Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

A-level CHEMISTRY

Paper 3

Wednesday 19 June 2019 Morning Time allowed: 2 hours

Materials

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 90.

Advice
- You are advised to spend about 70 minutes on **Section A** and 50 minutes on **Section B**.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
Section B	
TOTAL	

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Section A

Answer **all** questions in this section.

0 1 Sodium thiosulfate reacts with dilute hydrochloric acid as shown.

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + SO_2(g) + S(s) + H_2O(l)$$

0 1 . 1 Give the simplest ionic equation for this reaction.

[1 mark]

_____

0 1 . 2 The gas SO_2 is a pollutant.

State the property of SO_2 that causes pollution when it enters rivers.

Give an equation to show the reaction of SO_2 with water.

[2 marks]

Property _____

Equation _____

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0 1 . 3 Draw a diagram to show the shape of a molecule of H_2O
Include any lone pairs of electrons.

State the H–O–H bond angle.

Explain this shape and bond angle.

[4 marks]

Diagram

Bond angle _____

Explanation _____

_____

_____

_____

_____

_____

_____

_____

Question 1 continues on the next page

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0 1 . 4 The initial rate of the reaction between sodium thiosulfate and hydrochloric acid can be monitored by measuring the time taken for a fixed amount of sulfur to be produced.

Describe an experiment to investigate the effect of temperature on the initial rate of this reaction.

Include

- a brief outline of your method
- how you will measure the time taken for a fixed amount of sulfur to be formed
- how you will present your results in graphical form
- a sketch of the graph that you would expect.

[6 marks]

Do not write outside the box

13

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0 2 This question is about sulfuric acid and its salts.

0 2 . 1 Draw the displayed formula of a molecule of H_2SO_4

[1 mark]

0 2 . 2 In aqueous solution, sulfuric acid acts as a strong acid. The H_2SO_4 dissociates to form HSO_4^- ions and H^+ ions.

The HSO_4^- ions act as a weak acid and dissociate to form SO_4^{2-} ions and H^+ ions.

Give an equation to show each stage in the dissociation of sulfuric acid in aqueous solution.

Include appropriate arrows in your equations.

[2 marks]

Equation 1 _____

Equation 2 _____

Do not write outside the box

0 2 . 3 A student is required to make 250 cm^3 of an aqueous solution that contains an accurately measured mass of sodium hydrogensulfate ($NaHSO_4$).

Describe the method that the student should use to make this solution.

[4 marks]

Extra space

Question 2 continues on the next page

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0 2 . 4 A solution that contains 605 mg of $NaHSO_4$ in 100 cm^3 of solution has a pH of 1.72

Calculate the value of K_a for the hydrogensulfate ion (HSO_4^-) that is behaving as a weak acid.
Give your answer to three significant figures.

State the units of K_a

[6 marks]

K_a _____ Units _____

0 2 . 5 Some sodium sulfate is dissolved in a sample of the solution from question **02.4**.

Explain why this increases the pH of the solution.

[2 marks]

_____

_____

_____

_____

_____

_____

15

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Turn over for the next question

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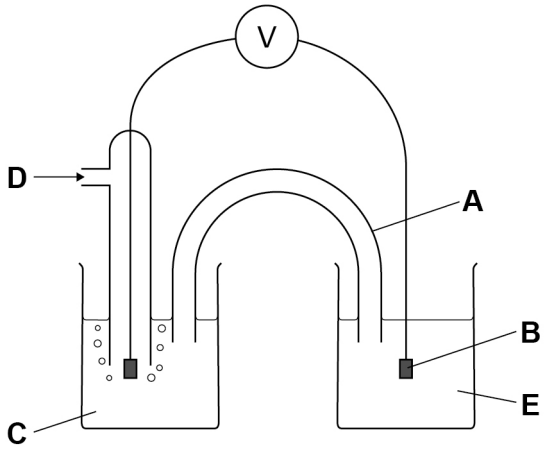
ANSWER IN THE SPACES PROVIDED

0 3 **Figure 1** represents the cell used to measure the standard electrode potential for the Fe^{3+}/Fe^{2+} electrode.

Figure 1



0 3 . 1 Name the piece of apparatus labelled **A**.

[1 mark]

0 3 . 2 State the purpose of **A**.

[1 mark]

0 3 . 3 Name the substance used as electrode **B** in **Figure 1**.

[1 mark]

Do not write outside the box

0 3 . 4 Complete **Table 1** to identify **C**, **D** and **E** from **Figure 1**.
Include the essential conditions for each.

[4 marks]

Table 1

	Identity	Conditions
C		
D		
E		

0 3 . 5 The standard electrode potential, $E^{\ominus}$, for the Fe^{3+}/Fe^{2+} electrode is +0.77 V

Give the ionic equation for the overall reaction in the cell in **Figure 1**.

State the change that needs to be made to the apparatus in **Figure 1** to allow the cell reaction to go to completion.

[2 marks]

Ionic equation _____

Change _____

_____

Question 3 continues on the next page

0 3 . 6 A student sets up a cell as shown in the cell representation.

$$Zn(s)|Zn^{2+}(aq)||Cu^{2+}(aq)|Cu(s)$$

The student measures the cell EMF, E_{cell}, with several different concentrations of Cu^{2+} ions and Zn^{2+} ions.

The results are shown in **Table 2**.

Table 2

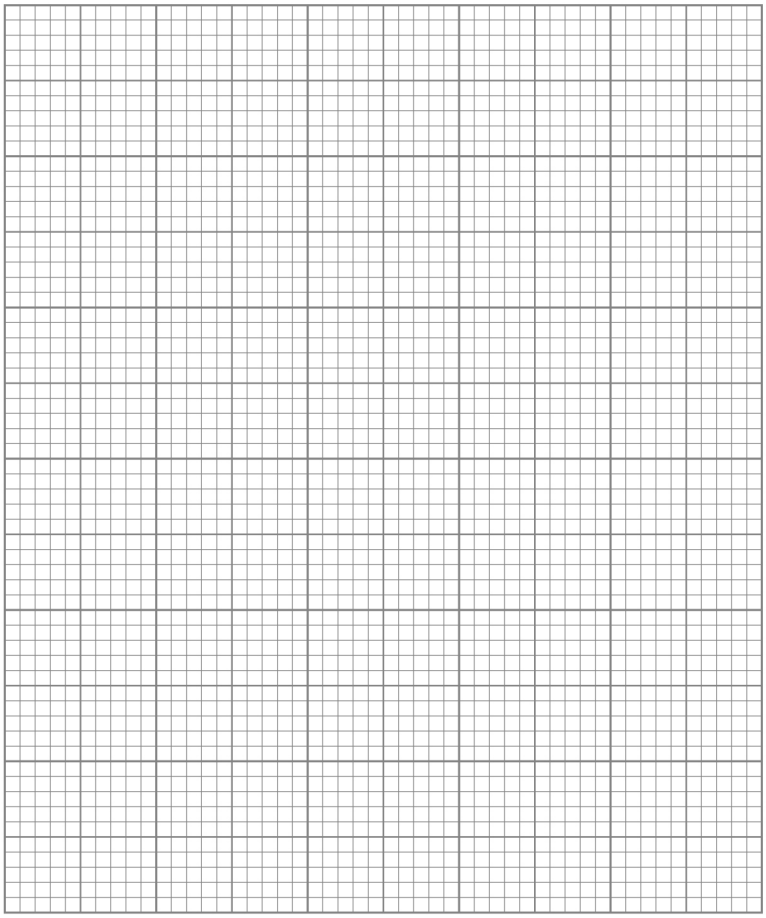
Experiment	$[Zn^{2+}]$ / mol dm^{-3}	$[Cu^{2+}]$ / mol dm^{-3}	$\ln\left(\frac{[Zn^{2+}]}{[Cu^{2+}]}\right)$	E_{cell} / V
1	0.010	1.0	–4.61	1.16
2	0.10	1.0	–2.30	1.13
3	1.0	1.0	0.00	1.10
4	1.0	0.10		1.07
5	1.0	0.010	4.61	1.04

Complete **Table 2** to show the value missing from experiment **4**.

Plot a graph of E_{cell} against ln ($[Zn^{2+}]/[Cu^{2+}]$) on the grid.

[3 marks]

E_{cell} / V



$$\ln\left(\frac{[Zn^{2+}]}{[Cu^{2+}]}\right)$$

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0 3 . 7 This equation shows how E_{cell} varies with concentration for this reaction.

$$E_{cell} = (-4.3 \times 10^{-5} \times T) \ln\left(\frac{[Zn^{2+}]}{[Cu^{2+}]}\right) + E^{\ominus}_{cell}$$

This equation is in the form of the equation for a straight line, y = mx + c

Calculate the gradient of your plotted line on the graph in question **03.6**.
You must show your working.

Use your gradient to calculate the temperature, T, at which the measurements of E_{cell} were taken.
(If you were unable to calculate a gradient you should use the value −0.016 V
This is **not** the correct value.)

[3 marks]

Gradient _____ V

T _____ K

0 3 . 8 In experiment **2** in **Table 2** the electrode potential of the Cu^{2+}/Cu electrode is +0.33 V

Use data from **Table 2** in question **03.6** to calculate the electrode potential for the Zn^{2+}/Zn electrode in experiment **2**.

Give one reason why your calculated value is different from the standard electrode potential for Zn^{2+}/Zn electrode.

[2 marks]

Electrode potential _____ V

Reason _____

_____

_____

17

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0 4 Ethanal reacts with potassium cyanide, followed by dilute acid, to form 2-hydroxypropanenitrile.

0 4 . 1 Name the mechanism for the reaction between potassium cyanide and ethanal.

[1 mark]

0 4 . 2 The 2-hydroxypropanenitrile formed by the reaction in question **04.1** is a mixture of equal amounts of two isomers.

State the name of this type of mixture.

Explain how the structure of ethanal leads to the formation of two isomers.

Draw 3D representations of the two isomers to show the relationship between them.

[5 marks]

Name

Explanation

3D representations

0 4 . 3 2-Hydroxypropanenitrile can be used in the synthesis of the monomer, acrylonitrile, CH_2=CHCN

Suggest a suitable reagent and conditions for the conversion of 2-hydroxypropanenitrile into acrylonitrile.

[2 marks]

Reagent _____

Conditions _____

0 4 . 4 Draw a section of the polymer polyacrylonitrile, showing three repeating units.

[1 mark]

9

Turn over for the next question

0 5 The percentage by mass of iron in a steel wire is determined by a student.

The student

- reacts 680 mg of the wire with an excess of sulfuric acid, so that all of the iron in the wire forms $Fe^{2+}(aq)$
- makes up the volume of the $Fe^{2+}(aq)$ solution to exactly 100 cm^3
- takes 25.0 cm^3 portions of the $Fe^{2+}(aq)$ solution
- titrates each portion with 0.0200 mol dm^{-3} potassium manganate(VII) solution.

0 5 . 1 Give the equation for the reaction between iron and sulfuric acid.

[1 mark]

0 5 . 2 The titration results are shown in **Table 3**.

Table 3

	1	**2**	**3**
Final volume / cm^3	22.90	45.60	22.60
Initial volume / cm^3	0.00	22.90	0.00
Titre / cm^3	22.90	22.70	22.60

Calculate the mean titre.

[1 mark]

Mean titre _____ cm^3

0 5 . 3 Give the overall ionic equation for the oxidation of Fe^{2+} by manganate(VII) ions, in acidic conditions.

[1 mark]

Do not write outside the box

0 5 . 4 State the colour change seen at the end point of the titration.

[1 mark]

_____

0 5 . 5 Name the piece of apparatus used for these stages of the method.

[1 mark]

Taking the 25.0 cm^3 portions _____

Adding the potassium manganate(VII) solution _____

0 5 . 6 The balance used to weigh the 680 mg of iron wire has an uncertainty of ±0.005 g

A container was weighed and its mass was subtracted from the total mass of the container and wire.

Calculate the percentage uncertainty in using the balance.

[1 mark]

% uncertainty _____

6

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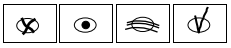
Section B

Answer **all** questions in this section.

Only **one** answer per question is allowed.
For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD  WRONG METHODS 

If you want to change your answer you must cross out your original answer as shown. 

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

You may do your working in the blank space around each question but this will not be marked. Do **not** use additional sheets for this working.

0 6 Which amount of sodium hydroxide would react exactly with 7.5 g of a diprotic acid, H_2A (M_r = 150)?

[1 mark]

A 50 cm^3 of 0.05 mol dm^{-3} NaOH(aq) ⬭

B 100 cm^3 of 0.50 mol dm^{-3} NaOH(aq) ⬭

C 100 cm^3 of 1.0 mol dm^{-3} NaOH(aq) ⬭

D 100 cm^3 of 2.0 mol dm^{-3} NaOH(aq) ⬭

0 7 Lead(II) nitrate and potassium iodide react according to the equation

$$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$$

In an experiment, 25.0 cm^3 of a 0.100 mol dm^{-3} solution of each compound are mixed together.

Which amount, in mol, of lead(II) iodide is formed?

[1 mark]

A 1.25×10^{-3} ⬭

B 2.50×10^{-3} ⬭

C 1.25×10^{-2} ⬭

D 2.50×10^{-2} ⬭

0 8 Nitrogen dioxide is produced from ammonia and air as shown in these equations

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g) \qquad \Delta H = -909 \text{ kJ mol}^{-1}$$

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g) \qquad \Delta H = -115 \text{ kJ mol}^{-1}$$

What is the enthalpy change (in kJ mol^{-1}) for the following reaction?

$$4NH_3(g) + 7O_2(g) \rightarrow 4NO_2(g) + 6H_2O(g)$$

[1 mark]

A –679 ⬭

B –794 ⬭

C –1024 ⬭

D –1139 ⬭

0 9 Which change leads to a higher concentration of SO_3 in this equilibrium mixture?

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -188 \text{ kJ mol}^{-1}$$

[1 mark]

A higher concentration of O_2 ⬭

B higher temperature ⬭

C lower pressure ⬭

D use of a catalyst ⬭

1 0 The results of an investigation of the reaction between **P** and **Q** are shown in this table.

Experiment	Initial [P] / mol dm^{-3}	Initial [Q] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.200	0.500	0.400
2	0.600	To be calculated	0.800

The rate equation is: $rate = k\,[\mathbf{P}]\,[\mathbf{Q}]^2$

What is the initial concentration of **Q** in experiment 2?

[1 mark]

A 0.167 ⬭

B 0.333 ⬭

C 0.408 ⬭

D 0.612 ⬭

Do not write outside the box

1 1 The equation for the reaction between sulfur dioxide and oxygen is shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

In an experiment, 2.00 mol of sulfur dioxide are mixed with 2.00 mol of oxygen. The total amount of the three gases at equilibrium is 3.40 mol

What is the mole fraction of sulfur trioxide in the equilibrium mixture?

[1 mark]

A 0.176 ⬭

B 0.353 ⬭

C 0.600 ⬭

D 1.200 ⬭

1 2 Nitrogen reacts with hydrogen in this exothermic reaction

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Which change increases the equilibrium yield of ammonia but has **no** effect on the value of the equilibrium constant K_p?

[1 mark]

A Add a catalyst ⬭

B Increase the partial pressure of nitrogen ⬭

C Decrease the temperature ⬭

D Decrease the total pressure ⬭

Do not write outside the box

1 3 The $E^{\ominus}$ values for two electrodes are shown.

$$Fe^{2+}(aq) + 2e^{-} \rightarrow Fe(s) \quad E^{\ominus} = -0.44\ V$$

$$Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s) \quad E^{\ominus} = +0.34\ V$$

What is the EMF of the cell $Fe(s)|Fe^{2+}(aq)||Cu^{2+}(aq)|Cu(s)$?

[1 mark]

A +0.78 V ⬭

B +0.10 V ⬭

C –0.10 V ⬭

D –0.78 V ⬭

1 4 Which atom has the greatest first ionisation energy?

[1 mark]

A H ⬭

B He ⬭

C Li ⬭

D Ne ⬭

1 5 What is the correct observation when barium metal is added to an excess of water?

[1 mark]

A Forms a colourless solution only ⬭

B Forms a colourless solution and effervesces ⬭

C Forms a white precipitate only ⬭

D Forms a white precipitate and effervesces ⬭

Do not write outside the box

1 6 An aqueous solution of a salt gives a white precipitate when mixed with aqueous silver nitrate and when mixed with dilute sulfuric acid.

Which could be the formula of the salt?

[1 mark]

A $BaCl_2$ ⬭

B $(NH_4)_2SO_4$ ⬭

C KCl ⬭

D $Sr(NO_3)_2$ ⬭

1 7 Which statement is **not** correct about the trends in properties of the hydrogen halides from HCl to HI ?

[1 mark]

A The boiling points decrease. ⬭

B The bond dissociation energy of H–X decreases. ⬭

C The polarity of the H–X bond decreases. ⬭

D They are more easily oxidised in aqueous solutions. ⬭

1 8 What is observed when concentrated hydrochloric acid is added to an aqueous solution of $CuSO_4$ until no further change occurs?

[1 mark]

A A colourless gas is evolved and a precipitate forms. ⬭

B A colourless gas is evolved and no precipitate forms. ⬭

C A precipitate forms that dissolves in an excess of concentrated hydrochloric acid. ⬭

D The solution changes colour and no precipitate forms. ⬭

1 9 What is the most suitable reagent for detecting the presence of carbonate ions in the presence of an excess of sulfate ions?

[1 mark]

A dilute NaOH(aq) ⬭

B dilute H_2SO_4(aq) ⬭

C $BaCl_2$(aq) ⬭

D NaCl(aq) ⬭

2 0 Methylbenzene reacts with a mixture of concentrated nitric acid and concentrated sulfuric acid.

What is the name of the mechanism for this reaction?

[1 mark]

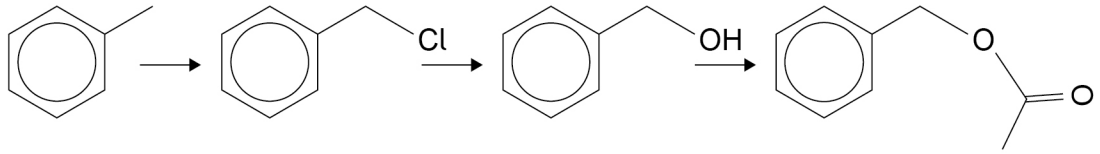
A Electrophilic addition ⬭

B Electrophilic substitution ⬭

C Nucleophilic addition ⬭

D Nucleophilic substitution ⬭

2 1 A possible synthesis of a compound found in jasmine flower oil is shown.



Which mechanism is **not** used in this synthesis?

[1 mark]

A Electrophilic substitution ⬭

B Nucleophilic substitution ⬭

C Free-radical substitution ⬭

D Nucleophilic addition-elimination ⬭

2 2 Which compound is formed when 1-phenylethanol reacts with acidified potassium dichromate(VI)?

[1 mark]

A $C_6H_5CH_2CH_2OH$ ⬭

B $C_6H_5CH_2CHO$ ⬭

C $C_6H_5COCH_3$ ⬭

D $C_6H_5CH_2COOH$ ⬭

Do not write outside the box

2 3 Three reagents are added separately to four organic compounds.

Which row shows the correct observations?

[1 mark]

		Sodium hydrogen carbonate	Acidified potassium dichromate(VI)	Tollens' reagent	
A	**Propan-1-ol**	effervescence	orange solution turns green	no visible change	⬭
B	**Propanal**	no visible change	orange solution turns green	silver mirror	⬭
C	**Propanone**	no visible change	no visible change	silver mirror	⬭
D	**Propanoic acid**	effervescence	no visible change	silver mirror	⬭

2 4 Which compound is formed by acid hydrolysis of phenylmethyl ethanoate?

[1 mark]

A $C_6H_5CH_2OH$ ⬭

B C_6H_5CHO ⬭

C $C_6H_5COCH_3$ ⬭

D C_6H_5COOH ⬭

2 5 A student is required to dry a liquid sample of pentanoic acid.

Which drying agent is suitable?

[1 mark]

A Calcium oxide ⬭

B Calcium sulfate ⬭

C Potassium hydroxide ⬭

D Potassium carbonate ⬭

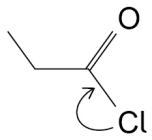
Do not write outside the box

2 6 The reaction between propanoyl chloride and benzene is an example of acylation.

Which is a correct representation of part of the mechanism of this reaction?

[1 mark]

A



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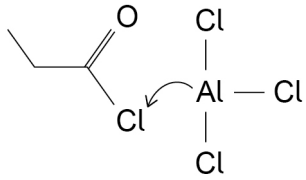

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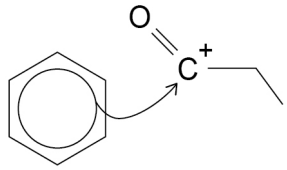

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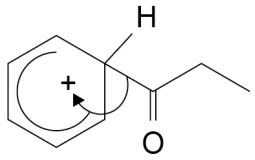


2 7 Methylamine reacts with bromoethane by substitution to produce a mixture of products.

Which compound is **not** a possible product of this reaction?

[1 mark]

A $C_2H_5NHCH_3$

B $(C_2H_5)_2NCH_3$

C $[(C_2H_5)_3NCH_3]^+ Br^-$

D $[(C_2H_5)_2N(CH_3)_2]^+ Br^-$

Do not write outside the box

2 8 Which polymer has hydrogen bonding between its chains?

[1 mark]

A Kevlar ⬭

B Polythene ⬭

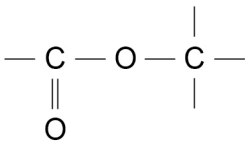
C PVC ⬭

D Terylene ⬭

2 9 Which structure shows part of a peptide link in a protein?

[1 mark]

A



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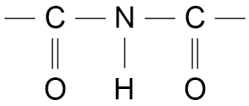
B



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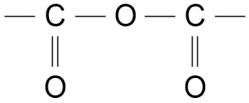
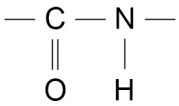
C



⬭

D



⬭

3 0 Two strands of DNA are linked together by hydrogen bonding between bases on each strand.

Which row shows the number of hydrogen bonds between the pair of bases?

Use the Data Booklet to help you answer this question.

[1 mark]

	Base 1	Base 2	Number of hydrogen bonds	
A	adenine	guanine	2	⬭
B	cytosine	thymine	2	⬭
C	guanine	cytosine	3	⬭
D	adenine	thymine	3	⬭

3 1 Which is **not** responsible for conduction of electricity?

[1 mark]

A The sodium ions in molten sodium chloride ⬭

B The electrons between layers of carbon atoms in graphite ⬭

C The bonding electrons in a metal ⬭

D The lone pair electrons on water molecules ⬭

Do not write outside the box

3 2 In the UK industrial ethanol is now produced by the direct hydration of ethene. This process has largely replaced the fermentation method.

Which is a likely reason for this change of method?

[1 mark]

A The direct hydration route produces purer ethanol. ⬭

B The direct hydration route employs milder conditions. ⬭

C The direct hydration route does NOT use a catalyst. ⬭

D The direct hydration route produces ethanol by a slower reaction. ⬭

3 3 Which alkene reacts with hydrogen bromide to give 2-bromo-3-methylbutane as the major product?

[1 mark]

A $(CH_3)_2C{=}CHCH_3$ ⬭

B $CH_3CH_2CH{=}CHCH_3$ ⬭

C $CH_3CH_2C(CH_3){=}CH_2$ ⬭

D $(CH_3)_2CHCH{=}CH_2$ ⬭

3 4 Which compound can be purified by forming a hot aqueous solution that recrystallises on cooling?

[1 mark]

A Cyclohexene ⬭

B Ethanoic acid ⬭

C Phenylamine ⬭

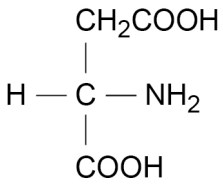
D Benzoic acid ⬭

Do not write outside the box

3 5 Use the Data Booklet to help you answer this question

Which is the main aspartic acid species present in an aqueous solution at pH = 14?
[1 mark]

A



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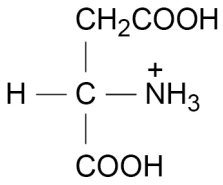

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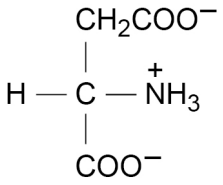
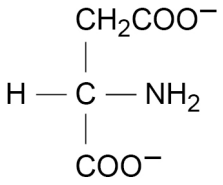


D



END OF QUESTIONS

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