15 What is the number of structural isomers with the molecular formula C_5H_{12}?

- ☒ **A** six
- ☒ **B** five
- ☒ **C** four
- ☒ **D** three

(Total for Question 15 = 1 mark)

---

20 Which molecule can exist as *E-Z* isomers?

- ☒ **A** 2-chloro-4-ethylhex-3-ene
- ☒ **B** 3-chloro-2-methylhex-2-ene
- ☒ **C** 2,3-dimethylhex-2-ene
- ☒ **D** 2,5-dichlorohex-3-ene

(Total for Question 20 = 1 mark)

---

18 Which is **not** a step in the reaction of chlorine with propane in ultraviolet radiation?

- ☒ **A** $C_3H_7^{\bullet} + Cl^{\bullet} \rightarrow C_3H_7Cl$
- ☒ **B** $C_3H_7^{\bullet} + C_3H_7^{\bullet} \rightarrow C_6H_{14}$
- ☒ **C** $C_3H_7^{\bullet} + Cl_2 \rightarrow C_3H_7Cl + Cl^{\bullet}$
- ☒ **D** $C_3H_7^{\bullet} + HCl \rightarrow C_3H_7Cl + H^{\bullet}$

(Total for Question 18 = 1 mark)

---

4 What is the best definition of a hydrocarbon?

- ☒ **A** a compound containing carbon, hydrogen and oxygen
- ☒ **B** a compound containing carbon and hydrogen only
- ☒ **C** a compound that contains single carbon to carbon bonds
- ☒ **D** a mixture containing carbon and hydrogen only

(Total for Question 4 = 1 mark)

19 Why does free radical substitution have limited use in industrial chemistry?

- ☒ **A** the reactions only occur in the upper atmosphere
- ☒ **B** initiation requires ultraviolet radiation
- ☒ **C** further substitution products are formed
- ☒ **D** termination reactions produce unwanted products

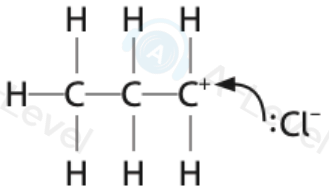
(Total for Question 19 = 1 mark)

10 Propene, $CH_3CH{=}CH_2$, reacts with hydrogen chloride, HCl, to form halogenoalkanes.

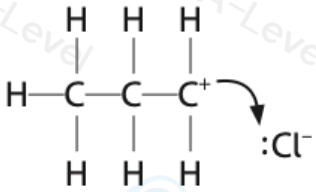
(a) Which of these steps is most likely to occur in the reaction?

(1)

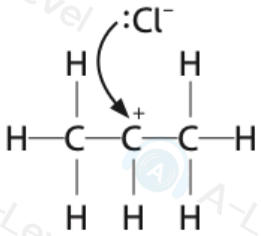
☒ **A**



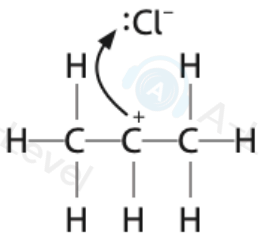
☒ **B**



☒ **C**



☒ **D**



(b) The reaction of propene with hydrogen chloride is an example of

(1)

☒ **A** free radical substitution

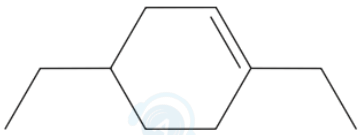
☒ **B** free radical addition

☒ **C** electrophilic substitution

☒ **D** electrophilic addition

(Total for Question 10 = 2 marks)

18 Which of these formulae are correct for the compound 1,4-diethylcyclohexene?



(i)
skeletal formula

$C_{10}H_{18}$

(ii)
molecular formula

C_5H_9

(iii)
empirical formula

☒ **A** none of the three

☒ **B** (i) only

☒ **C** (ii) and (iii) only

☒ **D** (i), (ii) and (iii)

(Total for Question 18 = 1 mark)

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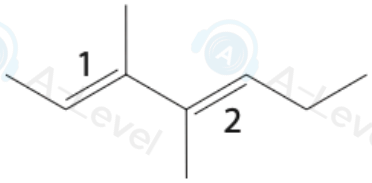
16 The molecule shown has two double bonds.

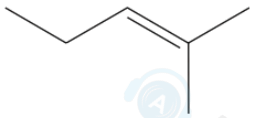


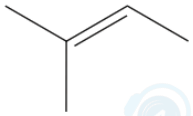
Which is the correct identification for each double bond?

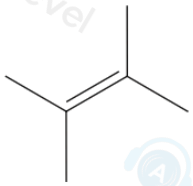
	Double bond 1	Double bond 2
☒ **A**	*E*	*E*
☒ **B**	*E*	*Z*
☒ **C**	*Z*	*E*
☒ **D**	*Z*	*Z*

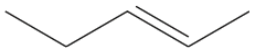
(Total for Question 16 = 1 mark)

18: Which molecule has a geometric isomer?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 18 = 1 mark)

13: Which type of reaction occurs when an alkane is cracked?

☒ **A** combustion

☒ **B** hydrolysis

☒ **C** neutralisation

☒ **D** thermal decomposition

(Total for Question 13 = 1 mark)

---

17 The substances formed from the combustion of petrol in car engines include

☒ **A** water, carbon dioxide and hydrogen

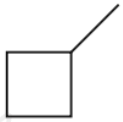
☒ **B** water, carbon monoxide and hydrogen chloride

☒ **C** water, carbon dioxide and sulfur dioxide

☒ **D** water, carbon particulates and hydrogen

(Total for Question 17 = 1 mark)

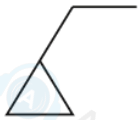
13 Cycloalkanes undergo free radical substitution reactions by the same mechanism as methane. Three isomeric cycloalkanes are shown.



Isomer **X**



Isomer **Y**



Isomer **Z**

Which react with chlorine to produce four different monochlorinated products?

- ☒ **A** All 3 isomers
- ☒ **B** Isomer **X** and Isomer **Z** only
- ☒ **C** Isomer **Y** and Isomer **Z** only
- ☒ **D** Isomer **X** only

(Total for Question 13 = 1 mark)

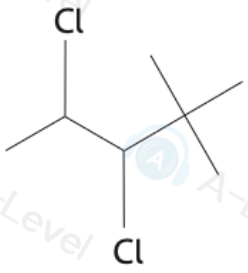
16 Which mixture could be formed when a **single** molecule of $C_{12}H_{26}$ is cracked?

- ☒ **A** butene, pentane and propene
- ☒ **B** hexane, butene and ethane
- ☒ **C** nonane and ethene
- ☒ **D** propene and decane

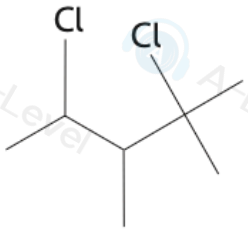
(Total for Question 16 = 1 mark)

16 Which is the skeletal structure for 3,4-dichloro-2,2-dimethylpentane?

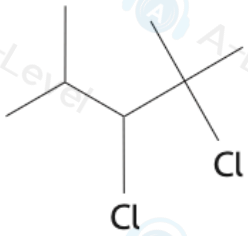
☒ **A**



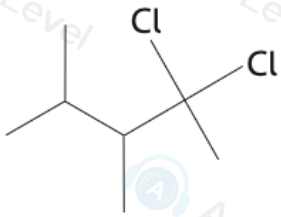
☒ **B**



☒ **C**



☒ **D**



(Total for Question 16 = 1 mark)

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16 Which statement about the cracking of crude oil is true?

The cracking of crude oil

☒ **A** separates the mixture into pure compounds

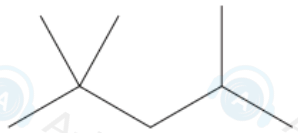
☒ **B** separates the mixture into fractions

☒ **C** separates saturated from unsaturated compounds

☒ **D** decreases the average number of carbon atoms per molecule

(Total for Question 16 = 1 mark)

18 Molecules of isooctane, found in petrol, have eight carbon atoms.
The skeletal formula of isooctane is shown.



(a) Give the molecular formula, empirical formula and IUPAC name for isooctane.

(3)

Molecular formula .....

Empirical formula .....

IUPAC name .....

(b) Isooctane and octane are isomers that are both found in crude oil.
Octane has a boiling temperature of 125 °C, and isooctane has a boiling temperature of 99 °C.

This difference in boiling temperature can be used to separate the two isomers in a laboratory.
The technique is the same as that used to separate crude oil.

(i) Name the technique that could be used for this separation.

(1)

.....

(ii) Describe how this technique separates isooctane from octane.

(2)

.....

.....

.....

.....

.....

(c) Isooctane is added to petrol to increase its octane rating.
Some high-performance engines need fuel with a higher octane rating.

(i) Write the equation for the complete combustion of isooctane.
State symbols are not required.

(1)

(ii) Carbon monoxide and nitrogen monoxide are both pollutants produced in car engines.
Describe how each pollutant is formed in car engines, including the conditions required.
You may include appropriate equations.

(4)

(iii) Identify another pollutant, other than carbon dioxide, carbon monoxide and nitrogen monoxide, produced in car engines.

(1)

.....

(d) Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds containing the same number of carbon atoms as isooctane.

(i) State the type and mechanism of this reaction.

(1)

.....

(ii) Give the essential condition required.

(1)

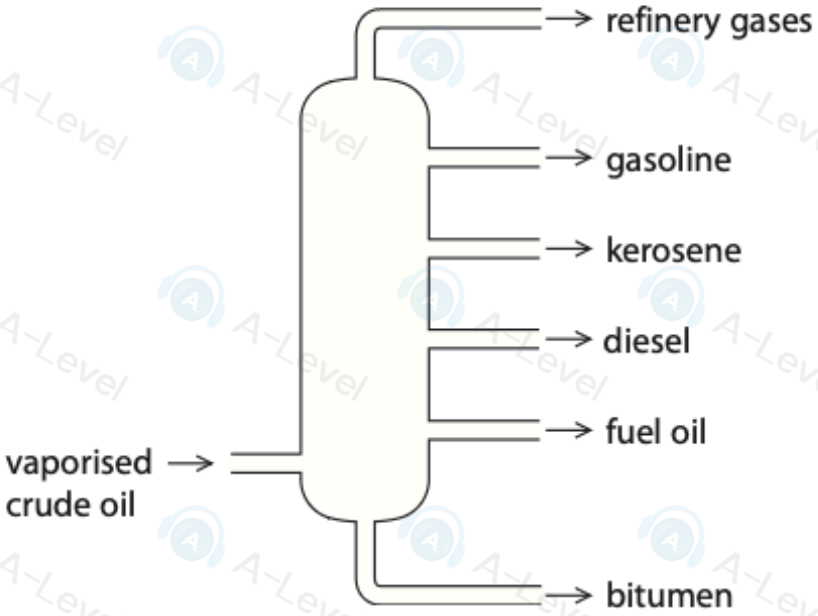
.....

(iii) One of the chlorinated compounds contains 44.1% carbon and 6.9% hydrogen by mass.

Calculate the molecular formula of this compound.

(3)

22 Crude oil is mainly a mixture of saturated hydrocarbons that can be separated by fractional distillation.
The diagram shows, in a simplified form, the products of fractional distillation.



(a) (i) State what is meant by a saturated hydrocarbon.

(2)

.....

.....

.....

.....

(ii) Describe how the fractions in crude oil are separated during fractional distillation.

(2)

(b) Butane, C_4H_{10}, is found in the refinery gases fraction of crude oil.
It is used as a propellant in pharmaceutical inhalers.
An inhaler that provides a total of 120 doses contains 1.55 g of butane.

Calculate the volume, in cm^3, of propellant used for each dose at 25 °C and 100 kPa.

Use the ideal gas equation and give your answer to an appropriate number of significant figures.

[$pV = nRT$ $R = 8.31\ J\ K^{-1}\ mol^{-1}$]

(5)

(c) Octane, C_8H_{18}, is found in the gasoline fraction of crude oil.

(i) Write an equation for the complete combustion of octane.
Include state symbols.

(2)

(ii) Give **two** reasons why alternative fuels, such as bioethanol, are being developed to replace those produced from crude oil.

(2)

.....

.....

.....

.....

.....

.....

(iii) Straight-chain alkanes, such as octane, are converted into branched-chain alkanes to improve the performance of petrol in car engines.

Name this conversion process.

(1)

.....

(iv) Give an equation using skeletal formulae for the conversion of octane into 2,5-dimethylhexane.
State symbols are not required.

(1)

(d) In steam cracking, a mixture of hydrocarbons and steam is heated to 850 °C for a very short time in the absence of oxygen.

(i) Give a reason why oxygen should be excluded during steam cracking.

(1)

.....

.....

.....

(ii) Ethene is the major product.

State one use of ethene.

(1)

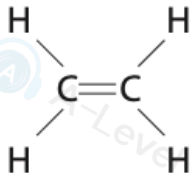
.....

.....

(e) Ethene reacts with hydrogen bromide to form bromoethane.

Draw the mechanism for this reaction.
Include curly arrows, and relevant lone pairs and dipoles.

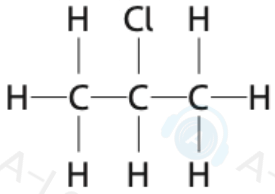
(3)





(Total for Question 22 = 20 marks)

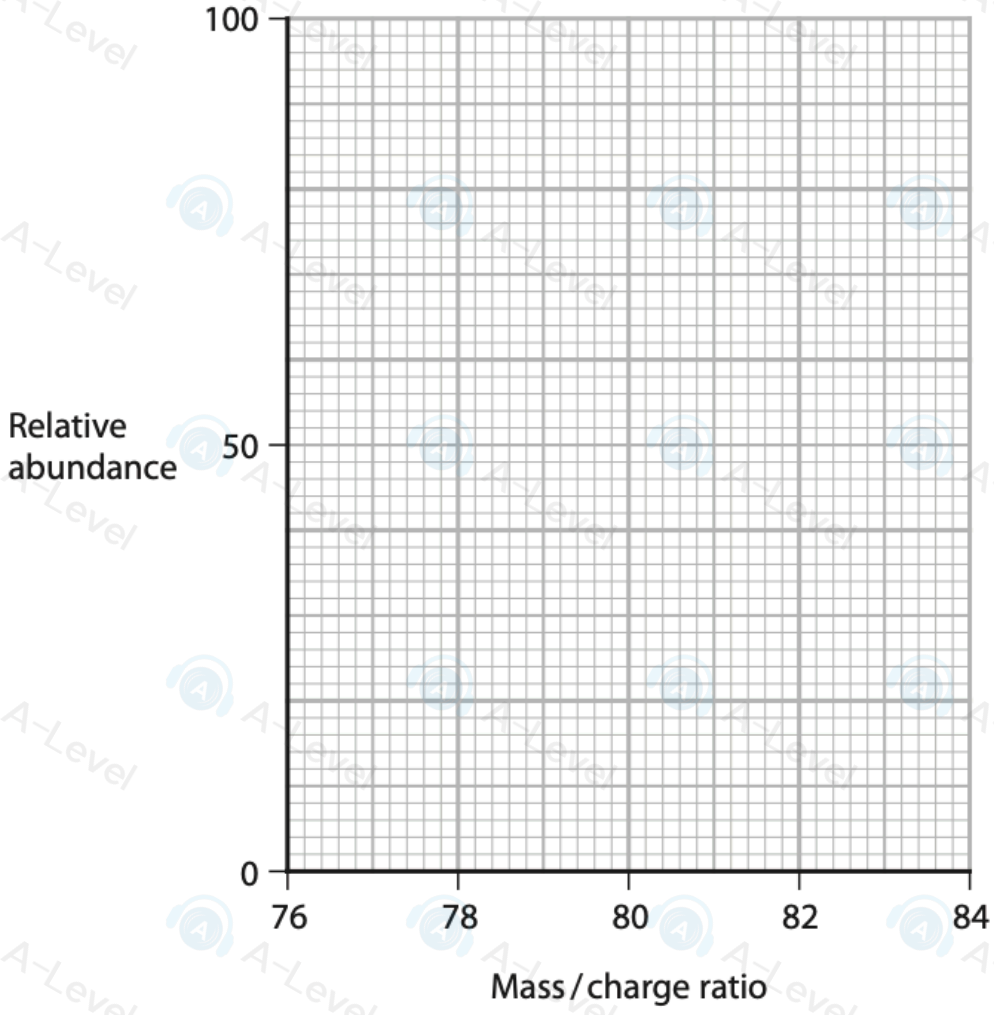
19 This question is about 2-Chloropropane.



(a) 2-Chloropropane has a relative molecular mass of 78.5 g mol^{-1}.
Chlorine has two common isotopes, ^{35}Cl and ^{37}Cl.
There are three times more ^{35}Cl atoms than ^{37}Cl atoms.
The main isotope of hydrogen is ^{1}H and that of carbon is ^{12}C.
The diagram shows a mass spectrum grid.

Draw the peaks for the molecular ions of 2-Chloropropane resulting from these isotopes.

(2)



(b) 2-Chloropropane can be produced by reacting propane with chlorine in a homolytic free radical reaction.

$$CH_3CH_2CH_3 + Cl_2 \rightarrow CH_3CHClCH_3 + HCl$$

(i) Show the initiation step of this reaction.
Include appropriate arrows and the conditions necessary for this step.

(2)

(ii) Using your answer to (b)(i), state what is meant by the terms homolytic and free radical.

(2)

homolytic

free radical

(iii) Suggest why this method has limited use in the synthesis of organic compounds.

(1)