Victorian Certificate of Education

CHEMISTRY 2026

Unit 2 Examination

Reading time: 10 minutes

Writing time: 90 minutes

Directions to students

Student's Name: _____

Teacher: _____

Structure of booklet

Section	Question to be answered	Total marks
Multiple choice	30	30
Short answer	4	62
	Total	92

Materials

- Students are permitted to bring into the examination room: pencils, highlighters, erasers, sharpeners, rulers, and an approved scientific calculator.

- Students are NOT permitted to bring into the examination room:
white out liquid/tape, phones or electronic devices, including smart watches.

- Students are provided with the following: Question and answer book of 20 pages and VCAA Data booklet.

The task

- Please ensure that you write your name and teacher's name on this booklet. This paper consists of short answer questions.

- There are a total of 92 marks available.

- Be sure to include states with all chemical equations.

- All numerical answers need to be quoted to the correct number of significant figures.

- All working out must be shown in the space provided.

Name _____

All answers must be completed like this example: A ■ C D

- If you make a mistake, **erase** the incorrect answer – **do not** cross it out.
- Marks will **not** be deducted for incorrect answers.
- No mark will be given if more than one answer is completed for any question.

For each question, **shade** the box that indicates your answer.

1 A B C D	11 A B C D	21 A B C D
2 A B C D	12 A B C D	22 A B C D
3 A B C D	13 A B C D	23 A B C D
4 A B C D	14 A B C D	24 A B C D
5 A B C D	15 A B C D	25 A B C D
6 A B C D	16 A B C D	26 A B C D
7 A B C D	17 A B C D	27 A B C D
8 A B C D	18 A B C D	28 A B C D
9 A B C D	19 A B C D	29 A B C D
10 A B C D	20 A B C D	30 A B C D

Section A – Multiple-choice questions

Instructions

• Answer **all** questions in pencil on your Multiple-Choice Answer Sheet.

• Choose the response that is **correct** or that **best answers** the question.

• A correct answer scores 1; an incorrect answer scores 0.

• Marks will **not** be deducted for incorrect answers.

• No marks will be given if more than one answer is completed for any question.

• Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

1. Consider the image of the water cycle shown on the right. Water exists in all three states on Earth mainly due to its:
   a. strong intramolecular covalent bonds
   b. strong intermolecular bonds
   c. weak intermolecular bonds due to dispersion forces
   d. weak intermolecular bonds formed by sharing valence electrons

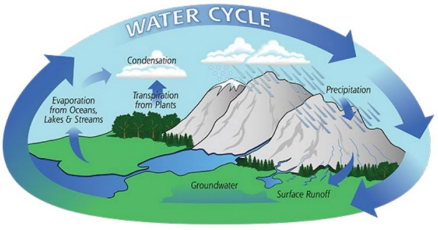


Image from NASA – water cycle

2. Which statement best explains why ice floats on liquid water?
   a. Ice molecules contain weaker covalent bonds than liquid water
   b. Hydrogen bonding forms an open lattice in ice, increasing volume
   c. Liquid water contains no hydrogen bonds
   d. Ice has a higher molar mass than liquid water

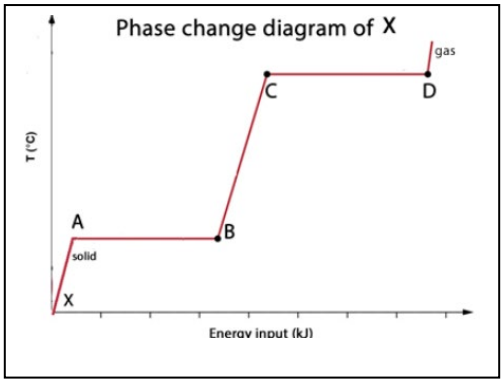
3. The daily average temperature range at Uluru, found in the desert of Central Australia, is between 15 °C and 20 °C. Where as in Melbourne, a coastal city, the temperature range is between a 5 °C and 10°C. This is best explained by:
   a. the higher than normal strength of dispersion forces acting between water molecules
   b. water's low molecular mass
   c. high ocean salinity
   d. water's high latent heat of vaporization

4. A large fresh water lake in East Gippsland is contaminated by lead. Which one process is most likely to be effective as a means of purifying the large amount of water?
   a. Treating the water with $FeCl_2$ followed by sand filtration
   b. Treating the water with AgCl followed by sand filtration
   c. Allow the lead ions (Pb^{2+}) to settle then filter via sand filtration
   d. Treating the water with $CoCl_2$ followed by fine paper filtration

5. When aqueous solutions of barium chloride and sodium sulfate are mixed, a precipitate forms. Which is the correct net ionic equation and spectator ions?
   a. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ and spectator ions are Cl^- and Na^+
   b. $BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$ and spectator ions are Cl^- and Ba^{2+}
   c. $Na^+(aq) + Cl^-(aq) \rightarrow NaCl(s)$ and spectator ions are Cl^- and Na^+
   d. $Ba^{2+}(aq) + 2Cl^-(aq) \rightarrow BaCl_2(s)$ and the spectator ion is Na^+

6. What is the energy required to heat 50.0 g of water from 35 °C to 65 °C.
   a. 6.27 J
   b. 627 J
   c. 6.27 kJ
   d. 0.627 MJ

7. Consider the phase change diagram of a molecular substance "X", shown on the right. What is happening between points C to D?
   a. Intramolecular bonds are being broken
   b. Particles of X are moving from the solid to the liquid phase
   c. The average kinetic energy of particles is increasing
   d. Intermolecular bonds are being broken



8. A 100 g sample of ice at 0.00 °C is heated until it becomes liquid water at 20.00 °C. Using the data below, calculate the total energy required to complete this process?
   Latent heat of fusion of ice = 334 J g^{-1}
   Specific heat capacity of water = 4.18 J g^{-1} $°C^{-1}$
   a. 8.36×10^3 kJ
   b. 3.34×10^4 J
   c. 41.8 kJ
   d. 4.18×10^3 J

The following information relates to questions 9 to 12

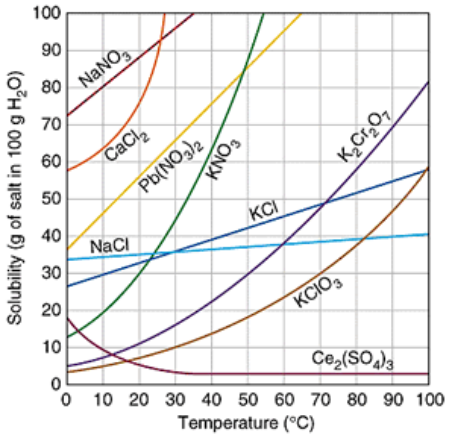


Figure 1 – solubility curves of different salts

9. 200 mL of a saturated solution KNO_3 is cooled from 51 °C to 20 °C. What mass of salt precipitates out of solution?
   a. Approximately 60 grams
   b. Approximately 120 grams
   c. Exactly 1.20 grams
   d. Exactly 1.82 grams

10. Using 300 g of distilled water, at 25 °C, a student is asked to make a saturated solution of $Pb(NO_3)_2$. What is the mass of lead nitrate that should be dissolved in the water?
   a. 120 grams
   b. 18.0 grams
   c. 180 grams
   d. 60.0 grams

11. A 150 grams of water is used to make a saturated solution of $K_2Cr_2O_7$ at 90 °C. This solution is then cooled to 50 °C. How many grams of $K_2Cr_2O_7$ will remain dissolved?
   a. 45 g
   b. 22 g
   c. 30 g
   d. 60 g

12. Which of the following procedures is most likely to yield pure $K_2Cr_2O_7$ crystals from a 100mL solution containing 40g of each of the salts NaCl, KNO_3 and $K_2Cr_2O_7$?
    a. Heat the mixture to 80 °C, then cool slowly to 40 °C so $K_2Cr_2O_7$ crystallises first
    b. Cool the mixture to 20 °C so that $K_2Cr_2O_7$ crystallises immediately
    c. Heat the mixture to 80 °C, then filter immediately
    d. Boil the mixture and evaporate the water to recover solid $K_2Cr_2O_7$

The following information relates to questions 13 to 16

Two 300 mL samples of acid solutions, one containing 1.5 M HNO_3 and the other 0.10 M HF, were analysed using the pH meter shown below.

Figure – pH meter

13. Which statement is true?
    a. The pH of the 1.5 M HNO_3 solution is 0.171
    b. The pH of the 1.5 M HNO_3 solution is 0.18
    c. The pH of the 0.10 M HF solution is 1.0
    d. The pH of the 0.10 M HF solution is 0.10

14. Which statement best compares the electrical conductivity of the two solutions?
    a. The 0.10 M HF solution has higher conductivity because it is less concentrated
    b. The 0.10 M HF solution has higher conductivity because it has a higher pH
    c. Both solutions have similar conductivity because they are both acids
    d. The 1.5 M HNO_3 solution has higher conductivity because it fully ionizes in water

15. A 5.0 mL sample of the 1.5 M HNO_3 solution was placed in a beaker and a further 95 mL of distilled water added to make the final solution. Which statement below is true when comparing the final solution to the original?
    a. The final solution will have a pH double that of the original but a lower conductivity
    b. The final solution will show no change in pH but have a lower conductivity than the original
    c. The final solution will have a pH close to 1.12 and a lower conductivity than the original
    d. The final solution will have a pH close to 1.5 and a higher conductivity than the original

16. Before use, the pH meter was calibrated using a standard 0.100 M HCl solution. Calibration is necessary to obtain:
    a. accurate pH measurements
    b. valid pH measurements free of random and systematic errors
    c. repeatable pH measurements
    d. reproducible but inaccurate pH measurements

17. A student measures the pH of a 0.100 M HCl solution five times using the same pH meter. The results are consistent at a pH of 1.1. Which statement is true?
    a. The measurements are accurate but not precise
    b. The measurements are precise but not accurate
    c. The measurements are valid and accurate
    d. The measurements are neither accurate nor precise

The following information relates to questions 18 and 19

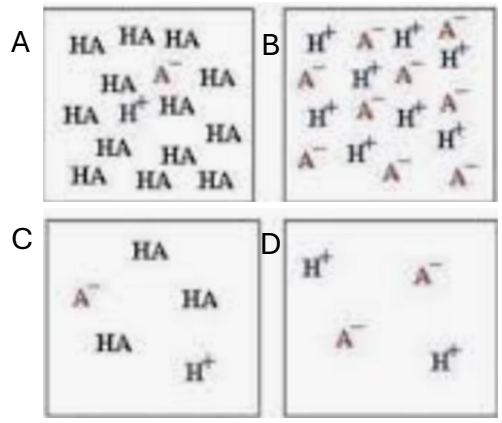


Figure 3 – Four different scenarios of a monoprotic acid (HA) in solution.

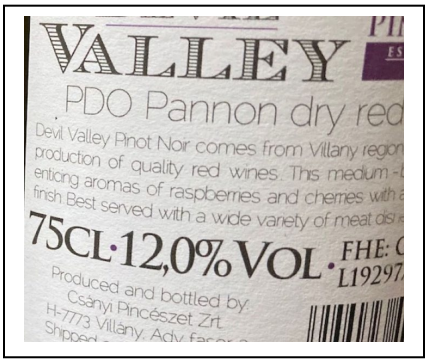
18. Which scenario shows the monoprotic acid (HA) as a strong acid in a dilute solution?
    a. A
    b. B
    c. C
    d. D

19. Which scenario shows a concentrated solution with a possible pH around 6.
    a. A
    b. B
    c. C
    d. D

20. Which one of the following pairs represent an acid/base conjugate pair.
    a. H_2SO_4/SO_4^{2-}
    b. HCO_3^-/CO_3^{2-}
    c. HCl/NO_3^-
    d. $NaHCO_3/Na^+$

21. A piece of magnesium metal was placed in a solution of acetic acid. The reaction quickly started to fizz producing a noticeable amount of gas. Which option below best represents the reaction?
    a. $CH_3COOH(aq) + Mg(s) \rightarrow CO_2(g) + MgCH_4(aq)$
    b. $2CH_3COOH(aq) + Mg(s) \rightarrow H_2(g) + Mg(OOCH_3)_2\,(aq)$
    c. $CH_3COOH(aq) + Mg(s) \rightarrow H_2(g) + MgOOCH_3\,(aq)$
    d. $2CH_3COOH(aq) + 2Mg(s) \rightarrow 2CO(g) + 4H_2(g) + 2MgOC\,(aq)$

22. The label of a bottle of wine is shown on the right. The bottle clearly labels the alcohol (ethanol) concentration as 12.0 %V/V. Given the density of ethanol as 0.789 g/mL, calculate the concentration of ethanol (46.1g/mol) in mol/litre in a 750 mL bottle of wine.
    a. 0.249 M
    b. 0.121 M
    c. 0.205 M
    d. 2.05 M



23. A 0.252 gram sample of freshly caught tuna meat was analysed for lead content and found to contain 1.38 X 10^{-5} grams of lead. Its concentration can best be given as:
    a. 5.48 ppm
    b. 0.56 % m/m
    c. 25.2 % m/m
    d. 54.8 ppm

24. Which option below best converts a concentration of sodium ions of 2.45 % m/v to mol L^-?
    a. 2.45 M
    b. 1.07 M
    c. 0.11 M
    d. 1.52 M

25. 0.214 grams of $KClO_3$ undergoes decomposition when strongly heated to produce oxygen gas and KCl.

$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$

A volume of 45.0 mL of gas at SLC was collected. What percentage of the original 0.214 g $kClO_3$ reacted?

a. 100 %
b. 98.0 %
c. 88.0 %
d. 69.3 %

26. A galvanic cell, when connected, produces a gas at the anode. A mass 3.20 grams of the gas is collected and stored in a 2.93 litre vessel at a pressure of 100 kPa and a temperature of 80.0 ^oC. The electrolytes in each cell are unknown. The reaction at the anode is narrowed down to three reactions as shown below. Which reaction is most likely taking place at the anode?

i. $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

ii. $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

iii. $2Br^-(aq) \rightarrow Br_2(g) + 2e^-$

a. ii only
b. ii and iii only
c. i only
d. iii only

27. Silver metal is deposited when copper metal is placed in a beaker with 0.10 M silver nitrate solution, as shown on the right. Which option below is true?

a. A spontaneous reaction takes place producing, predominantly, heat energy
b. Silver metal is oxidised in the presence of copper metal producing electrical energy
c. A nonspontaneous reaction takes place producing electrical energy
d. Copper metal undergoes oxidation in a spontaneous reaction producing electrical energy

The information below relates to questions 25 and 26

Iron oxide (Fe_2O_3) is reduced to Fe according to the equation below.

$$2Fe_2O_3(s) + 3C(s) \rightarrow 4Fe(s) + 3CO_2(g)$$

This overall reaction takes place in the blast furnace, shown below.

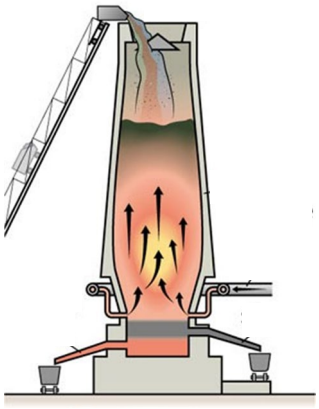
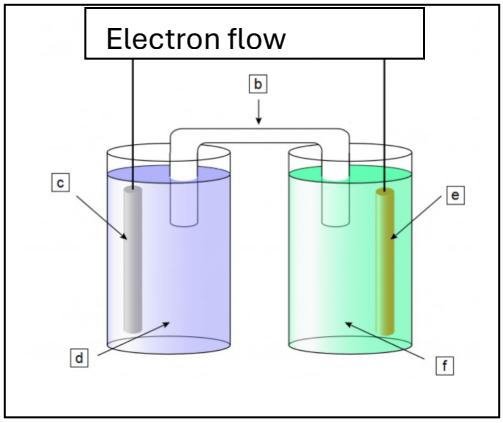


Figure 4 – Blast furnace

28. Which statement is correct.
    a. Fe^{3+} is the oxidant
    b. Fe_2O_3 is the oxidant
    c. The reduction half equation is $C(s) + O^{2-}(l) \rightarrow CO_2(g) + 2e^-$
    e. Oxidation takes place when oxygen gas (O_2) is converted to O^{2-} (l) ions.

29. Which statement correctly describes the change in oxidation numbers during this reaction?
    a. Iron is reduced from +2 to 0, while carbon is oxidised from 0 to +2
    b. Iron is oxidised from 0 to +3, while carbon is reduced from +4 to 0
    c. Iron is reduced from +3 to 0, while carbon is oxidised from 0 to +4
    d. Iron remains at +3, while carbon is oxidised from 0 to +4

30. Consider the template of a galvanic cell shown on the right.



Which of the following options describes a cell, that when connected, generates electrical energy with the highest possible EMF?

a. d = $Sn(NO_3)_2$ (aq), f = $Zn(NO_3)_2$ (aq)
c = electrode made of Sn, e = electrode made of Zn
b = KNO_3(aq), electron flow from right to left.

b. d = $Co(NO_3)_2$ (aq), f = $Zn(NO_3)_2$ (aq)
c = electrode made of Pt, e = electrode made of Zn
b = KNO_3(aq), electron flow from right to left.

c. d = $AgNO_3$(aq) f = $Zn(NO_3)_2$(aq)
c = electrode made of Sn, e = electrode made of carbon
b = $NaNO_3$(aq), electron flow from left to right.

e. d = $Zn(NO_3)_2$ (aq) f = $Fe(NO_3)_2$(aq)
c = electrode made of Zn, e = electrode made of Fe
b = $NaNO_3$(aq), electron flow from left to right.

End of section A

Section B

Instructions

- Answer **all** questions in the spaces provided.
- Write your responses in English.
- Give simplified answers to all numerical questions, with an appropriate number of significant figures. Unsimplified answers will not be given full marks.
- Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.
- Ensure that chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $H_2(g)$, NaCl(s).
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

1. A 0.250 g sample of magnesium metal is added to 300 mL of 0.100 M hydrochloric acid. A vigorous reaction occurs, producing a gas that ignites with a loud popping sound when exposed to a lit match.
   a. Write the chemical equation for the reaction taking place.

      _____ *3 marks*

   b. Is the reaction a redox reaction? Justify your answer with reference to oxidation numbers.

      _____
      _____
      _____
      _____
      _____*2 marks*

   c. Write the net ionic equation for this reaction.

      _____ *2 marks*

   d. Calculate the mass, in grams, of the gas formed during this reaction. *2 marks*

Continued on the next page

e. Combustion reactions are extremely important in a modern society as a source of energy.
The combustion of butane (C_4H_{10}) with atmospheric oxygen (O_2) releases a great deal of heat.

Figure 5 – Combustion of bottled butane

i. Write the chemical equation for the complete combustion reaction for butane and oxygen at SLC.

_____ *3 marks*

ii. Combustion reactions are redox reactions. Using oxidation numbers to justify that the reaction of butane with oxygen gas is a redox reaction.

_____
_____
_____
_____
_____*2 marks*

f. Acids react with metals to produce hydrogen gas and a salt. Nitric acid (HNO_3) and magnesium (Mg) metal react according to the redox reaction below.

$$2HNO_3(aq) + Mg(s) \rightarrow Mg(NO_3)_2\ (aq) + H_2(g)$$

i. Write the equation for the oxidation half reaction

_____ *1 mark*

ii. Write the equation for the reduction half reaction

_____ *1 mark*

Continued on the next page

g. Carbon dioxide and water are the biproducts of combustion of fossil fuels. Both are considered greenhouse gases, but only CO_2 is considered the main cause of climate change.

i. Explain why H_2O and CO_2 are considered greenhouse gases?

_____
_____
_____
_____
_____*2 marks*

ii. Explain why CO_2 and not H_2O is the main greenhouse gas that is of most concern.

_____
_____
_____
_____
_____
_____
_____*2 marks*

iii. The shells of fish are composed of calcium carbonate. Using two balanced chemical equations explain the significance of dissolved CO_2 in ocean acidification and on the subsequent health of shellfish.

Figure 6 - Shellfish have exoskeletons formed from calcium carbonate ($CaCO_3$)

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____*3 marks*

Continued on the next page

2. 6.30 grams of nitric acid is completely dissolved in 155 mL of distilled water.

   a. Calculate the nitric acid concentration in mol L^{-} *2 marks*

   b. Give the pH of the solution. *2 marks*

   c. Give the $[OH^{-}]$ *2 marks*

   d. The original 155 mL solution was diluted by the addition of 1.05 X 10^{5} L of distilled water. Calculate the pH of the diluted solution. *2 marks*

   e. Using the universal indicator chart in fig 6, give the colour change of the solution before and after dilution.

   _____

   _____

   _____

   _____*1 mark*

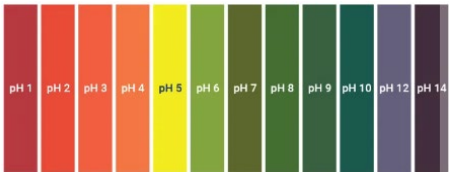


Figure 7 – Universal indicator chart

Continued on the next page

3. Redox reactions are fundamental to the operation of batteries, as they enable the controlled transfer of electrons that converts chemical energy into electrical energy. A galvanic cell, as shown in Figure 8, illustrates how this process provides the portable, reliable power that underpins modern society, from mobile phones and laptops to electric vehicles.

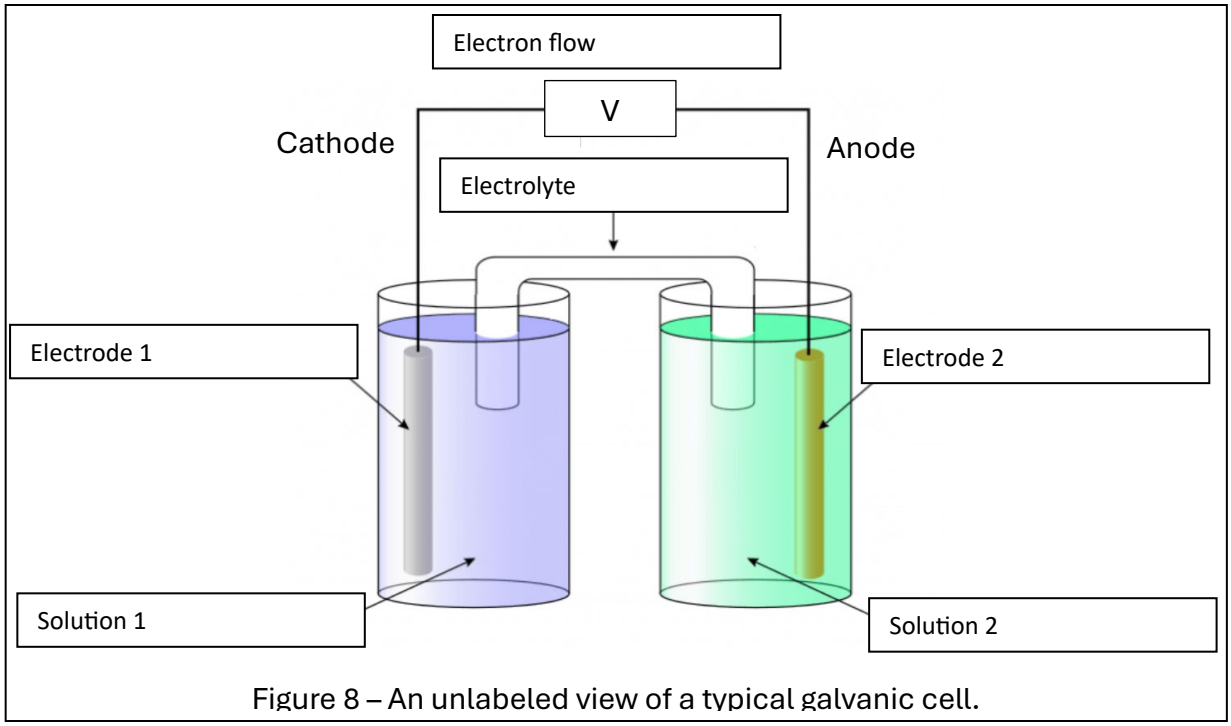


Figure 8 – An unlabeled view of a typical galvanic cell.

A student uses the setup shown in Figure 8 to construct a viable galvanic cell. The student is provided with the following solutions, a 1.0 M KNO_3 solution, 1.0 M $Cu(NO_3)_2$(aq) solution and a 1.0 M acidified solution containing a mixture of ClO_3^-(aq) and Cl^-(aq). The following material is also provided, a copper nail, iron nail and a carbon rod.

Given that the ClO_3^-/Cl^- half cell is found on the E^o series with a half cell potential of 1.21 V, answer the following questions.

a. Using the material listed, label each part of the diagram in fig 8 so that a viable galvanic cell is formed producing 0.87 V when connected and indicate the direction of electron flow by drawing an arrow in the box provided *6 marks*

b. Describe how the anode changes as the cell discharges. Provide a chemical half equation to justify your answer.

_____ *2 marks*

c. Give the half equation taking place at the cathode.

_____ *1 mark*

Continued on the next page

d. Give the overall equation of the cell

_____*2 marks*

e. The iron nail was placed as the electrode in the half cell containing the acidified solution with ClO_3^- ions. Give the voltmeter reading and explain your reasoning.

_____
_____
_____
_____
_____
_____
_____
_____*3 marks*

Continued on the next page

4. A commercial brand of antacid tablets is shown in Figure 9. Several groups are tasked with finding the average mass of the active ingredient calcium carbonate ($CaCO_3$) in each tablet.
Each group is provided with a standard 1.00 M HCl solution, antacid tablets, and titration apparatus.
The aim of the experiment was to measure the amount of $CaCO_3$ in each of three TUMS tablets.
Each group followed the exact same method:
    1. A tablet was crushed with a mortar and pestle and placed in a 200 mL conical flask.
    2. 100 mL of distilled water was added to dissolve the tablet.
    3. Two drops of phenolphthalein indicator were added.
    4. The solution was titrated against 1.00 M HCl and the volumes required to achieve a permanent colour change were recorded.

Figure 9 – TUMS antacid tablets

The results obtained by three groups titrating the contents of a TUMS tablet with 1 M HCl.

Group	Trial 1 (mL)	Trial 2 (mL)	Trial 3 (mL)	Average (mL)
1	15.05	14.95	15.00	15.00
2	14.00	14.00	14.00	14.00
3	15.00	15.00	15.00	15.00

Table 1 – Table of results showing the titres of four groups.

a. In what stoichiometric ratio does $CaCO_3(s)$ react with HCl(aq)?
$CaCO_3(s)$ _____ : HCl(aq) _____ *1 mark*

b. Using the group 1 results calculate the:
    i. amount , in mol, of HCl in an average titre. *1 mark*

Continued on the next page

ii. amount in milligrams of $CaCO_3$ in each tablet *2 marks*

c. What was the colour change observed at the endpoint?

_____*1 mark*

d. Are the results repeatable and reproduceable? Discuss.

_____
_____
_____
_____
_____
_____
_____*2 marks*

e. What type of error caused the discrepancy between group 2 results and the other groups? Justify your answer using a relevant example

_____
_____
_____
_____
_____
_____
_____*2 mark2*

f. What was the dependent variable in this investigation?

_____
_____*1 mark*

Continued on the next page

g. Table 2, shown below, shows a number of situation where errors may have been made in conducting the titration. Complete the table below by circling the one correct response in each cell. *6 marks*

Situation	Type of	Impact on the average titre	Precision of results
Conical flask in which the reactants were mixed was washed with distilled water.	No error Random error Systematic error	No impact Over estimation Under estimation	High Low
The burette was washed with distilled water and used to titrate all 4 trials yielding concordant results.	No error Random error Systematic error	No impact Over estimation Under estimation	High Low
During one trial, after crushing the tablet with a mortar and pestle, the crushed powder, was not fully washed into the conical flask.	No error Random error Systematic error	No impact Over estimation Under estimation	High Low
Two drops of phenol red indicator was used instead of phenolphthalein.	No error Random error Systematic error	No impact Over estimation Under estimation	High Low
The HCl solution in the burette contained tiny air bubbles at the start of the titration and soon disappeared.	No error Random error Systematic error	No impact Over estimation Under estimation	High Low
The mass of the antacid tablet was recorded incorrectly due to a miscalibrated balance.	No error Random error Systematic error	No impact Over estimation Under estimation	High Low

Table 2 – Incomplete table of 4 scenarios and the impact on the results of the titration between TUMS antacid tablet and a standard solution of HCl.

End of examination.