7.1 Crude oil, fuels and feedstock

Name: _____ Class: _____ Date: _____ **Total: 27 marks**

KEY WORDS alkane • fractional distillation • cracking

Objective

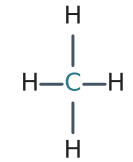
Name alkanes, explain fractional distillation, molecule-size trends, and cracking. Original questions for spec statements 4.7.1.1–4.7.1.4.

1 Key knowledge and worked examples

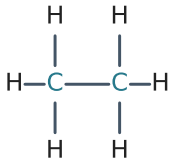
Crude oil – finite resource, ancient **plankton biomass** in mud. Hydrocarbons, mostly **alkanes** $\mathbf{C_nH_{2n+2}}$: methane CH_4, ethane C_2H_6, propane C_3H_8, butane C_4H_{10}.

Fractional distillation – separate by **evaporation and condensation**: small molecules, low boiling point, flammable, runny – collected at the **top**; large molecules, high boiling point, viscous, hard to ignite – at the **bottom**.

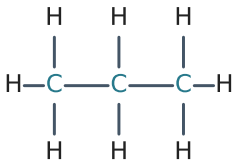
Methane · CH_4



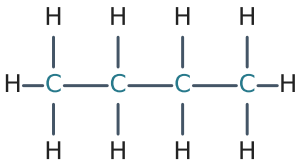
Ethane · C_2H_6



Propane · C_3H_8



Butane · C_4H_{10}



Cracking – **catalytic** (hot + catalyst) or **steam** (hot + steam) – gives a smaller **alkane** plus an **alkene**:

$C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$

Alkenes decolourise **bromine water** (orange → colourless).

Worked example (2 marks). Why does the petrol fraction come off higher in the column than diesel?

Petrol molecules are smaller than diesel molecules; smaller molecules have lower boiling points, so they condense higher up where it is cooler.

Worked combustion. Complete combustion of propane produces CO_2 and H_2O. Balance C first (three CO_2), then H (four H_2O), then O (ten O atoms, hence five O_2):

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

Check three C, eight H and ten O on each side. Change coefficients, not formula subscripts.

2 Practice

2.1 Give the formula of the alkane with four carbon atoms. [1]

2.2 State two trends in properties as hydrocarbon molecules get bigger. [2]

2.3 What type of hydrocarbon decolourises bromine water? [1]

3 Exam-style questions

3.1 Explain how fractional distillation separates crude oil into fractions. [4]

3.2 Balance and complete: $C_6H_{14} \rightarrow C_4H_{10}$ + _____. Name the missing product. [3]

3.3 Describe the two industrial methods of cracking and why cracking is commercially necessary. [5]

3.4 A fictional oil sample contains C_3H_8, C_2H_5OH and C_4H_{10}. Identify its hydrocarbons and explain why the whole sample cannot be given one molecular formula. [3]

3.5 Write a balanced equation for complete combustion of butane, C_4H_{10}. Explain why the molecular formula of butane must not be changed while balancing. [4]

3.6 A fictional burner needs fuel that flows in less than 15 s in a specified test and ignites readily. At the same temperature, fraction P flows in 12 s and ignites readily; Q flows in 30 s and needs strong heating to ignite. Choose a fraction and justify it against both requirements. Explain why the test does not show that Q's viscosity is exactly 2.5 times P's. [4]

Solutions

2.1 C_4H_{10}.

2.2 Any two of: boiling point rises; viscosity increases; flammability decreases.

2.3 An alkene – unsaturated.

3.1 The oil is heated and vapourised; the column is cooler towards the top; vapours condense at the level where the temperature equals their boiling point; molecules with similar boiling points – similar sizes – collect as the same fraction.

3.2 C_2H_4; $C_6H_{14} \rightarrow C_4H_{10} + C_2H_4$ is balanced – 6 C and 14 H each side; ethene.

3.3 Catalytic cracking – vaporised hydrocarbon passed over a hot catalyst; steam cracking – vaporised hydrocarbon mixed with steam at very high temperature. Cracking provides smaller alkanes for fuels, in higher demand than the large fractions supplied by distillation; and alkenes for polymers and other chemicals.

3.4 C_3H_8 and C_4H_{10} are hydrocarbons: only C and H. The whole sample is a mixture of different compounds, including oxygen-containing ethanol, and has no single fixed molecular formula.

3.5

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

Correct products, balanced C/H, oxygen coefficient with matching fuel coefficient. Changing a subscript changes the identity of the molecule; balance with coefficients instead. The equivalent equation with one butane and 6.5 oxygen is acceptable.

3.6 P: 12 s is below 15 s and it meets the ignition requirement. The ratio $r = 30/12 = 2.5$ is a flow-time ratio, not a calibrated viscosity ratio. Both requirements, not molecule size alone, decide this supplied comparison.