

## UNIT 1 SELF-QUIZ

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1. False: Carbonyl groups are present in alcohols, aldehydes, ketones, and esters. They are not present in ethers.
2. True
3. False: The formation of an alcohol when an alkene reacts with water in the presence of an acid is an example of an addition reaction.
4. False: Benzene *does not react* readily with bromine in addition reactions. *Bromine can only be added to a benzene ring by substitution reactions.*
5. False: When methanol and vinegar are allowed to react, *methyl ethanoate* and water are produced from the esterification reaction.
6. True
7. False: 1,2-dibromoethane can be produced from the *addition* reaction of bromine with ethene.
8. False: Polybutene is formed from addition reaction of butene monomers, and the polymer chain consists of carbon atoms single bonded to each other, with ethyl groups attached to *alternate* carbon atoms in the chain.
9. False: Condensation polymers such as *nylon* may have physical properties such as flexibility and strength as a result of the degree of crosslinkages present in the polymer. (*Polystyrene and polypropylene are addition polymers.*)
10. True
11. (d)
12. (e)
13. (b)
14. (e)
15. (d)
16. (c)
17. (c)
18. (d)
19. (d)
20. (a)
21. (c)
22. (d)
23. (c)
24. (b)
25. (e)
26. (e)

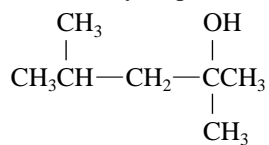
## UNIT 1 REVIEW

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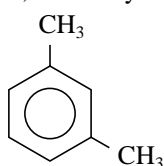
### Understanding Concepts

1. (a) alcohol  
(b) carboxylic acid  
(c) aldehyde  
(d) ether  
(e) amine  
(f) ketone  
(g) ester  
(h) amide  
(i) ketone  
(j) carboxylic acid
2. (a) carbonyl  
(b) carbonyl  
(c) hydroxyl  
(d) carbon-carbon double bond

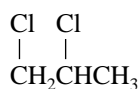
- (e) carbonyl (amide linkage)
  - (f) (ether linkage)
  - (g) carbonyl (ester linkage)
3. (a) 2,4-dimethyl-2-pentanol



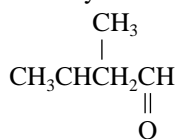
- (b) 1,2-ethandiol
- (c) 1,3-dimethylbenzene



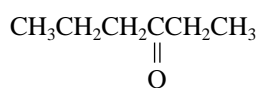
- (d) 1,2-dichloropropane



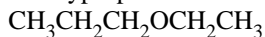
- (e) 2-methylbutanal



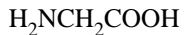
- (f) 3-hexanone



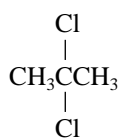
- (g) ethoxypropane



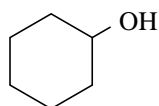
- (h) 2-aminoethanoic acid



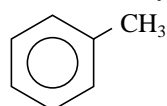
- (i) 2,2-dichloropropane



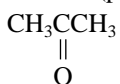
- (j) cyclohexanol



4. (a) toluene (methylbenzene)

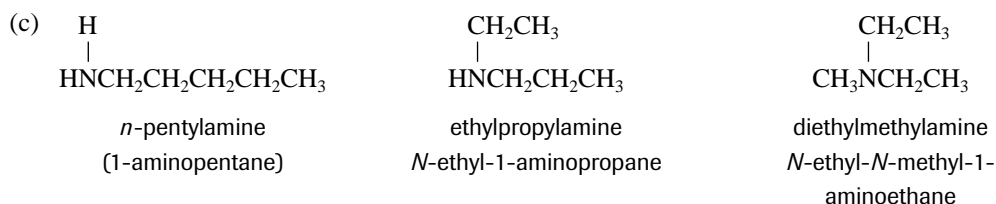
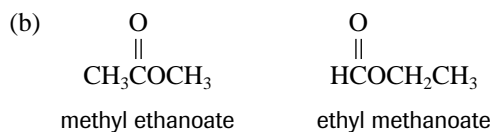
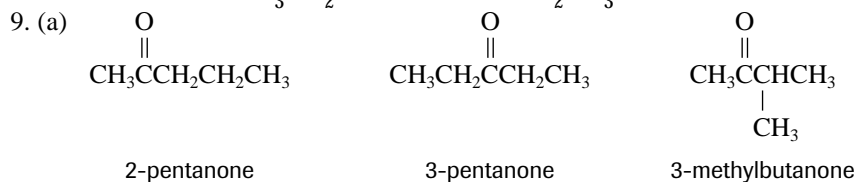


- (b) acetone (propanone)

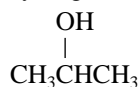


- (c) acetic acid (ethanoic acid)
- $$\begin{array}{c} \text{CH}_3\text{COH} \\ || \\ \text{O} \end{array}$$
- (d) formaldehyde (methanal)
- $$\text{HCHO}$$
- (e) glycerol (1,2,3-propantriol)
- $$\begin{array}{c} \text{CH}_2 - \text{CH} - \text{CH}_2 \\ | \quad | \quad | \\ \text{OH} \quad \text{OH} \quad \text{OH} \end{array}$$
- (f) diethyl ether (ethoxyethane)
- $$\text{CH}_3\text{CH}_2 - \text{O} - \text{CH}_2\text{CH}_3$$
5. (a) carbonyl group; carbon-carbon double bond; hydroxyl group  
 (b) carboxyl group  
 (c) amino group
6. (a) ethoxyethane, propanone: The carbonyl group in the ketone makes it more polar and thus it has stronger intermolecular attractions.  
 (b) ethanal, ethanoic acid: The acid has an additional hydroxyl group that the aldehyde does not have, making it more polar and capable of hydrogen bonding; thus, the acid has stronger intermolecular attractions.  
 (c) ethanol, 1-pentanol: Both molecules have a polar hydroxyl group, but the longer hydrocarbon chain in the pentanol increases its intermolecular van der Waals attractions.
7. (a) benzene, benzoic acid: The carboxyl group in benzoic acid makes it more polar and capable of hydrogen bonding with water; thus, the acid is more soluble in water.  
 (b) methyl ethanoate, ethanoic acid: The ester is less soluble in water than is the acid because the acid has a carbonyl group and a hydroxyl group capable of hydrogen bonding with water, but in the ester, the hydroxyl is lost, having been bonded in the ester linkage; thus, the acid is more soluble in water.  
 (c) 2-butanone, 2-butanol: The ketone has a carbonyl group, but the alcohol has a hydroxyl group that can hydrogen bond with water and is therefore more soluble in water.
8. (a) ethene from ethanol: dehydration, elimination
- $$\begin{array}{c} \text{H} \quad \text{OH} \\ | \quad | \\ \text{CH}_2 - \text{CH}_2 \end{array} \xrightarrow{\text{H}_2\text{SO}_4} \text{CH}_2 = \text{CH}_2 + \text{H}_2\text{O}$$
- (b) ethoxyethane from ethanol: dehydration, condensation
- $$\text{CH}_3\text{CH}_2\text{OH} + \text{HOCH}_2\text{CH}_3 \xrightarrow{\text{H}_2\text{SO}_4} \text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3 + \text{H}_2\text{O}$$
- (c) propanal from an alcohol: controlled oxidation
- $$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + (\text{O}) \rightarrow \begin{array}{c} \text{O} \\ || \\ \text{CH}_3\text{CH}_2\text{CH} \end{array}$$
- (d) a secondary pentanol from an alkene: addition, hydration
- $$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH} = \text{CH}_2 + \text{H}_2\text{O} \xrightarrow{\text{H}_2\text{SO}_4} \begin{array}{c} \text{OH} \\ | \\ \text{CH}_3\text{CH}_2\text{CH}_2\text{CHCH}_3 \end{array}$$
- (e) acetic acid from an alcohol: controlled oxidation
- $$\begin{array}{c} \text{O} \\ || \\ \text{CH}_3\text{CH}_2\text{OH} \end{array} + (\text{O}) \rightarrow \begin{array}{c} \text{O} \\ || \\ \text{CH}_3\text{CH} \end{array} + \text{H}_2\text{O}$$
- ethanol                      ethanal
- 
- $$\begin{array}{c} \text{O} \\ || \\ \text{CH}_3\text{CH} \end{array} + (\text{O}) \rightarrow \begin{array}{c} \text{O} \\ || \\ \text{CH}_3\text{C} - \text{OH} \end{array}$$
- ethanal                      ethanoic (acetic) acid

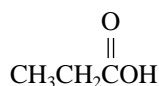
- (f) methoxymethane from methanol: condensation  
 $\text{CH}_3\text{OH} + \text{HOCH}_3 \rightarrow \text{CH}_3\text{OCH}_3 + \text{H}_2\text{O}$   
 (g) ethyl formate from ethanol and methanoic acid: esterification  
 $\text{HCOOH} + \text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{HCOOCH}_2\text{CH}_3$



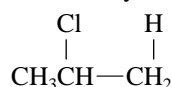
10. (a) hydrogenation



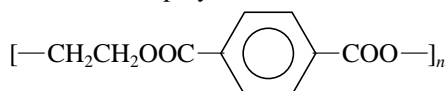
- (b) controlled oxidation



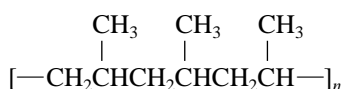
- (c) addition, hydrohalogenation



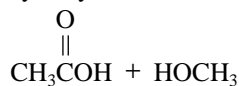
- (d) condensation, polymerization



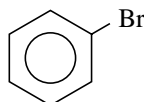
- (e) addition, polymerization



- (f) hydrolysis

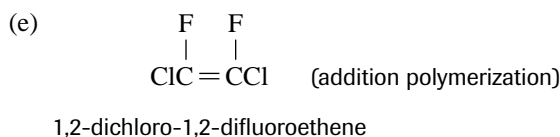
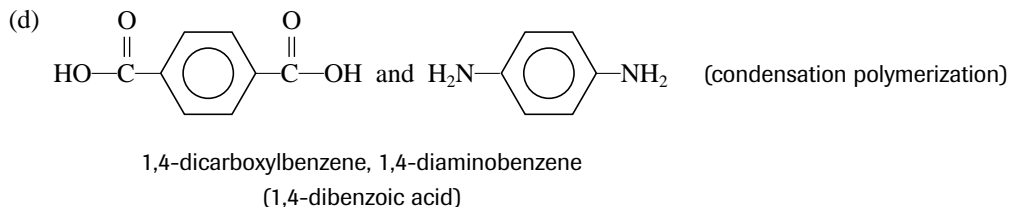
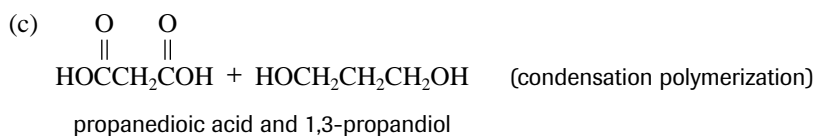


- (g) substitution, halogenation

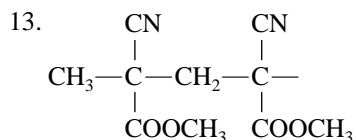
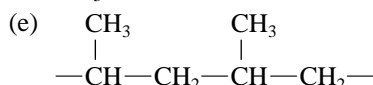
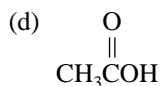
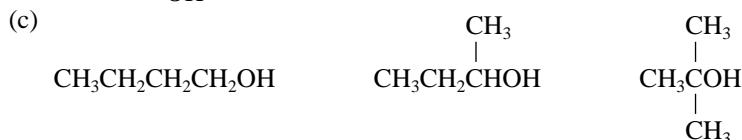
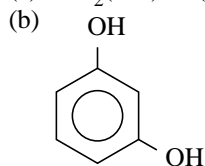


11. (a)  $\text{HOCH}_2\text{CH}_2\text{COOH}$  (condensation polymerization)  
 3-hydroxypropanoic acid

- (b)  $\text{CH}_3\text{CH}=\text{CH}_2$  (addition polymerization)  
 propene



12. (Sample structures of model-building activity)

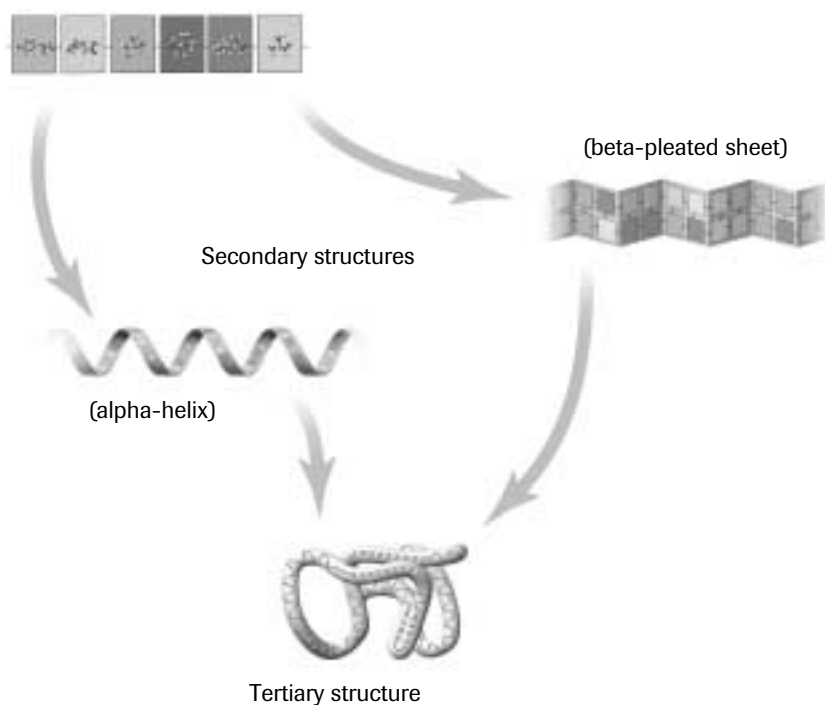


14. In inorganic compounds, the combining ratio of elements is restricted; so a limited number of compounds is possible. In organic compounds, carbon can form four bonds, and bond with other carbon atoms in straight chains, branched chains, or cyclic structures; thus, the possibilities for new compounds are much greater. For example, name specific examples of: new medicines, new synthetic materials for medical procedures, materials for preventing or cleaning up hazardous spills, materials for safety equipment or clothing.

15. (a) Starch is used in plants for energy storage and source. The orientation of the glucose–glucose linkages favours intrachain hydrogen bonds between hydroxyl groups, resulting in a helical structure. These chains are sufficiently small to make these polysaccharides soluble in water, and easily transported in the organism. Enzymes are present to break down starch into glucose.

(b) Glycogen is used in animals for energy storage and source. The orientation of the glucose–glucose linkages is similar to that in starch, with more branching, and favouring intrachain hydrogen bonds between hydroxyl groups, resulting in a helical structure. Similar to starch, glycogen is also soluble in water, and easily transported in the organism. Enzymes are present in animals to break down glycogen into glucose.

- (c) Cellulose is used for cell structure and strength in plants. The orientation of the glucose–glucose linkages favours interchain hydrogen bonds between hydroxyl groups, resulting in a linear structure. These interchain links produce a strong and inflexible structure of layered sheets of cellulose, insoluble in water, ideal for its function.
16. (Sample answer) Possible arguments: Genetically modified organisms are not natural because altered from natural state; plants are by definition natural and organic, whether the genes were modified or not; “organic” because no synthetic fertilizers and pesticides were used. Corn is composed of organic compounds such as carbohydrates, proteins, and fats and oils; thus, natural products such as corn are not chemical. Cereal is chemical because all matter is made of chemicals.
17. Functional groups: phosphate group, a ribose group (hydroxyl groups), a nitrogenous base (carbonyl groups, amino groups). The monomers are joined by a phosphate–ribose backbone that is formed by condensation reactions.
18. Primary structure



Primary structure, the amino acid sequence, determines the type and position of intrachain interactions, thus determining the secondary structure, coils or pleated sheets. The secondary structure determines the sections of the protein that can fold into globular shapes, or align to form fibrous proteins. These structural features determine the solubility, mobility, and strength of the proteins, and thus their function.

Each amino acid is coded by three nucleotides. The sequence of nucleotides in the DNA determines the sequence of amino acids that will be linked together to form a specific protein.

19. The long hydrocarbon chains in the fatty acids of triglycerides are similar to the hydrocarbons that release large amounts of energy when burned. Thus, fats and oils release more energy when burned than do carbohydrates, which contain more hydroxyl groups.
20. In unsaturated oils, the fatty acid components in the triglycerides contain double bonds. Since a molecule cannot rotate freely about a double bond, the long hydrocarbon component of the fatty acid has “bends” in the molecule. These bends prevent the fatty acid chains from packing as closely together as can saturated fatty acids. The distance between the fatty acid chains weakens the van der Waals attractions between molecules, and thus lowers the melting point. Thus, a more saturated triglyceride would have a higher melting point.

## Applying Inquiry Skills

### 21. Purpose

The purpose of this activity is to determine the identity of three compounds, to match labels for 1-propanol, propanal, and propanoic acid.

### Experimental Design

Propanoic acid can be identified by determining the pH of each compound, the lowest value being the acid. The aldehyde and the alcohol can be identified by comparing their boiling points; the aldehyde would have a lower boiling point than the alcohol.

### Prediction

The propanoic acid will have the lowest pH. The aldehyde will have a lower boiling point than the alcohol.

### Hypothesis

The carboxyl group of the propanoic acid has acidic properties, and carboxylic acids have pH values lower than 7; the other two compounds are not acidic. The aldehyde has a carbonyl group which, although polar, produces weaker intermolecular attractions than the hydroxyl group in the alcohol, because hydroxyl groups can hydrogen bond. Thus, since the hydrocarbon components in the two compounds are comparable, the alcohol will have a higher boiling point than the aldehyde.

### Safety Precautions

Wear eye protection and a lab apron. Do not use open flames. When test tubes are being heated, point them away from people. Dispose of the compounds in labelled containers.

### 22. Experimental Design

propane  $\rightarrow$  propene  $\rightarrow$  propanol  $\rightarrow$  propanone

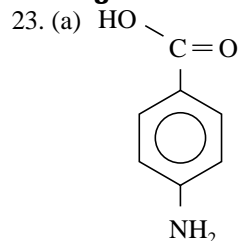
### Procedure

The propane is converted to the halide by substitution reaction with chlorine, with heat and UV light. Chloropropane is converted to propene by elimination reaction, in the presence of sodium hydroxide. The propene is converted to propanol by reaction with water, in the presence of sulfuric acid. The 2-propanol is converted to propanone by controlled oxidation with potassium permanganate.

### Safety Precautions

Wear eye protection and a lab apron. Do not use open flames. Work in well-ventilated area. Dispose of materials in labelled containers.

## Making Connections



- (b) PABA is benzoic acid with an added  $\text{NH}_2$  group, in position 4; thus, it has an additional polar group that is capable of hydrogen bonding. Prediction: solid at room temperature, with boiling point higher than that of benzoic acid. The presence of the carboxyl group and the amino group makes the molecule highly polar and capable of hydrogen bonding, making it soluble in water. The presence of the benzene ring makes it likely soluble in nonpolar solvents such as alcohol and ether as well. With the presence of both a carboxyl group and an amino group, PABA can undergo condensation reactions with other molecules, or undergo condensation polymerization with other PABA molecules.
- (c) (Sample answer) Sunscreens act by providing physical barriers to UV light (as by zinc oxide and titanium dioxide), or chemical barriers. PABA is a chemical sunscreen that acts by absorbing radiation in the wavelengths that are not visible to the human eye; they thus appear transparent and invisible on the skin. PABA is not soluble in water and so must be dissolved in alcohol for use; however, most of the PABA derivatives are water soluble. Sunlight consists of UVA rays (penetrate deep into the base layer of skin) and UVB rays (burning rays); both contribute to skin burning and skin cancer. PABA provides mostly UVB coverage between 260 and 330 nm; consumers should select a sunscreen that screens both UVA and UVB rays – the “broad spectrum” sunscreens.

PABA does pose some possible hazards: Although sunscreens should be used every day to prevent premature aging and skin cancer (80% of the Sun’s ultraviolet rays pass through the clouds on a cloudy day), sun exposure

is needed for vitamin D protection; thus, regular users of sunscreen may require vitamin D supplements. The original PABA was sometimes unpopular because it stained clothing; PABA esters such as glycerol PABA, pentyl dimethyl PABA, and octyl dimethyl PABA are now used. Some people are sensitive to PABA and its esters and should choose other sunscreens.

24. (Sample answers)

- (a) Chlorinated hydrocarbons such as tetrachloroethylene, also known as “perchloroethylene” (PERC), are used as cleaning solvents. The effects of PERC on humans include depression of the central nervous system; damage to the liver and kidneys; and impaired memory, confusion, and dizziness. There is also evidence that it may cause cancer in humans. Contamination of ground water from PERC occurs through dumping, spills, or bad practices. PERC does not evaporate and, since it is more dense than water, it is difficult to clean up spills.
- (b) Silicon wafers are used in the semiconductor industry for products such as personal computers, cellular phones, and car engines. An environmental issue arises from the use of large amounts of highly purified water and solvents to rinse and clean a silicon wafer. Scientists are developing new, environmentally friendly ways to manufacture the processors; one such project is the use of a gas-phase process that would replace the use of liquids for chip cleaning. Other research in plastics has resulted in a detergent that would dissolve in liquid  $\text{CO}_2$  and has excellent cleaning properties; this project has received a Green Chemistry award.

25. Desired properties of polymers for use in the dental industry include high tensile strength, durable, insoluble in water, nontoxic, does not soften at high temperatures (e.g., hot drinks). Shrinkage of the polymer is a common deficiency.

Dental polymers have three main components: a polymer matrix; fillers of various types, sizes, shapes; and a phase that bonds the other two phases.

Monomers may form branched or linear polymer chains. The linear polymer chains can have a parallel alignment and form crosslinkages between chains; this allows for a crystalline structure, which produces more of the desired properties.

Dental monomers form strong hydrogen bonds, influencing the polymerization process and the network structure formed.

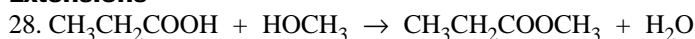
The polymerization process is usually initiated by chemical reduction–oxidation reactions, or by photochemical redox reactions. Dental fillings are generally cured using a curing lamp, a process that results in 2–3% shrinkage; this leads to eventual detachment of the filling from the cavity. Pulse lasers can cause numerous initiations of polymerization at the onset of curing, and may reduce the shrinkage of the fillings.

26. In high-pressure liquid chromatography (HPLC), one solvent — the mobile phase — is continuously applied to the column — the stationary phase. The mobile phase acts as a carrier for the sample solution that is injected into the stationary phase of the chromatography column. The components of the sample solution migrate according to the interactions of the components with the column, the degree of migration and separation of components being determined by the type of mobile phase and column. For example, those samples that have stronger interactions with the stationary phase than with the mobile phase will move more slowly, and thus have a longer retention time. Conversely, components that are highly soluble in the mobile phase will move along with this solvent, travelling further along the column.

Molecules can be separated on the basis of their structure, which includes their size, shape, charge, and hydrophylic/hydrophobic properties. These characteristics determine the type of solvent and gel selected.

27. (Sample answers) paper (natural, polymer); plastic pen (synthetic, polymer); cotton and polyester shirt (natural and synthetic, polymer); running shoes (synthetic, polymer); ketchup (natural, polymer); vinegar (natural, not polymer); butter (natural, not polymer); gasoline (natural, not polymer); television set (synthetic, polymer); CDs (synthetic, polymer)

### Extensions



$$\begin{aligned} n_{\text{methanol}} &= \frac{m}{M} \\ &= \frac{20.0 \text{ g}}{32.05 \text{ g/mol}} \end{aligned}$$

$$n_{\text{methanol}} = 0.624 \text{ mol}$$

$$\begin{aligned} n_{\text{propanoic acid}} &= \frac{m}{M} \\ &= \frac{40.0 \text{ g}}{74.09 \text{ g/mol}} \end{aligned}$$

$$n_{\text{propanoic acid}} = 0.540 \text{ mol}$$



The limiting reagent is propanoic acid.

$$\begin{aligned}n_{\text{methyl propanoate}} &= n_{\text{propanoic acid}} \\&= 0.540 \text{ mol}\end{aligned}$$

**Theoretical yield:**

$$\begin{aligned}m &= nM \\&= 0.540 \text{ mol} \times 88.12 \text{ g/mol}\end{aligned}$$

$$m = 47.6 \text{ g}$$

**Actual yield:** 35.2 g

$$\% \text{ yield} = \frac{35.2 \text{ g}}{47.6 \text{ g}} \times 100\%$$

$$\% \text{ yield} = 73.9\%$$

The theoretical yield of methyl propanoate was 47.6 g, and the percent yield was 73.9%.

29. (a) Calculate the amount of compound in sample:

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$\begin{aligned}&= \frac{100.0 \text{ kPa} \times 1.29 \text{ L}}{8.31 \frac{\text{kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 373 \text{ K}}\end{aligned}$$

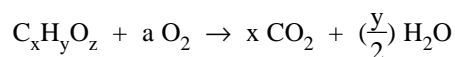
$$n = 0.0416 \text{ mol}$$

Calculate molar mass of compound:

$$\begin{aligned}M &= \frac{m}{n} \\&= \frac{3.00 \text{ g}}{0.0416 \text{ mol}}\end{aligned}$$

$$M = 72.12 \text{ g/mol}$$

Calculate amount of carbon dioxide and water produced in combustion:



$$m_{\text{CO}_2} = 7.35 \text{ g}$$

$$\begin{aligned}n_{\text{CO}_2} &= \frac{m}{M} \\&= \frac{7.35 \text{ g}}{44.01 \text{ g/mol}}\end{aligned}$$

$$n_{\text{CO}_2} = 0.167 \text{ mol}$$

$$m_{\text{H}_2\text{O}} = 3.01 \text{ g}$$

$$\begin{aligned}n_{\text{H}_2\text{O}} &= \frac{m}{M} \\&= \frac{3.01 \text{ g}}{18.02 \text{ g/mol}}\end{aligned}$$

$$n_{\text{H}_2\text{O}} = 0.167 \text{ mol}$$

Since 0.0416 mol of the compound produced 0.167 mol of  $\text{CO}_2$ ,

$$\text{number of C atoms in one molecule of compound} = \frac{0.167 \text{ mol}}{0.0416 \text{ mol}} = 4.01 \text{ atoms.}$$

Therefore, the compound must be  $\text{C}_4\text{H}_y\text{O}$ .

Since 0.0416 mol of the compound produced 0.167 mol of  $\text{H}_2\text{O}$ ,

$$\text{number of H atoms in compound} = 2 \times \frac{0.167 \text{ mol}}{0.0416 \text{ mol}} = 8.02 \text{ atoms.}$$

(Note that there are two atoms of H in each molecule of  $\text{H}_2\text{O}$ .)

Therefore, the compound must be  $\text{C}_4\text{H}_8\text{O}_z$ .

Calculate the number of atoms of O in the formula:

$$M_{\text{compound}} = 72.12 \text{ g/mol (calculated above)}$$

The formula contains 4 C atoms and 8 H atoms, totalling 56.12 g/mol.

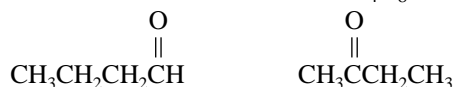
The remainder is accounted for by oxygen atoms:  $(72.12 - 56.12) \text{ g/mol}$

$$= 16.00 \text{ g/mol}$$

Therefore, the molecule must contain just one O atom.

The formula of the compound is therefore  $\text{C}_4\text{H}_8\text{O}$ .

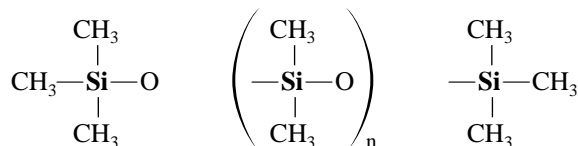
(b) Possible structural formulas for  $\text{C}_4\text{H}_8\text{O}$ :



(c) The compound is likely to be a saturated aldehyde or ketone. Evidence: not a hydrocarbon since it contains oxygen. Some polar groups are liquid at ordinary room temperatures, indicating intermolecular forces stronger than van der Waals attractions. Also, they are soluble in alcohols. May also be aldehydes or ketones, or esters: sweet minty odour; soluble in nonpolar solvents such as acetone. Saturated compound: does not undergo addition reaction with aqueous bromine.

### Exploring

30. A silicone is a polymer of silicon, oxygen, and organic groups, generally called an organo-silicon polymer (polydimethylsiloxane).



The properties of the polymer can vary widely, so silicone has many uses.

- Low-viscosity fluids: high compressibility, low temperature service and heat transfer properties; soluble in a great variety of solvents including petroleum oils; used as antifoam, flow-control aids in coating applications; has electronic cooling applications in magnetrons.
- Intermediate-viscosity fluids: provide safe, low volatility heat transfer media; used as mould releases for rubber, plastic, and glass parts; in delicate timing and photographic devices; as hydraulic fluids; in protective hand creams; as toners in photocopiers; in brake fluids.
- High-viscosity fluids: as internal lubricants; as liquid springs in shock absorbers; as an additive in paint; as stationary phases in gas chromatography.
- Breast implants: benefits – post-surgery breast replacement, cosmetic appeal; drawbacks – claims that rupture of implants linked to health problems, e.g., autoimmune disease, cancer, silicone infiltration of lymph nodes. Relationship of silicone to diseases is not definitive.

