Government of **Western Australia**
School Curriculum and Standards Authority

CHEMISTRY

ATAR course examination 2019

Marking key

Marking keys are an explicit statement about what the examining panel expect of candidates when they respond to particular examination items. They help ensure a consistent interpretation of the criteria that guide the awarding of marks.

2020/1727
Web Version of 2019/62937

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

Question No.	Answer
1	c
2	c
3	d
4	a
5	a
6	c
7	a
8	b
9	a
10	d
11	a
12	d
13	c
14	a
15	b
16	c
17	b
18	d
19	a
20	d
21	b
22	d
23	b
24	d
25	b

Section Two: Short answer **35% (106 Marks)**

Question 26 **(9 marks)**

(a) Describe the contents of the first and second test tubes once **any** reactions are complete. (4 marks)

Description	Marks
Test Tube I	
• salmon pink (brown/orange/copper colour) solid in	1
• a colourless liquid/solution	1
Test Tube II	
• black solid in a	1
• blue (green) liquid/solution	1
Total	**4**

(b) Write the balanced equation, with appropriate state symbols, for the reaction that takes place between the copper(II) oxide and the hydrochloric acid. (3 marks)

Description	Marks
Correct reactants and products	1
Balanced	1
Correct state symbols	1
Total	**3**
Example of a three mark response: $CuO(s) + 2\ H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(\ell)$	

(c) If the labels of test tubes (II) and (III) became smudged, describe **all** the observations that could be used to distinguish between these test tubes once **any** reactions are complete. (2 marks)

Description	Marks
Test tube II contains a black solid while test tube III contains a green solid	2
Test tube II contains no sign of a gas while test tube III contains colourless bubbles (no colours described)	1
Total	**2**
Note: Colour of solid - reference to both test tubes must be made as they each contain a different colour.	

Question 27 **(13 marks)**

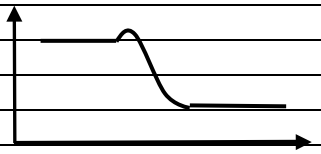
(a) Explain why a basic solution is produced when 'pool chlorine' is dissolved in the pool water. Include an equation in your answer. (4 marks)

Description	Marks
This basicity is due to the hydrolysis of the hypochlorite ion	1
causing an **excess** of $OH^-(aq)$ ions in solution or $[OH^-] > [H^+]$	1
Two marks for an equation	
Correct reactants and products	1
Equation is balanced	1
Total	**4**
Example of a two mark equation: $OC\ell^-(aq) + H_2O(\ell) \rightleftharpoons HOC\ell(aq) + OH^-(aq)$ Alternate equation: $Ca(OC\ell)_2(s) + 2\ H_2O(\ell) \rightleftharpoons 2\ HOC\ell(aq) + Ca^{2+}(aq) + 2\ OH^-(aq)$	
Note: The term 'hydrolysis', while desirable, is not essential; recognition that the hypochlorite ion reacts with water to produce hydroxide ions will suffice. Just saying hydrolysis is insufficient for a mark without referring to the production of the hydroxide ion.	

(b) State what happens to the pH of the pool water when 'pool acid' is added to the pool water. Include an equation to illustrate your statement. (3 marks)

Description	Marks
The pH will decrease as more 'Pool Acid' is added	1
Two marks for an equation	
Correct reactants and products	1
Equation is balanced	1
Total	**3**
Example of a two mark equation: $OC\ell^-(aq) + H_3O^+(aq) \rightleftharpoons HOC\ell(aq) + H_2O(\ell)$ Accept $OC\ell^-(aq) + H^+(aq) \rightleftharpoons HOC\ell(aq)$ $H_3O^+(aq) + OH^-(aq) \rightleftharpoons 2\ H_2O(\ell)$ $H^+(aq) + OH^-(aq) \rightleftharpoons H_2O(\ell)$	

(c) Sketch a clearly-labelled energy profile diagram illustrating the reaction between the 'pool chlorine' and the 'pool acid'. (6 marks)

Description	Marks
Diagram appropriately labelled:	
vertical axis (Potential) Energy or Ep or Enthalpy (H) **and** horizontal axis Reaction Co-ordinate or Reaction Progress	1
reactants on LHS horizontal line **and** products on RHS horizontal line	1
Ea: Activation Energy **and** ΔH: Change in Enthalpy or Heat of Reaction	1
Sketch clearly shows:	
ΔH is negative	1
ΔH is relatively large	1
Ea is very small relative to ΔH.	1
	
Total	**6**

Question 28 **(7 marks)**

(a) What is the oxidation number for the chlorine in:
- calcium hypochlorite, $Ca(OC\ell)_2$
- hydrochloric acid, $HC\ell$? (2 marks)

Description			Marks
Calcium hypochlorite	$Ca(OC\ell)_2$	+1	1
Hydrochloric acid	$HC\ell$	−1	1
		Total	**2**

(b) Write the **two** half-equations showing how chlorine gas is produced from both substances. (5 marks)

Description	Marks
Correctly identifying which half-equation is oxidation and which is reduction	1
Oxidation half-equation	
One mark for correct reactants and products	1
One mark for correct balancing	1
Example of a two mark response: $2\ C\ell^-(aq) \rightarrow C\ell_2(g) + 2e^-$	
Reduction half-equation	
One mark for correct reactants and products	1
One mark for correct balancing	1
Example of a two mark response: $Ca(OC\ell)_2(s) + 4\ H^+(aq) + 2e^- \rightarrow Ca^{2+}(aq) + 2\ H_2O(aq) + C\ell_2(g)$	
Total	**5**

Question 29 **(8 marks)**

(a) Combine these equations to produce an overall equation for the production of dihydrogen sulfate, $H_2SO_4(\ell)$, from sulfur dioxide, $SO_2(g)$. (2 marks)

Description	Marks
One mark for correct products and reactants	1
One mark for correct balancing	1
Total	**2**
Example of a two mark response: $2\ SO_2(g) + O_2(g) + 2\ H_2O(\ell) \rightleftharpoons 2\ H_2SO_4(\ell)$	

(b) Complete the following table by listing the advantages and disadvantages of using high temperatures and high pressures for the reaction represented by Equation 2 above. Consider yield, rate, cost and safety. (6 marks)

Description			Marks
High Temperature			
Advantage	increase rate		1
Disadvantages	two of:	decrease yield, high energy cost **or** high safety hazards, (more) expensive	1–2
High Pressure			
Advantages	increase rate increase yield		1 1
Disadvantage	high cost (of construction and maintaining pressure) **or** high safety hazards		1
		Total	**6**

Note:
- The answers may be expressed in different ways but must clearly indicate these understandings.
- No explanation required.

Question 30 **(15 marks)**

(a) Describe the laboratory process involved in determining the mass of chlorine in this sample of Salvarsan once it has been treated with the acid. You should reference any chemicals used and include a balanced equation in your answer. (6 marks)

Description	Marks
Step 1: React the resultant solution with excess (1) silver nitrate (silver ion) solution (1)	1-2
Step 2: Filter off the precipitate and wash	1
Step 3: Dry the precipitate	1
Step 4: Weigh precipitate	1
One mark for the equation	
Example of a one mark response: $Ag^+(aq) + C\ell^-(aq) \rightarrow AgC\ell(s)$	1
Total	**6**

Note:
- Accept alternative answers such as redox titrations, precipitations or answers that show the appropriate chemistry.

(b) Use this information to calculate the empirical formula of Salvarsan. Show **all** workings. (9 marks)

Description	Marks
Identifying the mass in 100 g (%) for C, H, Cℓ and N **or** converting % to mass in 5.22 g for C, H, Cℓ and N	1
Converting mass of arsenic in 5.22 g sample to 34.1%	1
Determining the % of oxygen	1
Conversion of % by mass to moles	1–4
Determining simplest ratio by dividing all by the factor of 0.455 or 0.456	1
Writing the empirical formula $C_6H_7AsC\ell NO$	1
Total	**9**

Example of a nine mark response:

	C	H	As	Cℓ	N	O
% (mass in 100g)	32.83	3.21	1.78x100/5.22 = 34.1	16.18	6.38	100 – (32.83 + 3.21 + 34.1 + 32.4 + 6.38) = 7.3
n	32.83/12.01 = 2.73	3.21/1.008 = 3.18	34.1/74.92 = 0.455	16.18/35.45 = 0.456	6.38/14.01 = 0.455	7.3/16.0 = 0.456
ratio (/0.455)	6	7	1	1	1	1

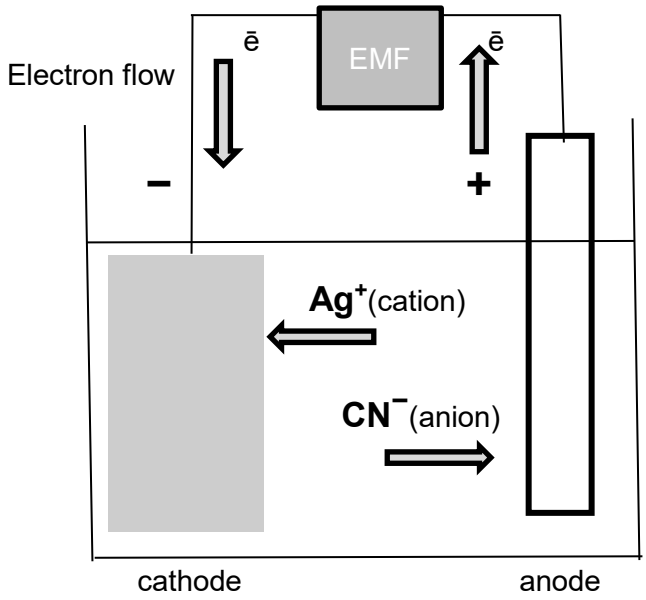
Empirical formula: $C_6H_7AsC\ell NO$

Question 31 **(13 marks)**

(a) Label the above diagram to show the:
- cathode and anode
- direction of electron flow
- direction of ion flow
- polarity (positive/negative) of each electrode. (4 marks)

Description	Marks
Diagram shows correctly labelled:	
cathode and anode	1
direction of electron flow	1
direction of ion flow (must show both ions)	1
polarity (positive/negative) of each electrode.	1
Total	**4**

Example of a four mark response:



Note:
- Allow follow through marks if anode and cathode are reversed.

(b) Explain this difference between these two cells. (3 marks)

Description	Marks
A salt bridge is required in a galvanic cell:	
to maintain electrical neutrality in a cell	1
and any one of the following:	
• to complete the circuit/connect the two cells • required for ion flow • electrons are forced through an external circuit.	1
and any one of the following:	
• a salt bridge is not needed in the electrolytic cell because the reaction is not spontaneous (so no need to separate half cells) • has an external power source.	1
Total	**3**

Note:
- Stating this is an electrolytic cell not a galvanic cell, while true, is insufficient for a mark.

(c) Explain why action is taken to maintain the pH above 8 as a safety precaution during the electroplating process using silver cyanide. (3 marks)

Description	Marks
In acidic conditions: • the cyanide ion (in the electrolyte) can be converted to (the highly toxic) hydrogen cyanide gas, **or** • hydrogen cyanide gas (HCN(g)) is produced	1
One mark each for any two of the following points: • by maintaining a basic pH in the electroplating cell limits the availability of H^+ ions • without hydrogen ions HCN does not form in significantly dangerous concentration • hydrogen cyanide is a weak acid. In the presence of hydroxide ions, the cyanide ion forms, reducing the likelihood of HCN existing in the solution • Equation $HCN(aq) + OH^-(aq) \rightarrow CN^-(aq) + H_2O(\ell)$.	1–2
Total	**3**

Note:

- The question can be answered in terms of equilibrium or candidates could also use hydrolysis of hydrogen cyanide equation.
- A traditional silver-plating solution contains $KAg(CN)_2(aq)$, $KCN(aq)$, and $K_2CO_3(aq)$. When sodium cyanide is added to a solution containing silver ions, AgCN first precipitates then dissolves when after adding more cyanide and cyanide ions are present in excess; the complex ions $[Ag(CN)_2]^-(aq)$ and $[Ag(CN)_3]^{2-}(aq)$ form.
- The electroplating plating of silver using the cyanide complex ions has been simplified for the sake of this question.
- Candidates are not required to know nor refer to the complex ions or processes involved.

Question 31 (continued)

(d) Suggest **three** other safety measures that should be taken during the electroplating process and indicate how each addresses a specific potential hazard to either the workers or the environment. (3 marks)

Description	Marks
One mark for each safety measure linked to a specific hazard (Reference to either the poisonous nature of the cyanide ion **or** the potential production of hydrogen cyanide gas.)	
Answers could include: • recycle and reuse or dispose of used chemicals via chemical dump rather than down drains or directly into the environment to avoid poisoning waterways or groundwater systems • wear a protective apron and face shield whenever there is the slightest chance that you will be splashed to prevent cyanide from being absorbed through the skin • wear gloves when handling cyanide to prevent cyanide from being absorbed through the skin • ensure cyanide is stored in a closed container to avoid breathing in cyanide gas or dust • keep workplaces and stores dry and well ventilated to avoid breathing in cyanide gas or dust • wash and dry the respirator after each use and seal it in a clean plastic bag to avoid breathing in cyanide gas or dust.	1–3
Total	**3**

Note:
- The safety measure must relate directly to the hazard stated.
- While understanding that cyanide is poisonous, it is not required knowledge as the question can be answered by drawing on the information given in the question:
  - the production of hydrogen cyanide, HCN(g), is a highly toxic substance
  - cyanide poisoning is a potential risk.
- Candidates need to demonstrate understanding in identifying a hazard and then explain a related preventative step. Saying ‘cyanide is poisonous so be careful not to come in contact with it’, is insufficient.

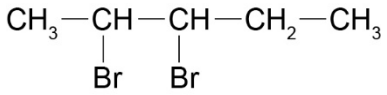
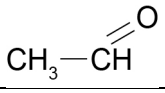
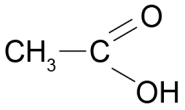
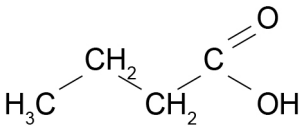
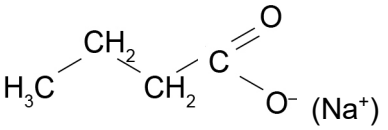
Question 32 **(9 marks)**

From a measuring cylinder, 34.0 mL of 0.114 mol L^{-1} nitric acid, $HNO_3(aq)$, is added to a flask containing 44.5 mL of 0.0556 mol L^{-1} solution of calcium hydroxide, $Ca(OH)_2(aq)$. Determine the pH of the final solution.

Description	Marks
$n(H^+)$ = 0.034 x 0.114 = 3.876 x 10^{-3} mol	1
shows ratio of either H^+ to OH^- or HNO_3 to $Ca(OH)_2$	1
$n(OH^-)$ = 0.0445 x 0.0556 x 2 = 4.9484 x 10^{-3} mol	1
As $n(H^+)$: $n(OH^-)$ is 1:1,	1
H^+ is the limiting reagent due to smaller number of moles (or other justification)	1
$n(OH^-$ excess) = 4.9484 x 10^{-3} − 3.876 x 10^{-3} mol = 1.0724 x 10^{-3} mol	1
$[OH^-]$ = 1.072 x 10^{-3} / 0.0785 = 0.01366 mol L^{-1}	1
$[H^+]$ = 1 x 10^{-14} / 0.01366 = 7.32 x 10^{-13} mol L^{-1}	1
pH = − log 7.32 x 10^{-13} = 12.1	1
Total	**9**

Question 33 **(12 marks)**

Complete the following tables by
(i) writing the structural formula of each compound listed
(ii) writing the structural formula of the organic product from the reaction
(iii) naming the organic product from the reaction.

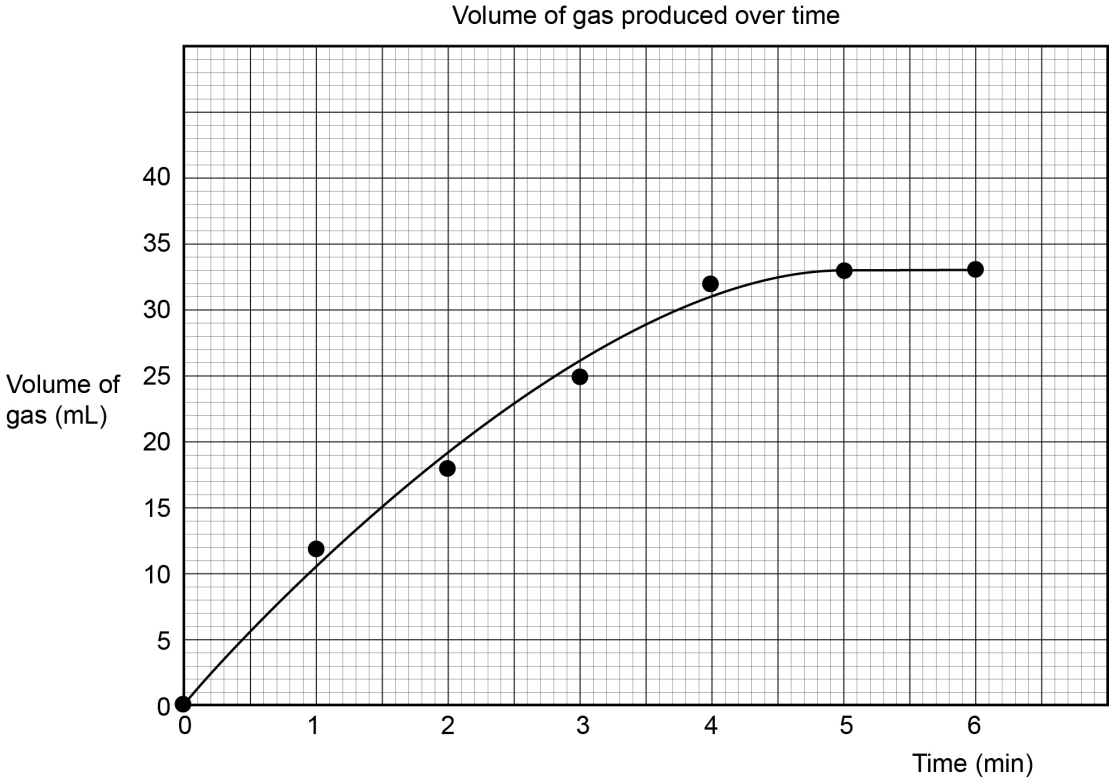
Description		**Marks**
Pent-2-ene reacting with $Br_2(aq)$		
Structural formula of original compound	$CH_3 - CH = CH - CH_2 - CH_3$	1
Structural formula of organic product		
One mark for correct hydrocarbon chain		1
One mark for correct placement of Br atoms		1
Example of a two mark response:		
Name of organic product	2,3-dibromopentane	1
Ethanal reacting with $KMnO_4(aq)/H^+(aq)$		
Structural formula of original compound		1
Structural formula of organic product		
One mark for correct hydrocarbon chain		1
One mark for correct placement of oxygen atoms		1
Example of a two mark response:		
Name of organic product	Acetic acid (ethanoic acid)	1
Butanoic acid(aq) reacting with $Na_2CO_3(aq)$		
Structural formula of original compound		1
Structural formula of organic product		
One mark for correct hydrocarbon chain		1
One mark for correct placement of oxygen atoms		1
Example of a two mark response:		
Name of organic product	butanoate ion/sodium butanoate	1
	Total	**12**

Question 34 **(12 marks)**

(a) Draw a labelled graph of the data provided in the grid below. (4 marks)

Description	Marks
Correctly labelled axes showing names and units	1
Appropriate scale	1
Correctly plotted points	1
Curve of best fit	1
Total	**4**

Example of a four mark response:



Note:
- Axes reversed – maximum 3 marks.
- No marks have been allocated for a title.

Question 34 (continued)

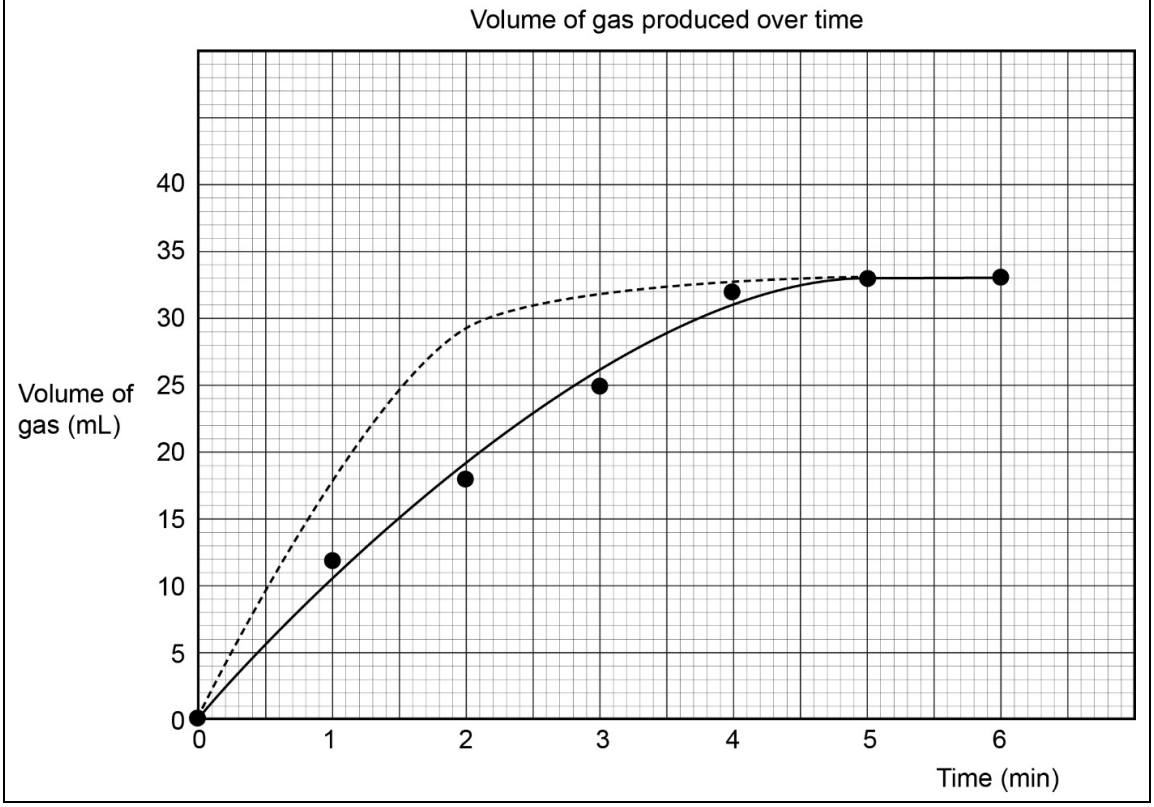
(b) Explain the shape of your graph in part (a) by referring to Collision Theory. (6 marks)

Description	Marks
Recognition that the rate at which carbon dioxide is evolved is a measure of the rate of reaction. The rate of change to the volume of the gas is a measure of reaction rate	1
From 0 to 4 minutes:	
• the slope of the curve decreases (indicates) /rate decreases	1
• concentration of H^+ decreases due to its consumption in the reaction	1
• surface area of $MgCO_3$ decrease	1
• therefore the frequency of collisions decreases.	1
After 4 minutes:	
• the magnesium carbonate all consumed, no more CO_2 produced, curve plateaus.	1
Total	**6**
Note: • For full marks, there must be reference to the specific particles involved in the reaction and the term 'frequency of collision' must be used.	

(c) Sketch and label a line on your graph in part (a) that shows the effect of conducting the same experiment at a higher temperature. (2 marks)

Description	Marks
Initial slope is steeper	1
Levels out earlier	1
Total	**2**

Example of a two mark response:



Question 35 **(8 marks)**

(a) (i) Indicate whether the diprotic acid is most likely to be sulfuric acid, $H_2SO_4(aq)$ or sulfurous acid, $H_2SO_3(aq)$, by **circling** your choice below. (1 mark)

Description	Marks
Sulfurous acid (is circled)	1
Total	**1**

(ii) Making reference to the titration curve shown above, give **two** reasons for your answer. (2 marks)

Description	Marks
One mark for each reason	
Answers could include: • 0.100 mol L^{-1} sulfuric acid would have a starting pH less than 1 • while the starting pH for sulfurous acid would be greater than 1 as it is a weak acid For copyright reasons this text cannot be reproduced in the online version of this document, but may be viewed at the link listed on the acknowledgements page. **or** sulfuric acid is a strong acid so its titration curve would have only one plateaux and one end point • the equivalence point of a strong acid titration is usually listed as 7.00. In the case of sulfuric acid, the second step of dissociation is not that strong, and end point is shifted up by tenths of the pH unit - but still very close to 7 • the first equivalence point is less than 7 (~4.2), the second equivalence point is (~9.6); this indicates a weak acid – thus sulfurous acid.	1–2
Total	**2**

Question 35 (continued)

(b) Predict the effect (increase, decrease or no change) on the calculated concentration of the acid for the following two systematic errors that can occur in a titration and justify your choice. (4 marks)

Description	Marks
Error I	
Circles decrease	1
Justification: • states that the acid solution is diluted (and so amount of NaOH(aq) required to reach equivalence point is less).	1
Error II	
Circles decrease	1
Justification: • states that as only first equivalence point reached, (less NaOH(aq) added than required to completely neutralised acid).	1
or	
Circles no change	1
Justification: • states first equivalence point reached and so requires calculation adjustments	1
Total	**4**
Note: • The justification must be correct for the noted change (increase, decrease, no change) to be allocated a mark.	

(c) State **one** reason why these errors are classified as systematic errors rather than random errors. (1 mark)

Description	Marks
Each error produces volumes of NaOH used that are either consistently above or below the actual value	1
Total	**1**
Note: • Just stating the same mistake is made each time is insufficient for a mark.	

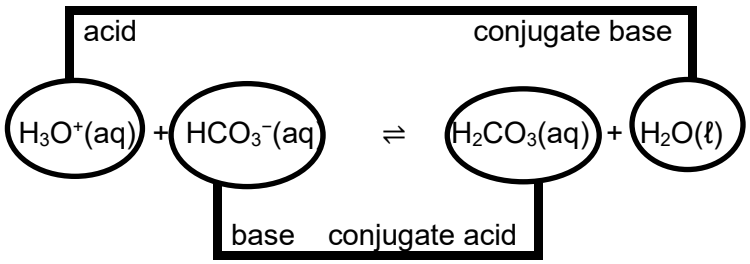
Section Three: Extended answer **40% (109 Marks)**

Question 36 **(20 marks)**

(a) Identify the **two** conjugate acid-base pairs in Equation 1 above, indicating clearly which is the acid and which is the base in each pairing. (2 marks)

Description	Marks
$H_3O^+(aq)$ - acid / $H_2O(\ell)$ – (conjugate) base	1
$HCO_3^-(aq)$ - base / $H_2CO_3(aq)$ – (conjugate) acid	1
Total	**2**

Example of a two mark response:



Note:
- The pairs may be expressed in various ways.
- Full marks may be awarded if the pairing and identification of acid and base is clear.
- One mark may be award if one pair is correct or there is ambiguity but chemical worth.

(b) Write the equilibrium constant expression for Equation 1. (2 marks)

Description	Marks
One mark for including 'K =' in the expression	1
One mark for correct structure of the concentration expression	1
Total	**2**

Example of a two mark response:

$$K = \frac{[H_2CO_3]}{[H_3O^+]\,[HCO_3^-]}$$

Note:
- One mark may be allocated if there is only one minor error
  eg: one charge sign left off.

(c) Combine Equations 1 and 2, to create an overall equation that shows the relationship between $HCO_3^-(aq)$ and $CO_2(aq)$. (2 marks)

Description	Marks
One mark each for:	
• correct products and reactants	1
• correct balancing.	1
Total	**2**

Example of a two mark response:

$$H_3O^+(aq) + HCO_3^-(aq) \rightleftharpoons 2\,H_2O(\ell) + CO_2(aq)$$

Question 36 (continued)

(d) Identify the effect on the blood's pH when each of the following components are removed: carbon dioxide and hydrogencarbonate ions. (2 marks)

Description				Marks
carbon dioxide	(increase)	decrease	no effect	1
hydrogencarbonate ions	increase	(decrease)	no effect	1
			Total	**2**

(e) State **two** conditions in terms of concentration that are necessary for this buffering capacity to be optimal. (2 marks)

Description	Marks
	1
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Total	**2**

(f) Use Le Châtelier's Principle to demonstrate that the kidneys' action can help to prevent excessively high blood pH. (3 marks)

Description	Marks
	1
	1
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Total	**3**

(g) State the effect of the 'paper-bag treatment' on the pH of the blood and explain why it is an effective treatment for hyperventilation. (3 marks)

Description	Marks
	1
	1
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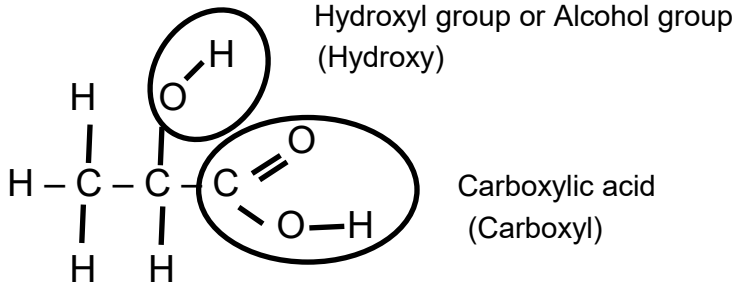
Total	**3**

Note:
- No specific mark is allocated for the equation, $2\ H_2O(\ell) + CO_2(aq) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$, stated in question.
- Le Châtelier's Principle (predicting tool) cannot be used to explain the effect.
- No reference to the re-establishing the oxygen/carbon dioxide balance is required.

(h) Draw the structural formula for lactic acid with **all** its functional groups circled and labelled. (4 marks)

Description	Marks
Drawing of diagram:	
• one mark for correct carbon chain	1
• one mark for correct positions of oxygen atoms	1
• one mark for correctly circling and naming the hydroxyl group	1
• one mark for correctly circling and naming the carboxylic acid.	1
Total	**4**

Example of a four mark response:



Question 37 **(24 marks)**

(a) Explain how detergents are able to remove grease from a surface by referring to the intermolecular forces present. Include a labelled diagram to illustrate your answer. (7 marks)

Description	Marks
Recognition that: • that the non-polar tail of the detergent ion exhibits dispersion forces	1
• which are similar in strength to, and so can overcome, the dispersion forces that exist between the oil molecules and so will dissolve in them	1
Recognition that: • that the charged head of the detergent ion exhibits stronger ion-dipole forces of attraction (and hydrogen bonds) with water molecules	1
• and so overcoming the hydrogen bonding between the water molecules dissolves preferentially in water	1
Demonstrates an understanding that • the grease/oil micelles formed remain suspended in the water and with agitation, can be removed	1
Labelled diagram illustrates:	
• 'tail – grease' interaction (dispersion- dispersion) interaction	1
• 'head– water' (ion-dipole) interaction.	1
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Total	**7**

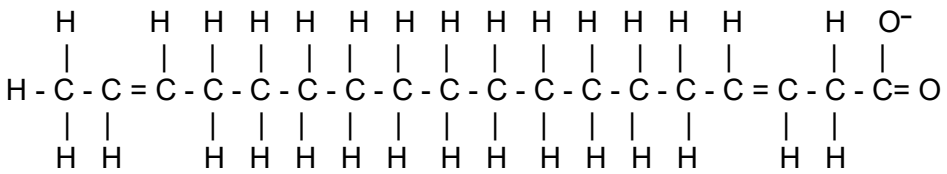
Note:
- Can be answered in terms of having sufficient energy to overcome the forces of attraction.
- Maximum one mark if diagram not clearly labelled.

(b) Explain why soaps are generally less effective than detergents as cleaning agents in hard water. Include a relevant equation in your answer. (4 marks)

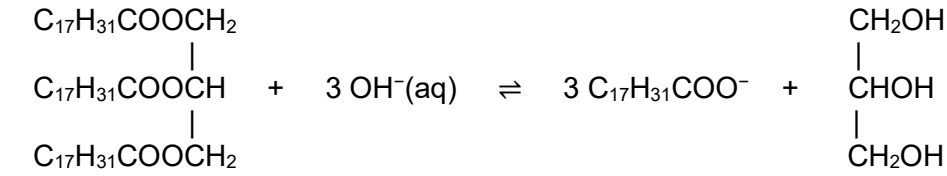
Description	Marks
Detergents do not combine with the ions present in hard water (e.g. Ca^{2+} or Mg^{2+}) to form insoluble precipitates	1
When the precipitate forms with soap (scum) the soap ions are no longer available to form micelles/not available to act as a cleaning agent	1
Equation:	
One mark for valid products and reactants with n > 12	1
One mark for correct balancing	1
Example: $Ca^{2+}(aq) + 2\ CH_3(CH_2)_nCOO^-(aq) \rightarrow Ca(CH_3(CH_2)_nCOO)_2(s)$.	
Total	**4**

Note:
- Any soap molecule is acceptable.

(c) Draw a structural diagram for the soap ion, $C_{17}H_{31}CO_2^-$ using the incomplete structure below. Show **all** atoms and bonds. (2 marks)

Description	Marks
Structural diagram includes:	
• COO^-	1
• all bonds including both double bonds.	1
Total	**2**
Example of a two mark response: 	
Note: • One triple bond instead of two double bonds is acceptable.	

(d) Write an equation showing the formation of this soap from the fat (triglyceride) shown below. (3 marks)

Description	Marks
Equation has:	
• a hydroxide with the fat	1
• correct products	1
• correct balancing.	1
Total	**3**
Example of a three mark response: 	
Note: • No mark penalty for using molecular versions with KOH or NaOH.	

Question 37 (continued)

(e) Predict and explain the conditions that would result in the highest yield of soap in the shortest amount of time. (8 marks)

Description	Marks
Predicts high temperature	1
Explains high temperature and higher rate due to:	
• a greater proportion of particles having sufficient energy to react when they collide	1
• a higher frequency of collision as the average kinetic energy of the particles is higher.	1
• higher yield as the forward rate will increase more than the reverse rate when temperature is increased.	1
Predicts high concentration of (sodium/potassium) hydroxide solution	1
Explains high concentration of sodium hydroxide solution and higher rate due to:	
• (more particles present in same volume, therefore) greater frequency of collisions and so greater number of successful collisions	1
• higher yield as forward reaction will be faster than reverse reaction until equilibrium re-established.	1
States agitation or removal	
Agitation will increase the surface area, increasing the contact/collisions between reacting particles and hence rate (will have no impact on yield) **or** Removal of product (soap/glycerol) as produced to minimise/inhibit reverse reaction	1
Total	**8**

Note:
- In order to achieve full marks, students must refer to the collision theory and reference both rate and yield for temperature and concentration of sodium hydroxide.
- Pressure changes do not affect this reaction.
- Oil/grease does not have a concentration and should not be referred to.
- Catalysts are not used in saponification. No penalty if a catalyst is referenced. Candidates do not need to state that catalysts have no effect on yield.

Question 38 **(18 marks)**

(a) For the following uses as an alternative to glass, identify which polymer would be the more appropriate. Justify your choice of polymer by comparing the effect of **two** relevant properties as listed for both polymers. (4 marks)

Description	Marks
Skylight:	
• justification	1-2
Safety glasses:	
• justification	1-2
Total	**4**

Example of a four mark response:

Use	Choice of polymer	Justification (sample answers)
Skylight	polymethyl methacrylate	• moderate UV resistance is more desirable than low UV resistance as it serves to provide protection from harmful UV radiation • lightweight is more desirable as it minimises added weight to the roof structure
Safety glasses	polycarbonate	• in order to protect eyes, it must have at least moderate chemical resistance to withstand chemical splashes, the low chemical resistance of polymethacrylate would be insufficient. • higher heat resistance is required to avoid melting and burning the wearer when protection from heat or sparks is required.

Note:
No marks are awarded to the choice of polymer as the choice is implied in the justification. The justification must be reasonable and match the polymer chosen for a mark to allocated. The focus of this question is that candidates can identify and reasonably link desirable properties to usage.

Skylight

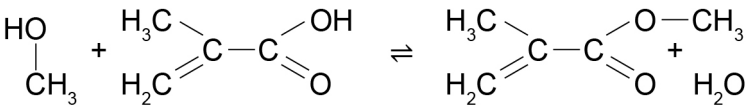
- Polycarbonate as the choice for use as a skylight may be awarded marks if the justifications given reasonably support that argument. For example, it could be argued that its relatively higher:
  - impact strength offers greater protection against hailstorm damage.
  - heat resistance offers longevity as it is in the sunshine all day.
  - chemical resistance offers more protection against; 'acid rain'.

Safety glasses

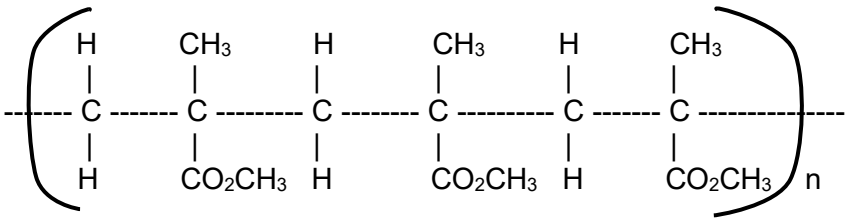
- Marks are only awarded for polycarbonate in use as safety glasses.

Question 38 (continued)

(b) Write a balanced equation for the esterification of methanol and methacrylic acid. Show the full structural formula of each species in the equation. (4 marks)

Description	Marks
Equation shows correct:	
• methanol structure	1
• carboxylic acid structure	1
• structure of the ester	1
• balancing (needs to include water).	1
Total	**4**
Example of a four mark response: 	

(c) Draw a section of a polymethyl methacrylate showing **all** atoms and at least **three** repeating units of the monomer. (3 marks)

Description	Marks
Continuing chain - no terminating ends	1
Correct repeating units (monomer)	1-2
Total	**3**
Example of a three mark response: 	
Note: • No marks for opening and adding into C=O double bonds.	

(d) Suggest an assumption that **must** be made regarding mole ratios of product to reactant for this reaction and then determine the mass of the methylpropenol isomer required to produce 1.50 tonne of methacrylic acid if the efficiency of this oxidation is 65%.
(Note: 1 tonne = 1000 kg.) (5 marks)

Description	Marks
Assumption: $n(C_4H_8O) = n(C_4H_6O_2)$	1
Calculation:	
$n(C_4H_6O_2) = 1.50 \times 10^6 / 86.088$ $= 1.742 \times 10^4$ mol	1
$m(C_4H_8O) = 72.104 \times 1.742 \times 10^4$ $= 1.256 \times 10^6$ g represents 65% efficiency	1
$m(C_4H_8O) = 100/65 \times 1.256 \times 10^6$ $= 1.93 \times 10^6$ g represents 100% efficiency	1
Correct molar masses	1
Total	**5**

(e) Why is polymethyl methacrylate classified as an addition polymer, while polycarbonate is classified as a condensation polymer? (2 marks)

Description	Marks
Polymethyl methacrylate is produced from: • one type of monomer (methyl methacrylate) that • contains a double bond across which two species are added.	1
Polycarbonate is produced from: • monomers with two different (reactive) functional groups. • (Hydrogen chloride is the by-product and so it is classified as a condensation polymer.)	1
Total	**2**

Question 39 **(13 marks)**

(a) Complete the table and determine the average titre. (2 marks)

Description	**Marks**
Table correctly completed	1
Average titre correctly calculated	1
Example of a two mark response: Titration Number / Volume Added (mL) 1 / 19.47 2 / 19.44 3 / 20.34 4 / 19.39 **Average titre** / **19.43(3)**	
Total	**2**

(b) Identify with what solution each of these pieces of glassware should be rinsed prior to their use in these titrations. (3 marks)

Description		**Marks**
Glassware item	**Rinse solution**	
5.00 mL pipette	The (concentrated) herbicide	1
20.00 mL pipette	diluted herbicide	1
250.0 mL volumetric flask	Distilled (deionised) water	1
	Total	**3**

(c) Demonstrate whether or not the experimentally-determined value of the acetic (ethanoic) acid concentration matches the value given on the herbicide label, bearing in mind that a difference of ± 5.00% is considered acceptable. Show **all** workings and reasoning. (8 marks)

Description	Marks
Average NaOH titre volume from part (a) = 0.01943 L	
Moles NaOH on average n = cV = 0.0947 x 0.01943 = 0.001840 mol	1
In 20 mL conical flask $n(CH_3COOH) = n(NaOH) = 0.001840$ mol	1
Concentration = 0.001840 / 0.02 = 0.09200 mol L^{-1}	1
In 250 mL volumetric flask, n = 0.09200 x 0.25 = 0.02300 mol	1
All from 5 mL sample… original concentration = 0.02300 / 0.005 = 4.6001 mol L^{-1}	1
$c(CH_3COOH)$ = 4.6001 x 60.052 = 276 g/L	1
The 5% range 295 is 280.25 – 309.75	1
• No • The experimentally determined concentration of acetic acid of 276.3 g L^{-1} falls outside of the error range (280.25 – 309.75 g L^{-1}) stated on the package and so does NOT match the value given on the herbicide label.	1
Total	**8**

Note:
- If the correct answer is clearly stated, full marks maybe awarded for:
  - the correct calculated concentration and error range is calculated
  - and the calculations and reasoning provided clearly demonstrates a correct method for determining the answer.
- If the answer is incorrect or ambiguous, marks may be awarded to the parts correctly completed as set out above.

Question 40 **(21 marks)**

(a) Calculate the concentration of $A\ell^{3+}$ ions remaining in the 5.0 L of leach solution. Give your answer in grams per litre (g L^{-1}) to the appropriate number of significant figures. (9 marks)

Description	Marks
In 5.0 L $m(Rb^+)$ = 1.30 x 5.0 = 6.5 g	1
$n(Rb^+)$ = m/M = 6.5 / 85.47 = 0.07605 mol	1
$n(A\ell^{3+})$ reacting = $n(Rb^+)$ = 0.07605 mol	1
$m(A\ell^{3+})$ initially present in 5.0 L = 1.86 x 5.0 = 9.3 g	1
$n(A\ell^{3+})$ initially present in 5.0 L = 9.3 / 26.98 = 0.34469 mol	1
$n(A\ell^{3+})$ left in 5.0 L = 0.34469 – 0.07605 = 0.26864 mol	1
$c(A\ell^{3+})$ = 0.26864 / 5.0 = 0.05372 mol L^{-1}	1
= 0.05372 x 26.98 = 1.44963 g L^{-1}	1
= 1.4 g L^{-1} (correct to two significant figures)	1
Total	**9**
Note: • Allow for follow-through marks.	

(b) Was sufficient K_2SO_4 solution added to precipitate all of the $A\ell^{3+}$ ions remaining in the leach solution? Justify your answer with relevant calculations. (4 marks)

Description	Marks
$n(K_2SO_4)$ added = $c(K_2SO_4) \times v(K_2SO_4)$ = 2.63 × 0.055 = 0.14465 mol	1
$n(K^+)$ added = 2 × 0.14465 = 0.2893 mol	1
From equation $n(K^+)$ required = $n(A\ell^{3+})$ = 0.26864 mol (from Part a)	1
$n(K^+)$ added (0.2893 mol) > $n(K^+)$ required (0.26864 mol) Therefore sufficient K_2SO_4 added to precipitate all the $A\ell^{3+}$	1
Total	**4**
Note: • Allow for follow-through marks, from part (a) and also in part (b).	

(c) Write a balanced overall equation to show the conversion of Fe^{2+} to Fe^{3+} by hydrogen peroxide. (3 marks)

Description	Marks
• correct reactants	1
• correct products	1
• correct balancing	1
Total	**3**

Overall equation:

$$H_2O_2(aq) + 2\ H^+(aq) + 2\ Fe^{2+}(aq) \rightarrow 2\ Fe^{3+}(aq) + 2\ H_2O(\ell)$$

Note:

- The overall equation is gained from:

$$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(\ell)$$
$$2 \times (Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-)$$
$$\text{or} \quad 2\ Fe^{2+}(aq) \rightarrow 2Fe^{3+}(aq) + 2e^-$$

(d) Calculate the percentage yield of lithium carbonate, (Li_2CO_3), based on the theoretical amount that should have been recovered. Use the concentration of $Li^+(aq)$ in the table on page 42. (6 marks)

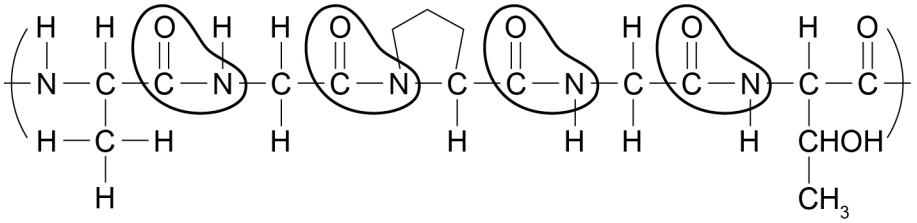
Description	Marks
$n(Li_2CO_3)$ recovered = 46.7 / 73.89 = 0.63202 mol	1
leach solution contains $[Li^+]$ = 2.13 g L^{-1} so, in 5.0 L there will be 2.13 x 5.0 = 10.65 g Li^+	1
$n(Li^+)$ = 10.65 / 6.94 = 1.53458 moles	1
$n(Li_2CO_3)$ = ½ x 1.534582 moles = 0.76729 moles	1
% yield = (0.63202 / 0.76729) x 100	1
= 82.37031 = 82% yield	1
Total	**6**

Question 41 **(15 marks)**

(a) List the names of the amino acids in the order in which they were drawn in the section of the protein given above. Do **not** use abbreviations. (3 marks)

Description	Marks
Has the five amino acids in correct order	2
Has a minimum of three amino acids in correct order	1
Amino acid names written in full	1
Total	**3**
A three mark response: Alanine – Glycine – Proline – Glycine – Threonine	

(b) Circle **one** peptide bond in the above structure. (1 mark)

Description	Marks
One peptide bond is circled	1
Total	**1**
Possible peptide bonds are circled below: 	

(c) What is the difference between the primary structure and the secondary structure of a protein? (2 marks)

Description	Marks
The primary structure of a protein is the sequence of alpha amino acids	1
The secondary structure is: • how the amide and carbonyl groups in a protein chain interact to form alpha helices and beta pleated sheets. **or** Secondary structure results from: • interactions (hydrogen bonding) between amide and carboxyl groups **or** • interactions in the protein chain to form alpha helices and beta pleated sheets.	1
Total	**2**

(d) Explain why the polar carbon compounds dissolve in water but the proteins do not. Illustrate your answer with the aid of a labelled diagram. (6 marks)

Description	Marks
An explanation includes a recognition that:	
• the sum of the forces of attraction (dispersion forces, **dipole-dipole and H-Bonding**) that exist **between** the molecules of the polar carbon compounds and water	1
• are sufficient in strength to overcome	1
• the sum of the forces of attraction (dispersion forces, **dipole-dipole and H-Bonding**) that exist between the molecules **within each** of the polar carbon compounds and water (and so dissolve)	1
• being large molecules, the dispersion forces of attraction between protein molecules is large	1
• the sum of attractive forces (dispersion forces, dipole-dipole and H-bonding) exerted by water molecules are insufficient in strength to disrupt the dispersion forces between the protein molecules (and so do not dissolve in water)	1
• an appropriately labelled diagram that shows the interactions within and/or between the molecules of polar carbon compounds and water.	1
Total	**6**

ACKNOWLEDGEMENTS

Question 31(a) Diagram of silver cyanide solution provided by courtesy of a member of the examining panel

Question 31(d) Text under answers could include adapted from: Department of Commerce.(2014). Cyanide–information on handling, storage and hazards: *Handling*.
Retrieved October, 2019, from
www.commerce.wa.gov.au/sites/default/files/atoms/files/cyanide.pdf

Question 35(a)(ii) Text under answer could include (3rd point) from: Titrations.info. (2009). Sulfuric acid: *End point detection*. Retrieved October, 2019, from
www.titrations.info/acid-base-titration-sulfuric-acid

Question 36(e)(f)(g) Marks descriptions adapted from**:** Casiday, R., & Frey, R. (2012). *Blood, sweat and buffers: pH regulation during exercise acid-based equilibria experiment*, p.7, p.10. Retrieved October, 2019, from
www.chemistry.wustl.edu/~edudev/LabTutorials/CourseTutorials/Tutorials/Buffers/Buffer.pdf

Question 37(a) Diagram of how a detergent works adapted from: Bone, G. (2011). *OCR gateway GCSE separate sciences student book*, p.172. Retrieved October, 2019, from
https://connect.collins.co.uk/repo1/Content/Live/Infuze/COL/GCSE_Science_Separate_SB_OCR_Gateway/content/Page172.htm

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