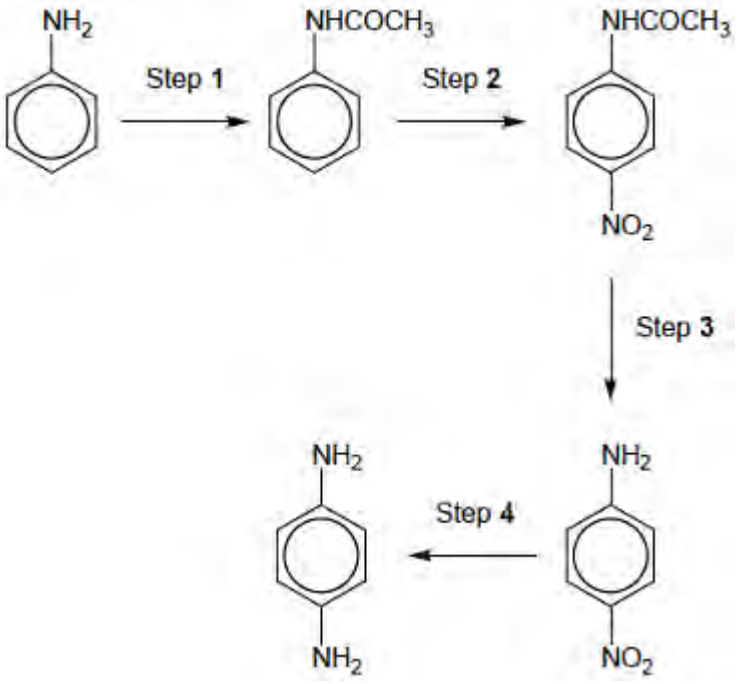
Q1. 1,4-diaminobenzene is an important intermediate in the production of polymers such as Kevlar and also of polyurethanes, used in making foam seating.

A possible synthesis of 1,4-diaminobenzene from phenylamine is shown in the following figure.



(a) A suitable reagent for step **1** is CH_3COCl

Name and draw a mechanism for the reaction in step **1**.

Name of mechanism .....

Mechanism

(5)

(b) The product of step **1** was purified by recrystallisation as follows.

The crude product was dissolved in **the minimum quantity of hot water** and the hot solution was filtered through a hot filter funnel into a conical flask. This filtration removed any insoluble impurities. The flask was **left to cool to room temperature**. The crystals formed were filtered off using a Buchner funnel and a clean cork was used **to compress the crystals in the funnel. A little cold water was then poured through the crystals.**
After a few minutes, the crystals were removed from the funnel and weighed.
A small sample was then used to find the melting point.

Give reasons for each of the following practical steps.

The minimum quantity of hot water was used

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The flask was cooled to room temperature before the crystals were filtered off

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The crystals were compressed in the funnel

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A little cold water was poured through the crystals

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(4)

(c) The melting point of the sample in part (b) was found to be slightly lower than a data-book value.

Suggest the most likely impurity to have caused this low value and an improvement to the method so that a more accurate value for the melting point would be obtained.

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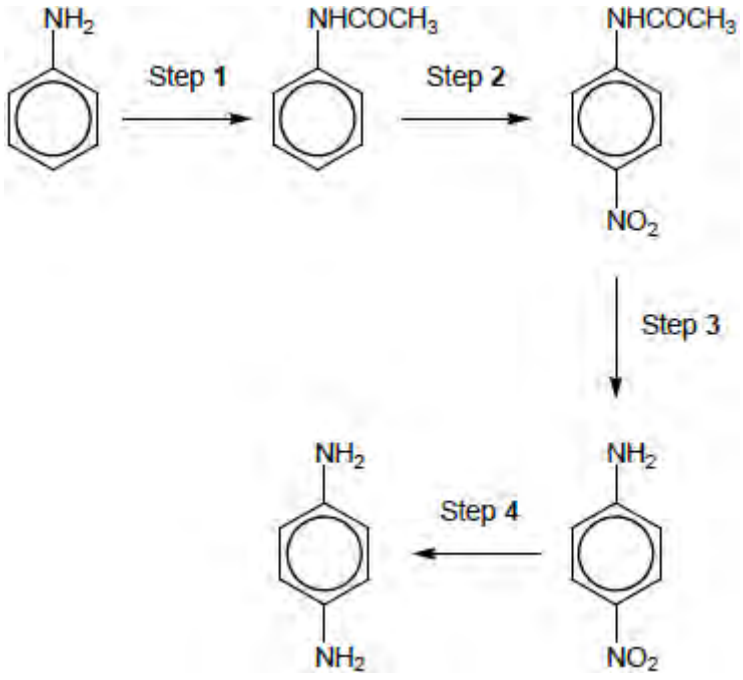
(2)

The figure above is repeated here to help you answer the following questions.



(d) In an experiment starting with 5.05 g of phenylamine, 4.82 g of purified product were obtained in step **1**.

Calculate the percentage yield in this reaction.
Give your answer to the appropriate number of significant figures.

Percentage yield = ...%

(3)

(e) A reagent for step **2** is a mixture of concentrated nitric acid and concentrated sulfuric acid, which react together to form a reactive intermediate.

Write an equation for the reaction of this intermediate in step **2**.

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(1)

(f) Name a mechanism for the reaction in step **2**.

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(1)

(g) Suggest the type of reaction occurring in step **3**.

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(1)

(h) Identify the reagents used in step **4**.

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(1)

(Total 18 marks)

Q2. The alcohol 2-methylpropan-2-ol, $(CH_3)_3COH$, reacts to form esters that are used as flavourings by the food industry. The alcohol can be oxidised to produce carbon dioxide and water.

A student carried out an experiment on a pure sample of 2-methylpropan-2-ol to determine its enthalpy of combustion. A sample of the alcohol was placed into a spirit burner and positioned under a beaker containing 50 cm^3 of water. The spirit burner was ignited and allowed to burn for several minutes before it was extinguished.

The results for the experiment are shown in **Table 1**.

Table 1

Initial temperature of the water / °C	18.1
Final temperature of the water / °C	45.4
Initial mass of spirit burner and alcohol / g	208.80
Final mass of spirit burner and alcohol / g	208.58

(a) Use the results from **Table 1** to calculate a value for the heat energy released from the combustion of this sample of 2-methylpropan-2-ol.
The specific heat capacity of water is 4.18 $J\ K^{-1}\ g^{-1}$.
Show your working.

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(2)

(b) Calculate the amount, in moles, of 2-methylpropan-2-ol burned in the experiment.
Hence calculate a value, in $kJ\ mol^{-1}$, for the enthalpy of combustion of 2-methylpropan-2-ol.
Show your working.

(If you were unable to calculate an answer to part (a), you should assume that the heat energy released was 5580 J. This is **not** the correct value.)

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(3)

(c) An equation for the combustion of 2-methylpropan-2-ol is

$$(CH_3)_3COH(l) + 6O_2(g) \longrightarrow 4CO_2(g) + 5H_2O(l)$$

Table 2 contains some standard enthalpy of formation data.

Table 2

	$(CH_3)_3COH(l)$	$O_2(g)$	$CO_2(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ **/ kJ mol^{-1}**	–360	0	–393	–286

Use the data from **Table 2** to calculate a value for the standard enthalpy of combustion of 2-methylpropan-2-ol. Show your working.

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(3)

(d) An accurate value for the enthalpy of combustion of 2-methylpropan-2-ol in which water is formed as a gas is –2422 kJ mol^{-1}.

Use this value and your answer from part (b) to calculate the overall percentage error in the student's experimental value for the enthalpy of combustion of 2-methylpropan-2-ol.

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(1)

(e) Suggest **one** improvement that would reduce errors due to heat loss in the student's experiment.

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(1)

(f) Suggest **one** other source of error in the student's experiment. Do **not** include heat loss, apparatus error or student error.

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(1)
(Total 11 marks)

Q3. A student carried out an experiment to find the mass of $FeSO_4.7H_2O$ in an impure sample, **X**.
The student recorded the mass of **X**. This sample was dissolved in water and made up to 250 cm^3 of solution.
The student found that, after an excess of acid had been added, 25.0 cm^3 of this solution reacted with 21.3 cm^3 of a 0.0150 mol dm^{-3} solution of $K_2Cr_2O_7$

(a) Use this information to calculate a value for the mass of $FeSO_4.7H_2O$ in the sample of **X**.

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(5)

(b) The student found that the calculated mass of $FeSO_4.7H_2O$ was greater than the actual mass of the sample that had been weighed out. The student realised that this could be due to the nature of the impurity.

Suggest **one** property of an impurity that would cause the calculated mass of $FeSO_4.7H_2O$ in **X** to be greater than the actual mass of **X**.
Explain your answer.

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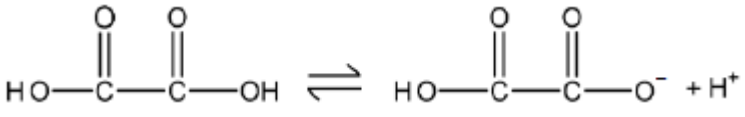
(2)
(Total 7 marks)

Q4. Ethanedioic acid is a weak acid.
Ethanedioic acid acts, initially, as a monoprotic acid.



(a) Use the concept of electronegativity to justify why the acid strengths of ethanedioic acid and ethanoic acid are different.

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(6)

(b) A buffer solution is made by adding 6.00×10^{-2} mol of sodium hydroxide to a solution containing 1.00×10^{-1} mol of ethanedioic acid ($H_2C_2O_4$).
Assume that the sodium hydroxide reacts as shown in the following equation and that in this buffer solution, the ethanedioic acid behaves as a monoprotic acid.

$$H_2C_2O_4(aq) + OH^-(aq) \longrightarrow HC_2O_4^-(aq) + H_2O(l)$$

The dissociation constant K_a for ethanedioic acid is 5.89×10^{-2} mol dm^{-3}.

Calculate a value for the pH of the buffer solution.
Give your answer to the appropriate number of significant figures.

pH = ...

(5)

(c) In a titration, the end point was reached when 25.0 cm^3 of an acidified solution containing ethanedioic acid reacted with 20.20 cm^3 of 2.00×10^{-2} mol dm^{-3} potassium manganate(VII) solution.

Deduce an equation for the reaction that occurs and use it to calculate the original concentration of the ethanedioic acid solution.

Equation .....

Calculation

Original concentration = ... mol dm^{-3}

(4)
(Total 15 marks)

Q5. Sodium phosphate and ammonia are formed when ammonium phosphate is heated with sodium hydroxide solution in a conical flask. There is **one** other product in this reaction.

(a) Complete and balance the equation for the reaction of ammonium phosphate with sodium hydroxide.

$(NH_4)_3PO_4$ + ... NaOH ⟶ Na_3PO_4 + ... NH_3 + ...

(2)

(b) Ammonia is an alkaline gas. Describe how you would use a named indicator to show that ammonia gas is released from the flask in this reaction. State the colour change that you would observe.

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(2)
(Total 4 marks)