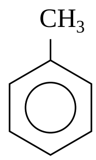
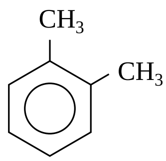
(c) acetylene
$CH\equiv CH$

(d) toluene, the toxic solvent used in many glues

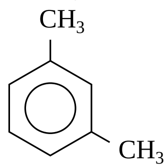


toluene

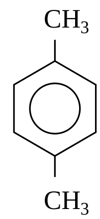
(e) the *o*-, *m*-, and *p*- isomers of xylene



i) *o*-xylene



ii) *m*-xylene



iii) *p*-xylene

### Making Connections

5. The graph shows a direct relationship between the number of carbon atoms and the boiling points of alkanes. This relationship is explained by the increasing number of van der Waals attractions between molecules, as the length of the carbon chain increases. As the intermolecular attraction increases, the amount of energy required to separate the molecules increases, resulting in a higher boiling point.

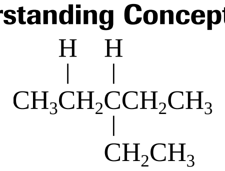
## 1.3 REACTIONS OF HYDROCARBONS

### PRACTICE

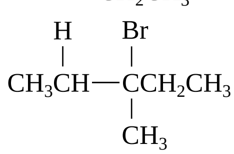
**(Page 27)**

### Understanding Concepts

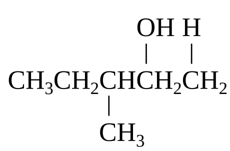
1. (a)



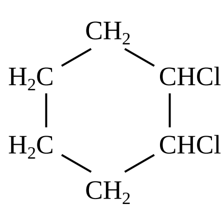
(b)



(c)



(d)



## PRACTICE

**(Page 27)**

### Understanding Concepts

2. When a double bond undergoes an addition reaction in which an H atom is added, the H atom adds to the C atom in the double bond that already bonds to more H atoms. Thus, the C atom that is already “rich” in H atoms, gets “richer” by gaining the additional H atom.

3. (a)

$$CH_3CH{=}CHCH_2CH_2CH_3 + Cl_2 \rightarrow CH_3\overset{\displaystyle Cl}{\overset{|}{C}}H{-}\overset{\displaystyle Cl}{\overset{|}{C}}HCH_2CH_2CH_3$$

2,3-dichlorohexane

(b)

$$CH_2{=}CHCH_2CH_3 + HBr \rightarrow \overset{\displaystyle H}{\overset{|}{C}}H_2{-}\overset{\displaystyle Br}{\overset{|}{C}}HCH_2CH_3$$

2-bromobutane

(c)

$$CH_2{=}CH\underset{\displaystyle CH_3}{\underset{|}{C}}HCH_2CH_3 + H_2O \rightarrow \overset{\displaystyle H}{\overset{|}{C}}H_2{-}\overset{\displaystyle OH}{\overset{|}{C}}H\underset{\displaystyle CH_3}{\underset{|}{C}}HCH_2CH_3$$

2-hydroxy-3-methylpentane

(d)

$$CH_3CH{=}\underset{\displaystyle CH_3}{\underset{|}{C}}CH_2CH_3 + H_2O \rightarrow CH_3\overset{\displaystyle H}{\overset{|}{C}}H{-}\overset{\displaystyle OH}{\underset{\displaystyle CH_3}{\underset{|}{\overset{|}{C}}}}CH_2CH_3$$

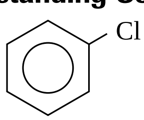
3-hydroxy-3-methylpentane

## PRACTICE

**(Page 30)**

### Understanding Concepts

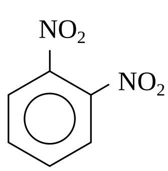
4. (a)




$+ \frac{1}{2}Cl_2$

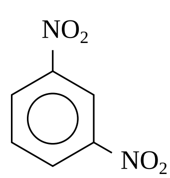
chlorobenzene

(b)



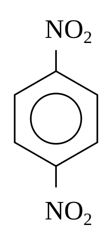

$+ H_2O$

i) 1,2-dinitrobenzene




$+ H_2O$

ii) 1,3-dinitrobenzene (favoured product)



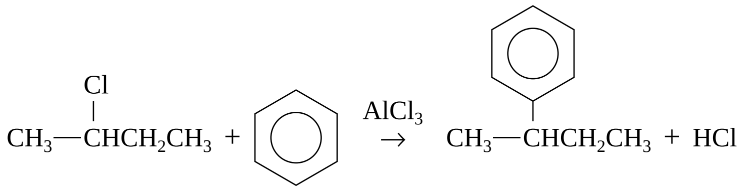

$+ H_2O$

iii) 1,4-dinitrobenzene

5. (Sample answer) Step 1: Prepare 2-chlorobutane from 1-butene and HCl.

$$CH_2{=}CHCH_2CH_3 + HCl \rightarrow \overset{\displaystyle H}{\overset{|}{CH_2}}{-}\overset{\displaystyle Cl}{\overset{|}{C}}HCH_2CH_3$$

Step 2: Prepare 2-phenylbutane from 2-chlorobutane and benzene, in the presence of a catalyst.




6. The terms “substitution” and “halogenation” both describe the reaction between benzene and bromine; the term “addition” does not. In the reaction, a bromine atom is attached to the benzene ring, displacing an H atom, but no double bonds are broken. It is thus a substitution reaction and not an addition reaction. Since the reaction results in the presence of a halogen atom (Br) on the benzene structure, it is also a general halogenation reaction.
7. The bonding structure in benzene is intermediate between that of single carbon–carbon bonds and double carbon–carbon bonds. All the carbon–carbon bonds around the benzene ring appear to be equivalent to each other. Evidence: Benzene is more reactive than hexane (with only single bonds) and less reactive than hexene (with a double carbon–carbon bond). Bond lengths between carbon atoms in a benzene ring are identical and are intermediate between the bond lengths of single and double carbon–carbon bonds.

## SECTION 1.3 QUESTIONS

**(Page 31)**

### Understanding Concepts

1. (Sample answers)
   (a) addition
   $HC{\equiv}CH + H_2 \rightarrow H_2C{=}CH_2$
   (b) hydrogenation
   $HC{\equiv}CH + H_2 \rightarrow H_2C{=}CH_2$
   (c) halogenation
   $HC{\equiv}CH + Cl_2 \rightarrow HClC{=}CHCl$
   (d) hydration
   $HC{\equiv}CH + H_2O \rightarrow H_2C{=}CH(OH)$
2. (a) addition, hydrogenation

$$CH_3\overset{\displaystyle CH_3}{\overset{|}{C}}{=}CHCH_3 + H_2 \rightarrow CH_3\overset{\displaystyle CH_3}{\overset{|}{C}}HCH_2CH_3$$

methyl-2-butene + hydrogen → 2-methylbutane

   (b) addition, halogenation

$$CH{\equiv}CH + 2\,Cl_2 \rightarrow \underset{\displaystyle Cl}{\underset{|}{\overset{\displaystyle Cl}{\overset{|}{CH}}}}{-}\underset{\displaystyle Cl}{\underset{|}{\overset{\displaystyle Cl}{\overset{|}{CH}}}}$$

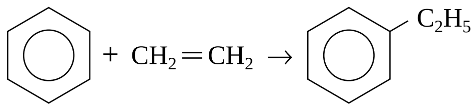
ethyne + chlorine → 1,1,2,2-tetrachloroethane

   (c) addition, hydrogenation

$$CH_3{-}C{\equiv}C{-}CH_3 + 2\,H_2 \rightarrow CH_3CH_2CH_2CH_3$$

2-butyne + hydrogen → butane

(d) substitution (for benzene), and addition (for ethene)



benzene + ethene → ethylbenzene

(e) combustion

$$CH_3CH{=}\overset{C_2H_5}{\overset{|}{C}}\underset{\underset{CH_3}{|}}{C}HCH_3 + 12\ O_2 \rightarrow 8\ CO_2 + 8\ H_2O$$

3-ethyl-4-methyl-2-pentene + oxygen → carbon dioxide + water

3. (a) addition, hydration

$$CH_3CH_2CH{=}CHCH_2CH_3 + H_2O \rightarrow CH_3CH_2\overset{H}{\overset{|}{C}}H_2\overset{OH}{\overset{|}{C}}HCH_2CH_3$$

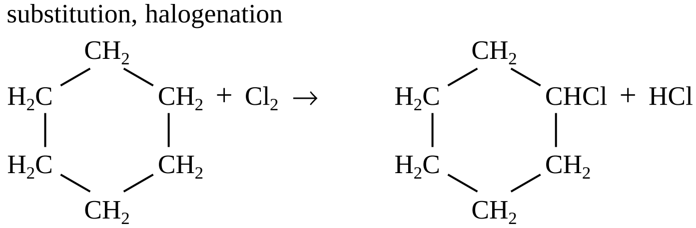
3-hexene + water →

(b) addition, hydrogenation

$$CH_3{=}CHCH_3 + H_2 \rightarrow CH_3CH_2CH_2CH_3$$

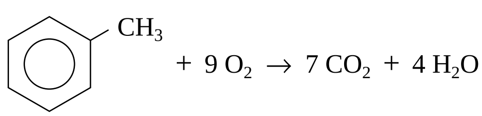
2-butene + hydrogen → butane

(c) substitution, halogenation



cyclohexane + $Cl_2$ →

(d) combustion



methylbenzene + oxygen → carbon dioxide + water

(e) addition

$$CH_3CH_3 + CH_3CH{=}CHCH_3 \rightarrow CH_3\overset{H}{\overset{|}{C}}H\overset{CH_2CH_3}{\overset{|}{C}}HCH_3$$

ethane + 2-butene → 3-methylpentane

## Applying Inquiry Skills

4. (a) propene and water, in the presence of $H_2SO_4$ catalyst
(b) cyclohexene and chlorine, at room temperature
(c) 2-methyl-2-pentene and water, in the presence of $H_2SO_4$ catalyst
(d) benzene and $Cl_2$, in the presence of $AlCl_3$ catalyst

### Making Connections

5. According to the balanced equation for the combustion of propane,
   $CH_3CH_2CH_3 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$,
   1 mol of propane reacts with 5 mol of oxygen to produce 3 mol of carbon dioxide and 4 mol of water vapour; that is, a total of 6 mol of gas reacts to produce a total of 7 mol of gas. The volume of gaseous product formed is greater than the volume of gaseous reactants, by a factor of 1 additional volume of product for each 6 volumes of reactants (17% increase).
6. Nonane would be the most effective solvent for removing oil stains because it is the least polar molecule, and would be most soluble with oil, which is nonpolar. The carbon–chlorine bonds and the carbon–oxygen bonds in the first two compounds are polar bonds (Cl and O are more electronegative than C), and thus, the molecules are more polar than nonane.
7. Trinitrotoluene (TNT) is a yellow, odourless solid produced by the substitution of three nitro ($NO_2$) groups for three hydrogen atoms in toluene ($C_6H_5CH_3$). The many nitro groups give the molecule excellent oxidizing properties, and allow it to react with the carbon atoms in the molecule to produce $CO_2$ and a large amount of energy. Consequently, TNT is one of the most stable of the high explosives and can be stored over long periods of time. It is the major component of dynamite. It does not attack metals, does not absorb moisture, and is practically insoluble in water.

   Swedish chemist Alfred Nobel created TNT in 1867 as a safe alternative to nitroglycerin, a highly volatile substance. Nobel created a substance that would absorb the nitroglycerin into an inert, solid form (typically “diatomaceous earth”). This form of the compound requires a detonation device to explode.

   TNT is used as an explosive in military shells, bombs, and grenades. It is also used for underwater blasting, blasting roads, demolishing buildings, mining, and creating tunnels.

   The misuse of TNT may result in environmental damage through waste waters and solid wastes caused from the manufacture of the compound, the processing and destruction of bombs and grenades, and the recycling of explosives.

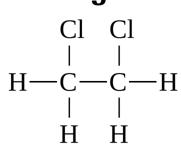
## 1.4 ORGANIC HALIDES

### PRACTICE

**(Page 33)**

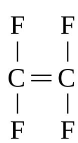
### Understanding Concepts

1. (a)



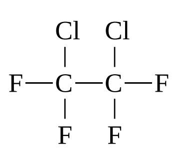
1,2-dichloroethane

(b)



tetrafluoroethene

(c)



1,2-dichloro-1,1,2,2-tetrafluoroethane