Module 7: Organic chemistry

Chapter 8: Hydrocarbons

Check your understanding 8.1

1 The valence electrons of carbon can share one, two or three pairs of electrons to form single, double or triple bonds. Carbon shares its valence electrons to form chain or ring structures that form the basis of all organic molecules. Valence electrons not involved in carbon–carbon bonding form bonds with atoms like hydrogen, oxygen, nitrogen and the halogens.

2 a Aromatic compounds contain a benzene ring, aliphatic compounds are organic compounds without a benzene ring.

b Saturated compounds only have single carbon–carbon bonds in the molecule. Unsaturated compounds have carbon–carbon double or triple bonds within the molecule.

c Alkanes have all carbon–carbon single bonds, alkenes contain at least one carbon–carbon double bond and alkynes contain at least one carbon–carbon triple bond.

3 Ball and stick models show the bonds between atoms clearly. Space-filling molecules do not show bonds, so will not show the difference between a carbon–carbon single, double or triple bond, but a ball and stick model will show the individual bonds.

4 Four single bonds give a tetrahedral shape around the carbon atom (as seen in row 1 of Table 8.1). A planar shape is seen when a carbon has a double bond and two singles (seen in row 2 of Table 8.1). A carbon with either two double bonds or one triple and one single bond will have a linear shape (row 3 and 4 of Table 8.1).

5 The differences between expanded, condensed and skeletal formulae are seen in Figure 8.5. Expanded formulae show the arrangement of each individual atom. Condensed formulae show the arrangement of the molecule but condenses the hydrogen atoms around each carbon. Skeletal formulae show no atoms, but only the arrangement of the carbon atoms.

Worked example 8.1

1 2,2-dimethylpropane

2 2,3,4,4-tetramethylhexane

Check your understanding 8.2

1 C_nH_{2n+2}

2 1 meth-, 2 eth-, 3 prop-, 4 but-, 5 pent-, 6 hex-, 7 hept-, 8 oct-, 9 non-, 10 dec-

3 Methane CH_4, ethane C_2H_6, propane C_3H_8, butane C_4H_{10}, pentane C_5H_{12}, hexane C_6H_{14}, heptane C_7H_{16}, octane C_8H_{18}, nonane C_9H_{20}, decane $C_{10}H_{22}$

4 **a** 3-methylpentane

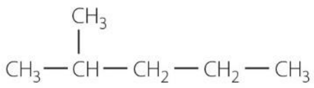
b 3-methylpentane

c 2,2-dimethylbutane

d 3-methylpentane

e 3,3,4,4-tetramethylhexane

5 **a**



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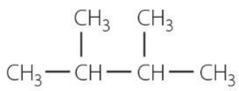

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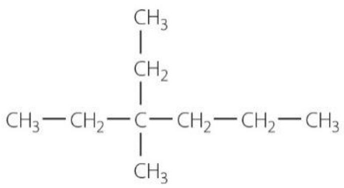

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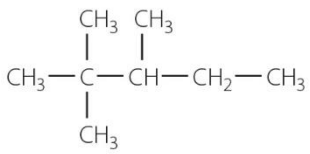

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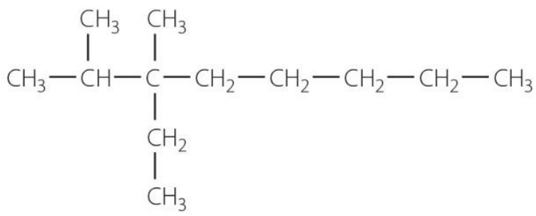
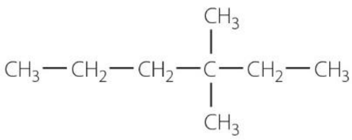
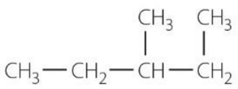


6 **a** Incorrect name, since the branches have not been given the lowest numbers. Correct name: 3,3-dimethylhexane



b Incorrect, since the longest continuous chain has 5 carbons, not 4.

Correct name: 3-methylpentane



Worked example 8.2

1 2,3-dimethyl-1-butene

2 4-methyl-2-hexene

Check your understanding 8.3

1 C_nH_{2n}

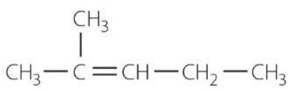
2 Alkanes have no carbon–carbon double bonds, all alkenes have at least one carbon–carbon double bond.

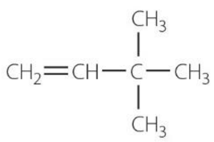
3 **a** 3-methyl-1-butene

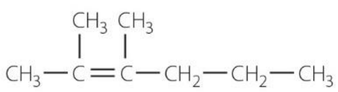
b 2,4-dimethyl-2-pentene

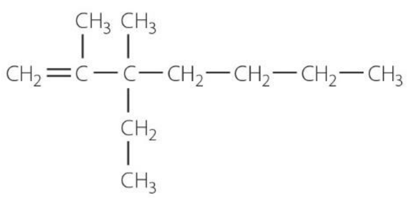
c 2,4,4-trimethyl-2-pentene

d 2,3-dimethyl-1-butene

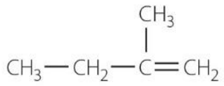
4 **a** 

b 

c 

d 

5 Incorrect, since smallest possible number has not been used for the double bond. Correct name: 2-methyl-1-butene



Check your understanding 8.4

1 C_nH_{2n-2}

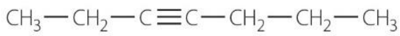
2 a 4-methyl-2-hexyne

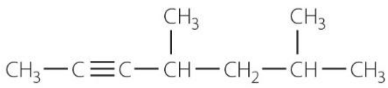
b 4-methyl-2-pentyne

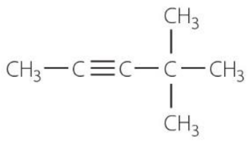
c 3,3-dimethyl-1-pentyne

d 4-methyl-2-pentyne

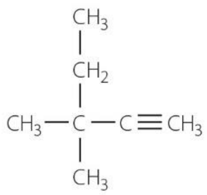
e 3,3-dimethyl-1-pentyne

3 a 

b 

c 

4 The longest chain has 5 carbons, not 4. The triple bond was not given the lowest number. Correct name: 3,3-dimethyl-1-pentyne.



Worked example 8.3

1 1-bromo-1,2-dichloro-2-fluoropropane

2 3,4,4,5-tetrachloro-3-methyl-1-pentyne

Check your understanding 8.5

1 a 1,2-dichloro-1-butene

b 2,2,3,3-tetrachloro-1-fluorobutane

c 3,4-dichloro-3,4-difluoro-1-pentyne

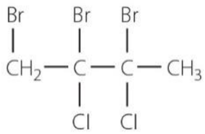
d 3-bromo-1,1,2-trichloro-1-butene

e 1,4,4-trichloro-2-methyl-1-pentene

f 1-bromo-2,2-dimethylbutane

g 4-bromo-2,4-dichloro-3-ethyl-2,3-dimethylhexane

2 a



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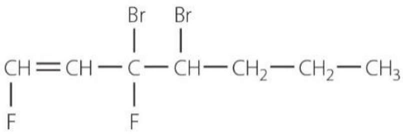

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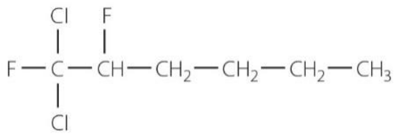
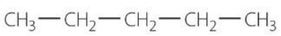


Check your understanding 8.6/8.7

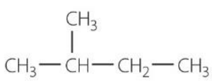
1 Structural isomers have the same molecular formula, but a different structure. For example, butane (C_4H_{10}) has the same molecular formula as 2-methylpropane (also C_4H_{10}), so they are isomers.

2 The two molecules in ‘a’ have the same molecular formula but different names. The top molecule is 2-methylpentane, the bottom molecule is 3-methylpentane. They are isomers. The two molecules in ‘b’ have different numbers of carbon atoms, so they are not isomers.

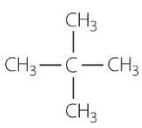
3 Pentane:



Pentane

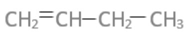


2-methylbutane

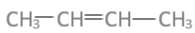


2,2-dimethylpropane

Butene:



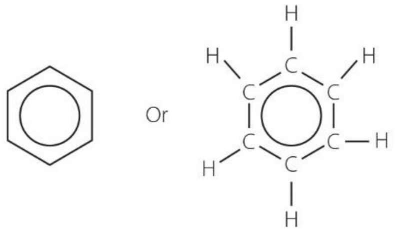
1-butene



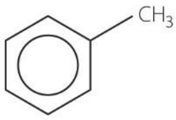
2-butene

4 Aromatic compounds contain the benzene molecule as part of its structure.

5 Parent compound is benzene – C_6H_6



6 The ring structure, including the delocalised electrons, is very stable and does not easily become disrupted to bond with other atoms.

7 

Check your understanding 8.8

1 Fuels, industrial solvents, lubricants

2 Feedstock for production of chemicals and polymers, artificial ripening of fruits, production of synthetic ethanol

3 A feedstock is a chemical used to manufacture other materials and chemicals. For example, ethene is used to make many polymers including polyethene, and is also used to make synthetic ethanol, which is then used as an industrial solvent.

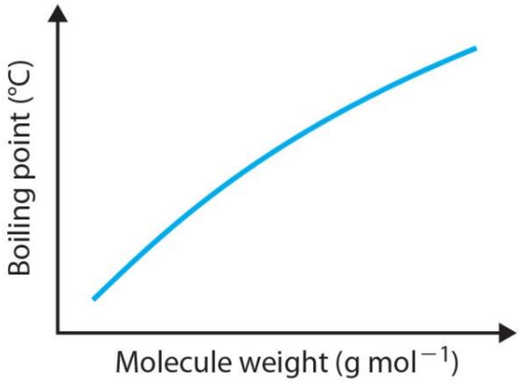
4 Alkanes have only weak dispersion forces between molecules due to the non-polar nature of the molecule. Dispersion forces do not require a lot of energy to break so they have low melting and boiling points.

5 As alkanes get larger and there are more atoms per molecule, the overall number of dispersion forces that form between molecules will increase. More dispersion forces will require more energy to break, giving higher boiling points. The first four alkanes have only relatively few dispersion forces between molecules and the temperature required to break them is lower than room temperature, so they are gases. Larger alkanes require a boiling point above room temperature, so they are liquids.

6 a Alkanes are non-polar covalent molecules with no dipole or ionic charges so have no ability to conduct electricity.

b Covalent molecules are unable to form bonds with polar molecules like water so are not soluble in water. They will form dispersion forces with non-polar solvents like cyclohexane so are soluble in non-polar solvents.

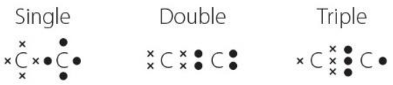
7 Alkanes, alkenes and alkynes are all non-polar hydrocarbon molecules with similar shapes and structures. They form the same bonds (dispersion forces) so will have similar physical properties, including melting and boiling points, and solubility.

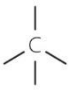
8 

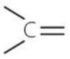
As the molecular weight of an alkane increases, the boiling point will also increase. As an alkane molecule increases in size, it is able to form more dispersion forces due to having more atoms in the molecule. With more dispersion forces between molecules, more energy is required to break these forces, resulting in a higher boiling point.

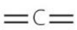
Chapter review questions

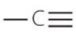
1 Carbon bonds readily to other carbon atoms, giving it the ability to form a wide range of structures including chains, rings and branched structures.

2 

3 **a** Tetrahedral 

b Planar 

c Linear 

d Linear 

4 Saturated compounds have only carbon–carbon single bonds within the molecule. Alkanes like methane and butane are saturated compounds. Unsaturated compounds have at least one double or triple carbon–carbon bond within the molecule. Alkenes like propene, and alkynes like pentyne, are unsaturated.

5 Aromatic compounds contain the benzene structure within the molecule and include benzene and phenolphthalein. Aliphatic compounds are hydrocarbons without a benzene molecule and include alkanes, alkenes and alkynes.

6

	Alkane	Alkene	Alkyne
General formula	C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}

Carbon number	Alkane	
1	CH_4	CH_4
2	C_2H_6	$CH_3—CH_3$
3	C_3H_8	$CH_3—CH_2—CH_3$
4	C_4H_{10}	$CH_3—CH_2—CH_2—CH_3$
5	C_5H_{12}	$CH_3—CH_2—CH_2—CH_2—CH_3$

Carbon number	Alkene	
2	C_2H_4	$CH_2{=}CH_2$
3	C_3H_6	$CH_2{=}CH—CH_3$
4	C_4H_8	$CH_2{=}CH—CH_2—CH_3$
5	C_5H_{10}	$CH_2{=}CH—CH_2—CH_2—CH_3$
6	C_6H_{12}	$CH_2{=}CH—CH_2—CH_2—CH_2—CH_3$

Carbon number	Alkyne	
2	C_2H_2	$CH{\equiv}CH$
3	C_3H_4	$CH{\equiv}C—CH_3$
4	C_4H_6	$CH{\equiv}C—CH_2—CH_3$
5	C_5H_8	$CH{\equiv}C—CH_2—CH_2—CH_3$
6	C_6H_{10}	$CH{\equiv}C—CH_2—CH_2—CH_2—CH_3$

7 **a** 2-methylbutane

b 4-ethyl-2,3,3-trimethylhexane

c 2-pentene

d 2,4,4-trimethyl-2-pentene

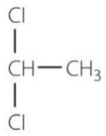
e 3,5-dimethyl-1-hexyne

f 4-methyl-2-hexyne

g 1,2-dichloro-3,3-difluoropentane

h 1,1,4-trichloro-1,2,4-trifluoro-2-heptene

8 **a**



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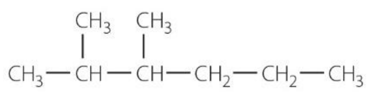

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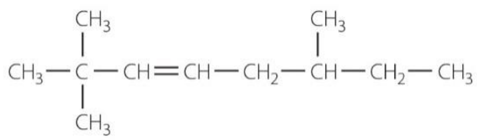

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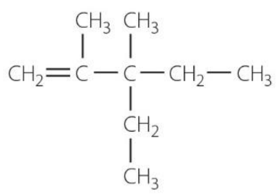

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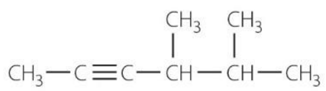

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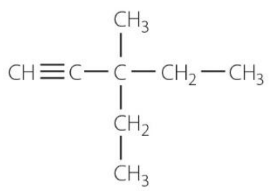

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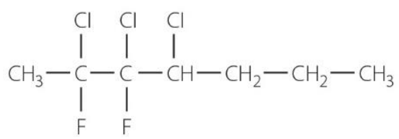

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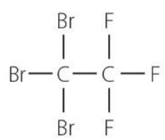
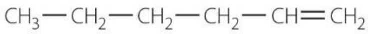
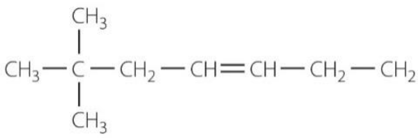


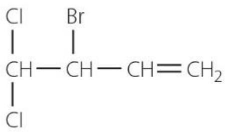
9 **a** The position of the double bond should be indicated with the smallest number possible. Correct name: 1-hexene.



b The position of the double bond should be indicated with the smallest number possible. Correct name: 6,6-dimethyl-3-heptene.



c The position of the double bond should be indicated with the smallest number possible. Bromo should come before chloro in the naming of substituents. Correct name: 3-bromo-4,4-dichloro-1-butene.



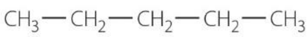
10 **a** No – same exact molecule (both 2-methylbutane)

b Yes (2-methylpentane and 3-methylpentane)

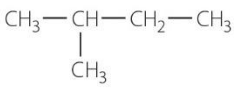
c No – same exact molecule (both 3-methylpentane)

d Yes (2,3-dimethylpentane and 2,4-dimethylpentane)

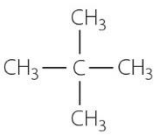
11 **a**



Pentane

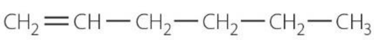


2-methyl butane

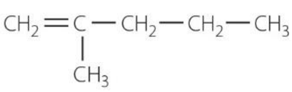


2,2-dimethylpropane

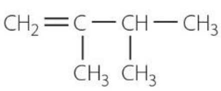
b



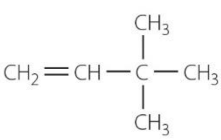
1-hexene



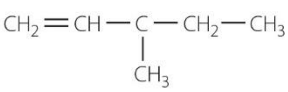
2-methyl-1-pentene



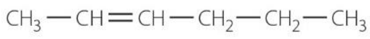
2,3-dimethyl-1-butene

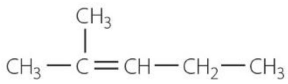


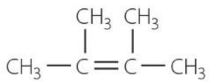
3,3-dimethyl-1-butene

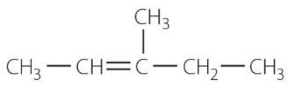


3-methyl-1-pentene

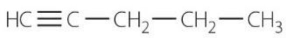
c  2-hexene

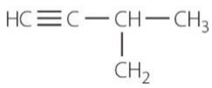
 2-methyl-2-pentene

 2,3-dimethyl-2-butene

 3-methyl-2-pentene

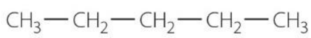
d

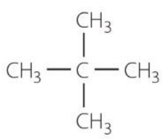
 1-pentyne

 3-methyl-1-butyne

12 Position isomers have a functional group like a double bond at different points on the main chain. An example of position isomers is 1-butene and 2-butene. Chain isomers rearrange the carbon skeleton (for example, butane and 2-methylpropane are chain isomers).

13 **a** Chain isomers

b 

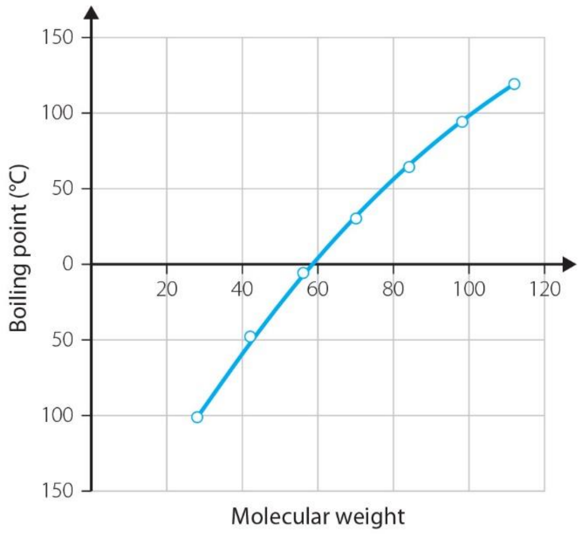


c Pentane will have a higher boiling point. Since the molecule is more linear than 2,2-dimethylpropane, it will be able to form more dispersion forces with other molecules. More dispersion forces require more energy to break, resulting in a higher boiling point.

14 **a**

Alkene	Molecular weight
Ethene	28.052
Propene	42.078
1-butene	56.104
1-pentene	70.130
1-hexene	84.156
1-heptene	98.182
1-octene	112.208

b



c As the molecular weight of the alkane increases, the boiling point also increases.

d As the molecular weight of an alkane increases, the boiling point will also increase. As an alkane molecule increases in size, it is able to form more dispersion forces due to having more atoms in the molecule. With more dispersion forces between molecules, more energy is required to break these forces, resulting in a higher boiling point.

15 a Compound Z, Compound X, Compound Y

b If compounds are from the same homologous series, then boiling point will increase with increasing molecular weight due to increased dispersion forces forming between larger molecules. More dispersion forces require more energy to break, resulting in a higher boiling point.

16 No. Hydrocarbons are non-polar molecules that have no dipole charge or ionic charge so are unable to conduct electricity.