TEMASEK JUNIOR COLLEGE

2024 JC2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME		CLASS	
CENTRE NUMBER	S	INDEX NUMBER	

Chemistry **9729/02**

Paper 2 Structured Questions **21 August 2024**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number, name and class on all the work 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.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.

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

For Examiner's Use		
Paper 1		**/30**
Paper 2	**Q1**	**/ 14**
	Q2	**/ 15**
	Q3	**/ 16**
	Q4	**/ 20**
	Q5	**/ 10**
	Total	**/75**
Paper 3		**/80**
TOTAL (%)		**/100**

This document consists of **21** printed pages and **3** blank pages.

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

1 **(a)** Table 1.1 shows the successive ionisation energies of an element **A**.

Table 1.1

ionisation energies / kJ mol^{-1}	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
element **A**	945	1794	2735	4839	6056	11690	14180	17370	20550	23830

(i) Explain why the successive ionisation energies of an element always increase. [1]

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(ii) Element **A** is in Period 4.

Using information from Table 1.1 and the *Data Booklet*, identify element **A**.

Explain your answer clearly. [2]

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(iii) State and explain how the first ionisation energy of element **A** will compare to that of the element to its right in the Periodic Table. [2]

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(b) **(i)** With the aid of a labelled diagram. describe the structure and bonding of barium. [2]

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(ii) Explain the trend in atomic radii down Group 2. [2]

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(iii) The density of magnesium and barium is 1.7 g cm^{-3} and 3.6 g cm^{-3} respectively.

Explain why the density of barium is significantly greater than that of magnesium. [1]

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[Turn over

(iv) When magnesium is burned in air, a mixture of the ionic solids magnesium oxide and magnesium nitride, Mg_3N_2, is formed. Adding water to Mg_3N_2 produces an alkaline gas and a white insoluble solid.

Suggest an equation for the reaction between Mg_3N_2 and water, and use it to calculate the mass of white insoluble solid that would be formed from 2.0g of Mg_3N_2. [2]

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(c) The scientific community was shocked at the recent claim of the discovery of an isotope of a new element, *unbibium*, with a mass number of 292. This is over 50 mass units higher than uranium, the heaviest known naturally-occurring element. There is a possibility that there is an ‘island of stability’ beyond the known Periodic Table at some very high atomic numbers.

(i) The scientists suggested that the atomic number of *unbibium* is 122.

How many neutrons are there in this isotope? [1]

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(ii) If *unbibium* really exists then it will require a new block of the Periodic Table, corresponding to the occupancy of another type of subshell, beyond the ***s***, ***p***, ***d*** and ***f***. This would be a ***g*** subshell, which is predicted to be found in the 5th shell of an atom, i.e. the ***5g*** subshell.

Based on the sequence of subshells in the Periodic Table, ***s***, ***p***, ***d***, ***f***, predict how many orbitals there are in a ***g*** subshell. [1]

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[Total: 14]

2 **(a)** The halogens and their compounds have many applications.

(i) Explain, in terms of structure and bonding, the trend in the volatility of the halogens. [2]

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(ii) When heated in chlorine, phosphorous form phosphorus pentachloride, PCl_5.

Explain the reaction of PCl_5 with water. Include the pH value of the resulting solution and write equation for the reaction that occurs. [2]

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There is said to be a diagonal relationship between elements of the second and third periods of the Periodic Table.

(iii) By analogy with the reaction of $SiCl_4$, suggest a balanced equation for the hydrolysis of BCl_3. [1]

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(iv) Explain why BCl_3 can undergo hydrolysis like $SiCl_4$. [1]

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(b) Oxoanions of Group 17 elements have the general formula XO_m^-, where m = 1, 2, 3 or 4. These oxoanions are strong oxidising agents.

(i) Suggest why fluorine does not form higher oxoanions where $m \geq 2$. [1]

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(ii) Draw the structure of the ClO_3^- ion to show its shape. [1]

1.25×10^{-3} mol of an aqueous bromate salt containing the BrO_m^- anion was added to excess potassium iodide. The resulting mixture was washed with hexane to dissolve the iodine, and the aqueous and organic layers were separated. Upon adding silver nitrate to the aqueous layer, a yellow precipitate and a pale cream precipitate were obtained.

(iii) Identify the two precipitates formed. [1]

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(iv) The iodine collected in the organic layer was titrated against 0.500 mol dm^{-3} sodium thiosulfate. 14.90 cm^3 of titrant was required to discharge the blue-black colour of the starch indicator.

Calculate the number of moles of electrons transferred per mole of BrO_m^-.

Hence determine the value of m. [2]

(c) Fig. 2.1 shows two cells connected in series. **Cell 1** and **Cell 2** involve the electrolysis of saturated solution of $CuBr_2$ and concentrated HX respectively, where X is one of the Group 17 elements.

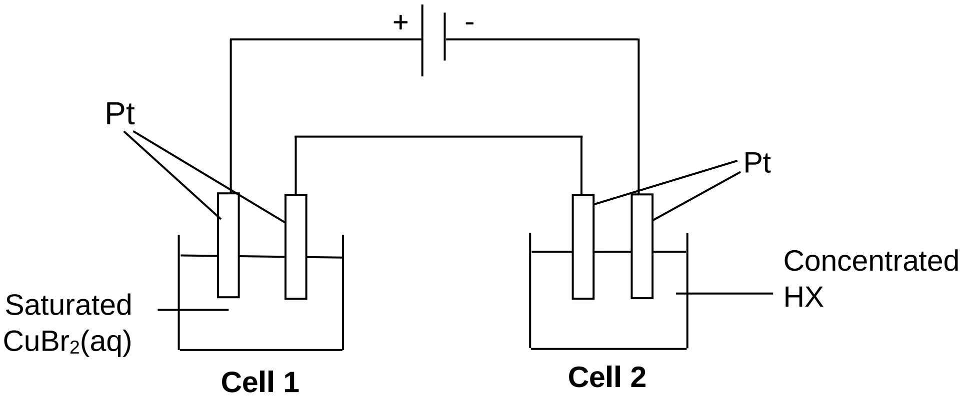

Fig. 2.1

(i) Write ion-electron equations for the reactions occurring at the cathode and anode in **Cell 1** during electrolysis. [2]

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(ii) A current of 22.8 A was passed through the saturated solution of $CuBr_2$ in **Cell 1**.

After 10 minutes, a halogen is formed at one of the electrodes in **Cell 2** and is collected by a syringe. It is found that the mass of the syringe increased by 5.04 g.

Identify X by calculating the M_r of the halogen produced. [2]

[Total: 15]

[Turn over

3 Table 3.1 shows the enthalpy change of combustion and hydrogenation of some substances.

Table 3.1

Substances	$\Delta H_{combustion}$ / kJ mol^{-1}	$\Delta H_{hydrogenation}$ / kJ mol^{-1}
but-1-ene (g)	-2717	-127
buta-1,3-diene (g)	-3187	-239
cyclopentadiene (g)	-2800	x
hydrogen (g)	-286	▨

(a) *Use of the Data Booklet is relevant to this question.*

0.422 g of but-1-ene, C_4H_8, was used to heat up 500 cm^3 of water from its initial temperature of 30 °C.

(i) Calculate the expected maximum temperature of the water. [2]

(ii) When the experiment was conducted in the laboratory, the maximum temperature of the water was found to be lower.

Suggest an explanation for this. [1]

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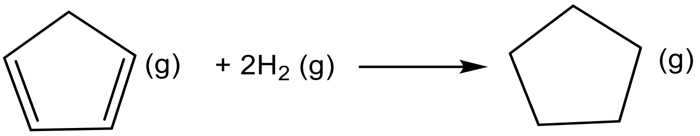
(b) Cyclopentadiene undergoes catalytic hydrogenation to form cyclopentane.



(i) Using data from the *Data Booklet*, calculate x, the enthalpy change of hydrogenation of gaseous cyclopentadiene. [2]

(ii) The hydrogenation reaction is thermodynamically favourable but it will not proceed without a catalyst.

Construct a labelled reaction pathway diagram to show how the addition of the catalyst speeds up the hydrogenation of cyclopentadiene.

Assume the hydrogenation of cyclopentadiene takes place via a one-step reaction. [2]

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(iii) Use data from Table 3.1 and the answer in **(b)(i)** to construct an energy cycle to calculate the enthalpy change of combustion of gaseous cyclopentane. [3]

(c) Alkadienes, such as buta-1,3-diene, are thermodynamically more stable due to conjugation where the π system exists over a series of atoms.

This extra stability can be shown by comparing the enthalpy change of hydrogenation of but-1-ene and buta-1,3-diene. Using data in Table 3.1, calculate the energy that is associated with the conjugated effect. [1]

[Turn over

(d) Buta-1,3-diene undergoes an equimolar addition reaction with HBr to produce a mixture of 1,2-addition and 1,4-addition products.

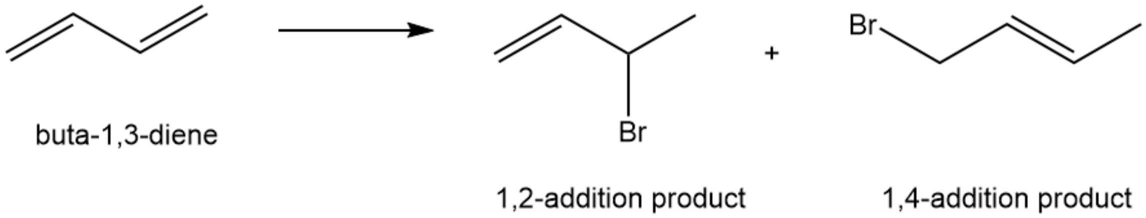

Fig. 3.1 shows the synthesis of compound **Q** from buta-1,3-diene. The first step involves a similar reaction to the above addition reaction between buta-1,3-diene and HBr.

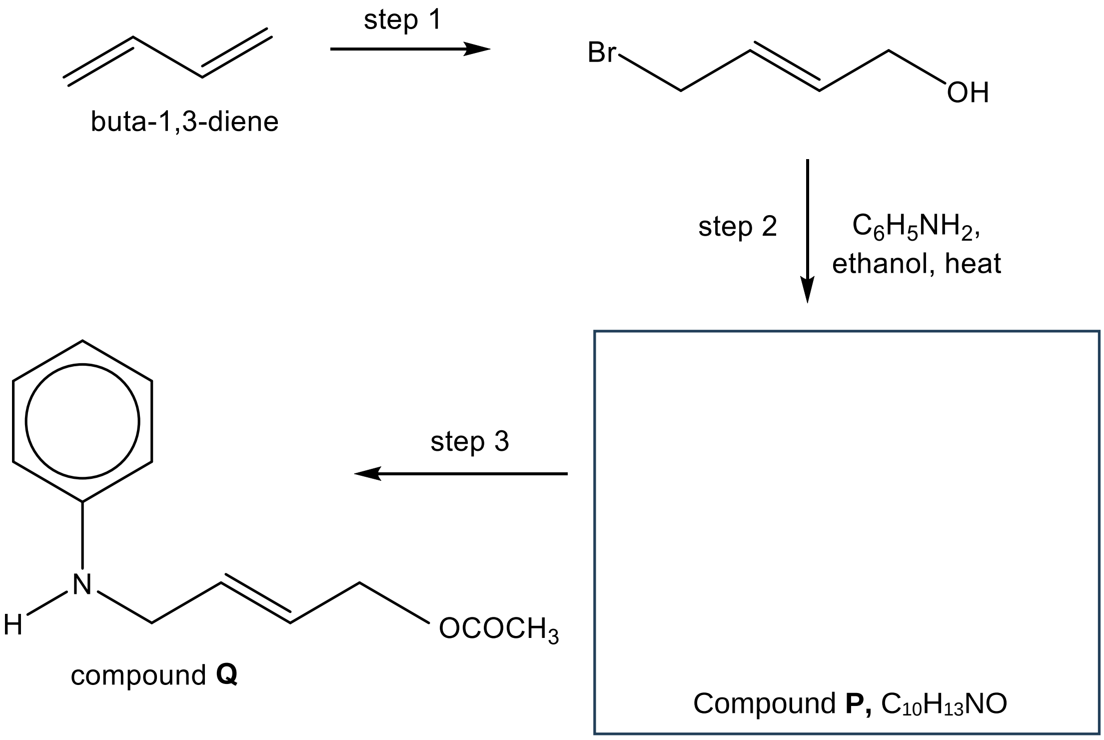

Fig. 3.1

(i) State the reagents and conditions for steps 1 and 3. [2]

Step 1: ....

Step 3: ....

(ii) Draw the structure of compound **P** in the box in **Fig. 3.1**. [1]

(iii) Suggest a chemical test between buta-1,3-diene and compound **Q**. [2]

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[Total: 16]

4 **(a)** The use of the *Data Booklet* is relevant to this question.

Iron is a transition element in Period 4 of the Periodic Table. The reaction scheme in Fig. 4.1 shows the chemistry of some iron-containing species.

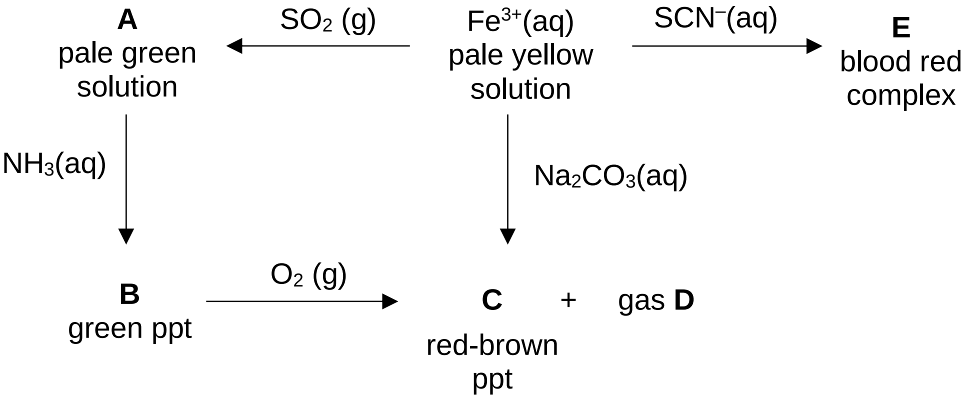

Fig. 4.1

(i) Define the term *transition element*. [1]

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(ii) State the full electronic configuration of an iron(III) ion. [1]

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(iii) State the role of NH_3(aq) in the reaction of **A** to form **B**.

Hence, explain the reactions taking place when NH_3(aq) is added to **A**. Include equations and the formula of all iron-containing species. [2]

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(iv) Identify compound **C** and gas **D**. [1]

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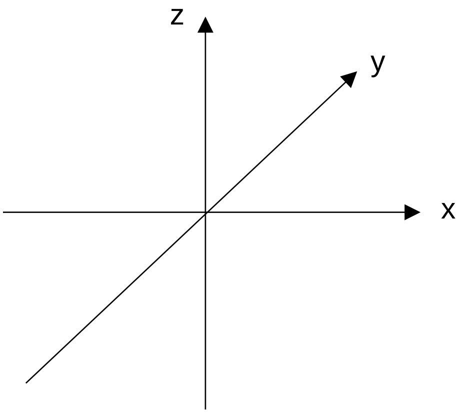
(v) When thiocyanate ions, SCN^-, is added to a solution of $Fe^{3+}(aq)$, an octahedral complex is formed.

Using the axes provided, sketch the shape of two d orbitals.

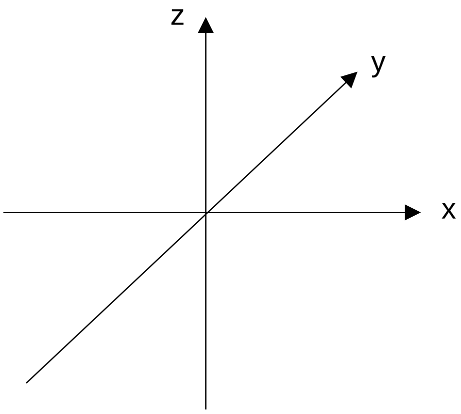
- One d orbital from the lower energy level in the octahedral complex.
- One d orbital from the higher energy level in the octahedral complex.

[2]

lower energy level



higher energy level



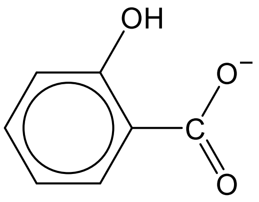
(vi) When SCN^- is added to $Fe^{3+}(aq)$, one water molecule of $Fe^{3+}(aq)$ is replaced by one SCN^- ion.

Draw a diagram to show the three-dimensional structure of the complex ion in **E**. Assume the SCN^- ligand coordinates via the N atom. [1]

[Turn over

(b) Transition metal complex ions are coloured. The formula of a complex ion can be determined using colorimetry. In colorimetry, the colorimeter is set to use the wavelength of light that is absorbed most strongly by the complex ion. The more concentrated the complex ion solution, the more intense its colour and so the higher the absorbance.

A purple complex is formed when salicylate, $C_6H_4(OH)CO_2^-$, is added to iron(III) ions, $Fe^{3+}(aq)$. A student carried out an experiment to determine the formula of complex ion formed between $Fe^{3+}(aq)$ and salicylate. Salicylate acts as a bidentate ligand, and has the structure shown below.



salicylate, $C_6H_4(OH)CO_2^-$

(i) State a colour in the visible spectrum from which a suitable wavelength of light might be chosen to test for the iron(III) complex formed with salicylate. [1]

(ii) Explain what is mean by the term *bidentate ligand*. [1]

The student prepared solutions containing different volumes of 0.025 mol dm^{-3} $Fe^{3+}(aq)$ and 0.050 mol dm^{-3} salicylate, and tested the absorbance of the solutions in the colorimeter.

Fig. 4.2 shows the relationship between absorbance and the volumes of $Fe^{3+}(aq)$ and aqueous salicylate used.

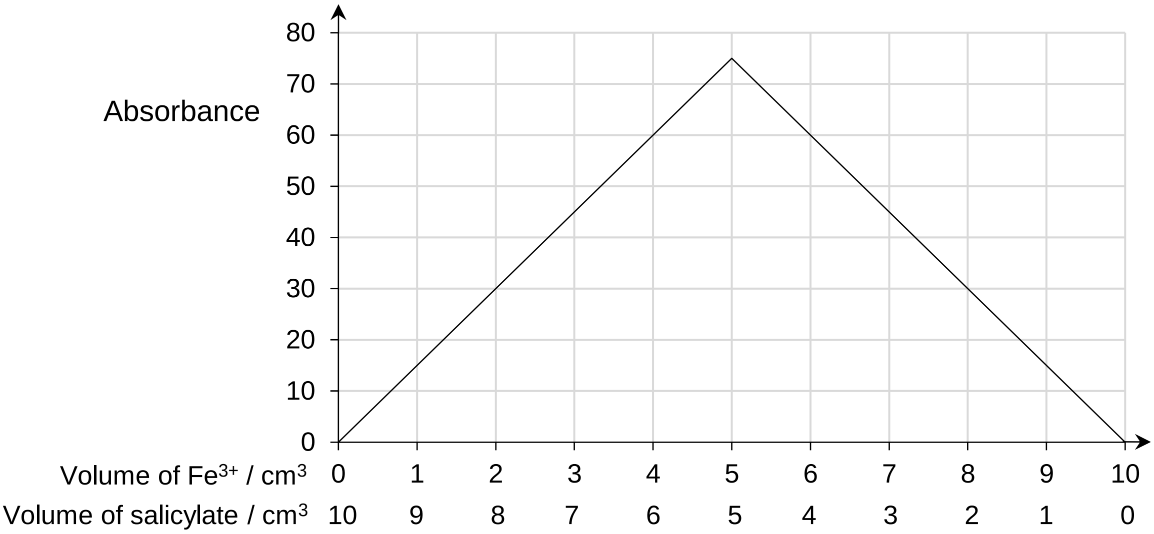


Fig. 4.2

(iii) The sample of Fe^{3+}(aq) was prepared from solid hydrated iron(III) nitrate, $Fe(NO_3)_3.9H_2O$.

Determine the mass of $Fe(NO_3)_3.9H_2O$ needed to prepare 250 cm^3 of a standard solution of 0.025 mol dm^{-3} Fe^{3+}(aq). [2]

(iv) Using Fig. 4.2, determine the number of moles of salicylate that forms a complex with 1 mole of Fe^{3+} ion. [2]

(v) Given that the iron(III) complex formed has a coordination number of 6, determine the formula of the complex ion formed between Fe^{3+}(aq) and salicylate, $C_6H_4(OH)CO_2^{-}$. [1]

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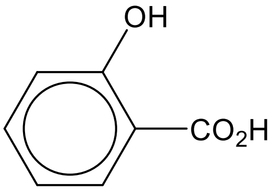
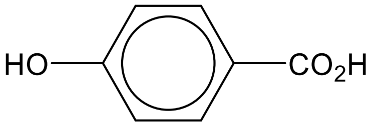
[Turn over

(c) The structures of salicylic acid and its isomer, **T**, are shown below.



salicylic acid

pK_a = 2.98



T

pK_a = 4.58

(i) With the aid of a suitable diagram, explain why the pK_a of salicylic acid is much lower than pK_a of **T**. [2]

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Aqueous sodium hydroxide is added to salicylic acid to form a buffer containing salicylic acid $C_6H_4(OH)CO_2H$ and sodium salicylate, $C_6H_4(OH)CO_2Na$.

(ii) Construct an equation to illustrate how this buffer can regulate the pH change when a small amount of alkali is added. [1]

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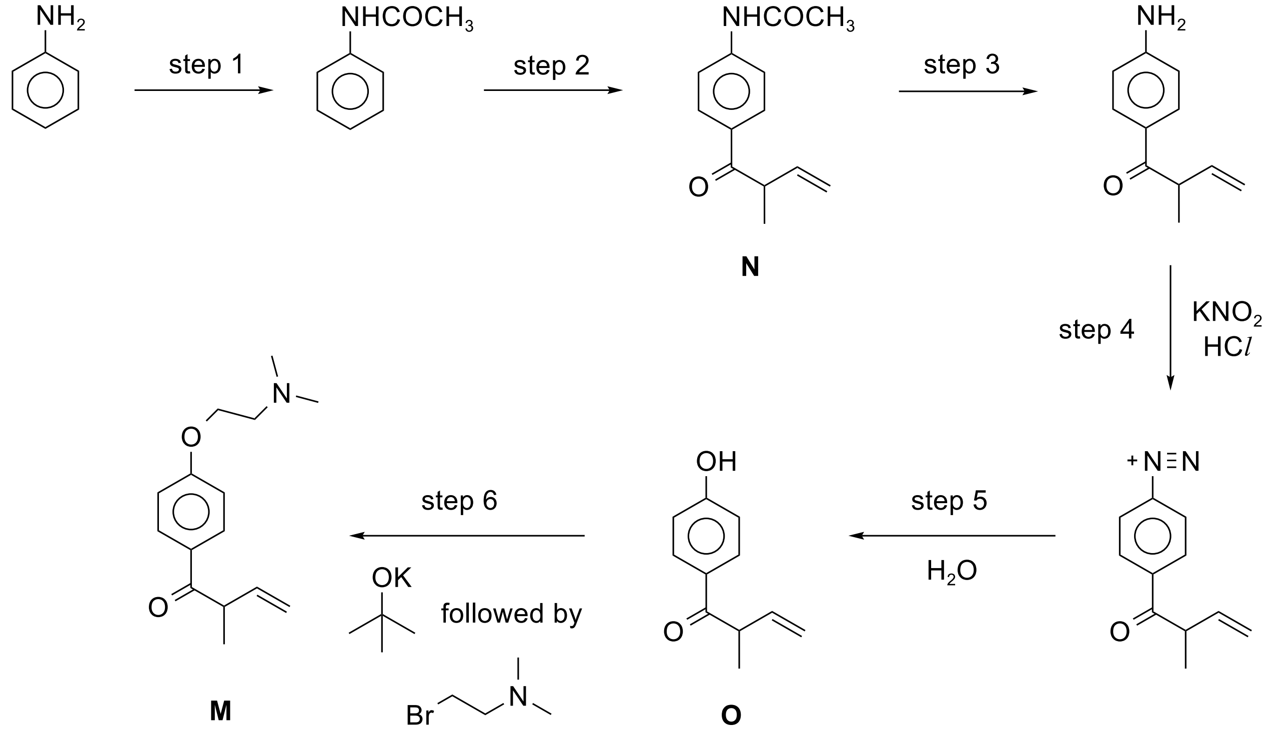
(iii) Calculate the volume of 0.200 mol dm^{-3} NaOH solution needed to mix with 15.0 cm^3 of a 0.100 mol dm^{-3} solution of salicylic acid to obtain a pH of 3.5. [2]

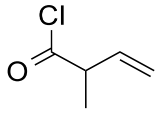
[Total: 20]

5 Phenylamine undergoes the following reaction scheme to produce compound **M**.



(a) **(i)** Suggest the reagent in step 1. [1]

(ii)



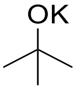
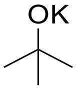
functions as an *electrophile* in step 2.

Explain the term *electrophile*. [1]

(iii) A student claimed that he was able to obtain compound **N** by carrying out step 2 directly on phenylamine.

Explain whether the student's claim is valid or not. [1]

(iv) Identify the oxidation states of the N atoms in the organic compounds before and after step 4. [1]

(v) With reference to the role of , explain why step 6 would not occur in the absence of . [1]

(b) **(i)** Compound **O** reacts with sodium borohydride to give **P**.

Deduce the structure of **P**. [1]

(ii) Explain the difference in reactivity between the alkene and the ketone functional groups towards sodium borohydride. [2]

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(c) After step 6 is completed, by-product **Q** is produced alongside **M**. Further analysis revealed that **Q** is $C_8H_{20}N_2Br_2$.

Draw the structure of **Q** and explain how it is formed as a by-product. [2]

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[Total: 10]

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