

SECTION A

Answer **all** questions in the spaces provided.

1 (a) Butane, C₄H₁₀, is a hydrocarbon which is used as a fuel.

(i) Explain what is meant by the term *hydrocarbon*.

.....
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(ii) Explain what is meant by the term *fuel*.

.....
.....

(iii) Write an equation for the complete combustion of butane.

.....

(iv) Write an equation for the incomplete combustion of butane to produce carbon monoxide and water.

.....

(v) Under what conditions would you expect incomplete combustion to occur?

.....

(5 marks)

(b) Three different carbocations are formed by breaking C – C bonds in separate molecules of butane during catalytic cracking. One of these structures is shown below. Give the structures of the other two carbocations.

Structure 1

Structure 2

Structure 3



(2 marks)

The Periodic Table of the Elements

■ The atomic numbers and approximate relative atomic masses shown in the table are for use in the examination unless stated otherwise in an individual question.

		I		II		III		IV		V		VI		VII		0	
1.0	H Hydrogen 1	6.9	Li Lithium 3	9.0	Be Beryllium 4	10.8	B Boron 5	12.0	C Carbon 6	14.0	N Nitrogen 7	16.0	O Oxygen 8	19.0	F Fluorine 9	20.2	Ne Neon 10
23.0	Na Sodium 11	24.3	Mg Magnesium 12	27.0	Al Aluminium 13	28.1	Si Silicon 14	31.0	P Phosphorus 15	32.1	S Sulphur 16	35.5	Cl Chlorine 17	39.9	Ar Argon 18	39.9	Ar Argon 18
39.1	K Potassium 19	40.1	Ca Calcium 20	47.9	Ti Titanium 22	50.9	V Vanadium 23	52.0	Cr Chromium 24	54.9	Mn Manganese 25	55.8	Fe Iron 26	58.7	Ni Nickel 28	58.9	Co Cobalt 27
85.5	Rb Rubidium 37	87.6	Sr Strontium 38	91.2	Zr Zirconium 40	92.9	Nb Niobium 41	95.9	Mo Molybdenum 42	98.9	Tc Technetium 43	101.1	Ru Ruthenium 44	106.4	Pd Palladium 46	102.9	Rh Rhodium 45
132.9	Cs Caesium 55	137.3	Ba Barium 56	178.5	Hf Hafnium 72	180.9	Ta Tantalum 73	183.9	W Tungsten 74	186.2	Re Rhenium 75	190.2	Os Osmium 76	195.1	Pt Platinum 78	192.2	Ir Iridium 77
223.0	Fr Francium 87	226.0	Ra Radium 88	227	Ac Actinium 89 †	227	Ac Actinium 89 †	227	Ac Actinium 89 †	227	Ac Actinium 89 †	227	Ac Actinium 89 †	227	Ac Actinium 89 †	227	Ac Actinium 89 †
65.4	Zn Zinc 30	63.5	Cu Copper 29	58.7	Ni Nickel 28	58.9	Co Cobalt 27	55.8	Fe Iron 26	54.9	Mn Manganese 25	52.0	Cr Chromium 24	50.9	V Vanadium 23	47.9	Ti Titanium 22
112.4	Cd Cadmium 48	107.9	Ag Silver 47	106.4	Pd Palladium 46	102.9	Rh Rhodium 45	101.1	Ru Ruthenium 44	98.9	Tc Technetium 43	95.9	Mo Molybdenum 42	92.9	Nb Niobium 41	91.2	Zr Zirconium 40
200.6	Hg Mercury 80	197.0	Au Gold 79	195.1	Pt Platinum 78	192.2	Ir Iridium 77	190.2	Os Osmium 76	186.2	Re Rhenium 75	183.9	W Tungsten 74	180.9	Ta Tantalum 73	178.5	Hf Hafnium 72
204.4	Tl Thallium 81	207.2	Pb Lead 82	209.0	Bi Bismuth 83	209.0	Po Polonium 84	210.0	At Astatine 85	210.0	Po Polonium 84	210.0	At Astatine 85	210.0	Po Polonium 84	210.0	Po Polonium 84
114.8	In Indium 49	118.7	Sn Tin 50	121.8	Sb Antimony 51	126.9	Te Tellurium 52	127.6	I Iodine 53	126.9	I Iodine 53	126.9	Te Tellurium 52	126.9	I Iodine 53	126.9	I Iodine 53
72.6	Ge Germanium 32	72.6	As Arsenic 33	74.9	Se Selenium 34	79.0	Br Bromine 35	79.9	Se Selenium 34	79.9	Br Bromine 35	79.9	Se Selenium 34	79.9	Br Bromine 35	79.9	Br Bromine 35
69.7	Ga Gallium 31	69.7	Ge Germanium 32	65.4	Zn Zinc 30	63.5	Cu Copper 29	63.5	Cu Copper 29	65.4	Zn Zinc 30	69.7	Ga Gallium 31	69.7	Ga Gallium 31	69.7	Ga Gallium 31
114.8	In Indium 49	118.7	Sn Tin 50	121.8	Sb Antimony 51	126.9	Te Tellurium 52	127.6	I Iodine 53	126.9	I Iodine 53	126.9	Te Tellurium 52	126.9	I Iodine 53	126.9	I Iodine 53
204.4	Tl Thallium 81	207.2	Pb Lead 82	209.0	Bi Bismuth 83	209.0	Po Polonium 84	210.0	At Astatine 85	210.0	Po Polonium 84	210.0	At Astatine 85	210.0	Po Polonium 84	210.0	Po Polonium 84
162.5	Dy Dysprosium 66	164.9	Ho Holmium 67	167.3	Er Erbium 68	168.9	Tm Thulium 69	173.0	Yb Ytterbium 70	175.0	Lu Lutetium 71	175.0	Lu Lutetium 71	175.0	Lu Lutetium 71	175.0	Lu Lutetium 71
252.1	Cf Californium 98	(252)	Es Einsteinium 99	(257)	Fm Fermium 100	(258)	Md Mendelevium 101	(259)	No Nobelium 102	(260)	Lr Lawrencium 103	(260)	Lr Lawrencium 103	(260)	Lr Lawrencium 103	(260)	Lr Lawrencium 103
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
247.1	Bk Berkelium 97	247.1	Cm Curium 96	243.1	Am Americium 95	239.1	Pu Plutonium 94	237.0	Np Neptunium 93	238.0	U Uranium 92	232.0	Th Thorium 90	232.0	Th Thorium 90	232.0	Th Thorium 90
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
247.1	Bk Berkelium 97	247.1	Cm Curium 96	243.1	Am Americium 95	239.1	Pu Plutonium 94	237.0	Np Neptunium 93	238.0	U Uranium 92	232.0	Th Thorium 90	232.0	Th Thorium 90	232.0	Th Thorium 90
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
247.1	Bk Berkelium 97	247.1	Cm Curium 96	243.1	Am Americium 95	239.1	Pu Plutonium 94	237.0	Np Neptunium 93	238.0	U Uranium 92	232.0	Th Thorium 90	232.0	Th Thorium 90	232.0	Th Thorium 90
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
247.1	Bk Berkelium 97	247.1	Cm Curium 96	243.1	Am Americium 95	239.1	Pu Plutonium 94	237.0	Np Neptunium 93	238.0	U Uranium 92	232.0	Th Thorium 90	232.0	Th Thorium 90	232.0	Th Thorium 90
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
247.1	Bk Berkelium 97	247.1	Cm Curium 96	243.1	Am Americium 95	239.1	Pu Plutonium 94	237.0	Np Neptunium 93	238.0	U Uranium 92	232.0	Th Thorium 90	232.0	Th Thorium 90	232.0	Th Thorium 90
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
247.1	Bk Berkelium 97	247.1	Cm Curium 96	243.1	Am Americium 95	239.1	Pu Plutonium 94	237.0	Np Neptunium 93	238.0	U Uranium 92	232.0	Th Thorium 90	232.0	Th Thorium 90	232.0	Th Thorium 90
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
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158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
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247.1	Bk Berkelium 97	247.1	Cm Curium 96	243.1	Am Americium 95	239.1	Pu Plutonium 94	237.0	Np Neptunium 93	238.0	U Uranium 92	232.0	Th Thorium 90	232.0	Th Thorium 90	232.0	Th Thorium 90
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
247.1	Bk Berkelium 97	247.1	Cm Curium 96	243.1	Am Americium 95	239.1	Pu Plutonium 94	237.0	Np Neptunium 93	238.0	U Uranium 92	232.0	Th Thorium 90	232.0	Th Thorium 90	232.0	Th Thorium 90
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
247.1	Bk Berkelium 97	247.1	Cm Curium 96	243.1	Am Americium 95	239.1	Pu Plutonium 94	237.0	Np Neptunium 93	238.0	U Uranium 92	232.0	Th Thorium 90	232.0	Th Thorium 90	232.0	Th Thorium 90
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	144.2	Nd Neodymium 60	140.9	Pr Praseodymium 59	140.1	Ce Cerium 58	140.1	Ce Cerium 58
247.1	Bk Berkelium 97	247.1	Cm Curium 96	243.1	Am Americium 95	239.1	Pu Plutonium 94	237.0	Np Neptunium 93	238.0	U Uranium 92	232.0	Th Thorium 90	232.0	Th Thorium 90	232.0	Th Thorium 90
158.9	Tb Terbium 65	157.3	Gd Gadolinium 64	152.0	Eu Europium 63	150.4	Sm Samarium 62	144.9	Pm Promethium 61	1							

Table 1
Proton n.m.r chemical shift data

Type of proton	δ/ppm
RCH_3	0.7–1.2
R_2CH_2	1.2–1.4
R_3CH	1.4–1.6
RCOCH_3	2.1–2.6
ROCH_3	3.1–3.9
RCOOCH_3	3.7–4.1
ROH	0.5–5.0

Table 2
Infra-red absorption data

Bond	Wavenumber/ cm^{-1}
C—H	2850–3300
C—C	750–1100
C=C	1620–1680
C=O	1680–1750
C—O	1000–1300
O—H (alcohols)	3230–3550
O—H (acids)	2500–3000

(c) Ethane can be cracked in the presence of a catalyst to produce ethene and hydrogen.

(i) Write an equation for this reaction.

.....

(ii) Give a suitable catalyst for this reaction.

.....

(iii) State **one** reason why cracking is important.

.....

.....

(3 marks)

$\frac{\quad}{10}$

TURN OVER FOR THE NEXT QUESTION

Turn over 

2 When chlorine reacts with trichloromethane, tetrachloromethane, CCl_4 , is formed.

(a) (i) Write the overall equation for this reaction.

.....

(ii) State **one** essential condition for this reaction.

.....

(2 marks)

(b) The mechanism for the chlorination of trichloromethane is free-radical substitution, which proceeds by a series of steps. Write equations for the steps named below in this chlorination.

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step

.....

(4 marks)

(c) (i) A chloroalkane, **W**, was shown to contain 37.2% carbon and 55.0% chlorine by mass. The remainder of the compound was hydrogen. Calculate the empirical formula of compound **W**.

.....

.....

.....

.....

(ii) What additional information would be needed to calculate the molecular formula of compound **W**?

.....

(4 marks)

Turn over ►

10

3 (a) Compounds with double bonds between carbon atoms can exhibit geometrical isomerism.

(i) Draw structures for the two geometrical isomers of 1,2-dichloroethene.

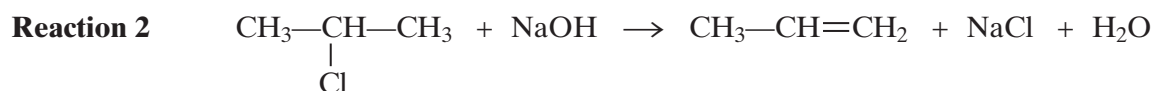
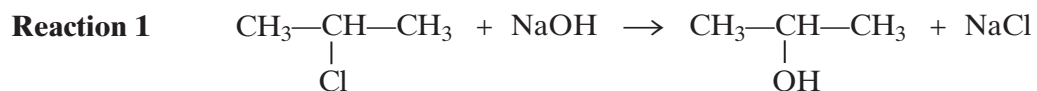
Isomer 1

Isomer 2

(ii) What feature of the double bond prevents isomer 1 from changing into isomer 2?

.....
(3 marks)

(b) When 2-chloropropane reacts with sodium hydroxide, two different reactions occur. Each reaction produces a different organic product.



(i) Outline a mechanism for **Reaction 1** and state the role of the hydroxide ion in this reaction.

Mechanism

Role of the hydroxide ion

- (ii) Outline a mechanism for **Reaction 2** and state the role of the hydroxide ion in this reaction.

Mechanism

Role of the hydroxide ion
(7 marks)

$\frac{\quad}{10}$

TURN OVER FOR THE NEXT QUESTION

Turn over 

4 (a) Four isomers with the formula C_4H_9OH are given below.

Isomer	Name
$CH_3CH_2CH_2CH_2OH$	butan-1-ol
$\begin{array}{c} CH_3 \\ \\ CH_3-C-CH_3 \\ \\ OH \end{array}$	2-methylpropan-2-ol
$\begin{array}{c} CH_3-CH-CH_2OH \\ \\ CH_3 \end{array}$	
$\begin{array}{c} CH_3CH_2-CH-CH_3 \\ \\ OH \end{array}$	

- (i) Complete the naming of the isomers in the table above.
- (ii) Name the type of isomerism shown by these four isomers.

.....
(3 marks)

(b) One of the isomers in part (a) is resistant to oxidation by acidified potassium dichromate(VI).

- (i) Identify this isomer.

.....

- (ii) This isomer can be dehydrated. Give a suitable dehydrating agent and write an equation for this dehydration reaction.

Dehydrating agent

Equation

(3 marks)

- (c) (i) Identify the isomer in part (a) which can be oxidised to a ketone. Give the structure of the ketone formed.

Isomer

Structure of the ketone

- (ii) Identify **one** of the isomers in part (a) which can be oxidised to an aldehyde. Give the structure of the aldehyde formed.

Isomer

Structure of the aldehyde

- (iii) Give a reagent that can be used in a test to distinguish between a ketone and an aldehyde. State what you would observe in the test.

Reagent

Observation with ketone

.....

Observation with aldehyde

.....

(7 marks)

- (d) Butan-1-ol can be oxidised to form a carboxylic acid. Using [O] to represent the oxidising agent, write an equation for this reaction and name the product.

Equation

Name of product

(2 marks)

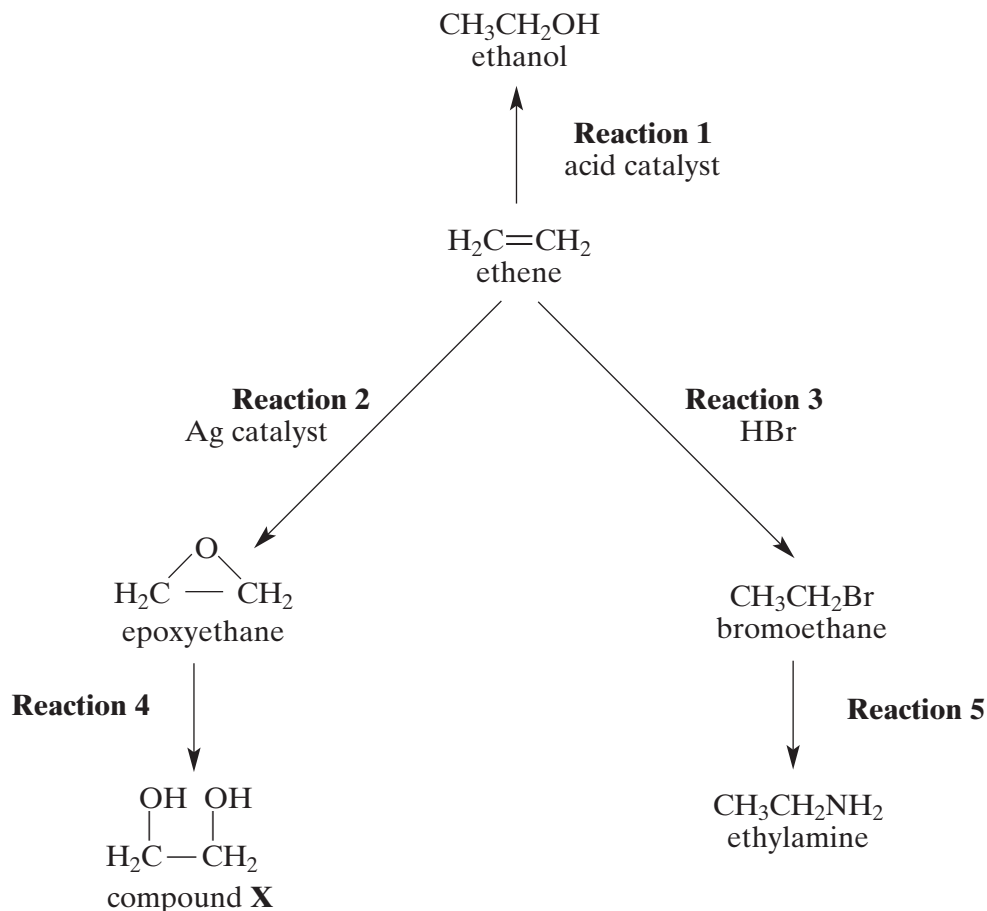
15

Turn over ►

SECTION B

Answer the question below in the space provided on pages 13 to 16 of this booklet.

- 5 Ethene can be converted into a variety of useful products as illustrated below.



- (a) Name and give a use for compound **X**. (2 marks)
- (b) Give a reagent for each of **Reactions 1, 2, 4** and **5**. (4 marks)
- (c) Outline a mechanism for **Reaction 3**. (4 marks)
- (d) Ethanol can be manufactured from ethene as shown in **Reaction 1** or by the fermentation of sugars. Outline the essential conditions and give an equation for the fermentation reaction. Compare the relative rates and the purity of the product obtained in each case by these two manufacturing processes. (5 marks)

END OF QUESTIONS