Supplementary Information

Interview questions

Questions in italics were used only when further clarification was needed.

Part 1

1. What do you think of, what comes to mind when you hear the word "analysis"? *What do you think the word "analysis" mean? What other words spontaneously come to mind when you hear the word "analysis"?* What do you think is possible for us to analyze?

2. What kinds of analysis do you know? *Can you think of any adjectives that can go along with the word analysis?*

3. *(If they have already responded to question 1, we ask them to reconsider or contribute anything more)* What are your thoughts and what comes to mind when you hear the words "chemical analysis*"? What materials can be analyzed by employing chemical analysis? How do we analyze a material? What steps do we follow when we analyze a material?*

4. Imagine we have five closed containers in front of us, containing one of the materials listed below: anesthetic, white wine, white vinegar, perfume and plastic film. However, we do not know which one is in each container. How can we find out which material is in each container?

Part 2

I will provide you with some information on the materials and their components. In particular, Table A displays some properties of the materials in the containers. Tables B, C and D show some properties of a component of these materials. Table E contains information regarding the structure, interactions with other molecules and spectrum of a component of each of these materials.

(Only for secondary students) A few words regarding spectra, which you may not have encountered in school before: There are certain techniques which employ technology to produce "images" known as spectra. More specifically, using nuclear magnetic resonance (^{13}C-NMR) spectra, we may determine how carbon atoms are connected in a molecule. Each signal (peak) in the spectrum corresponds to a particular carbon atom in the molecule and is determined by how the carbon atoms interact with others. Carbon atoms with the same neighboring atoms emit the same signal. The signal of carbon atoms connected to other atoms, such as oxygen, is to the left of the signal of carbon atoms which are bonded to hydrogen.

Table F provides more information about chemicals and their relationship to societal problems. Take as much time as you need to study these tables so that you can use them to answer some more questions.[1]

Table A					
material	**anesthetic**	**white wine**	**white vinegar**	**perfume**	**plastic film**
material properties	tasteless	spicy taste	acidic taste	bitter taste	tasteless
	odourless	mild odour	less mild odour	strong odour	odourless
	colourless	pale yellow	pale yellow	colourless to pale yellow	colourless to white
	gas	liquid	liquid	liquid	solid
origin	isolation from natural gas and oil	alcoholic fermentation of grapes	acetic fermentation of wine or fruit, e.g. apples	distillation of natural products (e.g., essential oils) or synthetic fragrances	oil by-product, synthetic
function - use	anesthesia in surgical procedures	beverage, antioxidant, preservative	food ingredient, preservative	cosmetic	packaging materials, films

Table B					
material	**anesthetic**	**white wine**	**white vinegar**	**perfume**	**plastic film**

component / ***component properties***	**ethane**	**ethanol**	**ethanoic acid**	**1-propanol**	**polyvinyl chloride (PVC)**
boiling point	-89 °C	78 °C	118 °C	97 °C	- breaks down and releases toxic vapors

[1] Most of the information about materials and compounds was retrieved from the database *PubChem*: https://pubchem.ncbi.nlm.nih.gov/

density	0,5 g/cm^3	0,8 g/cm^3	1,0 g/cm^3	0,8 g/cm^3	1,4 g/cm^3
solubility	Very low solubility in water. Soluble in organic solvents.	Very soluble in water. Soluble in many organic solvents.	Soluble in water in any ratio. Soluble in almost any organic solvent.	Soluble in water and some organic solvents.	Insoluble in water, very soluble in organic solvents.
acidity (pH)	neutral solution	neutral solution	acidic solution	neutral solution	neutral solution

Table C

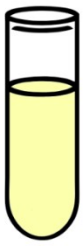
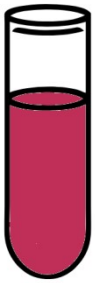
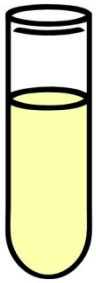
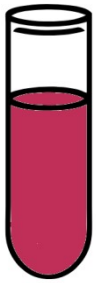
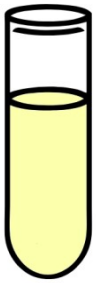
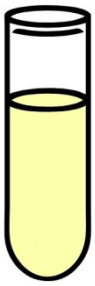
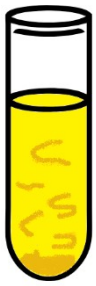
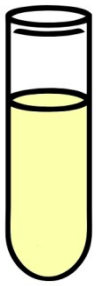
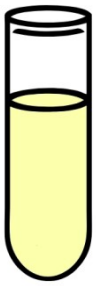
material	**anesthetic**	**white wine**	**white vinegar**	**perfume**	**plastic film**

component	**ethane**	**ethanol**	**ethanoic acid**	**1-propanol**	**polyvinyl chloride (PVC)**
Molecular formula	C_2H_6	C_2H_6O	$C_2H_4O_2$	C_3H_8O	$[C_2H_3Cl]_\nu$ (ν = 500 έως 1500)
Structural formula	CH_3CH_3	CH_3CH_2OH	CH_3COOH	$CH_3CH_2CH_2OH$	$[CH_2CHCl]_\nu$

Table D

material	**anesthetic**	**white wine**	**white vinegar**	**perfume**	**plastic film**

component / ***component properties***	**ethane**	**ethanol**	**ethanoic acid**	**1-propanol**	**polyvinyl chloride (PVC)**

Add $KMnO_4/H_2SO_4$ solution *which has a violet color.* *If the reaction occurs,* *the violet color disappears:* 					
Add $I_2/NaOH$ solution *If the reaction occurs,* *a yellow precipitate is produced:* 					

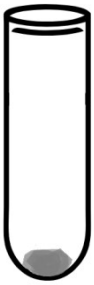
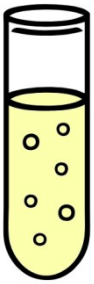
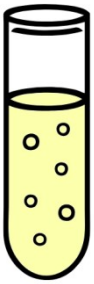
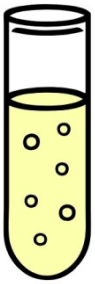
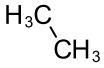
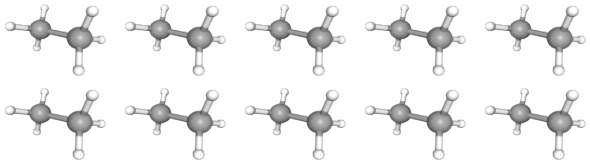
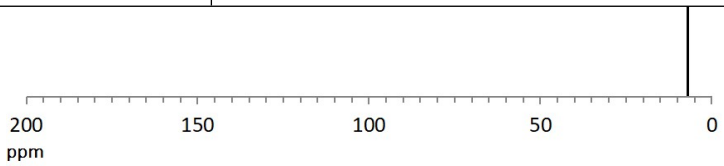
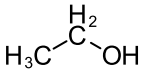
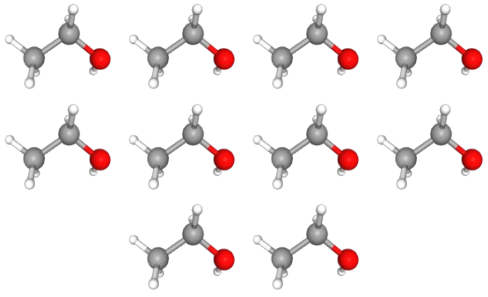
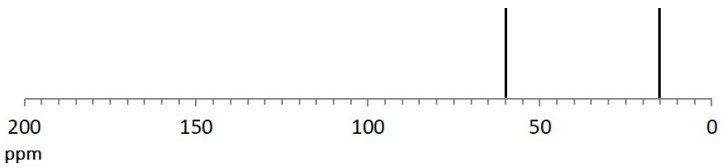
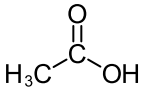
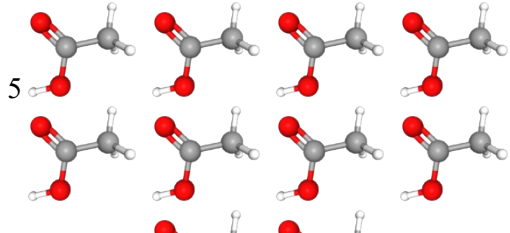
Add solid Na *If the reaction occurs,* *gas is produced:* 					

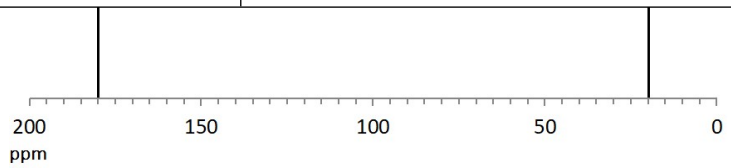
Table E

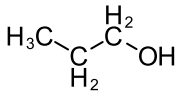
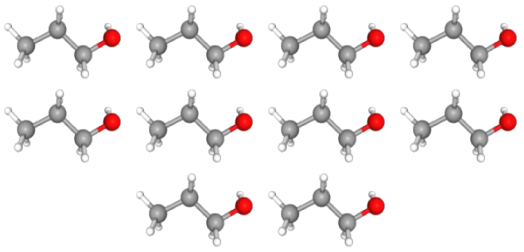
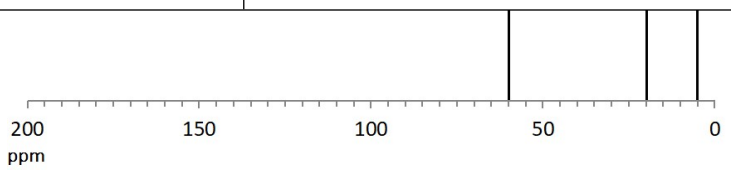
oxygen atom O carbon atom C hydrogen atom H chlorine Cl

anesthetic **ethane**		
^{13}C-NMR spectrum for ethane		

white wine **ethanol**		
^{13}C-NMR spectrum for ethanol		

white		

vinegar **ethanoic acid**	
^{13}C-NMR spectrum for ethanoic acid	

perfume **1-propanol**	 
^{13}C-NMR spectrum for 1-propanol	

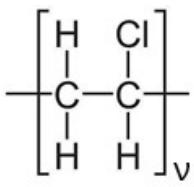
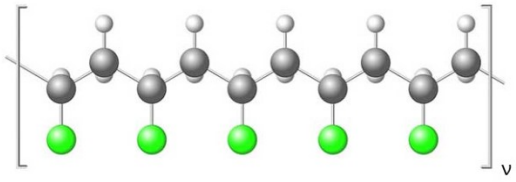
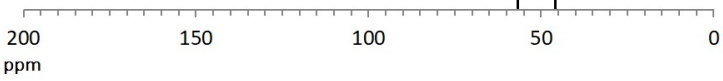
plastic film **polyvinyl chloride (PVC)**	 
^{13}C-NMR spectrum for polyvinyl chloride	

Table F

information about substances / **substance**	**ethane**	**ethanol**	**ethanoic acid**	**1-propanol**	**polyvinyl chloride (PVC)**
located in	hospital waste	liquid waste	liquid waste	liquid waste	liquid waste, landfills

relates to	number of surgical procedures performed amount of	alcohol consumption	food consumption	number of cosmetics used	amount of packaging purchased
fields that collaborate on the analysis and interpretation of results	medicine, biology	medicine, biology, nutrition	medicine, biology, nutrition	pharmacy	physics, environmental sciences
frequency of measurements	per week	per day	per day	per day	per month
where and how analysis is conducted	in the field with a portable instrument or in the laboratory	in the field with a portable instrument or in the laboratory	in the field with a portable instrument or in the laboratory	in the field with a portable instrument or in the laboratory	in the laboratory

5. a) If we could see inside a material, what would we see? *What is it made of? Give me an example or think about the specific materials you are given. How would you describe these components? Are these components made of something else?*
What do you think makes a material what it is? What makes one component different from another?
What changes in materials when a chemical reaction occurs and what remains the same?
How do you think spectra are produced?

b) Since we cannot see inside a material, how did you think in order to answer the question regarding what it is made of? From all the information you were provided, on what ground did you choose the specific information you used to provide your answers? *Why did you use this piece of information (and not some other)? If you used information from table xx, how would your answer change?*
Some of the information refers to certain properties. What do you think causes these properties? How are the properties related to the type of material?
c) Why do you think it is important to determine the components of these materials? *If you used information from table xx, how would your answer change?*

6. a) Describe a way you would suggest finding out which material is placed in each container. Tables B, C, D, and E give you some information about the main component of each of these materials. Since we cannot see inside each material, how can we find out what it is made of? *For example, what does wine contain? What procedure would we follow to identify this main component in each material? Can you think of any other way we could use to determine the existence of this component in the material?*

b) How did you think in order to find out which material exists in each container? How did you think of the way in which you will determine which component exists in a specific material? *What helped you?*
From all the information we provided you with, how did you choose which to use? *Why did you use this piece of information (and not some other)? If you had used information from table xx, how would your answer change?*

c) Why is the procedure you proposed important? *Why is it important to be able to find the components of materials using this specific procedure? Does the procedure you suggested have any advantages, disadvantages or utility compared to another procedure that one of your classmates might suggest or compared to using another table? If you used information from table xx, how would your answer change?*

7. Do you have a different perspective or additional comments on what chemical analysis is?

8. Many people argue that with the advancement of technology and the many new analytical methods which are based on it (complex instruments, computers, etc.), the classical (older) methods that do not involve the use of instruments (e.g., study of physical properties and chemical reactions, etc.) are no longer necessary and do not need to be taught in schools or universities. What are your thoughts about this? What is your opinion?