

## Organic Chemistry Mastery Booklet

Use your class notes to help you answer the below.

- Complete the below:  
Over  $m$  \_\_\_\_\_ of years,  $c$  \_\_\_\_\_  $o$  \_\_\_\_\_ forms from the remains of ancient  $b$  \_\_\_\_\_.  
 $C$  \_\_\_\_\_  $o$  \_\_\_\_\_ is a  $m$  \_\_\_\_\_ of  $c$  \_\_\_\_\_ called hydrocarbons, which contain  $c$  \_\_\_\_\_ and  $h$  \_\_\_\_\_ only. One type of hydrocarbon is called an alkane, which only has  $s$  \_\_\_\_\_ bonds between the atoms. There are many different types of alkane, and they all have different numbers of  $c$  \_\_\_\_\_ and  $h$  \_\_\_\_\_ atoms. Because it takes so long for  $c$  \_\_\_\_\_  $o$  \_\_\_\_\_ to form it is called a  $f$  \_\_\_\_\_  $r$  \_\_\_\_\_.
- Draw out and name the first four alkanes
- To work out the chemical formula of an alkane, use the **general formula**  $C_nH_{2n+2}$ . This means that if there are 4 carbons, there will be  $(2 \times 4) + 2$  hydrogens. If there are 6, there will be  $(2 \times 6) + 2$ . Write the formula for an alkane containing
  - 4 carbons
  - 6 carbons
  - 8 carbons
  - 25 carbons
  - 100 carbons
  - 90 hydrogens
  - 82 hydrogens
- Draw a molecule of nonane, which has 9 carbon atoms
- Alkanes are simple molecular substances. What properties would you expect them to have?
- Explain why methane does not conduct electricity.
- How many moles of methane are present in 100g of methane?
- How many **atoms** are present in 2 moles of methane?
- Challenge: nonane (see question 4) reacts with oxygen to form carbon dioxide and water. Construct and balance a symbol equation for this reaction*

The different alkanes all have different properties depending on the length of the chain (how many carbon atoms there are). Use the table to answer the questions

	Short chain	Long chain
Boiling point	Low	High
Viscosity (how thick it is)	Low (so very runny)	High (so very thick)
Flammability (how easy it is to set on fire)	High	Low

- Alkane X and alkane Y are tested against each other. Alkane X is a lot easier to set on fire than alkane Y. Which one has a longer chain?
- Alkane X and alkane Y are tested against each other. Alkane X is a lot easier to turn into a gas than alkane Y. Which one has a longer chain?
- Below are the boiling points of a number of alkanes. Put them in order of increasing chain length:

Alkane	A	B	C	D	E
Boiling point ( $^{\circ}C$ )	91	-28	430	65	23

- Two students are investigating the viscosity of alkane X and Y. They pour a sample of each alkane at the top of a ramp and see how long it takes to flow down. How would you expect the amount of time taken to flow down to relate to the length of the chain?
- Explain your answer to 8.
- A mixture of alkane D and alkane E from the table above is heated to  $30^{\circ}C$ . Explain why alkane E turns into a gas but alkane D does not.

The boiling point of a substance is the **temperature which a liquid will turn into a gas**. So water has a boiling point of  $100^{\circ}C$  so will **boil** into steam at that temperature.

It is also the **temperature at which a gas will turn back into a liquid**. So if steam is cooled down to  $100^{\circ}C$  it will **condense** back into a liquid.

Use the alkane data from the table above to answer the questions below.

16. Which alkane (from question 12) has the highest boiling point?
17. The alkanes are all heated to 500 °C. Explain why they will all turn into a gas.
18. From the temperature of 500 °C they are all cooled down. Which one will **condense** first?
19. Explain your answer to 13.
20. Which one will **condense** last?
21. Explain your answer to 15.
22. Compared to D, predict the viscosity of A.
23. Compared to B, predict the viscosity of C.
24. A mixture of A and D are heated up until they turn into a gas. Predict a temperature at which this might happen.
25. A and D are cooled down to a temperature of 80 °C. Which one will condense? Explain your answer.
26. A mixture of all the alkanes is cooled down to 0 °C. Which one is still a gas?
27. Alkane C has 15 carbons. How many hydrogens does it have?
28. Write out its chemical formula.
29. Alkane A has 11 carbons and E has 5. Predict how many carbons D has.
30. At what temperature does gaseous D condense?
31. Explain how you can use the boiling points of D and E to separate a mixture of them.
32. Alkane C has an  $M_r$  of 120. How many moles of C are in 25g?
33. What is the mass of 10 moles of C?
34. In the reaction below, methane reacts with chlorine:  
$$\text{CH}_4 + \text{Cl}_2 \rightarrow \text{CH}_2\text{Cl}_2 + \text{H}_2$$

If 40g of methane are used, how many moles of methane are used?
35. How many moles of  $\text{H}_2$  will be produced?
36. What is the mass of the  $\text{H}_2$  produced?
37. If 10g of methane are used, what mass of  $\text{H}_2$  will be produced?
38. What mass of  $\text{CH}_2\text{Cl}_2$  will be produced?
39.  $\text{CH}_2\text{Cl}_2$  can dissolve in water. If 30g are dissolved in 120cm<sup>3</sup> of water, what is the concentration in g/dm<sup>3</sup>?  
(triple only: what is the concentration in mol/dm<sup>3</sup>?)
40. If 15g of methane and 15g of chlorine are used, which is in excess and which is limiting?

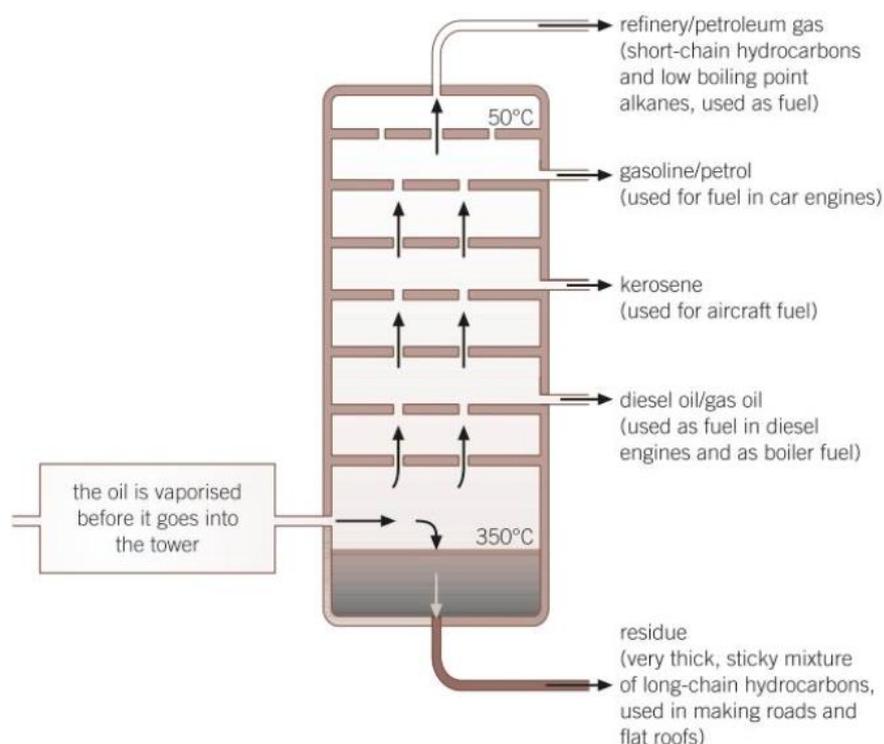
## Fractional distillation

Fractional distillation is how we separate the different alkanes in crude oil. First, the oil is heated up enough so that all the alkanes turn into a gas (boil). Next they are sent into a fractionating column, which is hot at the bottom and cool at the top.

As they are gases, they rise up the column. As they rise up the column they cool down. When they reach their boiling point they condense back into a liquid and can be collected. Because they all have different boiling points they are collected at different points on the column.

Use the data from the table on the first page to answer the questions:

41. Where will the alkanes with the lowest boiling points be collected?



42. Where will the alkanes with the highest boiling points be collected?
43. Which of the alkanes (from the table) will condense first?
44. Where will that alkane be collected from the column?
45. Which alkanes will not condense in the column?
46. Which alkane will condense highest up the column?
47. Where will the most flammable alkanes be collected?
48. Where will the most viscous alkanes be collected?
49. An alkane with 10 carbons is collected halfway up the column. One with 3 carbons is collected at the top, and one with 30 is collected at the bottom.
  - a. Where would one with 20 carbons be collected?
  - b. Where would one with 5 carbons be collected?
  - c. Where would one with two carbons be collected?
50. Icosane has a boiling point of 343.1 °C and has 20 carbons in its chain. Complete the sentence kernels below:
 

Icosane has a high boiling point because...

Icosane has a high boiling point but...

Icosane has a high boiling point therefore...
51. Octane has a boiling point of 125.6 °C. Describe how it can be separated using fractional distillation (normally 4 marks).
52. Octane has 8 carbon atoms. How many moles of octane are in 30g of octane?

### Complete Combustion

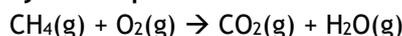
Combustion reactions are when a hydrocarbon reacts with oxygen (O<sub>2</sub>). Complete combustion **always** produces carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O). The reaction releases energy which can be used.

Example: the combustion of methane:

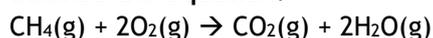
#### Word equation:

Methane + oxygen → carbon dioxide + water

#### Symbol equation:



#### Balance the equation:



53. Write word and balanced symbol equations for the combustion of:
  - a. Ethane
  - b. Propane
  - c. Butane
  - d. An alkane with 10 carbons (decane)
  - e. An alkane with 20 hydrogens (nonane)
54. Combustion reactions are exothermic. Draw a **reaction profile** for a combustion reaction.
55. 10g of ethane is completely combusted in oxygen. What mass of carbon dioxide is produced?  
*Triple only: if the reaction is conducted at room temperature, what volume of carbon dioxide is produced?*

### Incomplete Combustion

Incomplete combustion occurs when there is not enough oxygen. It can result in a range of products including carbon monoxide (which is a toxic gas) and soot. It also releases less energy. So for methane:

Methane + oxygen → carbon monoxide + water



Notice that the ratio of carbon atoms to oxygen atoms here is 1:3 but for complete combustion was 1:4

56. For ethane and propane write symbol equations for reactions where the products are CO and H<sub>2</sub>O
57. Explain why a blue flame in a Bunsen burner boils water quicker than a yellow flame
58. *Challenge: 10g of ethane is combusted in 15g of oxygen. Will this be complete or incomplete combustion?*

## Cracking

- There are long hydrocarbons and short ones
  - The shorter ones are more useful
  - Used as fuels and to help make polymers and other useful chemicals
- Cracking turns the long ones into shorter ones
  - One way is to pass over a hot catalyst
  - Another way is to mix with steam and heat to a high temperature
- Cracking produces shorter alkanes and alkenes
  - Alkenes are useful substances that are more reactive than alkanes
  - Alkenes are more reactive than alkanes
  - Alkenes turn bromine water colourless

## Questions:

59. Why do chemical plant owners commonly crack long hydrocarbons?
60. Balance the equation:  $C_{20}H_{42} \rightarrow C_{10}H_{22} + C_3H_6 + C_2H_4$
61. A student has three bottles. Two have alkanes and one has an alkene. How could they tell which is which?
62. What are the two main types of cracking?
63. How can alkanes be separated based on their boiling points?
64. Use your glossary to write a definition for thermal decomposition
65. How is cracking an example of thermal decomposition?
66. Dodecane (alkane with 12 carbon atoms) can be cracked into octane (eight carbons) and ethene ( $C_2H_4$ ). Write a word and balanced symbol equation for this reaction.
67. Write a word and balanced symbol equation for the complete combustion of octane.
68. In what way would you expect dodecane and octane to be different? (think about their properties)
69. Write a word and symbol equation for the combustion of methane. Use page 118 from the textbook or your energy changes booklet to work out the energy change of this reaction. The bond energy in C=O from  $CO_2$  is  $799\text{kJ/mol}$
70. Repeat this process for propane.

## Summary problem

Look at this equation:  $C_{10}H_{22} \rightarrow C_4H_{10} + C_3H_6$

71. Balance the equation
72. Explain how you know that cracking has occurred
73. Why is cracking carried out?
74. What are the two types of cracking?
75. Cracking is an endothermic reaction. Draw a reaction profile for cracking, and label the activation energy
76. A catalyst is often used for cracking. What is a catalyst?
77. How do catalysts increase the rate of a reaction?
78. All substances in the reaction are gases. How could the rate of the reaction be increased?
79. This is a reversible reaction. What is a reversible reaction?
80. The reaction is allowed to reach dynamic equilibrium. What is dynamic equilibrium?
81. What will the effect of increasing the temperature be on the position of the equilibrium? Explain your answer.
82. What will the effect of increasing the pressure be on the position of the equilibrium? Explain your answer.
83. Are all three substances in the equation hydrocarbons? Explain your answer.
84. The reactant is called decane, and is found in crude oil. What is crude oil?
85. Why is crude oil considered a finite resource?
86. Decane has a boiling point of  $174^\circ\text{C}$ . At  $200^\circ$  what state will it be?
87. Describe how fractional distillation is used to separate decane from crude oil.
88. What are the products of the complete combustion of decane?
89. Construct a symbol equation for this reaction

90. Decane has covalent bonds. What are covalent bonds?
91. Explain why decane does not conduct electricity.
92. In the reaction at the start of the problem, if 250g of  $C_{10}H_{22}$  are used, what mass of  $C_3H_6$  will be produced?
93. *Triple only: when 250g are used by a student, they obtain a percentage yield of 72%. What mass of  $C_3H_6$  did they actually obtain?*

#### Additional questions

- I. What state is fluorine at room temperature?
- II. What is a base?
- III. What charge will an ion of beryllium take?
- IV. Define inert
- V. Why is sodium not produced in the electrolysis of sodium chloride solution?
- VI. What are intermolecular forces?
- VII. How can you measure the quantity of a reactant or product?
- VIII. Is making bonds endothermic or exothermic?
- IX. Show two half equations for the reaction below:  $Al^{3+} + Fe \rightarrow Fe^{3+} + Al$
- X. For the extraction of which metals is electrolysis needed?
- XI. What is the formula of magnesium fluoride?
- XII. State the effect of increasing the concentration on the rate of reaction
- XIII. In terms of electrons, what do group 7 elements have in common?
- XIV. Give two examples of exothermic reactions.
- XV. Explain why increasing the pressure of a gas increases the rate of a reaction
- XVI. Which ions do the common acids form in solution?
- XVII. How many electrons can go in the first shell?
- XVIII. How do you test for an alkene?
- XIX. What is a base?
- XX. Is this process oxidation or reduction?  $Fe^{2+} \rightarrow Fe^{3+} + e^{-}$
- XXI. In terms of electrons, what do group 1 elements have in common?
- XXII. What is the name given to the structure of diamond, graphite and silicon dioxide?
- XXIII. What is an alkane?
- XXIV. Is this process oxidation or reduction?  $Na^{+} + e^{-} \rightarrow Na$
- XXV. Which ions are in  $CaCO_3$ ?