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**2020**

**BORED OF STUDIES TRIAL EXAMINATION**

# Chemistry

## **Marking Guidelines, Marker's Comments & Exemplar Responses**

## Section I

### Multiple-choice Answer Key

1	2	3	4	5	6	7	8	9	10
B	A	C	D	C	B	A	D	B	D
11	12	13	14	15	16	17	18	19	20
A	B	A	A	B	D	D	C	D	D

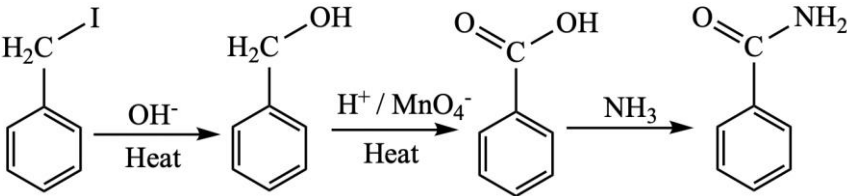
### Multiple-choice Explanations

Question	Ans	Explanation
1	B	<p>Functional group isomers have the same chemical formula but come from a different homologous series. Butanoic acid (<math>\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}</math>) has the formula <math>\text{C}_4\text{H}_8\text{O}_2</math> and methyl propanoate (<math>\text{CH}_3\text{O}(\text{CO})\text{CH}_2\text{CH}_3</math>) has the formula <math>\text{C}_4\text{H}_8\text{O}_2</math> as well. Therefore, they are isomers. They are functional group isomers as one is a carboxylic acid and the other is a ketone.</p> <p>In A, the molecules are isomers but are chain isomers (as only the parent length is different). In C, the molecules are not isomers as they have different formulas. In D, the molecules are isomers but are position and chain isomers.</p>
2	A	<p><math>\text{PbCl}_2(s) \rightleftharpoons \text{Pb}^{2+}(aq) + 2\text{Cl}^-(aq)</math></p> <p><math>K_{sp} = [\text{Pb}^{2+}][\text{Cl}^-]^2</math></p> <p><math>1.70 \times 10^{-5} = (x)(2x)^2</math></p> <p><math>1.70 \times 10^{-5} = 4x^3</math></p> <p><math>x = 0.0162 \text{ mol/L}</math></p> <p>This needs to be converted to g/L, so multiply by the molecular mass.</p> <p>Solubility = <math>0.0162 \times (207.2 + 2(35.45)) \text{ g/L} = 4.50 \text{ g/L}</math> (3 sf)</p>
3	C	<p>A buffer is made from a weak acid/base and its conjugate (one <math>\text{H}^+</math> difference). A has a strong acid and D has a strong acid so these are incorrect. B has a weak acid, however they are not conjugates as there are 2 <math>\text{H}^+</math> difference between them. C has a weak acid <math>\text{H}_2\text{PO}_4^-</math> and its conjugate <math>\text{HPO}_4^{2-}</math>.</p>
4	D	<p>Decolourising of bromine water indicates it has a double bond. Therefore, A is incorrect. Litmus paper turns from red to blue indicating a base, this</p>

		means that B and C are incorrect, as B is an amide (neutral) and C is a carboxylic acid (acidic). Therefore, the answer is D. Purple to colourless with $\text{H}^+/\text{MnO}_4^-$ indicates a primary or secondary alcohol. This group is present in D.
5	C	An ester is made from a carboxylic acid and alcohol. The left portion contains the COO which comes from a carboxylic acid with 2 carbon atoms i.e. ethanoic acid. The right portion comes from an alcohol containing 4 carbon atoms. Based on the connection it is butan-2-ol. Butan-1-ol would instead connect through the end as the OH is on a terminal carbon. The catalyst used is concentrated sulfuric acid.
6	B	The curve is for a weak acid + strong base. This is because initially the conductivity of the acid is being measured as it will be in the conical flask. There is a low conductivity in the graph indicating a lower number of ions (consistent with a partially ionised acid). The base is added from the burette. After the equivalence point only excess base is added and as there is a sharp increase in conductivity this indicates a high number of ions (consistent with a fully ionised base).
7	A	$[\text{NO}_2] = \frac{0.50}{2} = 0.25 \text{ mol/L}$ $[\text{N}_2\text{O}_4] = \frac{0.20}{2} = 0.10 \text{ mol/L}$ $Q = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{0.25^2}{0.10} = 0.625$ <p>Therefore, <math>Q &gt; K_{\text{eq}}</math></p> <p><math>Q</math> must approach <math>K_{\text{eq}}</math> to reach equilibrium so <math>Q</math> must decrease. Therefore <math>[\text{N}_2\text{O}_4]</math> must increase and <math>[\text{NO}_2]</math> must also increase.</p> <p>This is consistent with a left shift.</p>
8	D	The amount of base required in a neutralisation reaction is NOT dependent on the strength of the acid. The strength of the acid is linked to the reaction it has with water when ionised. Both reactions go to completion due to NaOH being a strong base. As both acids are monoprotic it means they will require the same amount of base.
9	B	A blue-green flame test indicates either copper or barium. Addition of sodium sulfate produced no precipitate, so it cannot be barium as it forms insoluble barium sulfate, which was not observed. Copper would not form precipitates with sodium sulfate or sodium chloride.

10	D	Adding KSCN increases $[\text{SCN}^-]$ shifting the equilibrium right (more red). A hot-water bath will increase the temperature shifting the equilibrium to the left as it is an exothermic reaction (more yellow). NaOH precipitates $\text{Fe}^{3+}$ forming insoluble $\text{Fe}(\text{OH})_3$ , therefore removing $\text{Fe}^{3+}$ shifting equilibrium left (more yellow).
11	A	The scenario being described obeys the Beer-Lambert Law: $A = \epsilon lc$ $0.213 = (2.00 \times 10^3)(1.00)c$ $c = 1.065 \times 10^{-4} \text{ mol/L}$ $n = cv = (1.065 \times 10^{-4})(0.010) = 1.065 \times 10^{-6} \text{ mol}$ $m = (1.065 \times 10^{-6})(55.85 + 6(2(1.008) + 16.00))$ $m = 1.75 \times 10^{-4} \text{ g (3 sf)}$
12	B	There are 2 signals in the $^1\text{H}$ -NMR indicating two hydrogen environments. Therefore 1-chloropropane is not possible (it has 3 hydrogen environments) and ethane is not possible (it has 1 hydrogen environment). Propane and 2-chloropropane both have 2 hydrogen environments.  However, the splitting patterns are different. Propane will have a septet and triplet whereas 2-chloropropane will have a septet and doublet.  Therefore 2-chloropropane is the correct answer.
13	A	For the first equation: $\frac{[\text{HI}]^2}{[\text{I}_2][\text{H}_2]} = 50$ This can be transformed into the second equilibrium constant by taking a reciprocal and square rooting so $\frac{[\text{I}_2]^{0.5}[\text{H}_2]^{0.5}}{[\text{HI}]} = \sqrt{\frac{1}{50}} = 0.141$ <p><b>Note:</b> You cannot just half the reaction because this wouldn't take into account that the molar ratios are powers and not coefficients in the <math>K</math> constant expression.</p>
14	A	The monomer contains a double bond, which forms an addition polymer by the breaking of the double bond and connection of repeating monomer units.  By moving all bonds not involved in the double to the vertical position and connecting 3 units, the polymer in option A is formed.

15	B	<p>The mass spectrometer detector only records species that form ions.</p> <p>Option B contains all the possible ions that could be detected and displayed in the mass spectrum.</p>
16	D	$n(\text{Ca}(\text{OH})_2) = cv = (0.040)(0.075) = 0.003 \text{ mol}$ $n(\text{HNO}_3) = cv = (0.040)(0.025) = 0.001 \text{ mol}$ <p>Since calcium hydroxide has two <math>\text{OH}^-</math> ions and nitric acid has one <math>\text{H}^+</math> then</p> $n(\text{OH}^-) = 0.006 \text{ mol}$ $n(\text{H}^+) = 0.001 \text{ mol}$ <p>Excess <math>n(\text{OH}^-) = 0.006 - 0.001 = 0.005 \text{ mol}</math></p> $c(\text{OH}^-) = \frac{n}{v} = \frac{0.005}{0.100} = 0.05 \text{ mol/L}$ $\text{pOH} = -\log_{10} 0.05 = 1.3$ $\text{pH} = 14 - \text{pOH} = 12.7$
17	D	<p>Highest pH indicates the most basic solution (i.e. the strongest base), so A and C are not possible, as these are acids. Option B and D represent the conjugate bases of the acids in A and C (if we remove the <math>\text{Na}^+</math> spectator ion). The <math>\text{p}K_b</math> of the conjugate bases come from: <math>\text{p}K_a + \text{p}K_b = 14</math></p> <p>For <math>\text{NaCHOO}</math>: <math>\text{p}K_b = 14 - 3.7 = 10.3</math></p> <p>For <math>\text{NaOCl}</math>: <math>\text{p}K_b = 14 - 7.5 = 6.5</math></p> <p>A lower <math>\text{p}K_b</math> corresponds to a stronger base.</p> <p>Therefore, <math>\text{NaOCl}</math> will be the stronger base and have the highest pH.</p>
18	C	$2\text{CH}_3\text{COOH}(aq) + \text{Ca}(\text{OH})_2(aq) \rightarrow \text{Ca}(\text{CH}_3\text{COO})_2(aq) + 2\text{H}_2\text{O}(l)$ <p>From graph equivalence point volume is 20 mL of <math>\text{CH}_3\text{COOH}</math>.</p> $n(\text{CH}_3\text{COOH}) = cv = (0.10)(0.020) = 0.002 \text{ mol}$ $n(\text{Ca}(\text{OH})_2) = 0.5n(\text{CH}_3\text{COOH}) = 0.001 \text{ mol}$ $m(\text{Ca}(\text{OH})_2) = (0.001)(40.008 + 2(16.00 + 1.008)) = 0.074096 \text{ g}$ <p>Concentration in g/L</p> $c(\text{Ca}(\text{OH})_2) = \frac{0.074096}{0.010} = 7.4 \text{ g/L (2 sf)}$

19	D	<p>C is a carboxylic acid, B is a primary alcohol and A is a haloalkane.</p> 
20	D	<p> <math>\text{Ca}(\text{NO}_3)_2(aq) + \text{SO}_4^{2-}(aq) \rightarrow \text{CaSO}_4(s) + 2\text{NO}_3^-(aq)</math> </p> $n(\text{CaSO}_4) = \frac{0.2}{40.08 + 32.07 + 4(16.00)} = 0.00147 \text{ mol}$ $n(\text{SO}_4^{2-}) = n(\text{CaSO}_4) = 0.00146 \text{ mol}$ <p>Given</p> $\text{S}(s) + 3/2 \text{O}_2(g) + \text{O}^{2-}(aq) \rightarrow \text{SO}_4^{2-}(aq)$ $n(\text{S}) = n(\text{SO}_4^{2-}) = 0.00147$ $m(\text{S}) = (0.00147)(32.07) = 0.0471 \text{ g}$ $\% m(\text{S}) = \frac{0.0471}{15.0} \times 100 = 0.314\%$

## Section II

### Question 21 (a)

Criteria	Marks
<ul style="list-style-type: none"><li>Provides correct comment about equilibrium position</li></ul>	1

#### *Sample answer:*

$K > 1$  indicating there are more products than reactants, so the equilibrium lies to the right.

#### *Marker's comments:*

This question was well answered by students. The best responses made a clear link to the equilibrium constant definition.

#### *Exemplar student answer:*

(a) What does the value of the equilibrium constant ( $K_{eq}$ ) indicate about the position of the equilibrium?

The value of  $K_{eq} > 1$ , indicating more products are present are present ( $K_{eq} = \frac{[C][D]}{[A]^2}$ ), so equilibrium position lies to the right, towards the products.

### Question 21 (b)

Criteria	Marks
<ul style="list-style-type: none"> <li>Correct equilibrium constant expression</li> <li>Correct RICE table or equivalent to find equilibrium concentrations</li> <li>Correctly finds concentration of B</li> </ul>	3
<ul style="list-style-type: none"> <li>Any two of the above</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above</li> </ul>	1

**Sample answer:**

	$2A(g) \rightleftharpoons B(g) + C(g)$		
	A	B	C
R	2	1	1
I	0.50	0	0
C	$-2x$	$+x$	$+x$
E	$0.50 - 2x$	$x$	$x$

$$K = \frac{[B][C]}{[A]^2}$$

$$4.0 = \frac{x^2}{(0.50 - 2x)^2}$$

$$2.0 = \frac{x}{0.50 - 2x}$$

$$2.0(0.50 - 2x) = x$$

$$1.0 - 4x = x$$

$$5x = 1.0$$

$$x = 0.2 \text{ mol/L (2 sf)}$$

**Marker's comments:**

This question was moderately well answered by students. The best responses used a RICE table in their answer and used a square root instead of expanding and solving a quadratic, although some students were able to arrive at the correct answer using the quadratic.

Many students lost a mark on this question due to simple mathematical errors, such as:

- Incorrectly writing the change for compound A was  $-x$ , when it should be  $-2x$ .
- Solving the quadratic and making substitution errors in the formula or incorrectly assuming that the  $\frac{1}{3}$  mol/L solution was the  $x$  value. In this case the equilibrium concentration of A was  $0.50 - 2x$ . If  $x = \frac{1}{3}$ , the value would be negative.
- Assuming that the approximation of  $0.50 - 2x$  could be made. In this case it cannot, as  $K$  is not a small number at 4.0.



**Exemplar student answer:**

- (b) Initially 5.0 moles of A was added to a sealed 10.0 L container and allowed to come to equilibrium. Calculate the equilibrium concentration of B.

	$2A(g) \rightleftharpoons B(g) + C(g)$	$K_{eq} = \frac{[B][C]}{[A]^2} = 4$
I	0.5      0      0	
C	$-2x$ $+x$ $+x$	$x^2 = 4$
E	0.5 $-2x$ $x$ $x$	$(0.5-2x)^2$

$$\frac{x}{0.5-2x} = 2$$

$$x = 2(0.5-2x)$$

$$x = 1-4x$$

$$5x = 1 \Rightarrow x = \frac{1}{5}$$

Question 21 continues on page 15

$$[B] = 0.2 \text{ mol L}^{-1}$$

$$\approx 0.20 \text{ mol L}^{-1}$$

(2sf)

### Question 21 (c)

Criteria	Marks
<ul style="list-style-type: none"><li>Determines reaction is exothermic</li><li>Provides link to graph (i.e. equilibrium shifting left due to an increase in temperature)</li><li>Links this to either Le Chatelier's Principle or Collision Theory correctly</li></ul>	2
<ul style="list-style-type: none"><li>Any correct statement from the above</li></ul>	1

#### *Sample answer:*

The graph shows the equilibrium is shifting left due to an increase in temperature. [A] increases, while [B] and [C] decrease. This would be consistent with an exothermic reaction. By increasing the temperature, the equilibrium shifts towards the left (the endothermic side) by Le Chatelier's Principle to minimise the disturbance (i.e. decrease heat). This means that the forward reaction (right side) is exothermic.

#### *Marker's comments:*

This question was well answered by students. The best responses included a definition of Le Chatelier's Principle in terms of minimising the disturbance and made reference to the graph in explaining their answer.

#### *Exemplar student answer:*

At time  $T$ , the temperature of the reaction vessel was increased.

Explain with reference to the graph whether the reaction is exothermic or endothermic.

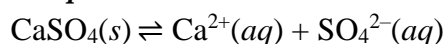
$$2A(g) \rightleftharpoons B(g) + C(g)$$

When the temperature of the reaction vessel is increased, Le Chatelier's principle predicts that the heat ~~is~~ absorbing endothermic reaction will be favoured until a new equilibrium is established.

The increase in the concentration of the reactants and decrease in the concentration of the products <sup>as seen on the graph</sup> indicates that the reverse reaction is favoured. Hence, the reverse reaction is endothermic and the forward reaction is exothermic.

**Question 22 (a)**

Criteria	Marks
<ul style="list-style-type: none"> <li>Finds moles of CaSO<sub>4</sub> or concentration</li> <li>Includes a relevant chemical equation</li> <li>Finds <math>K_{sp}</math> value correctly</li> <li>Finds diluted concentrations</li> <li>Finds <math>Q</math> value correctly AND explains reason for why a precipitate is not formed (i.e. link to saturation has not been reached)</li> </ul>	5
<ul style="list-style-type: none"> <li>Finds all of the above but makes 1 or 2 mistakes</li> </ul>	3-4
<ul style="list-style-type: none"> <li>Finds some of the above points or provides some relevant information</li> </ul>	1-2

**Sample answer:**

$$n(\text{CaSO}_4) = \frac{0.21}{40.08 + 32.07 + 4(16.00)} = 0.00154 \text{ mol}$$

$$c(\text{CaSO}_4) = \frac{n}{v} = \frac{0.00154}{0.100} = 0.0154 \text{ mol/L}$$

$$K = [\text{Ca}^{2+}][\text{SO}_4^{2-}] = (0.0154)(0.0154) = 2.4 \times 10^{-4} \text{ (2 sf)}$$

Both solutions are diluted from 100 mL to 200 mL, therefore the diluted concentrations are:

$$[\text{Ca}(\text{NO}_3)_2] = 0.5 \times 0.0010 = 0.0005 \text{ mol/L}$$

$$[\text{Ca}^{2+}] = [\text{Ca}(\text{NO}_3)_2] = 0.0005 \text{ mol/L}$$

$$[\text{Na}_2\text{SO}_4] = 0.5 \times 0.0010 = 0.0005 \text{ mol/L}$$

$$[\text{SO}_4^{2-}] = [\text{Na}_2\text{SO}_4] = 0.0005 \text{ mol/L}$$

$$Q = [\text{Ca}^{2+}][\text{SO}_4^{2-}] = (0.0005)(0.0005) = 2.5 \times 10^{-7} \text{ (2 sf)}$$

As  $Q < K_{sp}$  no precipitate forms. The solution has not reached the saturation point as the forward reaction (i.e. dissolution) is still favoured.

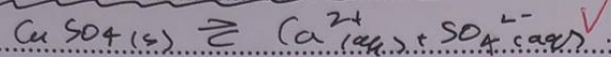
**Marker's comments:**

Most students calculated  $K_{sp}$  correctly. However, mistakes for the  $Q$  calculation included:

- Not accounting for the dilution factor or only finding moles and not concentration.
- Not explaining the answer  $Q < K_{sp}$  statement. For a question with the verb 'predict' the statement  $Q < K_{sp}$  is satisfactory. However, this question with the verb 'explain' requires the reason behind this. This was the determining factor between exemplar responses and 1/3 mark answers.

**Exemplar student answer:**

Consider saturated solution:



$$0.21 \text{ g of } \text{CaSO}_4 \Rightarrow n(\text{CaSO}_4) = \frac{0.21}{136.15} = 0.00154241645$$

$$\therefore [\text{Ca}^{2+}] = [\text{SO}_4^{2-}] = 0.015424... \text{ M} \quad \left( \begin{array}{l} \text{as } \uparrow \text{ moles} \\ \text{is} \\ \text{for } 100 \text{ mL} \end{array} \right)$$

$$\therefore K_{sp} = [\text{Ca}^{2+}][\text{SO}_4^{2-}] = (0.015424...)^2 = 2.379... \times 10^{-4}$$

For second experiment:

$$[\text{Ca}^{2+}] = \frac{0.1 \times 0.001}{0.2} = 0.0005 \text{ M}$$

$$[\text{SO}_4^{2-}] = \frac{0.1 \times 0.001}{0.2} = 0.0005 \text{ M}$$

$$\therefore Q_{sp} = [\text{Ca}^{2+}][\text{SO}_4^{2-}] = (0.0005)^2 = 2.5 \times 10^{-7}$$

$\therefore$  since  $Q_{sp} < K_{sp}$ , the forward reaction is favored to reach equilibrium and so no ppt will form. as the

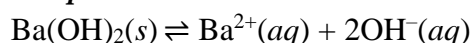
Question 22 continues on page 17

salt will form. Explaining the results of the experiment

### Question 22 (b)

Criteria	Marks
<ul style="list-style-type: none"><li>Relevant chemical equation included (this could be slightly different to the sample answer)</li><li>Provides link to Le Chatelier's Principle or equilibrium shift to explain the lower solubility in NaOH (common ion effect)</li></ul>	2
<ul style="list-style-type: none"><li>Provides one of the above</li></ul>	1

#### Sample answer:



The solubility in the NaOH solution is lower because the presence of  $\text{OH}^{-}$  ions shifts the equilibrium to the left by Le Chatelier's Principle (when an equilibrium system is disturbed it undergoes a chemical reaction to minimise the disturbance) favouring the reverse reaction. This therefore means a precipitate is formed more easily

#### Marker's comments:

This question was well answered by students. The best responses provided a relevant chemical equation and link to equilibrium shifts when explaining their answer.

Students can improve on the following aspects:

- Reading the question carefully as some students forgot to include a chemical equation.
- Understanding the question is asking for 'explain' the results, rather than to provide the calculation for the results in the table. This would not be required for a 2-mark question.

Highlighting and underlining key parts of the question can also assist.

#### Exemplar student answer:

Explain the reason for the large difference in solubility in these cases. Include a chemical equation in your answer.

$\text{Ba}(\text{OH})_2(\text{s}) \rightleftharpoons \text{Ba}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq})$   
when  $\text{OH}^{-}$  is present, the equilibrium is disturbed ( $[\text{OH}^{-}] \uparrow$ )  
and it shifts to the left to remove the extra  $\text{OH}^{-}$  ions  
(common ion effect). (according to Le Chatelier's Principle)  
Thus, more solid  $\text{Ba}(\text{OH})_2$  is produced in NaOH  
compared to water  $\therefore \text{Ba}(\text{OH})_2$  is much more  
soluble in water (0.044M) than NaOH (0.001M)

End of Question 22



### Question 23

Criteria	Marks
<ul style="list-style-type: none"> <li>Links amphiprotic property to proton transfer</li> <li>Provides a relevant chemical equation for acidic behaviour</li> <li>Provides a relevant chemical equation for basic behaviour</li> </ul>	2
<ul style="list-style-type: none"> <li>Any of the above points or partially correct chemical equation</li> </ul>	1

#### Sample answer:

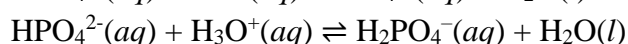
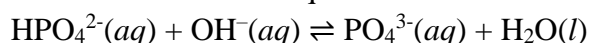
Amphiprotic substances can act as acids ( $\text{H}^+$  donor) or bases ( $\text{H}^+$  acceptor).

$\text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{PO}_4^{3-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$ , shows it acting as an acid as it donates  $\text{H}^+$ .

$\text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{PO}_4^-(\text{aq}) + \text{OH}^-(\text{aq})$ , shows it acting as a base as it accepts  $\text{H}^+$ .

#### Answers could include:

Alternative chemical equations:



#### Marker's comments:

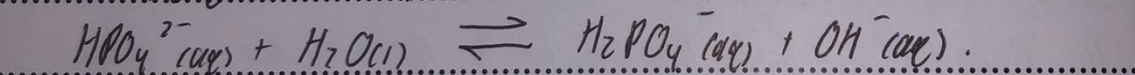
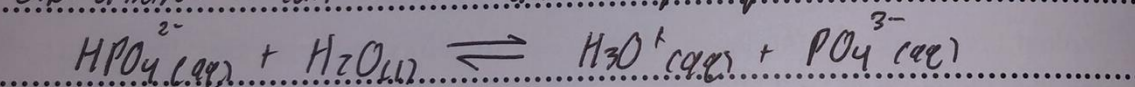
This question was surprisingly poorly answered by a large number of students. The best responses provided a short concise definition of amphiprotic substances and wrote equations without the spectator ion. Students need to recall that  $\text{Na}^+$  ions and other ions such as  $\text{K}^+$  ions are spectator ions and therefore should not be included in the equation. Instead the equations should only be written with  $\text{HPO}_4^{2-}$ . Some responses also had incorrect charges on the ions. Partial marks were awarded in these two cases.

#### Exemplar student answer:

Sodium hydrogen phosphate ( $\text{Na}_2\text{HPO}_4$ ) is an example of an amphiprotic substance.

With reference to TWO chemical equations, explain the term amphiprotic and justify the statement that  $\text{Na}_2\text{HPO}_4$  is amphiprotic.

The term amphiprotic means that the compound can act as an acid and a base. It can donate and accept protons ( $\text{H}^+$ ).



Evident in the chemical equations,  $\text{HPO}_4^{2-}$  can accept and donate protons, meaning that it is amphiprotic.

### Question 24

Criteria	Marks
<ul style="list-style-type: none"> <li>• Correct chemical equation for the dissociation of the base</li> <li>• Correct equilibrium constant expression</li> <li>• Finds the <math>[\text{OH}^-]</math> concentration</li> <li>• Finds pOH</li> <li>• Finds pH</li> </ul>	3
<ul style="list-style-type: none"> <li>• Any 3 or 4 of the above</li> </ul>	2
<ul style="list-style-type: none"> <li>• Any 1 or 2 of the above</li> </ul>	1

*Sample answer:*

	$\text{C}_2\text{H}_5\text{NH}_2(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{C}_2\text{H}_5\text{NH}_3^+(aq) + \text{OH}^-(aq)$		
	$\text{C}_2\text{H}_5\text{NH}_2$	$\text{C}_2\text{H}_5\text{NH}_3^+$	$\text{OH}^-$
R	1	1	1
I	0.10	0	0
C	$-x$	$+x$	$+x$
E	$0.10 - x$	$x$	$x$

$$K = \frac{[\text{C}_2\text{H}_5\text{NH}_3^+][\text{OH}^-]}{[\text{C}_2\text{H}_5\text{NH}_2]}$$

$$5.6 \times 10^{-4} = \frac{x^2}{0.10 - x}$$

As  $K$  is small, can use the approximation  $0.10 - x \approx 0.10$

$$5.6 \times 10^{-4} = \frac{x^2}{0.10}$$

$$x^2 = 5.6 \times 10^{-5}$$

$$x = 0.00748 \text{ mol/L}$$

$$\text{pOH} = -\log_{10} 0.00748 = 2.126$$

$$\text{pH} = 14 - \text{pOH} = 11.87 \text{ (2 dp)}$$

**Marker's comments:**

Those students who were able to correctly write the equation and equilibrium expression were in most cases able to correctly arrive at the answer. The better responses made use of a RICE table.

Students can improve on:

- Justifying why they made an approximation if the quadratic formula wasn't used.
- Rounding their final answer to decimal places instead of significant figures. For calculations involving logarithms the rounding is after the decimal place, so in this case 2 decimal places.

Although no marks were deducted in this instance for these two aspects if the question was 4 marks deductions would have been made for these things.

**Exemplar student answer:**

Calculate the pH of a 0.10 M solution of ethanamine.

$$\text{C}_2\text{H}_5\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_2\text{H}_5\text{NH}_3^+(\text{aq}) + \text{OH}^-(\text{aq})$$

I	0.1	0	0
C	-x	+x	+x
E	0.1-x	x	x

$$K_b = \frac{[\text{OH}^-][\text{C}_2\text{H}_5\text{NH}_3^+]}{[\text{C}_2\text{H}_5\text{NH}_2]} = \frac{x^2}{0.1-x}$$

but as weak base, so  $K_b$  small, so  $0.1 \gg x$  so  $0.1 - x \approx 0.1$

$$\therefore K_b = 5.6 \times 10^{-4} = \frac{x^2}{0.1} \quad x^2 = 5.6 \times 10^{-5}, \quad x = 7.4833 \times 10^{-3}$$

$$\therefore [\text{OH}^-] = x = 7.4833 \times 10^{-3} \text{ M}$$

$$\text{pOH} = 2.1259$$

$$\text{pH} = 14 - \text{pOH} = 11.874$$

$$= 11.87 \quad (2. \text{ d.p.})$$

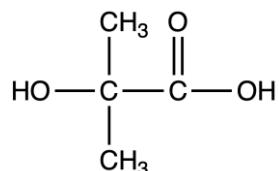
↓  
as initially 2.s.f



**Question 25 (a)**

Criteria	Marks
<ul style="list-style-type: none"><li>Provides correct structure of the monomer</li></ul>	1

*Sample answer:*



*Marker's comments:*

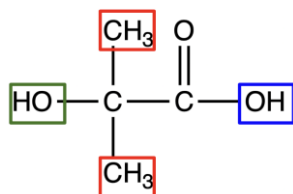
This question was well answered by students. Some students can improve their answer by recalling for a condensation polymer, water needs to be added back into the monomer unit.

**Question 25 (b)**

Criteria	Marks
<ul style="list-style-type: none"><li>Identifies correct number of peaks</li></ul>	1

*Sample answer:*

There are 3 hydrogen environments therefore 3 peaks, as labelled below:



*Marker's comments:*

This question was well answered by most students.

### Question 25 (c)

Criteria	Marks
<ul style="list-style-type: none"> <li>Finds molar mass of monomer with OR without water</li> <li>Correctly finds number of monomer units</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above correctly completed or finds number of monomer units without the removal of water</li> </ul>	1

#### Sample answer:

A condensation polymerisation follows:  $N$  monomer  $\rightarrow$  Polymer +  $(N - 1)$  Water

This is because for a polymer made up of  $N$  monomers, there are  $N - 1$  linkages between these monomers. Since each linkage created releases water in the polymerisation process then there are also  $N - 1$  water molecules. The monomer chemical formula is  $C_4H_8O_3$

Molar mass of monomer =  $4(12.01) + 8(1.008) + 3(16.00) = 104.104 \text{ g/mol}$

Molar mass of water =  $2(1.008) + 16.00 = 18.016 \text{ g/mol}$

$N \times \text{Molar mass of monomer} = \text{Molar mass of polymer} + (N - 1) \times \text{Molar mass of water}$

$$104.104N = 1.29 \times 10^5 + (N - 1)18.016$$

$$104.104N = 1.29 \times 10^5 + 18.016N - 18.016$$

$$86.088N = 1.2898 \times 10^5$$

$$N = 1498.26 = 1500 \text{ (3 sf)}$$

#### Marker's comments:

This question was fairly well answered by students. Some students lost marks on not accounting for the water loss or making simple mathematical errors in rearranging equations. Some students used other approaches to the question which were awarded the full marks provided the correct answer was found.

#### Exemplar student answer:

(c) The molecular weight of the polymer formed was  $1.29 \times 10^5 \text{ g/mol}$ . 2

Using your structure from part (a), determine the number of monomer units required to produce a polymer with this molecular weight.

mm (monomer) =  $104.104 \text{ g/mol}$

mm ( $H_2O$ ) =  $18.016 \text{ g/mol}$

when forming polymer with  $k$  monomers, you lose  $k-1$   $H_2O$  molecule

$\therefore 1.29 \times 10^5 = 104.104 \times k - 18.016(k-1)$

$128981.984 = 86.088k$

$k = 1498.2574$

$\therefore$  need 1499 such monomers (round up as 1498 would not be sufficient)

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## Question 26

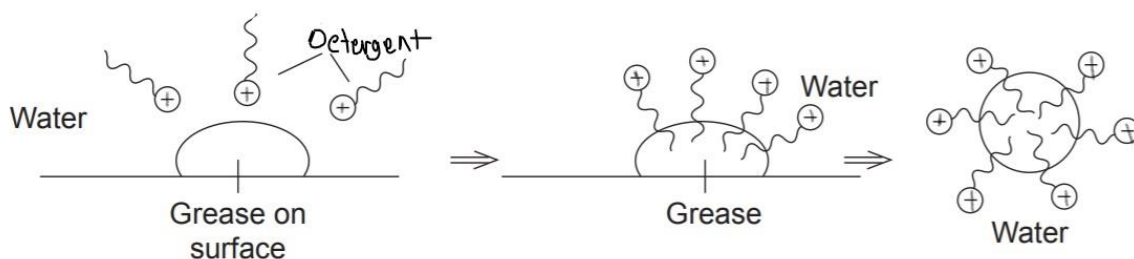
Criteria	Marks
<ul style="list-style-type: none"> <li>Explains why soap is ineffective in hard water (precipitates) while cationic detergent is still effective</li> <li>Explains cleaning action with reference to the hydrophobic and hydrophilic parts of soap and how they bind to oil and water</li> <li>Mentions the intermolecular force(s)</li> <li>Provides labelled relevant diagram(s)</li> </ul>	4
<ul style="list-style-type: none"> <li>All of the above but missing one point</li> </ul>	3
<ul style="list-style-type: none"> <li>Missing two points (or missing a point and wrong statement given)</li> </ul>	2
<ul style="list-style-type: none"> <li>One relevant piece of information or point from the above</li> </ul>	1

### Sample answer:

Soap is ineffective in hard water as it makes a precipitate. This stops their cleaning ability as they are unable to form micelles:



The cationic detergent cannot make precipitates in hard water as the head group is positively charged so will repel  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions. Therefore, it is still effective in hard water. The hydrophobic hydrocarbon tail forms dispersion forces with oil molecules and the hydrophilic head forms ion-dipole forces with water molecules. These forces lead to the formation of a micelle and stable emulsion. A scrubbing action then removes oil off from the surface and leaves the object clean.



Source: [NESA 2019 Additional Questions](#)

### Marker's comments:

This question was fairly well answered by students with most receiving  $\frac{3}{4}$  or all marks.

The key distinctions between these responses with those scores were:

- No diagram(s) included. Students need to remember to read the question carefully to not miss important details. Stronger responses included these diagram(s) and they were well labelled in most cases and assisted in supporting their response.
- Including a chemical equation. This was not required for the full marks, but students who included this were able to better justify the poor cleaning action of soap.
- Stronger responses made reference to the intermolecular forces (dispersion and/or ion-dipole forces). This was the main reason students did not get full marks. Mentioning these forces is important as it is what leads to the tail binding to oil and the head group binding to water.

Another general comment is that students should be more concise. The exemplar response shown below shows how this can be achieved. Some responses which received full marks wrote almost double compared to this with the same information. This highlights an inefficient allocation of exam time and how the choice of words can impact the length of a response.

### Exemplar student answer:

Compare the cleaning action of the soap molecule and cationic detergent when removing oil from surfaces in hard water. Include a diagram(s) to support your answer.

Both soaps and cationic detergents have a hydrophobic, non-polar, hydrocarbon tail that forms dispersion forces with the oil molecules. They both act as surfactants, reducing the surface tension of water so it spreads more on the surface. The cationic detergent's quaternary ammonium ion head will form dipole-dipole forces with the hard water, <sup>causing</sup> ~~causing~~ a micelle to be formed as a <sup>hard</sup> suspension in water. However, the soap molecule will form insoluble salts in hard water, causing the soap to form calcium precipitates. This causes the soap to be unable to act as a bridge between the oil and water, causing it to be unable to clean grease off surfaces.

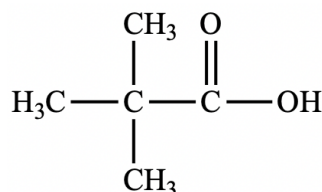
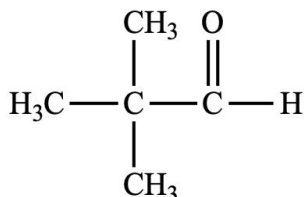
The diagrams illustrate the mechanisms of cationic detergents and soaps. The left diagram, titled 'Cationic Detergent:', shows a surfactant molecule with a wavy hydrophobic tail and a quaternary ammonium head (N<sup>+</sup> with four methyl groups). The tail is shown interacting with an oil droplet on a surface via 'd-d forces' (dispersion forces). The head is shown interacting with water molecules via 'dipole-dipole (d-d) forces'. A note '(O denotes H<sub>2</sub>O)' is included. The right diagram, titled 'Soap', shows a chemical reaction where a soap molecule (represented as a wavy tail and a carboxylate head, -COO<sup>-</sup>) reacts with a calcium ion (Ca<sup>2+</sup>) from hard water. The product is an insoluble calcium soap precipitate, shown as a wavy tail and a -COO-Ca<sup>2+</sup> head, labeled 'insol.'.

## Question 27

Criteria	Marks
<ul style="list-style-type: none"> <li>Analysis of IR spectrum</li> <li>Analysis of mass spectrum</li> <li>References the reactivity in their answer</li> <li>Analysis of <math>^1\text{H}</math>-NMR (must reference to all of signal amount, integration and splitting/multiplicity)</li> <li>Analysis of <math>^{13}\text{C}</math>-NMR (comments on signal amount, needs to make at least one assignment of a certain chemical shift)</li> <li>Structure of A correctly drawn</li> <li>Structure of B correctly drawn</li> </ul>	5
<ul style="list-style-type: none"> <li>Missing one or two of the above OR incomplete analysis OR partially incorrect structure(s)</li> </ul>	4
<ul style="list-style-type: none"> <li>Makes reference to at LEAST 3 of the above with partially correct structures</li> </ul>	2-3
<ul style="list-style-type: none"> <li>Provides one of the above pieces of relevant information</li> </ul>	1

### Sample answer:

Compound A (left), Compound B (right)



**Reactivity:** Compound A is an aldehyde or primary alcohol as it oxidises to produce Compound B a carboxylic acid as it gives off bubbles when  $\text{Na}_2\text{CO}_3$  is added.

**IR:** Strong sharp peak at  $1700\text{ cm}^{-1}$  ( $\text{C}=\text{O}$ ) and collection of strong sharp peaks at  $2600\text{--}2950\text{ cm}^{-1}$  ( $\text{C-H}$ ). The IR indicates Compound A is an aldehyde.

**MS:** 86 m/z molecular ion peak, consistent with  $\text{C}_5\text{H}_{10}\text{O}$  as  
Molar mass =  $5 \times 12.01 + 10 \times 1.008 + 16.00 = 86.13$

**$^{13}\text{C}$ -NMR:** Has 3 peaks indicating 3 carbon environments. 208 ppm is  $\text{C}=\text{O}$  in an aldehyde, 52 ppm is  $\text{C}-\text{C}=\text{O}$  and 28 ppm is  $\text{C}-\text{C}$ .

**$^1\text{H}$ -NMR:** Has 2 peaks indicating 2 hydrogen environments. 1.3 ppm - singlet with 9H integration ( $3 \times \text{CH}_3$  with no hydrogen neighbours), 9.6 ppm - singlet with 1H integration ( $\text{CH}$  with no hydrogen neighbours).



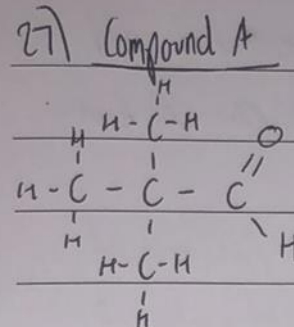
### Marker's comments:

This was well answered by most students who received a 4/5 or all marks. The best responses were concise (e.g. used headings) and made reference to all of the features on the spectra.

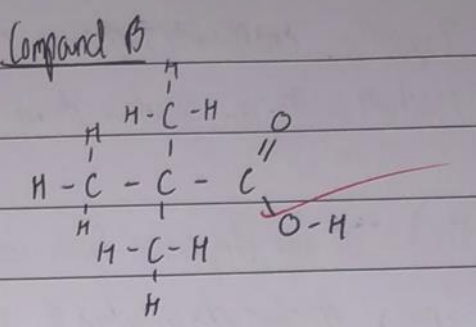
The main distinction between the responses receiving those marks was the discussion of the  $^{13}\text{C}$ -NMR and  $^1\text{H}$ -NMR. Very few students made an assignment of peaks in the  $^{13}\text{C}$ -NMR and reference to the multiplicity and integration in the  $^1\text{H}$ -NMR in justifying their structures.

### Exemplar student answer:

27) Compound A



Compound B



Since compound A oxidises to form compound B, evident in the decolourisation of acidified ~~potassium~~ permanganate, it must be a primary alcohol, a secondary alcohol or an aldehyde. Since compound B produces bubbles when in the presence of sodium carbonate, it must be a carboxylic acid, undergoing a neutralisation reaction. Hence, compound A must be a primary alcohol or an aldehyde. The absence of an absorption at  $> 3100\text{cm}^{-1}$  in compound A's IR spectrum indicates that no hydroxyl ( $-\text{OH}$ ) functional group is present. Hence, compound A must be an aldehyde<sup>(\*)</sup>. The molecular ion peak in its mass spectrum indicates that it has a molecular mass of  $86\text{g mol}^{-1}$ , meaning ~~indicating~~ that it must be an isomer of pentanal.

continued on extra paper

End of Question 27

<sup>(\*)</sup> This is reinforced by the absorption at  $\approx 1700\text{cm}^{-1}$ , corresponding to a carbonyl ( $\text{C}=\text{O}$ ) functional group.

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The  $^{13}\text{C}$  NMR spectrum displays three peaks indicating that there will be identical carbon environments. The tall peak at  $25\text{ ppm}$  corresponds to the three terminating methyl groups of the aldehyde, reinforced by the 9H integration of the peak at  $1.3\text{ ppm}$  on the  $^1\text{H}$  NMR spectrum. The peak at  $207\text{ ppm}$  on the  $^{13}\text{C}$  NMR spectrum refers to the carbon environment containing the  $-\text{CHO}$  aldehyde functional group. This is the singlet on the  $^1\text{H}$  NMR spectrum, with a significantly larger chemical shift due to its close proximity with the oxygen atom. As a result, the only structure that compound A can take is 2,2-dimethylpropanal. Compound B is the carboxylic acid formed from oxidising B and hence, can only have the structure as seen above.

### Question 28 (a)

Criteria	Marks
• Provides a balanced chemical equation with states AND catalyst	1

**Sample answer:**

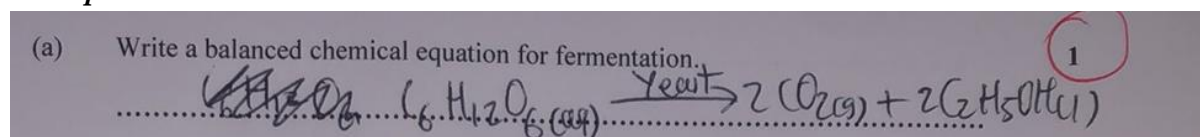


**Marker's comments:**

This was surprisingly a question that more than 50% of students lost a mark on. Students need to remember to include the catalyst for certain reactions in the Module 7 Organic Chemistry section. In this case of fermentation, the catalyst yeast must be specified on the arrow, as the reaction will not occur without this important condition.

Writing zymase on the arrow was also accepted (as the enzyme in yeast).

**Exemplar student answer:**



### Question 28 (b)

Criteria	Marks
• Provides the reason that anaerobic conditions are needed	1

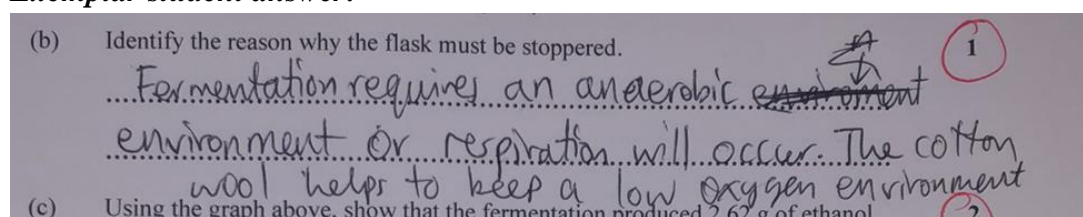
**Sample answer:**

Fermentation is a chemical process that requires an anaerobic (low oxygen) environment. The use of the cotton wool provides a partial seal to the flask decreasing the amount of oxygen flowing in.

**Marker's comments:**

This was another question many students lost a mark on. Common wrong answers included, it is to prevent carbon dioxide loss or ethanol evaporation. The key point that many students missed is anaerobic conditions doesn't mean absence of oxygen, rather a low oxygen amount, so the cotton wool will be a satisfactory seal to keep out the large majority of inflowing oxygen.

**Exemplar student answer:**





### Question 28 (c)

Criteria	Marks
<ul style="list-style-type: none"> <li>Calculates moles of carbon dioxide from the graph</li> <li>Correctly shows mass of ethanol formed is 2.62 g</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above included</li> </ul>	1

#### Sample answer:

The mass loss is due to CO<sub>2</sub> being lost

$$m(\text{CO}_2) = 120.0 - 117.5 = 2.5\text{g}$$

$$n(\text{CO}_2) = \frac{2.5}{12.01 + 2(16.00)} = 0.0568 \text{ mol}$$

$$n(\text{C}_2\text{H}_5\text{OH}) = n(\text{CO}_2) = 0.0568 \text{ mol}$$

$$m(\text{C}_2\text{H}_5\text{OH}) = 0.0568 \times (2(12.01) + 6(1.008) + 16.00) = 2.62 \text{ g (3 sf)}$$

#### Marker's comments:

This question was mostly well answered by students. Some students did not understand why the mass was being lost and incorrectly made assumptions such as it was due to ethanol being made. Students need to recall that the Law of Conservation of Mass means that during a chemical reaction the mass does not change, so therefore the mass lost cannot be due to a substance being made, but rather in this case loss of carbon dioxide from the system into the environment.

#### Exemplar student answer:

(c) Using the graph above, show that the fermentation produced 2.62 g of ethanol. 2

$m(\text{CO}_2) \text{ lost from graph} = 120 - 117.5 = 2.5\text{g}$

$n(\text{CO}_2) = \frac{m}{\text{MM}} = \frac{2.5}{44.01} = 0.056 \dots \text{mole}$

$n(\text{C}_2\text{H}_5\text{OH}) = n(\text{CO}_2) \text{ (1:1 ratio)}$

$n(\text{C}_2\text{H}_5\text{OH}) = 0.056 \dots \text{moles}$

$m(\text{C}_2\text{H}_5\text{OH}) = n \times \text{MM} = (0.056 \dots)(12.01 \times 2 + 6 \times 1.008 + 16)$

$m(\text{C}_2\text{H}_5\text{OH}) = 2.62\text{g (3sf)}$

Question 28 continues on page 24

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### Question 28 (d)

Criteria	Marks
<ul style="list-style-type: none"> <li>Finds <math>\Delta H</math></li> <li>Finds moles of ethanol</li> <li>Finds molar heat of combustion</li> <li>Finds percentage heat lost</li> </ul>	4
<ul style="list-style-type: none"> <li>All of the above but missing one point</li> </ul>	3
<ul style="list-style-type: none"> <li>Two of the above correctly found</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above correctly found</li> </ul>	1

#### Sample answer:

$$\Delta H = mc\Delta T = (0.200)(4.18)(29.5 - 20.0) = 7.942 \text{ kJ}$$

$$n(\text{C}_2\text{H}_5\text{OH}) = \frac{2.62}{2(12.01) + 6(1.008) + 16.00} = 0.0568 \text{ mol (or taken from part (c))}$$

To calculate heat absorbed by the can of water per mole of ethanol

$$\Delta H_c = \frac{7.942}{0.0568} = 139.8 \text{ kJ/mol}$$

The proportion of heat absorbed by the can of water is

$$\% \text{ Heat absorbed} = \frac{139.8}{1370} \times 100 = 10.21\%$$

$$\% \text{ Heat lost} = 100\% - 10.21\% = 89.8\% \text{ (3 sf)}$$

#### Marker's comments:

Most students were able to correctly find the percentage of heat lost. Some students incorrectly stopped at 10.2% for heat lost. This would instead be the heat absorbed as it has contributed to increasing the temperature of the water.

#### Exemplar student answer:

Question 28 (continued)

(d) The enthalpy of combustion of ethanol is 1370 kJ/mol. The 2.62 g of ethanol produced was used to heat 200 mL of water in a can from 20.0°C to 29.5°C.

Calculate the percentage of heat lost to the environment.

$\Delta H = \frac{mc\Delta T}{n}$   $n = \frac{m}{M_m}$   $= \frac{2.62}{2(12.01) + 6(1.008) + 16} = 0.0568 \text{ mol}$

$mc\Delta T = (0.2)(4.18)(29.5 - 20)$

$= 7.942 \text{ kJ}$

$\therefore \Delta H = \frac{7.942}{0.0568} = 139.8 \text{ kJ mol}^{-1} \text{ (3 sf)}$

$\% \text{ loss} = \frac{1370 - 139.8}{1370} \times 100 = 89.8\% \text{ (3 sf)}$

4

### Question 29

Criteria	Marks
<ul style="list-style-type: none"><li>Analyses enthalpy of the two reactions correctly</li><li>Analyses entropy changes in terms of disorder and justifies changes</li><li>Calculates Gibbs Free Energy correctly</li><li>Links spontaneity to sign of Gibbs Free Energy</li></ul>	4
<ul style="list-style-type: none"><li>All of the above but missing one point OR incomplete analysis of the entropy and enthalpy</li></ul>	3
<ul style="list-style-type: none"><li>Two of the above points included</li></ul>	2
<ul style="list-style-type: none"><li>One of the above points included</li></ul>	1

#### *Sample answer:*

**Combustion:** exothermic process as heat is released (-715 kJ/mol). Entropy is a measure of disorder in a system. The entropy change for combustion is positive which indicates that disorder is increasing. This is because the C is changing from solid to CO<sub>2</sub> gas.

$$\Delta G = \Delta H - T\Delta S = (-715) - (25 + 273)(0.0029) = -716 \text{ kJ/mol (3 sf)}$$

Since  $\Delta G < 0$  then the reaction does not require input energy and is spontaneous.

**Photosynthesis:** endothermic process which absorbs heat (+2803 kJ/mol). Entropy decreases as the entropy change is negative. This is because 12 particles become 7 particles in the reaction.

$$\Delta G = \Delta H - T\Delta S = (2803) - (25 + 273)(-0.212) = 2870 \text{ kJ/mol (3 sf)}$$

Since  $\Delta G > 0$  then the reaction requires input energy and is non-spontaneous.

#### *Marker's comments:*

This question was moderately well answered. Some common mistakes by students included:

- Not 'analysing' the data provided in terms of the equations and the table. Most students were able to recognise the meaning of a positive entropy or negative entropy in terms of disorder from the table. However, they did not explicitly explain the reason which involved referencing the chemical equations – for example commenting on the change in state in equation 1 and change in particle number in equation 2. This is necessary as the question is asking for an analysis which means you need to give in depth reasoning for the values.
- In the calculation two common mistakes were to not change the 25 °C to 298 K and secondly to not change the entropy value from J to kJ before using the formula for Gibbs Free Energy (i.e. divide it by 1000).
- Some responses just calculated Gibbs Free energy but did not actually analyse the entropy and enthalpy. This highlights not all parts of the question were read carefully.

**Exemplar student answer:**

Analyse the processes in terms of enthalpy and entropy. By calculating Gibbs Free Energy ( $\Delta G$ ) determine the spontaneity of the reactions at 25 °C.

combustion of coal has a negative  $\Delta H$ , which means it is exothermic (heat is produced); photosynthesis has a positive  $\Delta H$ , meaning it is endothermic (absorbs heat from the environment). combustion of coal has a +ve  $\Delta S$ , which is due to solid coal having less freedom of movement than  $CO_2$ , thus entropy increases (as product side is less ordered); ~~the~~ photosynthesis has a -ve  $\Delta S$ , due to glucose being a larger molecule and there being less moles on the product side than the reactant side.

$$\Delta G_{\text{combustion}} = -715 - 298.15 \times \left( \frac{2.9}{1000} \right) = -715.86463$$

$< 0$

$\therefore$  combustion of coal is spontaneous at 25°C

$$\Delta G_{\text{photosynthesis}} = 2803 - 298.15 \times \left( \frac{-212}{1000} \right)$$

$-25 -$

$$= 2866.2075$$

$> 0$

$\therefore$  photosynthesis is not spontaneous at 25°C

### Question 30 (a)

Criteria	Marks
<ul style="list-style-type: none"><li>Provides purpose in terms of heating and rate of reaction</li><li>Provides purpose in terms of cooling and preventing loss of volatiles</li></ul>	2
<ul style="list-style-type: none"><li>Provides one of the above points</li></ul>	1

#### *Sample answer:*

Esterification is a slow reaction. Therefore, by gently heating the reaction mixture the reaction rate is increased as more molecules have a greater collisional energy. Cooling using a condenser is used to prevent the evaporation of volatiles produced by the heating process.

#### *Marker's comments:*

Better responses were concise and clearly stated the two main reasons. Most responses were able to mention the purpose of the cooling condenser in refluxing in preventing loss of volatiles. However, many students were not able to make the link between why this is required in the first place. If the key purpose of refluxing is to prevent loss of volatiles the materials would not be heated. The main purpose of refluxing is to allow for a way to increase reaction rate by heating the reaction vessel (which is why volatiles are produced and then need to be recaptured as a secondary purpose of refluxing).

Some responses although they obtained the marks wrote 10-12 lines for a 2-mark question. Students should remember that the number of lines provided and the marks amount is a guide to how detailed the answer needs to be. Roughly speaking if a question is 2 marks you need to do 2 different things. Writing more does not always indicate that you are providing more detail, which was a common aspect throughout some responses to this question. Although, this did not lead to any mark losses, it is an inefficient allocation of exam time to a certain question.

#### *Exemplar student answer:*

(a) Explain the purpose of refluxing when producing an ester.

The process of reflux allows for the esterification process to occur at higher temperatures without the use of an open flame, thereby increasing the rate of reaction by allowing a greater proportion of reactant particles to have energy over the activation barrier.

Another purpose of reflux is to maximise yield by preventing the escape of valuable, vapourised chemicals. This occurs through the condensing tube, where the vapours are cooled & collected as a liquid in the round-bottom flask.

### Question 30 (b)

Criteria	Marks
<ul style="list-style-type: none"><li>• Correct safety issue and a relevant safety precaution</li></ul>	1

#### *Sample answer:*

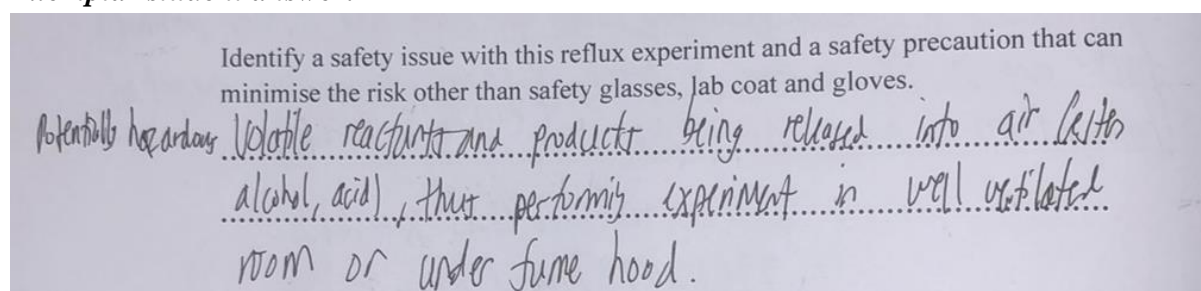
Examples can include, but are not limited to:

- Fumes are made in the experiment that can be toxic if inhaled, so use a fume cupboard or well-ventilated area
- Using a heating mantle or water bath instead of an open flame as the materials being used are flammable
- Spitting of reaction mixture when being heated, so use a stirrer bar or boiling chips to help prevent this
- Heating a volatile compound can lead to pressure build up, so an open top should be used

#### *Marker's comments:*

This was a well answered question by all students.

#### *Exemplar student answer:*





### Question 30 (c)

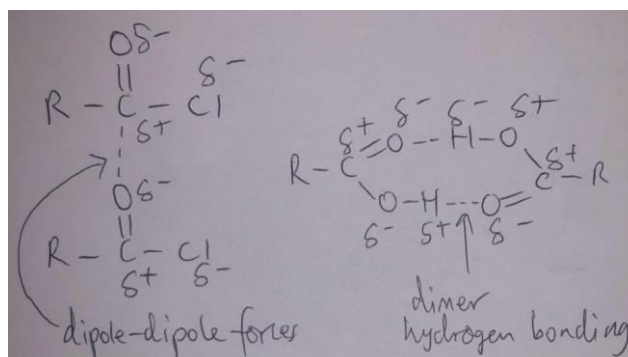
Criteria	Marks
<ul style="list-style-type: none"><li>Explains trend of why carboxylic acid is higher than acid chloride</li><li>Explains trend relating carbon amount and boiling point</li><li>Includes diagram(s) in answer showing the intermolecular forces</li></ul>	3
<ul style="list-style-type: none"><li>Missing one of the above points</li></ul>	2
<ul style="list-style-type: none"><li>Provides one relevant point from the above</li></ul>	1

#### *Sample answer:*

Boiling point is a measure of the intermolecular forces present and how much energy is needed to overcome them. Trends:

1) The carboxylic acid of the same carbon amount as the acid chloride always has a higher boiling point. This is because carboxylic acids are polar molecules which contain moderately strong dipole-dipole interactions and strong dimer (2×) hydrogen bonding. Acid chlorides are polar but only have dipole-dipole interactions. Therefore, carboxylic acids have stronger intermolecular forces and a higher boiling point.

2) In both graphs as carbon amount increases the boiling point also increases. This is because of an increase in dispersion forces from a larger number of electrons present, hence a higher boiling point.



#### *Marker's comments:*

Students need to remember to read the question carefully. Some students missed the part of the question where it asks for “diagrams to support your answer” or only mentioned 1 trend. See the plural of trends in the question indicating you need to give more than 1 trend. Better responses included these diagrams and made explicit reference to the trends in the graphs and intermolecular forces used to explain them.

Another trend some students were able to identify is that as carbon amounts increased the two graphs converged as dispersion forces became the dominant intermolecular force. This was originally in the marking criteria however due to the graph only showing this change slightly it was decided that it should not negatively impact students who did not include it. If the gradient change was more prominent this trend should also be included.

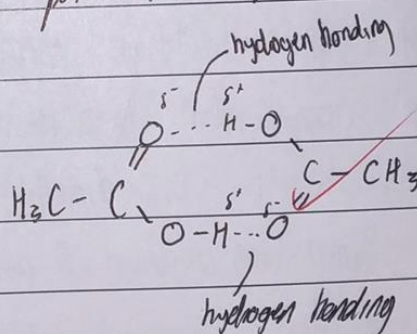
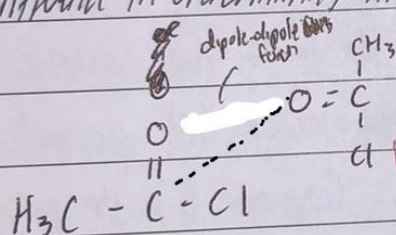
**Exemplar student answer:**

Explain the trends in the boiling points in the above graph. Use diagrams to support your answer.

Both compounds are polar and hence, will experience dipole-dipole attraction forces between their molecules. However, the hydroxyl ( $\text{-OH}$ ) functional group in carboxylic acids facilitates hydrogen bonding, a stronger intermolecular force that requires more energy input to break, resulting in higher boiling points. Hence, carboxylic acids have higher boiling points. As the molar mass increases, the strength ...

30c) ... of the dispersion forces increase due to increased frequency of unequal electron distribution & resulting from the increased number of electrons present. This will increase the boiling points for both homologous series as the <sup>strength of the</sup> intermolecular forces present increase for both.

As molar mass increases, the boiling points ~~for~~ for the two homologous series converge as the compounds become increasingly non-polar. The dispersion force attractions become the primary intermolecular force and the hydrogen bonding in carboxylic acids has less of an influence in determining the boiling points of carboxylic acids.





### Question 30 (d)

Criteria	Marks
<ul style="list-style-type: none"><li>Explains trend in solubility of carboxylic acids</li></ul>	1

#### *Sample answer:*

The solubility of carboxylic acids decreases as the carbon chain length increases. An increase in dispersion forces means the molecule becomes more non-polar like. As water is polar it is unable to dissolve the longer chain alcohols, which cannot be dissolved by hydrogen bonding and dipole-dipole interactions.

#### *Marker's comments:*

This was a well answered question by the majority of students.

#### *Exemplar student answer:*

Explain the trend in the solubility of the carboxylic acids.

As chain carbon amount increase dispersion force  
strengths increases but strength of  
hydrogen bonding remains the same.  
So the molecule becomes more <sup>non</sup> polar  
and the non polar section can't be solvation  
by polar water  
leading to a lower solubility

End of Question 30

### Question 31 (a)

Criteria	Marks
<ul style="list-style-type: none"><li>Links lines in spectra to being a signature for the elements</li></ul>	1

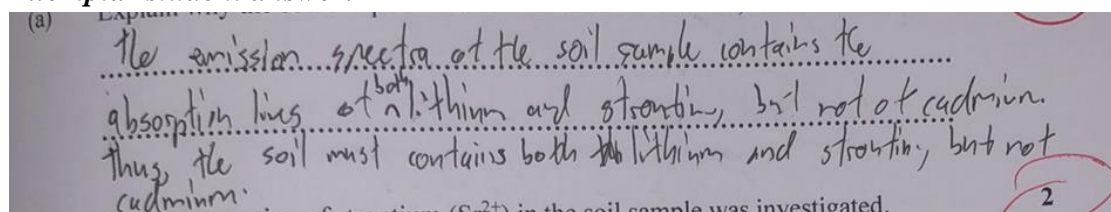
#### *Sample answer:*

The lines in the emission spectra from the metals show lithium and strontium are present as these spectral lines are present. Cadmium is missing many spectral lines so is not present.

#### *Marker's comments:*

This was a well answered question by all students.

#### *Exemplar student answer:*



### Question 31 (b)

Criteria	Marks
<ul style="list-style-type: none"><li>Identifies it is due to the lamp containing the element to be analysed</li><li>Links this to specific wavelengths of light emitted by lamp</li></ul>	1

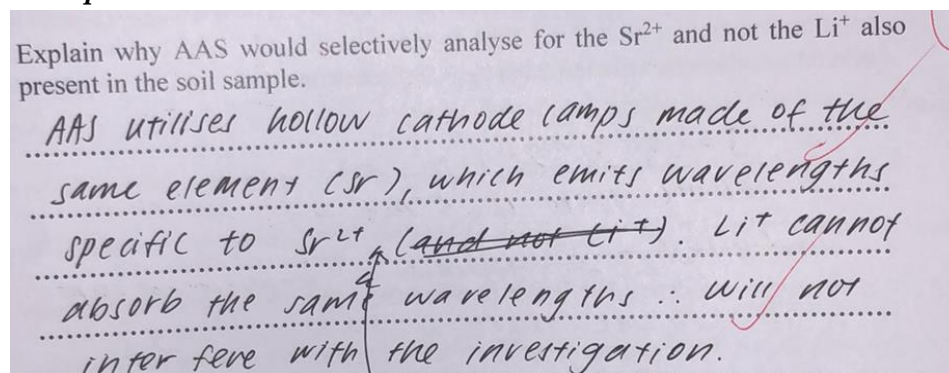
#### *Sample answer:*

The lamp in AAS contains the element to be analysed. In this case it contains strontium. The lamp therefore produces specific wavelengths of light that can only be absorbed by strontium ions in the sample. Therefore, other metals such as lithium do not interfere with the measurement that is obtained as they do not absorb light at these wavelengths.

#### *Marker's comments:*

Mostly well answered. The best answers made links between the lamp and wavelength.

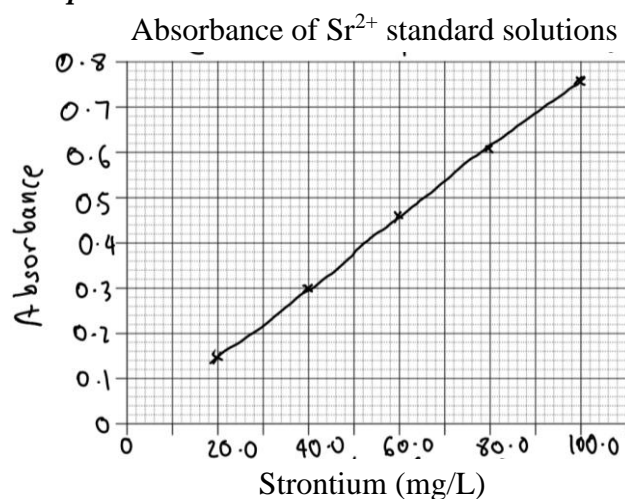
#### *Exemplar student answer:*



### Question 31 (c)

Criteria	Marks
<ul style="list-style-type: none"> <li>Plots data points and draws line of best fit only inside data values</li> <li>Labelled axes, title included and suitable scale</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above included</li> </ul>	1

**Sample answer:**

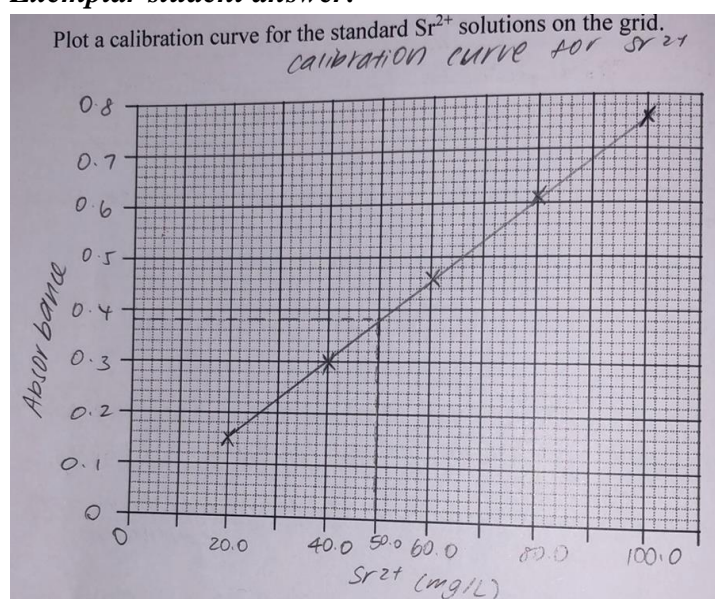


**Marker's comments:**

A fair portion of students did not get full marks. Weaker responses included:

- Not including a title or axis labels with units
- Drawing outside the calibration curve data points, for example connecting it to 0. Students need to remember that when drawing graphs, we can ONLY draw inside the data range as it is not guaranteed that the same relationship continues outside it.

**Exemplar student answer:**



### Question 31 (d)

Criteria	Marks
<ul style="list-style-type: none"> <li>• Uses graph to find <math>\text{Sr}^{2+}</math> concentration</li> <li>• Finds undiluted concentration or mass in the original sample</li> <li>• Finds percentage mass of strontium in the original sample</li> <li>• Makes comment on allowable level</li> </ul>	2
<ul style="list-style-type: none"> <li>• Uses graph to find concentration of <math>\text{Sr}^{2+}</math> AND/OR finds percentage mass in a diluted form AND/OR doesn't make a comment on level</li> </ul>	1

#### Sample answer:

From graph 0.38 absorbance is 50.0 mg/L of  $\text{Sr}^{2+}$  in the diluted solution.  
 10.0 mL has been diluted to 100.0 mL so with a dilution factor of 10 there are  
 $50.0 \times 10 = 500 \text{ mg/L of } \text{Sr}^{2+}$

The volume is 250 mL so there are  
 $500 \times 0.250 = 125 \text{ mg} = 0.125 \text{ g of } \text{Sr}^{2+}$

$$\% m(\text{Sr}^{2+}) = \frac{0.125}{12.00} \times 100 = 1.0\% \text{ (2 sf)}$$

This is above the limit

#### Marker's comments:

Well answered overall. However, some responses forgot to account for the dilution factor and therefore came to the incorrect conclusion. Better responses made a clear indication on the graph in part (c) to show the value they used in their calculation for part (d) and had a clear and easy to follow calculation structure.

#### Exemplar student answer:

(d) A 12.00 g sample of the soil was dissolved in 250.0 mL of water. 10.0 mL of this solution was further diluted to a final volume of 100.0 mL. The absorbance of the diluted solution was determined to be 0.38. Determine if the level of strontium in the soil sample is within the allowable level. 2

$[\text{Sr}^{2+}] = 50 \text{ mg/L (from graph)}$

$[\text{Sr}^{2+}]_{\text{undiluted}} \sim 500 \text{ mg/L}$

$m(\text{Sr}^{2+}) = 500 \times 0.25$

$= 125 \text{ mg}$

$\% \text{ by mass} = \frac{125 \times 10^{-3}}{12} \times 100\%$

$\sim 1.04\% \text{ (3sf)}$   $\therefore$  The level of strontium in the soil sample is not within the allowable level

### Question 32

Criteria	Marks
<ul style="list-style-type: none"><li>Identifies reaction (2) is the Bronsted-Lowry process</li><li>Provides justification in terms of both reactions i.e. why the first reaction is not a Bronsted-Lowry process and the second one is.</li></ul>	2
<ul style="list-style-type: none"><li>One of the above is provided</li></ul>	1

#### *Sample answer:*

In the Bronsted-Lowry theory, acids donate protons to bases. Therefore the 2<sup>nd</sup> reaction is a Bronsted-Lowry acid-base reaction as a proton is transferred from hydrogen chloride to ammonia. There is no proton transfer in the 1<sup>st</sup> reaction so it is not a Bronsted-Lowry process.

#### *Marker's comments:*

This was an all-around well answered question by the majority of students. One aspect that could be improved by students is when given a verb such as “justify” to ensure that in providing their reasoning they explain why the answer they did not select is incorrect. The better responses provided some form of a definition for the Bronsted-Lowry acid-base reactions and used this in supporting their justification.

#### *Exemplar student answer:*

Identify which reaction is a Bronsted-Lowry reaction. Include a reason to justify the selection that you make.

A Bronsted & Lowry reaction must involve a proton transfer.  
In reaction 2,  $\text{NH}_3$  accepts a proton to become  $\text{NH}_4^+$ , while  $\text{HCl}$  donates a proton to become  $\text{Cl}^-$ . Thus, a proton transfer occurs, so (2) is a Bronsted-Lowry reaction.  
~~No Bronsted-Lowry reaction occurs in (1).~~ (No proton transfer occurs in (1), so it is not a Bronsted-Lowry reaction).

Question 33 (3 marks)



### Question 33

Criteria	Marks
<ul style="list-style-type: none"> <li>Includes a relevant chemical equation in the answer</li> <li>Identifies sodium acetate is a basic salt (or base)</li> <li>Links equilibrium shift to decreasing hydronium ions using Le Chatelier's principle to explain the colour</li> </ul>	3
<ul style="list-style-type: none"> <li>Provides 2 of the above points</li> </ul>	2
<ul style="list-style-type: none"> <li>Provides 1 of the above points</li> </ul>	1

#### Sample answer:

Sodium acetate ( $\text{NaCH}_3\text{COO}$ ) is a basic salt. The  $\text{Na}^+$  ion is a weak conjugate acid so is unable to react with water. The  $\text{CH}_3\text{COO}^-$  is a moderately strong conjugate base so when added to water produces  $\text{OH}^-$  ions:  $\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$ . These  $\text{OH}^-$  ions react with  $\text{H}_3\text{O}^+$  so that  $\text{OH}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l})$ . This decreases the  $[\text{H}_3\text{O}^+]$ , therefore the equilibrium is disturbed. By Le Chatelier's principle the equilibrium shifts right to minimise disturbance. This increases the  $[\text{Ind}^-]$ , therefore explaining the colour change to pink.

#### Marker's comments:

Note that both equations are not required (but there should at least be one) but a stronger answer should be aiming to show both of them. Better responses showed a correct chemical equation and used this along with Le Chatelier's Principle to explain the observations.

#### Exemplar student answer:

Describe why this colour change occurs. In your answer include a chemical equation(s).

Sodium acetate dissociates to produce  $\text{CH}_3\text{COO}^-$ , by

$$\text{NaCH}_3\text{COO}(\text{aq}) \rightarrow \text{Na}^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$$

$\text{CH}_3\text{COO}^-$  is a weak base, that will react with water to produce hydroxide ions:

$$\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$$

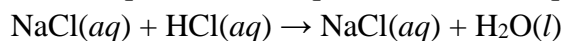
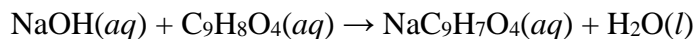
These hydroxide ions then react with  $\text{H}_3\text{O}^+$  to produce  $\text{H}_2\text{O}$

$$\text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l})$$

Thus,  $[\text{H}_3\text{O}^+]$  decreases while the quantity of water increases. By Le Chatelier's principle predicts that the indicator system will thus shift to the right to increase  $[\text{H}_3\text{O}^+]$ , so the colourless  $[\text{Ind}]$  decreases while the pink  $[\text{Ind}^-]$  increases, thus turning the solution pinky as observed.

**Question 34 (a)**

Criteria	Marks
<ul style="list-style-type: none"> <li>Provides 2 balanced chemical equations</li> </ul>	2
<ul style="list-style-type: none"> <li>Provides 1 balanced chemical equation</li> </ul>	1

**Sample answer:****Marker's comments:**

This question was well answered by most students. The most common mistakes were to forget to include states and incorrectly removing an oxygen atom from the carboxylic acid.

**Question 34 (b)**

Criteria	Marks
<ul style="list-style-type: none"> <li>Finds average titre without outlier</li> <li>Finds excess moles of NaOH</li> </ul>	2
<ul style="list-style-type: none"> <li>One of the above OR does not remove outlier in calculation</li> </ul>	1

**Sample answer:**

Average volume of HCl titre, noting that 24.0 mL is an outlier

$$\bar{v}(\text{HCl}) = \frac{22.0 + 22.1 + 21.9}{3} = 22.0 \text{ mL}$$

$$n(\text{HCl}) = cv = (0.0170)(0.022) = 3.74 \times 10^{-4} \text{ mol}$$

$$\text{Excess } n(\text{NaOH}) = n(\text{HCl}) = 3.74 \times 10^{-4} \text{ mol (3 sf)}$$

**Marker's comments:**

This question was well answered by most students.

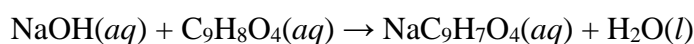
**Question 34 (c)**

Criteria	Marks
<ul style="list-style-type: none"> <li>Finds initial moles of NaOH</li> <li>Finds moles of 2-acetoxybenzoic acid</li> <li>Finds percentage mass of 2-acetoxybenzoic acid</li> <li>Proves manufacturer's claim is invalid</li> </ul>	3
<ul style="list-style-type: none"> <li>All but one of the above missing</li> </ul>	2
<ul style="list-style-type: none"> <li>One or two of the above included</li> </ul>	1

**Sample answer:**

$$\text{Initial } n(\text{NaOH}) = cv = (0.0150)(0.035) = 5.25 \times 10^{-4} \text{ mol}$$

$$n(\text{NaOH}) \text{ reacted with } \text{C}_9\text{H}_8\text{O}_4 = 5.25 \times 10^{-4} - 3.74 \times 10^{-4} = 1.51 \times 10^{-4} \text{ mol}$$



$$n(\text{C}_9\text{H}_8\text{O}_4) = n(\text{NaOH}) \text{ reacted with } \text{C}_9\text{H}_8\text{O}_4 = 1.51 \times 10^{-4} \text{ mol}$$

$$m(\text{C}_9\text{H}_8\text{O}_4) = 1.51 \times 10^{-4} \times (9(12.01) + 8(1.008) + 4(16.00)) = 2.72 \times 10^{-2} \text{ g}$$

Since the tablet is 200 mg then

$$\%m(\text{C}_9\text{H}_8\text{O}_4) = \frac{2.72 \times 10^{-2}}{0.200} \times 100 = 13.6\% \text{ (3 sf)}$$

Since this is less than 25% then the claim is invalid.

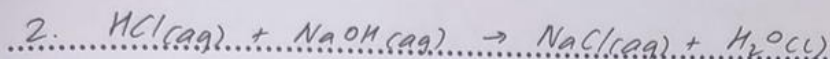
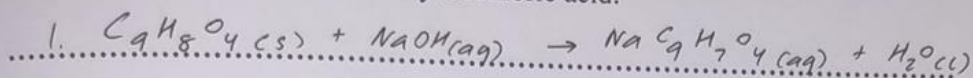
**Marker's comments:**

This question was fairly well answered. The best responses had a well-structured method in their working out such as labelling of the different types of mole (excess, initial, reacted) involved in this back-titration question.



**Exemplar student answer:** for (a) to (c)

- (a) Write balanced chemical equations for the TWO reactions of sodium hydroxide with 2-acetoxybenzoic acid and hydrochloric acid.



- (b) Determine the number of moles of excess sodium hydroxide.

$$V_{\text{HCl titre}} = \frac{22.0 + 22.1 + 21.9}{3} = 22 \text{ mL (discarding rough titre)}$$

$$n_{\text{HCl}} = cV = 0.017 \text{ M} \times 22 \times 10^{-3} \text{ L} = 3.74 \times 10^{-4} \text{ mol}$$

$$\therefore n_{\text{NaOH excess}} = n_{\text{HCl}} = 3.74 \times 10^{-4} \text{ mol (3 s.f.)}$$

$$(1:1 \text{ molar ratio, from (a)})$$

- (c) Calculate the percentage by mass of 2-acetoxybenzoic acid in the aspirin tablet. Use this to show the claim by the manufacturer is invalid.

$$n_{\text{NaOH total}} = cV = 0.015 \text{ M} \times 35 \times 10^{-3} \text{ L} = 5.25 \times 10^{-4} \text{ mol}$$

$$n_{\text{NaOH reacted}} = n_{\text{NaOH total}} - n_{\text{NaOH excess}} \\ = 5.25 \times 10^{-4} \text{ mol} - 3.74 \times 10^{-4} \text{ mol} = 1.51 \times 10^{-4} \text{ mol}$$

$$n_{\text{C}_9\text{H}_8\text{O}_4} = n_{\text{NaOH reacted}} \quad (1:1 \text{ molar ratio, from (a)}) \\ = 1.51 \times 10^{-4} \text{ mol}$$

$$m_{\text{C}_9\text{H}_8\text{O}_4} = n \times \text{MM} = 1.51 \times 10^{-4} \times (9 \times 12.01 + 8 \times 1.008 + 4 \times 16) \\ = 27.2 \text{ mg (3 s.f.)}$$

$$\therefore \% \text{ by mass of C}_9\text{H}_8\text{O}_4 \text{ in tablet} = \frac{m_{\text{C}_9\text{H}_8\text{O}_4}}{m_{\text{tablet}}} \times 100\% \\ = \frac{27.2 \text{ mg}}{200 \text{ mg}} \times 100\% \\ = 13.6\% \quad (3 \text{ s.f.}) < 25\%$$

$\therefore$  manufacturer's claim is invalid.

### Question 34 (d)

Criteria	Marks
<ul style="list-style-type: none"><li>Links to equivalence point (pH 7)</li><li>How it lies within the range of the indicator being used</li></ul>	1

#### *Sample answer:*

The titration is between a strong base and strong acid so has a pH 7 equivalence point. Therefore, phenol red would be suitable as it changes colour in this range.

#### *Marker's comments:*

This question was well answered by most students. The best responses clearly stated that the colour change of the indicator (endpoint) was directly related to approximately the equivalence point for the titration reaction.

#### *Exemplar student answer:*

(d) Explain why phenol red (pH range: 6.2 - 8.2) was chosen as the pH indicator for the sodium hydroxide and hydrochloric acid titration.

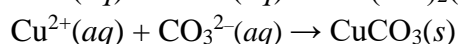
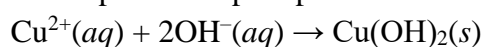
...because as NaOH is a strong base and HCl is a strong acid...  
the equivalence point of their neutralisation reaction is around  
pH=7, in phenol red's working range.

### Question 34 (e)

Criteria	Marks
<ul style="list-style-type: none"><li>• Correct identification of copper</li><li>• Includes chemical equation(s) showing precipitates being made</li><li>• Provides reasoning for the answer and why other metals aren't present</li></ul>	2
<ul style="list-style-type: none"><li>• One of the above points is included</li></ul>	1

#### Sample answer:

$\text{Cu}^{2+}$  is the ion present.  $\text{Pb}^{2+}$  and  $\text{Ag}^+$  would produce precipitates with all the solutions as no precipitate was made when chloride is added and sulfate is added these are not present.  $\text{Ba}^{2+}$  would produce a precipitate with sulfate as well. The equations for the  $\text{Cu}^{2+}$  precipitates are:



#### Marker's comments:

This question was well answered by most students. The better responses were concise and provided a chemical equation. Some answers, whilst still receiving full marks, wrote additional information irrelevant to the question.

#### Exemplar student answer:

Use the results above to determine the identity of the heavy metal present. Include at LEAST one balanced ionic equation in your answer showing the formation of precipitates.

...Copper ion ( $\text{Cu}^{2+}$ )... as it doesn't form precipitate with  $\text{Cl}^{-}$  ions, it's neither  $\text{Pb}^{2+}$  nor  $\text{Ag}^{+}$ ; as it doesn't form precipitate with  $\text{SO}_4^{2-}$ , it's not  $\text{Ba}^{2+}$ , therefore it's copper.

$$\text{Cu}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Cu}(\text{OH})_2(\text{s})$$
$$\text{Cu}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{CuCO}_3(\text{s})$$

### Question 35

Criteria	Marks
<ul style="list-style-type: none"> <li>All correct structures with correct bonding type e.g. Compound G has positive on sodium and negative on oxygen and not a covalent bond</li> <li>Names reaction types in their justification</li> <li>Adequate justification and reasoning for the structures to distinguish other possible structures that could have been used (e.g. Compound F is a tertiary alcohol as it is not oxidised)</li> </ul>	8
<ul style="list-style-type: none"> <li>One incorrect structure and adequate justification OR all correct structures but inadequate justification for some structures</li> </ul>	6-7
<ul style="list-style-type: none"> <li>Same as above but 2-3 incorrect structures</li> </ul>	4-5
<ul style="list-style-type: none"> <li>Some information and/or structures provided that are correct</li> </ul>	2-3
<ul style="list-style-type: none"> <li>Identifies some information that is relevant</li> </ul>	1

#### Sample answer:

	Structure	Justification
<b>A</b>	$  \begin{array}{c}  \text{CH}_3 \\    \\  \text{H}_2\text{C}=\text{C}-\text{CH}_2-\text{CH}_3  \end{array}  $	Alkene that needs to have a methyl group as E is a tertiary alcohol and have the C=C on the end to make a primary alcohol (D) as well.
<b>B</b>	$  \begin{array}{c}  \text{CH}_3 \\    \\  \text{H}_2\text{C}-\text{C}-\text{CH}_2-\text{CH}_3 \\    \quad   \\  \text{Br} \quad \text{H}  \end{array}  $	Forms from the addition of HBr. It is the isomer that makes the carboxylic acid in the next step so has to have Br on the terminal carbon.
<b>C</b>	$  \begin{array}{c}  \text{CH}_3 \\    \\  \text{H}_2\text{C}-\text{C}-\text{CH}_2-\text{CH}_3 \\    \quad   \\  \text{H} \quad \text{Br}  \end{array}  $	The other isomer of HBr addition. Makes the tertiary alcohol in the next step so needs to be on the second carbon.

<b>D</b>	$  \begin{array}{c}  \text{CH}_3 \\    \\  \text{HO} - \text{H}_2\text{C} - \text{C} - \text{CH}_2 - \text{CH}_3 \\    \\  \text{H}  \end{array}  $	Substitution reaction of OH for Br. Came from B so OH goes on the end. It is a primary alcohol as it makes a carboxylic acid in the next step.
<b>E</b>	$  \begin{array}{c}  \text{CH}_3 \\    \\  \text{CH}_3 - \text{C} - \text{CH}_2 - \text{CH}_3 \\    \\  \text{OH}  \end{array}  $	Substitution reaction of OH for Br. Came from C so Br goes on the middle carbon. Tertiary alcohol as not oxidised.
<b>F</b>	$  \begin{array}{c}  \text{O} \quad \text{CH}_3 \\     \quad   \\  \text{HO} - \text{C} - \text{C} - \text{CH}_2 - \text{CH}_3 \\    \\  \text{H}  \end{array}  $	Carboxylic acid as made from oxidation of a primary alcohol. Also, produces carbon dioxide gas when sodium carbonate is added.
<b>G</b>	$  \begin{array}{c}  \text{O} \quad \text{CH}_3 \\     \quad   \\  \text{Na}^+ \text{ } ^-\text{O} - \text{C} - \text{C} - \text{CH}_2 - \text{CH}_3 \\    \\  \text{H}  \end{array}  $	A carboxylic acid + metal carbonate produces carbon dioxide, water and a salt. G is the salt.
<b>H &amp; I</b>	$  \begin{array}{c}  \text{O} \quad \text{CH}_3 \\     \quad   \\  \text{H}_2\text{N} - \text{CH}_2 - \text{CH}_2 - \text{O} - \text{C} - \text{C} - \text{CH}_2 - \text{CH}_3 \\    \\  \text{H}  \end{array}  $ <p style="text-align: center;">AND</p> $  \begin{array}{c}  \text{H} \quad \text{O} \quad \text{CH}_3 \\    \quad    \quad   \\  \text{HO} - \text{CH}_2 - \text{CH}_2 - \text{N} - \text{C} - \text{C} - \text{CH}_2 - \text{CH}_3 \\    \\  \text{H}  \end{array}  $	<p>The two isomers form because the carboxylic acid F can react with either functional group in the HO-CH<sub>2</sub> – CH<sub>2</sub>-NH<sub>2</sub>.</p> <p>If it reacts through the alcohol (OH) group it produces the top product.</p> <p>If it reacts through the amine (NH<sub>2</sub>) group it makes the bottom product.</p>

### Marker's comments:

There were varying levels of answers provided to this question by students. The better responses provided the structures with the correct bonding (covalent or ionic) and in justifying their answer made specific reference to the chemical processes occurring such as using terms like oxidation, hydrohalogenation and condensation (or esterification and acidification). They also used specific terminology such as primary alcohol and tertiary alcohol to explain certain chemical observations.

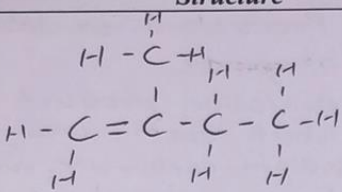
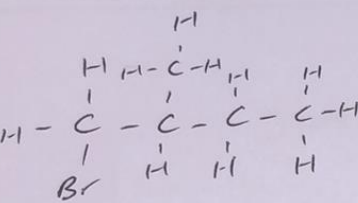
Some students provided the names of each compound. This was not required for the question and no marks were awarded for doing this. Students should remember to read the question carefully to ensure the information they provide is relevant to what the question requires.

Some common mistakes made by some students in answering the question included:

- Correctly determining that Compound E was a tertiary alcohol with a branched structure and then proceeding to use a linear carbon backbone for other structures such as the carboxylic acid. Students should note that in the HSC syllabus there is no reaction that can rearrange carbon atoms and therefore these students should have continued using the same branched carbon structure for the other molecules.
- Forgetting to include hydrogen atoms. Some students left carbon atoms without any hydrogens drawn or labelled as CH<sub>3</sub> or CH<sub>2</sub>. If a student did this once no marks were deducted, but if this occurred more than once a mark was deducted for this error.
- Incorrectly drawing a bond between oxygen and sodium in Compound G. This is an ionic compound. The line bond is only applicable for covalent bonds.
- Forgetting to provide reaction names in their justification. For example, a statement like "it came from compound B" is not an adequate justification for a structure.

**Exemplar student answer:** 2 different exemplars are provided for this long response question

### Student 1:

	Structure	Justification
A		-General formula of an alkene which undergoes hydrohalogenation to form 2 different products, one of which can form an alcohol (E) that doesn't oxidise. The other alcohol is primary, indicating branching and double bond is clear together
B		Position of Br must allow for primary alcohol to be formed, so Br must be on the end.



Question 55 (continued)

	Structure	Justification
C		Position of Br must allow for tertiary alcohol to be formed, so must be on carbon with extra methyl group
D		Oxidises to form a carboxylic acid, primary alcohol ↓ due to reaction with sodium carbonate
E		Doesn't oxidise in presence of $H^+/MnO_4^-$ , tertiary alcohol
F		<del>Product of oxidation of primary</del> Oxidation product which reacts with sodium carbonate, must be a carboxylic acid (indicated by salt formation)

	Structure	Justification
G		Sodium carboxylate salt formed after neutralisation of carboxylic acid with sodium carbonate



H	$  \begin{array}{ccccccc}  & & H & & & & \\  & &   & & H & H & \\  H & H & H & H & H & H & H \\    &   &   &   &   &   &   \\  H-C & -C- & C- & C- & N- & C- & C- \\    &   &   &   &   &   &   \\  H & H & H & H & H & H & H  \end{array}  $	Two products formed from condensation reaction, let H be formed due to reaction of amine and acid group, forms an amide linkage
I	$  \begin{array}{ccccccc}  & & H & & & & \\  & &   & & H & H & \\  H & H & H & H & H & H & H \\    &   &   &   &   &   &   \\  H-C & -C- & C- & C- & O- & C- & C- \\    &   &   &   &   &   &   \\  H & H & H & H & H & H & H  \end{array}  $	let I be formed due to reaction of <sup>alcohol hydroxy</sup> group and acid, forms an ester linkage.

### Student 2:

	Structure	Justification
A	$  \begin{array}{ccccccc}  & & CH_3 & & H & H & \\  & &   & &   &   & \\  H & -C= & C- & C- & C- & H \\    & & &   &   & & \\  H & & & H & H & &   \end{array}  $	The carbon-carbon double bond must be in a position where <del>hydrohalogenation</del> a primary and <del>and tertiary</del> a primary and tertiary alcohol can be produced via a hydrohalogenation reaction.
B	$  \begin{array}{ccccccc}  & & CH_3 & & H & H & \\  & &   & &   &   & \\  Br-C & -C- & C- & C- & H \\    &   &   &   & \\  H & H & H & H &   \end{array}  $	This will later form <del>or</del> a primary alcohol that can be oxidised to a carboxylic acid. Hence, the Br substituent must be on a terminating carbon.

Question 35 (continued)		Justification
	Structure	
C	$  \begin{array}{ccccccc}  & & CH_3 & & H & H & \\  & &   & &   &   & \\  H & -C- & C- & C- & C- & H \\    & &   &   &   & & \\  H & & Br & H & H & &   \end{array}  $	The Br substituent must be in a position where substitution with an OH <sup>™</sup> substituent will produce a tertiary alcohol.

D	$  \begin{array}{ccccccc}  & \text{H} & & \text{CH}_3 & & \text{H} & & \text{H} \\  &   & &   & &   & &   \\  \text{HO} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{H} \\  &   & &   & &   & &   \\  & \text{H} & & \text{H} & & \text{H} & & \text{H}  \end{array}  $	<p>This must be a primary alcohol as it oxidises to a carboxylic acid. We know the <math>\text{H}</math> substituent in compound B is substituted for a hydroxyl group.</p>
E	$  \begin{array}{ccccccc}  & \text{H} & & \text{CH}_3 & & \text{H} & & \text{H} \\  &   & &   & &   & &   \\  \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{H} \\  &   & &   & &   & &   \\  & \text{H} & & \text{OH} & & \text{H} & & \text{H}  \end{array}  $	<p>This <del>is</del> <sup>does</sup> not oxidise and hence, must be a tertiary alcohol.</p>
F	$  \begin{array}{ccccccc}  & & & \text{O} & & & & \text{CH}_3 & & \text{H} & & \text{H} \\  & & &    & & & &   & &   & &   \\  \text{HO} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{H} \\  & & & & & & &   & &   & &   \\  & & & & & & & \text{H} & & \text{H} & & \text{H}  \end{array}  $	<p>This reacts with sodium carbonate, a base, and hence it must be a carboxylic acid.</p>

	Structure	Justification
G	$  \begin{array}{ccccccc}  & & & \text{O} & & & & \text{CH}_3 & & \text{H} & & \text{H} \\  & & &    & & & &   & &   & &   \\  \text{Na}^+ & \text{O}^- & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{H} \\  & & & & & & &   & &   & &   \\  & & & & & & & \text{H} & & \text{H} & & \text{H}  \end{array}  $	<p>This is the salt formed from the neutralisation reaction between compound F and <math>\text{Na}_2\text{CO}_3</math>.</p>
H	$  \begin{array}{ccccccc}  & \text{H} & & \text{H} & & \text{H} & & \text{O} & & \text{CH}_3 & & \text{H} & & \text{H} \\  &   & &   & &   & &    & &   & &   & &   \\  \text{HO} & - & \text{C} & - & \text{C} & - & \text{N} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{H} \\  &   & &   & & & & & &   & &   & &   \\  & \text{H} & & \text{H} & & & & & & \text{H} & & \text{H} & & \text{H}  \end{array}  $	<p>This is the product of <del>the</del> a condensation reaction. The <math>\text{-OH}</math> functional group is taken from compound F and one of the hydrogens from the amine functional group is taken.</p>
I	$  \begin{array}{ccccccc}  & \text{H} & & \text{H} & & \text{H} & & \text{O} & & \text{CH}_3 & & \text{H} & & \text{H} \\  &   & &   & &   & &    & &   & &   & &   \\  \text{H} & - & \text{N} & - & \text{C} & - & \text{C} & - & \text{O} & - & \text{C} & - & \text{C} & - & \text{H} \\  & & & &   & &   & & & &   & &   & &   \\  & & & & \text{H} & & \text{H} & & & & \text{H} & & \text{H} & & \text{H}  \end{array}  $	<p>This is the product of a condensation reaction. The <math>\text{OH}</math> functional group is taken from the alcohol reagent and one hydrogen is taken from compound F's hydroxyl group.</p>