2016

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

Step	1	2	3	4
	$N_2 \rightarrow NH_3$	$NH_3 \rightarrow NO$	$NO \rightarrow NO_2$	$NO_2 \rightarrow HNO_3$

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) $2\ CrO_4^{2-} + 2\ H^+ \rightarrow Cr_2O_7^{2-} + H_2O$
(b) $2\ Cr^{2+} + 2\ H^+ \rightarrow 2\ Cr^{3+} + H_2$
(c) $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4\ H_2O + Cr_2O_3$
(d) $Cr_2O_3 + 3\ C \rightarrow 2\ Cr + 3\ CO$

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) $MnO_4^-(aq) + 8\ H^+(aq) + 5\ Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4\ H_2O(\ell) + 5\ Fe^{3+}(aq)$
(b) $Fe(s) + Pb^{2+}(aq) \rightarrow Fe^{2+}(aq) + Pb(s)$
(c) $Br_2(\ell) + 2\ Cl^-(aq) \rightarrow 2\ Br^-(aq) + Cl_2(g)$
(d) $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$

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

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)
$A^{2+}(aq)$		No visible reaction	Solid A forms
$B^{2+}(aq)$	Solid B forms		Solid B forms
$C^{2+}(aq)$	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) C > A > B.
(b) B > C > A.
(c) B > A > C.
(d) A > C > B.

DO NOT WRITE

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: _____

_____

Question 40 **(11 marks)**

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.

Equation one: $2\ CuFeS_2 + 2\ SiO_2 + 4\ O_2 \rightarrow Cu_2S + 2\ FeSiO_3 + 3\ SO_2$

Equation two: $Cu_2S + O_2 \rightarrow 2\ Cu + SO_2$

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

Reduction: _____

Oxidation: $S^{2-} + O_2 \rightarrow SO_2 + 2\ e^-$

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)

_____

_____

_____

_____

_____

_____

_____

_____

_____

See next page

See next page

2017
2. Copper reacts with nitric acid as shown in the redox equation below.

$Cu(s) + 4\,H^+(aq) + 2\,NO_3^-(aq) \rightarrow Cu^{2+}(aq) + 2\,NO_2(g) + 2\,H_2O(\ell)$

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) $4\,Fe(OH)_2(s) + 2\,H_2O(aq) + O_2(g) \rightarrow 4\,Fe(OH)_3(s)$
(b) $O_2(g) + 2\,H_2O(\ell) + 4\,e^- \rightarrow 4\,OH^-(aq)$
(c) $FeC\ell_3(s) \rightarrow Fe^{3+}(aq) + 3\,C\ell^-(aq)$
(d) $Pb^{2+}(aq) \rightarrow Pb^{4+}(aq) + 2\,e^-$

2017
10. Which one of the following reactions will be spontaneous under standard conditions?

(a) $Cr_2O_7^{2-}(aq) + 3\,H_2O_2(aq) + 8\,H^+(aq) \rightarrow 2\,Cr^{3+}(aq) + 7\,H_2O(\ell) + 3\,O_2(g)$
(b) $3\,O_2(g) + 4\,Au(s) + 12\,H^+(aq) \rightarrow 4\,Au^{3+}(aq) + 6\,H_2O(\ell)$
(c) $2\,Ag^+(aq) + 2\,Br^-(aq) \rightarrow 2\,Ag(s) + Br_2(\ell)$
(d) $2\,C\ell^-(aq) + I_2(s) \rightarrow C\ell_2(g) + 2\,I^-(aq)$

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)

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)

_____

_____

_____

_____

_____

_____

Question 27 **(6 marks)**

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

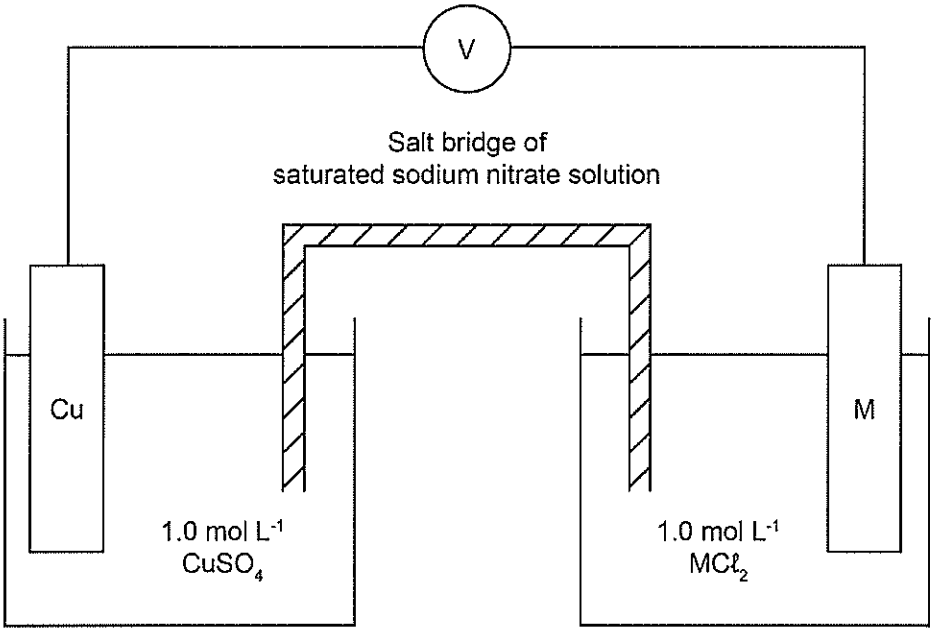
$$SCN^- + IO_3^- + C\ell^- \rightarrow SO_4^{2-} + HCN + IC\ell$$

Oxidation half-equation
Reduction half-equation
Overall equation

See next page

Question 34 **(7 marks)**

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



One electrode/electrolyte pair is Cu/Cu^{2+}. The other electrode is of an unknown metal, represented as M/M^{2+}. 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/Cu^{2+} cell. (2 marks)

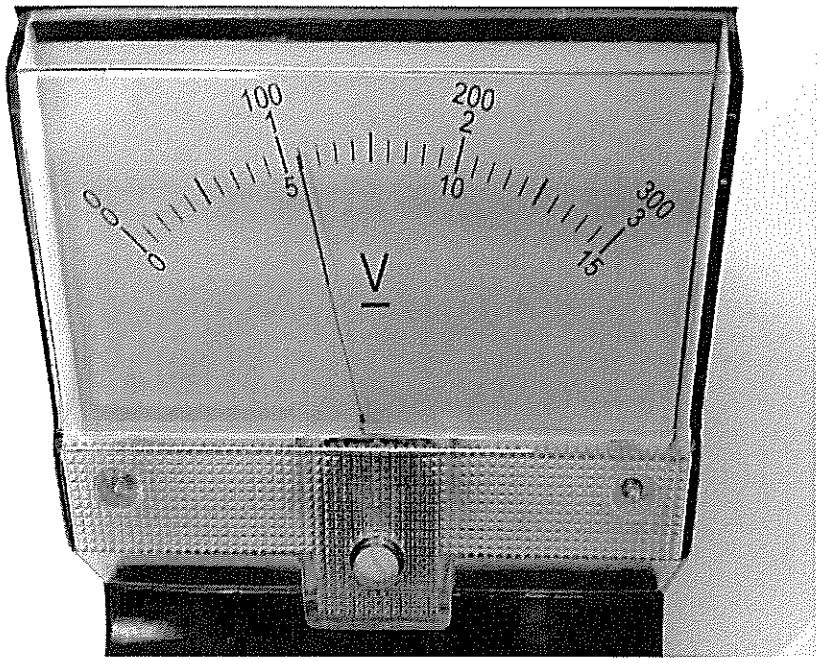
One: _____

_____

Two: _____

_____

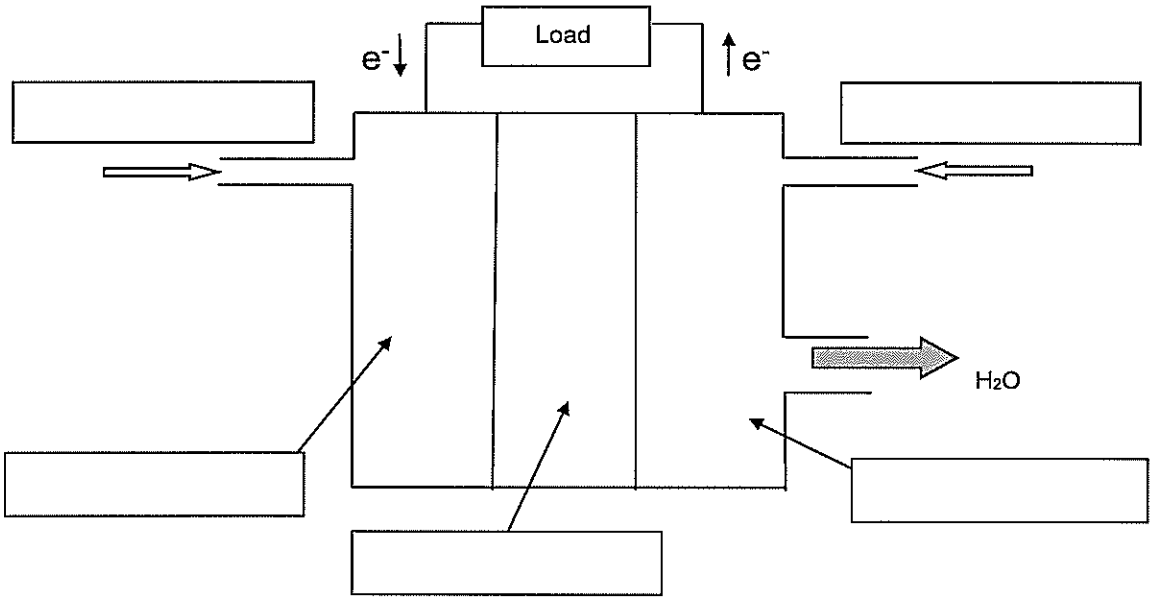
Below is a photograph of the voltmeter attached to the diagram of the cell on page 20. There are three scales on the voltmeter. The scale being used is the one with the range from 0 to 3 volts.



(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)

See next page

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, $Cr_2O_7^{2-}(aq)$, a reaction occurs resulting in $In^{3+}(aq)$ ions being produced. The equation for this reaction is shown below.

$$Cr_2O_7^{2-}(aq) + 14\ H^+(aq) + 2\ In(s) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(\ell) + 2\ In^{3+}(aq)$$

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

5. What is the calculated E^o 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 $Mo_2O_7^{2-}$ $HMoO_4^{2-}$
Which of the following lists these species in order of **increasing** oxidation number of molybdenum?

(a)	$HMoO_4^{2-}$	MoO_2	$Mo_2O_7^{2-}$
(b)	$Mo_2O_7^{2-}$	$HMoO_4^{2-}$	MoO_2
(c)	$Mo_2O_7^{2-}$	MoO_2	$HMoO_4^{2-}$
(d)	MoO_2	$HMoO_4^{2-}$	$Mo_2O_7^{2-}$

See next page

2018

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

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2018

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			
	$Re^{3+}(aq)$	$V^{2+}(aq)$	$Zr^{4+}(aq)$	$Ta^{3+}(aq)$
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

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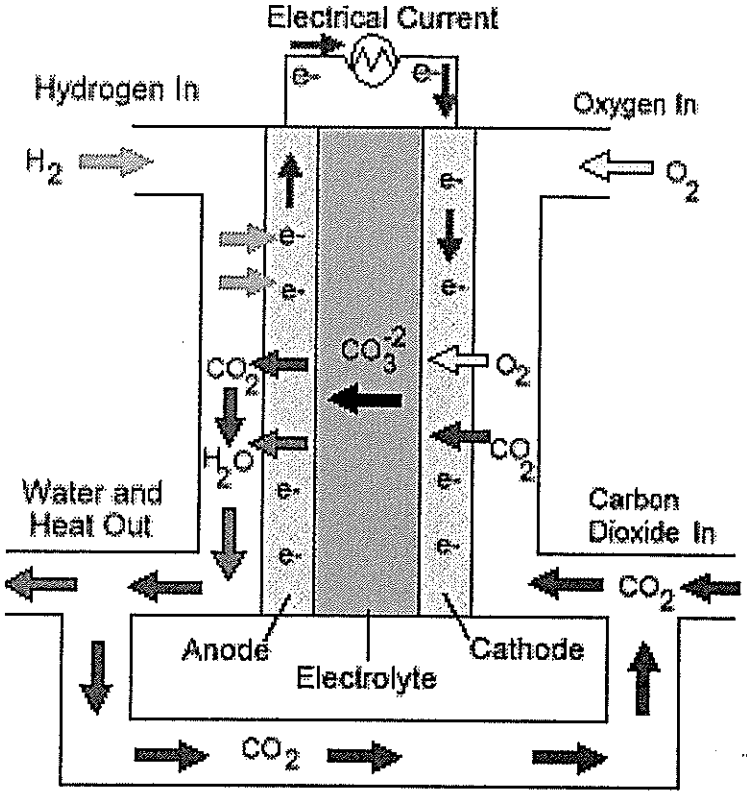
2018

Question 28 **(8 marks)**

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! :(

ıe 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)

See next page

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

One: _____

_____

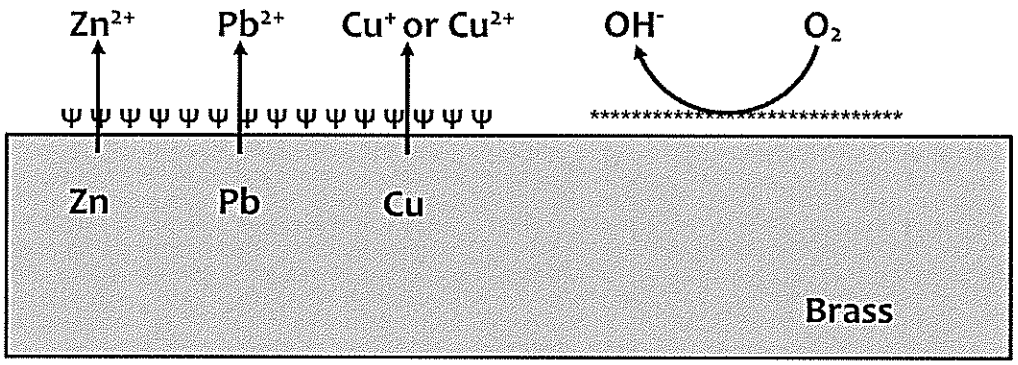
Two: _____

_____

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:

$$2\,Pb(s) + O_2(g) + 2\,H_2O(\ell) \rightarrow 2\,Pb(OH)_2(s)$$

What is the theoretical E^0 value for the overall Pb/O_2 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

See next page

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.

2019
17. In which of the following sets do all the **bolded** and <u>underlined</u> atoms have the same oxidation number?

(i) $H_2\underline{\mathbf{O}}$, $\underline{\mathbf{O}}_2$, $H_2\underline{\mathbf{O}}_2$
(ii) $H_2\underline{\mathbf{O}}_2$, $Na\underline{\mathbf{C}\ell}$, $Mg\underline{\mathbf{H}}_2$
(iii) $\underline{\mathbf{Na}}Cl$, $\underline{\mathbf{Li}}_2CO_3$, $\underline{\mathbf{K}}OH$
(iv) $\underline{\mathbf{Fe}}O$, $\underline{\mathbf{Fe}}_2O_3$, $\underline{\mathbf{Fe}}$

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

Question 28 **(7 marks)**

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

$$Ca(OC\ell)_2(s) + 4\,HC\ell(aq) \rightarrow CaC\ell_2(aq) + 2\,H_2O(\ell) + 2\,C\ell_2(g)$$

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, $Ca(OC\ell)_2$
- hydrochloric acid, $HC\ell$? (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)

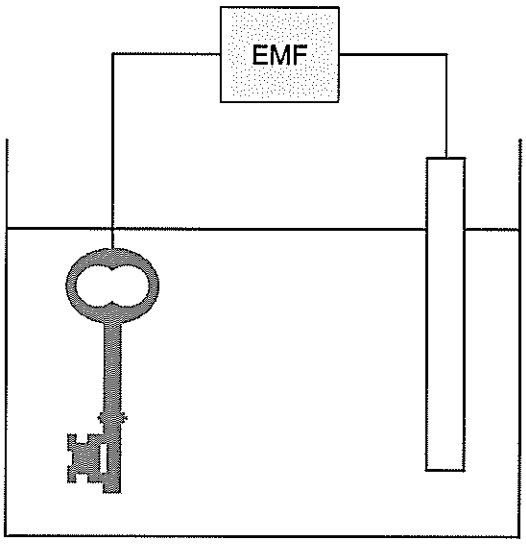
Oxidation half-equation

Reduction half-equation

See next page

Question 31 **(13 marks)**

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)

See next page

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)

2019

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: _____

_____

_____

2020
1. Holmium (Ho) reacts quickly with hot water to form holmium hydroxide and hydrogen:

$2\ Ho(s) + 6\ H_2O(\ell) \rightarrow 2\ Ho(OH)_3\ (aq) + 3\ H_2(g)$

The oxidising and reducing agents in this equation are

	Oxidising agent	Reducing agent
(a)	H_2O	H_2
(b)	Ho	H_2O
(c)	H_2O	Ho
(d)	$Ho(OH)_3$	Ho

2020
3. Oxidation-reduction reactions involve the transfer of

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

2020
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

2020
7. The following equation shows the reaction between copper and concentrated nitric acid:

$$4\ HNO_3(\ell) + Cu(s) \rightarrow Cu(NO_3)_2(aq) + 2\ NO_2(g) + 2\ H_2O(\ell)$$

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 HNO_3 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

See next page

2020
19. The following half-equations show some predicted standard reduction potentials for seaborgium (Sg) oxides:

$2\ SgO_3(s) + 2\ H^+(aq) + 2\ e^- \rightarrow Sg_2O_5(s) + H_2O(\ell)$ $E^0 = -0.046$ V

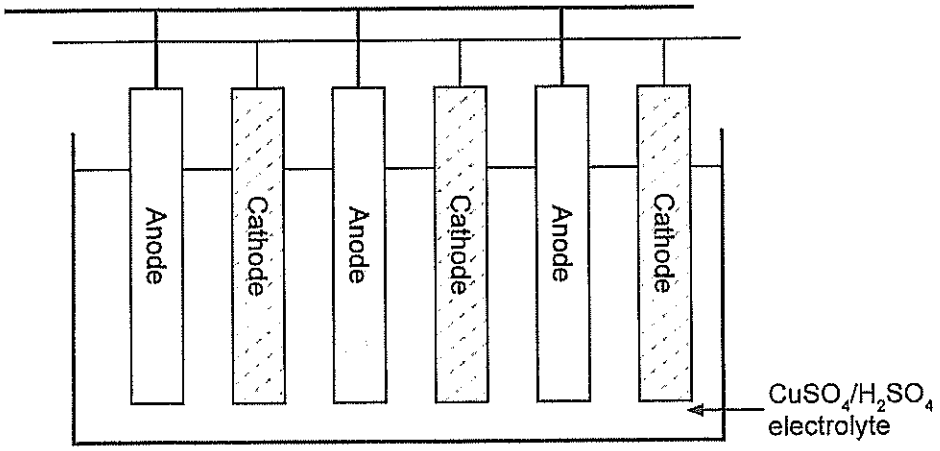
$Sg_2O_5(s) + 2\ H^+(aq) + 2\ e^- \rightarrow 2\ SgO_2(s) + H_2O(\ell)$ $E^0 = +0.11$ V

$SgO_2(s) + 4\ H^+(aq) + e^- \rightarrow Sg^{3+}(aq) + 2\ H_2O(\ell)$ $E^0 = -1.34$ V

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 Cu^{2+} 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.

Question 27 **(8 marks)**

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

Question 30 **(7 marks)**

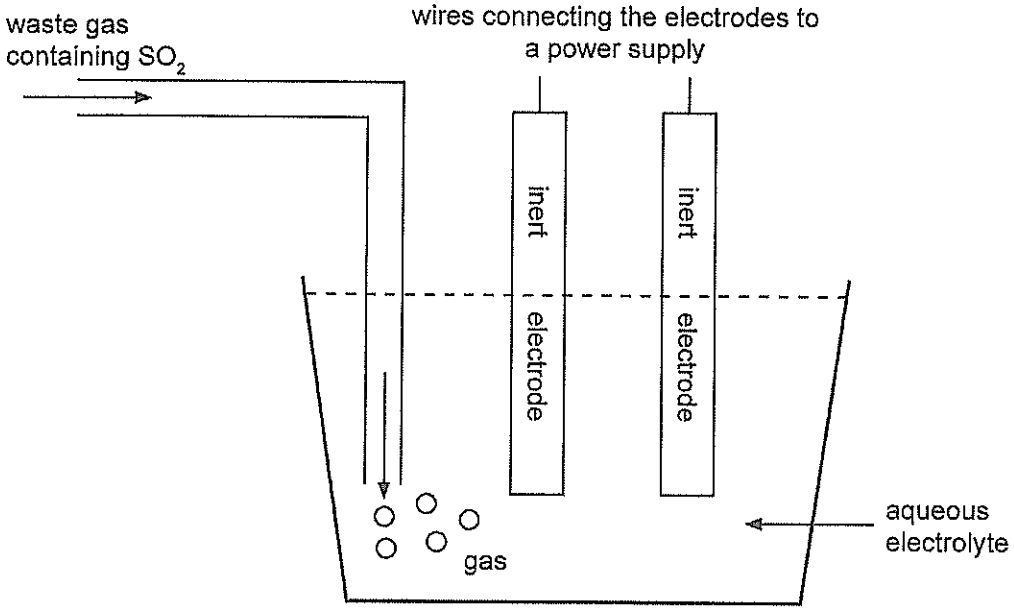
Sulfur dioxide must be removed from waste industrial gases before they are released into the atmosphere. One method of doing this is the electrolytic conversion of sulfur dioxide into dithionate ($S_2O_6^{2-}$):

$$2\ SO_2(g) + 2\ H_2O(\ell) \rightarrow S_2O_6^{2-}(aq) + 2\ H^+(aq) + H_2(g)$$

(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:

$$HPO_4^{2-}(aq) + H_3O^+(aq) \rightleftharpoons H_2PO_4^-(aq) + H_2O(\ell)$$

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

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(b) Explain how the $HPO_4^{2-}/H_2PO_4^-$ prevented any significant pH change when the SO_2 was bubbled into the solution. (5 marks)

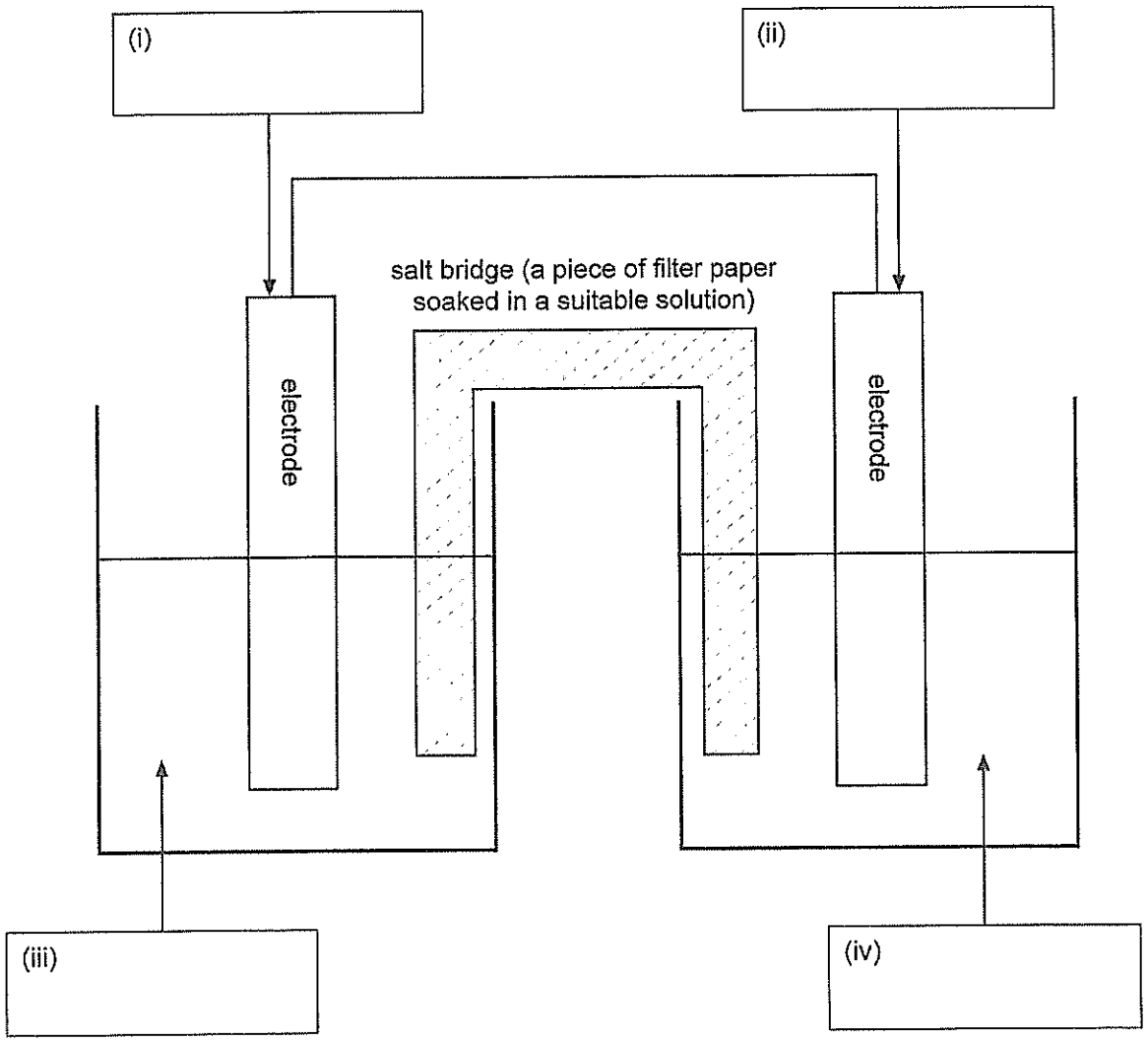
Question 36 **(16 marks)**

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)



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(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)