# 5. The Use of Isotopes

(i) Isotopic Labelling

Example 1: Hydrolysis of Ester

(a) (a) → $RC-O-H + H^{18}O-R'$

$$RC-O-R' \xrightarrow{H_2,^{18}O}$$

(b) (b) → $RC-^{18}OH + H-OR'$
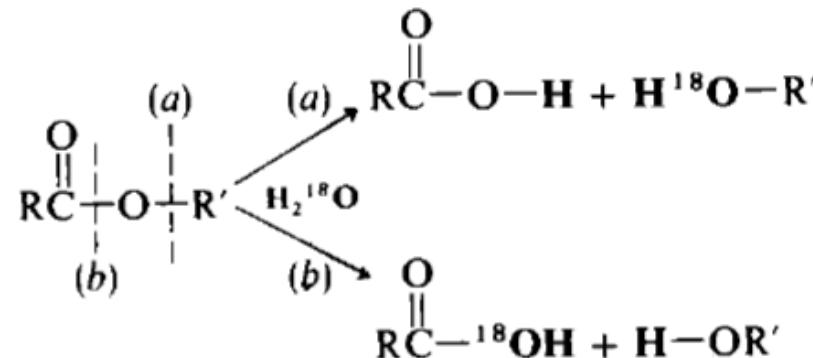
Example 2: Cannizzaro reaction

$$PhC-H + PhC-H \xrightarrow[H_2O]{^{\ominus}OH} PhC-O^{\ominus} + PhC-H$$

D$_2$O
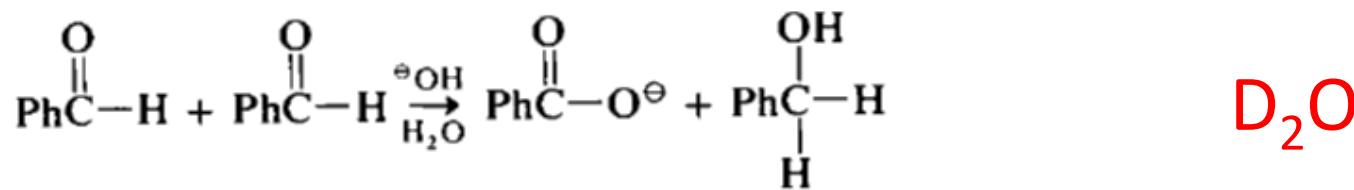
Example 3: The Conversion of Carboxylic Acid Salts to Nitriles

RCOO⁻ + BrCN   →   RCN + CO$_2$

$N\equiv C-Br$

$$\frac{k_H}{k_D} \sim 7$$
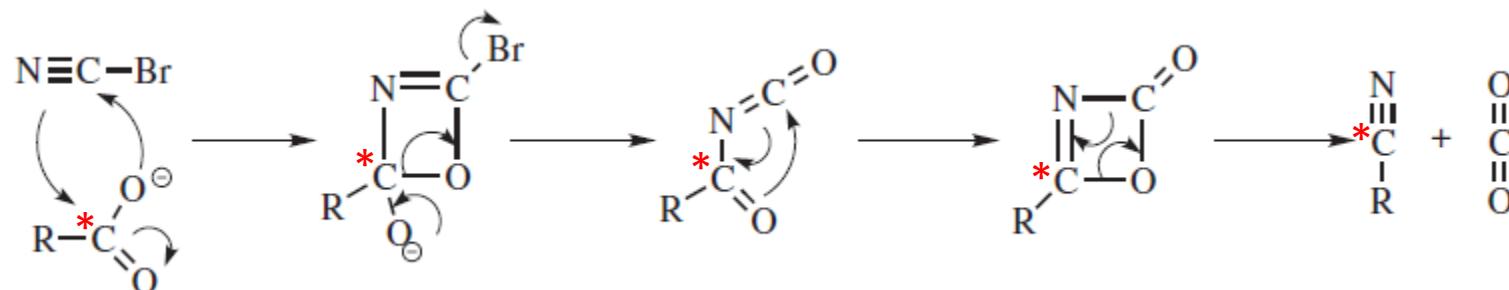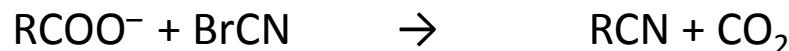
C-H bond breaking involves in the rate-determining step. This is called Primary Kinetic Isotopic Effect (PKIE)

$$\frac{k_H}{k_D} \sim 1$$

C-H bond breaking does not involve in the rate-determining step

Potential energy

Dissociation energy for a C—H bond

Dissociation energy for a C—D bond

Internuclear distance
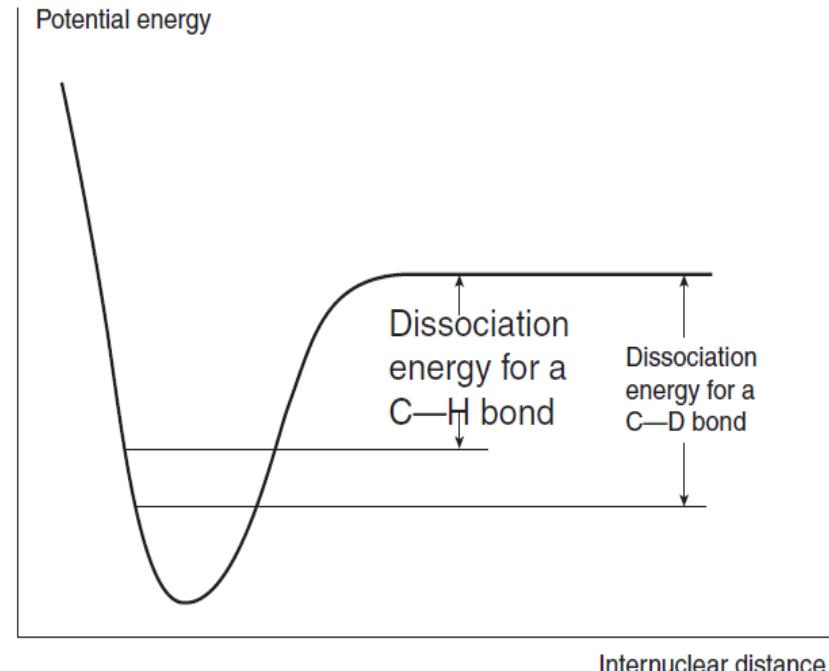
Example 1: Nitration of benzene

H — benzene ring + $^{\oplus}NO_2$ ⟶ NO₂-benzene ring + $H^{\oplus}$

$$\frac{k_H}{k_D} \sim 1$$

Benzene + $^{+}\overset{\cdot}{N}O_2$ $\underset{\text{slow}}{\overset{50^0C}{\rightleftharpoons}}$ [ring with NO₂ and H]$^{\oplus}$

[ring with NO₂ and H]$^{\oplus}$ + HSO_4^{-} $\xrightarrow{\text{fast}}$ ring-NO₂ + H_2SO_4

Nitrobenzene
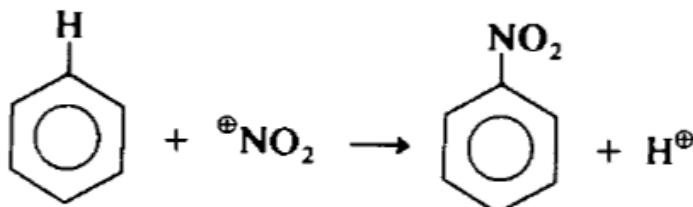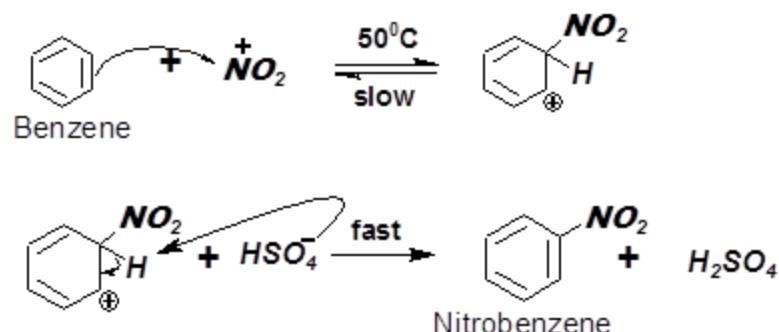
Example 2: Oxidation of diphenyl methl alcohol

$$Ph_2C{\overset{OH}{\underset{H}{<}}} \xrightarrow[\ominus OH]{MnO_4^{\ominus}} Ph_2C{=}O \qquad \frac{k_H}{k_D} = 6.7$$
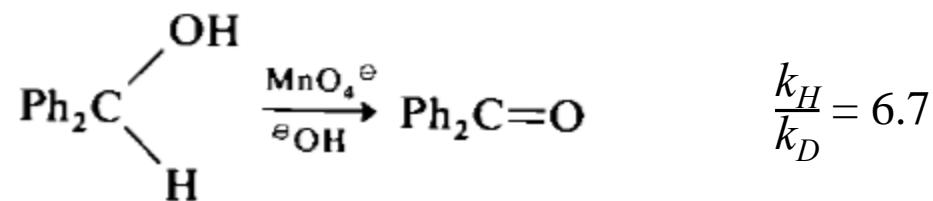
Example 3: Use of other isotopes

$$HO^{\ominus} + {}^{(14)}_{12}CH_3{-}I \rightarrow HO{-}{}^{(14)}_{12}CH_3 + I^{\ominus} \qquad \frac{k_{12C}}{k_{14C}} = 1{\cdot}09\ (25°)$$

$$PhCH_2{-}{}^{(37)}_{35}Cl + H_2O \rightarrow PhCH_2{-}OH + H^{\oplus}\,{}^{(37)}_{35}Cl^{\ominus} \qquad \frac{k_{35Cl}}{k_{37Cl}} = 1{\cdot}0076\ (25°)$$
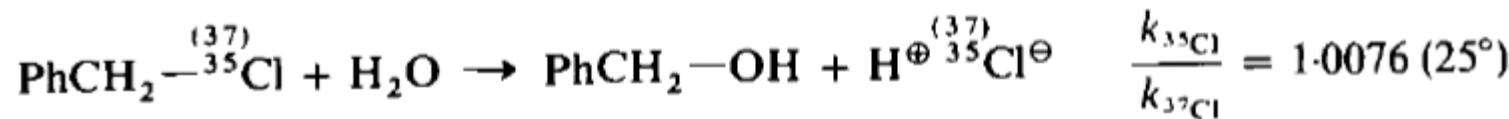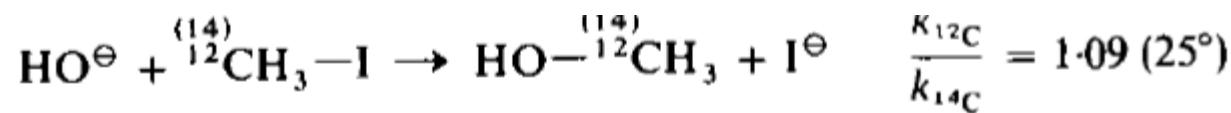
(ii) Isotopic Scrambling

Example1: E1cB$_R$ reaction
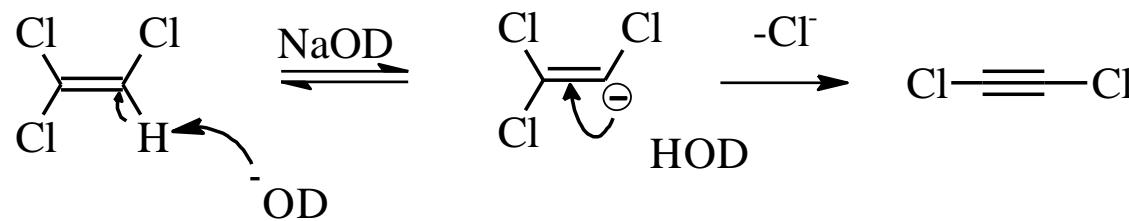
Example 2: Claisen rearrangement