

Supporting Information (S-3 and S-4)

A Complete Structure Investigation of an Organic Molecule for Chemistry Students; An Analysis of Aspartame

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The Pre-Laboratory Questionnaire (S-3)

10 First letter of your birthplace:

Last digit of your house number:

First letter of your favorite pet:

Second letter of your mother's first name:

15 The survey will be anonymous. Therefore, we have included some questions at the top of the sheet that together generate a code. This way, we can compare the results pairwise for each student, while maintaining anonymity.

Pre-laboratory questions -general background and knowledge of analytical methods

Circle/mark your answer.

20 1. How much time, on average, did you spend per week working on the curriculum for this subject, KJE302 (attending lectures and/or reading lecture notes/textbooks)?

None	Less than 1 hour per week	1-2 hours per week	2-4 hours per week	More than 4 hours per week
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2. How much time, on average, did you spend per week solving spectrum tasks in this subject besides lectures?

Less than 1 hour per week	1-2 hours per week	2-3 hours per week	4-5 hours per week	More than 5 hours per week
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Describe your familiarity with the various analytical methods after the laboratory exercise by marking from 1-5 in the table:

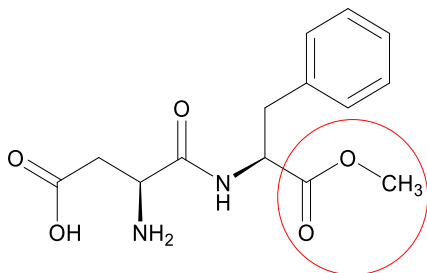
Question number	Analytical Method	Not familiar	Slightly familiar	Familiar	Well familiar	Very well familiar
3	Describe your familiarity with IR (infrared spectroscopy) before the project started	1	2	3	4	5
4	Describe your familiarity with UV-VIS (UV-visible spectroscopy) before the project started	1	2	3	4	5
5	Describe your familiarity with NMR (nuclear magnetic resonance spectroscopy) before the project started	1	2	3	4	5
6	Describe your familiarity with MS (mass spectrometry) before the project started	1	2	3	4	5

30 Pre-laboratory questions -theoretical questions

Circle/mark your answer.

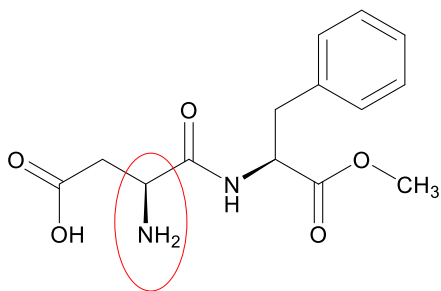
General – understanding the chemical structure

1. Identify the functional group marked in the structure.



- Acid
- Amine
- Ether
- Ester
- Acid chloride

2. Identify the functional group marked in the structure.



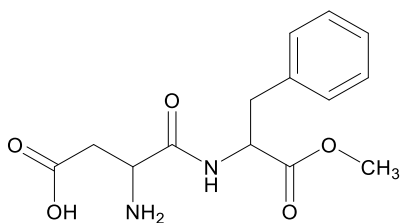
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- a. Acid
- b. Amine
- c. Ether
- d. Ester
- e. Amide

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3. Which group of aspartame has the highest pK_a value in water at 7.87?

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- a. The acid group
- b. The protonated amine
- c. The ether group
- d. The ester group
- e. The amide group

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65 UV-VIS spectroscopy

1. Why are quartz cuvettes used to record the UV spectrum of aspartame?

- a. Aspartame absorbs light in the UV range
- b. Aspartame absorbs light in the IR range
- c. Aspartame does not absorb light
- d. Aspartame absorbs visible light
- e. Aspartame absorbs both visible and UV light

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2. Beer-Lambert's law is valid in UV-VIS spectroscopy and describes the relationship between low concentrations in solutions and ...

- 75 a. Volume
b. Pressure
c. Temperature
d. Absorbance
80 e. Functional group

3. What type of electrons give rise to absorbance in UV-VIS spectroscopy above 200 nm?

- a. Valence electrons
b. It is not electrons that give rise to absorbance, but protons
85 c. Electrons in s-orbitals
d. Pi-electrons
e. Lone pair electrons

IR spectroscopy

- 90 1. What causes absorbance in IR spectroscopy?

- a. Removal of an electron from a molecule forming a molecular ion M^+
b. Molecular vibration (stretching and bending) that changes the molecule's dipole moment
c. Molecular vibration (stretching and bending) that does not change the molecule's dipole moment
d. Atomic nuclei being exposed to a strong magnetic field
95 e. Excitation of electrons from ground state orbitals to higher energy levels

2. What wavenumber range in an IR spectrum is used to identify functional groups of a compound?

- a. 400 - 1000 cm^{-1}
b. 1000 - 1300 cm^{-1}
100 c. 1300 - 1650 cm^{-1}
d. 1650 - 4000 cm^{-1}
e. 4000 - 5000 cm^{-1}

3. What wavenumber range in an IR spectrum is used to determine if a compound gives rise to C-H stretching where the carbon atom is single-bonded to another carbon?

- a. 400 - 1000 cm^{-1}
b. 2850 - 3000 cm^{-1}
c. 3000 - 3100 cm^{-1}
d. 3100 - 4000 cm^{-1}
110 e. 4000 - 5000 cm^{-1}

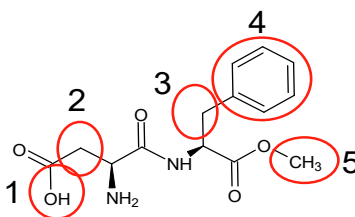
4. What wavenumber range in an IR spectrum is used to determine if a compound gives rise to C-H stretching where the carbon atom is double-bonded to another carbon?

- 400 - 1000 cm^{-1}
- 2850 - 3000 cm^{-1}
- 3000 - 3100 cm^{-1}
- 3100 - 4000 cm^{-1}
- 4000 - 5000 cm^{-1}

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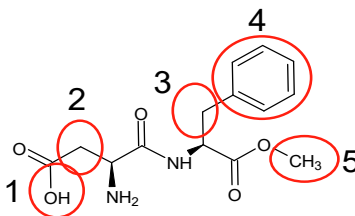
NMR spectroscopy

- 120 1. Which group (labeled 1-5) in the aspartame molecule gives signals in a ^1H -NMR spectrum at 7.36 ppm?



1	2	3	4	5
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2. Which part of the aspartame molecule (labeled 1-5) will give a distinct singlet in the ^1H -NMR spectrum?



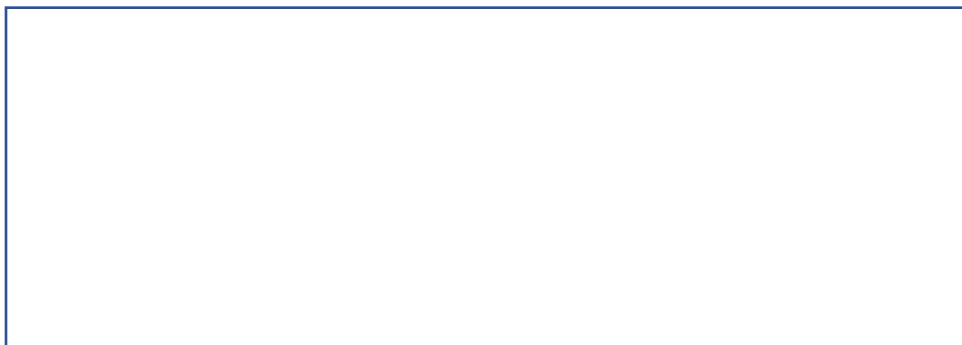
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1	2	3	5	5
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3. Mention three factors that are important to consider when choosing a solvent for NMR experiments.

130 **GC-MS – Gas chromatography with mass spectrometry detection**

1. What is the function of GC in GC-MS?



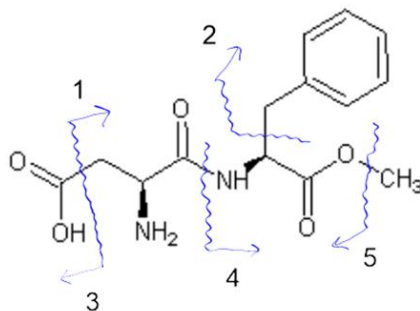
2. Which group in the aspartame molecule would you expect to participate in a McLafferty rearrangement?

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- The aromatic ring
- The ester group
- The amide group
- The acid group
- The acid group and ester group

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3. Which fragment of the aspartame molecule causes the base peak in the MS spectrum?



1	2	3	4	5
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145 **The Post-Laboratory Questionnaire (S-4)**

First letter of your birthplace:

Last digit of your house number:

First letter of your favorite pet:

150 Second letter of your mother's first name:

Post-laboratory questions

155 1. Did you receive sufficient guidance/information in the laboratory when performing the analysis?

Far too little	Too little	Adequate	Too much	Far too much
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2. What was the total learning outcome of the laboratory project?

Very low	Low	Medium	High	Very high
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3. What was the learning outcome of the exercise on aspartame?

Very low	Low	Medium	High	Very high
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4. If you answered “low” or “very low” to question 3, what could have been done differently to improve your learning outcome?

5. How do you consider the overall difficulty of the analysis of aspartame?

Very easy	Easy	Medium	Difficult	Very difficult
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170 6. Approximately how many minutes-did you spend preparing the report section of the aspartame analysis?

Less than 60 minutes	From 60 to 90 minutes	From 90 to 120 minutes	From 120 to 180 minutes	More than 180 minutes
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Mark in table from 1-5 how much you agree with the following statements:

Question number	After the project, I have	Strongly disagree	Slightly disagree	Unchanged (as before)	Slightly agree	Strongly agree
7	... increased my understanding of how instrumental analyses are conducted	1	2	3	4	5
8	... increased my knowledge about aspartame and its molecular properties/chemistry	1	2	3	4	5
9	... increased my understanding of different analytical methods` strengths/advantages	1	2	3	4	5
10	... increased my understanding of structure elucidation	1	2	3	4	5

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Describe your familiarity with the various analytical methods after the laboratory exercise by marking from 1-5 in the table:

Question number	Analytical Method	Not familiar	Slightly familiar	Familiar	Well familiar	Very well familiar
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12	Describe your familiarity with UV-VIS (UV-visible spectroscopy) after the laboratory exercise	1	2	3	4	5
13	Describe your familiarity with NMR (nuclear magnetic resonance spectroscopy) after the laboratory exercise	1	2	3	4	5
14	Describe your familiarity with MS (mass spectrometry) after the laboratory exercise	1	2	3	4	5

15. This project was

Not interesting	Slightly interesting	Okey	Interesting	Very interesting
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16. This project was

Not educational	Slightly educational	Okey	Educational	Very educational
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185 17. Do you have suggestions for changes to the laboratory project?

A large, empty rectangular box with a thin blue border, intended for students to provide suggestions for changes to the laboratory project.

To evaluate the students' theoretical learning outcomes from the laboratory project, the questions titled “**Pre-laboratory – theoretical questions**” in S-3 were included in the post-laboratory questionnaire for comparison.