Question No. 1 of 10

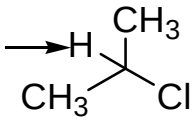
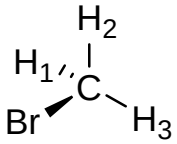
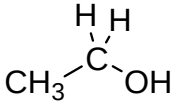
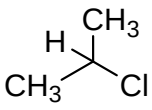
Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question #01	Question 1. Which statement concerning NMR spectroscopy is ***incorrect***? (A) Only nuclei with an even number of neutrons or protons can give rise to an NMR signal. (B) The most common nuclei used in NMR are ^{1}H and ^{13}C. (C) Integration of the NMR spectrum gives the area under a peak that is proportional to the number of hydrogens that give rise to the peak. (D) Spin-spin coupling results in the splitting of signals and occurs when the magnetic field of the proton of interest is affected by protons on adjacent carbons.
Feedback on Each Answer Choice	A. Correct! Only nuclei with an odd number of neutrons or protons can give rise to an NMR signal.
	B. Incorrect! ^{1}H and ^{13}C are the most common nuclei used in NMR. Go back and review the background and theory behind NMR spectroscopy.
	C. Incorrect! Integration of each signal allows you to determine the number of hydrogens that gave rise to that signal. Go back and review the background and theory behind NMR spectroscopy.
	D. Incorrect! When the magnetic field around protons affect the magnetic fields of protons on adjacent carbons, the signals of the hydrogens located on adjacent carbons are split. Go back and review the background and theory behind NMR spectroscopy.
Solution	(1) Recall the background and theory behind NMR spectroscopy. NMR spectroscopy is a method of structure determination based on the relative positions of hydrogens and carbons in a spectrum. Only nuclei with an odd number of neutrons or protons can give rise to an NMR signal. The most common nuclei used in NMR are ^{1}H and ^{13}C. There are many factors you must take into consideration to determine the structure of an organic molecule. Chemical shift, integrations, spin-spin coupling and coupling constants all contribute to give a complete picture of the molecule. Integration of the NMR spectrum gives the area under a peak that is proportional to the number of hydrogens that give rise to the peak. Spin-spin coupling results in the splitting of signals and occurs when the magnetic field of the proton of interest is affected by protons on adjacent carbons. (2) Read each statement carefully and choose the one that is correct. Therefore, the correct answer is (A).

Question No. 2 of 10

Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question #02	Question 2. Which statement regarding ^{1}H NMR is ***correct***? (A) The number of signals indicates the total number of protons in the compound. (B) A signal in the form of a triplet indicates there three hydrogens in the same carbon. (C) The chemical shift of a signal indicates what kind of electronic environment the proton is in. (D) One can tell how many hydrogens are on adjacent carbons with a multiplet signal.
Feedback on Each Answer Choice	A. Incorrect! The number of signals indicates the number of different types of protons. Go back and review the information of ^{1}H NMR in the tutorial.
	B. Incorrect! A triplet indicates the proton(s) of interest's signal is being split by two hydrogens on adjacent carbon(s). Go back and review the information of ^{1}H NMR in the tutorial.
	C. Correct! The chemical shift of a signal (where the signal shows up in the spectrum) can tell you a lot about the electronic environment the proton is surrounded by.
	D. Incorrect! One can not determine the number of hydrogens on adjacent carbons with a multiplet signal. Go back and review the information of ^{1}H NMR in the tutorial.
Solution	(1) Recall the background and theory behind NMR spectroscopy. The chemical shift of a signal indicates what kind of electronic environment the proton is in. More electron poor hydrogens show up downfield (from TMS the internal standard) while more electron rich protons show up upfield towards the signal for TMS. The number of signals indicates the number of different protons present in the molecule. Spin-spin splitting gives clues to the structures surrounding your proton of interest. A signal that is in the form of a triplet indicates that there are two hydrogens located on adjacent atoms from the proton that gave rise to the initial signal. The only splitting pattern one can not determine the adjacent carbons' environment from is the multiplet. (2) Read each statement carefully and determine which of the four is the correct one. Therefore, the correct answer is (C).

Question No. 3 of 10

Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question #03	Question 3. Predict the ^{1}H NMR splitting for the indicated hydrogen.  (A) Quartet (B) Quintet (C) Sextet (D) Septet
Feedback on Each Answer Choice	A. Incorrect! The indicated hydrogen would not appear as a quartet in the proton spectrum. Go back and review spin-spin coupling in NMR.
	B. Incorrect! The indicated hydrogen would not appear as a quintet in the proton spectrum. Go back and review spin-spin coupling in NMR.
	C. Incorrect! The indicated hydrogen would not appear as a sextet in the proton spectrum. Go back and review spin-spin coupling in NMR.
	D. Correct! The indicated hydrogen would appear as a septet due to the six neighboring hydrogens on adjacent carbons.
Solution	(1) Recall the method for determining the splitting pattern for a hydrogen. To determine the splitting pattern of a particular hydrogen, you count all the hydrogens that are within three bonds of the hydrogen of interest. Add one to that number to obtain the number of peaks that will occur in the signal. For example, methyl bromide:  The hydrogens on the one carbon are considered to be equivalent because they are in the same electronic environment. Equivalent hydrogens do not split each other. However, there are no other hydrogens around on adjacent carbons because there is only one carbon in the molecule. Therefore, the hydrogens in methyl bromide will appear as a singlet. But in ethanol, there is more than one carbon and there are hydrogens on adjacent carbons:  The hydrogens of the methyl group are split by the two hydrogens on the adjacent carbon. The methyl hydrogens will show up as a triplet (2Hs + 1 = 3 peaks). (2) Determine the splitting of the indicated hydrogen in the picture.  The indicated hydrogen is surrounded by 6 other hydrogens on adjacent carbons so 6 + 1 = 7. The indicated hydrogen will appear as a septet. Therefore, the correct answer is (D).

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Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question #04	Question 4. What type of proton would be found in the frequency range of 6.0-9.5 ppm in a ^{1}H NMR spectrum? (A) Aromatic hydrogens (B) Hydrogens attached to carbon-carbon double bond (C) Alkyl hydrogens (D) Hydrogen attached to a carbonyl of an aldehyde
Feedback on Each Answer Choice	A. Correct! Aromatic hydrogens (hydrogens attached to an aromatic ring) are found in the frequency range of 6.0-9.5 ppm.
	B. Incorrect! Vinylic hydrogens (hydrogens attached to carbon-carbon double bond) are found in the frequency range of 4.6-5.7 ppm. Go back and review the frequency tables for ^{1}H NMR.
	C. Incorrect! Alkyl hydrogens are found in the frequency range of 0.8-1.9 ppm. Go back and review the frequency tables for ^{1}H NMR.
	D. Incorrect! A hydrogen attached to a carbonyl of an aldehyde is found in the frequency range of 9.0-10.0 ppm. Go back and review the frequency tables for ^{1}H NMR.
Solution	(1) Recall the frequencies of the different types of protons in ^{1}H NMR. It would be a good idea to have a general idea where the different types of hydrogens show up in a proton NMR. The range from 6.5-9.0 ppm is traditionally considered to be the aromatic region since protons bonded to aromatic rings have resonances that show up in this region. Therefore, the correct answer is (A).

Question No. 5 of 10

Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question #05	Question 5. In ^{13}C NMR, what kind of carbon would give a triplet signal? (A) C (no hydrogens bonded to carbon) (B) CH (C) CH_2 (D) CH_3
Feedback on Each Answer Choice	A. Incorrect! A quaternary carbon (one bonded to four other carbons and no hydrogens) will not give a triplet signal. It will give a singlet signal. Go back and review spin-spin splitting in ^{13}C NMR.
	B. Incorrect! A tertiary carbon (one bonded to three other carbons and one hydrogen) will not give a triplet signal. It will give a doublet signal. Go back and review spin-spin splitting in ^{13}C NMR.
	C. Correct! A secondary carbon (one bonded to two other carbons and two hydrogens) will give a triplet signal in a ^{13}C NMR spectrum.
	D. Incorrect! A primary carbon (one bonded to one other carbon and three hydrogens) will not give a triplet signal. It will give a quartet signal. Go back and review spin-spin splitting in ^{13}C NMR.
Solution	(1) Recall the details of spin-spin splitting in ^{13}C NMR. In ^{13}C NMR, the spin-spin splitting of the carbon signals result from the interaction of the interaction of the carbon's magnetic environment with the environments of the hydrogens bonded to it. Quaternary carbons show up as singlets (since there are no hydrogens on a quaternary carbon to split the signal), tertiary carbons as doublets, secondary carbons as triplets and primary carbons as quartets. Therefore, the correct answer is (C).

Question No. 6 of 10

Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question #06	Question 6. What type of carbon will be found in the frequency range of 175-220 ppm in a ^{13}C NMR? (A) Carbonyl carbon of ester, amide, carboxylic acid (B) Carbon bonded to oxygen of alcohol (C) Carbon of nitrile functional group (D) Carbonyl carbon of an aldehyde or ketone
Feedback on Each Answer Choice	A. Incorrect! Carbonyl carbons of ester, amide, or carboxylic acids do not show up in the frequency range of 175-220 ppm but instead in the range of 150-185 ppm. Go back and review the frequency tables for ^{13}C NMR.
	B. Incorrect! Carbons bonded to oxygens of alcohols do not show up in the frequency range of 175-220 ppm but instead in the range of 45-90 ppm. Go back and review the frequency tables for ^{13}C NMR.
	C. Incorrect! Carbons of nitrile groups do not show up in the frequency range of 175-220 ppm but instead in the range of 105-130 ppm. Go back and review the frequency tables for ^{13}C NMR.
	D. Correct! The resonances of carbonyl carbons of aldehydes and ketones show up in the frequency range of 175-220 ppm.
Solution	(1) Recall the frequencies of carbons in ^{13}C NMR. Again, it is important that you have a general idea of where the different types of carbons show up in a ^{13}C NMR. The electron poor carbons show up further downfield from 0 ppm while the electron rich carbons show up close to 0 ppm in the upfield region. In the range of 175-220 ppm range, one would typically find the carbons of aldehydes and ketones' carbonyls. Therefore, the correct answer is (D).

Question No. 7 of 10

Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question #07	Question 7. What is mass spectrometry used for? (A) Determining the molecular formula and structure of an organic compound. (B) Determining the available electronic transitions of an organic compound. (C) Determining the electronegativities of the atoms comprising the molecule. (D) Determining the empirical formulas of compounds.
Feedback on Each Answer Choice	A. Correct! Mass spectrometry is used to determine the molecular formula and structure of an organic compound.
	B. Incorrect! Mass spectrometry is not used to determine the available electronic transitions of an organic compound. Go back and review the theory behind mass spectrometry.
	C. Incorrect! Mass spectrometry is not used to determine the electronegativities of the atoms comprising an organic compound. Go back and review the theory behind mass spectrometry.
	D. Incorrect! Mass spectrometry is not used to determine the empirical formula of an organic compound. Go back and review the theory behind mass spectrometry.
Solution	(1) Recall the theory behind mass spectrometry. Mass spectrometry is an analytical tool for identifying unknown compounds. It is useful for determining the molecular formula and the molecular structure of both large and small organic molecules. The unknown samples are bombarded with a stream of electrons which ionize the molecules. The ionized molecules are unstable and fragment. Based on the fragmentations, one can reconstruct the molecular structure of the molecules. (2) Read each statement carefully and choose the one that best describes the purpose of mass spectrometry. Therefore, the correct answer is (A).

Question No. 8 of 10

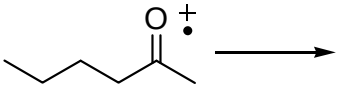
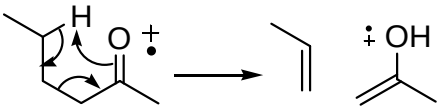
Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question #08	Question 8. What type of species does the mass spectrometer detect? (A) carbanion (B) neutral radical (C) carbocation (D) neutral compound
Feedback on Each Answer Choice	A. Incorrect! Carbanions are not detected in mass spectrometry. Go back and review the details of mass spectrometry.
	B. Incorrect! Neutral radicals are not detected in mass spectrometry. Go back and review the details of mass spectrometry.
	C. Correct! Carbocations are detected in mass spectrometry.
	D. Incorrect! Neutral compounds are not detected in mass spectrometry. Go back and review the details of mass spectrometry.
Solution	(1) Recall the theory behind mass spectrometry. When an electron stream is used to ionize a sample in mass spectrometry, an electron is kicked out from the original molecule forming a radical cation. This radical cation is called the molecular ion or parent peak usually begins to fragment into different species. In some cases, a compound can fragment into other cations, anions or radicals. However, the detector on the mass spectrometry only “sees” cationic species. Therefore, cations give rise to the peaks in a mass spectrum. Therefore, the correct answer is (C).

Question No. 9 of 10

Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question #09	Question 9. What is indicated when in a mass spectrum there is a M+2 peak of the same approximate size as the molecular ion peak? (A) There are two isotopes of chlorine present in the sample. (B) The sample is impure—two compounds are present with a difference of two in their molecular weights. (C) There are two isotopes of bromine present in the sample. (D) The isotope ^{13}C is present in the molecule.
Feedback on Each Answer Choice	A. Incorrect! If chlorine is present in a sample, the M+2 peak will be a third of the size of the molecular ion peak. Go back and review the information on interpreting mass spectra.
	B. Incorrect! An impure sample placed on a mass spectrometer would not yield the results described above. Go back and review the information on interpreting mass spectra.
	C. Correct! Bromine has two major isotopes: ^{79}Br and ^{81}Br. If these are both present in a sample, it gives rise to a M+2 peak of similar intensity to the molecular ion peak.
	D. Incorrect! If ^{13}C is present in a sample, there is a M+1 peak not a M+2 peak. Go back and review the information on interpreting mass spectra.
Solution	(1) Recall the theory behind mass spectrometry. The presence of isotopes is evident in a mass spectrum. If ^{13}C is present in a molecule, a M+1 peak will be seen in the spectrum. The relative abundance of the peak is low (i.e. very short peak0 because ^{13}C makes up about 1% of the total amount of carbon. The other two commonly seen isotopes in mass spectrums are chlorine and bromine. Chlorine's two most abundant isotopes are ^{35}Cl and ^{37}Cl. They are both present in nature with ^{35}Cl making up approximately 75% of the total amount of chlorine. When present in a mass spectrum, one sees the molecular ion (this molecule corresponds to one containing the ^{35}Cl isotope) and a M+2 peak which corresponds to the molecule that contains the ^{37}Cl. The molecular ion peak is approximately 3 times bigger (since ^{35}Cl's relative abundance is approximately 3 times more) than the M+2 peak. Bromine's two most abundant isotopes are ^{79}Br and ^{81}Br. They are both present in nature with ^{79}Br making up approximately 50.6% of the total amount of bromine. When present in a mass spectrum, one sees the molecular ion (this molecule corresponds to one containing the ^{79}Br isotope) and a M+2 peak which corresponds to the molecule that contains the ^{81}Br. The molecular ion peak and the M+2 peak are approximately the same size with the molecular ion peak being slightly higher than the M+2 peak. Therefore, the correct answer is (C).

Question No. 10 of 10

Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question #10	Question 10. What product(s) would you expect this ketone to yield after undergoing the McLafferty rearrangement?  (A) An alkene and an enol (B) An alkyl fragment and a carbonyl fragment (C) An alkyl fragment and a molecule of carbon monoxide (D) An alkyne and a ketone
Feedback on Each Answer Choice	A. Correct! This ketone will yield an alkene and an enol fragment after undergoing the McLafferty rearrangement.
	B. Incorrect! An alkyl fragment and a carbonyl fragment will not be obtained after a McLafferty rearrangement of a ketone. Go back and review the different types of fragmentations functional groups undergo.
	C. Incorrect! An alkyl fragment and a molecule of carbon dioxide will not be obtained after a McLafferty rearrangement of a ketone. Go back and review the different types of fragmentations functional groups undergo.
	D. Incorrect! An alkyne and a ketone will not be obtained after a McLafferty rearrangement of a ketone. Go back and review the different types of fragmentations functional groups undergo.
Solution	(1) Recall the McLafferty rearrangement. Only carbonyl compounds can undergo the McLafferty rearrangement. The one above could be expected to rearrange in this manner since it is a ketone. The products of a McLafferty rearrangement are an alkene and an enol:  And though drawn as the enol bearing the cationic radical, in reality either piece could be the cation radical. Therefore, the correct answer is (A).