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 1) _____
   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 2) _____
   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 3) _____
   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** 4) _____
   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. 5) _____
   A) C_2H_4 and C_2H_2
   B) C_2H_6 and C_3H_8
   C) C_2H_4 and C_3H_6
   D) C_2H_2 and C_2H_6
   E) C_2H_4 and C_2H_6

6) Which choice represents the carbon skeleton of 1,6–octadiene? 6) _____
   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–C
   D) C–C=C–C=C–C–C–C
   E) C–C=C–C–C–C–C=C

7) Which choice represents the carbon skeleton of 2,5–octadiene? 7) _____

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–C
D) C=C–C–C=C–C=C–C
E) C–C=C–C=C–C–C–C

8) Which choice represents the carbon skeleton of 2,4–octadiene? 8) _____

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–C
D) C=C–C–C=C–C=C–C
E) C–C=C–C=C–C–C–C

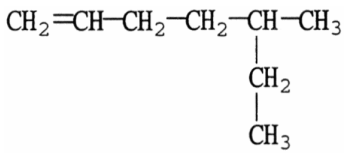
9) How many hydrogen atoms are contained in a molecule of 1,4–hexadiene? 9) _____

A) 18 B) 6 C) 14 D) 10 E) 12

10) How many hydrogen atoms are contained in a molecule of cyclopentene? 10) _____

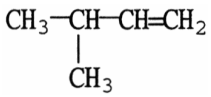
A) 12 B) 5 C) 8 D) 6 E) 10

11) What is the IUPAC name of the molecule shown? 11) _____



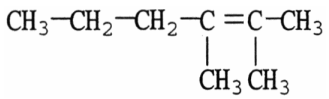
A) 5–ethyl–1–hexene
B) 3–methyl–6–heptene
C) 2–ethyl–5–hexene
D) octene
E) 5–methyl–1–heptene

12) What is the IUPAC name of the molecule shown? 12) _____



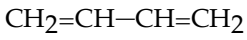
A) 1,1–dimethyl–2–propene
B) 2–methyl–3–butene
C) 3–methyl–1–butene
D) 3–methyl–1,2–butene
E) isopentene

13) What is the IUPAC name of the molecule shown? 13) _____



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? 14) _____



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? 15) _____
A) benzene
B) hexane
C) 1,3–butadiene
D) ethylene
E) acetylene

16) Which molecule represents 4–ethyl–2–hexyne? 16) _____
A) $(CH_3CH_2)_2CHC{\equiv}CCH(CH_2CH_3)_2$
B) $(CH_3CH_2)_2CHC{\equiv}CCH_3$
C) $CH_3CH_2C{\equiv}CCH_2CH_2CH_3$
D) $CH_3CH_2CH_2C{\equiv}CCH_3$
E) $CH_3CH_2CH_2CH_2C{\equiv}CCH_3$

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

17) This question has three parts: 17) _____
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.

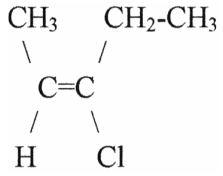
18) This question has three parts: 18) _____
a. Sketch the carbon skeleton of 3–ethyl–2,5–hexadiene.
b. Explain why this name is **not** correct.
c. Give the correct name and molecular formula of the compound with the carbon skeleton you drew.

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

19) The cause of cis–trans isomerism is 19) _____
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.

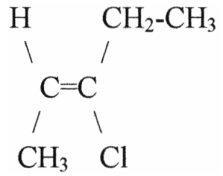
20) Cis–trans isomerism occurs when 20) _____
A) a branched alkane has a halogen added to two adjacent carbon atoms.
B) hydrogen is added to both of the carbon atoms in a double bond.
C) the carbons in an alkene double bond each have two different substituent groups.
D) the carbons in the para position 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 21) _____



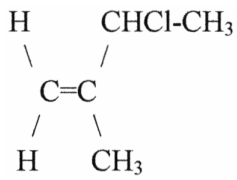
A) cis–3–chloro–2–pentene
B) monochloro–2–cis–pentene
C) trans–3–chloro–2–pentene
D) cis–3–chloro–3–pentene
E) trans–3–chloro–3–pentene

22) The name of the molecule shown is 22) _____



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

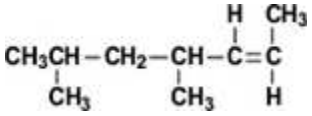
23) The name of the molecule shown is 23) _____



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? 24) _____
A) $(CH_3)_2C{=}CHCH_3$
B) $CH_3CH{=}CHCl$
C) $(CH_3)_2C{=}C(CH_3)_2$
D) $CH_3CH{=}C(CH_3)_2$
E) $CH_3CH{=}CCl_2$

25) What is the IUPAC name of the compound shown? 25) _____



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** 26) _____
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 27) _____
A) 120°. B) 109.5°. C) 105°. D) 90°. E) 180°.

28) The bond angle about a carbon atom involved in a triple bond is 28) _____
A) 105°. B) 180°. C) 120°. D) 90°. E) 109.5°.

29) Alkanes and alkenes are similar in all of the following properties **except** 29) _____
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** 30) _____
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 31) _____
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 32) _____
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? 33) _____
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? 34) _____
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? 35) _____
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 36) _____
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 CO_2, H_2O, 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 37) _____
A) two reactants combine to form one new product with no extra atoms.
B) a hydrocarbon reacts with oxygen to produce CO_2, H_2O, 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 38) _____
A) two reactants combine to form one new product with no extra atoms.
B) a hydrocarbon reacts with oxygen to produce CO_2, H_2O, 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 39) _____
A) a single reactant splits into two products.
B) a hydrocarbon reacts with oxygen to produce CO_2, H_2O, 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. 40) _____
A) addition
B) oxidation
C) combustion
D) substitution
E) reduction

41) When an alkene undergoes hydrogenation, the product is an 41) _____
A) alkene. B) alkyne. C) aromatic. D) alkane. E) alcohol.

42) When an alkene undergoes a hydration reaction the product is an 42) _____
A) aromatic. B) ether. C) alcohol. D) alkyne. E) alkane.

43) All of the following are examples of addition reactions of alkenes **except** 43) _____

A) chlorination.
B) hydration.
C) oxidation.
D) hydrogenation.
E) bromination.

44) Which reactant should be used to convert propene to 2–chloropropane? 44) _____

A) BrCl B) Cl_2 C) NaCl D) HCl E) H_2

45) Which reactant should be used to convert propene to 1,2–dichloropropane? 45) _____

A) BrCl B) NaCl C) HCl D) H_2 E) Cl_2

46) Which of the following reactions involves addition of two different elements to an alkene? 46) _____

A) bromination
B) hydrogenation
C) chlorination
D) hydrohalogenation
E) none of the above

47) When 2–butene reacts completely with bromine, the product is 47) _____

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? 48) _____

$(CH_3)_2C{=}CHCH_3 + HCl \rightarrow$?????

A) $(CH_3)_2CH{-}CH_2CH_2Cl$
B) $(CH_3)_2CCl{-}CHClCH_3$
C) $(CH_3)_2CCl{-}CH_2CH_3$
D) $Cl_2CH{-}CHClCH_3$
E) $(CH_3)_2CH{-}CHClCH_3$

49) Markovnikov's Rule refers to _____ 49) _____

A) The rate of hydrogen addition to an alkene with alkyl group substituents.
B) The temperature difference observed in the boiling points of *cis* and *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 50) _____
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 51) _____
A) $CH_2{=}CH_2{-}CH_3$.
B) $CH_3{-}CH_2{=}CH_2{-}CH_3$.
C) $CH_2{=}CH_2{-}CH_2Cl$.
D) $CH_2{=}CH_2$.
E) $CHCl{=}CH_2$.

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

53) The name of the polymer formed from $CH_2{=}CH_2$ is 53) _____
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 54) _____
average among two possible structures is
A) double bonding.
B) oxidation.
C) resonance.
D) polymerization.
E) cis–trans isomerism.

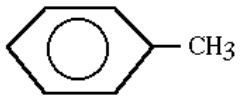
55) Which phrase most accurately describes the structure common to all aromatic compounds? 55) _____
A) a ring described as 1,3,5–hexatriene
B) identical bonds between all 6 carbon atoms, with 6 electrons moving freely
C) a six–membered ring with easily broken carbon–carbon bonds
D) a six–membered ring 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 56) _____
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 57) _____



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

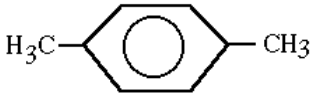
58) When the aromatic ring is named as a side chain or functional group, it is referred to as the _____ group. 58) _____

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

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

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

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



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. 61) _____

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

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

A) nitration.
B) bromination.
C) sulfonation.
D) chlorination.
E) hydrogenation.

63) Bromobenzene can be prepared from benzene by reaction with _____ 63) _____

A) HBr
B) Br_2
C) Br_2 and $FeBr_3$
D) HBr and H_20
E) Br_2 and KBr

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

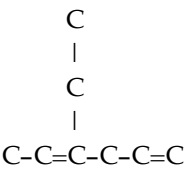
Match the following.

64) saturated
65) unsaturated
66) monomer
67) polymer
68) phenol
69) resonance
70) meta–dichlorobenzene
71) phenyl
72) para–dichlorobenzene
73) aniline
74) ortho–dichlorobenzene
75) aromatic
76) ortho–xylene

A) a concept used to describe a molecule structure as an average of two or more similar structures
B) a simple molecule that can be joined with many others to form a large molecule
C) another name for 1,2–dichlorobenzene
D) the term used when a benzene ring is a side chain or substituent group; abbreviated as $C_6H_5^-$
E) another name for 1,3–dichlorobenzene
F) another name for 1,4–dichlorobenzene
G) a term describing a hydrocarbon in which additional C—H bonds can be formed
H) the common name for aminobenzene
I) refers to a class of compounds containing a specific 6–membered ring structure with delocalized electrons
J) a large molecule made from many smaller molecules, often of only one or two kinds
K) a term describing a hydrocarbon which has the maximum number of C—H bonds possible
L) the common name for 1,2–dimethlybenzene
M) the common name for hydroxybenzene

64) _____
65) _____
66) _____
67) _____
68) _____
69) _____
70) _____
71) _____
72) _____
73) _____
74) _____
75) _____
76) _____

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 C_6H_{10}.
18) a.



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 C_8H_{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