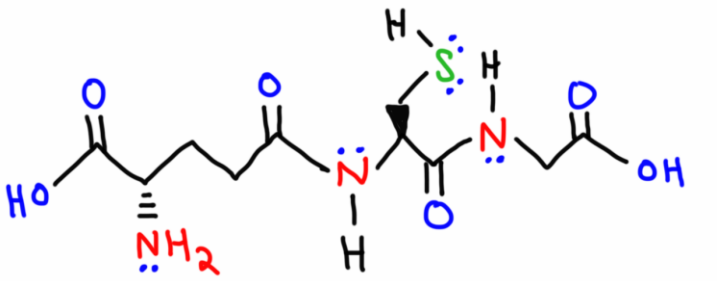
Organic Chemistry Exam 1 Worksheet

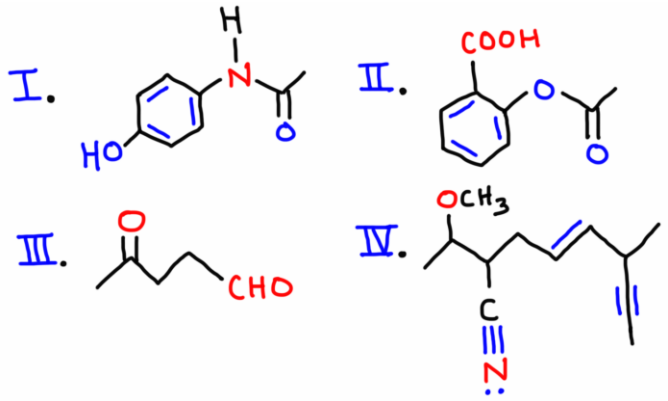
Organic Chemistry Tutor

1. Glutathione (GSH) is a tripeptide molecule composed of three amino acids – Glutamic Acid, Cysteine, and Glycine. It functions as an antioxidant capable of neutralizing free radicals and plays a role in detoxification. Which of the following functional groups is not found in Glutathione?



A. Carboxylic Acid
B. Ketone
C. Amine
D. Thiol
E. Amide

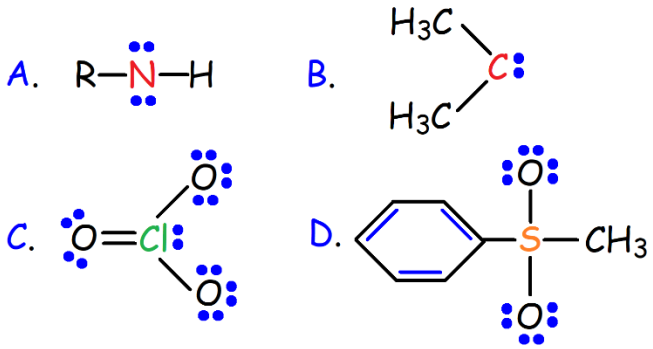
2. Identify the functional groups found in each molecule shown below:



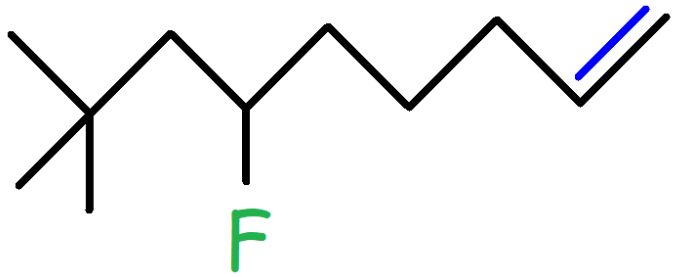
3. Draw a Lewis structure for each molecule shown below:

I. CH_3CN
II. C_2H_2
III. $C_6H_5\text{-}CH_2\text{-}N_2^+$
IV. CH_3COCH_3
V. CH_3CO_3H
VI. $CH_3CO_2CH_3$
VII. $CH_3(CH_2)_3CHO$
VIII. $(CH_3)_2CHCONH_2$

4. Which of the following Lewis structures contain a colored atom with a formal charge of 2+?

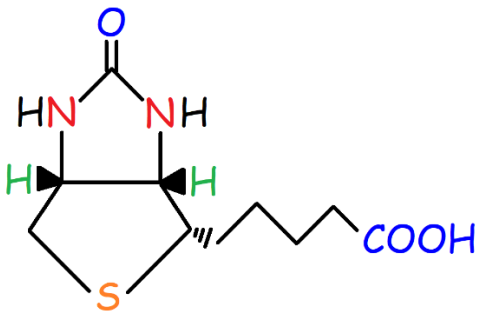


5. What is the condensed formula for the skeletal structure shown below?



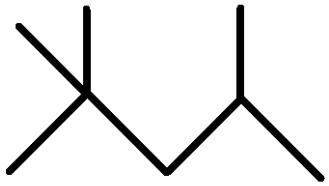
A. $(CH_3)_3CCH_2CHF(CH_2)_3CHCH_2$
B. $(CH_3)_3CCH_2CHF(CH_2)_3CH_2CH_3$
C. $(CH_3)_3CCHCHF(CH_2)_3CH_2CH_3$
D. $(CH_3)_2CHCH_2CHF(CH_2)_3CHCH_2$
E. $(CH_3)_2CHCH_2CF(CH_2)_3CHCH_3$

6. Consider the chemical structure of Biotin – Vitamin B7. How many hydrogen atoms are in this molecule?



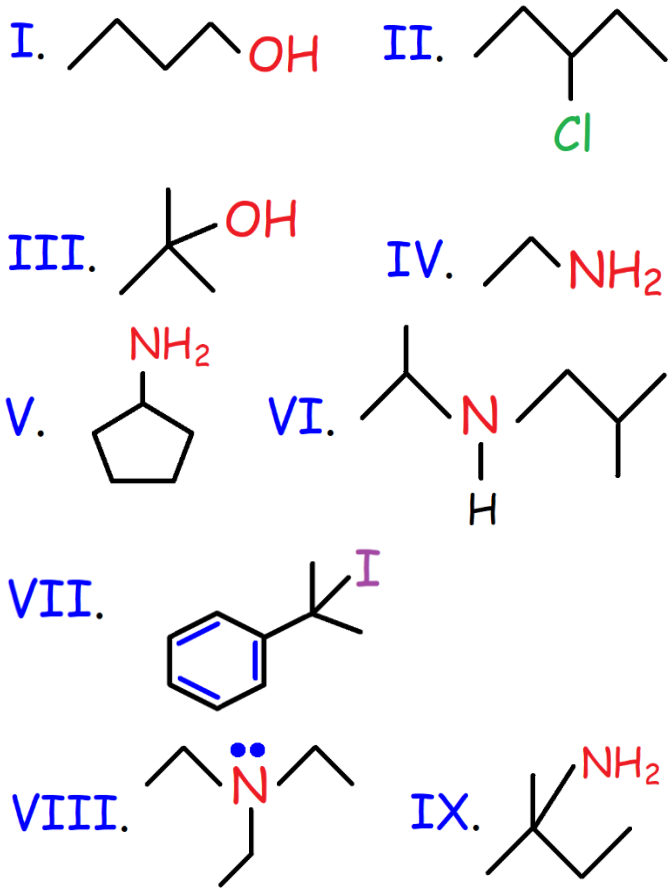
A. 14
B. 15
C. 16
D. 17
E. 18

7. Consider the structure of iso-octane, a compound found in gasoline. How many primary hydrogen atoms are found in this molecule?



A. 0
B. 1
C. 2
D. 9
E. 15

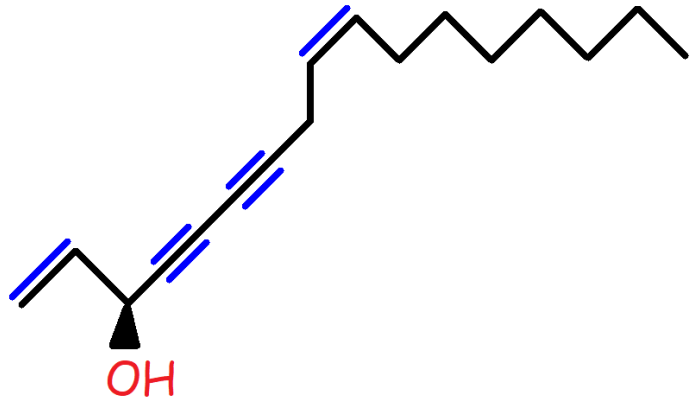
8. Identify each functional group and determine if it's primary, secondary, or tertiary.



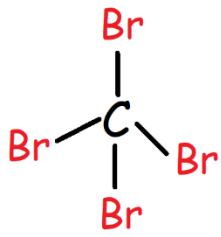
9. Which of the following bonds is most polar?

A. C-C
B. C-H
C. H-F
D. N-H
E. C-O

11. Falcarinol is a natural antifungal agent found in carrots that has been studied for its potential anticancer activity. How many sigma and pi bonds are present in falcarinol?



10. Which molecule has the largest dipole moment?

A.


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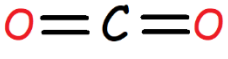

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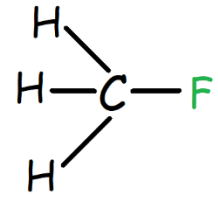
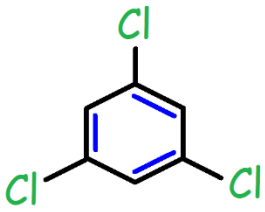
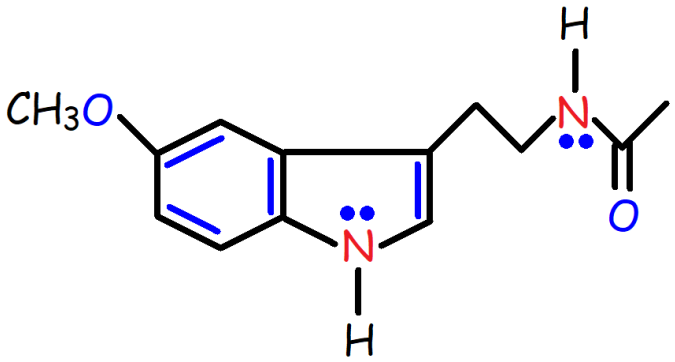
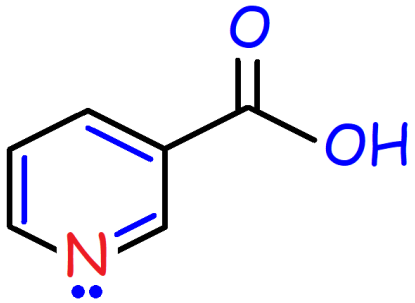


D.


12. Melatonin is a hormone produced by the body from the amino acid Tryptophan. Melatonin is associated with the circadian rhythms regulating the sleep-wake cycle. The chemical structure of Melatonin is shown below. What is the molecular formula of Melatonin?

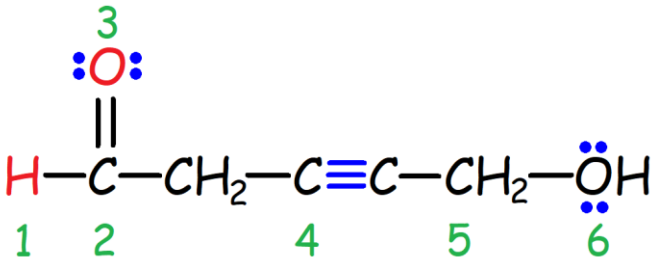


13. The chemical structure of Niacin, a form of Vitamin B_3, is shown below. In what type of orbital does the Nitrogen lone pair reside?

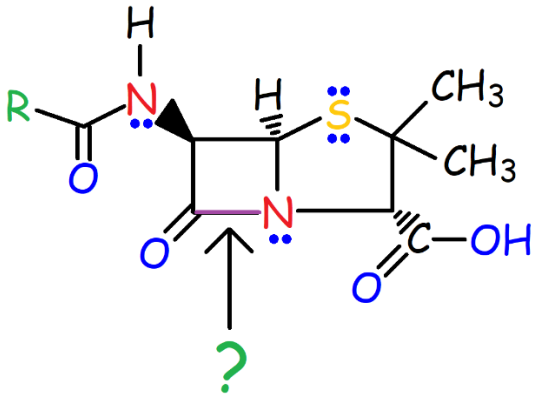


A. s
B. p
C. sp
D. sp^2
E. sp^3

14. Identify the hybridization of the indicated atoms shown below from left to right.



15. The core chemical structure of Penicillin, a natural B-lactam antibiotic, is shown below. What type of orbital overlap is present in the indicated bond?



A. $sp^2 - sp^2$
B. $sp^3 - sp$
C. $sp^2 - sp^3$
D. $sp^2 - sp$
E. $sp^3 - sp^3$

16. Rank the following Carbon-Carbon bonds in order of increasing bond strength.

I. $H_3C\text{-}CH_3$ II. $H_2C{=}CH_2$ III. $HC{\equiv}CH$

17. Rank the following Carbon-Carbon bonds in order of increasing bond length.

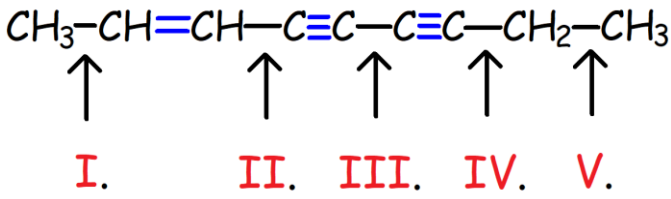
I. $H_3C\text{-}CH_3$ II. $H_2C{=}CH_2$ III. $HC{\equiv}CH$

18. The C-C bond energy in Ethane is 377 kJ/mol and the C-C bond energy in Ethylene is 720 kJ/mol. Given this information, would you expect the π bond in Ethylene to be weaker or stronger than the σ bond in Ethane?

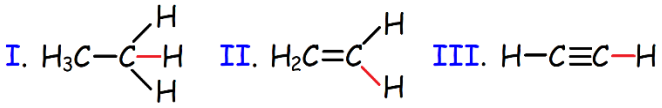
19. Rank the following Hydrogen Halides in order of increasing bond strength and in order of increasing bond length.

I. H-F II. H-Cl III. H-Br IV. H-I

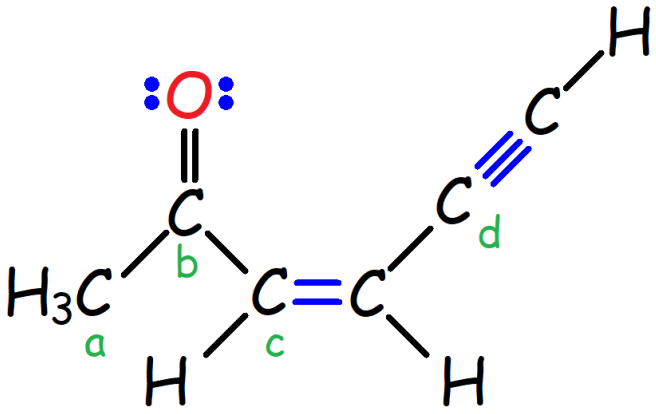
20. Rank the indicated bonds in order of decreasing bond length.



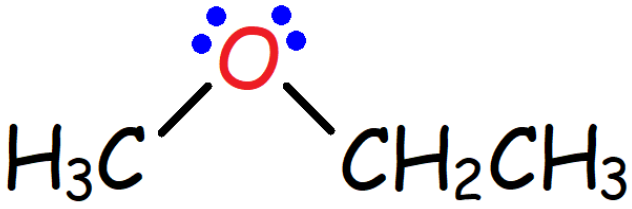
21. Rank the indicated bonds in order of increasing bond strength:



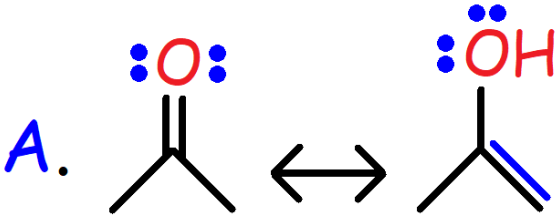
22. What is the molecular geometry and approximate bond angle for the indicated atoms shown below?

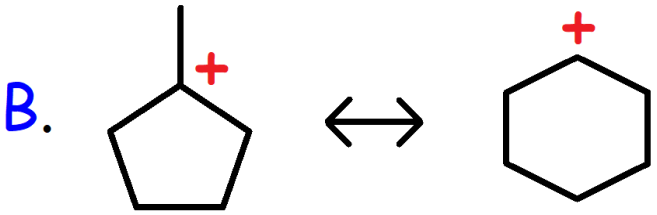


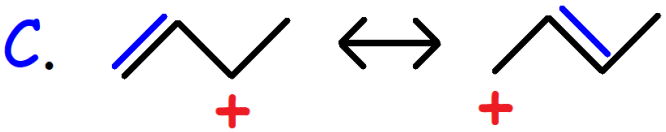
23. Consider the chemical structure of ethyl methyl ether. (a) What is the molecular geometry of the Oxygen atom? (b) What is the electron-pair geometry of the Oxygen atom?

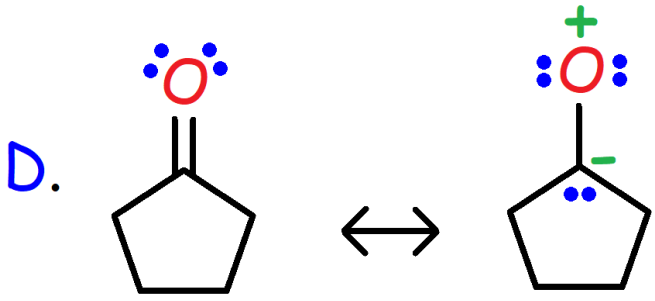


24. Which of the following pairs of structures represent resonance structures?

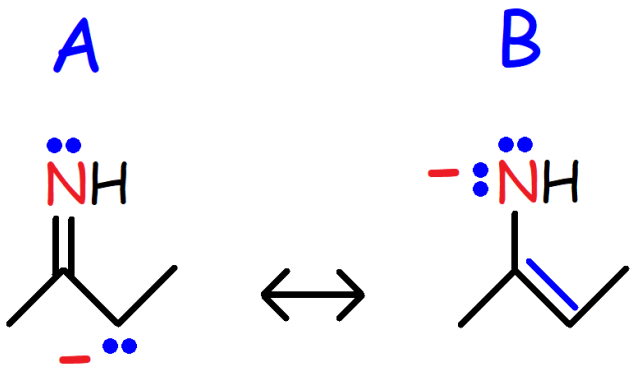
A. 

B. 

C. 

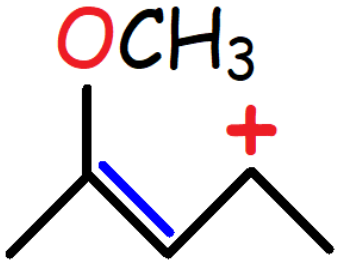
D. 

25. Consider the resonance structures shown below. Which structure is the major resonance contributor?

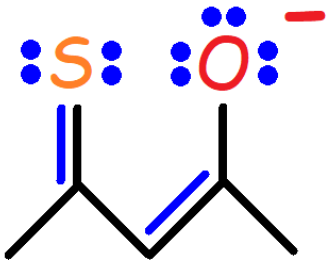


26. How many resonance structures can be drawn for the Cyanate ion ($^{-}$OCN)?

27. Consider the structure shown below. (a) Draw all possible resonance structures. (b) Identify the major resonance contributor. (c) Draw the resonance hybrid.



28. Consider the structure shown below. (a) Draw all possible resonance structures. (b) Identify the major resonance contributor. (c) Draw the resonance hybrid.



29. Which of the following statements is false?

A. Lewis acids are electron-pair acceptors.

B. A Bronsted-Lowry acid is a proton donor.

C. A strong acid will generate a very weak base in an acid-base reaction.

D. Strong acids have a large K_a value.

E. Strong acids have a high pK_a value.

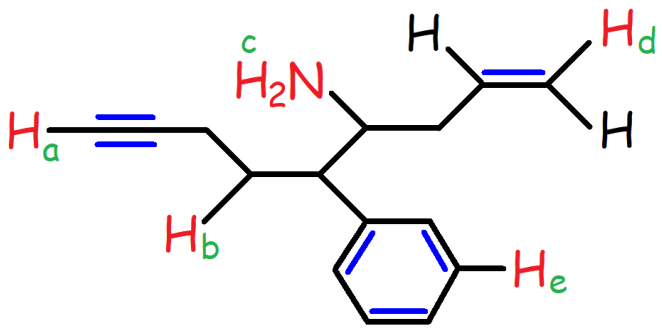
30. Which of the following is not an acid?

A. BH_3
B. HF
C. $AlCl_3$
D. CF_3OCF_3
E. $(CH_3)_3C^+$

31. Which of the following is the strongest acid?

A. CH_4
B. NH_3
C. HBr
D. H_2O
E. HI

32. Which proton will a non-bulky strong base abstract preferentially?



33. Rank the following acids in order of increasing acid strength:

I. CH_2FCOOH
II. CH_3COOH
III. $CH_2BrCOOH$
IV. $CH_3CHBrCH_2CH_2COOH$
V. CF_3COOH
VI. $CH_3CH_2CHBrCH_2COOH$

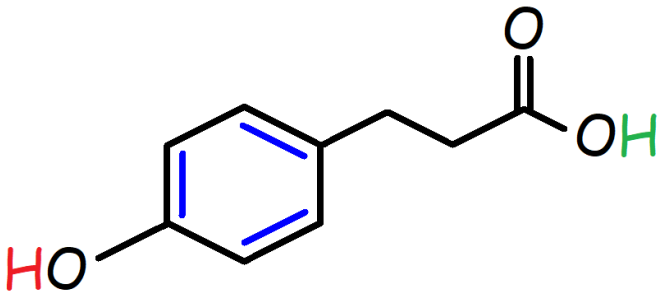
34. Which of the following acids have the lowest pKa value?

I. CH_3CH_2OH
II. CH_3COOH
III. $H_2N\text{-}CH_2\text{-}CH_2\text{-}SO_3H$

35. Which of the following molecules have the highest pKa?

A. CH_3OH
B. H_2O
C. EtOH
D. Cyclohexanol
E. $(CH_3)_3C\text{-}OH$

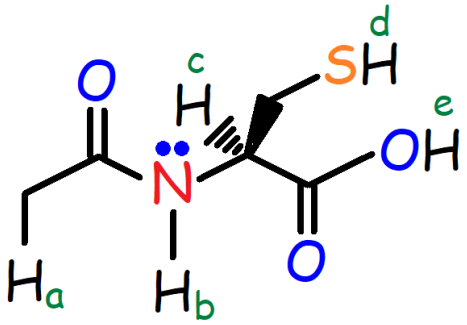
36. Which proton is more acidic? The green or red proton?



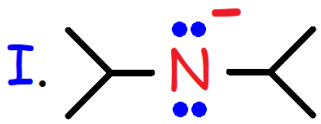
37. Rank the following acids in order of increasing acidity.

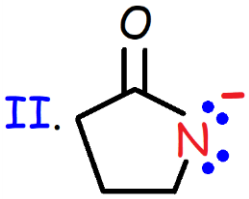
I. CH_3OH II. $CH_3OH_2^+$ III. CH_3NH_2 IV. $CH_3NH_3^+$

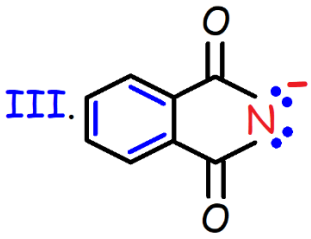
38. Consider the chemical structure of N-acetyl Cysteine (NAC) shown below. Rank the following in order of decreasing pKa values.



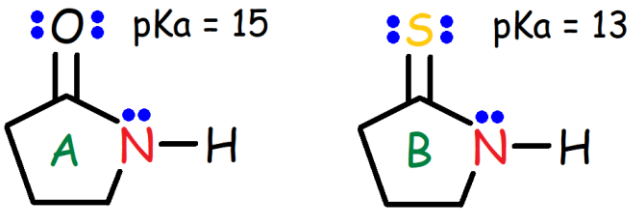
39. Which of the following represents the strongest base?

I. 

II. 

III. 

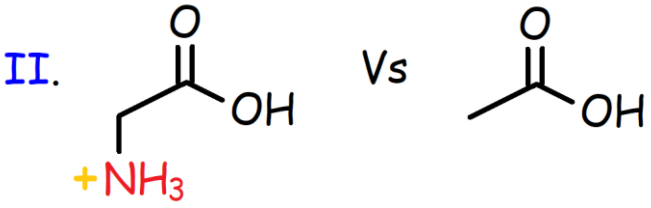
40. Which of the following effects explain why compound B is more acidic than compound A?

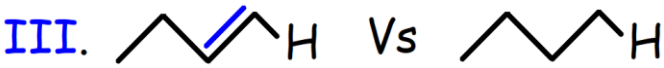


A. Inductive Effect
B. Hybridization
C. Electronegativity
D. Electron Delocalization
E. Atomic Size

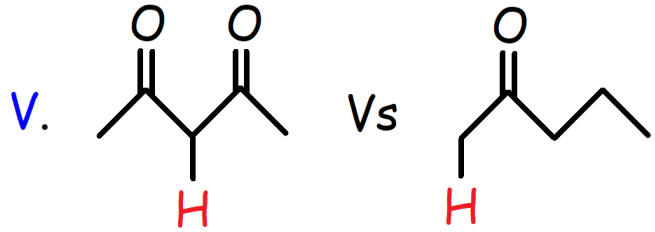
41. Circle the strongest acid. Determine the effect associated with each example. (Inductive effect, Hybridization, Electronegativity, Electron Delocalization, or Atomic Size?)

I. 

II. 

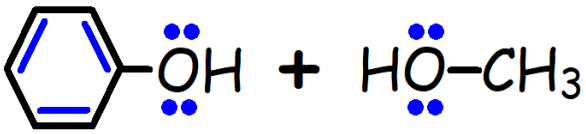
III. 

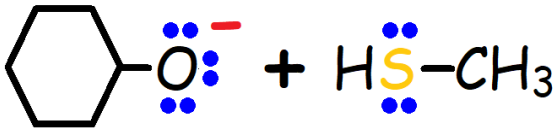
IV. 

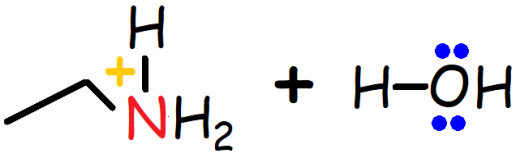
V. 

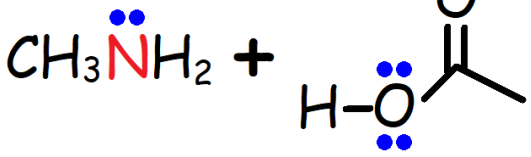
VI. 

42. Consider the reaction shown below. (a) Predict the products of the reaction. (b) Draw the curved arrows to show the flow of electrons. (c) Identify the Bronsted-Lowry acid and base as well as the conjugate acid and base. (d) Predict the position of equilibrium – is the reaction reactant favored or product favored?

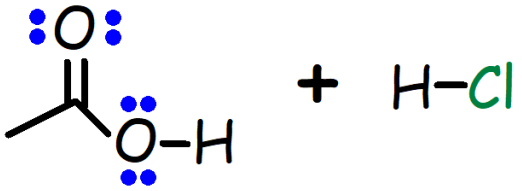
I. 

II. 

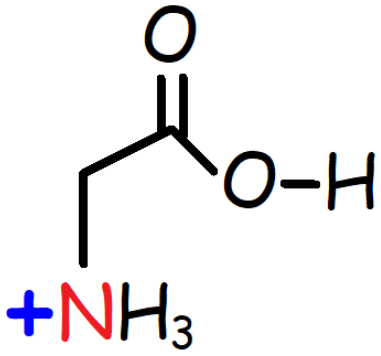
III. 

IV. 

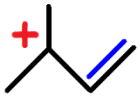
V. 

VI. 

43. The chemical structure of the amino acid Glycine is shown below. The pKa values are 2.3 and 9.6. What is the predominant form of Glycine at a pH of 7?



44. Which of the following carbocations is most stable?

A. 

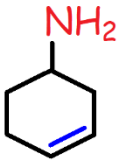
B. 

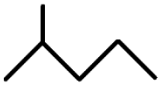
C. 

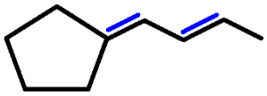
D. 

45. Which of the following structures represent a saturated compound?

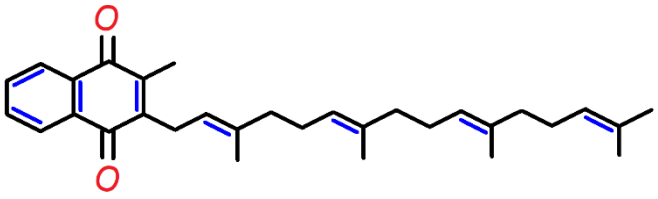
A. 

B. 

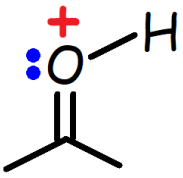
C. 

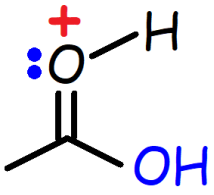
D. 

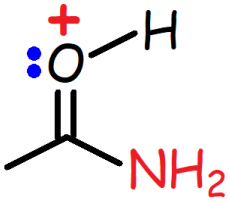
47. Menatetrenone (MK-4) is a form of vitamin K-2 usually found in fermented foods. What is the index of hydrogen deficiency (IHD) of Menatetrenone?

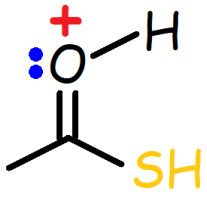


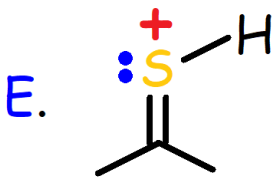
46. Which of the following protons is most acidic?

A. 

B. 

C. 

D. 

E. 

48. Calculate the Index of Hydrogen Deficiency (IHD) for each of the following molecular formulas: (a) C_5H_{10} (b) C_4H_8O (c) $C_6H_{11}Br$ (d) C_7H_9N

49. How many hydrogen atoms are present in (a) a saturated hydrocarbon with 15 Carbon atoms? (b) an unsaturated 18-Carbon hydrocarbon with an IHD value of 4?

50. Draw an uncharged Lewis structure for each molecular formula: (a) C_5H_{12} (b) C_3H_6O (c) $C_6H_{10}N$ (d) C_4H_7Br.

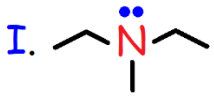
51. Which of the following molecules have the highest boiling point?

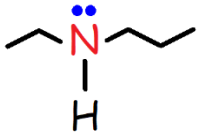
A. $CH_3CH_2CH_2CH_2CH_2CH_3$
B. $CH_3(CH_2)_6CH_3$
C. $(CH_3)_4C$
D. $(CH_3)_2CHCH_2CH_3$
E. $CH_3CH_2CH_2CH_2CH_3$

52. Which of the following molecules will have the lowest boiling point?

A. $CH_3CH_2CH_2CH_3$
B. $CH_3CH_2OCH_2CH_3$
C. $(CH_3)_2CHOCH_3$
D. $CH_3CH_2CH_2CH_2OH$

53. Rank the following compounds in order of increasing boiling point.

I. 

II. 

III. 

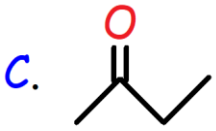
IV. 

V. 

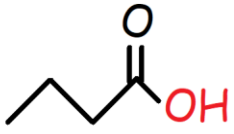
54. Which of the following compounds have the highest boiling point?

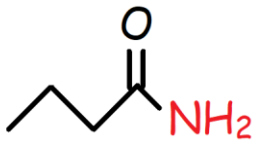
A. 

B. 

C. 

D. 

E. 

F. 

55. Which of the following compounds have the lowest boiling point?

A. $CH_3CH_2CH_2CH_2$-**OH**
B. $CH_3CH_2CH_2CH_2$-**I**
C. $(CH_3)_3C$-**Cl**
D. $CH_3CH_2CH_2CH_2$-**Cl**
E. $CH_3CH_2CH_2CH_2$-**SH**

56. Consider the melting points of various alkanes shown below. As the number of carbon atoms increase from an odd number to an even number, why is there such a large increase in the melting point values?

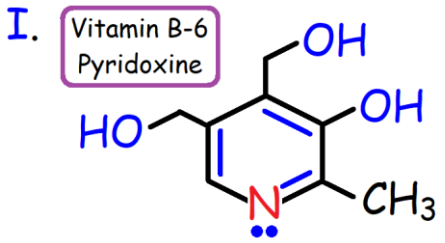
Alkanes:	**Melting Point:**
Methane	-182° C
Ethane	-183° C
Propane	-188° C
Butane	-138° C
Pentane	-130° C
Hexane	-95° C
Heptane	-91° C
Octane	-57° C
Nonane	-51° C
Decane	-30° C

57. Which of the following compounds have the highest solubility in water?

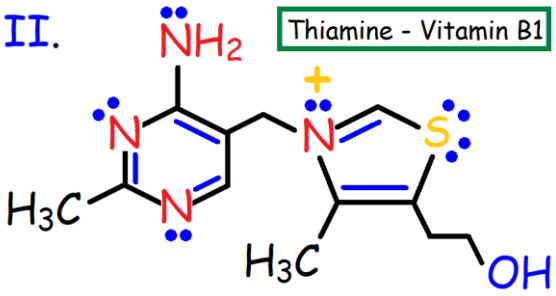
A. 1-Hexanol
B. 1-Butanol
C. Heptane
D. Di-isopropyl Ether

58. Consider the chemical structures shown below. Identify each vitamin as either water-soluble or fat-soluble.

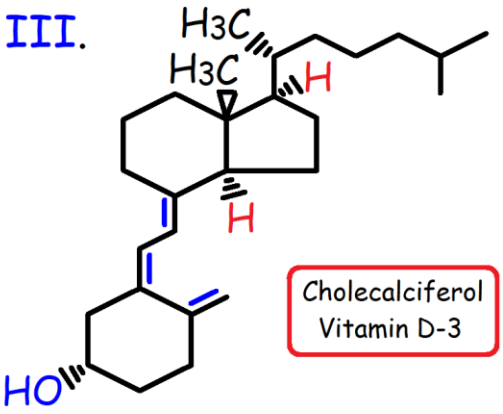
I.



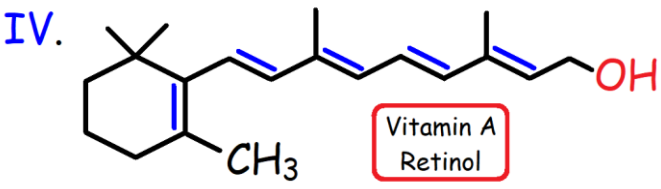
II.



III.



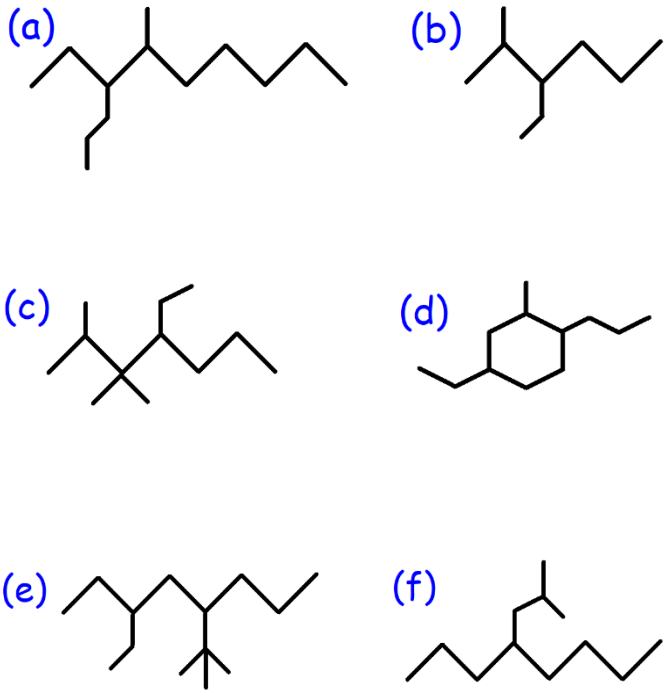
IV.



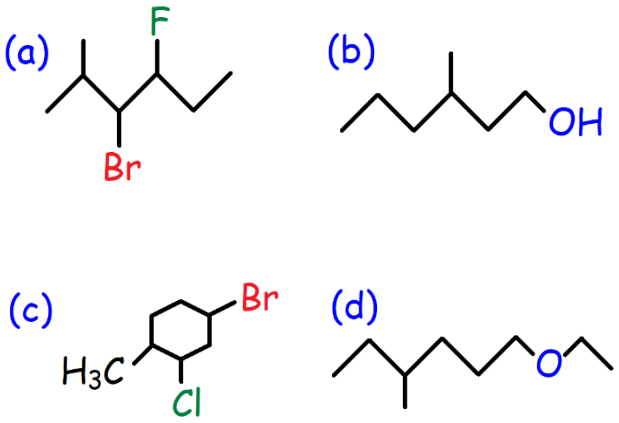
59. Draw a skeletal structure for each of the following molecules:

(a) 4-bromo-1-chlorohexane
(b) 3-ethyl-2,4-dimethyloctane
(c) 1-ethyl-3-methylcyclopentane
(d) 2,2,3-trimethyl-4-phenylheptane

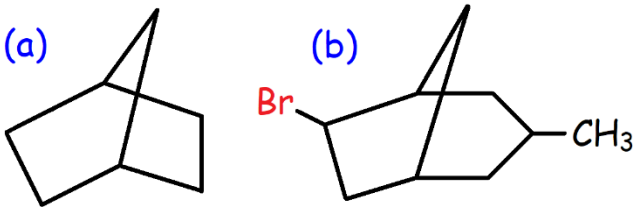
60. Provide the IUPAC nomenclature for each compound shown below.



61. Give the IUPAC nomenclature for each molecule shown below.



62. Provide the IUPAC nomenclature for each bicyclic compound shown below.



63. Which of the following alkyl halides have the greatest solubility in water?

A. CH_3CH_2-**Br**
B. CH_3CH_2-**Cl**
C. $CH_3CH_2CH_2CH_2$-**I**
D. CH_3CH_2-**F**
E. $CH_3CH_2CH_2CH_2$-**Br**

64. What type of orbital overlap is present in the C-H bond of the methyl cation ($+CH_3$)? Draw the orbital picture of the methyl cation.

65. Draw the orbital picture of Acetylene (C_2H_2).

66. Which of the following alkanes have the highest density?

A. $CH_3CH_2CH_2CH_2CH_3$ – Pentane
B. $CH_3CH_2CH_2CH_2CH_2CH_3$ – Hexane
C. $CH_3(CH_2)_6CH_3$ – Octane
D. $CH_3(CH_2)_8CH_3$ - Decane

67. The heat of combustion for Octane, 2,5-dimethylhexane, and 2,2,3,3,-tetramethylbutane are -5470 kJ/mol, -5460 kJ/mol, and -5452 kJ/mol respectively. Based on this data, which of the three alkanes listed above would you expect to be most stable?

68. Which of the following statements is false?

A. Longer straight-chained alkanes have a higher melting point than shorter straight-chained alkanes.

B. The density of an alkane increases with increasing molecular weight.

C. Branched alkanes are more stable than straight-chained alkanes.

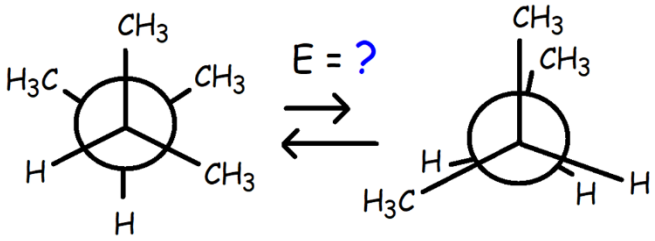
D. Branched alkanes have a lower boiling point than straight-chained alkanes.

E. Alkanes are nonpolar molecules that have London dispersion forces which makes them water-soluble.

69. (a) Draw the Newman projections for butane along the C2-C3 bond. (b) Identify the most stable conformation. (c) Draw a potential energy diagram with respect to the degree of rotation about the C2-C3 bond.

70. Calculate the energy barrier to rotation for the process shown below:

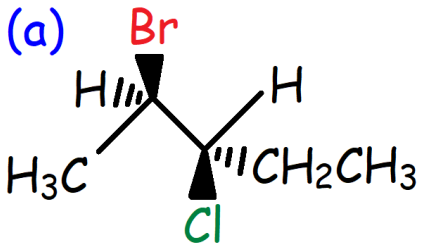
Group Interaction	Potential Energy
CH_3–CH_3 Gauche	3.8 kJ/mol
H-H Eclipse	4 kJ/mol
H-CH_3 Eclipse	6 kJ/mol
CH_3-CH_3 Eclipse	11 kJ/mol

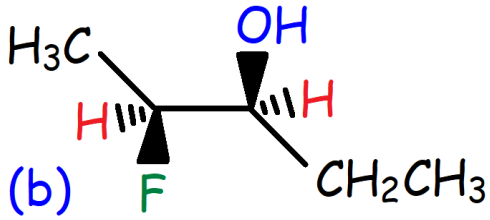


71. Draw the least stable conformation of 2-methylbutane along the C2-C3 bond. Determine the relative potential energy of this conformation.

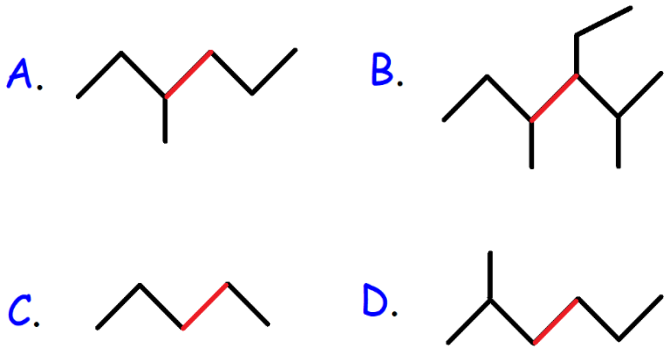
Group Interaction	Potential Energy
CH_3–CH_3 Gauche	3.8 kJ/mol
H-H Eclipse	4 kJ/mol
H-CH_3 Eclipse	6 kJ/mol
CH_3-CH_3 Eclipse	11 kJ/mol

72. Convert each perspective formula into a Newman projection.

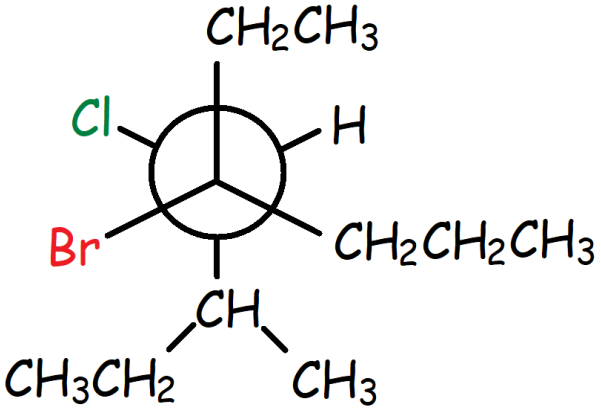




73. Which of the following highlighted bonds have the highest energy barrier to rotation?

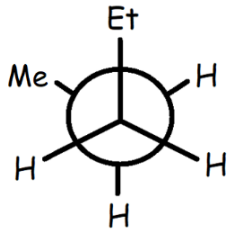


74. What is the IUPAC nomenclature of the Newman projection shown below?

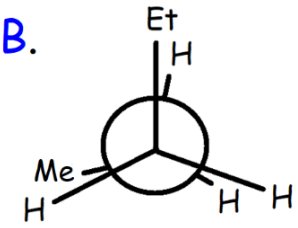


75. Which of the following conformations contain steric strain only?

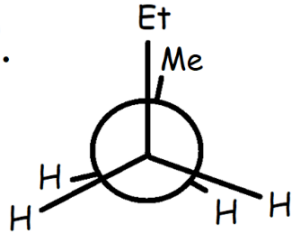
A.



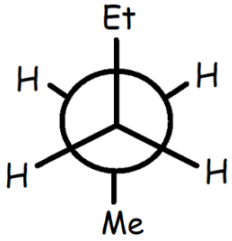
B.



C.



D.

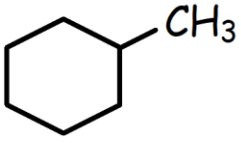


76. Which of the following cycloalkanes have the least amount of angle strain?

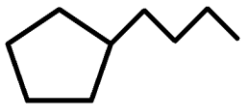
A.

B.

C.



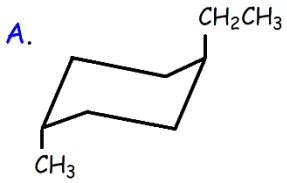
D.



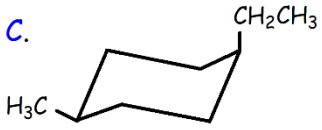
77. The heat of combustion per CH_2 group for Cyclopentane and Cycloheptane are -658 kJ/mol and -657 kJ/mol respectively. Which cycloalkane has less angle strain? Cyclopentane or Cycloheptane?

78. Which of the following chair conformations of 1-ethyl-4-methylcyclohexane is most stable?

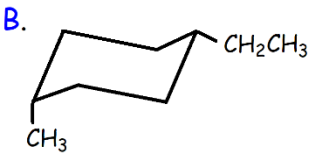
A.



C.

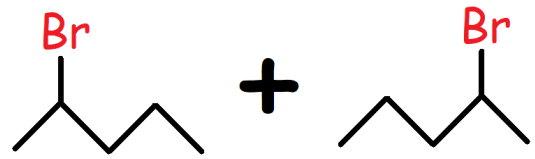


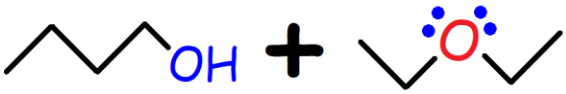
B.

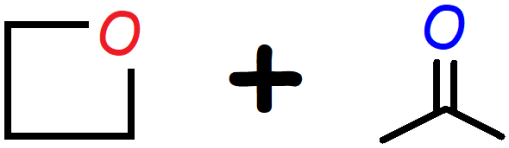


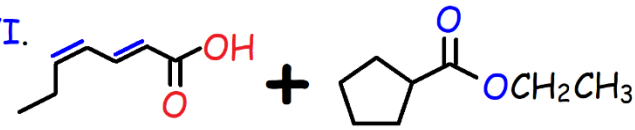
D.

79. Draw the most stable chair conformation of trans-1-methyl-3-isopropylcyclohexane.

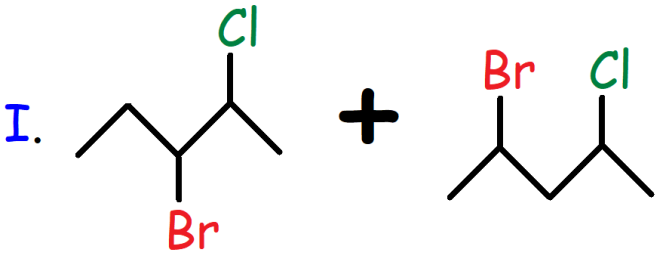
III. 

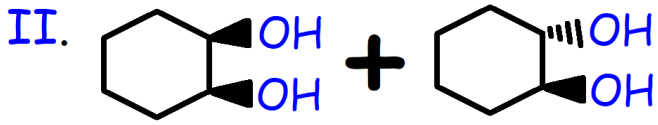
IV. 

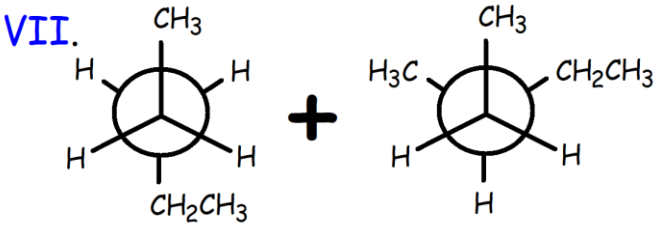
V. 

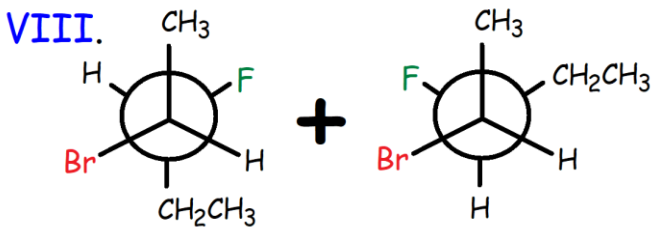
VI. 

80. Describe the relationship of each pair of compounds as constitutional isomers, conformers, cis-trans isomers, identical compounds, or completely different compounds.

I. 

II. 

VII. 

VIII. 

81. Which of the following statements is false?

A. Constitutional Isomers have the same chemical formula, but the atoms are connected differently.

B. Stereoisomers have the same chemical formula with the same connectivity, but the atoms are arranged in space differently.

C. Cis-Trans geometric isomers are diastereomers – a type of stereoisomer.

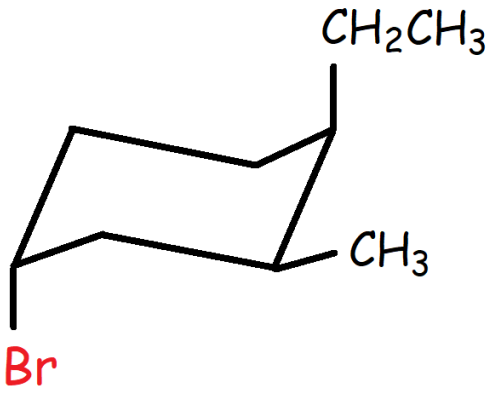
D. Constitutional isomers have the same physical properties but differ in chemical properties.

E. Conformational Isomers have the same chemical formula, same connectivity but differ in atomic spatial arrangement by rotation and have different chemical potential energies.

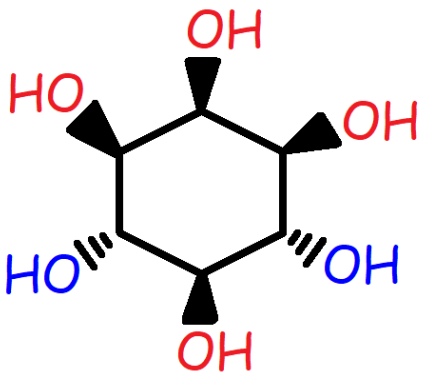
82. Which of the following conformations of Cyclohexane is the least stable?

A. Chair Conformation
B. Boat Conformation
C. Twist-Boat Conformation
D. Half-Chair Conformation

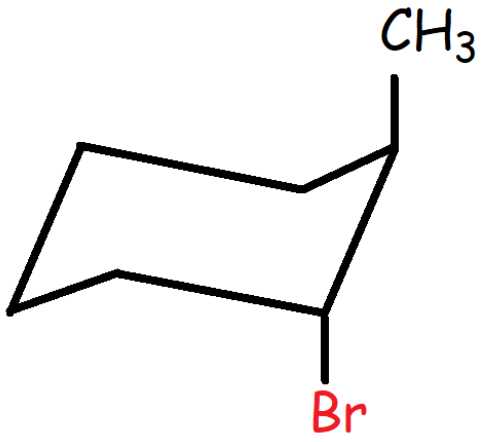
83. What is the IUPAC nomenclature for the compound shown below?



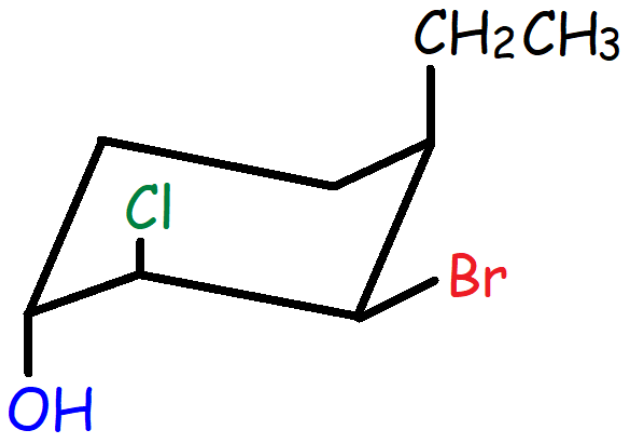
84. The chemical structure of Inositol, formerly known as Vitamin B8, is shown below. Draw a chair conformation of this molecule.



85. Perform a ring flip on the chair conformation shown below.

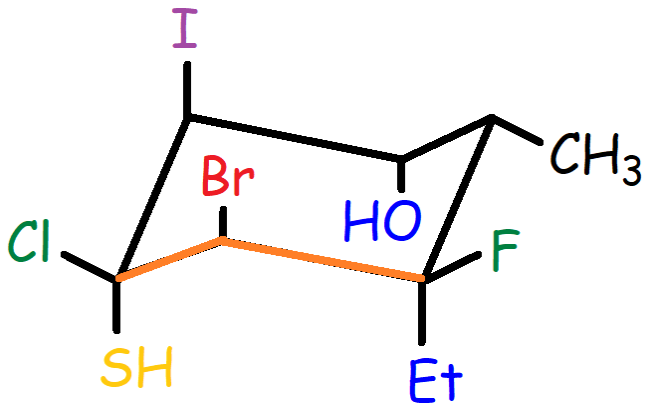


86. Convert the chair conformation into a bond line structure.



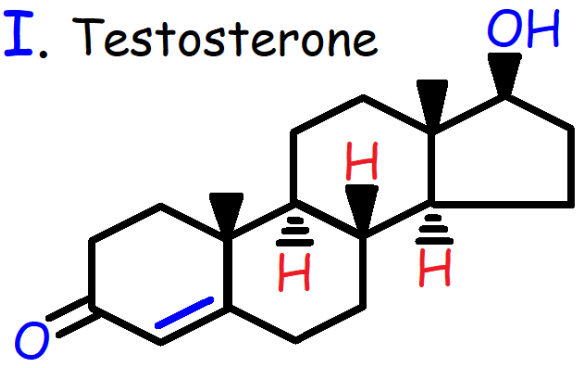
87. Decalin is a 10-carbon organic molecule containing two cyclohexane rings that are fused. The fused rings share two adjacent carbon atoms. Draw the chair conformation of cis and trans Decalin. Which isomer is more stable? Cis or Trans Decalin?

88. Convert the chair conformation into a Newman projection viewing it through the indicated bonds shown below.

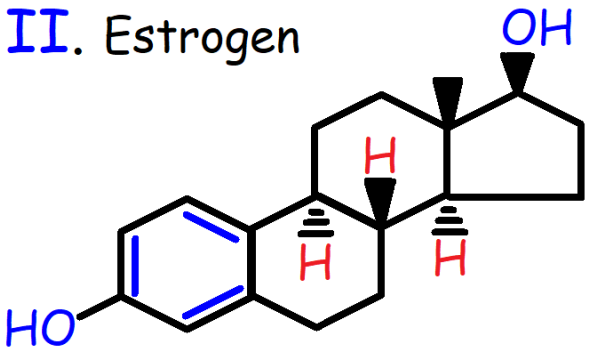


89. Rank the following compounds in order of increasing water solubility.

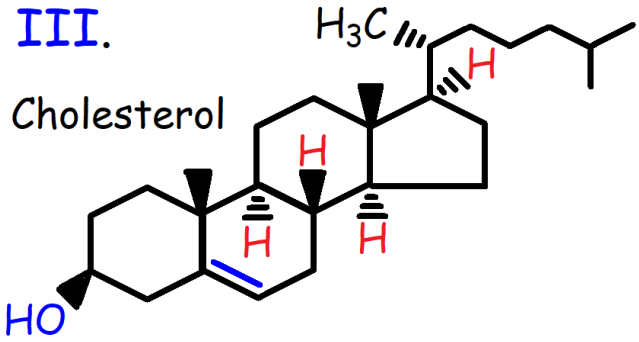
I. Testosterone



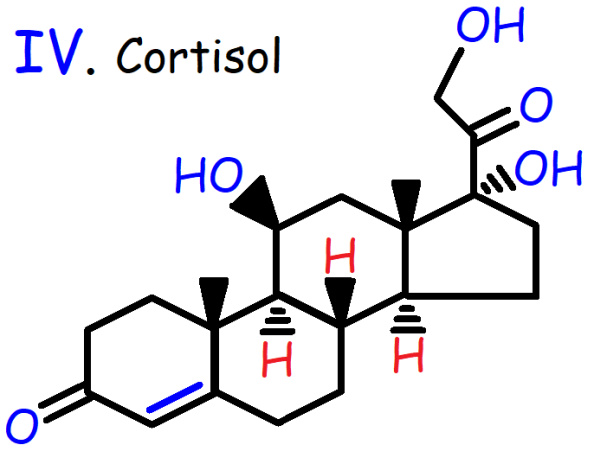
II. Estrogen



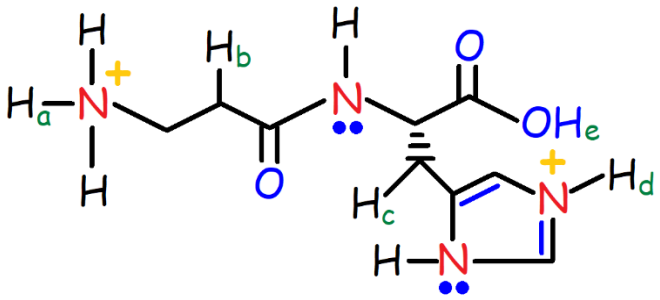
III. Cholesterol



IV. Cortisol



90. Carnosine is a dipeptide composed of the amino acids B-Alanine and Histidine. Carnosine is an antioxidant found in foods that is known to resist the effects of glycation. Rank the highlighted protons in Carnosine in order of increasing acidity.

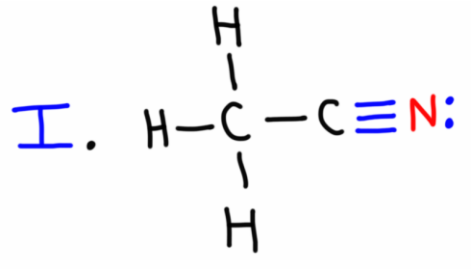


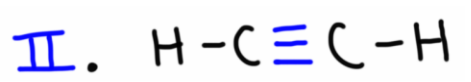
Answers:

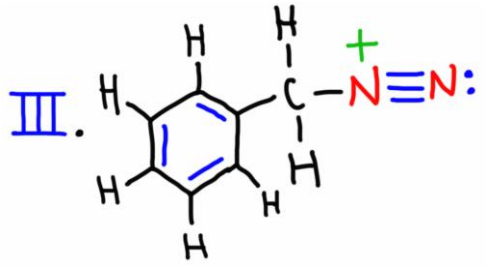
1. B

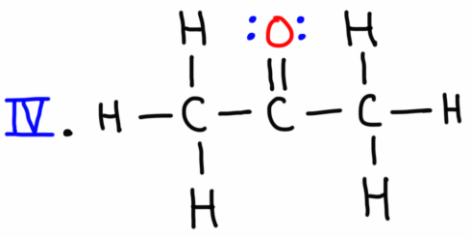
2. I. Alcohol, Aromatic Ring, and Amide
II. Carboxylic Acid, Aromatic Ring, and Ester
III. Ketone and Aldehyde
IV. Ether, Nitrile, Alkene, and Internal Alkyne

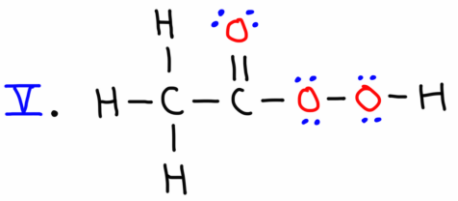
3.

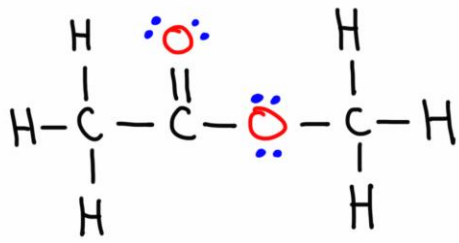


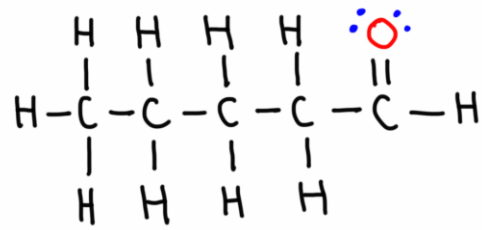


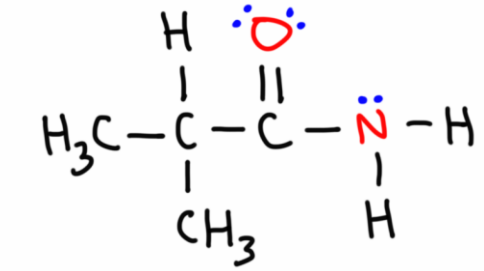






VI. 

VII. 

VIII. 

4. D
5. A
6. C
7. E

8. I. Primary Alcohol II. Secondary Alkyl Halide III. Tertiary Alcohol IV. Primary Amine V. Primary Amine VI. Secondary Amine VII. Tertiary Benzylic Halide VIII. Tertiary Amine IX. Primary Amine

9. C
10. C

11. 41 σ and 6 π bonds
12. $C_{13}H_{16}N_2O_2$

13. D

14. 1 = s, 2 = sp^2, 3 = sp^2, 4 = sp, 5 = sp^3, and 6 = sp^3.

15. C

16. I < II < III
17. III < II < I

18. 720 – 377 = 343 kJ/mol of π bond energy which is less than the σ bond energy of 377 kJ/mol. Therefore, the π bond is expected to be weaker than the σ bond.

19. Bond Strength: IV < III < II < I
Bond Length: I < II < III < IV

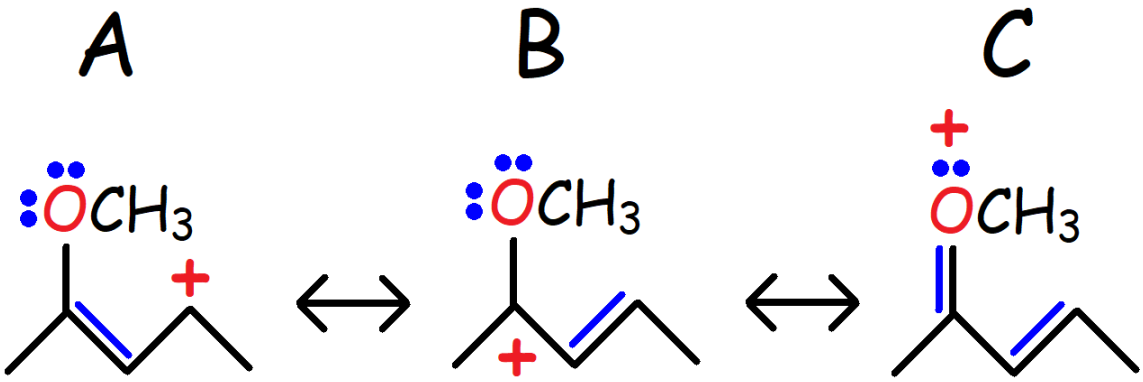
20. V > I > IV > II > III
21. I < II < III

22a. Tetrahedral, 109.5^0, sp^3 hybridization.
22b. Trigonal Planar, 120^o, sp^2 hybridization.
22c. Trigonal Planar, 120^0, sp^2 hybridization.
22d. Linear, 180^0, sp hybridization.

23a. Bent
23b. Tetrahedral

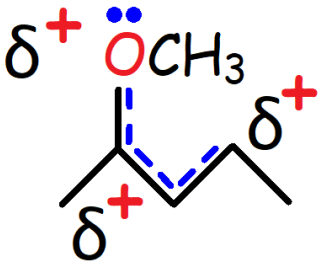
24. C
25. Structure B
26. 3

27a.

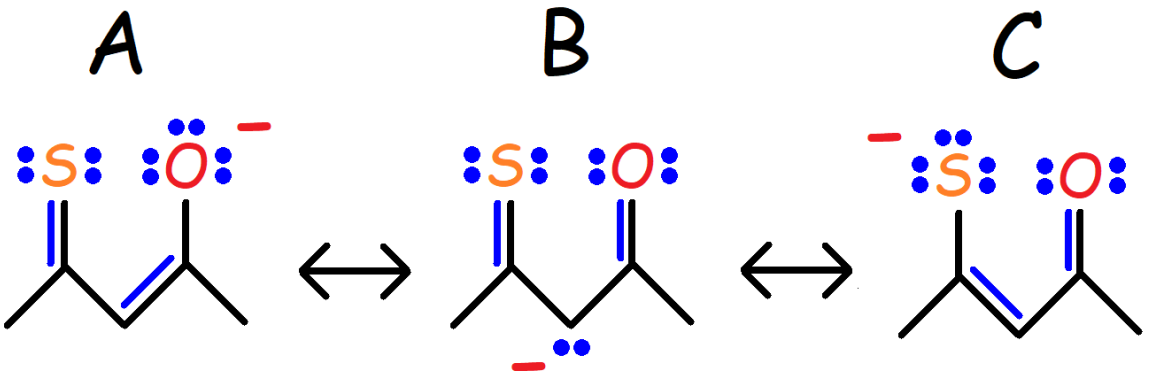


27b. Structure C is the major resonance contributor – it is the most stable structure due to the fact that all empty orbitals are filled with electrons.

27c.

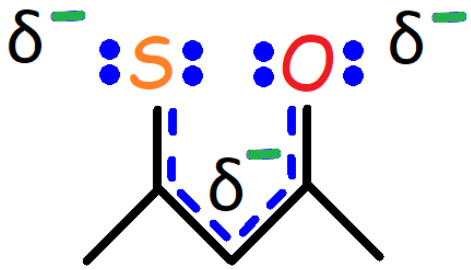


28a.



28b. Structure C is the major resonance contributor – it is the most stable structure due to the relatively large size of the Sulfur atom compared to the Oxygen and Carbon Atom. Larger atoms can stabilize a negative charge much better than smaller atoms.

28c.



29. E
30. D
31. E
32. Proton a
33. II < IV < VI < III < I < V
34. III
35. E
36. The green proton is more acidic.
37. III < I < IV < II
38. $H_c > H_a > H_b > H_d > H_e$
39. I
40. E

41.

I. $CH_3CH_2PH_2$ – Atomic Size

II. H_3N^+-CH_2COOH – Inductive Effect & Electronegativity

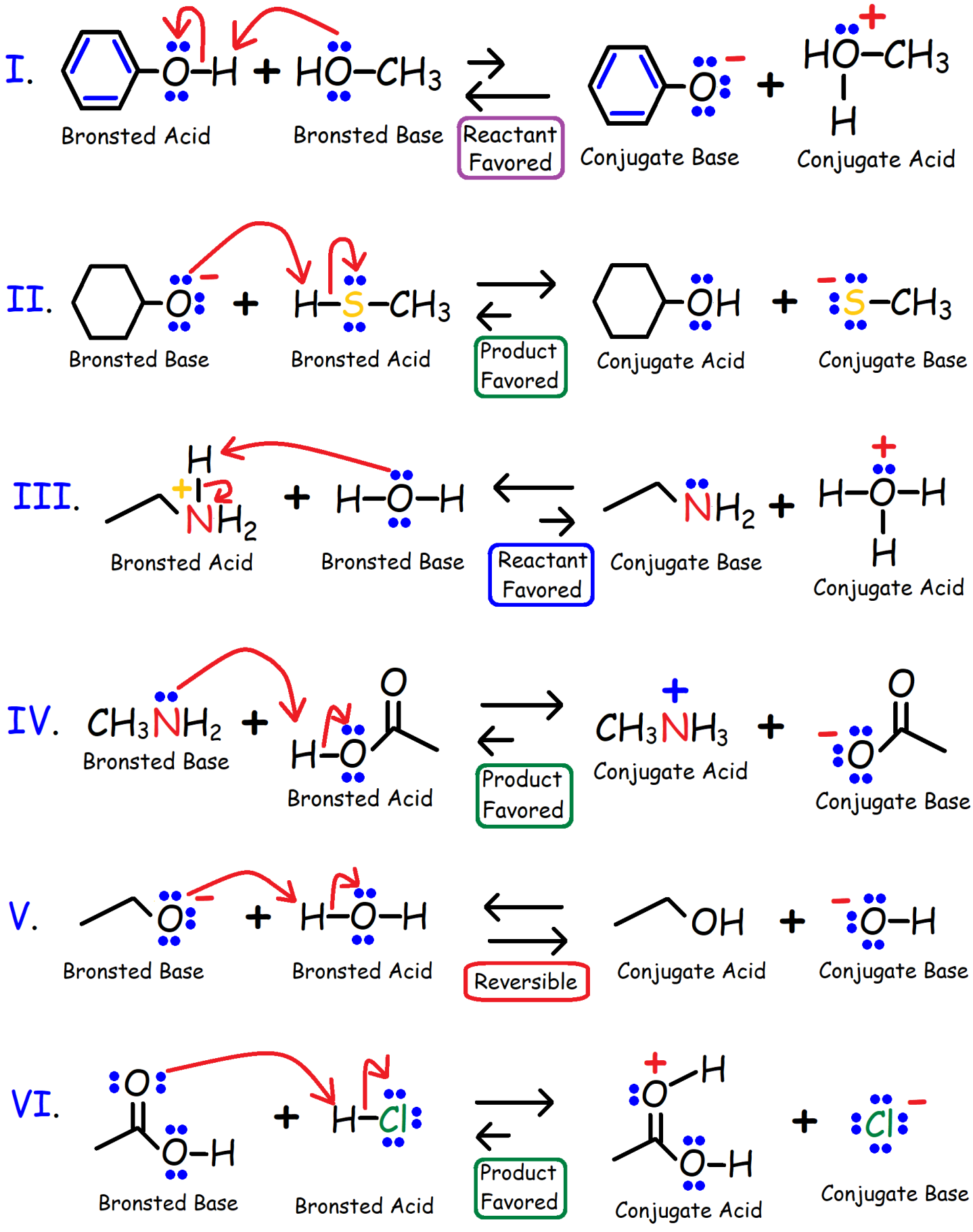
III. $CH_3CH_2CH{=}CH_2$ – Hybridization

IV. C_6H_5-SH – Electronegativity

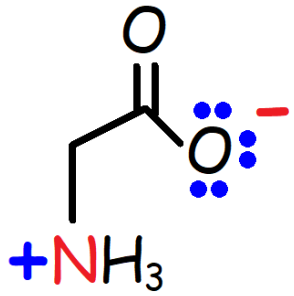
V. $CH_3COCH_2COCH_3$ – Electron Delocalization, Inductive Effect, and Electronegativity

VI. $CH_3CH_2CH{=}CH_2$ – Electron Delocalization

42.


I.
Bronsted Acid
Bronsted Base
Reactant Favored
Conjugate Base
Conjugate Acid
II.
Bronsted Base
Bronsted Acid
Product Favored
Conjugate Acid
Conjugate Base
III.
Bronsted Acid
Bronsted Base
Reactant Favored
Conjugate Base
Conjugate Acid
IV.
Bronsted Base
Bronsted Acid
Product Favored
Conjugate Acid
Conjugate Base
V.
Bronsted Base
Bronsted Acid
Reversible
Conjugate Acid
Conjugate Base
VI.
Bronsted Base
Bronsted Acid
Product Favored
Conjugate Acid
Conjugate Base

43.

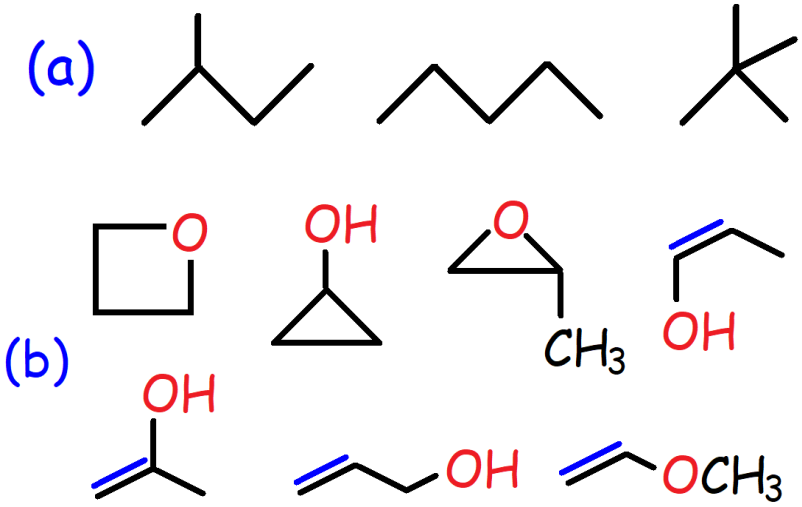


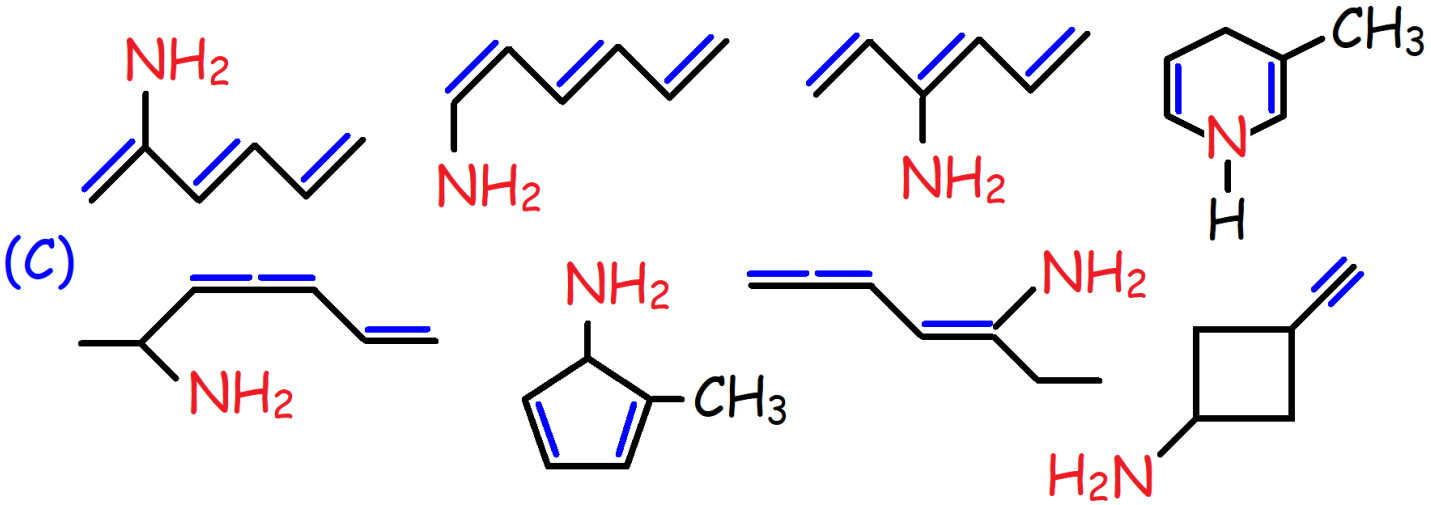
44. A
45. C
46. E
47. IHD = 12

48a. 1
48b. 1
48c. 1
48d. 4

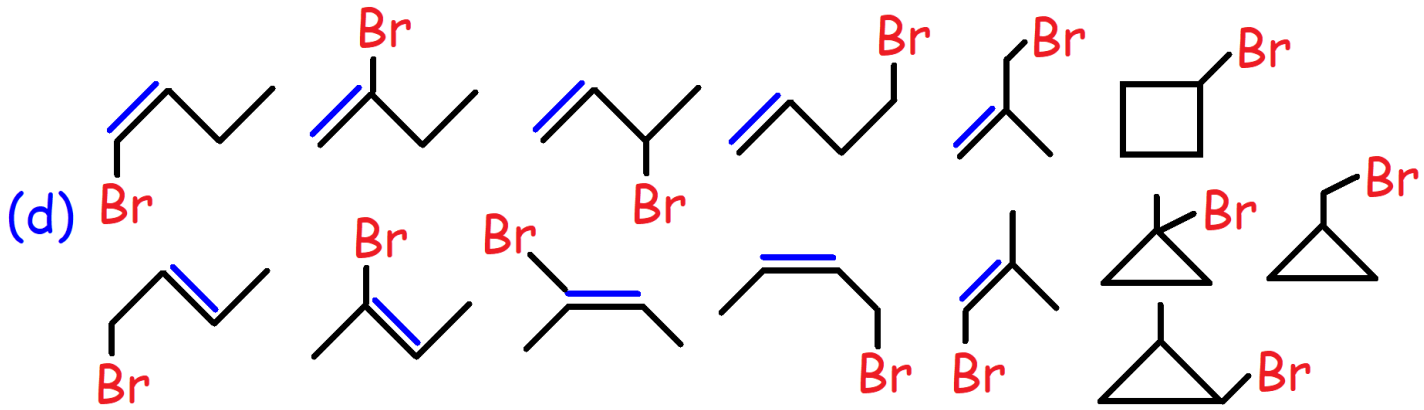
49a. 32
49b. 30

50.





(There are many more structures that can be drawn for $C_6H_{10}N$)



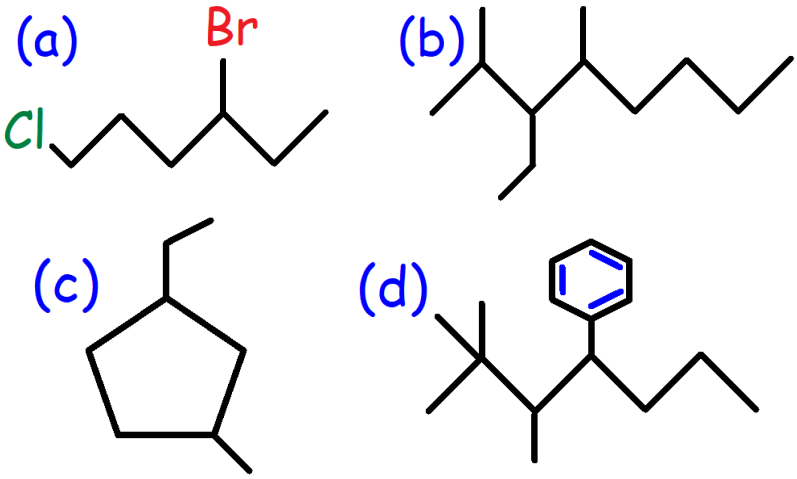
51. B
52. D
53. I < III < II < IV < V
54. F
55. C

56. It's due to packing. Hydrocarbons with an even number of Carbon atoms can pack better when placed adjacent to each other leading to increased Van Der Waal Interactions.

57. B

58. I. Water-soluble II. Water-soluble III. Fat-soluble IV. Fat-soluble

59.



60a. 4-ethyl-5-methyldecane
60b. 3-ethyl-2-methylhexane
60c. 4-ethyl-2,3,3-trimethylheptane
60d. 4-ethyl-2-methyl-1-propylcyclohexane
60e. 5-(1,1-dimethylethyl)-3-ethyloctane
60f. 4-(2-methylpropyl)octane

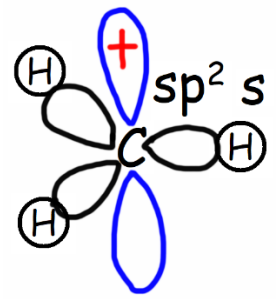
61a. 3-bromo-4-fluoro-2-methylhexane
61b. 3-methyl-1-hexanol
61c. 4-bromo-2-chloro-1-methylcyclohexane
61d. 1-ethoxy-4-methylhexane

62a. Bicyclo[2.2.1]heptane
62b. 6-bromo-3-methylbicyclo[3.2.1]Octane

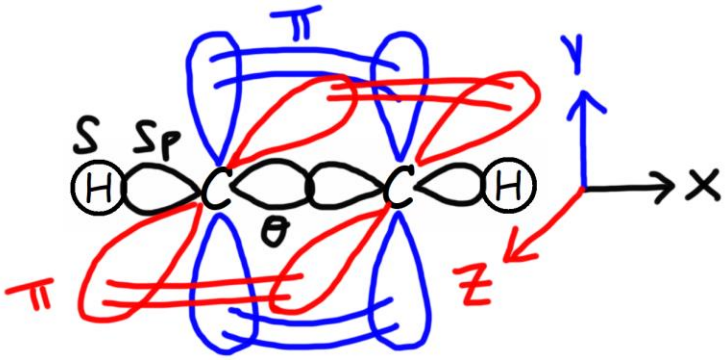
63. D

64a. The C-H bond has a sp^2-s orbital overlap.

64b.



65.

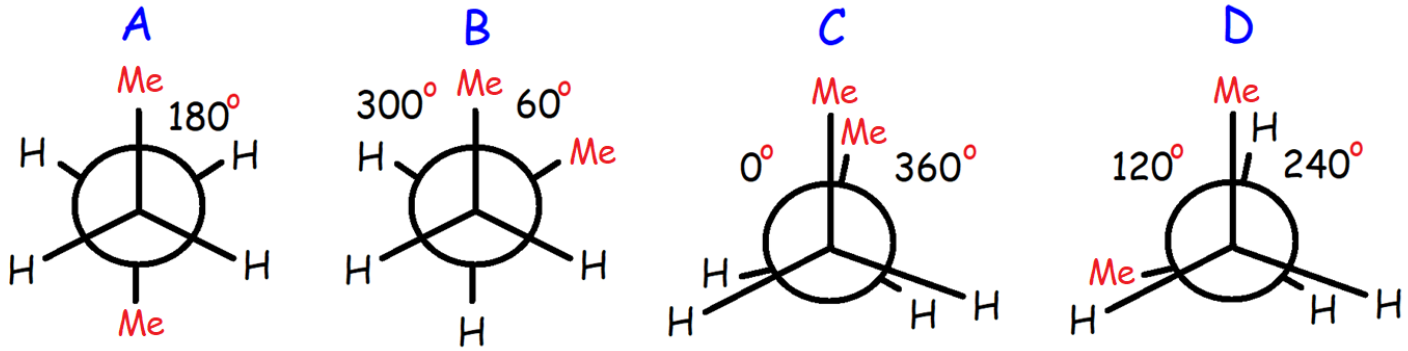


66. D

67. 2,2,3,3-tetramethylbutane

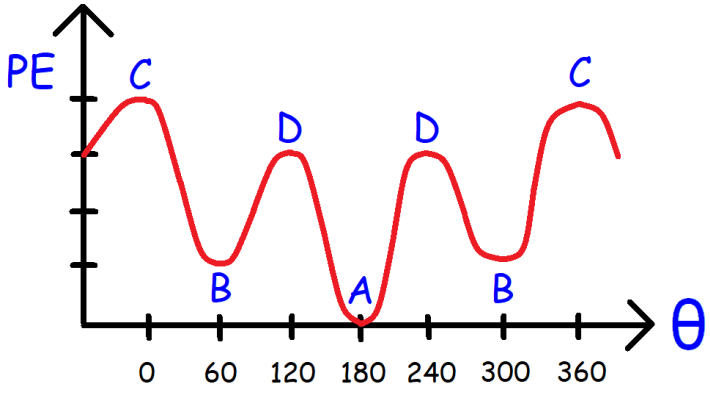
68. E

69a.



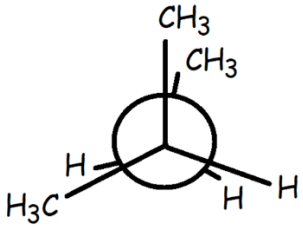
69b. Structure A is the most stable conformation.

69c.



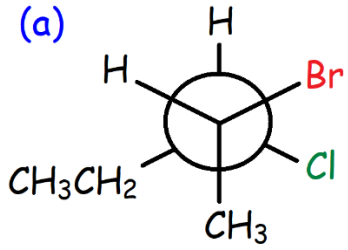
70. 9.6 kJ/mol

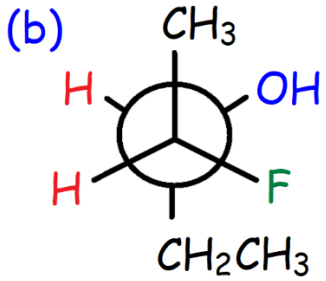
71a.



71b. 21 kJ/mol

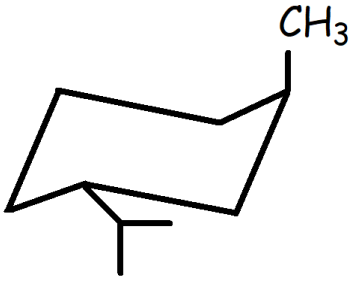
72.





73. B
74. 5-bromo-4-chloro-5-ethyl-3-methyloctane
75. A
76. C
77. Cycloheptane
78. D

79.

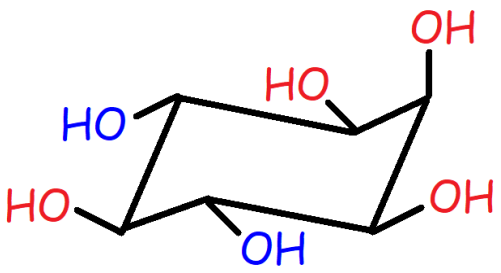


80.
I. Constitutional Isomers
II. Cis-Trans Isomers
III. Identical Compounds
IV. Constitutional Isomers
V. Constitutional Isomers
VI. Different Compounds
VII. Different Compounds
VIII. Conformers

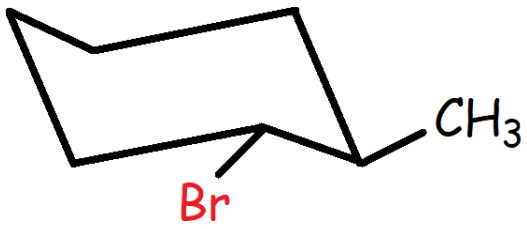
81. D
82. D

83. 4-bromo-1-ethyl-2-methylcyclohexane

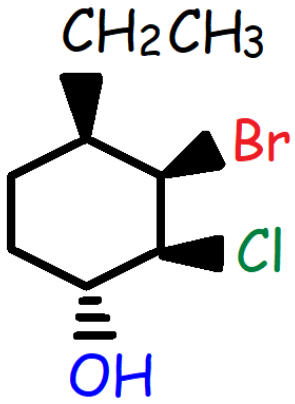
84.



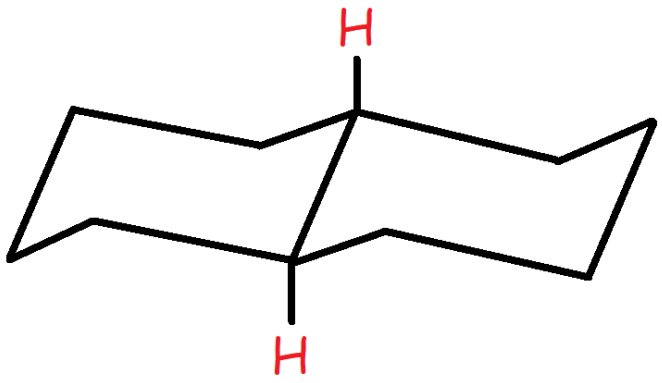
85.



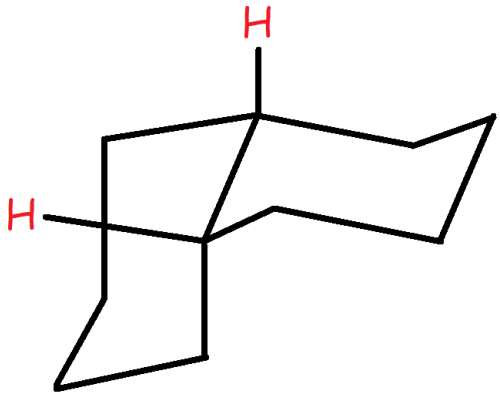
86.



87a. Trans Decalin:

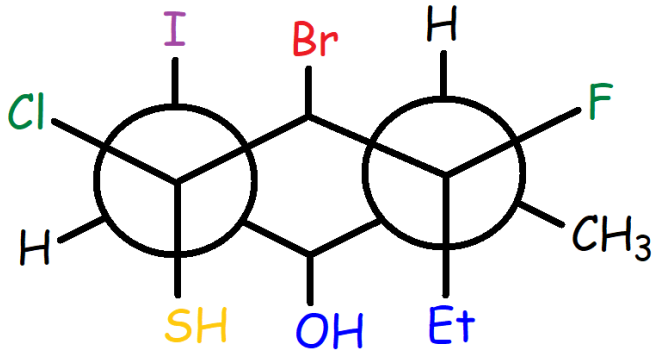


Cis Decalin:



87b. Trans Decalin is more stable than cis Decalin because the 2nd ring has two equatorial substituents. The 2nd ring for cis Decalin has one equatorial substituent and one axial substituent.

88.



89. III < I < II < IV

90. $H_C < H_b < H_a < H_D < H_e$