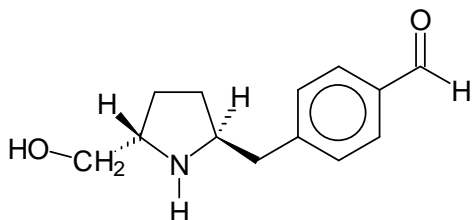
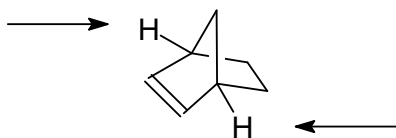


MARK ONE ANSWER FOR EACH QUESTION ON BOTH THE EXAM AND YOUR SCANTRON!

1. What is the unit of "wave number"?  
A. Hertz      B.  $\text{cm}^2$       C.  $\text{cm}^{-1}$       D. ppm      E. nanometers
2. Chlorine has two isotopes,  $^{35}\text{Cl}$  and  $^{37}\text{Cl}$ . What percentage of chlorine is  $^{37}\text{Cl}$ ?  
A. approx. 25%    B. approx. 50%    C. approx. 75%    D. approx. 1.1%    E. approx. 0.06%
3. Why is it usually **not possible** to integrate the peaks of  $^{13}\text{C}$  NMR spectra, to obtain the relative abundances of the carbons?  
A. Because the peaks are too narrow  
B. Because the peak areas depend largely on the spin relaxation times of the carbons  
C. Because the abundance of  $^{13}\text{C}$  is too low  
D. Because the carbons are coupled to the protons  
E. Because all the peaks in  $^{13}\text{C}$  NMR spectra have identical peak areas
4. When looking at an NMR spectrum, the left-hand side of the plot is the...  
A. fingerprint region                      B. downfield side                      C. upfield side  
D. delta region                              E. chemical shift region
5. What can we say about isotopes with spin quantum numbers of zero?  
A. They are invisible to NMR  
B. They are visible, but give rise to very broad peaks  
C. They don't exist  
D. They are radioactive  
E. They have negative chemical shifts
6. How many exchangeable protons does the compound below have?

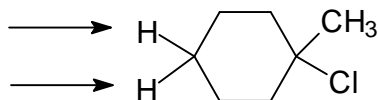


- A. none      B. one      C. two      D. three      E. four
7. How many signals would you expect for a decoupled  $^{13}\text{C}$  NMR spectrum of the alkene below?
- 
- ClC1=CC=C(C=C1)/C=C/C2=CC=C(C=C2)Cl
- A. three      B. four      C. five      D. six      E. seven
8. What is the relationship for the highlighted pair of protons in the compound below?



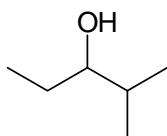
A. homotopic B. enantiotopic C. diastereotopic D. heterotopic (E is not a valid choice)

9. What is the relationship for the highlighted pair of protons in the compound below?



A. homotopic B. enantiotopic C. diastereotopic D. heterotopic (E is not a valid choice)

10. Consider the alcohol below. It can undergo both elimination and alpha cleavage. Which prominent fragments would these processes produce?

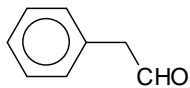


A.  $m/z = 30, 42$  and  $80$       B.  $m/z = 29, 43$  and  $84$       C.  $m/z = 18, 23,$  and  $55$   
 D.  $m/z = 17, 55$  and  $67$       E.  $m/z = 59, 73$  and  $84$

11. What is the smallest number of carbons a ketone can have, which is able to undergo a McLafferty rearrangement?

A. two      B. three      C. four      D. five      E. six

12. How many signals would you expect to see in a decoupled <sup>13</sup>C spectrum of the aldehyde below?



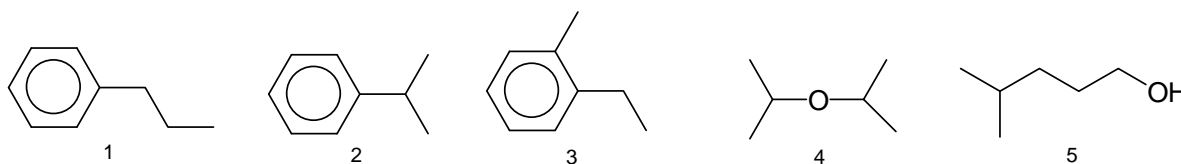
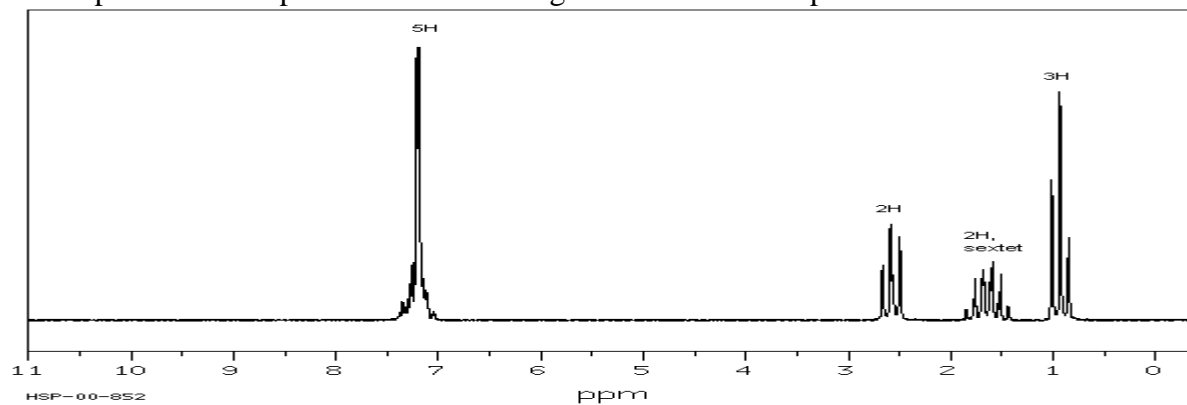
A. two      B. three      C. four      D. five      E. six

13. How many signals would you expect to see in a decoupled <sup>13</sup>C spectrum of the compound below?



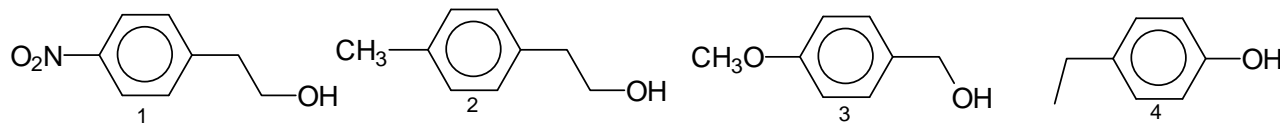
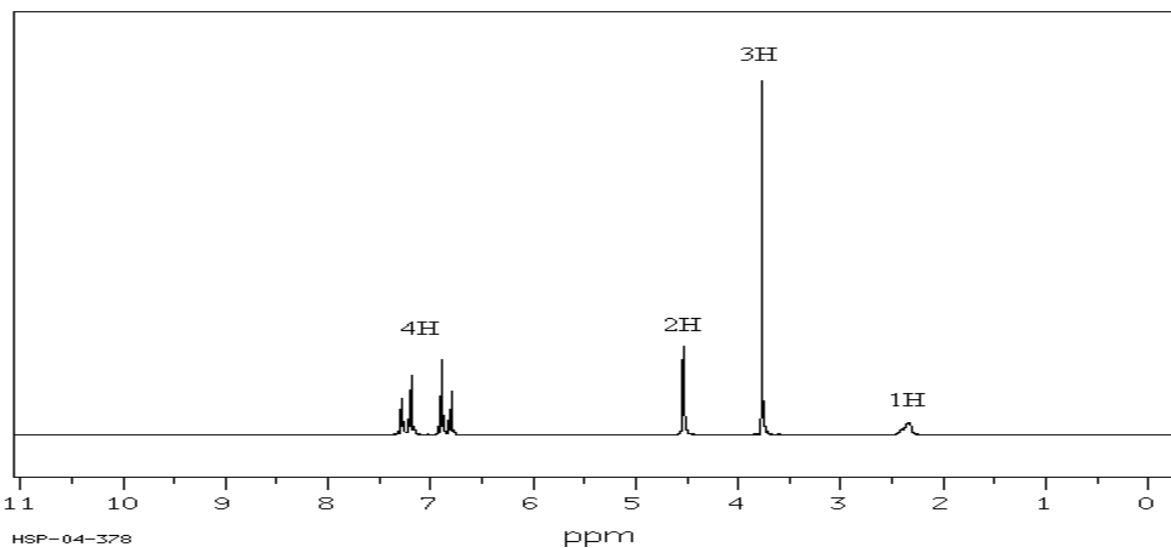
A. two      B. three      C. four      D. five      E. six

14. The proton NMR spectrum below belongs to one of the compounds below. Which one?



A. compound 1    B. compound 2    C. compound 3    D. compound 4    E. compound 5

15. The proton NMR spectrum below belongs to one of the compounds below. Which one?

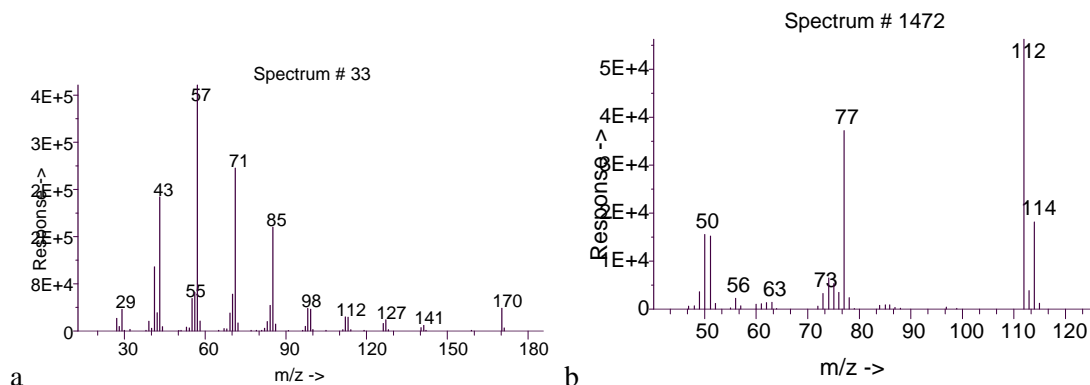


A. compound 1    B. compound 2    C. compound 3    D. compound 4  
 E. both structures 3 and 4 are compatible with this spectrum

16. What happens to energy gap between the parallel and antiparallel spin states of protons as the magnetic field strength of the NMR spectrometer doubles, e.g. from 4 Tesla to 8 Tesla?

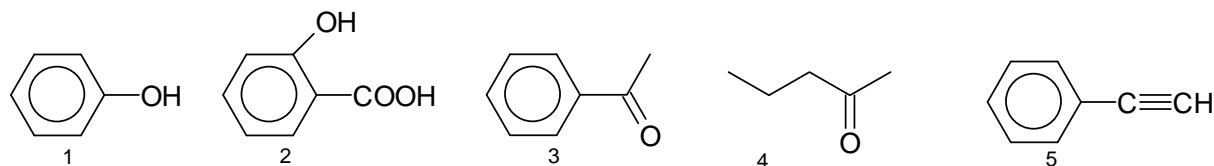
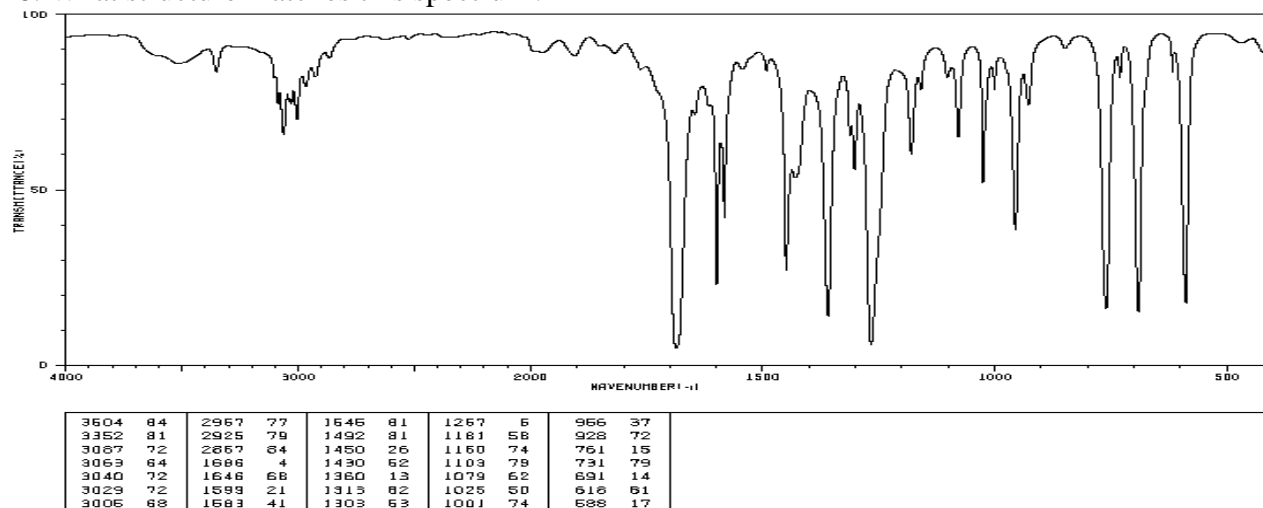
A. Nothing, its stays the same    B. Its doubles    C. It quadruples  
 D. It decreases    E. It changes in unpredictable ways

17. Consider the mass spectra below and select the best statement. The heaviest  $m/z$  values correspond to  $M^+$ .



- a b
- A. The left spectrum (a) indicates the presence of a phenyl group  
 B. Both spectra indicate presence of an odd number of nitrogen atoms  
 C. The right spectrum (b) indicates the presence of a benzyl group  
 D. The left spectrum (a) indicates the presence of a bromine atom  
 E. The right spectrum (b) indicates the presence of a chlorine atom

18. What structure matches this spectrum?



- A. compound 1    B. compound 2    C. compound 3    D. compound 4    E. compound 5

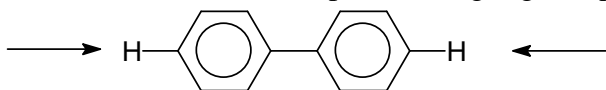
19. What is the molecular formula for anthracene?

- A.  $C_{14}H_{20}$     B.  $C_{14}H_{12}$     C.  $C_{14}H_{10}$     D.  $C_{14}H_{14}$     E.  $C_{14}H_8$

20. The mass spectrum of a compound displays  $M^+$  at  $m/z = 115$ , with a minor  $M+1$  peak. What formula matches this spectrum?

- A.  $C_6H_{10}O_2$     B.  $C_6H_9Cl$     C.  $C_3H_5Br$     D.  $C_6H_{14}N_2$     E.  $C_7H_{17}N$

21. What is the relationship for the highlighted pair of protons in the compound below?



A. homotopic B. enantiotopic C. diastereotopic D. heterotopic (E is not a valid choice)

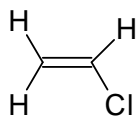
22. Many mass spectra show an intense peak with  $m/z = 91$ . What does it correspond to?

A. an allyl cation B. a cyclopentenyl cation C. a cyclohexatrienyl cation  
D. a cycloheptadienyl cation E. a cycloheptatrienyl cation

23. What is the base peak of a mass spectrum?

A. The peak with the highest  $m/z$  ratio  
B. The peak with the lowest  $m/z$  ratio  
C. The smallest peak that can be seen  
D. The peak used to calibrate the x axis  
E. The largest peak in the spectrum

24. How many coupling constants would we need to know to draw a tree diagram for the spin-spin splitting of the compound below?



A. Two three-bond coupling constants  
B. One two bond coupling constant and two three-bond coupling constants  
C. Two two-bond coupling constants  
D. One two bond coupling constant, two three-bond coupling constants, and one four-bond coupling constant  
E. One two bond coupling constant

25. What are the x axis units of a mass spectra?

A. frequency, in Hertz  
B. no unit applies (dimensionless)  
C. atomic mass, divided by charge  
D. molecular weight  
E. atomic number

**26. This is exam version B. Please mark B on your scantron!**

Key exam 232-01\_1\_100b:

1. C
2. A
3. B
4. B
5. A
6. C
7. C
8. B
9. C
10. E
11. D
12. E
13. B
14. A
15. C
16. B
17. E
18. C
19. C
20. E
21. A
22. E
23. E
24. B
25. C