Candidate Full Name	Candidate Number

Anglo-Chinese School
(Independent)

YEAR 6 PRELIMINARY EXAMINATION 2020

INTERNATIONAL BACCALAUREATE DIPLOMA PROGRAMME

CHEMISTRY HIGHER LEVEL
Paper 2

Monday **14 September 2020** **2 hours 15 minutes**

INSTRUCTIONS TO CANDIDATES

- Write your **candidate number in the box above**.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- A calculator is required for this paper.
- A copy of the Chemistry Data Booklet is required for this paper.
- Write your answers in the boxes provided.
- The maximum marks for this examination paper is **90 marks**.

For examiner's use	
Qn 1	/5
Qn 2	/9
Qn 3	/9
Qn 4	/16
Qn 5	/7
Qn 6	/11
Qn 7	/10
Qn 8	/11
Qn 9	/4
Qn 10	/8
Wrong s.f. /units	
Total	/90

This question paper consists of 22 printed pages including this cover page.

Answer **all** questions. Write your answers in the boxes provided.

1. Known for its silver, shiny appearance, chromium is used to coat cars, stoves and other appliances to protect them from corrosion and to improve their looks.

(a) Mass spectroscopic analysis of a sample of chromium gave the following results:

Isotopes in the sample	^{50}Cr	^{52}Cr	^{53}Cr	^{54}Cr
Percentage abundance	4.25	83.05	9.90	2.80

(i) Calculate the relative atomic mass of this sample of chromium to two decimal places. [2]

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(ii) Write the electronic configuration of chromium. [1]

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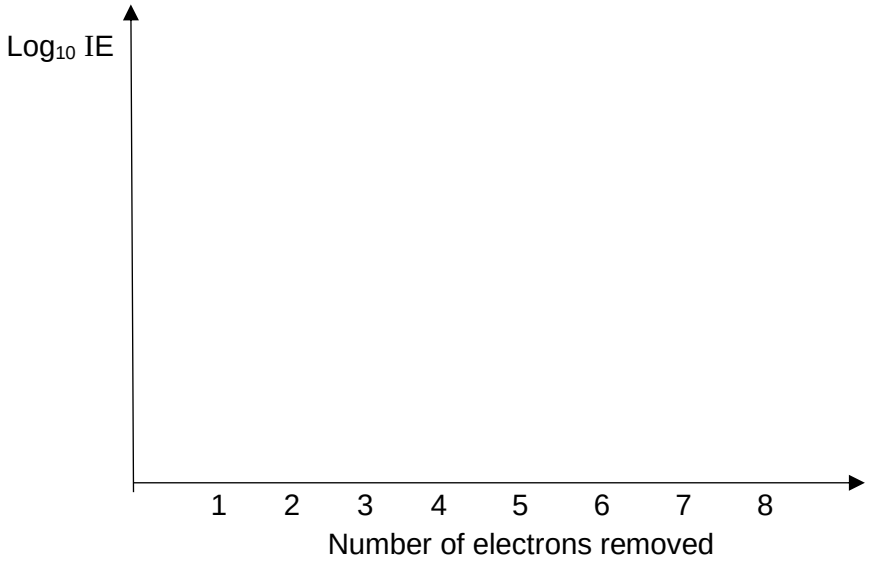
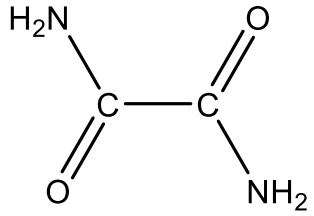
(b) Sketch a graph to show the changes in Log_{10} IE, ionisation energy, as the first 8 electrons of a chlorine atom are successively removed. [2]



2. (a) The structural formula of ethanediamide is shown.



Predict the electron domain and molecular geometries at the nitrogen and carbon atoms, applying the VSEPR theory. [3]

	Electron domain geometry	**Molecular geometry**
Nitrogen	……	……
Carbon	……	Trigonal planar

(b) (i) Suggest **one** reason why ethanediamide is a solid and ammonia is a gas at room temperature. [1]

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(ii) Sketch **two** different hydrogen-bonding interactions between ammonia and water molecules. [2]

(This question continues on the following page)

(Question 2 continued)

(c) (i) Describe how sigma (σ) and pi (π) bonds present in ethanediamide are formed. [2]

sigma (σ):

.....

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pi (π):

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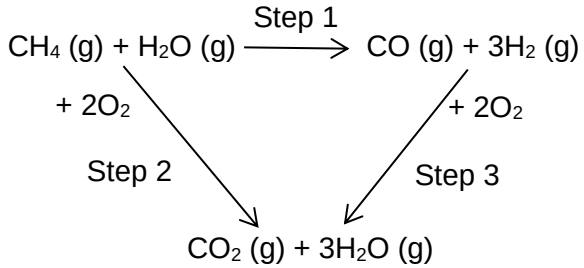
(ii) State the number of σ and π bonds in a molecule of ethanediamide. [1]

sigma (σ): .....

pi (π) : .....

3. Consider the following energy cycle:



(a) Using data from section 12 of the data booklet, calculate the enthalpy change for Step 1. [2]

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(b) Suggest **one** reason why the calculation of ΔH value using Hess's Law can be considered accurate and **one** reason why it can be considered approximate. [2]

Accurate :

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Approximate :

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(This question continues on the following page)

(Question 3 continued)

(c) (i) Using the standard entropy of hydrogen, $S^{\ominus}(H_2)$ = 114.7 J K^{-1} mol^{-1} and section 12 of the data booklet, calculate the standard entropy change for Step 1. [2]

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(ii) Using your answers in (a) and (c)(i), calculate the $\Delta G^{\ominus}$ of the reaction and predict if the reaction is spontaneous.
(You may assume the $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ values for Step 1 to be +1000 kJ mol^{-1} and +200 J K^{-1} mol^{-1} if you did not obtain an answer for (a) and (c)(i).) [3]

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4. In a typical iodine clock reaction, a solution of hydrogen peroxide is first mixed with hydrochloric acid, starch and sodium thiosulfate. Subsequently, potassium iodide is added to the mixture. This resulted in two reactions occurring in the reaction mixture.

In the first reaction, iodide ions are oxidised slowly by acidified hydrogen peroxide to form iodine.

Reaction **I** H_2O_2 (aq) + $2I^-$ (aq) + $2H^+$ (aq) $\rightarrow$ I_2 (aq) + $2H_2O$ (l)

In the second reaction, iodine is reduced to iodide ions as they are generated.

Reaction **II** $2S_2O_3^{2-}$ (aq) + I_2 (aq) $\rightarrow$ $S_4O_6^{2-}$ (aq) + $2I^-$ (aq)

When all the sodium thiosulfate present has reacted, excess iodine will appear in the solution producing an immediate deep blue colour with starch indicator.

A series of experiments were carried out using different volumes of the five reagents, each solution was made up to the same total volume with water. The following results were obtained.

Expt no.	Volume of 0.100 mol dm^{-3} H_2O_2 / cm^3	Volume of 0.100 mol dm^{-3} KI / cm^3	Volume of 0.100 mol dm^{-3} HCl / cm^3	Volume of 0.050 mol dm^{-3} $Na_2S_2O_3$ / cm^3	Volume of starch indicator / cm^3	Volume of water / cm^3	Time taken for the appearance of deep blue colour / s
1	18	12	6	2	3	59	23.0
2	6	12	12	2	3	65	70.0
3	6	18	12	2	3	59	47.0
4	12	12	12	2	3	59	35.0

(a) If sodium thiosulfate was not added to the reaction mixture for reaction **II** to take place, the completion of reaction **I** could still be observed by the appearance of an immediate deep blue colour with starch indicator, with a shorter time recorded.

Explain how adding a small amount of sodium thiosulfate will improve the precision of the results. [1]

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(Question 4 continued)

(b) Explain the purpose of adding water in each experiment. [1]

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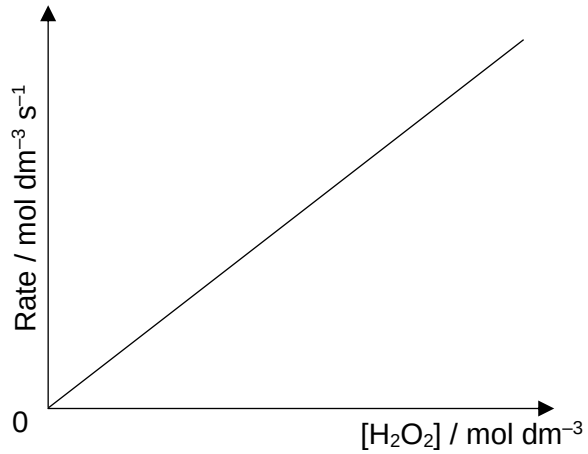
(c) Calculate the relative initial rate of reaction for each of these experiments. [2]

Experiment number	Time taken for the appearance of deep blue colour / s	Relative rate ($\frac{1}{\text{time}}$)
1	23.0	.....
2	70.0	.....
3	47.0	.....
4	35.0	.....

(d) In another experiment conducted, the concentration of hydrogen peroxide was found to have a linear relationship with the rate of reaction, as shown in the graph below.



Deduce the order of reaction with respect to hydrogen peroxide. [1]

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(Question 4 continued)

(e) Using your answers in (c) and (d), deduce, with reasons, the order of reaction with respect to I^- and H^+ in reaction **I**. [2]

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(f) Write the overall rate equation for the reaction and state the unit of the rate constant. [2]

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(g) Suggest, with reasons, which of the following mechanisms, **A** or **B**, fits the observed kinetics data for reaction **I**. [2]

Mechanism **A**

$2H^+ (aq) + 2I^- (aq) \rightarrow 2HI (aq)$ (fast)

$2HI (aq) + H_2O_2 (aq) \rightarrow I_2 (aq) + 2H_2O (l)$ (slow)

Mechanism **B**

$H_2O_2 (aq) + I^- (aq) \rightarrow H_2O (l) + OI^- (aq)$ (slow)

$H^+ (aq) + OI^- (aq) \rightarrow HIO (aq)$ (fast)

$HIO (aq) + I^- (aq) + H^+ (aq) \rightarrow I_2 (aq) + H_2O (l)$ (fast)

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(Question 4 continued)

(h) Iron is a transition metal known to exist as ions with oxidation numbers of +2 or +3. Fe^{2+} (aq) ions can be used to catalyse reaction **I**.

(i) State the type of catalyst Fe^{2+} (aq) ions is functioning in reaction **I** and explain why it can function as this type of catalyst. [2]

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(ii) Iron in the +3 oxidation number is known to form an oxide that exhibits amphoteric properties.

Name another element in Period 3 that forms an amphoteric oxide. [1]

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(iii) Write the balanced chemical equations, illustrating the amphoteric properties of the Period 3 oxide stated in (h)(ii). [2]

Reaction with HCl: .....

Reaction with NaOH: .....

5. Methanol is one of the alternative fuels proposed to replace fossil fuels. It has the advantage of more efficient energy production and ease of storage as compared to other alternatives.

Methanol can be formed from carbon monoxide and hydrogen as shown below.

$$CO\,(g) + 2H_2\,(g) \rightleftharpoons CH_3OH\,(g) \qquad \Delta H = -90.8\ kJ$$

An equilibrium was established at 25 ^oC and the reaction mixture was found to contain 2.8 mol of CO, 3.2 mol of H_2 and 1.6 mol of methanol in a 10.0 dm^3 sealed vessel.

(a) (i) Deduce an expression for the equilibrium constant, K_c for the reaction. [1]

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(ii) Calculate the value of K_c at the stated condition. [2]

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(iii) State the effect of the following changes on the position of equilibrium and the production of methanol. [2]

The volume of the vessel is halved:

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Temperature is increased:

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(This question continues on the following page)

(Question 5 continued)

(b) Standard Gibbs free energy change, $\Delta G^{\ominus}$, is related to K_c by the following equation.

$$\Delta G^{\ominus} = - RT \ln K_c$$

Using this equation and your answer in (a)(ii), calculate $\Delta G^{\ominus}$ in kJ mol^{-1} for the formation of methanol from carbon monoxide and hydrogen at 25 ^{o}C.
(You may assume the value of K_c to be 10 if you did not obtain an answer for (a)(ii).)

[2]

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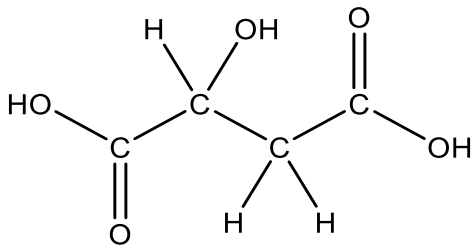
6. In 1785, Scientist Carl Wilhelm Scheele isolated malic acid, $C_4H_6O_5$, from apples. It is a main organic acid found in most fruits other than citric acid, $C_6H_8O_7$. Due to its pure flavour, it is commonly used as artificial vinegar flavouring in food such as potato chips.

The structure of malic acid is shown.



The equations for the first and second dissociation of malic acid in water are given below:

1st dissociation

$C_4H_6O_5\,(aq) + H_2O\,(l) \rightleftharpoons C_4H_5O_5^-\,(aq) + H_3O^+\,(aq)$ $\quad pK_{a1} = 3.40$

2nd dissociation

$C_4H_5O_5^-\,(aq) + H_2O\,(l) \rightleftharpoons C_4H_4O_5^{2-}\,(aq) + H_3O^+\,(aq)$ $\quad pK_{a2} = 5.20$

(a) Identify **one** Bronsted-Lowry conjugate acid-base pair in the 2nd dissociation equation. [1]

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(b) A student states that $C_4H_5O_5^-$ is an *amphiprotic* species but not an *amphoteric* species. Comment, giving a reason, if you agree or disagree with the student. [3]

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(This question continues on the following page)

(Question 6 continued)

(c) The dissociation of acid in water is an endothermic process. State the effect (increase / decrease / no change) on the concentration of hydrogen ions, $[H^+]$ and on pK_{a1}, when the temperature is increased. [2]

Effect on $[H^+]$	Effect on pK_{a1}

(d) By considering only the **first** dissociation equation of malic acid, calculate the pH of a solution of 1.00 mol dm^{-3} malic acid. [3]

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(e) Considering only the **second** dissociation equation of malic acid, determine the proportion of $[C_4H_5O_5^-]$ and $[C_4H_4O_5^{2-}]$, in terms of $\frac{[C_4H_4O_5^{2-}]}{[C_4H_5O_5^-]}$, that should be mixed to form an acidic buffer solution of pH 4.6. [2]

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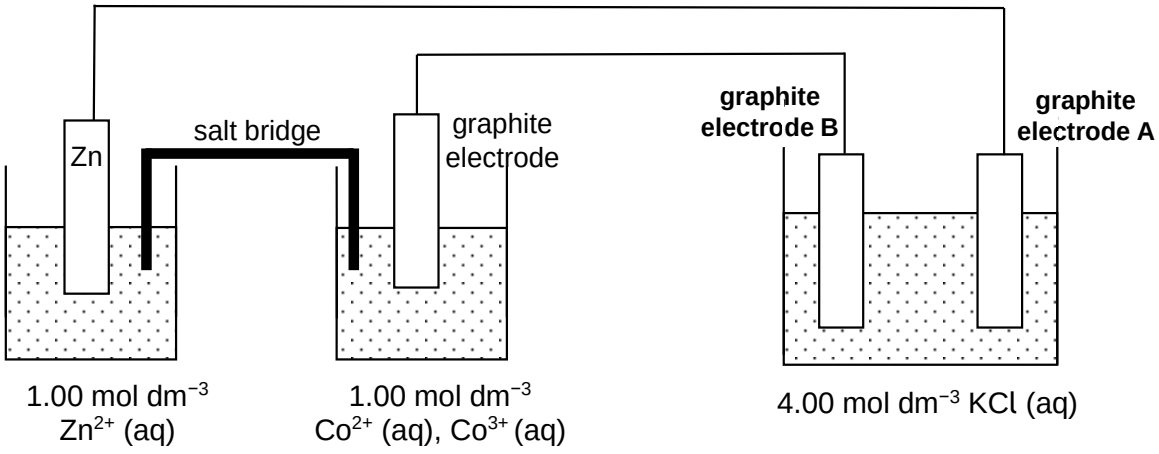
7. The following setup was prepared in a school laboratory using a concentrated potassium chloride solution. The standard electrode potential, $E^{\ominus}(Co^{3+}/Co^{2+})$ is +1.89 V.



(a) Using the information in section 24 of the data booklet, annotate on the diagram above the direction of electron flow. [1]

(b) (i) Deduce the half equations for **Cell 1**. [2]

Anode : ……..……

Cathode : ……...

(ii) Determine the standard cell potential for the reaction in **Cell 1** using data from section 24 of the data booklet. [2]

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(This question continues on the following page)

(Question 7 continued)

(c) (i) State the polarity of the electrodes and identify the products formed at the electrodes in **Cell 2.** [2]

Electrode	Polarity (+/−)	Product
A		
B		

(ii) 150 cm^3 of a colourless gas was collected at electrode **A** in **Cell 2** after 10.0 minutes at standard temperature and pressure. Refer to section 2 of the data booklet, calculate the current produced by the battery setup. [3]

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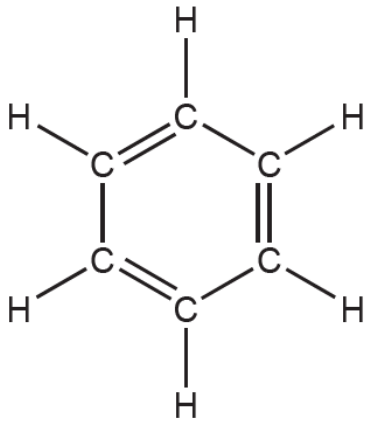
8. (a) The structure of an organic molecule can be used to predict the type of reaction it can undergo. The Kekulé structure of benzene suggests that it should readily undergo addition reactions.



Discuss two pieces of evidence, **one** physical and **one** chemical, which suggest that the above diagram is **not** the structure of benzene. [2]

Physical evidence:

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Chemical evidence:

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(This question continues on the following page)

(Question 8 continued)

(b) The benzene ring of phenylethene reacts with the nitronium ion, NO_2^+, via electrophilic substitution and the C=C double bond reacts with hydrogen bromide, HBr, via electrophilic addition.

Compare and contrast these two reactions in terms of their reaction mechanisms. [2]

One similarity:

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One difference:

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(c) Sketch the mechanism of the reaction between phenylethene and hydrogen bromide to form the **major product**, using curly arrows to represent the movement of electron pairs. [4]

(This question continues on the following page)

(Question 8 continued)

(d) The major product that is formed in (c) can exist as isomers. Explain why the major product can exist in two forms and state the relationship between these isomers. [3]

Explanation:

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Relationship:

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9. Organic compounds often have isomers. There are many possible isomers for the formula $C_5H_{10}O$.

(a) A straight-chain molecule of $C_5H_{10}O$ contains a carbonyl group. The compound cannot be oxidised by acidified potassium dichromate(VI) solution. Deduce the structural formulas of the two possible isomers. [2]

(b) (i) An alcohol can be oxidised to another isomer of $C_5H_{10}O$ by acidified dichromate(VI) ions, with immediate distillation. State the IUPAC name of this alcohol. [1]

….....

(ii) Formulate an equation for the reaction that occurs in (b)(i). State symbols are not required. [1]

….....

10. (a) Bromine consists of two isotopes, ^{79}Br and ^{81}Br, in 1:1 ratio. In the following table, identify the fragments responsible for the m/z values obtained from the mass spectrum of 1,2–dibromopropane. [2]

m/z values	**fragment**
202	
200	
79	

(b) State the number of signals present in the ^{1}H NMR spectrum of 1,2-dibromopropane and the relative ratio of the peak areas. [2]

Number of signals: .....

The relative ratio of the peak areas: .....

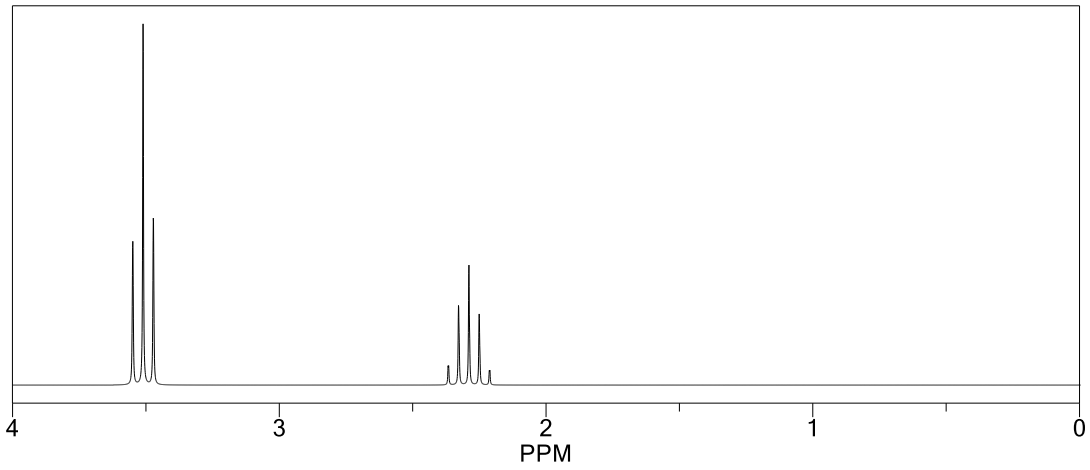
(c) An isomer of 1,2–dibromopropane, compound **X** produces only a single peak in the ^{1}H NMR spectrum.

Draw the full structural formula of this isomer, compound **X**. [1]

(This question continues on the following page)

(Question 10 continued)

(d) Another isomer of 1,2–dibromopropane, compound **Y** produced the following ^{1}H NMR spectrum. The chemical shift values are listed in the table below.



Chemical shift/ppm	Peak area	Splitting pattern
3.51	4	Triplet
2.29	2	Multiplet

(i) Deduce the number of adjacent non-equivalent hydrogen atoms next to the hydrogen atoms responsible for the peak at 3.51 ppm. [1]

….....

(ii) State, giving a reason, the number of chemical environments the hydrogen atoms of this compound **Y** are in. [1]

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….....

(iii) Hence, draw the skeletal formula of compound **Y**. [1]

End of Paper