Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Tuesday 18 June 2024

Morning (Time: 1 hour 45 minutes)

Paper reference **9CH0/02**

Chemistry

Advanced

PAPER 2: Advanced Organic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **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 90.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing 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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Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 This question is about organic compounds that contain a halogen atom or a nitrogen atom.

(a) Equal amounts of four bromoalkanes were added to separate test tubes containing 2 cm^3 of a silver nitrate solution.
The mixtures were heated in a water bath.

Which bromoalkane would be the **first** to form a precipitate?

(1)

- ☐ **A** 1-bromobutane
- ☐ **B** 2-bromobutane
- ☐ **C** 1-bromo-2-methylpropane
- ☐ **D** 2-bromo-2-methylpropane

(b) Which pair of reactants will form an *N*-substituted amide?

(1)

- ☐ **A** CH_3COCl and NH_3
- ☐ **B** CH_3CH_2OH and NH_3
- ☐ **C** CH_3COCl and CH_3NH_2
- ☐ **D** CH_3CH_2OH and CH_3NH

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(c) Ammonia reacts with bromoethane as shown.

$$2NH_3 + CH_3CH_2Br \rightarrow NH_4Br + CH_3CH_2NH_2$$

(i) Explain, by referring to the reaction mechanism, the roles of ammonia in the formation of each of the products of this reaction.

(3)

(ii) What conditions are needed for this reaction?

(1)

		Method of heating	Solvent
☐	**A**	heat in a sealed tube	ethanol
☐	**B**	heat under reflux	ethanol
☐	**C**	heat in a sealed tube	water
☐	**D**	heat under reflux	water

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(d) The halogenoalkane, 1-bromobutane, can be formed by the reaction of butan-1-ol with sodium bromide and sulfuric acid.

$$CH_3CH_2CH_2CH_2OH + NaBr + H_2SO_4 \rightarrow CH_3CH_2CH_2CH_2Br + NaHSO_4 + H_2O$$

Calculate the atom economy, by mass, for the formation of 1-bromobutane.
Give your answer to **one** decimal place.

[A_r values: H = 1.0 C = 12.0 O = 16.0 Na = 23.0 S = 32.1 Br = 79.9]

(2)

(Total for Question 1 = 8 marks)

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2 This question is about Grignard reagents.

A Grignard reagent is formed by reacting bromoethane with magnesium under reflux.

$$CH_3CH_2Br + Mg \rightarrow CH_3CH_2MgBr$$

(a) The most suitable solvent for this reaction is

(1)

- ☐ **A** cyclohexane
- ☐ **B** ether
- ☐ **C** ethyl ethanoate
- ☐ **D** hexane

(b) State the use of Grignard reagents in organic synthesis.

(1)

(c) In their reactions, the Grignard reagent is best described as

(1)

- ☐ **A** a carbocation
- ☐ **B** an electrophile
- ☐ **C** a nucleophile
- ☐ **D** a radical

(d) Grignard reagents must be kept dry.

Predict the **organic** product that forms when CH_3CH_2MgBr reacts with water. Justify your answer by considering the polarity of both CH_3CH_2MgBr and water.

(2)

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(e) Which compound will form a **tertiary** alcohol when it reacts with a Grignard reagent, followed by acid hydrolysis?

(1)

- ☐ **A** CO_2
- ☐ **B** HCHO
- ☐ **C** CH_3CHO
- ☐ **D** CH_3COCH_3

(Total for Question 2 = 6 marks)

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3 This question is about hydrogen peroxide, H_2O_2 .

(a) Draw a dot-and-cross diagram of a molecule of hydrogen peroxide.

(1)

(b) Hydrogen peroxide decomposes to form water and oxygen.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

Explain, using oxidation numbers, why the decomposition of hydrogen peroxide is classified as a disproportionation reaction.

(3)

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(c) The decomposition of hydrogen peroxide is catalysed by iodide ions, $I^-(aq)$.

The kinetics of this reaction were investigated using different concentrations of hydrogen peroxide and iodide ions.
The results are shown in the table.

Experiment	$[H_2O_2(aq)]$ / mol dm^{-3}	$[I^-(aq)]$ / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
1	0.100	0.0500	8.90×10^{-7}
2	0.400	0.0500	3.56×10^{-6}
3	0.200	0.100	3.56×10^{-6}

(i) Deduce the order of reaction with respect to hydrogen peroxide and to iodide ions.

(2)

Order with respect to hydrogen peroxide

Order with respect to iodide ions

(ii) Write the rate equation for the reaction using your answer to (c)(i).

(1)

(iii) Calculate the rate constant, *k*, using data from Experiment 3.
Include units in your answer.

(2)

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(d) The breakdown of hydrogen peroxide with iodide ions as a catalyst is the basis of the demonstration 'Elephant's Toothpaste'.
The presence of a detergent results in a rapid eruption of foam as the oxygen gas is released.

(i) Describe the test and the positive result that confirms the gas produced is oxygen.

(1)

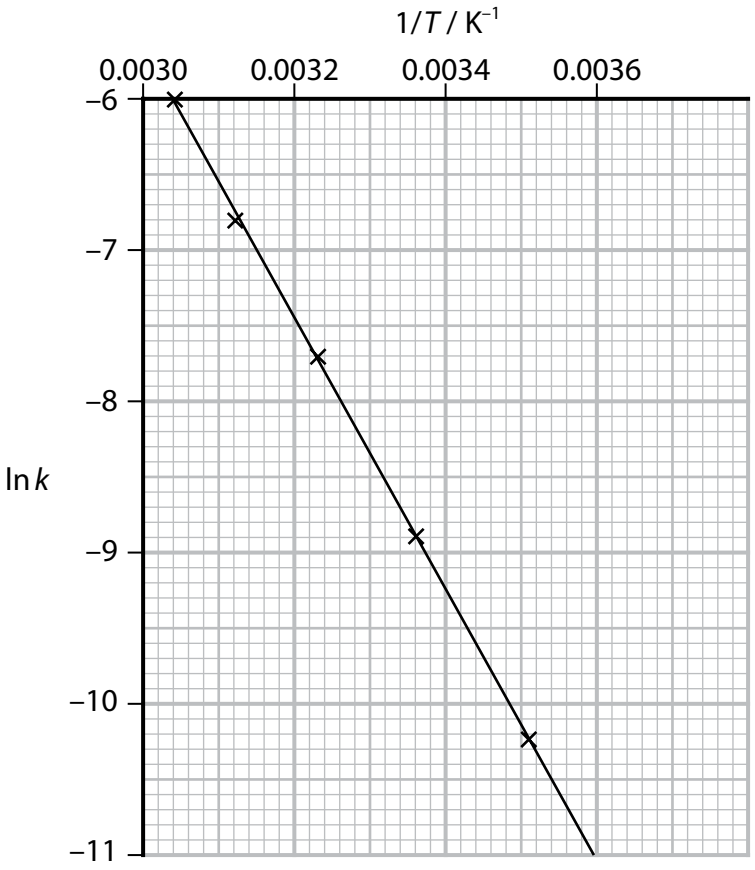
(ii) The foam produced often has a slight yellow / brown colour.

Explain what causes this colour, which is **not** caused by the detergent.

(2)

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(e) The effect of temperature on the rate of the decomposition of hydrogen peroxide without a catalyst was also investigated.
A graph of ln *k* against 1/temperature (1/*T*) was plotted.



(i) Determine the gradient of the graph.
Include units in your answer. You must show your working on the graph.

(3)

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(ii) Calculate the activation energy, E_a, of the reaction, in kJ mol^{-1}, using your answer to (e)(i) and the Arrhenius equation shown.

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

[Gas constant (R) = 8.31 J mol^{-1} K^{-1}]

(1)

(f) Another way to write the Arrhenius equation is shown.

$$k = Ae^{-E_a/RT}$$

The constant A is often called the collision factor as it is linked to the orientation of the particles colliding in a reaction.

The decomposition of hydrogen peroxide is also catalysed by aluminium.

Calculate a value for A at 370 K, for the catalysed decomposition of hydrogen peroxide with an activation energy, E_a, of 5.02×10^4 J mol^{-1} and a numerical value for the rate constant of 1.60×10^{-3}.
Units are **not** required.

(2)

(Total for Question 3 = 18 marks)

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***4** Discuss the role society, and chemists in particular, can play in order to contribute to a more sustainable use of polymers.

Your answer should consider

- the different ways of dealing with waste polymers
- how chemists can limit the problems caused by the disposal of polymers.

(6)

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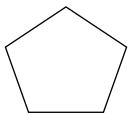
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(Total for Question 4 = 6 marks)

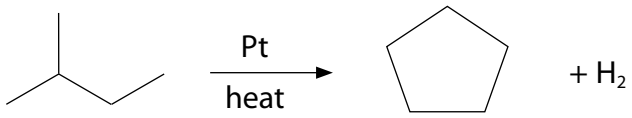
5 This question is about cyclic compounds.

(a) The hydrocarbon cyclopentane is present in some fuels and is used in the manufacture of insulation for freezers.



cyclopentane

Cyclopentane can be synthesised by passing 2-methylbutane over a hot platinum catalyst.



2-methylbutane cyclopentane

Name the type of reaction that takes place in this synthesis.

(1)

(b) The energy density of a fuel is defined as the energy released per dm^3 of the liquid fuel burned.

A sample of cyclopentane with a mass of 30.0 g releases 1.41 MJ of energy.

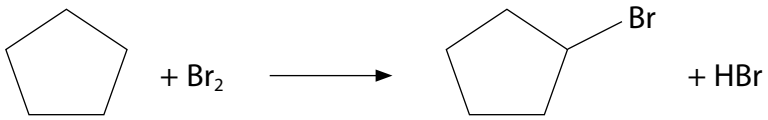
Calculate the energy density of cyclopentane.
Include units in your answer.

[Density of cyclopentane = 0.751 g cm^{-3}]

(2)

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(c) Under appropriate conditions, cyclopentane reacts with bromine to form bromocyclopentane.



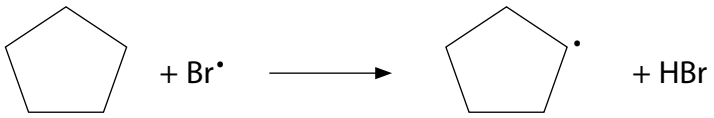
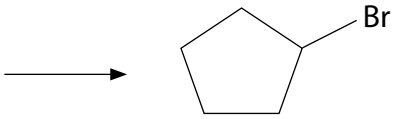
cyclopentane bromocyclopentane

(i) State the condition needed to initiate the reaction.

(1)

(ii) Complete the table showing the steps of the mechanism of this reaction. Curly arrows are not required.

(3)

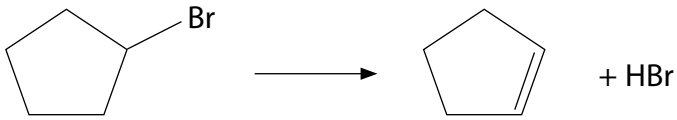
Step	Equation(s)
Initiation	
Propagation	1.  2.
Termination	

(iii) Draw the structure of the organic product of an alternative termination step.

(1)

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(d) Bromocyclopentane forms cyclopentene when heated under reflux with a concentrated solution of potassium hydroxide in ethanol.



(i) Explain why the solvent ethanol is treated with anhydrous sodium sulfate before use in this reaction.

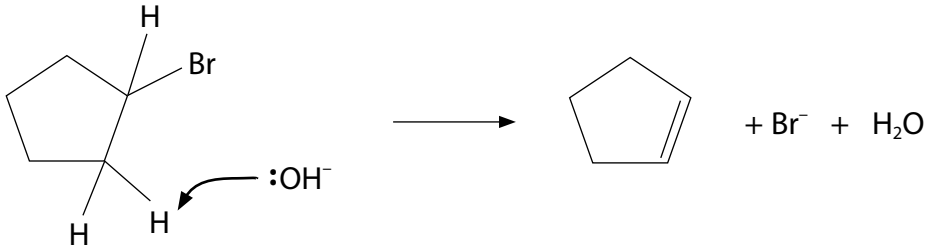
(2)

(ii) Give the name of the reaction shown in the equation.

(1)

(iii) Predict the mechanism for the reaction by adding two curly arrows.

(1)



(Total for Question 5 = 12 marks)

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6 This question is about nuclear magnetic resonance (NMR) spectroscopy.

(a) Which part of the electromagnetic spectrum is used in NMR?

(1)

- ☐ **A** infrared
- ☐ **B** radio waves
- ☐ **C** ultraviolet
- ☐ **D** X-ray

(b) Explain why tetramethylsilane, TMS, is used in NMR spectroscopy.

(2)

(c) A secondary amine, **Q**, has the molecular formula $C_6H_{15}N$.
The low resolution ^1H NMR spectrum of **Q** has three peaks.

(i) State what is meant by the term 'secondary amine'.

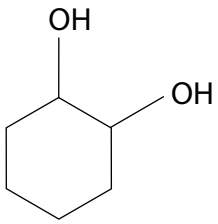
(1)

(ii) Deduce the structure of **Q**.

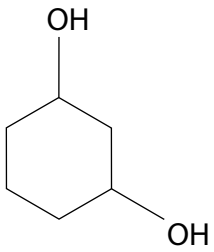
(1)

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(d) Two cyclic alcohols have the structures shown.



cyclohexane-1,2-diol



cyclohexane-1,3-diol

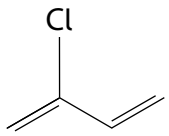
Show that the ^{13}C NMR spectra of these compounds can be used to distinguish between the two alcohols, labelling the diagrams to justify your answer.

(2)

(Total for Question 6 = 7 marks)

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7 This question is about polymers, an example of which is neoprene, a synthetic rubber material.
It is formed by the polymerisation of chloroprene.



chloroprene

(a) What is the IUPAC name of chloroprene?

(1)

- ☐ **A** 3-chlorobuta-1,3-diene
- ☐ **B** 2-chlorobuta-2,4-diene
- ☐ **C** 3-chlorobuta-2,4-diene
- ☐ **D** 2-chlorobuta-1,3-diene

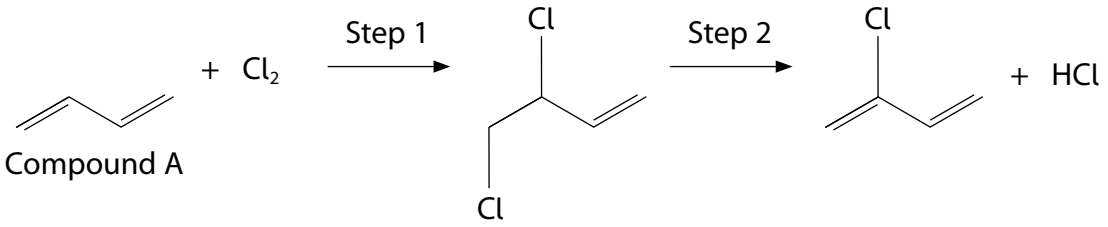
(b) Calculate the volume, **in cm^3**, occupied by 10.0 g of chloroprene in the gaseous phase, at 80.0 °C and 205 kPa.
Give your answer to an appropriate number of significant figures.

[Gas constant (R) = 8.31 $J\,mol^{-1}\,K^{-1}$]

(5)

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(c) Chloroprene is formed by first adding chlorine, Cl_2, to Compound A and then removing hydrogen chloride from the product of this reaction.



Compound A

(i) Explain how chlorine, Cl_2, can act as an electrophile in Step 1 even though a chlorine molecule is symmetrical.
You may find it helpful to include a diagram.

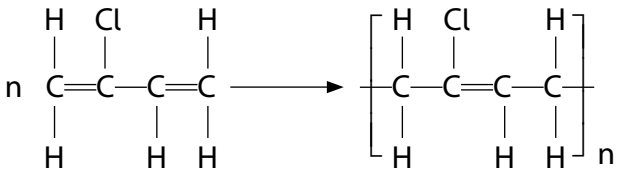
(2)

(ii) Draw the mechanism for Step 1.
Include curly arrows, and any relevant lone pairs and dipoles.

(3)

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(iii) Chloroprene polymerises to form neoprene as shown.



Give the name of the type of reaction that occurs when chloroprene polymerises.

(1)

(d) Flexible and water-resistant materials can be made by combining neoprene with polyester fabric.

A polyester may be made by the reaction of benzene-1,4-dicarboxylic acid with ethane-1,2-diol.

(i) Explain why ethane-1,2-diol is soluble in water.
A detailed description of the forces involved is not required.

(2)

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(ii) The molar mass of a polyester is 8400 g mol^{-1}.

Calculate the number of polymer molecules in 4.25 mg of this polyester.

[Avogadro constant (L) = 6.02×10^{23} mol^{-1}]

(2)

(iii) A student spilled a small amount of 0.40 mol dm^{-3} sodium hydroxide solution onto a polyester laboratory coat. A hole formed in the laboratory coat as the result of a chemical reaction.

What type of reaction occurred?

(1)

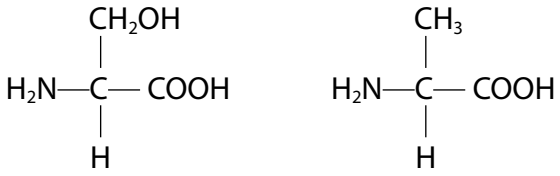
- ☐ **A** dehydration
- ☐ **B** hydrolysis
- ☐ **C** neutralisation
- ☐ **D** redox

(Total for Question 7 = 17 marks)

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8 This question is about amino acids and related compounds.

The structures of two amino acids are shown.



serine alanine

(a) Both amino acids contain a chiral carbon atom.

(i) State what is meant by the term 'chiral carbon atom'.

(1)

(ii) Draw diagrams of the two stereoisomers of **alanine**, showing their three-dimensional shape.

(2)

(b) Draw the **skeletal** formulae of the two dipeptides that could form when serine and alanine react.

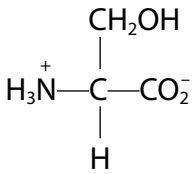
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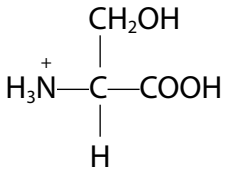
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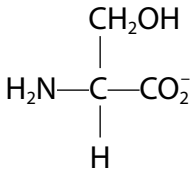
(c) Serine exists as a zwitterion.

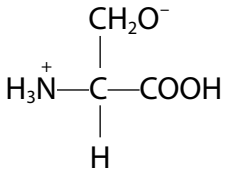
What is the formula of this zwitterion?

(1)

☐ **A** 

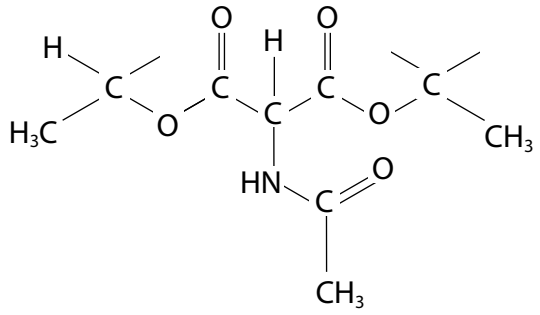
☐ **B** 

☐ **C** 

☐ **D** 

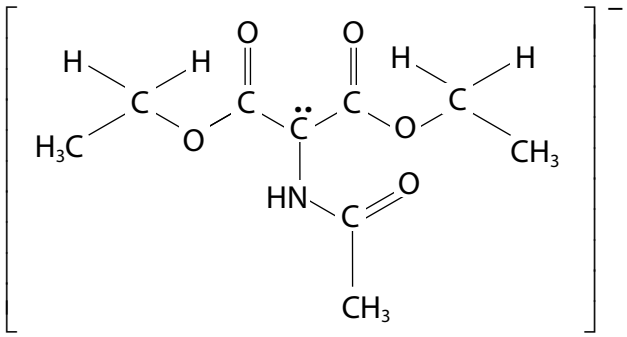
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(d) Alanine can be synthesised as shown.



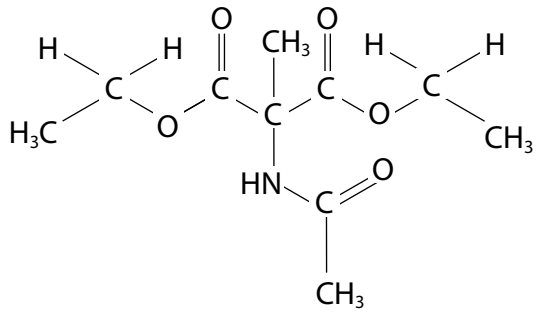
Compound **X**

Step 1 $C_2H_5O^-Na^+$



$+ C_2H_5OH + Na^+$

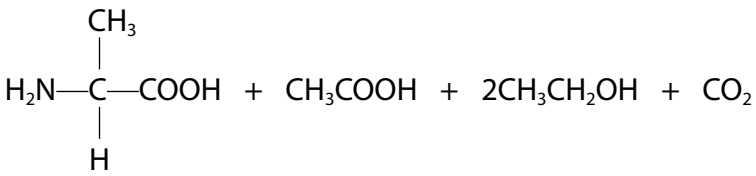
Step 2 CH_3Br



$+ Br^-$

Compound **Y**

Step 3



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(i) Sodium ethoxide, C_2H_5ONa, needed in Step 1, is formed by the reaction of sodium with ethanol.

Write the equation for this reaction.
State symbols are not required.

(1)

(ii) Name the **two** functional groups present in Compound **Y**.

(2)

(iii) Give the reagent needed and conditions required for Step 3.

(2)

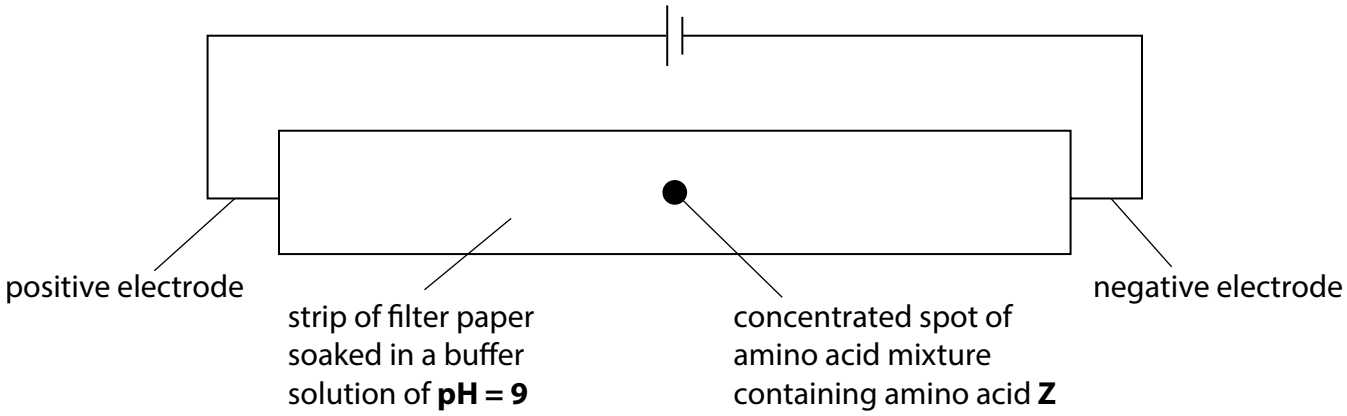
(iv) Calculate the mass of Compound **X** required to make 15.0 g of alanine, assuming the overall yield of the synthesis is 55 %.

(3)

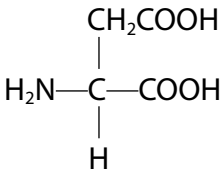
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(e) A mixture of amino acids can be separated using a technique called paper electrophoresis. A simplified diagram is shown.

The movement of the amino acid on the paper depends on any charge on the amino acid, and this is determined by the pH of the buffer solution.



Amino acid **Z** has the structure shown.



amino acid **Z**

Explain in which direction, if any, amino acid **Z** would move when a current flows in the circuit with a buffer solution of pH = 9.

(2)

(Total for Question 8 = 16 marks)

TOTAL FOR PAPER = 90 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 yet fully authenticated

140 **Ce** cerium 58	141 **Pr** praesodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinum 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
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

* Lanthanide series

* Actinide series