# 2.24 Alkanes, Alkenes and Crude Oil: 1-hour Pack

AQA 8464 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

**Answer ALL questions. Show all your working.**

**1** Long-chain hydrocarbon fractions from crude oil are cracked to form smaller, more useful molecules.

**(a)** State two reasons why oil companies crack long-chain hydrocarbon fractions. **(2)**

**(b)** Describe the two sets of conditions that can be used to crack hydrocarbons. **(2)**

**(Total for Question 1 is 4 marks)**


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**2** Required practical: Jamal carries out an experiment in the school laboratory to crack liquid paraffin, a mixture of long-chain alkanes, using a catalyst. Paraffin-soaked mineral wool is placed at one end of a horizontal boiling tube, with the catalyst positioned further along the tube. The tube is heated and the gas produced is collected over water.

**(a)** Name a suitable catalyst for this experiment. **(1)**

**(b)** Describe how Jamal should carry out this experiment, from heating the tube to collecting the gas produced. **(3)**

**(c)** Jamal bubbles the collected gas through orange bromine water. State and explain the result he should observe. **(2)**

**(d)** Explain why it is important to heat the catalyst before heating the paraffin-soaked wool, rather than the other way round. **(3)**

**(Total for Question 2 is 9 marks)**

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**3** Ethene, $C_2H_4$, is the simplest alkene.

**(a)** Draw the displayed structural formula of ethene, showing the double bond between the two carbon atoms and all hydrogen atoms. **(2)**

**(b)** Write a balanced symbol equation for the addition reaction between ethene and bromine. **(2)**

**(Total for Question 3 is 4 marks)**


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**4** A student combusts 0.250 g of propane, $C_3H_8$, in excess oxygen. Calculate the mass of $CO_2$ produced. Relative atomic masses: C = 12.0, H = 1.0, O = 16.0.

**(a)** Show the balanced equation and substitute values to calculate the mass of $CO_2$ produced. Show working in steps and state units. **(4)**

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**(Total for Question 4 is 4 marks)**

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**5** Hydrogenation of alkenes converts them to alkanes. Ethene reacts with hydrogen in the presence of a catalyst.

**(a)** Write the balanced equation for the hydrogenation of ethene to form ethane, including state symbols where appropriate. **(2)**

**(b)** Explain why a catalyst is used and why hydrogenation is useful industrially. **(2)**

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**(Total for Question 5 is 4 marks)**

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**6** Cracking is the thermal decomposition of long-chain hydrocarbons into shorter, more useful molecules. In a cracking reaction, atoms are conserved, so the equation must balance.

**(a)** Complete and balance the following cracking equation: $C_{10}H_{22} \rightarrow C_8H_{18}$ + ____ **(2)**

**(b)** Higher tier only. A sample of dodecane, $C_{12}H_{26}$, is cracked to produce propene, $C_3H_6$, and one other alkane molecule. Determine the molecular formula of this other product. **(2)**

**(Total for Question 6 is 4 marks)**


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**7** Crude oil is a finite resource made up of a mixture of hydrocarbons. It is separated using fractional distillation, but some of the fractions produced do not match the quantities needed by society, so they are processed further by cracking. Explain how fractional distillation separates crude oil into fractions, and explain why cracking is then used to process some of these fractions.

**(Total for Question 7 is 6 marks)**


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**8** Propane ($C_3H_8$) undergoes complete combustion according to the equation: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$. (Relative atomic masses: Ar(C) = 12, Ar(H) = 1, Ar(O) = 16.) A sample of 4.4 g of propane is burned completely, producing 7.2 g of water alongside the carbon dioxide.

**(a)** Calculate the relative formula mass (Mr) of propane. **(1)**

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**(b)** Calculate the mass of carbon dioxide produced when the 4.4 g sample of propane is completely combusted. **(3)**

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**(c)** Using the law of conservation of mass, calculate the mass of oxygen, $O_2$, that reacted with the 4.4 g sample of propane. **(2)**

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**(Total for Question 8 is 6 marks)**

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**9** Required practical style: Investigating how heating a hydrocarbon affects the completeness of combustion by measuring soot on a glass plate placed above a candle flame.

**(a)** Outline a simple method to compare soot deposition when burning propane and butane, stating the control variables you would keep the same. Do not list apparatus only; give key steps. **(3)**

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**(b)** Give one practical improvement that would reduce systematic error in this investigation and explain why it helps. **(2)**

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**(Total for Question 9 is 5 marks)**


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# Mark scheme · 2.24 Alkanes, Alkenes and Crude Oil: 1-hour Pack

## Question 1

(a) there is greater demand for shorter-chain hydrocarbons (e.g. petrol) than crude oil naturally supplies, oe **B1**

(a) cracking also produces alkenes, which are used to manufacture polymers and other useful chemicals, oe **B1**

**(a) Answer: Demand for short-chain fractions (like petrol) exceeds supply; cracking also produces alkenes, used to make polymers.**

(b) catalytic cracking uses a catalyst (e.g. aluminium oxide) with a moderately high temperature, oe **B1**

(b) steam cracking uses a very high temperature mixed with steam, and no catalyst, oe **B1**

**(b) Answer: Catalytic cracking uses a catalyst and a moderately high temperature; steam cracking uses a very high temperature with steam and no catalyst.**

## Question 2

(a) aluminium oxide (accept broken pot/pumice/porous pot) **B1**

**(a) Answer: Aluminium oxide (or broken pot/pumice).**

(b) heat the catalyst strongly first, oe **B1**

(b) then heat/move the flame along to heat the paraffin-soaked mineral wool, so that paraffin vapour passes over the hot catalyst, oe **B1**

(b) collect the gas produced by displacement of water (delivery tube leading into an inverted, water-filled test tube in a trough of water), oe **B1**

**(b) Answer: Heat the catalyst strongly first, then heat the paraffin-soaked mineral wool so its vapour passes over the hot catalyst, and collect the gas produced over water.**

(c) the bromine water is decolourised, turning from orange(-brown) to colourless **B1**

(c) because the gas contains alkenes (unsaturated hydrocarbons with a C=C double bond), which react with the bromine in an addition reaction, oe **B1**

**(c) Answer: The bromine water turns from orange to colourless, because the cracked gas contains alkenes, which react with bromine by addition.**

(d) ensures the catalyst is already at the high temperature needed for cracking by the time the hydrocarbon vapour reaches it, oe **B1**

(d) this maximises the amount/rate of cracking, giving a better yield of useful products, oe **B1**

(d) reduces the risk of unreacted paraffin vapour condensing and blocking the delivery tube (or another valid safety/efficiency point), oe **B1**

**(d) Answer: Heating the catalyst first ensures it is hot enough for cracking as soon as paraffin vapour reaches it, maximising the yield of cracked products and reducing the risk of unreacted vapour condensing and blocking the tube.**

## Question 3

(a) correct skeleton showing a C=C double bond between the two carbon atoms **M1**

(a) all four hydrogen atoms correctly shown, two joined to each carbon **A1**

**(a) Answer: H H**
**\ /**
**C=C**
**/ **
**H H**
**(two carbons joined by a double bond, each carbon also joined to two hydrogen atoms)**

(b) correct reactant formulae: $C_2H_4$ and $Br_2$ **M1**

(b) correct product and balancing: $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$ cao (accept displayed formula showing 1,2-dibromoethane) **A1**

**(b) Answer: $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$**

## Question 4

(a) balanced equation shown: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ or equivalent balancing **M1**

(a) calculates Mr of propane = 3x12.0 + 8x1.0 = 44.0 and Mr of $CO_2$ = 12.0 + 2x16.0 = 44.0 **M1**

(a) uses moles: moles propane = 0.250 / 44.0 and moles $CO_2$ = 3 x moles propane **M1**

(a) mass $CO_2$ = moles $CO_2$ x Mr $CO_2$ = 0.250 / 44.0 x 3 x 44.0 = 0.750 g cao **A1**

**(a) Answer: 0.750 g**

## Question 5

(a) shows ethene + $H_2$ -> ethane with correct stoichiometry **M1**

(a) $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$ cao **A1**

**(a) Answer: $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$**

(b) states catalyst provides alternative route with lower activation energy or adsorption of reactants on surface **M1**

(b) explains industrial usefulness such as converting unsaturated fats to saturated fats or producing alkanes for fuels, oe **A1**

**(b) Answer: A catalyst provides a lower energy pathway, often by adsorbing reactants on its surface, increasing reaction rate. Hydrogenation is useful to make saturated products like alkanes for fuels or to harden vegetable oils in food industry.**

## Question 6

(a) carbon and hydrogen atoms conserved: 10-8=2 carbons, 22-18=4 hydrogens, giving $C_2H_4$ **M1**

(a) named/identified as ethene cao **A1**

**(a) Answer: $C_2H_4$ (ethene)**

(b) carbon and hydrogen atoms conserved: 12-3=9 carbons, 26-6=20 hydrogens **M1**

(b) $C_9H_{20}$ cao **A1**

**(b) Answer: $C_9H_{20}$**


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## Question 7

**Level 1** Simple, isolated statement(s), e.g. that crude oil is a mixture separated by fractional distillation, and/or that cracking happens, with little or no linking of ideas. **1-2**

**Level 2** A clear description of fractional distillation OR a clear explanation of why cracking is used, with some correct detail, but the two processes are not both explained and linked together. **3-4**

**Level 3** A detailed, logically linked explanation covering both how fractional distillation separates crude oil (evaporation, temperature gradient in the column, condensing according to boiling point/chain length) and why cracking is needed (mismatch between the fractions supplied and the quantities of products in demand, so long-chain fractions are cracked to produce more useful shorter alkanes and alkenes). **5-6**

**Indicative content:**

- crude oil is a mixture of hydrocarbons, mostly alkanes, with a range of chain lengths and boiling points
- the crude oil is heated so that it vaporises and enters the fractionating column as a vapour
- the column has a temperature gradient: hot at the bottom, cooler towards the top
- vapours rise up the column and condense when they cool to below their boiling point
- shorter-chain hydrocarbons have lower boiling points (weaker intermolecular forces), so condense higher up, further from the bottom
- longer-chain hydrocarbons have higher boiling points (stronger intermolecular forces), so condense lower down, nearer the bottom
- fractions are collected at different heights, each fraction being a mixture of hydrocarbons with similar chain lengths/boiling points
- the quantities of each fraction produced do not match the quantities that society demands, e.g. there is much greater demand for petrol/diesel and for alkenes (used to make polymers) than for some long-chain fractions
- cracking is the thermal decomposition of larger, less useful hydrocarbon molecules into smaller, more useful alkanes (e.g. for fuels) and alkenes (e.g. for making polymers)
- cracking conditions: catalytic cracking uses a catalyst and a moderately high temperature; steam cracking uses a very high temperature with steam
- cracking allows the oil industry to better match the supply of fractions to the demand from consumers and industry

## Question 8

(a) 44 cao **B1**

**(a) Answer: 44**

(b) moles of propane = mass / Mr = 4.4 / 44 = 0.1 mol **M1**

(b) moles of $CO_2$ = 0.1 x 3 = 0.3 mol, using the mole ratio from the balanced equation (ft from their moles of propane) **M1**

(b) mass of $CO_2$ = 0.3 x 44 = 13.2 g cao (ft) **A1**

**(b) Answer: 13.2 g**

(c) total mass of products = mass $CO_2$ (ft from b) + mass $H_2O$ = 13.2 + 7.2 = 20.4 g **M1**

(c) mass $O_2$ = 20.4 - 4.4 = 16.0 g (awrt 16.0, ft) **A1**

**(c) Answer: 16.0 g**

## Question 9

(a) states method steps: burn each gas with same apparatus and place a clean glass plate at a fixed height above the flame to collect soot, repeat or time for fixed period, oe **M1**

(a) states at least two control variables such as same distance of plate from flame, same volume or flow rate of gas, same burning time, same air flow, oe **M1**

(a) states how to compare results quantitatively, e.g. measure darkness by photographing and comparing greyscale or measure mass increase of plate, oe **A1**

**(a) Answer: Burn each gas under the same conditions, place a clean glass plate at a fixed height above each flame for a fixed time, then compare soot by mass increase or greyscale of photographs. Controls: plate distance, burning time, gas flow rate and room air flow.**

(b) suggests an improvement, e.g. use a clamp and fixed spacer to ensure exact plate distance or use a balance with higher precision to measure mass change **M1**

(b) explains reduction of systematic error, e.g. ensures consistent plate height so soot deposition is comparable or smaller balance uncertainty reduces bias, oe **A1**

**(b) Answer: Use a clamp with a fixed spacer so the plate height above each flame is identical; this ensures the same portion of flame is sampled and reduces systematic bias between trials.**


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