AQA

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level CHEMISTRY

Paper 3

Wednesday 17 June 2020 Morning Time allowed: 2 hours

Materials

For this paper you must have:
- the Periodic Table/Data Booklet, 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.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
Section B	
TOTAL	

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

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

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Section A

Answer **all** questions in this section.

0 1 This question is about emissions of oxides of nitrogen from petrol and diesel engines.

0 1 . 1 Explain how oxides of nitrogen are formed in engines.

[2 marks]

0 1 . 2 State why it is desirable to decrease emissions of oxides of nitrogen from vehicles.

[1 mark]

0 1 . 3 Modern diesel vehicles use diesel exhaust fluids, such as AdBlue, to decrease emissions of oxides of nitrogen.

AdBlue reacts with water in the hot exhaust gases to form ammonia.
In the presence of a catalyst the ammonia reacts with oxides of nitrogen to form nitrogen and water.

Give the oxidation state of nitrogen in each of NO_2, NH_3 and N_2

Complete the equation for the reaction between NO_2 and NH_3

[2 marks]

Oxidation state of nitrogen in

NO_2 _____ NH_3 _____ N_2 _____

Equation

_____ NO_2 + _____ NH_3 → _____ N_2 + _____ H_2O

Do not write outside the box

0 1 . 4 Petrol vehicles have a catalytic converter which decreases emissions of oxides of nitrogen.
Platinum in the catalytic converter acts as a heterogeneous catalyst.

State the meaning of the term heterogeneous catalyst.

[2 marks]

0 1 . 5 Some carbon particulates are also formed in both diesel and petrol vehicles.

Explain why carbon particulates are formed.

[1 mark]

8

Turn over for the next question

Do not write outside the box

0 2 This question is about oxides.

0 2 . 1 Sodium oxide forms a solution with a higher pH than magnesium oxide when equal amounts, in moles, of each oxide are added separately to equal volumes of water.

State why both oxides form alkaline solutions.

Suggest why sodium oxide forms a solution with a higher pH than the solution formed from magnesium oxide.

[2 marks]

0 2 . 2 Give an equation for the reaction between phosphorus(V) oxide and water.

[1 mark]

0 2 . 3 In the Contact process, sulfur(IV) oxide is converted into sulfur(VI) oxide using vanadium(V) oxide as a catalyst.

Give **two** equations to show how the vanadium(V) oxide acts as a catalyst in this process.

[2 marks]

Equation 1 _____

Equation 2 _____

5

Do not write outside the box

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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0 3 . 1 Explain why complexes formed from transition metal ions are coloured.

[3 marks]

The iron content of iron tablets can be determined by colorimetry.

Method:
- Dissolve a tablet in sulfuric acid.
- Oxidise all the iron from the tablet to $Fe^{3+}(aq)$.
- Convert the $Fe^{3+}(aq)$ into a complex that absorbs light of wavelength 490 nm
- Make the solution up to 250 cm^3
- Measure the absorbance of light at 490 nm with a colorimeter.
- Use a calibration graph to find the concentration of the iron(III) complex.

0 3 . 2 Calculate the energy, in J, gained by each excited electron in the absorption at 490 nm

Speed of light, $c = 3.00 \times 10^8$ m s^{-1}
Planck constant, $h = 6.63 \times 10^{-34}$ J s

[3 marks]

Energy gained by each electron _____ J

Do not write outside the box

0 3 . 3 Describe how a calibration graph is produced and used to find the concentration of the iron(III) complex.

[3 marks]

0 3 . 4 The concentration of iron(III) in the solution is 4.66×10^{-3} mol dm^{-3}

Calculate the mass, in mg, of iron in the tablet used to make the 250 cm^3 of solution.

[2 marks]

Mass of iron in the tablet _____ mg

11

Turn over ►

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0 4 Cisplatin, $[Pt(NH_3)_2Cl_2]$, is used as an anti-cancer drug.

0 4 . 1 Cisplatin works by causing the death of rapidly dividing cells.

Name the process that is prevented by cisplatin during cell division.

[1 mark]

After cisplatin enters a cell, one of the chloride ligands is replaced by a water molecule to form a complex ion, **B**.

0 4 . 2 Give the equation for this reaction.

[2 marks]

Do not write outside the box

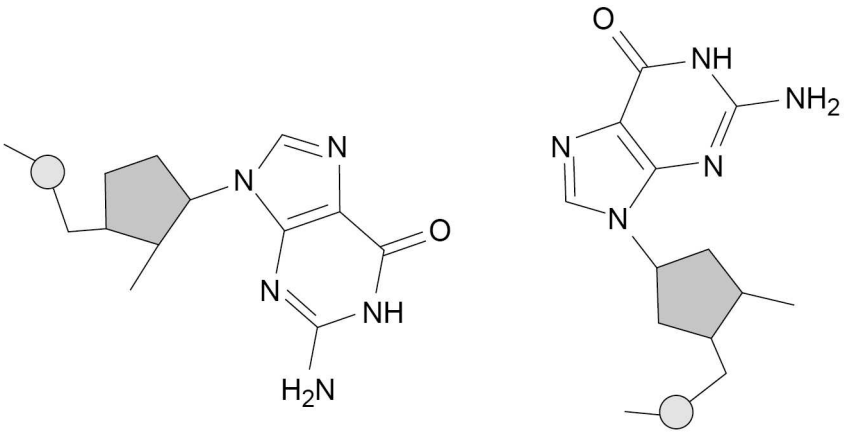
0 4 . 3 When the complex ion **B** reacts with DNA, the water molecule is replaced as a bond forms between platinum and a nitrogen atom in a guanine nucleotide.
The remaining chloride ligand is also replaced as a bond forms between platinum and a nitrogen atom in another guanine nucleotide.

Figure 1 represents two adjacent guanine nucleotides in DNA.

Complete **Figure 1** to show how the platinum complex forms a cross-link between the guanine nucleotides.

[2 marks]

Figure 1



Question 4 continues on the next page

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An experiment is done to investigate the rate of reaction in Question **04.2**.

0 4 . 4 During the experiment the concentration of cisplatin is measured at one-minute intervals.

Explain how graphical methods can be used to process the measured results, to confirm that the reaction is first order.

[3 marks]

In another experiment, the effect of temperature on the rate of the reaction in Question **04.2** is investigated.

Table 1 shows the results.

Table 1

Temperature T / K	**$\frac{1}{T}$ / K^{-1}**	**Rate constant k / s^{-1}**	**ln k**
293	0.00341	1.97×10^{-8}	−17.7
303	0.00330	8.61×10^{-8}	−16.3
313	0.00319	3.43×10^{-7}	−14.9
318		6.63×10^{-7}	
323	0.00310	1.26×10^{-6}	−13.6

0 4 . 5 Complete **Table 1**.

[2 marks]

Do not write outside the box

0 4 . 6 The Arrhenius equation can be written in the form

$$\ln k = \frac{-E_a}{RT} + \ln A$$

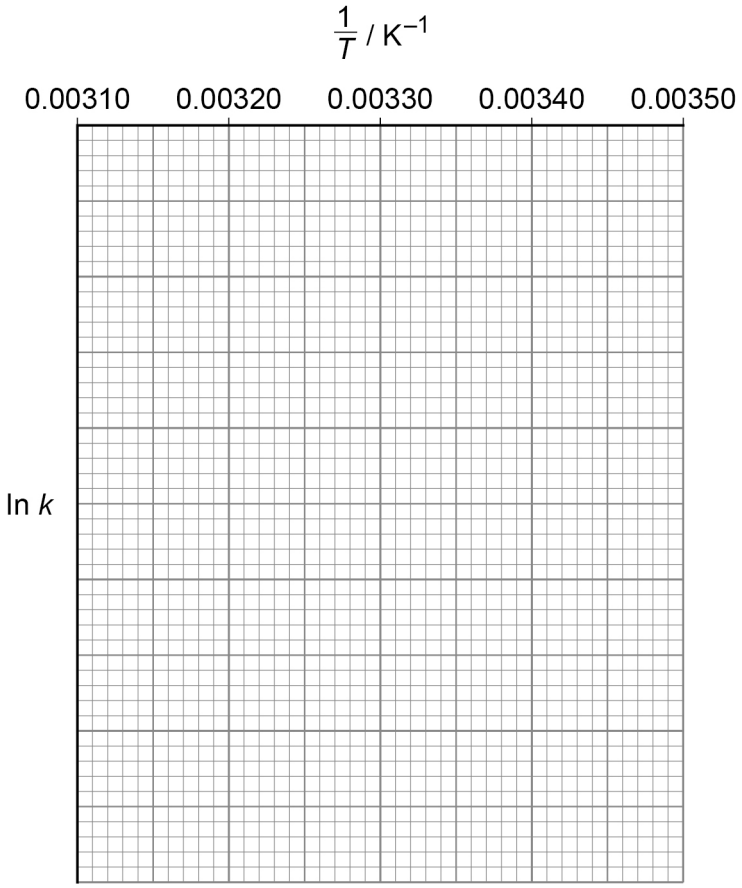
Use the data in **Table 1** to plot a graph of ln k against $\frac{1}{T}$ on the grid in **Figure 2**.

Calculate the activation energy, E_a, in kJ mol^{-1}

The gas constant, R = 8.31 J K^{-1} mol^{-1}

[5 marks]

Figure 2



E_a _____ kJ mol^{-1}

15

Turn over ►

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0 5 A bomb calorimeter can be used for accurate determination of the heat change during combustion of a fuel.

A bomb calorimeter is a container of fixed volume that withstands the change in pressure during the reaction.

The fuel is mixed with pure oxygen in the calorimeter, ignited and the temperature change is recorded.

The total heat capacity (C_{cal}) of the calorimeter is calculated using a fuel for which the heat change is known.

In an experiment to calculate C_{cal}, 2.00 g of hexane (M_r = 86.0) is ignited.
A temperature change (ΔT) of 12.4 °C is recorded.

Under the conditions of the experiment, 1.00 mol of hexane releases 4154 kJ of energy when combusted.

0 5 . 1 The heat energy released in the calorimeter, $q = C_{cal}\Delta T$

Calculate the heat capacity (C_{cal}) in kJ K^{-1}

[3 marks]

C_{cal} _____ kJ K^{-1}

0 5 . 2 When the experiment is repeated with 2.00 g of octane (M_r = 114.0) the temperature change recorded is 12.2 °C

Calculate the heat change, in kJ mol^{-1}, for octane in this combustion reaction.

If you were unable to calculate a value for C_{cal} in Question **05.1**, use 6.52 kJ K^{-1} (this is **not** the correct value).

[2 marks]

Heat change _____ kJ mol^{-1}

Do not write outside the box

0 5 . 3 State why the heat change calculated from the bomb calorimeter experiment is **not** an enthalpy change.

[1 mark]

0 5 . 4 The thermometer used to measure the temperature change of 12.2 °C in Question **05.2** has an uncertainty of ± 0.1 °C in each reading.

Calculate the percentage uncertainty in this use of the thermometer.

Suggest **one** change to this experiment that decreases the percentage uncertainty while using the same thermometer.

[2 marks]

Percentage uncertainty _____

Change _____

8

Turn over for the next question

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0 6 Standard electrode potentials are measured by comparison with the standard hydrogen electrode.

0 6 . 1 State the substances and conditions needed in a standard hydrogen electrode.

[3 marks]

It is difficult to ensure consistency with the setup of a standard hydrogen electrode. A $Cu^{2+}(aq)/Cu(s)$ electrode ($E^{\ominus}$ = +0.34 V) can be used as a secondary standard.

A student does an experiment to measure the standard electrode potential for the $TiO^{2+}(aq)/Ti(s)$ electrode using the $Cu^{2+}(aq)/Cu(s)$ electrode as a secondary standard.

A suitable solution containing the acidified $TiO^{2+}(aq)$ ion is formed when titanium(IV) oxysulfate ($TiOSO_4$) is dissolved in 0.50 mol dm^{-3} sulfuric acid to make 50 cm^3 of solution.

0 6 . 2 Describe an experiment the student does to show that the standard electrode potential for the $TiO^{2+}(aq)/Ti(s)$ electrode is −0.88 V

The student is provided with:

- the $Cu^{2+}(aq)/Cu(s)$ electrode set up ready to use
- solid titanium(IV) oxysulfate (M_r = 159.9)
- 0.50 mol dm^{-3} sulfuric acid
- a strip of titanium
- laboratory apparatus and chemicals.

Your answer should include details of:

- how to prepare the solution of acidified $TiO^{2+}(aq)$
- how to connect the electrodes
- measurements taken
- how the measurements should be used to calculate the standard electrode potential for the $TiO^{2+}(aq)/Ti(s)$ electrode.

[6 marks]

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Do not write outside the box

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0 6 . 3 Give the half-equation for the electrode reaction in the $TiO^{2+}(aq)/Ti(s)$ electrode in acidic conditions.

[1 mark]

0 6 . 4 **Table 2** shows some electrode potential data.

Table 2

Electrode reaction	$E^{\ominus}$ / V
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O(l)$	+0.96

Use the data in **Table 2** to explain why copper does **not** react with most acids but does react with nitric acid.

Give an equation for the reaction between copper and nitric acid.

[3 marks]

Explanation

Equation

13

Turn over for Section B

Do not write outside the box

Section B

Answer **all** questions in this section.

Only **one** answer per question is allowed.
For each question 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 7 When heated, a sample of potassium chlorate(V) ($KClO_3$) produced 67.2 cm^3 of oxygen, measured at 298 K and 110 kPa

$$2\,KClO_3(s) \rightarrow 2\,KCl(s) + 3\,O_2(g)$$

What is the amount, in moles, of potassium chlorate(V) that has decomposed?

The gas constant, $R = 8.31\,J\,K^{-1}\,mol^{-1}$

[1 mark]

A 9.95×10^{-4} ⬭

B 1.99×10^{-3} ⬭

C 2.99×10^{-3} ⬭

D 4.48×10^{-3} ⬭

Do not write outside the box

0 8 Which has a bond angle of 109.5°?

[1 mark]

A C (diamond) ⬭

B C (graphite) ⬭

C NH_2^- ⬭

D NH_3 ⬭

0 9 Which reaction has an enthalpy change equal to the standard enthalpy of formation of silver iodide?

[1 mark]

A $Ag(g) + \frac{1}{2} I_2(g) \rightarrow AgI(s)$ ⬭

B $Ag(s) + \frac{1}{2} I_2(s) \rightarrow AgI(s)$ ⬭

C $Ag^+(g) + I^-(g) \rightarrow AgI(s)$ ⬭

D $Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$ ⬭

1 0 Some bond enthalpies are given.

Bond	**C–H**	**O–H**	**O=O**	**C=O**
Bond enthalpy/ kJ mol^{-1}	412	463	496	743

Which is the enthalpy change of this reaction in kJ mol^{-1}?

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

[1 mark]

A +698 ⬭

B +228 ⬭

C –228 ⬭

D –698 ⬭

Turn over ►

Do not write outside the box

1 1 In which conversion is the metal reduced?

[1 mark]

A $Cr_2O_7^{2-} \rightarrow CrO_4^{2-}$ ⬭

B $MnO_4^{2-} \rightarrow MnO_4^{-}$ ⬭

C $TiO_2 \rightarrow TiO_3^{2-}$ ⬭

D $VO_3^{-} \rightarrow VO^{2+}$ ⬭

1 2 The rate expression for the reaction between **X** and **Y** is

$$rate = k[\mathbf{X}]^2[\mathbf{Y}]$$

Which statement is correct?

[1 mark]

A The rate constant has units $mol^{-1}\ dm^3\ s^{-1}$ ⬭

B The rate of the reaction is halved if the concentration of **X** is halved and the concentration of **Y** is doubled. ⬭

C The rate increases by a factor of 16 if the concentration of **X** is tripled and the concentration of **Y** is doubled. ⬭

D The rate constant is independent of temperature. ⬭

1 3 Which statement about pH is correct?

[1 mark]

A The pH of a weak base is independent of temperature. ⬭

B At temperatures above 298 K, the pH of pure water is less than 7. ⬭

C The pH of 2.0 mol dm^{-3} nitric acid is approximately 0.30 ⬭

D The pH of 0.10 mol dm^{-3} sulfuric acid is greater than that of 0.10 mol dm^{-3} hydrochloric acid. ⬭

Do not write outside the box

1 4 A 0.10 mol dm^{-3} aqueous solution of an acid is added slowly to 25 cm^3 of a 0.10 mol dm^{-3} aqueous solution of a base.

Which acid–base pair has the highest pH at the equivalence point?

[1 mark]

A CH_3COOH and NaOH ⬭

B CH_3COOH and NH_3 ⬭

C HCl and NaOH ⬭

D HCl and NH_3 ⬭

1 5 In the test for a halide ion in aqueous solution, dilute nitric acid is added before the addition of silver nitrate solution.

Why is nitric acid added?

[1 mark]

A It increases the concentration of nitrate ions. ⬭

B It prevents the precipitation of silver compounds other than halides. ⬭

C It prevents the silver nitrate being precipitated. ⬭

D It provides the acidic solution required for precipitation. ⬭

1 6 Which shows the major product(s) formed when chlorine reacts with cold, dilute, aqueous sodium hydroxide?

[1 mark]

A NaCl only ⬭

B NaClO only ⬭

C NaCl and NaClO ⬭

D NaCl and $NaClO_3$ ⬭

Do not write outside the box

1 7 Which shows the electron configuration of an atom of a transition metal?

[1 mark]

A [Ar] $4s^2 3d^0$ ⬭

B [Ar] $4s^2 3d^8$ ⬭

C [Ar] $4s^2 3d^{10}$ ⬭

D [Ar] $4s^2 3d^{10} 4p^1$ ⬭

1 8 Which will **not** act as a ligand in the formation of a complex ion?

[1 mark]

A CH_4 ⬭

B CO ⬭

C H_2O ⬭

D NH_3 ⬭

1 9 Which shows the correct oxidation state and co-ordination number of cobalt in $[Co(NH_3)_5Cl]Cl_2$?

[1 mark]

	oxidation state	**co-ordination number**	
A	+2	5	⬭
B	+2	6	⬭
C	+3	5	⬭
D	+3	6	⬭

Do not write outside the box

2 0 Which statement is **not** correct?

[1 mark]

A $CuCl_4^{2-}$ is square planar. ⬭

B NH_4^+ is tetrahedral. ⬭

C $[Co(H_2NCH_2CH_2NH_2)_3]^{2+}$ is octahedral. ⬭

D $[Fe(H_2O)_6]^{2+}$ is octahedral. ⬭

2 1 Which compound decolourises acidified potassium manganate(VII) solution?

[1 mark]

A $Al_2(SO_4)_3$ ⬭

B $CuSO_4$ ⬭

C $FeSO_4$ ⬭

D $Fe_2(SO_4)_3$ ⬭

2 2 Which has *E*-*Z* isomers?

[1 mark]

A $C_2H_2Br_2$ ⬭

B C_2H_3Br ⬭

C $C_2H_4Br_2$ ⬭

D C_2H_5Br ⬭

Turn over for the next question

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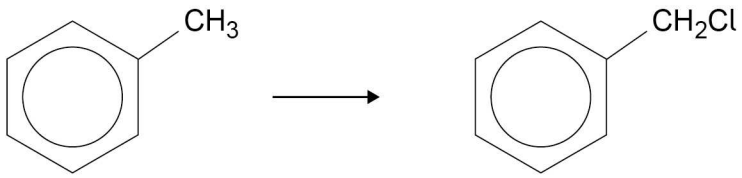
2 3 Which is the mechanism for this conversion?



[1 mark]

A Addition-elimination ⬭

B Electrophilic substitution ⬭

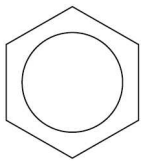
C Free-radical substitution ⬭

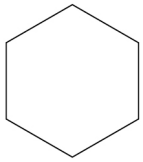
D Nucleophilic substitution ⬭

2 4 Which compound decolourises bromine water in the absence of sunlight?

[1 mark]

A $CH_3CH_2CH_2Br$ ⬭

B  ⬭

C  ⬭

D $CH_3CH_2CHCH_2$ ⬭

2 5 Which compound reacts to form a ketone when warmed with an acidified solution of potassium dichromate(VI)?

[1 mark]

A $CH_3CH_2CH_2OH$ ⬭

B $(CH_3)_2CHOH$ ⬭

C CH_3CH_2CHO ⬭

D $(CH_3)_2CHCOOH$ ⬭

Do not write outside the box

2 6 Which does **not** contain an asymmetric carbon atom?

[1 mark]

A $CH_3CH(CH_3)CH_2CH_3$ ⬭

B $CH_3CH_2CH(CH_3)CH_2CH_2CH_3$ ⬭

C $CH_3CH(OH)CH_2OH$ ⬭

D $CH_3CH_2CHClCH_3$ ⬭

2 7 Which reaction involves addition-elimination?

[1 mark]

A $(CH_3)_2CHBr + KOH \rightarrow CH_3CH=CH_2 + KBr + H_2O$ ⬭

B $CH_3COCl + C_6H_5OH \rightarrow CH_3COOC_6H_5 + HCl$ ⬭

C $CH_3CH=CH_2 + Cl_2 \rightarrow CH_3CHClCH_2Cl$ ⬭

D $CH_3CH_2CH_2Br + NaOH \rightarrow CH_3CH_2CH_2OH + NaBr$ ⬭

2 8 Which compound reacts with hydrogen bromide to give 2-bromo-3-methylbutane as the major product?

[1 mark]

A $(CH_3)_2C=CHCH_3$ ⬭

B $CH_3(CH_2)_2CH=CH_2$ ⬭

C $CH_3CH_2C(CH_3)=CH_2$ ⬭

D $(CH_3)_2CHCH=CH_2$ ⬭

Turn over for the next question

Do not write outside the box

2 9 Which forms a polymer with $ClOC(CH_2)_8COCl$?

[1 mark]

A $NH_2CH_2CH_2NH_2$ ⬭

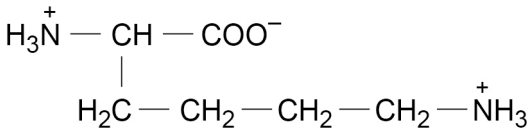
B $(CH_3CO)_2O$ ⬭

C $CH_3CH_2CONH_2$ ⬭

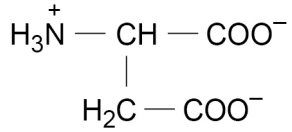
D NH_2CH_2COOH ⬭

3 0 Which structure shows the zwitterion of an amino acid?

[1 mark]

A


⬭

B


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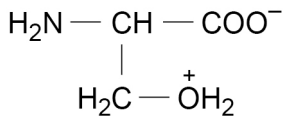
C


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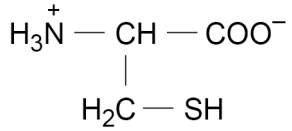
D


⬭

3 1 What is the minimum volume, in cm^3, of 0.02 mol dm^{-3} $KMnO_4$ solution needed to oxidise 0.01 mol of VO^{2+}?

$$5VO^{2+} + MnO_4^- + H_2O \rightarrow 5VO_2^+ + Mn^{2+} + 2H^+$$

[1 mark]

A 10 ⬭

B 50 ⬭

C 100 ⬭

D 200 ⬭

Do not write outside the box

3 2 Which is the concentration of NaOH(aq), in mol dm^{-3}, that has pH = 14.30?

$K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6} at 25 °C

[1 mark]

A –1.16 ⬭

B 5.01×10^{-15} ⬭

C 2.00×10^{14} ⬭

D 2.00 ⬭

3 3 What are the units of the rate constant for a third order reaction?

[1 mark]

A mol dm^{-3} s^{-1} ⬭

B mol^{-1} dm^3 s^{-1} ⬭

C mol^2 dm^{-6} s^{-1} ⬭

D mol^{-2} dm^6 s^{-1} ⬭

3 4 What is the pH of 0.015 mol dm^{-3} sulfuric acid?

[1 mark]

A –1.82 ⬭

B –1.52 ⬭

C 1.52 ⬭

D 1.82 ⬭

Turn over for the next question

Do not write outside the box

3 5 Which compound is formed when phenyl benzenecarboxylate is hydrolysed under acidic conditions?

[1 mark]

A $C_6H_5CH_2OH$ ⬭

B C_6H_5CHO ⬭

C $C_6H_5COCH_3$ ⬭

D C_6H_5COOH ⬭

3 6 A student rinsed the apparatus before starting an acid-base titration.
The results of the titration showed that the volume of acid added from the burette was larger than expected.

Which is a possible reason for this?

[1 mark]

A The conical flask was rinsed with water before the titration. ⬭

B The walls of the conical flask were rinsed with water during the titration. ⬭

C The pipette was rinsed only with water. ⬭

D The burette was rinsed only with water. ⬭

30

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**
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