UNIT 7

INTRODUCTION TO ORGANIC CHEMISTRY

Answers

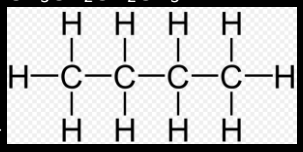
Lesson 1 – What are organic molecules?

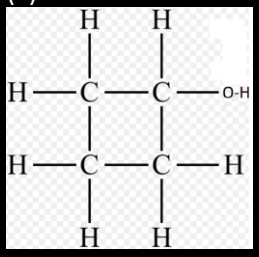
Test your knowledge 1.1: Classifying simple organic molecules

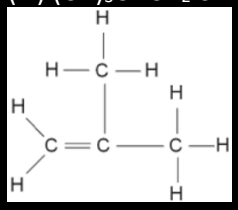
(i) alkene; unbranched aliphatic hydrocarbon	(ii) alcohol; unbranched aliphatic	(iii) bromoalkene; branched aliphatic
(iv) cycloalkane; branched alicyclic hydrocarbon	(v) alkyne; unbranched aliphatic Hydrocarbon	(vi) cycloalcohol; unbranched alicyclic
(vii) alkene; branched aliphatic hydrocarbon	(viii) cyclochloroalkane; branched alicyclic	(ix) alkane; branched aliphatic hydrocarbon

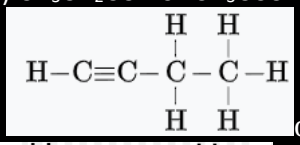
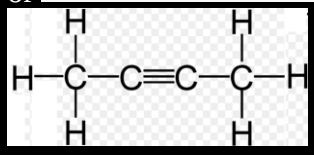
Lesson 2 – How can we draw and write organic molecules?

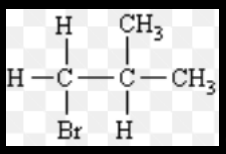
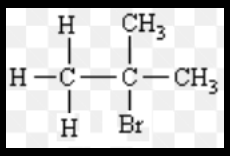
Test your knowledge 2.1: Drawing simple organic molecules

(a) (i) $CH_3CH_2CH_2CH_3$ or 

(ii) 

(iii) $(CH)_3CHCH_2$ or 

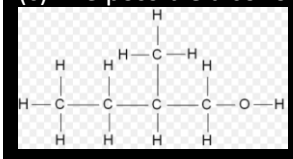
(iv) CH_3CH_2CCH or CH_3CCCH_3  or  or

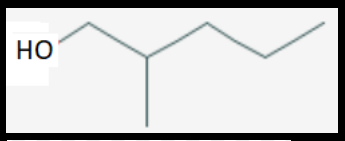
(v) $(CH_3)_2CHCH_2Br$ or $(CH_3)_3CBr$ or  or 

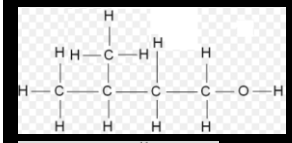
Note – there are other correct answers to (a) (i) – (v) using combinations of displayed and skeletal formulae

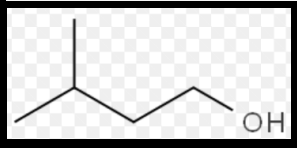
(b) (i) C_4H_{10}, C_2H_5; (ii) C_4H_8O, C_4H_8O; (iii) C_4H_8, CH_2; (iv) C_4H_6, C_2H_3; (v) C_4H_9Br, C_4H_9Br

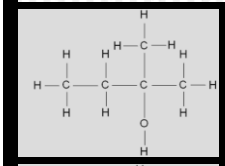
(c) five possible alcohols:



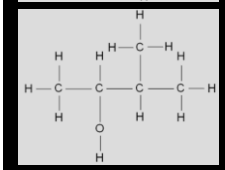
$CH_3CH_2CH(CH_3)CH_2OH$ 

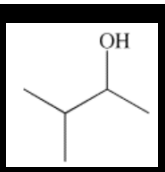


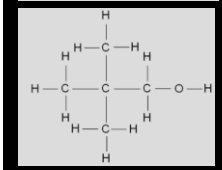
$(CH_3)_2CHCH_2CCH_2OH$ 



$(CH_3)_2C(OH)CH_2CH_3$ 



$CH_3CH(OH)CH(CH_3)_2$ 



$(CH_3)_3CCH_2OH$ 

Molecular formula: $C_5H_{12}O$; empirical formula: $C_5H_{12}O$

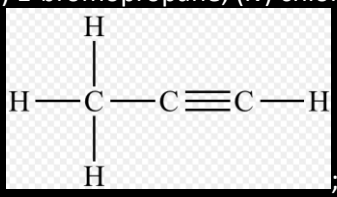
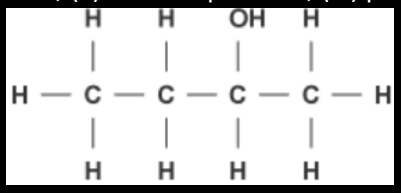
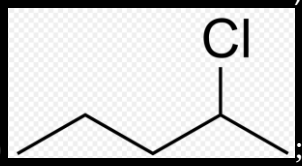
(d) (i) C_nH_{2n-2}; (ii) $C_nH_{2n}O$

UNIT 7 – INTRODUCTION TO ORGANIC CHEMISTRY

Lesson 3 – How do we name organic compounds?

Test your knowledge 3.1: Naming simple organic molecules

(a) (i) pent-1-ene; (ii) but-2-yne; (iii) 1-bromopropane; (iv) chloroethane; (v) 3-chloropentane; (vi) pentan-3-ol

(b) (i)  ; (ii)  ; (iii)  ; (iv) CH_3I; (v) $CH_3CH_2CH_2OH$

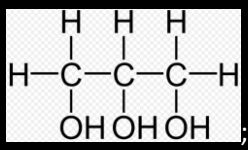
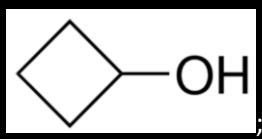
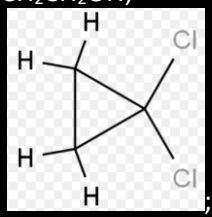
Note: any correct displayed, structural or skeletal formula is acceptable

Lesson 4 – How do we name more complex organic compounds?

Test your knowledge 4.1: Naming more complex organic molecules

(a) (i) propan-1,3-diol; (ii) 1-bromo,1-chloroethane; (iii) 2-methylpent-1-ene; (iv) 3-methylpentan-2-ol; (v) 4-methylpent-1-yne; (vi) 2,2,4-trimethylpentane; (vii) cyclopentene; (viii) 1,3-dimethylcyclobutane; (ix) 1-iodo,2-methylcyclopropane

(b) (i) $HO\text{-}CH_2\text{-}CH_2\text{-}OH$; (ii) $BrCH_2CHBrCH_3$; (iii) $(CH_3)_2CHCH(OH)CH_2CH_3$; (iv) $(CH_3)_2CHCH_2CH_2OH$;

(v) $CH_2{=}CH(CH_3)CH_2CH_3$; (vi)  ; (vii)  ; (viii)  ; (ix) 

Note: displayed or structural or skeletal or any correct combination is acceptable

Lesson 5 – How can we predict, recognise and classify isomers?

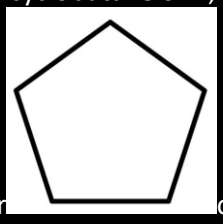
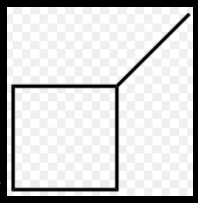
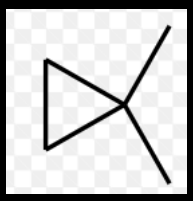
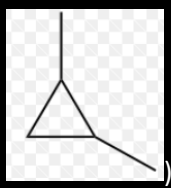
Summary Activity 5.1: What are isomers?

- 2; 1-chloropropane ($CH_3CH_2CH_2Cl$) and 2-chloropropane ($CH_3CHClCH_3$); in 1-chloropropane the Cl is attached to C_1 but in 2-chloropropane the Cl is attached to C_2
- 4; but-1-ene ($CH_3CH_2CH{=}CH_2$), but-2-ene ($CH_3CH{=}CHCH_3$), methylpropene ($(CH_3)_2CH{=}CH_2$), cyclobutane (□); but-1-ene and but-2-ene are different because the functional group is on a different position; methylpropene is different from but-1-ene and but-2-ene because it is branched; cyclobutane is different because it does not have a C=C bond

Test your knowledge 5.2: Recognising structural isomerism

(a) $CHCl_2CCH_3$ (1,1-dichloropropane) and CH_2ClCH_2Cl (1,2-dichloropropane); positional isomerism

(b) (i) $CH_3(CH_2)_2CH=CH_2$; (ii) $CH_3CH=CHCH_2CH_3$ (pent-2-ene); (iii) either $CH_2=C(CH_3)CH_2CH_3$ (2-methylbut-1-ene) or $(CH_3)_2C=CHCH_3$ (2-methylbut-2-ene) or $(CH_3)_2CHCH=CH_2$ (3-methylbut-1-ene); (iv) Either cyclopentane or methylcyclobutane or 1,1-dimethylcyclopropane or 1,2-dimethylcyclopropane

(either  or  or  or )

(c) Four: $CH_3CH_2CH_2CH_2OH$ (butan-1-ol), $CH_3CH(OH)CH_2CH_3$ (butan-2-ol), $(CH_3)_2CHCH_2OH$ (methylpropan-1-ol), $(CH_3)_3COH$ (methylpropan-2-ol)

(d) Butane, as it has a larger surface area, so stronger Van der Waal's forces between the molecules

Extension 5.3: Further structural isomerism

(a) $CH_3(CH_2)_2CH=CH_2$ (pent-1-ene), $CH_3CH=CHCH_2CH_3$ (pent-2-ene); $CH_2=C(CH_3)CH_2CH_3$ (2-methylbut-1-ene), $(CH_3)_2C=CHCH_3$ (2-methylbut-2-ene), $(CH_3)_2CHCH=CH_2$ (3-methylbut-1-ene)

(b) $CH_3(CH_2)_3CH_2OH$ (pentan-1-ol); $CH_3CH(OH)CH_2CH_2CH_3$ (pentan-2-ol); $CH_3CH_2CH(OH)CH_2CH_3$ (pentan-3-ol); $(CH_3)_2CHCH_2CH_2OH$ (3-methylbutan-1-ol); $(CH_3)_2CHCH(OH)CH_3$ (3-methylbutan-2-ol) $(CH_3)_2C(OH)CH_2CH_3$ (2-methylbutan-2-ol); $CH_3CH_2CH(CH_3)CH_2OH$ (2-methylbutan-1-ol); $(CH_3)_3CCH_2OH$ (dimethylpropanol)

Lesson 6 – What are stereoisomers?

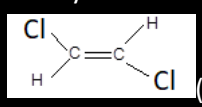
Activity 6.1: Why can single bonds rotate and why can double bonds not rotate?

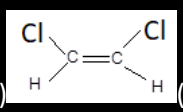
Equipment needed per group: 4 pieces of scrap paper and 3 sharp pencils

The students should notice that if two pieces of paper are connected by only one pencil, it is possible to rotate them both independently; if the pieces of paper are connected by two pencils a few cm apart, however, it is no longer possible to rotate one piece of paper without rotating the other

Test your knowledge 6.2: Geometrical isomerism

(a) A and B can be cyclopentane, methylcyclobutane, 1,1-dimethylcyclopropane or 1,2-dimethylcyclopropene; E and F are cis pent-2-ene and trans pent-2-ene; D is pent-1-ene; C is either 2-methylbut-1-ene or 3-methylbut-1-ene or 2-methylbut-2-ene

(b) 

(trans 1,2-dichloroethene) 

(cis 1,2-dichloroethene); 1,1-dichloroethene does not have two different groups attached to the C atoms in the C=C bond (one C has 2 Cl atoms and the other has 2 H atoms); 1,2-dichloroethane has single bonds only, so has free rotation around all bonds

UNIT 7 – INTRODUCTION TO ORGANIC CHEMISTRY

Lesson 7 – What is crude oil and why is it useful?

Summary Activity 7.1: Why do different hydrocarbons have different boiling points?

- Van der Waal's forces (intermolecular forces)
- Larger molecules mean more/stronger Van der Waal's forces, as more electrons and more surface area mean more temporary and induced dipoles
- They increase as the molecule gets larger, so more electrons/greater surface area means more temporary and induced dipoles
- Smaller surface area, so weaker Van der Waal's forces

Test your knowledge 7.2: Processing crude oil

(a) (i) a mixture of hydrocarbons with similar boiling points; (ii) column is hotter at the bottom than at the top; vaporised hydrocarbon molecules rise up the column; molecules cool down; larger molecules with higher boiling points condense first and are collected nearer the bottom of the column; smaller molecules with lower boiling points condense later and are collected nearer the top of the column; (iii) any five from liquefied petroleum gas – gas for camping and cooking; petrol – fuel for cars; naphtha – petrochemicals; kerosene – fuel for aeroplanes; diesel – fuel for lorries and central heating; mineral oil – lubrication and petrochemicals; fuel oil – fuel for ships; wax – candles and grease; bitumen – road surfacing

(b) (i) $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$ or $C_{10}H_{22} \rightarrow C_6H_{14} + C_4H_8$ or any balanced equation producing one alkane and one alkene; (ii) $C_{12}H_{26} \rightarrow C_8H_{18} + 2C_2H_4$ or $C_{12}H_{26} \rightarrow C_6H_{14} + C_2H_4 + C_4H_8$ or any balanced equation producing one alkane and two alkenes; (iii) $C_6H_{14} \rightarrow C_6H_{12} + H_2$

(c) Cracking produces higher value, higher demand alkanes and alkenes; reforming produces

Lesson 8 – why are alkanes useful?

Summary Activity 8.1: Exothermic reactions

- A reaction in which chemical potential energy is converted into heat energy (causing the temperature to rise)
- They are useful because the heat energy released can be used for heating, to make electricity or to power vehicles
- All reactions have an activation energy (energy needed to break bonds in the reactants); sometimes heat or a spark is needed to make sure that the reactants have this energy
- "fuel" is a substance which can be used to create useful energy; "combustion" is the reaction of a substance with oxygen

Test your knowledge 8.2: Alkanes as fuels

(a) (i) $C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$; (ii) $C_4H_{10} + 4.5O_2 \rightarrow 4CO + 5H_2O$; (iii) $C_6H_{14} + 3.5O_2 \rightarrow 6C + 7H_2O$

(b) Any three from: CO – formed when hydrocarbons burn in limited oxygen; C – formed when hydrocarbons burn in very limited oxygen; hydrocarbons – formed when hydrocarbons vaporise and escape before having a chance to burn; SO_2 – formed when S impurities in petrol burn as the fuel burns; NO – formed when N_2 in the air reacts with O_2 at high temperature or in the presence of a spark'

(c) A number showing how resistant a fuel is to knocking, on a scale in which heptane is 0 and 2,2,4-trimethylpentane is 100

Lesson 9 – What are the typical reactions of alkanes, alkenes and alkynes?

Test your knowledge 9.1: Simple reactions of hydrocarbons

(a) ethane: $C_2H_4 + H_2 \rightarrow C_2H_6$ or $C_2H_5X + H_2 \rightarrow C_2H_6 + HX$ (X = any halogen); ethene: $C_2H_6O \rightarrow C_2H_4 + H_2O$; ethyne: $CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$

(b) addition: organic molecule gains atoms without losing any, eg $C_2H_4 + H_2 \rightarrow C_2H_6$; substitution: replacement of one atom or group of atoms on an organic molecule with another, eg $C_2H_5X + H_2 \rightarrow C_2H_6 + HX$; elimination: loss of atoms from an organic molecule without replacement, eg $C_2H_6O \rightarrow C_2H_4 + H_2O$

(c) add bromine: ethene will decolorise it but alkane will not; or add $KMnO_4$: alkene will decolorise it but ethane will not

(d) Add silver nitrate and ammonia solution; ethyne will give a yellow-white precipitate but ethene will not

(e) (i) CH_3CH_2Cl (or any isomer of $C_2H_4Cl_2$ or $C_2H_3Cl_3$ or $C_2H_2Cl_4$ or C_2HCl_5 or C_2Cl_6) (substitution); (ii) $CH_3CHBrCH_3$ or CH_3CH_2Br (addition) (iii) $CH_3CH_2CH(OH)CH_2OH$ (hydroxyoxidation); (iv) CH_2=CHCl (addition)

Lesson 10 – What are aromatic compounds?

Test your knowledge 10.1: Benzene

(a) Ring of six carbon atoms; all C-C bonds intermediate between single and double bonds as p-electrons delocalised; each carbon also bonded to one hydrogen, C_6H_6

(b) (i) $C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$; (ii) $C_6H_6 + 3Cl_2 \rightarrow C_6H_6Cl_6$

(c) Delocalised electrons makes structure stable; substitution reactions preserve the delocalised structure but addition reactions break it; substitution therefore preferred

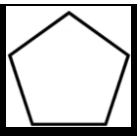
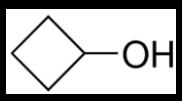
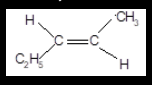
(d) To make polystyrene; to increase octane number of petrol, to make pharmaceuticals

(e) Contains a benzene ring

Lesson 11 – What have I learned about Organic Chemistry?

11.1 END-OF-TOPIC QUIZ

UNIT 7 – INTRODUCTION TO ORGANIC CHEMISTRY

1. (i) eg $(CH_3)CHCH_3$ (or any branched alkane); (ii) $CH_2{=}CHCH_3$ (or any unbranched alkene); (iii)  (or any unbranched cycloalkane); (iv)
2. (i) $(CH_3)_2CHCH_2CH_3$; (ii) $CH_3CH{=}CHCH_2CH_3$; (iii) $(CH_3)_2CHCH_2CH_2OH$; (iv) $CH_2BrCHBrCH_3$; (v) 
3. 1,1-dimethylcyclopentane; (ii) propan-1-ol; (iii) methylbut-2-ene; (iv) 2-bromomethylpropane; (v) chlorocyclopropane
4. $CH_3CH_2CH_2OH$ (propan-1-ol) and $CH_3CH(OH)CH_3$ (propan-2-ol)
5. (i) $CH_3CH_2CH_2CH{=}CH_2$ and $CH_3CH_2CH{=}CHCH_3$, or two from $(CH_3)_2C{=}CHCH_3$ and $(CH_3)_2CHCH{=}CH_2$ and $CH_3CH_2C(CH_3){=}CH_2$; (ii) any of the five alkenes with cyclopentane, methylcyclobutane, 1,1-dimethylcyclopropane or 1,2-dimethylcyclopropane; (iii) one of the unbranched alkenes and one of the branched alkenes; (iv)  and
6. methane, ethane, propane; boiling point increases due to more electrons per molecule and larger surface area leading to stronger Van der Waal's forces between molecules
7. column is hotter at the bottom than at the top; vaporised hydrocarbon molecules rise up the column; molecules cool down; larger molecules with higher boiling points condense first and are collected nearer the bottom of the column; smaller molecules with lower boiling points condense later and are collected nearer the top of the column
8. eg $C_8H_{18} \rightarrow C_6H_{14} + C_2H_4$ or any balanced combination of one alkane and one or more alkenes
9. $C_6H_{14} \rightarrow C_6H_{12} + H_2$
10. Any three from: liquefied petroleum gas – gas for camping and cooking; petrol – fuel for cars; naphtha – petrochemicals; kerosene – fuel for aeroplanes; diesel – fuel for lorries and central heating; mineral oil – lubrication and petrochemicals; fuel oil – fuel for ships; wax – candles and grease; bitumen – road surfacing
11. (i) $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$; (ii) $CH_4 + 1.5O_2 \rightarrow CO + 2H_2O$ or $CH_4 + O_2 \rightarrow C + 2H_2O$
12. S present naturally in crude oil and most fractions; when fuel is burned, S burns to five SO_2; it is an acidic gas and dissolves in water to form acid rain
13. Add bromine to both; pent-1-ene will decolorise but cyclopentane will not (or use $KMnO_4$)
14. $CH_3CH_2CH_2CHBrCH_3$ and $CH_3CH_2CH_2CH_2CH_2Br$
15. Delocalised ring is stable; addition reactions break the delocalised ring so are not favoured; substitution reactions do not break the ring so are preferred