Tr JoelPCM Academic Council

Advanced Secondary Curriculum (ASC) • Chemistry Assessment • NCDC 2026

CHEMISTRY

PAPER 2 — PRACTICAL

3 Hours 15 Minutes

NCDC • 2026

Candidate Name: ______________________________	Centre Name: ______________________________
Index Number: ______________________________	Year: 2026

INSTRUCTIONS TO CANDIDATES

1. Do not open this booklet until you are told to do so.
2. Answer BOTH items — Item 1 and Item 2 are COMPULSORY.
3. For each item you must: (a) design an experiment, and (b) write a full structured report.
4. Your report MUST include: Aim, Variables & Hypothesis, Materials & Reagents, Methodology, Risks & Mitigations, Data Presentation, Data Analysis & Interpretation, Conclusion & Recommendations.
5. Use headings, clear scientific language, balanced equations, and data tables/graphs throughout.
6. All tables must have titles, column headings with units, and correct significant figures.
7. Graphs must have titles, labelled axes with units, correct scales, and plotted points with error bars.
8. Show ALL calculations. Include sources of error and percentage uncertainty where relevant.
9. Begin practical work only when instructed by the supervisor. Observe all safety rules.
10. Atomic masses: H=1; C=12; N=14; O=16; S=32; K=39; Cu=63.5; I=127; Faraday constant F=96,500 C mol^{-1}

PAPER 2 ASSESSMENT STRUCTURE (Following NCDC ASC 2026 Guidelines)

- 2 compulsory practical items — each drawn from a different construct.
- Item 1 — Construct AO3: Stoichiometry, Thermochemistry & Reaction Kinetics (Topic 13: Reaction Kinetics)
- Item 2 — Construct AO4: Chemical Equilibria & Electrochemical Systems (Topic 10: Electrochemistry)
- Each item scored on 7 criteria × 4 marks = 28 marks per item. Total: 56 marks.
- Science process skills tested: Aim/Variables/Hypothesis • Materials • Methodology • Risks
  Data Presentation • Data Analysis & Interpretation • Conclusion & Recommendations

SCORE 4 DESCRIPTOR (what an excellent response looks like):
Aim: Precise and directly linked to theory. Variables: All correctly identified (IV, DV, ≥4 controlled).
Hypothesis: Testable, quantitative, with theoretical justification linked to the chemistry.
Materials: Complete list with correct spelling, concentrations, volumes; no unnecessary items.
Methodology: Detailed, numbered, logical, replicable steps; safety and accuracy addressed throughout.
Risks: ≥3 specific hazards with GHS symbols; PPE, controls, spill/first aid, disposal all stated.
Data: Well-formatted table with title, units, sig. figs.; appropriate graph with labelled axes and error bars.
Analysis: Correct calculations with working; uncertainty included; graph interpreted against hypothesis.
Conclusion: Supported by data; hypothesis addressed; limitations acknowledged; real-world recommendations given.

ITEM 1 — Compulsory

Item 1

Construct: AO3 — Stoichiometry, Thermochemistry & Reaction Kinetics

Construct / Topics:
Topic 13: Reaction Kinetics | Context: Water Pollution & Industrial Discharge

The National Environment Management Authority (NEMA) of Uganda has received reports from communities near the Namanve Industrial Park in Kampala that sections of the Namanve stream — which feeds into Lake Victoria — are turning dark brown and emitting a pungent odour near factory discharge points. Aquatic biodiversity in the affected sections has declined sharply.

Laboratory analysis of effluent from the industrial park has confirmed the simultaneous presence of hydrogen peroxide (H_2O_2) from a textile bleaching facility and potassium iodide (KI) from a dyeing factory. When these chemicals mix in the slightly acidic stream water, the following reaction produces iodine (I_2), which causes the characteristic dark discolouration:

$$H_2O_2(aq) + 2KI(aq) + H_2SO_4(aq) \rightarrow I_2(aq) + K_2SO_4(aq) + 2H_2O(l)$$

NEMA believes that the concentration of H_2O_2 in the effluent is the critical factor controlling how fast this pollution reaction proceeds. The authority has contracted your research team to investigate how varying the concentration of H_2O_2 affects the rate of this reaction, so that a legally enforceable maximum discharge concentration limit for H_2O_2 can be established. Your team must design the investigation, conduct experiments, analyse the results, and submit a formal scientific report with evidence-based recommendations to NEMA.

REAGENTS AND MATERIALS PROVIDED:
- FA1 — 0.20 mol dm^{-3} hydrogen peroxide solution (H_2O_2)
- FA2 — 0.10 mol dm^{-3} potassium iodide solution (KI)
- FA3 — 0.50 mol dm^{-3} sulfuric acid solution (H_2SO_4)
- FA4 — 0.010 mol dm^{-3} sodium thiosulfate solution ($Na_2S_2O_3$)
- FA5 — 1% starch indicator solution
- Distilled water
- Standard laboratory glassware: burettes, pipettes (10 cm^3, 25 cm^3), conical flasks (100 cm^3, 250 cm^3),
- measuring cylinders, stopwatch (digital), thermometer, white tile, water bath (for temperature control)
- Safety equipment: fume cupboard, safety goggles, nitrile gloves, lab coat

Scientific Background:

• The IODINE CLOCK technique is used to measure the rate of this reaction. A fixed, small volume of $Na_2S_2O_3$ and starch is added to the reaction mixture. The $Na_2S_2O_3$ rapidly converts I_2 back to I^- as it forms. The moment ALL the $Na_2S_2O_3$ is consumed, the next drop of I_2 produced

reacts instantly with the starch, turning the solution BLUE-BLACK. The time (t) from mixing to this colour change is the measurement.
• Since the same fixed amount of I_2 must be produced before the colour change occurs: Rate $\propto$ 1/t.
• By varying [H_2O_2] while keeping [KI], [H_2SO_4], [$Na_2S_2O_3$], and temperature constant, you can determine the order of reaction with respect to [H_2O_2] by plotting log(rate) vs log[H_2O_2].
• If the reaction is first order in [H_2O_2]: rate = k[H_2O_2], a graph of rate vs [H_2O_2] will be linear through the origin.
• If second order: rate = k[H_2O_2]^2, a graph of rate vs [H_2O_2]^2 will be linear, or the log-log plot gives gradient = 2.

TASK

Design an experiment to investigate the research question and write a structured report of your findings. Your report must include ALL components listed in the scoring criteria.
Design a quantitative investigation to determine the order of reaction with respect to the concentration of hydrogen peroxide (H_2O_2), and write a formal scientific report for NEMA.

Your report MUST include the following sections:

SECTION 1 — AIM
State a precise, theory-linked aim for this investigation.

SECTION 2 — VARIABLES
(i) Independent variable (IV): State what you will change and the range of values.
(ii) Dependent variable (DV): State what you will measure and the units.
(iii) Controlled variables: Identify at least FOUR. For each, state how you will control it.

SECTION 3 — HYPOTHESIS
State a testable, quantitative hypothesis. Predict the order of reaction and link your prediction to collision theory (effect of concentration on collision frequency).

SECTION 4 — MATERIALS AND REAGENTS
List ALL apparatus and chemicals with quantities, sizes, and concentrations. Show how you will prepare at least FIVE different concentrations of H_2O_2 by dilution of FA1 with water. Show the dilution calculation for at least TWO concentrations.

SECTION 5 — METHODOLOGY
Write a detailed, numbered, step-by-step procedure that is replicable by another scientist. Include: (i) how you set up and zero your glassware, (ii) how you prepare each diluted H_2O_2 solution, (iii) how you set up the iodine clock reaction and start timing, (iv) what you observe and when you stop timing, (v) how many repeats you perform and how you handle anomalous results, (vi) how you process the time data into rates.

SECTION 6 — RISKS AND MITIGATIONS

Identify at least THREE hazards. For each: (i) name the hazard and its GHS hazard symbol, (ii) describe the specific risk it poses, (iii) state the control measure and PPE, (iv) state the first aid and disposal procedure.

SECTION 7 — DATA PRESENTATION

(i) Complete the results table provided (Table 1) for at least 5 concentrations with 3 repeats each.

(ii) Sketch Graph 1 (rate = 1/t vs $[H_2O_2]$) and Graph 2 (log(rate) vs $\log[H_2O_2]$) using the axes provided. Label all axes with units and scales.

SECTION 8 — DATA ANALYSIS AND INTERPRETATION

(i) Show the calculation of mean time, rate (1/t), and $[H_2O_2]$ for each experiment.

(ii) Show how you determine the order of reaction from the gradient of the log-log plot.

(iii) Calculate the rate constant (k) from your data. Include units.

(iv) Calculate the percentage uncertainty in your timing measurements.

(v) Interpret your results against your hypothesis.

SECTION 9 — CONCLUSION AND RECOMMENDATIONS

(i) State the order of reaction with respect to $[H_2O_2]$, supported by evidence.

(ii) Recommend a maximum safe discharge concentration of H_2O_2 that NEMA should enforce.

(iii) State at least TWO limitations of this laboratory investigation.

(iv) Suggest at least TWO specific improvements to the investigation.

(v) Describe how these findings could be applied to real-world monitoring of the Namanve stream.

Table 1 — Results Table: Effect of $[H_2O_2]$ on Rate of Reaction (Complete during practical)

Expt.	Vol. FA1(cm^3)	Vol. H_2O(cm^3)	$[H_2O_2]$($mol\ dm^{-3}$)	t_1(s)	t_2(s)	t_3(s)	Mean t(s)	Rate=1/t(s^{-1})

Graph 1 — Rate (1/t) vs $[H_2O_2]$ (plot and draw best-fit line; label axes with units)

Graph 2 — log(Rate) vs log[H_2O_2] (plot and draw best-fit line; state gradient = order of reaction)

CALCULATIONS SPACE — Section 8 (Show all working below):

Example calculation of [H_2O_2] after dilution:
$C_1V_1 = C_2V_2$: ________________ × ________________ = ________________ × ________________

∴ [H_2O_2] = ________________ mol dm^{-3}

Rate = 1/t = ________________ s^{-1} Gradient of log-log plot = ________________

Order of reaction w.r.t. [H_2O_2] = ________________

Rate constant k: Rate = k $[H_2O_2]^n$ → k = Rate / $[H_2O_2]^n$ = _______________ Units of k: _______________

% uncertainty in timing = (½ × precision of stopwatch / mean time) × 100 = _______________ %

Scoring Rubric — Item 1

Basis of Evaluation	Score 4	Score 3	Score 2	Score 1
Aim, Variables& Hypothesis	Aim precise, theory-linked. IV, DV, ≥4 controlled variables all correctly identified; controlled variables each explained. Hypothesis quantitative, testable, linked to collision theory with order prediction.	Aim precise. Variables mostly correct (minor gap). Hypothesis testable with qualitative prediction and some collision theory linkage.	General aim. Incomplete variables. Hypothesis plausible but generic, limited theoretical rationale.	Vague/missing aim. Variables largely incomplete. Hypothesis vague or absent.
Materials& Reagents	Complete, accurately spelled list with concentrations and volumes for all tests. Dilution calculations shown for ≥2 concentrations. No unnecessary items.	Mostly complete. Dilution shown for at least one concentration. Minor omissions.	Most essential items. Notable omissions. Dilution partially addressed.	List incomplete or inaccurate. Key reagents missing (e.g. $Na_2S_2O_3$ or starch absent).
Methodology(Logical Flow)	Detailed numbered sequence; iodine clock setup fully described; ≥5 concentrations prepared correctly; repeats specified; anomaly handling included; replicable by another scientist; temperature control addressed.	Detailed, logical. Mostly clear. Minor gap in iodine clock description or concentration preparation.	Steps provided but incomplete or disorganised. Concentration preparation partially described. Repeats mentioned but not detailed.	No logical sequence. Steps incomplete. No safety or accuracy measures.
Risks& Mitigations	≥3 specific hazards with correct GHS symbols. PPE, controls, spill/first aid, and disposal procedures all present and compliant with policy. H_2SO_4 and H_2O_2 hazards both addressed.	Major hazards and PPE listed. GHS mostly correct. Reasonable mitigations with minor gaps.	Basic hazards acknowledged. Generic PPE. No GHS symbols or disposal steps.	Few hazards noted. Mitigations insufficient or inappropriate.
Data Presentation	Table well-formatted: title, all column headings, units, sig. figs., ≥5 concentrations, 3 repeats. Both graphs sketched with title,	Mostly correct table. Both graphs present with minor labelling gap.	Basic table with some units. One graph present with limited labelling.	Disorganised table. Missing units/labels. No graphs or inappropriate type.

Basis of Evaluation	Score 4	Score 3	Score 2	Score 1
	axes labelled with units, correct curve shape, error bars indicated.			
Data Analysis& Interpretation	Correct calculations for [H_2O_2], mean t, rate (1/t); working shown. Gradient of log-log plot used to find order. k calculated with correct units. Uncertainty calculated. Results interpreted against hypothesis. Anomalies addressed.	Calculations correct; basic uncertainty; order determined; sound interpretation with minor gaps.	Essential calculations done; limited uncertainty; order partially determined; interpretation reasonable but superficial.	Calculation errors. No uncertainty. Order not determined. Weak interpretation.
Conclusion& Recommendations	Conclusion directly supported by data. Order stated with evidence. Specific NEMA concentration limit recommended with scientific justification. ≥2 limitations acknowledged. ≥2 improvements suggested. Real-world stream monitoring implications discussed.	Supported conclusion. Order stated. NEMA recommendation given. Some limitations and improvements noted.	Conclusion loosely tied to data. Generic NEMA note. Generic limitation mentioned.	Conclusion weak or unsupported. No NEMA recommendation. No limitations.

ITEM 2 — Compulsory

Item 2

Construct: AO4 — Chemical Equilibria & Electrochemical Systems

Construct / Topics:
Topic 10: Electrochemistry | Context: Industrial Electroplating Quality Control

RwandaMetals Finishing Ltd (RMFL), a metal plating company in Kigali, Rwanda, provides copper electroplating services to the electronics and jewellery manufacturing industries. The company has been experiencing inconsistent copper coating thickness and declining current efficiency in their electroplating baths. The quality control manager suspects that gradual depletion of Cu^{2+} ions in the $CuSO_4$ electrolyte is the root cause.

The relevant electrode reactions during copper electroplating are:

Cathode (reduction): $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ [E° = +0.34 V]

Anode (oxidation): $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ [copper anode dissolves]

As [Cu^{2+}] in the bath falls over time, the cathode increasingly reduces H^+ instead of Cu^{2+}, producing H_2 gas (pitting defects) and reducing current efficiency. RMFL has contracted your team as electrochemical consultants to investigate how [$CuSO_4$] affects the mass of copper deposited and the current efficiency of the cell. The company needs you to identify the optimal [$CuSO_4$] range to maintain product quality and minimise energy waste.

REAGENTS AND MATERIALS PROVIDED:

- FB1 — 1.0 mol dm^{-3} copper(II) sulfate solution ($CuSO_4$)
- FB2 — 0.5 mol dm^{-3} sulfuric acid solution (H_2SO_4) — to improve conductivity
- Distilled water
- Pre-cleaned, pre-weighed copper anode (mass recorded by supervisor)
- Pre-cleaned, pre-weighed steel cathode plates (mass recorded before each experiment)
- DC power supply (0–12 V, 0–5 A), ammeter, voltmeter, connecting wires, crocodile clips
- Beakers (250 cm^3, 500 cm^3), measuring cylinders, stopwatch (digital)
- Analytical balance (±0.001 g), fine sandpaper, acetone (for electrode cleaning)
- Safety: gloves, goggles, lab coat, fume cupboard available

Scientific Background:

• FARADAY'S LAW: The theoretical mass of copper deposited is given by:
$m(\text{theoretical}) = (M \times I \times t) / (n \times F)$ where M = 63.5 g mol^{-1}, n = 2, F = 96,500 C mol^{-1}, I = current (A), t = time (s)

• CURRENT EFFICIENCY (%): = (actual mass deposited / theoretical mass) × 100

• RATE OF DEPOSITION: = actual mass deposited (g) / time (s) [g s^{-1}]

• At LOW [Cu^{2+}]: reduction of H^+ to H_2 competes with Cu^{2+} reduction → lower current efficiency, pitting, pale deposits.

• At HIGH [Cu^{2+}]: more Cu^{2+} ions available at cathode → higher efficiency, uniform, bright deposits.

• The NERNST EQUATION predicts: E_cell = E° + (0.0592/n) × log[Cu^{2+}] — lower [Cu^{2+}] reduces cell voltage.

TASK

Design an experiment to investigate the research question and write a structured report of your findings. Your report must include ALL components listed in the scoring criteria.

Design a quantitative investigation to determine how the concentration of $CuSO_4$ electrolyte affects the rate of copper deposition and current efficiency. Write a formal scientific report for RwandaMetals Finishing Ltd.

Your report MUST include the following sections:

SECTION 1 — AIM
State a precise aim linking the investigation to Faraday's Law and industrial electroplating quality.

SECTION 2 — VARIABLES
(i) Independent variable: state what you change and the range (at least 5 values).
(ii) Dependent variables: state all measured quantities and their units.
(iii) Controlled variables: identify at least FOUR and explain how each is maintained.

SECTION 3 — HYPOTHESIS
State a testable, quantitative hypothesis predicting how [$CuSO_4$] affects rate of deposition and current efficiency. Link to Faraday's Law, ion concentration, and the Nernst equation.

SECTION 4 — MATERIALS AND REAGENTS
List all apparatus and chemicals with quantities, concentrations, and sizes. Show how to prepare at least FIVE different [$CuSO_4$] solutions from FB1 by dilution. Show full $C_1V_1 = C_2V_2$ calculations for at least TWO concentrations. Include the volume of FB2 (H_2SO_4) to add to each solution.

SECTION 5 — METHODOLOGY
Write a detailed, numbered procedure. Include: (i) electrode cleaning, drying, and weighing procedure, (ii) circuit assembly and how to check connections, (iii) how you fix current and time for each experiment, (iv) how you re-weigh the cathode after each experiment, (v) how to calculate actual and theoretical mass deposited for each [$CuSO_4$], (vi) number of repeats and anomaly handling, (vii) how to clean/restore electrodes between experiments.

SECTION 6 — RISKS AND MITIGATIONS
Identify at least THREE hazards. For each: (i) GHS symbol and hazard name, (ii) specific risk, (iii) control measure and PPE required, (iv) first aid and disposal procedure.

SECTION 7 — DATA PRESENTATION

(i) Complete Table 2 provided for at least 5 concentrations.

(ii) Sketch Graph 3 (rate of Cu deposition vs [$CuSO_4$]) and Graph 4 (current efficiency vs [$CuSO_4$]) on the axes provided. Label axes with units; indicate expected curve shape.

SECTION 8 — DATA ANALYSIS AND INTERPRETATION

(i) Show the Faraday's Law calculation for theoretical mass of Cu for one experiment.

(ii) Show the calculation of current efficiency (%) for one experiment.

(iii) Show how you calculate rate of deposition for one experiment.

(iv) Calculate the percentage uncertainty in mass measurement using the balance precision.

(v) Explain how graphs 3 and 4 support or refute your hypothesis.

(vi) Identify any anomalous data points and suggest reasons for them.

SECTION 9 — CONCLUSION AND RECOMMENDATIONS

(i) State the optimal [$CuSO_4$] range for maximum deposition rate and current efficiency, supported by data.

(ii) Acknowledge at least TWO limitations of your laboratory investigation vs industrial conditions.

(iii) Recommend at least TWO specific measures RMFL should implement to maintain electrolyte quality.

(iv) Suggest how RMFL could use the Nernst equation to predict when the bath needs replenishment.

(v) Discuss one broader implication of your findings for sustainable industrial electroplating.

Table 2 — Results Table: Effect of [$CuSO_4$] on Cu Deposition and Current Efficiency

Ex pt.	[$CuSO_4$](mol dm^{-3})	Initial cathode mass (g)	Final cathode mass (g)	Actual mass deposite d (g)	Curre nt I(A)	Time t(s)	Theoretic almass (g)	Curren tefficie ncy (%)

FARADAY'S LAW CALCULATION — Section 8 (Show full working):

Given: I = _______ A, t = _______ s, M(Cu) = 63.5 g mol^{-1}, n = 2, F = 96,500 C mol^{-1}

m(theoretical) = (M × I × t) / (n × F) = (_____ × _____ × _____) / (2 × 96500) m(theoretical) = ________________________ g

Current efficiency = (m actual / m theoretical) × 100 = (_____ / _____) × 100 = _______ %

Rate of deposition = m actual / t = _______ / _______ = _______ g s^{-1}

% uncertainty in mass = (precision of balance / measured mass) × 100 = (0.001 / ______) × 100 = _______ %

Graph 3 — Rate of Cu deposition (g s^{-1}) vs [$CuSO_4$] (mol dm^{-3}) — label axes, mark units, show expected curve

Graph 4 — Current efficiency (%) vs [$CuSO_4$] (mol dm^{-3}) — label axes, mark units, show expected curve

Scoring Rubric — Item 2

Basis of Evaluation	Score 4	Score 3	Score 2	Score 1
Aim, Variables& Hypothesis	Aim precise and directly linked to Faraday's Law and industrial electroplating. IV, DV (both rate and efficiency), ≥4 controlled variables correctly identified and explained. Hypothesis quantitative, testable, links to Nernst equation and current efficiency.	Aim precise. Variables mostly correct. Hypothesis testable with Faraday linkage and qualitative prediction.	General aim. Incomplete variables. Hypothesis plausible but generic.	Vague aim. Variables largely missing. Hypothesis absent or unrelated to chemistry.
Materials& Reagents	Complete list; correctly spelled; all apparatus with sizes and concentrations. Dilution calculations shown for ≥2 concentrations using $C_1V_1=C_2V_2$. H_2SO_4 volume included. No unnecessary items.	Mostly complete. Dilution shown for at least one. Minor omissions.	Most items present. Notable omissions. Dilution partially addressed.	List incomplete. Key items missing (e.g. balance, ammeter, or electrodes absent).
Methodology(Logical Flow)	Detailed numbered steps: electrode prep/weighing, circuit setup, fixed I and t, re-weighing, ≥5 concentrations, repeats, anomaly handling, electrode cleaning between runs — all described clearly and replicably.	Detailed and logical. Most steps clear. Minor gap in electrode prep or anomaly handling.	Steps provided but incomplete or disorganised. Lacks detail in weighing or repeat handling.	No logical sequence. Steps incomplete. Safety not addressed.
Risks& Mitigations	≥3 specific hazards with GHS symbols. PPE, controls, first aid, and disposal all present. Electrical hazard and corrosive $CuSO_4$/H_2SO_4 both identified.	Major hazards listed. GHS mostly correct. Reasonable mitigations. Minor gaps.	Basic hazards. Generic PPE. No GHS or disposal detail.	Few hazards. Insufficient mitigations. No PPE or GHS.
Data Presentation	Table well-formatted: title, all 9 columns, units, sig. figs., ≥5 concentrations. Both	Mostly correct table. Both graphs mostly correct with minor labelling gap.	Basic table with some units. One graph present with limited labelling.	Disorganised table. Missing labels. No graphs or inappropriate type.

Basis of Evaluation	Score 4	Score 3	Score 2	Score 1
	graphs sketched with titles, labelled axes + units, correct curve shapes (increasing then plateau for rate; increasing curve for efficiency).			
Data Analysis& Interpretation	Faraday calculation fully shown; current efficiency and rate calculated correctly; working shown; % uncertainty calculated; both graphs interpreted against hypothesis; anomalies identified and explained; Nernst equation referenced.	Faraday correct; rate and efficiency calculated; sound interpretation; minor uncertainty gap.	Faraday attempted; limited rate/efficiency; interpretation reasonable but superficial.	Calculation errors or absent. No uncertainty. Weak interpretation.
Conclusion& Recommendations	Conclusion directly supported by data. Optimal [$CuSO_4$] range stated with evidence. ≥2 limitations vs industrial conditions acknowledged. ≥2 specific RMFL recommendations with justification. Nernst replenishment strategy suggested. Sustainability discussed.	Supported conclusion. Optimal range suggested. Some limitations and RMFL recommendations offered.	Conclusion loosely tied to data. Generic RMFL notes. Generic limitations mentioned.	Conclusion weak or unsupported. No recommendations. No limitations.

END OF PAPER 2 — PRACTICAL

Designed & Produced by TR JOELPCM | Following NCDC ASC Assessment Guidelines 2026

For more papers and solutions contact:
📞 **0788477510** ✉ **joelamanyire3@gmail.com**
"Transforming Learners Through Excellence"