Practical Final Exam 2026

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Q1-1

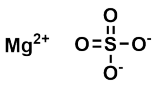
English (Official)

Measuring Magnesium 37%

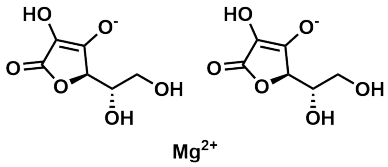
PREPARATION:

- **SAMPLE** 8.250 g of $MgSO_4 \cdot 7\,H_2O$ and 10.000 g of $Mg(asc)_2$ are dissolved in 400 mL of dest. water in a 500 mL volumetric flask. 25 mL of H_2SO_4 are added. Shake well. The solution is topped up to 500.0 mL and shaken vigorously.
  Hand out 20.00 mL (+/- a bit; note down exactly! [20.00 -- 22.00 mL]) of this stock solution to each student. This will amount to the correct amount (330 mg and 400 mg each) and to a 1% sulfuric acid conc. once diluted.
- **EDTA** Prepare TWO 2 L volumetric flasks with EACH 7.445 g EDTA DISODIUM SALT DIHYDRATE (MW: 372.24). Dissolve and top up.
  Hand each student approx. 150 mL in a plastic flask.
- **IODINE** Prepare a 0.05 M iodine soln. from an ampoule. Do this an hour before the exam (the xs. iodide in the sol. can be oxidised by air). Transfer 400 mL EACH into TWO 2 L vol. flasks. Dilute to 2 L.
  Distribute approx. 150 mL to each student in a glass Schott flask.
- **BUFFER** Into approx. (use Schott flask) 2 L of DI water, dissolve 15 mL 25% ammonia and 2.5 mL HCl. Shake well.
  Distribute 75 mL per student into a plastic flask.
- **ERIOCHROME T** Take 5 g 5% Erio T in NaCl and "dilute" it with 20 g of NaCl. Grind well in mortar and pestle.
  Distribute 1 g per student into a HPLC vial.
- **STARCH** Take 2.5 g of starch and dissolve it in 250 mL of DI water. Stir and heat well until everything is dissolved.
  Distribute 10 mL of the solution to each student in a cappable vial.

In this problem, you will be determining the composition of a sample containing magnesium(II) sulfate $MgSO_4$ and magnesium(II) ascorbate, $Mg(asc)_2$, using different titration techniques.



Magnesium sulfate



Magnesium ascorbate

Materials

- 1 × 10.00 mL volumetric pipette
- 1 × 50 mL graduated cylinder
- 1 × 50 mL burette
- 1 × small glass funnel
- 1 × squirt bottle containing deionised water
- 1 × universal pH indicator paper strips
- 5 × plastic pipette
- 1 × 10 mL graduated pipette
- 1 × 100 mL beaker
- 1 × Schott flask labelled "Waste Q1"
- 1 × small metal spatula
- 1 × stirring plate/hot plate
- 1 × 100 mL volumetric flask containing sample
- 3 × 200 mL Erlenmeyer flask

Chemicals

- 120 mL 0.010 mol L^{-1} EDTA solution
- 75 mL Schwarzenbach buffer, pH 10
- vial with a small amount of Eriochrome T dispersed in sodium chloride
- 120 mL 0.010 mol L^{-1} Iodine solution
- 10 mL 1% aqueous starch solution
- 1 × solution in 100 mL volumetric flask containing acidified $MgSO_4$, $Mg(asc)_2$

Safety

- $MgSO_4$ and $Mg(asc)_2$ are not classified as hazardous but **should be handled** with care. **Avoid** unnecessary exposure, inhalation of dust, and contact with eyes or bare skin, as mild irritation may occur.
- EDTA and Eriochrome T may be harmful if swallowed and may cause irritation to the skin and eyes. Dust may irritate the respiratory tract. **Avoid** inhalation and contact with skin and eyes.
- Dilute sulfuric acid and Schwarzenbach buffer (containing ammonia and ammonium salts) may cause irritation to the skin, eyes, and respiratory tract. **Avoid** contact with skin and eyes and avoid inhalation of vapours. Although dilute, exposure **should be kept** to a minimum.
- Iodine is an irritant and oxidising agent that is known for staining (skin). **Wear** goggles and gloves when handling it. **Clean up** small spills with a paper towel.

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Q1-4

English (Official)

Procedure

Complexometric Titration of Mg^{2+}

1. You have received a sample containing unknown amounts of $MgSO_4$ and $Mg(asc)_2$ in a 100.00 mL volumetric flask. **Fill** the volumetric flask with deionised water to the 100.00 mL mark and **mix** well. This solution will from now on be referred to as "the sample solution".
2. **Transfer** 10.00 mL of your sample solution into a clean 200 mL wide-necked Erlenmeyer flask using a volumetric pipette.
3. **Add** 15 mL of buffer solution.
4. **Dilute** the solution with deionised water until approximately 50 mL.
5. **Check** the pH of your solution using pH paper strips. It should be around pH = 10. If necessary, **adjust** the pH of your solution using the buffer solution until pH = 10.
6. While swirling the solution, **add** a small amount (tip of a spatula) of the indicator Eriochrome T. **Avoid** adding too much indicator to make the titration as accurate as possible. Your solution should have a light wine-red colour.
7. **Fill** your 50 mL burette with 0.010 mol L^{-1} EDTA solution.
8. **Titrate** the solution in your 200 mL Erlenmeyer flask slowly, until you achieve a persistent colour change from red to blue. As soon as you observe the colour change, **stop** the titration and **note** the volume of EDTA solution you used in the table below.
9. **Dispose** of any generated aqueous waste in the waste container labelled "Waste Q1".
10. **Repeat** steps 2 to 9 as many times as you deem necessary.

Titration Run	V_{EDTA} / mL
1	
2	
3	
4	
5	

Iodometric Titration

1. **Transfer** 10.00 mL of your sample solution into a 200 mL wide-necked Erlenmeyer flask using a volumetric pipette.
2. **Dilute** the solution with deionised water to approximately 50 mL.
3. **Add** ten drops of starch solution.
4. **Fill** your 50 mL burette with 0.010 mol L^{-1} iodine solution.
5. **Titrate** the solution in your 200 mL Erlenmeyer flask slowly, until the solution is no longer colourless. **Stop** the titration and **note down** the volume of iodine solution you used in the respective table below.
6. **Dispose** of any generated aqueous waste in the waste container labelled "Waste Q1".
7. **Repeat** steps 1 to 6 as many times as you deem necessary.

Titration Run	V_{I_2} / mL
1	
2	
3	
4	
5	

Theory Questions

1.1 **Give** your accepted values for the volumes of EDTA and I_2 necessary to reach the respective endpoints. 30.0 pt

SOLUTION:

The exact amount depends on what the students were given. However, if 330 mg $MgSO_4 \cdot 7\,H_2O$ and 400 mg $Mg(asc)_2$ were given out, the volumes should be:

$V_{EDTA} = 24.07$ mL $V_{I_2} = 21.36$ mL

12.0 pts each for a fully accurate titration, within $V_{\text{master value}} \pm \Delta V_1$, where ΔV_1 is the standard deviation of the titration of the master value (5 titrations).
decreases linearly to 0.0 pts at $V_{\text{master value}} \pm \Delta V_2$ where ΔV_2 is four times the standard deviation of the titration of the master value (5 titrations).

24.0 pts total.

1.2 **Explain** which chemical species give rise to the red and blue colour respectively in the complexometric titration. 1.0 pt

SOLUTION:

The wine-red colour comes from a complex between Eriochrome T (the indicator) and Mg^{2+}. Once all the Mg^{2+} is "trapped" in EDTA, the red complex no longer exists (outcompeted by EDTA, which binds way more strongly) and the Eriochrome T is present in its unbound, dark blue form.
0.5 pts for mentioning Eriochrome T interacts/complexes with the ions, giving red.
0.5 pts for mentioning free Eriochrome T being blue or for a notion/feeling that the Eriochrome T is displaced.

1.0 pts total.

1.3 **Calculate** the total mass of magnesium in grams in the sample you received for this task using your results. **Note:** If you do not have an accepted volume, you may use $V'_{\text{EDTA}} = 30.15\,\text{mL}$ instead. The molar mass of Mg^{2+} is $M_{Mg^{2+}} = 24.305\,\text{g mol}^{-1}$. 2.5 pt

SOLUTION:

At the equivalence points, the following holds: $c_{Mg^{2+}} \cdot V_{Mg^{2+}} = V_{\text{EDTA}} \cdot c_{\text{EDTA}}$, i.e. $c_{Mg^{2+}} = \frac{V_{\text{EDTA}} \cdot c_{\text{EDTA}}}{V_{Mg^{2+}}}$.

Given that the entire sample contained 10x as much total magnesium (only an aliquot was titrated!), the entire sample has

$n(Mg^{2+})_{\text{sample}} = c_{Mg^{2+}} \cdot V_{\text{sample}}$.

Substituting leads to

$n(Mg^{2+})_{\text{sample}} = \frac{V_{\text{EDTA}} \cdot c_{\text{EDTA}}}{V_{Mg^{2+}}} \cdot V_{\text{sample}}$

With $M_{Mg^{2+}} = 24.31\,\text{g mol}^{-1}$ this leads to

$m_{Mg^{2+}} = n(Mg^{2+})_{\text{sample}} \cdot M_{Mg^{2+}} = \frac{V_{\text{EDTA}} \cdot c_{\text{EDTA}}}{V_{Mg^{2+}}} \cdot V_{\text{sample}} \cdot M_{Mg^{2+}} = \frac{V_{\text{EDTA}} \cdot 0.01\,\text{mol L}^{-1}}{10.0\,\text{mL}} \cdot 100\,\text{mL} \cdot 24.31\,\text{g mol}^{-1}$

more simply, $m_{Mg^{2+}} = V_{\text{EDTA}} \cdot 0.002\,43\,\text{g mL}^{-1}$

For the "correct" value of $V_{\text{EDTA}} = 24.07\,\text{mL}$, this leads to $m_{Mg^{2+}} = 0.0584\,\text{g}$

if the students used $V'_{\text{EDTA}} = 30.15\,\text{mL}$, their result should be $m_{Mg^{2+}} = 0.0733\,\text{g}$

0.5 pts for the equation for the end point.

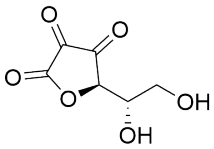
1.0 pts for a correct expression that gives $n(Mg^{2+})$.

0.5 pts for $m_{Mg^{2+}}$.

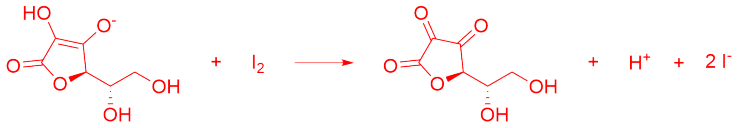
0.5 pts for the correct numerical result.

2.5 pts total.

1.4 **Write down** the stoichiometric equation for the iodometric titration. **Use** the molecular formula for ascorbic acid and its oxidised product. **Hint**: The structure of the oxidation product of ascorbic acid is shown below: 2.0 pt



SOLUTION:



2.0 pts for correctly balanced equation.
partial points may be awarded for wrong but consistent reactions.

2.0 pts total.

1.5 **Calculate** the total mass of ascorbate in grams in the sample you received for this task. **Note**: If you do not have an accepted volume, you may use $V'_{I_2} = 12.75\,\text{mL}$ instead. The molar mass of ascorbate is $M_{asc^-} = 175.124\,\text{g mol}^{-1}$. 2.5 pt

SOLUTION:

At the equivalence points, the following holds (1:1 stoichiometry) : $c_{asc^-} \cdot V_{asc^-} = V_{I_2} \cdot c_{I_2}$, i.e. $c_{asc^-} = \frac{V_{I_2} \cdot c_{I_2}}{V_{asc^-}}$.

Given that the entire sample contained 10x as much total ascorbate (only an aliquot was titrated!), the entire sample has

$n(asc^-)_{sample} = c_{asc^-} \cdot V_{sample}$.

Substituting leads to

$n(asc^-)_{sample} = \frac{V_{I_2} \cdot c_{I_2}}{V_{asc^-}} \cdot V_{sample}$

With $M_{asc^-} = 175.124\,\text{g mol}^{-1}$ this leads to

$m_{asc^-} = n(asc^-)_{sample} \cdot M_{asc^-} = \frac{V_{I_2} \cdot c_{I_2}}{V_{asc^-}} \cdot V_{sample} \cdot M_{asc^-} = \frac{V_{I_2} \cdot 0.01\,\text{mol L}^{-1}}{10.0\,\text{mL}} \cdot 100\,\text{mL} \cdot 175.124\,\text{g mol}^{-1}$

more simply, $m_{asc^-} = V_{I_2} \cdot 0.017\,512\,4\,\text{g mL}^{-1}$

For the "correct" value of $V_{I_2} = 21.36\,\text{mL}$, this leads to $m_{asc^-} = 0.374\,\text{g}$

if the students used $V'_{I_2} = 12.75\,\text{mL}$, their result should be $m_{asc^-} = 0.2233\,\text{g}$

0.5 pts for the equation for the end point.

1.0 pts for a correct expression that gives $n(asc^-)$.

0.5 pts for m_{asc^-}.

0.5 pts for the correct numerical result.

2.5 pts total.

1.6 **Write down** the formula for calculating the total mass of sulfate $m_{SO_4^{2-}}$ in the sample you received for this task, given the moles of magnesium $n_{Mg^{2+}}$ and ascorbate n_{asc^-}. 1.0 pt

SOLUTION:

As every sulfate comes from a magnesium ion, that was not from magnesium ascrobate, we need to subtract the number of magnesium ions stemming from ascorbate from the full number of magnesium ions. As every ascorbate "brings" half a magensium ion, we can express this as:

$m_{SO_4^{2-}} = n_{SO_4^{2-}} \cdot M_{SO_4^{2-}} = (n_{Mg^{2+}} - \frac{1}{2} n_{asc^-}) \cdot M_{SO_4^{2-}}$

1.0 pts for the correct formula.

1.0 pts total.

1.7 **Explain** how you would directly determine the total amount of sulfate in the sample. 1.0 pt

SOLUTION:

Many individual solutions possible.
Ideas: gravimetry with Ca^{2+} or Ba^{2+} etc.
Various titrations that work.
etc.

1.0 pt for any correct answer that is deemed fine.
Partial points may be awarded for not fully thought out ideas.

1.0 pt total.

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Q2-1

English (Official)

Diels-Alder: The Lord of the (Fused) Ring 34%

PREPARATION:

- **EVENING BEFORE** a) make sure the reflux condensers are connected and work (no dripping!). b) Have students put out a 100 mL rbf. c) Have them put out the crystallising dish. d) Have them set up the heating plate.
- **FURAN** Add a bit of ice water to the crystallising dish. Inside, place the 100 mL rbf. Add 4 mL of furan per student. Keep on ice and seal tightly.
- **MALEIC ANHYDRIDE** In a vial, distribute 2 g of maleic anhydride to each student. Seal the vial tightly.
- **DIETHYL ETHER** Distribute 50 mL in small Schott flasks.
- **ETHLY ACETATE** Distribute in 20 mL vials. Cap tightly.

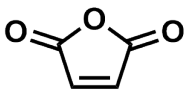
One of the earliest reports of the Diels-Alder reaction dates to January 1929, when the German chemists Otto Diels and Kurt Alder reported their publication titled: "Synthesen in der hydro-aromatischen Reihe, II. Mitteilung: Über Cantharidin". The authors were attempting the synthesis of various interesting natural products, including Cantharidin. They discovered that furan and cyclopentadiene react readily with maleic anhydride, producing bicyclic ring structures, which were further elaborated into derivatives of natural products, such as Cantharidin.

In a Diels-Alder reaction, an electron-rich diene reacts with an electron-poor dieneophile, producing a substituted cyclohexene. If cyclic dienes, for example, furan, are used, the products of the Diels-Alder reaction are bicyclic ring structures, which are hard to synthesise with other methods.

Although this reaction was reported almost a century ago, it is still subject to discussion, especially concerning the stereochemical course of the reaction.

Today, we are going to replicate the reaction between furan and maleic anhydride.

Furan



Maleic anhydride

Materials

- 1 × 10 mL graduated pipette
- 2 × 100 mL round-bottom flask
- 1 × ice bath
- 1 × stirring plate/hot plate
- 1 × weighed glass vial with your name
- 1 × stir bar
- 4 × plastic pipette
- 1 × Büchner filter
- 2 × filter paper fitting for Büchner funnel
- 1 × suction flask
- 1 × reflux condenser
- 1 × spatula

Chemicals

2.00 g maleic anhydride
30 mL diethyl ether
4.0 mL furan ($\rho_{\text{furan}} = 0.936\,\text{g}\,\text{cm}^{-3}$), in a 100 ml round-bottomed flask on your bench
deionised water
20 mL ethyl acetate
crushed ice

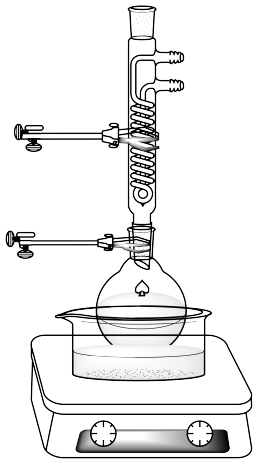
Safety

- Diethyl ether, ethyl acetate and furan are highly flammable liquids whose vapours may form explosive or flammable mixtures with air. **Keep** them away from heat, sparks, and open flames, and **use only** in well-ventilated areas. **Avoid** direct inhalation of vapours and unnecessary exposure, as vapours may cause dizziness or irritation and contact with skin or eyes may cause irritation. Exposure to furan **should be kept** to an absolute minimum, and prolonged exposure **should be avoided**.
- Maleic anhydride is a corrosive and sensitising substance that may cause severe irritation or burns to the skin and eyes and may irritate the respiratory tract. **Avoid** inhalation of dust or vapours and **prevent** contact with skin and eyes. Exposure **should be kept** to a minimum, and prolonged or repeated exposure **should be avoided**, as allergic reactions may occur after repeated contact.

Procedure

Synthesis

1. **Add** 12 mL of diethyl ether to the 100 mL round-bottom flask containing 4.0 mL of furan.
2. **Add** a stir bar.
3. **Stir** the mixture until a homogeneous solution is obtained.
4. **Add** 2.00 g (all of your) solid maleic anhydride, provided to you in a glass vial.
5. **Keep** the reaction mixture at room temperature until all the maleic anhydride has dissolved.
6. **Add** the reflux condenser to the flask and **raise** your hand, so an assistant can come to check your setup, shown in the figure below, and help you start the heating to 35 °C. **Monitor** the temperature continuously with a thermometer.
7. **Keep stirring** the reaction for at least 60 min.
8. **Let** the reaction cool down to room temperature.
9. **Filter** the precipitated product using a Büchner filter. **Keep** the filtrate in the flask until the end of the exam.
10. **Wash** your product with 3 mL ice-cold diethyl ether.



Set-up with the 100 mL round-bottomed flask and reflux condenser clamped over a water bath.

Purification by Recrystallisation

1. **Add** your solid product to a clean, 100 mL round-bottom flask equipped with a stir bar.
2. **Add** 1 mL of ethyl acetate.
3. **Raise** your hand, so an assistant can come to check your setup and help you start the heating of the water bath to 80 °C.
4. When the ethyl acetate starts boiling, **add** more ethyl acetate (only a small amount, a few drops at a time) and **stir** the solution until the solution is boiling again.
5. **Repeat** this process of adding small amounts of ethyl acetate at boiling temperature until all the

product has dissolved. **Make sure** to use as little solvent as possible.

6. **Stop** the heating and **let** the solution cool back down to room temperature.
7. **Cool** the solution further by placing it into an ice water bath for 15 min. **Request** an ice bath from your laboratory assistants.
8. **Filter** the precipitated product using a Büchner filter.
9. **Leave** the product to dry further for at least 15 min (vacuum off).

Theory Questions

2.1 **Transfer** the solid into the glass vial labelled with "Product" and **place it** on the first level of your workspace shelf. 20.0 pt

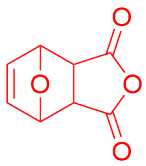
SOLUTION:

13.0 pts to be awarded for purity-adjusted yield (using 1H-NMR and an IS). A threshold is to be set, above which 10.0 pts are awarded. Below the threshold, the points decrease linearly to 0.0 pts at 0% yield.
7.0 pts to be awarded for purity (using 1H-NMR again). Same linear decrease as above.

20.0 pts total.

2.2 **Draw** the product of the reaction. You can use the provided molecular scaffold below. **Hint:** The sum formula of the product is $C_8H_6O_4$. 2.0 pt

SOLUTION:



2.0 pts for correct structure.
Up to 1.5 pts for wrong structure that fits the given sum formula.

2.0 pts total.

2.3 **Write down** the formula for calculating the yield of your reaction, given the quantities added to the reaction ($m_{\text{maleic anhydride}}$, V_{furan}, m_{product}, M). Otto, a student at the Swiss Chemistry Olympiad, obtained 3.00 g of product via the same synthesis you just performed. **Calculate** the yield of his synthesis. 3.0 pt

SOLUTION:

First, to figure out what the limiting reagent is:

$$n_{\text{furan}} = \frac{m_{\text{furan}}}{M_{\text{furan}}} = \frac{V_{\text{furan}} \cdot \rho_{\text{furan}}}{M_{\text{furan}}} = \frac{4\,\text{mL} \cdot 0.936\,\text{g mL}^{-1}}{68.075\,\text{g mol}^{-1}} = 55\,\text{mmol}$$

$$n_{\text{maleic anhydride}} = \frac{m_{\text{maleic anhydride}}}{M_{\text{maleic anhydride}}} = \frac{2.0\,\text{g}}{98.057\,\text{g mol}^{-1}} = 20.4\,\text{mmol}$$

Therefore, the maleic anhydride is the limiting reagent as can be inferred from the 1:1 stoichiometry (see molecular formula).

A theoretical yield of 100% would in that case be 20.4 mmol. With the product having $M_{\text{product}} = 166.132\,\text{g mol}^{-1}$, this would give us a mass $m^{100\%}_{\text{product}} = M_{\text{product}} \cdot 20.4\,\text{mmol} = 3.39\,\text{g}$.

The formula for yield is therefore:

$$\text{Yield} = (100\%\cdot)\frac{m_{\text{product}}}{\frac{m_{\text{maleic anhydride}}}{M_{\text{maleic anhydride}}} \cdot M_{\text{product}}} = (100\%\cdot)\frac{m_{\text{product}} \cdot M_{\text{maleic anhydride}}}{M_{\text{product}} \cdot m_{\text{maleic anhydride}}}$$

Thus we can also determine Otto's yield as:

Otto's yield $= 88.5\%$.

1.0 pt for figuring out the limiting reagent.

1.0 pt for the formula giving the yield (if limiting reagent was determined as being furan (wrong), a "correct" formula will give full points).

1.0 pt for the correct numerical result for Otto's yield.

3.0 pts total.

2.4 **Explain** the problem with adding too much ethyl acetate during the recrystallisation of the product. 2.0 pt

SOLUTION:

If too much ethyl acetate is added, less (or none) of the product crystallises upon cooling, meaning (the entirety of the) yield is lost.

2.0 pts for correct reasoning.

2.0 pts total.

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Q3-1

English (Official)

Incognito Ions 29%

PREPARATION:

- **SILVER NITRATE** In 500 mL, dissolve 8.5 g of silver nitrate. Distribute 15 mL per student.
- **BARIUM CHLORIDE** In 500 mL of water, dissolve 10.41 g of barium chloride (12.2 g if it's the dihydrate). Distribute 15 mL per student. Only do this an hour before the exam and keep the solutions away from air, due to barium carbonate's low solubility.
- **COPPER SULFATE** Dissolve 37.0 g of $CuSO_4 \cdot 5\,H_2O$ in 500 mL of water. Hand out 15 mL per student.
- **HYDROCHLORIC ACID** Dilute 41.6 mL of 37% HCl to 500 mL total. Distribute 15 mL per student.
- **SULFURIC ACID** Dilute 28 mL of sulfuric acid up to 500 mL total. Distribute 15 mL each.
- **AMMONIA** Dissolve 76.9 mL of 25% ammonia to 500 mL total. Hand out 15 mL each.
- **SODIUM HYDROXIDE** In 500 mL of water, dissolve 20 g of NaOH. Hand out 15 mL each.

In this task, you will be performing qualitative inorganic analysis to determine the nature of three solutions, each containing one unknown inorganic salt.

Materials

- 1 × test tube rack
- 8 × plastic pipette
- 18 × test tube

Chemicals

- 15 mL 1 mol L^{-1} HCl
- 15 mL 2 mol L^{-1} NH_3
- 15 mL unknown sample **A**
- 15 mL unknown sample **C**
- 15 mL 1 mol L^{-1} H_2SO_4
- 15 mL 1 mol L^{-1} NaOH
- 15 mL unknown sample **B**
- deionised water

Safety

- Dilute solutions of salts **A**, **B** and **C** may be harmful if swallowed and may cause irritation to the skin and eyes. They may additionally stain skin and clothing.
- 1 mol L^{-1} hydrochloric acid and 1 mol L^{-1} sulfuric acid are strongly acidic solutions that may cause irritation or burns to the skin and serious irritation or damage to the eyes. **Avoid** contact with skin and eyes, and **avoid** inhalation of vapours.

- 2 mol L^{-1} ammonia solution and 1 mol L^{-1} sodium hydroxide are strongly alkaline solutions that may cause irritation to the skin and serious irritation or damage to the eyes. Ammonia may also release vapours that irritate the respiratory tract. **Avoid** contact with skin and eyes, and **avoid** inhalation of vapours.

Identification of Cations

1. **Transfer** a bit (≈ 1 mL) of **A** into one of the test tubes.
2. **Dilute** the aliquot with ≈ 10 mL of water.
3. Carefully **add** some of the 1 mol L^{-1} HCl, drop by drop.
4. **Swirl** the test tube gently.
5. **Add** more of the 1 mol L^{-1} HCl until you have added around 2 mL.
6. **Note** your observations below.
7. **Repeat** steps 1 through 6 with the 1 mol L^{-1} H_2SO_4 first, and then with the 2 mol L^{-1} NH_3 and the 1 mol L^{-1} NaOH.
8. **Repeat** steps 1 through 7 with **B** and then **C** instead of **A**.

SOLUTION:

	A	**B**	**C**
HCl	white precipitate ↓	no reaction	no reaction
H_2SO_4	no reaction	white precipitate ↓	no reaction
NH_3	no reaction	no reaction	initally turquoise ↓ excess: dark blue sol.
NaOH	brown ↓	no reaction after some time, perhaps white clouding due to $BaCO_3$ ↓ forming from CO_2 dissolving in basic sol.	blue ↓

Identification of Anions

1. **Perform** other tests with the **chemicals listed for this task**.
2. **Note** the observations clearly in the box below.

SOLUTION:

A and **B**: white precipitate ↓
A and **C**: no reaction
B and **C**: white precipitate ↓

Adding an excess of NH_3 to either **A** + HCl the mixture of **A** and **B** will redissolve the white precipitate.
Might also work with **A** + NaOH.
Adding HCl to **B** + H_2SO_4 or **B** + **C** does nothing.

Practical Final Exam 2026

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Q3-5

English (Official)

Ion Reactions

Ion	HCl	H_2SO_4	NH_3	NaOH	additional info.
Ag^+	↓	maybe clouding	maybe brown ↓ excess: sol.	brown ↓	AgCl (colourless) sol. in aq. NH_3 AgBr (pale yellow) sol. in aq. NH_3 AgI (yellow) not sol. in aq. NH_3 AgSCN (colourless) compl. insol. Ag_3PO_4: yellow ↓
Al^{3+}				↓ excess: sol.	
Ba^{2+}		↓ compl. insol.	maybe clouding	maybe clouding	$BaSO_4$ insol. even with excess HCl
Co^{2+}			orange		
Cu^{2+}	in conc. HCl: slight green		turquoise ↓ excess: dark blue sol.	blue ↓	I^-: brown sol.+ white ↓
Cu^+				red ↓	CuSCN ↓
Fe^{2+}			green ↓	green ↓	FeS: insol. black ↓
Fe^{3+}			orange-brown ↓	orange-brown ↓	Fe_2S_3: insol. black ↓ SCN^-: deep red I^-: light brown
Mn^{2+}				black ↓	Mn^{2+} is a very faint pink MnS ↓
Na^+					
NH_4^+				smell	
Ni^{2+}			green ↓ excess: blue sol.	green ↓	
Zn^{2+}			↓ excess: sol.	↓ excess: sol.	ZnS ↓

Theory Questions

It is now your job to determine the composition of **A** (a nitrate salt), **B** and **C**. **Note**: The unknown ions are only from the ones that appear in the table.

3.1 **Fill in** the table with the test reactions. **Note** any further observations and experiments in the appropriate box. 14.0 pt

SOLUTION:

solutions can be found directly in the table/box above.

1 pt for each table cell with a correct/appropriate/feasible result.

1.0 pt for each correct/useful observation in the box for a maximum of two observations (2.0 pts).

14.0 pts total.

3.2 **Identify** the cation in **A**. **Justify** your choice with at least two observations. 2.0 pt

SOLUTION:

Cation: Ag^{+}

Justification:

- white precipitate with Cl^{-}
- brown precipitate with NaOH
- the formed AgCl redissolves when xs. NH_3 is added

1.0 pts for the correct ion

0.5 pts for any correct observation, up to two observations (1.0 pt)

2.0 pts total

3.3 **Identify** the cation in **B**. **Justify** your choice with at least two observations. 2.0 pt

SOLUTION:

Cation: Ba^{2+}

Justification:

- white precipitate with SO_4^{2-}
- the formed $BaSO_4$ is compl. insoluble even with excess HCl

1.0 pts for the correct ion

0.5 pts for any correct observation, up to two observations (1.0 pt)

2.0 pts total

3.4 **Identify** the cation in **C**. **Justify** your choice with at least two observations. 2.0 pt

SOLUTION:

Cation: Cu^{2+}

Justification:

- matches the behaviour with NH_3
- blue precipitate/clouding with NaOH
- Cu^{2+} is blue in solution

1.0 pts for the correct ion

0.5 pts for any correct observation, up to two observations (1.0 pt)

2.0 pts total

3.5 **Identify** the anion in **B**. **Justify** your choice with at least two observations. 3.0 pt

SOLUTION:

Anion: Cl^-

Justification:

- Ag^+ precipitates white
- the formed AgCl is sol. in xs. NH_3

1.0 pt for the correct identification of the anion.

1.0 pt for each correct observation in justifying, for a maximum of two observations (2.0 pts)

3.0 pts total

3.6 **Identify** the anion in **C**. **Justify** your choice with at least two observations. 3.0 pt

SOLUTION:

Anion: SO_4^{2-} (HSO_4^- is also accepted, as they have no way of distinguishing the two other than sketchy pH approximations)

Justification:

- precipitates Ba^{2+}
- formed $BaSO_4$ is insol. in xs. HCl

1.0 pt for the correct identification of the anion.

1.0 pt for each correct observation in justifying, for a maximum of two observations (2.0 pts)

3.0 pts total

3.7 **Write** balanced chemical equations for the precipitation (and redissolution) of Al^{3+} and (excess) NaOH. 2.0 pt

SOLUTION:

Precipitation:

$Al^{3+} + 3\,OH^- \longrightarrow Al(OH)_3\downarrow$ or $2\,Al^{3+} + 6\,OH^- \longrightarrow Al_2O_3\downarrow + 3\,H_2O$ (both accepted)

Redissolution:

$Al(OH)_3 + OH^- \longrightarrow [Al(OH)_4-]$ or $Al_2O_3 + 3\,H_2O + 2\,OH^- \longrightarrow 2\,[Al(OH)_4]^-$

1.0 pt for each correctly balanced equation for a process.

2.0 pts total.

3.8 **Write** a balanced chemical equation for the mixing of Cu^{2+} and I^-. 2.0 pt

SOLUTION:

$2\,Cu^{2+} + 4\,I^- \longrightarrow 2\,CuI\downarrow + I_2$

0.5 pts for involving CuI.

0.5 pts for involving I_2.

1.0 pt for correct stoichiometry.

2.0 pts total.

3.9 **Write** a balanced chemical equation for the addition of NH_3 to Co^{2+}. 2.0 pt

SOLUTION:

$Co^{2+} + 6\,NH_3 \longrightarrow [Co(NH_3)_6]^{2+}$

1.0 pt for creating (any!) Co^{2+}-ammine complex.

1.0 pt for the correct number of ammines.

2.0 pts total.