

Write your name here

Surname	Other names
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**Pearson Edexcel**  
International  
Advanced Level

Centre Number	Candidate Number
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**Chemistry**  
**Advanced Subsidiary**  
**Unit 2: Application of Core Principles of Chemistry**

Wednesday 26 October 2016 – Morning <b>Time: 1 hour 30 minutes</b>	Paper Reference <b>WCH02/01</b>
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Candidates may use a calculator.	Total Marks
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### Instructions

- Use **black** ink or 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.*
- Questions labelled with an **asterisk** (\*) are ones where the quality of your written communication will be assessed  
– *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

### Advice

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- 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 What are the shapes of the  $\text{BF}_3$  and  $\text{PH}_3$  molecules?

	$\text{BF}_3$	$\text{PH}_3$
<input type="checkbox"/> A	pyramidal	pyramidal
<input type="checkbox"/> B	pyramidal	trigonal planar
<input type="checkbox"/> C	trigonal planar	pyramidal
<input type="checkbox"/> D	trigonal planar	trigonal planar

(Total for Question 1 = 1 mark)

2 What are the C—C—C bond angles in diamond and graphite?

	Diamond	Graphite
<input type="checkbox"/> A	$109.5^\circ$	$109.5^\circ$
<input type="checkbox"/> B	$109.5^\circ$	$120^\circ$
<input type="checkbox"/> C	$120^\circ$	$109.5^\circ$
<input type="checkbox"/> D	$120^\circ$	$120^\circ$

(Total for Question 2 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

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- 3 Which describes the polarity of the C—Cl bond and the polarity of the molecule trichloromethane, CHCl<sub>3</sub>?

	Polarity of C—Cl bond	Polarity of molecule
<input type="checkbox"/> A	non-polar	non-polar
<input type="checkbox"/> B	non-polar	polar
<input type="checkbox"/> C	polar	non-polar
<input type="checkbox"/> D	polar	polar

(Total for Question 3 = 1 mark)

- 4 Which isomer, with the formula C<sub>7</sub>H<sub>16</sub>, will have the **lowest** boiling temperature?

- A CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>
- B (CH<sub>3</sub>)<sub>2</sub>CHCH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>
- C CH<sub>3</sub>CH<sub>2</sub>C(CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>
- D (CH<sub>3</sub>)<sub>2</sub>CHC(CH<sub>3</sub>)<sub>3</sub>

(Total for Question 4 = 1 mark)

- 5 Which is a disproportionation reaction?

- A CaCO<sub>3</sub> → CaO + CO<sub>2</sub>
- B 2H<sub>2</sub>O<sub>2</sub> → 2H<sub>2</sub>O + O<sub>2</sub>
- C 2H<sub>2</sub>S + 3O<sub>2</sub> → 2SO<sub>2</sub> + 2H<sub>2</sub>O
- D Mg(OH)<sub>2</sub> → MgO + H<sub>2</sub>O

(Total for Question 5 = 1 mark)

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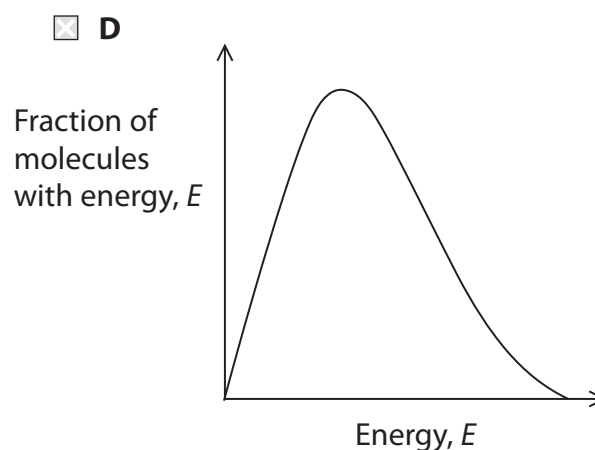
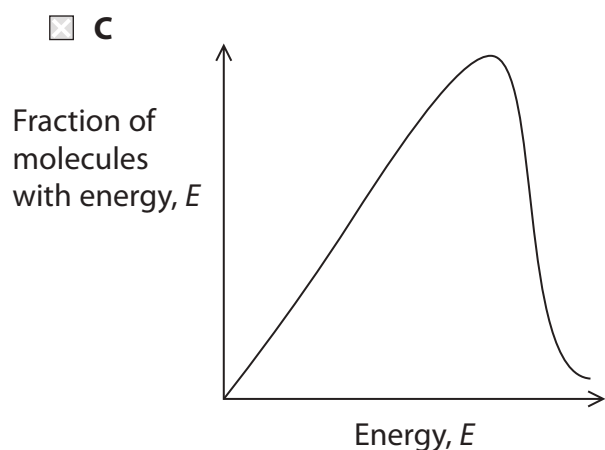
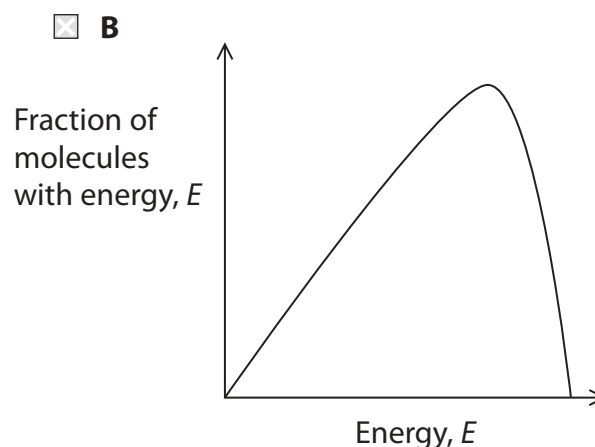
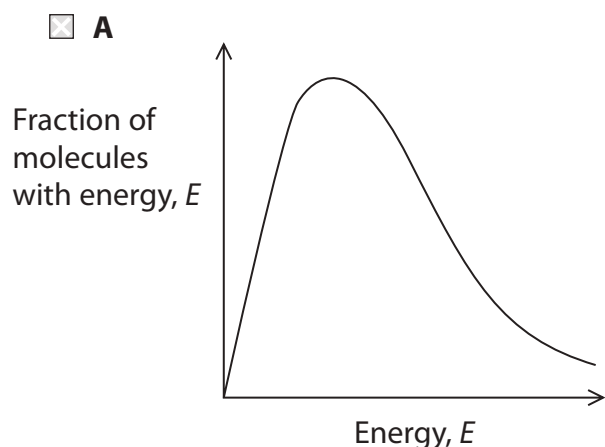


- 6 Which shows the trend in solubility of the hydroxides and sulfates of the Group 2 elements going **up** the group from barium to magnesium?

	Solubility of Group 2 hydroxides	Solubility of Group 2 sulfates
<input type="checkbox"/> A	decreases	decreases
<input type="checkbox"/> B	decreases	increases
<input type="checkbox"/> C	increases	decreases
<input type="checkbox"/> D	increases	increases

(Total for Question 6 = 1 mark)

- 7 Which diagram shows a Maxwell-Boltzmann distribution of molecular energies?



(Total for Question 7 = 1 mark)

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- 8 The rate of the reaction between sodium thiosulfate solution and dilute hydrochloric acid increases as the concentration of sodium thiosulfate increases.

Which of these occurs when the concentration of the sodium thiosulfate solution increases at constant temperature?

	Activation energy	Particles
<input type="checkbox"/> A	decreases	collide more frequently
<input type="checkbox"/> B	decreases	collide with more energy
<input type="checkbox"/> C	stays the same	collide more frequently
<input type="checkbox"/> D	stays the same	collide with more energy

(Total for Question 8 = 1 mark)

- 9 Consider the following exothermic reaction.



If the mass of A, and the volume and concentration of the solution of B are constant, which of these changes in conditions will result in the fastest initial rate?

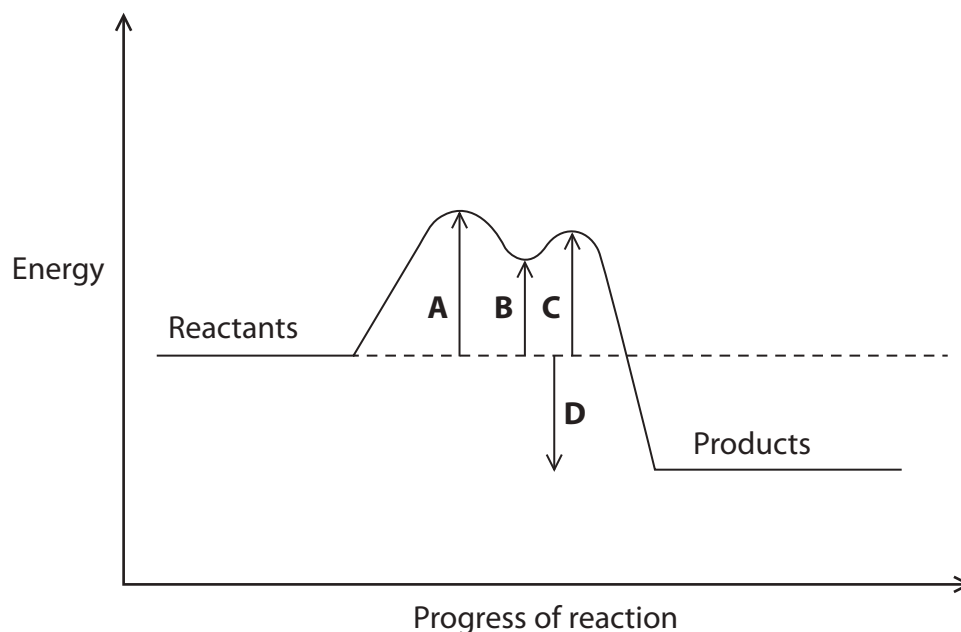
	Size of solid particles of A	Temperature
<input type="checkbox"/> A	doubled	decreased by 10°C
<input type="checkbox"/> B	doubled	increased by 10°C
<input type="checkbox"/> C	halved	decreased by 10°C
<input type="checkbox"/> D	halved	increased by 10°C

(Total for Question 9 = 1 mark)

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10 The reaction profile for an exothermic catalysed reaction is shown.

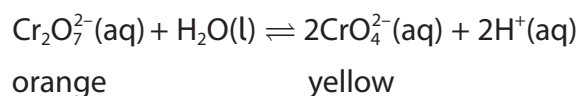


Which arrow represents the activation energy for this reaction?

- A
- B
- C
- D

(Total for Question 10 = 1 mark)

11 An aqueous solution contains dichromate(VI) ions,  $\text{Cr}_2\text{O}_7^{2-}$ , and chromate(VI) ions,  $\text{CrO}_4^{2-}$ , in equilibrium. This solution is a pale orange colour.



What would be seen when a few drops of concentrated sodium hydroxide solution are added to the equilibrium mixture?

- A No visible change.
- B The mixture turns green.
- C The mixture turns a deeper orange.
- D The mixture turns yellow.

(Total for Question 11 = 1 mark)

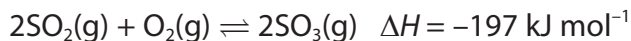
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12 The following system was allowed to reach equilibrium at 450 °C.



How would a decrease in pressure and an increase in temperature affect the equilibrium position?

	Shift in equilibrium position with a decrease in pressure	Shift in equilibrium position with an increase in temperature
<input type="checkbox"/> A	left	left
<input type="checkbox"/> B	left	right
<input type="checkbox"/> C	right	left
<input type="checkbox"/> D	right	right

(Total for Question 12 = 1 mark)

13 What is the empirical formula of a bromoalkane containing, by mass, 22.0% carbon, 4.6% hydrogen and 73.4% bromine?

(Relative atomic masses: C = 12, H = 1, Br = 80)

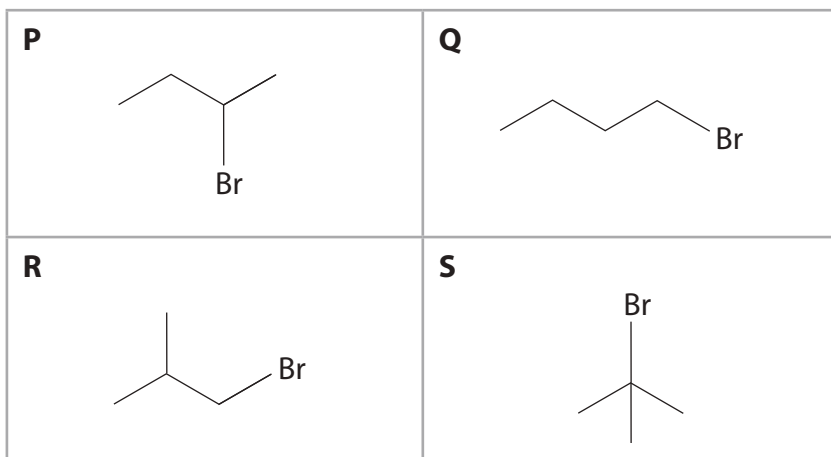
- A C<sub>3</sub>H<sub>7</sub>Br
- B C<sub>2</sub>H<sub>5</sub>Br
- C C<sub>2</sub>H<sub>3</sub>Br
- D CH<sub>3</sub>Br

(Total for Question 13 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.



14 Four isomers with the formula  $C_4H_9Br$  are shown.



Which of the isomers are primary halogenoalkanes?

- A P and R
- B P and S
- C Q and R
- D Q only

(Total for Question 14 = 1 mark)

15 How many different alkenes could be formed when 2-iodopentane,  $CH_3CHICH_2CH_2CH_3$ , reacts with **alcoholic** potassium hydroxide?

- A 1
- B 2
- C 3
- D 4

(Total for Question 15 = 1 mark)

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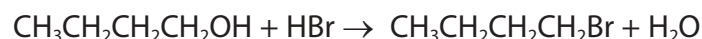
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16 1-bromobutane can be made from butan-1-ol.



What mass of 1-bromobutane is formed from 3.7 g of butan-1-ol if the yield is 56%?

(Relative molecular masses: butan-1-ol = 74, 1-bromobutane = 137)

- A 3.84 g
- B 6.85 g
- C 12.23 g
- D 76.72 g

(Total for Question 16 = 1 mark)

17 Which of these molecules does **not** absorb infrared radiation?

- A carbon monoxide
- B carbon dioxide
- C oxygen
- D water

(Total for Question 17 = 1 mark)

18 Glucose is fermented to produce ethanol.



What is the atom economy, by mass, for the production of ethanol in this reaction?

(Relative molecular masses:  $\text{C}_6\text{H}_{12}\text{O}_6 = 180$ ,  $\text{C}_2\text{H}_5\text{OH} = 46$ ,  $\text{CO}_2 = 44$ )

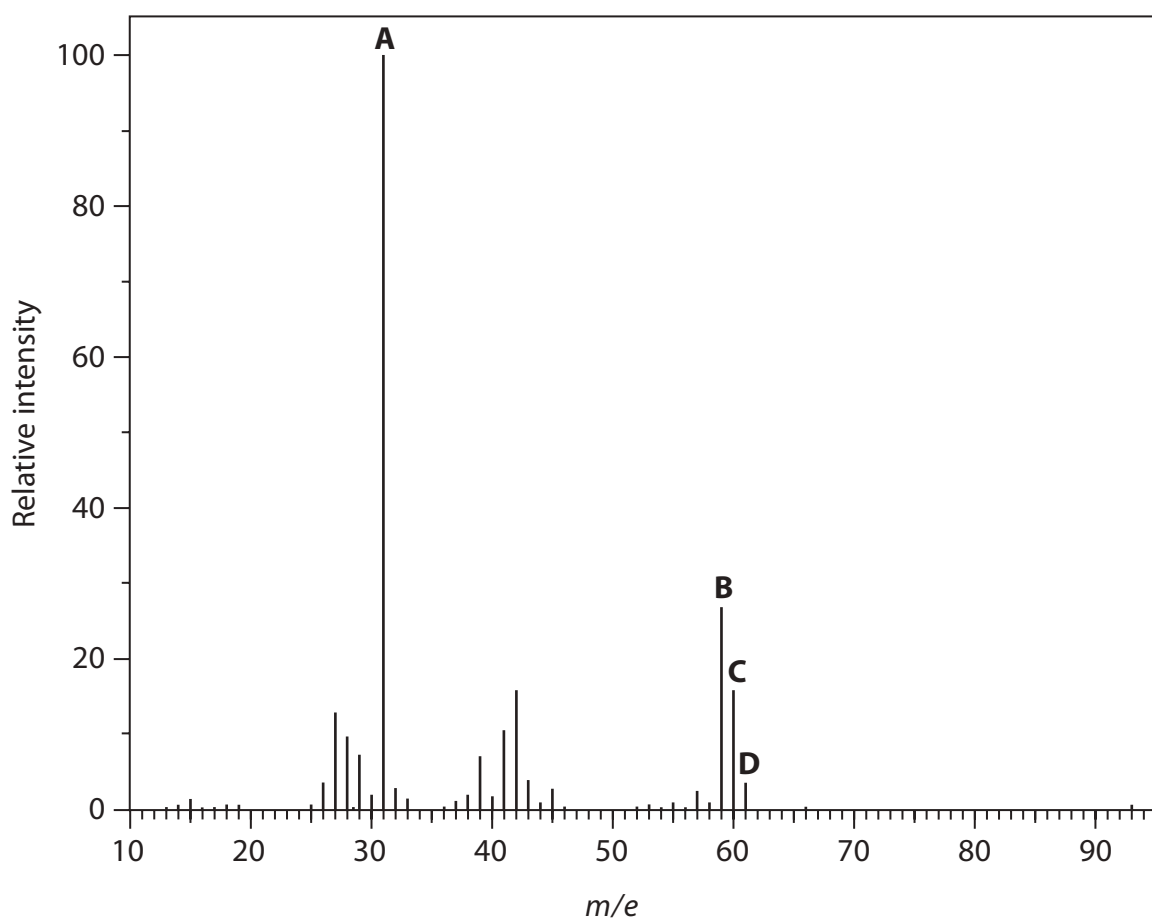
- A 25.6%
- B 48.9%
- C 50.0%
- D 51.1%

(Total for Question 18 = 1 mark)

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19 The mass spectrum of propan-1-ol is shown.



Which peak represents the molecular ion for propan-1-ol containing a carbon-13 isotope?

- A
- B
- C
- D

(Total for Question 19 = 1 mark)

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20 Compounds containing oxygen are sometimes added to hydrocarbon fuels to reduce incomplete combustion and improve engine performance.

Which contains the greatest number of oxygen atoms?

(Relative molecular masses:  $\text{CH}_3\text{OH} = 32$ ,  $\text{C}_2\text{H}_5\text{OH} = 46$ ,  $\text{CH}_2\text{OHCH}_2\text{OH} = 62$ ,  $\text{C}_4\text{H}_9\text{OH} = 74$ )

- A 8.0 g of methanol,  $\text{CH}_3\text{OH}$
- B 9.2 g of ethanol,  $\text{C}_2\text{H}_5\text{OH}$
- C 6.2 g of ethane-1,2-diol,  $\text{CH}_2\text{OHCH}_2\text{OH}$
- D 7.4 g of butan-1-ol,  $\text{C}_4\text{H}_9\text{OH}$

(Total for Question 20 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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## SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

21 This question is about the carbonates and nitrates of elements in Group 1 and Group 2 of the Periodic Table.

(a) Many of the metal ions of Group 1 and Group 2 can be identified using flame tests.

(i) State the colour given to a flame by barium nitrate.

(1)

(ii) Explain the origin of the flame colour.

(3)

(b) Sodium nitrate and magnesium nitrate decompose when they are heated.

Write equations to show the thermal decomposition of each of these nitrates.  
State symbols are not required.

(i) Sodium nitrate

(1)

(ii) Magnesium nitrate

(1)

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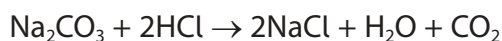
(d) Hydrated sodium carbonate has the formula  $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ .

A student determined the value of  $x$  in the formula of a sample of hydrated sodium carbonate. The following procedure was used.

- Use 2.50 g of hydrated sodium carbonate to prepare  $250 \text{ cm}^3$  of solution.
- Use a pipette to transfer  $25.0 \text{ cm}^3$  of the sodium carbonate solution to a conical flask.
- Add a few drops of methyl orange indicator to the conical flask.
- Titrate the solution with  $0.105 \text{ mol dm}^{-3}$  hydrochloric acid until concordant results are obtained.

The student's mean titre was  $16.65 \text{ cm}^3$ .

The equation for the reaction is



\* (i) Calculate the amount, in moles, of sodium carbonate,  $\text{Na}_2\text{CO}_3$ , in the  $250 \text{ cm}^3$  of solution in the volumetric flask.

(3)

amount  $\text{Na}_2\text{CO}_3$  in  $250 \text{ cm}^3 = \dots\dots\dots \text{ mol}$



(ii) Calculate the molar mass of  $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$  and hence the value of  $x$ .

(2)

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P 5 0 7 0 6 A 0 1 5 2 8

- (iii) Another student carried out the same experiment but obtained a different answer. The method this student used for preparing the sodium carbonate solution is shown.

I weighed 2.50 g of hydrated sodium carbonate in a weighing bottle and then tipped the solid into a 250 cm<sup>3</sup> volumetric flask.

I dissolved the solid in a small amount of distilled water and then added distilled water up to the mark.

I then carried out a series of titrations.

Identify **two** errors that the student made in preparing this solution and explain the effect these errors will have on the titration volumes.

(4)

Error 1.....

.....

Effect on the titration volumes.....

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Error 2.....

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Effect on the titration volumes.....

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(Total for Question 21 = 19 marks)

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22 This question concerns the halogens and some of their compounds.

- (a) A halogen dissolves in water to form a yellow solution, and in cyclohexane to form a purple solution.

Name the halogen.

(1)

- (b) Oxygen difluoride,  $\text{OF}_2$ , is produced in the reaction between fluorine and cold, dilute sodium hydroxide solution.



Give the oxidation numbers of fluorine and oxygen in all of the species in the equation above and use them to explain why this is a redox reaction.

(3)

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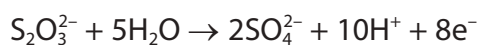
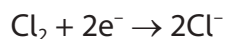
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(c) Chlorine oxidises thiosulfate ions,  $S_2O_3^{2-}$ , to sulfate(VI) ions.

The ionic half-equations for the reaction are



Write the overall equation for the reaction.

(1)

(d) The boiling temperatures of the hydrogen halides are shown.

Hydrogen halide	Boiling temperature / K
HF	293
HCl	188
HBr	206
HI	238

\* (i) London forces are present in **all** of these compounds.

Describe how these forces arise.

(2)

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(ii) State why the London forces are greater in hydrogen iodide than in hydrogen bromide. (1)

(iii) Explain why the boiling temperature of hydrogen fluoride is higher than that of hydrogen chloride. (2)

(e) In the solid state, phosphorus(V) chloride exists as  $[\text{PCl}_4]^+$  and  $[\text{PCl}_6]^-$  ions.

Predict the shapes of these ions. Fully justify your answers. (4)

Shape  $[\text{PCl}_4]^+$  .....

Shape  $[\text{PCl}_6]^-$  .....

Justification

(Total for Question 22 = 14 marks)



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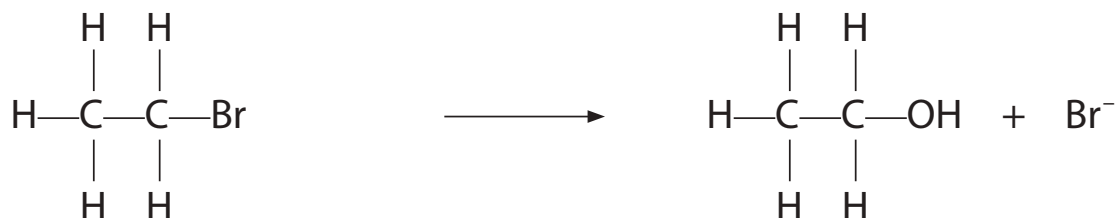
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23 This question is about mechanisms involving halogenoalkanes.

(a) Bromoethane reacts with dilute aqueous potassium hydroxide in a nucleophilic substitution reaction to form ethanol.

(i) Complete the mechanism for the reaction by adding curly arrows and the relevant dipole.

(3)



(ii) Explain the meaning of the term **nucleophilic substitution** in this mechanism.

(2)

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- (b) Chlorofluorocarbons, CFCs, were used for refrigerants, solvents and aerosol propellants because they are unreactive and neither flammable nor toxic.

However, in the stratosphere, ultraviolet radiation breaks CFCs into free radicals and these react with ozone.

Write the equation for the formation of two free radicals from a molecule of chlorotrifluoromethane,  $\text{CF}_3\text{Cl}$ . Curly arrows are not required.

(1)

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(Total for Question 23 = 6 marks)

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TOTAL FOR SECTION B = 39 MARKS

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## SECTION C

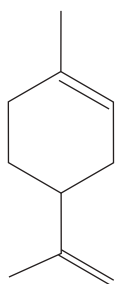
Answer ALL the questions. Write your answers in the spaces provided.

24

Many organic compounds have characteristic odours.

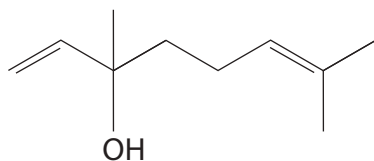
Some of these odours are pleasant, and the organic compounds are used in perfumes, soaps, deodorants, shampoos and other cosmetics.

Limonene is a colourless liquid which is present in the rind of lemons.



limonene

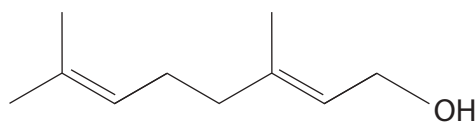
Linalool occurs in lavender oil.



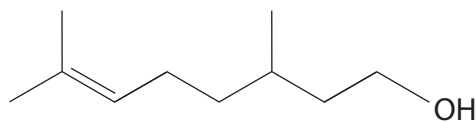
linalool

Geraniol and citronellol occur in lemon grass.

They have rose-like odours.



geraniol



citronellol

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(a) (i) Give the **molecular** formula for linalool. (1)

(ii) Give the **empirical** formula for limonene. (1)

(iii) Which of these four compounds are structural isomers? (1)

(iv) Which of these four compounds show(s) geometric isomerism? (1)

(b) Describe simple test tube reactions to identify the two functional groups present in linalool.

Give the reagents required and the observations you would make. (4)

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- \* (c) (i) Explain whether it is possible to distinguish between limonene, linalool, geraniol and citronellol using **only** infrared spectroscopy.

(2)

- (ii) Describe a chemical test that could be used to distinguish between samples of linalool and geraniol. Give the result of the test for both compounds.

(2)

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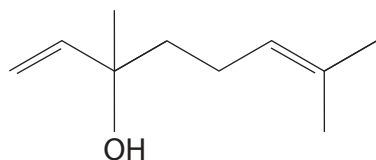
(d) The four organic compounds react with hydrogen gas, in the presence of a suitable catalyst.

(i) Name a suitable catalyst for the reaction with hydrogen.

(1)

(ii) Complete the balanced equation for the reaction of linalool with excess hydrogen.

(1)



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- (iii) A sample of lavender oil contained 70.0% by mass of linalool and no other unsaturated compounds. Calculate the minimum volume of hydrogen gas, measured at room temperature and pressure, needed to completely reduce 2.55 g of this lavender oil.

(The molar volume of hydrogen at room temperature and pressure is  $24.0 \text{ dm}^3 \text{ mol}^{-1}$ . The molar mass of linalool is  $154 \text{ g mol}^{-1}$ )

(3)

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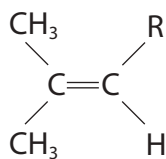
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(e) Hydrogen bromide reacts with C=C bonds such as those in citronellol.

Draw the mechanism for the reaction of hydrogen bromide with citronellol.

You should use the formula



to represent a molecule of citronellol.

Include the dipole on the hydrogen bromide molecule.

(4)

(Total for Question 24 = 21 marks)

TOTAL FOR SECTION C = 21 MARKS

TOTAL FOR PAPER = 80 MARKS



# The Periodic Table of Elements

	1	2											3	4	5	6	7	0 (8)		
			(1)	(2)											(13)	(14)	(15)	(16)	(17)	(18)
	6.9	9.0	Li	Be											B	C	N	O	F	He
	lithium	beryllium	3	4											boron	carbon	nitrogen	oxygen	fluorine	helium
	23.0	24.3	Na	Mg											Al	Si	P	S	Cl	Ar
	sodium	magnesium	11	12											aluminium	silicon	phosphorus	sulfur	chlorine	argon
	39.1	40.1	K	Ca											Ga	Ge	As	Se	Br	Kr
	potassium	calcium	19	20											gallium	germanium	arsenic	selenium	bromine	krypton
	85.5	87.6	Rb	Sr											In	Sn	Sb	Te	I	Xe
	rubidium	strontium	37	38											indium	tin	antimony	tellurium	iodine	xenon
	132.9	137.3	Cs	Ba											Tl	Pb	Bi	Po	At	Rn
	caesium	barium	55	56											thallium	lead	bismuth	polonium	astatine	radon
	[223]	[226]	Fr	Ra											81	82	83	84	85	86
	francium	radium	87	88											81	82	83	84	85	86

	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)										
	45.0	47.9	50.9	52.0	54.9	55.8	58.9	58.7	63.5	65.4										
	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn										
	scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel	copper	zinc										
	21	22	23	24	25	26	27	28	29	30										
	88.9	91.2	92.9	95.9	[98]	101.1	102.9	106.4	107.9	112.4										
	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd										
	yttrium	zirconium	niobium	molybdenum	technetium	ruthenium	rhodium	palladium	silver	cadmium										
	39	40	41	42	43	44	45	46	47	48										
	138.9	178.5	180.9	183.8	186.2	190.2	192.2	195.1	197.0	200.6										
	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg										
	lanthanum	hafnium	tantalum	tungsten	rhenium	osmium	iridium	platinum	gold	mercury										
	57	72	73	74	75	76	77	78	79	80										
	[227]	[261]	[262]	[266]	[264]	[277]	[268]	[271]	[272]											
	Ac*	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg											
	actinium	rutherfordium	dubnium	seaborgium	bohrium	hassium	meitnerium	darmstadtium	roentgenium											
	89	104	105	106	107	108	109	110	111											

	(13)	(14)	(15)	(16)	(17)	(18)
10.8	12.0	14.0	16.0	19.0	4.0	
B	C	N	O	F	He	
boron	carbon	nitrogen	oxygen	fluorine	helium	
5	6	7	8	9	2	
27.0	28.1	31.0	32.1	35.5	20.2	
Al	Si	P	S	Cl	Ne	
aluminium	silicon	phosphorus	sulfur	chlorine	neon	
13	14	15	16	17	10	
69.7	72.6	74.9	79.0	79.9	83.8	
Ga	Ge	As	Se	Br	Kr	
gallium	germanium	arsenic	selenium	bromine	krypton	
31	32	33	34	35	36	
114.8	118.7	121.8	127.6	126.9	131.3	
In	Sn	Sb	Te	I	Xe	
indium	tin	antimony	tellurium	iodine	xenon	
49	50	51	52	53	54	
204.4	207.2	209.0	[209]	[210]	[222]	
Tl	Pb	Bi	Po	At	Rn	
thallium	lead	bismuth	polonium	astatine	radon	
81	82	83	84	85	86	

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

	(13)	(14)	(15)	(16)	(17)	(18)
165	167	169	173	175		
Ho	Er	Tm	Yb	Lu		
holmium	erbium	thulium	ytterbium	lutetium		
67	68	69	70	71		
[254]	[253]	[256]	[254]	[257]		
Es	Fm	Md	No	Lr		
einsteinium	fermium	mendeleevium	nobelium	lawrencium		
99	100	101	102	103		

	(13)	(14)	(15)	(16)	(17)	(18)
163	165	167	169	173	175	
Dy	Ho	Er	Tm	Yb	Lu	
dysprosium	holmium	erbium	thulium	ytterbium	lutetium	
66	67	68	69	70	71	
[251]	[254]	[253]	[256]	[254]	[257]	
Cf	Es	Fm	Md	No	Lr	
californium	einsteinium	fermium	mendeleevium	nobelium	lawrencium	
98	99	100	101	102	103	

	(13)	(14)	(15)	(16)	(17)	(18)
159	163	165	167	169	173	175
Tb	Dy	Ho	Er	Tm	Yb	Lu
terbium	dysprosium	holmium	erbium	thulium	ytterbium	lutetium
65	66	67	68	69	70	71
[245]	[251]	[254]	[253]	[256]	[254]	[257]
Bk	Cf	Es	Fm	Md	No	Lr
berkelium	californium	einsteinium	fermium	mendeleevium	nobelium	lawrencium
97	98	99	100	101	102	103

	(13)	(14)	(15)	(16)	(17)	(18)
157	159	163	165	167	169	173
Gd	Tb	Dy	Ho	Er	Tm	Lu
gadolinium	terbium	dysprosium	holmium	erbium	thulium	lutetium
64	65	66	67	68	69	70
[247]	[245]	[251]	[254]	[253]	[256]	[257]
Cm	Bk	Cf	Es	Fm	Md	Lr
curium	berkelium	californium	einsteinium	fermium	mendeleevium	lawrencium
96	97	98	99	100	101	102

	(13)	(14)	(15)	(16)	(17)	(18)
152	157	163	165	167	169	173
Eu	Gd	Dy	Ho	Er	Tm	Lu
europium	gadolinium	dysprosium	holmium	erbium	thulium	lutetium
63	64	66	67	68	69	70
[243]	[247]	[251]	[254]	[253]	[256]	[257]
Am	Cm	Cf	Es	Fm	Md	Lr
americium	curium	californium	einsteinium	fermium	mendeleevium	lawrencium
95	96	98	99	100	101	102

	(13)	(14)	(15)	(16)	(17)	(18)
147	150	152	157	163	165	167
Pm	Sm	Eu	Gd	Dy	Ho	Er
promethium	samarium	europium	gadolinium	dysprosium	holmium	erbium
61	62	63	64	66	67	68
[237]	[242]	[243]	[247]	[251]	[254]	[257]
Np	Pu	Am	Cm	Cf	Es	Fm
neptunium	plutonium	americium	curium	californium	einsteinium	fermium
93	94	95	96	98	99	100

	(13)	(14)	(15)	(16)	(17)	(18)
141	144	150	152	157	163	165
Pr	Nd	Sm	Eu	Gd	Dy	Ho
praseodymium	neodymium	samarium	europium	gadolinium	dysprosium	holmium
59	60	62	63	64	66	67
[231]	238	[242]	[243]	[247]	[251]	[254]
Pa	U	Pu	Am	Cm	Cf	Es
protactinium	uranium	plutonium	americium	curium	californium	einsteinium
91	92	94	95	96	98	99

	(13)	(14)	(15)	(16)	(17)	(18)
140	141	150	152	157	163	165
Ce	Pr	Sm	Eu	Gd	Dy	Ho
cerium	praseodymium	samarium	europium	gadolinium	dysprosium	holmium
58	59	62	63	64	66	67
[232]	[231]	238	[242]	[247]	[251]	[254]
Th	Pa	U	Pu	Am	Cm	Cf
thorium	protactinium	uranium	plutonium	americium	curium	californium
90	91	92	94	95	96	98

\* Lanthanide series  
\* Actinide series

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