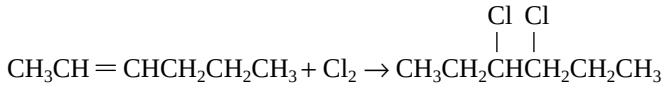
3. True
4. False: In an amide, the nitrogen atom is connected to at least one carbon atom, while in an amine, the nitrogen atom may be connected to 1, 2, or 3 hydrogen atoms.
5. False: When 1-pentanol and 3-pentanol are each oxidized in a controlled way, they produce pentanal and 3-pentanone, respectively.
6. (b)
7. (b)
8. (a)
9. (e)
10. (b)
11. (c)
12. (e)
13. (c)
14. (e)
15. (c)

CHAPTER 1 REVIEW

(Page 96)

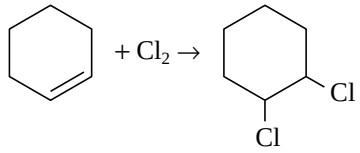
Understanding Concepts

1. (a)

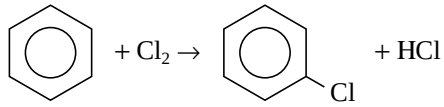


$$CH_3CH{=}CHCH_2CH_2CH_3 + Cl_2 \rightarrow CH_3CH_2\underset{\displaystyle Cl}{\overset{\displaystyle Cl}{\underset{|}{\overset{|}{C}}}}HCH_2CH_2CH_3$$

(b)

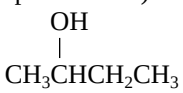


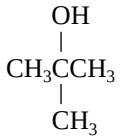
(c)



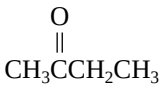
Reactions in (a) and (b) are addition reactions, and the reaction in (c) is a substitution reaction.

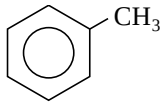
2. C, B, D, A. The reason for this is that more polar compounds have higher boiling points as a result of increased intermolecular forces of attraction. C is an alkane and is nonpolar; B is more polar than C because of its carbonyl group; D is more polar than B because of its OH group, which is capable of hydrogen bonding; A is more polar than D because it has an OH group and a carbonyl group.
3. (Sample answers)

(a)


(b)


(c) $CH_3OCH_2CH_2CH_3$

(d)


(e)


(f) $CH_3CH{=}CHCH{=}CHCH_3$

(g) $CH_3CH_2CH_2\overset{\overset{O}{\|}}{C}H$

(h) $CH_3\overset{\overset{O}{\|}}{C}OH$

(i) $H\overset{\overset{O}{\|}}{C}OCH_3$

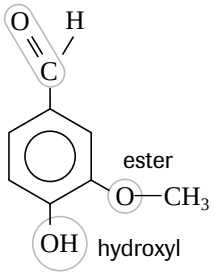
4. The ketone could be

$CH_3\underset{\underset{OH}{|}}{C}HCH_2CH_2CH_3$ or $CH_3CH_2\underset{\underset{OH}{|}}{C}HCH_2CH_3$ or $CH_3\underset{\underset{OH}{|}}{C}H\underset{\underset{CH_3}{|}}{C}HCH_3$

2-pentanol 3-pentanol 3-methyl-2-butanol

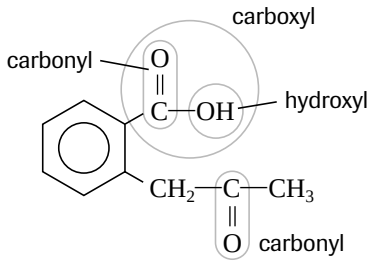
5. (a) alkene: 2-butene
   (b) ether: methoxymethane
   (c) alcohol: 2-methyl-1-butanol
   (d) alkyne: propyne
   (e) ester: methyl butanoate
   (f) aldehyde: propanal
   (g) ketone: butanone
   (h) amine: 1-aminobutane
   (i) alcohol: 3,4-dihydroxy-1-hexene
   (j) amide: *N*-ethyl butanamide

6. (a) carbonyl



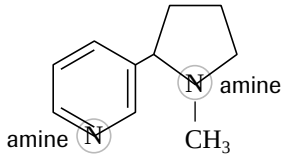
vanillin, used as food flavouring

(b)



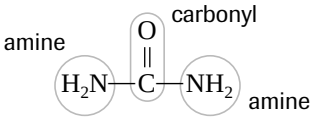
acetylsalicylic acid, used as an analgesic

(c)



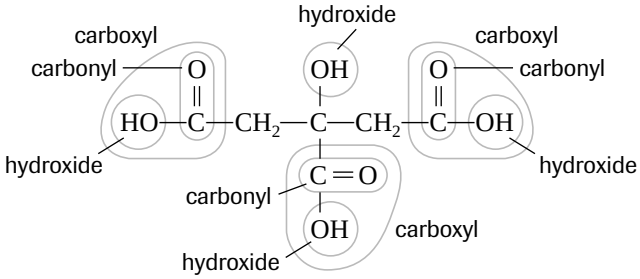
nicotine, a component of tobacco smoke

(d)



urea, synthesized by animals

(e)



citric acid, synthesized by some fruits

7. (a)

$$CH_3CH_3 + Br{-}Br \rightarrow \overset{\displaystyle Br}{\overset{|}{C}}H_2CH_3 + HBr$$

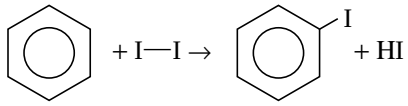
ethane + bromine → bromoethane + hydrogen bromide
alkane inorganic alkylhalide inorganic
substitution reaction

(b)

$$CH_2{=}CHCH_3 + Cl{-}Cl \rightarrow CH_2\overset{\displaystyle Cl}{\overset{|}{C}}H\overset{\displaystyle Cl}{\overset{|}{C}}H_3$$

propane + chlorine → 1,2-dichloropropane
alkane inorganic alkyl halide
addition reaction

(c)



benzene + iodine → iodobenzene + hydrogen iodide
aromatic hydrocarbon inorganic alkyl halide inorganic
substitution reaction

(d)

$$CH_3CH_2\overset{\displaystyle H}{\overset{|}{C}}H\overset{\displaystyle Cl}{\overset{|}{C}}H_2 + OH^- \rightarrow CH_3CH_2CH{=}CH_2 + H_2O + Cl^-$$

1-chlorobutane + hydroxide ion → 1-butene + water + chloride ion
alkyl halide alkene
elimination reaction

(e)

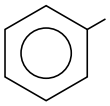
$$CH_3CH_2CH_2\overset{\displaystyle O}{\overset{\|}{C}}{-}OH + CH_3OH \rightarrow CH_3CH_2CH_2\overset{\displaystyle O}{\overset{\|}{C}}{-}OCH_3 + HOH$$

butanoic acid + methanol → methyl butanoate + water
carboxylic acid alcohol ester
esterification reaction, condensation reaction

(f)

$$\overset{\displaystyle H}{\overset{|}{C}}H_2\overset{\displaystyle OH}{\overset{|}{C}}H_2 \rightarrow CH_2{=}CH_2 + HOH$$

ethanol → ethene + water
alcohol alkene
elimination reaction, dehydration reaction

(g)  $+ O_2 \rightarrow CO_2 + H_2O$

methylbenzene + oxygen → carbon dioxide + water
(phenyl methane)
alkane
combustion, oxidation

(h) $CH_3CH_2OH \rightarrow CH_3CHO \rightarrow CH_3COOH$

ethanol → ethanal → ethanoic acid
alcohol aldehyde carboxylic acid
controlled oxidation

(i) $CH_3CH(OH)CH_3 \rightarrow CH_3COCH_3$

2-propanol → propanone
alcohol ketone
controlled oxidation

(j) $NH_3 + CH_3CH_2CH_2CH_2COOH \rightarrow CH_3CH_2CH_2CH_2CONH_2 + HOH$

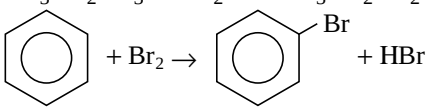
ammonia + pentanoic acid → pentanamide + water
inorganic carboxylic acid amide
condensation reaction

(k) $NH_2 + CH_3 \rightarrow CH_3{-}NH_2 + H{-}H$

ammonia + methane → methylamine + hydrogen
inorganic alkane amine
condensation reaction

8. (Sample answers)

(a) $CH_3CH_2CH_3 + Cl_2 \rightarrow CH_3CH_2CH_2Cl + HCl$

(b)  $+ Br_2 \rightarrow$ $+ HBr$

(c) $CH_3CH_2OH + 3\,O_2 \rightarrow 2\,CO_2 + 3\,H_2O$

(d) $CH_3CH(OH)CH_2CH_3 \xrightarrow{H_2SO_4} CH_3CH{=}CHCH_3 + H_2O$

(e) $CH_3CH_2CH_2CHO + (O) \rightarrow CH_3CH_2CH_2COOH$

(f) $CH_3CH(OH)CH_2CH_2CH_3 + (O) \rightarrow CH_3COCH_2CH_2CH_3 + H_2O$

(g) $CH_3COOH + CH_3(CH_2)_4CH_2OH \xrightarrow{H_2SO_4} CH_3COOCH_2(CH_2)_4CH_3 + H_2O$

(h) $CH_3(CH_2)_3COOCH_3 + H_2O \xrightarrow{NaOH} CH_3(CH_2)_3COOH + CH_3OH$

(i) $CH_3CH_2CH_2OH + (O) \rightarrow CH_3CH_2CHO + H_2O$

(j) $CH_2{=}CHCH_2CH_3 + H_2O \xrightarrow{H_2SO_4} CH_3CH(OH)CH_2CH_3$

(k) $CH_3COOH + HN(CH_2CH_2CH_3)_2 \rightarrow CH_3CON(CH_2CH_2CH_3)_2 + H_2O$

9. Start with ethene and 3-hydroxy-1-butanol.

$CH_2{=}CH_2 + H_2O \rightarrow CH_3CH_2OH$

$CH_3CH(OH)CH_2CH_2OH + (O) \rightarrow CH_3CH(OH)CH_2CHO + H_2O$

$CH_3CH(OH)CH_2CHO + (O) \rightarrow CH_3CH(OH)CH_2COOH$

$CH_3CH(OH)CH_2COOH + CH_3CH_2OH \xrightarrow{H_2SO_4} CH_3CH(OH)CH_2COOCH_2CH_3 + H_2O$

10. (Sample answers)

(a) $CH_2{=}CHCH_3 + H_2O \rightarrow CH_3CH(OH)CH_3$

$$CH_3CH(OH)CH_3 + (O) \rightarrow CH_3\overset{\overset{O}{\|}}{C}CH_3 + H_2O$$

(b) $CH_3COOCH_3 + NaOH \rightarrow CH_3COONa + CH_3OH$

(c) $CH_3CH_2CH_2OH + (O) \rightarrow CH_3CH_2CHO + H_2O$

(d) $CH_3CH_2CH_2OH + (O) \rightarrow CH_3CH_2CHO + H_2O$

$CH_3CH_2CHO + (O) \rightarrow CH_3CH_2COOH$

(e) $$CH_2{=}CH_2 + Cl_2 \rightarrow \overset{\overset{Cl}{|}}{CH_2}\overset{\overset{Cl}{|}}{CH_2}$$

(f) *N*,*N*-dimethylethanamide from an alkane, an alkene, and ammonia

$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$

$CH_3Cl + NH_3 \rightarrow HN(CH_3)_2 + 2\ HCl$

$CH_2{=}CH_2 + HCl \rightarrow CH_3CH_2Cl$

$HN(CH_3)_2 + CH_3CH_2Cl \rightarrow CH_3CH_2N(CH_3)_2 + HCl$

Applying Inquiry Skills

11. (a) $C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2$

(b) $n_{C_2H_4} = \dfrac{m}{M}$

$= \dfrac{2.00\ \text{kg}}{28.06\ \text{g/mol}}$

$n_{C_2H_4} = 71.3\ \text{mol}$

$n_{C_2H_4Cl_2} = n_{C_2H_4} = 71.3\ \text{mol}$

theoretical yield $= m_{C_2H_4Cl_2}$

$= nM$

$= 71.3\ \text{mol} \times 98.96\ \text{g/mol}$

theoretical yield $= 7.06\ \text{kg}$

actual yield $= 6.14\ \text{kg}$

$\text{percentage yield} = \dfrac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$

$= (6.14\ \text{kg}/7.06\ \text{kg}) \times 100\%$

percentage yield $= 87.0\%$

(c) The actual yield would be less than the theoretical yield if the reactants were impure, if there were some loss of product, or if the reaction were incomplete.

12. The three alcohols have different boiling points that increase in the order: methanol, ethanol, and 1-pentanol. The alcohols can be separated by fractional distillation, using common laboratory equipment. Each alcohol is collected at its boiling point and condensed. All three alcohols have hydroxyl groups capable of hydrogen bonding; the larger alcohols have longer nonpolar hydrocarbon chains that increase the van der Waals attractions.

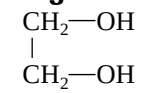
13. The ester ethyl ethanoate is synthesized from a reaction between ethanol and ethanoic acid, in the presence of concentrated sulfuric acid. Ethanol can be synthesized from hydration of ethene with water, in the presence of sulfuric acid. Ethanoic acid can be synthesized from controlled oxidation of ethanol to ethanal and further to ethanoic acid, using an oxidizing agent such as sodium dichromate or potassium permanganate.

Safety precautions:

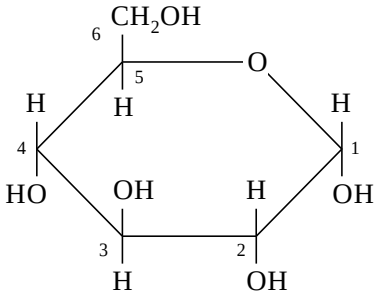
Wear eye protection and a lab apron; use a fume hood when handling concentrated sulfuric acid.

14. The solid formed is the ester. The ester has a lower melting point and solubility in aqueous solvents because it lacks the hydroxyl group present in both alcohols and carboxylic acids, and thus does not hydrogen bond.

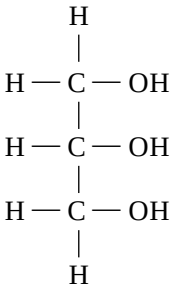
Making Connections

15. 

ethylene glycol



glucose



glycerol

(a) 2-propanol, ethylene glycol, glycerol, and glucose have, in sequence, increasing numbers of hydroxyl groups, and are thus in increasing order of capability to hydrogen bond, and are in increasing order of relative melting point and boiling point.

(b) 2-propanol, ethylene glycol, glycerol, and glucose have, in sequence, increasing numbers of hydroxyl groups, and are thus in increasing order of capability to hydrogen bond, and are in increasing order of their solubility in water.

(c) The sweet taste of ethylene glycol attracts animals who ingest it and suffer from its toxic effects.

(d) The three compounds all taste sweet and all have hydroxyl groups bonded to carbon chains.

16. (a) $CH_3COOH + CH_3CH_2CH_2CH_2CH_2OH \rightarrow CH_3COOCH_2CH_2CH_2CH_2CH_3 + H_2O$

(b) (Answers will vary, but should refer to the raw materials and the method of synthesis.)

(c) The most commonly used natural source of vanilla flavouring is the vanillin plant, *Vanilla planifolia*, a member of the orchid family. Vanillin, a glucoside, is extracted from ripe vanillin beans, using ethanol and water, under cool temperatures to reduce flavour loss. The extract is then aged from a few days to several years.

Synthetic vanilla flavouring contains a blend of natural vanilla and synthetic chemicals, and cannot be legally labelled "natural." The first synthetic vanilla was made from coniferin, and later from euganol, found in cloves. More recently, synthetic vanilla is made from ethyl vanillin (made from coal tar), or lignin vanillin, a byproduct of the paper industry. In the 1930s, the Ontario Paper Company solved an environmental problem by turning their industrial waste, a sulfite liquor, into synthetic vanilla.