Student Number

PEM

2014

Chemistry

TRIAL HIGH SCHOOL CERTIFICATE EXAMINATION

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board approved calculators may be used
- A data sheet and Periodic Table are provided at the back of this paper
- Write your student number in the space provided

Total marks – 100

Section I Pages 2-14 **75 marks**
This section has two parts, Part A and Part B

Part A – 20 marks
- Attempt Questions 1-20
- Allow about 35 minutes for this part

Part B – 55 marks
- Attempt Questions 21-34
- Allow about 1 hour and 40 minutes for this part

Section II Pages 15-19 **25 marks**

25 marks
- Attempt **ONE** Question from Questions 35-36
- Allow about 45 minutes for this section

Section I

75 marks

Part A - 20 marks
Attempt Questions 1-20
Allow about 35 minutes for this part

Use the multiple choice answer sheet for Questions 1-20.

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1. What is the common name of CH_2=CHCl?

   A. PVC
   B. chloroethane
   C. vinyl chloride
   D. dicarbotrihydrochlorine

2. Which of the following is NOT a suitable method to distinguish between propene and octane?

   A. state
   B. solubility in water
   C. molar heat of combustion
   D. reaction with bromine water

3. Cellulose an example of which of the following?

   A. a hydrocarbon
   B. a petrochemical
   C. an addition polymer
   D. a condensation polymer

4. What is a difference between the combustion and the fermentation of glucose?

   A. Combustion is exothermic, fermentation is not.
   B. Combustion produces water, fermentation does not.
   C. Combustion needs a catalyst, fermentation does not.
   D. Combustion produces carbon dioxide, fermentation does not.

5. Ethylene can be obtained by which of the following methods?

A. dehydration of ethanol
B. condensation of methane
C. combustion of polyethylene
D. fractional distillation of crude oil

6. In which of the following mixtures would a reaction occur?

A. $Cu_{(s)} + AgNO_{3(aq)}$
B. $Zn_{(s)} + Mg(NO_3)_{2(aq)}$
C. $Pb_{(s)} + Ca(NO_3)_{2(aq)}$
D. $Fe_{(s)} + Al(NO_3)_{3(aq)}$

7. In which of the following is there a decrease in the oxidation state of the underlined element?

A. $2H\underline{I} + Br_2 \rightarrow I_2 + 2HBr$
B. $\underline{Ba} + 2H_2O \rightarrow Ba(OH)_2 + H_2$
C. $H_3PO_4 + 3\underline{Ag}NO_3 \rightarrow 3HNO_3 + Ag_3PO_4$
D. $Cu_2SO_4 + \underline{Fe_2}(SO_4)_3 \rightarrow 2CuSO_4 + 2FeSO_4$

8. Which of the following is a correct nuclear equation for the production of a transuranic element?

A. $^{239}_{94}Pu \rightarrow ^{4}_{2}He + ^{235}_{92}U$
B. $^{238}_{92}U \rightarrow ^{4}_{2}He + ^{234}_{90}Th$
C. $^{92}_{36}Kr + ^{142}_{56}Ba + ^{1}_{0}n \rightarrow ^{235}_{92}U$
D. $^{208}_{82}Pb + ^{86}_{36}Kr \rightarrow ^{293}_{118}Uuo + ^{1}_{0}n$

9. This is the equation of a system at equilibrium:

$$CaCO_{3(s)} \rightleftarrows CaO_{(s)} + CO_{2(g)} \qquad \Delta H = 178 \text{ kJ mol}^{-1}$$

The addition of which of the following would result in more products?

A. $CaCO_{3(s)}$
B. $CaO_{(s)}$
C. $CO_{2(g)}$
D. heat

10. These are the colours of four indicators at low and high pH, and the pH range in which they change colour.

Name of indicator	Colour at low pH - intermediate - high pH	Colour change in pH range
methyl orange	red - orange - yellow	3.1 - 4.4
bromocresol green	yellow - green - blue	3.8 - 5.4
bromothymol blue	yellow - green - blue	6.0 - 7.6
phenolphthalein	colourless - pale pink - red	8.3 - 10

A solution was known to be either 10^{-6} mol L^{-1} hydrochloric acid or 10^{-6} mol L^{-1} ethanoic acid. A single one of the four indicators in the table was sufficient to determine that the solution was 10^{-6} mol L^{-1} ethanoic acid.

Which indicator was used?

A. methyl orange
B. bromocresol green
C. bromothymol blue
D. phenolphthalein

11. In which of the following pairs of ionic compounds does the first one form an acidic solution and the second one a basic solution?

A. ammonium chloride and calcium ethanoate
B. aluminium nitrate and potassium chloride
C. sodium carbonate and magnesium nitrate
D. barium ethanoate and lithium carbonate

12. A student prepared a primary standard solution of benzoic acid in a volumetric flask, and used it to standardise a sodium hydroxide solution.

For which pieces of equipment should distilled water be the last rinse before the start of the experiment?

A. pipette and burette
B. burette and conical flask
C. volumetric flask and pipette
D. conical flask and volumetric flask

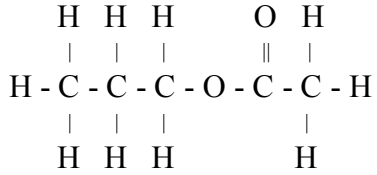
13. In which of the following pairs is the second substance the conjugate acid of the first substance?

A. OH^- H_3O^+
B. SO_4^{2-} H_2SO_4
C. HPO_4^{2-} $H_2PO_4^-$
D. NH_4^+ NH_3

14. Which of the following has the highest boiling point?

A. propanoic acid
B. butanoic acid
C. 1-propanol
D. 1-butanol

15. What reactants are needed to produce this ester?



A. 1-propanol and propanoic acid
B. 1-propanol and ethanoic acid
C. ethanol and propanoic acid
D. ethanol and ethanoic acid

16. A small sample of a white solid was added to nitric acid, resulting in the formation of bubbles as the solid disappeared. Another sample of the same solid changed a colourless Bunsen flame to red.

The white solid could have been which of the following salts?

A. $BaCO_3$
B. $BaCl_2$
C. $CaCO_3$
D. $CaCl_2$

17. Atomic absorption spectroscopy (AAS) is the most suitable method to find the concentration of the named ions in which solution?

A solution which contains
A. 10 ppm zinc ions
B. 10 % w/v zinc ions
C. 10 ppm sulfate ions
D. 10 % w/v sulfate ions

18. Which of these statements is true about the atmosphere?

A. Most ozone is found in the upper region of the troposphere.
B. Air density increases with increasing altitude throughout the atmosphere.
C. The stratopause is the boundary between the lowest two layers of the atmosphere.
D. There is a gradual increase in temperature from the lower to the higher part of the stratosphere.

19. Which of the following causes the LEAST damage to the ozone layer?

A. hydrofluorocarbons (HFCs)
B. chlorofluorocarbons (CFCs)
C. bromofluorocarbons (halons)
D. nitrogen oxides (NO_x)

20. Biochemical oxygen demand (BOD) is an indication of which of the following?

A. the rate at which oxygen is produced by aquatic plants in full sunlight
B. the number of anaerobic bacteria in a 1 L sample from a body of still water
C. the amount of oxygen needed by organisms in 1 L of water in 5 days in the dark
D. the quantity of oxygen needed to decompose 1 g of fertiliser in 1 L of river water

Section I (continued)

Part B - 55 marks
Attempt Questions 21-34
Allow about 1 hour and 40 minutes for this part

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Question 21 (4 marks)

Identify a use for polystyrene AND state two properties which make polystyrene suitable for the use you gave and explain why each of these properties make it suitable for the use. **4**

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Question 22 (3 marks)

The heat of combustion of ethanol is -2.96×10^4 $J.g^{-1}$. If all the energy from the combustion of 0.50 g of ethanol could be used to heat up 100 g of water without any loss of heat to the environment or to the calorimeter, what would be the temperature change of the water? **3**

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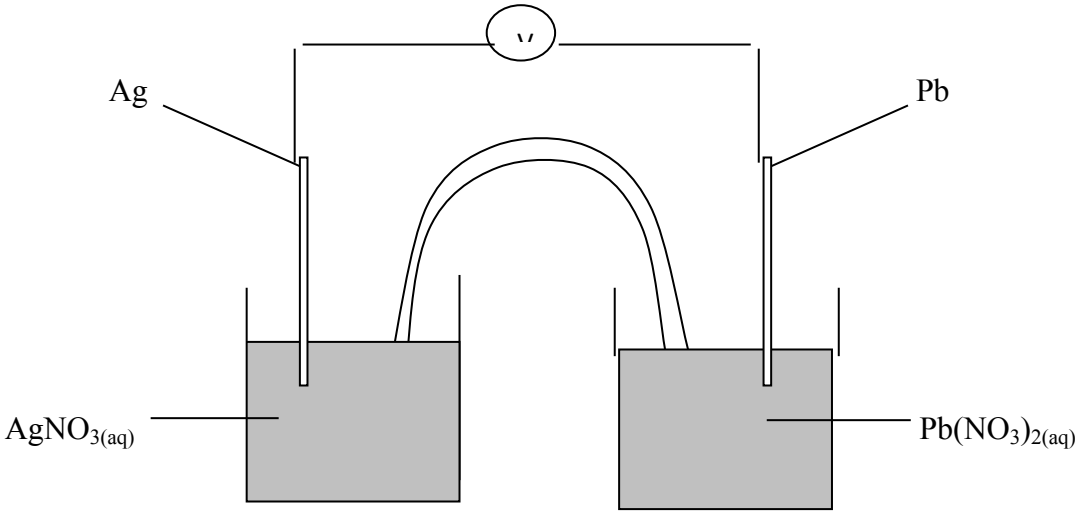
Question 23 (4 marks)

The following standard galvanic cell has a potassium nitrate gel as a salt bridge.



a. What is the function of the salt bridge? **1**

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b. On the diagram identify the cathode, and indicate the direction of the nitrate ions in the salt bridge. **1**

c. Write the equation for the reaction in the lead half cell. **1**

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d. Calculate the theoretical maximum voltage of this cell. **1**

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Question 24 (2 marks)

Identify an instrument that can be used to detect radiation, and explain how it works. **2**

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Question 25 (2 marks)

The great forests of Europe have been seriously damaged by acid rain as a result of industrial activity. **2**

Identify an industrial process which results in a gas that can produce acid rain, AND using this gas as a reactant write an equation for the production of acid rain.

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Question 26 (3 marks)

These are the results of a Year 12 student's "Decarbonation of a Soft Drink" experiment. The molar mass of carbon dioxide is 44.01 g mol^{-1}. **3**

Initial mass of carbonated soft drink + bottle	1098.60 g
Mass of soft drink + bottle at the end of the experiment	1092.50 g

Calculate the volume that the escaped carbon dioxide would occupy at 100 kPa and 25 ^{o}C.

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Question 27 (2 marks)

a. Name this compound: $CH_3CH_2CHFCHCl_2$ **1**

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b. Draw an **isomer** of this compound showing all bonds. **1**

Question 28 (6 marks)

a. Describe the formation of a co-ordinate covalent bond. **1**

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b. Draw the Lewis electron dot structure of an ozone molecule. **1**

c. Explain with the use of equations why a small quantity of chloromethane, CH_3Cl, may cause a lot of ozone depletion. **4**

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Question 29 (2 marks)

Describe the composition and design of a microscopic membrane filter. **2**

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Question 30 (5 marks)

a. Calculate the mass of pure sodium carbonate, Na_2CO_3, that is needed to prepare 250 mL of 0.20 mol L^{-1} primary sodium carbonate solution. **2**

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b. This standard sodium carbonate solution was used in a titration to calculate the concentration of an approximately 0.1 mol L^{-1} hydrochloric acid. 25.0 mL samples of the acid were used in each titration. The average volume of sodium carbonate that was needed per titration was 6.7 mL.

Calculate the pH of the acid to 2 decimal places. **3**

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Question 31 (3 marks)

a. Draw a labelled diagram of the reflux set-up that you used to prepare an ester in the laboratory. **2**

b. Explain the need for refluxing. **1**

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Question 32 (6 marks)

a. Explain, with the aid of an equation, why during the production of ammonia an increase in temperature results in a faster rate of reaction but in a lower yield. **3**

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b. Apart from carrying out the manufacture at a moderately high temperature, what other methods are used to increase the rate of the reaction as well as increasing the yield of ammonia before the reaction reaches equilibrium? **3**

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Question 33 (7 marks)

One of the reasons for the research into finding alternatives for fossil fuels is that the supply is diminishing. Another reason is that the combustion of fossil fuels produces substances which are harmful to the environment.

a. Discuss the possible products of the combustion of fossil fuels under different conditions, and the hazard each may pose. **5**

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b. Name an alternative substance that can be used, or potentially used, in the petro-chemical industry instead of chemicals derived from crude oil, and explain how it can replace petroleum products. **2**

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Question 34 (6 marks)

In order to find the sulfate content of a lawn fertiliser, a student weighed out some fertiliser in a beaker and mixed it with 100 mL of 1 molar hydrochloric acid. She heated the mixture to boiling while stirring, then filtered the mixture rinsing the residue with small quantities of water. Next she added barium chloride solution to the filtrate until no more precipitate formed. She filtered the precipitate using a pre-weighed filter paper, then rinsed the residue in the filter paper with a few millilitres of water. She placed the filter paper with the precipitate into a drying oven overnight, then weighed them.

Here are her results:

mass of beaker	108.45 g
mass of beaker plus fertiliser	112.45 g
mass of filter paper	0.97 g
mass of filter paper plus precipitate	6.61 g

a. Explain with the help of equations the reason for adding hydrochloric acid. **2**

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b. The molar mass of barium sulfate is 233.4 g mol^{-1}. Calculate the mass percentage of sulfate in this fertiliser. **4**

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Section II

25 marks
Attempt ONE question from Questions 35-36
Allow about 45 minutes for this section

Show all relevant working in questions requiring calculations.

Question 35 - Industrial Chemistry (25 marks)

Answer all parts of this question in the Answer Booklet.

a.

i. This is the equilibrium expression, and the value of the equilibrium constant K for a reversible reaction at 25 ^{o}C: **2**

$$K = \frac{[Zn(CN)_4^{2-}]}{[Zn^{2+}][CN^-]^4} = 10^{17}$$

Write the equation for this reaction, **and** describe the concentrations of the Zn^{2+} and CN^- ions at equilibrium. (No calculation is required.)

ii. Explain why decreasing the volume of the container shifts the position of the equilibrium in some but not in all reversible gaseous reactions. **3**

b. Sulfur is insoluble in water and has a moderately low melting point. The density of sulfur-water-air foam is less than 1.0 g cm^{-3}. **5**

Describe the Frasch process used to extract sulfur from elemental sulfur deposits. In your description explain how the above properties of sulfur allow this method of extraction. You may use a diagram to aid your explanation.

Question 35 continues on page 17

c. i. Write equations for the electrolysis of molten sodium chloride and the electrolysis of dilute sodium chloride solution. Name the substance formed at the anode in each equation. **3**

ii. Identify the main environmental contaminant involved in the extraction of sodium hydroxide during its manufacture using the mercury process and the diaphragm process; and describe the effect of each of these contaminants on human health. **2**

d. Below is the general formula of the active ion of anionic surfactants (soaps and anionic synthetic detergents):

non-polar "tail" anionic "head"

i. Explain how these surfactants help in cleaning greasy dishes. **3**

ii. Describe how these two anionic surfactants differ in hard water. **1**

iii. Give one use for each of these two surfactants which makes it more suitable than the other surfactant. **2**

e. Determine the criteria used to locate a chemical plant which manufactures sodium carbonate by the Solvay process. **4**

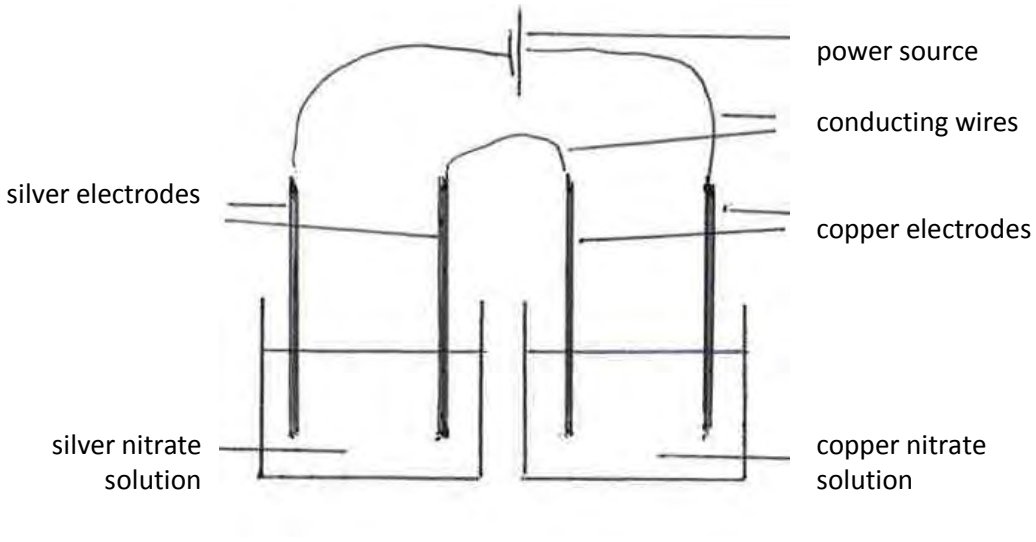
End of Question 35

Question 36 — Shipwrecks, Corrosion and Conservation (25 marks)

Answer all parts of this question in the Answer Booklet.

a. i. Describe Michael Faraday's contribution to our understanding of electrochemistry. **2**

ii. A beaker containing silver nitrate solution and two pure silver electrodes was connected by means of conducting wires to another beaker containing copper nitrate and two pure copper electrodes as shown in the diagram. **3**



When electricity was passed through the circuit, one electrode in each beaker increased in mass while the mass of the other decreased. The current was turned off when the mass of one of the silver electrodes increased by 5.4 g.
Calculate the mass increase of the copper electrode. (Show working.)

b. An electrolytic cell was constructed using platinum electrodes in a dilute copper(II) sulfate solution.

i. Describe, using equations, what happens **2**
- at the anode
- at the cathode

ii. Describe the difference in the products of this electrolysis if iron electrodes had been used instead of platinum ones. **1**

Question 36 continues on page 19

c. Aluminium and iron have both been used as window frames. Aluminium frames need no maintenance, while iron frames need to be painted and then repainted after a certain time.

i. Explain the reason why aluminium is more corrosion resistant although it is a more reactive metal than iron is. **3**

ii. There are several other methods of protecting iron objects from rusting. For example, machine parts made of iron are greased, and iron sheets for roofs are coated either with zinc (galvanised) or with tin. **5**

Compare in terms of electrochemistry the advantage and disadvantage of tin coating and galvanising iron as a means of protection from corrosion. In your answer refer to the relative reactivity of the three metals, and write equations for the chemical reactions involved.

d. It used to be assumed that sunken ships at great depth were protected from corrosion due to the low water temperature which slows chemical reactions, and due to the high pressures which decrease the solubility of gases that might act as reactants in corrosion reactions. However, ships do corrode even at very great depths. **3**

Identify the main agents that cause corrosion of ships at great depths, and explain how they cause the corrosion.

e. Discuss the range of chemical procedures which can be used to clean artefacts from wrecks and give an example of the use of each procedure. Include chemical equations. **5**

End of paper

DATA SHEET

Avogadro constant, N_A ..... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) ..... 22.71 L

at 25°C (298.15 K) ..... 24.79 L

Ionisation constant for water at 25°C (298.15 K), K_w ..... 1.0×10^{-14}

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Specific heat capacity of water ..... 4.18×10^3 J kg^{-1} K^{-1}

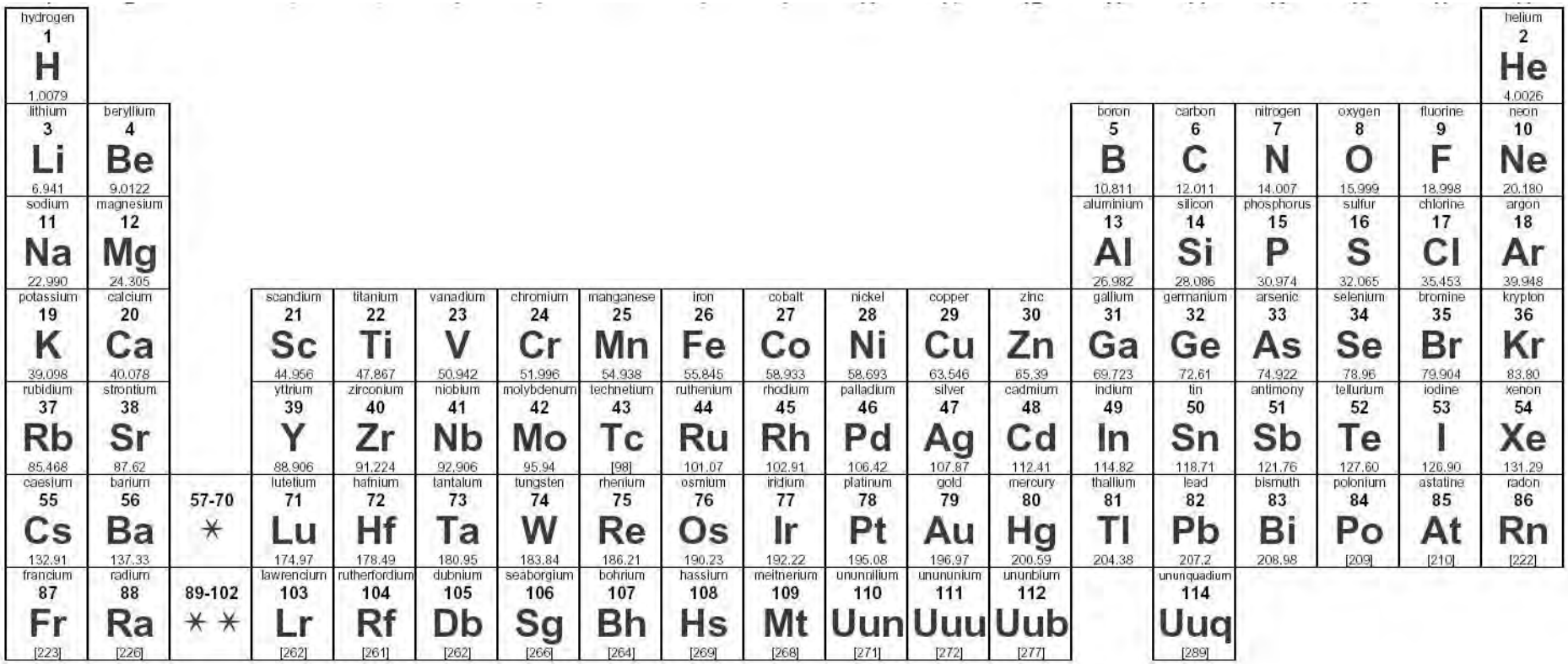
Some useful formulae

$\text{pH} = -\log_{10}[\text{H}^+]$ $\Delta H = -mC\Delta T$

Some standard potentials

$K^+ + e^-$	⇄	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	⇄	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	⇄	$Ca(s)$	–2.87 V
$Na^+ + e^-$	⇄	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	⇄	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	⇄	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	⇄	$Mn(s)$	–1.18 V
$2H_2O + 2e^-$	⇄	$H_2(g) + 2OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	⇄	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	⇄	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	⇄	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	⇄	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	⇄	$Pb(s)$	–0.13 V
$2H^+ + 2e^-$	⇄	**$H_2(g)$**	**0.00 V**
$SO_4^{2-} + 4H^+ + 2e^-$	⇄	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	⇄	$Cu(s)$	0.34 V
$O_2(g) + 2H_2O + 4e^-$	⇄	$4OH^-$	0.40 V
$Cu^+ + e^-$	⇄	$Cu(s)$	0.52 V
$I_2(s) + 2e^-$	⇄	$2I^-$	0.54 V
$I_2(aq) + 2e^-$	⇄	$2I^-$	0.62 V
$Fe^{3+} + e^-$	⇄	Fe^{2+}	0.77 V
$Ag^+ + e^-$	⇄	$Ag(s)$	0.80 V
$Br_2(l) + 2e^-$	⇄	$2Br^-$	1.08 V
$Br_2(aq) + 2e^-$	⇄	$2Br^-$	1.10 V
$O_2(g) + 2H^+ + 2e^-$	⇄	H_2O	1.23 V
$Cl_2(g) + 2e^-$	⇄	2Cl–	1.36 V
$Cr_2O_7 + 14H^+ + 6e^-$	⇄	$2Cr^{3+} + 7H_2O$	1.36 V
$Cl_2(aq) + 2e$	⇄	$2Cl^-$	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	⇄	$Mn^{2+} + 4H_2O$	1.51 V
$F_2(g) + 2e^-$	⇄	F^-	2.89 V 2

PERIODIC TABLE OF THE ELEMENTS



HSC Chemistry Trial Examination 2014 - Marking guidelines

Section I, Part A MULTIPLE-CHOICE ANSWER - KEY 1 mark each

Question	1	2	3	4	5	6	7	8	9	10
Answer	C	B	D	B	A	A	D	D	D	C

Question	11	12	13	14	15	16	17	18	19	20
Answer	A	D	C	B	B	C	A	D	A	C

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Section I, Part B - MARKING CRITERIA AND SAMPLE ANSWERS

QUESTION 21

Criteria	Marks
• Gives a use • Gives two properties of polystyrene • Explains the suitability of each property for the use	4
• Gives a use • Gives two properties of polystyrene • Explains the suitability of one property for the use	3
• Gives a use • Gives one property of polystyrene • Explains the suitability of the property for the use	2
• Gives a use • Gives two properties of polystyrene	1

Sample answer

Use: food packaging

Properties suitable for this use: It is clear, so we can see what is inside.

It is resistant to most chemicals, so will not react with food stored in it.

QUESTION 22

Criteria	Marks
• Correctly multiplies heat of combustion with mass • Finds change of temperature using value from first step • States that it is an increase in temperature and gives value of increase with units	3
• Two of the above steps	2
• One of the above steps	1

Sample answer

Energy gained by water from combustion of 0.50 g ethanol = $0.50 \times 2.96 \times 10^4 = 1.48 \times 10^4$ J

$\Delta T = q/mc = 1.48 \times 10^4 / 100 \times 4.18 = 35.4$

The temperature of the water would increase by 35.4 C^o.

(OR by 35 C^o correct to 2 significant figures)

QUESTION 23 a

Criteria	Marks
• Correct explanation	1

Sample answer

The salt bridge allows the migration of ions between the half cells in order to balance the charges in each half cell.

QUESTION 23 b

Criteria	Marks
• "Cathode" label is on the silver electrode • An arrow at the salt bridge points to the right	1

QUESTION 23 c

Criteria	Marks
• Correct equation	1

Sample answer

$Pb_{(s)} \rightarrow Pb^{2+}_{(aq)} + 2e^-$

QUESTION 23 d

Criteria	Marks
• Correct calculation	1

Sample answer

$Pb \rightarrow Pb^{2+} + 2e^-$ (+) 0.13 V

$Ag^+ + e^- \rightarrow Ag$ (+) 0.80 V

Maximum voltage = 0.13 + 0.80 = 0.93 V

QUESTION 24

Criteria	Marks
• Identifies instrument • Explains how it works	2
• Identifies instrument	1

Sample answer

Cloud chamber.

Radiation ionises some of the molecules of the supersaturated vapour in the chamber. Other vaporised molecules condense on the ions creating a fine trail of visible droplets.

QUESTION 25

Criteria	Marks
• Names a gas • Identifies industrial process that produces this gas • Writes correct equation for named gas reacting with water	2
• Names a gas • Identifies industrial process that produces this gas OR • Names a gas • Writes correct equation for named gas reacting with water	1

Sample answer

The smelting of sulfide ores, as well as any industrial process that involves the burning of coal or petroleum oil, produces sulfur dioxide (which can oxidise to form sulfur trioxide).

$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$

$(SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)})$

QUESTION 26

Criteria	Marks
• Correctly calculates mass of escaped CO_2 • Correctly calculates number of moles of CO_2 • Correctly calculates volume of CO_2	3
• two of the above	2
• one of the above	1

Sample answer

$m_{CO2 \text{ that escaped}} = 1098.60 - 1092.50 = 6.10$ g

$n_{CO2} = m/MM = 6.10/44.01 = 0.1386$ mol

$V_g = n \times V_{molar} = 0.1386 \times 24.79 = 3.44$ L (correct to 3 sig fig)

OR $V = nRT/P = 0.1386 \times 8.31 \times (273+25) /100 = 3.44$ L (correct to 3 sig fig)

QUESTION 27 a

Criteria	Marks
• Correct name	1

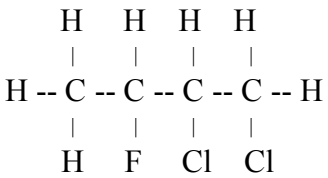
Sample answer

1,1-dichloro-2-fluorobutane

QUESTION 27 b

Criteria	Marks
• Correct drawing of any correct isomer (i.e. NOT 1,1-dichloro-2-fluorobutane)	1

Sample answer



QUESTION 28 a

Criteria	Marks
• Correct description	1

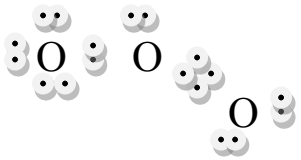
Sample answer

A lone pair of electrons from one atom provides both electrons that are needed to form a covalent bond between two atoms.

QUESTION 28 b

Criteria	Marks
• Correct drawing	1

Sample answer



QUESTION 28 c

Criteria	Marks
• Correct explanation of the three stages with correct equations	4
• Correct explanation of two of the three stages with correct equations OR • Correct explanation of the three stages with two correct equations	3
• Correct explanation of two of the three stages one correct equations OR • Correct explanation of the three stages without correct equations OR • No explanation but three correct equations	2
• Correct explanation of one of the three stages with correct equation OR • Correct explanation of two of the three stages without equations OR • No explanation but two correct equations	1

Sample answer

When chloromethane is exposed to ultraviolet radiation it forms a methyl radical and a chlorine radical.

$$CH_3Cl_{(g)} \xrightarrow{UV\ radiation} {}^{\bullet}CH_{3(g)} + {}^{\bullet}Cl_{(g)}$$

The chlorine radical reacts with an ozone molecule to form a chlorine oxide radical and an oxygen molecule.

$$Cl^{\bullet}_{(g)} + O_{3(g)} \rightarrow O_{2(g)} + ClO^{\bullet}_{(g)}$$

The chlorine radical is regenerated, and is then able to react with other ozone molecules.

$$2ClO^{\bullet}_{(g)} \rightarrow 2Cl^{\bullet}_{(g)} + O_{2(g)}$$

(OR $\quad ClO^{\bullet}_{(g)} + O^{\bullet}_{(g)} \rightarrow Cl^{\bullet}_{(g)} + O_{2(g)}$)

QUESTION 29

Criteria	Marks
• States correct composition • Correctly describes design	2
• States correct composition OR • Correctly describes design	1

Sample answer

The membrane is made from a synthetic polymer such as cellulose acetate which is dissolved in a non-polar solvent together with water-soluble powders of a particular size. The mixture is spread out over a plate and left until all the solvent evaporates and a polymer membrane is formed. It is then placed in water where the water-soluble particles dissolve leaving microscopic sized holes in the membrane.

QUESTION 30 a

Criteria	Marks
• Correctly calculates number of moles of Na_2CO_3 • Correctly calculates molar mass of Na_2CO_3 • Correctly calculates mass of Na_2CO_3	2
• Two of the above	1

Sample answer

a. n_{Na2CO3} needed = CV = 0.20 x 0.25 = 0.050 mol

$MM_{Na2CO3} = 2(22.99) + 12.01 + 3(16.00) = 106$ g mol^{-1}

m = n x MM = 0.050 x 106 = 5.3 g (2 sig fig)

QUESTION 30 b

Criteria	Marks
• Correctly calculates number of moles of Na_2CO_3 • Correctly calculates number of moles of HCl (i.e. double that of Na_2CO_3) • Correctly calculates concentration of HCl • Correctly calculates pH to two decimal places	3
• Three of the above	2
• Two of the above	1

Sample answer

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

n_{Na2CO3} = CV = 0.20 x 0.0067 = 0.00134 mol

$n_{HCl} = 2n_{Na2CO3}$ 2 x 0.00134 = 0.00268 mol

C_{HCl} = n/V = 0.00268/0.025 = 0.1072 mol L^{-1}

pH = -log 0.1072 = 0.97

QUESTION 31 a

Criteria	Marks
• Correct drawing • All pieces of equipment correctly labelled	2
• Correct drawing OR • Correct drawing of incomplete set-up • All pieces of equipment correctly labelled	1

Sample answer

Drawing: A test tube or a flask containing a liquid is fitted vertically with an air condenser or a water condenser and is heated by a flame or a hot plate or a water bath or a heating mantle. The liquid does not touch the condenser.

Labels: flask/test tube; condenser; heat source; reaction mixture

QUESTION 31 b

Criteria	Marks
• Increased rate of reaction • Prevention of loss from reaction vessel	1

Sample answer

To speed up the reaction (by carrying out the reaction at boiling temperature) without losing volatile reactants or products (by recondensing the vaporised substances back into the reaction vessel).

QUESTION 32 a

Criteria	Marks
• Correctly explains that heating speeds up the reaction • States that the production of ammonia is exothermic • States or indicates by an equation that the reaction is reversible • States that increased temperature favours the reverse reaction, resulting in a lower yield	3
• Correctly explains that heating speeds up the reaction • Two of the three points needed to explain lower yield OR • Does not explain increased rate, but fully explains decreased yield	2
• Correctly explains that heating speeds up the reaction OR • Does not explain increased rate but demonstrates some understanding of le Chatelier	1

Sample answer

An increase in temperature speeds up the reaction due to an increased rate of successful collisions between the reactant particles.

Ammonia production is a reversible process. Since the forward reaction is exothermic, an increase in heat will favour the reverse reaction as it uses up some of this increased heat (Le Chatelier), resulting in lower yield.

QUESTION 32 b

Criteria	Marks
• High pressure • Catalyst • Removal of product	3
• Two of the above	2
• One of the above	1

Sample answer

high pressure, catalyst, removal of product

QUESTION 33 a

Criteria	Marks
• Fossil fuels are mainly (carbon or) hydrocarbons • In sufficient air get CO_2 and H_2O • If not enough oxygen get come CO and soot (C) as well • Hazard of CO_2 • Hazard of CO • Hazard of soot	5
• Five of the above	4
• Four of the above	3
• Three of the above	2
• Two of the above	1

Sample answer

Fossil fuels are mainly carbon (in coal) or hydrocarbons (in crude oil and in natural gas). In plentiful oxygen coal combusts to form carbon dioxide, hydrocarbons form water and carbon dioxide.

Carbon dioxide is a greenhouse gas which may contribute to global warming.

If there is insufficient oxygen the products will also include carbon monoxide and soot.

Carbon monoxide is a poisonous gas (which combines with haemoglobin in the blood, preventing oxygen to be carried to the cells).

Soot is a visual pollutant and a lung irritant.

QUESTION 33 b

Criteria	Marks
• Names a correct alternative to chemicals derived from crude oil	2
• Explains why it is a suitable replacement	1

Sample answer

Ethanol can be used as an alternative fuel in cars. Instead of deriving ethanol from the petrochemical industry, it can be obtained by the fermentation of sugars derived from plants, which are a renewable resource.

QUESTION 34 a

Criteria	Marks
• Explains fully • Writes at least two correct equations	2
• Explains fully • OR • Writes an explanation that demonstrates some understanding • Writes one correct equation	1

Sample answer

The acid can remove other cations (carbonate, hydroxide and phosphate) which, if present in the fertiliser, would precipitate with the barium. (In high enough concentration soluble barium hydroxide becomes insoluble.)

$2H^+_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)}$

$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

$2H^+_{(aq)} + PO_4^{3-}{}_{(aq)} \rightarrow H_2PO_4^-{}_{(aq)}$

QUESTION 34 b

Criteria	Marks
• Correctly calculates mass of fertiliser • Correctly calculates mass of barium sulfate precipitate • Correctly calculates number of moles of barium sulfate • Correctly calculates mass of sulfate • Correctly calculates mass percentage of sulfate	4
• Four of the above	3
• Three of the above	2
• Two of the above	1

Sample answer

mass of fertiliser = 112.45 - 108.45 = 4.00 g

mass of barium sulfate precipitate = 6.61 - 0.97 = 5.64 g

number of moles of barium sulfate = n/MM = 5.64/233.4 = 0.0242 mol

mass of sulfate (SO_4^{2-}) = n x MM = 0.0242 x (32.06 + 4 x 16.00) = 2.32 g

mass % of sulfate = mass of sulfate x 100/mass of fertiliser = 2.32 x 100/4.00 = 58%

QUESTION 35 - INDUSTRIAL CHEMISTRY

QUESTION 35 a i

Criteria	Marks
• Correct equation	2
• Correct explanation	1

Sample answer

$Zn^{2+}_{(aq)} + 4CN^{-}_{(aq)} \rightleftarrows Zn(CN)_4^{2-}{}_{(aq)}$

At equilibrium the concentrations of the Zn^{2+} and CN^- ions are very small. (The large K indicates that the reaction had gone almost to completion.)

QUESTION 35 a ii

Criteria	Marks
• States that decreasing the volume of the container increases the pressure (or concentration) of the gas • Correctly explains the effect of increased pressure on the position of the equilibrium where a shift results in a decreased number of gas molecules • Correctly explains that a shift does not happen if there is no resultant change in the number of gas molecules	3
• Gives a good but not full explanation	2
• Shows some understanding of le Chatelier's Principle	1

Sample answer

According to Le Chatelier, when a system at equilibrium is disturbed, the equilibrium shifts to minimise the imposed change and a new equilibrium is established. When the volume of the container is decreased pressure increases. If possible, a reaction will occur that will partially reduce the increased pressure. This can only occur if the reaction will result in a decreased number of gas molecules. However, if the number of gas molecules of reactants and products of the equilibrium equation are the same, no shift occurs.

QUESTION 35 b

Criteria	Marks
• Fully describes the Frasch process (with or without the help of a diagram) • Explains the significance of sulfur's moderate melting point • Explains the significance of the density of the sulfur-water-air foam • Explains the significance of sulfur's insolubility in water	5
• Partially describes the Frasch process • Explains the significance of sulfur's moderate melting point • Explains the significance of the density of the sulfur-water-air foam • Explains the significance of sulfur's insolubility in water	4
• Explains the significance of sulfur's moderate melting point • Explains the significance of the density of the sulfur-water-air foam • Explains the significance of sulfur's insolubility in water OR • Partially describes the Frasch process • Explains the significance of two of sulfur's properties OR • Fully describes the Frasch process • Explains the significance of one of sulfur's properties	3
• Fully describes the Frasch process OR • Partially describes the Frasch process • Explains the significance of one of sulfur's properties OR • Explains the significance of two of sulfur's properties	2
• Partially describes the Frasch process OR • Explains the significance of one of sulfur's properties	1

Sample answer

In the Frasch process superheated water under high pressure is pumped into the underground sulfur deposits. Due to sulfur's relatively low melting temperature this is hot enough to melt the sulfur. Compressed air is pumped into the melted sulfur-water mixture forming a sulfur-water-air foam which is forced to the surface. Because the density of this foam is less than the density of the water it floats on the condensed water and it can be skimmed off. On standing the air leaves the foam. Because sulfur does not dissolve in water the sulfur and the water separate into different layers. The water is drained off, leaving sulfur.

QUESTION 35 c i

Criteria	Marks
• Correct equation for the electrolysis of molten NaCl • Correct equation for the electrolysis of dilute NaCl • Correct identification of the gases discharged at the anodes	3
• Two correct equations • Correct identification of the gas discharged at one of the anodes OR • One correct equation • Correct identification of the gases discharged at each of the anodes	2
• One correct equation OR • Correct identification of the gases discharged at each of the anodes	1

Sample answer

Electrolysis of molten sodium chloride:

$2NaCl_{(l)} \rightarrow 2Na_{(l)} + Cl_{2(g)}$ Chlorine is discharged at the anode.

Electolysis of dilute sodium chloride solution:

$2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$ Oxygen is discharged at the anode.

QUESTION 35 c ii

Criteria	Marks
• Identifies mercury and asbestos as the environmental contaminants • Describes the effect of each on human health	2
• Identifies one of the contaminants • Describes its effect on human health	1

Sample answer

In the mercury process mercury is the main contaminant. If it leaks into the waterways it enters the food chain via aquatic plants and animals. Humans eating these accumulate the mercury in their body leading to nerve and brain damage.

In the diaphragm process asbestos is the main contaminant. Tiny airborne asbestos fibres can be breathed in and may be lodged in the lungs causing breathing irritation, and may develop into life threatening lung problems.

QUESTION 35 d i

Criteria	Marks
• States that the ionic head dissolves in water • States that the non-polar tail dissolves in grease • Explains how these properties help clean dishes	3
• States that the ionic head dissolves in water • States that the non-polar tail dissolves in grease	2
• States that the ionic head dissolves in water OR • States that the non-polar tail dissolves in grease	1

Sample answer

The non-polar tail dissolves in the non-polar grease while the ionic head dissolves in the polar water, thus the surfactant acts as a bridge between the grease and water aiding dispersal of grease in the water.

QUESTION 35 d ii

Criteria	Marks
• Gives correct difference	1

Sample answer

Soap forms scum (a precipitate) in hard water but (anionic) detergents do not.

QUESTION 35 d iii

Criteria	Marks
• Gives a correct use for each detergent that makes it more suitable than the other one	2
• Gives a correct use for one detergent that makes it more suitable than the other one	1

Sample answer

Soap is the preferred surfactant for cleansing the body, as it is gentler on the skin than synthetic detergents.

Anionic synthetic detergents are used in top-loading washing machines, as they clean well and the suds keep the dirt away from the clothes more effectively than soap.

QUESTION 35 e

Criteria	Marks
• Gives four correct criteria	4
• Gives three correct criteria	3
• Gives two correct criteria	2
• Gives one correct criterion	1

Sample answer

Near supply of raw materials (salt water and limestone), i.e. near the sea and/or near limestone quarry.

Near transport, i.e. near a shipping port or a train line, to bring in new materials and take away sodium carbonate.

Downstream and downwind from main urban centres to minimise the effect of pollution on humans.

Near disposal sites. Non-polluting calcium chloride used to be dumped in the open sea.

At a site with sufficient land for cooling ponds.

At a place where infrastructure is available for the workforce.

QUESTION 36 - SHIPWRECKS, CORROSION AND CONSERVATION

QUESTION 36 a i

Criteria	Marks
• Gives full correct answer	2
• Gives partially correct answer	1

Sample answer

Faraday's Laws of Electrolysis state that the mass of an element produced by electrolysis depends on the quantity of electricity, the atomic mass of the element and the valency of the element.

QUESTION 36 a ii

Criteria	Marks
• Correctly calculates the number of moles of silver • Correctly calculates the number of moles of copper • Correctly calculates the mass of copper	3
• Performs two correct calculations	2
• Performs one correct calculation	1

Sample answer

$n_{Ag} = m/MM = 5.4/107.9 = 0.050$ mol

$n_{e^-} = n_{Ag} = 0.050$ mol

$n_{Cu} = 1/2\ n_{e^-} = 0.050/2 = 0.025$ mol

$m_{Cu} = n \times MM = 0.025 \times 63.55 = 1.6$ g (correct to 2 significant figures)

QUESTION 36 b i

Criteria	Marks
• Writes correct equation of the reaction at the anode • Writes correct equation of the reaction at the cathode	2
• Writes two correct equations without reference to the electrodes OR • Writes two correct equations but refers to the wrong electrodes OR • Writes one correct equation for a named electrode	1

Sample answer

At the anode: oxygen bubbles form

$$2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$$

At the cathode: copper is deposited

$$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$$

QUESTION 36 b ii

Criteria	Marks
• Gives correct answer for the anode • Does not give incorrect answer for the cathode. (Does not need to mention the cathode.)	2
• Correct answer for the anode and an incorrect answer for the cathode OR • Incorrect answer for the anode but a correct statement regarding the cathode	1

Sample answer

At the anode: the iron electrode oxidises.

$$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$$

(The cathode reaction is unchanged.)

QUESTION 36 c i

Criteria	Marks
• States that aluminium oxide is formed • Explains how aluminium oxide layer protects aluminium from further corrosion • Explains formation of rust • Explains why rust does not protect the remaining iron from further corrosion	3
• Three of the above	2
• Two of the above	1

Sample answer

Aluminium reacts quickly with oxygen in the air, forming a stable layer of aluminium oxide which adheres to the metal beneath it, protecting the aluminium from further corrosion.
Iron reacts slowly with oxygen and moisture in the air, forming a porous layer of hydrated iron oxide (rust) which does not adhere to the metal beneath it. As the rust flakes off, new metal surface is exposed to further corrosion.

QUESTION 36 c ii

Criteria	Marks
• Advantage and disadvantage of galvanising • Advantage and disadvantage of tin coating • Correct explanation for corrosion of tin coated iron • Correct equation for corrosion of tin coated iron • Correct explanation for sacrificial corrosion of zinc • Correct equations for sacrificial corrosion of zinc	5
• Five of the above	4
• Four of the above	3
• Three of the above	2
• Two of the above	1

Sample answer

Both tin and zinc can be passivating metals providing good protection as long as the coating on the iron is intact. If there is a break in the mechanical protection provided by the tin coating the iron will corrode fast, being more reactive than tin.

$2Fe_{(s)} + O_{2(g)} + 2H_2O_{(l)} \rightarrow Fe^{2+}_{(aq)} + 2Fe(OH)_{2(s)}$ (OR $Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$)

If there is a break in the mechanical protection provided by the zinc coating, the zinc, being more reactive than the iron, will become a sacrificial metal. The electrons lost by the exposed iron will be replaced by electrons from the zinc. This protection will last as long as there is any zinc left in contact with the iron.

$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$ $\quad Fe^{2+}_{(aq)} + Zn_{(s)} \rightarrow Fe_{(s)} + Zn^{2+}_{(aq)}$

Tin coating is cheaper but does not provide chemical protection. Once the coating is broken the iron corrodes quickly.

Galvanising if more expensive but provides chemical protection when the coating is broken.

QUESTION 36 d

Criteria	Marks
• Identifies sulfur-reducing bacteria • Explains well in words and/or by equations how they cause the corrosion of iron	3
• Identifies sulfur-reducing bacteria • Does not explain well but shows understanding of how they cause the corrosion of iron	2
• Identifies sulfur-reducing bacteria • OR • Shows some understanding of conditions (besides cold temperature and high pressure) at great sea depth	1

Sample answer

At great depth the main agents of corrosion are anaerobic sulfur-reducing bacteria. In the absence of dissolved oxygen, these bacteria get their energy by converting sulfate ions, which are present in seawater but do not react with iron, to hydrogen sulfide, which does.

$SO_4^{2-}_{(aq)} + 10H^+_{(aq)} + 8e^- \rightarrow H_2S_{(aq)} + 4H_2O_{(l)}$

$H_2S_{(aq)} + Fe_{(s)} \rightarrow FeS_{(s)} + 2H^+_{(aq)} + 2e^-$

In addition, the waste products of the bacteria increase the acidity of the water, which speeds up corrosion.

$Fe_{(s)} + 2H^+_{(aq)} \rightarrow Fe^{2+}_{(aq)} + H_{2(g)}$

* Note: Other equations are also possible, e.g.:

$SO_4^{2-}(aq) + 5H_2O(l) + 8e^- \rightarrow HS^-(aq) + 9OH^-(aq)$

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

Overall

$4Fe(s) + SO_4^{2-}(aq) + 5H_2O(l) \rightarrow 4Fe^{2-}(aq) + HS^-(aq) + 9OH^-(aq)$

Then

$4Fe^{2+}(aq) + HS^-(aq) + 7OH^-(aq) \rightarrow FeS(s) + 3Fe(OH)_2(s) + H_2O(l)$

QUESTION 36 e

Criteria	Marks
• Identifies at least two methods • Explains the methods • Provides at least two correct equations	5
• Identifies three methods • Explains the methods (No equations) OR • Identifies two methods • Explains the methods • Provides one correct equation	4
• Identifies at least one method • Explains one method • Provides the correct equation	3
• Identifies at least one method • Explains one method OR • Identifies at least one method • Provides the correct equation	2
• Shows some understanding of cleaning artefacts from wrecks	1

Sample answer

Artefacts covered with calcium carbonate deposits:

After physically chipping away calcium carbonate deposits, the artefacts are soaked in dilute acid which reacts with the solid carbonate

$$CaCO_{3(s)} + 2H^{+}_{(aq)} \rightarrow Ca^{2+}_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

(This method is suitable for metals that do not react with acids, i.e. copper and silver artefacts)

Oxidised metal artefacts are cleaned and restored by electrolysis, using the artefacts as the cathode.

e.g. $CuS_{(s)} + 2e^{-} \rightarrow Cu_{(s)} + S^{2-}_{(aq)}$

If more reactive metals are involved the electrolyte is made slightly alkaline to prevent the formation of hydrogen ions which would react with the metal.

Insoluble chlorides are also treated with electrolysis, with chlorine being discharged at the anode.

$2Cl^{-} \rightarrow Cl_{2(g)} + 2e^{-}$