

Solutions 2026

All answers must be completed like this example :

☐ A ☒ B ☐ C ☐ D

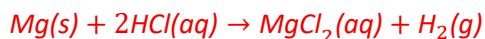
- If you make a mistake, **erase** the incorrect answer – **do not** cross it out.
- Marks will **not** be deducted for incorrect answers.
- No mark will be given if more than one answer is completed for any question.

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

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.



1-----mark for correct species

1-----mark for balanced equation

1-----mark for correct states

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

Yes, this is a redox reaction because oxidation and reduction occur simultaneously. 1-----mark

Magnesium is oxidised:

Mg goes from oxidation number 0 in Mg(s) to +2 in Mg²⁺(aq).

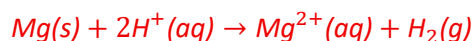
Hydrogen ions are reduced:

H goes from +1 in H⁺(aq) to 0 in H₂(g).

Since electrons are transferred, the reaction is a redox reaction.

1-----mark for correct explanation

c. Write the net ionic equation for this reaction.



1-----mark correct states and species

1-----mark for balanced charge

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

1-----mark for correctly identifying the limiting reactant

m = 0.0103 × 2.02 = 0.0208 g 1----- mark for correct mass of H₂ using the limiting reactant. Consequential marks given if wrong limiting reactant was stated

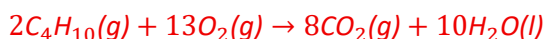
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- e. Combustion reactions are extremely important in a modern society as a source of energy. The combustion of butane (C_4H_{10}) with atmospheric oxygen (O_2) releases a great deal of heat.



Figure 5 – Combustion of bottled butane

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



1-----mark

1-----mark for correct state of water (l) at SLC

1-----mark correct species eg CO_2 for complete combustion

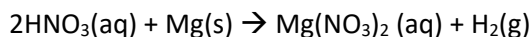
1-----mark balanced equation

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

Carbon in butane has an average oxidation number of -2.5 and increases to $+4$ in $CO_2 \rightarrow$ oxidation. 1-----mark

Oxygen goes from 0 in O_2 to -2 in CO_2 and $H_2O \rightarrow$ reduction. 1-----mark

- 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.



- 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 CO₂ is considered the main cause of climate change.

- i. Explain why H₂O and CO₂ are considered greenhouse gases?

Both H₂O and CO₂ have bond vibrations in the IR band of the electromagnetic spectrum. 1-----mark

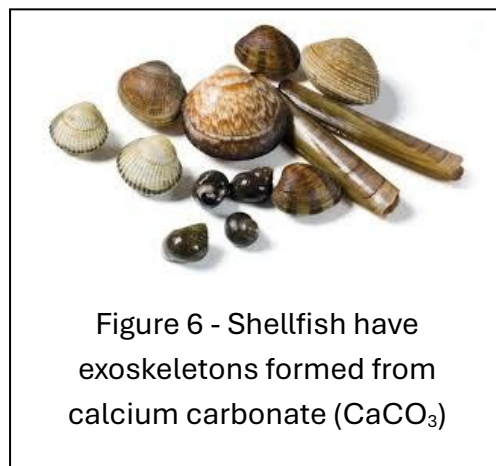
They absorb and re-emit infrared radiation due to their bond vibrations. This traps heat in the atmosphere, contributing to the greenhouse effect. 1-----mark

- ii. Explain why CO₂ and not H₂O is the main greenhouse gas that is of most concern.

Water vapour concentration is controlled by temperature and the water cycle, so it does not accumulate long-term. It also forms clouds that play a vital role in deflecting UV energy from reaching the surface of the Earth where it becomes IR. 1-----mark

CO₂ persists in the atmosphere for decades to centuries and its concentration is directly increased by human activities, making it the primary driver of climate change. 1-----mark

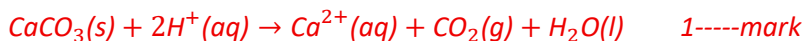
- iii. The shells of fish are composed of calcium carbonate. Using two balanced chemical equations explain the significance of dissolved CO₂ in ocean acidification and on the subsequent health of shellfish.



Dissolved CO₂ reacts with water:



Carbonic acid releases H⁺ ions which react with carbonate, such as calcium carbonate



This dissolves the carbonate in the shells of fish, weakening shells and harming shellfish.

1-----mark

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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⁻¹

$$n = \frac{6.30}{63.0} = 0.100 \text{ mol} \quad 1\text{-----mark}$$

$$c = \frac{0.100}{0.155} = 0.645 \text{ M} \quad 1\text{-----mark}$$

b. Give the pH of the solution.

$$pH = -\log(0.645) = 0.190$$

1-----mark correct formula

1-----mark for correct pH

c. Give the [OH⁻]

$$pOH = 14 - 0.190 = 13.810 \quad 1\text{-----mark correct formula}$$

$$[OH^-] = 1.55 \times 10^{-14} \text{ M} \quad 1\text{-----mark correct molarity in scientific notation.}$$

d. The original 155 mL solution was diluted by the addition of 1.052 X 10⁵ L of distilled water. Calculate the pH of the diluted solution.

$$C_1V_1 = C_2V_2 \text{ (dilution formula)}$$

$$C(H_3O^+) = 0.100 / 105200 = 9.50 \times 10^{-7} \text{ M} \quad 1\text{-----mark}$$

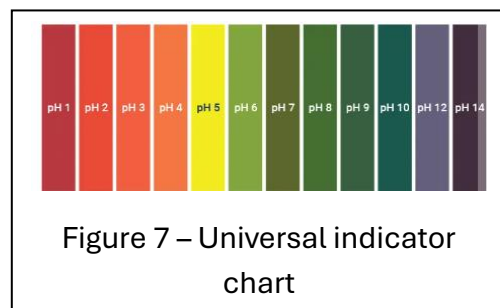
$$pH = -\log(9.50 \times 10^{-7}) = 6.022 \quad 1\text{-----mark}$$

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

Before dilution: **red**

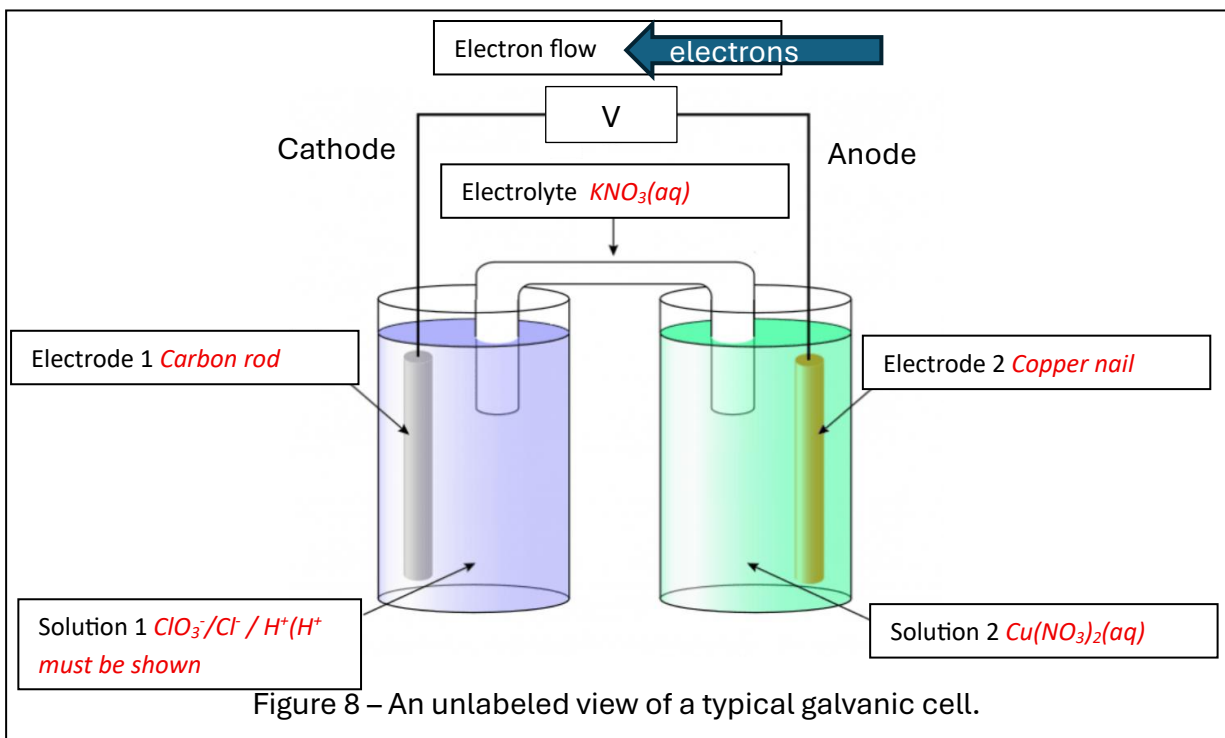
After dilution: **light green or olive green**

1-----mark



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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.



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 $\text{Cu}(\text{NO}_3)_2(\text{aq})$ solution and a 1.0 M acidified solution containing a mixture of $\text{ClO}_3^-(\text{aq})$ and $\text{Cl}^-(\text{aq})$. The following material is also provided, a copper nail, iron nail and a carbon rod.

Given that the $\text{ClO}_3^-/\text{Cl}^-$ half cell is found on the E° 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

1-----mark for each. Solution 1 must indicate it is acidified

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

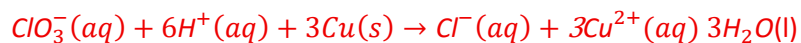
Electrode corrodes (dissolves), losses mass. 1-----mark

$\text{Cu(s)} \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$ 1-----mark

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

$\text{ClO}_3^-(\text{aq}) + 6\text{H}^+(\text{aq}) + 6\text{e}^- \rightarrow \text{Cl}^-(\text{aq}) + 3\text{H}_2\text{O(l)}$ 1-----mark

- d. Give the overall equation of the cell



1-----mark balanced for charge

1-----mark balanced for elements and correct states

- 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.

Voltmeter reading = 0 V *1-----mark*

Iron would undergo oxidation instead of acting as an inert electrode because it is the strongest reductant present. 1-----mark

Direct contact between ClO_3^- and $\text{Fe}(\text{s})$ would result in heat energy being produced. 1-----mark

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.

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 the three groups are shown in the table below.

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

- a. In what stoichiometric ratio does $\text{CaCO}_3(\text{s})$ react with $\text{HCl}(\text{aq})$?

$\text{CaCO}_3(\text{s})$ _____ 1 : $\text{HCl}(\text{aq})$ 2__ 1-----mark

- b. Using the group 1 results calculate the:

- i. amount, in mol, of HCl in an average titre.

$$n = 1.00 \times 0.0150 = 0.0150 \text{ mol} \quad 1-----mark$$

- ii. amount in milligrams of CaCO_3 in each tablet

$$n = \frac{0.0150}{2} = 0.00750 \text{ mol} \quad 1-----mark$$

$$\text{Mass of } \text{CaCO}_3 \text{ in grams} = 0.00750 \times 100.1 = 0.750 \text{ g or } 0.751 \text{ g}$$

$$\text{mass in milligrams} = 750 \text{ mg or } 751 \text{ mg} \quad 1-----mark$$

Continued on the next page

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

From pink to clear

1-----mark

- d. Are the results repeatable and reproduceable? Discuss.

Group 1 and 3 results are repeatable and reproducible.

1-----mark

Group 2 results are repeatable but not reproducible compared to the other groups

1-----mark

- e. What type of error caused the discrepancy between group 2 results and the other groups?

Justify your answer using a relevant example

A systematic error occurred, 1-----mark

accompanied by any valid example of such an error, such as incorrect standardisation of HCl or consistent misreading of the burette (parallax error).

1-----mark

- f. What was the dependent variable in this investigation?

Volume of HCl used to reach an endpoint of a titration with one tablet of antacid.

1-----mark

No mark for just saying Volume of HCl.

Accept also

The calculated amount (or mass) of CaCO_3 in the tablet, provided the student explicitly states that this value depends on the measured titre volume.

- 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
1. Conical flask in which the reactants were mixed was washed with distilled water.	No error	No impact	High
	Random error	Over estimation	Low
	Systematic error	Under estimation	
2. The burette was washed with distilled water and used to titrate all 4 trials yielding concordant results.	No error	No impact	High
	Random error	Over estimation	Low
	Systematic error	Under estimation	
3. 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	No impact	High
	Random error	Over estimation	Low
	Systematic error	Under estimation	
4. Two drops of phenol red indicator was used instead of phenolphthalein.	No error	No impact	High
	Random error	Over estimation	Low
	Systematic error	Under estimation	
5. The HCl solution in the burette contained tiny air bubbles at the start of the titration and soon disappeared.	No error	No impact	High
	Random error	Over estimation	Low
	Systematic error	Under estimation	
6. The mass of the antacid tablet was recorded incorrectly due to a miscalibrated balance.	No error	No impact	High
	Random error	Over estimation	Low
	Systematic error	Under estimation	

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

1-----mark for each correct row.

Scenario 1 Conical flask was washed with distilled water before mixing reactants

Washing the flask does not change the number of moles reacting; it just adds water, which doesn't affect the reaction. Hence should have no impact on the endpoint.

Scenario 2 Burette was washed with distilled water instead of HCl

Residual water dilutes the HCl, so more acid is required to reach the endpoint in all trials. Results overestimated but are consistent, however, inaccurate.

Scenario 3 Crushed tablet powder was not fully washed into the conical flask

Less solid reacted, so less HCl is required for that trial only. This reduces reproducibility.

Scenario 4 Two drops of phenol red used instead of phenolphthalein

Phenol red changes color at pH 6.8–8.4, but the equivalence point for CaCO_3 titrated with HCl is acidic approximately at pH 4–5. You are starting in a basic solution. As you add acid, the pH drops. Phenol red changes color before reaching the true endpoint (since its transition range is above the equivalence point for this titration). This means the endpoint is observed too early, giving a smaller volume of HCl than actually needed.

Scenario 5 Tiny air bubbles in the burette at the start of titration

Air bubbles cause inaccurate initial readings for that trial only.

Scenario 6 Miscalibrated balance used to weigh the tablet

The mass of the tablet is not measured during the titration itself, therefore the titre depends only on the volume of HCl required to neutralize the CaCO_3 in one tablet. Scales were never used. As per the stem of the question the aim was to measure the volume of 1 M HCl needed to neutralize the contents of each tablet.