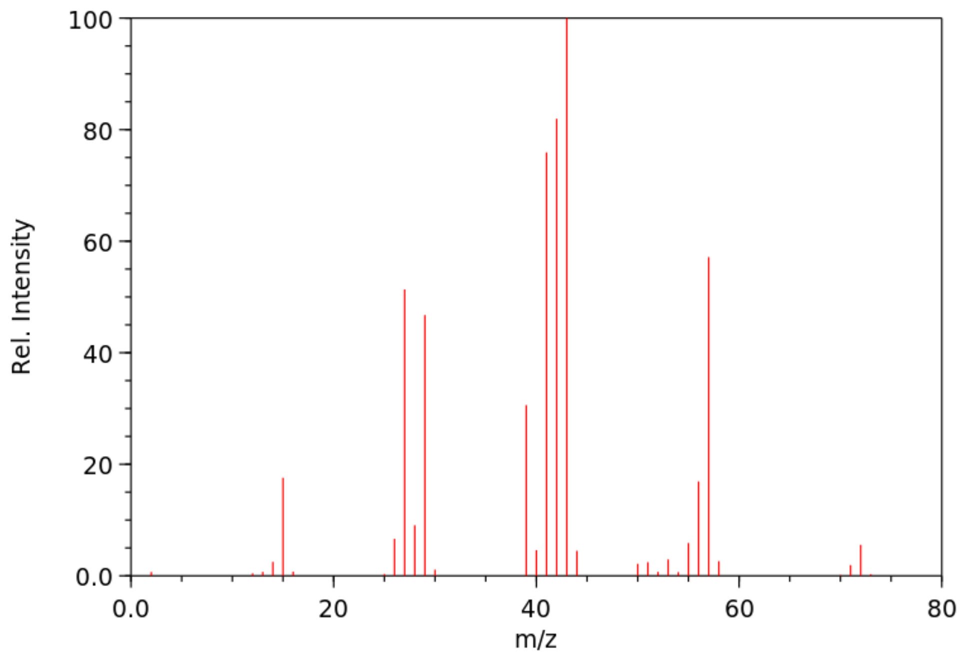
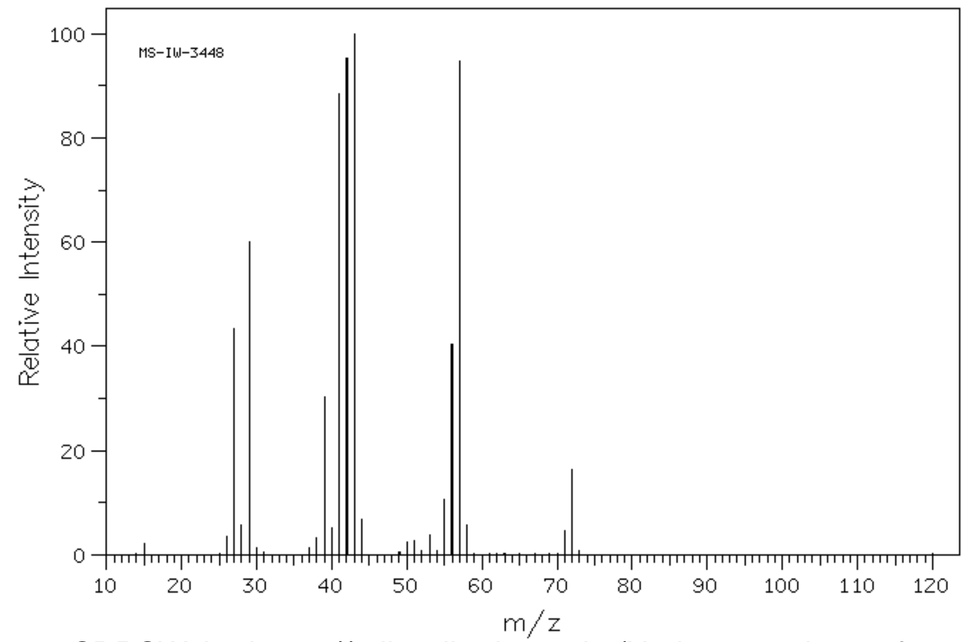
Why Mass Spectrometry?

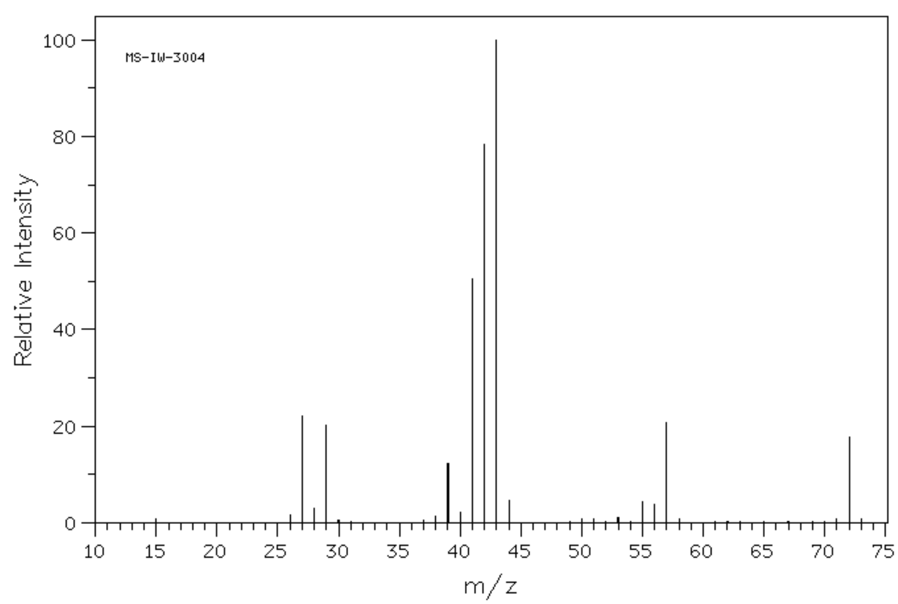
Identify known compounds: Fingerprinting



NIST Chemistry WebBook
(https://webbook.nist.gov/

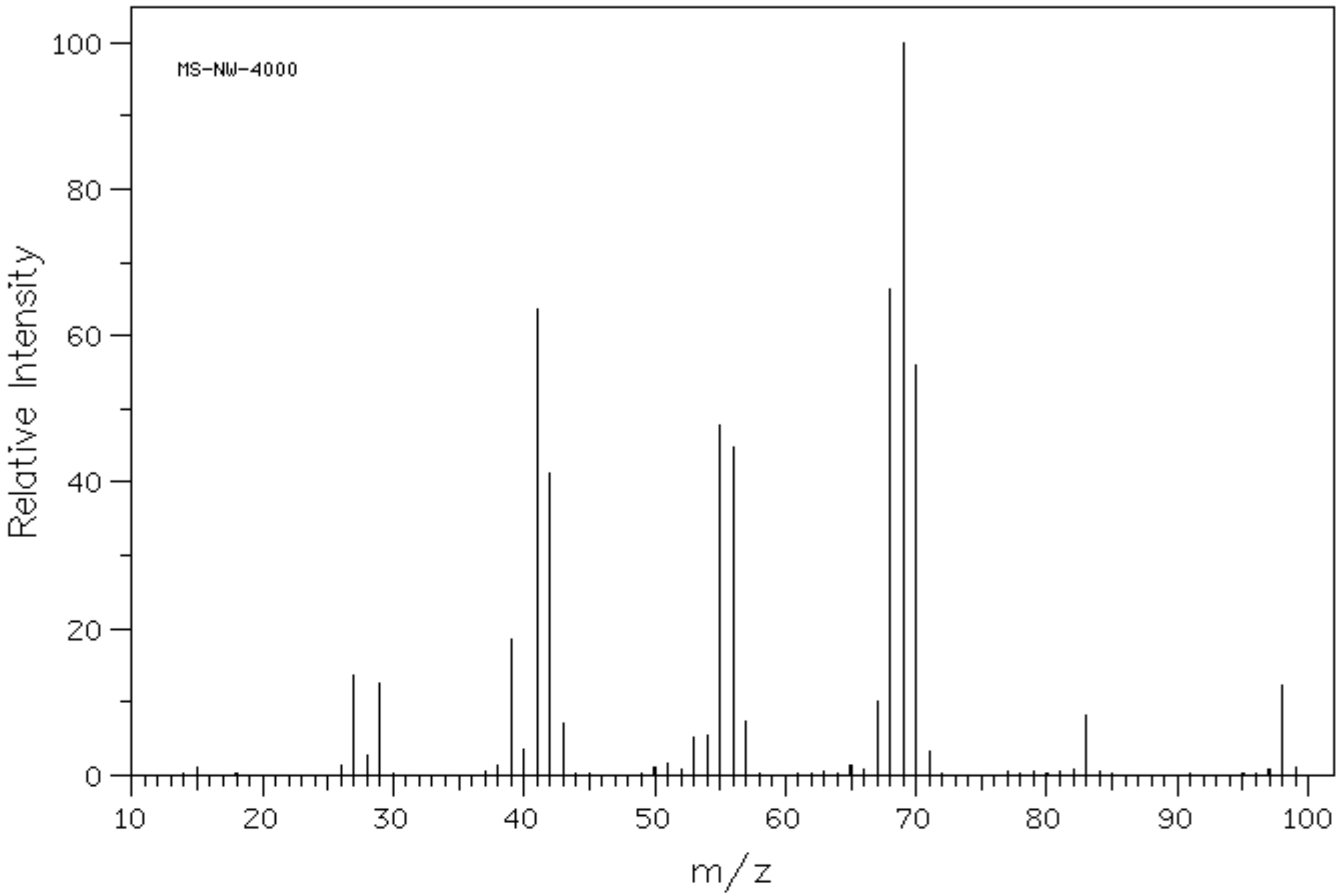


SDBSWeb : https://sdbs.db.aist.go.jp (National Institute of Advanced Industrial Science and Technology, March 2006)



Why Mass Spectrometry?

Determine molar mass and structure of unknown compounds.



SDBSWeb : https://sdbs.db.aist.go.jp (National Institute of Advanced Industrial Science and Technology, Jan 2019)

Why Mass Spectrometry?

Determine 1° structures of polypeptides (protein ladder sequencing).

1. 5% phenylisocyanate 95% phenylisothiocyanate (PC)
2. Trifluoroacetic acid
3. repeat

PC-Glu-Gly-Val-Asn-Asp-Asn-Glu-Glu-Gly-Phe-Phe-Ser-Ala-Arg

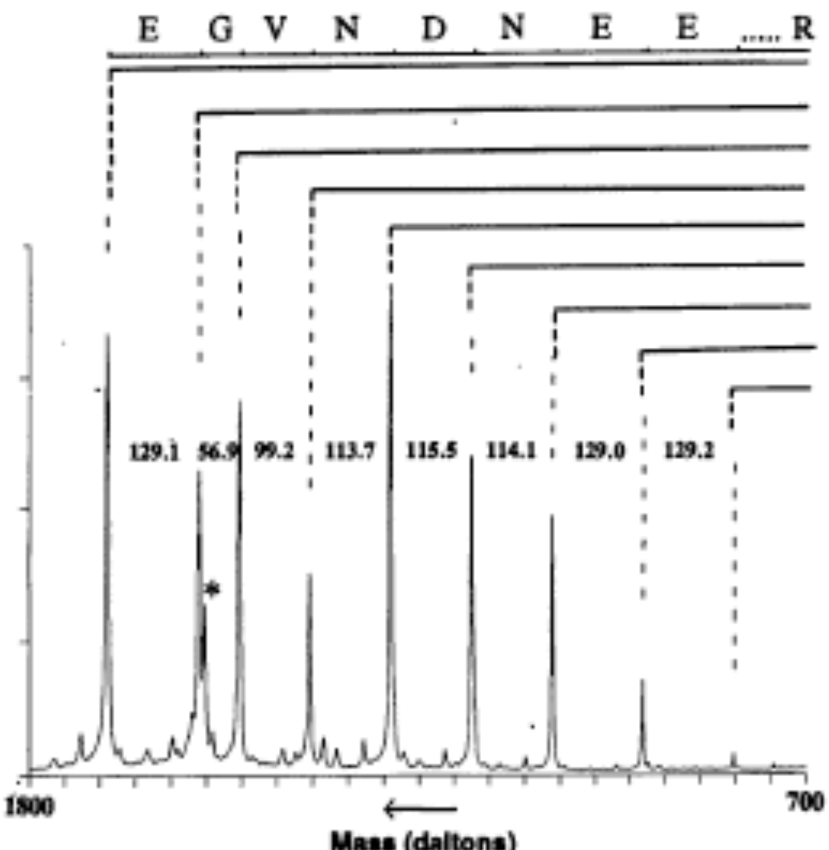
PC-Gly-Val-Asn-Asp-Asn-Glu-Glu-Gly-Phe-Phe-Ser-Ala-Arg

PC-Val-Asn-Asp-Asn-Glu-Glu-Gly-Phe-Phe-Ser-Ala-Arg

PC-Asn-Asp-Asn-Glu-Glu-Gly-Phe-Phe-Ser-Ala-Arg

PC-Asp-Asn-Glu-Glu-Gly-Phe-Phe-Ser-Ala-Arg

PC-Asn-Glu-Glu-Gly-Phe-Phe-Ser-Ala-Arg

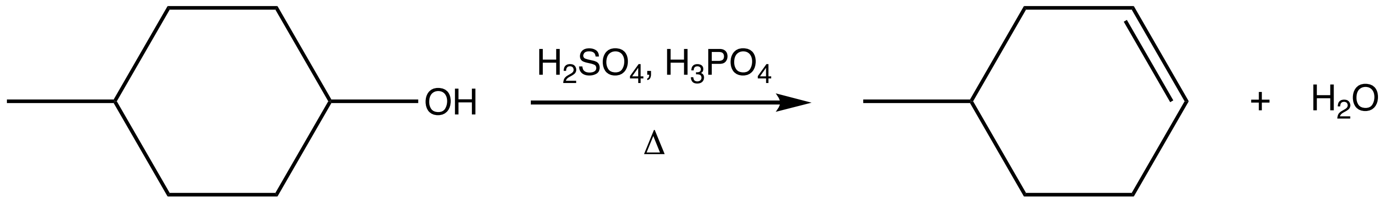


Brian T. Chait; Rong Wang; Ronald C. Beavis; Stephen B. H. Kent

Science, New Series, Vol. 262, No. 5130, Genome Issue. (Oct. 1, 1993), pp. 89-92.

Why Mass Spectrometry?

Confirm synthesis of target compound.



IR Data: OH vs no OH, no C=C vs C=C

MS Data: molar mass and high-resolution mass spectrometry to confirm formula

NMR Data

Why Mass Spectrometry?

HRAM GC-MS/MS

For comprehensive characterization of samples in a single analysis with high-confidence compound discovery, identification and quantitation, a GC system can be combined with a high resolution accurate mass (HRAM) mass spectrometer.

https://www.thermofisher.com/us/en/home/industrial/mass-spectrometry/gas-chromatography-mass-spectrometry-gc-ms/gc-ms-systems/high-resolution-accurate-mass-gc-ms.html

Overview

Describe the basics of how mass spectrometry works.

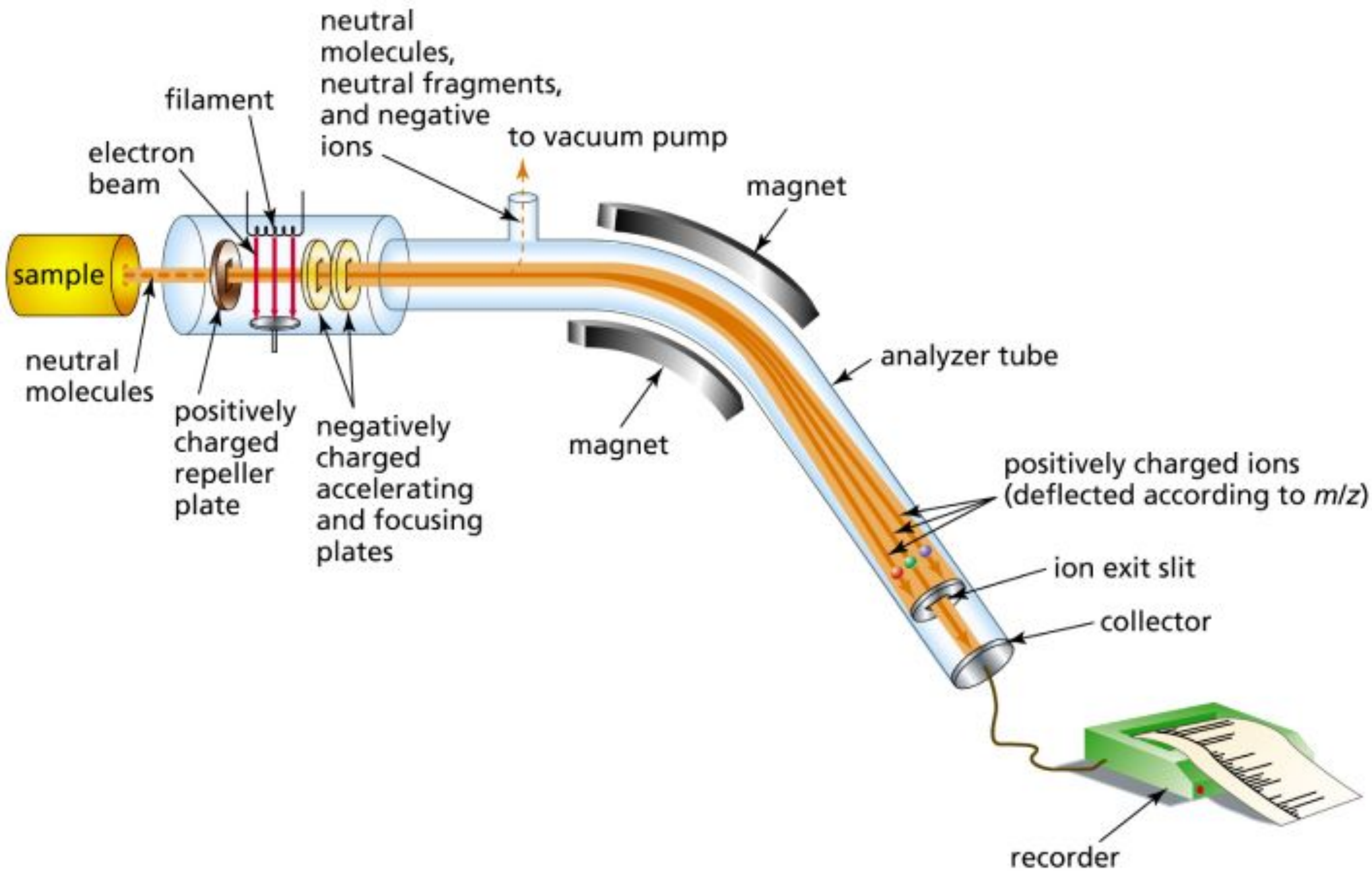
Examine the affects that isotopes and their natural abundance has on the mass spectrum

Consider methods for determining the formulas of compounds

Predict common fragmentation patterns for different functional groups

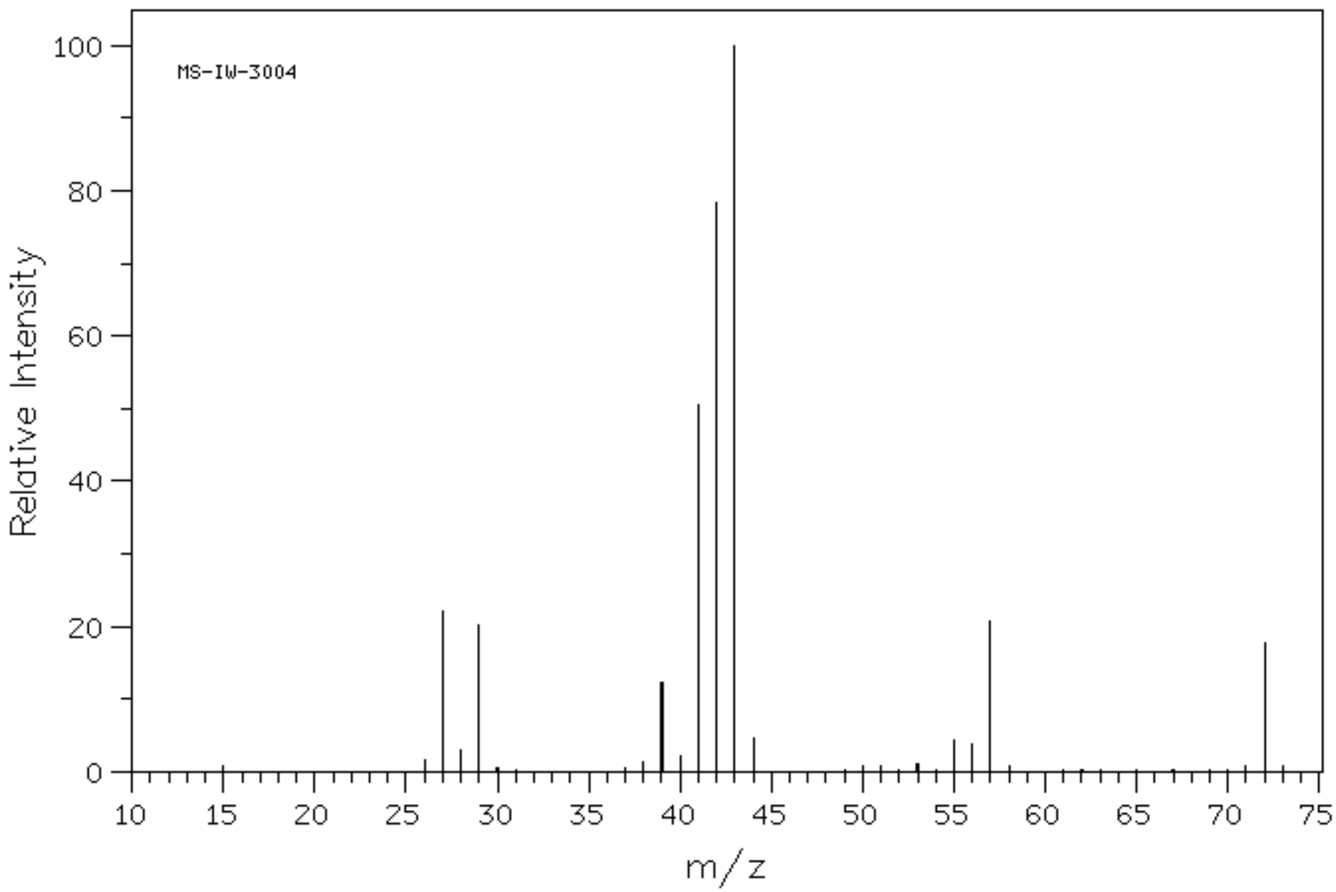
Unless indicated otherwise, all mass spectra that follow have been downloaded from the SDBSWeb : https://sdbs.db.aist.go.jp (National Institute of Advanced Industrial Science and Technology)

Schematic Representation of a Mass Spectrometer



Organic Chemistry, 8th ed., Bruice, Pearson 2016

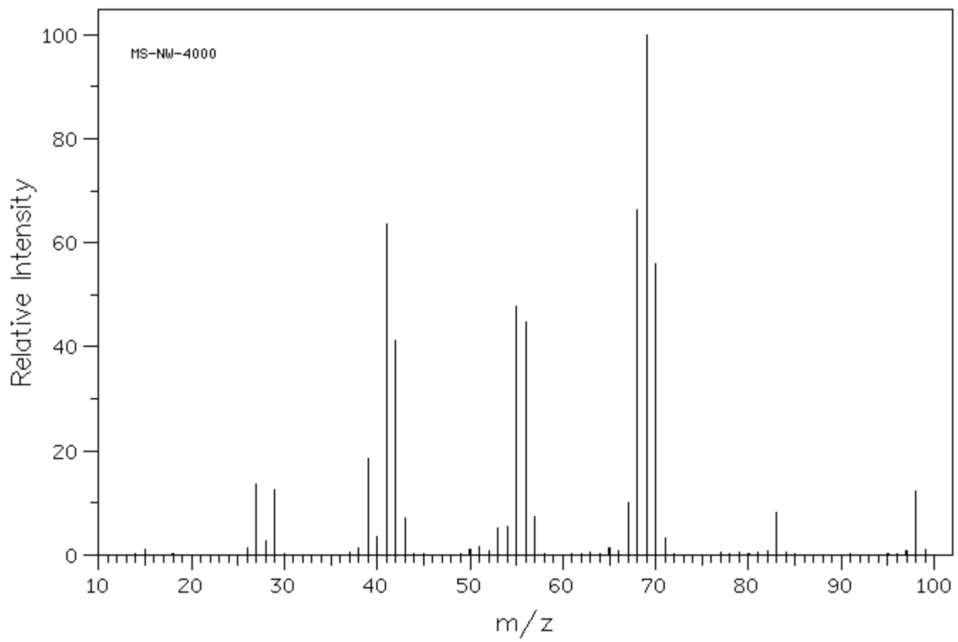
Mass Spectrum of Pentane

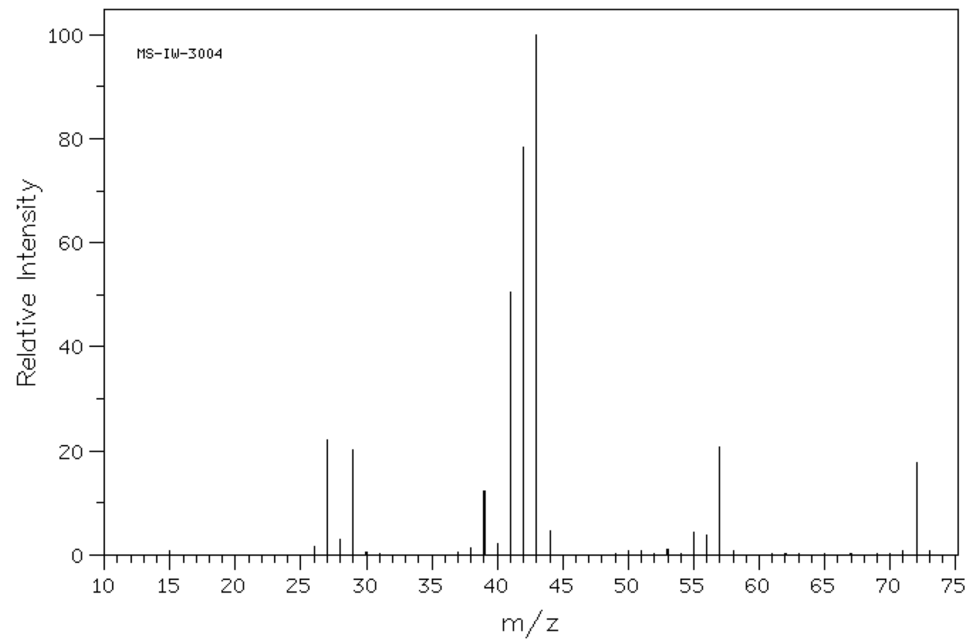


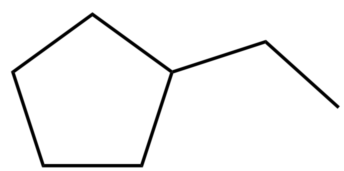
The Scale

The Base Peak

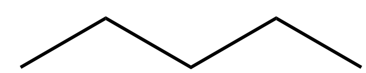
The Molecular Ion





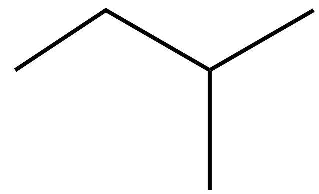


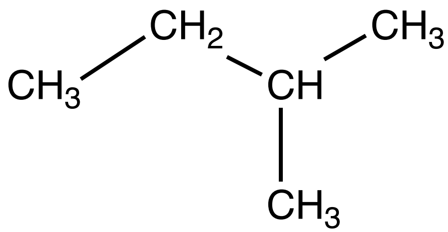
Molecular Weight: 98.1890

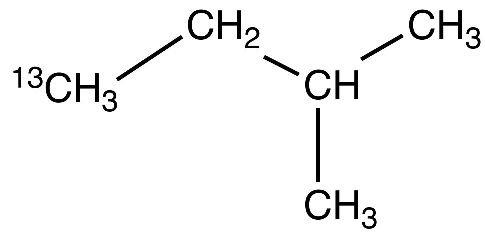


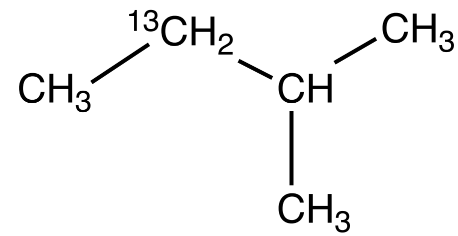
Molecular Weight: 72.1510

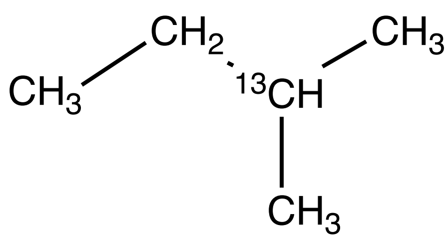
Determining Formulas Using m+1 Peaks

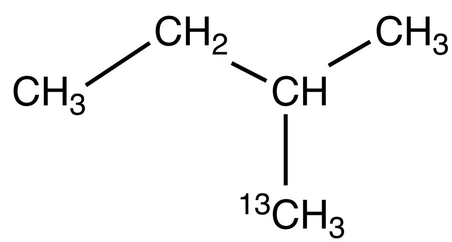


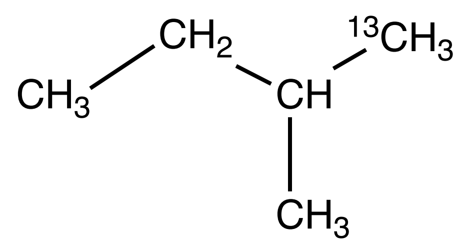




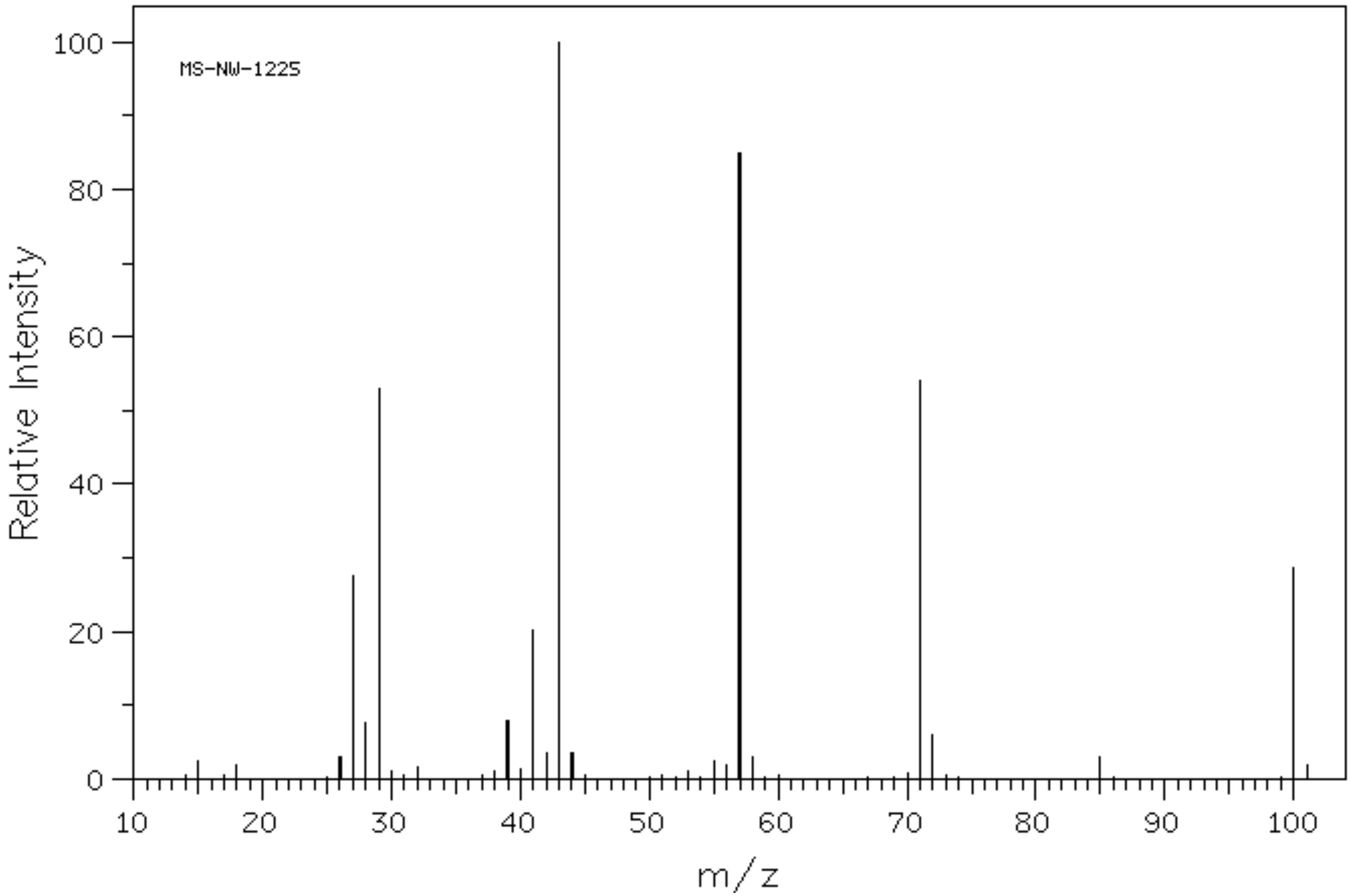




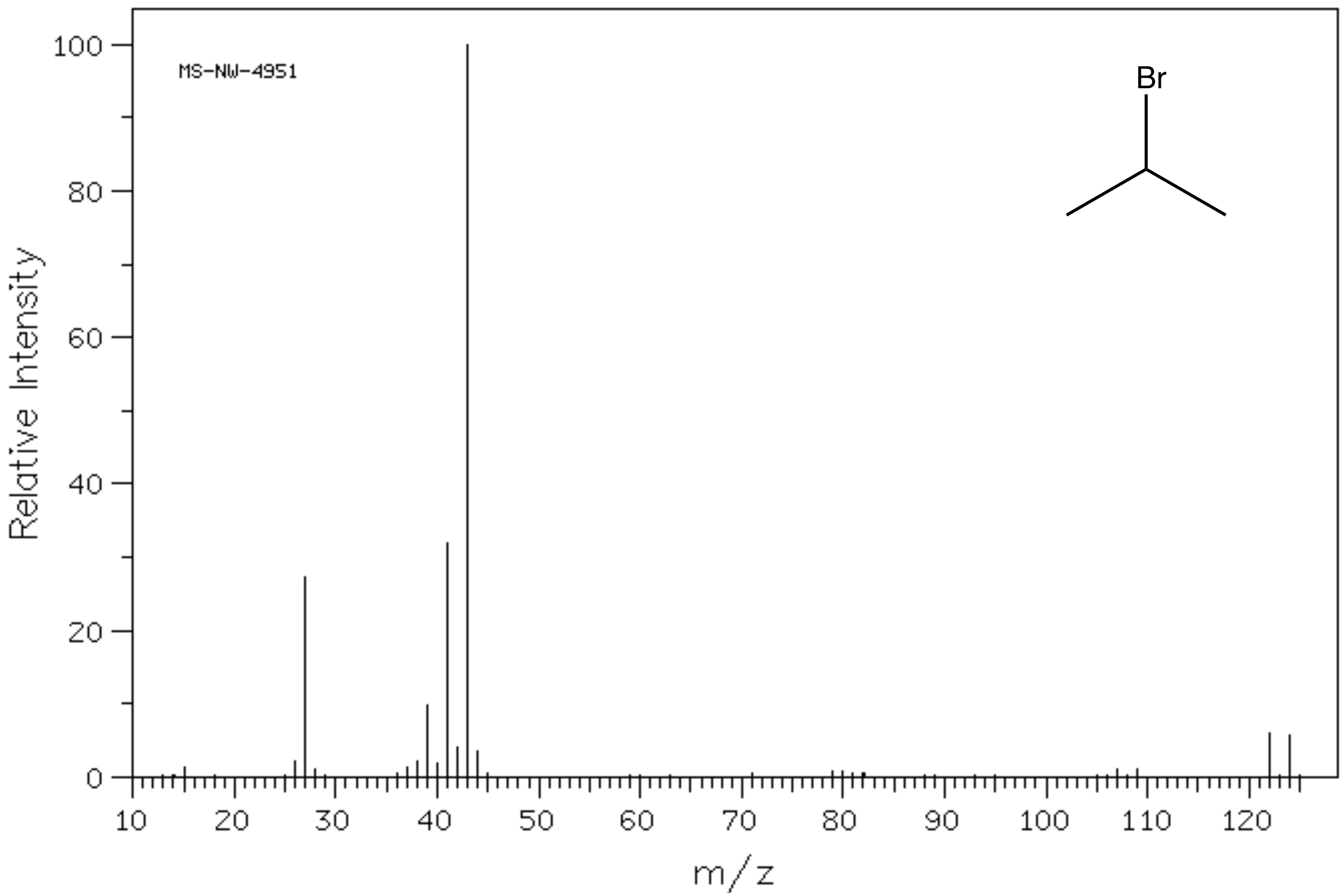


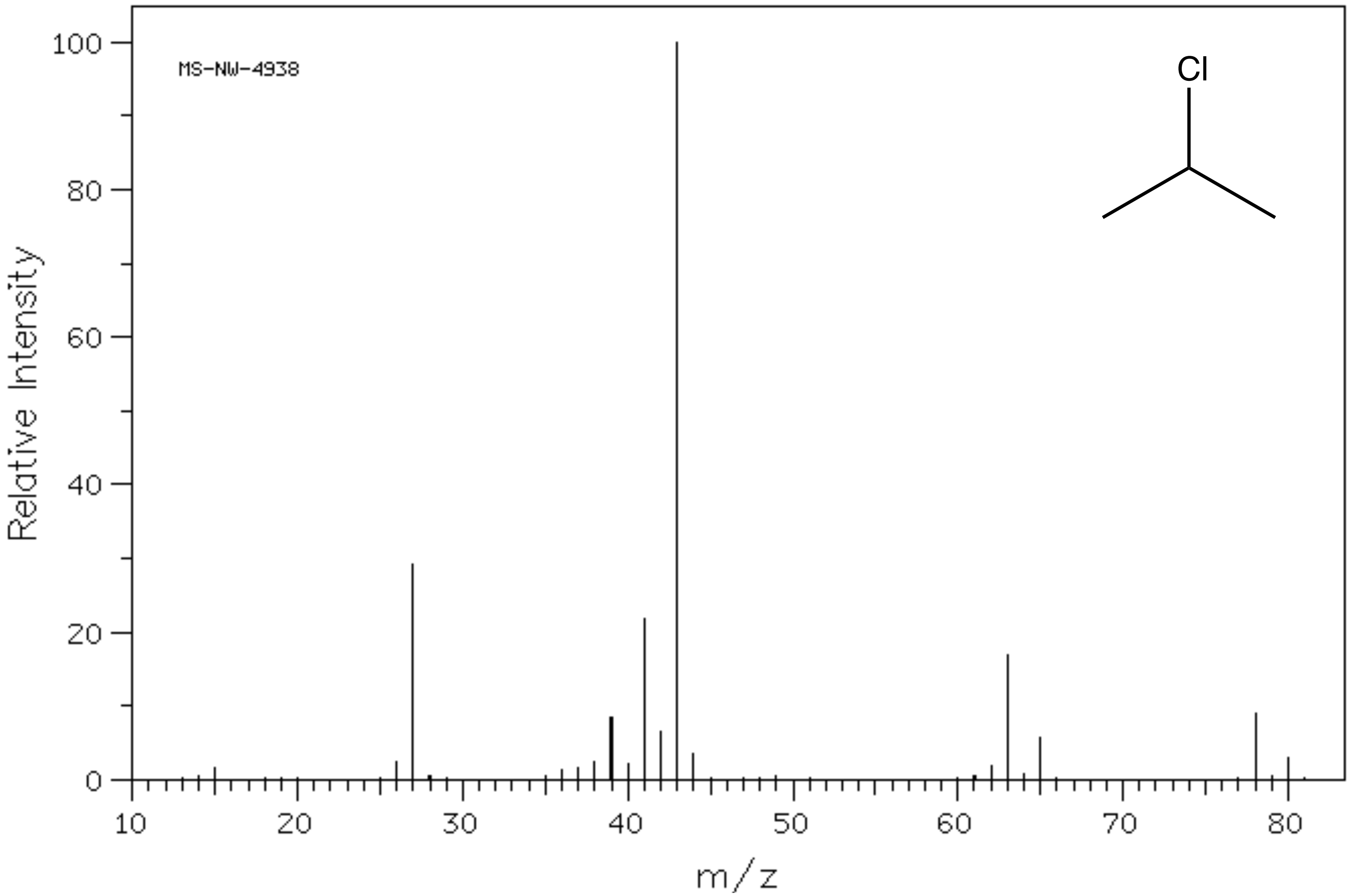


$$\# \text{ C atoms} = \frac{\text{intensity of m+1 peak}}{\text{intensity of (m) + (m+1) peaks}} \quad \frac{1}{0.011}$$



m/z	%
14.0	0.5
15.0	2.4
17.0	0.4
18.0	1.8
26.0	2.9
27.0	27.6
28.0	7.5
29.0	53.0
30.0	1.1
31.0	0.6
32.0	1.6
37.0	0.4
38.0	1.0
39.0	7.9
40.0	1.2
41.0	20.3
42.0	3.6
43.0	100.0
44.0	3.4
45.0	0.4
50.0	0.3
51.0	0.4
53.0	1.0
54.0	0.2
55.0	2.4
56.0	1.8
57.0	84.9
58.0	3.1
59.0	0.3
60.0	0.4
67.0	0.3
69.0	0.3
70.0	0.7
71.0	54.0
72.0	6.1
73.0	0.4
74.0	0.2
85.0	2.9
100.0	28.6
101.0	2.0


MS-NW-4951
Br
Relative Intensity
100
80
60
40
20
0
10
20
30
40
50
60
70
80
90
100
110
120
m/z


MS-NW-4938
Cl
Relative Intensity
100
80
60
40
20
0
10
20
30
40
50
60
70
80
m/z

m and m+1 peaks

Cl

Br

Comparing m and m+1 peaks

The "Rule of 13"

High Resolution Mass Spectrometry

Determine the number of CH units that "fit into" the peak.

If only C and H present, the remainder must be the number of H atoms present.

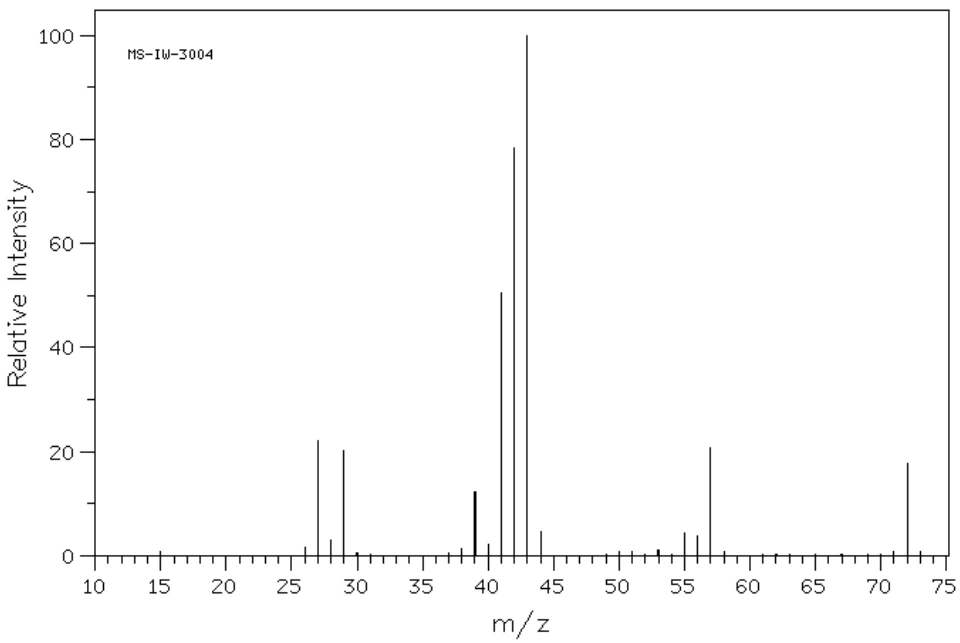
If other atoms present, "make room" for them by removing CH units.

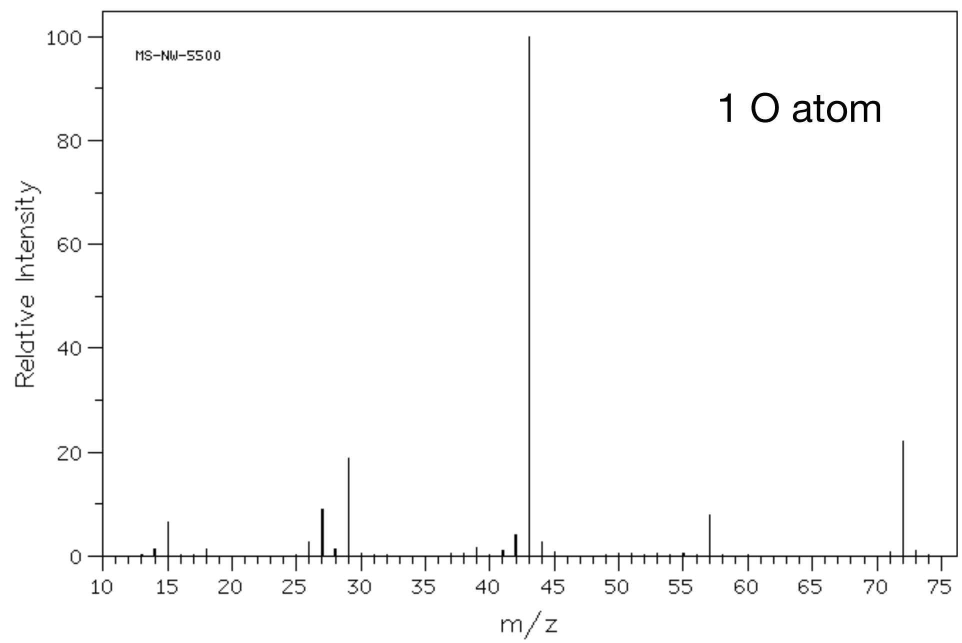
C_4H_{10} would have a peak at m/z of 58.01

Determine the number of CH units that "fit into" the peak.

If only C and H present, the remainder must be the number of H atoms present.

If other atoms present, "make room" for them but removing CH units.





High Resolution Mass Spectrometry: Using exact mass to determine formulae

C_9H_{14}	$C_7H_{10}N_2$	$C_8H_{10}O$	$C_7H_6O_2$	$C_4H_{10}O_4$	$C_4H_{10}S_2$
122.1096 u	122.0845 u	122.0732 u	122.0368 u	122.0579 u	122.0225 u

CH_3OCH_3
Exact Mass: 46.04

CH_3CH_2OH
Exact Mass: 46.04

Comparing m and m+1 peaks

Advantage: Don't need to know whether other atoms are present as part of the ion

Disadvantage: Can be made inaccurate by overlapping peaks and the presence of atoms with m+1 isotopes like nitrogen

The "Rule of 13"

Advantage: Don't need to worry about other atoms with m+1 isotopes
Don't need to worry about overlapping peaks

Disadvantage: Need to know whether other atoms are part of the ion
Doesn't work well with large molecules

High Resolution Mass Spectrometry

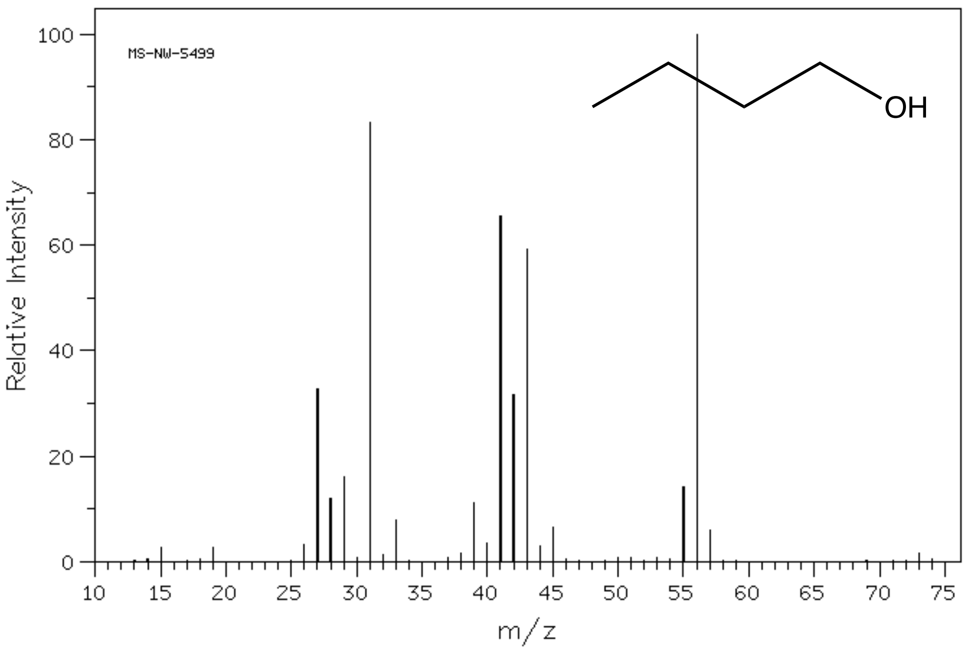
Advantage: Computer and instrument can determine many formulas with minimal operator input

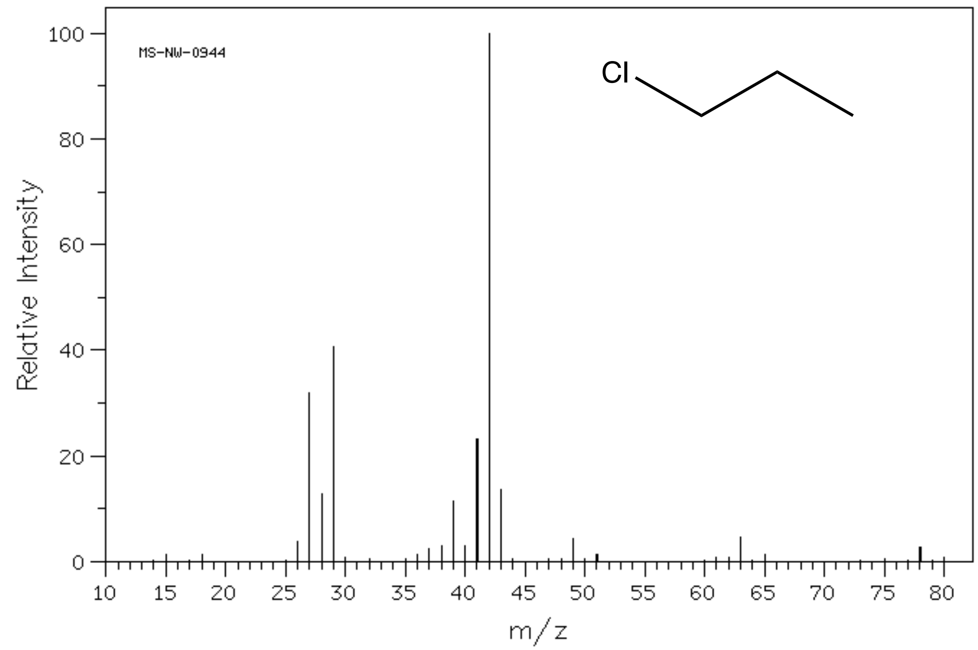
Disadvantage: Very expensive
The larger the molecule the harder it is to determine formula

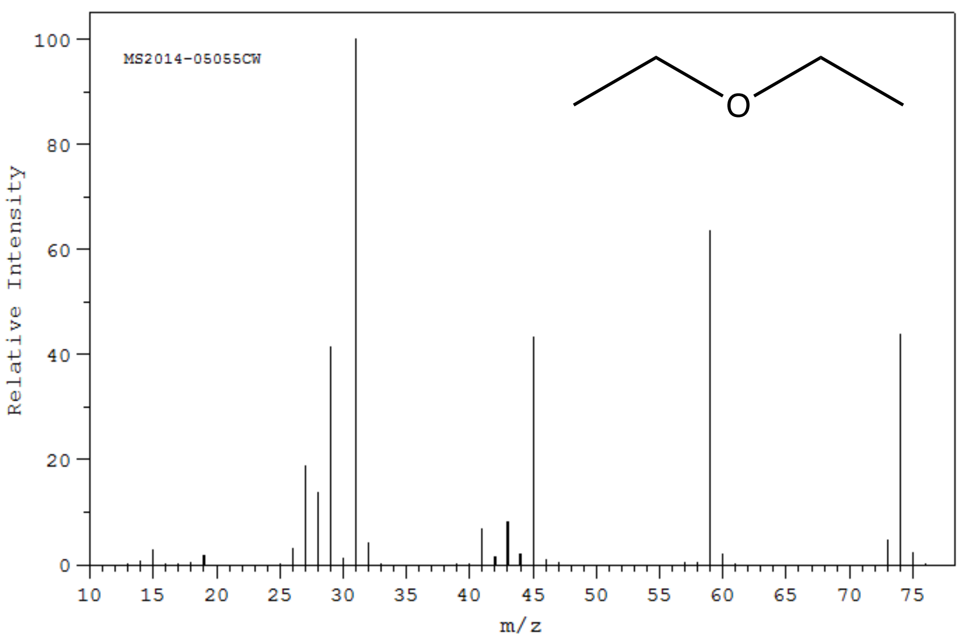
Fragmentation Patterns Can Help Identify Compounds

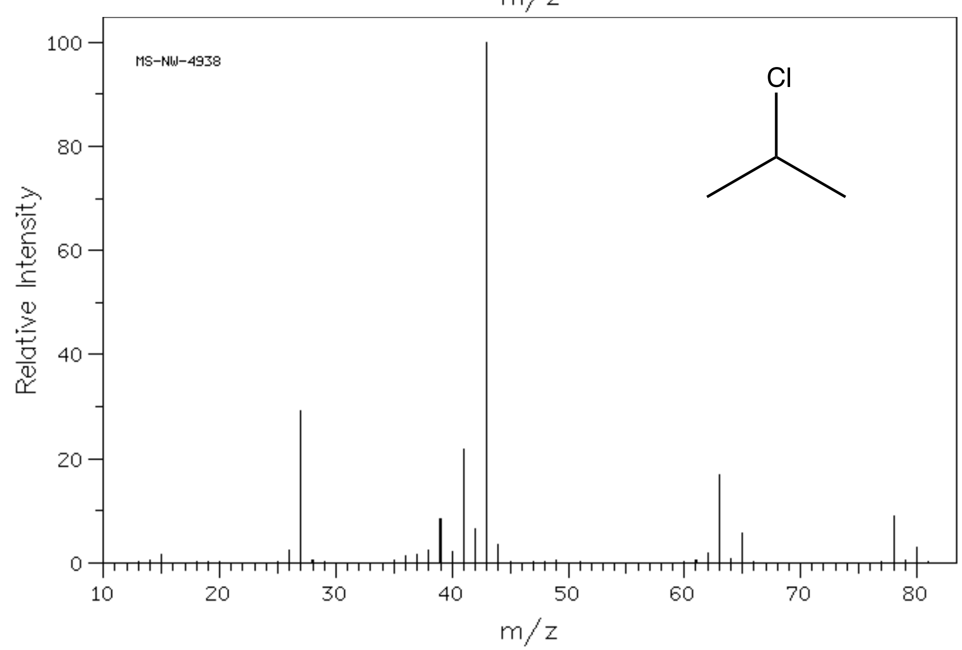
$CH_3CH_2OCH_2CH_3$ vs $CH_3CH_2CH_2CH_2OH$

$ClCH_2CHCH_3$ vs $CH_3CHClCH_3$





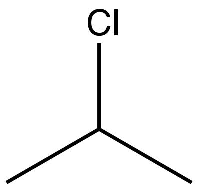


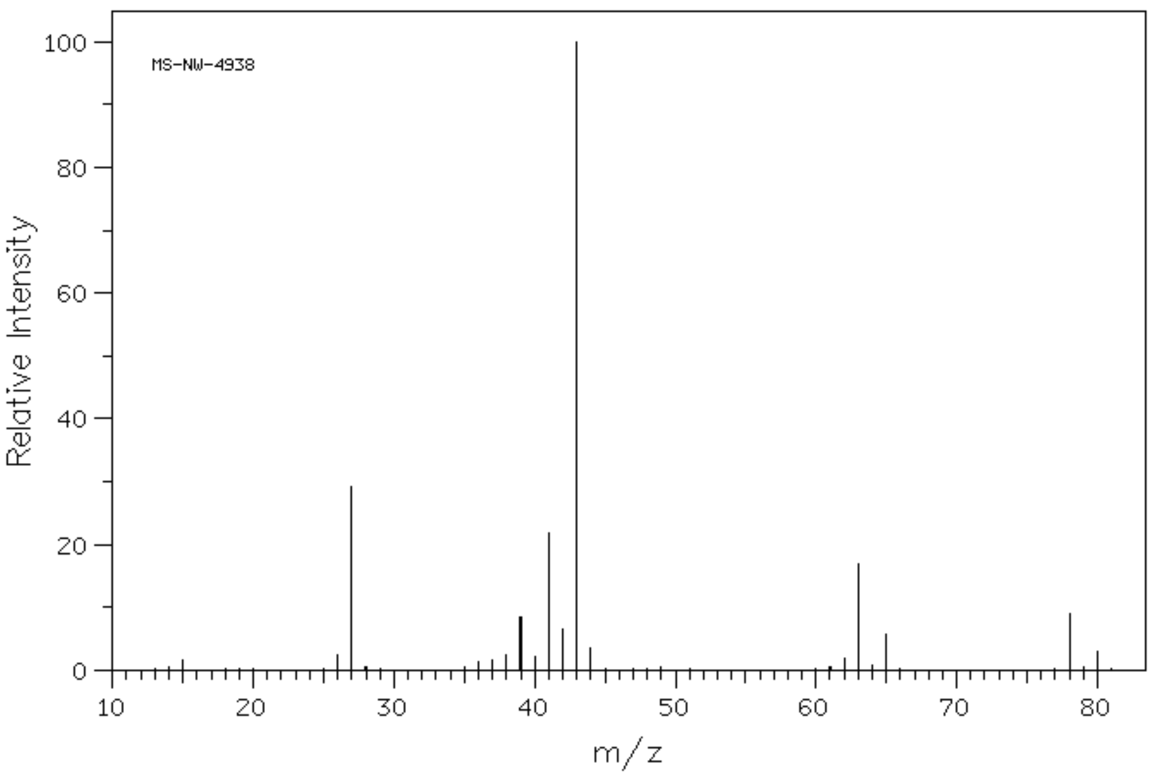


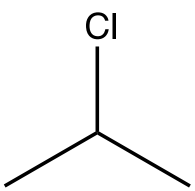
Homolytic vs Heterolytic Cleavage

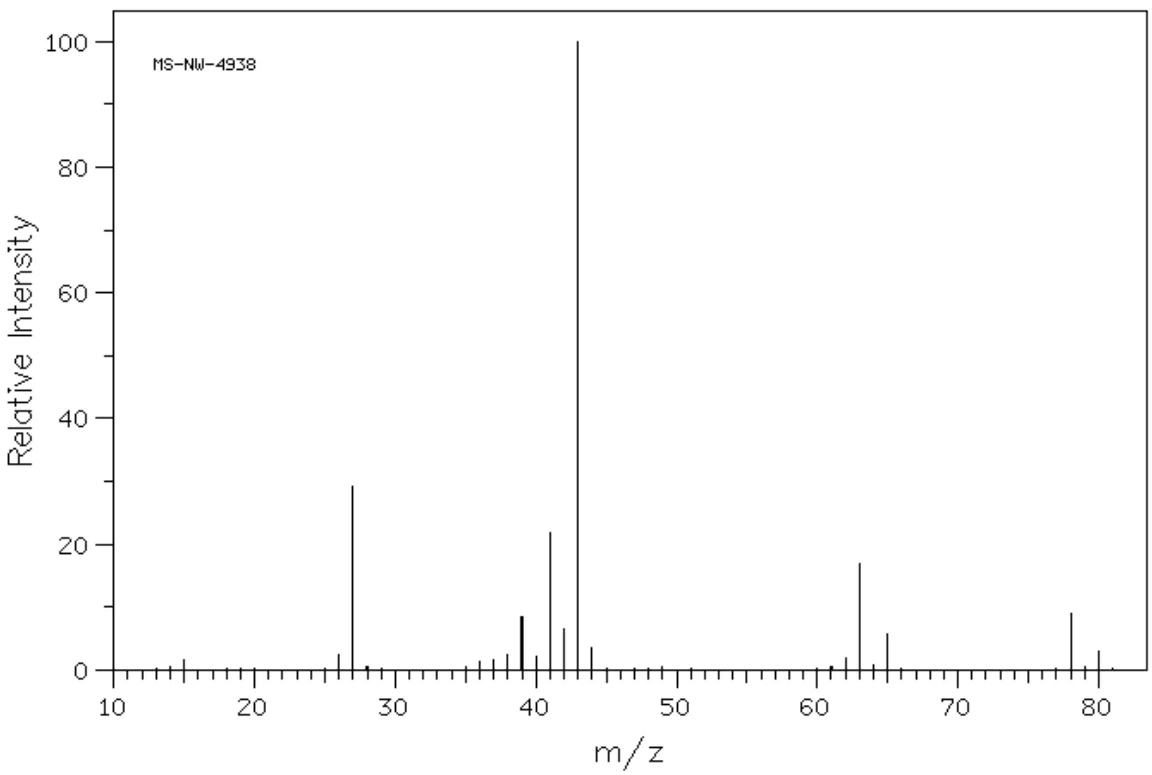
Homolytic

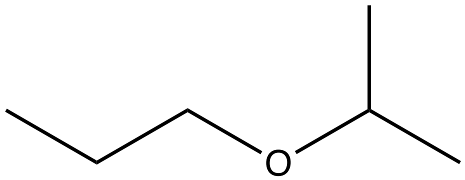
Heterolytic

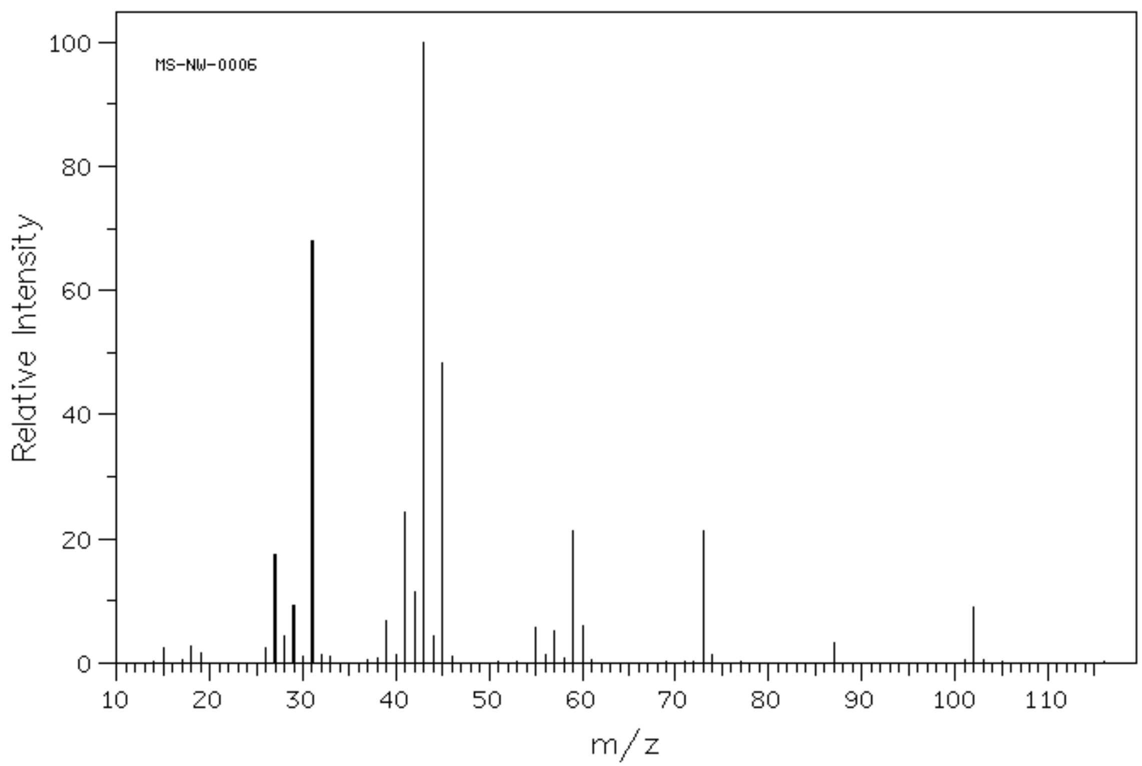

Cl


MS-NW-4938
Relative Intensity
100
80
60
40
20
0
10
20
30
40
50
60
70
80
m/z


Cl


MS-NW-4938
Relative Intensity
m/z
100
80
60
40
20
0
10
20
30
40
50
60
70
80


O


MS-NW-0006
Relative Intensity
m/z
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10
20
30
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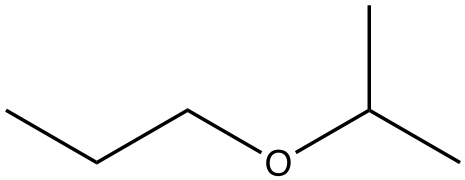
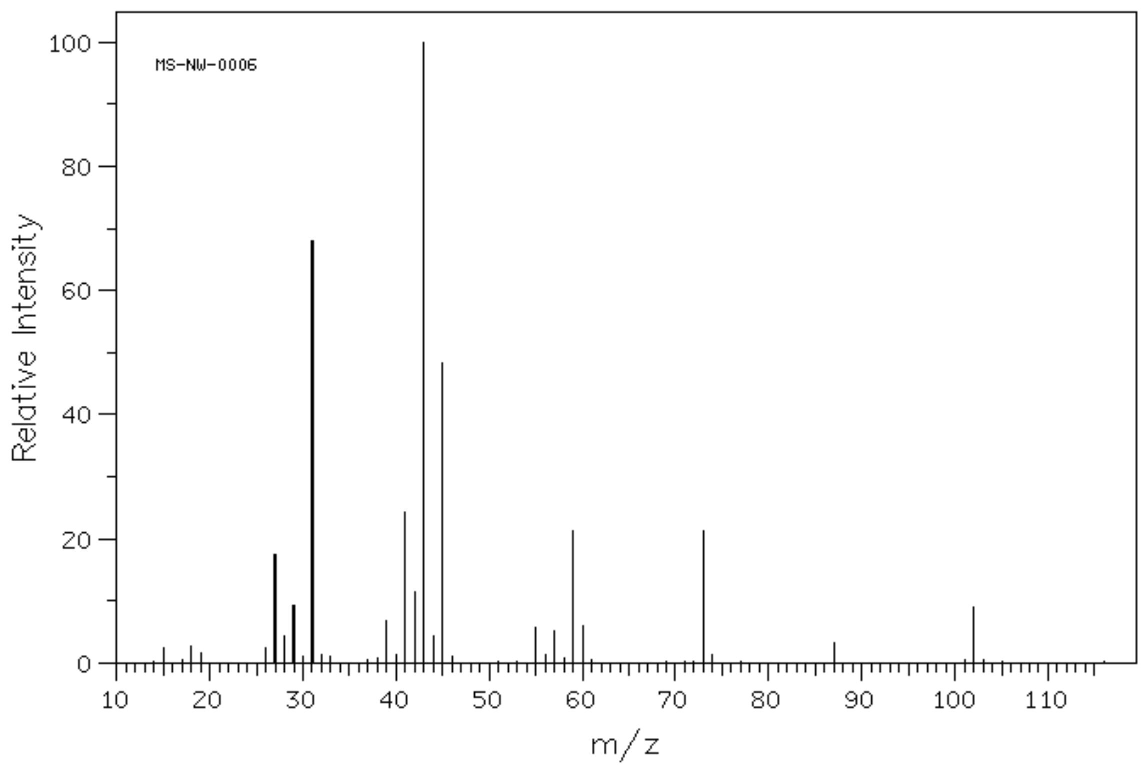
70
80
90
100
110


O


MS-NW-0006
Relative Intensity
m/z
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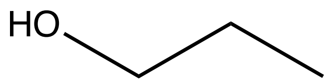
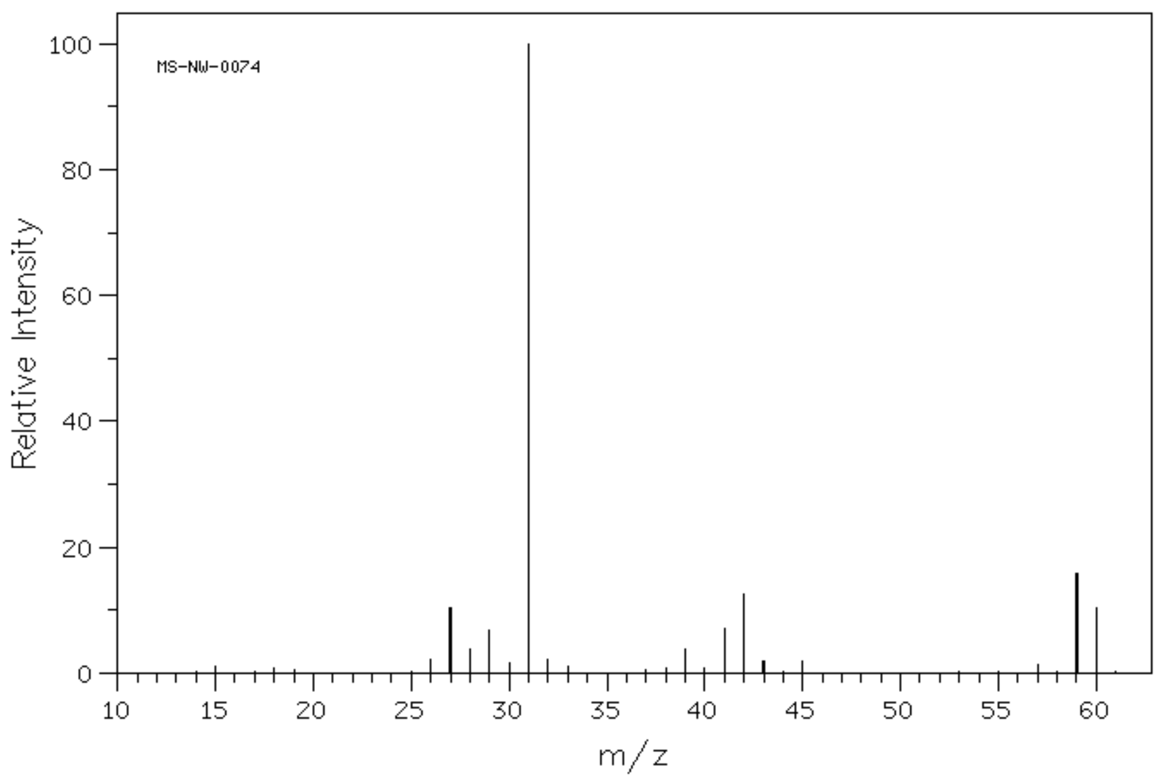
40
60
80
100
10
20
30
40
50
60
70
80
90
100
110


HO


MS-NW-0074
Relative Intensity
m/z
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60
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20
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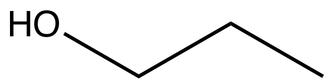
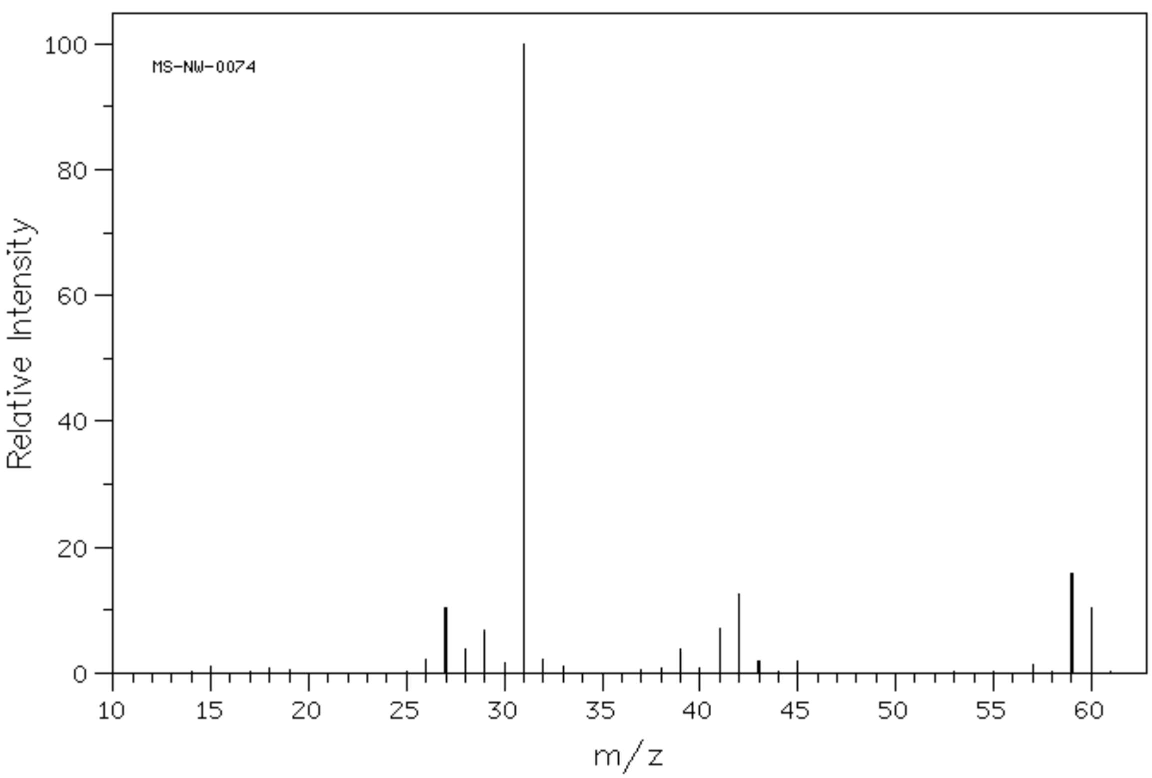
10
15
20
25
30
35
40
45
50
55
60


HO


MS-NW-0074
Relative Intensity
m/z
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80
60
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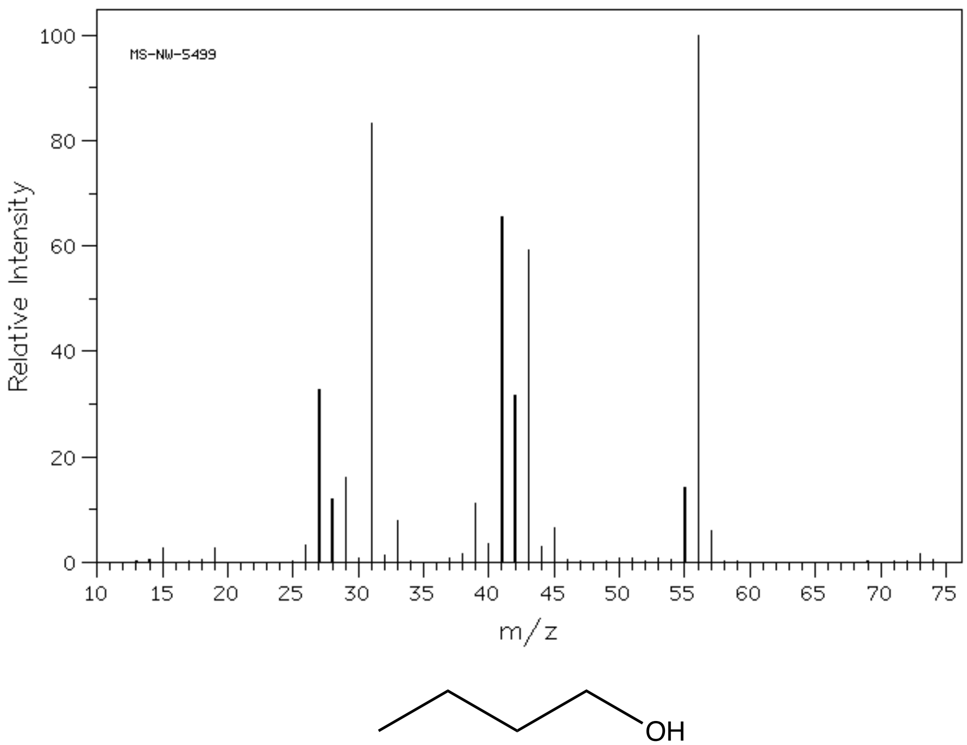
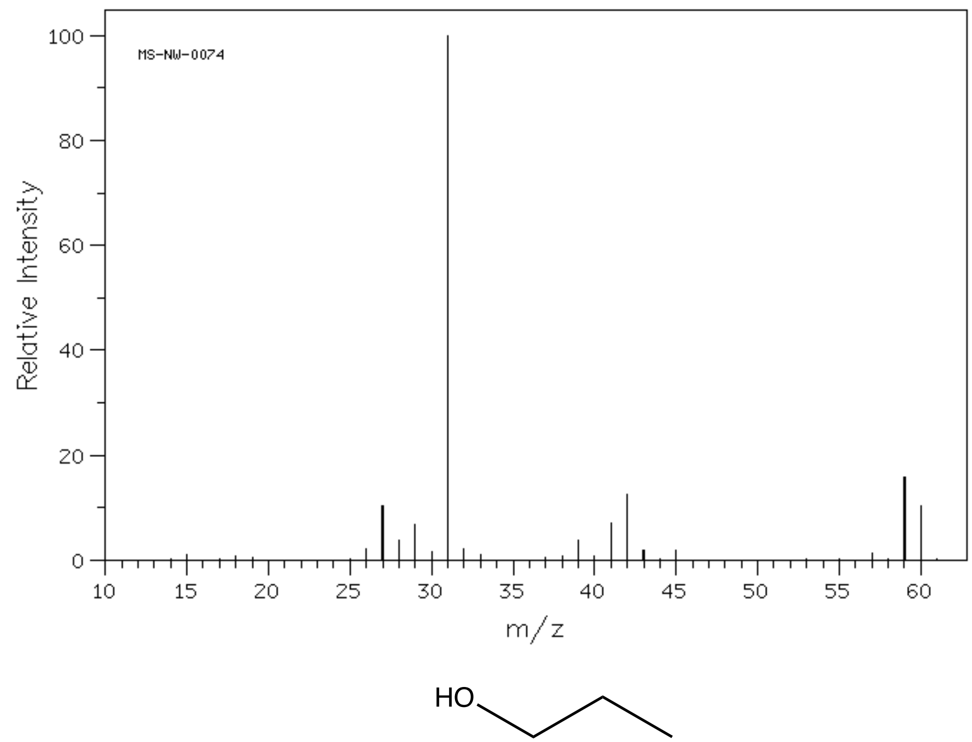
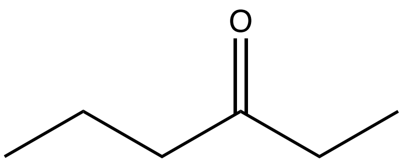
45
50
55
60


MS-NW-5499
Relative Intensity
m/z
OH


MS-NW-0074
Relative Intensity
m/z
HO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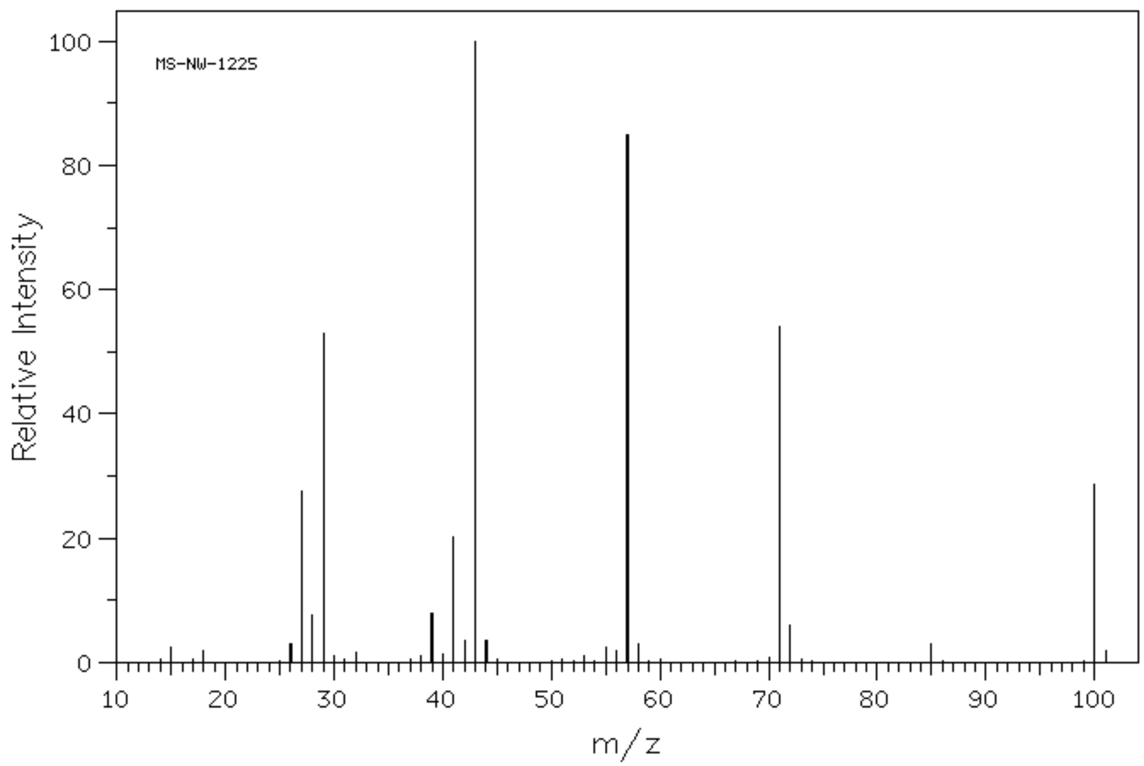
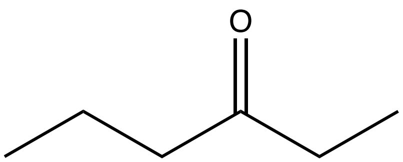
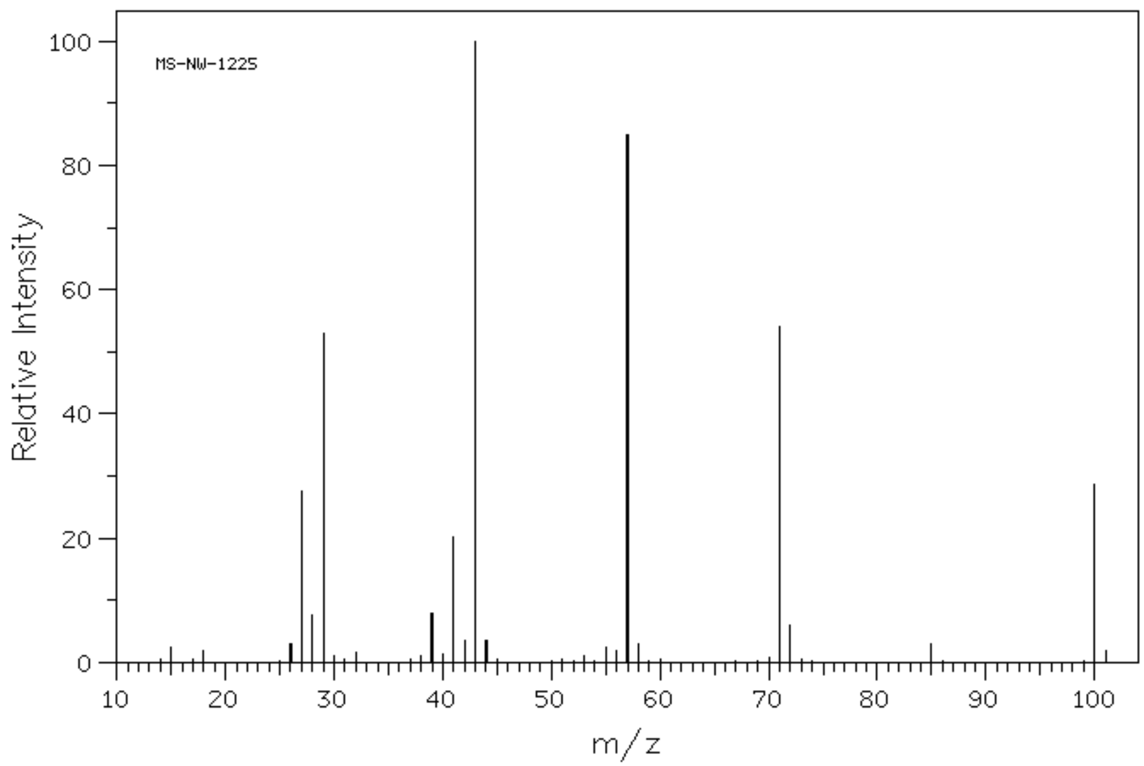
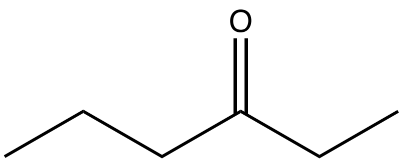
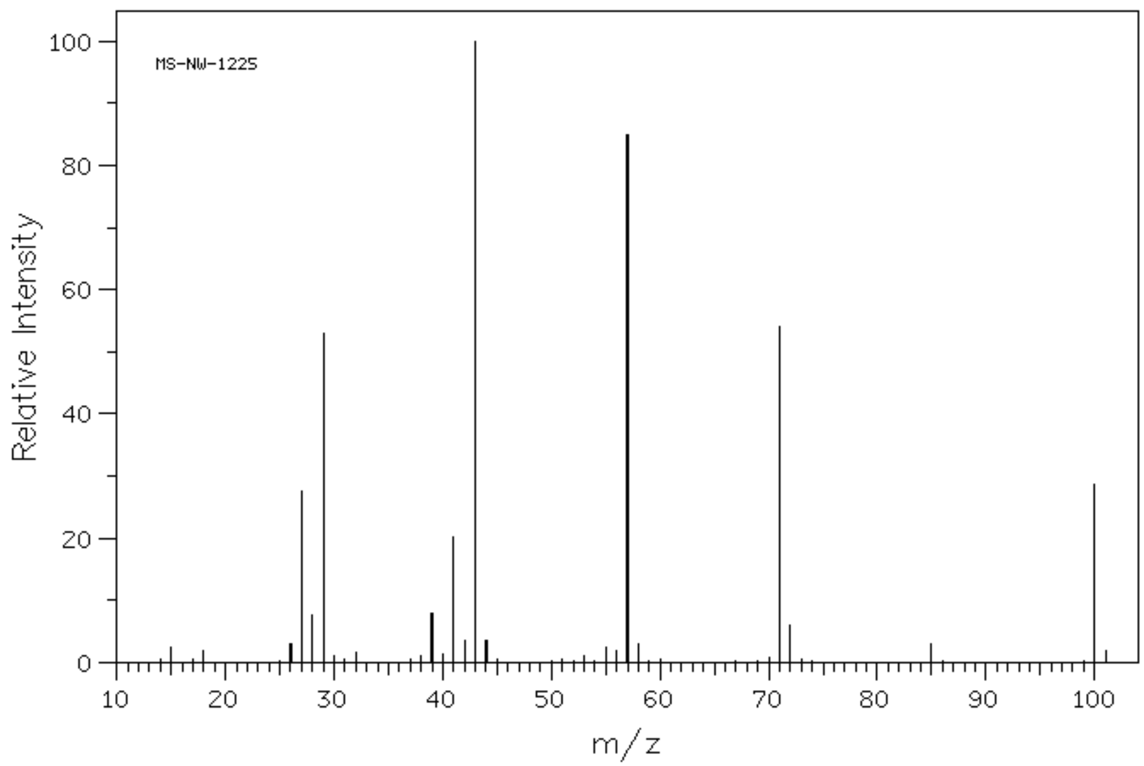
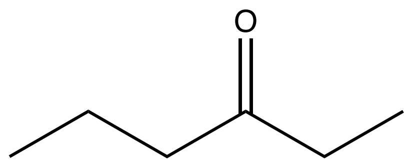

MS-NW-1225
Relative Intensity
m/z
0
20
40
60
80
100
10
20
30
40
50
60
70
80
90
100


O


MS-NW-1225
Relative Intensity
m/z
0
20
40
60
80
100
10
20
30
40
50
60
70
80
90
100


O


MS-NW-1225
Relative Intensity
m/z
0
20
40
60
80
100
10
20
30
40
50
60
70
80
90
100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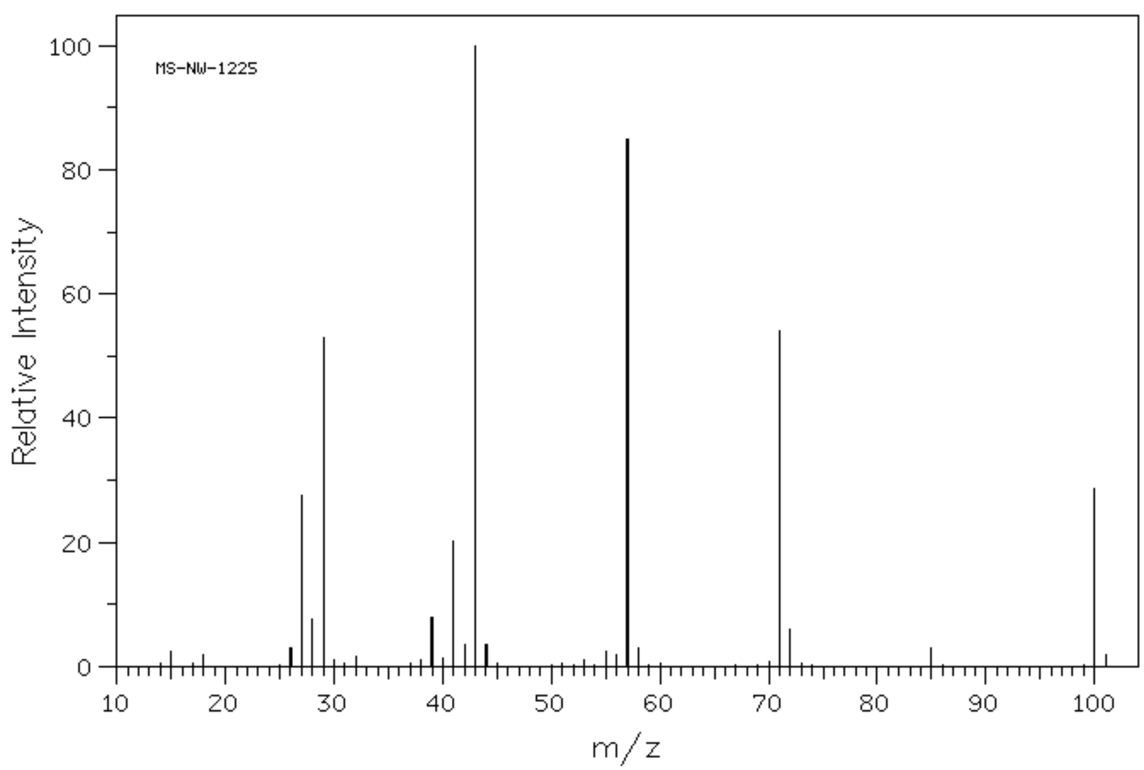
MS-NW-1225
Relative Intensity
m/z
100
80
60
40
20
0
10
20
30
40
50
60
70
80
90
100