

LECTURE 4

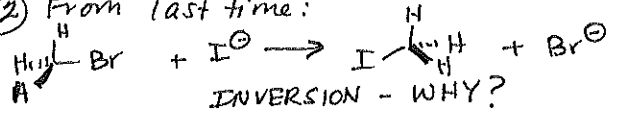
① LECTURE 4

FMO: More examples
 Universal Effects that govern rxns & structure

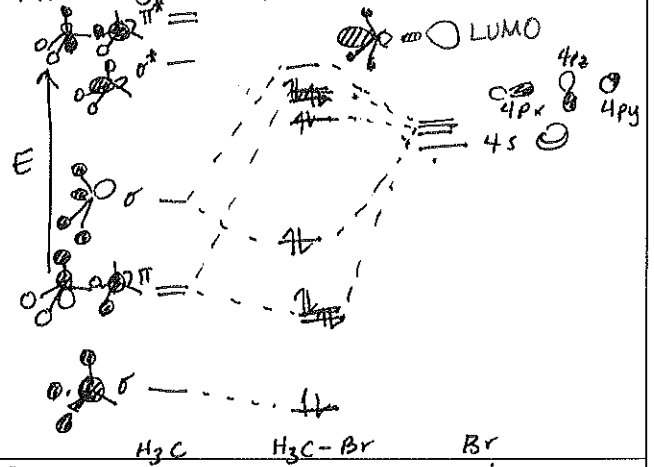
HSAB
 Baldwin's Rules

PS#2 due Tues 9/15/09
 CHEM634 tonight: Basic OM mechanisms
 Probably no catalysis.

② From last time:



MO Diagram of CH₃Br (14e⁻)



③ FMO Theory depends on frontier orbitals → MUST BE HOMO & LUMO.



Backside Attack
 ↓
 Symmetry Allowed.



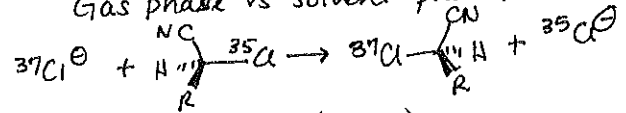
Frontside Attack
 ↓
 Not Symmetry Allowed.

④ 3 universal Effects Governing Chemical Reactions & Structure:

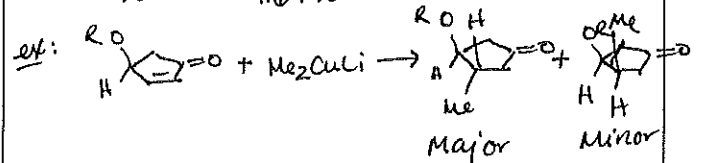
① Steric Effects

Hofmann Ber Dtsch Chem Ges 1872, 5, 704.
 " " " " 1875, 8, 61.

ex Brauman et al. Science 2002, 295, 2245.
 Gas phase vs solvent phase?

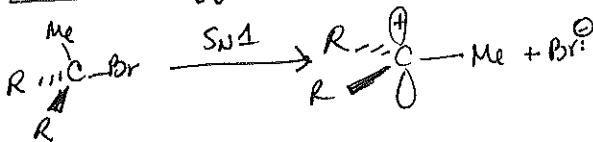


$\frac{\text{R}}{\text{CH}_3}$ $\frac{\text{K (molecular } 5. \text{ cm}^3)}{1.0 \times 10^{-11}}$ (Larger effect in solvent)
 $\frac{\text{tBu}}{1.6 \times 10^{-12}}$



⑤

② Electronic Effects (Inductive)



Rate ↓ as R becomes more EN.
 Inductive effects: Through-bond polarization

Field Effects: Through-space polarization

⑥

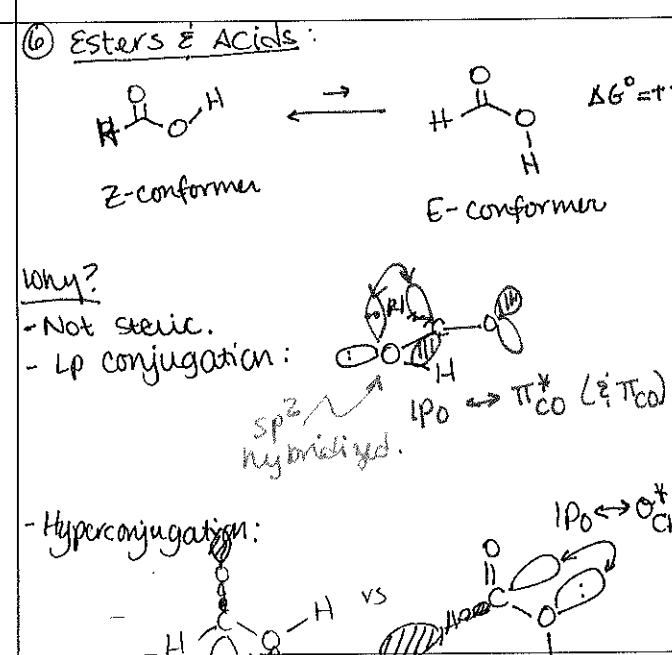
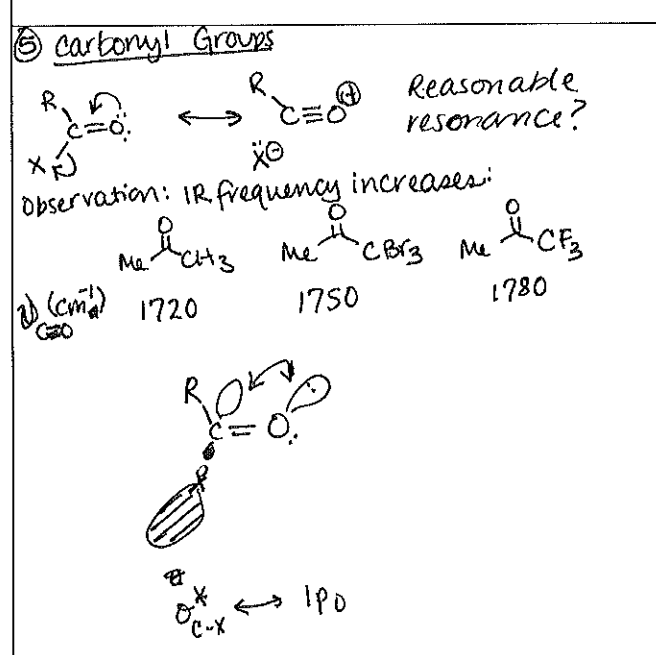
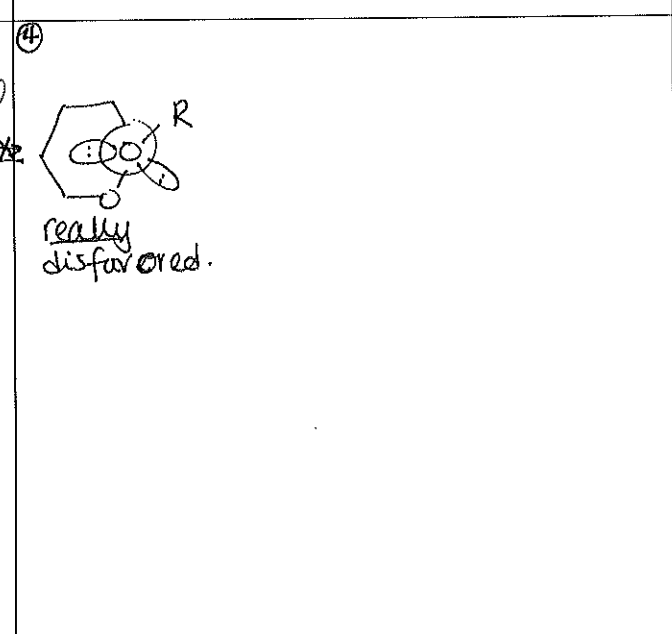
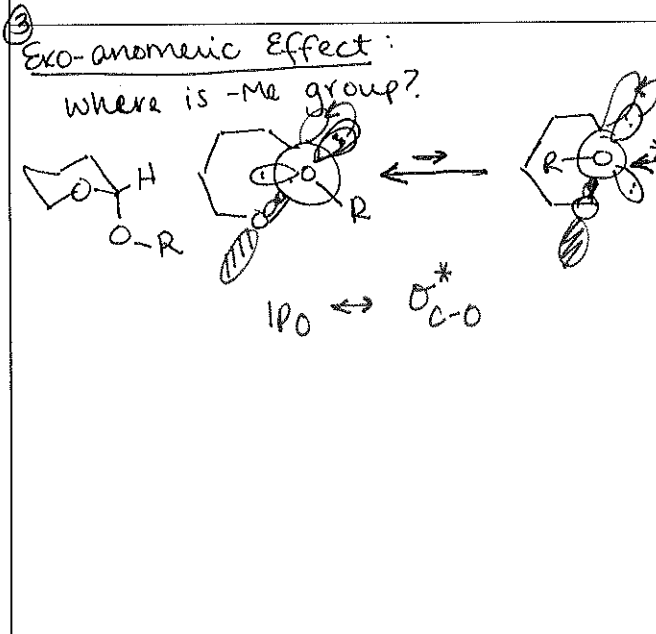
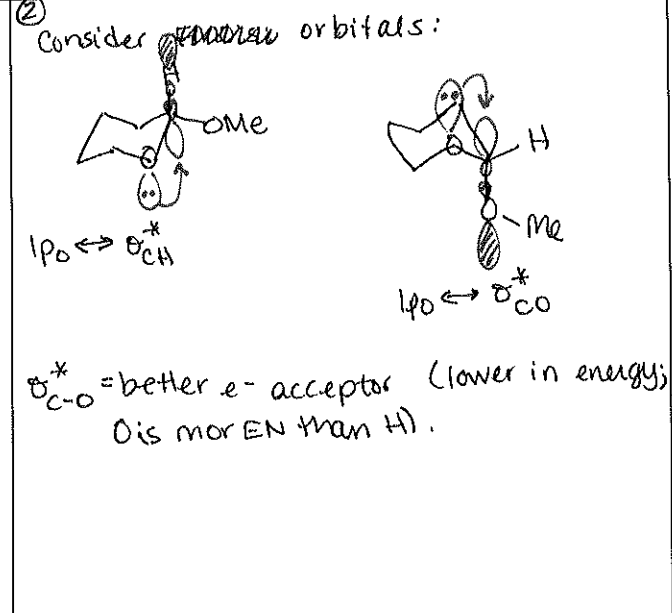
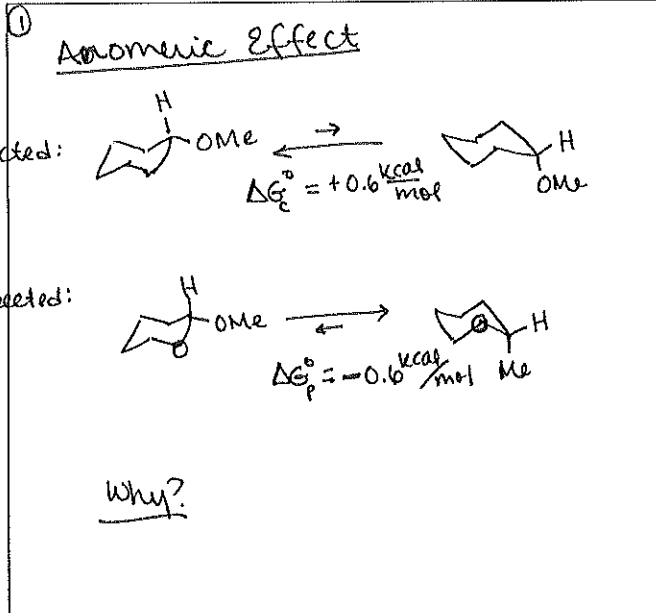
③ Stereoelectronic Effects

≡ Geometrical constraints placed upon ground & transition states by orbital overlap considerations.

Fukui Postulate for Rxns:
 "During the course of chemical rxns, the interaction of the highest filled (HOMO) & lowest unfilled (antibonding) molecular orbital (LUMO) in reacting species is very important to the stabilization of the transition structure."

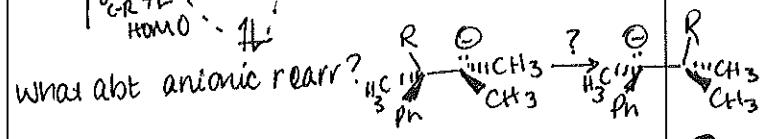
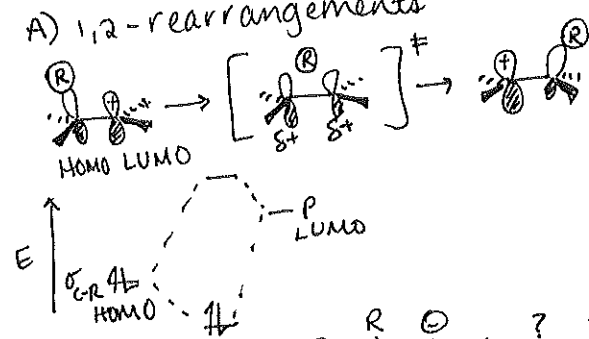
We use FMO to understand \star stereoelectronic effects!

Using FMO to understand Stereoelectronic Effects...

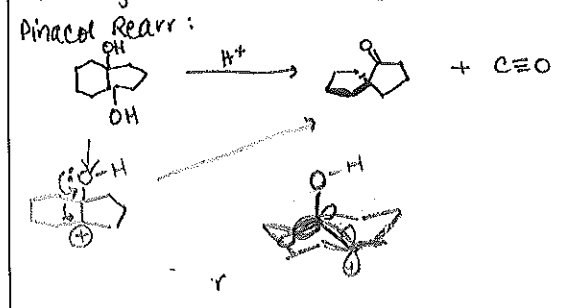


⑦ Using FMO to understand stereoelectronic effects...

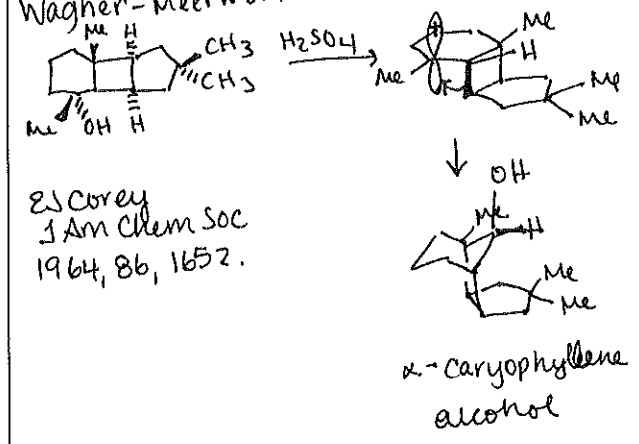
① Carbocation Stabilization
A) 1,2-rearrangements



⑧ 1,2 sigmatropic Rearrangements:

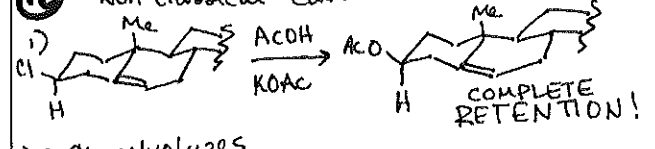


⑨ Wagner-Meerwein Rearr



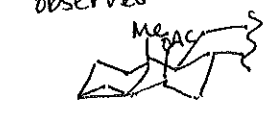
EJ Corey
J Am Chem Soc
1964, 86, 1652.

⑩ "Non-classical" Carbonium Ions:



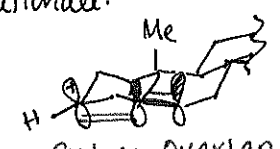
2) β-Cl solvolyzes faster than α-Cl

3) Sometimes, cholesterol i-acetate is observed

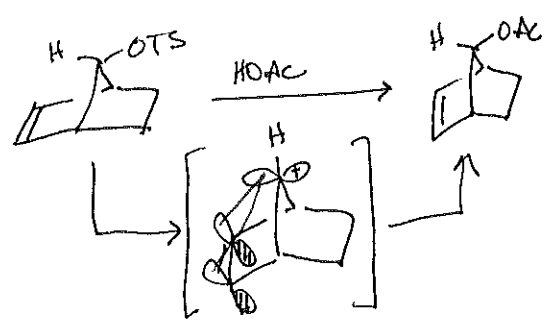


Shopee J Chem Soc 1946, 1147.
Winstein J Am Chem Soc 1954, 76, 18.

Rationale:

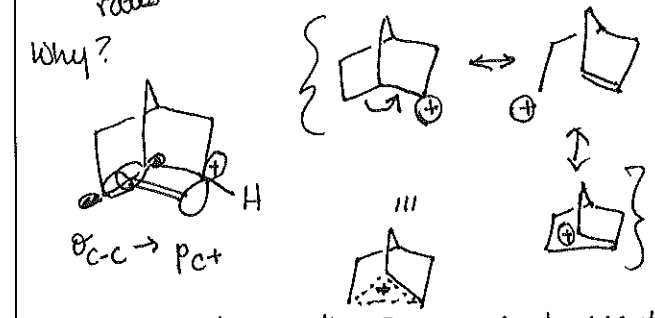
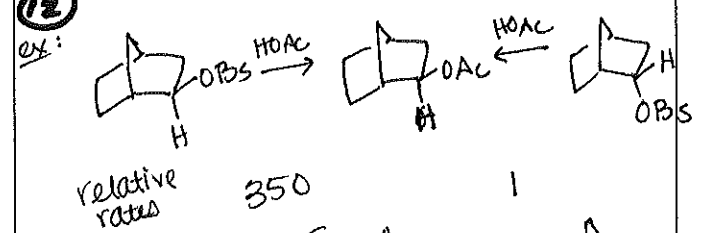


⑪ Norbornenyl Example:



- Complete retention
- 10¹⁰ x's faster than saturated system.

⑫ ex:



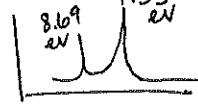
Resonance or intermediates?
Delocalized or localized?
Winstein vs. Brown

"An Innocent Bystander Looks at the 2-Norbornenyl Cation"
Walkey Acc Chem Res 1983, 16, 44B.

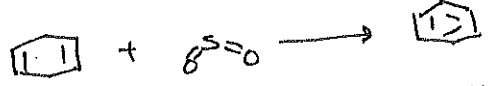
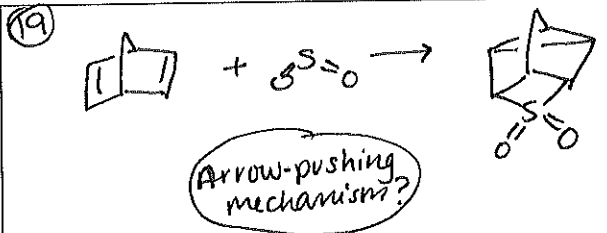
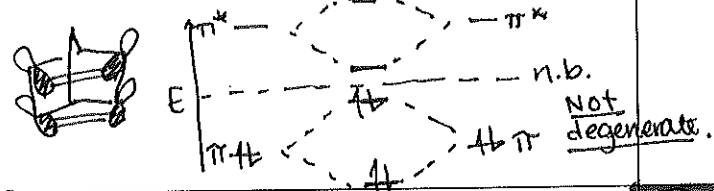
18) Examples of FMO to explain expt
 ① Are dbl bonds equivalent?
 If yes, expect:

$$E \begin{array}{c} \text{---} \pi^* \\ \text{---} \pi \\ \text{---} \pi \\ \text{---} \pi \end{array}$$
 nonbonding

Predict ESCA \rightarrow 1 peak for π e⁻s.
 It gives 2 peaks!
 WHY??



Justification: π -bonds must interact:
 HOMO Conjugation (through space interaction)

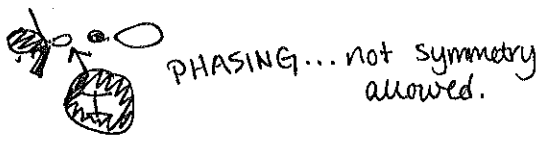


De Lucchi & Lucchini
 JCS Chem Commun
 1992, 1105.

20) S_N2 Rxn: Why Inversion?
I- + CH3Br >> I-CH3 + Br-
 I⁻ HOMO + CH₃Br LUMO
 BACKSIDE ATTACK



FRONTSIDE ATTACK

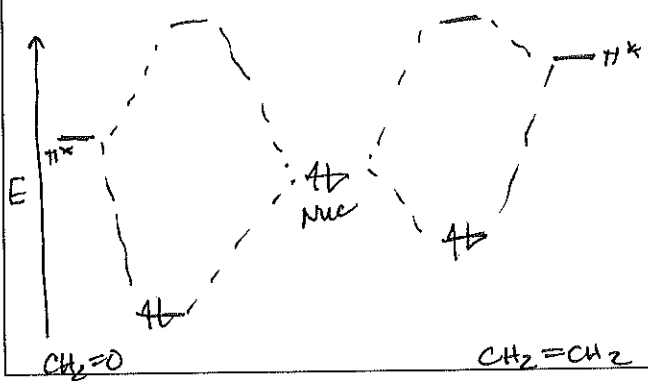


21) Cationic Rearrangements
Ph-CH2-CH2-CH3 >> Ph-CH-CH2-CH3
 HOMO LUMO
 E
 σ_{C-R} HOMO
 P LUMO

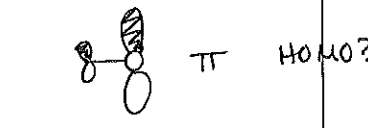
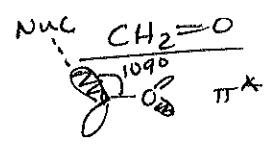
What abt anionic rearrangements?
Ph-CH2-CH2-CH2- >> Ph-CH-CH2-CH2-

End of LECTURE 3.

22) Nucleophilic Attack on π -Systems
H2C=CH2 + Nu- >> Nu-CH2-CH2-
 HOMO $\psi = C_1X + C_2X$
 $C_1 = C_2$
 LUMO $\psi = C_1X + C_2X$
 $C_1 \neq C_2$

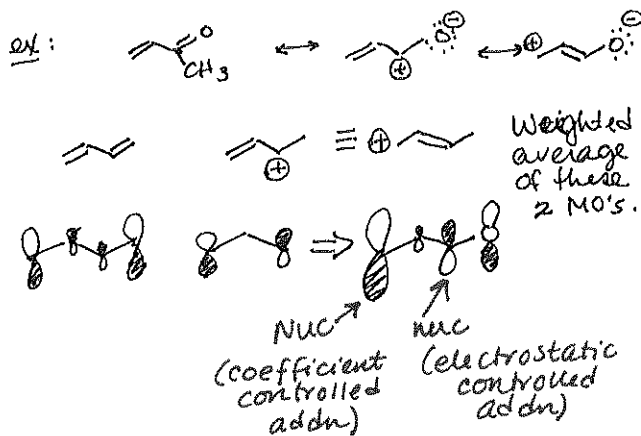


23) What do π/π^* look like?
CH2=CH2
 π
 π^*
 orthogonal approach for E⁺ attack.



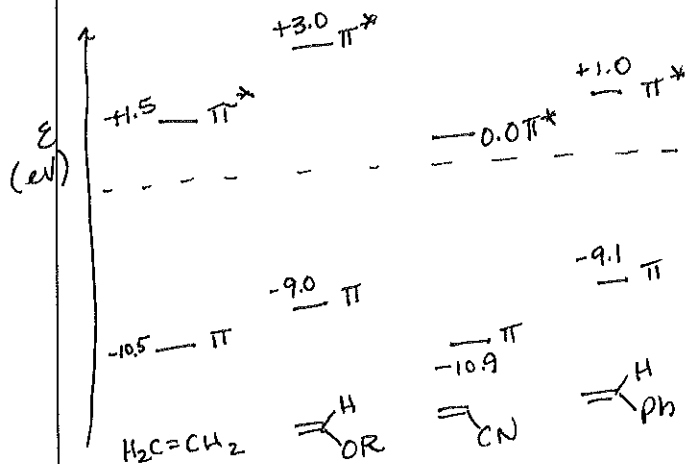
BURGI-DUNITZ ANGLE
 \hookrightarrow largest overlap.

24) What abt conjugated systems w/ het atoms?



Burgi-Dunitz angle is also important in conj. systems.

26) Quantitation:



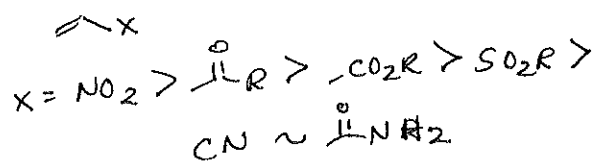
25) Final Comments on FMO:

- Heteroatoms lower energy of orbital
ex: H2C=CH2 vs H2C=O
- Substituent effects:

Perturbation	Effect
extra conjugation	HOMO ↑ / LUMO ↓
e- donating -OR, -NR ₂	HOMO ↑ / LUMO ↑
e- withdrawing -CO ₂ R, -CR ₂ , -CN, -NO ₂	HOMO ↓ / LUMO ↓

27)

Reactivity:



Ordering requires extensive computation.

28) Anomeric Effect

Baldwin's Rules for Ring Closure (A&P), 10.9.4) → TABLE 10.5

3 factors to consider:

1) Ring Size

5 > 6 > 3 > 7 > 4 > 8-10
 easier ring to form hardest

True for nucleophilic, radical & cationic ring closures

2) Regiochemistry of attack

exo - places cation, radical or anion exo to ring



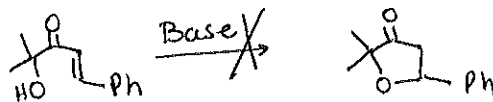
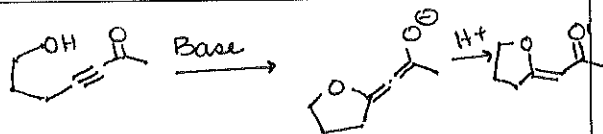
endo - places cation, radical or anion endo to ring



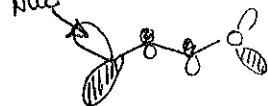
3) Hybridization undergoing attack:

sp = dig
 sp² = trig
 sp³ = tet

See Table 10.5 for "Rules"



Consider π*: Nuc cannot approach on Bürgi-Dunitz angle.



13 Nucleophilic Attack on π -systems

(See notes at end of Lecture 3.)

14 Hard/Soft Acid/Base Theory

- ϵ_i Polarizability
- qualitative arguments to explain reactivity
 - Relatively large atom or ion w/ a small effective nuclear charge is relatively easily distorted (polarized) by external charge \equiv SOFT
 - Compact e^- distribution from higher net nuclear charge & less effective screening \equiv HARD

- 15 Ref: Pearson et al. J Am Chem Soc 1967, 89, 1827.
 " J. Org. Chem. 1989, 54, 1423.
 " Acc Chem Res. 1993, 26, 250.

Anion Hardness increases w/ electronegativity & \ominus charge
 $F^\ominus > Cl^\ominus > Br^\ominus > I^\ominus$
 $F^\ominus > {}^\ominus H_2O > {}^\ominus NH_2 > {}^\ominus CH_3$

Cation Hardness decreases w/ size & increases w/ \oplus charge

$H^\oplus > Li^\oplus > Na^\oplus > K^\oplus$ H^\oplus infinitely hard (no e^- or neutrons!)

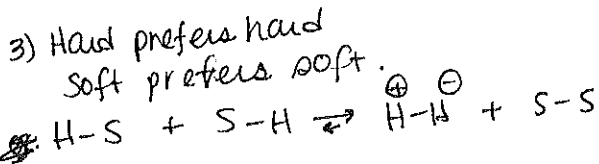
Metal ion hardness increases w/ oxid. state.

- 16 Polyatomic molecules hardness & softness related to HOMO/LUMO gap.
 Larger gap = greater hardness.

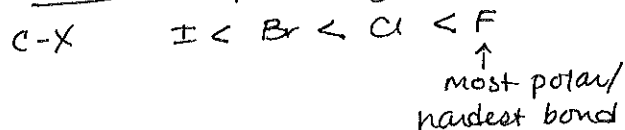
17 e^- cloud shrinks.

Generalities:

- 1) Hard-Hard interactions dominated by electrostatics
- 2) Softer compds usually more reactive & more nucleophilic (wants to donate e^- to El^+)
 nucleophilicity:
 $CH_3^\ominus > {}^\ominus NH_2 > {}^\ominus OH > H^\ominus > F^\ominus$



18 Hard-soft ϵ_i Polarizability



Polarizability & Hybridization

$sp^3 > sp^2 > sp$ \leftarrow lower ϵ_i , closer to nucleus.
 more polarizable \leftarrow less polarizable.

Note: Polarization is directional.

