Answer **all** the questions.

1. The **molecular formula** of cyclohexane is C_6H_{12}.

What is the **empirical formula** of cyclohexane?

A CH
B CH_2
C C_6H_{12}
D $C_{12}H_{24}$

Your answer ☐

[1]

2. A student has a solution of ammonium sulfate.

Describe how he can obtain a pure dry sample of ammonium sulfate.

---

[1]

3. Tim is separating the colours in a sample of black ink using paper chromatography.

He puts a spot of black ink onto filter paper.

He dips the filter paper into ethanol in a beaker.

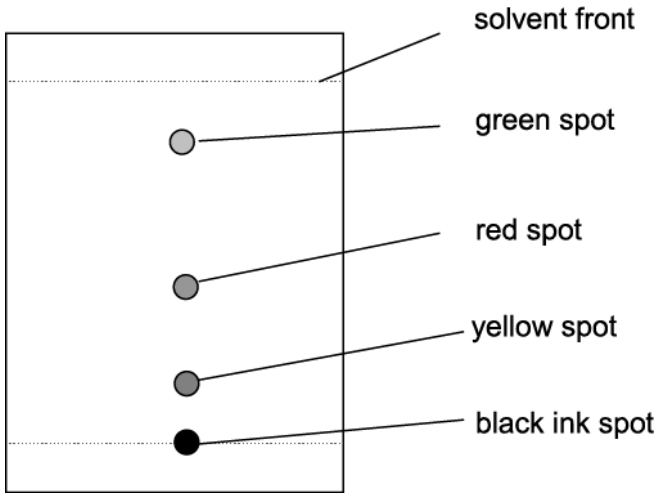
What is the name given to **ethanol** in this experiment?

A gas phase
B mobile phase
C solid phase
D stationary phase

Your answer ☐

[1]

4. Look at Tim's chromatogram.



What is the R_f value of the **green** spot? Use a ruler to help you.

A 0.17
B 0.42
C 0.83
D 1.00

Your answer ☐

[1]

5. The **molecular formula** of decene is $C_{10}H_{20}$.

What is the **empirical formula** of decene?

A CH_2
B C_2H_4
C C_5H_{10}
D $C_{20}H_{40}$

Your answer ☐

[1]

6(a). A student is separating a mixture of three substances, **A**, **B** and **C**.

Look at the table. It gives information about these substances.

Substance	State at room temperature	Melting point (°C)	Boiling point (°C)	Solubility in water
A	liquid	0	100	soluble
B	liquid	–117	78	soluble
C	solid	1535	2750	insoluble

A and **B** mix together completely.

* Suggest how the student can separate the mixture to get pure samples of substances **A**, **B** and **C**.

Explain in detail how each method works.

[6]

(b). The student has separated a **pure** sample of substance **B** from the mixture.

Suggest how the student can check that the sample of substance **B** is pure.

---

[2]

7. Which technique is the best for separating pure water from a solution of sodium chloride in water?

A crystallisation
B chromatography
C filtration
D distillation

Your answer ☐

[1]

8. The **molecular formula** of decene is $C_{10}H_{20}$.

What is the **empirical formula** of decene?

A CH_2
B C_2H_4
C C_5H_{10}
D $C_{20}H_{40}$

Your answer ☐

[1]

9. Phil is a research chemist.

He investigates a new pharmaceutical drug.

Phil extracts the drug from the leaves of a plant.

He purifies the drug and then checks to see if he has made a pure sample.

Phil uses two tests to check the purity of the drug

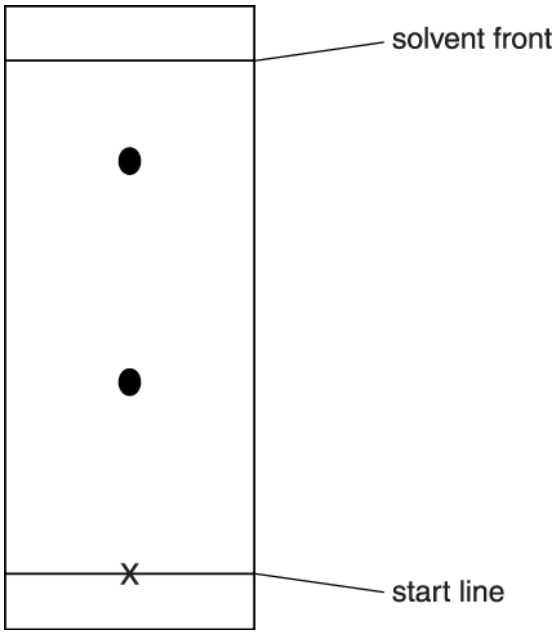
- melting point
- thin layer chromatography.

Look at the results of his tests.

Melting point

Substance	Melting point in °C
pure drug	175
sample of the drug obtained from plant	171 – 173

Thin layer chromatogram of sample of the drug obtained from the plant.



Write about **how** a sample of the drug is obtained from the leaves of a plant.

What do the results of his tests show about the purity of the sample?

The quality of written communication will be assessed in your answer to this question.

[6]

10. Sodium hydrogencarbonate decomposes when it is heated.

sodium hydrogencarbonate	→	sodium carbonate	+	carbon dioxide	+	water
$2NaHCO_3$	→	Na_2CO_3	+	CO_2	+	H_2O

The table shows the relative formula masses, M_r, of the substances in the equation.

Substance	Relative formula mass
$NaHCO_3$	84
Na_2CO_3	106
CO_2	44
H_2O	18

Show that the relative formula mass of Na_2CO_3 is 106.

The relative atomic mass, A_r, of C = 12, O = 16 and of Na = 23.

[1]

11. Phil is a research chemist.

He investigates a new pharmaceutical drug.

Phil extracts the drug from the leaves of a plant.

He purifies the drug and then checks to see if he has made a pure sample.

Phil uses two tests to check the purity of the drug

- melting point
- thin layer chromatography.

Look at the results of his tests.

Melting point

Substance	Melting point in °C
pure drug	175
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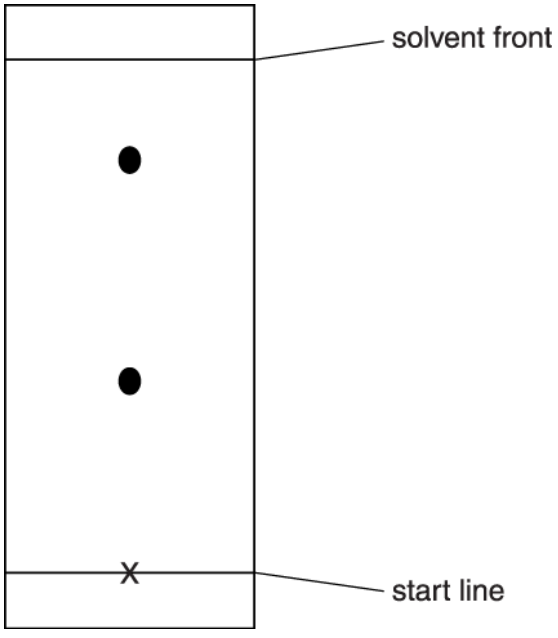


Write about **how** a sample of the drug is obtained from the leaves of a plant.

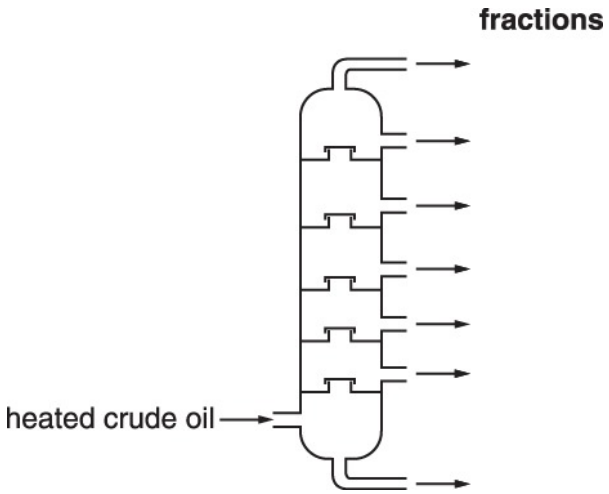
What do the results of his tests show about the purity of the sample?

The quality of written communication will be assessed in your answer to this question.

[6]

12. Crude oil is separated into many fractions by fractional distillation.

The diagram shows a fractionating column.



Look at the table. It shows the boiling point range for some of the fractions.

Fraction	Boiling point range in °C
bitumen	above 350
heating oil	240 to 350
paraffin	120 to 240
petrol	20 to 70
LPG	−160 to 20

Write down the name of the fraction which 'exits' from the **bottom** of the fractionating column.

[1]

13(a). Stowmarket Synthetics manufacture ethanoic acid, $C_2H_4O_2$, by two different processes.

Process **1**	$C_2H_6O + O_2$? $C_2H_4O_2 + H_2O$
Process **2**	CH_4O + ? CO $C_2H_4O_2$

Look at the table of relative formula masses.

Compound	Formula	Relative formula mass, *Mr*
ethanol	C_2H_6O	
oxygen	O_2	32
ethanoic acid	$C_2H_4O_2$	60
water	H_2O	18
methanol	CH_4O	32
carbon monoxide	CO	28

The relative atomic mass of H = 1, of C = 12, and of O = 16.

Calculate the relative formula mass of ethanol, C_2H_6O.

---

relative formula mass = _ _ _ _ _ _ _ _ _ _ _ _ _ _

[1]

(b). In process **2** Stowmarket Synthetics use 320 g of methanol.

They make 600 g of ethanoic acid.

What mass of carbon monoxide do they need?

---

mass of carbon monoxide = _ _ _ _ _ _ _ _ _ g

[1]

(c). Stowmarket Synthetics know that the **atom economy** of a process is important.

Water is a waste product in process **1**.

Show that the atom economy for making ethanoic acid by process **1** is 77%.

---

[2]

(d). Stowmarket Synthetics also know that the **percentage yield** of a process is important.

The factory uses 5.2 tonnes of methanol in process **2**.

A scientist predicts they should make 9.8 tonnes of ethanoic acid.

They actually make 9.5 tonnes of ethanoic acid.

Show that the percentage yield of ethanoic acid is 97%.

---

[2]

14. A compound found on Mars has the molecular formula C_4H_{10}.

What is the **empirical** formula for this compound?

---

[1]

15(a). Another compound found on Mars has the molecular formula C_4H_{10}.

What is the **empirical** formula for this compound?

_ _

[1]

(b). Another compound found on Mars contains iron and oxygen.

The compound contains 70% by mass of iron and 30% by mass of oxygen.

Calculate the empirical formula of this compound.

The relative atomic mass, *A*r, of O = 16 and of Fe = 56.

empirical formula is _

[3]

16. Look at the molecular formula of some compounds.

Which **two** compounds have the same **empirical** formula?

Choose from

CH_4	C_2H_2	C_2H_4
C_2H_6	C_3H_4	C_6H_6

answer _____ and _____

[1]

17. Look at the molecular formula of these compounds.

Which **two** compounds have the same **empirical** formula?

Choose from

CH_4	C_2H_2	C_2H_4
C_2H_6	C_3H_4	C_6H_6

answer _____ and _____

[1]

18. Fractional distillation separates crude oil into useful fractions.

The fractions have different boiling temperatures.

Look at the table.

It shows some information about fractions obtained from crude oil.

Fraction	Boiling temperature in °C
bitumen	above 350
LPG	less than 40
fuel oil	300 – 350
heating oil	250 – 300
petrol	40 – 200
paraffin	200 – 250

Use ideas about intermolecular forces to explain how fractional distillation separates crude oil into fractions and list the fractions in the position, from top to bottom, that they 'exit' the fractionating column.

The quality of written communication will be assessed in your answer to this question.

---

[6]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			B	1	
			Total	**1**	
2			Slow evaporation of solution / heat solution over a steam bath (1)	1	
			Total	**1**	
3			B	1	
			Total	**1**	
4			C	1	
			Total	**1**	
5			A	1	
			Total	**1**	

Question			Answer/Indicative content	Marks	Guidance
6	a		**Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** **Suggestion would enable pure samples of all three components to be obtained in the correct sequence with clear explanations of why the methods work.** *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** **Suggestion would enable pure samples of two of the components of the mixture to be obtained with an attempt at an explanation.** *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** **Suggestion would enable a pure sample of one of the components to be obtained.** *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** *No response or no response worthy of credit.*	6	**AO1.2: Knowledge of process of fractional distillation** • Use fractional distillation to separate substance **A** from substance **B**. • Substance **B** will come off first as it has lowest boiling point. • Stronger forces between molecules in substance **A** / ora. **AO2.2: Apply knowledge of process of fractional distillation** • Fractional distillation works as substances **A** and **B** have different boiling points. • As substance **C** is insoluble in water. • Because there are differing forces of attraction between the molecules. **AO3.3a: Analyse information in the table to develop experimental procedure** • Heat mixture to boil off substances **A** and **B** leaving pure **C**. • Filter mixture to remove substance **C**. • Substance **C** can be washed with water and dried.
	b		measure its melting point or boiling point (1) if pure melting point or boiling point will be sharp / if impure melting point is lowered / if impure boiling point is elevated (1)	2	
			Total	**8**	

Question			Answer/Indicative content	Marks	Guidance
7			D	1	
			Total	**1**	
8			A	1	
			Total	**1**	

Question			Answer/Indicative content	Marks	Guidance
9			**Level 3** **Describes two stages of extracting drug from plant material** **AND** **Explains why the drug is impure using both melting point and chromatography data.** Quality of communication does not impede communication of science at this level. (5-6 marks) **Level 2** **Answer describes one stage of extracting drug from plant material AND explains why the drug is impure using either melting point or chromatography data** **OR** **Answer describes two stages of extracting drug from plant material.** **OR** **Explains why the drug is impure using both melting point and chromatography data.** Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) **Level 1** **Describes one stage of extracting drug from plant material** **OR** **Explains why the drug is impure using either melting point or chromatography data.** Quality of communication impedes communication of the science at this level. (1 – 2 marks) **Level 0** **Insufficient or irrelevant science.** **Answer not worthy of credit.** (0 marks)	6	**This question is targeted at grades up to C** **Indicative scientific points for extraction may include:** • Crushing (plant material) • Boiling (with a solvent) • Dissolving (with a solvent) / solvent extraction • Chromatography • Crystallisation • Evaporation • Filtration **Indicative scientific points for analysis may include:** • Drug is impure • Chromatography shows that there are (at least) two substances (so not pure) • Melting point is below that of the pure sample so not pure • Melting point is a range so not pure **Use the L1, L2, L3 annotations in Scoris, do not use ticks** **<u>Examiner's Comments</u>** This question was about pharmaceutical drugs. The six mark question was a common question with the higher tier examination paper and candidates found it very challenging. Most candidates were not able to use the melting point or chromatography data to explain why the sample was impure. Candidates did not appreciate that the two spots on the chromatography paper indicated two compounds. In terms of describing how the drug is extracted from a plant most candidates gave the name of a process but were not able to give an accurate description of what happened with the process. A significant

Question			Answer/Indicative content	Marks	Guidance
					proportion of the candidates made no attempt to answer the question.
			Total	**6**	
10			(2 x 23) + 12 + (3 x 16) (1)	1	mark is for the working out and **not** for the final answer **allow** 23 + 23 + 12 + 16 + 16 + 16 etc. **Examiner's Comments** This question was about the thermal decomposition of sodium hydrogencarbonate. Most candidates were able to show how to calculate the relative formula mass of sodium hydrogencarbonate.
			Total	**1**	

Question			Answer/Indicative content	Marks	Guidance
11			**Level 3]** **Describes two stages of extracting drug from plant material** **AND** **Explains why the drug is impure using both melting point and chromatography data.** Quality of communication does not impede communication of science at this level. (5-6 marks) **[Level 2]** **Describes one stage of extracting drug from plant material AND explains why the drug is impure using either melting point or chromatography data** **OR** **Describes two stages of extracting drug from plant material** **OR** **Explains why the drug is impure using both melting point and chromatography data.** Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) **[Level 1]** **Describes one stage of extracting drug from plant material** **OR** **Explains why the drug is impure using either melting point or chromatography data.** Quality of communication impedes communication of the science at this level. (1 – 2 marks) **[Level 0]** **Insufficient or irrelevant science.** **Answer not worthy of credit.** (0 marks)	6	**This question is targeted at grades up to C** **Indicative scientific points for extraction may include:** • Crushing (plant material) • Boiling (with a solvent) • Dissolving (with a solvent) / solvent extraction • Chromatography • Crystallisation • Evaporation • Filtration **Indicative scientific points for analysis may include:** • Drug is impure • Chromatography shows that there are (at least) two substances (so not pure) • Melting point is below that of the pure sample so not pure • Melting point is a range so not pure **Use the L1, L2, L3 annotations in RM Assessor;** **do not use ticks** **<u>Examiner's Comments</u>** This question focused on pharmaceutical drugs. This 6 mark question focused on how drugs are obtained from plants was targeted up to grade C. Candidates were also required to draw conclusions about the purity of a drug from melting point and chromatography data. At the simplest level, candidates who described one stage in extracting the drug from plant material, or drew a conclusion using one piece of data, scored Level 1. Many candidates gained credit at Level 2 by describing two stages of the drug extraction. A description of two stages of the drug extraction and an

Question			Answer/Indicative content	Marks	Guidance
					explanation of why the drug is impure using both melting point and chromatography data was required to gain credit at Level 3. Of the two test results, the melting point was discussed correctly more frequently than the chromatography. A common misconception was that the drug was pure because the melting point was close to the pure sample.
			Total	**6**	
12			bitumen (1)	1	**allow** phonetic spelling **Examiner's Comments** Many candidates could interpret the data in the table.
			Total	**1**	

Question			Answer/Indicative content	Marks	Guidance
13	a		46 (1)	1	**ignore** units **Examiner's Comments** Most candidates could correctly calculate the relative formula mass of ethanol.
	b		280 (g) (1)	1	unit **not** needed **ignore** incorrect units **Examiner's Comments** Just over half of all candidates could correctly work out the mass of carbon monoxide needed for the reaction.
	c		atom economy = $\frac{60}{60+18}$ / $\frac{60}{46+32}$ / $\frac{60}{78}$ (1) **but** atom economy = $\frac{60}{60+18} \times 100$ / $\frac{60}{46+32} \times 100$ / $\frac{60}{78} \times 100$ (2)	2	**allow** atom economy formula in words for one mark i.e. atom economy = $\frac{\text{total Mr of desired products}}{\text{total Mr of all products}} \times 100$ (1) or atom economy = $\frac{\text{total Mr of desired products}}{\text{total Mr of all reactants}} \times 100$ (1) **Examiner's Comments** Just over half of all candidates could correctly work out the mass of carbon monoxide needed for the reaction.
	d		percentage yield = $\frac{9.5}{9.8}$ (1) **but** percentage yield = $\frac{9.5}{9.8} \times 100$ (2)	2	**allow** percentage yield formula in words for one mark e.g. percentage yield = $\frac{\text{actual yield}}{\text{predicted yield}} \times 100$ or percentage yield = $\frac{\text{am}}{\text{pm}} \times 100$ **Examiner's Comments** Although better answered than part (d), a significant number of candidates omitted the question. Better candidates showed a good understanding of the ideas involved, scoring both marks.

Question			Answer/Indicative content	Marks	Guidance
			Total	**6**	
14			C_2H_5 (1)	1	**allow** any order of symbols **not** C^2H^5 / C2H5 / or use of lower case H **Examiner's Comments** The concept of empirical formula is not well understood except by better candidates. Many candidates gave numerical answers, calculating molar masses.
			Total	**1**	

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>15</td><td>a</td><td></td><td>C_2H_5 (1)</td><td>1</td><td>allow any order of symbols

not C^2H^5 / C2H5 / or use of lower case H

<u>?Examiner's Comments</u>??

Candidates often deduced the correct empirical formula as C_2H_5 although some candidates gave the molecular formula and others worked out the molar mass.</td></tr>
<tr><td></td><td>b</td><td></td><td>FIRST LOOK AT THE ANSWER
IF ANSWER = Fe_2O_3 AWARD 3 MARKS

<table><tr><td>symbols</td><td>Fe</td><td>O</td></tr><tr><td>mole ratio</td><td>$\frac{70}{56}$ or 1.25</td><td>$\frac{30}{16}$ or 1.875</td></tr><tr><td>simplest mole ratio</td><td>$\frac{1.25}{1.25}$ or 1</td><td>$\frac{1.875}{1.25}$ or 1.5</td></tr></table>mole ratio (1)

simplest mole ratio (1)

empirical formula is Fe_2O_3 (1)</td><td>3</td><td>If fraction is the wrong way around = 0 marks for the question

If divide by atomic number = 0 marks for the question

If just use ratio of masses = 0 for the question

allow ecf from mole ratio

allow ecf from simplest ratio

allow $FeO_{1.5}$ = 2 marks for the question

<u>?Examiner's Comments</u>??

Candidates found this empirical formula calculation very challenging. Even candidates who calculated the mole ratio often rounded the ratio incorrectly to end up with FeO_2 or stated the formula was $FeO_{1.5}$. Common misconceptions included using the mass ratio rather than the mole ratio or using atomic number to calculate the mole ratio rather than the relative atomic mass. A significant proportion of candidates left this question blank.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>4</td><td></td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
16			C_2H_2**and** C_6H_6 (1)	1	**both** needed if no answer on answer line **allow** other ways of indicating the correct answer e.g. circling, ticking or underlining **Examiner's Comments** A significant proportion of candidates chose the two correct hydrocarbons.
			Total	**1**	
17			C_2H_2**and** C_6H_6 (1)	1	**both** needed if no answer on answer line **allow** other ways of indicating the correct answer e.g. circling, ticking or underlining **Examiner's Comments** Just under half of candidates understood what was meant by an empirical formula and gave C_2H_2 and C_6H_6. Incorrect answers frequently involved methane, CH4 and ethene, C_2H_4.
			Total	**1**	

Question			Answer/Indicative content	Marks	Guidance
18			**Level 3 (5–6 marks)** **Comprehensively explains the process of fractional distillation in terms of molecular size, intermolecular forces and boiling points** **AND** **Applies knowledge of temperature gradient in fractionating tower to correctly list the fractions in the order they 'exit' the tower.** Quality of written communication does not impede communication of the science at this level. **Level 2 (3–4 marks)** **Attempts to explain the process of fractional distillation in terms of molecular size and / or intermolecular forces and boiling points** **AND** **Applies knowledge of temperature gradient in fractionating tower to list the fractions in the order they 'exit' the tower.** Quality of written communication partly impedes communication of the science at this level. **Level 1 (1–2 marks)** **Describes the process of fractional distillation, but answer may be simplistic and lacking in detail** **OR** **lists the fractions in the correct order.** Quality of written communication impedes communication of the science at this level. **Level 0 (0 marks)** Insufficient or irrelevant science. Answer not worthy of credit.	6	**This question is targeted at grades up to A*.** **Indicative scientific points at levels 2 and 3 may include:** • smaller molecules, eg LPG / petrol / paraffin, have weaker or fewer intermolecular forces / ora • smaller molecules have lower boiling points with weaker or fewer intermolecular forces / ora • during boiling the weak intermolecular forces break but covalent bonds within the molecule do not. **Indicative scientific points at Level 1 may include:** • crude oil is heated • fractionating column has temperature gradient (cold at top and hot at bottom) • order of fractions, from top, is: LPG petrol paraffin heating oil fuel oils bitumen **Use the L1, L2, L3 annotations in scoris; do not use ticks.** **Examiner's Comments** This 6 mark question was targeted at all grades up to, and including, grade A* and discriminated well. The question required candidates to analyse the data in order to list the fractions in the positions that they 'exit' the fractionating column and then to explain how fractional distillation separates crude oil into fractions. At level 3 (5-6 marks) all aspects of the question needed to be addressed and candidates were required to explain the process of fractional

Question			Answer/Indicative content	Marks	Guidance
					distillation in terms of molecular size, intermolecular forces and boiling points. Some candidates continue to confuse fractional distillation and cracking.
			Total	**6**	