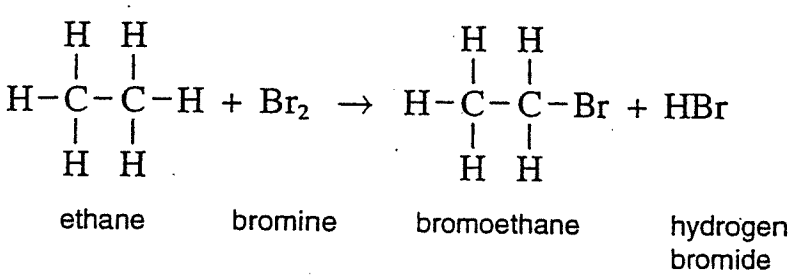
ORGANIC REACTIONS

As noted earlier, organic reactions typically proceed at much slower rates than do inorganic reactions. For this reason, the use of catalysts is a common practice. In many organic reactions, only the functional group is involved. The greater part of the reacting molecules remain unchanged during the course of the reaction, and can easily be identified in the products.

Substitution

As the name implies, substitution reactions involve replacing one kind of atom or group with another kind of atom or group. For the saturated hydrocarbons, all substitution reactions (except for the special cases of combustion and thermal decomposition) involve replacement of hydrogen atoms. The halogen (F, Cl, Br, I) derivatives of the alkanes can be prepared by substitution reactions between the alkane and the halogen. The general term for these reactions is halogen *substitution*.

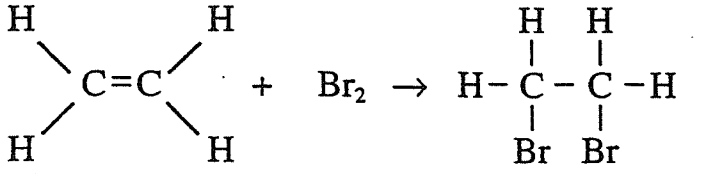


Preparation of the halogen derivatives by substitution always results in a by-product of the hydrogen halide.

Addition

Addition reactions involve *adding* two or more atoms to carbon atoms that are attached to other carbon atoms by double or triple bonds. Thus, addition reactions are generally limited to the unsaturated hydrocarbons. Addition reactions take place more easily than substitution reactions. Their rates are often as fast as those of ionic reactions. As a result, unsaturated compounds are considered more reactive than saturated compounds. Furthermore, those with triple bonds (alkynes) tend to be more reactive than those with double bonds (alkenes). Addition of hydrogen to an unsaturated compound, however, usually requires the presence of a catalyst and an elevated temperature. The hydrogen addition reaction is called

hydrogenation. Addition reactions between unsaturated hydrocarbons and chlorine and bromine to produce halogen derivatives take place at room temperature.



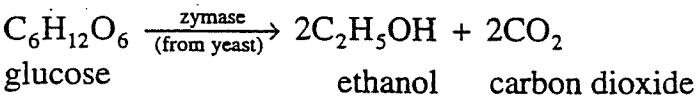
ethene + bromine → 1,2–dibromoethane

Addition reactions are characterized by the formation of a single product. This is in contrast with substitution reactions in which more than one product is typical.

Fermentation

Fermentation is a process ordinarily associated with living systems. Enzymes produced by the living organisms serve as catalysts for the reactions in which organic molecules are broken down.

For example, the fermentation of glucose is shown:

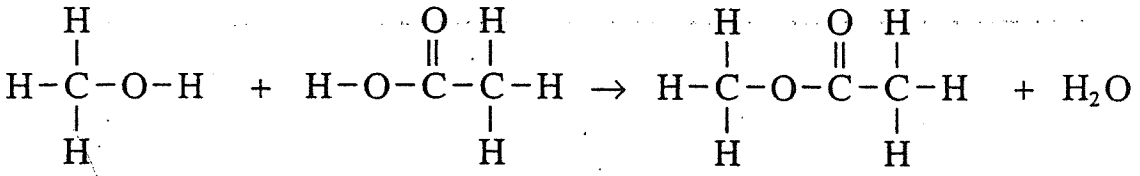


glucose → ethanol + carbon dioxide

Esterification

Esterification derives its name from the name of the products, esters. Esterification involves the reaction between an organic acid and an alcohol to produce an ester and water.

Esters have a first and last name. The first name is derived from the alcohol name with a *-yl* ending. The last name comes from the organic acid with an *-ate* ending.

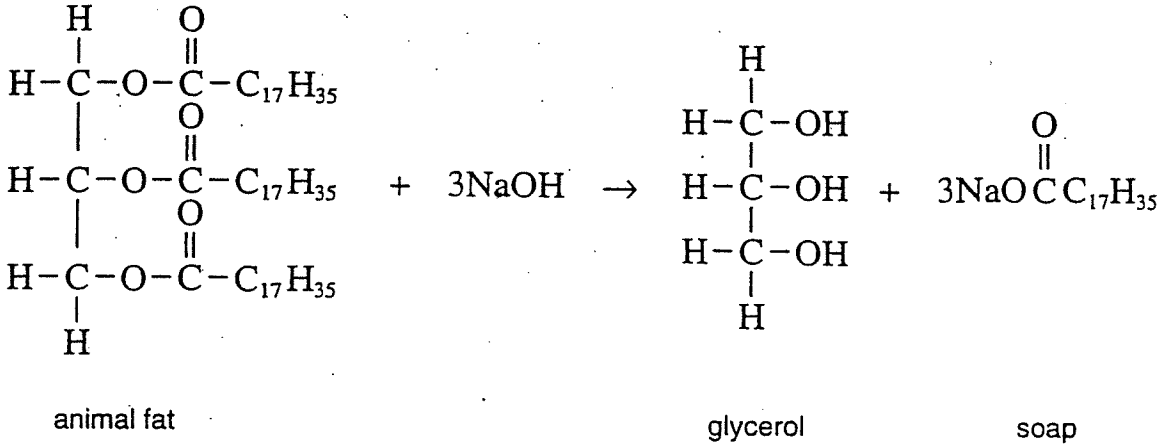


methanol + ethanoic acid → methyl ethanoate (ester)

Since esterification involves an acid and an –OH group, it is often compared with neutralization of inorganic acids with bases, producing salts and water. (See p. 163) Esterification, however, is not an ionic reaction, and esters are covalent compounds. Esterification is a slow reaction, usually requiring a catalyst, and it is reversible. Esters are responsible for the aromas associated with many fruits, flowers, and leaves. Lipids (fats and oils) are esters formed from esterification of glycerol (1, 2, 3-propantriol) by long-chain organic acids (fatty acids).

Saponification

The hydrolysis of fats (complex esters) by bases is called *saponification*. The organic salts that are produced are soaps. Glycerol, an alcohol, is a second product of saponification reactions and is considered a byproduct in the manufacture of soap.



"Like dissolves like" is a useful saying. Polar solutes dissolve best in polar solvents (like water), and non-polar solutes dissolve best in non-polar solvents (like hydrocarbons). soap can bring non-polar solutes together with polar solvents because it is both. One end of the soap molecule is a long hydrocarbon chain attracting it to non-polar stains like grease.

The other end ($-\overset{O}{\overset{\|}{C}}-ONa$) is polar and attracted to water.

Combustion

Saturated hydrocarbons react readily with oxygen under conditions of combustion. Such reactions result in the oxidation of the carbon to carbon monoxide or carbon dioxide, depending on the amount of oxygen available. The oxygen bonds with hydrogen from the hydrocarbon to form water as well as the oxide of carbon. Oxidation reactions have great significance because of the liberation of energy associated with them. Energy is derived from fuels by combustion and from food by cellular respiration, both processes involving oxidation reactions.

$$CH_4 + O_2 \rightarrow CO_2 + H_2O + \text{heat}$$

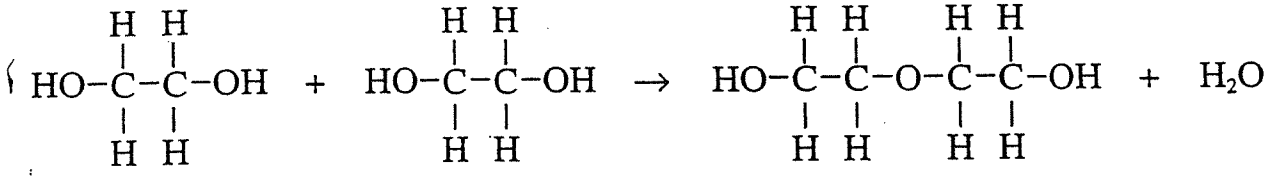
methane — carbon dioxide — water

Polymerization

Polymerization is a name given to reactions in which large molecules are made from smaller molecules. Polymerization occurs in nature in the production of proteins and starches by living organisms. Synthetic rubbers, plastics, and fibers are results of polymerization reactions.

Polymers are composed of many repeating units, called monomers, which are joined together by one of two types of polymerization reactions—condensation or addition.

Condensation. Condensation polymerization results from joining monomers by dehydration. It is sometimes called dehydration synthesis (because of the removal of water).

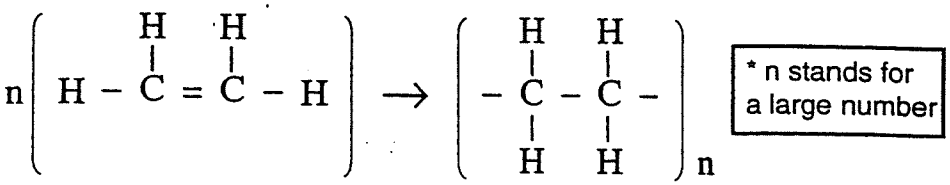


monomer monomer dimer (polymer)

This process may be repeated to produce a long-chain polymer. Monomers involved in condensation must have at least two functional groups. Examples of condensation polymers include silicones, polyesters, polyamides, phenolic plastics, and nylons.

Addition. Addition polymerization, as do all addition reactions, involves opening of double and triple bonds of unsaturated hydrocarbons.

Vinyl plastics, such as polyethylene and polystyrene, are examples of addition polymers.



ethene (the monomer) → polyethylene or polyethene (the polymer)

QUESTIONS

Answer the following questions using Tables P, Q, and R of the *Reference Tables for Physical Setting/Chemistry.*

1. The organic reaction

$$HCOOH + CH_3CH_2CH_2CH_2OH \rightarrow HCOOCH_2CH_2CH_2CH_3 + HOH,$$

is an example of

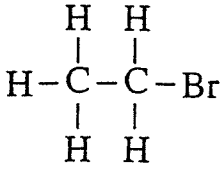
(1) fermentation
(2) esterification
(3) polymerization
(4) saponification

2. Alkanes differ from alkenes in that alkanes

(1) are hydrocarbons
(2) are saturated compounds
(3) have the general formula C_nH_{2n}
(4) undergo addition reactions

3. Which molecule is represented by X in the reaction

$$H - C \equiv C - H + 2Br_2 \rightarrow X?$$

(1)


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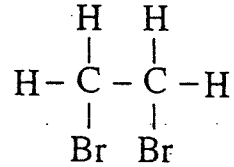

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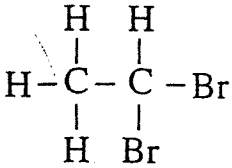

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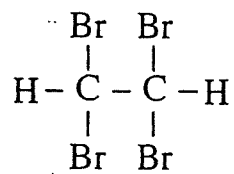
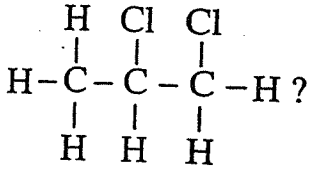


4. Which equation represents an esterification reaction?

(1) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$
(2) $C_5H_{10} + H_2 \rightarrow C_5H_{12}$
(3) $C_3H_8 + Cl_2 \rightarrow C_3H_7Cl + HCl$
(4) $HCOOH + CH_3OH \rightarrow HCOOCH_3 + HOH$

5. What is the correct IUPAC name for



(1) 1,2-dichlorobutane
(2) 2,3-dichlorobutane
(3) 1,2-dichloropropane
(4) 2,3-dichloropropane

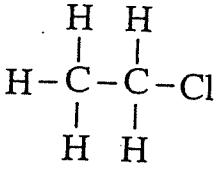
6. Which equation represents a substitution reaction?

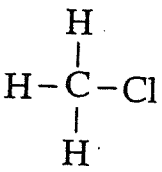
(1) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
(2) $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$
(3) $C_3H_6 + H_2 \rightarrow C_3H_8$
(4) $C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$

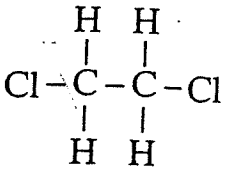
7. Which reaction produces ethanol as one of the principal products?

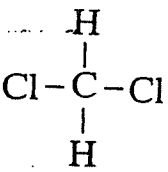
(1) an esterification reaction
(2) a neutralization reaction
(3) a saponification reaction
(4) a fermentation reaction

8. Which is the product of the reaction between ethene and chlorine?

(1) 

(2) 

(3) 

(4) 

9. In which type of reaction are long-chain molecules formed from smaller molecules?

(1) substitution
(2) saponification
(3) fermentation
(4) polymerization

10. Cellulose is an example of

(1) a synthetic polymer
(2) a natural polymer
(3) an ester
(4) a ketone

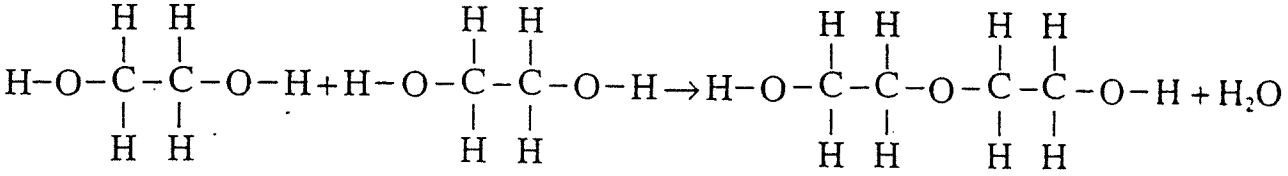
11. A reaction between CH_3COOH and an alcohol produced the ester CH_3COOCH_3. The alcohol used in the reaction was

(1) CH_3OH (2) C_2H_5OH (3) C_3H_7OH (4) C_4H_9OH

12. An alcohol and an organic acid are combined to form water and a compound with a pleasant odor. This reaction is an example of

(1) saponification (2) esterification (3) polymerization (4) fermentation

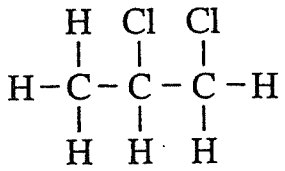
13. Given the equation:

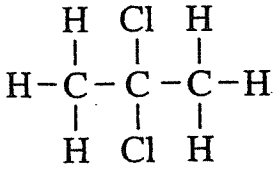


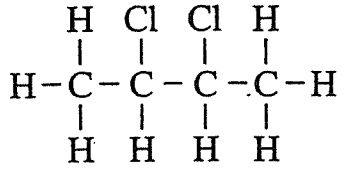
Which type of reaction is represented?

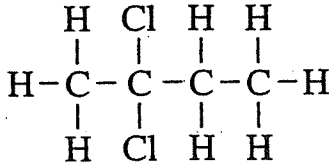
(1) condensation polymerization
(2) addition polymerization
(3) esterification
(4) saponification

14. Which is the formula of 2,2-dichloropropane?

(1) 

(2) 

(3) 

(4) 

15. The type of reaction represented by the equation

$$C_2H_4 + H_2 \rightarrow C_2H_6$$ is called

(1) substitution (2) polymerization (3) addition (4) esterification

16. Which reaction is used to produce polyethylene $(C_2H_4)_n$ from ethylene?

(1) addition polymerization
(2) substitution
(3) condensation polymerization
(4) reduction

17. The process of opening double bonds and joining monomer molecules to form polyvinyl chloride is called

(1) addition polymerization
(2) condensation polymerization
(3) dehydration polymerization
(4) neutralization polymerization

18. Which hydrocarbon will undergo a substitution reaction with chlorine?

(1) methane (2) ethyne (3) propene (4) butene