Quality Assessment Task

Internal Assessment HSC CHEMISTRY

INTRODUCTION

Component and Tasks:

Syllabus option "Shipwrecks, Corrosion and Conservation" and in particular to outcomes in Parts 5 and 6.

Part 5 states: When a ship sinks, the rate of corrosion may be dependent on the final depth of the wreck.

Part 6 states: Predictions of slow corrosion at great depths are incorrect.

Open-ended investigation, report writing, research, open-book test.

- First-hand investigation and secondary research about the effect of the depth of water on the rate of corrosion of a shipwreck.
- Preparation and submission of a report on the first-hand investigation and secondary research.
- Open-book test involving short answer questions related to the investigation and research.

This task relates to the following ***Chemistry syllabus outcomes:***
H8, H11, H12, H13, H14.

This Assessment Task will be **marked out of 44**. Your teacher will advise you of the actual value of this task for your internal assessment.

The marks for each section of the task are indicated in brackets.

Class **time** of four 50 minute lessons will be allocated for you to carry out the required practical work.

Your reports and research may also be done at this time or as homework.

The open-book test will be of 30 minute duration and will be done in class time.

Your reports and research findings must be handed in immediately after you have completed the open book test. Use the space provided for answers on the open book test.

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TASK

Overall aim: To research the effect of the depth of water on the rate of corrosion of a shipwreck.

Section 1.

Students should perform and write a report relating to a first-hand investigation to compare and describe the rate of corrosion of metals in different

- oxygen concentrations
- temperatures
- salt concentrations.

Section 2.

Students should research secondary sources to:

1. identify the gases normally dissolved in the ocean, compare their concentrations in the oceans to their concentrations in the atmosphere.
2. identify the ions normally dissolved in the ocean and relate these findings to the corrosion of metals.
3. identify the effect of temperature and pressure on the solubility of gases and salts.
4. explain why the concentrations of selected gases changes with increasing depth in the oceans and relate these findings to the corrosion of metals at different depths
5. identify the effects of changes in temperature with depth on the rate of corrosion of metals
6. identify the chemical reactions involved in corrosion of metals at great depth and explain how these reactions differ from corrosion in shallow water.

The results of this research should be presented in a report.

Students should compare the conclusions drawn from their first-hand investigation to the understandings gained from secondary research and hence make an overall assessment of the effect of the depth of water on the rate of corrosion of a shipwreck.

Sections 1 and 2 will be assessed out of a total of **28 marks**

Section 3.

Open-book test. (16 marks)

You may bring with you to the test ONLY your completed reports from Sections 1 and 2. You will refer to your research and first-hand investigation to respond to short-answer questions on the topic.

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Marking Scale

You will be assessed on the:

- Description of techniques used for carrying out the first hand investigation. (1)
- Accuracy and efficiency in carrying out your planned procedure, minimising hazards and wastage of resources, and use of safe work practices. (3)
- Measurement, observation and recording of results in accessible and recognisable form, repeating trials as appropriate. (2)
- Accuracy using symbols and equations to express chemical changes.(2)
- Validity of conclusions reached from your first-hand investigation. (3)
- Accuracy of information and validity of conclusions gained from secondary research.(10)
- Validity of the overall conclusions reached. (2)
- Presentation of the reports on both the first hand-investigation and secondary research. This includes the clarity and layout of the reports and the appropriate use of tables, diagrams and chemical equations. (4)
- Referencing of resources used for research. (1)
- Responses to short-answer questions in the form of an open-book test on the topic. (16)

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OPEN-BOOK TEST

Time allowed: 30 minutes

Total marks: 16

You may bring with you into the test ONLY your completed reports from Sections 1 and 2. You will refer to your research and first-hand investigation to respond to short-answer questions on the topic.

Question 1. (5 marks)

How does the solubility of oxygen in water vary with temperature?

_____

_____

How does the solubility of sodium chloride vary with temperature?

_____

_____

How does the solubility of oxygen vary with pressure?

_____

_____

How do the temperature and pressure change as the depth of ocean water increases?

_____

_____

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Question 2. (2 marks)

Why does the concentration of oxygen gas dissolved in ocean water decrease as depth of ocean water increases?

Question 3. (3 marks)

Why does the metal iron corrode much more rapidly in salt water than in distilled water? Use equations and/or diagrams to illustrate your answer.

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Question 4 (3 marks)

Explain why your first-hand investigations would lead you to the conclusion that corrosion of shipwrecks should not be expected to occur in deep ocean water.

Question 5 (3 marks)

Explain why shipwrecks like the Titanic, which lie in deep water, are extensively corroded.

End of Test

FOR THE TEACHER

ASSESSMENT MATRIX

QAT Code	*Tasks*	*Outcome/s*	*Components*
QATCHEM1A	First-hand investigation. Model making. Report writing. Graphing skills. Analysis of secondary data.	H7, H8, H9, H10, H11, H12, H13, H14, H15.	Core Module 1: Production of Materials
QATCHEM1B	Topic Test: Short-answer questions.	H4, H5, H6, H7, H8, H9, H10, H11, H12, H13, H14, H15, H16.	Core Module 1: Production of Materials
QATCHEM2A	First-hand investigation. Documentation of results. Model making. Analysis of results and interpretation of chemical data. Chemical calculations.	H6, H9, H10, H11, H13, H14.	Core Module 2: Acidic Environment
QATCHEM2B	Topic Test: Multiple choice and short-answer questions.	H1, H2, H6, H7, H8, H9, H10, H11, H12, H13, H14, H15, H16.	Core Module 2: Acidic Environment
QATCHEM3A	Research. Report writing. Model making. Open-book test.	H2, H3, H6, H7, H8, H9, H16.	Core Module 3: Chemical Monitoring and Management
QATCHEM3B	Topic Test: Multiple choice and short-answer questions.	H2, H3, H6, H7, H8, H9, H11, H12, H13, H14, H15, H16.	Core Module 3: Chemical Monitoring and Management
QATCHEM4A	Open-ended investigation. Model making. Secondary research. Report writing. Open-book test.	H1, H3, H5, H7, H8, H9, H10, H11, H12, H13, H14.	Option: Industrial Chemistry.
QATCHEM4B	Topic Test: Short-answer questions.	H1, H3, H5, H7, H8, H9, H10, H11, H12, H13, H14, H15, H16	Option: Industrial Chemistry.*
QATCHEM5A	First-hand investigation. Secondary research. Report writing. Open-book test.	H8, H11, H12, H13, H14.	Option: Shipwrecks, Corrosion and Conservation.
QATCHEM5B	Topic Test: Short-answer questions.	H3, H5, H6, H7, H8, H10, H13, H14.	Option: Shipwrecks, Corrosion and Conservation.*
QATCHEM6A	Revision questions /Trial Examination of Core Modules. Multiple choice and short-answer questions.	All	Core Modules 1, 2 and 3
QATCHEM6B	Revision questions /Trial Examination of Core Modules. Multiple choice and short-answer questions.	All	Core Modules 1, 2 and 3

* 6A and 6B may be coupled with 4B ad 5B to form full trial examination.

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General comments for teachers.

- The INTRODUCTION page and the first two TASK pages for this QAT should be given to students well in advance of the dates set for the first-hand investigation.
- Individual students, not the teacher, should determine the nature of the investigation and the equipment needed.
- Students should be asked to place an order for the equipment they need to carry out their investigation approximately one week before the date set for the first-hand investigation. This will allow time for the laboratory staff to prepare kits for individual students and will also allow the teacher to assess the suitability of equipment requested.
- Students should be given several days to complete the research and reports after the practical investigation.
- The reports and the answers to test questions should be handed in together, at the conclusion of the open-book test.

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SOLUTION PATHWAY

MARKING GUIDE
Sections 1 and 2
Description of techniques used for carrying out the first-hand investigation. (1)
A clear, easily interpreted description of the method used.

Accuracy and efficiency in carrying out your planned procedure, minimising hazards and wastage of resources, and use of safe work practices. (3)
Method should test only one variable at a time.
Correct use of controls.
Testing of more than one metal (e.g. iron and aluminium)

Measurement, observation and recording of results in accessible and recognisable form, repeating trials as appropriate. (2)
Clear record of observations, results.
Repeated experiments if appropriate.

Accuracy using symbols and equations to express chemical changes. (2)
Report on practical investigation explains chemical changes involved and correctly uses symbols and equations.

Validity of conclusions reached from your first-hand investigation. (3)
Conclusions are correct and logically follow from the practical results obtained.
Conclusions must consider each variable separately (oxygen, temperature, salt concentration) and each metal tested.
Results dependant on metals used in testing.

Accuracy of information and validity of conclusions reached from secondary research. (Total of 10 marks, made up as follows)

1. **Correct identification of the gases normally dissolved in the ocean. Comparison of their concentrations in the oceans to their concentrations in the atmosphere. (1)**

Gas	Concentration in atmosphere at 20°C	Concentration in oceans at surface at 20°C
	(mol/L)	(mol/L)
Nitrogen	3×10^{-2}	6×10^{-4}
Oxygen	8×10^{-3}	3×10^{-4}
Carbon dioxide	1.5×10^{-5}	1.4×10^{-5}

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2. Correct identification of the ions normally dissolved in the ocean. (1)

Ion	Concentration (mol/L)
Na^+	0.47
K^+	0.010
Mg^{2+}	0.053
Ca^{2+}	0.010
Cl^-	0.55
SO_4^{2-}	0.028

Correct explanation of how this affects the corrosion process. (1)

The presence of ions in water accelerates the corrosion process. Corrosion is a galvanic process. The solution of salts is classified as an electrolyte which facilitates the passage of electric current. While current flows in the metal from anode to cathode, the negative ions flow in the vicinity of the metal surface from the cathodic site to the anodic site. This flow of ions prevents build up of charge around the electrodes which would stop the flow of electrons and hence the whole corrosion process. Hence, the presence of ions in water accelerates the corrosion process.

3. Correct explanation of the effect of temperature and pressure on the solubility of gases and salts. (2)

With increase in temperature, the solubility of all gases decreases.
With increase in pressure, the solubility of all gases increases.
With increase in temperature, the solubility of salts generally increases. However, for sodium chloride the solubility decreases very slightly as temperature increases. Thus in the oceans, the temperature differences have little impact on the concentrations of salts present in solution.

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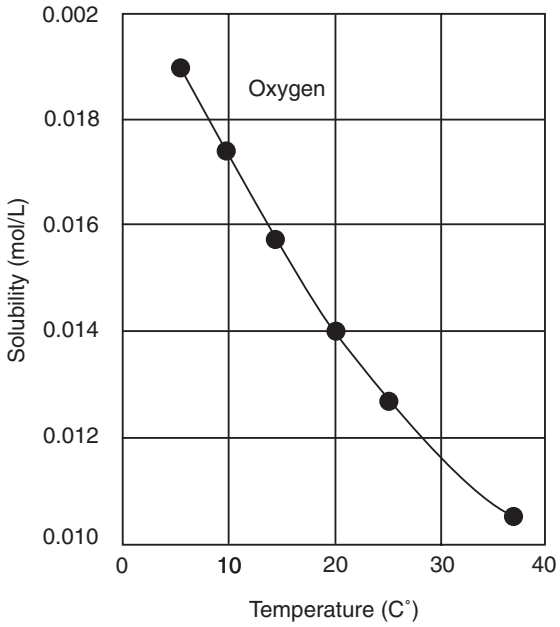

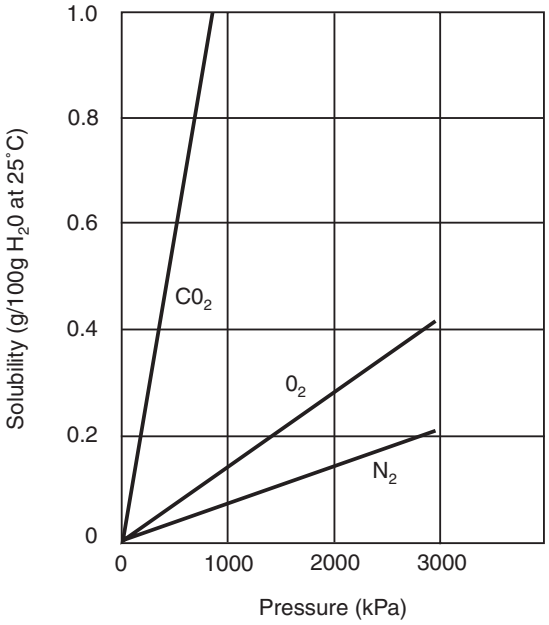

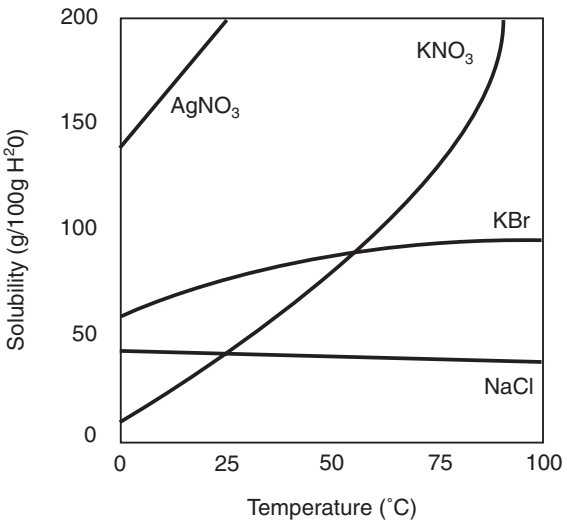

Diagrams from 'Shipwrecks, Corrosion and Conservation' B. Hegarty (Warringal Publications 2002)

4. Explain why the concentrations of selected gases change with increasing depth in the oceans and relate these findings to the corrosion of metals at different depths (2)

The concentrations of gases such as oxygen and nitrogen decrease rapidly as depth increases. These gases enter the ocean at the surface. Diffusion does not take the gases to great depths, there are no convection currents at depth to mix the water and oxygen is removed by aerobic organisms in the upper regions.

As a result, the corrosion of metals by water and oxygen occurs most in shallow water or at the surface.

Corrosion at great depths depends on different redox reactions which occur in anaerobic conditions and are not related to the gases from air.

5. Identify the effect of changes in temperature with depth on the rate of corrosion of metals (1)

As temperature decreases as depth of water increases (moving away from solar energy source), then the rate of corrosion would be expected to decrease as depth increases. The rate of all reactions decreases as temperature decreases.

6. Identify the chemical reactions involved in corrosion of metals at great depth and explain how these reactions differ from corrosion in shallow water (2)

Shipwrecks at great depths are corroded by electrochemical reactions in the presence of anaerobic bacteria. The bacteria are sulfur reducing species whose wastes cause reduction of sulfate ions in the water to hydrogensulphide ions.

$SO_4^{2-} + 5H_2O + 8e^- \rightleftharpoons HS^- + 9OH^-$

$4Fe(s) \rightleftharpoons 4Fe^{2+} + 8e^-$

The overall reaction which occurs at depth is

$4Fe(s) + SO_4^{2-} + 5H_2O \rightleftharpoons FeS(s) + 3Fe(OH)_2\ (s) + H_2O\ (l) + 2OH^-$

Black iron II sulfide forms on the steel as well as iron II hydroxide. This is NOT oxidized to rust because of the absence of oxygen.

In shallow water the reaction depends on oxygen.

$Fe(s) \rightleftharpoons Fe^{2+}(aq) + 2e^-$

$O_2\ (g) + 2H_2O\ (l) + 4e^- \rightleftharpoons 4OH^-$

The overall equation is

$2Fe\ (s) + O_2\ (g) + 2H_2O\ (l) \rightleftharpoons 4OH^- + 2Fe^{2+}(aq)$

The iron II hydroxide is then oxidised to iron II oxide (rust).

$4\ Fe(OH)_2 + O_2 \rightarrow 2(\ Fe_2O_3.H_2O) + 2H_2O$

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Validity of the overall conclusions reached. (2)
The overall conclusion should indicate that :

- Corrosion caused by oxygen and water decreases significantly with depth (no oxygen and very cold at great depth)
- Corrosion caused by presence of anaerobic bacteria and sulfate ions still occurs at depth.
- First-hand investigations ONLY relate to conditions at surface or near surface where oxygen concentration is high.

Presentation of the reports on both the first hand investigation and secondary research. (4)
This includes the clarity and layout of the reports and the appropriate use of tables, diagrams and chemical equations.

Referencing of resources used for research. (1)
Correct method of referencing, range of references and inclusion of bibliography.

Section 3
Responses to short-answer questions in the form of an open-book test on the topic (16)

Question 1. (5 marks)
The solubility of oxygen decreases as temperature of water increases.
The solubility of sodium chloride decreases slightly (stays the same) as temperature increases.
The solubility of oxygen increases as pressure increases.
As depth increases the temperature of water decreases and the pressure increases.

Question 2. (2 marks)
Gases only diffuse slowly down from the surface of the water and aerobic organisms use the oxygen for respiration. No significant movement of the water occurs as little convection current.

Question 3. (3 marks)
Corrosion of iron is a galvanic process, the reactions occurring at an anode and a separate cathode. Salt water contains sodium and chloride ions which are at greater concentration than the ions in distilled water. The ions in the electrolyte of a galvanic cell facilitate the passage of electrons from the anode to the cathode. The ions move in the solution to prevent build up of charge in any place which would reduce or stop the flow of current.

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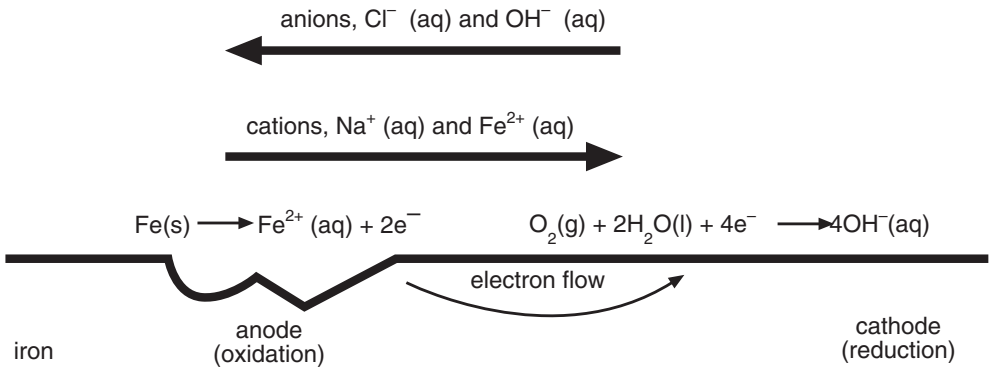
Assuming that the shipwreck is mainly iron
The reactions which occur are
$Fe(s) \rightleftharpoons Fe^{2+}(aq) + 2e^-$ at the anode
$O_2\ (g) + 2H_2O\ (l) + 4e^- \rightleftharpoons 4OH^-$ at the cathode



Extract from 'Shipwrecks, Corrosion and Conservation, B. Hegarty (Warringal Publications 2002)

Question 4 (3 marks)

The first hand investigations only consider the conditions occurring at the surface or in shallow water, where oxygen is present in some concentration and the redox reaction occurs by oxygen and water picking up the electrons from the iron at the cathode.
The first hand investigations would imply that at low temperature and low oxygen concentration then little or no corrosion would occur.
The experiments carried out in the laboratory cannot simulate the anaerobic conditions, with specific bacteria, that allow a different reaction at depth.

Question 5 (3 marks)

Shipwrecks like the Titanic, which lie in deep water, are extensively corroded by a different redox reaction than that occurring in shallow water.
Shipwrecks at great depths are corroded by electrochemical reactions in the presence of anaerobic bacteria. The bacteria are sulfur reducing species whose wastes cause reduction of sulfate ions in the water to hydrogensulphide ions.
Assuming that the shipwreck is mainly iron:
$SO_4^{2-} + 5H_2O + 8e^- \rightleftharpoons HS^- + 9OH^-$

$4Fe(s) \rightleftharpoons 4Fe^{2+} + 8e^-$

The overall reaction which occurs at depth is
$4Fe(s) + SO_4^{2-} + 5H_2O \rightleftharpoons FeS(s) + 3Fe(OH)_2\ (s) + H_2O\ (l) + 2OH^-$

Black iron II sulfide forms on the steel as well as iron II hydroxide. This is NOT oxidized to rust because of the absence of oxygen.