RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME								
CLASS	2	0	J					
CENTRE NUMBER	S					INDEX NUMBER		

H2 CHEMISTRY 9729/02

Paper 2 Structured Questions **15 September 2021**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number, class and name on all the work that you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions in the spaces provided on the Question Paper. If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use								
Question Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
Marks	/12	/9	/12	/9	/8	/18	/7	/
significant figures			**units**				**Total**	/75

This document consists of **23** printed pages and **1** blank page.

1 In recent years, there has been worldwide interest in the possible extraction of "shale gas" (a form of natural gas) as an important energy source.

(a) One of the problems associated with using shale gas is its variable composition.

Table 1.1 shows the percentage composition of shale gas from four different sources **J**, **K**, **L** and **M**.

Table 1.1

source	CH_4	C_2H_x	C_3H_y	CO_2	N_2
J	80.3	8.1	2.3	1.4	7.9
K	82.1	14.0	3.5	0.1	0.3
L	88.0	0.8	0.7	10.4	0.1
M	77.5	4.0	0.9	3.3	14.3

In the formulae above, *x* and *y* are variables.

(i) Draw the structures of three possible hydrocarbons with 3 carbon atoms.

[3]

(ii) State the source of shale gas, **J**, **K**, **L** or **M**, that will likely provide the most energy when completely burned.

Explain your answer.

……

……

[1]

(iii) Suggest a method by which carbon dioxide can be removed from shale gas.

……

……

[1]

(b) Fracking is the process of drilling down into the earth before a high-pressure water mixture is directed at the rock to release the shale gas inside.

Water, sand and chemicals are injected into the rock at high pressure which allows the gas to flow out to the head of the well.

Magnesium hydroxide is one of the chemicals that can be used to control pH.

The equation for the formation of the gaseous hydroxide ion is shown.

$$\tfrac{1}{2}H_2(g) + \tfrac{1}{2}O_2(g) + e^- \rightarrow OH^-(g) \qquad \Delta H = \Delta H_f(OH^-(g))$$

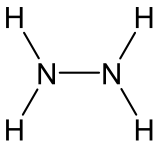
Use the data from Table 1.2 and the *Data Booklet*, construct a Born-Haber cycle to calculate $\Delta H_f(OH^-(g))$.

Table 1.2

	ΔH / kJ mol^{-1}
standard enthalpy change of atomisation of Mg(s)	+148
standard enthalpy change of formation of $Mg(OH)_2(s)$	–925
lattice energy of $Mg(OH)_2(s)$	–2993

[3]

(c) Hydrazine, N_2H_4, can be also used as an energy source and is stored as a liquid. It reacts exothermically with oxygen to give only gaseous products.



hydrazine

(i) Hydrazine reacts with oxygen according to the following equation.

$$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

Given that the standard enthalpy change of vapourisation of hydrazine is +36.9 kJ mol^{-1}, calculate the enthalpy change of the above reaction with relevant data from the *Data Booklet*.

[2]

(ii) Explain, using Gibbs free energy change, why the reaction of hydrazine with oxygen is spontaneous at all temperatures.

……

……

……

……

…… [2]

[Total: 12]

2 **(a)** **(i)** Describe the reactions of the chlorides, $MgCl_2$ and PCl_5, with water. Write equations for all reactions that occur, and suggest the pH of the resulting solutions.

Relate the reactivity of these chlorides to their structures and bonding.

……

……

……

……

……

……

……

……

……

…… [3]

(ii) Carbon is in the same group as silicon. Suggest and explain if CCl_4 will react with water.

……

…… [1]

(b) Phosphorus exist in isotopes, mainly ^{31}P, ^{32}P and ^{33}P. ^{31}P is the most stable isotope.

(i) Define *isotopes*.

……

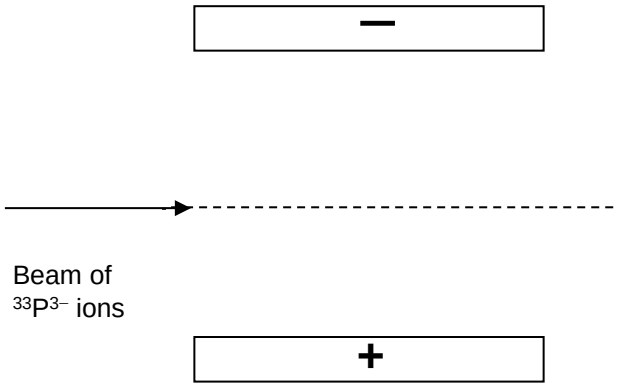
…… [1]

(ii) ^{31}P being the most stable isotope can react with chlorine to form phosphorus chloride. Phosphorus in phosphorus chloride can exhibit variable oxidation states. Based on your knowledge in periodicity, state the two common oxidation states of phosphorus in phosphorus chloride.

…… [1]

(iii) Phosphorus can exist as cations or anions.

The angle of deflection for a beam of $^{31}P^{+}$ ions in an electric field is 6°. Calculate the angle of deflection for a beam of $^{33}P^{3-}$ ions in the same electric field and show in the diagram below how a beam of $^{33}P^{3-}$ ions will deflect in the electric field.



[2]

(iv) ^{32}P is unstable and decays rapidly to another element. During the decay, a neutron is converted to a proton with the release of an electron, forming a charged ion.

Write an equation to show the reaction.

…… [1]

[Total : 9]

3 The use of the *Data Booklet* is relevant in this question.

Values of the standard reduction potentials for certain silver species are given in Table 3.1. All ionic states refer to aqueous ions but other state symbols have been omitted.

Table 3.1

Electrode reaction	$E^{\ominus}$ / V
$Ag^{2+} + e^- \rightleftharpoons Ag^+$	+2.00
$Ag_2S + 2e^- \rightleftharpoons 2Ag + S^{2-}$	−0.69

These data are relevant to **(a)**, **(b)** and **(c)**.

(a) Copper and silver are transition elements found in Group 11 and they can be found in their metallic form in nature. Even though copper and silver are analogous to each other, i.e. both have certain similarities in their physical and chemical properties, there are some differences as well.

(i) It is found that Cu^+ ions form a pink solid in a blue solution. Explain why this can occur.

……

……

…… [1]

(ii) On the contrary, Ag^+ ions remain stable in water but not Ag^{2+} ions.

Use the data in Table 3.1, together with data from the *Data Booklet*, to explain why this is so for both silver species. Support your answers with relevant calculations where necessary.

……

……

……

……

……

……

…… [2]

(b) 'Toning' of a coin is the result of a chemical reaction between the metal surface of the coin and an atmospheric element.

When a silver coin is subjected to prolonged exposure to air and sulfide-containing compounds such as hydrogen sulfide, the surface will develop a tarnish which is predominantly silver(I) sulfide, Ag_2S.

Depending on the thickness and unevenness of the tarnish layer, the coins can exhibit a range of colours, in which a coin with rainbow toning or unusual toning patterns are unique and has significantly high value to coin collectors.

Example of natural toning on a silver dollar coin

(i) Construct a balanced equation for the formation of silver(I) sulfide on the silver coin via exposure in air and hydrogen sulfide.

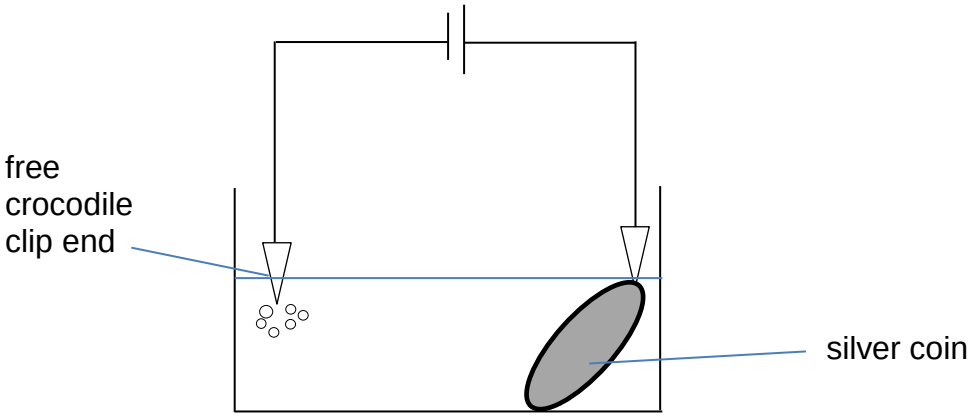
……..……..... [1]

(ii) Calculate the E_{cell} for this reaction.

……

…… [1]

(c) Nowadays, silver coins can be toned artificially via electrolysis. An example of the setup is given below:



The electrolyte is prepared by adding sodium hydroxide and sulfur in hot water to form a concentrated aqueous solution of sodium sulfide. The silver coin is clamped with a crocodile clip and submerged in the electrolyte. The reaction begins when the free crocodile clip end comes in contact with the electrolyte.

(i) Effervescence can be seen at the free crocodile clip end. Identify the gas evolved and explain why the gas is produced.

……

……

……

…… [2]

(ii) Given that a current of 50 mA passes through the circuit in the setup above, calculate the time taken, in seconds, for 1.50×10^{-4} g of silver(I) sulfide to be deposited on the coin.

……

……

……

…… [2]

(d) Table 3.2 shows the numerical values of lattice energies for the silver halides. These have been determined from experimental data or theoretically calculated.

Table 3.2

Silver halide	Experimental value / kJ mol^{-1}	Theoretical value / kJ mol^{-1}
AgF	−953	−920
AgC*l*	−908	−833
AgBr	−900	−815
AgI	−883	−778

(i) By quoting appropriate data from the *Data Booklet*, explain why the theoretical lattice energy values of the silver halides decrease from AgF to AgI.

……

……

……

…… [2]

(ii) Silver fluoride and silver iodide have the same crystal structure. There is close agreement between the experimental and theoretical values of lattice energy for AgF but not for AgI.

Suggest a reason for this.

……

…… [1]

[Total: 12]

4 Amines are a class of compounds widely used in the agricultural industry. Ethylamine, $CH_3CH_2NH_2$ (pK_b = 3.3), is widely used in the production of herbicides.

(a) 25.0 cm^3 of 0.888 mol dm^{-3} aqueous ethylamine was placed in a conical flask. 33.90 cm^3 of sulfuric acid was required to completely neutralise the ethylamine.

(i) Calculate the initial pH of aqueous ethylamine in the conical flask.

[2]

(ii) Calculate the concentration of the dilute sulfuric acid used in the experiment.

[1]

(b) (i) A universal indicator solution was used in the experiment. The colours corresponding to the pH of the solution in the conical flask are as shown in Fig. 4.1.

Using appropriate calculations, state the colour of the solution mixture at equivalence point.

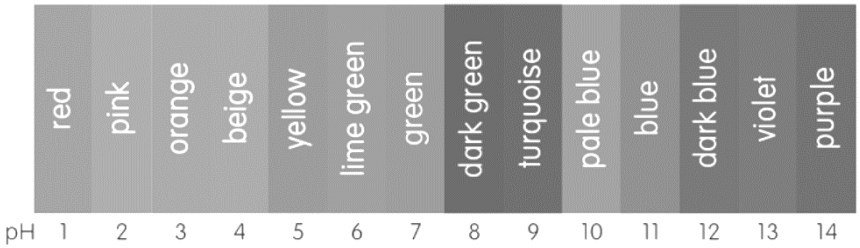


Fig. 4.1

[2]

(ii) Chemist Holmes performed the experiment using another indicator from Table 4.1. State and explain which indicator is the most suitable choice.

Table 4.1

Indicator	Colour in acid	Colour in alkali	pH range over which the colour change occurs
Alizarin yellow	Yellow	Orange	10.1 – 13.0
Chlorophenol red	Yellow	Violet	4.8 – 6.7
Methyl orange	Red	Yellow	3.1 – 4.4
Phenolphthalein	Colourless	Pink	8.2 – 10.0

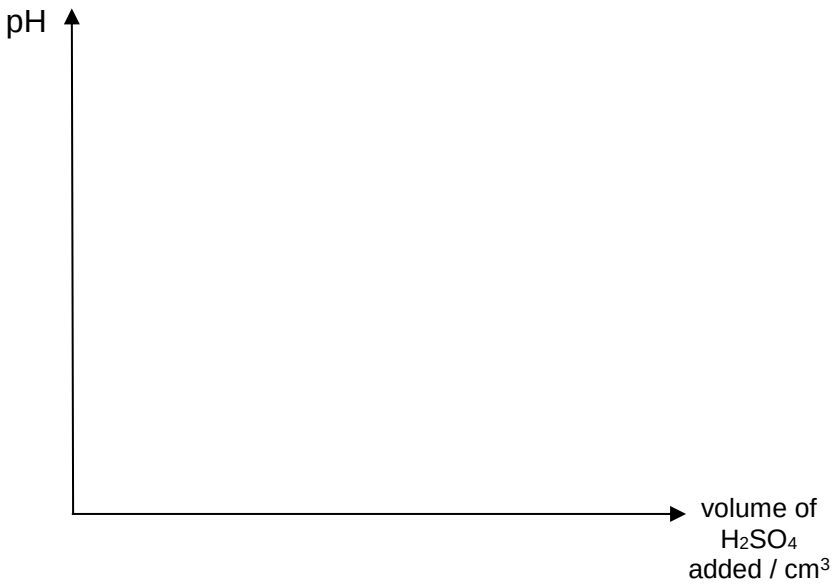
……

…… [1]

(c) Calculate the pH of the solution mixture when 50.00 cm^3 of sulfuric acid has been added.

[1]

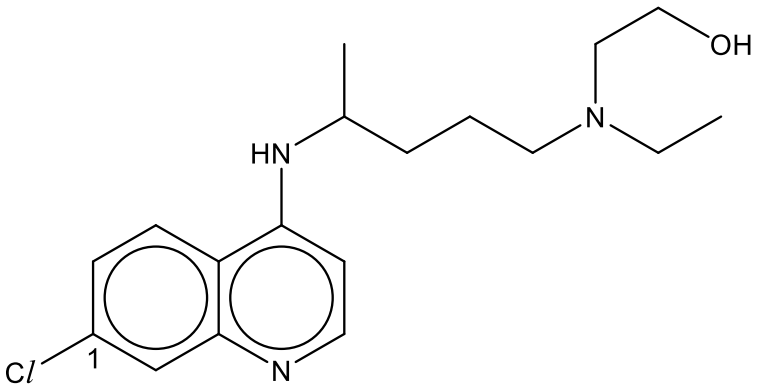
(d) Using information and your answers from **(a)**, **(b)** and **(c)**, sketch the shape of the pH curve of the titration between aqueous ethylamine and sulfuric acid.



[2]

[Total: 9]

5 **(a)** Hydroxychloroquine (HCQ) is a drug used in the treatment of arthritis and malaria. During the initial months of the Covid-19 pandemic, it was also touted as a drug for the prevention and treatment of Covid-19 which drove up the demand for HCQ. Subsequent drug trials indicated low efficacy of the drug in reducing mortality in patients. In June 2020, the U.S. Food and Drug Administration revoked its emergency authorisation of HCQ in the treatment of Covid-19.

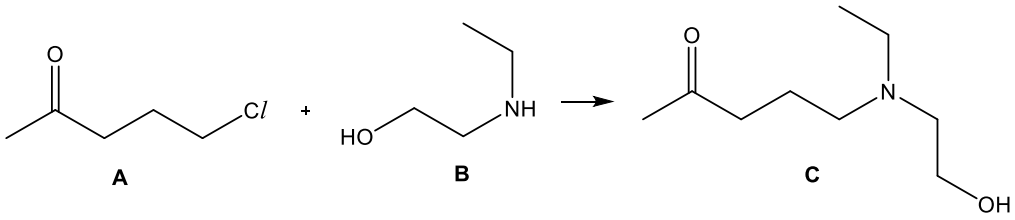


HCQ

State the oxidation number of carbon labelled 1 in HCQ.

…….. [1]

(b) The large-scale production of HCQ requires a key precursor **C** to be produced and its synthetic route is shown below.



A **B** **C**

(i) Suggest reasons why the synthesis of **C** should not be carried out under

- acidic conditions
- **very** alkaline conditions

Under acidic conditions

……..

……..

……..

Under **very** alkaline conditions

……..

……..

…….. [2]

(ii) Explain why it is necessary to use a limited amount of **A** in the synthesis to have a larger yield of **C**.

……..

……..

…….. [1]

(c) Patients with severe Covid-19 symptoms often need breathing support. This is because infected lungs are less effective at absorbing oxygen into the bloodstream.

In our bodies, haemoglobin can bind up to four molecules of oxygen.

$$Hb(aq) + 4O_2(aq) \ll Hb(O_2)_4(aq)$$

(i) Write an expression for K_c in this reaction, stating its units.

……..

…….. [1]

(ii) Experiments have shown that when $[O_2] = 8.1 \times 10^{-6}$ mol dm^{-3}, the concentration of Hb and $Hb(O_2)_4$ are equal.

Use this information to calculate a value for K_c.

[1]

(iii) All Singapore households are recently issued with an oximeter to monitor their blood oxygen saturation levels. Individuals whose blood oxygen levels are 94% and below should see a doctor immediately.

Use your value of K_c to calculate the $[O_2]$ necessary for 94% of the Hb to be converted to $Hb(O_2)_4$.

[1]

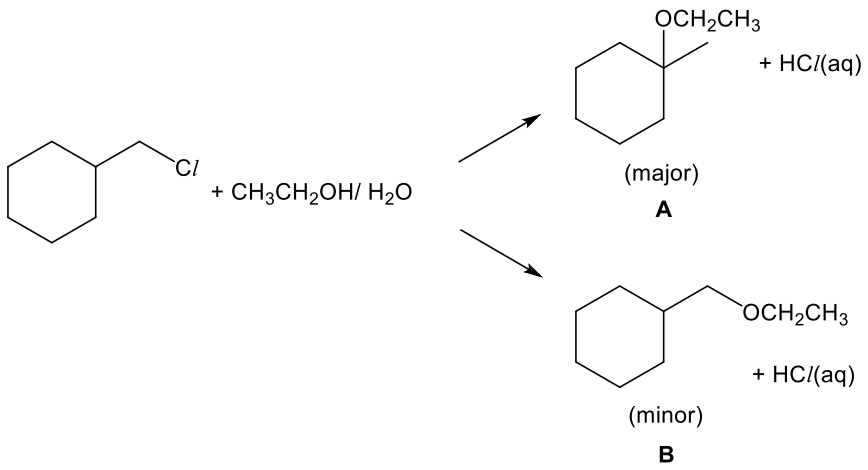
(iv) State what the K_c value indicates about the position of equilibrium.

……...

…… [1]

[Total: 8]

6 (Chloromethyl)cyclohexane undergoes nucleophilic substitution reaction with ethanol in the ethanol/water mixture. This reaction is known as the solvolysis of (chloromethyl)cyclohexane. Isomer **A** is produced rather than isomer **B**.



(a) Suggest and explain why ethanol reacts predominantly instead of water.

.....

..... [1]

The kinetics of the solvolysis of 0.0150 mol dm^{-3} (chloromethyl)cyclohexane in 15% ethanol/water mixture is studied using conductivity measurements. The measurements were recorded at 5 seconds interval and given in the units of microsiemens per centimetre ($\mu S\ cm^{-1}$). The conductivity is directly proportional to the amount of isomer **A** present in the sample.

Fig. 6.1 shows the conductivity recorded against time for this experiment.

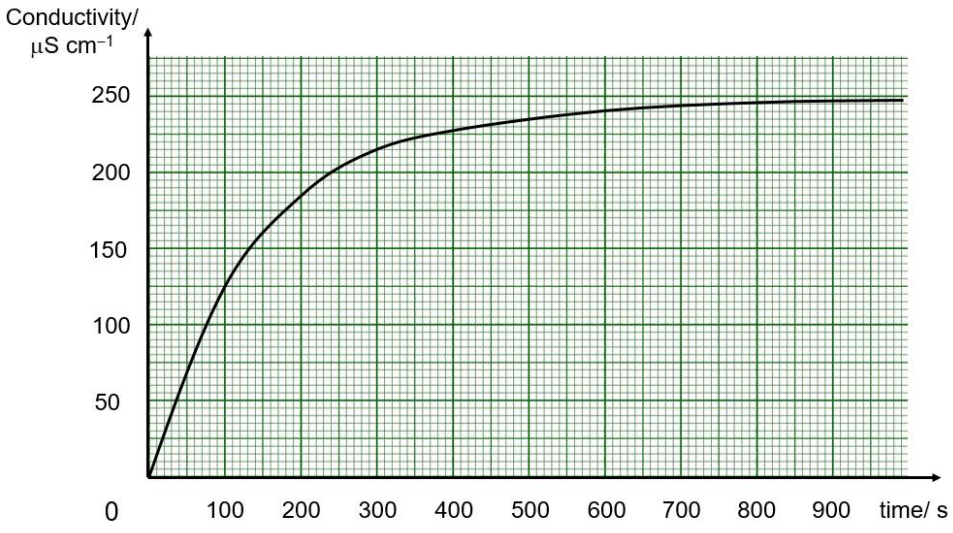


Fig 6.1

(b) In terms of structure and bonding, explain why

- the conductivity is zero initially
- the conductivity increases

……

……

……

……

…… [2]

(c) **(i)** Show how the initial rate of reaction for this experiment could be determined using Fig. 6.1.

[Assume that the rate of change of conductivity is equivalent to the rate of reaction.]

[2]

(ii) Deduce the order of reaction with respect to (chloromethyl)cyclohexane. Explaining your reasoning.

……

……

……

…… [2]

(iii) The ethanol/ water mixture was changed from 15.0% to 30.0% and a new experiment carried out at the same temperature. When a similar graph was plotted, the gradient at each point remained the same.

Deduce the order of reaction with respect to ethanol. Explain your reasoning.

……

……

……

…… [2]

(iv) Suggest the rate equation for the reaction that would result from the proposed mechanism.

…… [1]

(v) The concentration of the organic solution can be calculated using this simplified equation:

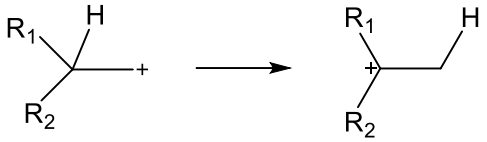
Conductivity = 7000[(chloromethyl)cyclohexane]

Calculate the value of the initial rate in mol dm^{-3} s^{-1}, hence determine the rate constant and its units, using your equation from **(c)(iv)**.

[3]

(vi) The solvolysis reaction proceeds via two intermediates.

One intermediate is formed first, and it will then go on to form its isomer, which is more stable. In this process, a hydrogen shift occurs where the hydrogen atom moves from one atom to the adjacent atom. An example is shown below.



Draw the mechanism for the solvolysis of (chloromethyl)cyclohexane to form the major product. The mechanism follows the following steps:

- bond breaking occurs to form an carbocation intermediate
- hydrogen shift occurs to produce a more stable intermediate
- ethanol attacks the intermediate
- deprotonation occurs to produce the major product

Show all charges, relevant lone pairs and the movement of electron pairs by using curly arrows.

[3]

(d) Different halogenoalkanes have different reactivity towards nucleophilic substitution.

(i) Explain why (bromomethyl)cyclohexane reacts at a faster rate than (chloromethyl)cyclohexane.

……

……

…… [1]

(ii) The difference in reactivity is also dependent on the stability of the leaving group. The more stable the halide ion, the better the leaving group and the faster the rate of reaction. The pK_a values of HX is given below.

Halide (X^-)	pK_a (HX)
F^-	+3
Cl^-	–7
Br^-	–9
I^-	–10

Considering pK_a of HX and the stability of the halide ion, suggest a reason for the faster rate of reaction for (bromomethyl)cyclohexane.

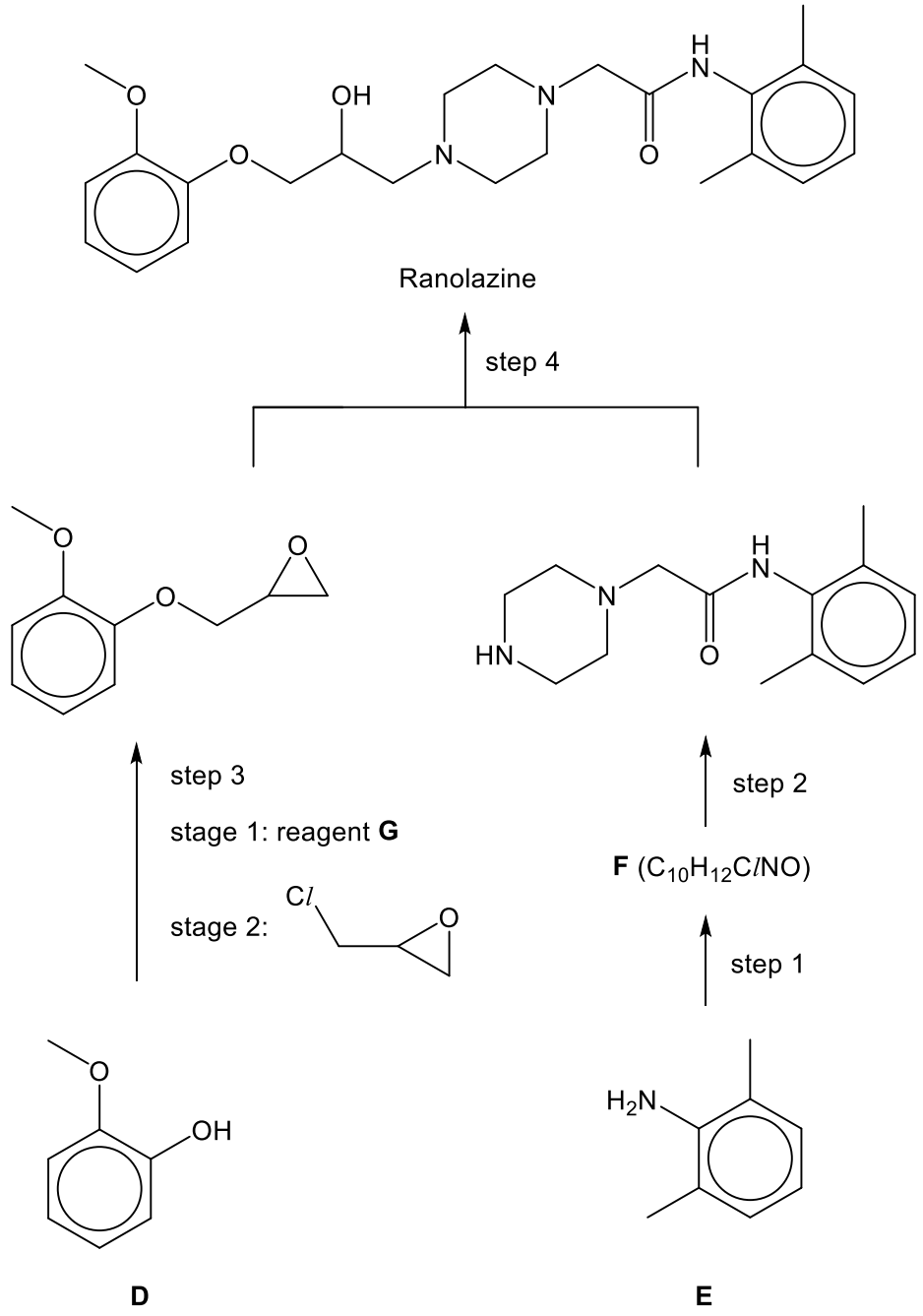
……

……

…… [1]

[Total: 18]

7 **(a)** Compounds **D** and **E** can be used to synthesise Ranolazine in several steps.



(i) Suggest a structure for the organic compound **F**.

[1]

(ii) Suggest reagents and conditions for each of the steps 1 and 2, and reagent **G**.

Step 1: ……

Step 2: ……

Reagent **G**: …… [3]

(b) **(i)** State the hybridisation of the unsaturated carbon in CH_3CN.

…….. [1]

(ii) Hence, suggest the difference in bond length between the C–C bond acetonitrile (CH_3CN) and ethane (CH_3CH_3).

……..

……..

……..

…….. [2]

[Total: 7]