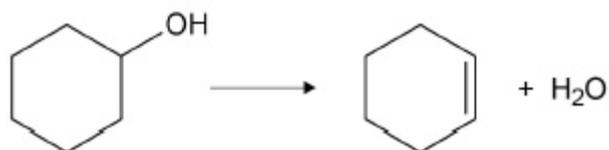


**Q15.**

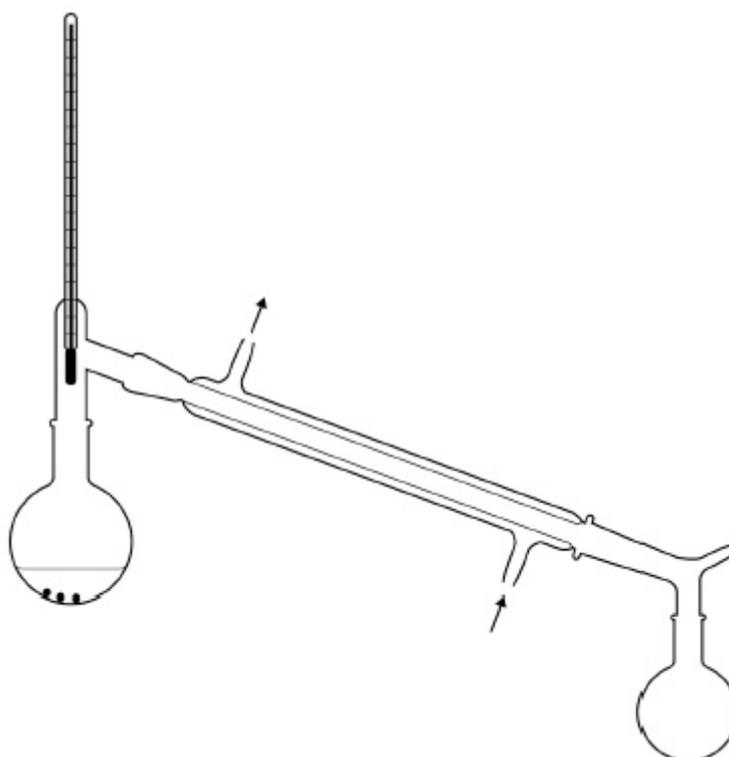
Cyclohexene (boiling point = 83 °C) can be prepared by the dehydration of cyclohexanol (boiling point = 161 °C) using concentrated phosphoric acid.



A student prepared cyclohexene by placing 10 cm³ of cyclohexanol (density = 0.96 g cm⁻³) into a round-bottomed flask.

3 cm³ of concentrated phosphoric acid were then carefully added to the flask.

The student added a few anti-bumping granules and set up the apparatus shown in the diagram.



- The student heated the mixture and collected the liquid that distilled at temperatures below 100 °C
- The distillate was poured into a separating funnel and washed by shaking with sodium carbonate solution.
- Periodically, the separating funnel was inverted and the tap opened.
- The aqueous layer was discarded and the final organic product was dried using anhydrous calcium chloride.
- After the product was dried, the drying agent was removed by filtration under reduced pressure.



- (a) The student collected 5.97 g of cyclohexene in the experiment.

Calculate the percentage yield of cyclohexene.

Percentage yield _____ %

(3)

- (b) Describe a test-tube reaction, on the product, to show that the cyclohexanol had been dehydrated.

State what you would observe. _____

(2)

- (c) Suggest why sodium carbonate solution was used to wash the distillate.

(1)

- (d) Explain why it is important to open the tap of the separating funnel periodically.

(1)

- (e) Give a property of anhydrous calcium chloride, other than its ability to absorb water, that makes it suitable as a drying agent in this preparation.

(1)



- (f) Describe the apparatus used to remove the drying agent by filtration under reduced pressure. Your description of the apparatus can be either a labelled diagram or a description in words.

(2)

- (g) A sample of cyclohexene has been contaminated with cyclohexanol. The cyclohexene can be separated from the cyclohexanol by column chromatography. Silica gel is used as the stationary phase and hexane as the mobile phase.

Explain why cyclohexene has a shorter retention time than cyclohexanol.

(2)

- (h) Explain how an infrared spectrum would confirm that the cyclohexene obtained from the chromatography column did not contain any cyclohexanol.

(1)

(Total 13 marks)

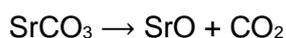
**Q16.**

A sample of strontium ore is known to contain strontium oxide, strontium carbonate and some inert impurities. To determine the mass of strontium carbonate present, a student weighed a sample of the solid ore and then heated it in a crucible for 5 minutes. The sample was allowed to cool and then reweighed. This heating, cooling and reweighing was carried out three times.

The results are set out in the table.

Mass of crucible / g	9.85
Mass of crucible and ore sample / g	16.11
Mass of crucible and sample after first heating / g	14.66
Mass of crucible and sample after second heating / g	14.58
Mass of crucible and sample after third heating / g	14.58

- (a) When strontium carbonate is heated it decomposes according to the following equation.



Give a reason why the mass of the solid sample changed during the experiment.

(1)

- (b) Use the data in the table to calculate the mass of strontium carbonate in the original ore sample. Give your answer to an appropriate precision.

Mass of strontium carbonate = ___ g

(5)



- (c) Each balance reading has an uncertainty of ± 5.00 mg.

Calculate the percentage error in the initial mass of ore used.

Percentage error = _____ %

(1)

- (d) The mass of inert impurities in the sample was 347 mg.

Deduce the mass of SrO in the sample and justify any assumption made in calculating your answer.

(If you have been unable to answer part (b), assume the mass of strontium carbonate was 4.85 g. This is **not** the correct answer.)

Mass of SrO = _____

(2)

- (e) Strontium metal can be extracted by heating strontium oxide with aluminium metal.

In this reaction, strontium vapour and solid aluminium oxide are formed.

Write an equation for the reaction and state the role of the aluminium in the process. Explain why strontium forms a vapour but aluminium oxide is formed as a solid.

Equation

Role of aluminium _____

Explanation _____

(5)

(Total 14 marks)



- (b) The students collected a 20 cm³ sample of liquid and weighed it. The mass of the sample was 16 g.

The density of ethanol is 0.79 g cm⁻³ and that of water 1.00 g cm⁻³.

Use these data to calculate the mass of ethanol in the sample collected.

You should assume that the volume of the sample is equal to the sum of the volumes of water and ethanol.

Mass of ethanol = _____ g

(2)

(Total 8 marks)

Q18.

This question is about reactions of calcium compounds.

- (a) A pure solid is thought to be calcium hydroxide. The solid can be identified from its relative formula mass.

The relative formula mass can be determined experimentally by reacting a measured mass of the pure solid with an excess of hydrochloric acid. The equation for this reaction is



The unreacted acid can then be determined by titration with a standard sodium hydroxide solution.

You are provided with 50.0 cm³ of 0.200 mol dm⁻³ hydrochloric acid.

Outline, giving brief practical details, how you would conduct an experiment to calculate accurately the relative formula mass of the solid using this method.



(8)

- (b) A 3.56 g sample of calcium chloride was dissolved in water and reacted with an excess of sulfuric acid to form a precipitate of calcium sulfate.

The percentage yield of calcium sulfate was 83.4%.

Calculate the mass of calcium sulfate formed.

Give your answer to an appropriate number of significant figures.

Mass of calcium sulfate formed = _____ g

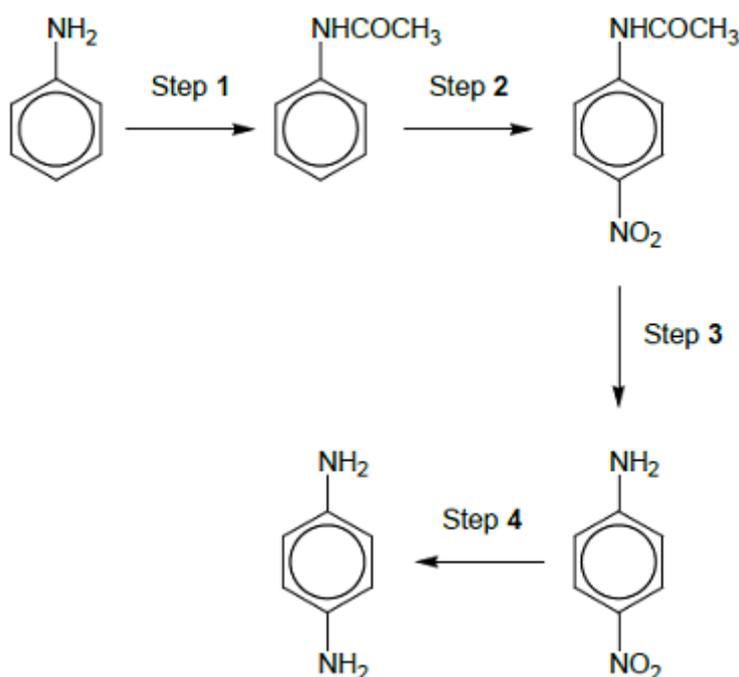
(3)

(Total 11 marks)

Q19.

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

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

The crystals were compressed in the funnel

A little cold water was poured through the crystals



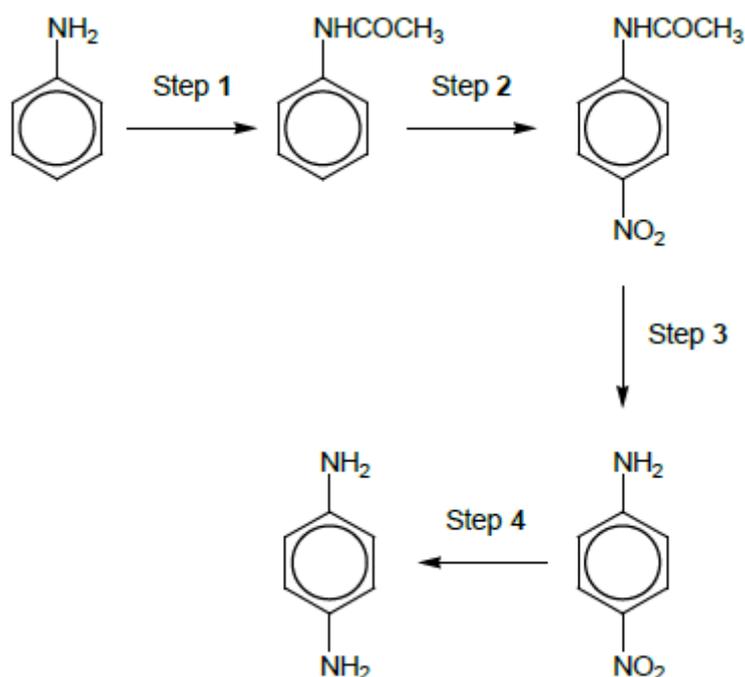
(4)

- (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.

(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.

(1)

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

(1)

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

(1)

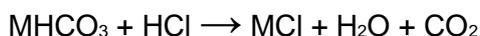
- (h) Identify the reagents used in step 4.

(1)

(Total 18 marks)

**Q20.**

This question is about a white solid, MHCO_3 , that dissolves in water and reacts with hydrochloric acid to give a salt.



A student was asked to design an experiment to determine a value for the M_r of MHCO_3 . The student dissolved 1464 mg of MHCO_3 in water and made the solution up to 250 cm^3 . 25.0 cm^3 samples of the solution were titrated with $0.102 \text{ mol dm}^{-3}$ hydrochloric acid. The results are shown in the table.

	Rough	1	2	3
Initial burette reading / cm^3	0.00	10.00	19.50	29.25
Final burette reading / cm^3	10.00	19.50	29.25	38.90
Titre / cm^3	10.00	9.50	9.75	9.65

- (a) Calculate the mean titre and use this to determine the amount, in moles, of HCl that reacted with 25.0 cm^3 of the MHCO_3 solution.

(3)

- (b) Calculate the amount, in moles, of MHCO_3 in 250 cm^3 of the solution. Then calculate the experimental value for the M_r of MHCO_3 . Give your answer to the appropriate number of significant figures.

(3)



- (c) The student identified use of the burette as the largest source of uncertainty in the experiment.

Using the same apparatus, suggest how the procedure could be improved to reduce the percentage uncertainty in using the burette.

Justify your suggested improvement.

Suggestion _____

Justification _____

(2)

- (d) Another student is required to make up 250 cm³ of an aqueous solution that contains a known mass of MHCO_3 . The student is provided with a sample bottle containing the MHCO_3 .

Describe the method, including apparatus and practical details, that the student should use to prepare the solution.

(6)

(Total 14 marks)

**Mark Scheme****Q15.**

- (a) **M1** Moles of cyclohexanol = $(10 \times 0.96)/100.0 = 0.096$
Correct answer scores all 3 marks 1
- M2** Max mass of cyclohexene = $0.096 \times 82.0 = 7.87(2)$
 $= M1 \times 82.0$ (process mark) 1
- M3** % yield = $(5.97 / 7.87) \times 100 = 76\%$ (Allow range 75.8 – 76)
 $= (5.97 / M2) \times 100$ (process mark) 1
- Alternative method
- M1** Moles of cyclohexanol = $(10 \times 0.96)/100.0 = 0.096$
- M2** Moles of cyclohexene = $5.97/82.0 = 0.0728$
- M3** % yield = $0.0728 / 0.096 \times 100 = 76\%$ (allow range 75.8 – 76)
 $= (M2 / M1) \times 100$
Allow 1/3 for 62(.2)%
- (b) Add bromine (water)
If M1 not correct then only allow M2 if reagent involves bromine (water) 1
- Would turn (from orange to) colourless / decolourise
Do not allow incorrect starting colour, but allow brown/red/yellow
Not discolour.
Ignore clear 1
- (c) Na_2CO_3 would neutralise/react with/remove (phosphoric) acid/ $\text{H}_3\text{PO}_4/\text{H}^+$ 1
- (d) avoid pressure build-up / release pressure / release CO_2 /air/gas / prevent stopper blowing out
Ignore explosion
Do not allow an incorrect named gas
Allow idea that build-up of gas/ CO_2 would lead to increased pressure/stated effect of increased pressure 1
- (e) Does not dissolve in/react with the cyclohexene
Allow remains a solid/is inert in cyclohexene
Allow organic product/organic compound formed/ organic layer/distillate instead of cyclohexene
Do not allow if answer implies cyclohexanol



Do not allow if answer says does not react with products
Ignore references to filtration
Do not allow insoluble/unreactive unless qualified by implied
reference to cyclohexene

1

(f) If diagram drawn:

M1 diagram of basic set up to include flask or tube with side-arm/Buchner flask, flat-bottomed funnel/Buchner funnel, filter paper

M2 apparatus should work, flow through, air-tight connection between flask and funnel, arrow/label/description (to vacuum pump)

Do not allow "standard" Y-shaped funnel

1

If description given:

M1 Buchner funnel/flat-bottomed funnel containing filter paper

M2 Buchner flask/side-arm flask connected to vacuum pump

Do not allow just "funnel"

Penalise M2 if described apparatus would not actually work.

1

(g) Cyclohexene is less polar than cyclohexanol / cyclohexanol is more polar than cyclohexene

It = cyclohexene

Allow cyclohexene is non-polar and cyclohexanol is polar

1

Cyclohexene has a greater affinity/attraction for the mobile phase/hexane / cyclohexanol has a greater affinity/attraction for the stationary phase/silica

Allow cyclohexanol held in the stationary phase for longer

Allow cyclohexene is more soluble in the mobile phase/hexane or converse for cyclohexanol

Allow references to hydrogen bonds between cyclohexanol and silica

1

(h) Would be no peak at $3230 - 3550 \text{ cm}^{-1}$ due to O—H((alcohol))

OR

There would be no additional peaks in the fingerprint region compared to a pure sample / fingerprint region exactly matches cyclohexene

Need wavenumber and bond for mark

1

[13]

Q16.

(a) CO_2 gas escapes or is lost

1



(b) Mass CO₂ = 16.11 – 14.58 = 1.53 g 1

$$M_r \text{ CO}_2 = 44.0$$

$$\text{Mol CO}_2 = 1.53 / 44.0 = 3.48 \times 10^{-2} \quad 1$$

$$\text{Mol SrCO}_3 = 3.48 \times 10^{-2} \quad 1$$

$$\text{Mass SrCO}_3 = \text{mol} \times M_r = 3.48 \times 10^{-2} \times 147.6$$

$$\text{Mass SrCO}_3 = 5.13 \text{ (g)}$$

1 mark for the answer and 1 for 3 sf precision

Allow 5.14 g (as a result of rounding)

2

(c) Percentage error = $\frac{0.01}{6.26} \times 100$

$$= 0.160 \text{ (\%)}$$

1

(d) Original Mass SrO = 6.26 – 0.347 – 5.13

$$= 0.783 \text{ g (or 783 mg)}$$

$$\text{OR } 6.26 - 0.347 - 4.85 = 1.063 \text{ g}$$

Allow 0.773 g or 773 mg (from rounding error in part (b))

1

Justification: All SrCO₃ reacted because heated to constant mass.

1



1

Al acts as a reducing agent

1

Sr is collected as a vapour because

1

Al₂O₃ is an ionic lattice and so has strong ionic attractions

1

Than Sr which is a metallic structure with (relatively) weaker bonding

1

[14]

Q17.

- (a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3

All stages are covered and the explanation of each stage is generally correct and virtually



complete.

Answer communicates the whole process coherently and shows a logical progression through the distillation apparatus. The first two points in stage 1 are in the correct order and all other steps are in a logical order for carrying out the practical.

5-6 marks

Level 2

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies.

Answer is mainly coherent and shows a progression through the distillation apparatus.

Some steps in each stage may be out of order and incomplete but the first two points in stage 1 are in the correct order.

3-4 marks

Level 1

Most points are covered but the explanation of each stage may be incomplete or may contain inaccuracies.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning. The first two points in stage 1 are present but not necessarily in the correct order.

1-2 marks

Level 0

Insufficient correct chemistry to warrant a mark.

Omission of heating of the apparatus.

0 marks

Indicative content:

Stage 1

- *Turn on the water.*
- *Heat the flask, with a Bunsen burner.*
- *This causes water and ethanol vapours to be produced.*

Stage 2

- *Vapours pass up the fractionating column A.*
- *Water and ethanol are separated in column A.*
- *Water condenses back into the flask in column A.*

Stage 3

- *Observe the thermometer at B to keep the temperature at or below the boiling point of ethanol.*
Only ethanol vapour (with a little water) passes into the condenser.
- *Use the condenser at part C to cool the vapours and condense the ethanol back into a liquid.*

(b) Volume of sample = volume of ethanol + volume of water

Let m = mass of ethanol

$$20 = m / 0.79 + (16 - m) / 1.00$$



$$1.266m - m = 20 - 16$$

1

$$0.266m = 4 \text{ so } m = 15 \text{ (g)}$$

1

[8]

Q18.

- (a) Stage 1: appreciation that the acid must be in excess and calculation of amount of solid that permits this

Statement that there must be an excess of acid

1

$$\text{Moles of acid} = 50.0 \times 0.200 / 1000 = 1.00 \times 10^{-2} \text{ mol}$$

1

2 mol of acid react with 1 mol of calcium hydroxide therefore moles of solid weighed out must be less than half the moles of acid = $0.5 \times 1.00 \times 10^{-2} = 5.00 \times 10^{-3} \text{ mol}$

1

$$\text{Mass of solid must be } 5.00 \times 10^{-3} \times 74.1 =$$

1

Stage 2: Experimental method

Measure out 50 cm³ of acid using a pipette and add the weighed amount of solid in a conical flask

1

Titrate against 0.100 (or 0.200) mol dm⁻³ NaOH added from a burette and record the volume (v) when an added indicator changes colour

1

Stage 3: How to calculate M_r from the experimental data

$$\text{Moles of calcium hydroxide} = 5.00 \times 10^{-3} - (v/2 \times \text{conc NaOH}) / 1000 = z \text{ mol}$$

1

$$M_r = \text{mass of solid} / z$$

1

Extended response

Maximum of 7 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

- (b) Moles of calcium chloride = $3.56 / 111.1 = 3.204 \times 10^{-2}$

1

$$\text{Moles of calcium sulfate} = 3.204 \times 10^{-2} \times 83.4 / 100 = 2.672 \times 10^{-2}$$

1

$$\text{Mass of calcium sulfate} = 2.672 \times 10^{-2} \times 136.2 = 3.6398 = 3.64 \text{ (g)}$$

Answer must be to 3 significant figures

1

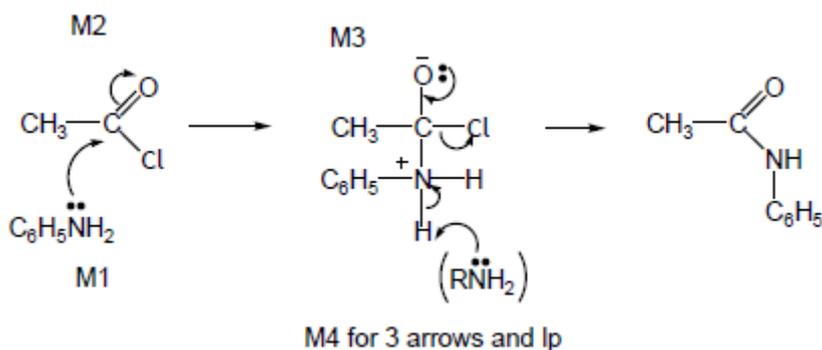
[11]



Q19.

- (a) (nucleophilic) addition-elimination
Not electrophilic addition-elimination

1



Allow C_6H_5 or benzene ring

Allow attack by $:NH_2C_6H_5$

M2 not allowed independent of M1, but allow M1 for correct attack on C^+

M3 for correct structure with charges but lone pair on O is part of M4

M4 (for three arrows and lone pair) can be shown in more than one structure

4

- (b) **The minimum quantity of hot water was used:**

To ensure the hot solution would be saturated / crystals would form on cooling

1

The flask was left to cool before crystals were filtered off:

Yield lower if warm / solubility higher if warm

1

The crystals were compressed in the funnel:

Air passes through the sample not just round it

Allow better drying but not water squeezed out

1

A little cold water was poured through the crystals:

To wash away soluble impurities

1

- (c) Water

Do not allow unreacted reagents

1

Press the sample of crystals between filter papers

Allow give the sample time to dry in air

1



(d) M_r product = 135.0

1

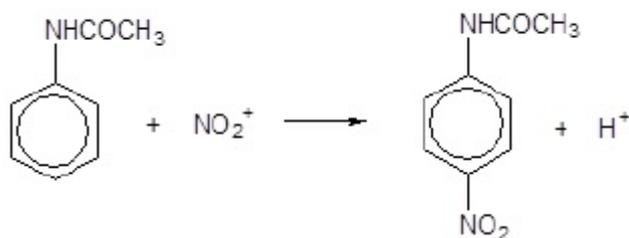
$$\text{Expected mass} = 5.05 \times \frac{135.0}{93.0} = 7.33 \text{ g}$$

1

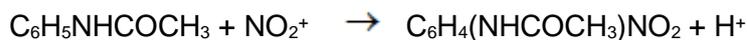
$$\text{Percentage yield} = \frac{4.82}{7.33} \times 100 = 65.75 = 65.8(\%)$$

Answer must be given to this precision

(e)



OR



1

(f) Electrophilic substitution

1

(g) Hydrolysis

1

(h) Sn / HCl

Ignore acid concentration; allow Fe / HCl

1

[18]

Q20.

(a) Selects correct titres

If 3 or more titres used them MAX 1 for conseq M3

1

$$\begin{aligned} \text{mean titre} &= \frac{9.75 + 9.65}{2} \\ &= 9.7(0) \text{ cm}^3 \\ &\text{Calculates mean} \end{aligned}$$

1

$$\text{mol HCL} = 0.102 \times 9.70/1000 = 9.89 \times 10^{-4}$$

(allow 9.9×10^{-4} for M3 but check not via 4 titres in which case only 1 mark)

Calculates mol (working or result gains credit)

9.92×10^{-4} scores 1 if all 4 titres used



9.83×10^{-4} scores 1 if titres 1,2, and 3 used

1

- (b) mol $\text{MHCO}_3 = \text{ANS } 3.1 \times 10 (= 9.89 \times 10^{-3})$
Use ecf if wrong mean calculated above

1

$$\text{Mr} = \frac{1464/1000}{M1}$$

1

Mr = 148 (3sf)

Allow ecf following wrong mass conversion

1

- (c) Suggestion: Use a larger mass of solid OR use a more concentrated solution of MHCO_3 OR less concentrated / more dilute solution of HCl OR more MHCO_3

1

Cannot score justification mark unless suggestion correct, but suggestion could be after justification

Justification: So a larger titre/reading will be needed OR larger volume of HCl
Assume reference to the solution means the MHCO_3

1

- (d) This question is marked using levels of response.

Level 3

Must use volumetric flask to access level 3
 Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.

All stages are covered and the description of each stage is complete

6 marks

All stages are covered but up to 2 omissions/errors from different stages. If 2 omissions/errors from same stage only level 2 possible

5 marks

Level 2

Answer is mainly coherent and shows progression from stage 1 to stage 3

All stages are covered but 3 omissions/errors

4 marks

All stages are attempted

3 marks

Level 1

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

2 stages attempted

2 marks

1 stage attempted

1 mark

**Level 0**

Insufficient correct chemistry to gain a mark.

0 marks

Indicative Chemistry content**Stage 1:** transfers known mass of solid

a) Weigh the sample bottle containing the solid on a (2 dp) balance

b) Transfer to beaker* and reweigh sample bottle

c) Record the difference in mass

Or

d) Place beaker* on balance and tare

e) Transfer solid into beaker

f) Record mass

Or

g) Known mass provided

h) Transfers (known) mass into beaker*

i) Wash all remaining solid from sample bottle into beaker

Allow use of weighing boat

*Allow other suitable glassware including volumetric flask

Stage 2: Dissolves in water

a) Add distilled / deionised water

b) Stir (with a glass rod) or swirl

c) Until all solid has dissolved

Stage 3: Transfer, washing and agitationa) Transfer to volumetric / graduated flask. Allow if a clear description/diagram given eg long necked flask with 250 cm³ mark

b) With washings

c) Make up to 250 cm³ / mark with water

d) Shakes/inverts/mixes

6

[14]