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#### **Essential Notes on Organic Chemistry**

## **Learning Outcomes:**

Students should be able to:

#### **Fuels and Crude Oil**

- a) Name natural gas, mainly methane, and petroleum as sources of energy.
- **b)** Describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation.
- **c)** Name the following fractions and state their uses:
  - i) Petrol (gasoline) as a fuel in cars.
  - ii) Naphtha as feedstock for the chemical industry.
  - iii) Paraffin (kerosene) as a fuel for heating and cooking and for aircraft engines.
  - iv) Diesel as a fuel for diesel engines.
  - v) Lubricating oils as lubricants and as sources of polishes and waxes.
  - vi) Bitumen for making road surfaces.
- **d)** State that the naphtha fraction from crude oil is the main source of hydrocarbons used as the feedstock for the production of a wide range of organic compounds.
- **e)** Describe the issues relating to the competing uses of oil as an energy source and as a chemical feedstock.

#### **Alkanes**

- a) Describe an homologous series as a group of compounds with a general formula, similar chemical properties and showing a gradation in physical properties as a result of increase in the size and mass of the molecules, *e.g.* melting and boiling points; viscosity; flammability.
- **b)** Describe the alkanes as a homologous series of saturated hydrocarbons with the general formula  $C_nH_{2n+2}$ .
- c) Draw the structures of branched and unbranched alkanes, C1 to C4, and name the unbranched alkanes, methane to butane.
- **d)** Define isomerism and identify isomers.
- e) Describe the properties of alkanes (exemplified by methane) as being generally unreactive except in terms of burning and substitution by chlorine.

#### **Alkenes**

- a) Describe the alkenes as a homologous series of unsaturated hydrocarbons with the general formula  $C_nH_{2n}$ .
- **b)** Draw the structures of branched and unbranched alkenes, C2 to C4, and name the unbranched alkenes, ethene to butene.
- c) Describe the manufacture of alkenes and hydrogen by cracking hydrocarbons and recognise that cracking is essential to match the demand for fractions containing smaller molecules from the refinery process.
- **d)** Describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine.
- **e)** Describe the properties of alkenes (exemplified by ethene) in terms of combustion, polymerisation and the addition reactions with bromine, steam and hydrogen.
- f) State the meaning of polyunsaturated when applied to food products.
- **g)** Describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetable oils to form a solid product.

#### **Alcohols**

- a) Describe the alcohols as a homologous series containing the –OH group.
- **b)** Draw the structures of alcohols, C1 to C4, and name the unbranched alcohols, methanol to butanol.
- c) Describe the properties of alcohols in terms of combustion and oxidation to carboxylic acids.
- **d)** Describe the formation of ethanol by the catalysed addition of steam to ethene and by fermentation of glucose.
- **e)** State some uses of ethanol, *e.g.* as a solvent; as a fuel; as a constituent of alcoholic beverages.

#### **Carboxylic Acids**

- a) Describe the carboxylic acids as a homologous series containing the -CO<sub>2</sub>H group.
- **b)** Draw the structures of carboxylic acids, methanoic acid to butanoic acid and name the unbranched acids, methanoic to butanoic acids.
- c) Describe the carboxylic acids as weak acids, reacting with carbonates, bases and some metals.
- **d)** Describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or acidified potassium dichromate(VI).
- **e)** Describe the reaction of a carboxylic acid with an alcohol to form an ester, *e.g.* ethyl ethanoate.
- f) State some commercial uses of esters, e.g. perfumes; flavourings; solvents.

#### **Macromolecules**

- a) Describe macromolecules as large molecules built up from small units, different macromolecules having different units and/or different linkages.
- **b)** Describe the formation of poly(ethene) as an example of addition polymerisation of ethene as the monomer.
- c) State some uses of poly(ethene) as a typical plastic, e.g. plastic bags; clingfilm.
- d) Deduce the structure of the polymer product from a given monomer and vice versa.
- **e)** Describe nylon, a polyamide, and *Terylene*, a polyester, as condensation polymers, the partial structure of nylon being represented as:

And the partial structure of Terylene as:

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(Details of manufacture and mechanisms of these polymerisations are not required).

- **f)** State some typical uses of man-made fibres such as nylon and *Terylene*, *e.g.* clothing; curtain materials; fishing line; parachutes; sleeping bags.
- g) Describe the pollution problems caused by the disposal of non-biodegradable plastics.

# 1. In Chemistry, what is meant by the term "organic"?



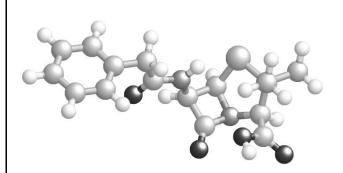
• What is organic, and what is inorganic?

Organic:	<ul><li>Inorganic:</li></ul>

. . . . .


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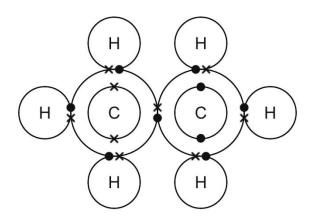
# 2. What are the essential characteristics of an organic compound?



• "Ball-and-stick" model of the antibiotic penicillin.


# 3. Bonding in organic compounds.

- The dot-and-cross diagram for *ethane*, C<sub>2</sub>H<sub>6</sub>, is given below:
- In the space provided below, draw the dot-and-cross diagram for *ethene*, C<sub>2</sub>H<sub>4</sub>:



4. What properties of carbon make it so versatile?

C - C bond enthalpy = 348 kJ/mol C = C bond enthalpy = 612 kJ/mol

5. Homologous series.

**Alcohols** 

Carboxylic acids

Alkanes:

Alkenes:

Carboxylic Acids:

6.	Namina	etraight_chain	alkanos
Ο.	maming	straight-chain	aikanes.

1) Methane

2) .....  $C_2H_6$ 

Propane .....

4)  $C_4H_{10}$ 

5) Pentane

C<sub>6</sub>H<sub>14</sub> .....

7) Heptane ......

8) ..... C<sub>8</sub>H<sub>18</sub>

Nonane

10) .....  $C_{10}H_{22}$  • Define the term *hydrocarbon*:

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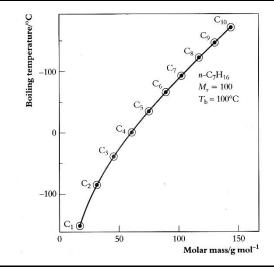
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• Define the term saturated:

• In the space provided below, give the full structural formulae of hexane:

# 7. Physical properties of the first ten straight-chain alkanes.




# 8. Naming alkenes.

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# 9. Naming halogenoalkanes.





# 10. Naming alcohols.

H   H-C-O	
H-C-O H-C-O	
H $H$ $H$	
H-C-C-C-O H H H H	
Н	
H	
H H O H H-C-C-C-H I I I H H H	

# 11. Naming carboxylic acids.

H O H-C-C H O-H	
H O-H	
H H O	
H H O H-C-C-C H H O-H	
H H H O H-C-C-C-C I I I H H H O-H	
Н Н Н O—H	

## 12. Crude oil – formation of crude oil.

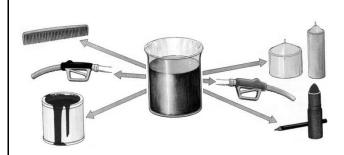


## 13. Crude oil – general properties of crude oil.



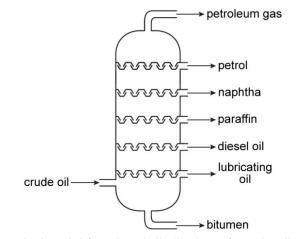
 An oil rig, used to access crude oil trapped below rocks under the sea bed.

#### 14. Crude oil - uses.



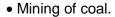
• Some uses of crude oil, e.g. used to make plastics, petrol and diesel.

#### 15. Crude oil – fractional distillation.



• Industrial fractional distillation of crude oil.

# 16. Crude oil - catalytic cracking of long-chain hydrocarbons. liquid alkane on mineral fibre aluminium oxide ethene very strong • Apparatus used to "crack" a long-chain hydrocarbon in the laboratory. Fossil fuels – environmental problems. • Consequence of an oil spillage at sea. 18. Fossil fuels - environmental problems.



# 19. Fossil fuels – environmental problems.



• Atmospheric pollution from burning fossil fuels.


#### 20. Isomerism.

• Are the two molecules drawn below the same, or different?

• Are the two molecules drawn below the same, or different?

#### 21. Isomerism.

• Are the two molecules drawn below the same, or different?

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isomers of C₅H₁₂:	isomers of C <sub>6</sub> H <sub>14</sub> :								
23. Calculation of empirical formulae and mo	lecular formulae.								
a) Calculate the <i>empirical formula</i> of the hydrocarbon that has the following percentage composition:									
C = 85.7 % H = 14.3 %									
<b>b)</b> Given that the relative molecular mass of the hydrocarbon is 42.0, calculate the <i>molecular</i> formula of the hydrocarbon.									
$A_{\rm r}[{\rm C}] = 12.0  A_{\rm r}[{\rm H}] = 1.00$									
24. Calculation of empirical formulae and mo	lecular formulae.								
a) Calculate the <i>empirical formula</i> of the compound that has the following percentage composition:									
C = 60.0 % H = 13.4 % O = 26.6 %									
<b>b)</b> Given that the relative molecular mass of the compound is 60.0, calculate the <i>molecular</i> formula of the hydrocarbon.									
$A_r[C] = 12.0$ $A_r[H] = 1.00$ $A_r[O] = 16.0$									

• Give the full structural formulae of the *three* • Give the full structural formulae of the *five* 

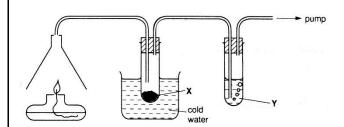
22. Isomerism.

25. Classification of reactions in organic chemistry - addition.

26. Classification of reactions in organic chemistry – elimination.

27. Classification of reactions in organic chemistry - substitution.

# 28. Reactions of the alkanes – complete combustion and incomplete combustion.

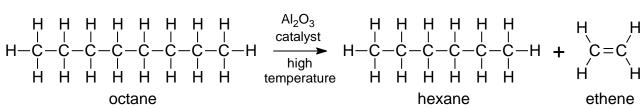


- Equation for complete combustion of C<sub>2</sub>H<sub>6</sub>:
- Equation for incomplete combustion of C<sub>3</sub>H<sub>8</sub>:
- .....
- Reagent **X** = anhydrous copper(II) sulfate.
  - Reagent **Y** = limewater.
- .....

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#### 29. Reactions of the alkanes - substitution.

## 30. Reactions of the alkanes - cracking.



- Write a balanced chemical equation to show the cracking of dodecane, C<sub>12</sub>H<sub>26</sub>, to form an eight carbon alkane and four carbon alkene:
  - Write a balanced chemical equation to show the cracking of dodecane, C<sub>12</sub>H<sub>26</sub>, to form two identical alkenes and hydrogen:

## 31. Reactions of the alkenes - addition.

# 32. Reactions of the alkenes – addition of hydrogen (catalytic hydrogenation).

#### 33. Reactions of the alkenes – manufacture of margarine.

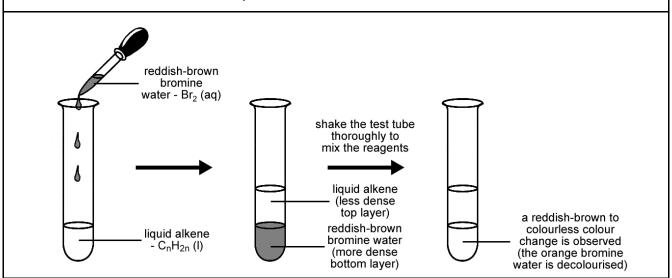
## 34. Reactions of the alkenes – addition of a halogen.

temperature

$$C = C$$
 $C = C$ 
 $C = C$ 

room

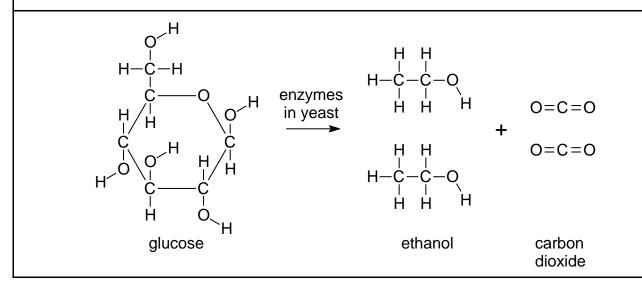
## 35. Reactions of the alkenes – qualitative test for unsaturation.



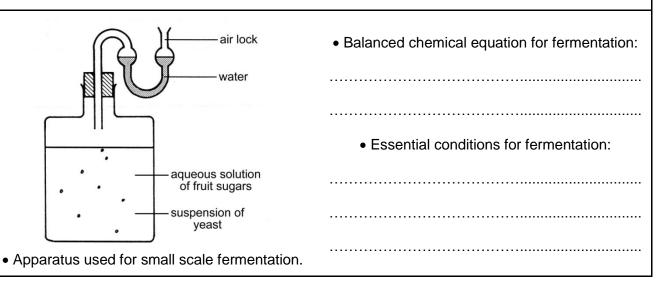
#### 36. Reactions of the alkenes - addition of a hydrogen halide.

#### 37. Reactions of the alkenes - addition of water.

# 38. Alcohols – the fermentation of glucose to ethanol and carbon dioxide.



# 39. Alcohols – the fermentation of glucose to ethanol and carbon dioxide.



# 40. Alcohols – synthesis from alkenes.

#### 41. Alcohols - combustion.



• Write the balanced chemical equation for the complete combustion of ethanol, C<sub>2</sub>H<sub>5</sub>OH:

Write the balanced chemical equation for the

complete combustion of propanol, C<sub>3</sub>H<sub>7</sub>OH:

• A spirit burner – used to burn liquid fuels, such as alcohols.

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#### 42. Alcohols - dehydration.

• Alcohols can be dehydrated (removal of water) to form alkenes. This is achieved by warming the alcohol with either concentrated sulfuric acid or concentrated phosphoric acid.

#### 43. Alcohols - oxidation.

• Alcohols can be oxidised to carboxylic acids. Typical oxidising agents are: a) acidified potassium manganate(VII) – KMnO<sub>4</sub> – changes colour from purple to colourless. **b)** acidified potassium dichromate(VI) – K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> – changes colour from orange to green.

ethanol 
$$H = \begin{pmatrix} H & H & \text{acidified} \\ H & H & \text{KMnO}_4 \end{pmatrix} + \begin{pmatrix} H & O \\ KMnO_4 \end{pmatrix} + \begin{pmatrix} H & O \\ H & H \end{pmatrix} + \begin{pmatrix} H & O \\ H & H \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H & O \\ H & O \end{pmatrix} + \begin{pmatrix} H$$

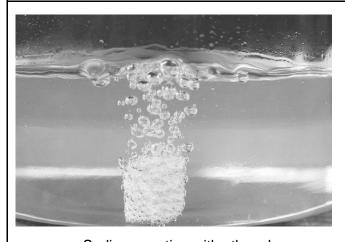
#### Alcohols - oxidation. 44.



• The ethanol in an alcoholic drink can react with oxygen in the air to form ethanoic acid.

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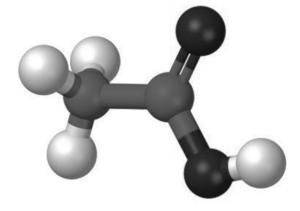
#### 45. Alcohols - Reaction with sodium.



Sodium reacting with ethanol.

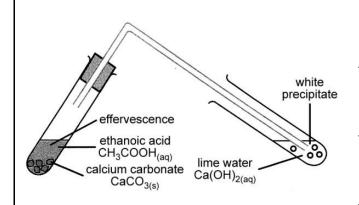
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# 46. Carboxylic acids – general properties.



• "Ball-and-stick" model of ethanoic acid.


47. Carboxylic acids – general reactions.



- Carboxylic Acid + Carbonate
  - Carboxylic Acid + Metal
- Carboxylic Acid + Alkali / Base
- Reaction between ethanoic acid and calcium carbonate.

# calofalli carbonate.

#### 48. Carboxylic acids – reaction with alcohols to form esters (esterification)

ethanoic acid

methanol

methyl ethanoate

water

propanoic acid

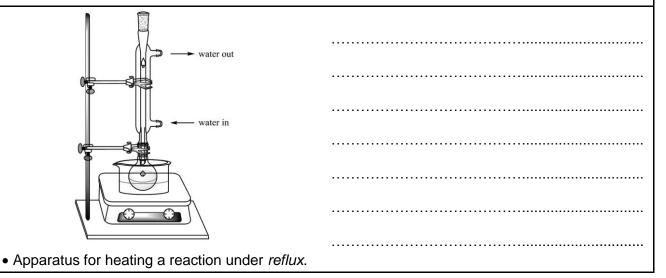
ethanol

# 49. Carboxylic acids - reaction with alcohols to form esters (esterification).

conc. H<sub>2</sub>SO<sub>4</sub>

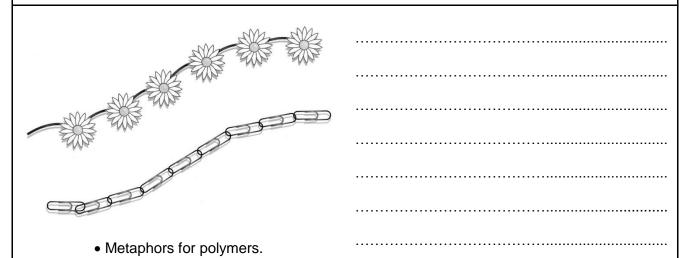
# 50. Carboxylic acids - ester hydrolysis

# 51. Carboxylic acids – laboratory preparation of esters.

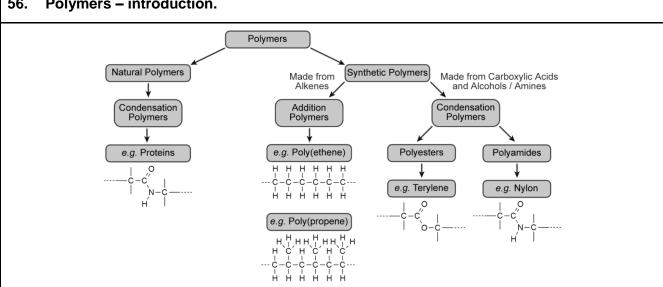


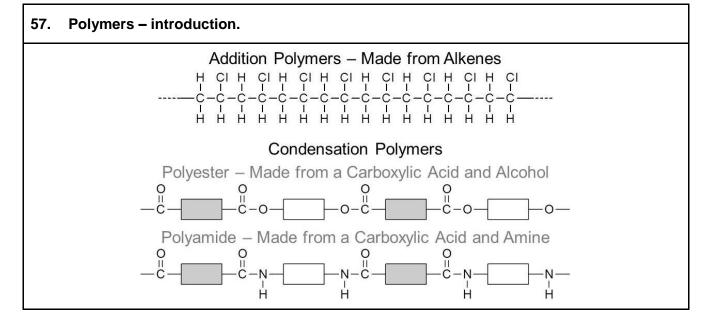
52. Carboxylic acids – properties and uses of esters.									
Esters are often used in perfumery.									
53. Polymers – introduction.									
<ul> <li>Bottles made of poly(propene).</li> </ul>									
54. Polymers – introduction.									
<ul> <li>Pellets of different polymers used as raw materials in the chemical industry.</li> </ul>									

#### 55. Polymers - introduction.



#### 56. Polymers - introduction.





## 58. Polymers - addition polymers.

• The balanced chemical equation for this reaction is written as:  $nC_2H_4$  (g)  $\rightarrow$  ( $C_2H_4$ )<sub>n</sub> (s)

## 59. Polymers - addition polymers.

#### 60. Polymers - addition polymers.

# 61. Polymers – addition polymers.

• Give the full structural formula of the monomer used to make the polymer shown below.

# 62. Polymers - addition polymers.

• Give the full structural formula of the monomer used to make the polymer shown below.

# 63. Polymers – condensation polymers – polyesters.



• Terylene is a polyester used to make synthetic fibres.


# 64. Polymers – condensation polymers – formation of a polyester.

## 65. Polymers – condensation polymers – formation of a polyester.

#### 66. Polymers – condensation polymers – hydrolysis of a polyester.

# 67. Polymers – condensation polymers – polyamides.



• Nylon is an example of a polyamide.

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# 68. Polymers – condensation polymers – formation of a polyamide.

polyamide

# 69. Polymers – condensation polymers – formation of a polyamide.

#### 70. Polymers - condensation polymers - hydrolysis of a polyamide.

# Polymers - environmental pollution.



• Most synthetic polymers are non-biodegradable.

#### Polymers – environmental pollution. **72**.



• Reduce, reuse, recycle.


## Additional Notes

• Scan the QR code given below to view the answers to this assignment.



http://www.chemist.sg/organic\_chem/worksheets/essential\_notes\_organic\_chem\_ans.pdf