

Hydrocarbons as fuels

Question Paper

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Hydrocarbons
Sub-Topic	Hydrocarbons as fuels
Paper Type	Theory
Booklet	Question Paper

Time Allowed: 74 minutes

Score: /61

Percentage: /100

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	77.5%	70%	62.5%	57.5%	45%	<45%

1 Petrol and diesel fuel are both used in internal combustion engines. Petrol may be regarded as having the formula C_9H_{20} and diesel fuel as having the formula $C_{14}H_{30}$.

(a) (i) To which class of compounds do these two hydrocarbons belong?

.....

(ii) Write a balanced equation for the complete combustion of petrol.

.....

[2]

(b) When petrol or diesel fuel are used in internal combustion engines, several different products of the incomplete combustion of the fuel may be formed.

(i) Name **two** of these products that do not contain hydrogen.

..... and

(ii) Choose one of these and state a hazard it causes.

product

hazard

(iii) Write a balanced equation for the formation of **one** of the products in (i) from diesel fuel.

.....

[4]

(c) Define the term *standard enthalpy change of combustion*.

.....

.....

..... [2]

(d) A 1.00 cm^3 sample of $\text{C}_{14}\text{H}_{30}$ was completely burnt in air.
The heat produced raised the temperature of 250 g of water by $34.6\text{ }^\circ\text{C}$.
Assume no heat losses occurred during this experiment.
The density of $\text{C}_{14}\text{H}_{30}$ is 0.763 g cm^{-3} .

(i) Use relevant data from the *Data Booklet* to calculate the amount of heat released in this experiment.

(ii) Use the data above and your answer to (i) to calculate the energy produced by the combustion of 1 mol of $\text{C}_{14}\text{H}_{30}$.

[5]

[Total: 13]

2 Carbon dioxide, CO_2 , makes up about 0.040% of the Earth's atmosphere. It is produced by

animal respiration and by the combustion of fossil fuels.

In animal respiration, oxygen reacts with a carbohydrate such as glucose to give water, carbon dioxide and energy.

The typical daily food requirement of a human can be considered to be the equivalent of 1.20 kg of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$.

You should express all of your numerical answers in this question to three significant figures.

(a) Construct a balanced equation for the complete oxidation of glucose.

.....

(ii) Use your equation to calculate the amount, in moles, of CO_2 produced by one person in one day from 1.20 kg of glucose.

(iii) On the day on which this question was written, the World population was estimated to be 6.82×10^9 .

Calculate the total mass of CO_2 produced by this number of people in one day. Give your answer in tonnes. [1 tonne = 1.00×10^6 g]

- (b) When fossil fuels are burned in order to give energy, carbon dioxide and water are also produced.

The hydrocarbon octane, C_8H_{18} , can be used to represent the fuel burned in motor cars. A typical fuel-efficient motor car uses about 4.00 dm^3 of fuel to travel 100 km.

- (i) Construct a balanced equation for the complete combustion of octane.

.....

- (ii) The density of octane is 0.700 g cm^{-3} .

Calculate the amount, in moles, of octane present in 4.00 dm^3 of octane.

- (iii) Calculate the mass of CO_2 produced when the fuel-efficient car is driven for a distance of 100 km.

[5]

- (c) Calculate how many kilometres the same fuel-efficient car would have to travel in order to produce as much CO_2 as is produced by the respiration of 6.82×10^9 people during one day. Use your answer to (a)(iii).

[2]

- (d) Carbon dioxide is one of a number of gases that are responsible for global warming. When fossil fuels such as octane are burned in a car engine, other atmospheric pollutants are also produced.

Give the formula of **one** atmospheric pollutant that may be produced in a car engine, other than CO_2 , and state how this pollutant damages the environment.

pollutant

damage caused

[2]

[Total: 14]

- 3 Hydrogen is the most abundant element in the Universe, although on Earth only very small quantities of molecular hydrogen have been found to occur naturally.

Hydrogen is manufactured on a large scale for use in the chemical industry and is also regarded as a possible fuel to replace fossil fuels in internal combustion engines.

- (a) State **one** large scale use of hydrogen in the chemical industry.

..... [1]

One common way of producing hydrogen on a large scale for use in the chemical industry is by the steam 'reforming' of methane (natural gas), in which steam and methane are passed over a catalyst at 1000–1400 K to produce carbon monoxide and hydrogen.



- (b) Use the information above to state and explain the effect on the equilibrium position of the following changes.

- (i) increasing the pressure applied to the equilibrium

.....
.....

- (ii) decreasing the temperature of the equilibrium

.....
.....

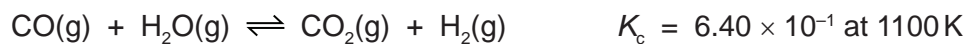
[4]

- (c) What will be the effect on the rate of the reaction of increasing the pressure at which it is carried out? Explain your answer.

.....
.....

[2]

- (d) Further hydrogen can be obtained by the ‘water-gas shift’ reaction in which the carbon monoxide produced is reacted with steam.



A mixture containing 0.40 mol of CO, 0.40 mol of H₂O, 0.20 mol of CO₂ and 0.20 mol of H₂ was placed in a 1 dm³ flask and allowed to come to equilibrium at 1100 K

- (i) Give an expression for K_c for this reaction.
- (ii) Calculate the amount, in moles, of each substance present in the equilibrium mixture at 1100 K.

	CO(g)	+	H ₂ O(g)	⇌	CO ₂ (g)	+	H ₂ (g)
initial moles	0.40		0.40				

[5]

[Total: 12]

4 The residues from organohalogen pesticides are known to be a major cause of the decline in numbers of different birds of prey in many countries. These residues are concentrated in birds at the top of food chains.

(a) Analysis of the bodies of birds of prey show that the pesticide residues accumulate in the fatty tissues of the birds. This is because of the high partition coefficient between the fat in the tissues and water found in blood.

Explain what is meant by the term *partition coefficient*.

.....
.....
.....[2]

(b) A particular pesticide has a partition coefficient of 8.0 between the solvent hexane and water. If a 25 cm³ sample of water containing 0.0050 g of the pesticide is shaken with a 25 cm³ sample of hexane, calculate the mass of pesticide that will dissolve in the hexane layer.

[2]

(c) Compounds used as pesticides may contain bromine or chlorine.

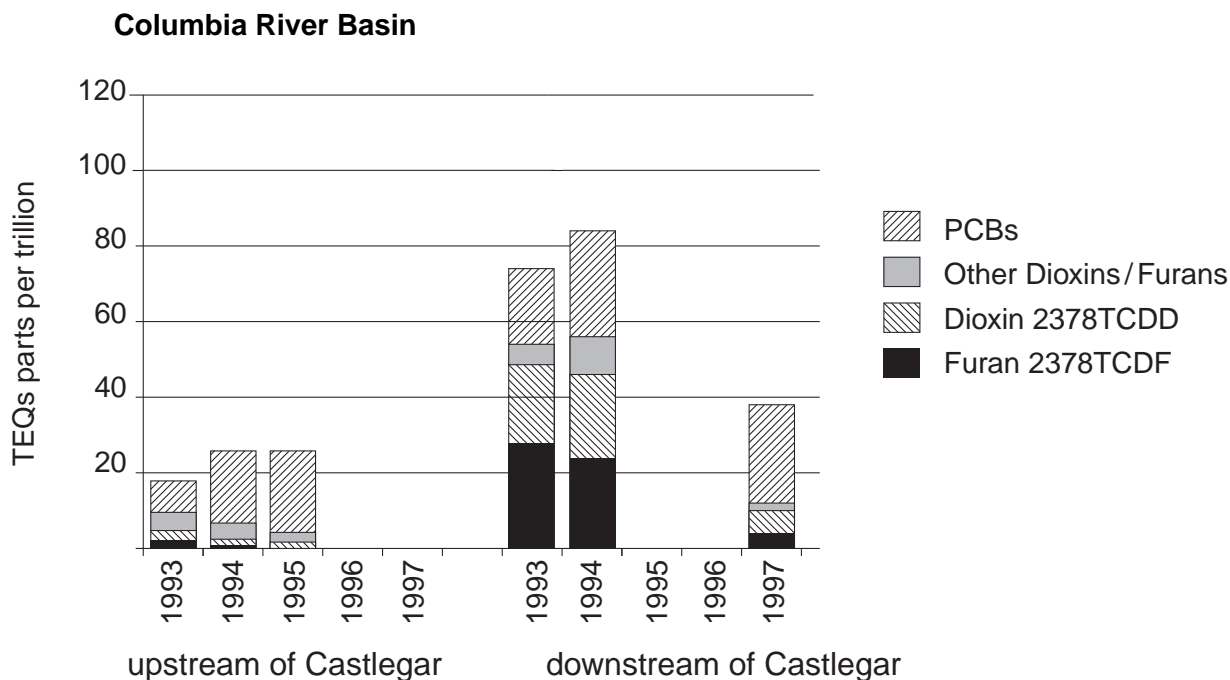
(i) What would be the difference in the ratio of the M: M+2 peaks if the pesticide contained one chlorine rather than one bromine atom?

.....

(ii) If a given pesticide contains **two** chlorine atoms per molecule, deduce the relative heights of the M, M+2 and M+4 peaks.

[3]

- (d) The following graph shows the occurrence of pesticide residues in the eggs of fish-eating birds of prey upstream and downstream of a paper mill at Castlegar on the Columbia River in Canada.



PCBs, the dioxin 2378TCDD, and the furan 2378TCDF all come from chemicals containing chlorine.

- (i) Suggest which compounds are present directly as a result of the paper mill.

.....

- (ii) By studying the data for 1994, suggest which chemical(s) come from sources other than the paper mill.

.....

- (iii) Compare the downstream data for 1994 with that for 1997. Suggest what might be responsible for the change.

.....

- (iv) A molecule of 2378TCDD contains four chlorine atoms. How many molecular ion peaks would this compound show in its mass spectrum?

.....

[4]

[Total:11]

- 5 Most submarines travel under water using electrical power from batteries. The German engineer Helmut Walter designed a diesel engine that could be used to propel a submarine beneath the surface of the sea. Instead of taking air from above the surface of the sea, Walter's engine used hydrogen peroxide, H_2O_2 , to provide oxygen for a conventional diesel engine.

Hydrogen peroxide may be catalytically decomposed to give water and oxygen.

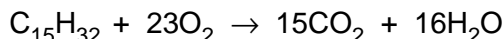
- (a) (i) What is meant by the term *catalyst*?

.....
.....

- (ii) Construct a balanced equation for the decomposition of H_2O_2 .

..... [3]

Diesel fuel may be considered to consist of the hydrocarbon $\text{C}_{15}\text{H}_{32}$ which reacts completely with oxygen according to the following equation.



- (b) (i) To which homologous series does $\text{C}_{15}\text{H}_{32}$ belong?

.....

- (ii) Use the equation above and your answer to (a)(ii) to calculate the amount, in moles, of H_2O_2 , that will provide sufficient oxygen for the complete oxidation of one mole of $\text{C}_{15}\text{H}_{32}$.

amount of H_2O_2 = mol

[3]

A submarine equipped with a Walter engine used 212 tonnes of diesel fuel during an underwater voyage. The submarine also carried concentrated aqueous H_2O_2 .
[1 tonne = 10^6 g]

(c) (i) Calculate the amount, in moles, of diesel fuel used during the underwater voyage.

amount of diesel fuel = mol

(ii) Use your answers to **(b)(ii)** and **(c)(i)** to calculate the mass, in tonnes, of hydrogen peroxide used during the underwater voyage.

mass of H_2O_2 = tonnes
[4]

(d) The exhaust products of the Walter engine were passed into the sea.

What would happen to them?

..... [1]

[Total: 11]