CHEMISTRY
UNIT 3 + 4
2021

MARKING GUIDE

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

1	a □ b □ c □ d ■
2	a ■ b □ c □ d □
3	a □ b ■ c □ d □
4	a □ b □ c ■ d □
5	a □ b ■ c □ d □

11	a ■ b □ c □ d □
12	a □ b □ c □ d ■
13	a □ b □ c ■ d □
14	a □ b □ c □ d ■
15	a □ b □ c ■ d □

21	a □ b ■ c □ d □
22	a □ b □ c ■ d □
23	a □ b ■ c □ d □
24	a □ b □ c ■ d □
25	a □ b □ c ■ d □

6	a □ b ■ c □ d □
7	a □ b □ c □ d ■
8	a □ b □ c □ d ■
9	a □ b □ c ■ d □
10	a □ b ■ c □ d □

16	a ■ b □ c □ d □
17	a ■ b □ c □ d □
18	a □ b □ c □ d ■
19	a □ b □ c □ d ■
20	a ■ b □ c □ d □

(1 mark per question)

Section Two: Short answer   **35%**   **(81 marks)**

Question 26   **(12 marks)**

(a)   Determine the empirical formula of the amino acid.   (7 marks)
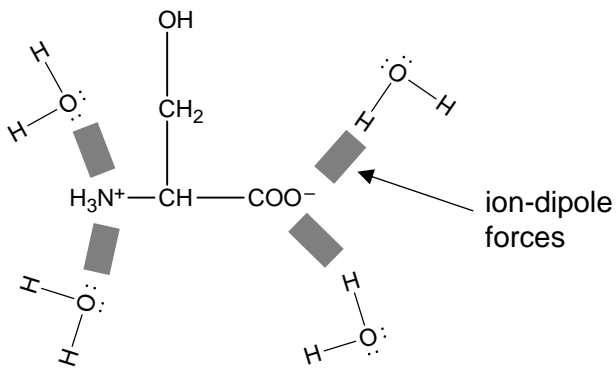
Description	Marks
Calculating moles of H	1
Calculating mass of H	1
Calculating mass of N	1
Calculating mass of O	1
Calculating moles of C/N/O	1
Determining simplest ratio by dividing all by moles of N	1
Writing empirical formula as $C_3H_7NO_3$	1
Total	7

Example of a seven mark response

$n(H) = 2 \times n(H_2O) = (122 \times 0.8223) / (8.314 \times 470.15) = 0.05133$ mol
$m(H) = 0.05133 \times 1.008 = 0.05174$ g

	C	H	N	O
mass (g)	0.2641	0.05174	$(13.33/100) \times$ 0.7707 $= 0.10273$	$0.7707 -$ $(0.2641 +$ $0.05174 +$ $0.10273)$ $= 0.35213$
moles (mol)	0.2641 / 12.01 $= 0.02199$	0.05133	0.10273 / 14.01 $= 0.00733$	0.35213 / 16.00 $= 0.02201$
ratio	0.02199 / 0.00733 = 2.999	0.05133 / 0.00733 = 7.000	0.00733 / 0.00733 = 1	0.02201 / 0.00733 = 3.002
	3	7	1	3

Empirical formula is $C_3H_7NO_3$

(b)   If the molecular mass of the amino acid is 105.1 g mol^{-1}, determine its identity.   (2 marks)

Description	Marks
M(EF) = 105.096 g mol^{-1}, therefore MF = EF	1
Serine	1
Total	2

(c)   When the amino acid is dissolved in water, ion-dipole forces form. Draw a diagram
        illustrating the arrangement of these forces.   (3 marks)

Description	Marks
Serine (or other amino acid) drawn in zwitterion form	1
Correct orientation of water around positive charge	1
Correct orientation of water around negative charge	1
Total	**3**

Example of a three mark response

Note:
Award mark for correct zwitterionic structure of **any** amino acid.

Question 27 **(9 marks)**

(a)   A few drops of bromine water were added to a test tube containing sodium iodide solution, and the mixture was briefly shaken. (3 marks)

Description	Marks
Equation $Br_2(aq) + 2\,I^-(aq) \rightarrow I_2(aq) + 2\,Br^-(aq)$	
Correct species	1
Correct balancing	1
Observations Orange and colourless solutions mix to form a brown solution.	1
Total	3
Note: State symbols are not required for full marks. Also accept formation of 'purple solid' as observation.	

(b)   Excess nitric acid was poured over zinc carbonate powder. (3 marks)

Description	Marks
Equation $ZnCO_3(s) + 2\,H^+(aq) \rightarrow Zn^{2+}(aq) + CO_2(g) + H_2O(l)$	
Correct species	1
Correct balancing	1
Observations White solid dissolves (to form a colourless solution) and a colourless (odourless) gas is produced / effervescence is observed.	1
Total	3
Note: State symbols are not required for full marks.	

(c)   A few drops of acidified sodium dichromate solution were added to a sample of propan-2-ol, and the mixture was gently warmed. (3 marks)

Description	Marks
Equation $3\,CH_3CHOHCH_3(l) + Cr_2O_7^{2-}(aq) + 8\,H^+(aq) \rightarrow 3\,CH_3COCH_3(aq) + 2\,Cr^{3+}(aq) + 7\,H_2O(l)$	
Correct species	1
Correct balancing	1
Observations Orange and colourless solutions mix to form a deep green solution.	1
Total	3
Note: State symbols are not required for full marks. Award one mark if a correctly balanced oxidation half-equation is given.	

Question 28 (6 marks)

Describe how you could experimentally determine whether this reaction, as written, is endothermic or exothermic. Include the observations that would allow you to reach this conclusion, and justify your answer using Le Chatelier's principle.

Description	Marks
Increase the temperature of the glass vial.	1
An increase in temperature will favour the endothermic direction in order to use up the heat / decrease the temperature.	1
If the mixture becomes darker brown then the reverse reaction is favoured.	1
Thus the equation is exothermic as written.	1
If the mixture becomes paler brown then the forward reaction is favoured.	1
Thus the equation is endothermic as written.	1
Total	**6**

Alternate response:
- Decrease the temperature of the glass vial.
- A decrease in temperature will favour the exothermic direction in order to produce more heat / increase the temperature.
- If the mixture becomes darker brown then the reverse reaction is favoured.
- Thus the equation is endothermic as written.
- If the mixture becomes paler brown then the forward reaction is favoured.
- Thus the equation is exothermic as written.

Question 29   **(9 marks)**

(a)   Identify the strongest acid. Justify your answer.   (2 marks)

Description	Marks
CCl_3COOH	1
It has the highest K_a value, indicating the ionisation of the acid occurs to the greatest extent. **or** It has the highest K_a value, indicating the highest ratio of product to reactant concentration.	1
Total	**2**
Note: Do not accept 'has the highest K_a value' as only justification.	

(b)   Which salt solution is likely to have turned yellow? Justify your answer.   (3 marks)

Description	Marks
CCl_3COOK	1
The stronger the acid, the weaker the conjugate base. **or** Anions derived from strong acids have little tendency to hydrolyse.	1
Therefore the pH is likely to be (the closest to) 7 and thus yellow.	1
Total	**3**

(c)   Explain why the $CH_2ClCOOK(aq)$ solution turned purple. Use a relevant chemical equation to support your answer.   (3 marks)

Description	Marks
The $CH_2ClCOO^-(aq)$ ion hydrolyses with water to produce $OH^-(aq)$.	1
Therefore $[OH^-] > [H_3O^+]$ and solution will be basic / turn purple.	1
$CH_2ClCOO^-(aq) + H_2O(l) \rightleftharpoons CH_2ClCOOH(aq) + OH^-(aq)$	1
Total	**3**
Note: State symbols are not required for full marks.	

(d)   When cresol red was added to the $CH_2ClCOOK(aq)$ solution, which of these would have been the predominant indicator structure present?   (1 mark)

Description	Marks
Structure A (circled)	1
Total	**1**

Question 30 **(6 marks)**

(a) Identify the oxidant and reductant in this process, using oxidation numbers to support your answer. (2 marks)

Description			Marks
Oxidant	$O_2(g)$	(0) to (-2)	1
Reductant	Fe(s)	(0) to (+3)	1
		Total	**2**
Note: Award one mark if species and oxidation numbers are correct but answers have been given the wrong way around i.e. do not correspond to 'oxidant' and 'reductant'.			

(b) Complete the following table, by giving a brief description of how each method results in a reduced rate of iron corrosion. (4 marks)

Description		Marks
Appling a coat of paint to a steel structure such as the Eiffel Tower.	Prevents oxygen and water from coming into contact with the iron.	1
Connecting the negative terminal of a DC power supply to an underground gas pipeline, and the positive terminal to a protective electrode.	Any two of the following; • This method is called cathodic protection. • The pipeline is held at a negative potential which prevents oxidation. • The protective electrode is oxidised preferentially / oxidation occurs at the protective electrode.	2
Mixing small amounts of chromium with molten iron to produce 'stainless steel'.	Alloying with other metals can change the properties of the iron (resulting in improved corrosion resistance).	1
	Total	**4**

Question 31   (10 marks)

Complete the table below, by drawing the structural formulae for the organic compounds that match each of the descriptions.

Description	Marks
(structural formula: $H-CH_2-CH=CH-CHF-CH_2F$ drawn as full structure with H, double bond between C2 and C3, F atoms on C4 and C5)	2
(structural formula: $H-CH_2-C(CH_3)(OH)-CH_2-CH_3$ drawn as full structure)	2
(structural formula: $H_2N-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-NH_2$ drawn as full structure)	2
(structural formula: $H-CH_2-CH(CH_3)-C(=O)-OH$ drawn as full structure)	2
(structural formula: $H-C(=O)-O-CH_2-CH_2-CH_2-CH_3$ ester drawn as full structure)	2
Total	10

Note:
In each case, one mark may be awarded if structure includes minor error.
Accept either full or semi-structural formulae.

Question 32   **(9 marks)**

(a)   State how the following changes would affect the rate of the forward reaction, once equilibrium had been re-established.   (3 marks)

Description		Marks
Increasing the volume of the system.	decreased	1
Decreasing the temperature of the system.	decreased	1
Increasing the partial pressure of $NH_3(g)$.	increased	1
	Total	**3**

(b)   State how the following changes would affect the position of equilibrium.   (3 marks)

Description		Marks
Increasing the state of subdivision of $NH_4OCONH_2(s)$.	no change	1
Injecting $CO_2(g)$ into the system.	shift left	1
Increasing the volume of the system.	shift right	1
	Total	**3**

(c)   State how the following changes would affect the value of K_c.   (3 marks)

Description		Marks
Increasing the partial pressure of $NH_3(g)$.	no change	1
Decreasing the temperature of the system.	decreased	1
Decreasing the volume of the system.	no change	1
	Total	**3**

Question 33 **(6 marks)**

(a) Write an equation for the buffer that would be formed when a small amount of shampoo is
     mixed with water.   (2 marks)

Description	Marks
$C_6H_8O_7(aq) + H_2O(l) \rightleftharpoons C_6H_7O_7^-(aq) + H_3O^+(aq)$ **or** $C_6H_8O_7(aq) + OH^-(aq) \rightleftharpoons C_6H_7O_7^-(aq) + H_2O(l)$ *	
Correct species	1
Double arrow	1
Total	**2**
Note: Do not award mark for 'double arrow' if equation is incorrect. State symbols are not required for full marks.	

(b) Explain how this buffer maintains its mildly acidic pH, despite the presence of a small
     concentration of $OH^-(aq)$ being produced by the detergents in the shampoo.   (4 marks)
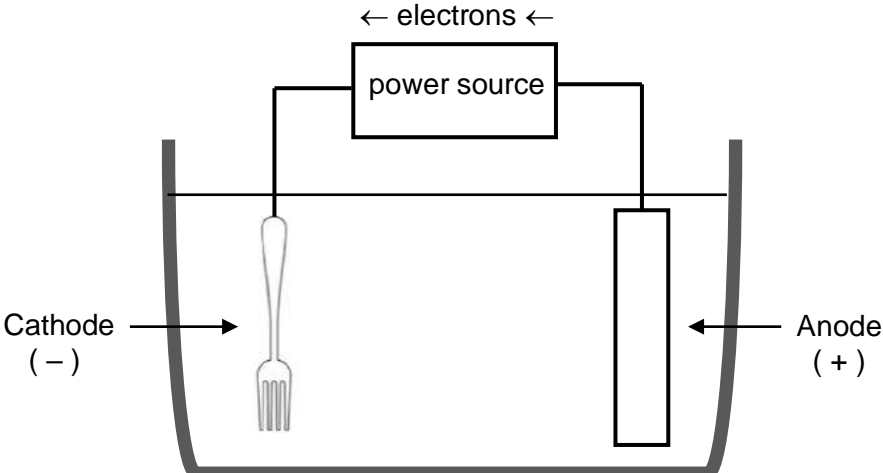
Description	Marks
The $OH^-(aq)$ neutralises and thereby decreases the $[H_3O^+]$.	1
Both forward and reverse reaction rates decrease (due to a decreased frequency of collisions), but the forward rate does not decrease by as much. **or** The reverse reaction rate is decreased, relative to the forward reaction rate.	1
This results in the equilibrium position shifting to the right. **or** This results in the forward reaction being favoured.	1
The $[H_3O^+]$ is thus increased, maintaining pH.	1
Total	**4**
Alternate response (if students have given buffer equation with $OH^-(aq)$ in part (a)*): • The increased concentration of $OH^-(aq)$ increases the frequency of collisions between the reactants. • The forward rate is increased, relative to the reverse reaction rate. • This results in the equilibrium position shifting to the right. • The $[OH^-]$ is thus decreased, maintaining pH. Alternate response: • The $OH^-(aq)$ will react with the conjugate acid buffer component ($C_6H_8O_7$). • $C_6H_8O_7(aq) + OH^-(aq) \rightleftharpoons C_6H_7O_7^-(aq) + H_2O(l)$ • The additional $OH^-(aq)$ is therefore neutralised, forming water. • Since the $[H_3O^+]$ is restored to a similar level, the pH is maintained by the buffer.	

Question 34 (8 marks)

(a) Write balanced oxidation and reduction half-equations, as well as an overall equation for this chemical reaction. (5 marks)

Description	Marks
Oxidation $H_3PO_2(aq) + H_2O(l) \rightarrow H_3PO_3(aq) + 2 H^+(aq) + 2 e^-$	
Correct species	1
Correct balancing	1
Reduction $Ag^+(aq) + 1 e^- \rightarrow Ag(s)$	
Correct species and balancing	1
Overall $H_3PO_2(aq) + H_2O(l) + 2 Ag^+(aq) \rightarrow H_3PO_3(aq) + 2 H^+(aq) + 2 Ag(s)$	
Correct species	1
Correct balancing	1
Total	**5**
Note: State symbols are not required for full marks.	

(b) On the diagram above, label (3 marks)
- the direction of electron flow through the wire,
- the cathode and the anode, and
- the polarity (sign) of the electrodes.

Description	Marks
Electron flow (right to left) labelled	1
Cathode (left) and anode (right) correctly labelled	1
Negative (left) and positive (right) correctly labelled	1
Total	**3**
Example of a three mark response 	
Note: Award mark for labelling polarity either on electrodes or on power source.	

Question 35 **(6 marks)**

(a) Explain, in terms of intermolecular forces, how SDS is able to break apart and destroy these coronavirus particles. (4 marks)

Description	Marks
SDS has both a hydrophilic / polar head and a hydrophobic / non-polar tail.	1
Both the non-polar tail and the cell membrane interact (primarily) through dispersion forces.	1
The polar head is able to interact with the surrounding aqueous environment through ion-dipole forces.	1
This allows the SDS to embed in the cell membrane and disrupt / break apart the virus particles.	1
Total	**4**

(b) Explain why liquid hand wash containing SDS is equally effective in both hard and soft water. (2 marks)

Description	Marks
SDS will not precipitate / form a scum in hard water (as it is a detergent).	1
Therefore the surfactant ions will still be able to perform their cleaning function (equally well in both soft and hard water).	1
Total	**2**

Section Three: Extended answer   **40%   (91 marks)**

Question 36   **(20 marks)**

(a)   Considering the uses above, suggest three (3) physical properties that PEVA is likely to
         have.   (3 marks)

Description	Marks
Any three of the following: • light weight • flexible • soft / squishy • durable • able to be coloured • moldable / easily shaped • waterproof / water repellant	3
Total	**3**

(b)   State whether PEVA is made by addition or condensation polymerisation. Justify your
         answer.   (2 marks)

Description	Marks
Addition polymerisation.	1
Both monomers contain double carbon-carbon bonds / an alkene group.	1
Total	**2**

(c)   Draw a segment of PEVA comprised of four (4) monomer units. Your diagram should take
         into account the percentage composition of the monomers.   (3 marks)

Description	Marks
Polymer segment shows at least one unit of ethylene (monomer 1) drawn correctly	1
Polymer segment shows at least one unit of vinyl acetate (monomer 2) drawn correctly	1
Segment shows 4 units with a 1:3 ratio of ethylene:vinyl acetate	1
Total	**3**
Note: Accept the four monomers joined and oriented in any order. Marks not deducted for terminating ends or inclusion of brackets at ends.	

(d)   Describe why thermoplastic polymers are generally much easier to recycle than thermosetting polymers.   (2 marks)

Description	Marks
When heated, the polymer will melt and can therefore be reshaped.	1
When cooled, the polymer hardens and can therefore been transformed into a new object.	1
Total	**2**

(e)   Explain, in terms of structure and bonding, why crosslinked-PEVA is stronger and has a higher melting point, than regular PEVA .   (4 marks)

Description	Marks
Crosslinking increases the size / length of the polymer chains.	1
This decreases the mobility of the polymer chains / ability of polymer chains to slide past one another (thus making the polymer stronger).	1
The increased M increases the strength of the dispersion forces.	1
Therefore a greater amount of heat is required to disrupt the bonding (resulting in a higher melting point).	1
Total	**4**

(f)   Calculate the maximum volume of gaseous vinyl acetate, measured at 195 °C and 855 kPa, that could be produced. State your final answer to the appropriate number of significant figures.   (6 marks)

Description			Marks
$n(CH_2CH_2)$	=	$(388 \times 10^3) / 28.052$	1
	=	13831.46 mol	
$n(CH_3COOH)$	=	$(471 \times 10^3) / 60.052$	1
	=	7843.20 mol	
CH_3COOH is limiting reagent, since $n(CH_3COOH) < n(CH_2CH_2)$			1
n(vinyl acetate)	=	7843.20 mol	1
V(vinyl acetate)	=	$(7843.20 \times 8.314 \times 468.15) / 855$	1
	=	35704 L	
	=	35.7 kL **or** 3.57×10^4 L (3 SF)	1
Total			**6**

Question 37   **(19 marks)**

(a)   Explain this statement, including two (2) reasons that sodium hydroxide is **not** an appropriate primary standard.   (4 marks)

Description	Marks
The sodium hydroxide is a standard solution because it has an accurately known concentration.	1
Sodium hydroxide is not a primary standard because the solid cannot be accurately weighed and dissolved in water to produce a standard solution.	1
Any two of the following: • Sodium hydroxide is deliquescent • Sodium hydroxide is hygroscopic • The molar mass of sodium hydroxide is too low • Sodium hydroxide reacts with $CO_2(g)$ in the air • Sodium hydroxide is difficult to obtain in pure form / with known purity	2
Total	**4**

(b)   Determine which of the standard NaOH(aq) solutions would be most appropriate for use in this titration. Show all workings.   (3 marks)

Description	Marks
c(lactic acid in fresh milk) = 1.8 g L^{-1} Therefore c(lactic acid) = 1.8 / 28.052 = 0.01998 mol L^{-1}	1
Since the acid and base are reacting in a 1:1 stoichiometric ratio, it is desirable that they have similar concentrations.	1
The chemist should use **0.02073 mol L^{-1}** NaOH(aq) (circled)	1
Total	**3**

(c)   Calculate the concentration of lactic acid in the open milk sample, in grams per litre, and thus determine whether the milk would be classified as 'sour' or not.   (7 marks)

Description			Marks
n(NaOH)	=	0.03141 x 0.02213	1
	=	0.0006951 mol	
n(lactic acid in 25 mL)	=	0.0006951 mol	1
n(lactic acid in 100 mL)	=	0.0006951 x (100/25)	1
	=	0.0027804 mol	
	=	n(lactic acid in 50 mL milk)	1
m(lactic acid in 50 mL milk)	=	0.0027804 x 90.078	1
	=	0.25045 g	
c(lactic acid in 50 mL milk)	=	0.25045 / 0.050	1
	=	5.009 g L^{-1} (i.e. less than 8.1 g L^{-1})	
No, the milk is not sour (circled)			1
		Total	**7**

(d)   Define the 'tertiary structure' of a protein.   (2 marks)

Description	Marks
The folding of the polypeptide chain to produce the overall protein shape.	1
Created by the bonds and interactions between the amino acid side chains.	1
Total	**2**

(e)   Complete the polypeptide segments in the following table, to show how the tertiary structures formed by these amino acids may be disrupted by pH changes.   (2 marks)

Description		Marks

Aspartic acid – low pH
 	
$COOH$
$\mid$
CH_2
$\mid$
- - - - - N — C — C - - - -
  $\mid$ $\mid$ $\parallel$
  H   H   O
	Aspartic acid – high pH
	
	COO^-
	$\mid$
	CH_2
	$\mid$
	- - - - - N — C — C - - - -
	  $\mid$ $\mid$ $\parallel$
	  H H O
		1

Lysine – low pH
 	
$NH_3{}^+$
$\mid$
$(CH_2)_4$
$\mid$
- - - - - N — C — C - - - -
  $\mid$ $\mid$ $\parallel$
  H   H   O
	Lysine – high pH
	
	NH_2
	$\mid$
	$(CH_2)_4$
	$\mid$
	- - - - - N — C — C - - - -
	  $\mid$ $\mid$ $\parallel$
	  H H O
		1

	Total	**2**

(f)   Identify the type of tertiary structure that is predominantly affected by changes in surrounding pH.   (1 mark)

Description	Marks
Ionic bonding	1
Total	**1**

Question 38   **(19 marks)**

(a)   Explain why combustion of biodiesel results in overall lower carbon emissions than petrodiesel.   (2 marks)

Description	Marks
The carbon in biodiesel comes from renewable sources / plant material.	1
Plants have taken CO_2 out of the atmosphere, therefore less overall carbon emissions than diesel from non-renewable fossil fuels.	1
Total	**2**

(b)   Explain, in terms of intermolecular forces, why the cloud point of soy biodiesel is higher than that of petrodiesel.   (4 marks)

Description	Marks
Petrodiesel only exhibits dispersion forces.	1
Biodiesel exhibits dispersion forces of greater strength due to its larger M.	1
Biodiesel also has a polar ester group and therefore exhibits some dipole-dipole forces.	1
Therefore the sum of intermolecular forces in biodiesel is greater than petrodiesel (resulting in a higher cloud point). **or** Therefore a greater amount of energy would be required to overcome the intermolecular forces in biodiesel (resulting in a higher cloud point).	1
Total	**4**

(c)   State the relationship between the percentage of unsaturated fatty acid present in the component triglycerides, and the cloud point of a biodiesel.   (1 mark)

Description	Marks
The higher the percentage of unsaturated fatty acids, the lower the cloud point of the biodiesel.	1
Total	**1**

(d)   Explain the relationship stated in part (c), in terms of intermolecular forces. Your answer should include a definition of 'unsaturated fatty acids'.   (4 marks)

Description	Marks
Unsaturated fatty acids have one or more double carbon-carbon bonds.	1
These double bonds (usually in cis conformation) cause the fatty acid chains to be bent rather than linear.	1
This makes it harder for the molecules to pack together / reduces the surface area in contact between the molecules / reduces interactions between the molecules.	1
Therefore resulting in weaker dispersion forces (and thus a lower cloud point).	1
Total	**4**

(e)   If the yield of this process was 92.1%, calculate the mass of soybean oil that reacted.
                                                                                                        (6 marks)

Description			Marks
m(soy biodiesel)	= =	0.882 x 7545 6654.69 kg	1
	=	6654690 g	1
n(soy biodiesel)	= =	6654690 / 294.462 22599.5 mol	1
n(soybean oil)	= =	22599.5 / 3 7533.16 mol	1
n(soybean oil inc. yield)	= =	7533.16 x (100/92.1) 8179.33 mol	1
m(soybean oil)	= =	8179.33 x 879.354 7192526 g (7.19 t or 7.19 x 10^6 g)	1
		Total	**6**

(f)   Identify two (2) reasons why 'the use of enzymes' is one of the twelve principles of green
        chemistry.   (2 marks)

Description	Marks
Any two of the following: • Allows use of lower temperature and/or pressure • Aligns with less harmful synthesis / use of milder conditions • Can be reused / minimises waste • Purer product formed / less refining required • Results in a lower energy input	2
Total	**2**

Question 39   **(19 marks)**

(a)   Explain, in terms of the chemical processes occurring, how a galvanic cell is able to
         produce an electrical current.   (4 marks)

Description	Marks
Galvanic cells make use of a spontaneous redox reaction.	1
Oxidation occurs at the anode, where electrons are lost.	1
Reduction occurs at the cathode, where electrons are gained.	1
The electrons travel via an external pathway, generating an electric current.	1
Total	**4**

(b)   Calculate the electrical potential difference produced by a **single** lead-acid cell under
         standard conditions.   (1 mark)

Description	Marks
2.05 V	1
Total	**1**

(c)   Calculate the mass of $PbSO_4(s)$ that would have formed at the cathode.   (7 marks)

Description			Marks
$[H^+$ at start]	=	$10^{-0.80}$	1
	=	0.15849 mol L^{-1}	
$n(H^+$ at start)	=	0.15849×0.5	1
	=	0.079245 mol	
$[H^+$ at end]	=	$10^{-3.5}$	1
	=	0.00031623 mol L^{-1}	
$n(H^+$ at end)	=	0.00031623×0.5	1
	=	0.00015811 mol	
$n(H^+$ used)	=	$0.079245 - 0.00015811$	1
	=	0.079097 mol	
$n(PbSO_4$ formed)	=	$0.079097 / 4$	1
	=	0.019772 mol	
$m(PbSO_4$ formed)	=	019772×303.26	1
	=	5.996 g	
		(6.0 g)	
		Total	**7**

(d)   If the initial mass of the $PbO_2(s)$ cathode was 695 g, calculate its final mass.   (3 marks)

Description			Marks
n(PbO_2 used up)	=	n($PbSO_4$ formed)	1
	=	0.019772 mol	
m(PbO_2 used up)	=	0.019772 x 239.2	1
	=	4.7295 g	
Final cathode mass	=	695 – 4.7295 + 5.9960	1
	=	696.3 g	
		Total	**3**

(e)   Explain, in terms of the chemical processes occurring, how a secondary cell becomes recharged. Include the overall balanced redox equation for the recharging reaction occurring in the lead-acid battery.   (4 marks)

Description	Marks
A voltage / electric current is applied to the cell.	1
Thereby forcing a non-spontaneous redox reaction to occur.	1
This reverses the oxidation and reduction processes. **or** This converts the products of the discharge reaction back into reactants.	1
$2\,PbSO_4(s)\ +\ 2\,H_2O(l)\ \rightarrow\ PbO_2(s)\ +\ Pb(s)\ +\ 2\,SO_4^{2-}(aq)\ +\ 4\,H^+(aq)$	1
Total	**4**

Question 40 **(14 marks)**

(a) Complete the table below, regarding each step of this reaction sequence, by identifying;
- the name or formula of any additional reactant(s) required,
- the name or formula of any catalyst required, and
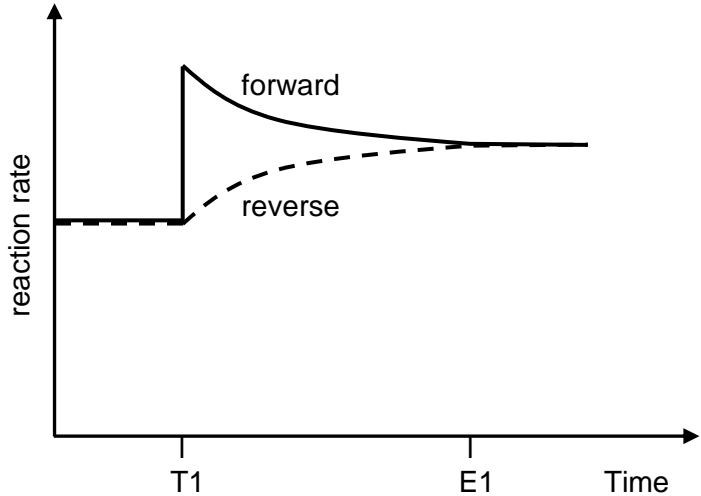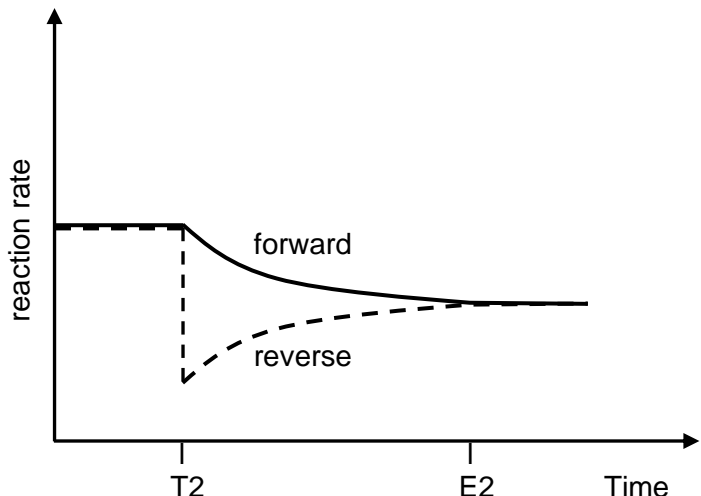- the type of reaction occurring. (7 marks)

	Description			Marks
A	H_2O	H_3PO_4 **or** H^+ **or** H_2SO_4	addition **or** hydration	3
B	MnO_4^- / H^+ **or** $Cr_2O_7^{2-} / H^+$		oxidation **or** redox	2
C		H_2SO_4 **or** H^+	esterification **or** condensation	2
			Total	**7**

(b) State what information the value of K_c provides about this equilibrium system. (1 mark)

Description	Marks
A slightly greater concentration of products than reactants is present at equilibrium. **or** Approximately equal concentrations of products and reactants are present at equilibrium.	1
Total	**1**

(c)   On the axes below, sketch graphs showing the effect of each of these changes on both the forward and reverse reaction rates, from the time of the imposed change until equilibrium is re-established. Consider each change in isolation.   (6 marks)

Description	Marks
(i) Addition of ethanol at Time T1 	
Shape of curves between T1 and E1	1
Forward and reverse correctly labelled	1
Curves merge and become horizontal at E1	1
(ii) Removal of water at Time T2 	
Shape of curves between T2 and E2	1
Forward and reverse correctly labelled	1
Curves merge and become horizontal at E2	1
Total	6
Note: Do not award marks for 'horizontal lines' if curves are sketched incorrectly.	