Please check the examination details below before entering your candidate information

Candidate surname	Other names
StemUp Model Solution	

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 ▶

P76896A

©2024 Pearson Education Ltd.
F:1/1/1/1/

P 7 6 8 9 6 A 0 1 3 2

Pearson

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_2

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(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)

One molecule of ammonia acts as a nucleophile: the lone pair on the nitrogen attacks the carbon with a partial positive charge ($C^{\delta+}$) of the C–Br bond, and Br leaves as Br^-.

This forms the intermediate ion $CH_3CH_2NH_3^+$.

A second molecule of ammonia acts as a base and removes a proton (H^+) from this intermediate, forming $CH_3CH_2NH_2$ and NH_4^+ (which with Br^- gives NH_4Br).

(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

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(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)

M_r of reactants = 74.0 + 102.9 + 98.1 = 275.0

M_r of $CH_3CH_2CH_2CH_2Br$ = 136.9

atom economy = (136.9 ÷ 275.0) × 100

= 49.782 %

atom economy = 49.8 %

(Total for Question 1 = 8 marks)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

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)

To form a new carbon–carbon bond, so increasing the length of the carbon chain.

(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)

Ethane, CH_3CH_3, is formed.

In CH_3CH_2MgBr the carbon bonded to Mg is partially negative ($C^{\delta-}–Mg^{\delta+}$). In water the hydrogen is partially positive ($O^{\delta-}–H^{\delta+}$), so the δ− carbon is attracted to and bonds with the δ+ hydrogen of water, forming a C–H bond.

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

(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)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

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)

The oxidation number of oxygen in H_2O_2 is −1.

In H_2O the oxidation number of oxygen is −2, so the oxygen has been reduced (from −1 to −2).

In O_2 the oxidation number of oxygen is 0, so the oxygen has been oxidised (from −1 to 0).

The same element, oxygen, is simultaneously oxidised and reduced, so this is a disproportionation reaction.

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(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)

Exp 1 to 2: $[H_2O_2]$ × 4, $[I^-]$ constant, rate × 4, so first order.

Exp 1 to 3: $[H_2O_2]$ × 2 and $[I^-]$ × 2, rate × 4, so first order in I^-.

Order with respect to hydrogen peroxide *first order*

Order with respect to iodide ions *first order*

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

(1)

rate = $k[H_2O_2][I^-]$

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

(2)

k = rate ÷ $([H_2O_2][I^-])$

$k = 3.56 \times 10^{-6} \div (0.200 \times 0.100)$

$k = 1.78 \times 10^{-4}$ dm^3 mol^{-1} s^{-1}

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

(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)

Insert a glowing splint into the gas; the glowing splint relights.

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

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

(2)

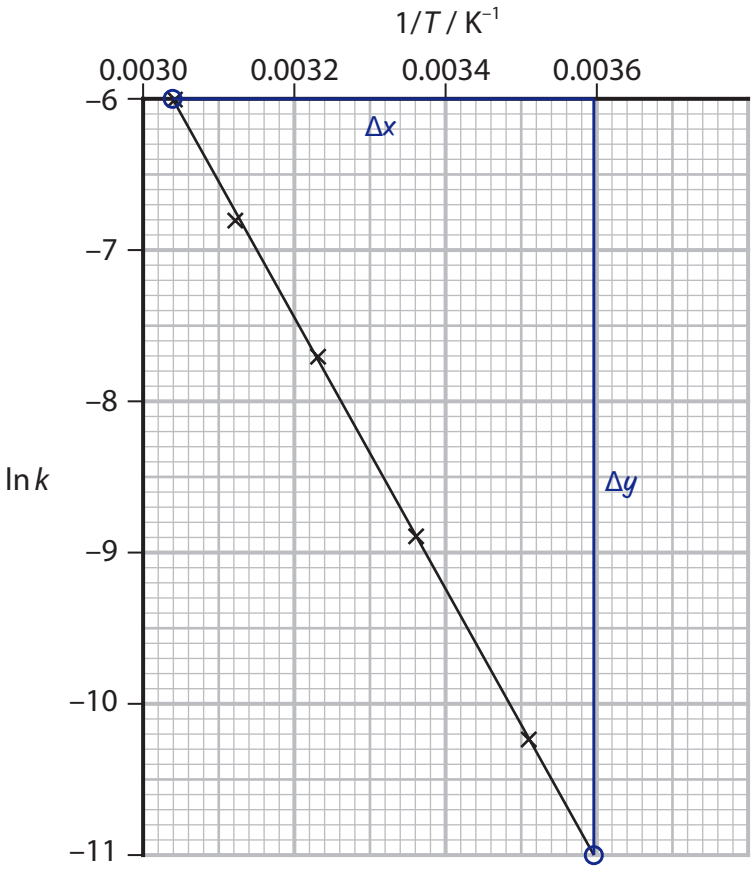
The colour is caused by iodine, $I_2(aq)$ (present as I_3^-).

It forms because some of the hydrogen peroxide oxidises the iodide ions to iodine:

$H_2O_2 + 2H^+ + 2I^- \rightarrow I_2 + 2H_2O$

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

(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.



Δy = −11 − (−6) = −5

Δx = 0.00360 − 0.00304
= 0.00056 K⁻¹

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

(3)

gradient = Δy ÷ Δx = −5 ÷ 0.00056

= −8929

gradient = −8930 K

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(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)

gradient = $-E_a \div R$

$E_a = 8929 \times 8.31 = 74\ 200$ J mol^{-1}

$E_a = (+)74.2$ kJ mol^{-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)

$A = k \div e^{-Ea/RT}$

$Ea \div RT = 50\ 200 \div (8.31 \times 370) = 16.327$

$e^{-16.327} = 8.116 \times 10^{-8}$

$A = 1.60 \times 10^{-3} \div 8.116 \times 10^{-8}$

$A = 1.97 \times 10^4$

(Total for Question 3 = 18 marks)

***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)

Most waste polymers are non-biodegradable, so if they go to landfill they remain for hundreds of years. Society, and chemists in particular, can reduce this in several ways.

Waste polymers can be collected, sorted into types and recycled (melted and remoulded into new objects) or re-used. This reduces landfill and saves crude oil, a finite raw material.

Waste polymers that cannot be recycled can be incinerated to release energy, which is used to generate electricity, so the polymer is used as a fuel.

Waste polymers can also be cracked (thermally decomposed) to re-form monomers and smaller, more useful molecules, which are then used as a feedstock to make new polymers or other chemicals.

Chemists can develop new biodegradable (and photodegradable) polymers, which decompose naturally, so they do not persist in landfill.

However, incinerating polymers such as PVC produces toxic and acidic gases such as HCl, as well as CO and dioxins. Chemists can develop techniques to minimise the emission of these harmful gases from incinerators.

For example, acidic gases such as HCl and SO_2 are removed by neutralising them with a base such as calcium oxide in gas scrubbers, CO is minimised by ensuring complete combustion, and CO_2 can be removed by carbon capture.

Therefore, by combining recycling, energy recovery and cracking with biodegradable polymers and cleaner incineration, polymers can be used more sustainably.

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

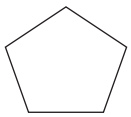
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(Total for Question 4 = 6 marks)

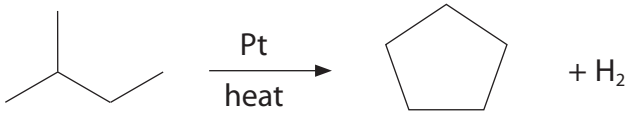
5 This question is about cyclic compounds.

(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)

Reforming

(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)

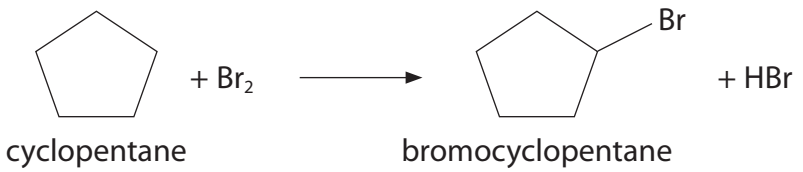
volume = 30.0 ÷ 0.751 = 39.947 cm^3 = 0.039947 dm^3

energy density = 1.41 ÷ 0.039947

energy density = 35.3 MJ dm^{-3}

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

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



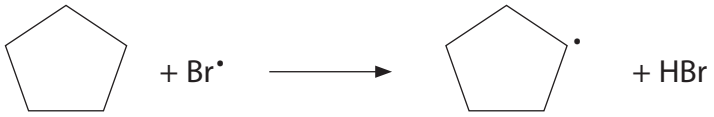
(i) State the condition needed to initiate the reaction.

(1)

Ultraviolet (UV) light

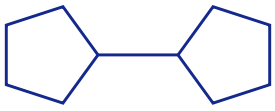
(ii) Complete the table showing the steps of the mechanism of this reaction. Curly arrows are not required.

(3)

Step	Equation(s)
Initiation	$Br_2 \rightarrow 2Br^{\bullet}$
Propagation	1.  2. 
Termination	

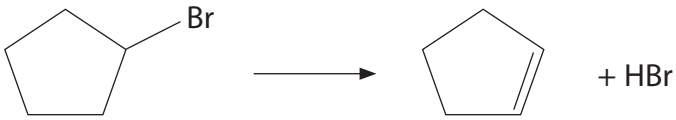
(iii) Draw the structure of the organic product of an alternative termination step.

(1)



DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

(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)

The anhydrous sodium sulfate removes water from the ethanol, so it dries the solvent.

If water were present, hydroxide ions would act as nucleophiles and (nucleophilic)

substitution would occur, forming some cyclopentanol instead of cyclopentene.

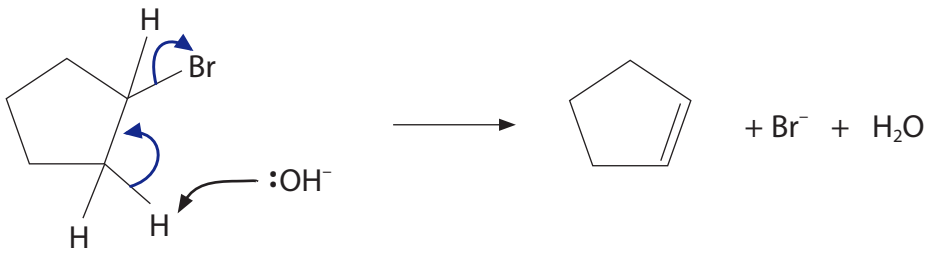
(ii) Give the name of the reaction shown in the equation.

(1)

Elimination

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

(1)



(Total for Question 5 = 12 marks)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

BLANK PAGE

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)

TMS is used as a standard (reference); its peak is given a chemical shift of 0 ppm and other shifts are measured relative to it.

All 12 hydrogens (and all 4 carbons) in TMS are equivalent, so it gives a single, strong peak well away from the peaks of most organic compounds. It is also inert, so it does not react with the sample.

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

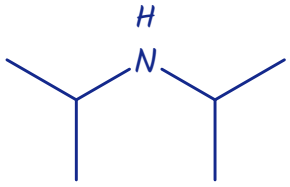
(i) State what is meant by the term 'secondary amine'.

(1)

The nitrogen atom of the amine group is bonded to two carbon atoms (two alkyl groups).

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

(1)

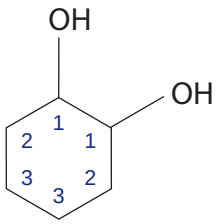


DO NOT WRITE IN THIS AREA

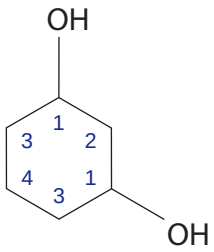
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(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)

Cyclohexane-1,2-diol has 3 carbon environments (labelled 1 to 3), so it gives 3 peaks in its ^{13}C NMR spectrum.

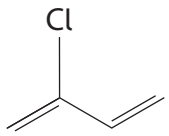
Cyclohexane-1,3-diol has 4 carbon environments (labelled 1 to 4), so it gives 4 peaks.

So the number of peaks (3 or 4) distinguishes the two alcohols.

(Total for Question 6 = 7 marks)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

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)

M_r of $C_4H_5Cl = 4(12.0) + 5(1.0) + 35.5 = 88.5$

$n = 10.0 \div 88.5 = 0.11299$ mol

$T = 80.0 + 273 = 353$ K; $p = 205 \times 10^3$ Pa

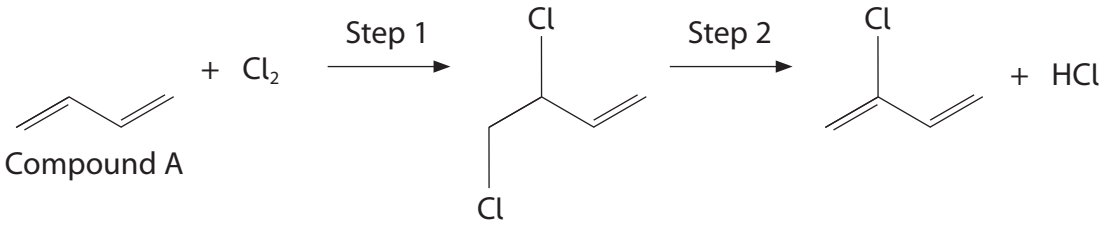
$V = nRT \div p = (0.11299 \times 8.31 \times 353) \div 205\,000$

$V = 1.6169 \times 10^{-3}$ m^3 $= 1.6169 \times 10^{-3} \times 10^6$ cm^3

volume = 1620 cm^3 (3 s.f.)

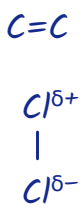
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

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



(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.

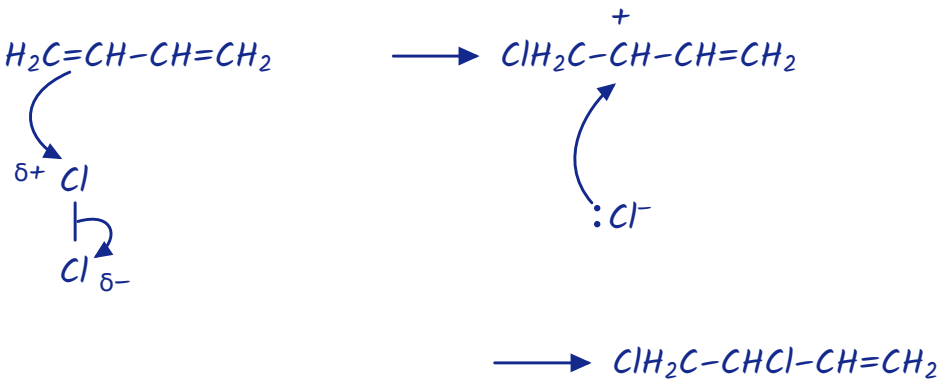
(2)



As the Cl_2 molecule approaches the electron-rich C=C double bond (high electron density in the π bond), the π electrons repel the electrons in the Cl–Cl bond. This induces a dipole: the chlorine atom nearest the double bond gains a partial positive charge ($Cl^{\delta+}$), so it can accept a pair of electrons and act as an electrophile.

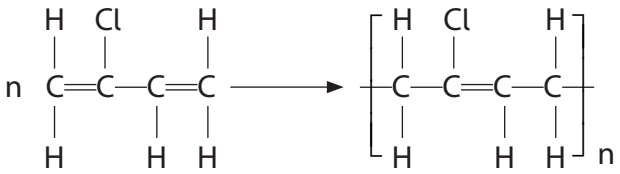
(ii) Draw the mechanism for Step 1.
Include curly arrows, and any relevant lone pairs and dipoles.

(3)



DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

(iii) Chloroprene polymerises to form neoprene as shown.



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

(1)

Addition (polymerisation)

(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)

Ethane-1,2-diol has two O–H groups, so it can form hydrogen bonds with water molecules.

The hydrogen bonds formed between ethane-1,2-diol and water are similar in strength to the hydrogen bonds broken in pure water and in pure ethane-1,2-diol, so it dissolves.

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(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)

4.25 mg = 4.25×10^{-3} g

$n = 4.25 \times 10^{-3} \div 8400 = 5.0595 \times 10^{-7}$ mol

number = $5.0595 \times 10^{-7} \times 6.02 \times 10^{23}$

number of molecules = 3.05×10^{17}

(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

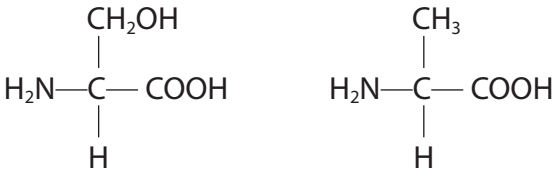
☒ **D** redox

(Total for Question 7 = 17 marks)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

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.

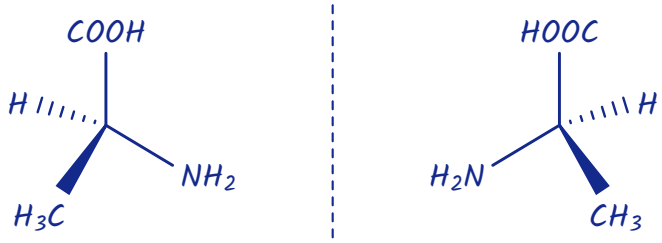
(i) State what is meant by the term 'chiral carbon atom'.

(1)

A carbon atom with four different atoms or groups of atoms attached to it.

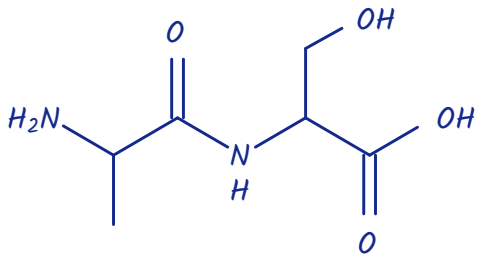
(ii) Draw diagrams of the two stereoisomers of **alanine**, showing their three-dimensional shape.

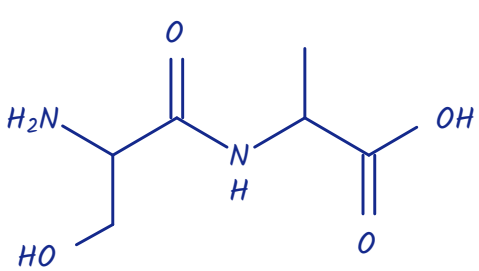
(2)



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

(2)





DO NOT WRITE IN THIS AREA

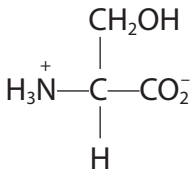
DO NOT WRITE IN THIS AREA

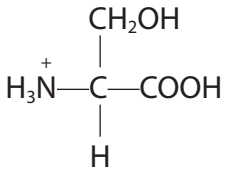
DO NOT WRITE IN THIS AREA

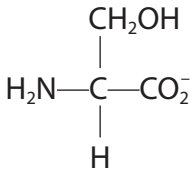
(c) Serine exists as a zwitterion.

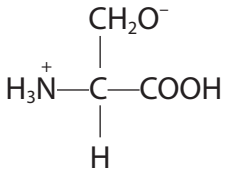
What is the formula of this zwitterion?

(1)

☒ **A** 

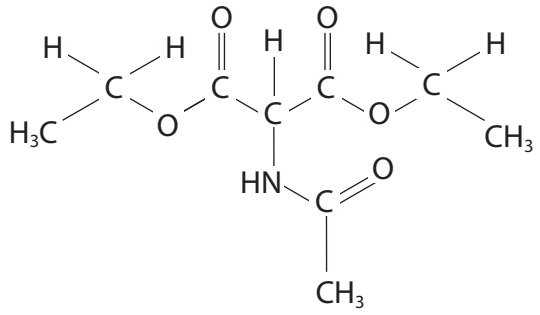
☒ **B** 

☒ **C** 

☒ **D** 

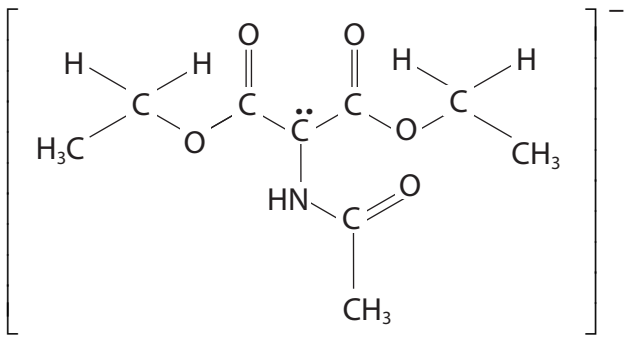
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

(d) Alanine can be synthesised as shown.



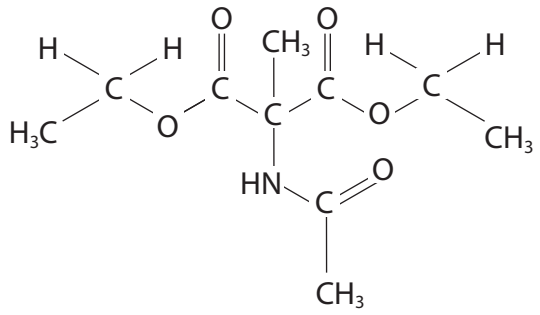
Compound **X**

Step 1 $C_2H_5O^-Na^+$



$+ C_2H_5OH + Na^+$

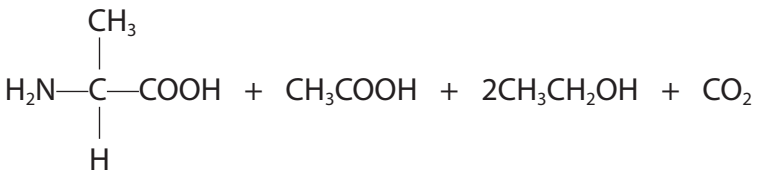
Step 2 CH_3Br



$+ Br^-$

Compound **Y**

Step 3



DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

(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)

$2C_2H_5OH + 2Na \rightarrow 2C_2H_5O^-Na^+ + H_2$

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

(2)

Ester

(N-substituted) amide

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

(2)

Reagent: hydrochloric acid, HCl(aq)

Conditions: heat under reflux

(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)

M_r of alanine = 89.0; $n = 15.0 \div 89.0 = 0.16854$ mol

at 55 % yield, $n(X)$ needed $= 0.16854 \times 100 \div 55 = 0.30644$ mol

M_r of X ($C_9H_{15}NO_5$) = 217.0

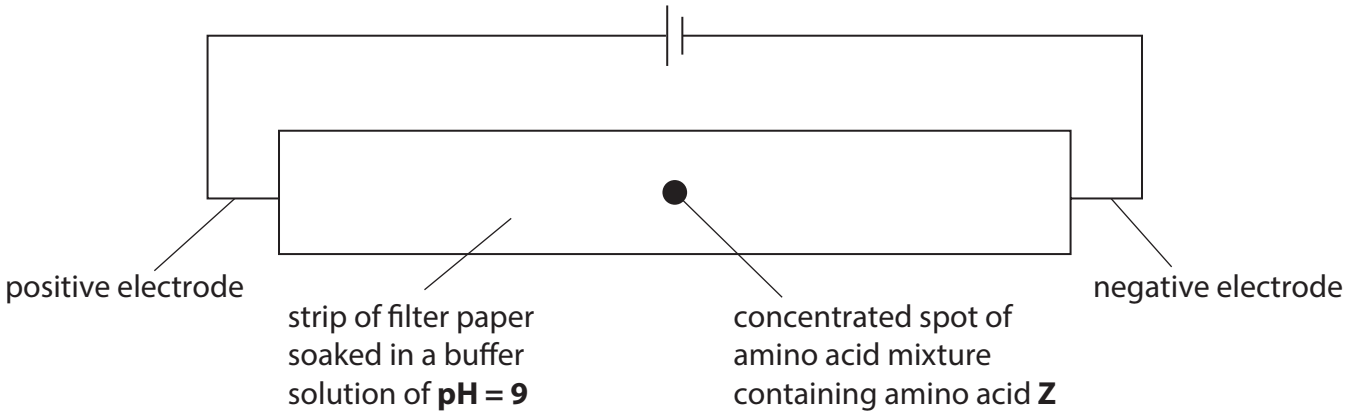
mass of X $= 0.30644 \times 217.0 = 66.496$ g

mass of Compound X = 66.5 g

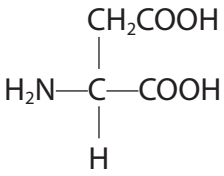
DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

(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)

At pH 9 (basic) both COOH groups lose a proton (H^+) to form COO^- groups, so the amino acid forms a negative ion, $H_2NCH(CH_2COO^-)COO^-$.

So it moves towards the positive electrode (to the left).

(Total for Question 8 = 16 marks)

TOTAL FOR PAPER = 90 MARKS

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

BLANK PAGE

BLANK PAGE

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

BLANK PAGE

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key: relative atomic mass / atomic symbol / name / atomic (proton) number									(13)	(14)	(15)	(16)	(17)	
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	(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

P 7 6 8 9 6 A 0 3 2 3 2

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA