

**Organic Chemistry, 9e (Wade)**  
**Chapter 1 Structure and Bonding**

1) While you were up late one night studying organic chemistry, you happened to see the last 5 minutes of an infomercial on TV. The spokesperson claimed that their brand of automobile tires were superior to all other brands on the market because they were made by using only natural rubber, isolated from the resin of rubber trees. How could a chemist test her claims that no petroleum products went into the manufacture of her brand of tires?

Answer: Compounds synthesized from petroleum products have a lower content of  $^{14}\text{C}$ . Plant-derived compounds are recently synthesized from  $\text{CO}_2$  in the air and have a higher  $^{14}\text{C}$  content.

Diff: 2

Section: 1.1

GO: G5

2) The atomic number of boron is 5. The correct electronic configuration of boron is:

A)  $1s^2 2s^3$

B)  $1s^2 2p^3$

C)  $1s^2 2s^2 2p^1$

D)  $2s^2 2p^3$

E)  $1s^2 2s^2 3s^1$

Answer: C

Diff: 1

Section: 1.2

LO: 1.1

3) How many distinct p orbitals exist in the second electron shell, where  $n = 2$ ?

A) 2

B) 3

C) 4

D) 5

E) 6

Answer: B

Diff: 1

Section: 1.2

4) The \_\_\_\_\_ tells us that each orbital can hold a maximum of 2 electrons.

A) aufbau principle

B) Pauli exclusion principle

C) Hund's rule principle

D) LeChatelier principle

E) uncertainty principle

Answer: B

Diff: 1

Section: 1.2

5) A node is a region of high electron density between the two atoms in a covalent bond.

Answer: FALSE

Diff: 1

Section: 1.2

6) When filling two or more orbitals of the same energy with electrons, the electrons will go into different orbitals rather than pair up in the same orbital.

Answer: TRUE

Diff: 1

Section: 1.2

7) Atoms with the same number of protons but different numbers of neutrons are called \_\_\_\_\_.

Answer: isotopes

Diff: 1

Section: 1.2

GO: G2

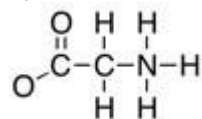
8) The electron density of \_\_\_\_\_ orbitals has spherical symmetry.

Answer: s

Diff: 1

Section: 1.2

9) The formal charge on the nitrogen on the structure shown below is:



Answer: N = +1

Diff: 1

Section: 1.7

LO: 1.3

GO: G2

MCAT LO: MCAT1.2

10) An oxygen atom has \_\_\_\_\_ valence electrons.

Answer: 6

Diff: 1

Section: 1.2

LO: 1.1

11) Which element in the second row of the periodic table has six valence electrons and a valence of two?

Answer: oxygen

Diff: 1

Section: 1.2

LO: 1.1

12) Orbitals which are equal in energy are referred to as \_\_\_\_\_.

- A) degenerate
- B) polar
- C) nodes
- D) filled
- E) nonpolar

Answer: A

Diff: 2

Section: 1.2

13) In a carbon atom, the 2s and 2p orbitals are the same energy.

Answer: FALSE

Diff: 2

Section: 1.2

LO: 1.1

14) The element with the electronic configuration  $1s^2 2s^2 2p^6 3s^1$  is \_\_\_\_\_.

Answer: sodium

Diff: 2

Section: 1.2

LO: 1.1

15) Provide the electron configuration of phosphorus.

Answer:  $1s^2 2s^2 2p^6 3s^2 3p^3$

Diff: 2

Section: 1.2

LO: 1.1

16) Draw the shape of a 2p orbital, including shading to indicate phase.

Answer:

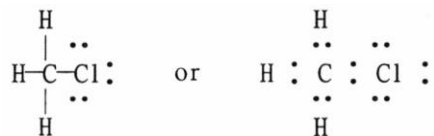


Diff: 2

Section: 1.2

17) Draw a correct Lewis structure for chloromethane,  $\text{CH}_3\text{Cl}$ , including all non-bonding lone pairs.

Answer:



Diff: 1

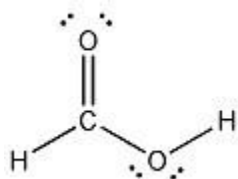
Section: 1.4

LO: 1.3

MCAT LO: MCAT1.2

18) Provide a Lewis structure for a molecule with molecular formula  $\text{CH}_2\text{O}_2$ .

Answer:



Diff: 2

Section: 1.4

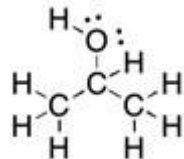
LO: 1.2

GO: G2

MCAT LO: MCAT11.2

19) Draw the Lewis structure for 2-propanol,  $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ , including all non-bonding lone pairs.

Answer:



Diff: 2

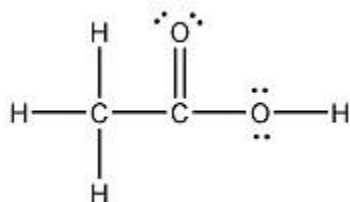
Section: 1.4

LO: 1.3

MCAT LO: MCAT1.2

20) Draw the Lewis structure of acetic acid,  $\text{CH}_3\text{CO}_2\text{H}$ , including all non-bonding lone pairs.

Answer:



Diff: 2

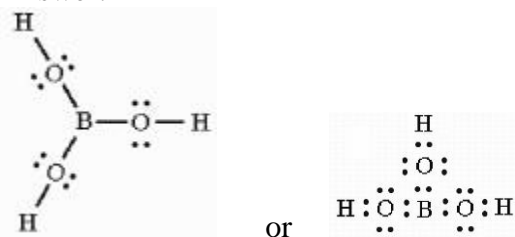
Section: 1.4

LO: 1.3

MCAT LO: MCAT1.2

21) Draw the Lewis structure for boric acid,  $B(OH)_3$ , including all non-bonding lone pairs.

Answer:



Diff: 2

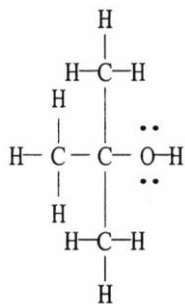
Section: 1.4

LO: 1.3

MCAT LO: MCAT1.3

22) Draw a correct Lewis structure for *tert*-butyl alcohol,  $(CH_3)_3COH$ , including all non-bonding lone pairs.

Answer:



Diff: 2

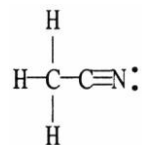
Section: 1.4

LO: 1.3

MCAT LO: MCAT1.3

23) Draw a correct Lewis structure for acetonitrile,  $CH_3CN$ , including all non-bonding lone pairs.

Answer:



Diff: 2

Section: 1.5

LO: 1.3

MCAT LO: MCAT1.3

24) Draw 2 possible Lewis structures for the compound with molecular formula  $C_3H_6$ .

Answer:



Diff: 2

Section: 1.10

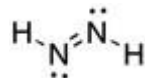
LO: 1.2

GO: G2

MCAT LO: MCAT1.1

25) Write a Lewis structure for a compound with the molecular formula  $H_2N_2$ .

Answer:



Diff: 2

Section: 1.5

LO: 1.3

MCAT LO: MCAT1.2

26) A carbon-hydrogen bond in ethane ( $CH_3CH_3$ ) is best described a \_\_\_\_\_.

- A) highly polar
- B) essentially nonpolar
- C) ionic
- D) a multiple bond
- E) resonance stabilized

Answer: B

Diff: 1

Section: 1.6

LO: 1.4

MCAT LO: MCAT1.3

27) The electronegativity of elements on the periodic table increases going \_\_\_\_\_ a column and to the \_\_\_\_\_ in each row.

- A) up; right
- B) up; left
- C) down; right
- D) down; left

Answer: A

Diff: 1

Section: 1.6

LO: 1.1

MCAT LO: MCAT1.5

28) Within a given row of the periodic table, electronegativity typically increases left to right across the row.

Answer: TRUE

Diff: 1

Section: 1.6

LO: 1.1

MCAT LO: MCAT1.5

29) Which of the following molecules contains a polar covalent bond?

A) H<sub>2</sub>

B) F<sub>2</sub>

C) CH<sub>3</sub>Cl

D) NaCl

E) He

Answer: C

Diff: 1

Section: 1.6

LO: 1.4

GO: G2

MCAT LO: MCAT1.3

30) Covalent bonds may be polar or nonpolar. What property of the atoms forming a given bond determines this?

Answer: Electronegativity

Diff: 2

Section: 1.6

LO: 1.4

31) The compound methylamine, CH<sub>3</sub>NH<sub>2</sub>, contains a C-N bond. In this bond, which of the following best describes the charge on the carbon atom?

A) +1

B) slightly positive

C) neutral

D) slightly negative

E) -1

Answer: B

Diff: 3

Section: 1.6

LO: 1.3

MCAT LO: MCAT1.5

32) The formal charge on oxygen in dimethyl ether,  $\text{CH}_3\text{OCH}_3$ , is \_\_\_\_\_.

- A) +2
- B) +1
- C) 0
- D) -1
- E) -2

Answer: C

Diff: 1

Section: 1.7

LO: 1.3

MCAT LO: MCAT1.2

33) For most compounds in which a nitrogen atom bears no formal charge, the valence of this nitrogen atom is \_\_\_\_\_.

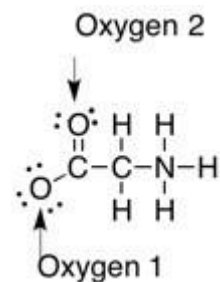
Answer: 3

Diff: 1

Section: 1.7

LO: 1.1

34) The formal charge on the oxygens in the compound below are \_\_\_\_\_.



- A) Oxygen 1: 0, Oxygen 2: 0
- B) Oxygen 1: -1, Oxygen 2: 0
- C) Oxygen 1: 0, Oxygen 2: -1
- D) Oxygen 1: +1, Oxygen 2: 0
- E) Oxygen 1: -1, Oxygen 2: -1

Answer: B

Diff: 2

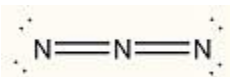
Section: 1.7

LO: 1.3

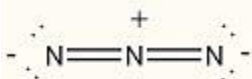
MCAT LO: MCAT1.2



35) Assign the correct formal charge to each nitrogen atom in the following Lewis structure. (All non-bonding electrons are included.)



Answer:



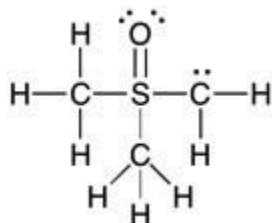
Diff: 2

Section: 1.7

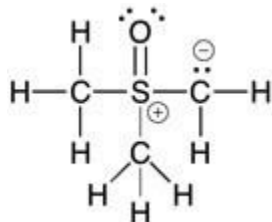
LO: 1.3

MCAT LO: MCAT1.2

36) Add the appropriate formal charge to each atom in the molecule below. It is not necessary to indicate formal charges when zero. (All non-bonding electrons are included.)



Answer:



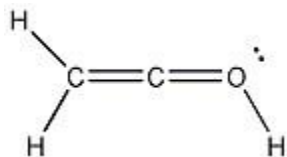
Diff: 2

Section: 1.7

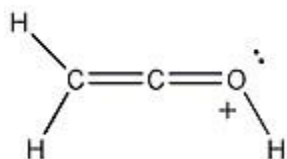
LO: 1.3

MCAT LO: MCAT1.2

37) Add the appropriate formal charge to each atom in the molecule below. It is not necessary to indicate formal charges when zero. (All non-bonding electrons are included.)



Answer:



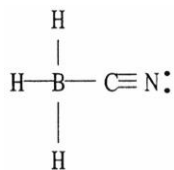
Diff: 2

Section: 1.7

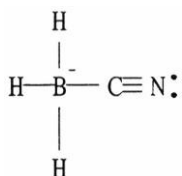
LO: 1.3

MCAT LO: MCAT1.2

38) One or more of the atoms in the structure shown should have nonzero formal charges. Redraw the structure and the atoms with non-zero formal charges.



Answer:



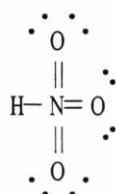
Diff: 2

Section: 1.7

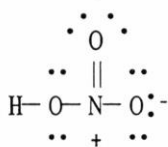
LO: 1.2

MCAT LO: MCAT1.3

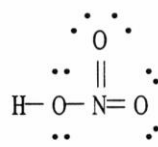
39) Which of the following are acceptable Lewis structures, including formal charges, for nitric acid, HNO<sub>3</sub>?



A



B



C

- A) A only
- B) B only
- C) C only
- D) both B and C
- E) A, B, and C

Answer: B

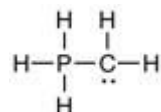
Diff: 3

Section: 1.7

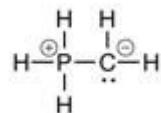
LO: 1.2

MCAT LO: MCAT1.3

40) One or more of the atoms in the structure shown should have nonzero formal charges. Add the correct formal charge/s. (All non-bonding electrons have been included.)



Answer:



Diff: 3

Section: 1.7

LO: 1.3

MCAT LO: MCAT1.2

41) In the compound sodium methoxide ( $\text{NaOCH}_3$ ), there is \_\_\_\_\_ bonding.

- A) ionic
- B) polar covalent
- C) nonpolar covalent
- D) a mixture of ionic and covalent
- E) resonance stabilized

Answer: D

Diff: 1

Section: 1.8

LO: 1.1

MCAT LO: MCAT1.3

42) Which of the following compounds are covalent compounds?

- A)  $\text{KCl}$
- B)  $\text{CF}_4$
- C)  $\text{NH}_3$
- D) both A and B
- E) both B and C

Answer: E

Diff: 2

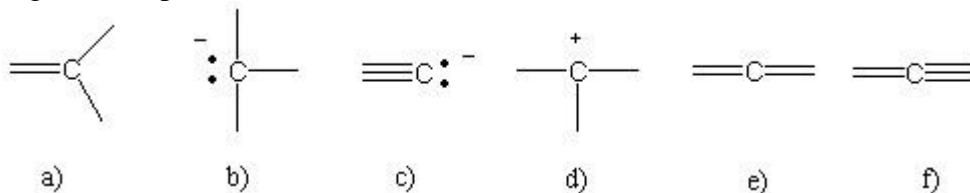
Section: 1.8

LO: 1.1

GO: G2

MCAT LO: MCAT1.3

43) Which of the following bonding patterns of carbon is not allowed in the formation of an organic compound?



Answer: f

Diff: 2

Section: 1.7

LO: 1.4

MCAT LO: MCAT1.2

44) When a negatively charged species is most appropriately depicted as a hybrid of several resonance forms, the negative charge present is considered to be rapidly moving between the resonance forms bearing the formal negative charge.

Answer: FALSE

Diff: 1

Section: 1.9

LO: 1.4

GO: G2

MCAT LO: MCAT1.3

45) When a molecule can best be represented as a series of resonance forms, each of these forms always contributes to the same degree in the hybrid.

Answer: FALSE

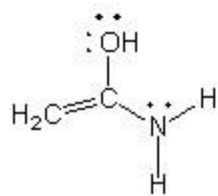
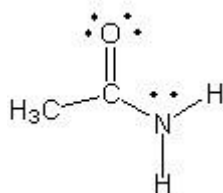
Diff: 1

Section: 1.9

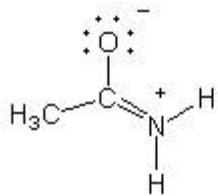
LO: 1.4

MCAT LO: MCAT1.3

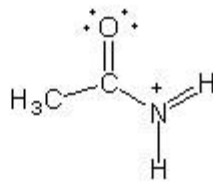
46) Which of the following structures (a-d) is another resonance structure of the following organic molecule?



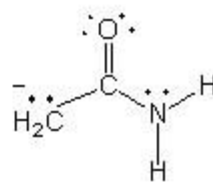
a)



b)



c)



d)

Answer: b

Diff: 2

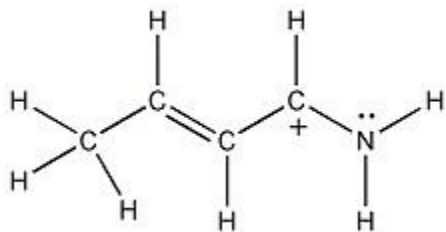
Section: 1.9

LO: 1.4

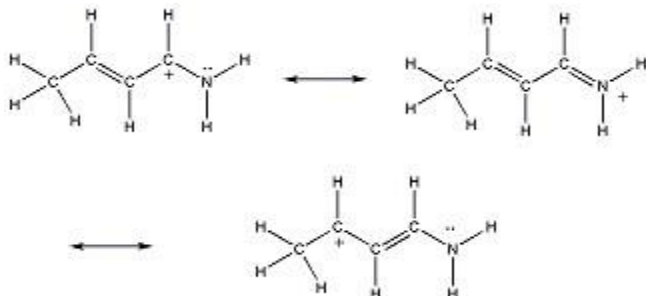
GO: G2

MCAT LO: MCAT1.3

47) One resonance structure of a cation is shown. Provide the other reasonable resonance structures.



Answer:



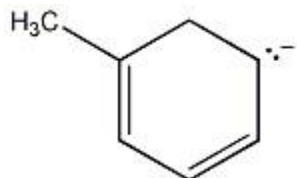
Diff: 2

Section: 1.9

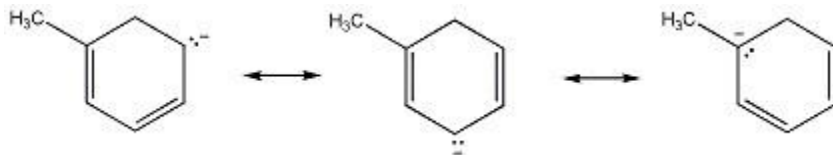
GO: G2

MCAT LO: MCAT2.3

48) Draw additional resonance contributors for:



Answer:



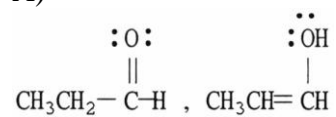
Diff: 2

Section: 1.9

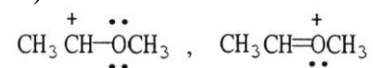
MCAT LO: MCAT2.3

49) Which of the following choices represent(s) a pair of resonance forms?

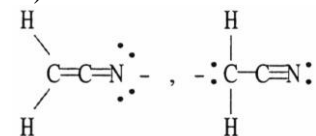
A)



B)



C)



D) both A and C

E) both B and C

Answer: E

Diff: 3

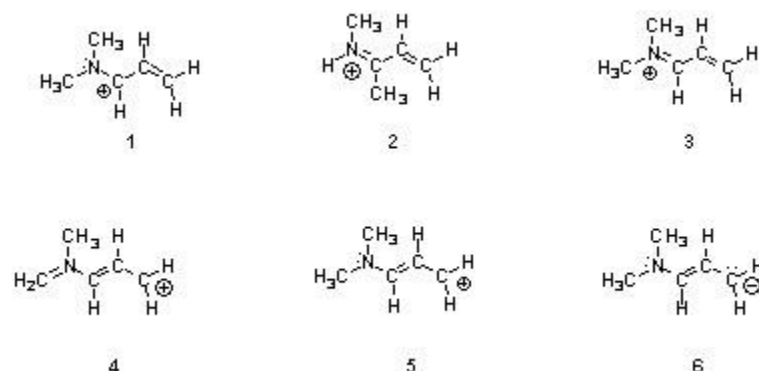
Section: 1.9

LO: 1.4

GO: G2

MCAT LO: MCAT1.3

50) Structures \_\_\_\_\_, shown below, are resonance structures, and structure \_\_\_\_\_ is the major contributor to the overall resonance hybrid.



- A) 2 & 4; 2  
 B) 1, 3 & 5; 3  
 C) 4 & 6; 6  
 D) 1, 3 & 5; 1  
 E) 1, 3, 4 & 5; 3

Answer: B

Diff: 3

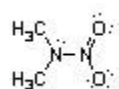
Section: 1.9

LO: 1.4

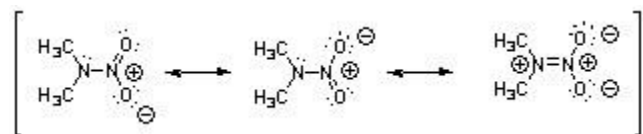
GO: G2

MCAT LO: MCAT1.3

51) Nitroamines are common functional groups found in energetic materials, such as RDX and HMX. For the structure below, draw two other significant resonance structures, include any formal charges, and indicate the hybridization on each nitrogen and oxygen.



Answer: All nitrogen and oxygen atoms are  $sp^2$  hybridized.



Diff: 3

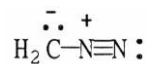
Section: 1.9

GO: G5

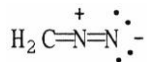
MCAT LO: MCAT2.3



52) Draw the other important resonance form of:



Answer:

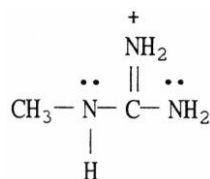


Diff: 3

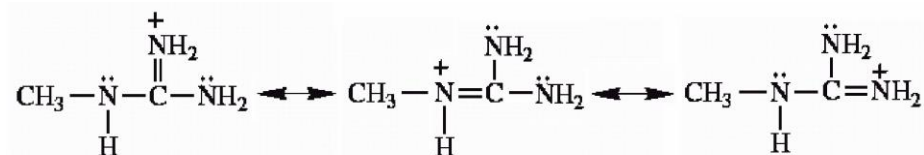
Section: 1.9

MCAT LO: MCAT2.3

53) Draw the important resonance forms for the structure shown below.



Answer:

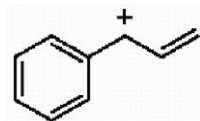


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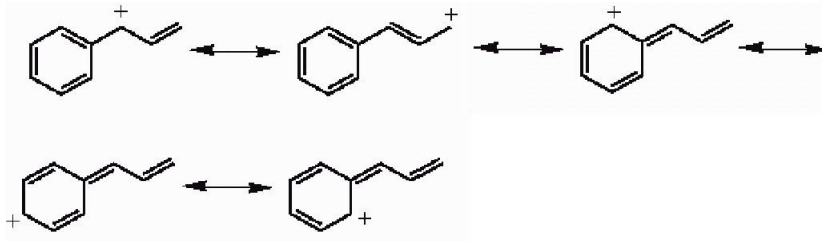
Section: 1.9

MCAT LO: MCAT2.3

54) Draw the important resonance forms for the structure shown below.



Answer:

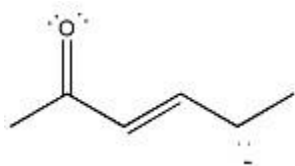


Diff: 3

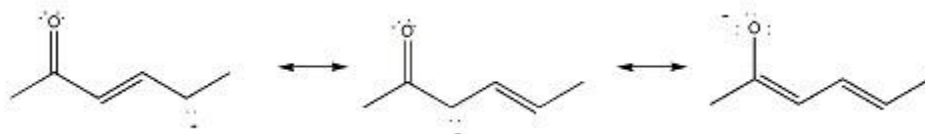
Section: 1.9

MCAT LO: MCAT2.3

55) Draw the important resonance forms of the structure below to indicate the delocalization of charge. Indicate which is the major contributor to the overall structure.



Answer:



The last structure is the major contributor (negative charge on the more electronegative element).

Diff: 3

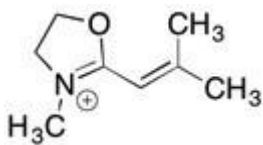
Section: 1.9

LO: 1.4

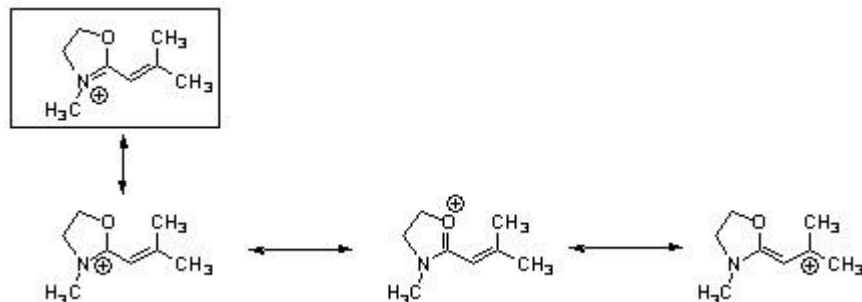
GO: G7

MCAT LO: MCAT2.3

56) Draw 3 significant resonance structures for the compound shown below. Place a box around the major contributor. Fill in any missing formal charges.



Answer:



Diff: 3

Section: 1.9

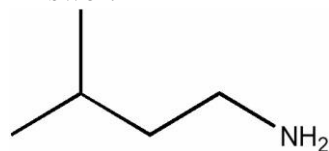
LO: 1.4

GO: G2, G7

MCAT LO: MCAT2.3

57) Draw a line-angle formula for  $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{NH}_2$ .

Answer:



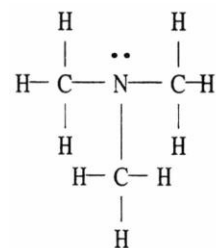
Diff: 1

Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

58) The Lewis structure of trimethylamine is shown below. Draw the condensed structural formula which corresponds to this Lewis structure.



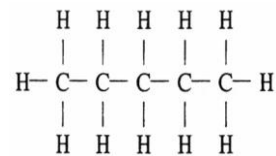
Answer:  $(\text{CH}_3)_3\text{N}$

Diff: 1

Section: 1.10

LO: 1.3

59) The Lewis structure of pentane is shown below. Draw the condensed structural formula which corresponds to this Lewis structure.



Answer:  $\text{CH}_3(\text{CH}_2)_3\text{CH}_3$

Diff: 1

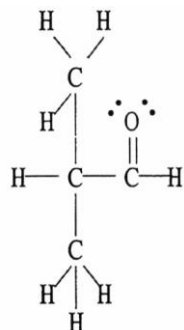
Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

60) Draw the complete Lewis structure for the compound whose condensed formula is  $(\text{CH}_3)_2\text{CHCHO}$ .

Answer:



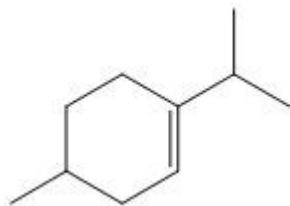
Diff: 1

Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

61) How many carbon atoms are present in the molecule shown?



A) 6

B) 8

C) 10

D) 11

E) 12

Answer: C

Diff: 1

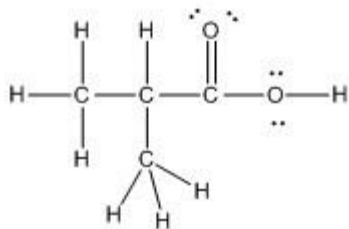
Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

62) Draw a complete Lewis structure, including lone pairs, for  $(\text{CH}_3)_2\text{CHCO}_2\text{H}$ .

Answer:



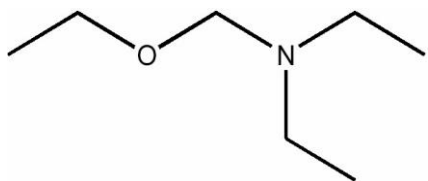
Diff: 2

Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

63) Which of the following condensed formulas represents the same compound as the line-angle structure shown?



A)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{CH}_2\text{N}(\text{CH}_2\text{CH}_2\text{CH}_3)_2$

B)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OCH}_2\text{N}(\text{CH}_2\text{CH}_3)_2$

C)  $\text{CH}_3\text{CH}_2\text{OCH}_2\text{N}(\text{CH}_2\text{CH}_3)_2$

D)  $\text{CH}_3\text{CH}_2\text{OCH}_2\text{N}(\text{CH}_2\text{CH}_2\text{CH}_3)_2$

E)  $\text{CH}_3\text{ON}(\text{CH}_3)_2$

Answer: C

Diff: 2

Section: 1.10

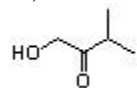
LO: 1.3

GO: G2

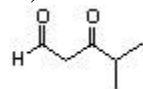
MCAT LO: MCAT1.2

64) Indicate the line-angle structure that corresponds to the condensed structure,  $\text{HOCH}_2\text{C}(\text{O})\text{CH}(\text{CH}_3)_2$ .

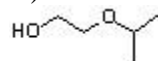
A)



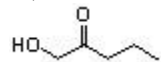
B)



C)



D)



Answer: A

Diff: 2

Section: 1.10

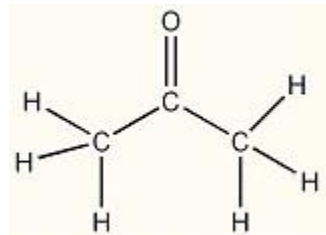
LO: 1.3

GO: G2

MCAT LO: MCAT1.2

65) A condensed structure for acetone is  $\text{CH}_3\text{COCH}_3$ . Provide the structural formula for acetone.

Answer:



Diff: 2

Section: 1.10

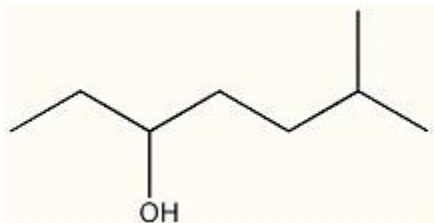
LO: 1.3

GO: G2

MCAT LO: MCAT1.2

66) Provide the line-angle formula for the alcohol  $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)_2$ .

Answer:



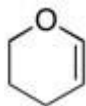
Diff: 2

Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

67) What is the molecular formula for the following line-angle structure?



Answer:  $\text{C}_5\text{H}_8\text{O}$

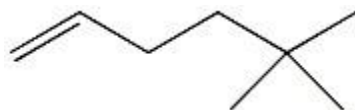
Diff: 2

Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

68) What is the molecular formula for the following line-angle structure?



Answer:  $\text{C}_8\text{H}_{16}$

Diff: 2

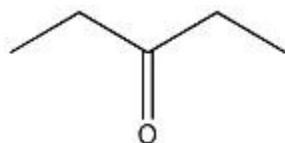
Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

69) Provide the line-angle formula (skeletal structure) for  $(\text{CH}_3\text{CH}_2)_2\text{C}=\text{O}$ .

Answer:



Diff: 2

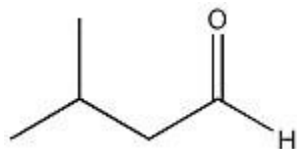
Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

70) Provide the line-angle formula (skeletal structure) for  $(\text{CH}_3)_2\text{CHCH}_2\text{CHO}$ .

Answer:



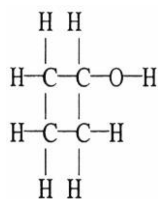
Diff: 2

Section: 1.10

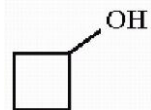
LO: 1.3

MCAT LO: MCAT1.2

71) Draw an acceptable line-angle formula for cyclobutanol (shown below).



Answer:



Diff: 2

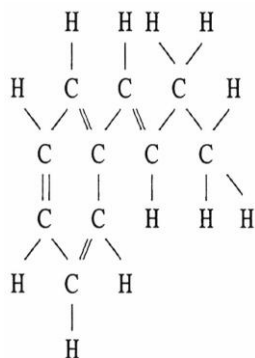
Section: 1.10

LO: 1.3

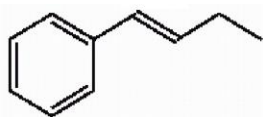
MCAT LO: MCAT1.2



72) Draw an acceptable line-angle formula for the compound shown below.



Answer:



Diff: 2

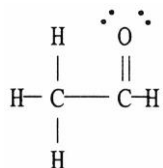
Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

73) Draw a correct Lewis structure for acetaldehyde,  $\text{CH}_3\text{CHO}$ .

Answer:



Diff: 2

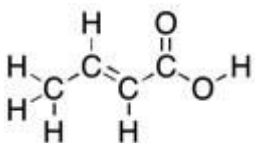
Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

74) Draw a correct Lewis structure for  $\text{CH}_3\text{CHCHCOOH}$ .

Answer:



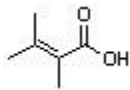
Diff: 2

Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

75) Which of the following condensed formulas correctly represents the line-angle structure shown below?



- A)  $\text{CH}(\text{CH}_3)_2\text{CH}(\text{CH}_3)\text{CO}_2\text{H}$
- B)  $\text{C}_2(\text{CH}_3)_3\text{CO}_2\text{H}$
- C)  $(\text{CH}_3)_2\text{CC}(\text{CH}_3)\text{CO}_2\text{H}$
- D)  $\text{C}(\text{CH}_3)_2\text{C}(\text{CH}_3)\text{CH}_2\text{CO}_2\text{H}$

Answer: C

Diff: 2

Section: 1.10

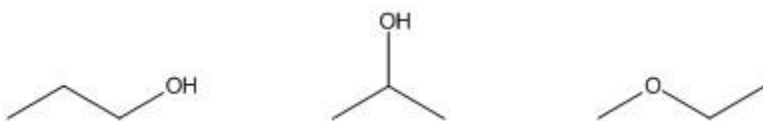
LO: 1.3

GO: G2

MCAT LO: MCAT1.2

76) Draw the line-angle formula for three compounds with molecular formula  $\text{C}_3\text{H}_8\text{O}$ .

Answer:



Diff: 2

Section: 1.10

LO: 1.2

GO: G2

MCAT LO: MCAT1.1

77) Provide the line-angle formula for  $\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)_2\text{CH}_2\text{CHO}$

Answer:



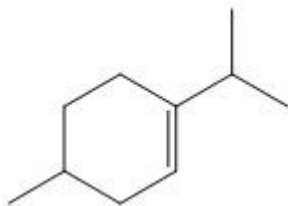
Diff: 2

Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

78) How many hydrogen atoms are present in the molecule shown?



Answer: 18

Diff: 2

Section: 1.10

LO: 1.3

MCAT LO: MCAT1.2

79) Draw condensed structures for the four compounds with formula  $C_3H_9N$ .

Answer:  $CH_3CH_2CH_2NH_2$

$CH_3CH_2NHCH_3$

$(CH_3)_2CHNH_2$

$(CH_3)_3N$

Diff: 3

Section: 1.10

LO: 1.2

GO: G2

MCAT LO: MCAT1.1

80) Compute the empirical and molecular formulas for the compound of molecular weight 180 g/mol which is shown to contain 40.0% C and 6.7% H by elemental analysis.

Answer: The empirical formula is  $CH_2O$  and the molecular formula is  $C_6H_{12}O_6$ .

Diff: 2

Section: 1.11

LO: 1.5

GO: G4

81) Compute the empirical and molecular formulas for the compound of molecular weight 86 g/mol which is shown to contain 55.8% C and 7.0% H by elemental analysis.

Answer: The empirical formula is  $C_2H_3O$  and the molecular formula is  $C_4H_6O_2$ .

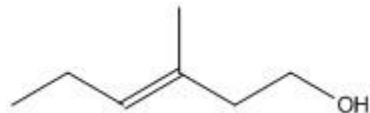
Diff: 2

Section: 1.11

LO: 1.5

GO: G4

82) What is the molecular formula for the molecule shown?



Answer: C<sub>7</sub>H<sub>14</sub>O

Diff: 2

Section: 1.11

LO: 1.3

MCAT LO: MCAT1.2

83) A sample of compound X is subjected to elemental analysis and the following percentages by weight are found: 39.97% C, 6.73% H, and 53.30% O. The molecular weight of X is 90. What is the empirical formula of X?

A) C<sub>6</sub>H<sub>8</sub>O

B) C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>

C) C<sub>4</sub>H<sub>10</sub>O<sub>2</sub>

D) C<sub>3</sub>H<sub>6</sub>O<sub>3</sub>

E) CH<sub>2</sub>O

Answer: E

Diff: 3

Section: 1.11

LO: 1.5

GO: G4

84) Calculate the empirical and molecular formulas of the compound with molecular weight 122 and an elemental analysis of 59.01% C, 4.97% H, 13.12% O, and 22.90% N.

Answer: Empirical and molecular formulas are the same: C<sub>6</sub>H<sub>6</sub>N<sub>2</sub>O.

Diff: 3

Section: 1.11

LO: 1.5

GO: G4

85) Calculate the molecular formula for the organic compound whose quantitative elemental analysis showed 48.6% carbon and 8.1% hydrogen by weight.

A) CH<sub>2</sub>O

B) C<sub>2</sub>H<sub>4</sub>O<sub>2</sub>

C) C<sub>2</sub>H<sub>6</sub>

D) C<sub>3</sub>H<sub>6</sub>O

E) C<sub>3</sub>H<sub>6</sub>O<sub>2</sub>

Answer: E

Diff: 3

Section: 1.11

LO: 1.5

GO: G4

86) The pH of a 150 mL aqueous solution of  $2.13 \times 10^{-3}$  M HCl is \_\_\_\_\_.

- A) -3.000
- B) 3.000
- C) 2.672
- D) 2.130
- E) none of the above

Answer: C

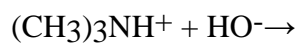
Diff: 2

Section: 2.4

LO: 1.7

GO: G4

87) Provide the products of the following acid-base reaction.

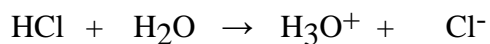


Answer:  $(\text{CH}_3)_3\text{N} + \text{H}_2\text{O}$

Diff: 2

Section: 2.5

88) In the following acid/base reaction, label the acid, base, conjugate acid and conjugate base.



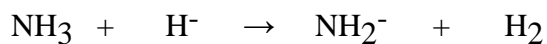
Answer:  $\text{HCl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^-$   
acid    base    conj. acid    conj. base

Diff: 2

Section: 2.5

GO: G2

89) In the following acid/base reaction, label the acid, base, conjugate acid and conjugate base.



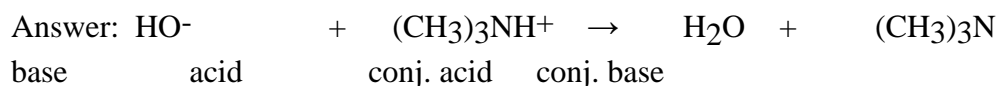
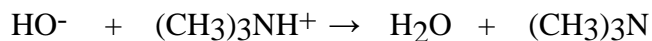
Answer:  $\text{NH}_3 + \text{H}^- \rightarrow \text{NH}_2^- + \text{H}_2$   
acid    base    conj. base    conj. acid

Diff: 3

Section: 2.5

GO: G2

90) In the following acid/base reaction, label the acid, base, conjugate acid and conjugate base.



Diff: 3

Section: 2.5

GO: G2

91) What is the  $pK_a$  and general acid strength of formic acid if its conjugate base form has a  $pK_b$  of 10.23?

- A) 3.77 - fairly strong weak acid
- B) 5.99 - moderately strong weak acid
- C) 14.00 - not an acid but rather a strong base
- D) 3.23 - fairly strong weak acid
- E) cannot be determined from the information given

Answer: A

Diff: 1

Section: 2.6

LO: 1.7

GO: G4

92) Provide the structure of the conjugate acid of ethanamine ( $\text{CH}_3\text{CH}_2\text{NH}_2$ )

Answer:



Diff: 1

Section: 2.5

93) The conjugate acid of ammonia,  $\text{NH}_3$ , is \_\_\_\_\_.

- A)  $\text{NH}_2^-$
- B)  $\text{NH}_2\text{OH}$
- C)  $\text{NH}_4^+$
- D) none of the above

Answer: C

Diff: 2

Section: 2.5

94) The  $K_a$  of formic acid is  $1.7 \times 10^{-4}$ . The  $pK_a$  of formic acid is \_\_\_\_\_.

- A) 1.70
- B) 4.00
- C) -2.36
- D) 3.77
- E) 10.38

Answer: D

Diff: 2

Section: 2.5

LO: 1.7

GO: G4

95) When methanol ( $\text{CH}_3\text{OH}$ ) acts as a base, its conjugate acid is \_\_\_\_\_.

- A)  $^-\text{CH}_2\text{OH}$
- B)  $\text{CH}_3\text{O}^-$
- C)  $\text{CH}_4\text{OH}$
- D)  $\text{CH}_3\text{OH}_2^+$
- E)  $\text{CH}_4\text{O}^+$

Answer: D

Diff: 2

Section: 2.5

96) Which of the following pairs of bases lists the stronger base first?

- A)  $\text{I}^- > \text{Cl}^-$
- B)  $\text{H}_2\text{O} > \text{HO}^-$
- C)  $\text{HO}^- > \text{H}_2\text{N}^-$
- D)  $\text{CH}_3\text{COO}^- > \text{HO}^-$
- E)  $\text{H}_2\text{N}^- > \text{CH}_3\text{COO}^-$

Answer: E

Diff: 3

Section: 2.6

LO: 1.6

GO: G2

97) According to the following  $pK_a$  values listed for a set of acids, which would lead to the strongest conjugate base?

- A) -2
- B) 1
- C) 7
- D) 25
- E) 50

Answer: E

Diff: 2

Section: 2.6

LO: 1.7

98) Strong bases usually contain positively charged atoms of high electronegativity and no resonance stabilization.

Answer: FALSE

Diff: 2

Section: 2.12

LO: 1.6

GO: G2

99) Rank the following compounds in order of increasing acidity:  $\text{CH}_3\text{OH}$ ,  $\text{HCl}$ ,  $\text{NH}_3$ , and  $\text{CH}_4$ .

Answer:  $\text{CH}_4 < \text{NH}_3 < \text{CH}_3\text{OH} < \text{HCl}$

Diff: 2

Section: 2.9

LO: 1.6

100) Rank the following compounds in order of increasing basicity:  $\text{CH}_3\text{O}^-$ ,  $\text{H}_2\text{N}^-$ ,  $\text{H}_2\text{O}$ , and  $\text{NH}_3$ .

Answer:  $\text{H}_2\text{O} < \text{NH}_3 < \text{CH}_3\text{O}^- < \text{H}_2\text{N}^-$

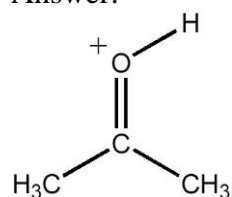
Diff: 2

Section: 2.9

LO: 1.6

101) Draw the structure of the conjugate acid of acetone ( $\text{CH}_3\text{COCH}_3$ ).

Answer:



Diff: 2

Section: 2.5



102) Methanol has a  $pK_a$  of 15.5. Calculate its  $K_a$ .

Answer:  $3.2 \times 10^{-16}$

Diff: 2

Section: 2.6

LO: 1.7

GO: G4

103) Write a completed equation for the acid-base pair shown below.

$\text{HCN} + \text{NaOH} \rightarrow$

Answer:  $\text{HCN} + \text{NaOH} \rightarrow \text{NaCN} + \text{H}_2\text{O}$

Diff: 2

Section: 2.5

104) Write a completed equation for the acid-base pair shown below.

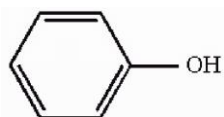
$\text{HCO}_2\text{H} + ^-\text{NH}_2 \rightarrow$

Answer:  $\text{HCO}_2\text{H} + ^-\text{NH}_2 \rightarrow \text{HCO}_2^- + \text{NH}_3$

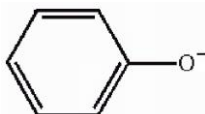
Diff: 2

Section: 2.5

105) The compound phenol is shown below. Provide the structure of the conjugate base of phenol.



Answer:



Diff: 2

Section: 2.5

GO: G2

106) Which of the following acids has the most stable conjugate base?

- A)  $\text{CH}_3\text{CO}_2\text{H}$
- B)  $\text{CH}_3\text{CHO}$
- C)  $\text{CH}_3\text{CH}_2\text{OH}$
- D)  $\text{CH}_3\text{CH}_2\text{SH}$
- E)  $\text{CH}_3\text{SO}_3\text{H}$

Answer: E

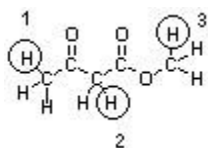
Diff: 2

Section: 2.9

LO: 1.6

GO: G7

107) Which proton is the most acidic in the compound below?



- A) 1
- B) 2
- C) 3
- D) They are all the same acidity.

Answer: B

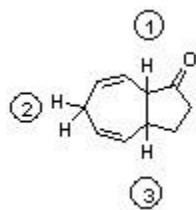
Diff: 3

Section: 2.12

LO: 1.6

GO: G2

108) Which sequence correctly ranks the following protons in order of increasing acidity?



- A)  $1 < 2 < 3$   
 B)  $2 < 3 < 1$   
 C)  $3 < 1 < 2$   
 D)  $3 < 2 < 1$   
 E)  $2 < 1 < 3$

Answer: D

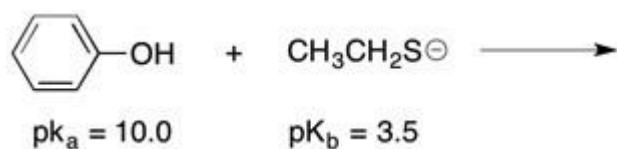
Diff: 3

Section: 2.12

LO: 1.6

GO: G2

109) Complete the following acid/base reaction and use  $pK_a$  or  $pK_b$  values to predict whether the equilibrium will favor the reactants or products:



Answer:



The stronger acid and the stronger base are both on the left side of the reaction (reactants); therefore, the equilibrium concentration should favor the products or right side of this equation.

Diff: 3

Section: 2.7

LO: 1.7

GO: G2, G7

110) Which is more acidic, HF or HI? Explain.

Answer: HI is more acidic. As a conjugate base  $I^-$  is more stable than  $F^-$ . The large size of the  $I^-$  ion allows the extra negative charge to be spread out in a large volume of space.

Diff: 3

Section: 2.9

LO: 1.6

111) Which is more acidic, methanesulfonic acid ( $\text{CH}_3\text{SO}_3\text{H}$ ) or propanoic acid ( $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$ )? Explain.

Answer: Methanesulfonic acid is considerably more acidic. The methanesulfonate ion is much more stable than the propanoate ion. Both of these conjugate bases are stabilized by resonance delocalization of the negative charge, but this delocalization is more extensive in the sulfonate.

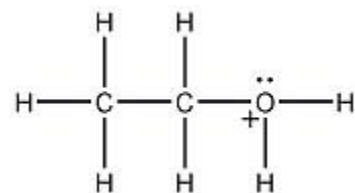
Diff: 3

Section: 2.12

LO: 1.6

112) Provide the Lewis structure of the conjugate acid of ethanol ( $\text{CH}_3\text{CH}_2\text{OH}$ ).

Answer:



Diff: 3

Section: 2.5

113) Consider the set of compounds,  $\text{NH}_3$ ,  $\text{HF}$ , and  $\text{H}_2\text{O}$ . Rank these compounds in order of increasing acidity and discuss your rationale.

Answer:  $\text{NH}_3 < \text{H}_2\text{O} < \text{HF}$

When determining relative acidity, it is often useful to look at the relative basicity of the conjugate bases. The stronger the acid, the weaker (more stable, less reactive) the conjugate base. In this case, one would look at the relative basicity of  $\text{F}^-$ ,  $\text{OH}^-$ , and  $\text{NH}_2^-$ . The relative strengths of these species can be gauged based on the electronegativity of the charged atom in each. Since fluorine is the most electronegative,  $\text{F}^-$  is the most stable, least reactive base in the group. This means that its conjugate acid,  $\text{HF}$ , is the strongest.

Diff: 3

Section: 2.9

LO: 1.6

GO: G2, G8

114) Methanesulfonic acid,  $\text{CH}_3\text{SO}_3\text{H}$ , has a  $\text{pK}_a$  of -7 while ethanol,  $\text{CH}_3\text{CH}_2\text{OH}$ , has a  $\text{pK}_a$  of 15.9. Which is the stronger acid and what accounts for this large difference in relative acidity?  
Answer: Methanesulfonic acid is the stronger acid. The lower the  $\text{pK}_a$ , the stronger the acid. A lower  $\text{pK}_a$  is associated with a larger  $K_a$  which signifies greater dissociation. The large relative difference in acidity in this case can be most easily seen by gauging the relative basicities of the conjugate bases. The weaker the base, the stronger the corresponding conjugate acid.

Methanesulfonate,  $\text{CH}_3\text{SO}_3^-$ , is considerably stabilized by resonance delocalization which is not found in ethoxide,  $\text{CH}_3\text{CH}_2\text{O}^-$ . This effect greatly reduces the basicity of methanesulfonate relative to ethoxide.

Diff: 3

Section: 20.12

LO: 1.6

GO: G2, G8

115) Would you predict trifluoromethanesulfonic acid,  $\text{CF}_3\text{SO}_3\text{H}$ , to be a stronger or weaker acid than methanesulfonic acid,  $\text{CH}_3\text{SO}_3\text{H}$ ? Explain your reasoning.

Answer: Trifluoromethanesulfonic acid is a stronger acid. Compare the strengths of the conjugate bases and remember that the weaker the base, the stronger the conjugate acid. Both bases are stabilized by resonance, but in the case of the trifluoro derivative, the presence of the highly electronegative fluorine atoms serves to delocalize the negative charge to an even greater extent due to the inductive effect. This additional delocalization makes trifluoromethanesulfonate a weaker base.

Diff: 3

Section: 2.12

LO: 1.6

GO: G2, G8

116) Consider the species  $\text{CH}_3\text{O}^-$ ,  $\text{NH}_2^-$ , and  $\text{CH}_3\text{COO}^-$ . Rank these ions in order of increasing basicity, and explain your rationale.

Answer:  $\text{CH}_3\text{COO}^- < \text{CH}_3\text{O}^- < \text{NH}_2^-$

The first factor to consider is the nature of the atom which bears the negative charge. The more electronegative the atom that bears the negative charge, the more stable the anion. Stable anions are less reactive and are hence weaker bases. Since O is more electronegative than N, the  $\text{NH}_2^-$  is the strongest base in the set. In the remaining two species, the negative charge is on the O, but in the case of  $\text{CH}_3\text{COO}^-$ , the negative charge is also delocalized by resonance.

Diff: 3

Section: 2.9

LO: 1.6

GO: G2, G7

117) Stabilization of a charged species usually results when this species can be more accurately depicted as a hybrid of several resonance forms. Why is this the case?

Answer: Stabilization results from delocalization of charge.

Diff: 3

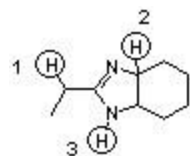
Section: 2.12

LO: 1.4

GO: G2

MCAT LO: MCAT1.3

118) Which sequence ranks the indicated protons in order of increasing acidity?



A)  $1 < 2 < 3$

B)  $2 < 1 < 3$

C)  $1 < 3 < 2$

D)  $3 < 2 < 1$

Answer: B

Diff: 3

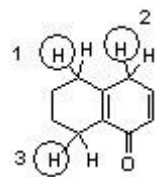
Section: 2.12

LO: 1.6

GO: G2

MCAT LO: MCAT2.5

119) Which sequence correctly ranks the following protons in order of increasing  $pK_a$  value?



A)  $3 < 1 < 2$

B)  $2 < 1 < 3$

C)  $3 < 2 < 1$

D)  $1 < 3 < 2$

Answer: B

Diff: 3

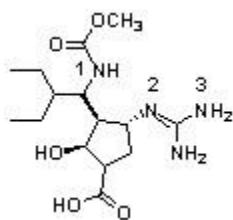
Section: 2.12

LO: 1.6

GO: G2

MCAT LO: MCAT2.5

120) Peramivir, shown below, has shown to be effective against the influenza B virus (*J. Med. Chem.* **2010**, 6421). Which sequence ranks the following nitrogen atoms in order of increasing basicity?



A) 2<3<1

B) 3<1<2

C) 1<3<2

D) 1<2<3

Answer: C

Diff: 3

Section: 2.12

LO: 1.6

GO: G2, G5

MCAT LO: MCAT2.5

121) The hydroxide ion (HO<sup>-</sup>) cannot function well as which of the following?

A) a Bronsted-Lowry base

B) a Lewis base

C) a nucleophile

D) an electron-pair acceptor

E) a proton acceptor

Answer: D

Diff: 1

Section: 2.13

LO: 1.6

GO: G7

122) Which of the following terms comes closest to describing an electrophile?

A) anion

B) Lewis base

C) Lewis acid

D) nucleophile

E) nonpolar

Answer: C

Diff: 2

Section: 2.13

LO: 1.8

MCAT LO: MCAT1.4

123) According to the Lewis definition, which of the following may act as acids?

- A)  $\text{NH}_3$
- B)  $\text{HCl}$
- C)  $\text{AlCl}_3$
- D) A & B
- E) A, B, & C

Answer: E

Diff: 2

Section: 2.13

LO: 1.8

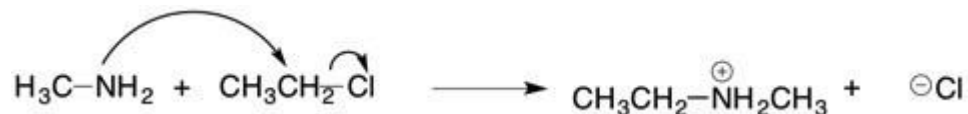
GO: G2

MCAT LO: MCAT1.4

124) Use the curved arrow formalism to show the movement of electron pairs in the following reaction.



Answer:



Diff: 2

Section: 2.14

LO: 1.8

GO: G2

MCAT LO: MCAT1.4

125) In the reaction below, label each reactant as a nucleophile or an electrophile.



Answer:  $\text{CH}_3\text{NH}_2$ , nucleophile

$\text{CH}_3\text{CH}_2\text{Cl}$ , electrophile

Diff: 2

Section: 2.13

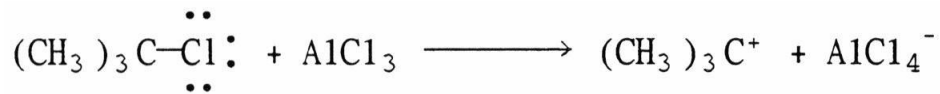
LO: 1.8

GO: G2

MCAT LO: MCAT1.4



126) Use the curved arrow formalism to indicate the movement of electron pairs in the following reaction.



Answer:



Diff: 2

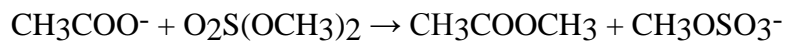
Section: 2.14

LO: 1.8

GO: G2

MCAT LO: MCAT1.4

127) In the reaction below, label each reactant as a nucleophile or an electrophile.



Answer:  $\text{CH}_3\text{COO}^-$ , nucleophile

$\text{O}_2\text{S}(\text{OCH}_3)_2$ , electrophile

Diff: 3

Section: 2.13

LO: 1.8

GO: G2

MCAT LO: MCAT1.4