Chemistry 2019 v1.4

IA2 high-level annotated sample response

November 2022

Student experiment (20%)

This sample of student work has been published by the QCAA to assist and support teachers to match evidence in student responses to the characteristics described in the instrument-specific marking guide (ISMG).

The following sample is an unedited authentic student response produced with permission. Any identifying features have been redacted from the response. It may contain errors and/or omissions that do not affect its overall match to the characteristics indicated.

Assessment objectives

2. apply understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies and process primary data
3. analyse experimental evidence about chemical equilibrium systems or oxidation and reduction
4. interpret experimental evidence about chemical equilibrium systems or oxidation and reduction
5. investigate phenomena associated with chemical equilibrium systems or oxidation and reduction through an experiment
6. evaluate experimental processes and conclusions about chemical equilibrium systems or oxidation and reduction
7. communicate understandings and experimental findings, arguments and conclusions about chemical equilibrium systems or oxidation and reduction

Queensland Government
Queensland Curriculum & Assessment Authority
221271

Instrument-specific marking guide (ISMG)

Criterion: Research and planning

Assessment objectives

2. apply understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies and process primary data
5. investigate phenomena associated with chemical equilibrium systems or oxidation and reduction through an experiment

The student work has the following characteristics:	Marks
• informed application of understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies demonstrated by – a considered rationale for the experiment – justified modifications to the methodology • effective and efficient investigation of phenomena associated with chemical equilibrium systems or oxidation and reduction demonstrated by – a specific and relevant research question – a methodology that enables the collection of sufficient, relevant data – considered management of risks and ethical or environmental issues.	5–6
• adequate application of understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies demonstrated by – a reasonable rationale for the experiment – feasible modifications to the methodology • effective investigation of phenomena associated with chemical equilibrium systems or oxidation and reduction demonstrated by – a relevant research question – a methodology that enables the collection of relevant data – management of risks and ethical or environmental issues.	3–4
• rudimentary application of understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies demonstrated by – a vague or irrelevant rationale for the experiment – inappropriate modifications to the methodology • ineffective investigation of phenomena associated with chemical equilibrium systems or oxidation and reduction demonstrated by – an inappropriate research question – a methodology that causes the collection of insufficient and relevant data – inadequate management of risks and ethical or environmental issues.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Analysis of evidence

Assessment objectives

2. apply understanding of chemical equilibrium systems or oxidation and reduction to modify experimental methodologies and process primary data
3. analyse experimental evidence about chemical equilibrium systems or oxidation and reduction
5. investigate phenomena associated with chemical equilibrium systems or oxidation and reduction through an experiment

The student work has the following characteristics:	Marks
• appropriate application of algorithms, visual and graphical representations of data about chemical equilibrium systems or oxidation and reduction demonstrated by correct and relevant processing of data • systematic and effective analysis of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by – thorough identification of relevant trends, patterns or relationships – thorough and appropriate identification of the uncertainty and limitations of evidence • effective and efficient investigation of phenomenon associated with chemical equilibrium systems or oxidation and reduction demonstrated by the collection of sufficient and relevant raw data.	5–6
• adequate application of algorithms, visual and graphical representations of data about chemical equilibrium systems or oxidation and reduction demonstrated by basic processing of data • effective analysis of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by – identification of obvious trends, patterns or relationships – basic identification of the uncertainty and limitations of evidence • effective investigation of phenomenon associated with chemical equilibrium systems or oxidation and reduction demonstrated by the collection of relevant raw data.	3–4
• rudimentary application of algorithms, visual and graphical representations of data about chemical equilibrium systems or oxidation and reduction demonstrated by incorrect or irrelevant processing of data • ineffective analysis of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by – identification of incorrect or irrelevant trends, patterns or relationships – incorrect or insufficient identification of the uncertainty and limitations of evidence • ineffective investigation of phenomenon associated with chemical equilibrium systems or oxidation and reduction demonstrated by the collection of insufficient and irrelevant raw data.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Interpretation and evaluation

Assessment objectives

4. interpret experimental evidence about chemical equilibrium systems or oxidation and reduction
6. evaluate experimental processes and conclusions about chemical equilibrium systems or oxidation and reduction

The student work has the following characteristics:	Marks
• insightful interpretation of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by justified conclusion/s linked to the research question • critical evaluation of experimental processes about chemical equilibrium systems or oxidation and reduction demonstrated by – justified discussion of the reliability and validity of the experimental process – suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence.	5–6
• adequate interpretation of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by reasonable conclusion/s linked to the research question • basic evaluation of experimental processes about chemical equilibrium systems or oxidation and reduction demonstrated by – reasonable description of the reliability and validity of the experimental process – suggested improvements and extensions to the experiment that are related to the analysis of evidence.	3–4
• invalid interpretation of experimental evidence about chemical equilibrium systems or oxidation and reduction demonstrated by inappropriate or irrelevant conclusion/s • superficial evaluation of experimental processes about chemical equilibrium systems or oxidation and reduction demonstrated by – cursory or simplistic statements about the reliability and validity of the experimental process – ineffective or irrelevant suggestions.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Communication

Assessment objectives

7. communicate understandings and experimental findings, arguments and conclusions about chemical equilibrium systems or oxidation and reduction

The student work has the following characteristics:	Marks
• effective communication of understandings and experimental findings, arguments and conclusions about chemical equilibrium systems or oxidation and reduction demonstrated by – fluent and concise use of scientific language and representations – appropriate use of genre conventions – acknowledgement of sources of information through appropriate use of referencing conventions.	2
• adequate communication of understandings and experimental findings, arguments and conclusions about chemical equilibrium systems or oxidation and reduction demonstrated by – competent use of scientific language and representations – use of basic genre conventions – use of basic referencing conventions.	1
• does not satisfy any of the descriptors above.	0

Task

See IA2 sample assessment instrument: Student experiment (20%) (available on the QCAA Portal).

Sample response

Criterion	Marks allocated	Provisional marks
Research and planning Assessment objectives 2, 5	6	6
Analysis of evidence Assessment objectives 2, 3, 5	6	6
Interpretation and evaluation Assessment objectives 4, 6	6	6
Communication Assessment objective 7	2	2
Total	**20**	**20**

The annotations show the match to the instrument-specific marking guide (ISMG) performance-level descriptors.

Research and Planning [5–6] **A specific and relevant research question** The research question is clearly defined. The independent variable and the dependent variable are clearly stated. **Communication [2]** **Acknowledgment of sources of information through appropriate use of referencing conventions** The use of in-text referencing fits the purpose of a scientific report. **Communication [2]** **Appropriate use of genre conventions** The response follows scientific conventions of chemical equations, units and significant figures correctly.	see body below

The effect of changing the concentration of the electrolyte solution (Copper(II) Nitrate) at the cathode on the voltage output produced by a galvanic cell

Rationale

A redox reaction is a reaction that involves the transfer of electrons through oxidation (loss of electrons) and the reduction (gain of electrons), inducing an electrical charge (Libretexts, 2020).

Galvanic cells utilise spontaneous redox reactions to convert chemical energy into electrical energy. It contains two half-cells, each with an electrode immersed in an electrolyte solution containing a dissolved salt of the corresponding metal. Those two electrodes are connected by a wire which allows the flow of electrons from the anode to the cathode, which produces a current that can be harnessed as electrical energy. A salt bridge between the solutions permits the movement of anions and cations, to ensure the system remains neutral (Johnson, 2020).

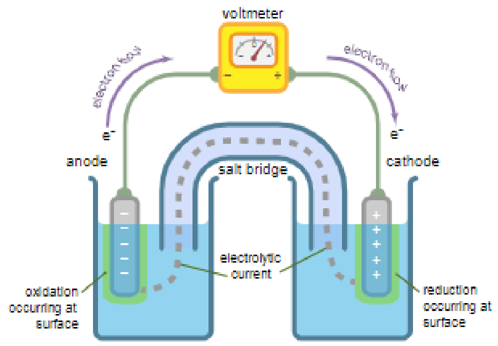


Figure 1: diagram of a galvanic cell

Due to differences in the standard electrode potentials of the half-cells, the more negative half-cell (anode) will spontaneously oxidise, to produce a metal cation, while losing an electron to the cathode half-cell, where a metal ion is produced, using that electron (Helmenstine, 2020).

Originally, the experiment was comparing the cell potential difference of several half-cell combinations, but in this experiment, a Zn|Cu galvanic cell will be utilised:

Anode: $Zn(s) \rightleftharpoons Zn(aq)^{2+} + 2e^-$ (-0.76)

Cathode: $Cu(aq)^{2+} + 2e- \rightleftharpoons Cu(s)$ (+0.34)

Overall reaction: $Cu(aq)^{2+} + Zn(s) \rightleftharpoons Cu(s) + Zn(aq)^{2+}$

The 2 electrolyte solutions used were $Cu(NO_3)_2$ and $Zn(NO_3)_2$. At the cathode, copper metal was immersed in $Cu(NO_3)_2$ solution and at the anode, zinc metal was immersed in $Zn(NO_3)_2$ solution.

Research and Planning [5–6] **A considered rationale for the experiment** The rationale links the application of appropriate scientific concepts to the development of the research question. The relationship between electrolyte concentration and voltage is considered and mathematically linked to the validity of the data collection to address the research question.	The potential difference of a galvanic cell is dependent on the difference in standard electrode potential between the cathode and anode. Under Standard Ambient Temperature Pressure (SATP); 298Kelvin, 1M Concentration and 100Kpa (Libretexts, 2019), potential difference can be calculated: $Ecell^0 = Ecathode^0 - Eanode^0$ However, when a variable such as concentration has been altered, the calculation of voltage must be adjusted to account for that change. To unify the standard cell potential with changing concentration, the Nernst equation at SATP may be used and $E = E^0 - \frac{0.0592}{n} logQ$ $E^0 = standard\ potential$ $E = reduction\ potential$ $n = number\ of\ moles\ of\ electrons$ $Q, reaction\ quotient = (\frac{products}{reactants})$ $E = E^0 - \frac{0.0592}{n} \log (\frac{Zn^{2+}}{Cu^{2+}})$ *Where* Zn^{2+} *is consistently 1M* $\therefore E = E^0 - \frac{0.0592}{n} \log (\frac{1}{Cu^{2+}})$ $E = E^0 - \frac{0.0592}{n} \log (Cu^{2+})^{-1}$ $E = E^0 + \frac{0.0592}{n} \log (Cu^{2+})$ *Since* E^0 *and* $\frac{0.0592}{n}$ *are constant throughout the experiment* $E \propto log(Cu^{2+})$

Research and Planning [5–6]

Justified modifications to the methodology

The response gives sound reasons for how the modifications to the methodology will refine, extend or redirect the original experiment, and includes strategies for achieving these modifications.

Modified Method

Type of Modification	Modification	Justification
Redirection	Instead of comparing the cell potential difference of several half-cell combinations, only the galvanic cell containing copper and zinc half-cells was investigated. Thus, the independent variable was changed to the concentration of the cathode electrolyte solution.	This will allow a more focussed application of electrolyte solution (cathode) concentration on cell potential difference. Accordingly, the relationship between potential difference and concentration could be explored.
Extension	Changing the number of concentrations of Copper Nitrate (0.2M, 0.4M, 0.6M, 0.8M, 1M) tested	This will more validly test whether the concentration of copper nitrate (cathode) affects voltage. Further, identification of patterns and trends, between independent and dependent variables can thus be established.
Refinement	Three trials for each concentration of Copper Nitrate were performed.	Ensure that the results are reliable by reducing random error. It will also allow the calculation of mean, and percentage of uncertainties.
Refinement	Polish both electrodes after every change in concentration	This will increase the validity of the experiment, as the electrode willnot have a metallic buildup, ensuring that the rate of oxidation and reduction is not inhibited.

Research and Planning [5–6]

Considered management of risks and ethical or environmental issues

The response shows careful and deliberate identification and planning to handle risks and ethical or environmental issues in the experiment.

Risk assessment

Hazard	Risk	Control measures
Glass equipment	Breakage of glass	Cautiously handle Stay aware of surroundings Listen to teachers' commands
1M Copper Sulphate 1M Potassium Nitrate 1M Zinc Nitrate	Skin irritation Eye irritation Inhalation: light headedness, respiratory irritation	Gloves Goggles Apron
Zinc metal Copper metal	Cuts Skin irritation	Cautiously handle Gloves

	To avoid harm to the environment, a waste container will be utilised to appropriately dispose of the product. There are not ethical concerns for this experiment

Analysis of evidence [5–6]

Collection of sufficient and relevant raw data

The raw data is adequate for forming a conclusion and has direct bearing upon the research question. Five variations of the independent variable and three repetitions of each measurement are adequate.

Results

Table 1: Raw Data

Copper (II) Nitrate Solution	Voltage, V ±0.005		
	Trial 1	Trial 2	Trial 3
25mL Cu(NO3)2	0.86	0.87	0.87
20mL Cu(NO3)2 + 5mL H20	0.89	0.88	0.89
15mL Cu(NO3)2 + 10mL H20	0.91	0.91	0.89
10mL Cu(NO3)2 + 15mL H20	0.92	0.92	0.93
5mL Cu(NO3)2 + 20mL H20	0.94	0.92	0.92

The data from table 1 was calculated through the processes shown in table 2.

Analysis of evidence [5–6]

Correct and relevant processing of data

Raw data is manipulated accurately to provide evidence that is applicable to the research question.

Table 2: Processing of $Cu(NO_3)_2$

Data	Formula	Calculation
Voltage measurement uncertainty	$\frac{Smallest\ graduation\ of\ measurement}{2}$	$\frac{0.01}{2}$ =0.005V
Concentration of $Cu(NO_3)_2$	$\frac{Original\ concentration\ \times volume\ of\ Cu(NO3)2}{total\ volume\ of\ solution}$	$\frac{1 \times 0.025}{0.025}$ =1M
Copper nitrate solution absolute error	$\frac{Smallest\ graduation\ of\ measurement}{2}$	$\frac{0.05 + 0.05}{2}$ =0.5mL
Concentration percentage uncertainty	$\frac{Absolute\ error}{Total\ volume} \times 100$	$\frac{1 \times 0.5}{25}$ = ±2%
Mean voltage at different concentrations	$\frac{\sum Voltage\ per\ trial}{3}$	$\frac{0.94 + 0.92 + 0.92}{3}$ =0.926667V
Absolute voltage uncertainty	$\frac{Largest\ voltage - smallest\ voltage}{2}$	$\frac{0.94 - 0.92}{2}$ =0.01V
Potential difference at 1M for both anodic and cathodic solutions	$E_{cell} = E_{cathode} - E_{anode}$	$0.34 - (-0.76)$ =1.1 V

Theoretical voltage (Nernst equation at 25°C)	$E^{O} - \frac{0.0591}{n\ of\ electrons\ transferred} Log(Q)$ *Q is the reaction quotient	$1.1 - \frac{0.0591}{2} Log(1)$ $= 1.1$V
Difference	$Actual - theoretical$	$0.926667 - 1.1$ $=$ -0.173333V
Percentage error	$\frac{Difference}{Theoretical\ voltage}$	$\frac{-0.173333}{1.1} \times 100\%$ $=$ -15.76%

Communication [2]

Fluent and concise use of scientific language and representations

The response represents data clearly so that the trends, patterns and relationships can be easily identified.

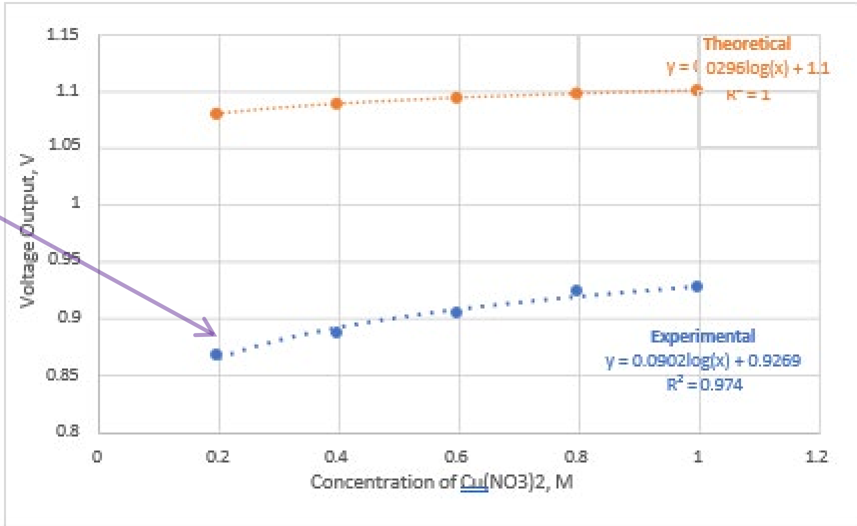
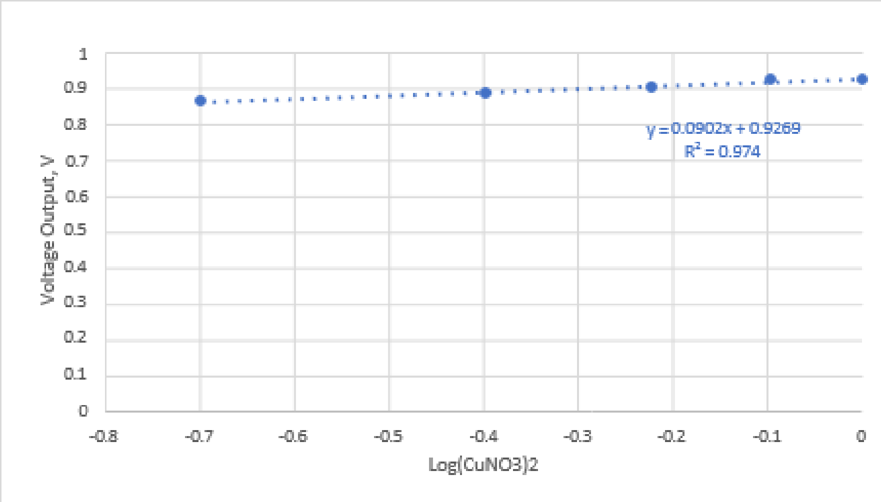


Figure 2: $Cu(NO_3)_2$ concentration, M vs Voltage Output, V

Table 3: processed data, Uncertainty of the mean, Theoretical voltage (V), Difference, and percentage difference

Concentration of Cu(NO3)2, M	Log(Cu(NO3)2)	Voltage, V	Theoretical value	Difference	Percentage difference
0.2 ± 2%	-0.6990	0.8667±0.577%	1.0793	0.212633	-19.7010
0.4 ± 2%	-0.3979	0.8867±0.564%	1.0882	0.201533	-18.5199
0.6 ± 2%	-0.2218	0.9033±0.554%	1.0934	0.190067	-17.3831
0.8 ± 2%	-0.0969	0.9233±0.542%	1.0971	0.173767	-15.8387
1 ± 1%	0	0.9267±0.540%	1.1	0.173333	-15.7576

	 *Figure 3: Log $Cu(NO_3)_2$ vs Voltage Output, V* **Trend, Patterns and relationships** Figure 2 displays the voltage output of a galvanic cell when increasing the concentration of copper nitrate. At 0.2M, the mean voltage was 0.867V, whilst the mean voltage was 0.927V at 1M (table 1).
Analysis of evidence [5–6] Thorough identification of relevant trends, patterns or relationships The identified trends, patterns and relationships are not superficial and allow a justified conclusion to the research question to be drawn.	This shows that there is an increase in voltage with increased cathode-electrolyte concentration. As suggested by the derivation of the Nernst equation, the experimental mean voltages were fitted to a logarithmic trendline (E_{Cell}=0.0902log(Cu^{2+})+0.9269), with a R^2 value of 0.974. This high R^2 value suggests that the data points exhibit minimal deviation, hence producing a strong correlation with the logarithmic trendline. In addition, this trendline was compared to the theoretical equation using Nernst equation (E_{Cell}=0.0296log(Cu^{2+})+1.1). The comparison of these voltage revealed a pattern that the theoretical voltages (1.097V-1.1V) were consistently higher than the experimental (0.867V-0.93V). Considering the relationship outlined in the rationale, the voltages of the experimental data were then plotted with log(Cu^{2+}) (Figure 3). Figure 3 illustrates a linear relationship (0.0902log(Cu^{2+})+0.9269) between log(Cu^{2+}) and the mean voltages, ruled by a high R^2 value of 0.974. When the log(0.2) or - 0.699 increased to log(1) or 0, the voltage increased from 0.867V to 0.927V. This strong fit, suggest that as log(Cu^{2+}) increases, the voltage output linearly increases, further supporting the hypothesised and theorized relationship between voltage and log(Cu^{2+}) (Figure 3). **Uncertainty and Limitations:**
Analysis of evidence [5–6] Thorough and appropriate identification of the uncertainty and limitations of evidence	Table 1 displayed the voltage output percentage uncertainties of the mean ranging from 0.542% to 1.107%. These low percentage uncertainties, reveal a small variance between trials, thus providing reliability of the mean voltage. Although relatively low, these percentage uncertainties could be a result of the concentration uncertainty at ≤2%, which may not have been truly indicative of the concentration that was

The response suitably identifies uncertainty and limitations of the data in a way that is not superficial or partial. The response examines the uncertainty to determine if the evidence that will be used to draw a conclusion to the research question is reliable and valid.	experimented. Further, the slight fluctuation of the data could be due to the limitation of the methodology and equipment of the experiment e.g. errors in measuring exact volumes. The high percentage difference between the theoretical and experimental voltages ranging from 18.7% to 24.5%, are likely due to the limitation of the methodology and environment of the experiment. Whilst completing the experimental process, the same 2 electrodes were utilized, where they were polished between concentration. The inability to polish the electrodes between trials could have potentially caused the buildup of oxidized (zinc) and reduced (copper) layers, inhibiting the rate of oxidation and reduction. In addition, to calculate the theoretical values of the potential difference, he Nernst equation at SATP was used, where only concentration and number of moles of electrons were considered. This meant that despite different temperature and pressure, the theoretical values were at SATP. Furthermore, the resistance within the filter-paper salt bridge, could have contributed to a decreased voltage output due to restricted ion movement.
Interpretation and evaluation [5–6] Justified discussion of the reliability and validity of the experimental process The response uses sound reasoning and evidence from the identification of uncertainties and limitations to support the consideration of the reliability and validity of the experimental process.	**Evaluation** The results produced from this experiment can be considered reliable and moderately valid, despite some inconsistencies. By completing three repetitions of each concentration of Copper Nitrate, the sample size could be considered sound but not thorough. With moderately high numbers of trials combined with a range of several concentrations, reliable trends, patterns, and ranges could be established for the data. The low percentage uncertainty of the mean ranged from 0.541% to 1.107%, suggesting low variability and high reliability. This was further supported by the R^2 value of 0.974, indicating that there was a strong correlation with the logarithmic relationship, as outlined in the rationale. Further, the results from this experiment suggest that 97% of the time, it would be likely a greater concentration of Cu^{2+} concentration, would result in a greater voltage output (Figure 2). In addition, the high percentage differences between the theoretical and experimental voltages due to experimental method limitations caused a decrease in data validity. These percentage differences ranged from -15.8% to -19.7%, indicating that the experimental voltages were significantly lower than the theoretical values, reducing the validity of the data (Table 2). Despite this, the experimental and theoretical data both portrayed logarithmic relationships as outlined in the rationale. Nevertheless, the modified methods were able to provide validity through the development of trends and patterns, however, were unable to provide accurate potential differences that were truly representative of the copper nitrate concentrations. Although this reaction is a good indication of the cathode electrolyte concentration, cell potential difference relationship, it may not be true for all

Interpretation and evaluation [5–6]

Suggested improvements and extensions to the experiment which are logically derived from the analysis of evidence.

The suggested modifications address the limitations of the experiment identified in the analysis.

Improvements

Analysis of Evidence	Improve by:
Systematic Error The filter-paper Salt bridge used was ineffective	Utilizing a glass salt bridge would decrease the resistance on cation and anion movements, resulting in increased voltage outputs.
Systematic Error Temperature was not recorded throughout the experiment and since it was completed over 2 days, the temperature was not constant	Recording the temperature prior and during experimentation to ensure the temperature is kept constant. Therefore, temperature can be considered when using the Nernst equation.
Systematic Error The zinc and copper electrodes were polished after every change in concentration	Polishing both electrodes after each trial, to minimize the buildup of oxidized and reduced layer on the electrode.

Extensions

Extension	Explanation
Exploring a larger range of Cu(NO3)2	Only concentrations of 0.2M-1M in increments 0.2M were explored. Hence by increasing the number of concentrations, would allow more thorough identification of trends and consistent patterns, whilst improving the validity of the data.
Changing the concentration of the anode.	By keeping the cathode concentration, zinc electrode and copper electrode a constant and changing the concentration of the anode and testing the voltage output, this would explore the validity of the Nernst equation.
Investigating the effect that temperature has on voltage.	Whilst the effect of concentration on voltage is known, it would be beneficial to explore the effect of temperature on the voltage. It would also be beneficial to explore how greatly it affects voltage in comparison to concentration.

Interpretation and evaluation [5–6]

Justified conclusion/s linked to the research question.

The response uses sound evidence and concepts, supported by scientific literature, to support the conclusion and relate results to the research question.

Conclusion

The report was aimed to investigate the effect of changing the cathode electrolyte concentration, copper nitrate, on voltage output of a galvanic cell, when keeping the concentration of the anode electrolyte solution, cathode electrode and anode electrode constant. The results of this experiment suggest that when increasing the concentration of Copper Nitrate from 0.2M to 1M, results in an increased voltage as derived by the Nernst equation (figure 2). This was supported by the logarithmic relationship $V = 0.0902\log10(Cu^{2+}) + 0.9269$, which was ruled with a high

	R^2 of 0.974, showing strong correlation to the logarithmic relationship. Concentration at 1M recorded the highest voltage of 0.93V (table 1). The 0.2M concentration resulted in the lowest voltage of 0.87V. It was hypothesised that an increase in cathode electrolyte concentration, would cause a further displacement of the equilibrium, hence creating a more spontaneous reaction, resulting in an increased voltage output. This hypothesis has been supported by the results produced. However due to limitations of the experimental method, this resulted in high percentage differences (up to -19.7%) between the experimental and theoretical voltages (Table 2). These high percentage differences suggest there were significant differences between the theoretical Voltages and experimental, making the results slightly invalid. However, low uncertainty means ranging from 0.542% to 1.107%, suggested high reliability.
Communication [2] Acknowledgment of sources of information through appropriate use of referencing conventions The use of reference list fits the purpose of a scientific report.	**Reference list** Helmenstine. (2020). What Is a Galvanic Cell?. Retrieved from https://www.thoughtco.com/galvanic- cell-definition-604080 Libretexts. (2019). 11.1: Galvanic Cells. Retrieved from https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Chemistry_(Zumdahl_and_Decoste)/11%3A_Electrochemistry/11.1%3A_Galvanic_Cells. Libretexts. (2019). Oxidation-Reduction Reactions. Retrieved from https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Electrochemistry/Redox_Chemistry/Oxidation-Reduction_Reactions. Johnson.K (2020). Can the concentration of the salt bridge be anything for this experiment to work?. Retrieved from https://www.enotes.com/homework-help/galvanic-cell-you-change-concentration-one-307505#:~:text=Changing%20the%20concentration%20of%20one,of%20the%20cell%20becomes%20steeper.

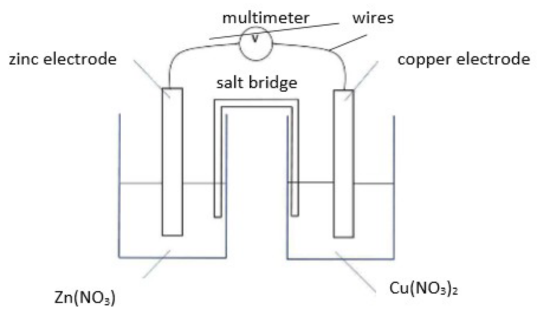
Appendices

Appendix 1: Original method

Table 1 Half-cells

Half-cell	Constituent parts
Zn/Zn^{2+}	50 mL beaker containing a zinc electrode and 25 mL of zinc nitrate solution
Cu/Cu^{2+}	50 mL beaker containing a copper electrode and 25 mL of copper(II) nitrate solution
Ag/Ag^{+}	50 mL beaker containing a silver electrode and 25 mL of silver nitrate solution

2. Join the $Zn/Zn^{2+}$and Cu/Cu^{2+} half-cells using the salt bridge. Attach two wires to the multimeter and clip the other end of one wire to the zinc electrode. Set the Multimeter to the 20 V setting and momentarily touch the second wire to the copper electrode. If the multimeter reading is negative swap the wires around terminals of the multimeter before continuing.
3. Record the voltage and identify the positive and negative electrodes in Table 2. (The positive electrode is connected to the positive terminal of the multimeter.)
4. Disconnect the leads. Remove and discard the salt bridge.
5. Repeat steps 2-4 for each of the other two combinations of half-cells.



Appendix 2: Risk assessment

Redacted for privacy

Items to be prepared by laboratory technician (training code 2)

2 * glass beakers
1 * multimeter
2 * wires (banana plug to alligator clip)
1 * permanent marker
1 * containment tray
3 * safety glasses, aprons, gloves
1 * waste container
1 * zinc electrode (Zn)
1 * copper electrode (Cu)
500mL of 1M zinc nitrate, Zn(NO3)2
500mL of 1M copper (II) nitrate, Cu(NO3)2
15 * strips of filter paper soaked in 0.1M potassium nitrate solution, KNO3

Procedure or reference, including variations

mygrammar.com

Equipment to be used

PVC apron

Potential hazards	*Standard handling procedures*
Releases toxic fumes if heated.	Do not use a PVC apron for any activity that involves high temperature.

glass beaker, 200 mL or less

Potential hazards	*Standard handling procedures*
Breakage of beaker. Cuts from chipped rims.	Inspect and discard any chipped or cracked beakers, no matter how small the damage. Sweep up broken glass with brush and dustpan; do not use fingers.

plastic waste container

copper electrode

zinc electrode

disposable plastic gloves

Potential hazards	*Standard handling procedures*
ALLERGY ALERT. May easily be punctured, allowing entry of liquid. Latex gloves may cause an allergic reaction to some people; check for latex allergies before use. Check for talc allergies, if gloves are powdered with talc. Organic solvents may damage gloves.	Take care not to puncture. Check for punctures before use. Use a type of glove that is suitable for the chemicals to be used.

marker pen (permanent marker)

Potential hazards	*Standard handling procedures*
Inhaling the contents may be harmful, due to toxic volatile solvents. May cause severe irritation, if used on skin as a cosmetic. An allergic reaction is possible. Pen liquid may be flammable.	Recap tightly after use. Do not allow students to inhale fumes. Consult the safety data sheet from the manufacturer before use.

digital multimeter

safety glasses

Potential hazards	*Standard handling procedures*
May transfer pathogens from one user to the next, e.g. eye infections, flu or coronavirus, which may enter the body through the conjunctiva. Scratched or dirty glasses may hinder vision, causing headaches during prolonged use.	Each student should preferably have own safety glasses. If safety glasses are shared, they should be disinfected between use. Safety goggles may be stored in a tank of detergent solution and removed as needed, rinsed and dried before use. Avoid scratching lenses during storage. Check and, if necessary, clean glasses before each use. Ensure that the safety glasses fit the shape of the face and provide protection around the edges, especially at the bottom (against upward splashes of liquid).

plastic tray

connecting wire

Potential hazards
Can be flicked and the end may cause eye injuries.

Chemicals to be used

copper(II) nitrate >0.8 M (>15% wt/wt) — $Cu(NO_3)_{2(aq)}$ CAS: 13778-31-9

Class: nc PG: none Users: 7-12 Training: 1,2,5

GHS data:
DANGER
Toxic if swallowed
Causes skin irritation
Causes serious eye irritation
Very toxic to aquatic life

Potential hazards	*Standard handling procedures*
Toxic. Irritate skin and eyes.	Solubility ~1000 g/L at 20°C.

zinc nitrate 0.79-1 M (15-20% wt/wt) — $Zn(NO_3)_{2(aq)}$ CAS: 10196-18-6

Class: nc PG: none Users: 7-12 Training: 1-5

GHS data:
DANGER
Harmful if swallowed
Causes skin irritation
Causes serious eye irritation
Very toxic to aquatic life with long lasting effects

Potential hazards
Toxic. Irritates skin, eyes and lungs.

potassium nitrate 0.1-1 M (1-10% wt/wt) — $KNO_{3(aq)}$ CAS: 7757-79-1

Class: nc PG: none Users: 7-12 Training: 1-5

GHS data:
WARNING Causes mild skin irritation

Potential hazards
May irritate eyes and skin.

Knowledge

I/we have read and understood the potential hazards and standard handling procedures of all the equipment, chemicals and biological items, including living organisms.
I/we have read and understood the Safety Data Sheets for all hazardous chemicals used in the experiment.
I/we have copies of the Safety Data Sheets of all the hazardous chemicals available in or near the laboratory.

Agreement by student(s)

Redacted for privacy