

2016

13.

Nitric acid can be manufactured from the element nitrogen using the steps below.

Step	1	2	3	4
	$\text{N}_2 \rightarrow \text{NH}_3$	$\text{NH}_3 \rightarrow \text{NO}$	$\text{NO} \rightarrow \text{NO}_2$	$\text{NO}_2 \rightarrow \text{HNO}_3$

The smallest change in the oxidation number of nitrogen is found in

- (a) step 1.
- (b) step 2.
- (c) step 3.
- (d) step 4.

2016

14.

Which one of the following is **not** a redox reaction?

- (a) $2\text{CrO}_4^{2-} + 2\text{H}^+ \rightarrow \text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{O}$
- (b) $2\text{Cr}^{2+} + 2\text{H}^+ \rightarrow 2\text{Cr}^{3+} + \text{H}_2$
- (c) $(\text{NH}_4)_2\text{Cr}_2\text{O}_7 \rightarrow \text{N}_2 + 4\text{H}_2\text{O} + \text{Cr}_2\text{O}_3$
- (d) $\text{Cr}_2\text{O}_3 + 3\text{C} \rightarrow 2\text{Cr} + 3\text{CO}$

2016

15.

Which one of the following shows the substances listed in order of increasing strength as reducing agents?

- (a) F^- , Al , Zn , Cu , I^-
- (b) I^- , F^- , Zn , Al , Cu
- (c) F^- , I^- , Cu , Zn , Al
- (d) Zn , Al , Cu , I^- , F^-

2016

16.

Which one of the following reactions would **not** produce a current at 25.0°C , when set up as a galvanic cell?

- (a) $\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{Fe}^{2+}(\text{aq}) \rightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\ell) + 5\text{Fe}^{3+}(\text{aq})$
- (b) $\text{Fe}(\text{s}) + \text{Pb}^{2+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq}) + \text{Pb}(\text{s})$
- (c) $\text{Br}_2(\ell) + 2\text{Cl}^-(\text{aq}) \rightarrow 2\text{Br}^-(\text{aq}) + \text{Cl}_2(\text{g})$
- (d) $\text{Fe}(\text{s}) + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq}) + \text{Cu}(\text{s})$

2016

17.

Three metals, A, B and C, were tested to compare their reactivity. Samples of each metal were placed separately into test tubes each containing a nitrate solution of the other metal ions. The following results were obtained.

	A(s)	B(s)	C(s)
$\text{A}^{2+}(\text{aq})$		No visible reaction	Solid A forms
$\text{B}^{2+}(\text{aq})$	Solid B forms		Solid B forms
$\text{C}^{2+}(\text{aq})$	No visible reaction	No visible reaction	

From these results, the metals arranged in order of decreasing strength as reducing agents can be concluded to be

- (a) $\text{C} > \text{A} > \text{B}$.
- (b) $\text{B} > \text{C} > \text{A}$.
- (c) $\text{B} > \text{A} > \text{C}$.
- (d) $\text{A} > \text{C} > \text{B}$.

Section Two: Short answer**35% (83 Marks)**

This section has **12** questions. Answer **all** questions. Write your answers in the spaces provided.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.

Suggested working time: 60 minutes.

**2016
Question 26**

(6 marks)

Galvanic cells and electrolytic cells are often constructed in the laboratory.

- (a) List **four** characteristics or components that these two types of cells have in common with each other. (4 marks)

One: _____

Two: _____

Three: _____

Four: _____

- (b) List **two** characteristics or components that can be used to distinguish between the two types of cells. State the characteristic or component for each cell. (2 marks)

One: _____

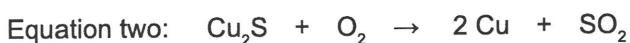
Two: _____

To be used in wiring, copper must be at least 99.9% pure. To obtain 99.9% pure copper from its most common ore, chalcopyrite (CuFeS_2), two processes must take place.

- (i) The first process occurs in a furnace where the chalcopyrite is converted to 'blister copper', which is approximately 98% pure due to impurities such as sand.
- (ii) The second process occurs in an electrolytic cell where the 'blister copper' undergoes electrolysis to produce copper at or above 99.9% purity.

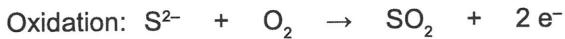
In the furnace, the ore is heated strongly with silica (silicon dioxide), calcium carbonate and air. The furnace reduces the copper(II) in the chalcopyrite first to copper(I) then to copper.

Below are the equations that represent the main processes occurring in the blast furnace.



- (a) Equation two can be represented as half equations. Write the reduction half equation. (1 mark)

Reduction: _____



In the electrolytic cell, the copper produced from the blast furnace is purified.

- (b) Explain the electrolytic process used to purify copper. Include:
 - a brief overview of the process
 - a labelled diagram of the electrolytic cell
 - the relevant oxidation and reduction half equations
 - a discussion of impurities and how they are separated from the copper. (10 marks)

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See next page

2017

2. Copper reacts with nitric acid as shown in the redox equation below.



Which one of the following states the change in the oxidation number of nitrogen?

- (a) 3+ to 0
- (b) 5+ to 4+
- (c) 3+ to 2+
- (d) 5+ to 0

2017

3.

In the electrolysis of molten calcium bromide, one mole of bromine molecules is formed for every one mole of calcium. This is because

- (a) the formula of calcium bromide is Ca_2Br .
- (b) the valency on a calcium ion is twice that on a bromide ion.
- (c) bromine is more reactive than calcium.
- (d) the atomic mass of bromine is twice that of calcium.

2017

4.

Which of the following are common to both galvanic and electrolytic cells?

- (i) a salt bridge
 - (ii) an external circuit
 - (iii) the transfer of electrons and movement of ions
 - (iv) at least two different reactions with distinct reduction potentials
- (a) i and ii only
 - (b) i, ii and iv only
 - (c) ii, iii and iv only
 - (d) i, ii, iii and iv

See next page

2017

9.

An example of an undesirable electrochemical process is the corrosion of metals. Which one of the following equations does **not** represent what might occur during corrosion?

- (a) $4 \text{Fe(OH)}_2(\text{s}) + 2 \text{H}_2\text{O}(\text{aq}) + \text{O}_2(\text{g}) \rightarrow 4 \text{Fe(OH)}_3(\text{s})$
- (b) $\text{O}_2(\text{g}) + 2 \text{H}_2\text{O}(\ell) + 4 \text{e}^- \rightarrow 4 \text{OH}^-(\text{aq})$
- (c) $\text{FeCl}_3(\text{s}) \rightarrow \text{Fe}^{3+}(\text{aq}) + 3 \text{Cl}^-(\text{aq})$
- (d) $\text{Pb}^{2+}(\text{aq}) \rightarrow \text{Pb}^{4+}(\text{aq}) + 2 \text{e}^-$

2017

10.

Which one of the following reactions will be spontaneous under standard conditions?

- (a) $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 3 \text{H}_2\text{O}_2(\text{aq}) + 8 \text{H}^+(\text{aq}) \rightarrow 2 \text{Cr}^{3+}(\text{aq}) + 7 \text{H}_2\text{O}(\ell) + 3 \text{O}_2(\text{g})$
- (b) $3 \text{O}_2(\text{g}) + 4 \text{Au}(\text{s}) + 12 \text{H}^+(\text{aq}) \rightarrow 4 \text{Au}^{3+}(\text{aq}) + 6 \text{H}_2\text{O}(\ell)$
- (c) $2 \text{Ag}^+(\text{aq}) + 2 \text{Br}^-(\text{aq}) \rightarrow 2 \text{Ag}(\text{s}) + \text{Br}_2(\ell)$
- (d) $2 \text{Cl}^-(\text{aq}) + \text{I}_2(\text{s}) \rightarrow \text{Cl}_2(\text{g}) + 2 \text{I}^-(\text{aq})$

Section Two: Short answer**35% (85 Marks)**

This section has **10** questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for the use of planning/continuing your answer to a question have been provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

**2017
Question 26****(13 marks)**

A limited amount of sodium metal was added to a beaker of distilled water containing a few drops of phenolphthalein.

- (a) (i) List **three** changes that would be observed. (3 marks)

One: _____

Two: _____

Three: _____

- (ii) Write the ionic equation for any reaction involving both sodium and water. Include **all state symbols**. (3 marks)

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Excess propene gas was bubbled through an aqueous bromine solution.

- (b) (i) Identify, by name or formula, any new substance/s produced. (1 mark)

- (ii) Write descriptions of the substances **before** and **after** mixing. (2 marks)

Before _____

After _____

A thick strip of lead metal was immersed into a small beaker containing a solution of 1.00 mol L⁻¹ iron(III) nitrate.

- (c) (i) Identify, by name or formula, any new substance/s produced. (1 mark)

- (ii) List **all** observations that would be made for any reaction, describing clearly the substances before and on completion of any reaction. (3 marks)

Balance the following redox equation by determining and then combining the oxidation and reduction half-equations. State symbols are **not** required.



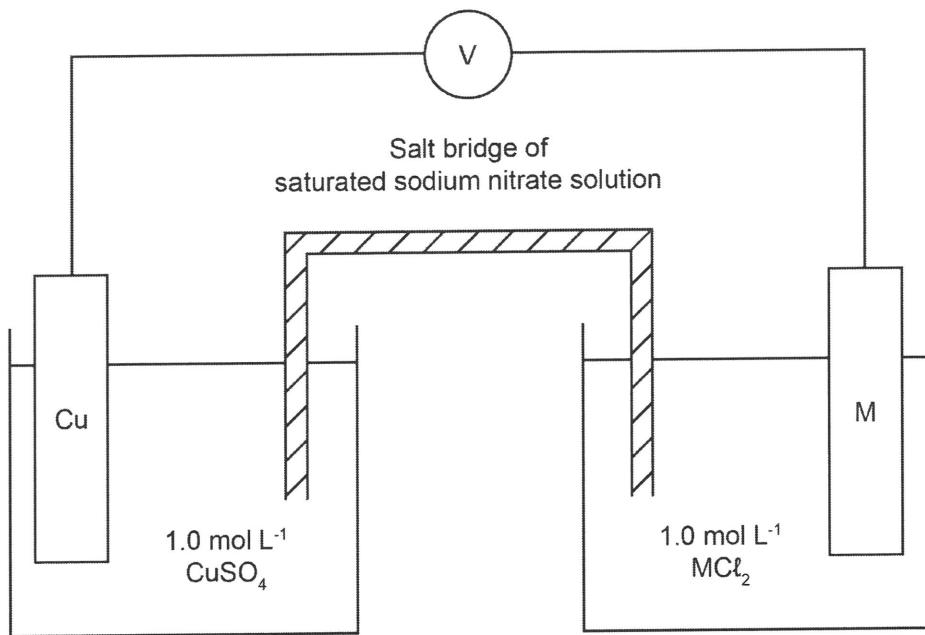
Oxidation half-equation

Reduction half-equation

Overall equation

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The diagram below represents a simple galvanic cell set up at 25.0 °C.



One electrode/electrolyte pair is Cu/Cu²⁺. The other electrode is of an unknown metal, represented as M/M²⁺. It was observed, that over time, the unknown metal electrode reduced in size and the solution remained colourless.

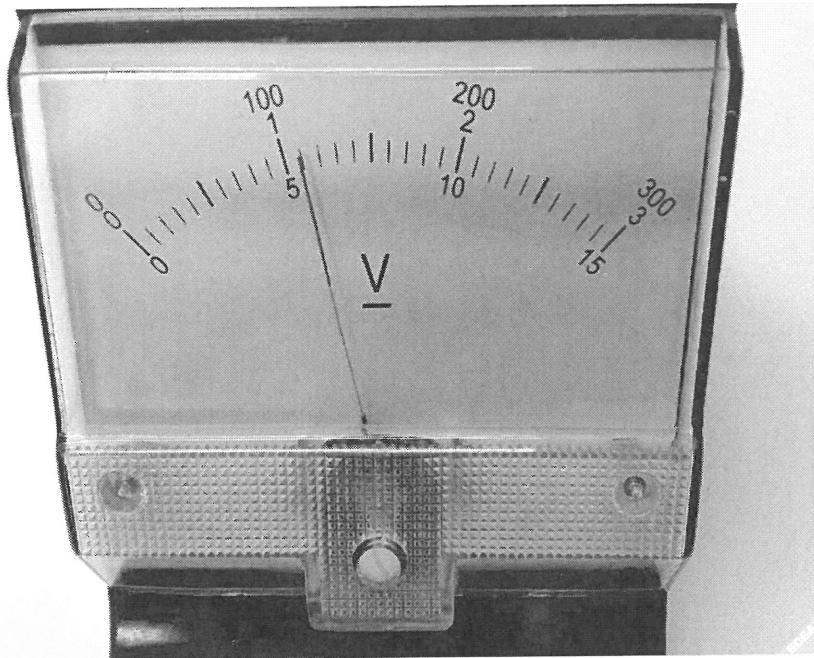
- (a) Write a chemical equation to show the reaction at the anode of the cell. (1 mark)

- (b) List **two** observations that would be expected in the Cu/Cu²⁺ cell. (2 marks)

One: _____

Two: _____

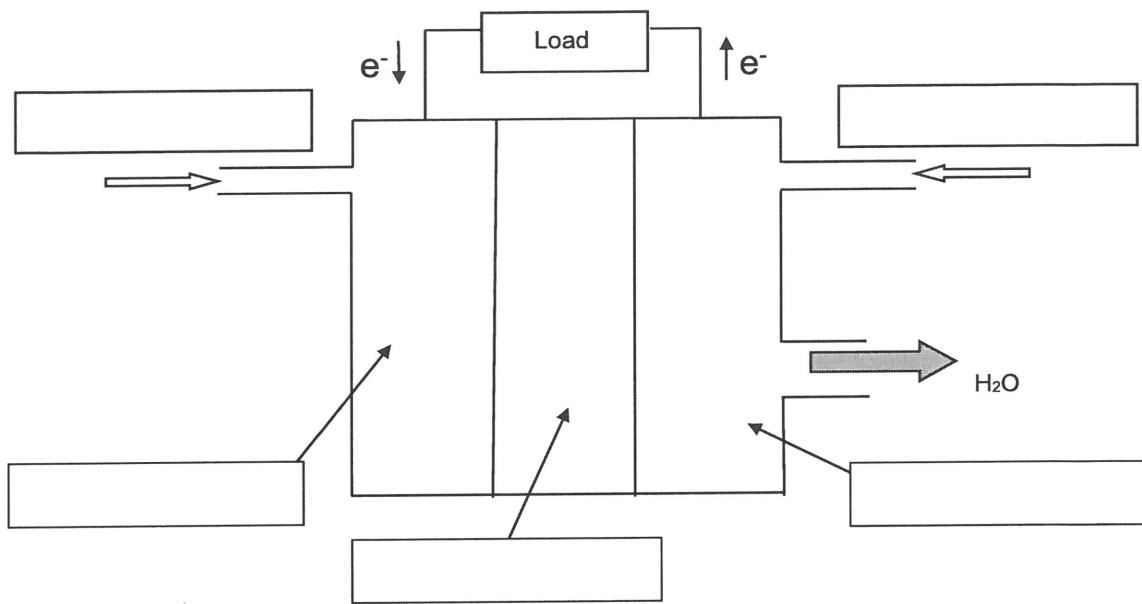
Below is a photograph of the voltmeter attached to the diagram of the cell on page 20. There are three scales on the voltmeter. The scale being used is the one with the range from 0 to 3 volts.



- (c) (i) To the appropriate degree of accuracy, what is the reading on the voltmeter?
(1 mark)

- (ii) Using the voltmeter reading and other relevant information, predict the identity of the unknown metal. Clear reasoning, including a calculation, **must** be provided.
(3 marks)

- (f) In the boxes provided, label the following diagram of a typical hydrogen-oxygen fuel cell. Include anode, cathode, electrolyte, hydrogen gas and oxygen gas. (3 marks)



- (g) Explain the function of the electrolyte. (2 marks)

- (h) From the table provided in the Chemistry Data booklet, calculate the EMF for the reaction between hydrogen gas and oxygen gas. (1 mark)

- (i) A hydrogen-oxygen fuel cell on the Apollo spacecraft generally produced an EMF of 1.21 V per cell. State **one** reason why the theoretical (calculated) value was not the same as the actual EMF generated by the fuel cells on the spacecraft. (1 mark)

2017 Q37 Cont

The tank that exploded during the mission provided oxygen for the fuel cells that powered the spacecraft.

- (e) List **two** advantages that fuel cells have over primary and secondary cells. (2 marks)

One: _____

Two: _____

2018

Questions 5 and 6 refer to the following information.

When a piece of indium metal, In(s), is placed in some acidified dichromate solution, $\text{Cr}_2\text{O}_7^{2-}$ (aq), a reaction occurs resulting in In^{3+} (aq) ions being produced. The equation for this reaction is shown below.



The EMF for this reaction at 25.0 °C was found to be +1.70 V.

5. What is the calculated E° value for the In^{3+}/In half-equation?

- (a) -0.34 V
- (b) 0.34 V
- (c) 1.36 V
- (d) 3.06 V

6. According to the Standard Reduction Potential Table, which of the following sets of metals **cannot** be oxidised by indium ion, In^{3+} , under standard conditions.

- (a) Sn, Cd, Fe, Cr
- (b) Mg, Na, Ca, Sr
- (c) Mn, Ni, Sn, Cu
- (d) Ni, Sn, Cu, Ag

7. Molybdenum, Mo, is present in each of the following species: MoO_2 $\text{Mo}_2\text{O}_7^{2-}$ HMnO_4^{2-} Which of the following lists these species in order of **increasing** oxidation number of molybdenum?

- (a) HMnO_4^{2-} MoO_2 $\text{Mo}_2\text{O}_7^{2-}$
- (b) $\text{Mo}_2\text{O}_7^{2-}$ HMnO_4^{2-} MoO_2
- (c) $\text{Mo}_2\text{O}_7^{2-}$ MoO_2 HMnO_4^{2-}
- (d) MoO_2 HMnO_4^{2-} $\text{Mo}_2\text{O}_7^{2-}$

See next page

25. Which of the following statement pairs can be used to distinguish between an electrolytic cell and a galvanic cell?

	Electrolytic cell	Galvanic cell
(a)	an electric current flows from an external electrical power source	the chemical reaction produces an electric current
(b)	oxidation occurs at the cathode	oxidation occurs at the anode
(c)	ions do not migrate through an electrolyte	ions migrate through an electrolyte
(d)	can be used to power a battery	can be used to electroplate metals such as copper and silver

Questions 14 and 15 refer to the following information.

A group of students decided to investigate the reactivity of four different transition metals; rhenium, vanadium, zirconium and tantalum. They did this by placing small pieces of each metal in separate test tubes with the appropriate test solutions. The 1.00 mol L^{-1} test solutions were prepared by dissolving the nitrate salt of each metal in distilled water. Their results are summarised in the table below.

Metal	Metal Ions			
	$\text{Re}^{3+}(\text{aq})$	$\text{V}^{2+}(\text{aq})$	$\text{Zr}^{4+}(\text{aq})$	$\text{Ta}^{3+}(\text{aq})$
Rhenium		no reaction	no reaction	no reaction
Vanadium	reaction occurs		no reaction	reaction occurs
Zirconium	reaction occurs	reaction occurs		reaction occurs
Tantalum	reaction occurs	no reaction	no reaction	

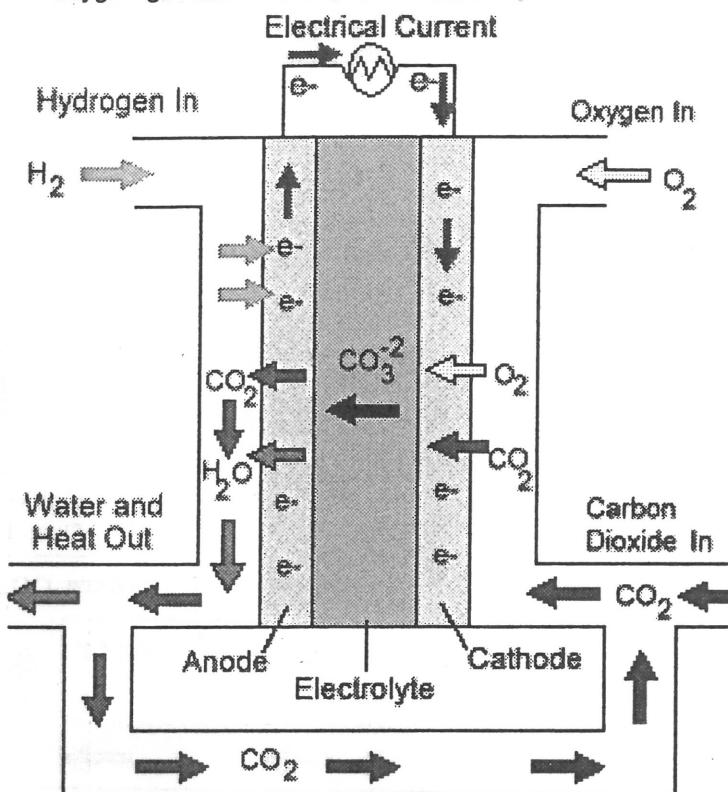
14. Which of these metals is the **most** easily oxidised?

- (a) rhenium
- (b) vanadium
- (c) zirconium
- (d) tantalum

15. Which of these metals is the **weakest** reducing agent?

- (a) rhenium
- (b) vanadium
- (c) zirconium
- (d) tantalum

An example of a galvanic cell is the molten carbonate fuel cell, represented in the diagram below. As this cell operates, hydrogen gas is reacted with the carbonate ion at the anode, while oxygen gas reacts with carbon dioxide gas at the cathode. The carbon dioxide gas is re-used.



The official
diagram is
missing! ;)

ie online version of this document.

I got this from
the internet,
hopefully it
will do the job.
:)

- (a) Write the half-equation to show the reaction at the electrode at which oxidation occurs. (3 marks)

- (b) Write the overall equation for the current-producing reaction. (3 marks)

- (c) State **two** reasons why this fuel cell is a more environmentally-friendly alternative to the internal combustion engine. (2 marks)

One: _____

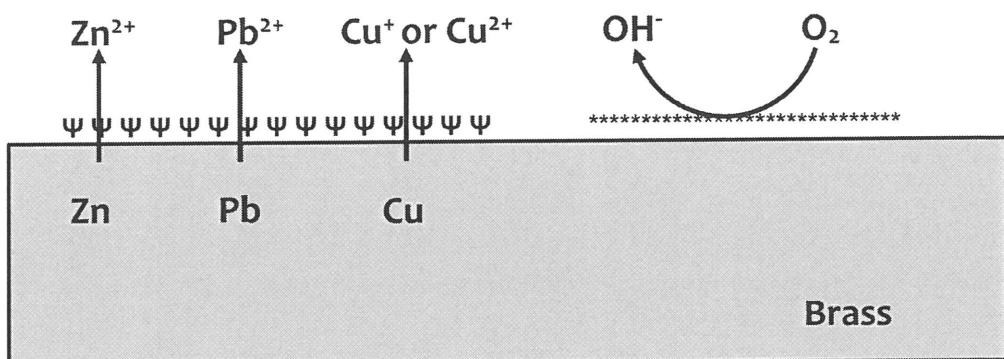
Two: _____

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Questions 5, 6 and 7 refer to the following information.

The corrosion of brass plumbing fixtures has been identified as a possible cause of the presence of lead in drinking water. Brass is an alloy of copper and zinc but can also contain lead to improve machinability.

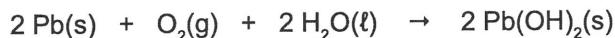
The corrosion of brass is a redox process, with an electrochemical cell forming on the surface of the brass as illustrated below.



5. Which one of the following correctly identifies the anodic region, cathodic region and direction of electron flow?

	Anodic region	Cathodic region	Direction of electron flow
(a)	Ψ	*	Ψ → *
(b)	*	Ψ	Ψ → *
(c)	Ψ	*	* → Ψ
(d)	*	Ψ	* → Ψ

6. The overall equation for the reaction of lead with oxygen is as follows:



What is the theoretical E° value for the overall Pb/O₂ reaction under standard conditions?

- (a) - 0.27 V
- (b) + 0.27 V
- (c) + 0.53 V
- (d) + 0.93 V

7. The composition of brass can be adjusted by adding various metals. Which one of the following metals would **not** undergo corrosion if added to brass?

- (a) silver
- (b) nickel
- (c) iron
- (d) strontium

2019

10. Which statement is correct?

- (a) Fluorine can be oxidised by potassium bromide solution but not by potassium iodide solution.
- (b) Chlorine can be oxidised by potassium fluoride solution but not by potassium iodide solution.
- (c) Chlorine can be reduced by potassium bromide solution but not by potassium iodide solution.
- (d) Bromine can be reduced by potassium iodide solution but not by potassium chloride solution.

201917. In which of the following sets do all the **bolded** and underlined atoms have the same oxidation number?

- (i) H_2O , O₂, H_2O_2
 - (ii) H_2O_2 , NaCl , MgH_2
 - (iii) NaCl, Li₂CO₃, KOH
 - (iv) FeO, Fe₂O₃, Fe
- (a) i and iv only
 - (b) ii and iii only
 - (c) iv only
 - (d) i, ii and iii only

As noted in Question 27, calcium hypochlorite and hydrochloric acid react according to the equation shown below.



In this reaction, the chlorine in calcium hypochlorite and the chloride from the hydrochloric acid are both converted to chlorine gas.

(a) What is the oxidation number for the chlorine in:

- calcium hypochlorite, $\text{Ca}(\text{OCl})_2$
- hydrochloric acid, HCl ?

(2 marks)

calcium hypochlorite

hydrochloric acid

Chlorine gas is produced by the oxidation of one of these substances and the reduction of the other.

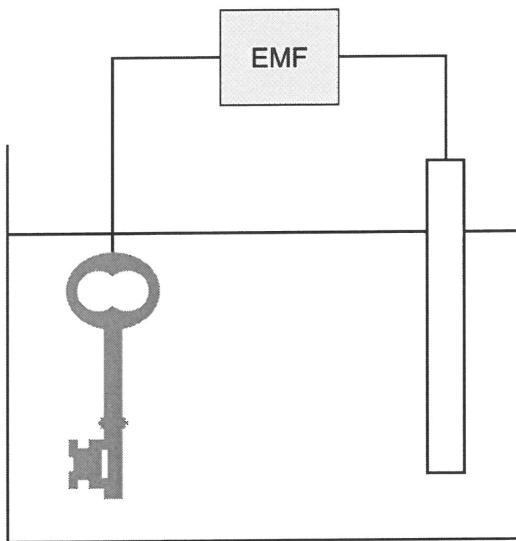
(b) Write the **two** half-equations showing how chlorine gas is produced from both substances.

(5 marks)

Oxidation half-equation

Reduction half-equation

A solution that contains silver cyanide, AgCN(aq), is used to plate a key with silver.



- (a) Label the above diagram to show the:
- cathode and anode
 - direction of electron flow
 - direction of ion flow
 - polarity (positive/negative) of each electrode.
- (4 marks)

A salt bridge is required in galvanic cells but is **not** required in the electroplating cell above.

- (b) Explain this difference between these two cells. (3 marks)

Use excerpts from the Material Safety Data Sheet for silver cyanide shown below to answer part (c) and part (d).

Material Safety Data Sheet**Silver Cyanide, 99%****Section 3 – Hazards Identification**

Warning! Contact with acids liberates hydrogen cyanide, HCN(g); a very toxic, flammable gas.

Potential Health Effects

Eye: May cause eye irritation.

Skin: May cause skin irritation ... impairing cellular respiration.

Ingestion: Harmful if swallowed. May cause irritation of the digestive tract, ... liver and kidney damage ... cardiac disturbances ... headache, dizziness, weakness, collapse, unconsciousness and possible death ... central nervous system effects ... asphyxiation.

Inhalation: May cause respiratory tract irritation, liver and kidney damage ... adverse central nervous system effects including headache, convulsions, and possible death. May cause cardiac damage. Inhalation may result in ... hyperpnea (abnormally rapid or deep breathing), and dyspnea (labored breathing) followed rapidly by respiratory depression. Pulmonary edema (lungs fill with fluid) may occur.

Section 5 – Fire Fighting Measures

.... During a fire, irritating and highly-toxic gases may be generated by thermal decomposition or combustion. Containers may explode when heated. Non-combustible, substance itself does not burn but may decompose upon heating to produce irritating, corrosive and/or toxic fumes. Runoff from fire control or dilution water may cause pollution.

- (c) Explain why action is taken to maintain the pH above 8 as a safety precaution during the electroplating process using silver cyanide. (3 marks)

Question 31 (continued)

- (d) Suggest **three** other safety measures that should be taken during the electroplating process and indicate how each addresses a specific potential hazard to either the workers or the environment. (3 marks)

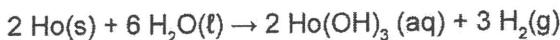
One: _____

Two: _____

Three: _____

2620

Holmium (Ho) reacts quickly with hot water to form holmium hydroxide and hydrogen:



The oxidising and reducing agents in this equation are

	Oxidising agent	Reducing agent
(a)	H ₂ O	H ₂
(b)	Ho	H ₂ O
(c)	H ₂ O	Ho
(d)	Ho(OH) ₃	Ho

2620
3.

Oxidation-reduction reactions involve the transfer of

- (a) protons.
- (b) electrons.
- (c) hydroxide ions.
- (d) hydrogen ions.

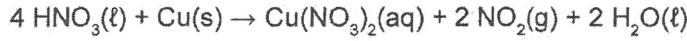
2620
6.

What type of redox reaction occurs in a galvanic cell and what is one possible use for such a cell?

	Type of redox reaction	Possible use of a galvanic cell
(a)	non-spontaneous	the plating of cheap metallic objects with precious metals
(b)	spontaneous	the plating of cheap metallic objects with precious metals
(c)	non-spontaneous	the production of an electric current for a torch
(d)	spontaneous	the production of an electric current for a torch

2620
7.

The following equation shows the reaction between copper and concentrated nitric acid:



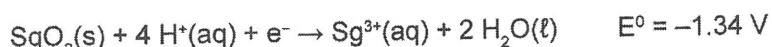
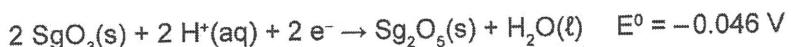
Observable changes associated with this reaction are the dissolving of the copper, the formation of a deep blue solution and the evolution of a pungent brown gas.

Which of the following are some of the atomic/molecular scale events needed for these observable changes to occur?

- (i) collisions between HNO₃ molecules and Cu atoms
 - (ii) donation and acceptance of protons
 - (iii) reduction of copper atoms
- (a) i only
 - (b) ii only
 - (c) i and iii only
 - (d) i, ii and iii

2020

19. The following half-equations show some predicted standard reduction potentials for seaborgium (Sg) oxides:

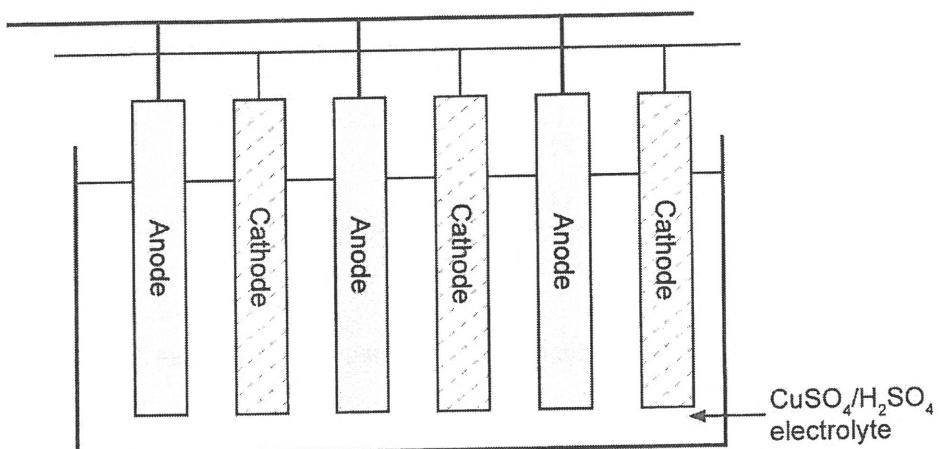


The strongest reducing agent is

- (a) SgO_3
- (b) Sg_2O_5
- (c) SgO_2
- (d) Sg^{3+}

2020

20. Impure copper must be purified before it is used in applications where very high electrical conductivity is required. The purification of copper, which is also known as electrorefining, can be performed in an electrochemical cell similar to the one shown below.



Which statement regarding this electrochemical cell is correct?

- (a) This cell requires the application of an external electrical potential difference for it to function.
- (b) During operation, the electrolyte becomes less blue because the concentration of Cu²⁺ ions in the electrolyte decreases.
- (c) This cell will not work because it does not have a salt bridge.
- (d) The impure copper is cast as cathodes.

Write balanced equations for any reactions occurring between the following substances and describe the observation(s).

If there is no reaction, write 'no reaction' for the equation and if there is no change observed, write 'no visible reaction' for the observations. Where applicable, use the colours stated in the Chemistry Data Booklet.

Iron filings and dilute hydrochloric acid

Equation
Observation(s)

Chromium(III) nitrate solution and magnesium ribbon

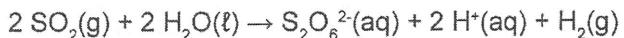
Equation
Observation(s)

Potassium chloride solution and bromine water

Equation
Observation(s)

See next page

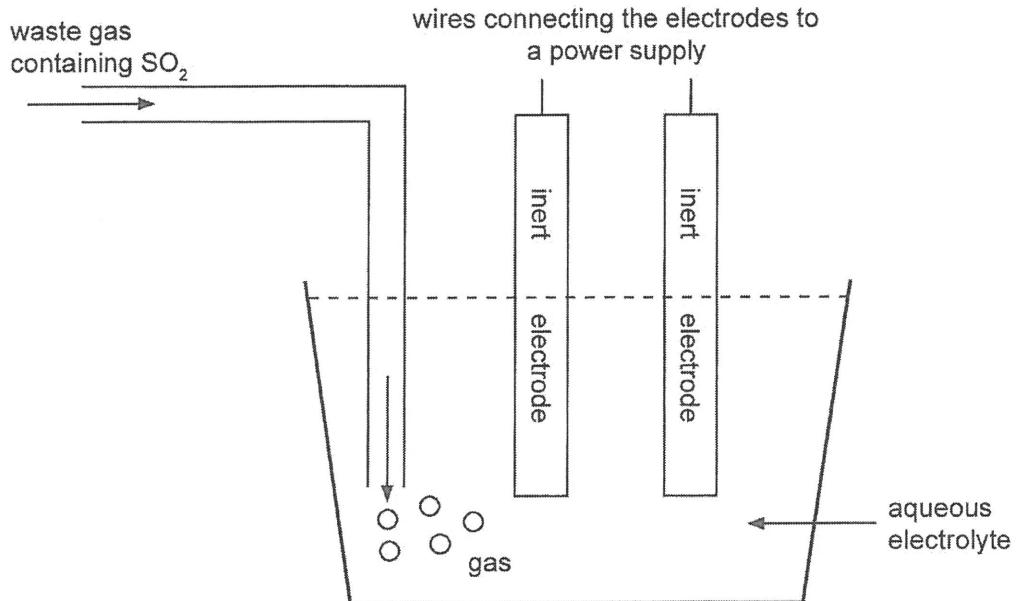
Sulfur dioxide must be removed from waste industrial gases before they are released into the atmosphere. One method of doing this is the electrolytic conversion of sulfur dioxide into dithionite ($\text{S}_2\text{O}_6^{2-}$):



- (a) Identify the atom that is oxidised and the atom that is reduced in this reaction. (2 marks)

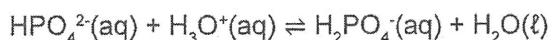
Atom that is oxidised	
Atom that is reduced	

An electrolytic cell, similar to the simplified one shown below, can be used for the above process.



A chemist, who was investigating this process, used 1.00 mol L^{-1} sodium perchlorate (NaClO_4) solution as the electrolyte. The chemist found that the pH of this electrolyte steadily decreased as more SO_2 -containing waste gas was treated. The final pH was 2.42.

The observed pH change prompted the chemist to change the electrolyte to a mixture of potassium hydrogen phosphate (K_2HPO_4) and potassium dihydrogenphosphate (KH_2PO_4), in which the following equilibrium occurred:



No significant pH changes occurred when this new electrolyte was used.

- (b) Explain how the $\text{HPO}_4^{2-}/\text{H}_2\text{PO}_4^-$ prevented any significant pH change when the SO_2 was bubbled into the solution. (5 marks)

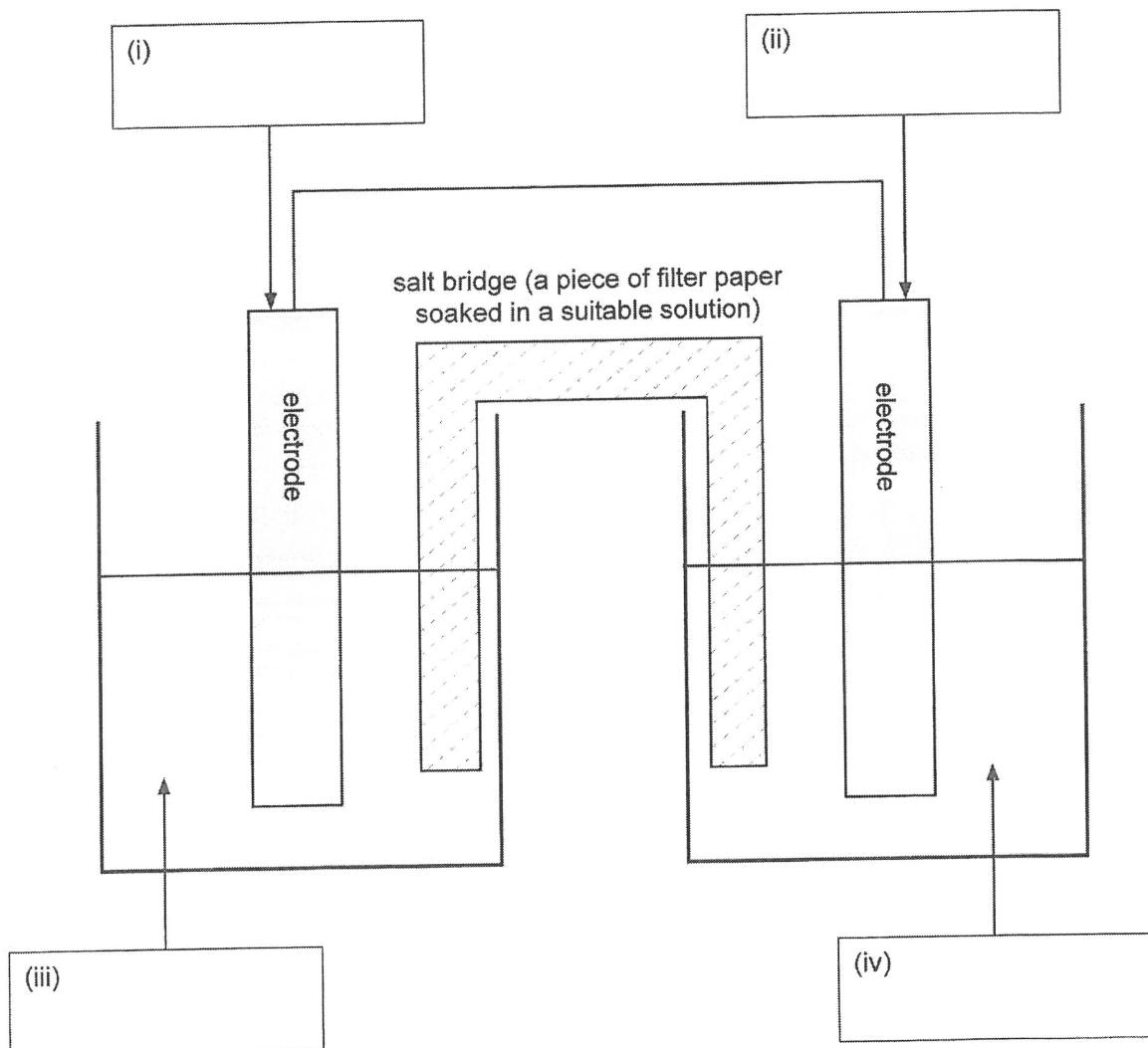
DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

A student was asked to build a functioning galvanic cell, having been provided with all of the required hardware plus the following substances:

- a piece of magnesium measuring 1 mm by 2 cm by 6 cm
- a piece of copper measuring 1 mm by 2 cm by 6 cm
- a 6 cm long graphite (carbon) rod with a diameter of 1 cm
- 1.0 mol L⁻¹ sodium carbonate solution
- 1.0 mol L⁻¹ magnesium sulfate solution
- 1.0 mol L⁻¹ copper(II) sulfate solution.

There was no requirement for the student to use all of these substances.

- (a) A partially-labelled diagram of the galvanic cell built by the student is shown below. What substances should the student have used in the parts labelled (i) to (iv) to build a functioning galvanic cell? Write the names of these substances in the boxes provided. (4 marks)



- (b) Add arrows to the diagram in part (a) to show the direction of movement of electrons through the external circuit. (1 mark)

- (c) Write the half-equations for the reactions occurring at the anode and the cathode in the student's galvanic cell. (4 marks)

Anode half-equation	
Cathode half-equation	

- (d) Calculate the electrical potential difference of the student's galvanic cell. Assume standard conditions. Include appropriate units in your answer. (2 marks)

- (e) Galvanic cells, such as the one shown in the diagram, need a salt bridge.

- (i) State why galvanic cells need a salt bridge. (1 mark)

- (ii) Describe, with reference to ion movement, how the salt bridge in a galvanic cell works. Also state why ion movement occurs as you have described. (4 marks)

2021

Which of the following statements is/are true for redox reactions?

- (i) Redox reactions involve the transfer of electrons from one species to another.
 - (ii) Complete combustion is a redox reaction, but incomplete combustion is not.
 - (iii) Oxidation is the gain of electrons while reduction is the loss of electrons.
 - (iv) Oxidation and reduction occur simultaneously.
-
- (a) i only
 - (b) i, ii and iv only
 - (c) i, iii and iv only
 - (d) i and iv only

CHEMISTRY

6

2021

10. Which of the following identifies the recharging ability of a particular type of electrochemical cell and provides an appropriate example?

	Electrochemical cell	Rechargeable	Example
(a)	primary	no	Leclanché cell
(b)	secondary	no	lead-acid accumulator
(c)	primary	yes	lead-acid accumulator
(d)	secondary	yes	Leclanché cell

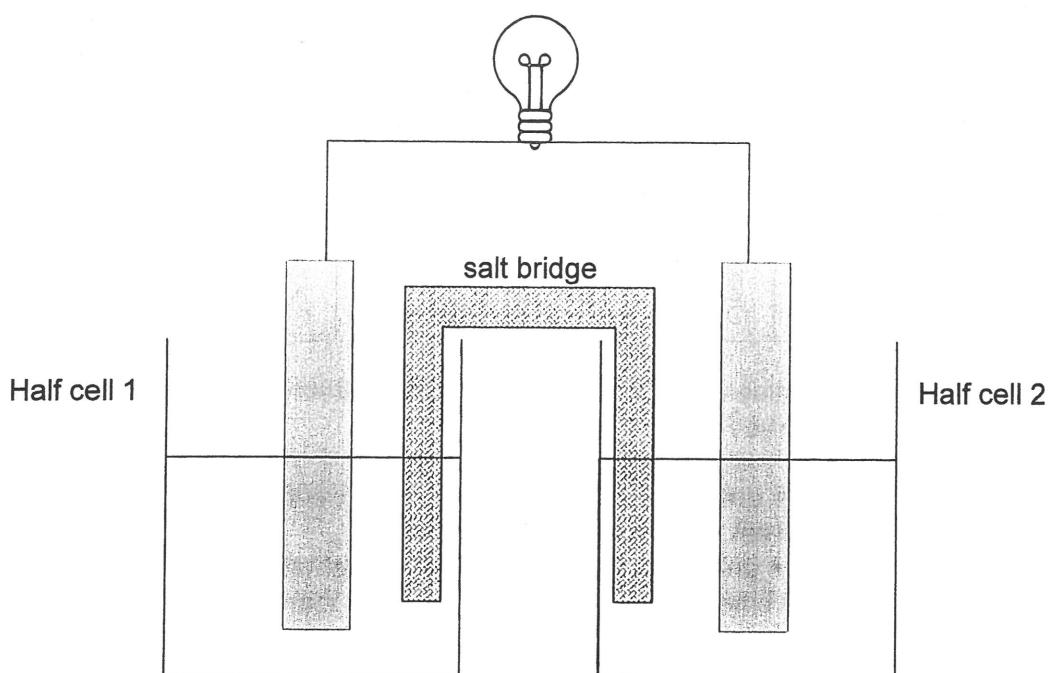
2021
22.

In an electrolytic cell used for plating objects with gold,

- (a) the object to be plated is the anode.
- (b) there must be a salt bridge connecting the anode and cathode half-cells.
- (c) the reaction is spontaneous and so no external potential difference is required.
- (d) a piece of pure gold is used as the positively charged electrode.

2021

Questions 12 and 13 refer to the following electrochemical cell, which contains a light globe.



2021

12. Which combination of electrodes and aqueous electrolytes will result in the possibility of the globe glowing? Assume standard conditions.

	Half cell 1		Half cell 2	
	Electrode	Electrolyte	Electrode	Electrolyte
(a)	graphite	$\text{Ni}(\text{NO}_3)_2\text{(aq)}$	silver	$\text{AgNO}_3\text{(aq)}$
(b)	silver	$\text{Ni}(\text{NO}_3)_2\text{(aq)}$	graphite	$\text{AgNO}_3\text{(aq)}$
(c)	nickel	$\text{Ni}(\text{NO}_3)_2\text{(aq)}$	silver	$\text{AgNO}_3\text{(aq)}$
(d)	nickel	$\text{AgNO}_3\text{(aq)}$	silver	$\text{Ni}(\text{NO}_3)_2\text{(aq)}$

2021

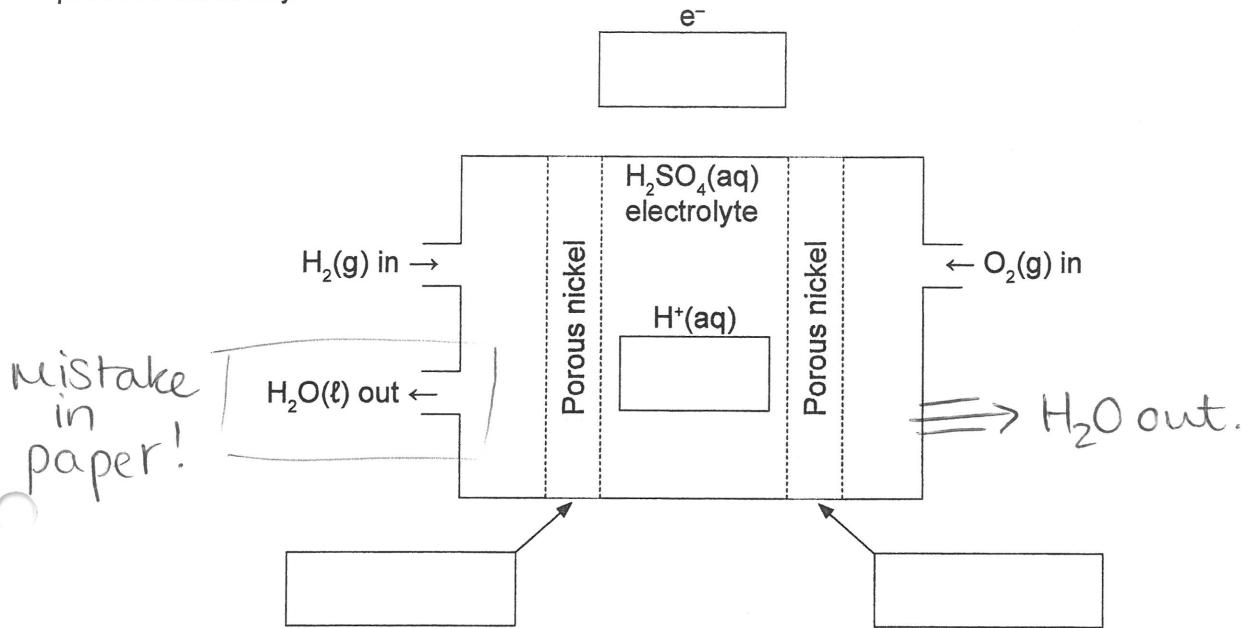
13. The salt bridge

- (a) provides the ions that are oxidised or reduced at the electrodes.
- (b) maintains the overall electrical and pH neutrality of the cell by facilitating the transfer of electrons and ions from one half cell to another.
- (c) provides the H_3O^+ and OH^- ions needed to maintain the pH neutrality of each half cell, preventing the build-up of electrical charge in the electrolytes.
- (d) provides ions and facilitates ion movement between the half cells to complete the electrical circuit.

(10 marks)

2021
Question 30

Fuel cells, such as the one shown in the diagram below, use gaseous hydrogen and oxygen to produce electricity.



In this particular fuel cell, which uses sulfuric acid as the electrolyte, the hydrogen and oxygen are circulated at very high pressure over porous nickel-platinum electrodes. Operating temperatures range from 25 to 90 °C.

- (a) Complete the above diagram by adding labels/arrows to show the:
- anode
 - cathode
 - direction of electron flow
 - direction of hydrogen ion flow.
- (4 marks)
- (b) Write balanced half-equations for the oxidation and reduction reactions and the equation for the overall reaction occurring in this fuel cell.
- (4 marks)

Oxidation half-reaction	
Reduction half-reaction	
Overall redox reaction	

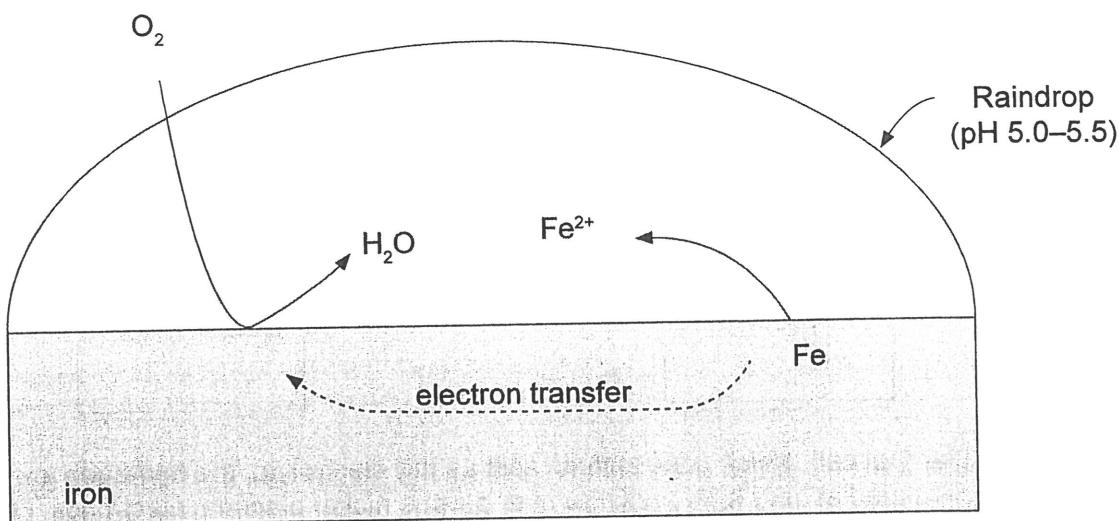
- (c) This fuel cell typically produces 0.7 V, which is significantly less than the predicted value of 1.23 V. State **two** specific conditions of this cell that would account for this observation.
- (2 marks)

One: _____

Two: _____

The corrosion of iron is an electrochemical process that results in the formation of a reddish-brown solid commonly known as rust, $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}(\text{s})$. Iron objects exposed to rainwater corrode relatively quickly.

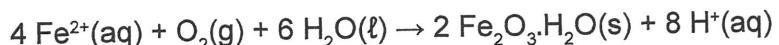
Iron corrosion occurs in two stages. During the first stage, an electrochemical cell is established on the iron surface, with electron transfer and Fe^{2+} ion formation occurring. This can be seen in the following diagram.



- (a) Write half-equations and the overall balanced equation for the reaction occurring in the above electrochemical cell. State symbols are **not** required. (4 marks)

Oxidation half-equation	
Reduction half-equation	
Redox equation	

- (b) During the second stage of iron corrosion, the newly formed Fe^{2+} ions migrate away from the iron surface and react with water and dissolved oxygen to form rust. The balanced equation for this reaction is shown below.



Use oxidation numbers to show that this reaction is a redox reaction.

(2 marks)

A corrosion chemist inspected an outdoor playground and found that most of the equipment containing iron showed signs of corrosion. The chemist suggested several different methods for protecting the playground equipment from further corrosion, including the use of sacrificial anodes.

- (c) State what is a sacrificial anode. (1 mark)

- (d) State the name of a metal that can be used as a sacrificial anode to protect the equipment from further corrosion. Use Standard Reduction Potentials to justify your choice. (2 marks)

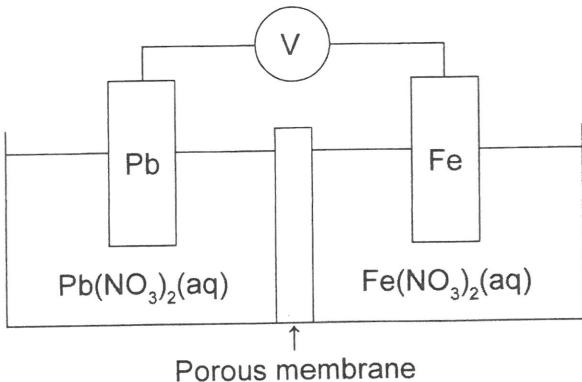
2022

2. Which of the following pairs represents the **greatest** difference in oxidation state of the underlined element?

- (a) $\underline{\text{Mn}}^{2+}$ and KMnO_4
- (b) $\underline{\text{CrO}}_4^{2-}$ and $\underline{\text{Cr}_2\text{O}_7}^{2-}$
- (c) $\underline{\text{Cl}}^-$ and $\text{H}\underline{\text{ClO}}_4$
- (d) $\underline{\text{S}}^{2-}$ and $\underline{\text{SO}}_3^{2-}$

2022

Questions 15 to 17 refer to the electrochemical cell below.



15. Which of the following series of labels **best** represents the cell above?

	Anode	Cathode	Direction of electron flow	Direction of anion flow
(a)	lead	iron	←	→
(b)	lead	iron	→	←
(c)	iron	lead	→	→
(d)	iron	lead	←	→

16. Using the standard reduction potentials, determine the theoretical value that the voltmeter would show for this electrochemical cell?

- (a) +0.31 V
- (b) +0.57 V
- (c) +0.64 V
- (d) +0.90 V

17. Which of the following reasons would cause the voltmeter to show a different value to the theoretical voltage?

- (i) the cell is at 100 kPa
- (ii) the cell is at 20 °C
- (iii) the $\text{Pb}(\text{NO}_3)_2$ solution is 0.1 mol L⁻¹ and the $\text{Fe}(\text{NO}_3)_2$ solution is 0.2 mol L⁻¹
- (iv) the lead and iron electrodes are in the opposite solution to that shown in the diagram above

- (a) i and ii
- (b) ii and iii
- (c) ii, iii and iv
- (d) iii and iv

See next page

Thermite is a mixture of aluminium and iron(III) oxide that, when ignited, rapidly produces a large amount of heat as it burns. The reaction is represented by the equation:



The heat produced in the reaction is sufficient to melt iron, which is why the reaction is used to weld iron railway tracks.

- (a) Use the following axes to sketch an energy profile diagram for the thermite reaction.

Label the:

- axes
- reactants and products
- activation energy
- change in enthalpy.

(4 marks)



- (b) In order for the reaction to occur, the iron(III) oxide and aluminium are mixed as powders and a heat source, such as burning magnesium, is used to ignite the mixture. Using your understanding of collision theory, explain these observations. (4 marks)

- (c) If the thermite reaction is 89.5% efficient, what mass of iron(III) oxide will be required to produce 667 kg of iron? Give your answer to the appropriate number of significant figures. (6 marks)

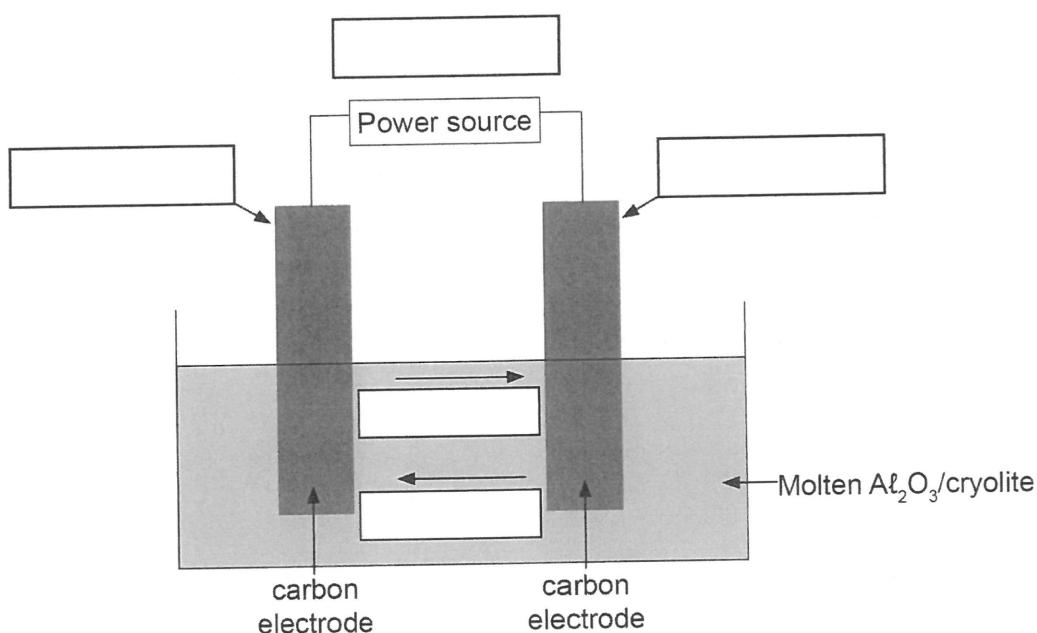
Aluminium can be refined through electrolysis. Molten aluminium oxide, which is mixed with a substance called cryolite to reduce the melting point, is electrolysed to produce aluminium and carbon dioxide, which is represented by the following equation:



- (d) On the diagram below, correctly place the following in the boxes:

- anode
- cathode
- direction of cation flow and direction of anion flow
- direction of electron flow.

(3 marks)



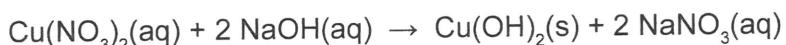
The copper cycle is a series of reactions involving copper.

Step 1: 2.54 g of copper is added to excess concentrated nitric acid to produce copper(II) nitrate, nitrogen dioxide and water.

- (a) Write balanced half-equations for the oxidation and reduction reactions and a balanced overall redox equation for the reaction in Step 1. (5 marks)

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

Step 2: Copper(II) nitrate is added to excess sodium hydroxide solution, according to the following equation:



- (b) Describe all the observations for this reaction, including colour changes. (2 marks)

Step 3: Copper(II) hydroxide is heated to produce copper(II) oxide and water vapour.

- (c) Write an equation for Step 3, including state symbols. (3 marks)

Step 4: Copper(II) oxide is added to excess dilute sulfuric acid solution.

- (d) Write an equation for this reaction. (2 marks)

Step 5: Excess magnesium metal is added to the copper(II) sulfate solution.

- (e) Write an equation for this reaction. (2 marks)

10. The following table summarizes the results of the study.

- (f) If 0.616 g of magnesium was required to react with the copper(II) sulfate, calculate the mass of copper produced and, therefore, the percentage yield of copper from the series of reactions. (4 marks)

2023
3.

The concentration of chloride ions in the ocean is approximately 35 000 ppm. Which of the following ions is **unlikely** to be present?

- (a) Ag^+
- (b) Pb^{2+}
- (c) Mg^{2+}
- (d) K^+

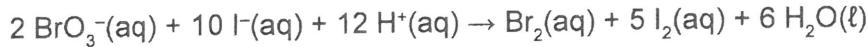
2023

4. In which of the following is vanadium in a +4 oxidation state?

- (a) NH_4VO_3
- (b) VOSO_4
- (c) $\text{V}(\text{H}_2\text{O})_6^{3+}$
- (d) V_2O_5

2023

5. Identify the oxidant in the following equation.



- (a) $\text{BrO}_3^-(\text{aq})$
- (b) $\text{I}^-(\text{aq})$
- (c) $\text{H}^+(\text{aq})$
- (d) $\text{Br}_2(\text{aq})$

CHEMISTRY

6

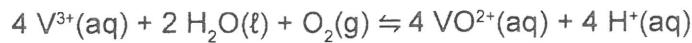
2023 15. Which of the following reactions will occur spontaneously under standard conditions at 25 °C?

- (i) $\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}_2(\text{aq})$
- (ii) $\text{Ni}^{2+}(\text{aq}) + 2 \text{Fe}^{2+}(\text{aq}) \rightleftharpoons \text{Ni}(\text{s}) + 2 \text{Fe}^{3+}(\text{aq})$
- (iii) $\text{H}_2\text{O}_2(\text{aq}) + 2 \text{CO}_2(\text{g}) \rightleftharpoons \text{H}_2\text{C}_2\text{O}_4(\text{aq}) + \text{O}_2(\text{g})$
- (iv) $\text{O}_2(\text{g}) + 2 \text{H}_2\text{S}(\text{aq}) \rightleftharpoons 2 \text{S}(\text{s}) + 2 \text{H}_2\text{O}(\ell)$

- (a) i and iv
- (b) ii and iii
- (c) iii and iv
- (d) i and ii

2023

20. An electrochemical cell, reaction shown below, has an E° value of +0.89 V.

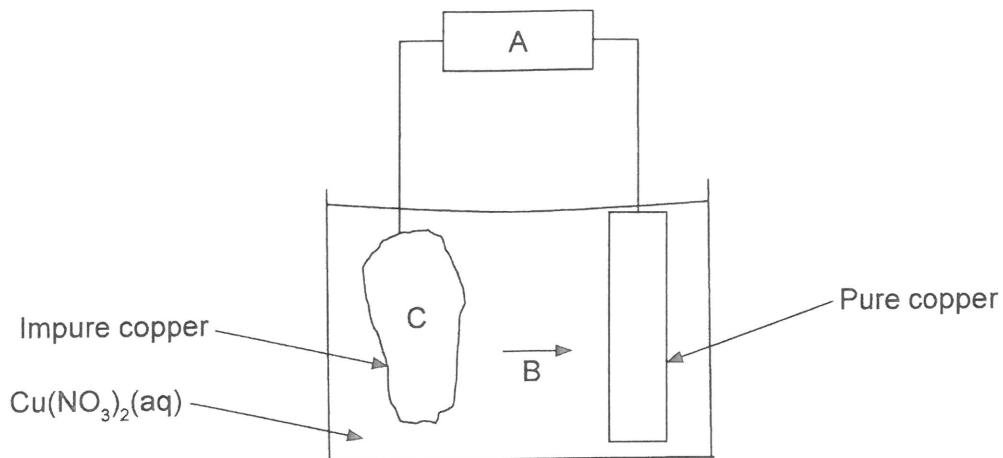


What is the standard reduction potential for the half-equation below?



- (a) -0.34 V
- (b) +1.57 V
- (c) +0.34 V
- (d) -1.57 V

2023 23. The cell below was set up by a student to demonstrate the purification of copper.

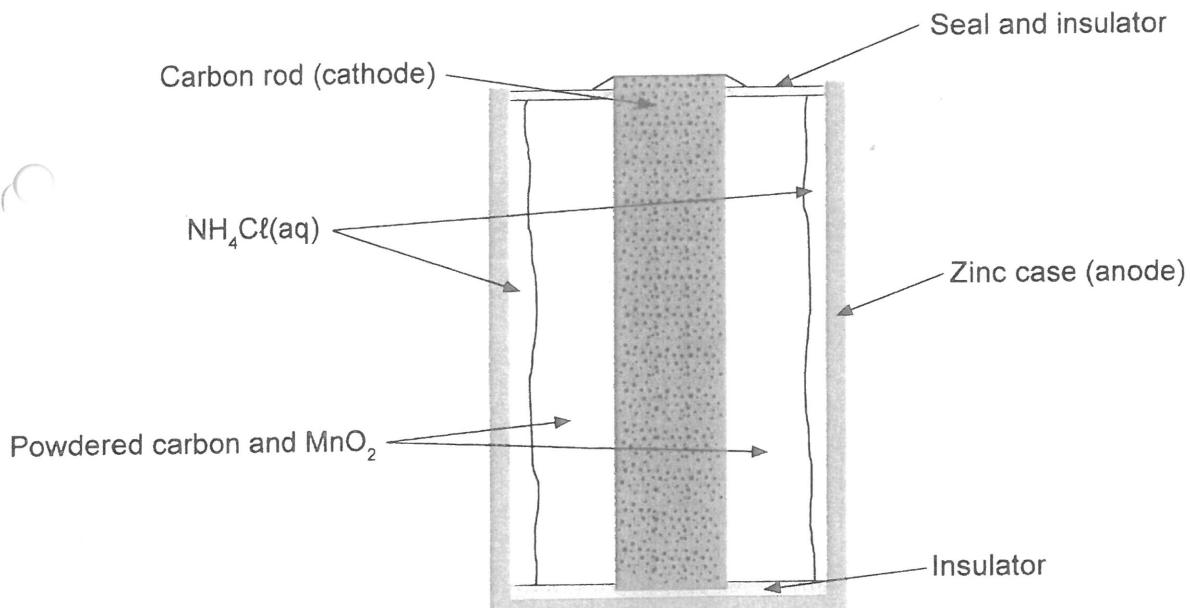


Which of the following are the correct labels, A, B and C, on the diagram?

	A	B	C
(a)	Voltmeter	Direction of anion flow	Anode
(b)	Power supply	Direction of cation flow	Anode
(c)	Voltmeter	Direction of anion flow	Cathode
(d)	Power supply	Direction of cation flow	Cathode

2023

Question 24 refers to the following diagram.



24. For the Leclanché dry cell shown above, which of the following statements **best** describes the role of the electrodes?

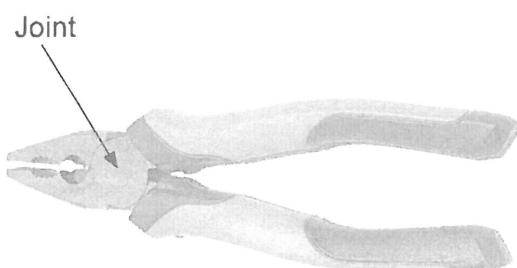
- (a) The zinc is oxidised; reduction of manganese dioxide occurs at the carbon.
- (b) The zinc is reduced; carbon is oxidised.
- (c) The carbon is reduced; oxidation of manganese dioxide occurs at the zinc.
- (d) The carbon is reduced; zinc is oxidised.

2023

Question 27

(10 marks)

A carpenter left a pair of pliers outside over a rainy period, which subsequently became rusty, causing the joint to seize. Rather than buy a new pair of pliers, the carpenter decided to submerge the rusty part of the pliers in phosphoric acid to remove the rust. Phosphoric acid converts rust into another substance that can easily be washed away.



- (a) Write an equation for the action of phosphoric acid on the rust. Assume rust is iron(III) oxide. Include state symbols in your answer. (3 marks)

- (b) Identify the best method that the carpenter could use to protect the pliers from rusting further. Explain how this method would be effective. (3 marks)

Method: _____

Explanation: _____

The carpenter noticed that his toolboxes in the back of his truck were also rusting. He decided to explore the use of a sacrificial anode as an option to prevent the toolboxes rusting.

- (c) State what a sacrificial anode is and explain how it is effective in preventing corrosion of the toolboxes. You should state which metal could be used for a sacrificial anode in your answer. (4 marks)

2023

Question 29

(8 marks)

Electrochemical cells are categorised as either galvanic cells or electrolytic cells. Identify **three** similarities and **three** differences with which to compare galvanic and electrolytic cells, using relevant examples of each cell type. You may choose to use diagrams to illustrate your answer.

Similarities: _____

Differences: _____

2023
Question 30

(12 marks)

Write a balanced ionic equation for any reactions occurring between the following substances and state any observations before and after mixing.

If there is no reaction, write 'no reaction' for the equation and if there is no change observed write 'no visible reaction'. Use the colours stated in the Data booklet if required.

- (a) A piece of iron wool is added to a 0.1 mol L^{-1} solution of copper(II) sulfate. (4 marks)

Equation

Observations

- (b) Calcium hydrogencarbonate powder is added to excess 1 mol L^{-1} nitric acid. (4 marks)

Equation

Observations

- (c) Excess chlorine gas is bubbled through a 0.1 mol L^{-1} sodium bromide solution. (4 marks)

Equation

Observations
