CHEMISTRY
UNITS 3 & 4
2022

MARKING GUIDE

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes
Working time for the paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:
This Question/Answer Booklet
Multiple-choice Answer Sheet
Chemistry Data Book

To be provided by the candidate:
Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.

Special items: calculators satisfying the conditions set by the SCSA for this subject.

IMPORTANT NOTE TO CANDIDATES

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One Multiple-choice	25	25	50	25	25
Section Two Short answer	9	9	60	83	35
Section Three Extended answer	5	5	70	94	40
				Total	100

Section One: Multiple-choice **25% (25 marks)**

1	a □	b ■	c □	d □	6	a □	b □	c □	d ■	11	a ■	b □	c □	d □
2	a ■	b □	c □	d □	7	a □	b □	c ■	d □	12	a ■	b □	c □	d □
3	a □	b □	c □	d ■	8	a □	b □	c □	d ■	13	a □	b □	c ■	d □
4	a □	b □	c □	d ■	9	a ■	b □	c □	d □	14	a □	b ■	c □	d □
5	a □	b □	c □	d ■	10	a □	b □	c □	d ■	15	a □	b □	c ■	d □

16	a □	b □	c ■	d □	21	a □	b □	c □	d ■					
17	a □	b □	c □	d ■	22	a □	b □	c ■	d □					
18	a □	b ■	c □	d □	23	a □	b ■	c □	d □					
19	a □	b □	c □	d ■	24	a □	b ■	c □	d □					
20	a ■	b □	c □	d □	25	a □	b ■	c □	d □					

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

Question 26 **(11 marks)**

(a) Complete the flow chart, by writing the name of each organic substance in the boxes labelled X, Y and Z. (3 marks)

Description	Marks
X is butan-1-ol	1
Y is butanoic acid	1
Z is butanone	1
Total	**3**

(b) Write a balanced ionic equation for the reaction that produced the colourless, odourless gas. (2 marks)

Description	Marks
Correct reactants and products	1
Balanced	1
Total	**2**
Examples of a two mark response: $2\ CH_3CH_2CH_2COOH(aq) + Na_2CO_3(s) \rightarrow 2\ CH_3CH_2CH_2COO^-(aq) + 2\ Na^+(aq) + CO_2(g) + H_2O(l)$ $2\ C_3H_7COOH(aq) + Na_2CO_3(s) \rightarrow 2\ C_3H_7COO^-(aq) + 2\ Na^+(aq) + CO_2(g) + H_2O(l)$	
Note: one mark may be allocated for the correctly balanced molecular equation	

(c) Rank the 3 original organic substances in order of boiling point, and explain your answer by referring to the intermolecular forces present in each substance. (6 marks)

Description	Marks
Butanoic acid > butan-1-ol > butanone	1
The greater the sum of intermolecular forces, the higher the boiling point.	1
Substances have similar M, therefore similar strength dispersion forces.	1
Butanone has only dipole-dipole forces (in addition to dispersion) and therefore has the lowest boiling point.	1
Butan-1-ol and butanoic acid have hydrogen bonding (in addition to dipole-dipole and dispersion forces) which elevate their boiling point.	1
The hydrogen bonding in butanoic acid is the strongest because the -COOH group is more polar than the -OH group. **or** Butanoic acid molecules form dimers, with stronger hydrogen bonds (than those in butan-1-ol). **or** The boiling point of butanoic acid is the highest because it has more potential hydrogen bonding sites (than butan-1-ol).	1
Total	**6**

Question 27 **(8 marks)**

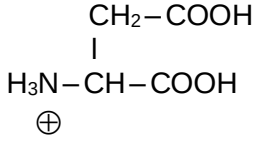
(a) Describe how the equations above demonstrate an understanding of the following terms. Your answer may refer to one or both equations, as required. (6 marks)

Description	Marks
Bronsted-Lowry theory:	
• one species (the aspartic acid) is acting as a proton (H^+) donor • whilst the other species (water) is acting as a proton (H^+) acceptor	2
Diprotic:	
• aspartic acid contains two ionisable / acidic hydrogens per molecule • illustrated by use of two successive ionisation equations	2
Weak acid:	
• partial ionisation of aspartic acid occurs • illustrated by use of reversible / double arrows in both equations	2
Total	**6**

(b) Which of the ionisation steps would have a higher K_a value? (circle your choice) (1 mark)

Description	Marks
Step 1 (circled)	1
Total	**1**

(c) Draw a structural diagram for the conjugate acid of 'aspartic acid'. (1 mark)

Description	Marks
Correct structural diagram (accept full or semi structural)	1
Total	**1**
Example of a correct structure: 	

Question 28 **(10 marks)**

(a) Using your knowledge of IUPAC nomenclature, match each of these 3 ingredients to their corresponding molecular structure. (3 marks)

Description		Marks
Molecule 1:	propanediol	1
Molecule 2:	citric acid	1
Molecule 3:	glyceryl oleate	1
	Total	**3**

(b) Describe a 'polypeptide'. (2 marks)

Description	Marks
Any two of the following:	
• condensation polymer • a naturally occurring polyamide • a long chain of amino acids • joined together by peptide / amide bonds / links	2
Total	**2**

(c) State the key difference between the secondary and tertiary structure of a protein. Give at least one example of each type of structure. (4 marks)

Description	Marks
Secondary structure:	
Interactions / hydrogen bonds that form between C=O and N-H groups of amino acids / within a protein chain. **or** Regular structures that form due to interactions / hydrogen bonding that occur between amino acids / within a protein chain.	1
and either of the following examples:	
• α-helix • β-pleated sheet	1
Tertiary structure:	
Various interactions which occur between the amino acid side chains.	1
and any one of the following examples:	
• dispersion forces • dipole-dipole forces • hydrogen bonds • ionic bonds • disulfide bridge	1
Total	**4**

(d) What does 'PET' stand for? (1 mark)

Description	Marks
polyethylene terephthalate	1
Total	**1**

Question 29 **(5 marks)**

(a) Write the equilibrium constant (K) expression for this system. (2 marks)

Description	Marks
Products over reactants	1
Correct indices	1
Total	**2**
Example of a two mark response: $K = \frac{[Mg^{2+}]\,[HCO_3^-]^2}{[CO_2]}$	

(b) Consider the effect of imposing the following changes on this system. Complete the table below by stating in which direction, if any, an equilibrium shift would occur. (3 marks)

Description		Marks
A small amount of $MgCO_3(s)$ is added.	no change	1
A few drops of 2 mol L^{-1} $MgCl_2(aq)$ is added.	left	1
The volume of the system is decreased.	right	1
Total		**3**

Question 30 **(11 marks)**

(a) What is an enzyme? (1 mark)

Description	Marks
A biological catalyst **or** A protein which acts as a catalyst	1
Total	**1**

(b) List four (4) additional advantages, relating to the principles of green chemistry, of the fermentation method of producing ethanol. (4 marks)

Description	Marks
Any four of the following:	
• use of a lower pressure • use of a lower temperature • no unwanted side reactions (due to use of catalyst) • no use of corrosive acid catalyst • use of renewable feedstock • less hazardous • (closer to) carbon neutral fuel	4
Total	**4**

(c) Complete the reaction sequence below, by filling in the boxes. (3 marks)

Description		Marks
Step 1:	H_2O	1
Step 2:	4 Cr^{3+}	1
Step 3:	CH_3CH_2OH	1
Total		**3**

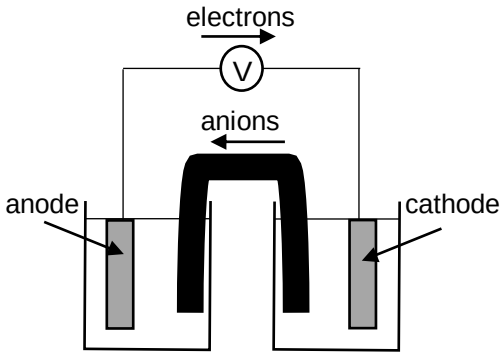
(d) Name the type of reaction occurring in each step of the sequence. (3 marks)

Description		Marks
Step 1:	addition / hydration	1
Step 2:	oxidation / redox	1
Step 3:	esterification / condensation	1
Total		**3**

Question 31 **(11 marks)**

(a) On the diagram above, label the (3 marks)

- anode and cathode
- direction of electron flow
- direction of anion flow through the salt bridge.

Description	Marks
Cathode and anode labels	1
Direction of electron flow label	1
Direction of anion flow label	1
Total	**3**
Example of a three mark response:  	

(b) Calculate the EMF of the cell under standard conditions. (1 mark)

Description	Marks
EMF = + 0.80 + 0.24 = + 1.04 V	1
Total	**1**

(c) Calculate the final mass of the silver electrode. (7 marks)

Description	Marks
n(Ni) = 10 / 58.69 = 0.170387 mol	1
n(Ag^+) = 1 x 0.5 = 0.5 mol	1
Appropriate working to demonstrate limiting reagent	
actual ratio Ag^+ / Ni = 2 stoichiometric ratio Ag^+ / Ni = 2.9345 **or** n(Ni required) = 0.25 mol n(Ag^+ required) = 0.34077 mol	1
Ni is limiting reagent (with appropriate justification)	1
n(Ag formed) = 2 x n(Ni) = 0.34077 mol	1
m(Ag formed) = 0.34077 x 107.9 = 36.7695 g	1
m(Ag electrode) = 10 + 36.7695 = 46.8 g	1
Total	**7**

Question 32 **(11 marks)**

(a) Explain, in terms of reaction rates, how this buffer would respond to the addition of $H_3O^+(aq)$ as caused by rainfall. Include a relevant chemical equation in your answer. (6 marks)

Description	Marks
An increase in H_3O^+ would neutralise / remove OH^- ions from the system.	1
Both forward and reverse reaction rates would decrease,	1
however the forward reaction rate decreases less than the reverse rate.	1
This results in the position of equilibrium shifting right,	1
resulting in production of more OH^- ions and therefore the pH is maintained.	1
Equation showing H_3O^+ reaction with conjugate base species	1
Example of correct equation: $H_3O^+(aq) + SiO_4^{4-}(aq) \rightarrow H_2O(l) + HSiO_4^{3-}(aq)$	
Total	**6**

(b) State the two (2) factors that would affect the buffering capacity of this system. (2 marks)

Description	Marks
Ratio of the concentrations of acid ($HSiO_4^{3-}$) and base (SiO_4^{4-})	1
Actual / absolute concentrations of acid ($HSiO_4^{3-}$) and base (SiO_4^{4-})	1
Total	**2**

(c) Use Le Chatelier's principle, to justify how an increase in the concentration of atmospheric $CO_2(g)$ can lower the ocean pH. (3 marks)

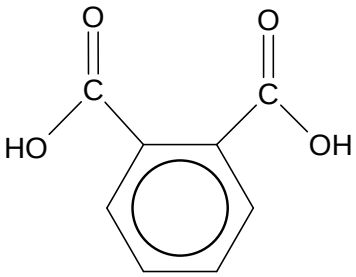
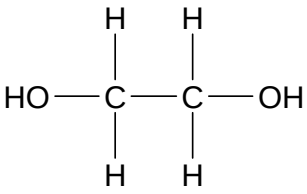
Description	Marks
An increase in CO_2 concentration favours the forward reaction / shifts the position of equilibrium to the right in equations 1, 2 and 3.	1
This counteracts the imposed change by decreasing the CO_2, but results in increased $[H_3O^+]$.	1
As $[H_3O^+]$ increases, pH is lowered (since $pH = -\log[H_3O^+]$).	1
Total	**3**

Question 33 **(8 marks)**

(a) What type of condensation polymer is shown? (1 mark)

Description	Marks
A polyester	1
Total	**1**

(b) Draw structural diagrams of the monomers used to produce this polymer. (2 marks)

Description	Marks
Diacid: 	1
Diol: 	1
Total	**2**

(c) Define ‘crosslinking’. (1 mark)

Description	Marks
The formation of (usually) covalent bonds between polymer chains.	1
Total	**1**

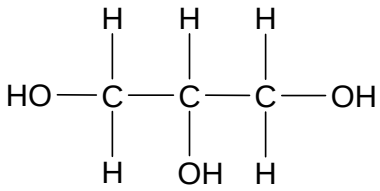
(d) Choose one (1) of these altered properties, and describe how crosslinking can result in this change to the polymer. (2 marks)

Description	Marks
Higher melting point:	
The crosslinked polymer chains have a much greater molecular mass (M) / The crosslinks result in formation of a polymer network.	1
This increases the strength of intermolecular forces (resulting in an increased melting point) / This results in a greater amount of heat required to melt the polymer (which may in fact char before melting).	1
Total	**2**

or

Description	Marks
Higher physical strength:	
The crosslinked polymer chains have a decreased ability to slide past each other / The crosslinks result in a polymer network.	1
This enables the polymer to withstand a greater application of force (resulting in an increased physical strength) / This results in a more rigid and strong polymer structure.	1
Total	**2**

(e) Draw a structural diagram and give the name for the **new** monomer that has been used to form this crosslinking polymer. (2 marks)

Description	Marks
Structure:  	1
Name: glycerol / propane-1,2,3-triol	1
Total	**2**

Section Three: Extended answer **40% (94 marks)**

Question 34 **(24 marks)**

(a) Calculate the minimum pressure that would need to be exerted by the $O_2(g)$ in the reaction chamber, to ensure sufficient $O_2(g)$ was present for all the chromite to react. State your answer to the appropriate number of significant figures. (5 marks)

Description		Marks
$n(FeCr_2O_4)$	= 3.21 x 10^6 / 223.85 = 14 339.96 mol	1
$n(O_2)$	= 7/4 x $n(FeCr_2O_4)$ = 25 094.93 mol	1
$P(O_2)$	= (25 094.93 x 8.314 x 1373.15) / (1500 x 10^3) = 190.995 kPa	1
	= 191 kPa (correct to 3 significant figures)	1
Correct conversions, t $\rightarrow$ g, kL $\rightarrow$ L, °C $\rightarrow$ K		1
	Total	**5**

If the combined yield of Step 1 and Step 2 is 68.9%;

(b) Calculate the mass of $Na_2Cr_2O_7(s)$ produced. (4 marks)

Description		Marks
Correct theoretical stoichiometric ratio of $n(Na_2Cr_2O_7) = n(FeCr_2O_4)$		1
$n(Na_2Cr_2O_7)$	= $n(FeCr_2O_4)$ x 68.9/100	1
	= 14 339.96 x 68.9/100 = 9 880.23 mol	1
$m(Na_2Cr_2O_7)$	= 9 880.23 x 261.98 = 2 588 423 g (2.59 x 10^6 g or 2.59 t)	1
	Total	**4**

(c) Calculate the percentage yield of Step 3. (3 marks)

Description		Marks
$n(Cr_2O_3$ theor.)	= $n(Na_2Cr_2O_7)$ = 9 880.23 mol	1
$m(Cr_2O_3$ theor.)	= 9 880.23 x 152 = 1 501 795 g (1.502 x 10^6 g or 1.502 t)	1
% yield	= 1.28 / 1.502 x 100 = 85.2 %	1
	Total	**3**
Alternate method: $n(Cr_2O_3$ actual) % yield	= 1.28 x 10^6 / 152 = 8 421.053 mol = 8 421.053 / 9 880.23 x 100 = 85.2 %	

(d) Calculate the concentration of $Cr^{3+}(aq)$ ions, in **grams per litre**, in the final solution. (4 marks)

Description	Marks
$n(Cr_2O_3$ actual) = $1.28 \times 10^6 / 152$ = 8 421.053 mol	1
$n(Cr^{3+})$ = $2 \times n(Cr_2O_3)$ = 16 842.105 mol	1
$c(Cr^{3+})$ = $16\,842.105 / 3500$ = 4.812 mol L^{-1}	1
$c(Cr^{3+})$ = 4.812×52 = 250.2 g L^{-1}	1
Total	**4**
Alternate method for final two steps: $m(Cr^{3+})$ = 16 842.105 x 52 = 875 789 g $c(Cr^{3+})$ = 875 789 / 3500 = 250.2 g L^{-1}	

(e) What is an electrolytic cell? (2 marks)

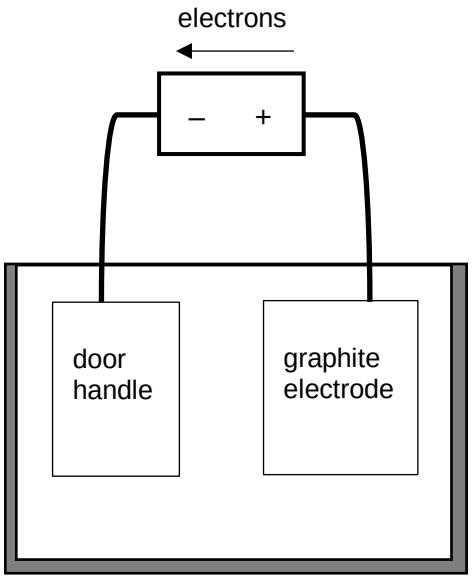
Description	Marks
One of the following:	
• cell that uses an external power source that • cell which converts electrical energy to chemical energy and	1
with either of:	
• drives a non-spontaneous redox reaction • causes a redox reaction with a negative EMF to occur	1
Total	**2**

(f) Describe how the electrolyte solution for this cell could be prepared to standard conditions, using the $Cr^{3+}(aq)$ solution. Your answer should include appropriate calculations. (4 marks)

Description	Marks
$n(Cr^{3+}$ required) = 1 x 850 = 850 mol	1
$V(Cr^{3+}$ required) = 850 / 4.812 = 176.64 L	1
Add 177 L of Cr^{3+} solution to tank, fill to 850 L with water	1
Cool solution to final temperature of 25 °C	1
Total	**4**
Alternate calculation method for two marks: V_1 = c_2V_2 / c_1 = 1 x 850 / 4.812 = 176.64 L Note: award follow through marks for correct working based on incorrect initial $Cr^{3+}(aq)$ concentration from part (d).	

(g) Add to this diagram by labelling; (2 marks)

- where you would connect the inert graphite electrode,
- where you would connect the car door handle, and
- the direction of electron flow.

Description	Marks
Door handle on left (-) Graphite on right (+)	1
Direction of electron flow label	1
Total	**2**
Example of a three mark response:  	

Question 35 **(10 marks)**

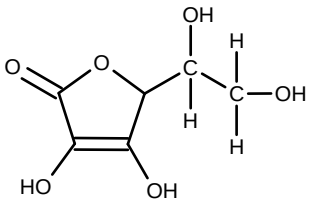
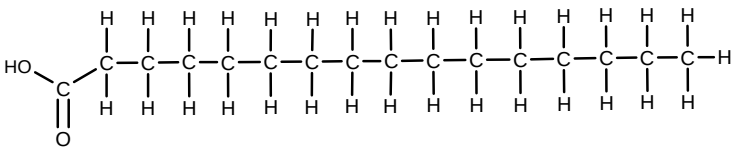
(a) Select an appropriate indicator from the table below for use in this titration. Justify your indicator choice, including a relevant chemical equation in your answer. (3 marks)

Description	Marks
Thymol blue	1
Basic solution at equivalence due to hydrolysis of $C_6H_7O_6^-$ (ascorbate ions)	1
Balanced equation	1
Total	**3**
Example of correct equation: $C_6H_7O_6^-(aq) + H_2O(l) \rightleftharpoons C_6H_8O_6(aq) + OH^-(aq)$	

(b) Calculate the concentration of Vitamin C in the dried gumbi-gumbi leaves, expressing your final answer as '**mg of Vitamin C per 100 g gumbi-gumbi leaves**'.
(You may assume the ascorbic acid was the only acidic substance present in the leaves.) (5 marks)

Description		Marks
n(NaOH)	= 0.01118 x 0.01828 = 0.00020437 mol	1
$n(C_6H_8O_6)$	= n(NaOH) = 0.00020437 mol	1
$m(C_6H_8O_6)$	= 0.00020437 x 176.124 = 0.0359945 g	1
	= 35.9945 mg (in 25 mL / in 30 g)	1
$m(C_6H_8O_6$ in 100 g)	= 35.9945 x 100/30 = 119.98 mg = 120 mg	1
Total		**5**

(c) Draw structural formulas for both ascorbic and palmitic acid. (2 marks)

Description	Marks
Ascorbic acid: 	1
Palmitic acid:  **or** $CH_3(CH_2)_{14}COOH$	1
Total	**2**

Question 36 **(17 marks)**

(a) Describe what is happening to both the forward and reverse reaction rates from Time 0 to Time E1. (3 marks)

Description	Marks
Decrease in forward reaction rate.	1
Increase in reverse reaction rate.	1
At time E1 the forward and reverse reaction rates become equal.	1
Total	**3**

(b) Complete the table below, by stating how the pressure and temperature of the system are different at Time E1, compared to Time 0. Justify each of your choices. (4 marks)

Description		Marks
Pressure		
Conditions	decreased (circled)	1
Justification	3 : 2 molar ratio of gaseous reactants : products	1
Temperature		
Conditions	increased (circled)	1
Justification	forward reaction is exothermic	1
Total		**4**

(c) Explain, in terms of the collision theory, why the actual temperature used in the Contact Process is not lowered to 300 °C. (4 marks)

Description	Marks
A lower temperature would:	
Decrease the frequency of collisions, and	1
decrease the average kinetic energy of the reacting particles.	1
This would result in a lower proportion of particles able to react / overcome the activation energy barrier,	1
therefore the reaction rate would decrease to non-viable levels.	1
Total	**4**

(d) State the change that was imposed, and justify why the system would temporarily be classified as an ‘open system’. (2 marks)

Description	Marks
Removal of $SO_3(g)$.	1
Matter being removed from the system (therefore classified as open).	1
Total	**2**

(e) State when (i.e. at Time E1, E2 or E3) the value of K_c would have been highest and when it would have been lowest. Justify your answers. (4 marks)
(Note: calculations of K_c values are not required.)

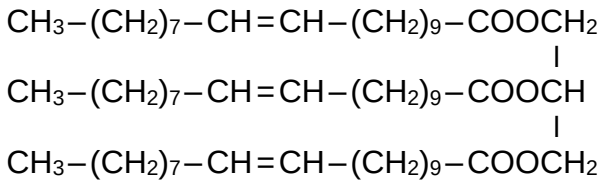
Description	Marks
Equal highest at E2 and E3.	1
Lowest at E1.	1
After E1, the temperature is decreased, which favours the forward reaction / increases the yield, and increases the value of K.	1
After E2, there are no imposed changes that would affect the value of K.	1
Total	**4**

Question 37 **(10 marks)**

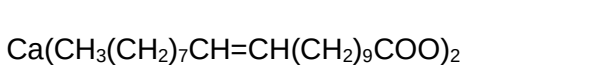
(b) Calculate the resulting pH of the sodium hydroxide solution. (4 marks)

Description	Marks
n(NaOH) = 7.86 x 0.380 = 2.9868 mol	1
c(NaOH final) = 2.9868 / 0.490 = 6.09551 mol L^{-1}	1
$[H^+]$ = $(1.0 \times 10^{-14}) / 6.09551$ = 1.64055×10^{-15} mol L^{-1}	1
pH = - log $(1.64055 \times 10^{-15})$ = 14.785 (14.8)	1
Total	**4**

(c) Draw a structural diagram of the triglyceride found in jojoba oil. (2 marks)

Description	Marks
Glycerol backbone (accept full or semi structural)	1
Three identical fatty acids (accept full or semi structural)	1
Total	**2**
Example of a two mark response: 	
Note: one mark may be allocated if there is only one minor error e.g. one H atom missing, one subscript error in fatty acid formula, etc	

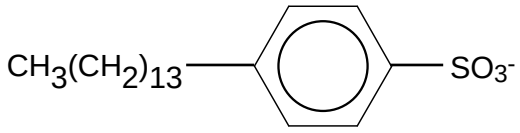
(d) Draw the chemical structure of the scum that would form if this soap was used in hard water. (2 marks)

Description	Marks
Both ions in formula correct (accept Ca^{2+}/ Mg^{2+}/ Fe^{2+})	1
Correct subscript (i.e. 2) for soap anion	1
Total	**2**
Example of a two mark response: 	
Note: one mark may be allocated if there is only one minor error e.g. one subscript error in fatty acid formula, etc	

(e) Draw a structural diagram for an anionic detergent with the same number of carbon atoms as the soap. Assume the detergent is an 'alkylbenzene sulfonate'. (2 marks)

Description	Marks
Benzene ring and sulfonate group (accept full or semi structural)	1
Alkyl group with 14 carbons (accept full or semi structural)	1
Total	**2**

Example of a two mark response:



Note:
one mark may be allocated if there is only one minor error
e.g. charge missing from sulfonate group, etc

Question 38 **(20 marks)**

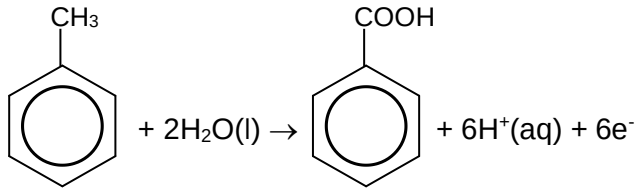
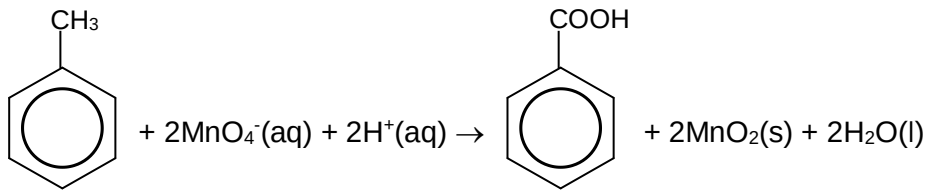
(a) Demonstrate that this is a redox reaction, using oxidation numbers to support your answer. (2 marks)

Description	Marks
Zinc is oxidised, oxidation number changes from (0) to (+2)	1
Carbon is reduced, oxidation number changes from (-2/3) to (-1)	1
Total	**2**

(b) Predict the substance formed, in addition to toluene. (1 mark)

Description	Marks
HCl / hydrochloric acid / hydrogen chloride	1
Total	**1**

(c) Write the oxidation and reduction half-equations and overall redox reaction for this process, assuming acidic conditions. (6 marks)

Description	Marks
Correctly identifying which half-equation is oxidation and which is reduction	1
Oxidation half-equation:	
Correct reactants and products	1
Correct balancing	1
Example of a two mark response:  **or** $C_7H_8(l) + 2H_2O(l) \rightarrow C_7H_6O_2(aq) + 6H^+(aq) + 6e^-$	
Reduction half-equation:	
Correct reactants and products	1
Correct balancing	1
Example of a two mark response: $MnO_4^-(aq) + 4H^+(aq) + 3e^- \rightarrow MnO_2(s) + 2H_2O(l)$	
Overall equation:	
Correctly written and balanced equation	1
Example of correct equation:  **or** $C_7H_8(l) + 2MnO_4^-(aq) + 2H^+(aq) \rightarrow C_7H_6O_2(aq) + 2MnO_2(s) + 2H_2O(l)$	
Total	**6**

(d) Determine the empirical formula of this compound and thereby identify it. (9 marks)

Description	Marks
Calculating moles and mass of C	2
Calculating moles and mass of H	2
Calculating moles and mass of O	2
Determining simplest ratio by dividing all by smallest moles	1
Writing empirical formula C_6H_6O	1
Stating compound is 'phenol'	1
Total	**9**

Example of a nine mark response:

	C	H	O
mass (g)	(12.01 / 44.01) x 1.905 = 0.5199	0.04328 x 1.008 = 0.04363	0.6789 – (0.51986 + 0.043629) = 0.1154
moles (mol)	0.5199 / 12.01 = 0.04329	2x [(168 x 0.5228) /(8.314 x 488.15)] = 0.04328	0.1154 / 16.00 = 0.007213
ratio	0.04329 / 0.007213 = 6.001	0.04328 / 0.007213 = 6.000	0.007213 / 0.007213 = 1.000
	6	6	1

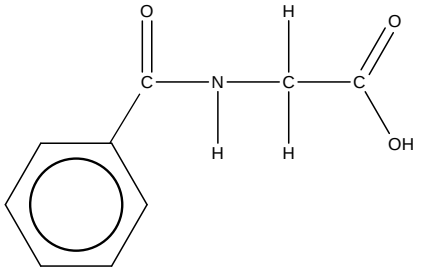
Empirical formula is C_6H_6O. The identity of the compound is phenol.

Note:
If mass/moles of oxygen not determined and benzene (C_6H_6) is given as answer, award a maximum of 6 marks.

(e) Draw the chemical structure of hippuric acid. (2 marks)

Description	Marks
Structure of benzoic 'half' without -OH group (accept full or semi structural)	1
Structure of glycine 'half' without -H group (accept full or semi structural)	1
Total	**2**

Example of a two mark response:



Note:
one mark may be allocated if there is only one minor error