MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) In organic chemistry, the term *unsaturated* means a molecule
   A) which contains one or more multiple bonds between carbon atoms.
   B) which can react by taking up one or more water molecules.
   C) which is formed from many smaller molecules.
   D) which has the maximum number of carbon–hydrogen bonds possible.
   E) with a specific six-membered ring structure.

2) The process used to produce simple alkenes is
   A) condensation of small molecules.
   B) cracking of alkanes.
   C) distillation of crude oil.
   D) polymerization of monomers.
   E) smelting of ores.

3) The organic chemical produced in the largest quantities in the U.S. is
   A) ethylene
   B) benzene.
   C) octane.
   D) polyethylene.
   E) sulfuric acid.

4) On the basis of the number of carbon–hydrogen bonds, all of the following families of compounds can be considered unsaturated except
   A) alkenes.
   B) alkynes.
   C) arenes.
   D) alkanes.
   E) none of the above

5) Ethylene and acetylene are the common names for the molecules _______ and _______, respectively.
   A) C₂H₄ and C₂H₂
   B) C₂H₆ and C₃H₈
   C) C₂H₄ and C₃H₆
   D) C₂H₂ and C₂H₆
   E) C₂H₄ and C₂H₆

6) Which choice represents the carbon skeleton of 1,6-octadiene?
   A) C=C–C=C–C=C–C=C
   B) C=C–C=C–C=C–C
   C) C–C=C–C=C–C=C–C
   D) C=C–C=C–C=C–C
   E) C=C–C=C–C=C=C
7) Which choice represents the carbon skeleton of 2,5-octadiene?
A) C-C=C-C-C-C=C
B) C-C=C-C-C-C-C
C) C-C=C-C=C-C-C
D) C-C=C-C=C=C-C
E) C=C=C-C=C-C=C

8) Which choice represents the carbon skeleton of 2,4-octadiene?
A) C=C=C=C-C-C=C=C
B) C=C=C=C-C=C=C
C) C=C=C=C=C-C=C
D) C=C=C=C=C=C-C
E) C=C=C=C=C=C-C

9) How many hydrogen atoms are contained in a molecule of 1,4-hexadiene?
A) 18
B) 6
C) 14
D) 10
E) 12

10) How many hydrogen atoms are contained in a molecule of cyclopentene?
A) 12
B) 5
C) 8
D) 6
E) 10

11) What is the IUPAC name of the molecule shown?
\[ \text{CH}_3 \text{=CH-CH}_2 \text{=CH-CH=CH}_3 \]
A) 5-ethyl-1-hexene
B) 3-methyl-6-heptene
C) 2-ethyl-5-hexene
D) octene
E) 5-methyl-1-heptene

12) What is the IUPAC name of the molecule shown?
\[ \text{CH}_3 \text{=CH-CH} \]
\[ \text{CH=CH}_2 \]
A) 1,1-dimethyl-2-propene
B) 2-methyl-3-butene
C) 3-methyl-1-butene
D) 3-methyl-1,2-butene
E) isopentene
13) What is the IUPAC name of the molecule shown?

\[ \text{CH}_3\text{CH}_2\text{CH}_2\text{C} = \text{C} - \text{CH}_3 \]

A) octene  
B) 2-methyl-3-methyl-2-hexene  
C) dimethylhexene  
D) 2,3-dimethyl-2-hexene  
E) 1,1,2-trimethyl-1-pentene

14) What is the IUPAC name of the molecule shown?

\[ \text{CH}_2\text{=CH} - \text{CH} = \text{CH}_2 \]

A) 1,4-butadiene  
B) 1,1-butadiene  
C) diethylene  
D) 1,3-butadiene  
E) 1,2-butadiene

15) Which of the following compounds is a saturated hydrocarbon?

A) benzene  
B) hexane  
C) 1,3-butadiene  
D) ethylene  
E) acetylene

16) Which molecule represents 4-ethyl-2-hexyne?

A) \((\text{CH}_3\text{CH}_2)_2\text{CHC}=\text{CCH}(\text{CH}_2\text{CH}_3)_2\)  
B) \((\text{CH}_3\text{CH}_2)_2\text{CHC}=\text{CCH}_3\)  
C) \(\text{CH}_3\text{CH}_2\text{C}=\text{CCH}_2\text{CH}_2\text{CH}_3\)  
D) \(\text{CH}_3\text{CH}_2\text{CH}_2\text{C}=\text{CCH}_3\)  
E) \(\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{C}=\text{CCH}_3\)

SHORT ANSWER. Write the word or phrase that best completes each statement or answers the question.

17) This question has three parts:
   a. Sketch the carbon skeleton of 2,5-hexadiene.
   b. Explain why this name is not correct.
   c. Give the correct name and molecular formula of the compound with the carbon skeleton you drew.

18) This question has three parts:
   a. Sketch the carbon skeleton of 3-ethyl-2,5-hexadiene.
   b. Explain why this name is not correct.
   c. Give the correct name and molecular formula of the compound with the carbon skeleton you drew.
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

19) The cause of cis–trans isomerism is
   A) strength of the double bond.
   B) stability of the double bond.
   C) vibration of the double bond.
   D) short length of the double bond.
   E) lack of rotation of the double bond.

20) Cis–trans isomerism occurs when
   A) a branched alkane has a halogen added to two adjacent carbon atoms.
   B) hydrogen is added to both of the carbon atoms in a double bond.
   C) the carbons in an alkene double bond each have two different substituent groups.
   D) the carbons in the para position of an aromatic have the same substituent groups.
   E) an alkene is hydrated according to Markovnikov’s Rule.

21) The name of the molecule shown is

   A) cis-3-chloro-2-pentene
   B) monochloro-2-cis-pentene
   C) trans-3-chloro-2-pentene
   D) cis-3-chloro-3-pentene
   E) trans-3-chloro-3-pentene

22) The name of the molecule shown is

   A) cis-3-chloro-3-pentene
   B) monochloro-2-cis-pentene
   C) trans-3-chloro-3-pentene
   D) trans-3-chloro-2-pentene
   E) cis-3-chloro-2-pentene
23) The name of the molecule shown is

A) cis-3-chloro-2-methyl-2-butene
B) 3-chloro-2-methylene-butane
C) 2-chloro-3-methylene-butane
D) trans-3-chloro-2-methyl-2-butene
E) 3-chloro-2-methyl-1-butene

24) Which molecule can have cis–trans isomers?
   A) \( (\text{CH}_3)_2\text{C} = \text{CHCH}_3 \)
   B) \( \text{CH}_3\text{CH} = \text{CHCl} \)
   C) \( (\text{CH}_3)_2\text{C} = \text{C(CH}_3)_2 \)
   D) \( \text{CH}_3\text{CH} = \text{C(CH}_3)_2 \)
   E) \( \text{CH}_3\text{CH} = \text{CCl}_2 \)

25) What is the IUPAC name of the compound shown?
   A) trans-2-nonene
   B) cis-2-nonene
   C) cis-4,6-dimethyl-2-heptene
   D) trans-2,4-dimethyl-5-heptene
   E) trans-4,6-dimethyl-2-heptene

26) All of the following are general properties of alkenes except
   A) less reactive than the corresponding alkanes.
   B) soluble in non-polar (organic) solvents.
   C) flammable.
   D) may exist as cis–trans isomers.
   E) low boiling points.

27) The bond angle about a carbon atom involved in a double bond is

28) The bond angle about a carbon atom involved in a triple bond is
29) Alkanes and alkenes are similar in all of the following properties except
   A) lack of toxicity.
   B) solubility in non-polar solvents.
   C) insolubility in water.
   D) reactivity.
   E) flammability.

30) Alkenes and simple aromatics are similar in all of the following properties except
   A) nonpolarity.
   B) insolubility in water.
   C) lack of toxicity.
   D) solubility in non-polar solvents.
   E) flammability.

31) The term used to describe the geometry of a carbon atom involved in a double bond is
   A) linear.
   B) trigonal planar.
   C) perpendicular.
   D) tetrahedral.
   E) distorted tetrahedral.

32) The term used to describe the geometry of a carbon atom involved in a triple bond is
   A) linear.
   B) perpendicular.
   C) distorted tetrahedral.
   D) trigonal planar.
   E) tetrahedral.

33) What is the ideal angle between the H–C–C bond in ethylene?
   A) 109.5°
   B) 180°
   C) 120°
   D) 90°
   E) none of the above

34) What is the ideal angle between the H–C–C bond in acetylene?
   A) 120°
   B) 109.5°
   C) 90°
   D) 180°
   E) none of the above

35) What is the ideal angle between the H–C–H bond in methane?
   A) 180°
   B) 90°
   C) 109.5°
   D) 120°
   E) none of the above
36) An addition reaction can best be described as a reaction in which
   A) a single reactant undergoes reorganization of its chemical bonds, producing an isomer of the reactant.
   B) two reactants combine to form one new product with no extra atoms.
   C) a hydrogen reacts with oxygen to produce CO₂, H₂O, and energy.
   D) a single reactant splits into two products.
   E) two reactants exchange atoms to give two new products.

37) An elimination reaction can best be described as a reaction in which
   A) two reactants combine to form one new product with no extra atoms.
   B) a hydrocarbon reacts with oxygen to produce CO₂, H₂O, and energy.
   C) a single reactant splits into two products.
   D) a single reactant undergoes reorganization of its chemical bonds, producing an isomer of the reactant.
   E) two reactants exchange atoms to give two new products.

38) A substitution reaction can best be described as a reaction in which
   A) two reactants combine to form one new product with no extra atoms.
   B) a hydrocarbon reacts with oxygen to produce CO₂, H₂O, and energy.
   C) a single reactant splits into two products.
   D) a single reactant undergoes reorganization of its chemical bonds, producing an isomer of the reactant.
   E) two reactants exchange atoms to give two new products.

39) A rearrangement reaction can best be described as a reaction in which
   A) a single reactant splits into two products.
   B) a hydrocarbon reacts with oxygen to produce CO₂, H₂O, and energy.
   C) a single reactant undergoes reorganization of its chemical bonds, producing an isomer of the reactant.
   D) two reactants combine to form one new product with no extra atoms.
   E) two reactants exchange atoms to give two new products.

40) Chemical reactions involving double bonds are generally referred to as ________ reactions.
    A) addition
    B) oxidation
    C) combustion
    D) substitution
    E) reduction

41) When an alkene undergoes hydrogenation, the product is an

42) When an alkene undergoes a hydration reaction the product is an
43) All of the following are examples of addition reactions of alkenes except
   A) chlorination.
   B) hydration.
   C) oxidation.
   D) hydrogenation.
   E) bromination.

44) Which reactant should be used to convert propene to 2-chloropropane?
   A) BrCl
   B) Cl₂
   C) NaCl
   D) HCl
   E) H₂

45) Which reactant should be used to convert propene to 1,2-dichloropropane?
   A) BrCl
   B) NaCl
   C) HCl
   D) H₂
   E) Cl₂

46) Which of the following reactions involves addition of two different elements to an alkene?
   A) bromination
   B) hydrogenation
   C) chlorination
   D) hydrohalogenation
   E) none of the above

47) When 2-butene reacts completely with bromine, the product is
   A) 2,3-dibromobutane.
   B) 2-bromobutane.
   C) 3-bromobutane.
   D) 1,2-dibromobutane.
   E) 1,3-dibromobutane.

48) According to Markovnikov’s rule, when HCl reacts with the molecule shown, which product will result?
   \[(\text{CH₃})₂\text{C}≡\text{CHCH}₃ + \text{HCl} → ????\]
   A) (\text{CH₃})₂\text{CH}–\text{CH₂CH}_2\text{Cl}
   B) (\text{CH₃})₂\text{CCl}–\text{CHClCH}_3
   C) (\text{CH₃})₂\text{CCl}–\text{CH₂CH}_3
   D) Cl₂\text{CH}–\text{CHClCH}_3
   E) (\text{CH₃})₂\text{CH}–\text{CHClCH}_3

49) Markovnikov’s Rule refers to
   A) The rate of hydrogen addition to an alkene with alkyl group substituents.
   B) The temperature difference observed in the boiling points of \text{cis} and \text{trans} alkenes.
   C) The ideal bond angle between substituents on a double bond.
   D) The color of a molecule containing multiple double bonds.
   E) The orientation an unsymmetrical reagent will take when added to an unsymmetrical alkene.
50) The commonly accepted mechanism for explaining alkene reactions involves formation of
   A) carbon atoms which have lost all their electrons.
   B) carbanions.
   C) carbon atoms with four electrons.
   D) carbocations.
   E) carbon atoms with 10 electrons.

51) The monomer unit used to produce polypropylene is
   A) CH₂=CH₂–CH₃.
   B) CH₃–CH₂=CH₂–CH₃.
   C) CH₂=CH₂–CH₂Cl.
   D) CH₂=CH₂.
   E) CHCl=CH₂.

52) The starting material for polymerization reactions is a(an)
   A) alkane.
   B) isomer.
   C) catalyst.
   D) dimer.
   E) monomer.

53) The name of the polymer formed from CH₂=CH₂ is
   A) polyethylene.
   B) polystyrene.
   C) polyvinyl chloride.
   D) polypropylene.
   E) none of the above

54) The concept that explains the properties of aromatic compounds based on a structure that is an
    average among two possible structures is
    A) double bonding.
    B) oxidation.
    C) resonance.
    D) polymerization.
    E) cis–trans isomerism.

55) Which phrase most accurately describes the structure common to all aromatic compounds?
    A) a ring described as 1,3,5-hexatriene
    B) identical bonds between all 6 carbon atoms, with 6 electrons moving freely
    C) a six–membered ring with easily broken carbon–carbon bonds
    D) a six–membered ring with 3 double and 3 single bonds
    E) none of the above

SHORT ANSWER. Write the word or phrase that best completes each statement or answers the question.

56) The term delocalization means "not limited to a particular place or area." Explain how this
    term describes the behavior of electrons in aromatic compounds.
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

57) The structure shown is

A) toluene.  
B) aniline.  
C) para-xylene.  
D) phenol.  
E) meta-xylene.

58) When the aromatic ring is named as a side chain or functional group, it is referred to as the _______ group.

A) benzyloyl  
B) benzyl  
C) toluyl  
D) xylyl  
E) phenyl

59) Which of the following is not the common name of an aromatic compound?

A) phenol  
B) aniline  
C) xylene  
D) toluene  
E) acetone

60) Using systematic names, the structure shown could be called

A) meta-dimethylbenzene.  
B) 1,2-dimethylbenzene.  
C) 1,3-dimethylbenzene.  
D) para-dimethylbenzene.  
E) ortho-dimethylbenzene.

61) The most common reactions involving aromatics are _______ reactions.

A) elimination  
B) oxidation  
C) addition  
D) substitution  
E) reduction

62) All of the following are common reactions of benzene except

A) nitration.  
B) bromination.  
C) sulfonation.  
D) chlorination.  
E) hydrogenation.
63) Bromobenzene can be prepared from benzene by reaction with ________
   A) HBr
   B) Br₂
   C) Br₂ and FeBr₃
   D) HBr and H₂O
   E) Br₂ and KBr

MATCHING. Choose the item in column 2 that best matches each item in column 1.

Match the following.

64) saturated  A) a concept used to describe a molecule structure as an average of two or more similar structures
65) unsaturated  B) a simple molecule that can be joined with many others to form a large molecule
66) monomer  C) another name for 1,2-dichlorobenzene
67) polymer  D) the term used when a benzene ring is a side chain or substituent group; abbreviated as C₆H₅-
68) phenol  E) another name for 1,3-dichlorobenzene
69) resonance  F) another name for 1,4-dichlorobenzene
70) meta-dichlorobenzene  G) a term describing a hydrocarbon in which additional C–H bonds can be formed
71) phenyl  H) the common name for aminobenzene
72) para-dichlorobenzene  I) refers to a class of compounds containing a specific 6–membered ring structure with delocalized electrons
73) aniline  J) a large molecule made from many smaller molecules, often of only one or two kinds
74) ortho-dichlorobenzene  K) a term describing a hydrocarbon which has the maximum number of C–H bonds possible
75) aromatic  L) the common name for 1,2-dimethylnaphthalene
76) ortho-xylene  M) the common name for hydroxybenzene
1) A
2) B
3) A
4) D
5) A
6) E
7) C
8) E
9) D
10) C
11) E
12) C
13) D
14) D
15) B
16) B
17) a. C-C=C=C=C=C
   b. This name is not correct because the chain was not numbered from the end that gives the lowest possible number for the first double bond.
   c. This compound should be named 1,4-hexadiene. Its molecular formula is \( \text{C}_6\text{H}_{10} \).
18) a. \[
\begin{array}{c}
  \text{C} \\
  \mid \\
  \text{C} \\
  \mid \\
  \text{C-C=C-C=C=C}
\end{array}
\]
   b. This name is not correct because the chain was not numbered from the end that gives the lowest possible number for the first double bond.
   c. This compound should be named 4-ethyl-1,4-hexadiene. Its molecular formula is \( \text{C}_8\text{H}_{14} \).
19) E
20) C
21) A
22) D
23) E
24) B
25) E
26) A
27) A
28) B
29) D
30) C
31) B
32) A
33) C
34) D
35) C
36) B
37) C
38) E
39) C
40) A  
41) D  
42) C  
43) C  
44) D  
45) E  
46) D  
47) A  
48) C  
49) E  
50) D  
51) A  
52) E  
53) A  
54) C  
55) B  

56) In a benzene ring, the six carbon atoms are often drawn in a ring with alternating single and double bonds between them. Another drawing shows a hexagon with a circle inside. In both cases, the six electrons not involved in the single bonds are thought to move freely around the ring, not really belonging to any particular pair of carbon atoms. This delocalization of electrons explains the observations that all the carbon-carbon bonds are the same length and that aromatics do not undergo addition reactions as would be expected if the extra electrons were localized. The delocalization of electrons stabilizes the ring system.

57) A  
58) E  
59) E  
60) D  
61) D  
62) E  
63) C  
64) K  
65) G  
66) B  
67) J  
68) M  
69) A  
70) E  
71) D  
72) F  
73) H  
74) C  
75) I  
76) L