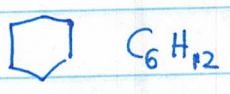


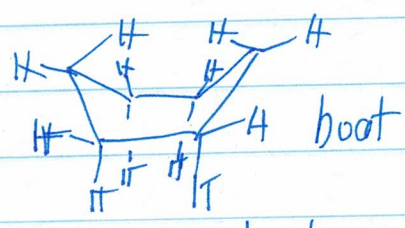
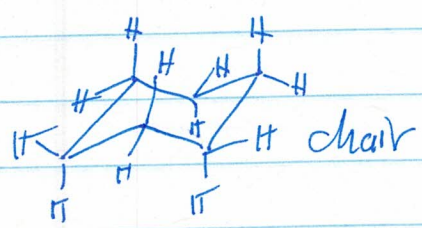
# Lecture XX: Conformations of Cyclohexane

03-06-2020



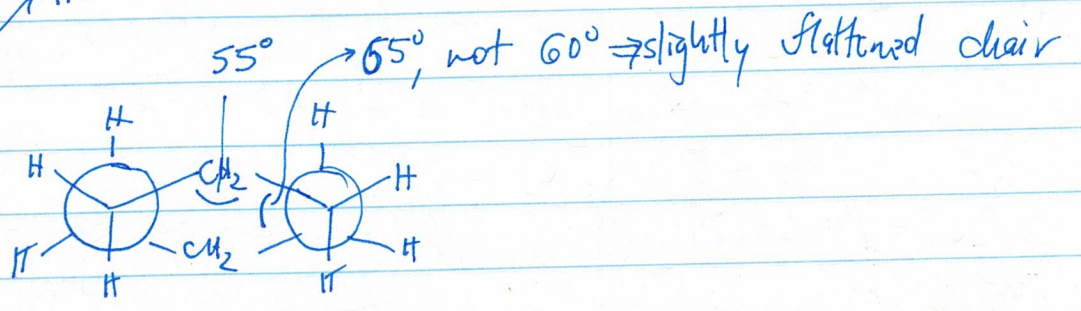
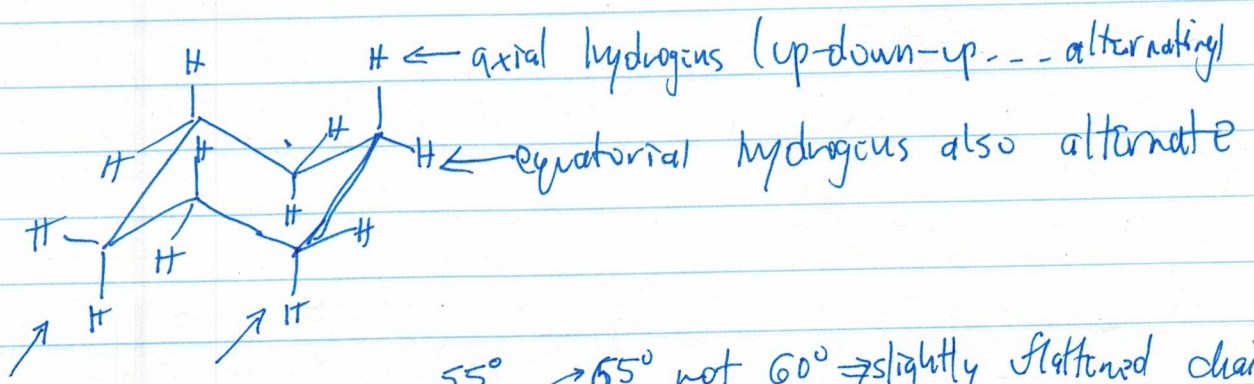
A planar cyclohexane would have an internal angle of  $120^\circ$  - a significant deformation from  $109.5^\circ$

Sachse first realized that cyclohexane cannot be planar and proposed chair and boat forms - but he thought they would be stable:



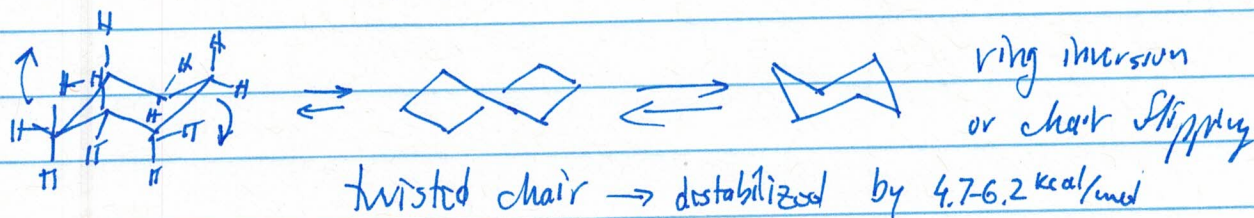
His ideas disappeared after his death, and the problem was largely ignored until the 1950s.

Barton and Hassel received Nobel Prize in 1969 for electron diffraction structure of cyclohexane.



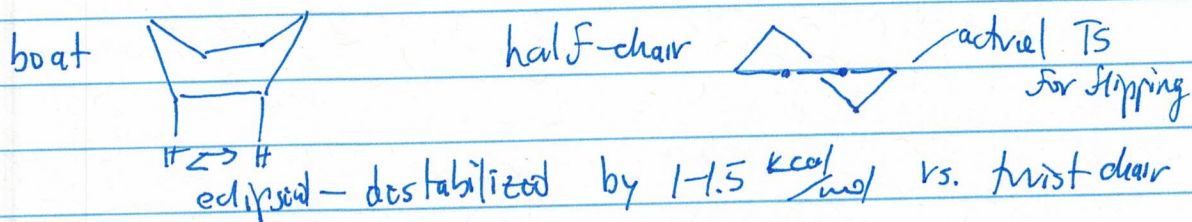
All equatorial hydrogens are homotopic, as are all axial ones. But to each other, they are diastereotopic.

Cyclohexane chair is dynamic:



$$\Delta G^\ddagger \sim 10 - 10.5 \frac{\text{kcal}}{\text{mol}}, \text{ determined for cyclohexane-}d_{14}$$

Two additional conformations:



If cyclohexanes are monosubstituted, chair flipping becomes interconversion between two diastereomers:



because of 1,3-diaxial strain, axial form is less stable.

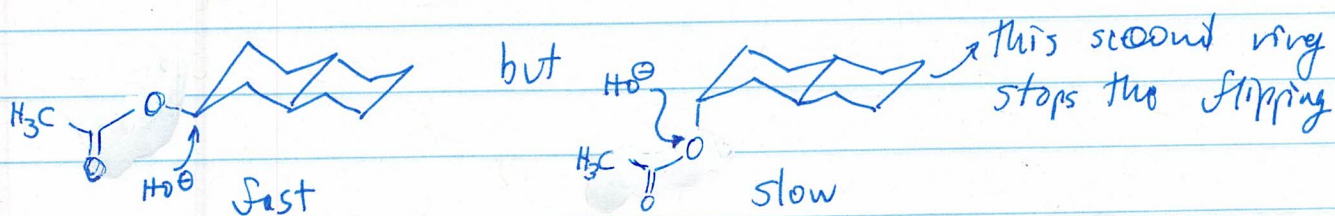
These can be distinguished @ rt by IR: e.g. C-Br<sub>axial</sub> 658 cm<sup>-1</sup>  
C-Br<sub>equat</sub> 685 cm<sup>-1</sup>

For NMR detection, they need to be cooled down. For chlorocyclohexane,

the two isomers are <sup>quite</sup> stable @ -150°C. Equilibrium @ -115°C

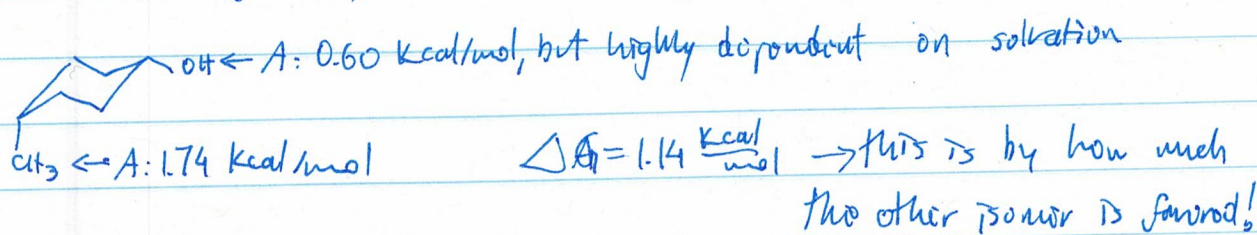
The difference in stability between an axial and an equatorial version of the molecule is called the "A-value", coined by Saul Winstein (JACS, 1955, 77, 5562). Bigger substituents prefer equatorial position more and have higher A values.

Axial/equatorial differences affect reactivity:



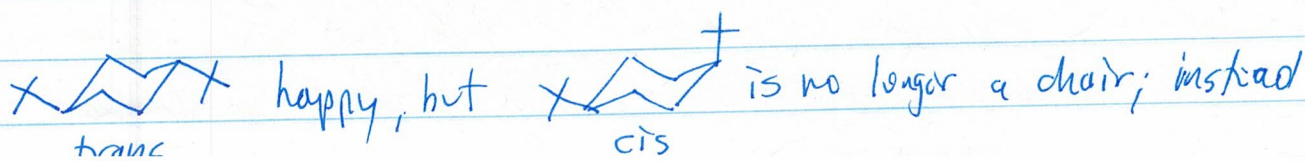
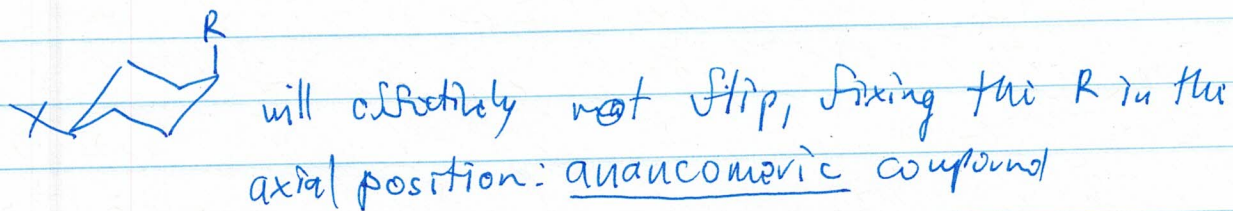
Reactions that are facilitated by steric bulk speed up with axial position: e.g. oxidations.

A values are generally additive for groups in 1,4-positions:

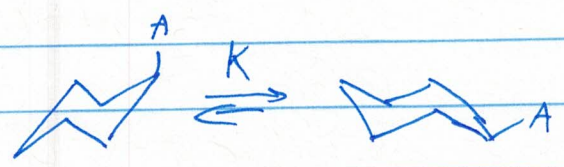
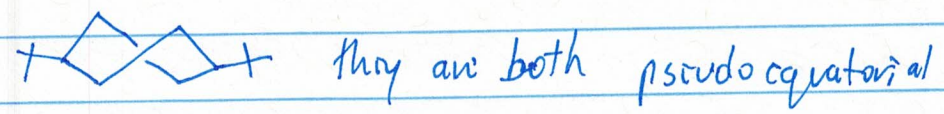


In 1,2-positions, disagreements between calculated and measured values are generally larger.

(CH<sub>3</sub>)<sub>3</sub>C- has the highest A value among the common groups: 4.7  $\frac{\text{kcal}}{\text{mol}}$



It distorts into a twisted chair:



From NMR, average  $\delta$  will be:

$$\delta = N_A \cdot \delta_A + N_B \cdot \delta_B$$

$$N_A + N_B = 1$$

$$\delta = (\delta_A + K\delta_B) N_A$$


$\rightarrow$  molar fractions

$$N_B / N_A = K$$

$$\delta = (\delta_A + K\delta_B) / (1 + K)$$

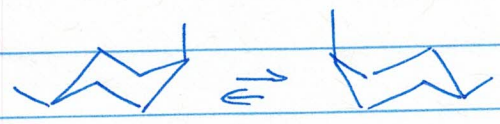
$$N_A = \frac{1}{1 + K}$$

$$K = \frac{\delta_A - \delta}{\delta - \delta_B}$$

A for OH group	various:	M	C <sub>6</sub> H <sub>12</sub>	it is	0.60 kcal/mol
"	"	"	CS <sub>2</sub>	" "	1.04 " "
"	"	"		" "	0.95 " "
"	"	"	H <sub>2</sub> O	" "	0.91 " "

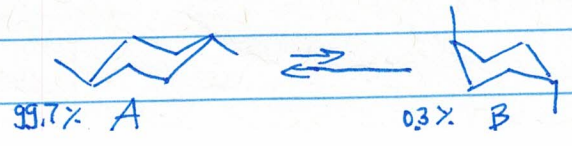
Disubstituted and oligosubstituted cyclohexanes

cis-1,4



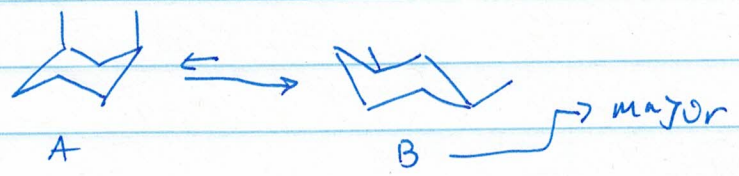
degenerate if the two groups are the same

trans-1,4



different  $\Delta G$  is  $2 \times 1.74 = 3.48$  kcal/mol  
more space

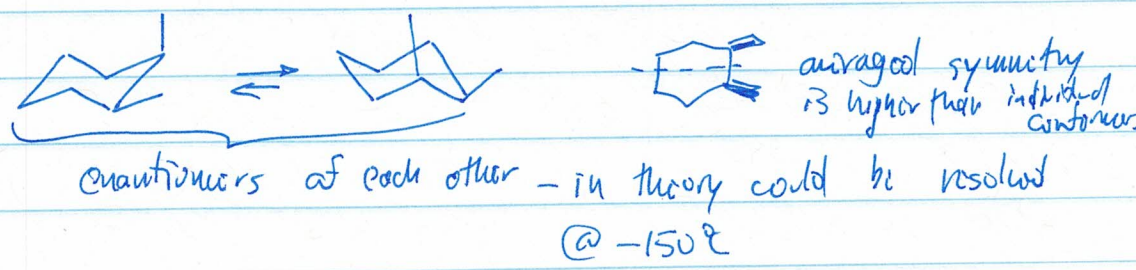
cis-1,3



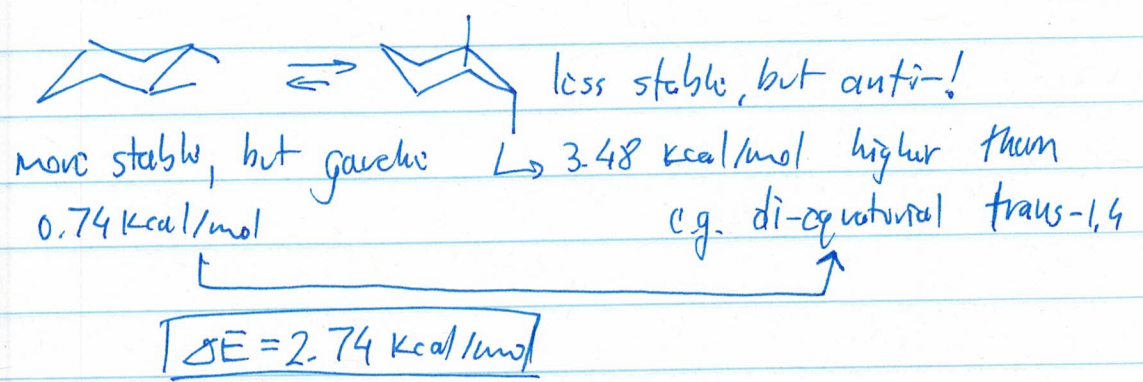
trans-1,3



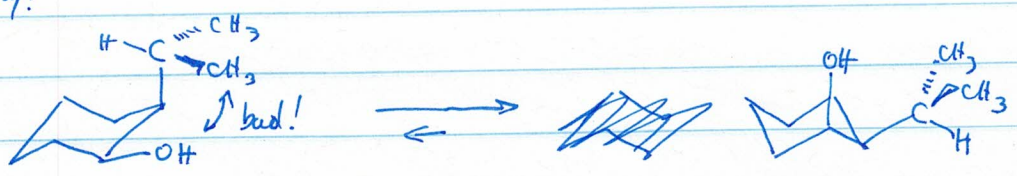
cis-1,2



trans-1,2

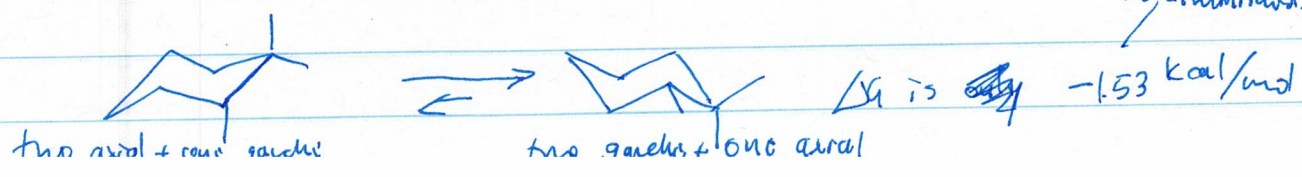


For 1,1 and 1,2-disubstituted cyclohexanes, additivity breaks down occasionally:

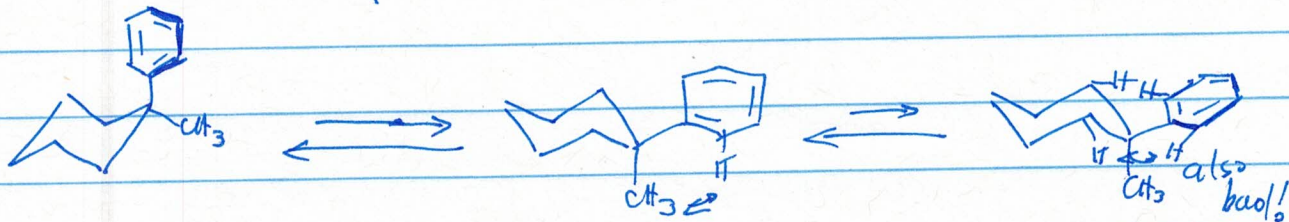


$\Delta G > A(i-M) - A(OH)$

second gauche is diminished!



In geminally disubstituted cyclohexanes, one substituent can interfere with the optimal rotamer of the other:



$A(\text{Ph}) = 2.87 \text{ kcal mol}^{-1}$        $A(\text{CH}_3) = 1.74 \text{ kcal mol}^{-1}$ , but axial phenyl is preferred!