

The background is a vibrant green with a complex, abstract pattern. It features several large, overlapping circles and a series of thin, curved lines that create a sense of motion and depth. The colors range from a bright, almost white green to a deep, dark green, with some areas appearing to glow or have a gradient effect.

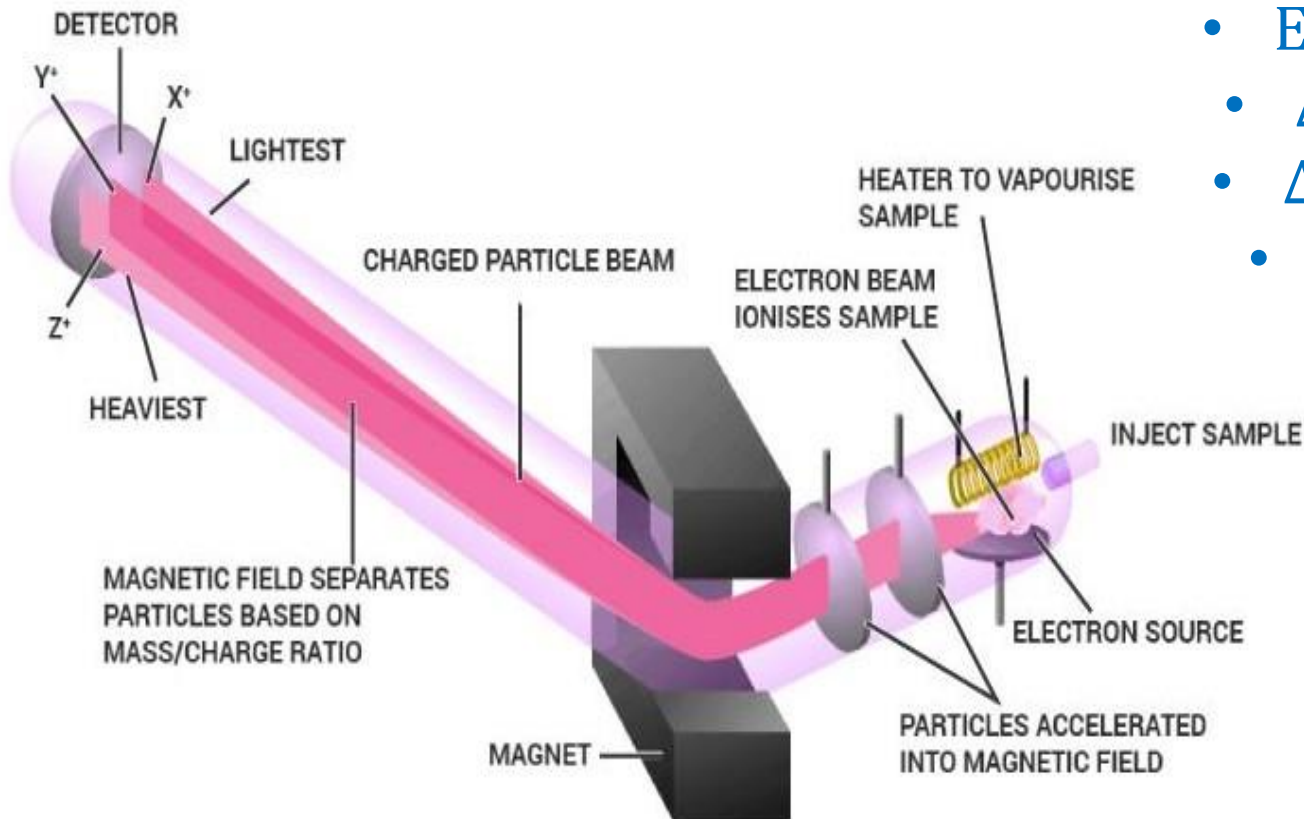
Λ. Χατζηαράπογλου

Φασματομετρία Μάζας

Αρχή φασματογράφου μάζας

Λειτουργίες:

- Εισαγωγή δείγματος
- Δημιουργία ιόντων
- Διαχωρισμός μαζών
- Ανίχνευση ιόντος



Πιέσεις: 10^{-7} – 10^{-8} (δημιουργία ιόντων), 10^{-9} (μαγνητικό αναλυτή)

Απαιτήσεις βάρους δείγματος:

Διαμέσου:

- εισαγωγής αερίου: $10^{-4} - 10^{-3}$ g
- GC : $10^{-9} - 10^{-15}$ g
- Απευθείας εισαγωγής : $10^{-6} - 10^{-4}$ g

Δημιουργία Ιόντων:

Η αλληλεπίδραση των ηλεκτρονίων και των ουδέτερων μορίων δημιουργεί θετικά φορτισμένα μοριακά ιόντα, σύμφωνα με :



Ή σπανιότερα σύμφωνα με :



Η ταχύτητα των ιόντων δίνεται από $v = \sqrt{\frac{2 \cdot z \cdot U}{m}}$

Διαχωρισμός Μαζών:

Η βασική εξίσωση της φασματομετρίας μάζας δίνεται ως

$$\frac{m}{z} = \frac{r_m^2 \cdot B^2}{2 \cdot U}$$

Και προέρχεται από το συνδυασμό των

$$z \cdot U = \frac{m \cdot v^2}{2}$$

$$r_m = \frac{m \cdot v}{z \cdot B}$$

Ανίχνευση Ιόντων:

Όταν το δυναμικό επιτάχυνσης και η ισχύς μαγνητικού πεδίου παραμένουν σταθερές

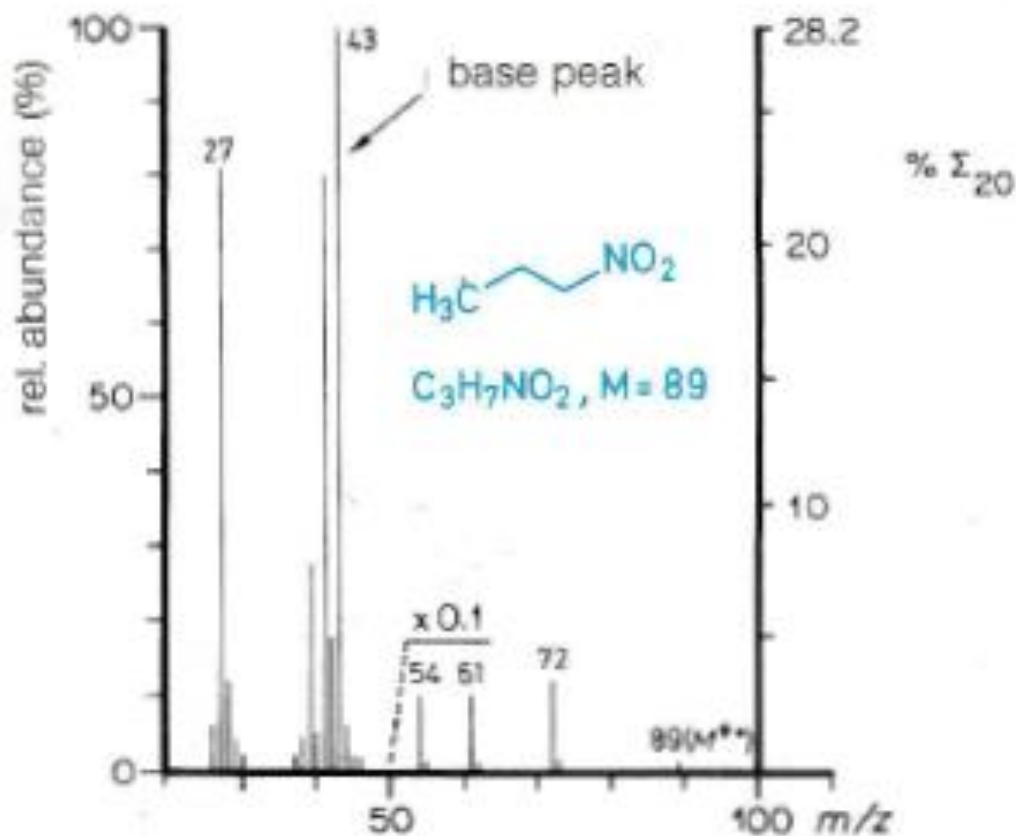
$$\frac{m}{z} = k \cdot r_m^2. \quad (k = \text{const.})$$

Αντίθετα, αν το δυναμικό επιτάχυνσης και η ακτίνα της τροχιάς παραμένουν σταθερές

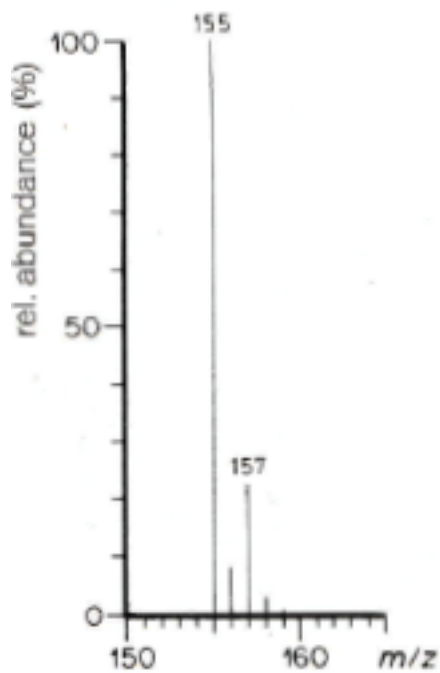
$$\frac{m}{z} = k \cdot B^2 \quad (k = \text{const.})$$

Θραυσματοποιήσεις Οργανικών Ενώσεων:

(70 eV)

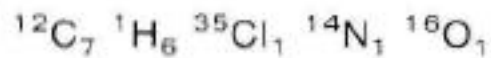


- **Monoisotopic elements:** ^{19}F , ^{31}P , ^{127}I ;
- **Elements with one very abundant isotope:**
($\geq 98\%$): $\text{H}(^1\text{H})$, $\text{C}(^{12}\text{C})$, $\text{N}(^{14}\text{N})$, $\text{O}(^{16}\text{O})$;
- **Elements with two abundant isotopes:**
 $\text{S}(^{32}\text{S}, ^{34}\text{S})$, $\text{Cl}(^{35}\text{Cl}, ^{37}\text{Cl})$, $\text{Br}(^{79}\text{Br}, ^{81}\text{Br})$.

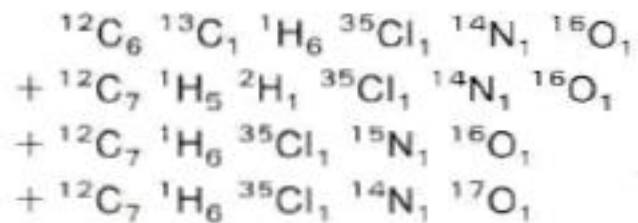


C₇H₆ClNO

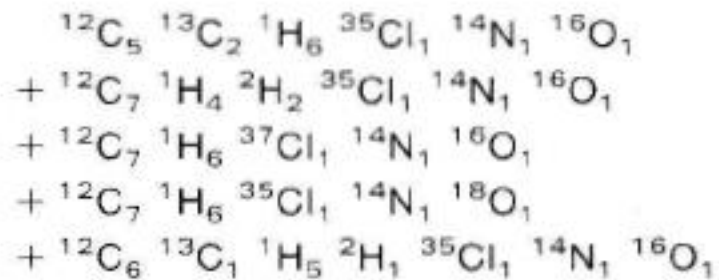
m/z = 155:



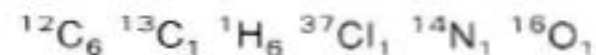
m/z = 156:



m/z = 157:



m/z = 158:



Κανόνας αζώτου:

Αν υπάρχει άζωτο στην οργανική ένωση

Όταν το μοριακό ιόν είναι περιττός αριθμός
υποδηλώνει
περιττό αριθμό ατόμων αζώτου N_1, N_3, N_5, \dots

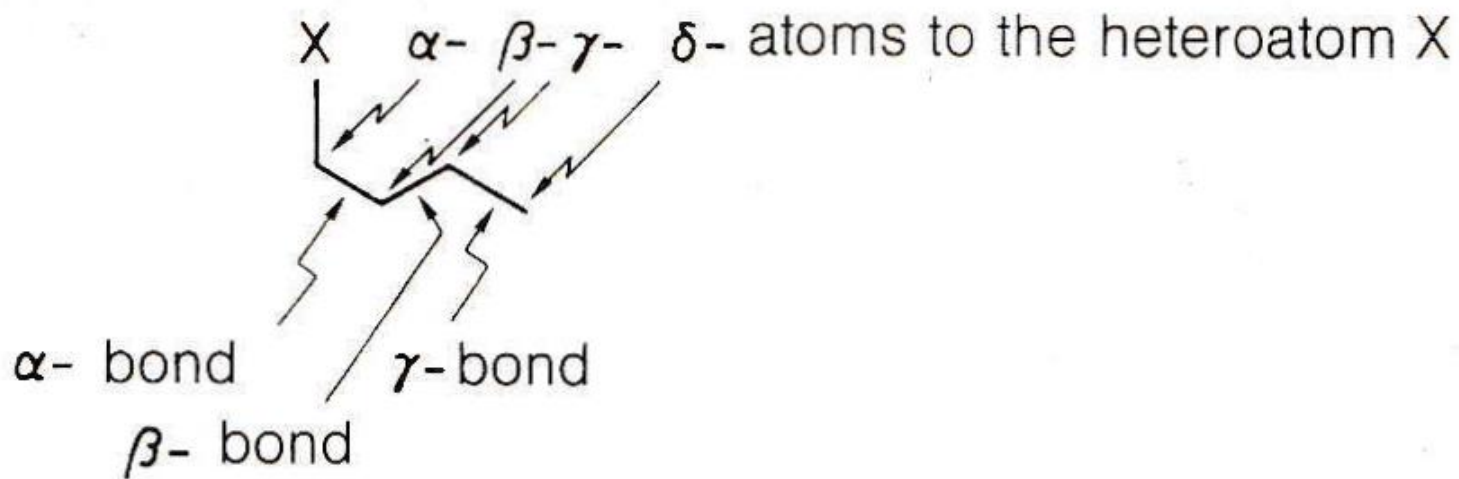
Όταν το μοριακό ιόν είναι άρτιος αριθμός
υποδηλώνει
άρτιο αριθμό ατόμων αζώτου N_2, N_4, N_6, \dots

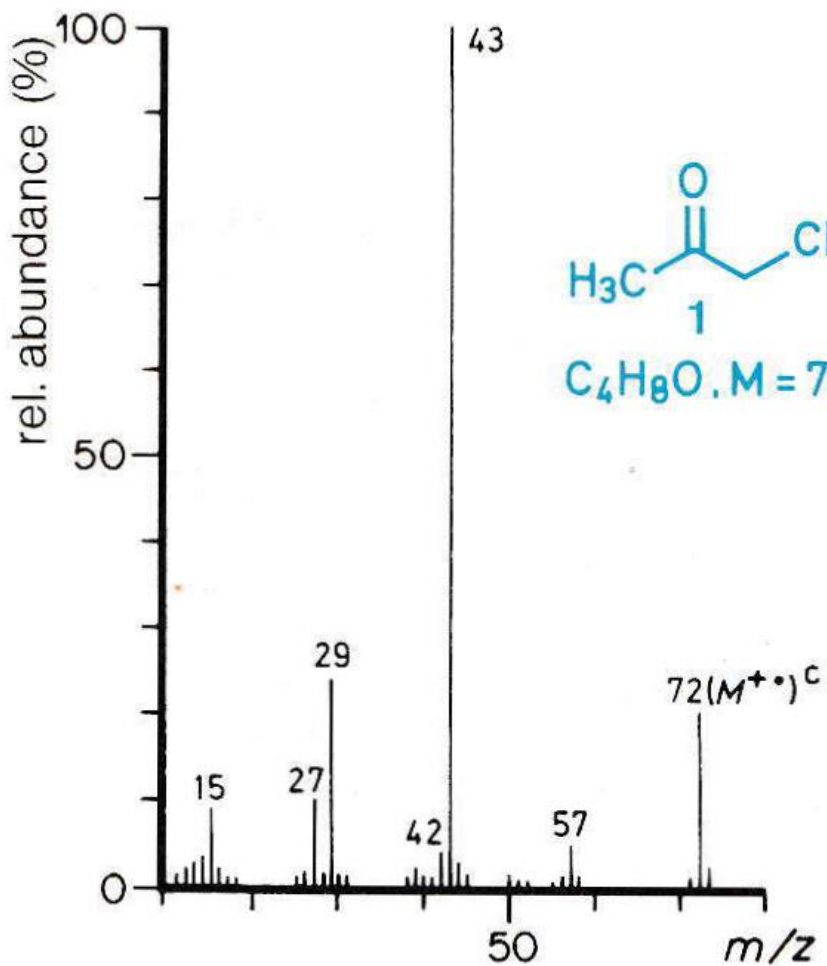
Δυναμικό ιονισμού (7-14 eV):

| | | | |
|------------------|----------|------------------|----------|
| <i>n</i> -hexane | 10.17 eV | ethanol | 10.48 eV |
| cyclohexane | 9.88 eV | acetaldehyde | 10.21 eV |
| cyclohexene | 8.95 eV | acetic acid | 10.35 eV |
| benzene | 9.25 eV | <hr/> | |
| anthracene | 7.23 eV | methylamine | 8.97 eV |
| | | aniline | 7.70 eV |
| | | <hr/> | |
| | | trifluoromethane | 13.84 eV |

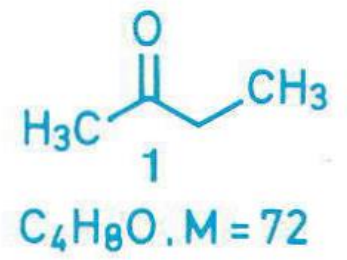
α-Απόσπαση

Norrish type I (φωτοχημεία)

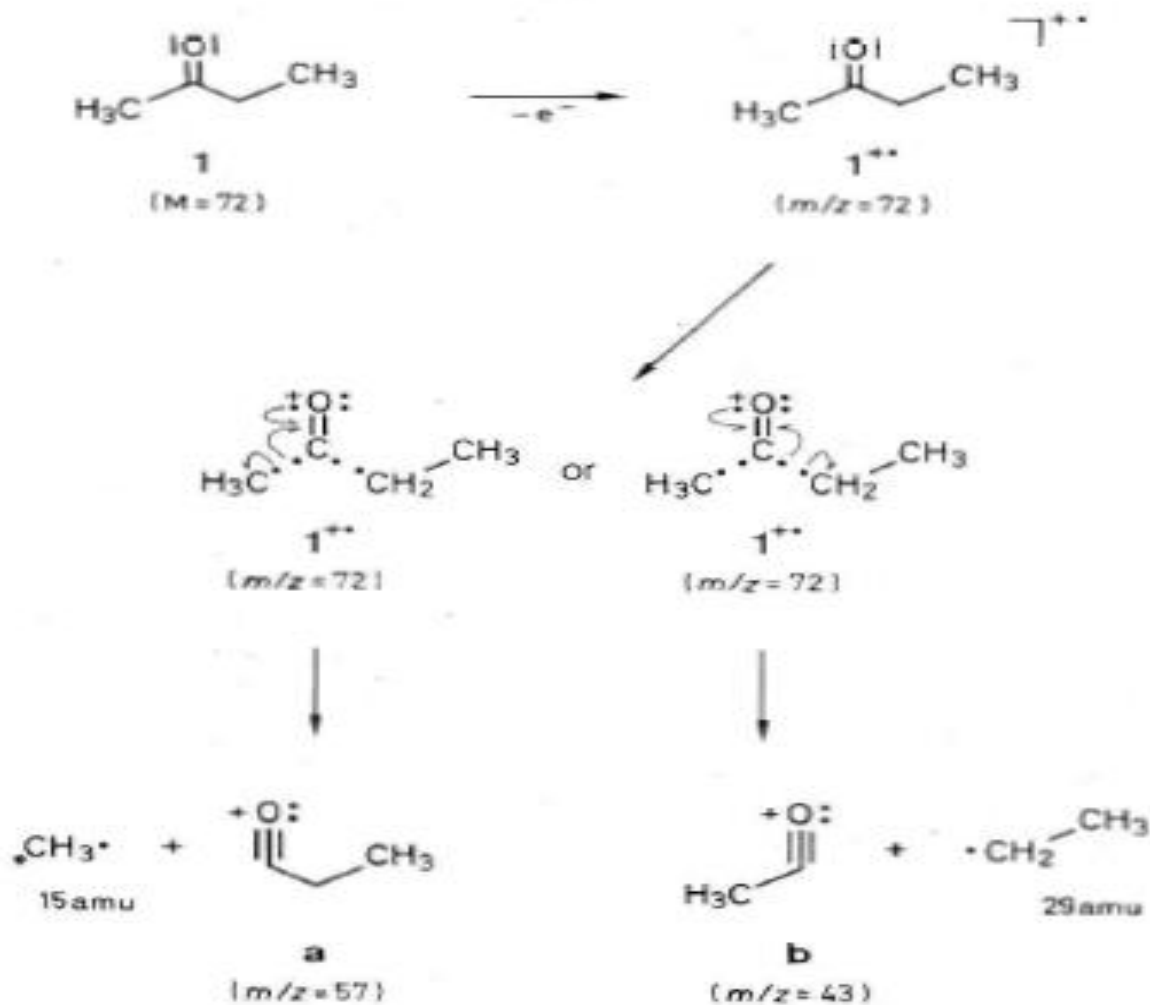




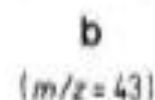
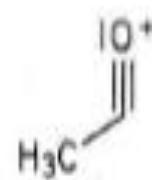
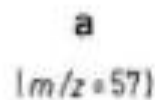
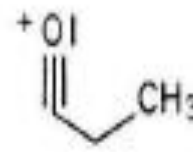
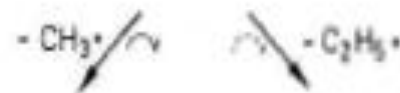
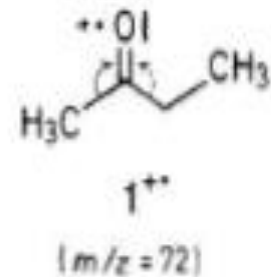
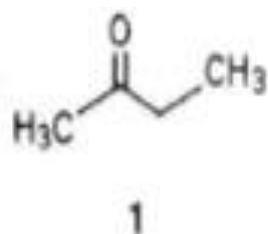
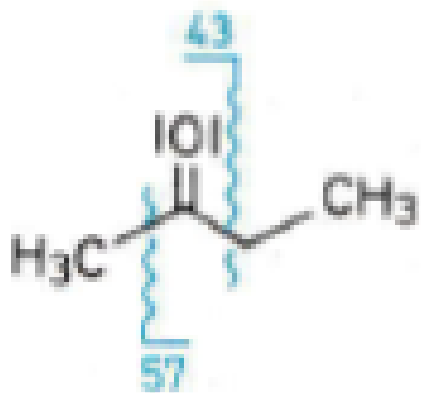
Δύο χαρακτηριστικά θραύσματα
m/z 57 και m/z 43

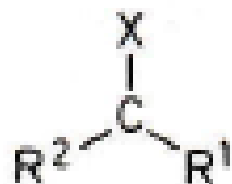


Αναλυτική περιγραφή θραυσματοποίησης



Απλή περιγραφή





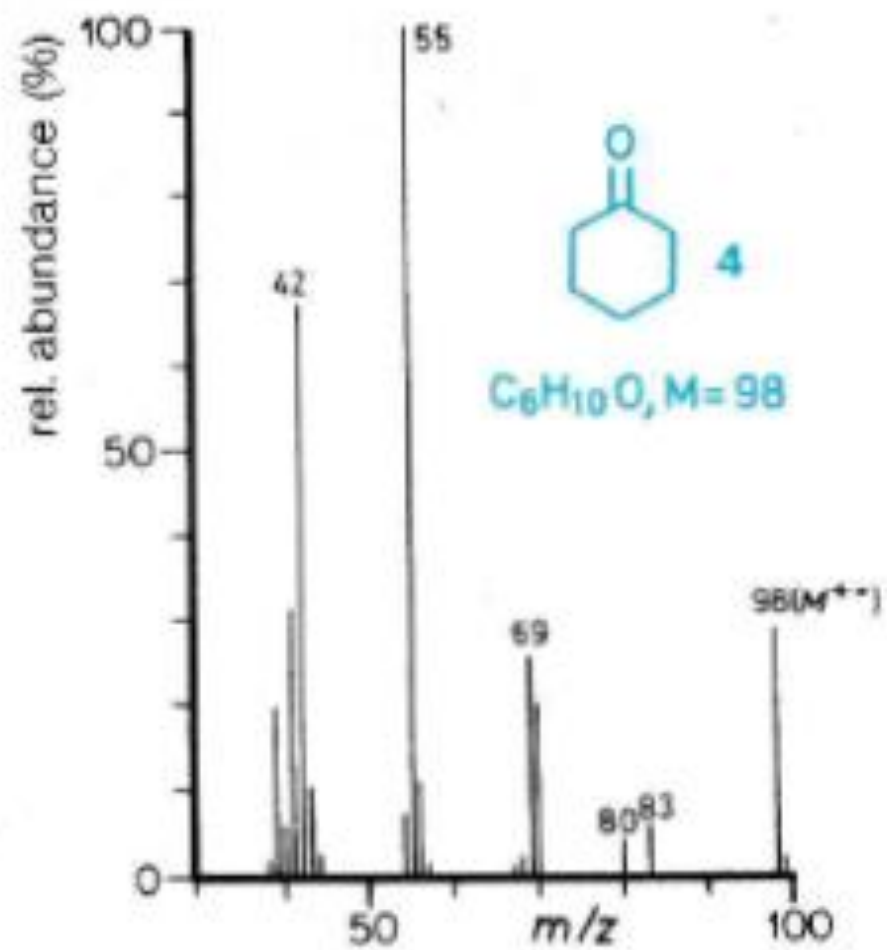
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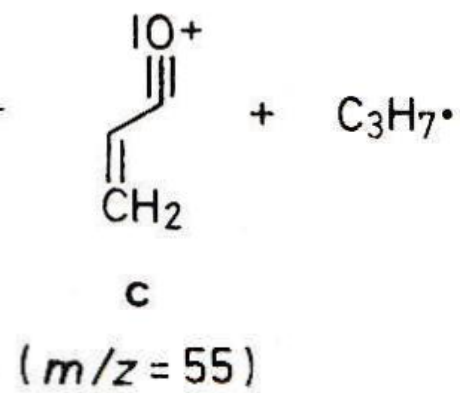
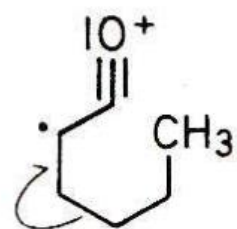
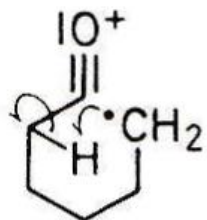
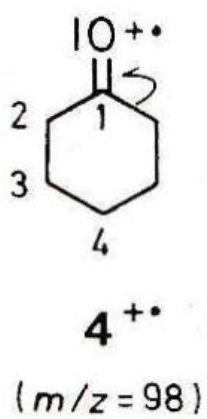
| X | R ¹ | R ² | M - R ¹ | | M - R ² | | Compound | M |
|--|-------------------------------|--------------------------------|--------------------|-----------------|--------------------|-----------------|----------------|-----|
| | all straight-chain | | <i>m/z</i> | rel. abund. (%) | <i>m/z</i> | rel. abund. (%) | | |
| ketones | | | | | | | | |
| $\begin{array}{c} \text{O} \\ \\ \text{C} \end{array}$ | CH ₃ | C ₂ H ₅ | 57 | 6 | 43 | 100 | 2-butanone | 72 |
| | CH ₃ | C ₄ H ₉ | 85 | 4 | 43 | 100 | 2-hexanone | 100 |
| | C ₂ H ₅ | C ₃ H ₇ | 71 | 61 | 57 | 100 | 3-hexanone | 100 |
| | C ₃ H ₇ | C ₄ H ₉ | 85 | 75 | 71 | 100 | 4-octanone | 128 |
| | C ₃ H ₇ | C ₆ H ₁₃ | 113 | 66 | 71 | 100 | 4-decanone | 156 |
| secondary alcohols | | | | | | | | |
| $\begin{array}{c} \text{OH} \\ \\ \text{C} \\ \\ \text{H} \end{array}$ | CH ₃ | C ₂ H ₅ | 59 | 19 | 45 | 100 | 2-butanol | 74 |
| | CH ₃ | C ₃ H ₇ | 73 | 6 | 45 | 100 | 2-pentanol | 88 |
| | CH ₃ | C ₄ H ₉ | 87 | 5 | 45 | 100 | 2-hexanol | 102 |
| | C ₂ H ₅ | C ₃ H ₇ | 73 | 41 | 59 | 100 | 3-hexanol | 102 |
| secondary thiols | | | | | | | | |
| $\begin{array}{c} \text{SH} \\ \\ \text{C} \\ \\ \text{H} \end{array}$ | CH ₃ | C ₂ H ₅ | 75 | 5 | 61 | 100 | 2-butanethiol | 90 |
| | CH ₃ | C ₃ H ₇ | 89 | 2 | 61 | 100 | 2-pentanethiol | 104 |
| amines | | | | | | | | |
| $\begin{array}{c} \text{NH}_2 \\ \\ \text{C} \\ \\ \text{H} \end{array}$ | CH ₃ | C ₂ H ₅ | 58 | 11 | 44 | 100 | 2-aminobutane | 73 |

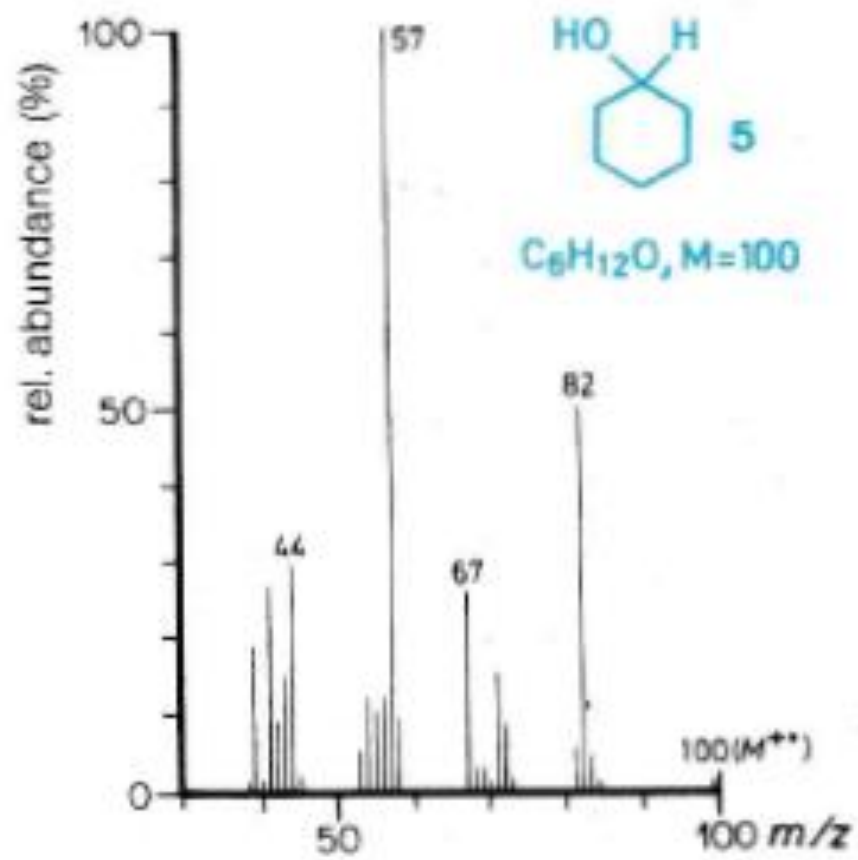


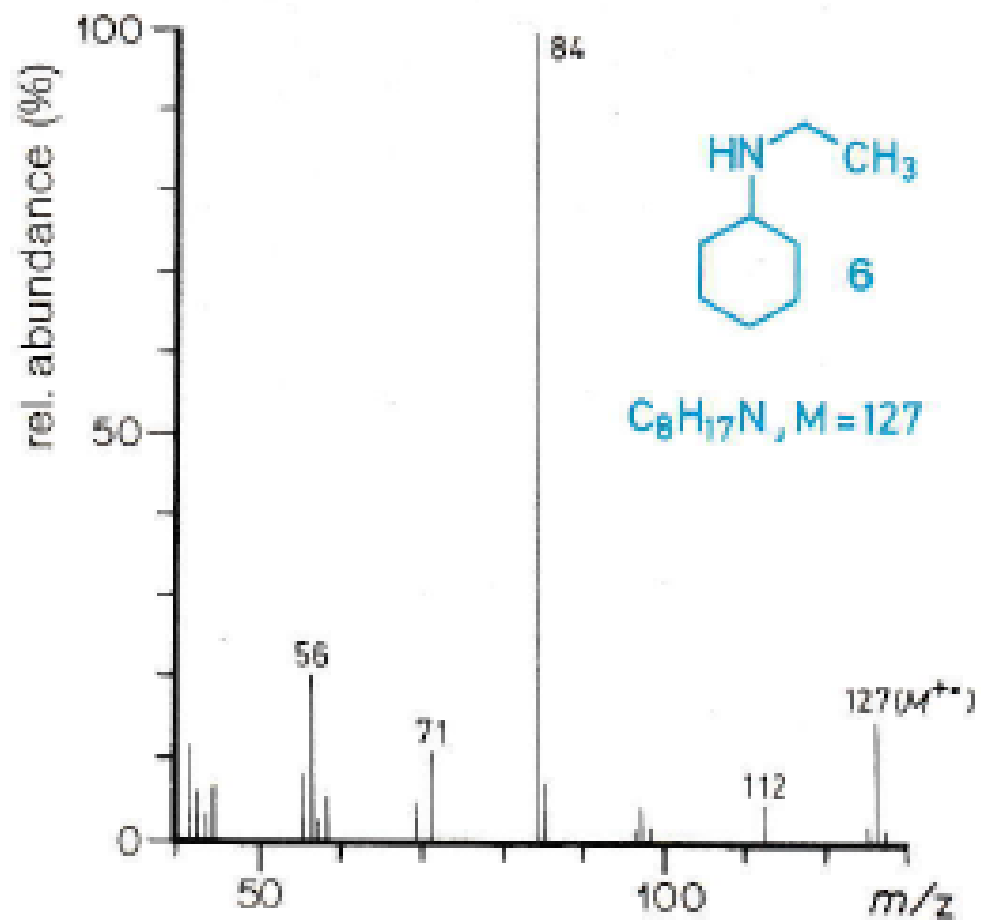
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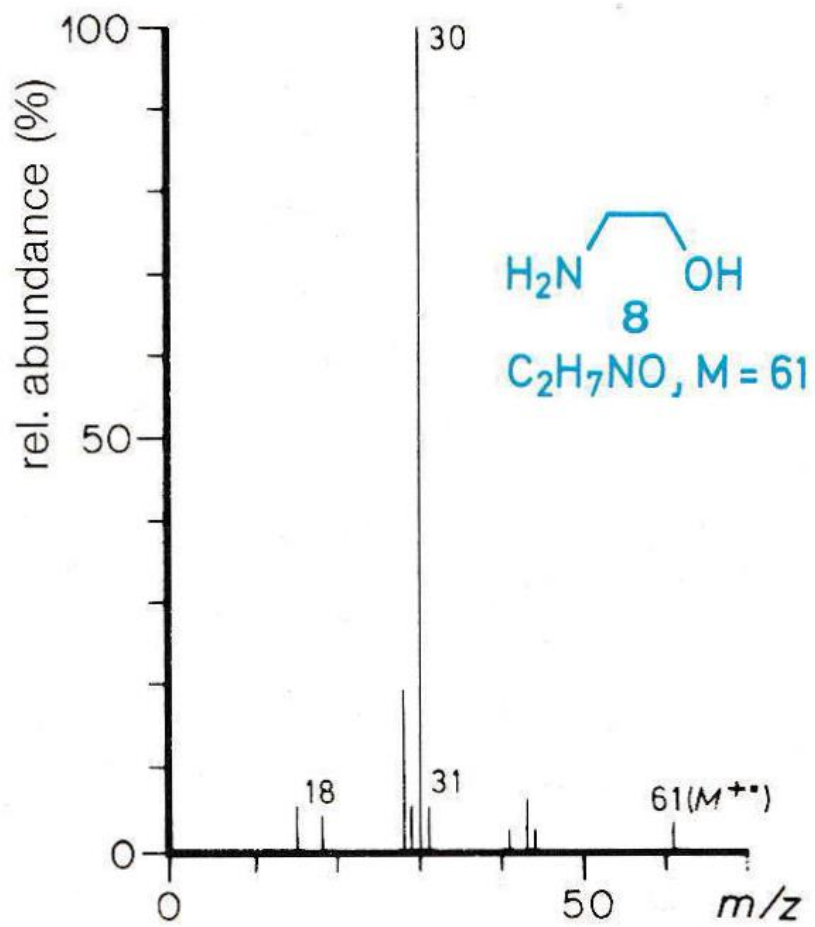
| | R ¹ | R ² | M - R ¹ | | M - R ² | | Compound | M |
|---------------|-------------------------------|-------------------------------|--------------------|-----------------|--------------------|-----------------|----------------------|-----|
| X | all straight-chain | | <i>m/z</i> | rel. abund. (%) | <i>m/z</i> | rel. abund. (%) | | |
| ethers | | | | | | | | |
| O | CH ₃ | C ₃ H ₇ | 87 | 2 | 59 | 100 | butyl ethyl ether | 102 |
| | C ₂ H ₅ | C ₃ H ₇ | 87 | 54 | 73 | 100 | butyl propyl ether | 116 |
| amines | | | | | | | | |
| NH | CH ₃ | C ₂ H ₅ | 72 | 10 | 58 | 100 | N-ethyl propyl amine | 87 |
| | C ₂ H ₅ | C ₃ H ₇ | 86 | 43 | 72 | 100 | butyl ethyl amine | 115 |




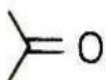
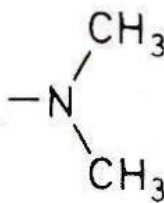




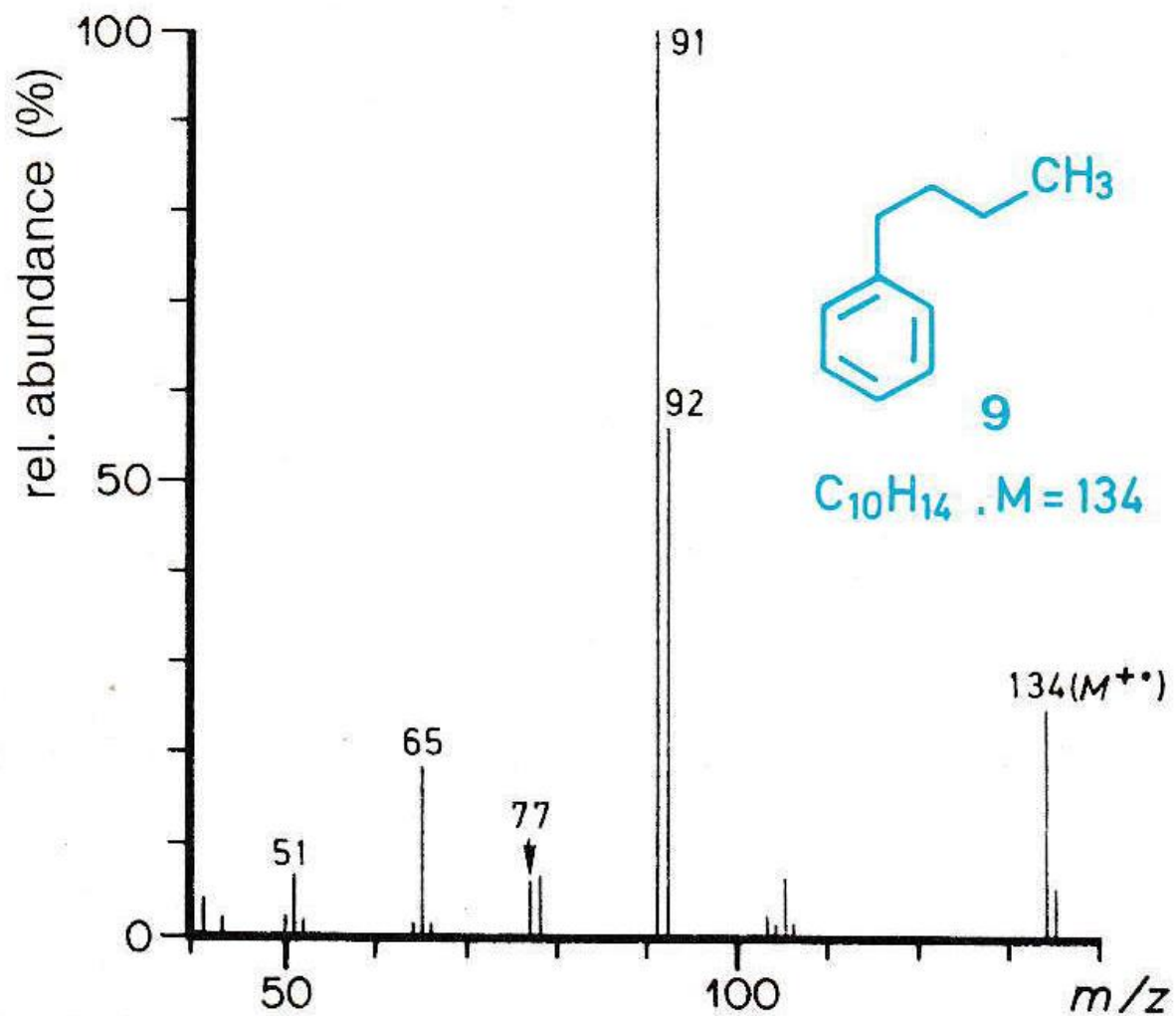


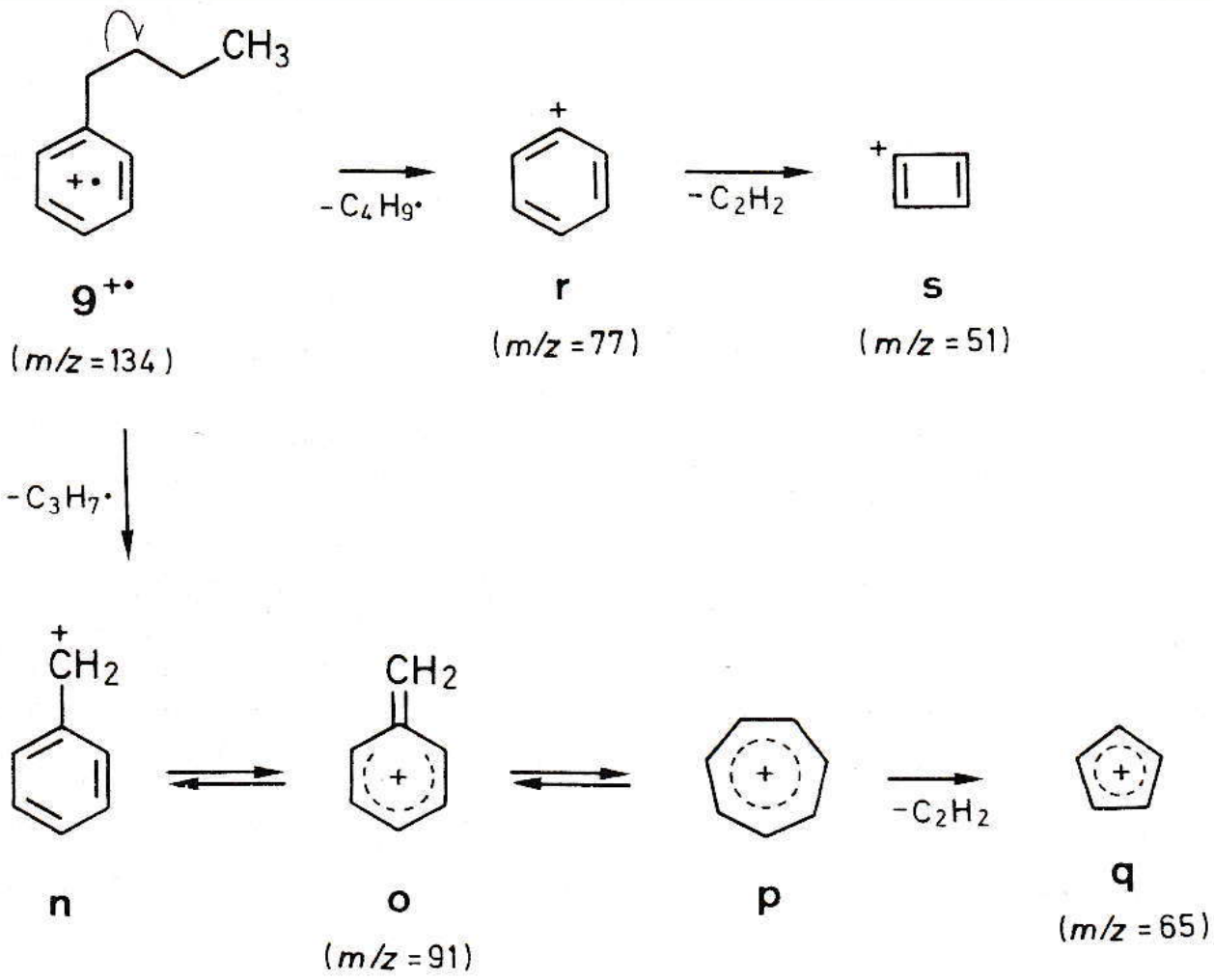


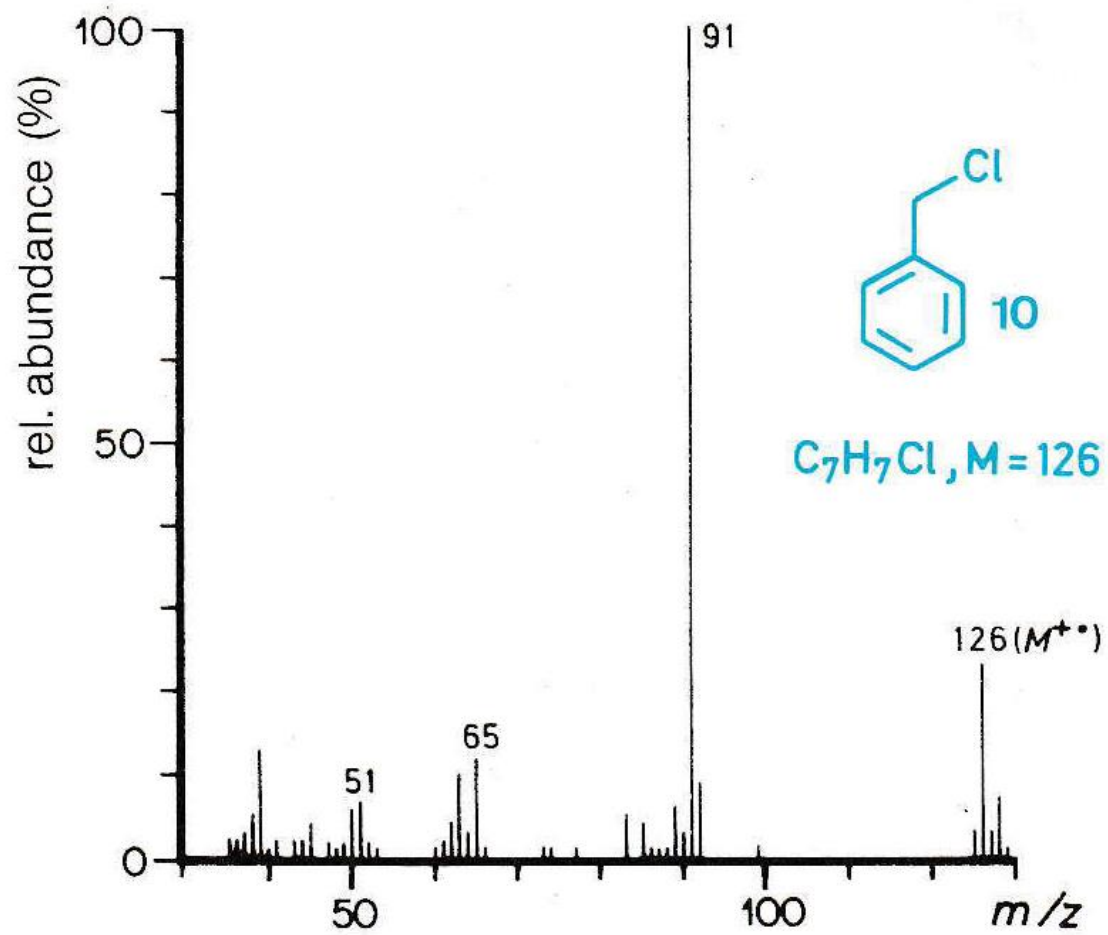
Επίδραση σταθεροποίησης φορτίου

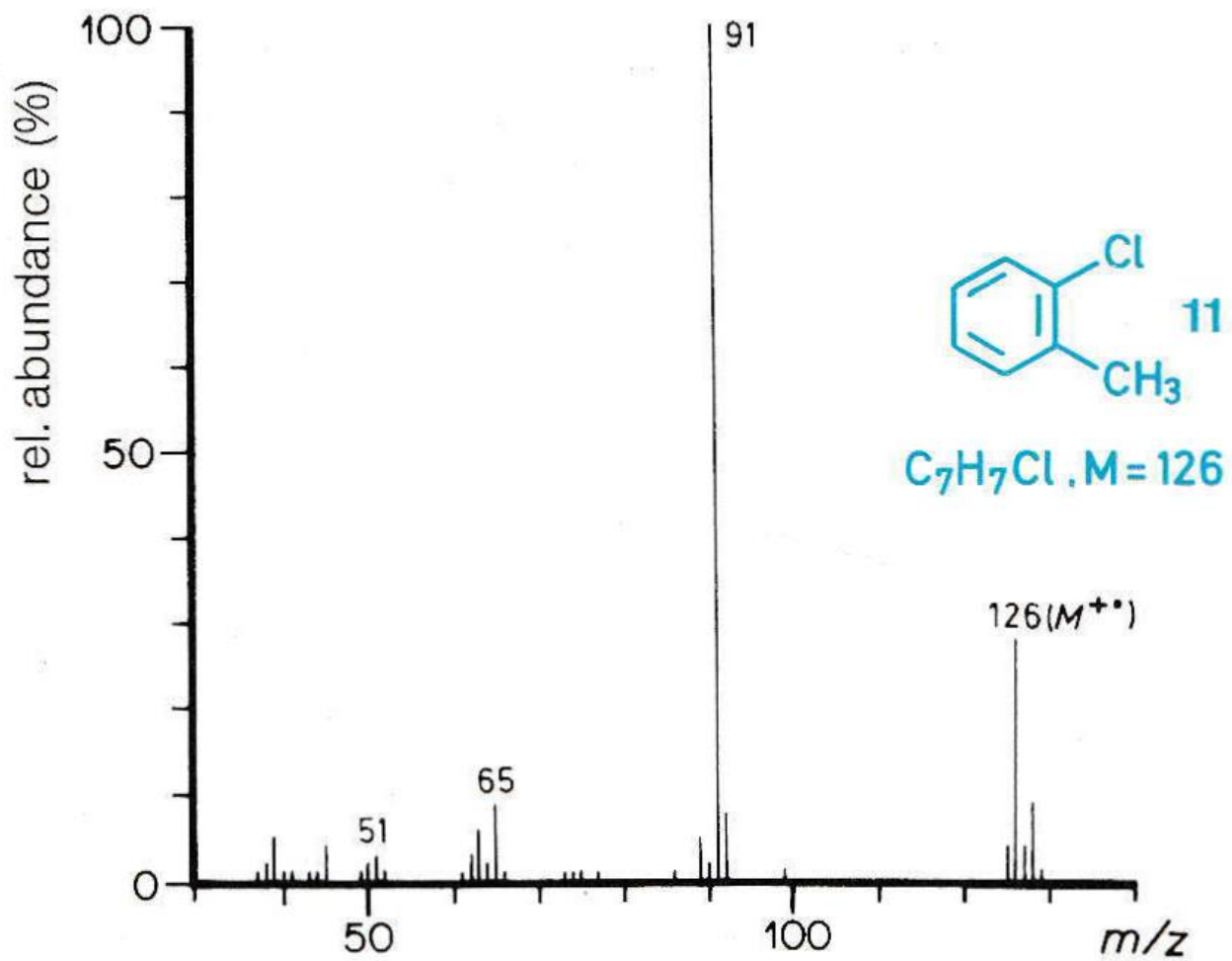
| Functional group | Ion abundance | Functional group | Ion abundance |
|---|---------------|---|---------------|
| —COOH | 1 | —I | 109 |
| —Cl | 8 | —SCH ₃ | 114 |
| —OH | 8 | —NHCOCH ₃ | 128 |
| —Br | 13 | —NH ₂ | 990 |
| —COOCH ₃ | 20 |  | 1600 |
|  | 43 |  | 2100 |
| —OCH ₃ | 100 | | |

Βενζυλο απόσπαση

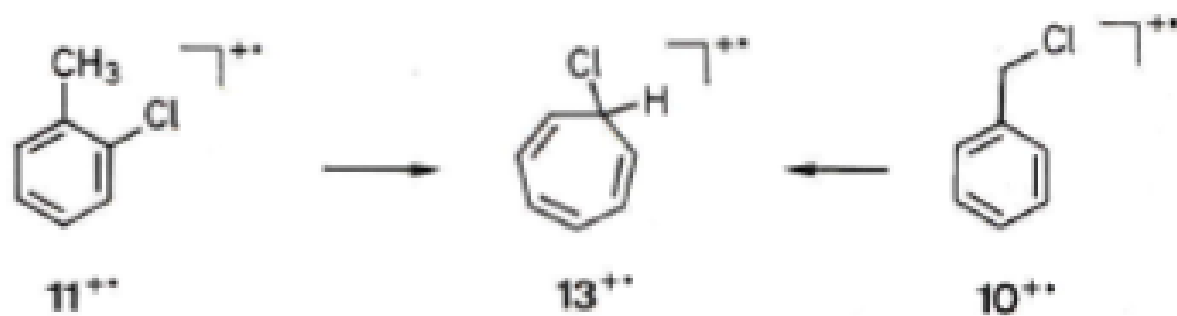


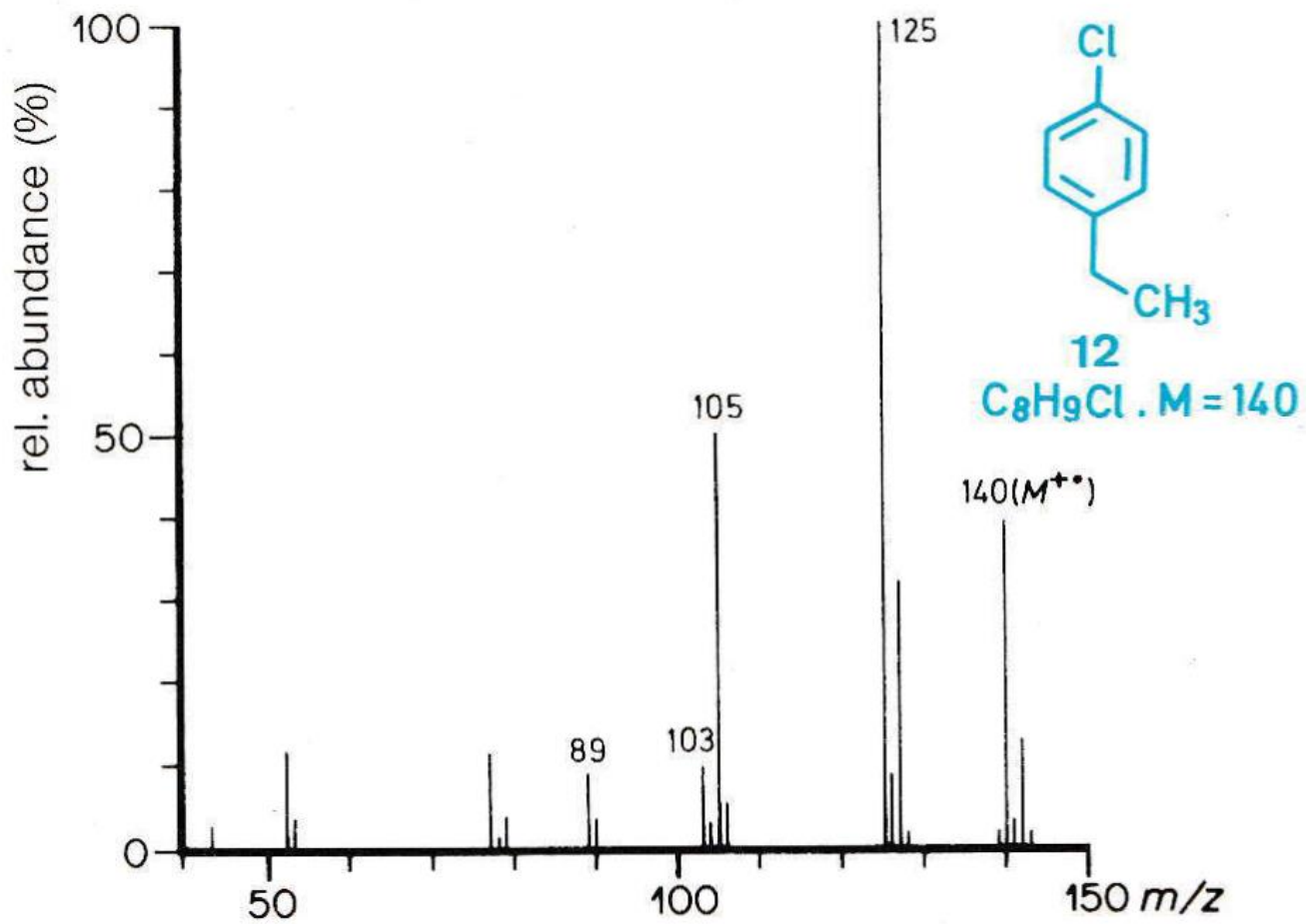




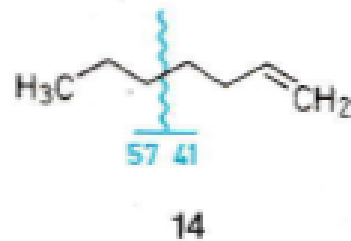
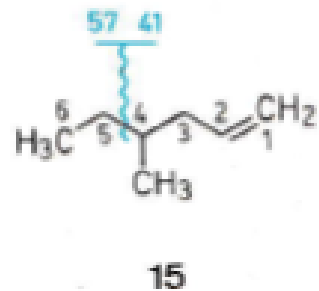


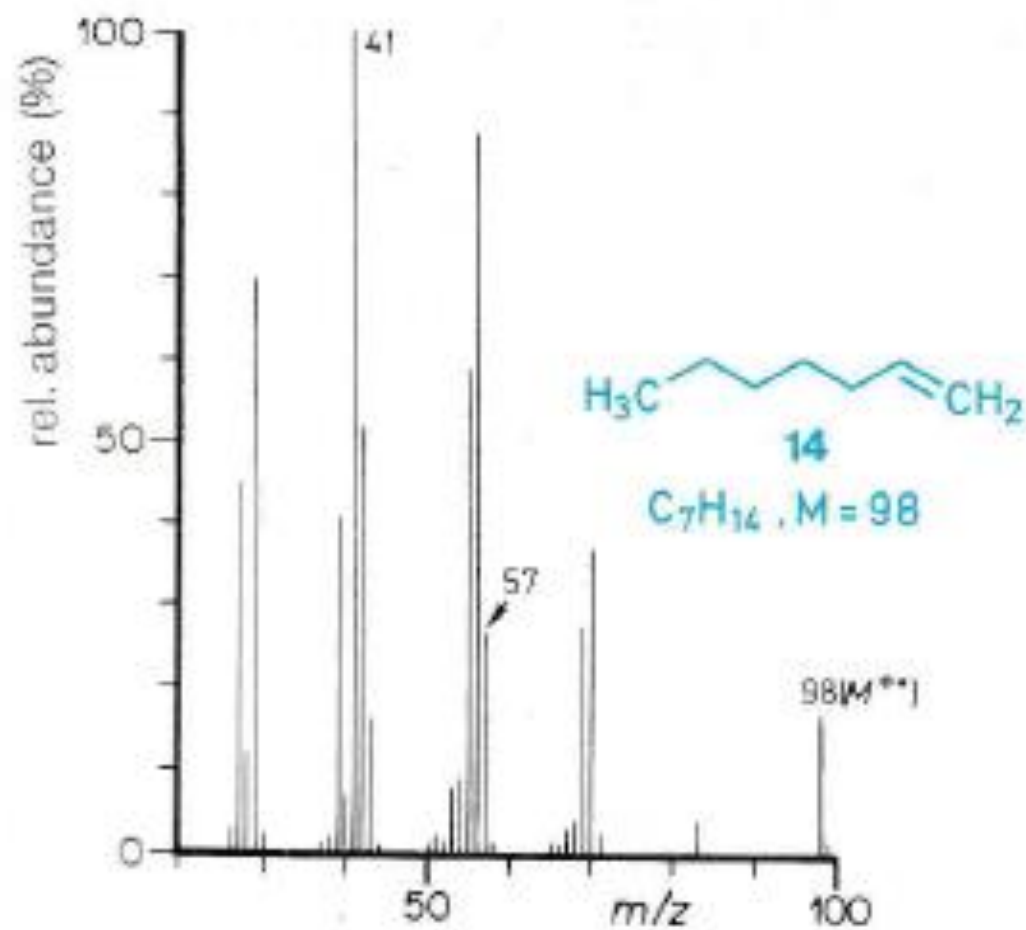
Εξήγηση:

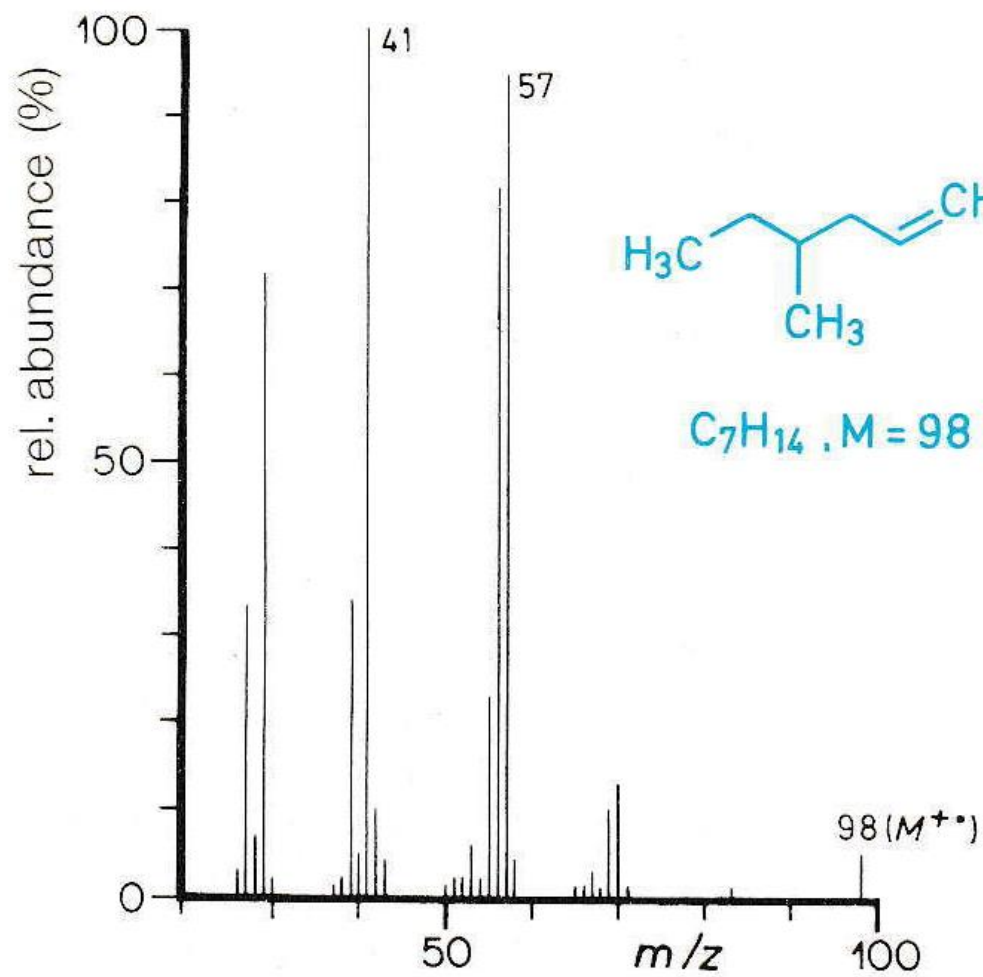




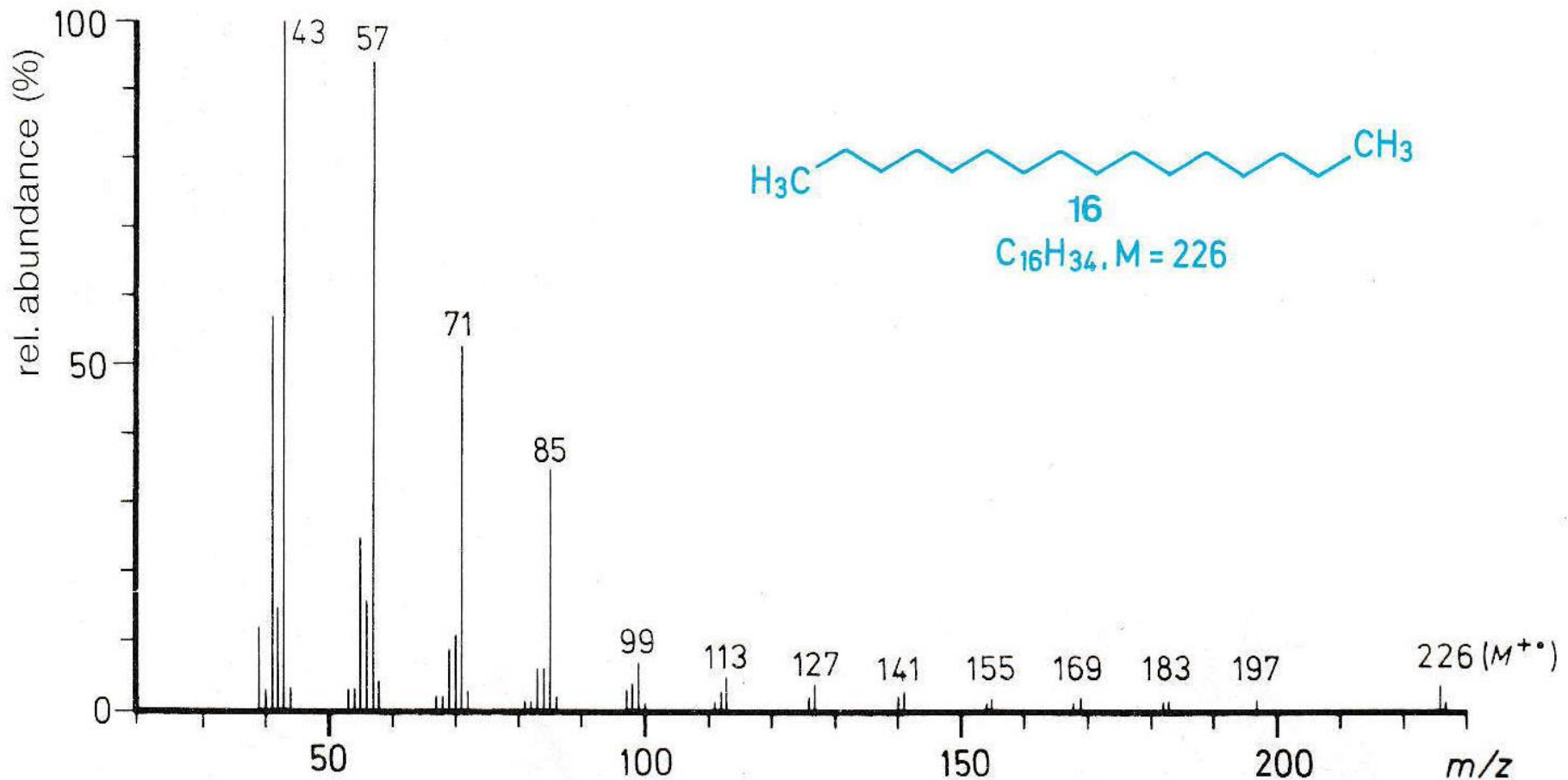
Άλλυλο απόσπαση

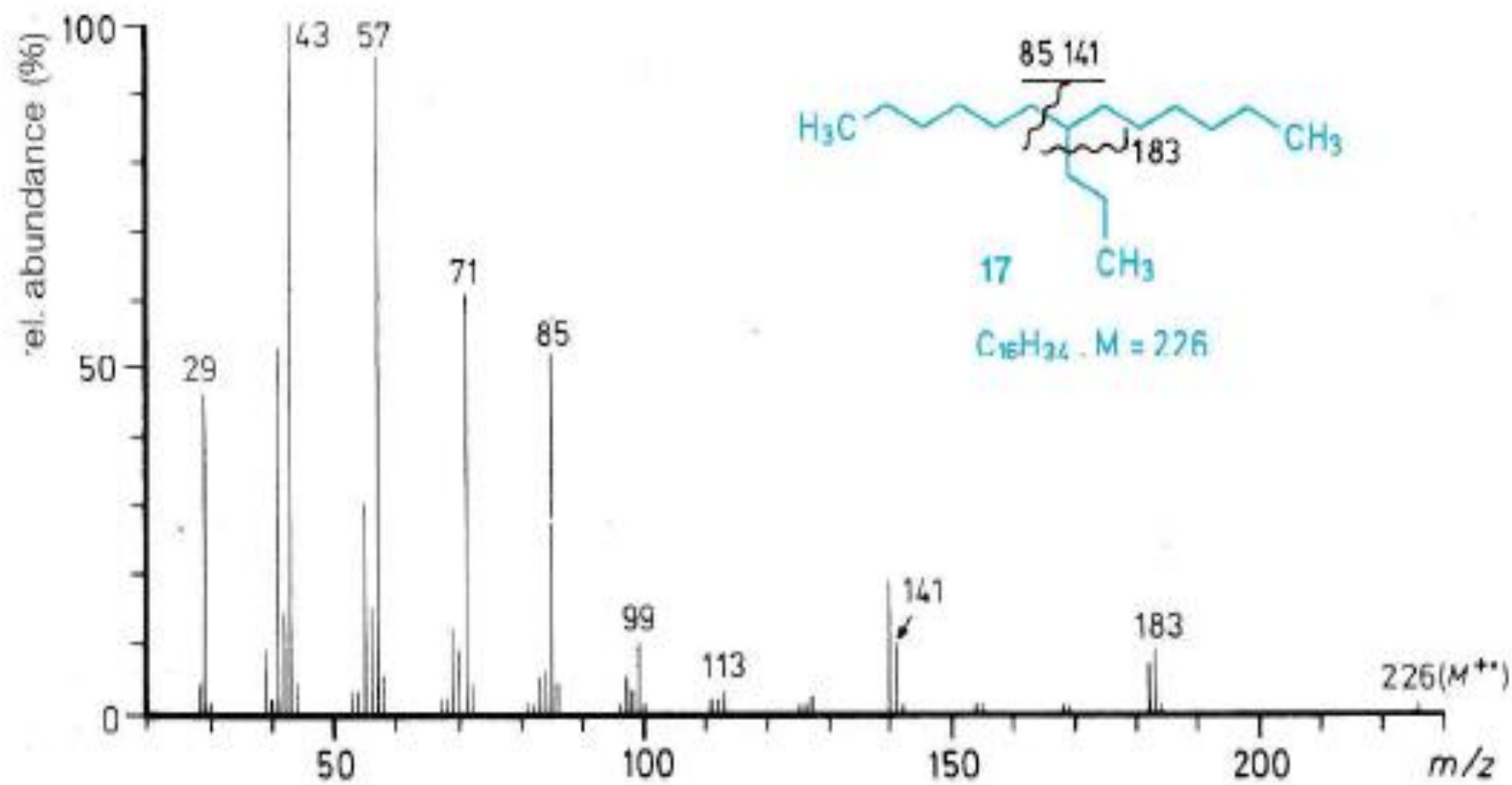


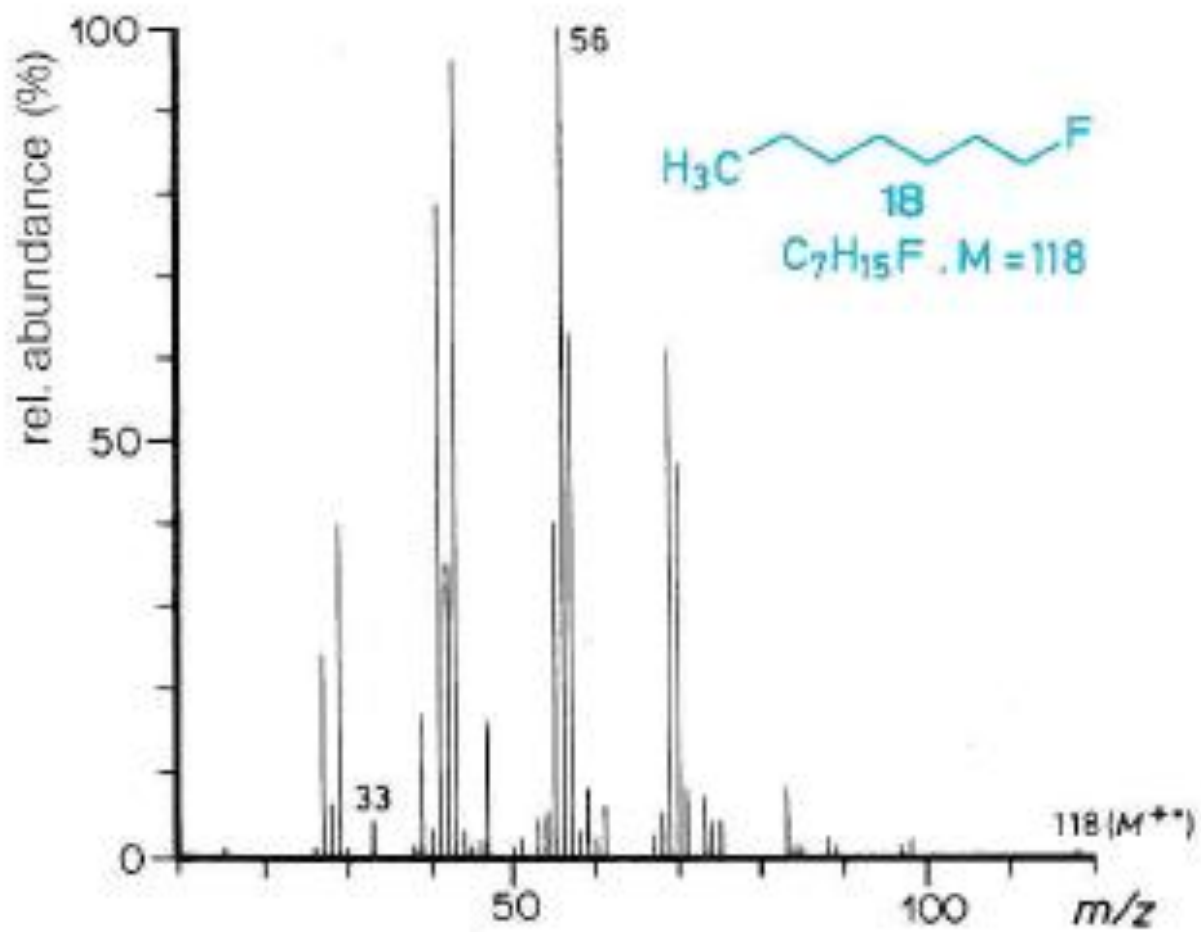


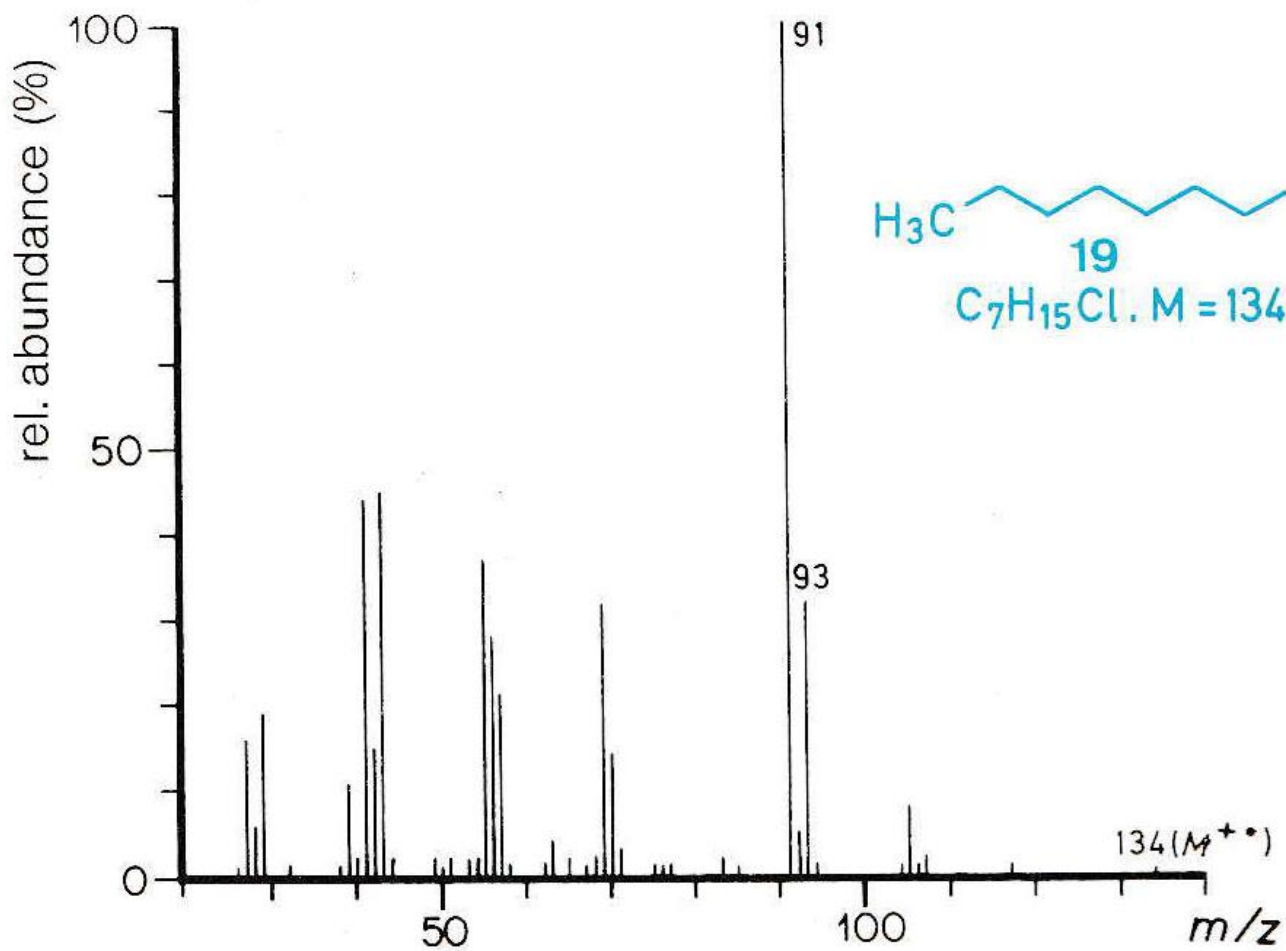


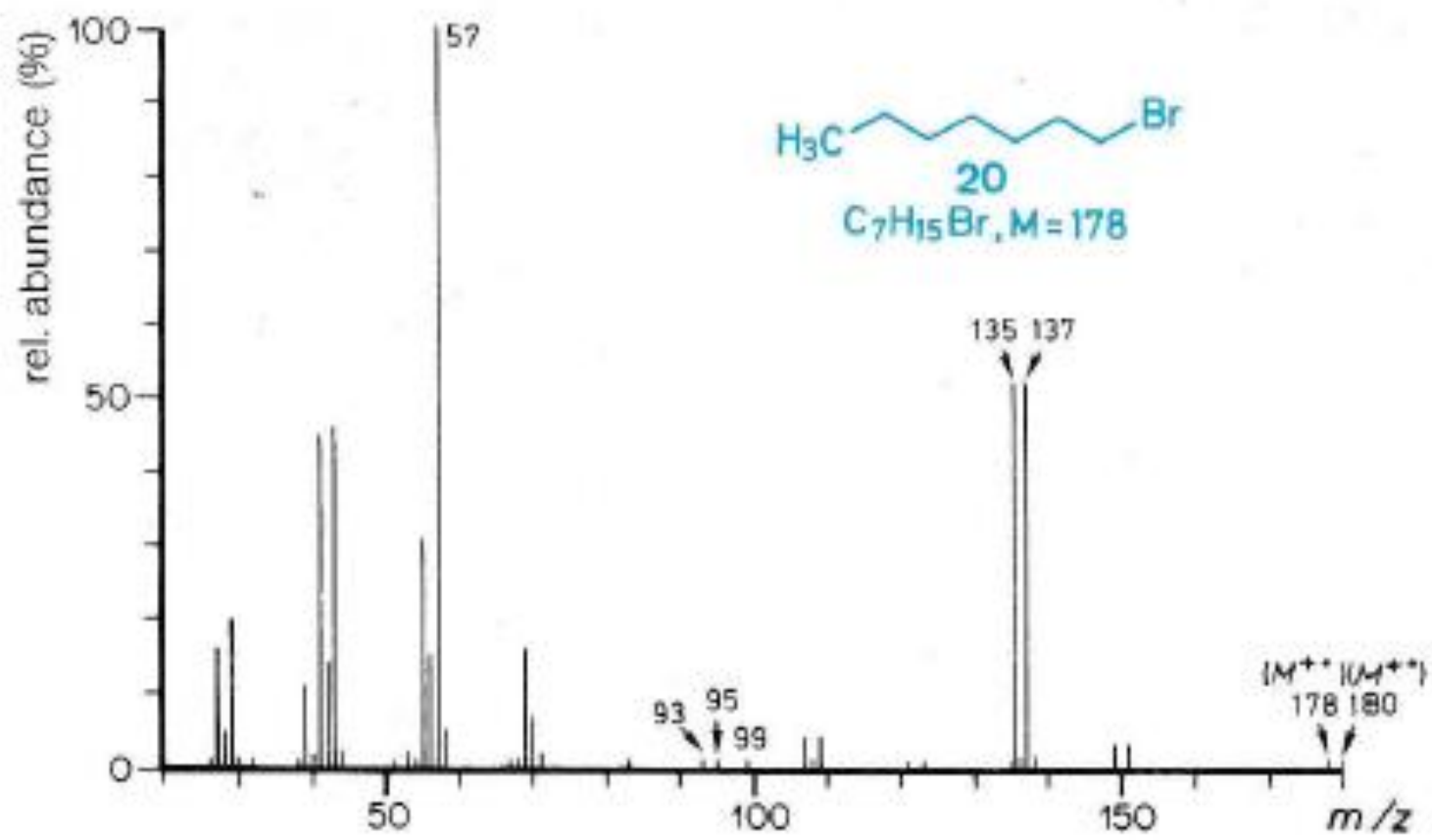
Απόσπαση «μη ενεργών» δεσμών









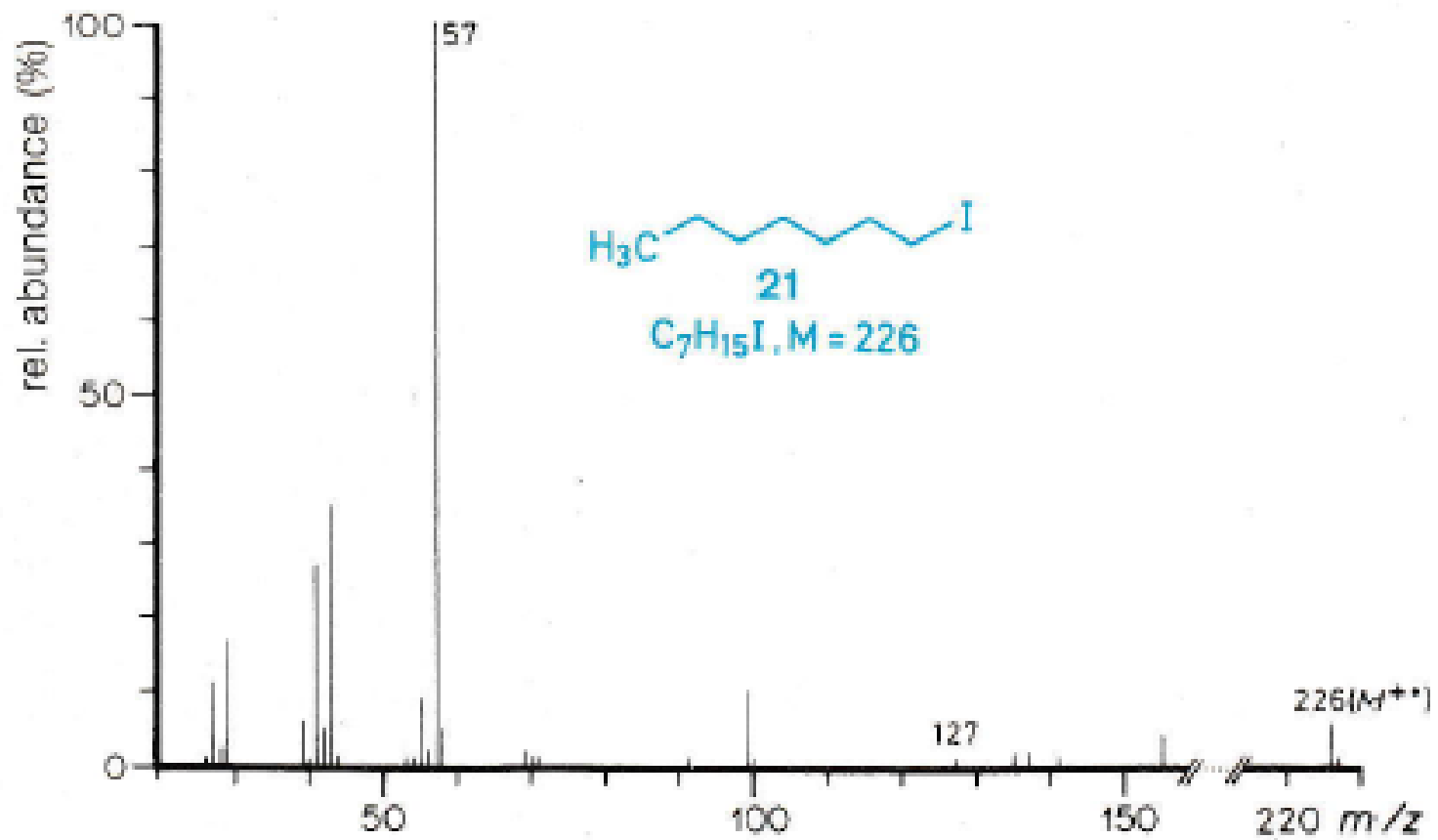




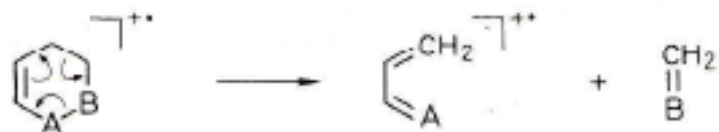
$$m/z = 91 + 93$$

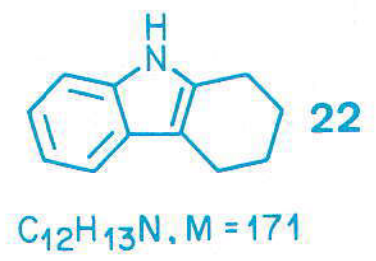
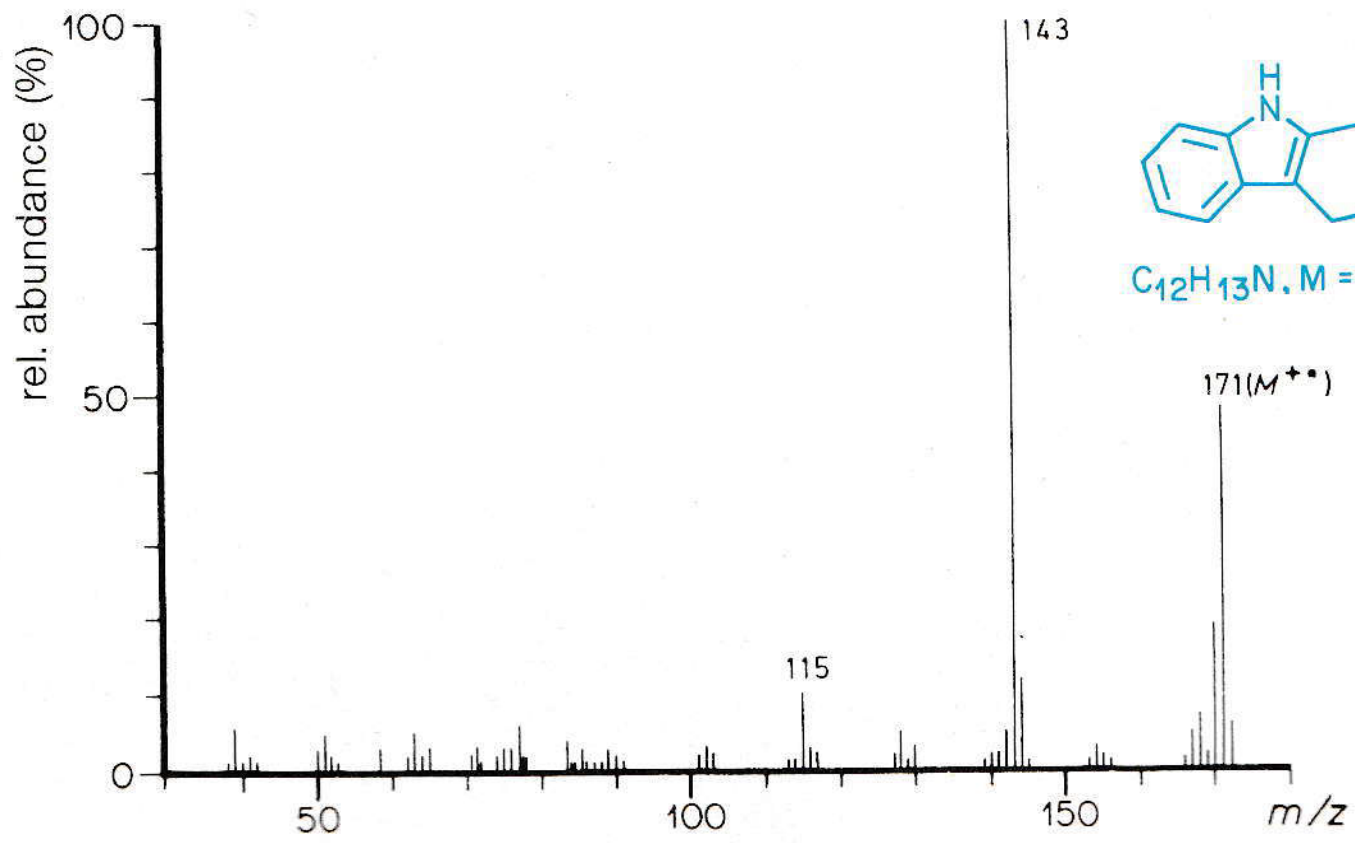


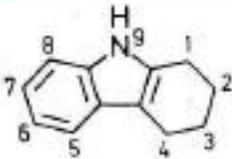
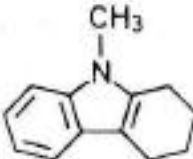
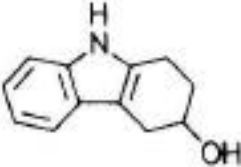
$$m/z = 135 + 137$$

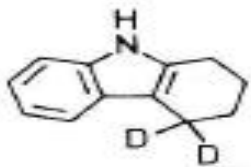
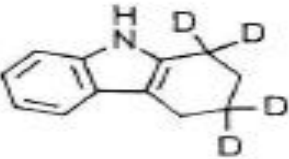
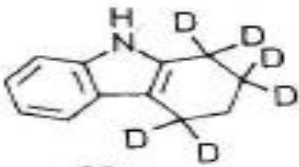


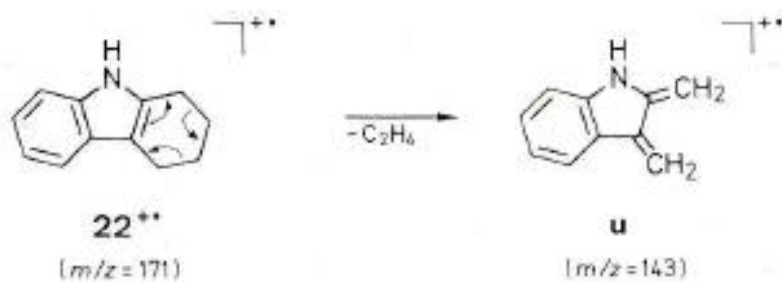
Η retro-Diels-Alder αντίδραση



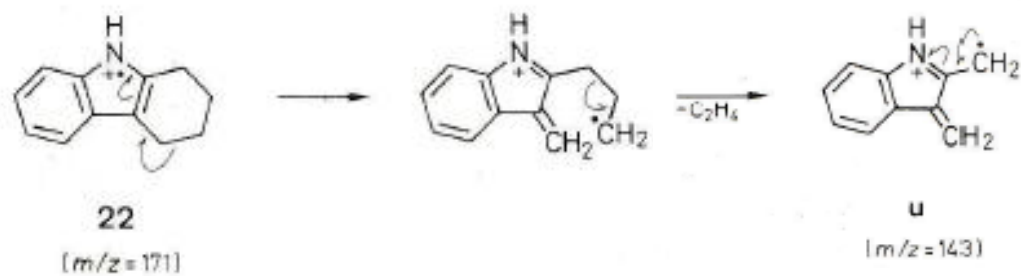


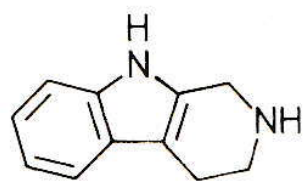
| Compound | M^{\bullet} | | | Fragment ion | | |
|--|---------------|--|--------------------|--------------|-----------------------------|--------------------|
| | m/z | difference from M^{\bullet} of 22 | rel. abundance (%) | m/z | difference from $m/z = 143$ | rel. abundance (%) |
|  22 | 171 | 0 | 63 | 143 | 0 | 100 |
|  23 | 185 | +14 | 50 | 157 | +14 | 100 |
|  24 | 187 | +16 | 43 | 143 | 0 | 100 |

| Compound | M^{\bullet} | | | Fragment ion | | |
|---|---------------|--|--------------------|--------------|-----------------------------|--------------------|
| | m/z | difference from M^{\bullet} of 22 | rel. abundance (%) | m/z | difference from $m/z = 143$ | rel. abundance (%) |
|  <p>22a</p> | 173 | + 2 | 62 | 145 | + 2 | 100 |
|  <p>22b</p> | 175 | + 4 | 62 | 145 | + 2 | 100 |
|  <p>22c</p> | 177 | + 6 | 80 | 147 | + 4 | 100 |

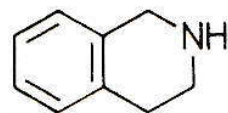


mechanism II

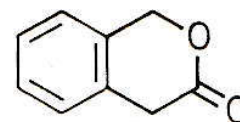




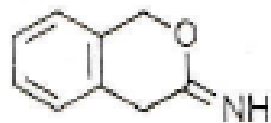
25



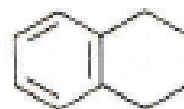
26



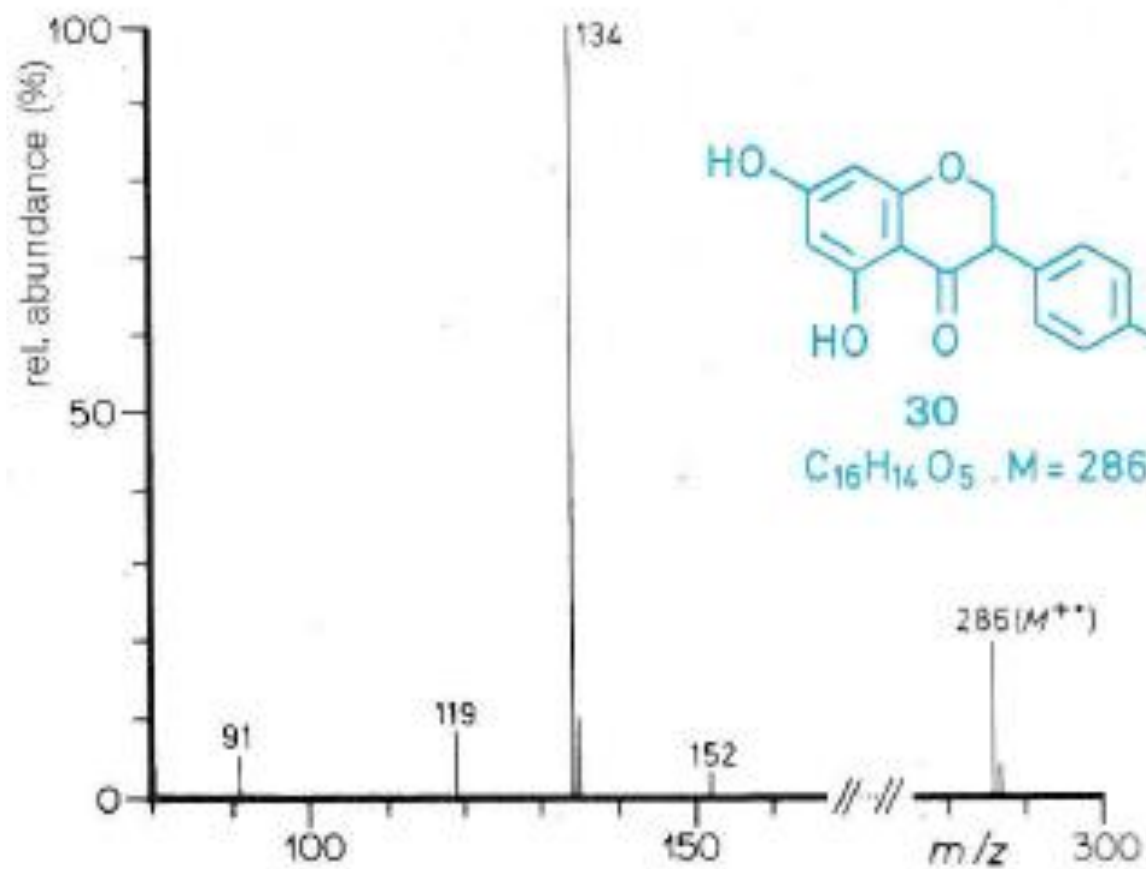
27

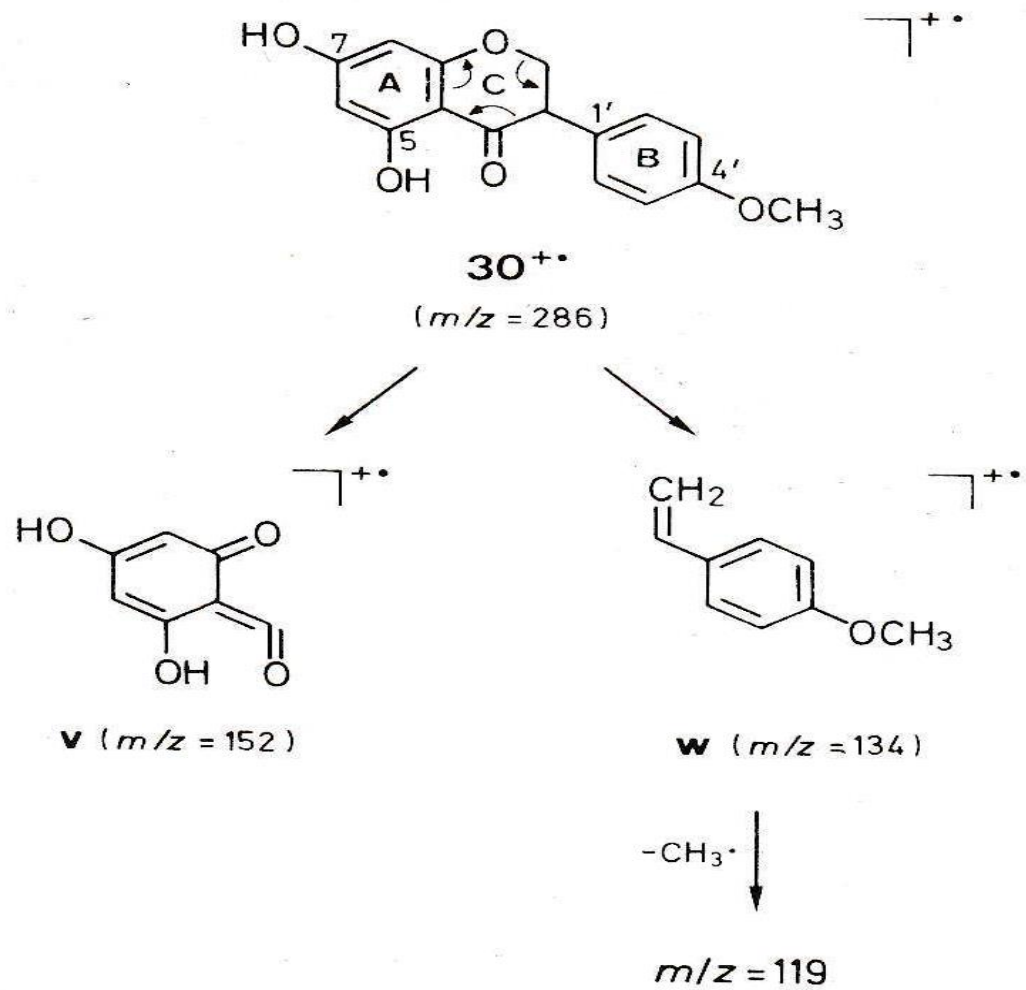


28



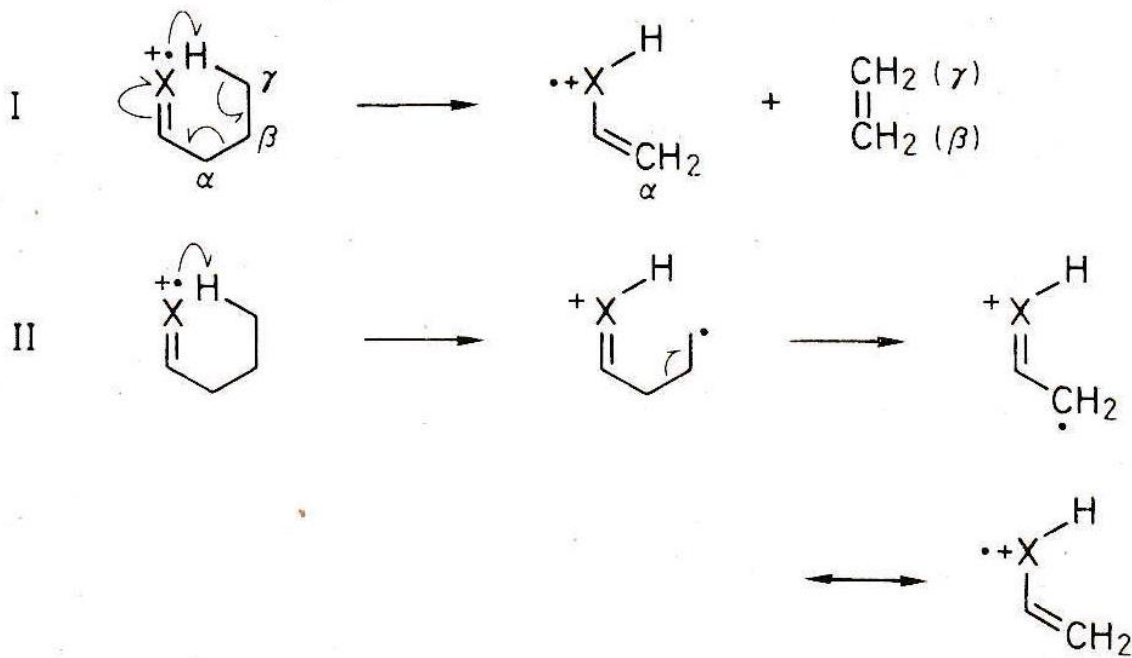
29

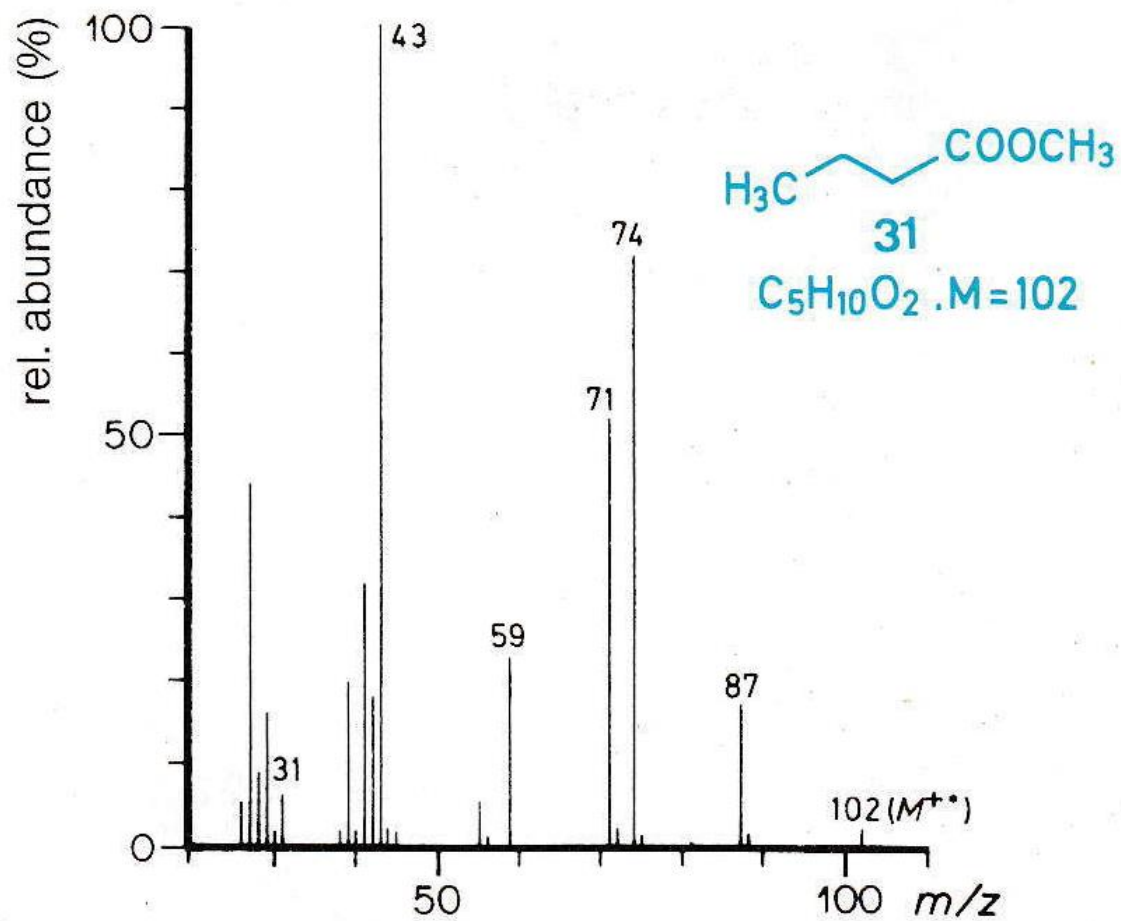




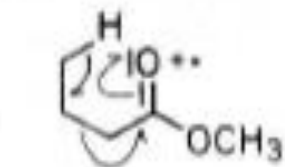
Η μετάθεση McLafferty

Τύπος Norrish II (φωτοχημεία)





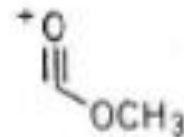
m/z 59, 74 χαρακτηριστικό των μεθυλο εστέρων



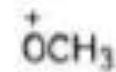
$31^{+\bullet}$

($m/z = 102$)

by α -cleavage:

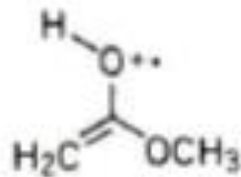


$m/z = 59$



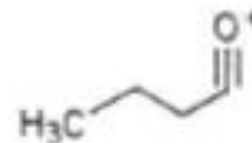
$m/z = 31$

$-C_2H_4$ ↓ McLafferty rearrangement

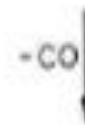


\times

($m/z = 74$)

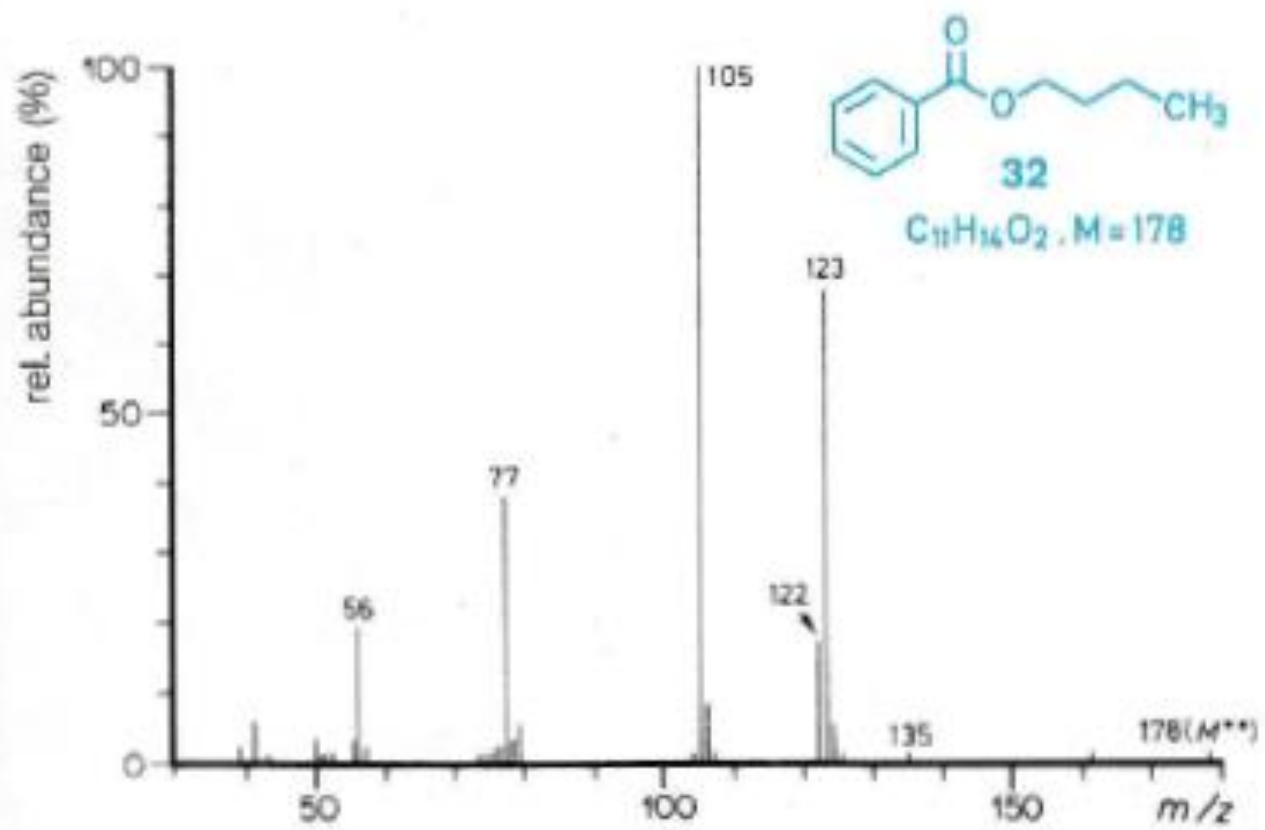


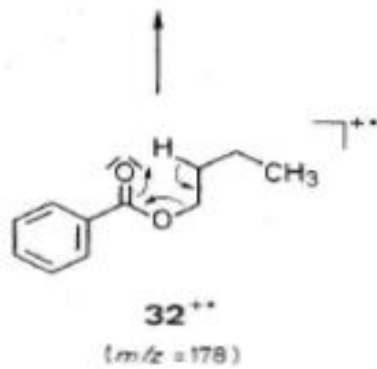
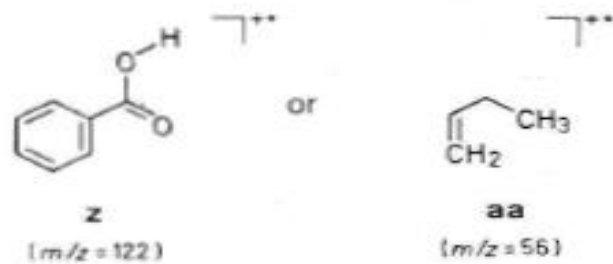
$m/z = 71$



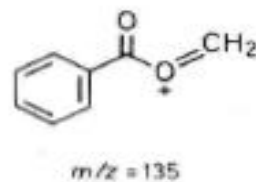
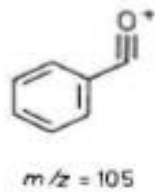
$m/z = 43$

m/z 88, 73 για αιθυλο εστέρες

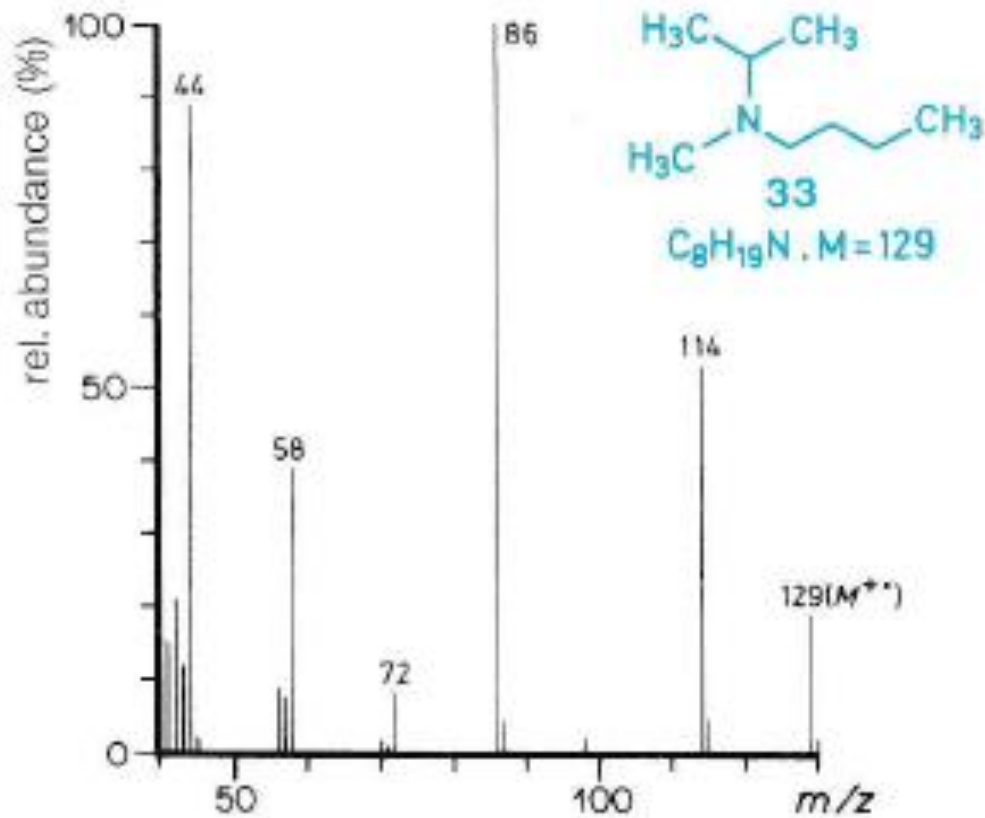


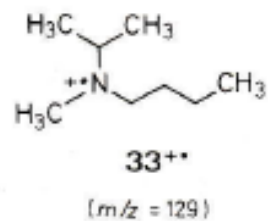


↓ α -cleavage

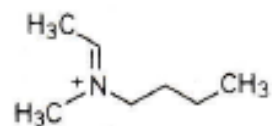


Η ονίυμ αντίδραση



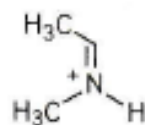


α-cleavage



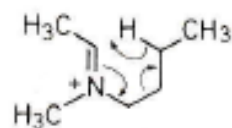
ab
(m/z = 114)

onium
reaction

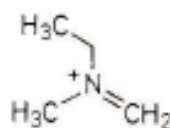


ae
(m/z = 58)

≡

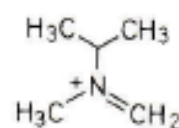


McLafferty
rearrangement



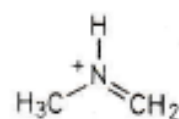
ad
(m/z = 72)

α-cleavage

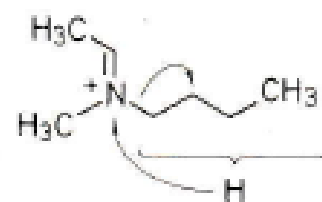


ac
(m/z = 86)

onium
reaction

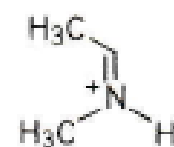


af
(m/z = 44)



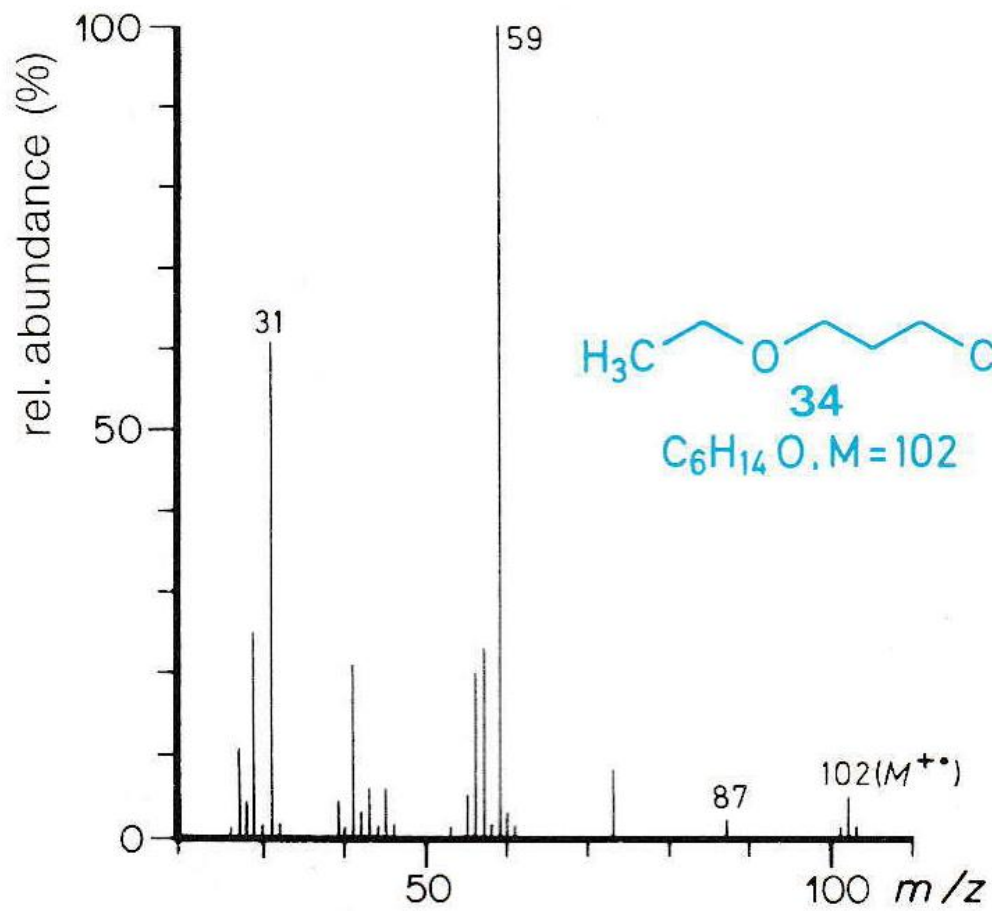
ab

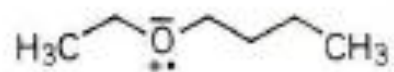
($m/z = 114$)



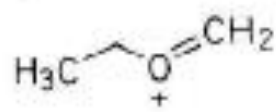
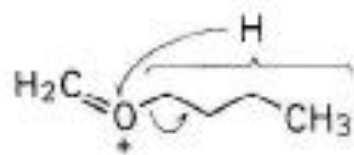
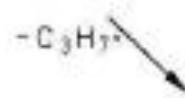
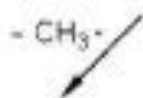
ae

($m/z = 58$)

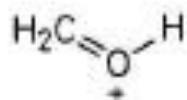
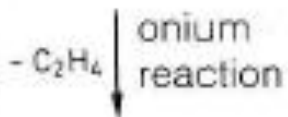
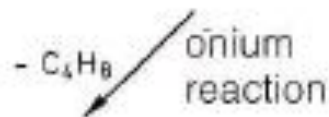




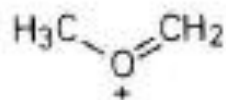
34^{+}
($m/z = 102$)



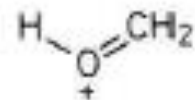
$m/z = 59$



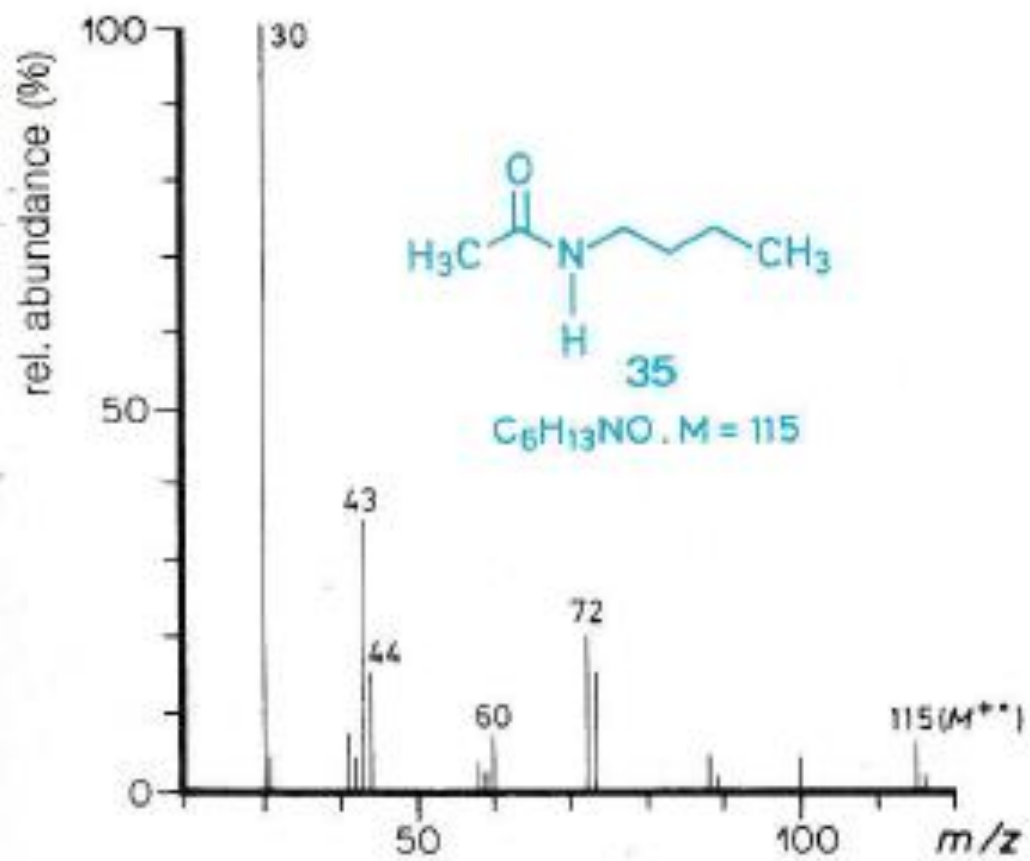
$m/z = 31$

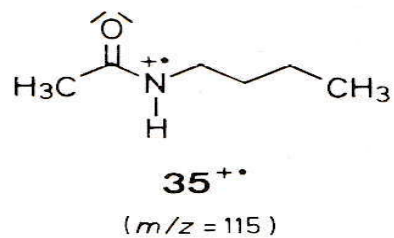


$m/z = 45$

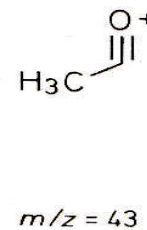


$m/z = 31$

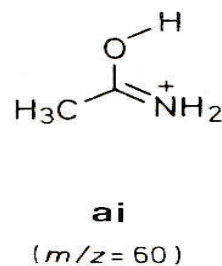
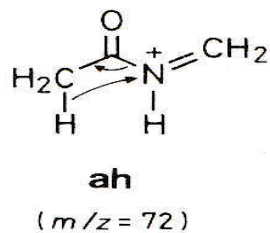




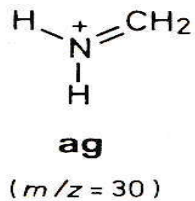
charge on O
 α -cleavage

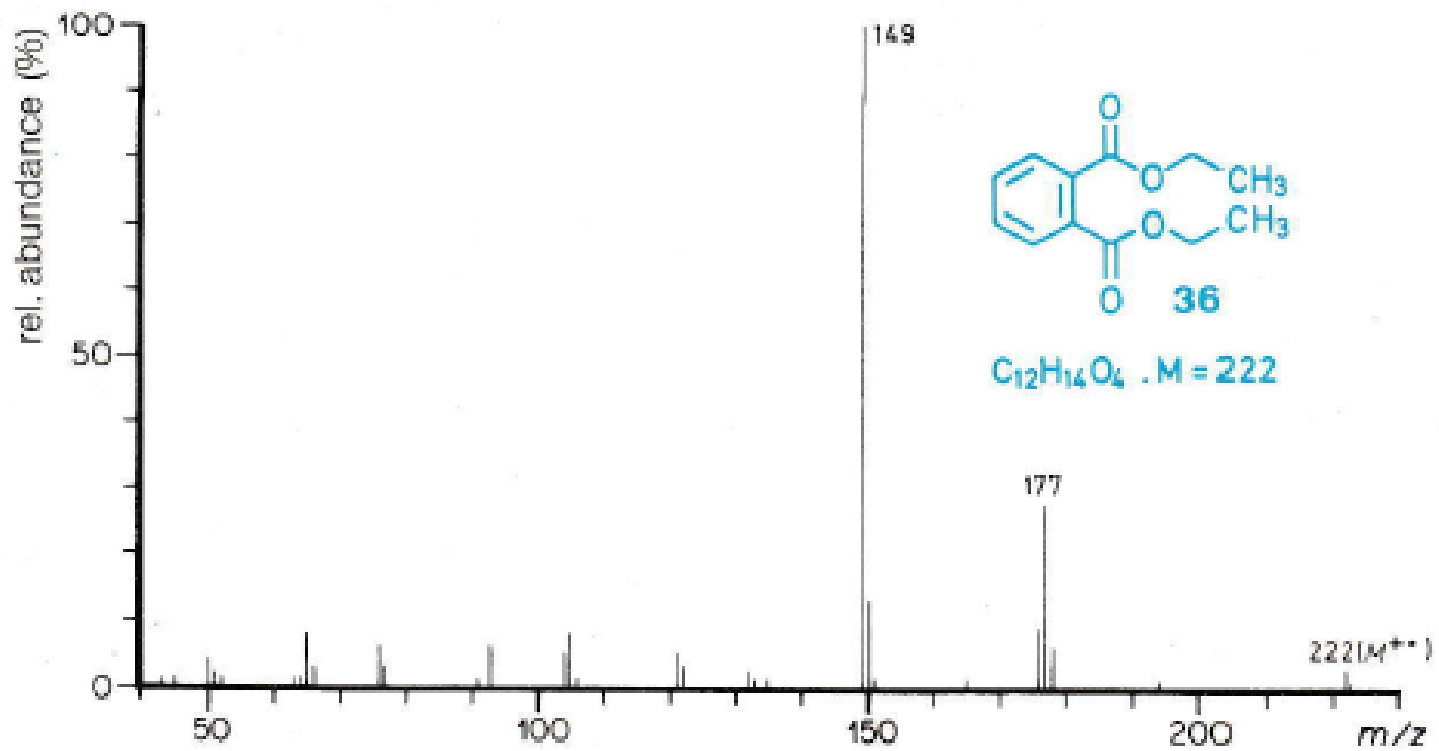


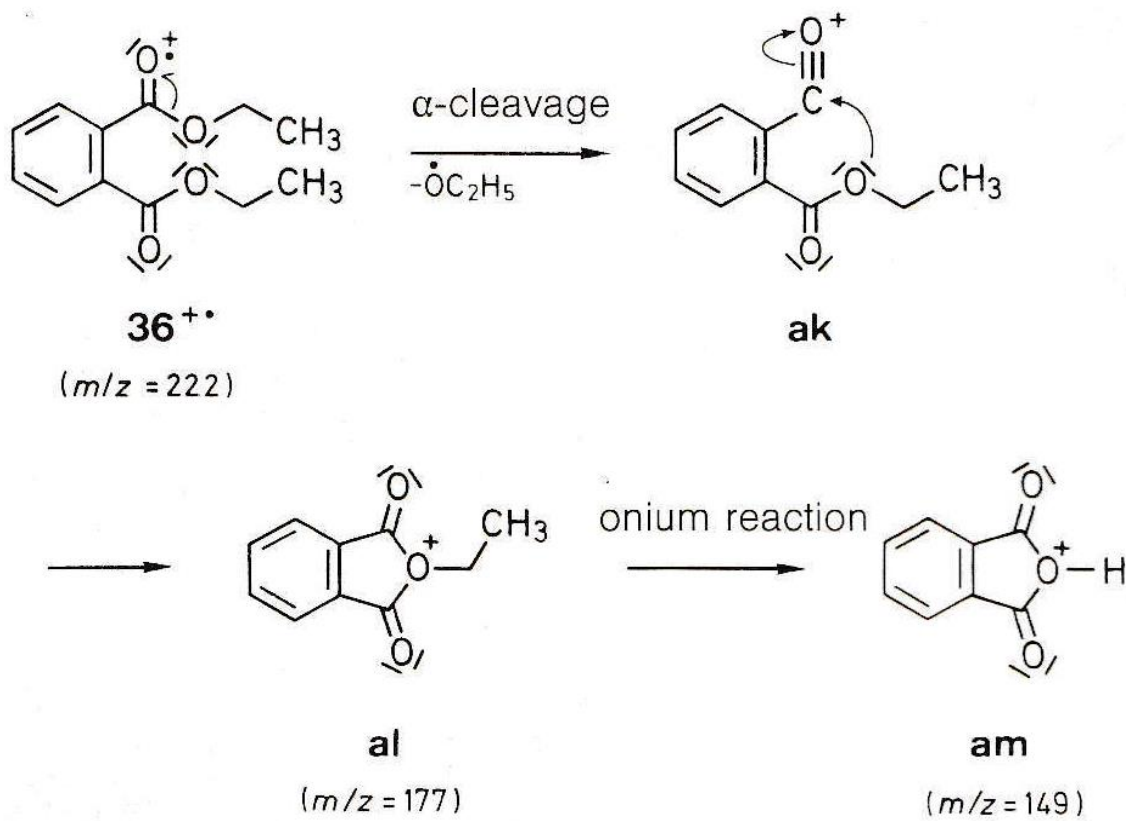
$-\text{C}_3\text{H}_7^{\bullet}$ α -cleavage



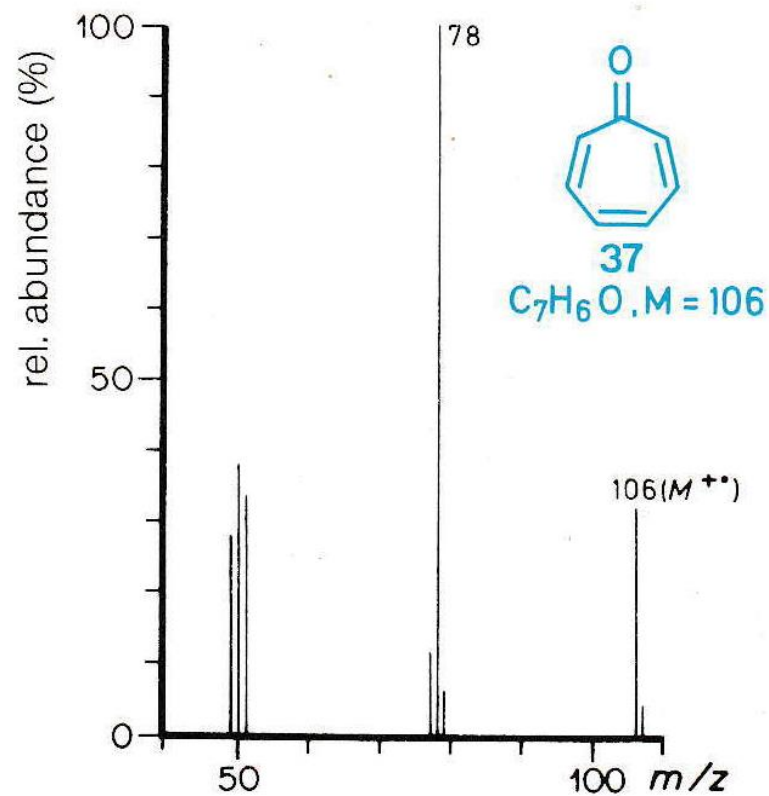
$\text{C}_2\text{H}_2\text{O}$ Onium
 reaction

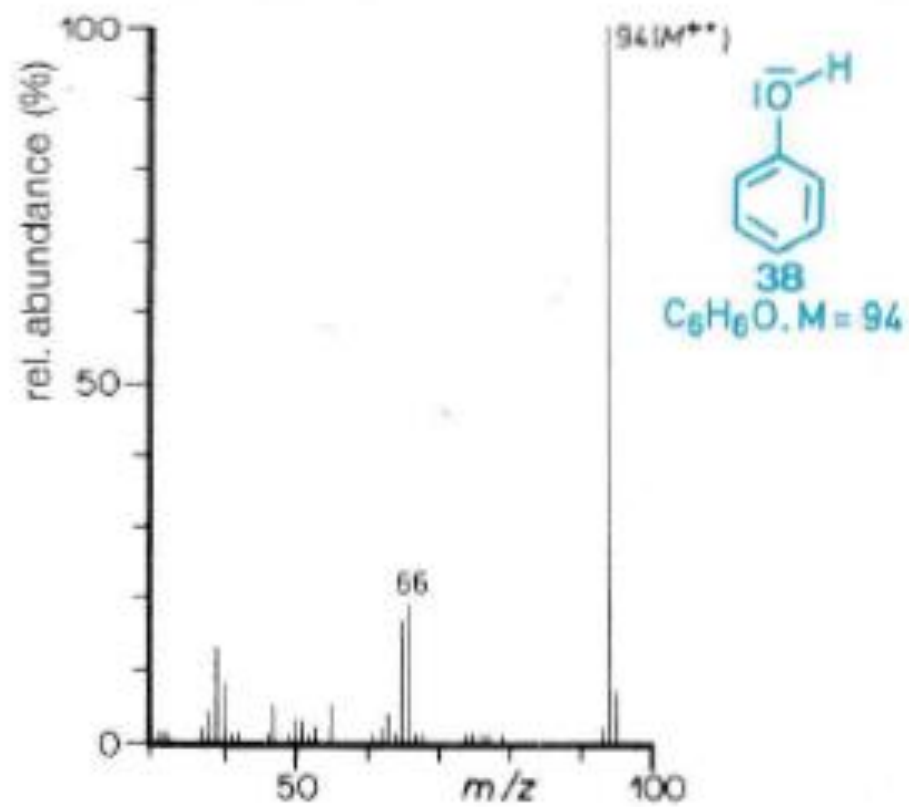


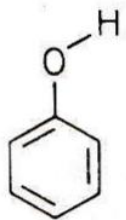




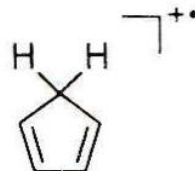
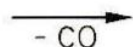
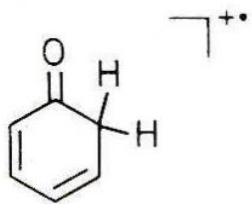
Απώλεια CO







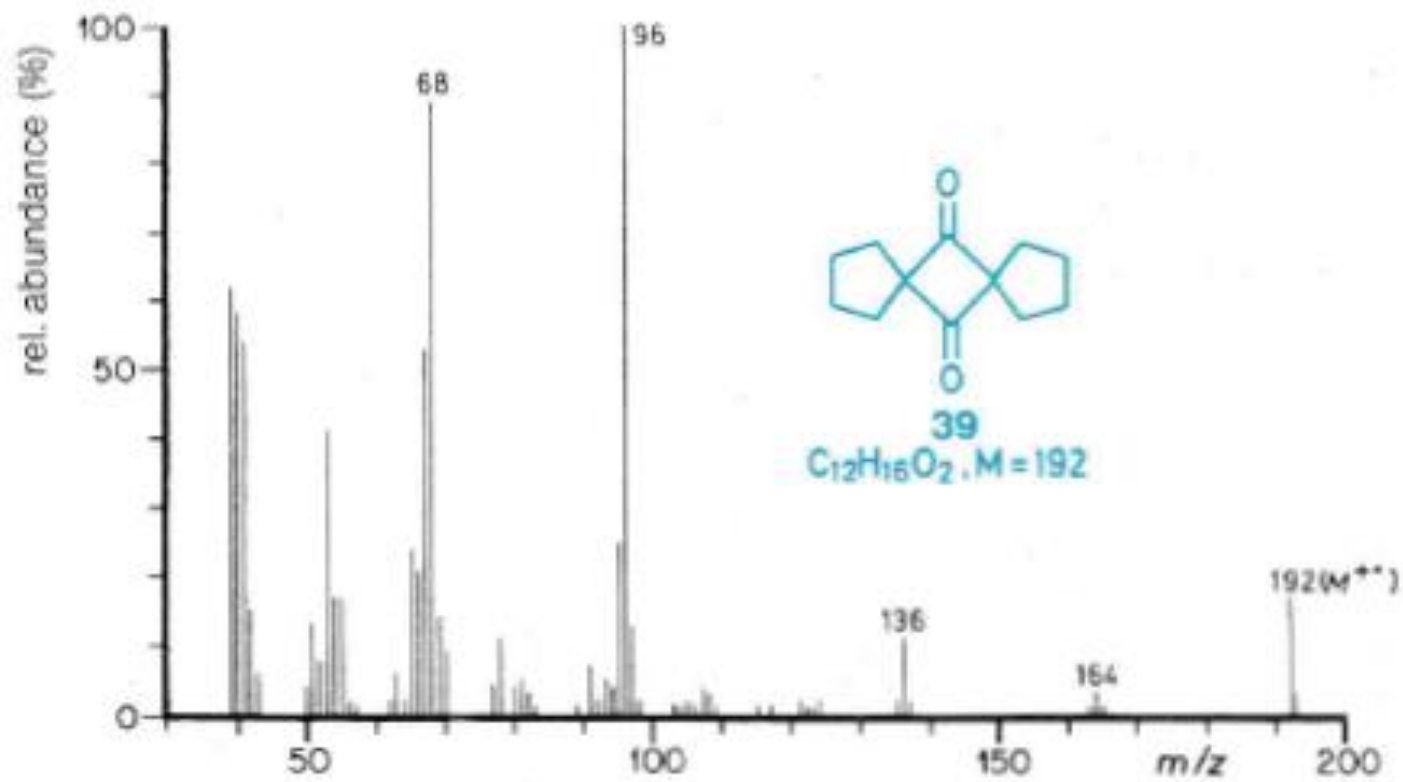
$38^{+\bullet}$
($m/z = 94$)

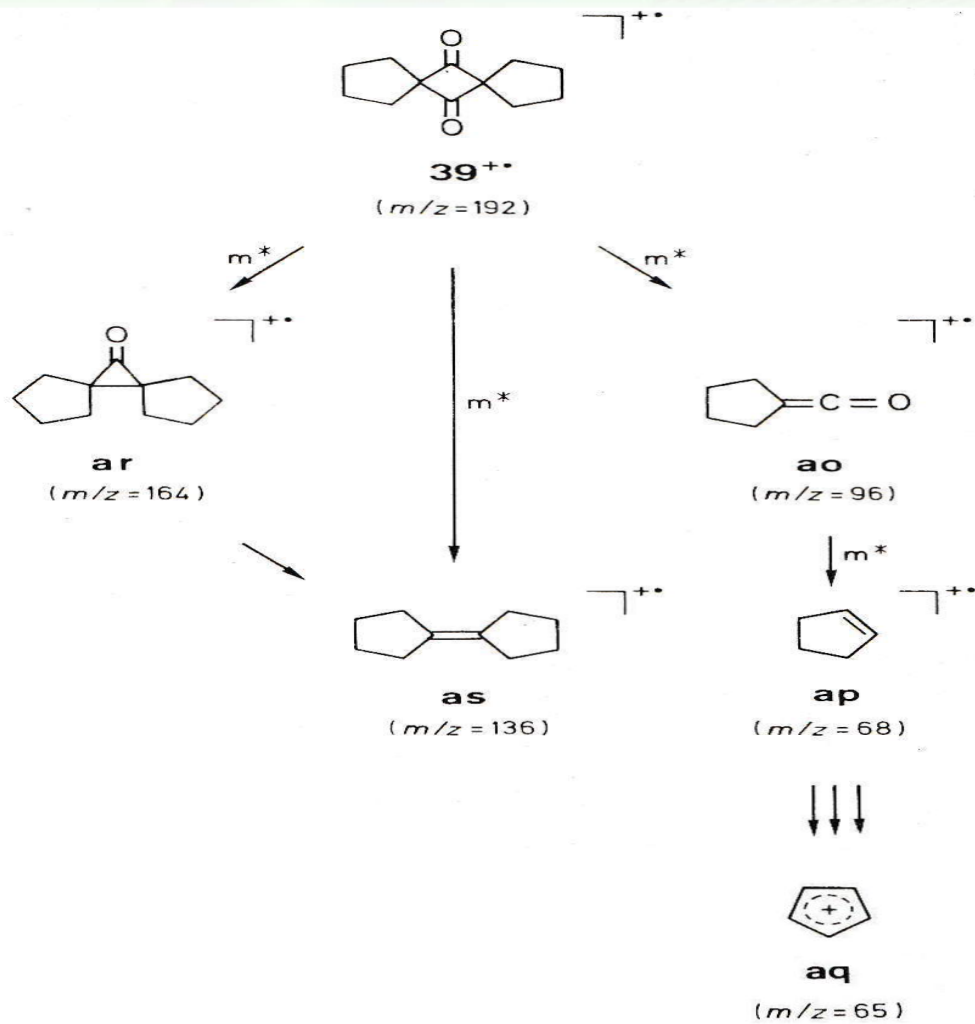


an
($m/z = 66$)



$m/z = 65$

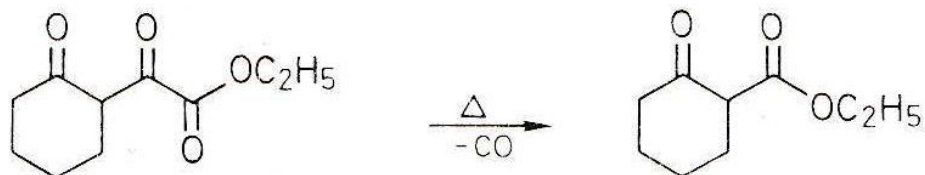




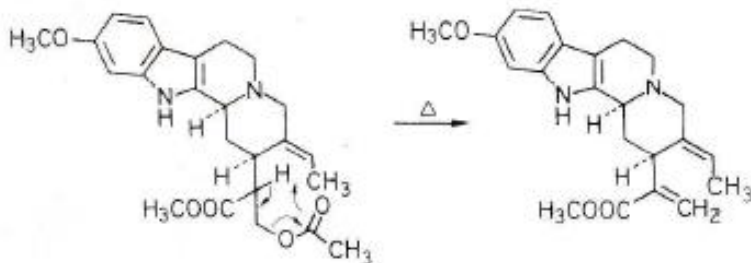
Θερμικές αντιδράσεις

Απώλεια CO_2 :

Απώλεια CO :



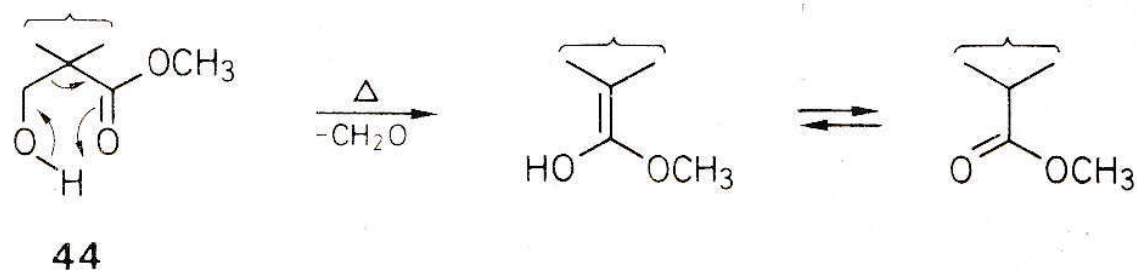
Απώλεια CH_3COOH :



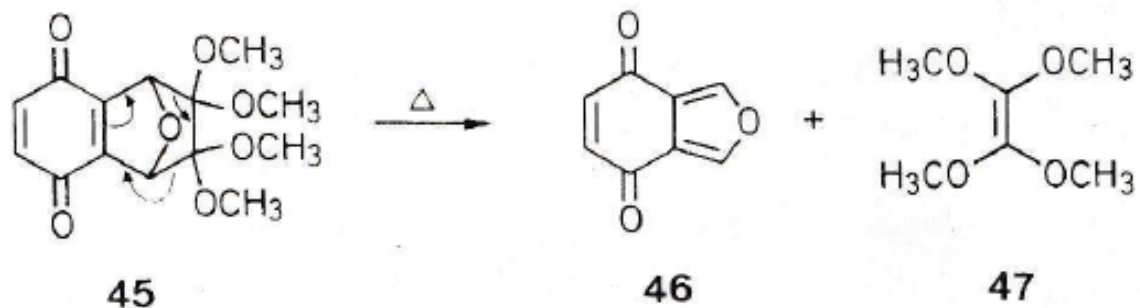
Απώλεια HX :

Retro αντιδράσεις

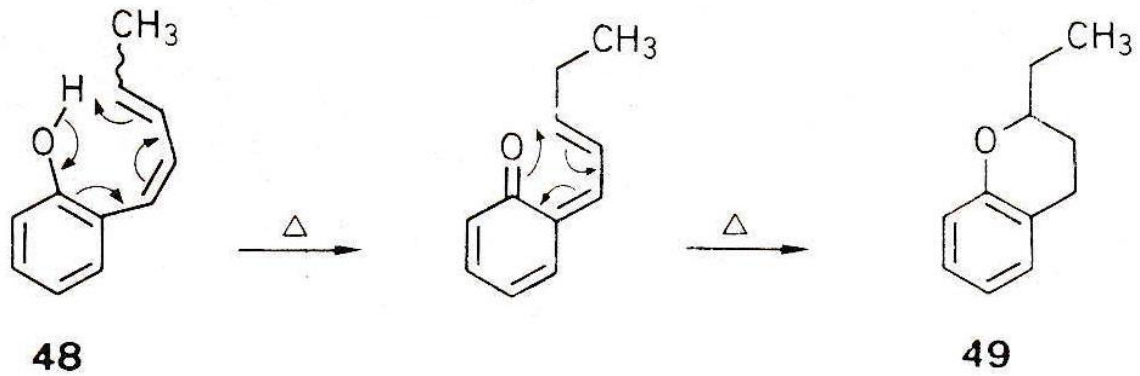
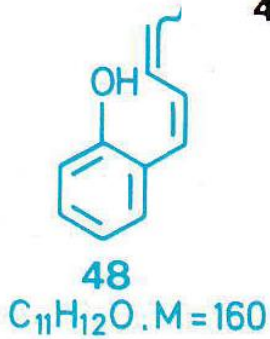
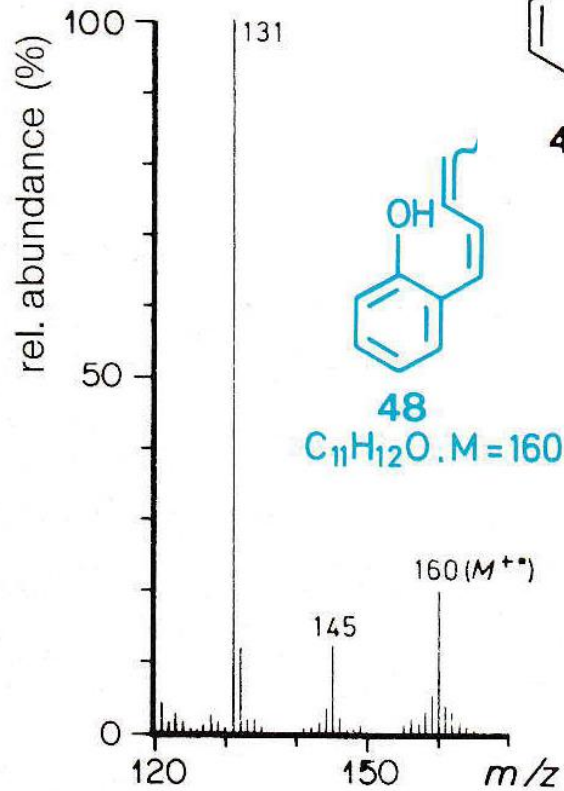
Retro αλδολική αντίδραση:



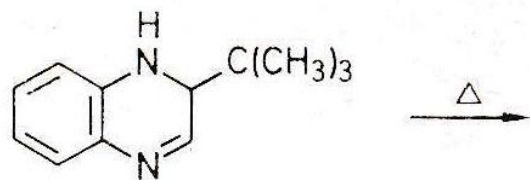
Retro Diels-Alder αντίδραση:



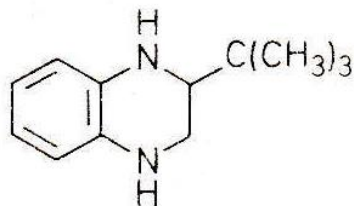
Ισομερείωση:



Υδρογόνωση και Αφυδρογόνωση:

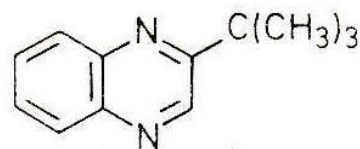


50



52

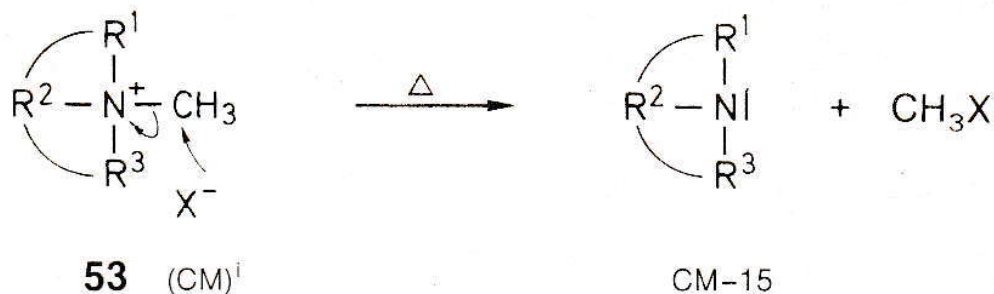
+



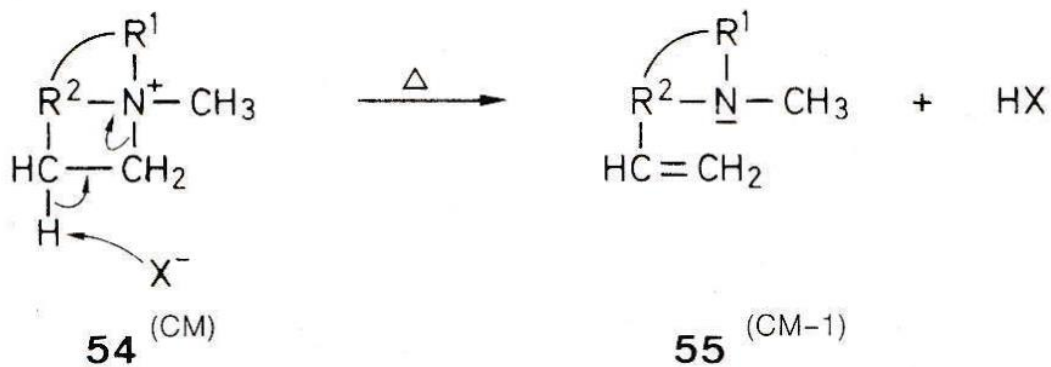
51

Πυρόλυση Τεταρτοταγών αζωτούχων ενώσεων:

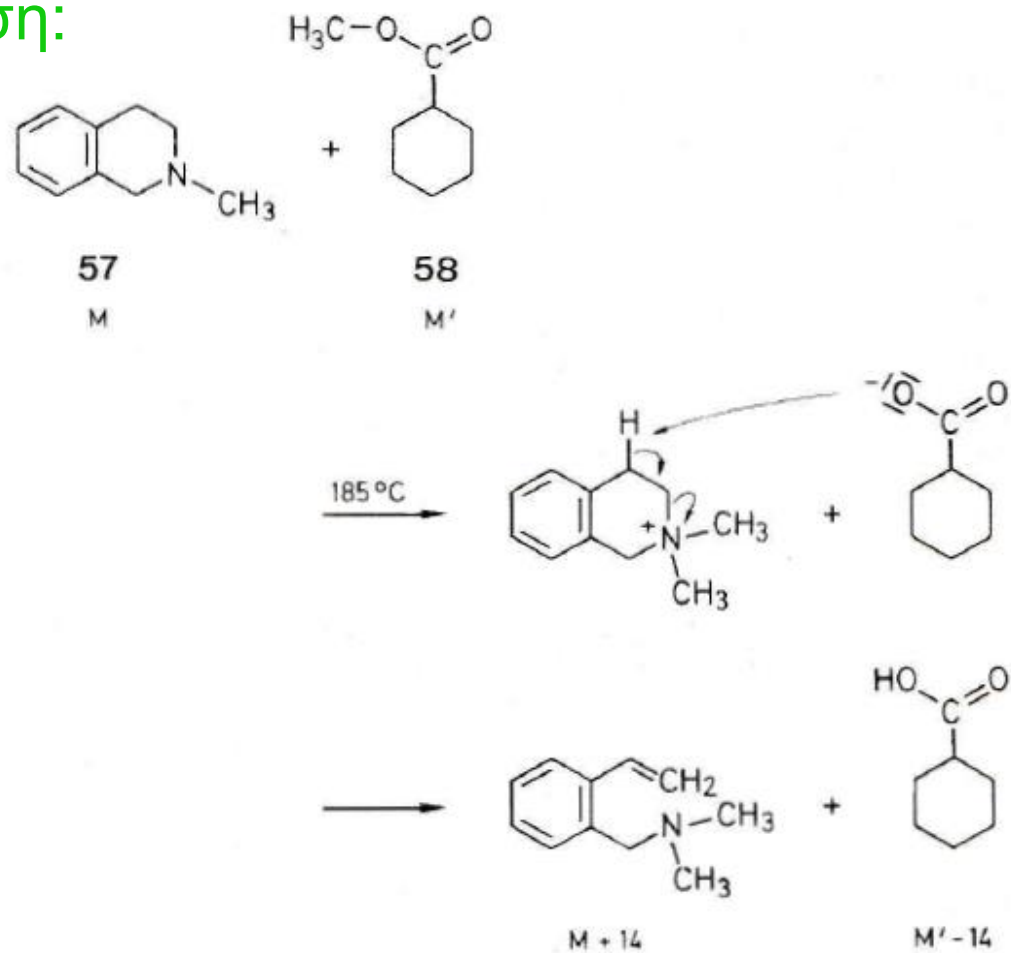
Αποαλκυλίωση:



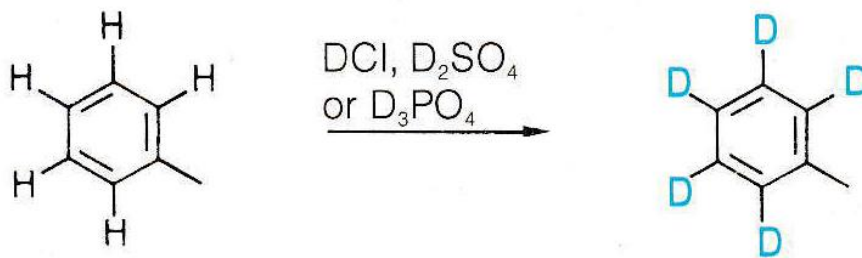
Απόσπαση Hofmann:



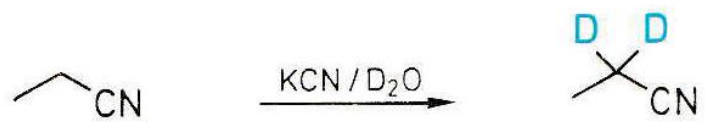
Τρανσαλκυλίωση:

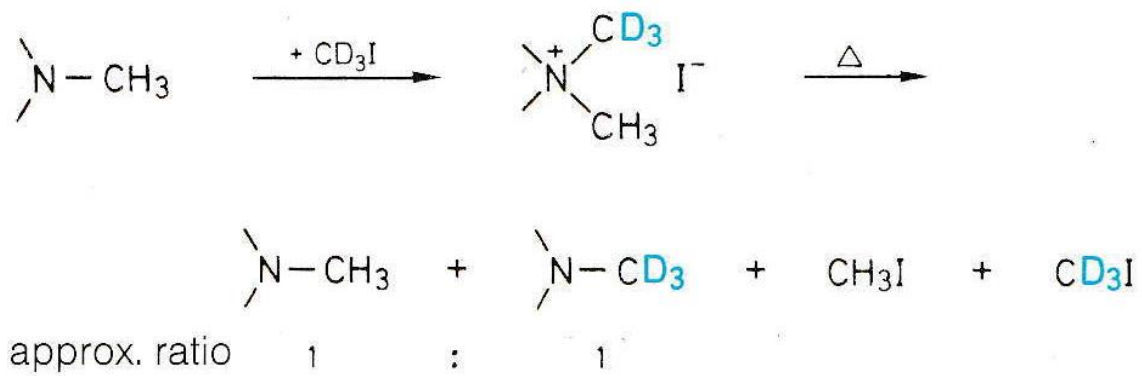


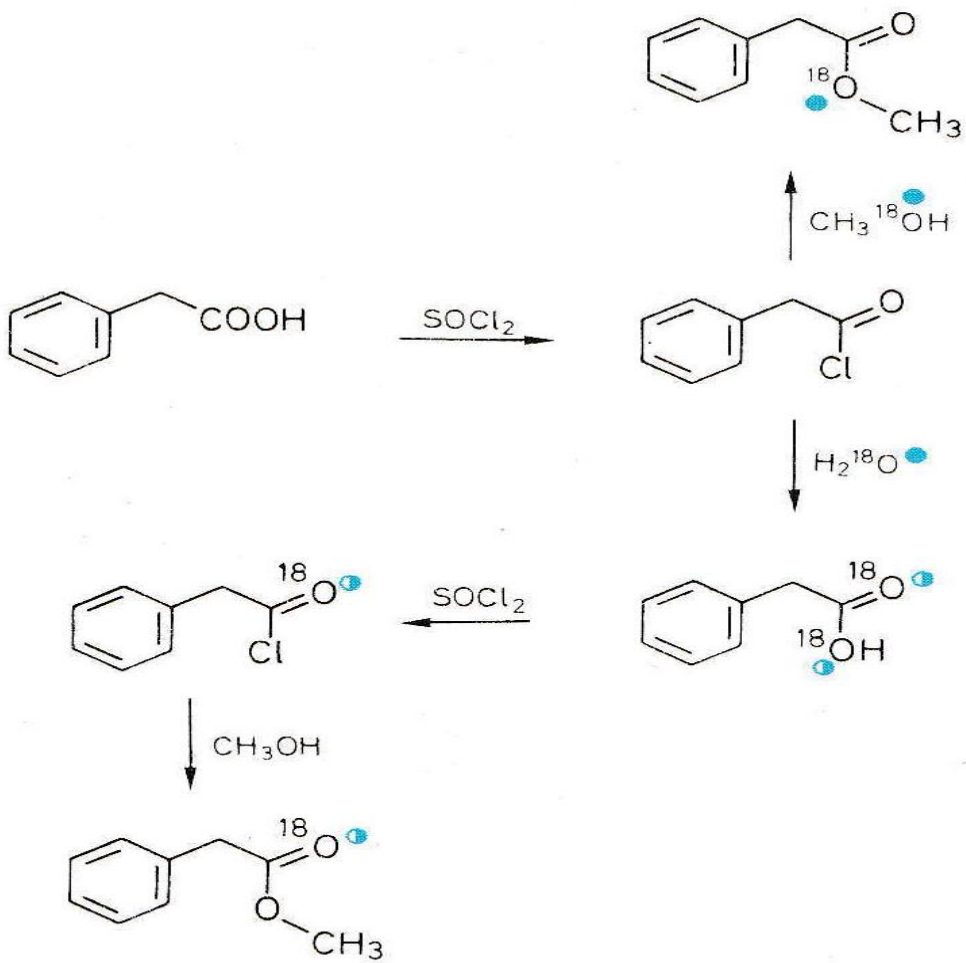
Αντιδράσεις Ισοτοπικής Επισήμανσης



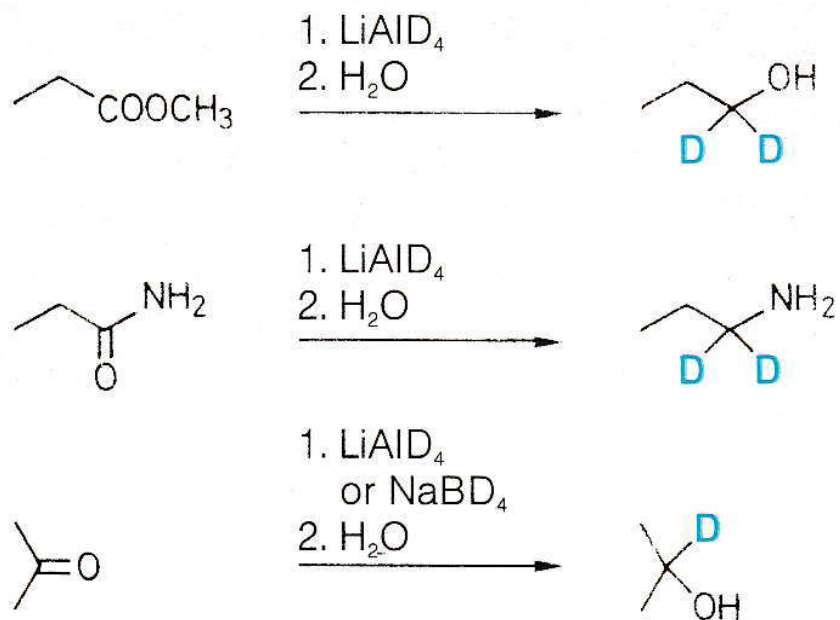


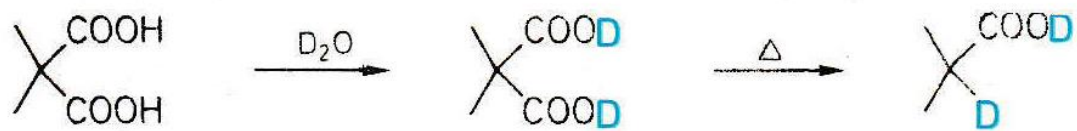
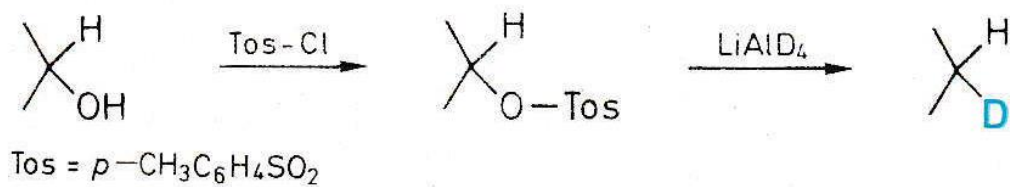






Αναγωγή





Χημικός Ιονισμός (CI)

ΕΙ Ιονισμός αερίου:



Αντίδραση:



Αποσύνθεση \longrightarrow δημιουργία φάσματος

Είτε ανταλλαγή φορτίου (CE):

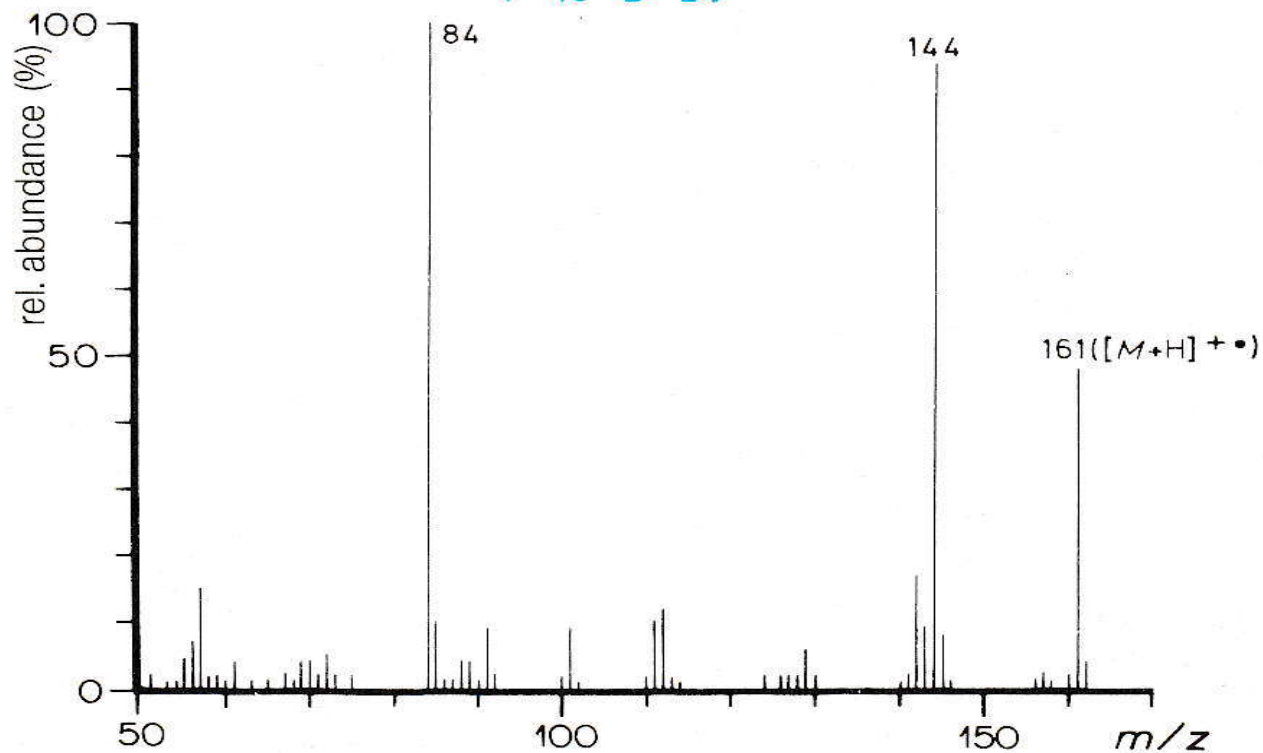


Χημικός ιονισμός με μεθάνιο:

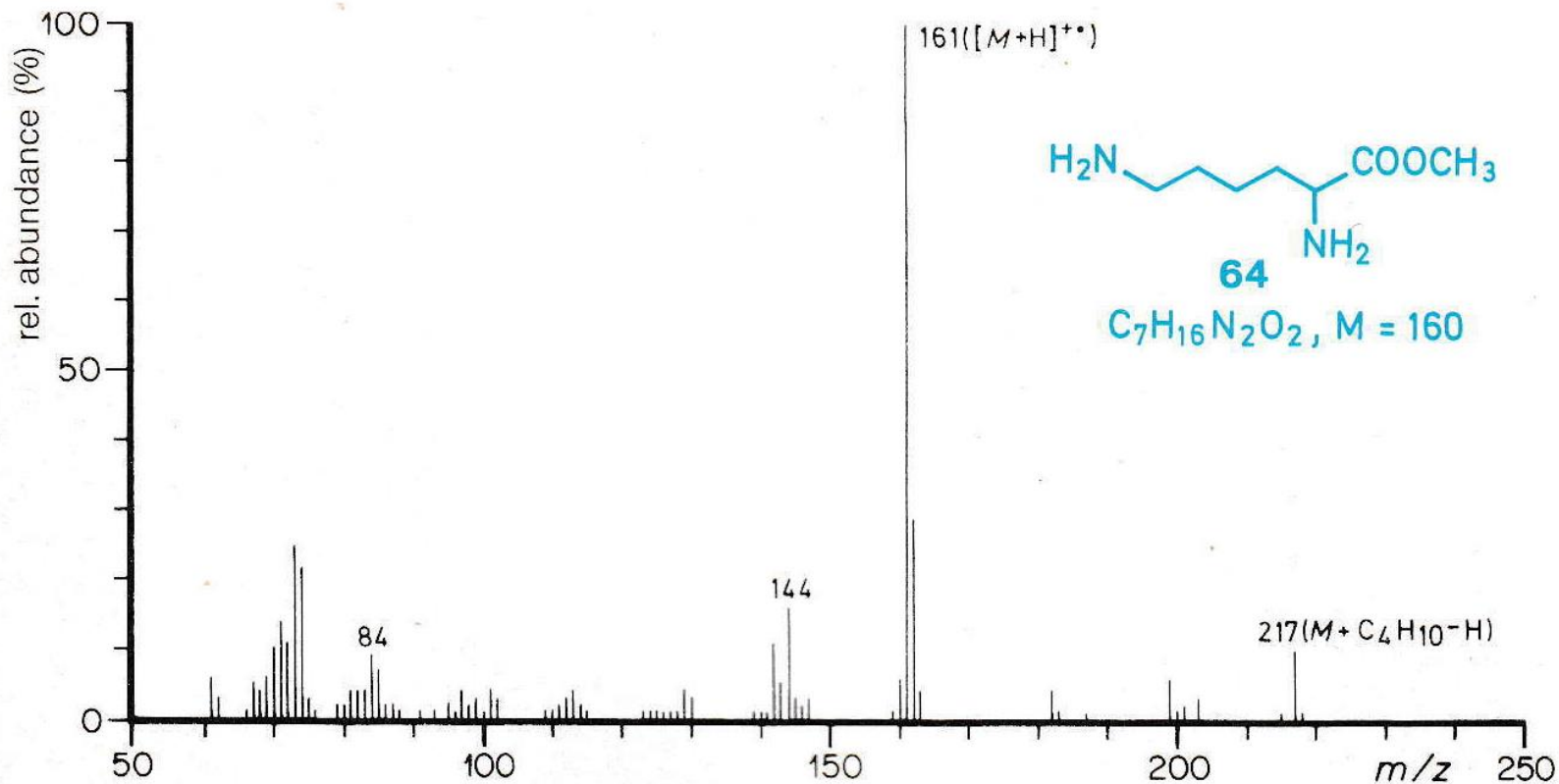


64

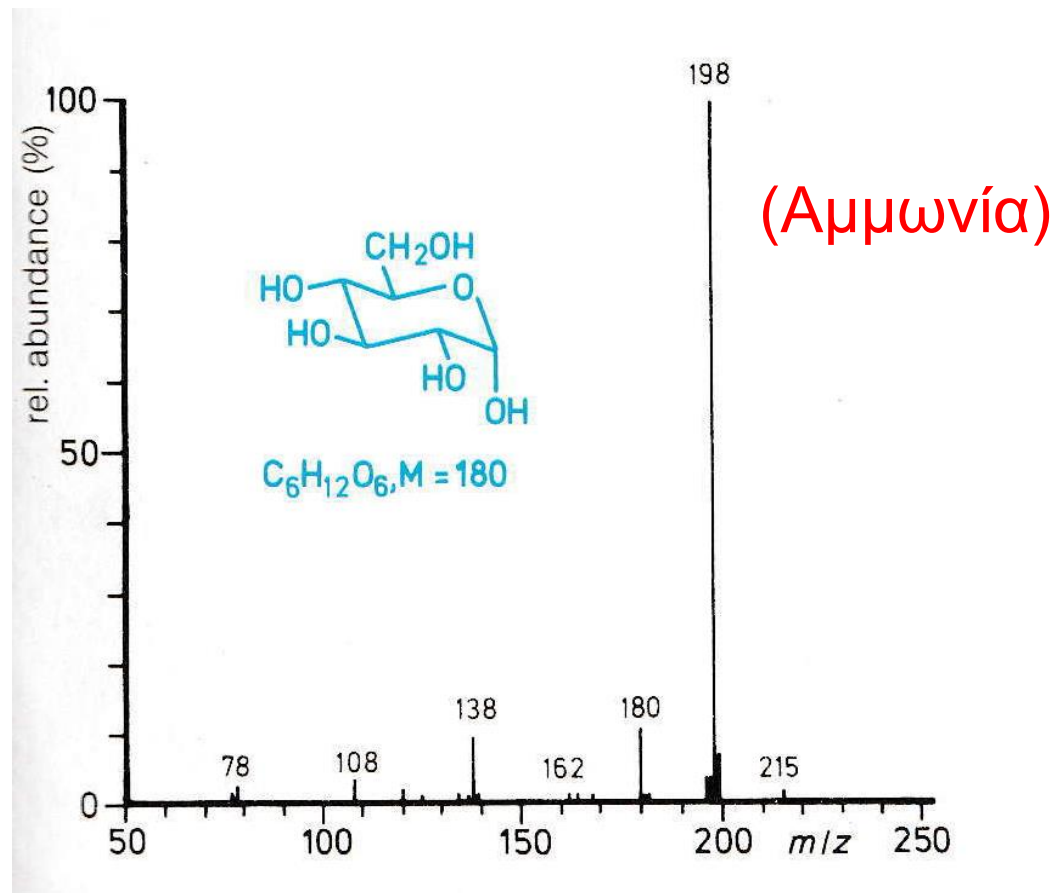
$C_7H_{16}N_2O_2$, $M = 160$



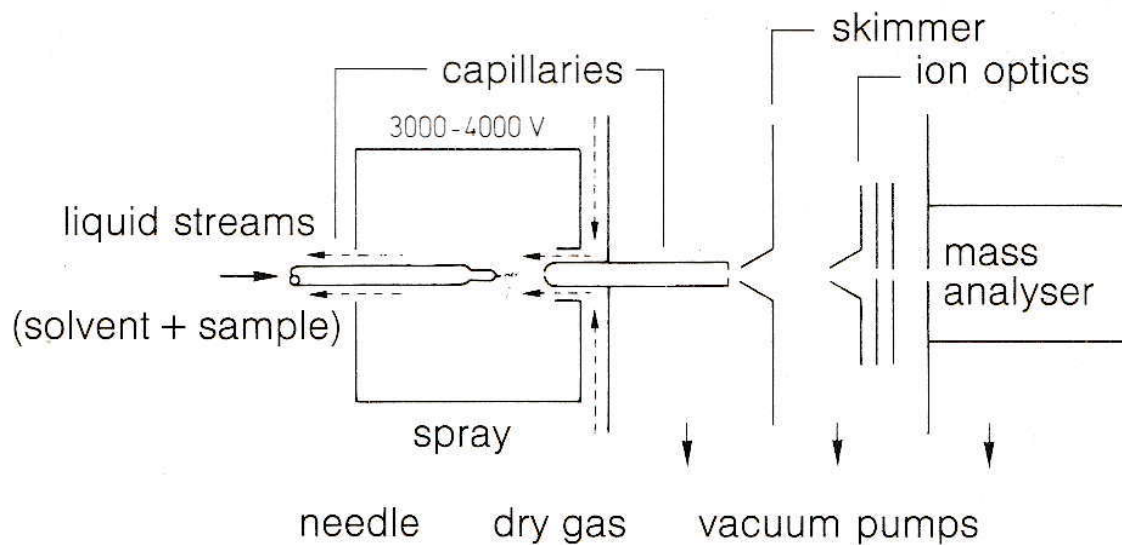
Χημικός ιονισμός με ισοβουτάνιο:



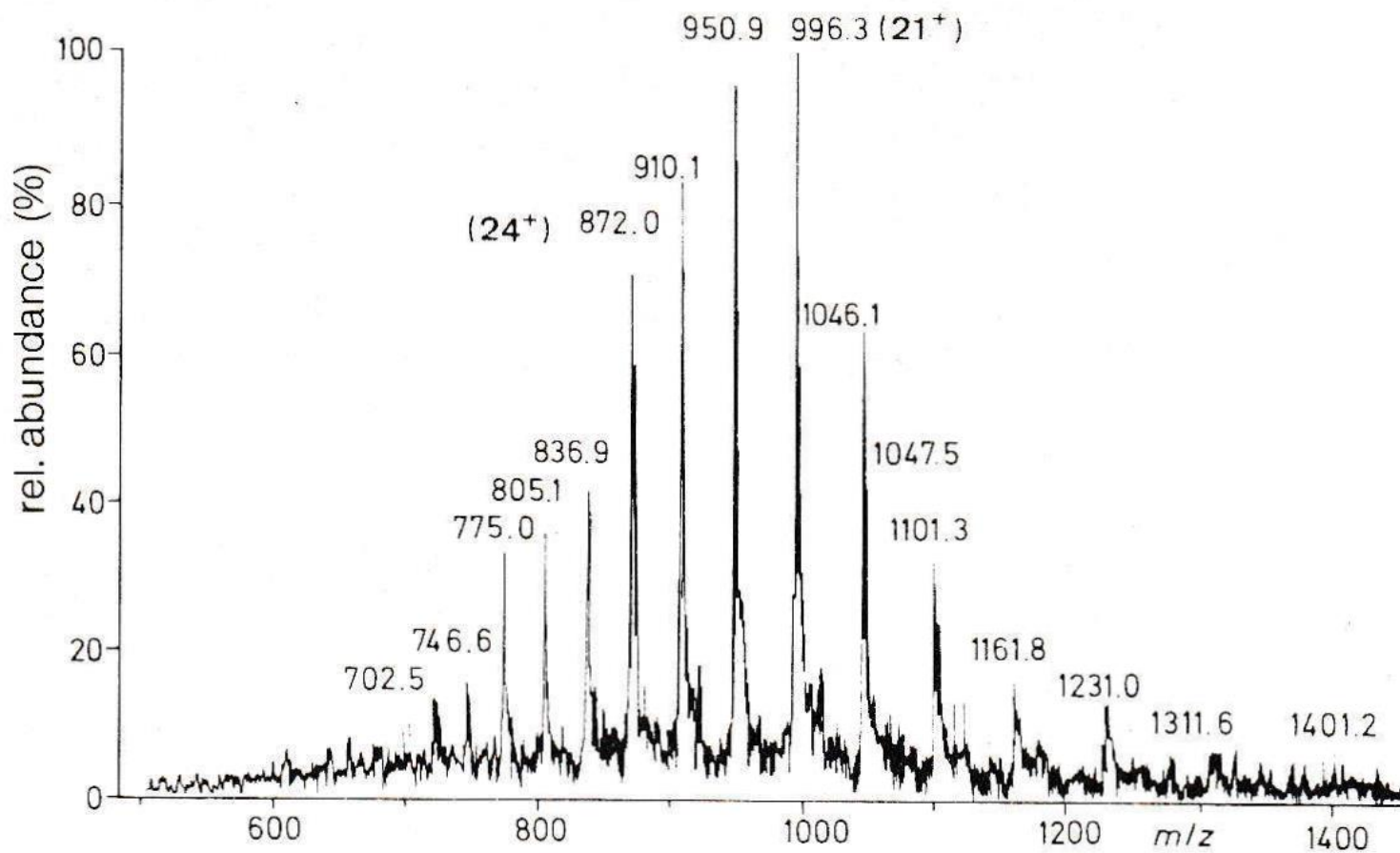
Απευθείας Χημικός Ιονισμός (DCI)



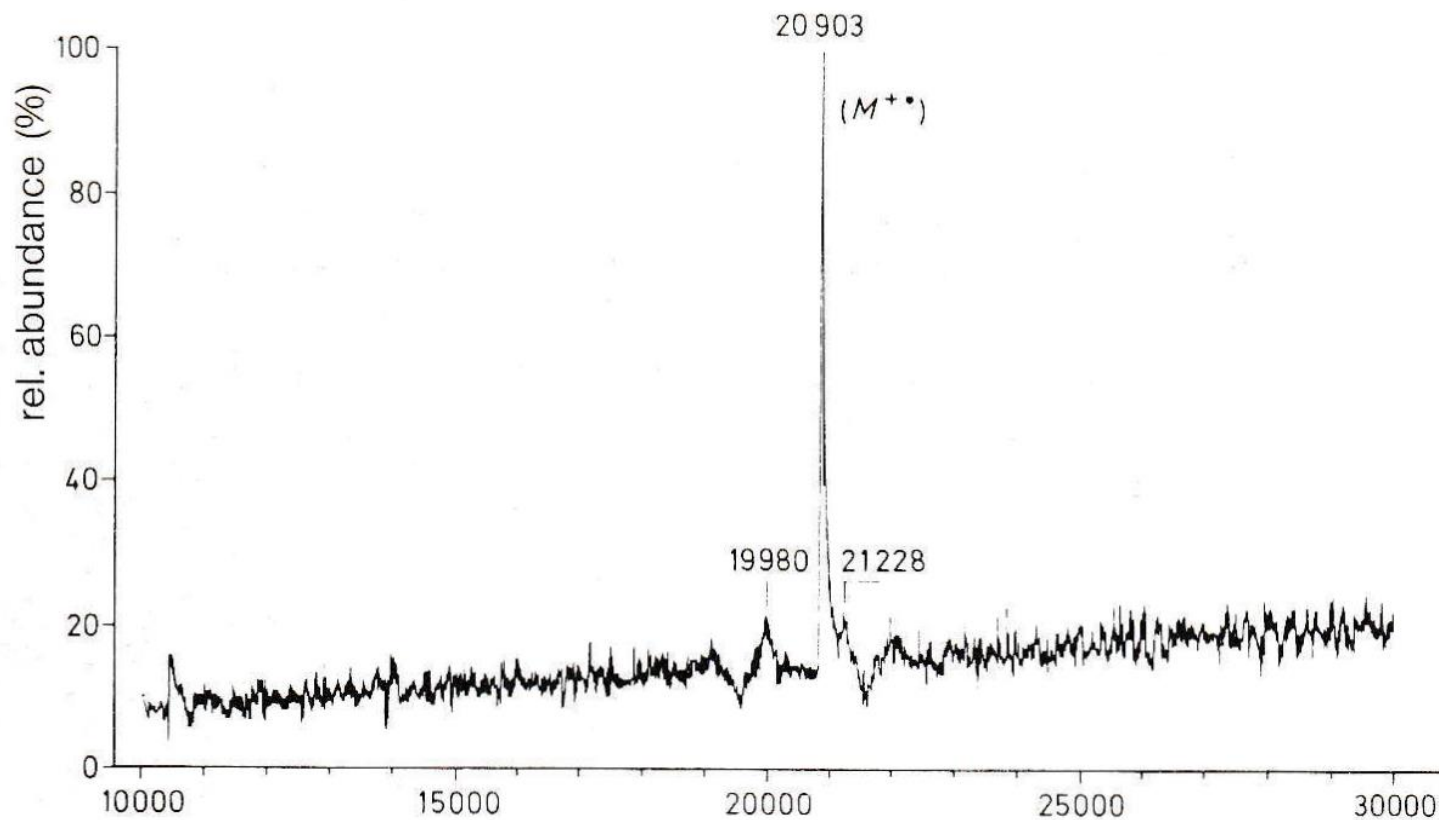
Electrospray ionisation (EI)



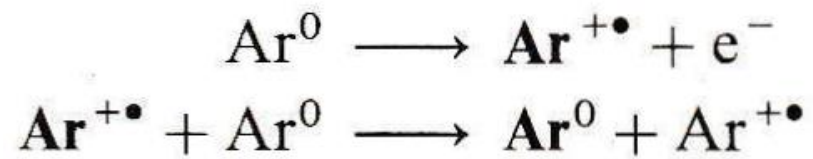
ESI φάσμα της ιντερλευκίνης 6



Αποσυζευγμένο ESI φάσμα της ιντερλευκίνης 6



Fast Atom Bombardment (FAB)



Field Distortion (FD)

The image features a vibrant green background with abstract, flowing, curved lines that create a sense of motion and depth. A horizontal white gradient bar is positioned across the middle of the image, providing a clean backdrop for the text.

Field Ionization (FI):

Προσδιορισμός μεγάλων μαζών

| Composition | Molecular weight ^{b)} | Exact mass of the molecular ion ^{c)} | Absolute abundance ⁴⁾ | Most abundant signal in the molecular ion region |
|--------------------|--------------------------------|---|----------------------------------|--|
| C_2H_4 | 28.05376 | 28.031300 | 97.7337 | 28 |
| $C_{20}H_{40}$ | 280.5376 | 280.31300 | 79.5138 | 280 |
| $C_{200}H_{400}$ | 2805.376 | 2803.1300 | 10.1023 | 2805 |
| $C_{2000}H_{4000}$ | 28053.76 | 28031.300 | 1×10^{-8} | 28053 |

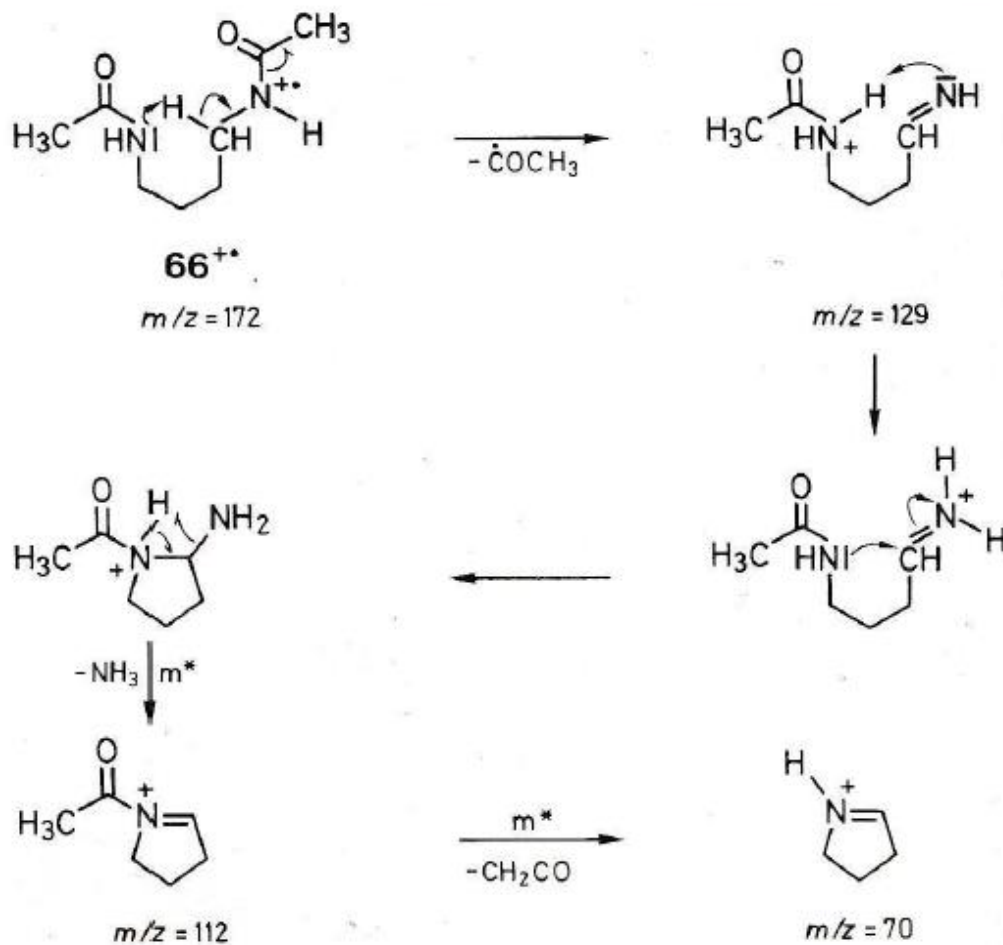
Μέθοδοι Ιονισμού

| Sample | Ionisation method (Abbreviation) |
|---|--|
| vaporisable ^{a)} | electron impact (EI) chemical ionisation (CI) |
| difficult to vaporise or cannot be vaporised | field ionisation (FI) atmospheric pressure ionisation (API) electrospray ionisation (ESI) field desorption (FD) laser desorption/ionisation (LDI) secondary ion mass spectrometry (SIMS) fast atom bombardment (FAB) direct chemical ionisation(DCI) thermal desorption (TD) thermospray ionisation (TSI) |

^{a)} including GC analyses

| ionisation method (abbreviation) | ionising particle | Types of ions | Possible additional signals | Normal mass region max. up to ca. | Possibility of thermal decomposition | Possibility for on-line combination with | Advantages | Disadvantages |
|---|---|---|--|-----------------------------------|--------------------------------------|--|--|--|
| Electron impact ionisation (EI) | e^- | M^{\bullet} and fragment ions | – | 3500 | yes | GC | <ul style="list-style-type: none"> – fragment ion signals = structural information. – largely correct abundances of the isotope signals. | <ul style="list-style-type: none"> – M^{\bullet} is sometimes absent. – (very) polar substances cannot be measured. |
| Chemical ionisation (CI) | charged reactant gas, e.g. CH_3^+ , NH_4^+ , Ar^{\bullet} | e.g. with NH_4^+ : M^{\bullet} , $[M + H]^+$, $[M + NH_4]^+$ and clusters | reactant gas and reactant gas clusters | 3500 | yes | GC | <ul style="list-style-type: none"> – suppression of fragmentation which results in more abundant ions in the M region. | <ul style="list-style-type: none"> – very polar substances cannot be measured. – in cases of uncertainty it is possible to differentiate between $[M + H]^+$ and e.g. $[M + NH_4]^+$ by changing the reactant gas. – incorrect abundances of the isotope signals. |
| Fast atom bombardment (FAB) | e.g. Ar^0 high kinetic energy | e.g. $[M + H]^+$, $[M + Na]^+$, $([M + K]^+)$ and clusters e.g. $[2 M + H]^+$ | signals from matrix clusters, e.g. $[2 \text{ glycerine} + H]^+$ | 3500 | very rare | – | <ul style="list-style-type: none"> – measurement of polar substances. | <ul style="list-style-type: none"> – reduced solubility of substances in the matrix (frequently used: glycerine). – fragmentation is rare. |
| Electrospray ionisation (ESI) | none (electrostatic) | $[M + H]^+$, $[M + Na]^+$, $([M + K]^+)$ and clusters | – | 100 000 | no | LC or HPLC | <ul style="list-style-type: none"> – multiply charged ions often produced (structurally dependent). – measurement of high molecular weight substances in solution. | <ul style="list-style-type: none"> – reduced choices for types of solvents. – big differences in the ionisation of particular classes of substances. – fragmentation very rare. |
| Thermospray ionisation (TSI) | frequently $CH_3CO_2NH_4$ | $[M + H]^+$, $[M + NH_4]^+$ | sometimes solvent clusters | 3500 | no | LC or HPLC | <ul style="list-style-type: none"> – measurement of polar substances in aqueous solutions. – fragment ions sometimes occur. | <ul style="list-style-type: none"> – reduced choices for types of solvents. – the presence of a vaporisable electrolyte is necessary. |

Υποβόθηση γειτονικής ομάδας



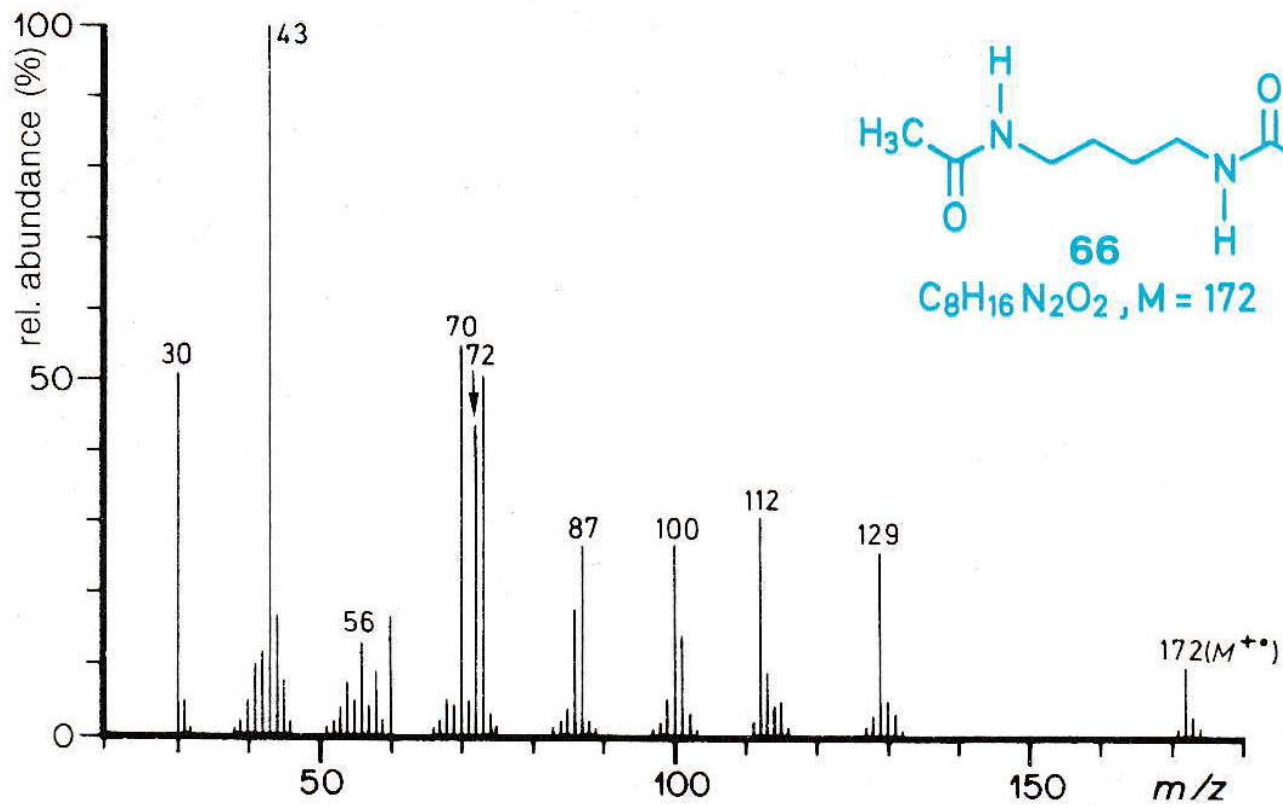
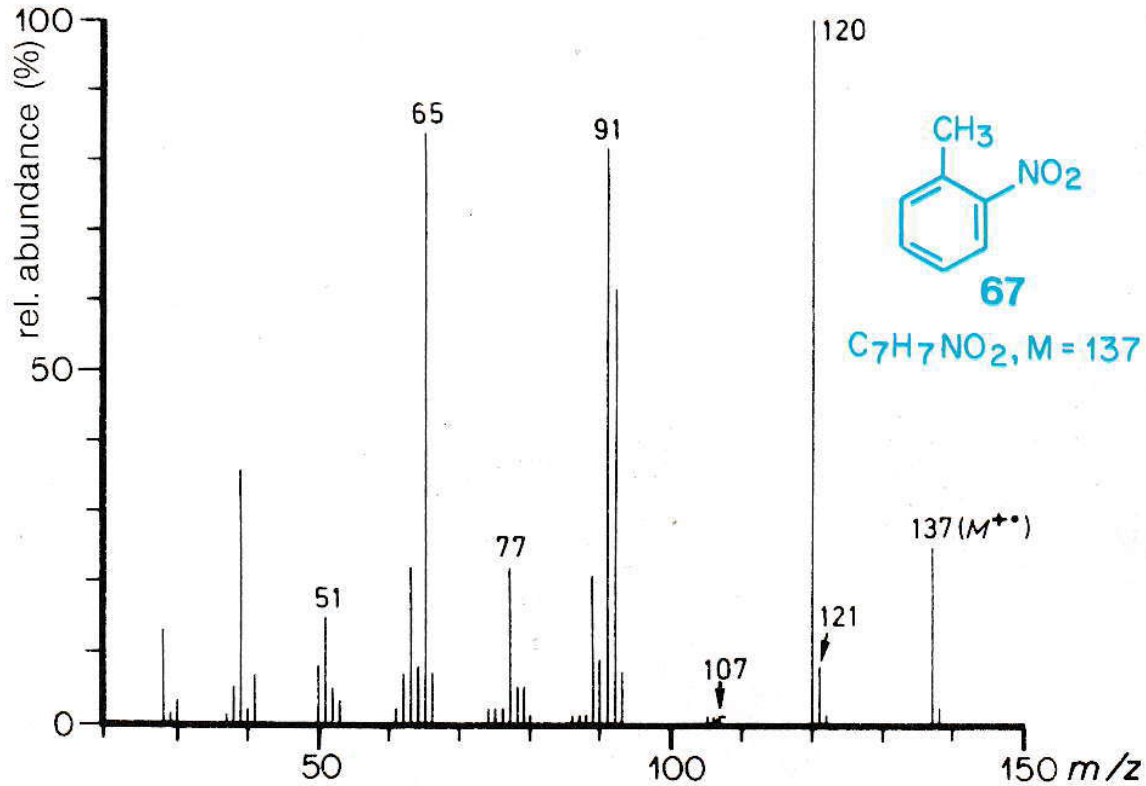
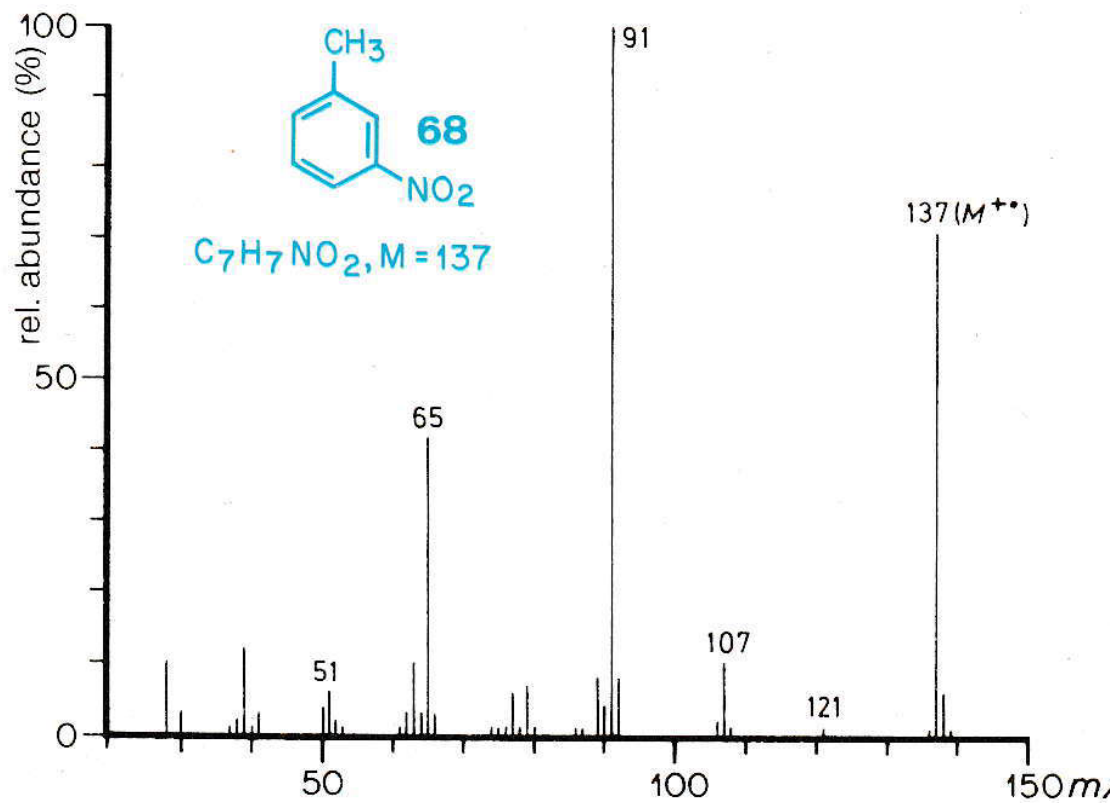
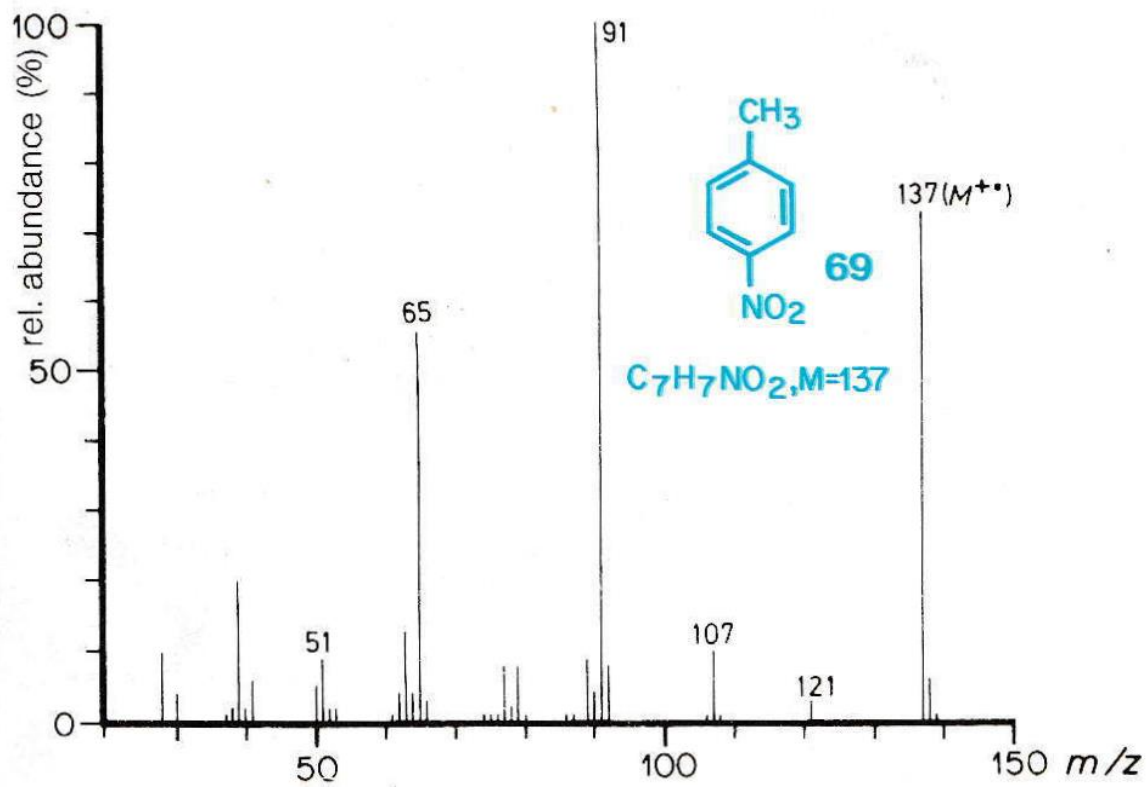


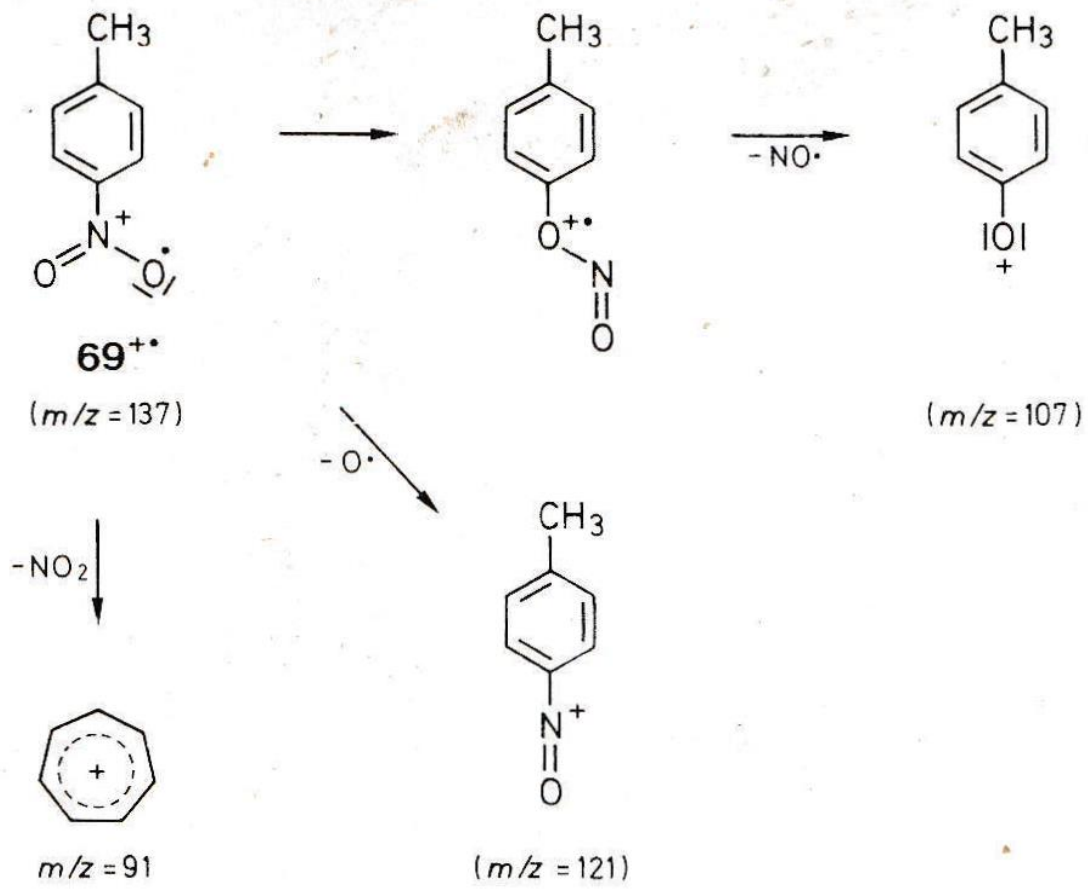
Fig. 4
 (= N,

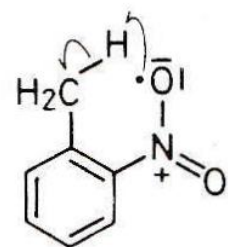
Ορθο επίδραση





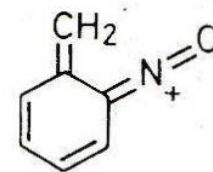
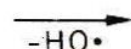
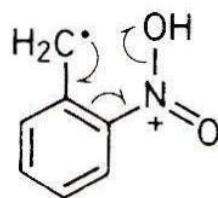






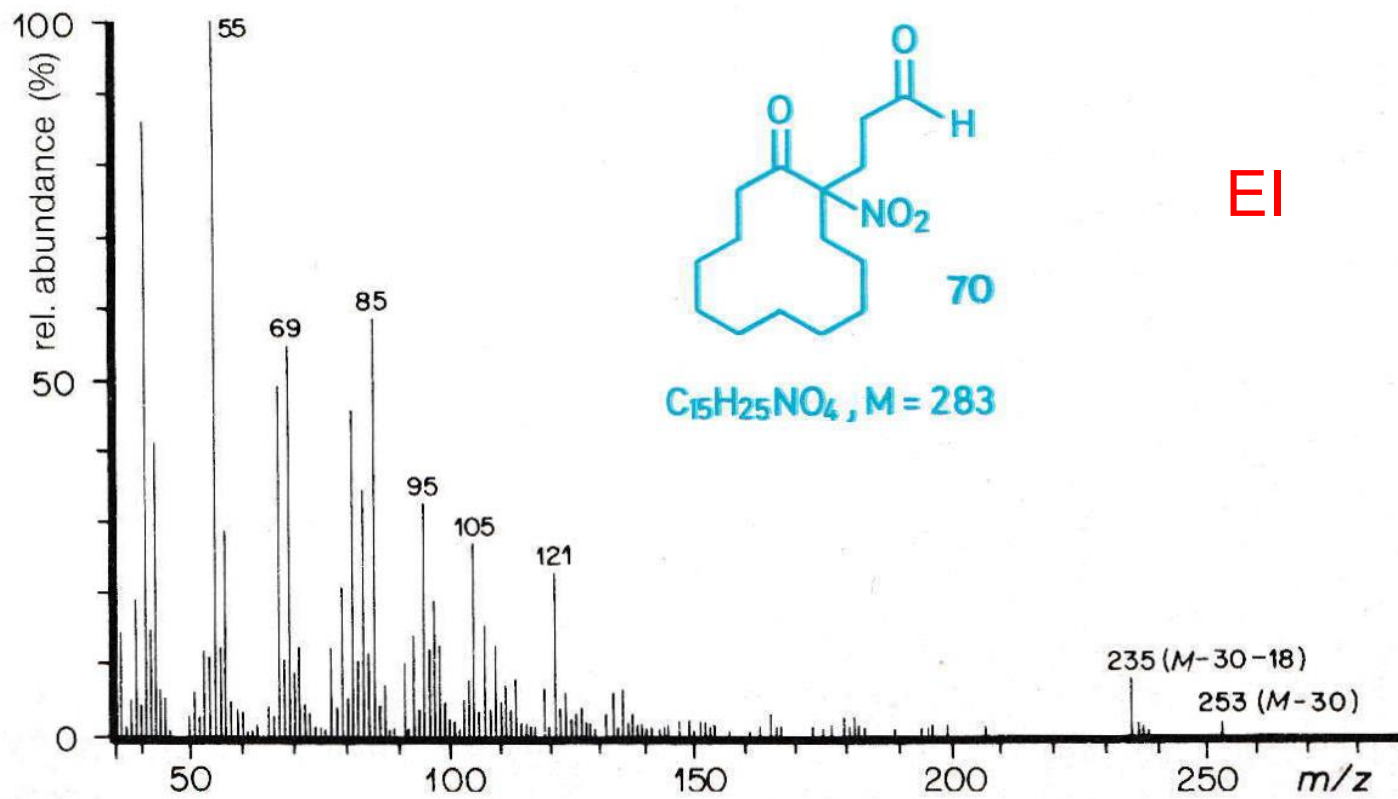
67^{+•}

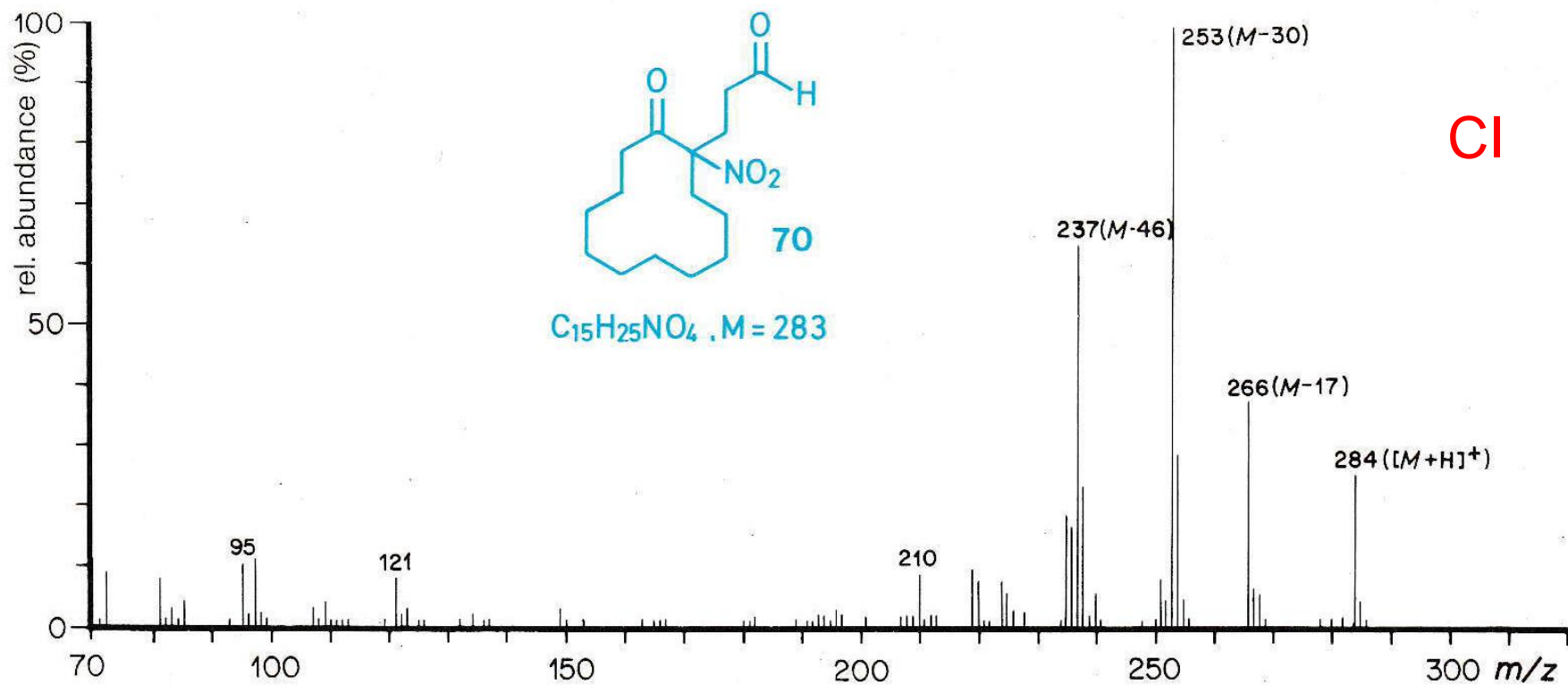
(*m/z* = 137)



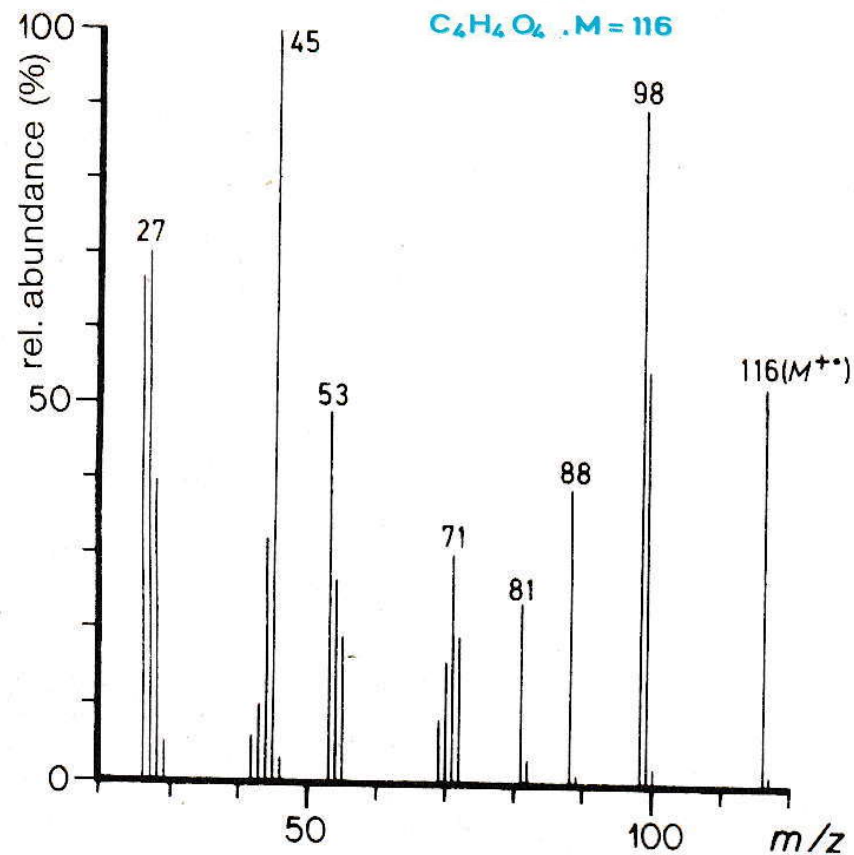
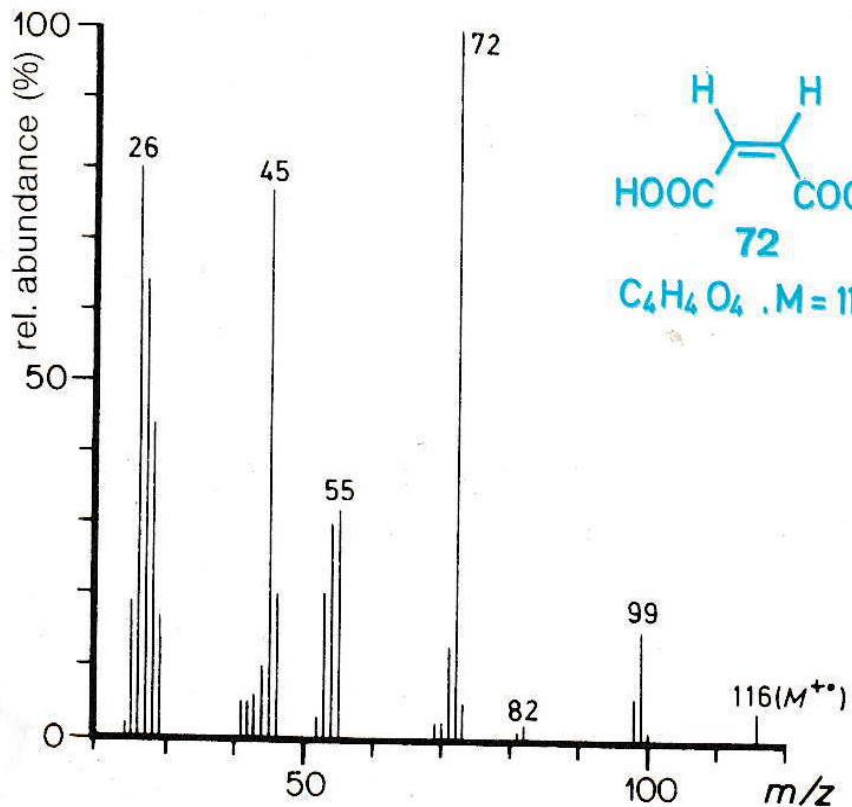
a

(*m/z* = 120)

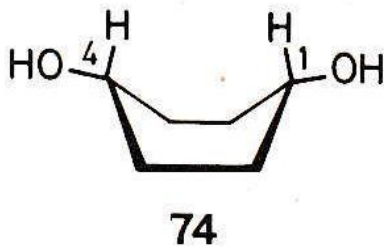




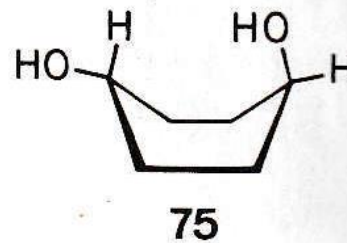
Γεωμετρικά Ισομερή



Διαστερομερή

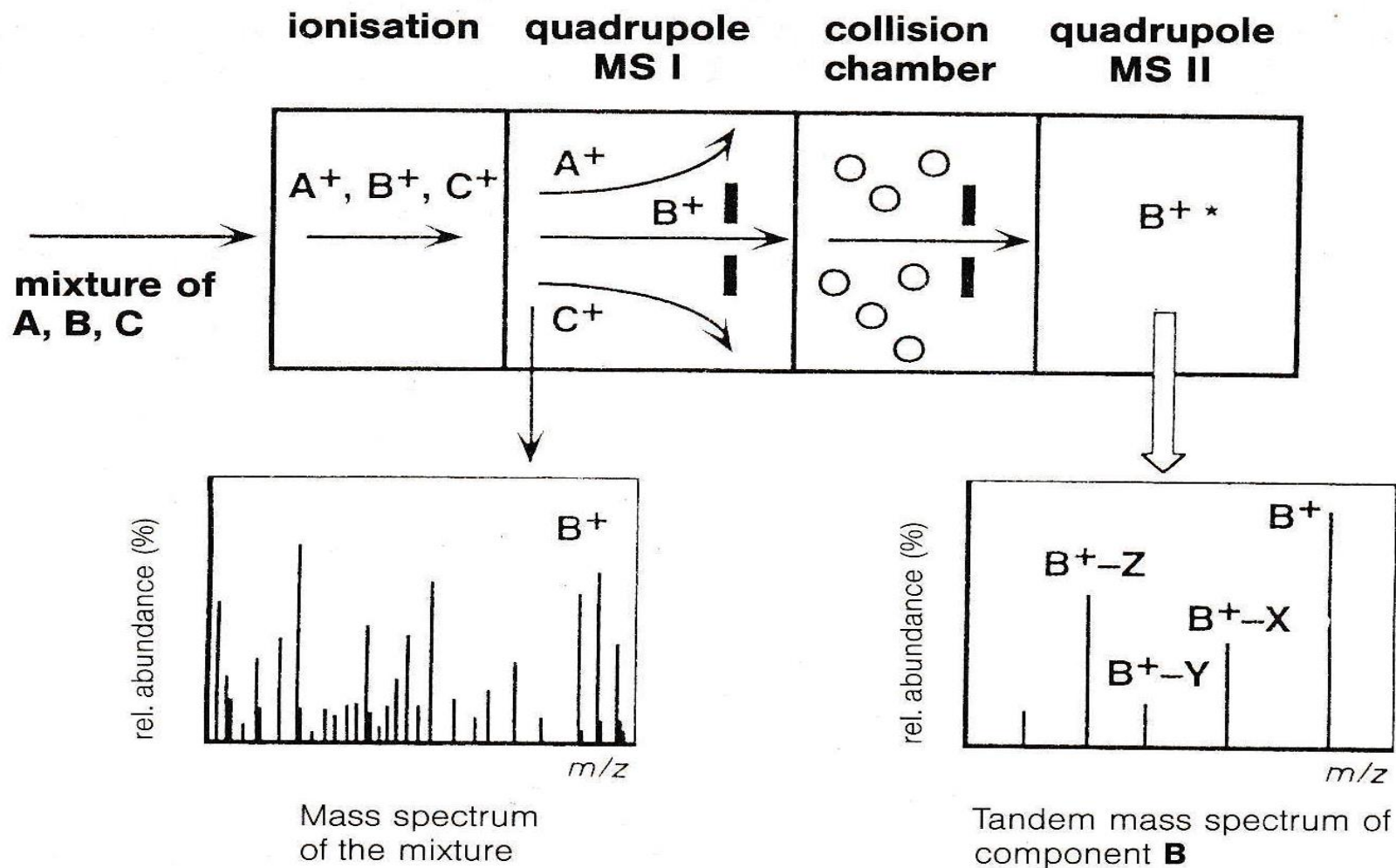


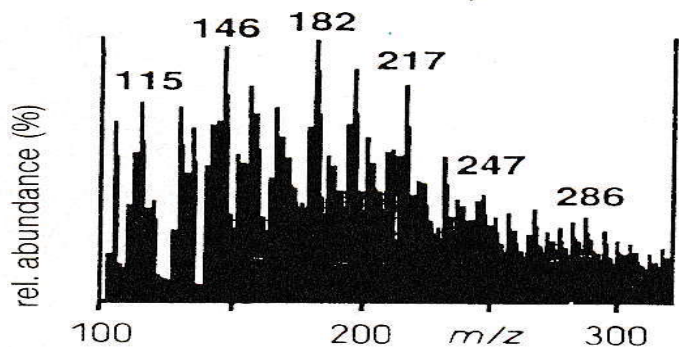
Απώλεια νερού 1,8%
και ακόλουθη
1,4-απόσπαση 0,9%



Απώλεια νερού 8,1%
και ακόλουθη
1,4-απόσπαση 7,3%

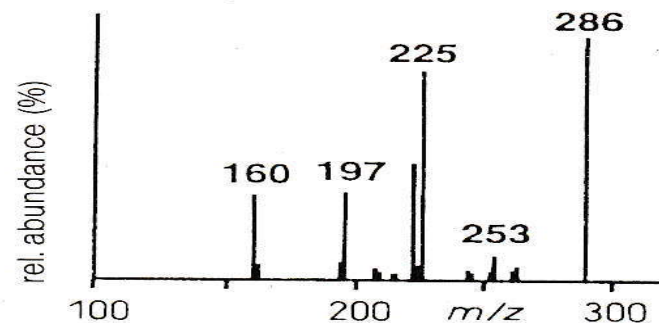
Tandem mass spectrometry





Coal sample contaminated with dioxin

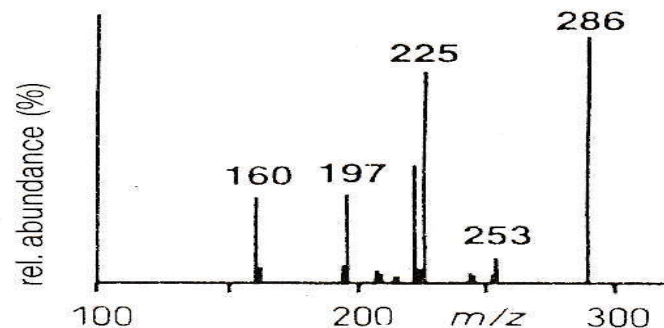
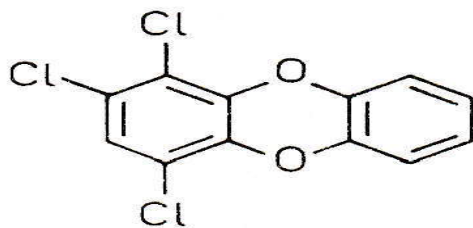
MS I



Tandem mass spectrum of the component with a molecular weight of 286

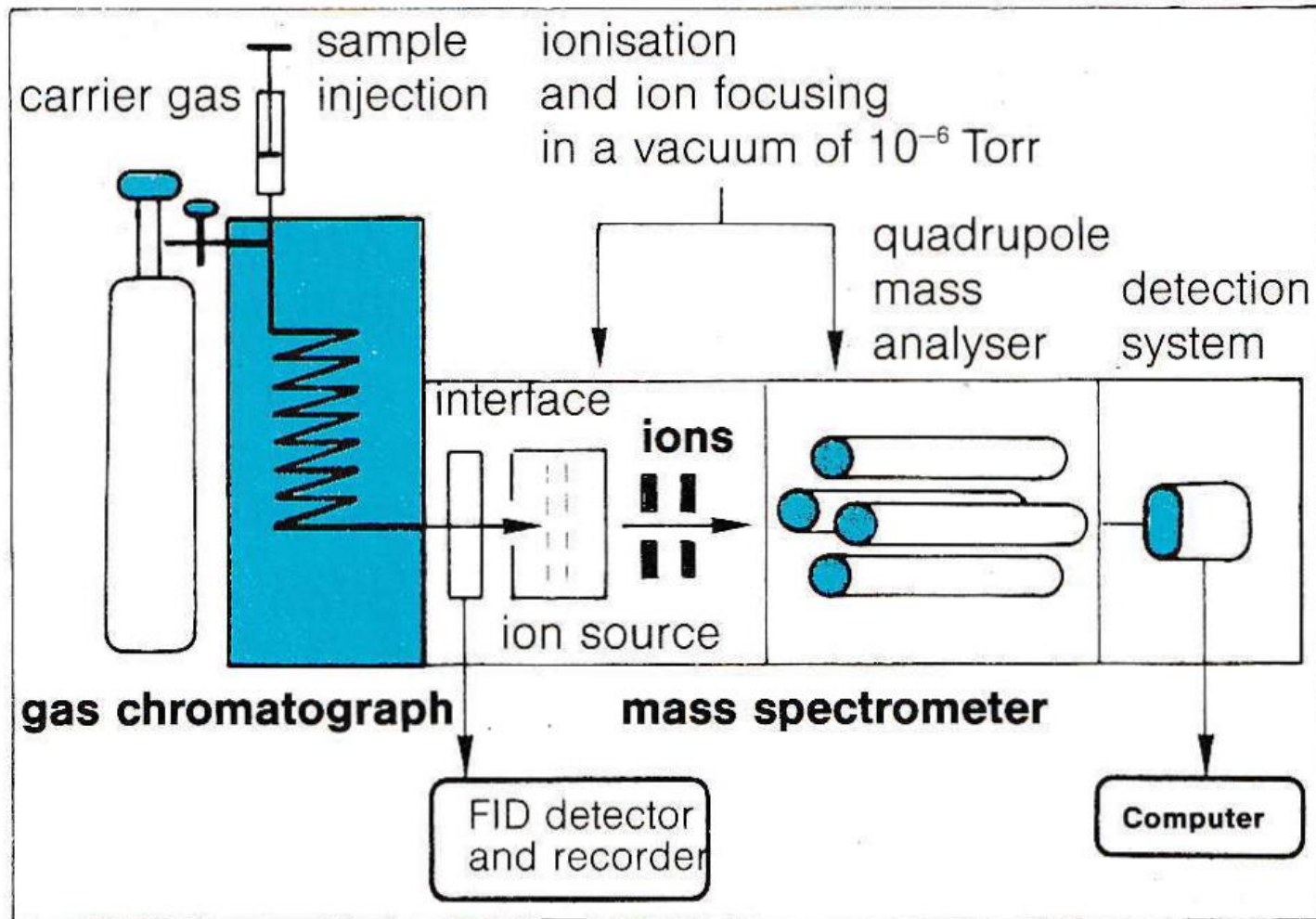
MS II

1,2,4-trichlorodibenzo-*p*-dioxin
molecular weight 286

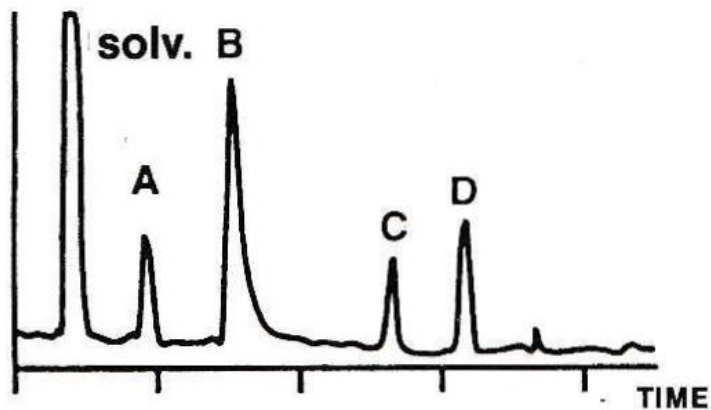


Mass spectrum of authentic 1,2,4-trichlorodibenzo-*p*-dioxin, recorded using the same procedure

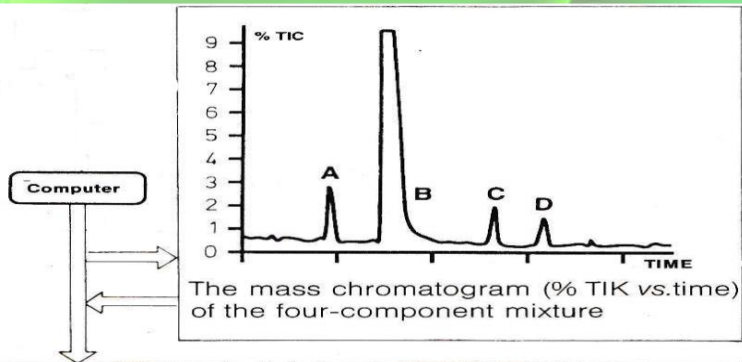
Συνδυασμός GC/MS



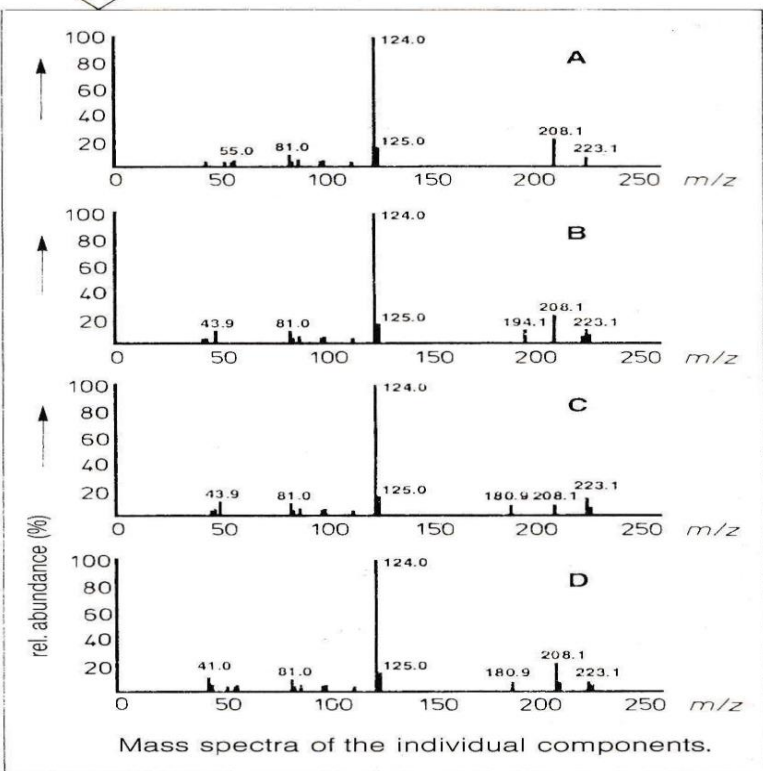
FID detector
and recorder



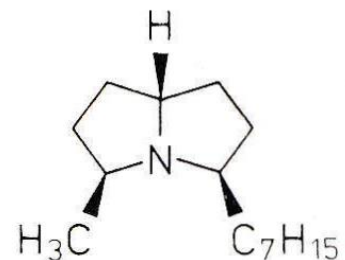
The gas chromatogram shows a qualitative representation of a four-component mixture (**A**, **B**, **C** and **D**). The first peak (solv.) comes from the solvent.



The individual spectra of **A**, **B** (main product, 95%, molecular weight 223), **C** and **D** are extracted from the mass chromatogram of a mixture of four diastereomeric pyrrolizidine derivatives and compared.



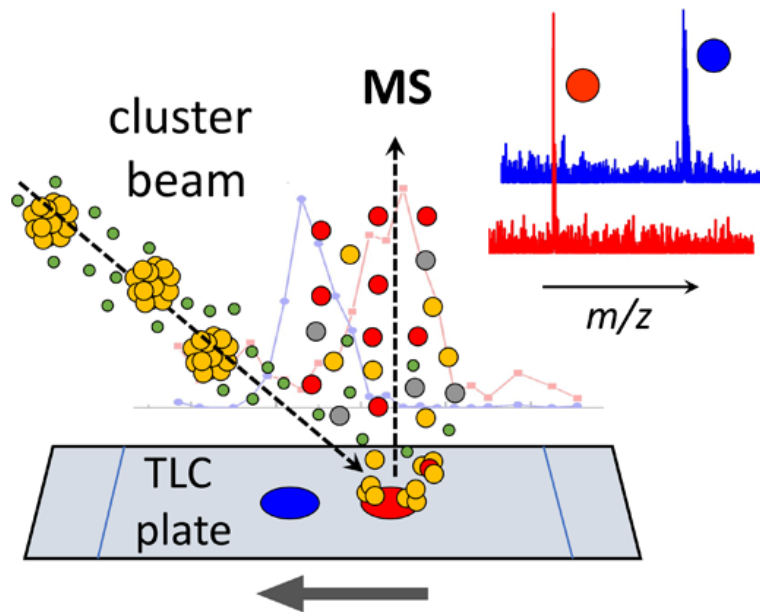
Structure of the main product, **B**



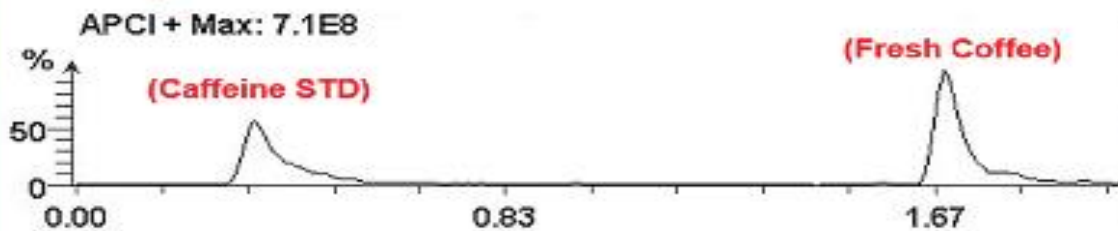
Χρήσεις:

- Ανάλυση αγνώστων οργανικών ενώσεων
- Περιβάλλον (ανίχνευση οργανικών ρυπαντών)
- Ποινική εγκληματολογία
- Επιβολή του νόμου(ναρκωτικά)
- Αθλητικό αντιντόπιγκ
- Ασφάλεια (ανίχνευση εκρηκτικών)
- Ανίχνευση παραγόντων χημικού πολέμου
- Ανάλυση τροφίμων, ποτών και αρωμάτων
- Αστροχημεία
- Ιατρική

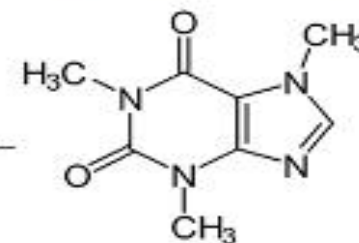
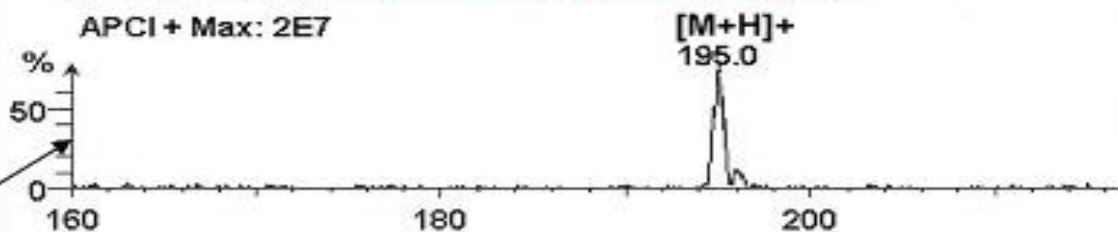
Συνδυασμός TLC/MS



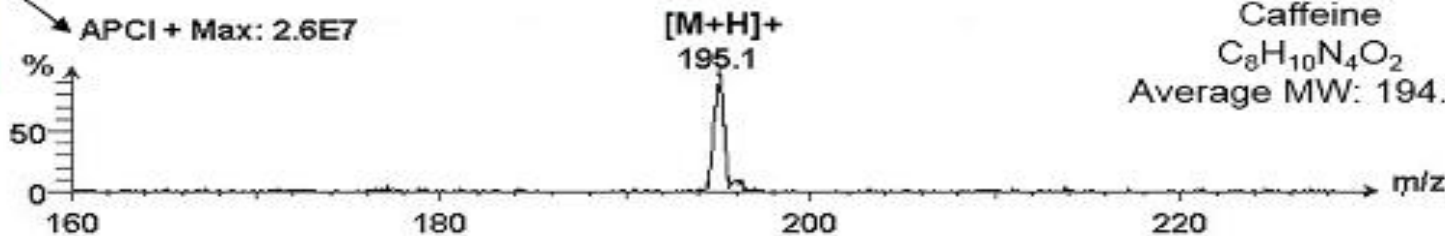
TIC of positive TLC-MS



Positive mass spectrum of Caffeine, (standard)

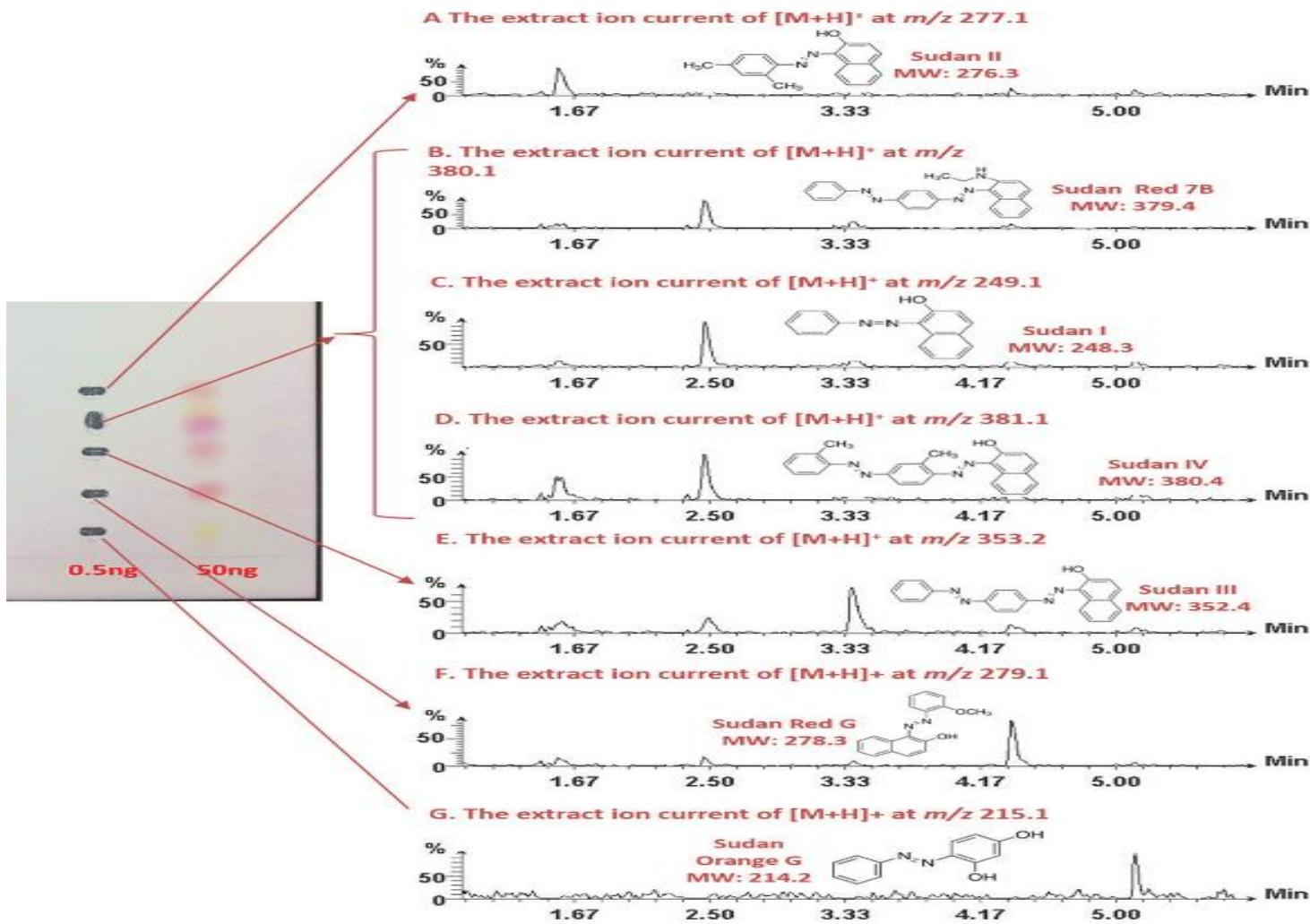


Positive mass spectrum of Caffeine, (fresh coffee)

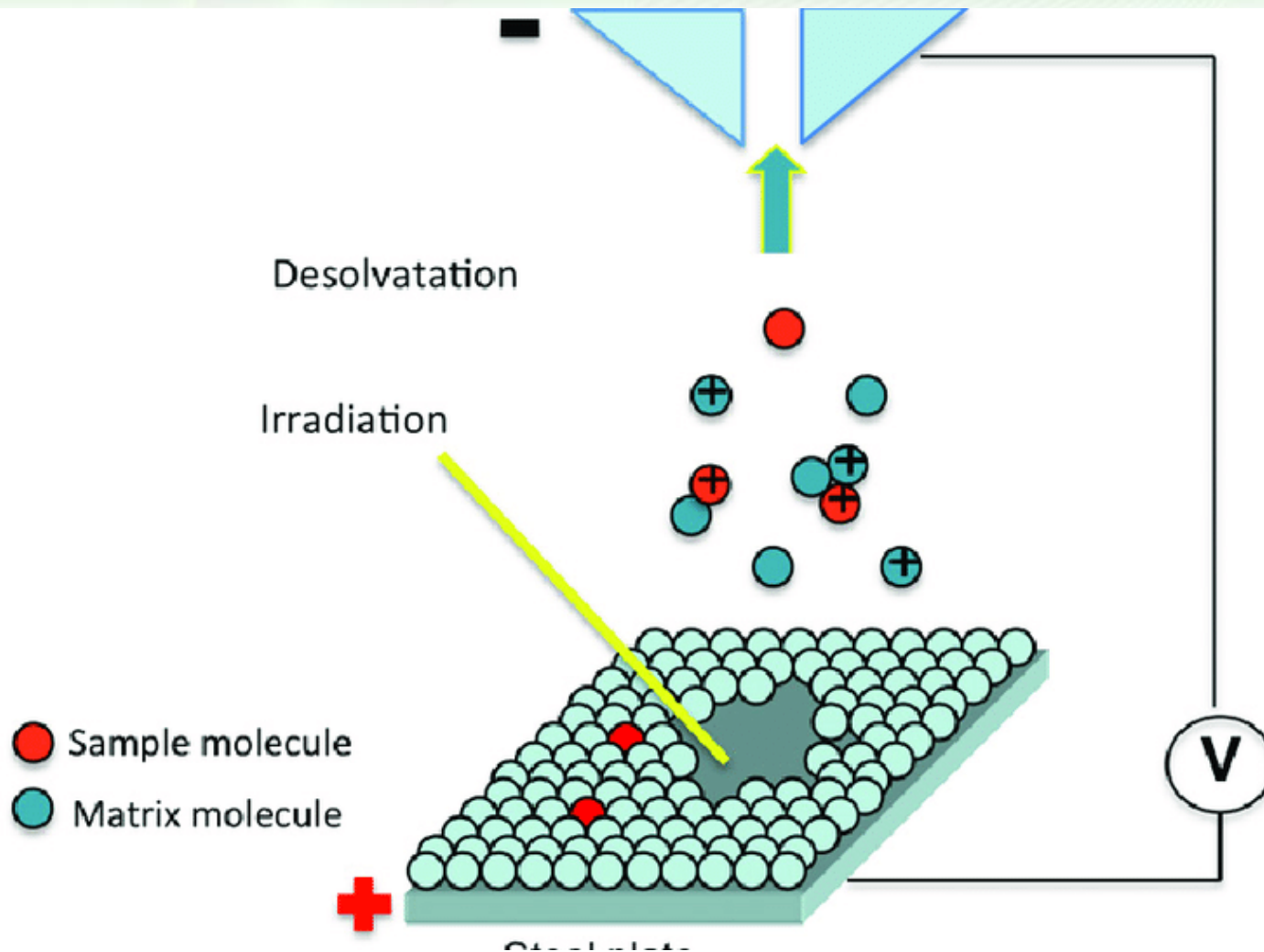


Caffeine
 $C_8H_{10}N_4O_2$
Average MW: 194.19

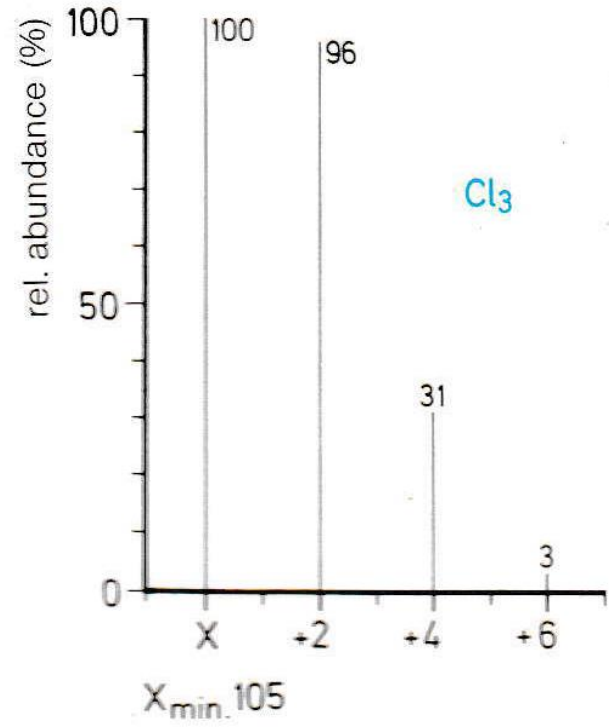
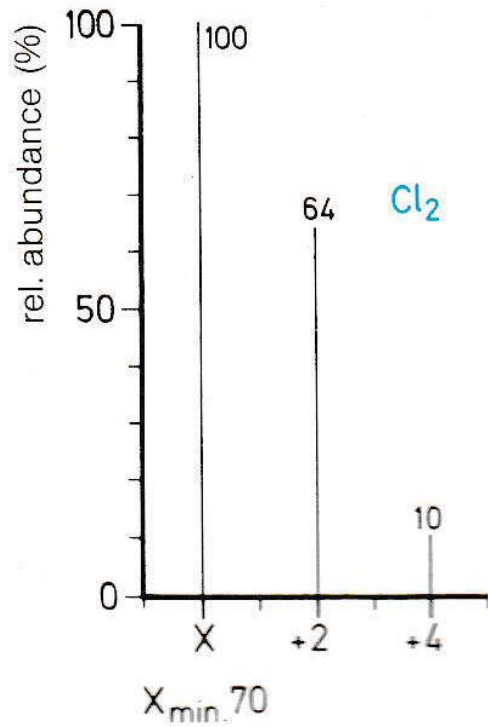
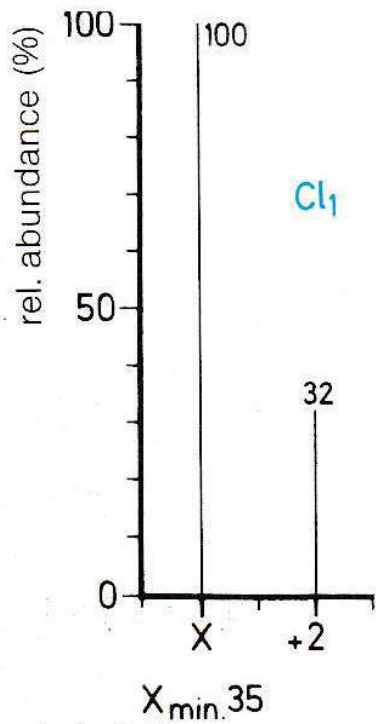
analysis of seven Sudan dyes (1 μL containing 0.5 ng applied to the TLC plate) in chili powder extract



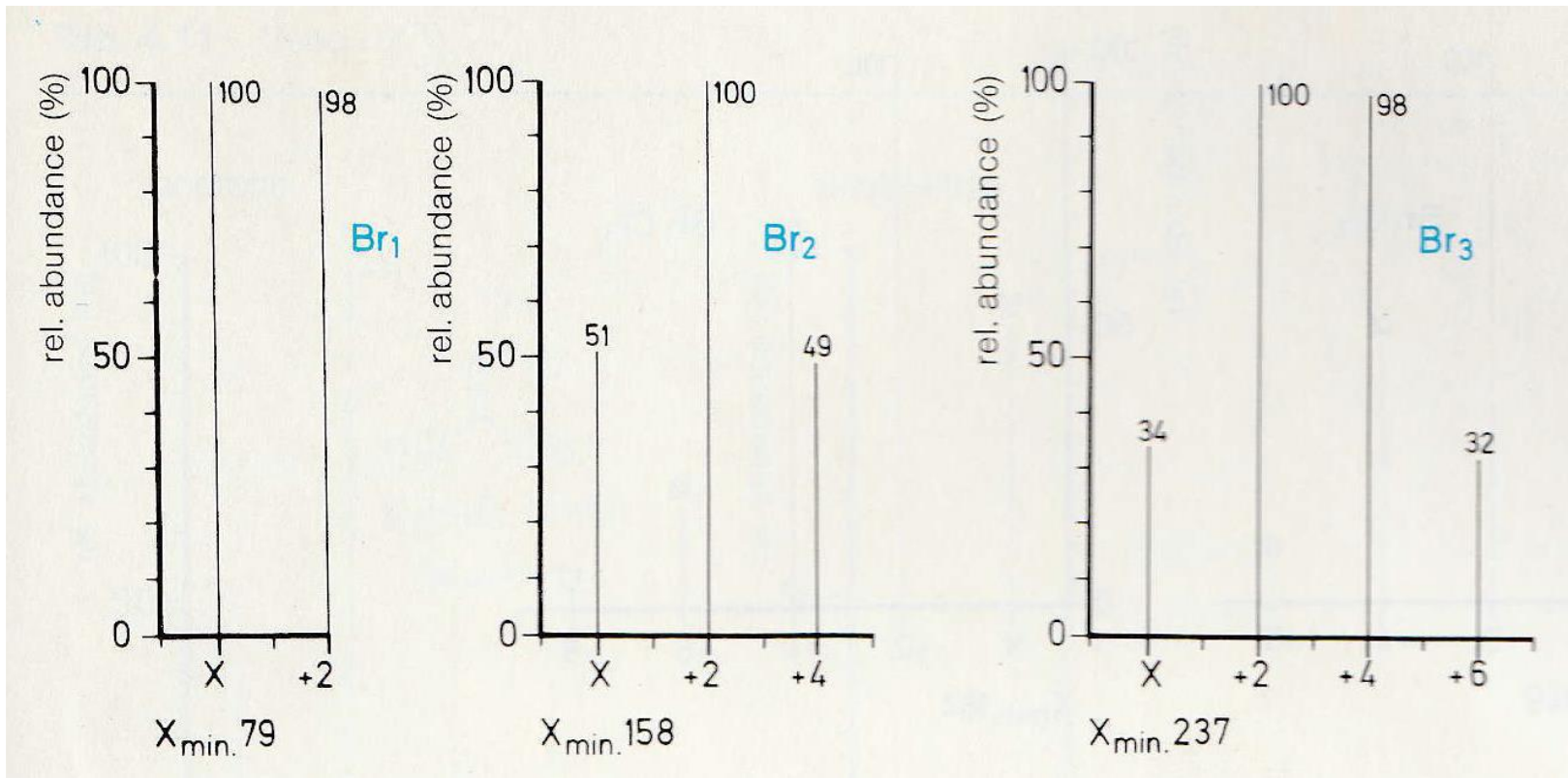
Laser distortion/ionization mass spectrometry



Ισοτοπικές σχέσεις Cl



Ισοτοπικές σχέσεις Br



Φάσματα μάζας διαλυτών

