REACTIONS OF HYDROCARBONS

Question 1.
Hydrocarbons undergo complete combustion (react with oxygen) to form carbon dioxide and water.

(a) methane (CH_4) + oxygen $\rightarrow$
(b) ethane (C_2H_6) + oxygen $\rightarrow$
(c) propane (C_3H_8) + oxygen $\rightarrow$
How many moles of water would be produced if 5 moles of propane were combusted?
(d) butane (C_4H_{10}) + oxygen $\rightarrow$
(e) pentane (C_5H_{12}) + oxygen $\rightarrow$
(f) hexane (C_6H_{14}) + oxygen $\rightarrow$
(g) ethene (C_2H_4) + oxygen $\rightarrow$
(h) ethyne (C_2H_2) + oxygen $\rightarrow$
(i) benzene (C_6H_6) + oxygen $\rightarrow$
(j) 2-pentene + oxygen $\rightarrow$
(k) 3,3-diethyl-4-methyl-1-heptyne + oxygen $\rightarrow$

Question 2.
For the following reactions, write the structural formulae of the products, include all possible isomers.

(a) $CH_3{-}CH_2{-}CH_3 + Cl_2 \xrightarrow{\text{U.V. light}}$ 2 isomers

(b) $CH_4 + Br_2 \xrightarrow{\text{dark}}$

(c) $CH_4 + Cl_2 \xrightarrow{\text{U.V. light}}$

(d) $CH_3{-}CH_2{-}CH_2Cl + Cl_2 \xrightarrow{\text{U.V. light}}$ 3 isomers

(e) $CH_3{-}CH_2{-}CH_2{-}CH_3 + F_2 \xrightarrow{\text{U.V. light}}$ 2 isomers

(f) $CHBr_3 + I_2 \xrightarrow{\text{U.V. light}}$

(g) $CH_3{-}CH{=}CH{-}CH_3 + H_2 \xrightarrow{Pt}$

(h) $HC \equiv CH + 2H_2 \xrightarrow{Pt}$

(i) $CH_3{-}CH{=}CH{-}CH(CH_3){-}CH_3 + Cl_2 \longrightarrow$

Question 3.
Write an equation for each of the following reactions. Use molecular and structural formulae and classify the reaction as combustion, addition, substitution, hydrogenation.

(a) Octane burns with oxygen gas.
(b) 2-methyl-1-pentene reacts with hydrogen.
(c) Chlorine reacts with ethene.
(d) Cyclohexene reacts with hydrogen gas.
(e) Benzene reacts with bromine in the presence of a $FeBr_3$ catalyst.
(f) Acetylene (ethyne) and oxygen react.

Question 4.
Write structural formulas for all organic compounds. State the type of reaction. Complete and balance the equation. Name the products.

(a) propene + hydrogen using a nickel catalyst
(b) cyclohexane + chlorine in the presence of U.V. light
(c) benzene + iodine in the presence of an FeI_3 catalyst
(d) 2-pentene + bromine
(e) propene + bromine
(f) propyne + (2 mol) iodine
(g) propane + bromine in the presence of U.V. light
(h) benzene + chlorine in the presence of an $FeCl_3$ catalyst
(i) ethane + (2 mol) iodine in the presence of U.V. light
(j) 2-butene + hydrogen using a nickel catalyst
(k) 1-hexene + fluorine
(l) 2-butyne + chlorine
(m) 4,4-dimethyl-2-pentyne + bromine
(n) hydrogenation of 2-methylpropene using a nickel catalyst
(o) addition of chlorine to 2-pentene *(halogenation)*
(p) addition of bromine to cyclopentene *(halogenation)*
(q). 4,5-dimethyl-2-hexyne + (2 mol) bromine

Question 5.
In excess oxygen, a hydrocarbon was fully combusted to produce equal volumes of carbon dioxide and water vapour under conditions of constant temperature and pressure. Its relative molecular mass was found to be 56 a.m.u.

(a) Determine the molecular formula of this hydrocarbon.
(b) The compound reacts with bromine vapour immediately on mixing. What does this illustrate about the compound?
(c) Write a possible structure for this compound, stating its name.
(d) Write an equation using structural formulae for the reaction between this compound and bromine vapour.
(e) State any observations that would be made when performing this reaction in the laboratory.
(f) Write down the likely structure of this compound if it had been found that the compound did *not* immediately react with the bromine vapour.

Question 6.
A hydrocarbon was found to contain 85.6% carbon and 14.4% hydrogen by mass, and to possess a molar mass of 28 grams. It reacted with bromine vapour to produce a particular product. Give the name of this product and write an equation to represent the reaction.

Question 7.
Stating any other reagents and by writing equations, indicate how you would carry out each of the following conversions.

(a) Ethene into ethane.
(b) 1-butene into 1,2-difluorobutane.
(c) Pentane into chloropentane.
(d) 2-pentyne into 2,2,3,3-tetrachloropentane.
(e) benzene into bromobenzene.
(f) cyclohexene into 1,2-dibromocyclohexane.

Question 8.
One mole of 3,3-dimethyl-1-pentyne is reacted with one mole of hydrogen gas in the presence of a platinum catalyst to produce compound X. Compound X is reacted with bromine vapour to produce compound Y. Give the names and structural formulae of compounds X and Y.

Question 9.
Consider the following reactions:

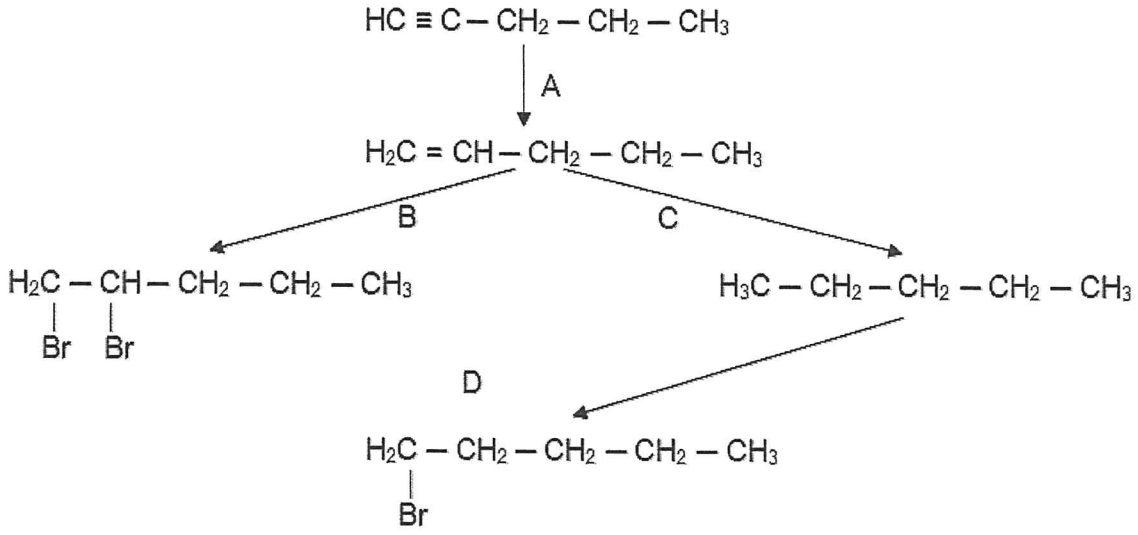
1. ethene + H^+/MnO_4^- → carbon dioxide
2. ethene + Br_2 → 1,2-dibromoethane
3. ethane + Br_2/u.v. light → bromoethane

(a) How are reactions 1. and 2. similar? How are they different?
(b) How are reactions 2. and 3. similar? How are they different?

Question 10.
A hydrocarbon was found to decolourise bromine water. One mole of the hydrocarbon was burnt in excess oxygen to produce four moles of carbon dioxide gas.

(a) What is the significance of the fact that the compound decolourises bromine water?
(b) Name the original hydrocarbon.
(c) Write an equation for the reaction between the hydrocarbon and bromine.
(d) Write an equation for the complete combustion of the hydrocarbon.

Question 11.
For each of the reactions A, B, C and D below, indicate the reagent(s) and any conditions necessary to cause the reaction. Indicate, also, if the reaction is substitution or addition.



Assign all compounds IUPAC or systematic names.

Answers

Question 1.

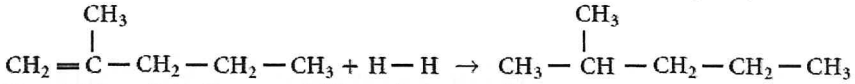
(a) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
(b) $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
(c) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
20 moles
(d) $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$
(e) $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$
(f) $2C_6H_{14} + 19O_2 \rightarrow 12CO_2 + 14H_2O$
(g) $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$
(h) $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$
(i) $2C_6H_6 + 15O_2 \rightarrow 12CO_2 + 6H_2O$
(h) $2C_5H_{10} + 15O_2 \rightarrow 10CO_2 + 10H_2O$
(i) $2C_{12}H_{22} + 35O_2 \rightarrow 24CO_2 + 22H_2O$

Question 2.

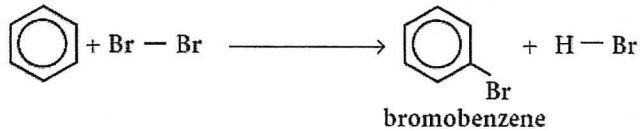
(a) $CH_3CH_2CH_2Cl$ & $CH_3CHClCH_3$ + HCl (in each case)
(b) no rxn
(c) CH_3Cl + HCl
(d) $CH_2ClCH_2CH_2Cl$ & $CH_3CHClCH_2Cl$ & $CH_3CH_2CHCl_2$ + HCl (in each case)
(e) $CH_3CH_2CH_2CH_2F$ & $CH_3CHFCH_2CH_3$ + HF (in each case)
(f) CBr_3I + HI
(g) $H_3CCH_2CH_2CH_3$
(h) H_3CCH_3
(i) $CH_3CHClCHClCH(CH_3)CH_3$

Question 3.

(a) $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ **combustion**
(b) 2-methyl-1-pentene + hydrogen → 2-methylpentane **addition - hydrogenation**



(c) $Cl_2 + C_2H_4 \rightarrow C_2H_4Cl_2$ **addition - halogenation**
(d) $C_6H_{10} + H_2 \rightarrow C_6H_{12}$ **addition - hydrogenation**
(e) $C_6H_6 + Br_2 \rightarrow C_6H_5Br + HBr$ **substitution**



bromobenzene

(f) $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$ **combustion**

Question 4.

(a) $CH_3CH=CH_2 + H_2 \rightarrow CH_3CH_2CH_3$
Propane
(b) $C_6H_{12} + Cl_2 \rightarrow C_6H_{11}Cl + HCl$
chlorocyclohexane + hydrogen chloride
(c) $C_6H_6 + I_2 \rightarrow C_6H_5I + HI$
iodobenzene + hydrogen iodide
(d) $CH_3CH=CHCH_2CH_3 + Br_2 \rightarrow CH_3CHBrCHBrCH_2CH_3$
2,3-dibromopentane
(e) $CH_3CH=CH_2 + Br_2 \rightarrow CH_3CHBrCH_2Br$
1,2-dibromopropane
(f) $CH_3C\equiv CH + 2I_2 \rightarrow CH_3CI_2CHI_2$
1,1,2,2-tetraiodopropane
(g) $CH_3CH_2CH_3 + Br_2 \rightarrow CH_3CH_2CH_2Br + HBr$
bromopropane + hydrogen bromide
(h) $C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$
chlorobenzene + hydrogen chloride
(i) $CH_3CH_3 + 2I_2 \rightarrow CH_2ICH_2I + 2HI$
diodoethane + hydrogen iodide
(j) $CH_3CH=CHCH_3 + H_2 \rightarrow CH_3CH_2CH_2CH_3$
butane
(k) $CH_2=CHCH_2CH_2CH_2CH_3 + F_2 \rightarrow CH_2FCHFCH_2CH_2CH_2CH_3$
1,2-difluorohexane
(l) $CH_3C\equiv CCH_3 + Cl_2 \rightarrow CH_3CCl=CClCH_3$

(m) $CH_3C{\equiv}CC(CH_3)_2CH_3 + Br_2 \rightarrow$ 2,3-dichloro-2-butene
$CH_3CBr{=}CBrC(CH_3)_2CH_3$
2.3-dibromo-4,4-dimethyl-2-pentene

(n) $CH_2{=}C(CH_3)CH_3 + H_2 \rightarrow$ $CH_3CH(CH_3)CH_3$
2-methylpropane

(o) $CH_3CH{=}CHCH_2CH_3 + Cl_2 \rightarrow$ $CH_3CHClCHClCH_2CH_3$
2,3-dichloropentane

(p) $C_5H_8 + Br_2 \rightarrow$ $C_5H_8Br_2$
1,2-dibromocyclopentane

(q) $CH_3C{\equiv}CCH(CH_3)CH(CH_3)CH_3 + 2Br_2 \rightarrow$ $CH_3CBr_2CBr_2CH(CH_3)CH(CH_3)CH_3$
2.2,3,3-tetrabromo-4,5-dimethylpentane

Question 5.

(a) $C_nH_{2n} \rightarrow nCO_2 + nH_2O$
It follows that hydrocarbon is unsaturated.
Its empirical formula mass = 12.01 +2(1.008) = 14.026
Molecular formula = $(\text{Empirical formula})_{n = 1, 2, 3, \text{etc.}}$
n = 56 ÷ 14.026 = 3.99 ≈ 4
Therefore formula = C_4H_8

(b) It is an unsaturated hydrocarbon, it has a C=C double bond.

(c)

$H_3C - HC = CH - CH_3$ 2-butene or (1-butene)

(d)

$$H_3C - HC = CH - CH_3 + Br_2 \rightarrow H_3C - \underset{\displaystyle Br}{\underset{|}{HC}} - \underset{\displaystyle Br}{\underset{|}{CH}} - CH_3$$

(e) The orange solution on addition to the colourless solution turns colourless.

(f)

$$\begin{array}{l} H_2C - CH_2 \\ \quad | \quad\ | \\ H_2C - CH_2 \end{array}$$

cyclobutane

Question 6.

	C	H
m =	85.6	14.4
n = m/M	85.6÷12.01	14.4÷1.008
n =	7.127	14.285
÷ 7.127	1	≈2
Formula	1	2

Its empirical formula mass = 12.01 +2(1.008) = 14.026
Molecular formula = $(\text{Empirical formula})_{n = 1, 2, 3, \text{etc.}}$
n = 28 ÷ 14.026 = 1.996 ≈ 2
Therefore formula = C_2H_4
$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

Question 7.

(a) Add H_2 using a Ni or Pt catalyst
$C_2H_4 + H_2 \rightarrow C_2H_6$

(b) Add F_2
$CH_2CHCH_2CH_3 + F_2 \rightarrow CH_2FCHFCH_2CH_3$

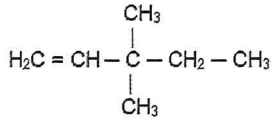
(c) Add HCl in the presence of U.V. light
$C_5H_{12} + HCl \rightarrow C_5H_{11}Cl + HCl$

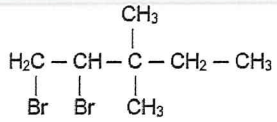
(d) Add (2 mol) Cl_2
$C_5H_8 + 2Cl_2 \rightarrow C_5H_8Cl_4$

(e) Add Br_2 in the presence of a $FeBr_3$ catalyst
$C_6H_6 + Br_2 \rightarrow C_6H_5Br + HBr$

(f) Add Br_2
$C_6H_{10} + Cl_2 \rightarrow C_6H_{10}Cl_2$

Question 8.

X  3,3-dimethyl-1-pentene

Y  1,2-dibromo-3,3-dimethyl-1-pentene

Question 9.

(a) Both reactions are similar in that the double bond undergoes reaction.
Both are different in that reaction 1 is a Red/Ox reaction and reaction 2 is an addition reaction.

(b) In both reactions bromine adds to each molecule
Reaction 2 is an addition reaction with only one product, whereas reaction 3 is a substution reaction with 2 products. An additional difference is that reaction 2 is fast whereas reaction 3 is slow and only in the presence of U. V. light.

Question 10.

(a) The compound is unsaturated. Bromine is a reagent used to diagnose C=C double bonds.
(b) Butene, C_4H_8. The compound has 4 C atoms as it produces 4 moles of CO_2.
(c) $C_4H_8 + Br_2 \rightarrow C_4H_8Br_2$
(d) $C_4H_8 + 6O_2 \rightarrow 4CO_2 + 4H_2O$

Question 11.

A.	H_2 with a Ni or Pt catalyst	Addition
B.	Br_2	Addition
C.	H_2 with a Ni or Pt catalyst	Addition
D.	HBr in U. V. light	Substitution