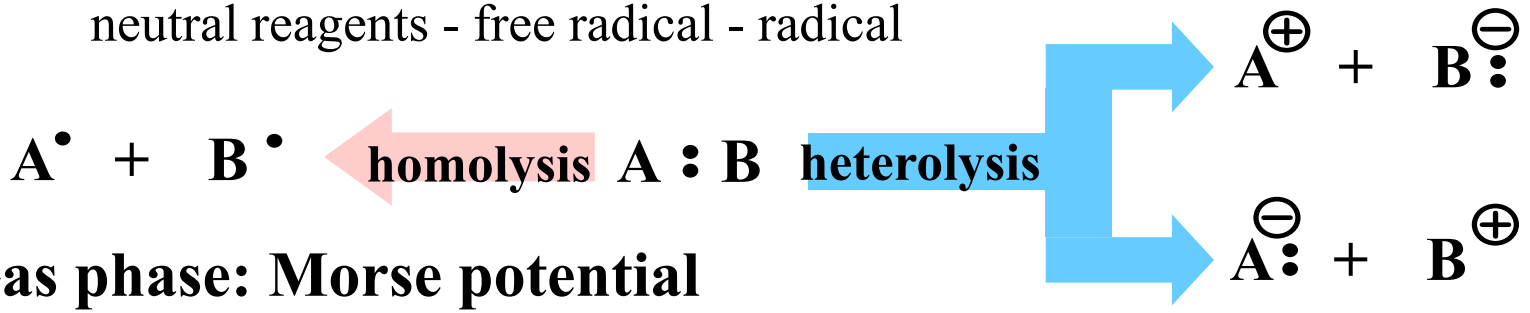
both



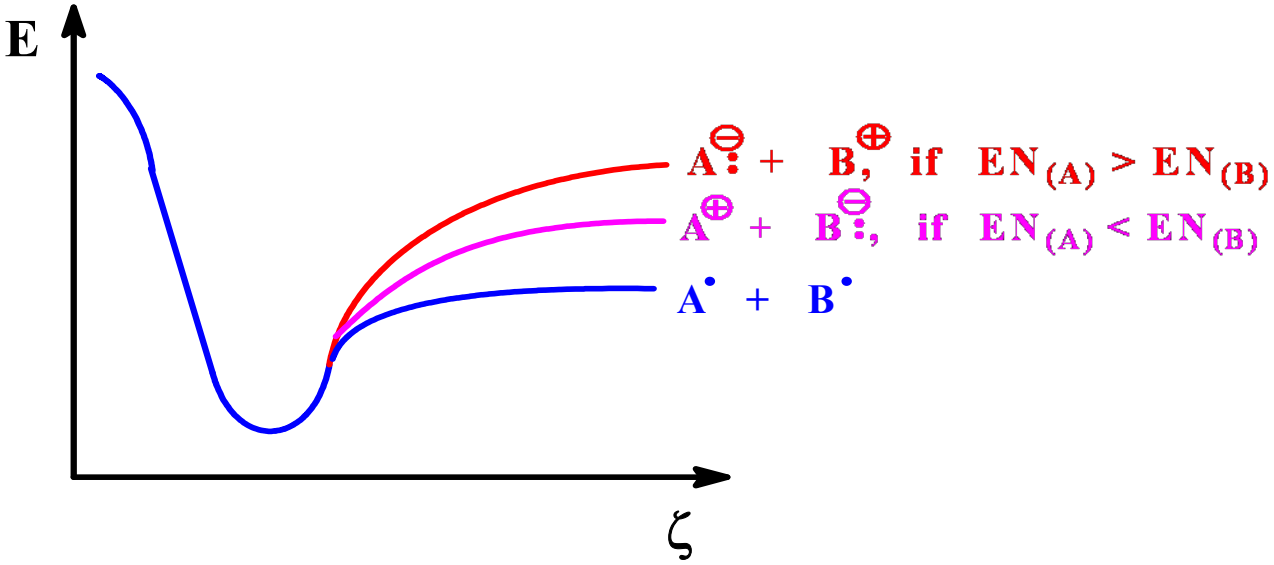
Reagent types:

Ionic reagents - electrophilic, nucleophilic reagents

neutral reagents - free radical - radical



Gas phase: Morse potential



$$E_N = f \frac{(IP + EA)}{2} \qquad f \sim 1/2$$

C	2.5	N	3.0
H	2.1	O	3.5
Li	1.0	F	4.0
K	0.8	Cl	3.0
Na	0.9	Br	2.8

Ionic character:

$$|\delta| = 1 - e^{-1/4[\Delta(E_N)]}$$

Electronegativity of groups

(H=2.176)

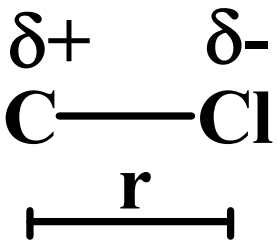
CH_3-	2.473	CCl_3-	2.666
CH_3CH_2-	2.482	C_6H_5-	2.717
CH_2Cl-	2.538	CF_3-	2.985
$CHCl_2-$	2.602	$CN-$	3.208
CBr_3-	2.561	NO_2-	3.421

NaCl

$$\Delta(E_N) = 3.0 - 0.9 = 2.1$$

C-Cl

$$\Delta(E_N) = 3.0 - 2.5 = 0.5$$



$$\vec{\mu} = |\delta| \vec{r}$$

dipole moment (polarity of bonds)

$\mu = Q \times r$

$e^- = 1{,}6 \times 10^{-19}$ Coulomb

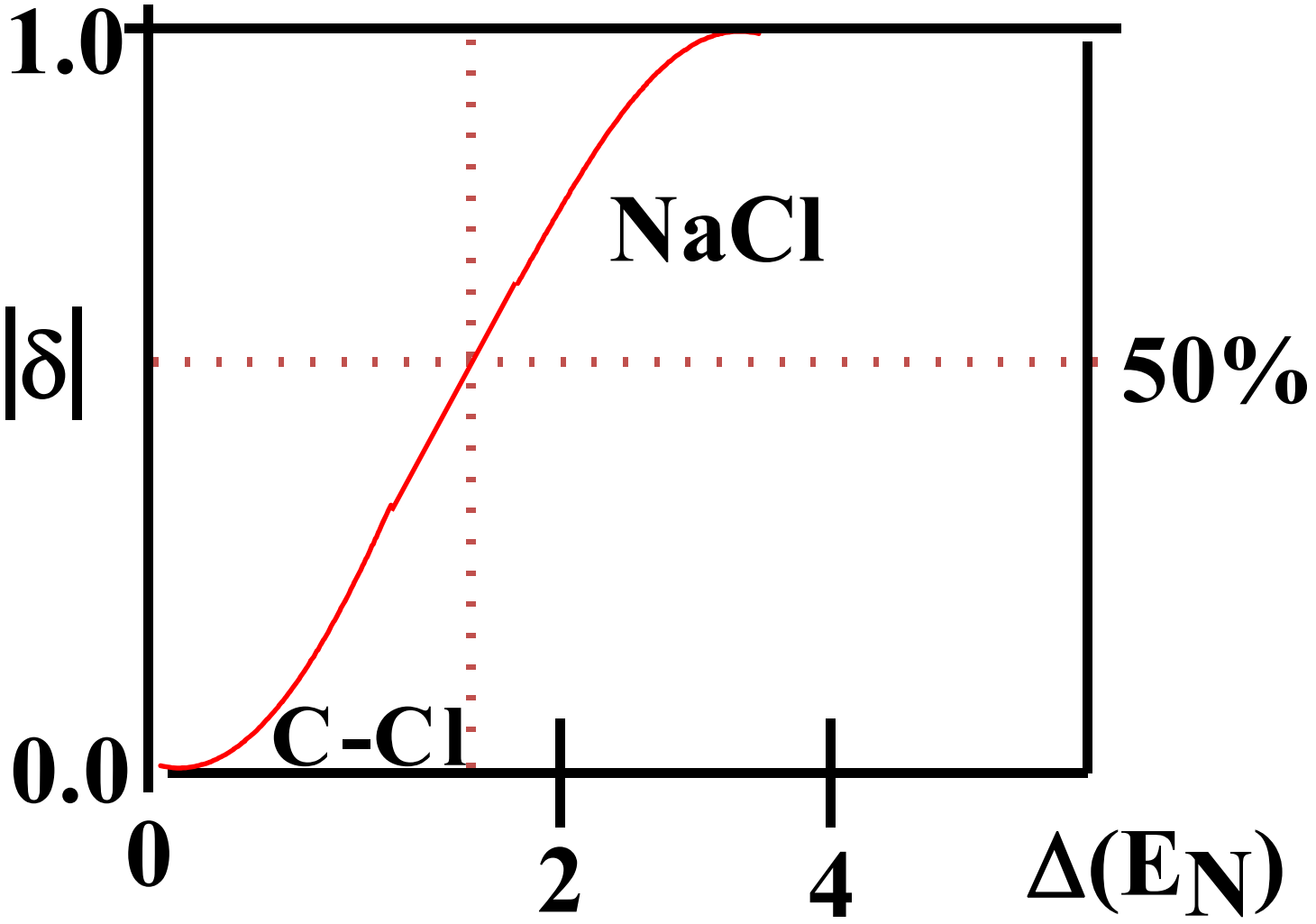
1 Debye = $3{,}336 \times 10^{-30}$ C m

Debye = D

Coulomb = C

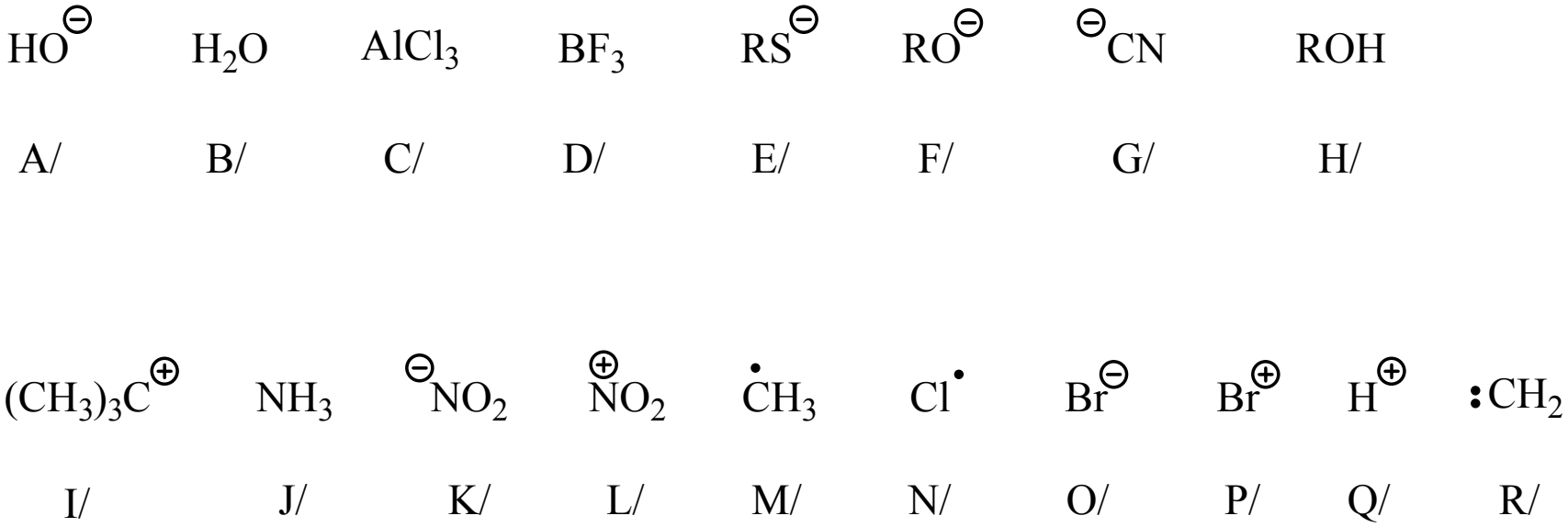
Dipole moment is a vector quantity, the vector product of which with the electric field strength, E, of a homogeneous field is equal to the torque. $T = p \times E$. The direction of the dipole moment is from the negative to the positive charge.

Debye is a non-SI unit of electric dipole moment. It is equal to the electric dipole moment for two charges of 10^{-10} franklin separated by 1 ångström, $D = 10^{-18}$ Fr cm $\approx 3.335\,64 \times 10^{-30}$ C m

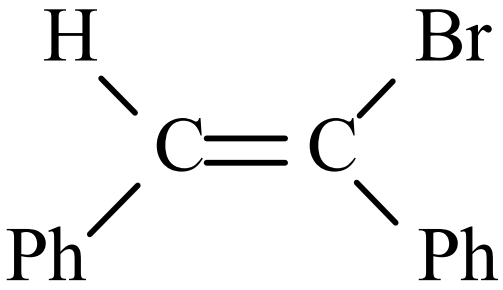

1.0
|δ|
0.0
NaCl
50%
C-Cl
0
2
4
Δ(EN)

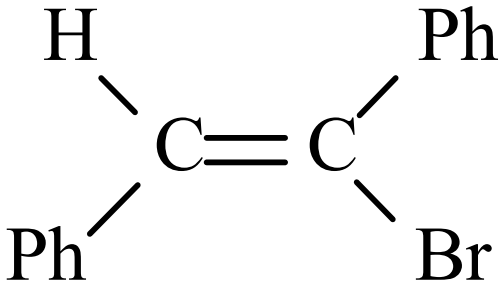
Some example and application on several reaction types

Arrange the following reagents: are they *electrophile*, *nucleophile*, or *radical?*

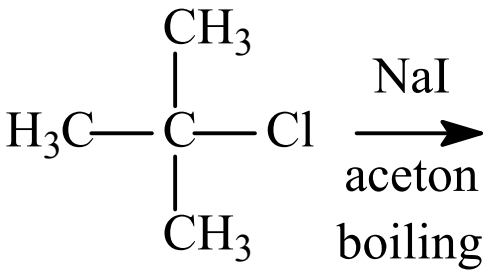


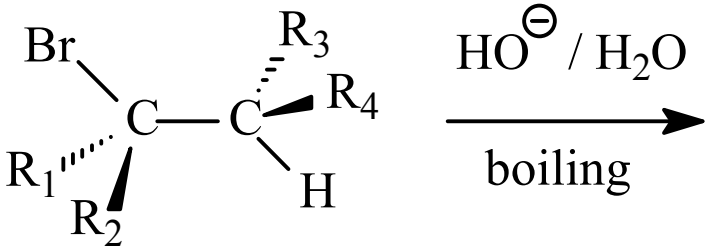
How would you prepare the following alkenes from dibromoethane? What is the stereochemical requirement of the reaction?



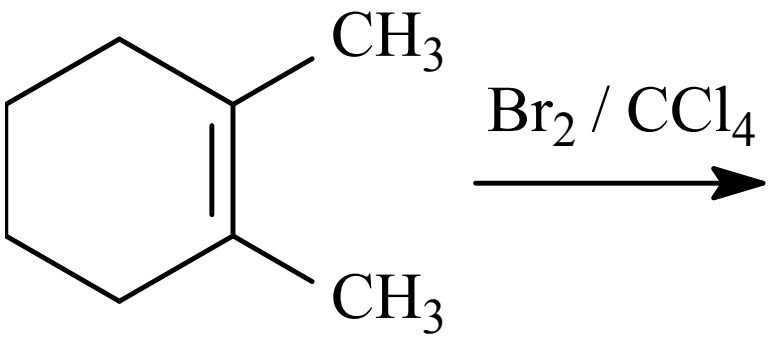


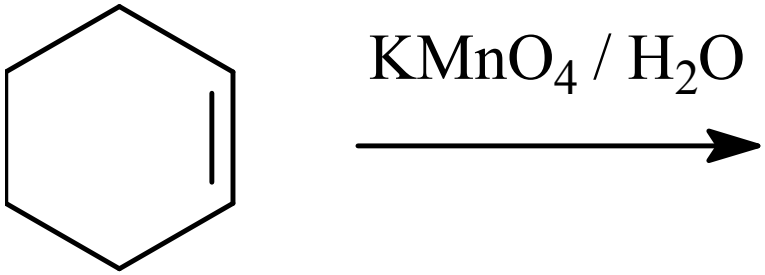
A/ Give the products of the following reactions!
B/ What is the molecularity and kinetics of them?

I/ 

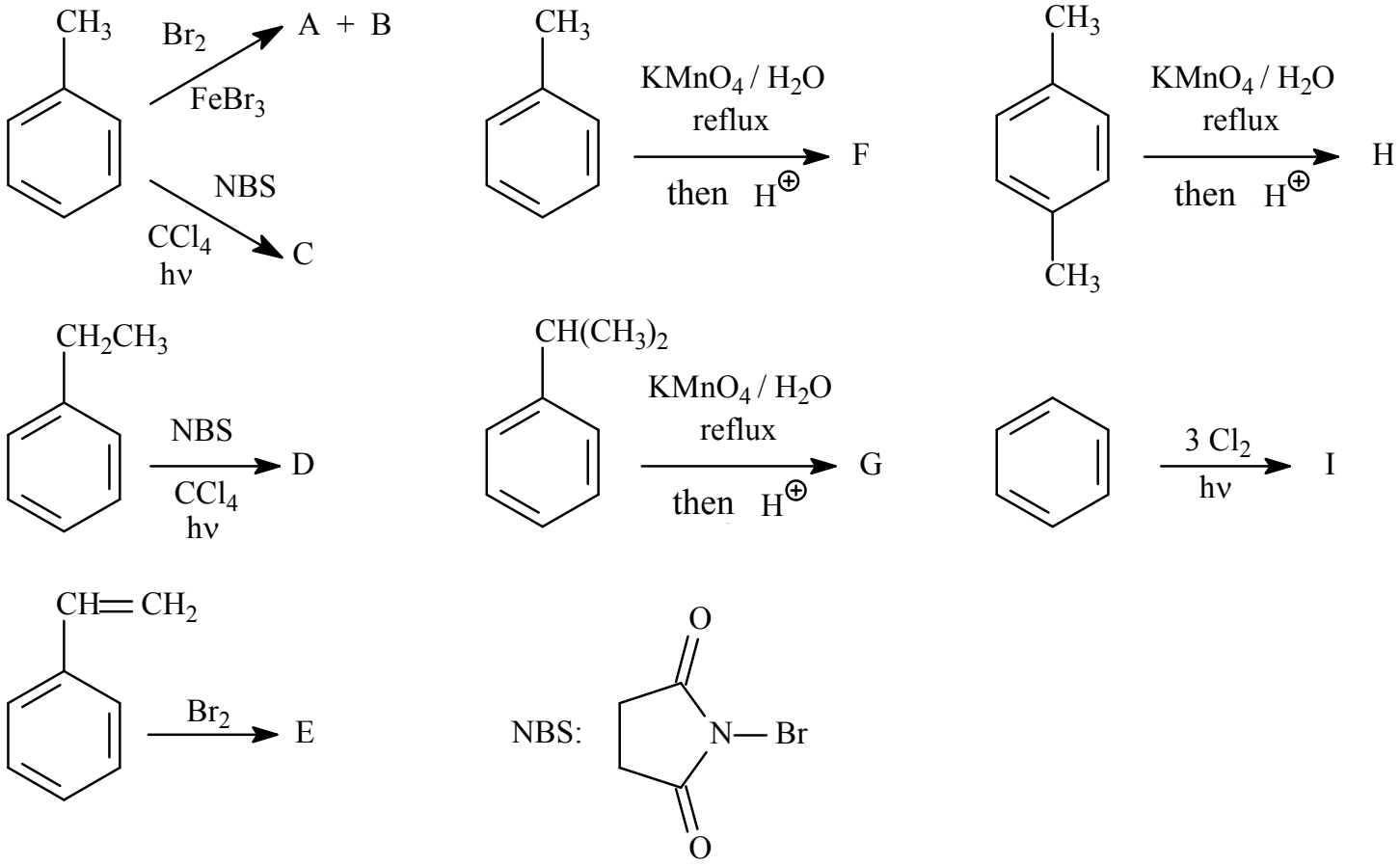
II/ 

What is the product of the following reactions? Determine stereochemistry.

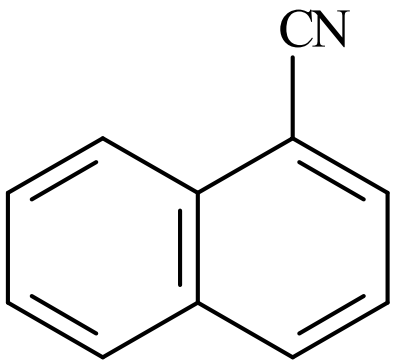




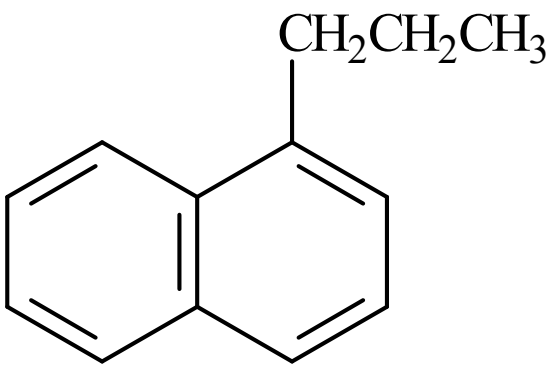
What are the products of the following reactions:



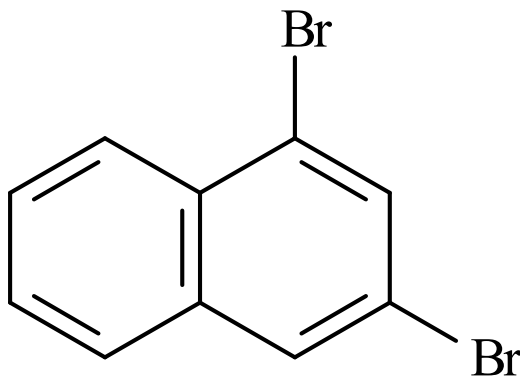
Prepare the following compounds from naphthalene:



A/



B/

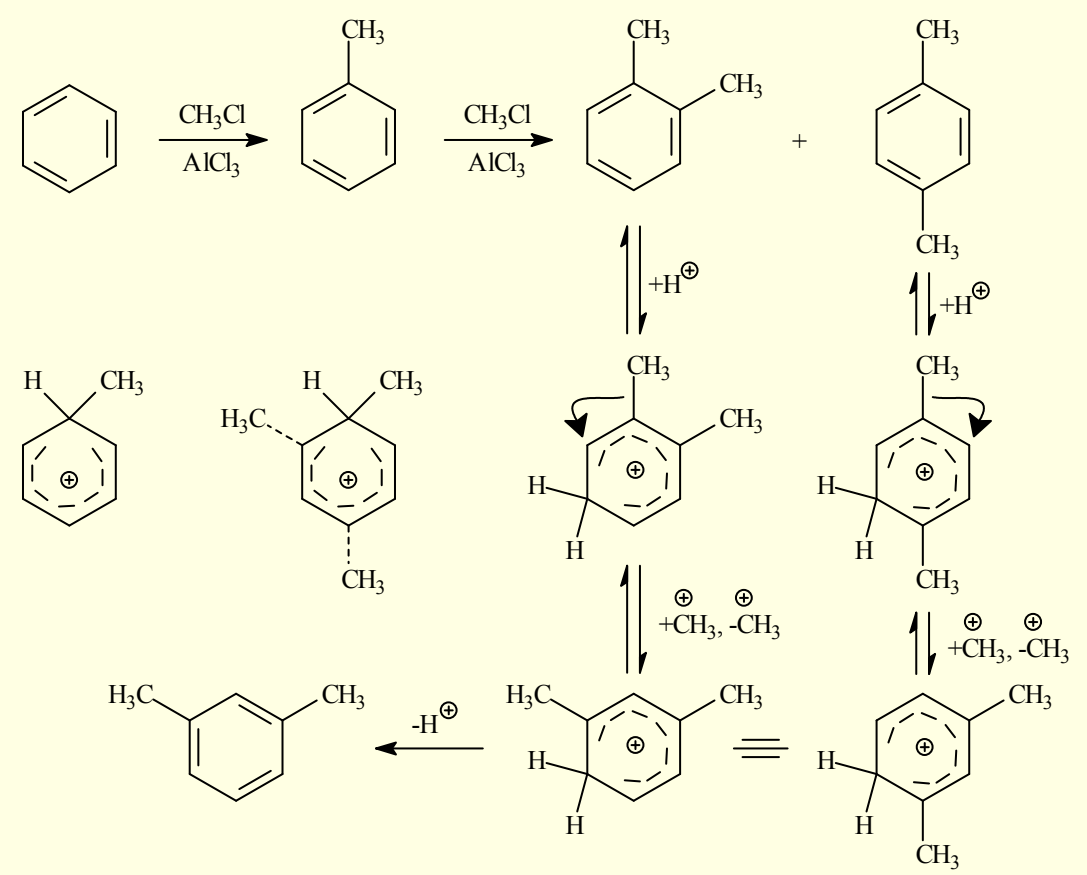


C/

Alkylation of benzene (S_EAr)

kinetically controlled reaction condition: *ortho* and *para* products

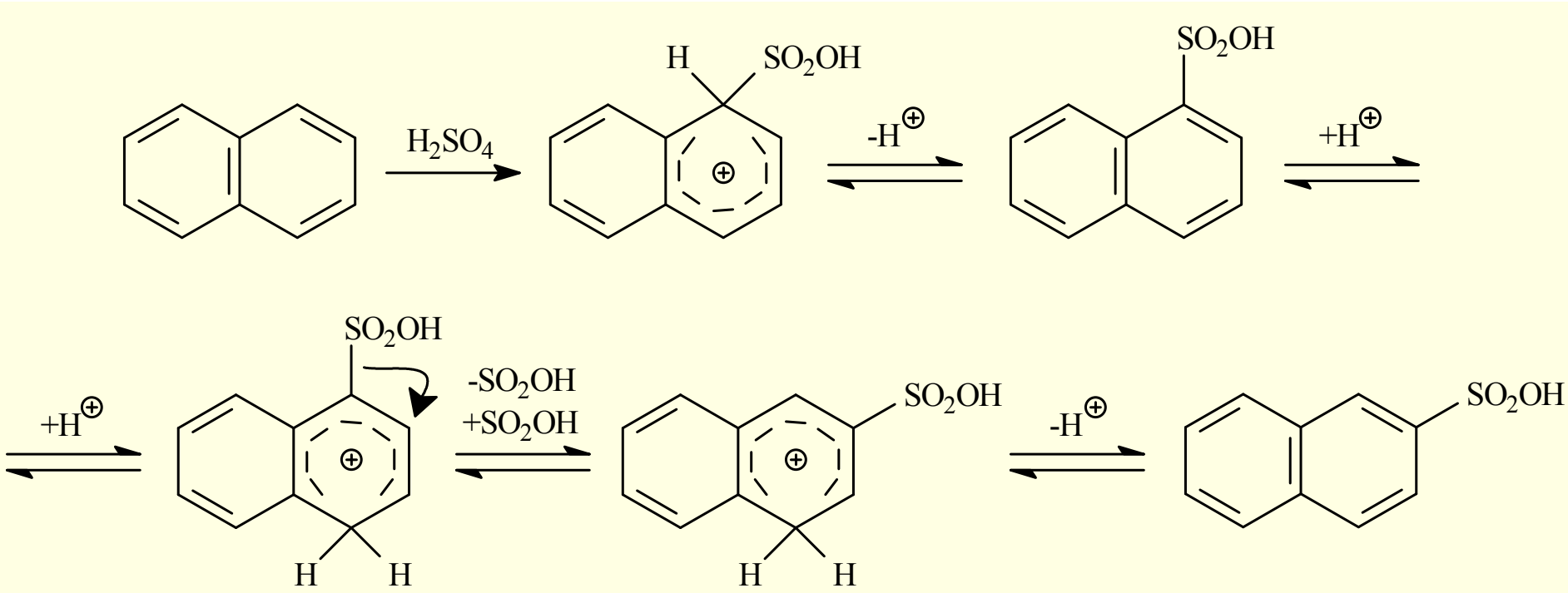
thermodinamically controlled conditions: *metha* product



Sulfonation of naphtalene

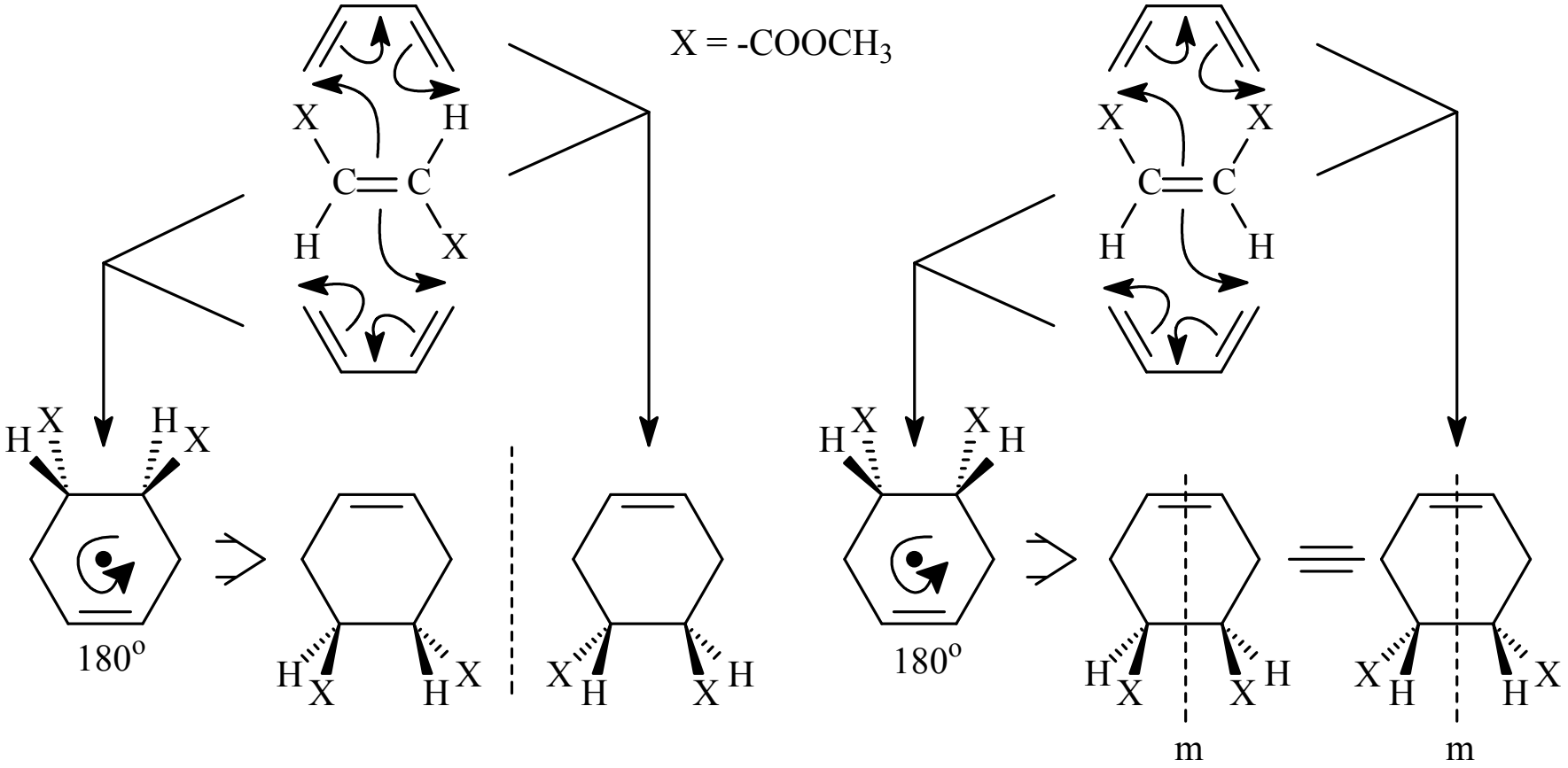
kinetically controlled: α product

thermodinamically controlled: β product



Diels-Alder reactions

concerted, stereospecific reaction, *cis* addition on both component



enantiomers

achiral, same compounds

S_N2 reaction route - linear transition state, configuration inversion

S_E2 reaction route - cyclic transition state, configuration retention