Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

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6340228845

CHEMISTRY **9701/41**

Paper 4 A Level Structured Questions **October/November 2020**

2 hours

You must answer on the question paper.

You will need: Data booklet

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **24** pages. Blank pages are indicated.

[Turn over

Answer **all** the questions in the spaces provided.

1 Nitrogen monoxide, NO, reacts with oxygen to form nitrogen dioxide, NO_2.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

The rate equation for the forward reaction is shown.

$$\text{rate} = k[NO]^2[O_2]$$

(a) Complete the following table.

the order of reaction with respect to [NO]	
the order of reaction with respect to $[O_2]$	
the overall order of reaction	

[1]

(b) Two separate experiments are carried out at 30 °C to determine the rate of the forward reaction.

experiment	[NO] / mol dm^{-3}	$[O_2]$ / mol dm^{-3}	rate / mol dm^{-3} s^{-1}
1	0.00300	0.00200	1.51×10^{-4}
2		0.00500	6.05×10^{-5}

(i) Use the data for experiment 1 to calculate the value of the rate constant, *k*. State the units of *k*.

k = ... units = ...
[2]

(ii) Calculate the value of [NO] in experiment 2.

[NO] = ... mol dm^{-3} [1]

(c) Define the term *rate-determining step*.

..... [1]

(d) Peroxodisulfate ions, $S_2O_8^{2-}$, react with iodide ions, I^-.

$$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$$

The rate equation for the reaction in the absence of any catalyst is shown.

$$\text{rate} = k[S_2O_8^{2-}][I^-]$$

(i) Suggest equations for a two-step mechanism for this reaction, stating which of the two steps is the rate-determining step.

step 1 .....

step 2 .....

rate-determining step = ...

[2]

(ii) A large excess of peroxodisulfate ions is mixed with iodide ions. Immediately after mixing, $[I^-] = 0.00780\,\text{mol dm}^{-3}$. Under the conditions used, the half-life of $[I^-]$ is 48 seconds.

Calculate the iodide ion concentration 192 seconds after the peroxodisulfate and iodide ions are mixed.

iodide ion concentration = ... mol dm^{-3} [1]

[Total: 8]

[Turn over

2 **(a)** The lattice energies of three ionic compounds are given.

compound	lattice energy / kJ mol^{-1}
LiF(s)	–1022
CaO(s)	–3513
SrO(s)	–3310

(i) Define the term *lattice energy*.

.....

.....

..... [2]

(ii) Explain why the lattice energy of CaO is more exothermic than the lattice energy of LiF.

.....

.....

..... [1]

(iii) Use the data in the table to estimate approximate values for the lattice energies of magnesium oxide and barium oxide.

ΔH_{latt}MgO(s) = ... kJ mol^{-1}

ΔH_{latt}BaO(s) = ... kJ mol^{-1}
[1]

(b) **(i)** Write an equation for the reaction between BaO and H_2O.
Include state symbols.

..... [1]

(ii) State and explain how the solubilities of the hydroxides of the Group 2 elements vary down the group.

.....

.....

.....

.....

.....

.....

..... [4]

(c) Use the following data and relevant data from the *Data Booklet* to calculate a value for the lattice energy of magnesium fluoride, $MgF_2(s)$.

You might find it helpful to construct an energy cycle.
Show your working.

electron affinity of F(g)	$= -348\,kJ\,mol^{-1}$
enthalpy change of atomisation of Mg(s)	$= +147\,kJ\,mol^{-1}$
enthalpy change of formation of $MgF_2(s)$	$= -1102\,kJ\,mol^{-1}$

$\Delta H_{latt} MgF_2(s)$ = ... [3]

(d) (i) Define the term *electron affinity*.

.....

..... [2]

(ii) The electron affinity of carbon, C(g), is $-120\,kJ\,mol^{-1}$.

Suggest an explanation for the difference between the electron affinity of fluorine and the electron affinity of carbon.

.....

.....

.....

..... [1]

[Total: 15]

[Turn over

3 **(a)** Identify the substances liberated at the anode and at the cathode during the electrolysis of aqueous sodium sulfate, $Na_2SO_4(aq)$.

anode .....

cathode .....
[1]

(b) When molten sodium chloride is electrolysed, chlorine is liberated at the anode and sodium is liberated at the cathode.

A sample of molten sodium chloride is electrolysed for 1.50 hours using a current of 4.50A.

Calculate the volume of chlorine and the mass of sodium that are liberated under room conditions.

volume of chlorine = ... dm^3

mass of sodium = ... g
[4]

(c) The equation representing the standard electrode potential, $E^{\ominus}$, for the reduction of $MnO_4^-(aq)$ to $Mn^{2+}(aq)$ in acid solution is given.

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l) \qquad E^{\ominus} = +1.52\,V$$

(i) Draw a diagram of the apparatus that would be used to measure the $E^{\ominus}$ value of this half-cell. Your diagram should be fully labelled to identify all apparatus, substances and conditions.

[4]

(ii) Use the *Data Booklet* to identify a substance that could be used to oxidise Mn^{2+} ions to MnO_4^- ions under standard conditions.

Write an equation for the reaction.

.....

.....

..... [2]

[Total: 11]

[Turn over

4 **(a)** **(i)** Give the mathematical expression for each of the terms pH and K_w.

pH = ...

K_w = ...
[2]

(ii) Calculate the pH of 0.027 mol dm^{-3} NaOH(aq).

pH = ... [1]

(b) The K_a value of chloric(I) acid, HC*l*O, is 3.72×10^{-8} mol dm^{-3}.

Calculate the pH of 0.010 mol dm^{-3} HC*l*O(aq).

pH = ... [1]

(c) Water and octan-1-ol form two layers when mixed.

Ethanamide is more soluble in water than it is in octan-1-ol. When 1.00 g of ethanamide is added to 50.0 cm^3 of water and this is then shaken with 50.0 cm^3 of octan-1-ol, it is found that the water layer contains 0.935 g of ethanamide at equilibrium.

(i) Calculate the partition coefficient, K_{pc}, for ethanamide in water and octan-1-ol.

K_{pc} = ... [1]

(ii) The 50.0 cm^3 of water containing 0.935 g of ethanamide is then shaken with 100.0 cm^3 of pure octan-1-ol under the same conditions.

Calculate the mass of ethanamide that is dissolved in the 100.0 cm^3 of octan-1-ol at equilibrium.

mass of ethanamide = ... g
[2]

[Total: 7]

5 A solution is made by dissolving $CuSO_4 \cdot 5H_2O$ in an excess of aqueous ammonia. This solution contains the copper complex $[Cu(NH_3)_4]^{2+}$.

(a) (i) Write an expression for the K_{stab} of $[Cu(NH_3)_4]^{2+}$.

K_{stab} =

[1]

(ii) State the colour of the solution of $[Cu(NH_3)_4]^{2+}$.

..... [1]

The solution of $[Cu(NH_3)_4]^{2+}$ is heated gently in a fume cupboard so that NH_3 is released. Some NH_3 remains in solution and some forms NH_3 gas. The colour of the solution changes; a precipitate of $Cu(OH)_2$ forms and is collected.

A sample of $Cu(OH)_2$ is added to concentrated hydrochloric acid. A reaction takes place forming a coloured copper complex, **Y**.

A sample of $Cu(OH)_2$ is added to dilute sulfuric acid. A reaction takes place forming a coloured copper complex, **Z**.

$[Cu(NH_3)_4]^{2+}$, **Y** and **Z** are different colours.

(b) Suggest an equation for the reaction of $[Cu(NH_3)_4]^{2+}$ to form $Cu(OH)_2$ as the aqueous solution of $[Cu(NH_3)_4]^{2+}$ is heated.

..... [1]

(c) Suggest an equation for the reaction of $Cu(OH)_2$ with concentrated hydrochloric acid, forming **Y**.

..... [2]

(d) Complete the table with the colour and geometry of complex **Y** and the colour, geometry and formula of complex **Z**.

	Y	**Z**
colour of complex		
geometry of complex		
formula of complex		

[2]

[Turn over

(e) Explain why complexes **Y** and **Z** are coloured and why their colours are different.

.....

.....

.....

.....

.....

.....

.....

..... [5]

[Total: 12]

6 **(a)** When 1.0 mol dm^{-3} $Na_2S_2O_3$(aq) is added to a solution containing Ag^+(aq) ions, a linear complex, **P**, is formed. $S_2O_3^{2-}$ ions are present in **P** as monodentate ligands.

(i) Define the term *monodentate ligand*.

.....

..... [2]

(ii) Give the formula of **P**, including its charge.

..... [1]

(b) When 1.0 mol dm^{-3} NaCN(aq) is added to a solution of **P**, a mixture which includes a second linear complex, **Q**, is formed. In this mixture the concentration of **Q** is much greater than the concentration of **P**.

(i) Write an equation for the reaction that occurs when NaCN(aq) is added to a solution of **P**.

..... [1]

(ii) Suggest a reason why the concentration of **Q** is much greater than the concentration of **P** in the mixture.

.....

.....

..... [1]

(iii) Name the type of reaction in which **P** forms **Q**.

..... [1]

[Turn over

(c) Platinum forms a complex ion with the formula $[Pt(CN)_2Cl_2]^{2-}$. In this complex ion the carbon atom of each CN^- ligand bonds to the platinum ion. This complex shows stereoisomerism.

(i) There are only two isomers of this complex.

Draw structures of these two isomers in the boxes below.

Pt

Pt

[1]

(ii) Describe the geometry of $[Pt(CN)_2Cl_2]^{2-}$.

..... [1]

(iii) Name the type of stereoisomerism shown by $[Pt(CN)_2Cl_2]^{2-}$.

..... [1]

[Total: 9]

7 Phenol, C_6H_5OH, is a weak acid.

(a) Phenol can be made from phenylamine, $C_6H_5NH_2$.

Give the reagents and conditions for this reaction.

.....

..... [2]

(b) Phenol reacts with dilute aqueous nitric acid under room conditions to give a mixture of two isomeric products with molecular formula $C_6H_5NO_3$.

Use the *Data Booklet* to draw the structural formulae of these two products in the boxes and name each product.

name .....

name .....

[2]

(c) Phenol reacts with an excess of aqueous bromine.

(i) Draw and name the organic product of this reaction in the box.

name .....

[2]

(ii) Describe **two** visual observations that can be made when phenol reacts with an excess of aqueous bromine.

observation 1 .....

observation 2 .....

[1]

(d) Write an equation for a neutralisation reaction in which phenol behaves as an acid.

..... [1]

(e) Water, phenol and ethanol can all behave as acids.

Place these three compounds in order of acidity, starting with the **most** acidic.
Explain your answer.

..... > ..... > .....

most acidic least acidic

.....

.....

.....

.....

.....

.....

[3]

[Total: 11]

8 Benzene, C_6H_6, can be obtained from crude oil.

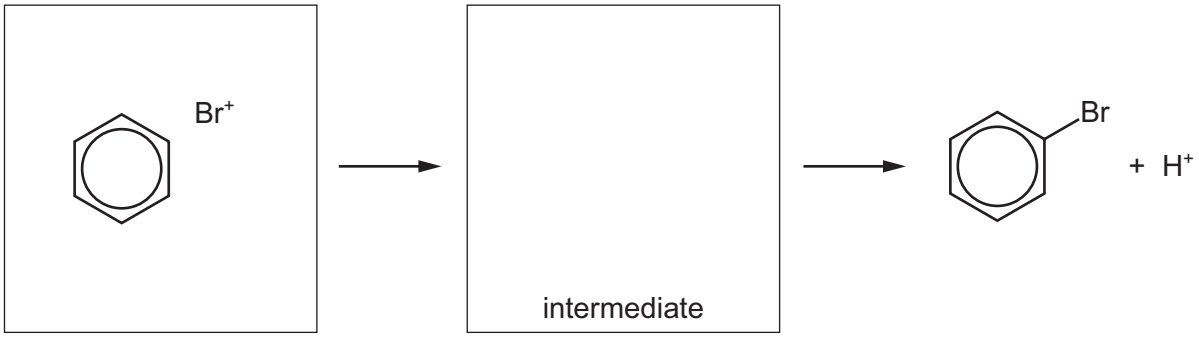
(a) Benzene reacts with bromine, in the presence of a suitable catalyst, forming bromobenzene as one product.

(i) Give the name or formula of the other product of this reaction.

..... [1]

(ii) In the presence of the catalyst, bromine can be considered to form the electrophile Br^+.

Complete the mechanism by which benzene reacts with Br^+, using curly arrows to show the movement of electron pairs.

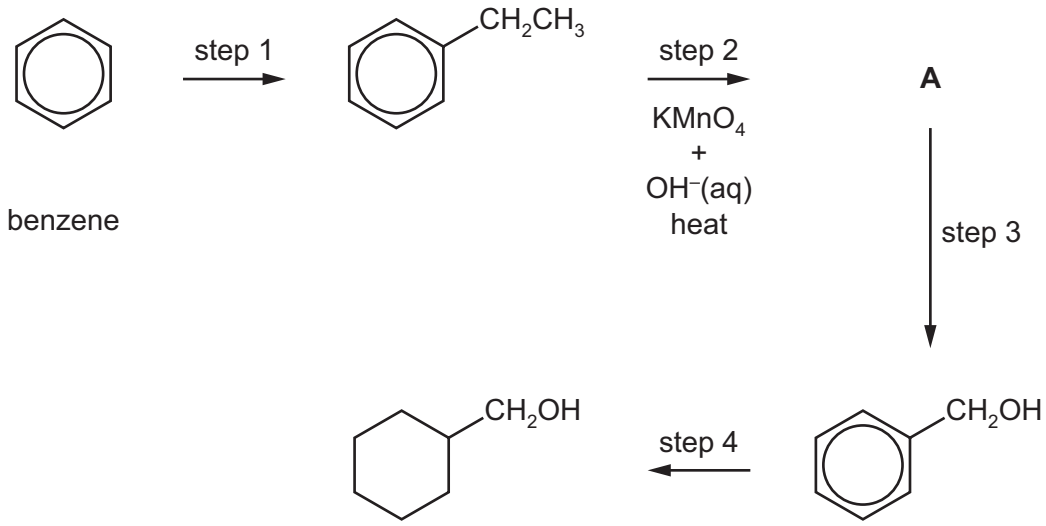


[2]

(iii) Name this mechanism.

..... [1]

(b) Benzene can be used as a starting material in the synthesis of cyclohexylmethanol, $C_6H_{11}CH_2OH$, as outlined below.



cyclohexylmethanol

(i) Identify a suitable reagent and a suitable catalyst for step 1.

reagent .....

catalyst .....

[2]

(ii) Draw the structure of **A**.

A

[1]

(iii) Identify suitable reagents for steps 3 and 4.

step 3 .....

step 4 .....
[2]

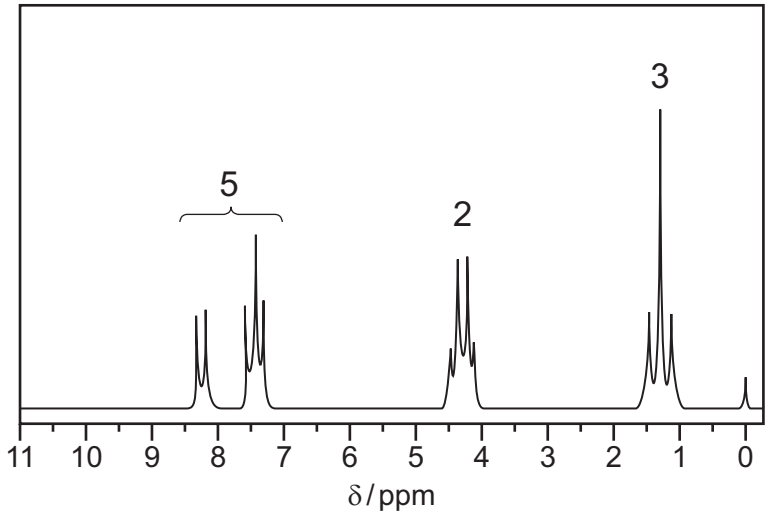
(iv) Deduce the number of peaks in the carbon-13 NMR spectrum of cyclohexylmethanol.

..... [1]

[Total: 10]

[Turn over

9 The proton NMR spectrum of compound **E** in the solvent $CDCl_3$ is shown. The molecular formula of compound **E** is $C_9H_{10}O_2$.



(a) Explain why $CDCl_3$ is used as a solvent instead of $CHCl_3$.

..... [1]

(b) Explain why TMS is added to give the small peak at chemical shift $\delta = 0$.

..... [1]

(c) Compound **E** is hydrolysed by hot NaOH(aq), giving two organic products only. One of these products is ethanol.

Name the functional group in compound **E** that is hydrolysed by hot NaOH(aq).

..... [1]

(d) (i) Describe and explain the splitting patterns of the peaks at $\delta = 1.4$ and $\delta = 4.3$.

splitting pattern at $\delta = 1.4$ .....

reason for splitting pattern at $\delta = 1.4$ .....

splitting pattern at $\delta = 4.3$ .....

reason for splitting pattern at $\delta = 4.3$ .....
[2]

(ii) Each molecule of compound **E** contains five protons which give rise to the peaks between $\delta = 7.0$ and $\delta = 8.5$.

Identify the functional group in compound **E** which contains these protons.

..... [1]

(iii) Give the structural formula of compound **E**.

[1]

(e) The mass spectrum of compound **E** includes fragment ions with *m*/*e* values of 29 and 77.

Give the formulae of these fragment ions.

fragment ion with *m*/*e* = 29 .....

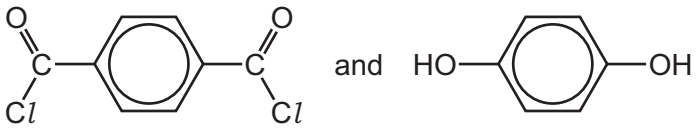
fragment ion with *m*/*e* = 77 .....

[2]

[Total: 9]

10 (a) The table shows three pairs of monomers that are capable of polymerisation.

Complete the table by identifying each type of polymerisation.

pair of monomers	type of polymerisation
$HOCH_2CH_2OH$ and $HO_2CCH_2CO_2H$	
	
CH_3CHCF_2 and CH_3CHCH_2	

[1]

(b) 2-aminopropanoic acid, $CH_3CH(NH_2)CO_2H$, can polymerise under suitable conditions. No other monomer is involved in this reaction.

(i) Draw a section of the polymer chain formed including **three** monomer residues. Clearly identify **one** repeat unit on your diagram.

[3]

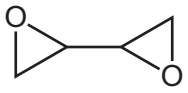
(ii) 2-aminopropanoic acid, $CH_3CH(NH_2)CO_2H$, exists as two stereoisomers.

Draw three-dimensional diagrams to show the two stereoisomers of 2-aminopropanoic acid. State the type of stereoisomerism shown.

type of stereoisomerism .....

[2]

(c) The skeletal formula of compound **W** is shown.



When **W** is mixed with a second compound, called a hardener, a polymerisation reaction occurs, producing a non-solvent-based adhesive.

(i) Give the name of this type of non-solvent-based adhesive.

..... [1]

(ii) The hardener is a diamine. A diamine has an alkyl chain with two amine groups which are not bonded to the same carbon atom.

Draw the structural formula of a compound that would make a suitable hardener.

[1]

[Total: 8]

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