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Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

October 2021

Pearson Edexcel International Advanced Level

Time 1 hour 30 minutes

Paper reference **WCH12/01**

Chemistry

International Advanced Subsidiary/Advanced Level
UNIT 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols

You must have:
Scientific calculator, Data Booklet

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk (*)** marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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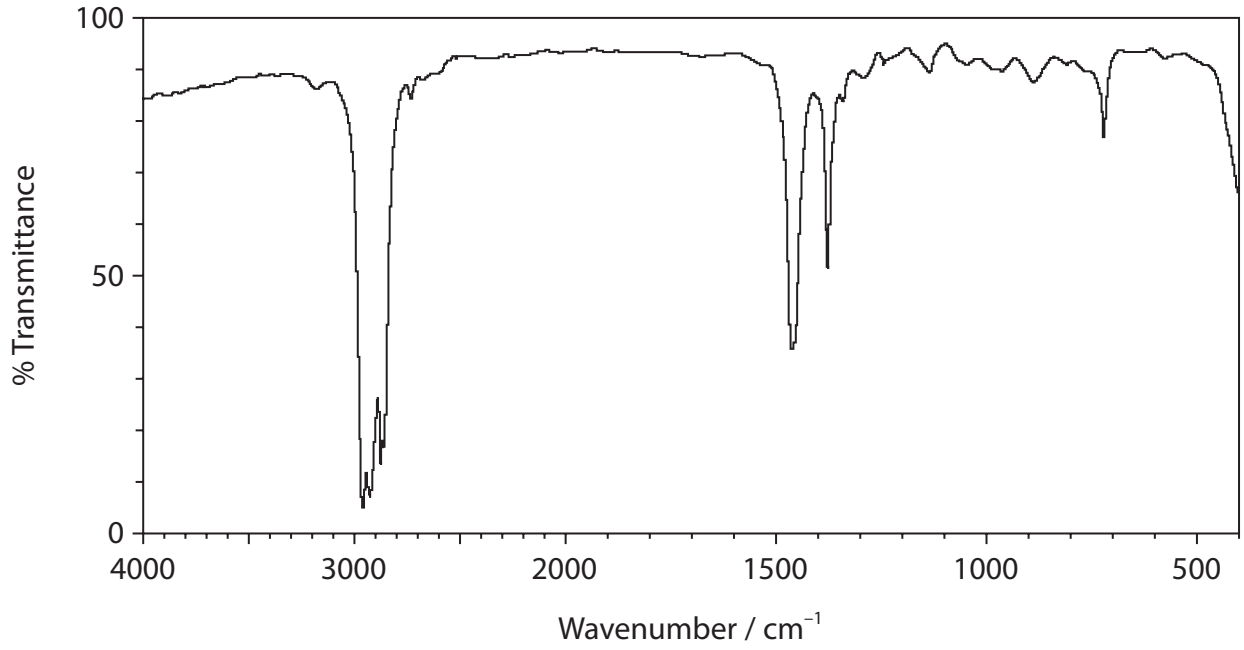
SECTION A

Answer ALL the questions in this section.

You should aim to spend no more than 20 minutes on this section.

For each question, select one answer from A to D and put a cross in the box ☒.
If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The infrared spectrum of an organic compound is shown.



Which of these compounds would give this infrared spectrum?

☒ **A** hexanal

☒ **B** hexane

☒ **C** hexanoic acid

☒ **D** hexan-1-ol

(Total for Question 1 = 1 mark)

2 Which of these compounds does **not** react with acidified potassium dichromate(VI)?

☒ **A** CH_3CH_2OH

☒ **B** $CH_3CHOHCH_3$

☒ **C** CH_3CH_2CHO

☒ **D** CH_3COCH_3

(Total for Question 2 = 1 mark)

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3 Which of these compounds is a tertiary alcohol?

- ☒ **A** 2-methylpropan-2-ol
- ☒ **B** 3-methylbutan-2-ol
- ☒ **C** 2,2-dimethylpropan-1-ol
- ☒ **D** 3,3-dimethylbutan-2-ol

(Total for Question 3 = 1 mark)

4 In a mass spectrum, the molecular ion is the ion which always has the

- ☒ **A** greatest abundance
- ☒ **B** greatest stability
- ☒ **C** highest charge
- ☒ **D** highest mass/charge ratio

(Total for Question 4 = 1 mark)

5 Butan-1-ol and butan-2-ol are isomers.

Which *m* / *z* value would be expected to have a significant peak in the mass spectrum of butan-1-ol but **not** that of butan-2-ol?

- ☒ **A** 15
- ☒ **B** 29
- ☒ **C** 43
- ☒ **D** 57

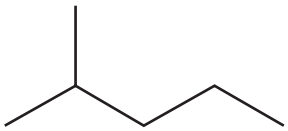
(Total for Question 5 = 1 mark)

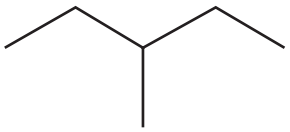
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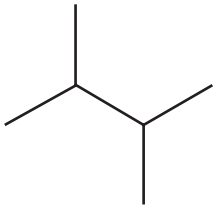
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6 Which of these isomers has the **highest** boiling temperature?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 6 = 1 mark)

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7 Organic reactions can be classified in different ways.

(a) How should the reaction shown be classified?

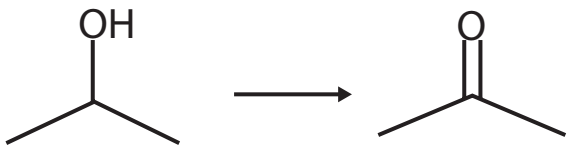
(1)



- ☒ **A** addition
- ☒ **B** oxidation
- ☒ **C** polymerisation
- ☒ **D** substitution

(b) How should the reaction shown be classified?

(1)



- ☒ **A** addition
- ☒ **B** oxidation
- ☒ **C** reduction
- ☒ **D** substitution

(Total for Question 7 = 2 marks)

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8 Data for some Group 1 and Group 2 cations are shown in the table.

Cation	Ionic radius / nm	Ionic charge
W	0.100	+2
X	0.138	+1
Y	0.113	+2
Z	0.149	+1

Which cation would be expected to form the nitrate with the **greatest** thermal stability?

- ☒ **A** W
- ☒ **B** X
- ☒ **C** Y
- ☒ **D** Z

(Total for Question 8 = 1 mark)

9 The equation for the complete combustion of propan-1-ol is shown.

$$C_3H_7OH(l) + 4½O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

2.00×10^{-3} mol of propan-1-ol undergoes complete combustion.

What mass of carbon dioxide is formed?

- ☒ **A** 0.0293 g
- ☒ **B** 0.0880 g
- ☒ **C** 0.132 g
- ☒ **D** 0.264 g

(Total for Question 9 = 1 mark)

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10 This question is about the reaction shown.

$$2KMnO_4 + xH_2C_2O_4 + yH_2SO_4 \rightarrow 2MnSO_4 + K_2SO_4 + 10CO_2 + zH_2O$$

(a) What values of x, y and z are needed to balance the equation?

(1)

	x	y	z
☒ **A**	5	6	8
☒ **B**	10	3	4
☒ **C**	5	3	8
☒ **D**	10	6	4

(b) What is the reducing agent in the reaction?

(1)

☒ **A** H^+

☒ **B** $C_2O_4^{2-}$

☒ **C** MnO_4^-

☒ **D** SO_4^{2-}

(Total for Question 10 = 2 marks)

11 What is the oxidation number of phosphorus in the phosphate ion, PO_4^{3-}?

☒ **A** –3

☒ **B** +3

☒ **C** +5

☒ **D** +7

(Total for Question 11 = 1 mark)

12 Which reaction is **not** a redox reaction?

☒ **A** $4KClO_3(s) \rightarrow 3KClO_4(s) + KCl(s)$

☒ **B** $2HCl(aq) + Ba(OH)_2(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$

☒ **C** $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

☒ **D** $Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HClO(aq)$

(Total for Question 12 = 1 mark)

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13 A student is provided with 25.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid.

What volume of distilled water should the student add to this solution to make a 0.0500 mol dm^{-3} solution?

- ☒ **A** 25.0 cm^3
- ☒ **B** 50.0 cm^3
- ☒ **C** 475 cm^3
- ☒ **D** 500 cm^3

(Total for Question 13 = 1 mark)

14 Which statement about the Group 7 elements chlorine, bromine and iodine is **not** correct?

- ☒ **A** boiling temperature increases down the group
- ☒ **B** reactivity increases down the group
- ☒ **C** first ionisation energy decreases down the group
- ☒ **D** electronegativity decreases down the group

(Total for Question 14 = 1 mark)

15 When iodine is dissolved in a non-polar organic solvent, the solution formed is

- ☒ **A** purple
- ☒ **B** orange
- ☒ **C** colourless
- ☒ **D** brown

(Total for Question 15 = 1 mark)

16 Which row shows the hydrogen halides in order of **increasing** boiling temperature?

	Lowest ⟶ Highest			
☒ **A**	HF	HCl	HBr	HI
☒ **B**	HI	HBr	HCl	HF
☒ **C**	HCl	HBr	HI	HF
☒ **D**	HF	HI	HBr	HCl

(Total for Question 16 = 1 mark)

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17 Solid potassium bromide reacts with concentrated sulfuric acid.

Which of these substances does **not** form?

- ☒ **A** bromine
- ☒ **B** hydrogen bromide
- ☒ **C** hydrogen sulfide
- ☒ **D** sulfur dioxide

(Total for Question 17 = 1 mark)

18 10.00 g of hydrated magnesium sulfate, $MgSO_4.7H_2O$, is heated to remove the water of crystallisation.

What mass of anhydrous magnesium sulfate, $MgSO_4$, is formed?

[Molar mass of $MgSO_4.7H_2O$ = 246.4 g mol^{-1}]

- ☒ **A** 2.84 g
- ☒ **B** 4.89 g
- ☒ **C** 5.11 g
- ☒ **D** 7.16 g

(Total for Question 18 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

Answer ALL the questions in this section.

Write your answers in the spaces provided.

19 This question is about enthalpy changes.

(a) An experiment was carried out to determine the enthalpy change of combustion for ethanol.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

1.19 g of ethanol was burned in a spirit burner. The heat energy from this combustion raised the temperature of 100 g of water from 21.6 °C to 63.9 °C.

(i) Calculate the number of moles of ethanol in 1.19 g.

[Molar mass of ethanol = 46.0 g mol^{-1}]

(1)

(ii) Calculate the heat energy required to raise the temperature of 100 g of water from 21.6 °C to 63.9 °C.

[Specific heat capacity of water = 4.18 J g^{-1} $°C^{-1}$]

(2)

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(iii) Use your answers to (a) (i) and (ii) to calculate a value for the enthalpy change of combustion of ethanol.
Give your answer to an appropriate number of significant figures and include a sign and units.

(3)

(iv) The value of the enthalpy change of combustion from this experiment was very inaccurate.

Give two reasons why this value was so inaccurate, apart from heat loss.

(2)

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(b) Mean bond enthalpies can be used to calculate a value for the enthalpy change of combustion of a compound.

(i) Give the meaning of the term 'mean bond enthalpy'.

(2)

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(ii) Calculate a value for the enthalpy change of combustion of methanol, using the information in the table and the equation shown.

(3)

$$CH_3OH + 1\frac{1}{2}O_2 \rightarrow CO_2 + 2H_2O$$

	C—H	C—O	O—H	O═O	C═O
Mean bond enthalpy / kJ mol^{-1}	413	358	464	498	805

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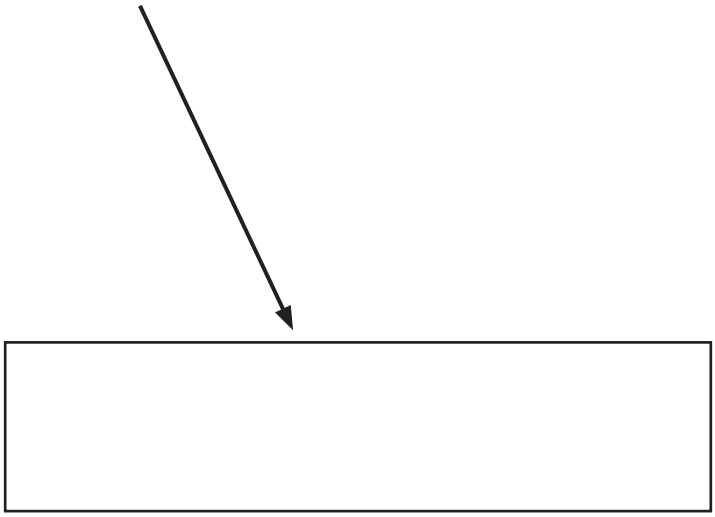
(c) Enthalpy changes of combustion can be used to calculate the enthalpy change of formation of a compound.

Substance	Standard enthalpy change of combustion, $\Delta_c H^{\ominus}$ / kJ mol^{-1}
C(s,graphite)	–394
$H_2(g)$	–286
$CH_3CHO(g)$	–1167

Complete the Hess cycle and use it to calculate the standard enthalpy change of formation for ethanal, CH_3CHO.

(3)

$$2C(s, \text{graphite}) + 2H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow CH_3CHO(g)$$



(Total for Question 19 = 16 marks)

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20 This question is about halogenoalkanes.

(a) The rates of hydrolysis of 1-chloropropane, 1-bromopropane and 1-iodopropane in reactions with aqueous silver nitrate solution were compared.

(i) State what would be measured in the experiment to compare the rates of hydrolysis.

(1)

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(ii) State which of these halogenoalkanes would hydrolyse the fastest. Justify your answer.

(2)

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(b) The equation for the hydrolysis of 1-chloropropane by aqueous hydroxide ions is shown.

$$CH_3CH_2CH_2Cl + OH^- \rightarrow CH_3CH_2CH_2OH + Cl^-$$

Give the mechanism for this hydrolysis.
Include curly arrows, and relevant dipoles and lone pairs.

(2)

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(c) The boiling temperatures of some halogenoalkanes are shown.

Halogenoalkane	Boiling temperature / °C
1-chloropropane	47
1-bromopropane	71
1-iodopropane	103

Explain the trend in boiling temperature of these halogenoalkanes by comparing the intermolecular forces involved.

Detailed explanations of the forces involved are not required.

(4)

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(d) In another experiment, 2-bromobutane is heated with ethanolic potassium hydroxide and an elimination reaction occurs.

Draw the **skeletal** formulae of the three possible organic products, giving their names.

(3)

Skeletal formula	Name

(Total for Question 20 = 12 marks)

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21 This question is about Group 1 metals.

(a) When potassium is placed into a beaker of cold water, potassium hydroxide and hydrogen are formed.

(i) Write the equation for this reaction. Include state symbols.

(2)

(ii) This is a redox reaction.

State which element is oxidised and which is reduced.
Justify your answer by giving the initial and final oxidation numbers of any element that changes oxidation state.

(2)

(iii) The reaction of potassium with water is very vigorous and a flame is seen.

State the colour of the flame.

(1)

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(b) The label has come off a bottle known to contain **M**, a Group 1 metal which is stored in oil.
A student carried out an experiment to determine the identity of **M**.

Procedure

Step **1** A small piece of **M** was wiped with tissue paper to remove the oil.
The piece of **M** was weighed and placed in a beaker of distilled water.

Step **2** After the reaction had finished, the contents of the beaker and washings were transferred to a 250.0 cm^3 volumetric flask. The solution was made up to the mark with distilled water and mixed thoroughly.

Step **3** A pipette was used to transfer 25.0 cm^3 portions of this solution to conical flasks. Each portion was then titrated with hydrochloric acid of concentration 0.400 $mol\,dm^{-3}$.

Results

Mass of metal, **M**	0.37 g
Mean titre of hydrochloric acid	12.80 cm^3

The reaction taking place is shown.

$$\mathbf{M}OH(aq) + HCl(aq) \rightarrow \mathbf{M}Cl(aq) + H_2O(l)$$

(i) The indicator used was phenolphthalein.

State the colour **change** at the end-point.

(2)

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(ii) Calculate the relative atomic mass of **M** and use it to identify the Group 1 metal, **M**.

(4)

(c) Another student repeated the experiment, using a different sample of metal **M**, but did not wipe off the oil before weighing it.

State how this would change the calculated value of the relative atomic mass of **M**. Justify your answer.

(2)

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(Total for Question 21 = 13 marks)

TOTAL FOR SECTION B = 41 MARKS

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SECTION C

Answer ALL the questions in this section.

Write your answers in the spaces provided.

22 This question is about ethanol and bioethanol.

The main fuel used as a petrol substitute is bioethanol. Bioethanol is ethanol that has been produced by fermentation. The starting material is usually some form of plant material rich in starch, such as wheat, maize or potatoes. Enzymes in yeast convert this material to simple carbohydrates such as glucose ($C_6H_{12}O_6$) and then to ethanol and carbon dioxide.

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$$

The mixture is left for several days until fermentation is complete.
The percentage of ethanol is never greater than 15 % because higher concentrations of ethanol kill the yeast.

A common blend of fuel is 95 % petrol and 5 % bioethanol. The engine does not need to be modified for this mixture.

(a) Give **one** advantage and **one** disadvantage of using bioethanol in petrol.

(2)

Advantage

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.....

Disadvantage

.....

.....

(b) Suggest why this fermentation must be carried out in the absence of air.

(1)

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(c) Suggest how the ethanol can be obtained, after filtering the fermentation mixture.

(1)

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(d) Ethanol is hygroscopic, which means it readily absorbs water from the air.

(i) Give a possible reason why ethanol is able to absorb water.

(1)

(ii) Suggest a problem arising from the hygroscopic nature of ethanol when using this fuel in a motor vehicle.

(1)

(e) Ethanol can also be produced by the hydration of ethene.

$$CH_2 = CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -45\,kJ\,mol^{-1}$$

*(i) Typical conditions are 300 °C and 60 atm with a catalyst of phosphoric acid.

Explain why these conditions are used, by describing the effect of changing the temperature and pressure on rate of reaction, equilibrium yield and cost.

(6)

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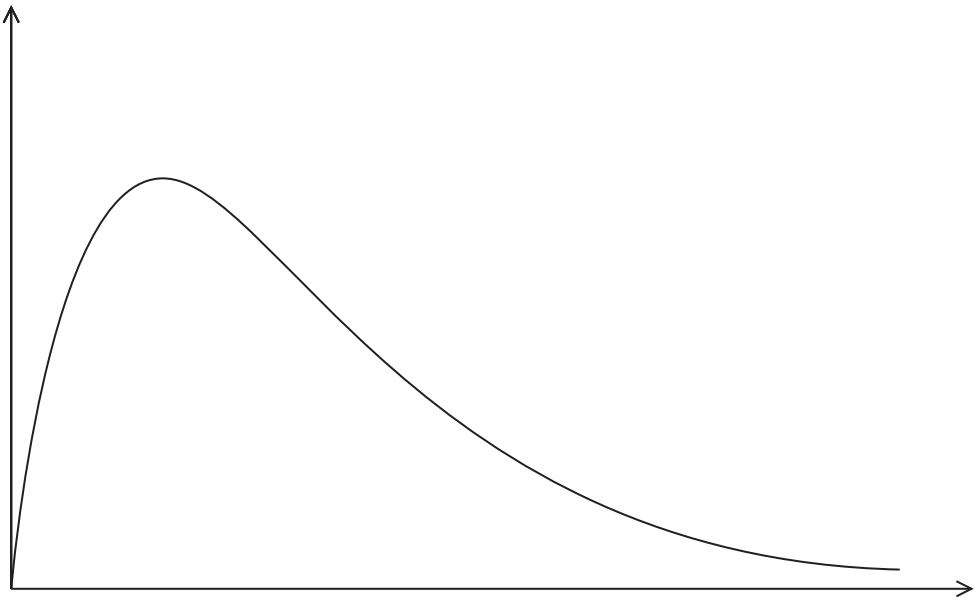
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(ii) The rate of this reaction is increased by using a catalyst of phosphoric acid.

Label the axes on the Maxwell–Boltzmann distribution curve and use it to explain how a catalyst increases the rate of reaction.

(4)

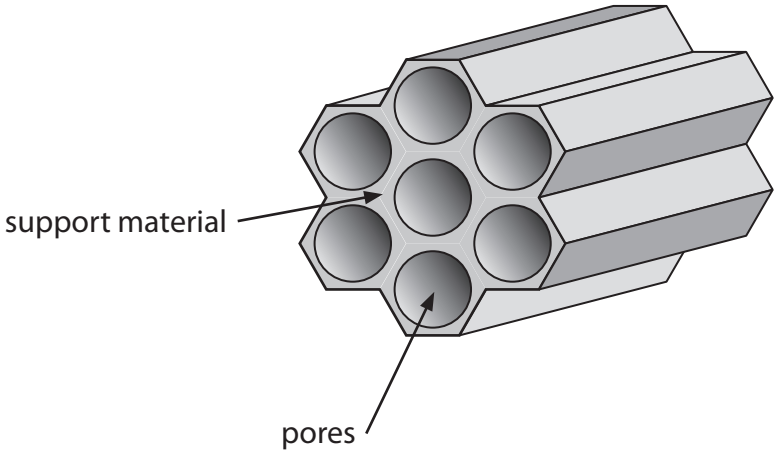


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(f) Catalysts such as phosphoric acid are bonded to a support material that contains lots of pores.



(i) Suggest the advantage of using support materials containing lots of pores.

(1)

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(ii) Under these conditions, only about 5 % of the ethene is converted into ethanol as it passes over the catalyst.

Suggest how the overall yield of this process can be improved to make it economically viable.

(2)

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(Total for Question 22 = 19 marks)

TOTAL FOR SECTION C = 19 MARKS
TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									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	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	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	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
* Actinide series	232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

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