

General Instructions

- This examination is split into 2 sessions, with one task in each session. After the 30 minute refreshment break, please return to your working place.
- Task 1 is 1 h 45 min, task 2 is 3 h 15 min long. Both tasks follow the same general procedure described on this page.
- Each task is delivered in two booklets; the two tasks share these general instructions. The question booklets contain the tasks with numbered questions translated to the language of your choice. The answer booklets contain numbered boxes corresponding to the questions. Only language-independent symbols and formulae are used in the answer booklets.
- You may begin working only when the **START** signal is given.
- Equipment for task 1 is on your desk at the start. Do not touch the equipment for task 2 in the box on the shelf.
- You should keep all items within the marked out area on the bench.
- Use only the pen and calculator provided. Do not write with the marker on paper; use it only to label labware. Do not write your answers in pencil; the pencil is only for the TLC plates.
- All results and answers must be clearly written with pen in the appropriate answer boxes of the **answer booklets**. Remember that only the answer booklet is collected. **Do not separate** the pages of the stapled answer booklets.
- Do not write on the back sides of the answer booklet! Markers will only see the printed sides of the answer booklet. Use the back sides of the question booklet if you need scratch paper. **Do not** draw anything into or close to the QR codes.
- For the multiple choice questions, **if you want to change your answer**, fill the tick box completely and then make a new box next to it.
- The official English version of the exam booklets is available on request for clarification only.
- You must **follow the safety rules** given in the IChO regulations. Any safety rule violation can result in your dismissal from the laboratory and the nullification of your practical examination.
- If you need a toilet break or any assistance, or want to review the official English version, raise your hand.
- If you need a replacement or refill, ask the lab supervisor. Both of you need to sign the table on the answer sheet. Only the first such incident (one item) is without penalty. Each further incident will result in the deduction of 1 point from your 40 practical exam points.
- The supervisors will announce a 30-minute warning before the STOP signal. You must stop your work immediately when the **STOP** signal is announced. Failure to stop working or writing can lead to nullification of your practical exam.
- After the supervisor tells you to do so, put **only your answer booklet** back into the envelope. You can keep the question booklet. Do not seal the envelope. The supervisors will collect it together with your TLC plates in their bag.
- Do not take the calculator or anything from the lab, except for the question booklets .

GOOD LUCK!

Practical

G0-2

Estonian English (Estonia)

Periodic Table

1																		18	
1 H 1.008	2																2 He 4.003		
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18		
11 Na 22.99	12 Mg 24.30	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95		
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80		
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc -	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3		
55 Cs 132.9	56 Ba 137.3	57-71	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po -	85 At -	86 Rn -		
87 Fr -	88 Ra -	89-103	104 Rf -	105 Db -	106 Sg -	107 Bh -	108 Hs -	109 Mt -	110 Ds -	111 Rg -	112 Cn -	113 Nh -	114 Fl -	115 Mc -	116 Lv -	117 Ts -	118 Og -		

57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm -	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
89 Ac -	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np -	94 Pu -	95 Am -	96 Cm -	97 Bk -	98 Cf -	99 Es -	100 Fm -	101 Md -	102 No -	103 Lr -

Problems and Grading Information

	Title	Question Pages	Answer Pages	Total Score	Percentage
1	Indicators	6	4	107	16
2	Titration on a balance	11	11	85	24
				Total	40

Safety

When in the laboratory students must respect the rules:

- Do not eat or drink in the lab. Chewing gum is not allowed.
- Work only in the designated area. Keep your work area and the common work areas tidy.
- No unauthorized experiments are allowed. No modification of the experiments is allowed.
- Inform your lab assistant about spills and broken glassware immediately. Inform the assistants about any accident.
- All waste must be properly discarded to prevent contamination or injury. Dispose the solutions in the containers with the correct labels. If any container is full inform your lab assistant.
- Contact lenses are prohibited in the laboratory.

During the examination, the students will be required to wear:

- pants covering their whole legs;
- closed and flat shoes;
- a lab coat with long sleeves;
- safety goggles fitting the contour of their face;
- if applicable, long hair and beards tied back.

Any student who fails to respect these rules will not be allowed to enter the lab along with the nullification of their practical exam and exclusion from the practical exam.

GHS Statements

The GHS hazard and precautionary statements associated with the materials used are indicated in the problems. Their meanings are as follows:

H-phrases Physical Hazards

H225: Highly flammable liquid and vapour

H272: May intensify fire: oxidizer

H290: May be corrosive to metals

H-phrases Health Hazards

H301: Toxic if swallowed

H302: Harmful if swallowed

H311: Toxic in contact with skin

H314: Causes severe skin burns and eye damage

H315: Causes skin irritation

H318: Causes serious eye damage

H319: Causes serious eye irritation

H331: Toxic if inhaled

H332: Harmful if inhaled

H336: May cause drowsiness or dizziness

H351: Suspected of causing cancer

H370: Causes damage to organs

H372: Causes damage to organs through prolonged or repeated exposure

H-phrases Environmental Hazards

H400: Very toxic to aquatic life

Task 1 Indicators (time 1 h 45 min)**Equipment and materials**

Item	Label	Quantity	Location
Test tube rack (positions labelled A1-E12)		1	desk
Test tubes, 5 cm ³		40	rack
Indicator solutions	Student code + A, B, C, D	4 × 5 cm ³	small centrifuge tubes, rack
Isopropyl alcohol eluents (acidic E _A , neat (neutral) E _N , basic E _B)	E _A , E _N , E _B	3 × 10 cm ³	small centrifuge tubes, rack
Spotting capillaries		5	small centrifuge tube, rack
Graduated plastic pipettes, 3 cm ³		15	desk
Graduated plastic pipettes, 1 cm ³		5	rack
Tweezers		1	rack
Pencil		1	rack
Ruler		1	desk
TLC plates (polar silica), 4 × 8 cm	Student code on bag	4	in labelled zip lock bag
250 cm ³ beakers for TLC chambers		3	desk
Aluminium foil pieces (TLC chamber covers), approx. 10 × 10 cm		3	desk
Filter paper strips (to be used as "wick" in TLC experiment)		3	desk
Unknown solutions	Student code + 1 – 8	8 × 30 cm ³	large centrifuge tubes
0.1 mol/dm ³ HCl solution	HCl	30 cm ³	large centrifuge tube

Practical

Q1-2

Estonian English (Estonia)

Permanent marker		1	desk
Distilled water		1	wash bottle
Distilled Water Jugs	H ₂ O		Desks
Goggles		1	desk
Calculator		1	desk
Pen		1	desk
Paper towels		1 roll	desk
UV lamp for TLC visualization		2 per lab	hoods
Nitrile gloves			next to the blackboard
Container for used capillaries			hoods

Acid-base indicators

Acid-base indicators are substances that exhibit different colours in their protonated and deprotonated forms. Since each protonation has a different equilibrium constant, the colour change for different indicators occurs at a different pH. Thus, in a solution at a given pH, one indicator may appear as 'acidic' and another as 'basic'. In this task, you will use four indicators. One of them has two distinct colour changes at two different pH values.

Your goal is to find the order of their transition pH and to identify the solutions of eight compounds according to different pH. You will start TLC experiments with the indicators first.

TLC experiments

Four centrifuge tubes, marked with capital letters **A–D**, contain methanolic solutions of the four indicators. Carry out TLC experiments on a **polar silica gel** stationary phase using the four indicator solutions. Handle the plates with tweezers or touch them only on their edges.

- Prepare 3 plates with a baseline and spots for each indicator using the pencil and ruler.
- Use capillaries to spot the solutions. Be very careful with the capillaries during your work and discard them into the designated container (under the hood) after all your plates are developed and ready.
- Make sure that the spots are dry, and all the solvent has evaporated (at least 2 minutes of standing).
- Develop the plates using the three isopropyl alcohol eluents (E_A – acidic, E_N – neutral, E_B – basic) in the beakers **closed (tightly) with aluminium foil**.
- Observe the colours of the spots during the run and after drying.
- You should allow the TLC to develop for at least 20 minutes, but **you should carry on with the other experiments** while the TLC is running.
- Mark the invisible spots with pencil using the UV lamp under the hood.
- Place the properly labelled plates in the zip lock bag labelled with your student code. The TLC plates will be marked (12 pt).

You can request one new plate without a penalty.

1.1	Identify the eluent that gives the best spots and best separation of the individual indicators. Tick the eluent code on the answer sheet.	2 pt
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In solution, most of these indicators form anions. Only one form of one of the indicators that is observable on the TLC plates is a neutral, molecular species. None of the other three indicators have a neutral form in the eluents used. Some of the indicators with several acidic groups can form dianions as well.

1.2. Based on your observations, **identify** the spots containing the neutral molecular species. **Select** the indicator which has a neutral form, and **tick** the eluent(s) where that indicator forms a neutral species. 5 pt

1.3. Based on your observations, **identify** the spot(s) containing dianions of their corresponding indicator molecule. 4 pt

Identification experiments

Four centrifuge tubes, marked with capital letters **A–D**, contain methanolic solutions of the four indicators. Each one comes with a plastic pipette. The concentrations of the indicator solutions are such that one drop of the indicator solution is sufficient to stain several cm^3 of solution.

There are eight large centrifuge tubes numbered **1–8**. Each tube contains a 0.1 mol/dm^3 aqueous solution of one of the following eight compounds. Perform experiments to identify the content of the unknown solutions.

You can use the indicator solutions **A–D**, hydrochloric acid (also at 0.1 mol/dm^3) and distilled water in addition to the unknown solutions.

H_3BO_3	$(\text{COOH})_2$	H_3PO_4	$\text{CH}_3\text{CH}_2\text{COOH}$
NaH_2PO_4	NaOH	$\text{CH}_3\text{CH}_2\text{COONa}$	Na_3PO_4

Hint: The test tube rack has labelled positions (A1-E12).

Dissociation data

H_3BO_3 : $\text{pK}_a = 9.15$

H_3PO_4 : $\text{pK}_{a1} = 2.15$, $\text{pK}_{a2} = 7.20$, $\text{pK}_{a3} = 12.35$

$\text{CH}_3\text{CH}_2\text{COOH}$: $\text{pK}_a = 4.87$

$(\text{COOH})_2$: $\text{pK}_{a1} = 1.27$, $\text{pK}_{a2} = 4.28$

- 1.4. **Give** the numbers of the centrifuge tubes containing the compounds listed in the table on the answer sheet. If you cannot distinguish between two or more solutions, **list** those as alternatives for partial marks. 52 pt

In the next 3 questions you need to describe the experiments and observations that you used to distinguish certain pairs of compounds.

Describe the experiments in the following fashion: $1\text{ cm}^3\text{ HCl} + 1\text{ cm}^3\text{ H}_2\text{O}$

Use the following language independent colour codes: **N**: colourless, **R**: red, **G**: green, **B**: blue, **Y**: yellow, **O**: orange **P**: pink **V**: violet, **Br**: brown, **Bk**: black, and their combinations: **YG**: yellowish green, **BG**: bluish green, etc.

N	R	G	B	Y	O	P	V	Br	Bk
YG	BG								

- 1.5 **Specify** the experiments and the observations that you used to distinguish $(\text{COOH})_2 - \text{H}_3\text{PO}_4$ on the answer sheet. 4 pt
Describe the experiment in column "EXP", **give** the indicator code in column "ABCD", and **give** the code of the observed colour in column "COLOUR". Make sure that you have observations for both solutions.

- 1.6 **Specify** the experiments and the observations that you used to distinguish $\text{NaOH} - \text{Na}_3\text{PO}_4$ on the answer sheet. 4 pt
Describe the experiment in column "EXP", **give** the indicator code in column "ABCD", and **give** the code of the observed colour in column "COLOUR". Make sure that you have observations for both solutions.

- 1.7 **Specify** the experiments and the observations that you used to distinguish $\text{CH}_3\text{CH}_2\text{COOH} - \text{CH}_3\text{CH}_2\text{COONa}$ on the answer sheet. 4 pt
Describe the experiment in column "EXP", **give** the indicator code in column "ABCD", and **give** the code of the observed colour in column "COLOUR". Make sure that you have observations for both solutions.

1.8 Select the letter code of the indicator that changes colour distinctly at two pH values and give its colour between the two changes using the colour codes. 4 pt

1.9 Give the colours of the indicators in $\text{pH} \approx 1.5$ and $\text{pH} \approx 13$ solutions using the colour codes. 8 pt

1.10 List the letter codes of the indicators in increasing order of their transition pH. Start with the indicator that changes colour in the most acidic medium, and make sure that the "three-colour" indicator appears twice. 8 pt

GHS hazard codes for the chemicals

Chemical	Hazard code
Indicator solutions	H225, H301, H302, H311, H319, H331, H370
Eluents	H225, H302, H315, H319, H336
Unknown solutions	H314, H318, H319
0.1 mol/dm^3 HCl solution	H290

Task 2 Titration on a balance (time 3 h 15 min)**Equipment and materials**

Item	Label	Quantity	Location
A box containing items for Task 2		1	on the desk, taken down from the shelf
Electronic balance (0.01 g accuracy)		1	box
Conical flasks (250 cm ³)		3	box
Plastic cups (250 cm ³)		24	box
Graduated plastic pipettes (3 cm ³)		15	box
Plastic spatulas		3	box
1% starch solution	Starch	7 cm ³	small vial, box
1% CuSO ₄ solution	CuSO ₄	7 cm ³	small vial, box
Solid Na ₂ S ₂ O ₃ · 5 H ₂ O	Na ₂ S ₂ O ₃ · 5 H ₂ O	6 g	small vial, box
Solid KI	KI	10 g	small vial, box
CH ₂ Cl ₂	CH ₂ Cl ₂	30 cm ³	centrifuge tube, box
~1% KI solution	KI, student code	50 cm ³	centrifuge tube, box
~1% KMnO ₄ solution	KMnO ₄ , student code	100 cm ³	dark glass bottle, box
~0.6% HCOONa solution	HCOONa, student code	80 cm ³	plastic bottle, box
1 mol dm ⁻³ H ₂ SO ₄ solution	H ₂ SO ₄	80 cm ³	plastic bottle, box
20% HCl solution	HCl	180 cm ³	plastic bottle, box
5% NaOH solution	NaOH	50 cm ³	plastic bottle, box
Saturated BaCl ₂ solution	BaCl ₂	50 cm ³	plastic bottle, box

Practical

Q2-2

Estonian English (Estonia)

Calculator		1	desk
Pen		1	desk
Permanent marker		1	desk
Distilled water		1	wash bottle
Goggles		1	desk
Paper towel		1 roll	desk
Waste containers for Part A, C, D (no organic)	Waste (A, C, D)		hoods
Waste containers for Part B (organic)	Waste (B)		hoods
Nitrile gloves			next to the blackboard
Distilled water jugs	H ₂ O		desks

Manganese has a varied chemistry and is widely used in classical analytical chemistry. The most commonly used manganese compound, potassium permanganate, is a strong oxidant whose behavior varies with pH. In this task, you will look into the reactions of permanganate and iodide ions in different media.

General procedure

Instead of accurate volumetric equipment (e.g., burettes, pipettes, volumetric flasks), you will use a balance to accurately measure the mass of reagent and titrant solutions.

- Use disposable plastic cups as containers (except for Part B). Mix their contents by careful swirling.
- Transferring solutions is best accomplished with graduated plastic disposable pipettes that can be used for volume measurements as well.
- Regularly zero the balance without any load (Press TARE). Measure and record the mass of each container before use. We recommend not using the TARE button otherwise.
- Never leave a load on the balance for a longer period and never overload the balance (more than 500 grams altogether) because the sensors can become damaged. All your bottles fit within this limit.
- Record all measured masses into the appropriate boxes on the answer sheets.
- Add the initial reagents to the container; measure and record the necessary masses. Remove the container from the balance.
- When titrating, measure the total mass of the titrant, its container and the pipette used to add it, altogether. Record this mass before the titration and once the end point is reached.
- Never run the titrations on the balance because they have built-in compensation for slow changes (i.e. drops) and your results might be inaccurate if you add drops to a container on the balance.
- Continue adding the reagent until the reaction is complete. Record the mass of the titrant, its container and the pipette used to add it. Deduce the mass of the titrant solution added.
- The critical points are different from a regular titration. The containers should not get wet outside. Adding anything to the reaction flask being weighed or transferring reactant from the container being measured requires attention and consideration.
- As usual in analytical chemistry, repeat the whole procedure as you find necessary. The reproducibility of this method is comparable, but not as high as for a volumetric titration. Report the individual results and the value you accepted for your calculations.
- Should the balance experience underload (| ____ | is displayed), long press the ON/OFF button to turn off the balance.
- The balance turns off after 3 minutes of inactivity.
- When using gloves, keep your hands away from the pan while reading the mass to avoid electrostatic effects.
- Should the balance behave strangely, or display text, ask the laboratory supervisor for assistance.

Use the following molar masses in your calculations:

$\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$	$\text{Na}_2\text{S}_2\text{O}_3$	KMnO_4	KI
248.18 g mol^{-1}	158.11 g mol^{-1}	158.03 g mol^{-1}	166.00 g mol^{-1}

Part A Determination of the exact concentration of permanganate solution in a dilute acid solution

Permanganate is most often used in acidic media (e.g., dilute sulfuric acid), because its reactions are usually fast and quantitative. You have a permanganate solution (KMnO_4 , mass fraction of approximately 1%).

Dissolve approximately 2.5 g of pure crystalline $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ ($M = 248.18\text{ g mol}^{-1}$) in water to yield about 50 g of solution in a plastic cup.

A.1 **Report** the accurate masses you used during the preparation of your thiosulfate solution on the answer sheet. 0.0 pt

A.2 **Calculate** the mass fraction (w_1) of $\text{Na}_2\text{S}_2\text{O}_3$ ($M = 158.11\text{ g mol}^{-1}$) in the solution you prepared. 2.0 pt

- Add 5 g of the permanganate solution into a plastic cup and record its accurate mass.
- Add 10 cm^3 of $1\text{ mol dm}^{-3}\text{ H}_2\text{SO}_4$ and 2 g of **solid** KI.
- Immediately titrate the iodine formed with the thiosulfate solution.
- Add 10 drops of starch solution close to the end point.
- Repeat the titration as necessary.

A.3 **Record** all your raw measurements (masses from the balance) on the answer sheet that are required to report data in question A.4. 0.0 pt

A.4 **Report** the masses for your titrations in the table on the answer sheet. For each titration **fill** a column. **Give** the mass of the KMnO_4 solution ($m(\text{KMnO}_4)$) and the mass of the $\text{Na}_2\text{S}_2\text{O}_3$ solution ($m(\text{Na}_2\text{S}_2\text{O}_3)$) and **calculate** the mass of $\text{Na}_2\text{S}_2\text{O}_3$ solution needed for 5.00 g permanganate solution ($m_{5.00\text{ g}}(\text{Na}_2\text{S}_2\text{O}_3)$). 1.0 pt

A.5 Give your accepted value for the mass of thiosulfate solution (m_1) needed for 5.00 g permanganate solution. 15.0 pt

A.6 Write balanced ionic equations relevant to the titration. 4.0 pt

A.7 Calculate the mass fraction (w_2) of KMnO_4 ($M = 158.03 \text{ g mol}^{-1}$) in the permanganate solution. 3.0 pt

Part B Reaction of iodide and permanganate in concentrated hydrochloric acid solution

In the presence of concentrated (>15%) hydrochloric acid, permanganate gives the same reduction product as in Part A, but iodide is oxidized to a different product.

- Use a conical flask. Add 10 g of the KI solution (mass fraction of approximately 1%) into the flask and record the accurate mass of the solution.
- Add 30 g of the 20% HCl solution and 5 cm³ of CH₂Cl₂.
- Immediately start titrating with the permanganate solution slowly with intense swirling throughout. Follow the mass of the bottle containing the titrant, and not the reaction mixture.
- The end point of the titration is when the colour appearing during the titration disappears completely from the organic phase.
- When close to the end point, give enough time to establish the partition equilibrium between the two phases.
- Repeat the titration as necessary.
- Should you want to reuse a flask, discard its contents into the container labelled "Waste B" under the hood. Wash it at the sink and dry the outside with paper towels.

B.1 **Record** all your raw measurements (masses from the balance) on the answer sheet that are required to report data in question B.2. 0.0 pt

B.2 **Report** the masses for your titrations in the table on the answer sheet. For each titration **fill** a column. 1.0 pt
Give the mass of the KI solution ($m(\text{KI})$) and the mass of the KMnO₄ solution ($m(\text{KMnO}_4)$) and **calculate** the mass of KMnO₄ solution needed for 10.00 g KI solution ($m_{10.00\text{ g}}(\text{KMnO}_4)$).

B.3 **Give** your accepted value for the mass of permanganate solution (m_2) needed for 10.00 g KI solution. 15.0 pt

B.4 **Pick** on the answer sheet the colour of the organic phase before the end of the titration and the species causing this colour. 2.0 pt
a) Purple MnO₄⁻ b) Purple I₂ c) Brown MnO₄⁻ d) Brown I₂

- B.5** Pick on the answer sheet the explanation why the colour of excess permanganate is not seen after the end of the titration. 2.0 pt
- a) Permanganate ions disproportionate and turn brown in very acidic solutions.
 - b) Permanganate ions react with the chloride ions present.
 - c) Permanganate ions react with dichloromethane.
 - d) The colour of permanganate is only visible in aqueous solution.

- B.6** Calculate the stoichiometric ratio of permanganate to iodide, $\frac{n(\text{MnO}_4^-)}{n(\text{I}^-)}$ for the titration reaction using the approximate composition of the iodide solution (1%). Show your work. 2.0 pt

- B.7** Give the integer oxidation state of the iodine in the dominant product formed. Show your work. 2.0 pt

Note: Best marks are not necessarily awarded to measurements reproducing expected integer values in the results.

- B.8** You can assume that the reaction leading to this product is quantitative. 3.0 pt
Calculate the exact mass fraction (w_3) of KI ($M = 166.00 \text{ g mol}^{-1}$) in the solution. Show your work.

Part C The reaction of permanganate in a strongly alkaline solution

Permanganate is a strong oxidizer in very basic solutions as well, but the reduction product is the green manganate ion (MnO_4^{2-}). **Follow the order** of the steps closely.

- Add 5 g of your KMnO_4 solution into a plastic cup and record its accurate mass.
- Add 5 cm^3 of the saturated BaCl_2 solution.
- Add 10 drops of 1% CuSO_4 solution to catalyse the titration reaction.
- Add 2.5 cm^3 of 5% NaOH solution.
- Immediately start the titration with the HCOONa solution. Always add the titrant dropwise.
- When the titrant is added slowly the desired bluish-black barium manganate precipitate appears early in the titration. Continue adding the titrant dropwise until the endpoint.
- The dark precipitate makes it difficult to observe the solution, but the presence or absence of unreacted permanganate in the solution can be clearly seen against a white background.
- Repeat the titration as necessary.

C.1 **Record** all your raw measurements (masses from the balance) on the answer sheet that are required to report data in question C.2. 0.0 pt

C.2 **Report** the masses for your titrations in the table on the answer sheet. For each titration **fill** a column. 1.0 pt
Give the mass of the KMnO_4 solution ($m(\text{KMnO}_4)$) and the mass of the HCOONa solution ($m(\text{HCOONa})$) and **calculate** the mass of HCOONa solution needed for 5.00 g permanganate solution ($m_{5.00\text{ g}}(\text{HCOONa})$).

C.3 **Give** your accepted value for the mass of formate solution (m_3) needed for 5.00 g permanganate solution. 10.0 pt

C.4 **Write** a balanced ionic equation for the oxidation of formate by permanganate in a strongly basic solution in the presence of barium chloride. **Indicate** the physical state (s = solid, g = gaseous, aq = aqueous solution, l = liquid) for each product and reactant. 2.0 pt

Part D Reaction of iodide and permanganate in a strongly alkaline solution

Iodide will give an oxidation product different from Part A and B under these conditions.

Make a 5-fold dilution from your KI solution. Prepare about 40 g of the dilute solution.

D.1 **Report** the accurate masses you used during the preparation of your dilute KI solution. 0.0 pt

D.2 **Calculate** the mass fraction (w_4) of KI in the dilute solution you prepared. 1.0 pt

Follow the order of the steps closely.

- Add 1 cm³ of 5% NaOH solution into a plastic cup.
- Add 3 g of your **diluted** KI solution and record its accurate mass.
- Add 10 g of your KMnO₄ solution and record its accurate mass.
- Add 10 drops of 1% CuSO₄ solution to catalyse the titration reaction.
- Then add 5 cm³ of the saturated BaCl₂ solution.
- The mixture will become even darker due to the formation of the bluish-black barium manganate precipitate.
- Immediately start the titration with the HCOONa solution. Always add the titrant dropwise.
- The dark precipitate makes it difficult to observe the solution, but the presence or absence of unreacted permanganate in the solution can be seen against a white background.
- Repeat the titration as necessary.

D.3 **Record** all your raw measurements (masses from the balance) on the answer sheet that are required to report data in D.4. 0.0 pt

D.4 **Report** the masses for your titrations in the table on the answer sheet. For each titration **fill** a column. 1.0 pt
Give the mass of the KI solution ($m(\text{KI})$), the mass of the KMnO₄ solution ($m(\text{KMnO}_4)$) and the mass of the HCOONa solution ($m(\text{HCOONa})$).

D.5 For each titration, **calculate** the mass of the KMnO₄ solution that reacted with 10.00 g dilute KI solution ($m_{10.00\text{ g}}(\text{KMnO}_4)$). **Report** your accepted value (m_4). 14.0 pt

D.6 **Calculate** the stoichiometric ratio of permanganate and iodide, $\frac{n(\text{MnO}_4^-)}{n(\text{I}^-)}$ for the reaction in a strongly basic solution. **Show** your work. 2.0 pt

Note: Best marks are not necessarily awarded to measurements reproducing the expected integer values in the results.

D.7 **Give** the integer oxidation state of iodine in the product(s). 2.0 pt

GHS hazard codes for the chemicals

Chemical	Hazard code
1% starch solution	No hazard
1% CuSO ₄ solution	H319, H412
Solid Na ₂ S ₂ O ₃ · 5 H ₂ O	H315, H319, H335
Solid KI	H372
CH ₂ Cl ₂	H351
~1% KI solution	H372
~1% KMnO ₄ solution	H272, H302, H400
~0.6% HCOONa solution	No hazard
1 mol dm ⁻³ H ₂ SO ₄ solution	H290, H314, H315, H318, H319
20% HCl solution	H290, H314, H335
5% NaOH solution	H290, H314, H315
Saturated BaCl ₂ solution	H301, H332, H319