CSSA

CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NSW

Centre Number

Student Number

DO NOT REMOVE PAPER FROM EXAM ROOM

2019

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Morning Session
Friday, 9 August 2019

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- NESA-approved calculators may be used
- Use the Multiple-Choice Answer Sheet provided
- Draw diagrams using pencil
- A data sheet and Periodic Table are provided SEPARATELY
- Write your Centre Number and Student Number on the top of this page

Total marks – 100

Section I Pages 2-11

20 marks

- Attempt Questions 1-20
- Allow about 35 minutes for this section

Section II Pages 12-29

80 marks

- Attempt Questions 21-36
- Allow about 2 hours and 25 minutes for this section

Section I

20 marks
Attempt Questions 1-20
Allow about 35 minutes for this section

Use the Multiple-Choice Answer Sheet for Questions 1-20.

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1 Which of the following situations correctly identifies a dynamic equilibrium system?

(A) An idling car engine where the flow of fuel and exhaust gases is constant.

(B) A beaker of concentrated salt (sodium chloride) solution.

(C) A newly opened can of lemonade soft drink.

(D) A solution containing equal parts sodium acetate and acetic acid.

2 Which isomer of C_6H_{12} will undergo an addition reaction with Br_2?

(A) cyclohexane

(B) ethylcyclobutane

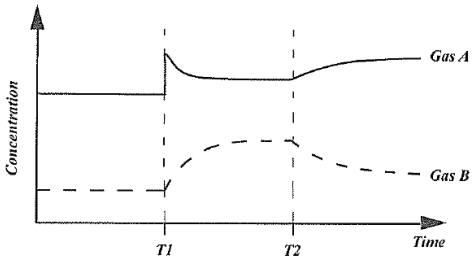
(C) 1-ethyl-1-methyl cyclopropane

(D) 2,3-dimethylbut-1-ene

3 A gaseous system, in a flask, may be represented by the equilibrium equation:

$$A\,(g) \rightleftharpoons 2\,B\,(g)$$

The concentration of A and B were recorded over time.



At time T_2, the temperature was increased. This indicates that the equilibrium, as written, is:

(A) exothermic and K decreased.

(B) endothermic and K increased.

(C) endothermic and K decreased.

(D) exothermic and K increased.

4 Which of the following is the correct K_a expression for the ionisation of ethanoic acid?

(A) $[H_3O^+][CH_3COO^-] / [CH_3COO^{2-}]$

(B) $[H_3O^+][\ CH_3COO^-]] / [CH_3COOH]$

(C) $[CH_3COOH] / [H_3O^+][\ CH_3COO^-]$

(D) $[H_3O^+][CH_3COOH]/[\ CH_3COO^-]$

5 One component of petrol is 2,2,4-trimethylpentane.

The enthalpy of combustion for 2,2,4-trimethylpentane, ΔH_c = - 5460 kJ mol^{-1}.

Calculate the mass of 2,2,4-trimethylpentane needed to heat 1 L of water by 50°C.

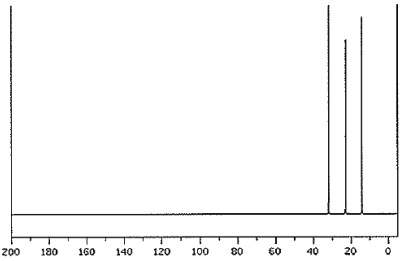
(A) 114.94 g

(B) 3.00 g

(C) 4.37 g

(D) 47.50 g

6 Identify which one of the compounds given below gives the following ^{13}C NMR spectrum:



(A) prop-1-ene

(B) hexane

(C) butanoic acid

(D) ethanol

7 Which of the following is the weakest acid?

	K_a (at 25°C)
(A)	7.0×10^{-5}
(B)	1.7×10^{-5}
(C)	8.0×10^{-3}
(D)	8.0×10^{-4}

8 A teacher prepares a dilute solution of cobalt(II) chloride in a small beaker, stirring until it becomes a consistent colour. The equilibrium is endothermic as written below:

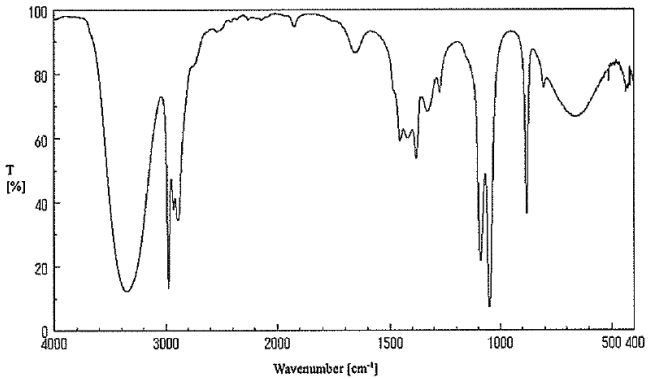
$$\underset{\textbf{PINK}}{[Co(H_2O)_6]^{2+}(aq)} + 4Cl^-(aq) \rightleftharpoons \underset{\textbf{BLUE}}{[CoCl_4]^{2-}(aq)} + 6H_2O(l)$$

She pours some of the solution into three separate test tubes. To the first test tube she adds some hydrochloric acid. To the next test tube she adds some silver nitrate solution, and a precipitate immediately forms. She places the last test tube in a larger beaker of ice water.

What would be the expected results for each test tube?

	HCl (aq) added	**$AgNO_3$(aq) added**	**Ice Bath**
(A)	More pink	More blue	More pink
(B)	More blue	More pink	More pink
(C)	More pink	More blue	More blue
(D)	More blue	More pink	More blue

9 An organic sample was analysed by IR spectroscopy. What is the compound?



(A) ethanol

(B) ethanal

(C) ethyl ethanoate

(D) ethane

10 Identify the conjugate acid/base pair:

(A) H_3O^+ / OH^-

(B) H_2BO_3 / HBO_3^{-2}

(C) $C_3H_6O_2$ / $C_3H_5O^-$

(D) H_2CrO_4 / $HCrO_4^-$

11 Determine the pH of the solution when 25 mL of 0.1 M LiOH is added to 35 mL of 0.1 M nitric acid.

(A) 0.23

(B) 0.47

(C) 1.8

(D) 7.0

12 After a class experiment on the solubility of ionic compounds, a teacher discovered an unlabelled beaker containing a colourless liquid. She suspected it was a nitrate solution of one of the compounds they had studied, so placed some of the liquid into three separate test tubes. She then added different solutions to each of the test tubes and recorded the results in a table.

Solution added	Observation
Sodium hydroxide	No reaction
Sodium sulfate	Milky precipitate
Sodium chloride	No reaction

The unknown solution could have been:

(A) barium nitrate

(B) copper(II) nitrate

(C) silver nitrate

(D) magnesium nitrate

13 Sodium hydroxide is added to a solution containing an unknown metal ion. A brown/orange precipitate is formed. Identify the ion present in the solution.

(A) copper(II)

(B) iron(II)

(C) iron(III)

(D) lead(II)

14 Which of the following substances is an amphiprotic salt?

(A) sodium carbonate

(B) sodium chloride

(C) sodium hydroxide

(D) sodium hydrogen phosphate

15 The copper(II) ion forms a complex ion in water $[Cu(H_2O)_6]^{2+}$, which forms a blue solution. Identify which of the following substances can substitute the water ligand without causing a change in the total oxidation state.

(A) Br^-

(B) NH_3

(C) CN^-

(D) Pb^{2+}

16 Some $Ca(NO_3)_2$ is dissolved in 100 mL of water. This solution is mixed with 300 mL of 0.010 M Na_2SO_4. A very faint precipitate of calcium sulfate is formed. If the K_{sp} value of calcium sulfate is 2.4×10^{-5}, how much calcium nitrate was dissolved to make the initial solution?

(A) 0.040 g

(B) 0.21 g

(C) 0.32 g

(D) 0.63 g

17 Indicate which test would NOT be suitable to distinguish between butan-1-ol and butanoic acid.

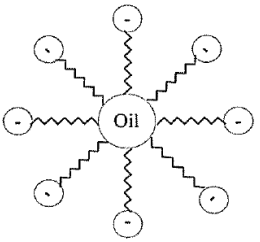
(A) measurement of the solution pH

(B) addition of sodium hydrogen carbonate

(C) addition of bromine water

(D) addition of acidified potassium dichromate solution

18 Which statement correctly describes the diagram below?



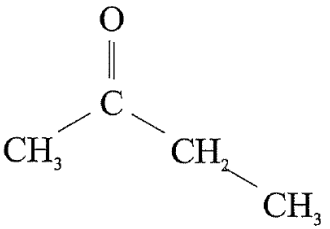
(A) The hydrophilic head of the soap molecule is polar and is attracted to water molecules. The hydrophobic tail is non-polar and forms micelles trapping the fats within the micelle.

(B) The hydrophilic head of the soap molecule is non-polar and is attracted to water molecules. The hydrophobic tail is polar and forms micelles trapping the fats within the micelle.

(C) The hydrophilic head of the soap molecule is polar and is attracted to oil molecules. The hydrophobic tail is non-polar and forms micelles trapping the water within the micelle.

(D) The hydrophobic head of the soap molecule is non-polar and is attracted to water molecules. The hydrophilic tail is non-polar and forms micelles trapping the fats within the micelle.

19 Name the following compound:



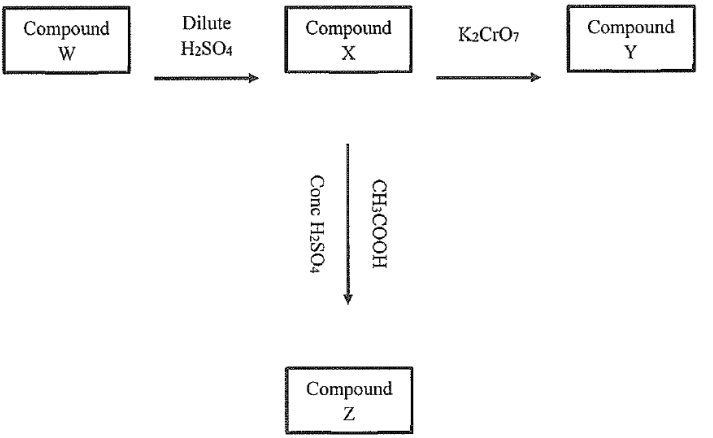
(A) butanal

(B) butan-2-one

(C) butan-3-one

(D) methylpropanal

20 Consider the following series of reactions:



Which row in the table correctly identifies the compounds W, X, Y and Z?

	W	X	Y	Z
(A)	propene	propan-1-ol	propanal	propyl ethanoate
(B)	propene	propan-1-ol	propanone	propyl ethanoate
(C)	propene	propanone	propan-1-ol	ethyl propanoate
(D)	propene	propanal	propan-1-ol	ethyl propanoate

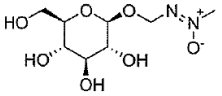
Section II

80 marks
Attempt Questions 21-36
Allow about 2 hours and 25 minutes for this section

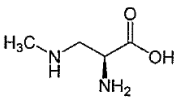
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided on s this space, clearly indicate which question you are answering.

Question 21 (5 marks)

Aboriginal and Torres Strait Islander Peoples have used the seeds of cycad plants to make a form of bread. Two of the toxins found within these seeds are shown below:



Cycasin



BMMA
(β-Methylamino-L-alanine)

(a) The toxins can be removed by leaching. Explain how features of each molecule allow for these compounds to be removed from the rest of the seeds by leaching. **3**

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(b) Small samples (0.5 mL) of each compound were extracted from some seeds. Outline a method for distinguishing between these samples. **2**

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Question 22 (5 marks)

(a) Write the equation for the dissociation of copper(II) chloride. **1**

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(b) Compare and contrast the relative solubility of lead(II) hydroxide and lead(II) phosphate. **2**

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(c) At a given temperature, the K_{sp} values of calcium chloride and aluminium nitrate are 1210 and 2160 respectively. Solutions of each ionic compound, the same volume at the same concentration, were left to evaporate under the exact same conditions. One solution started to precipitate when the concentration reached 2.99 mol L^{-1}, while the other precipitated when the concentration reached 6.71 mol L^{-1}. **2**

With the aid of appropriate equations and reference to K_{sp}, determine which compound precipitated first.

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Question 23 (9 marks)

(a) Kakadu plums are known to have a high concentration of Vitamin C (ascorbic acid, $C_6H_8O_6$). Ascorbic acid is a weak diprotic acid. **6**

A student juiced 100 g of Kakadu plums. The 20.0 mL of Kakadu juice recovered was then diluted to 100.0 mL in a volumetric flask. The student used sodium hydroxide solution with an approximate concentration of 0.1 M, which was standardised using oxalic acid $(COOH)_2$.

Justify in detail the method the student could use to determine the concentration of ascorbic acid in Kakadu plums.

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Question 23 continues on page 15

(b) The student achieved the following results with 15.00 mL aliquots of Kakadu plum ascorbic acid titrated against standardised 0.150 M sodium hydroxide. **3**

Trial	Volume of NaOH (mL)
1	14.60
2	11.65
3	12.80
4	11.70
5	11.60
6	11.65

Using the information provided, calculate the concentration of ascorbic acid in a Kakadu plum. Please show all calculations.

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Question 24 (7 marks)

(a) A 0.11 M solution of ammonium chloride was found to have a pH of 4.38. This is due to the hydrolysis of the ammonium ion: **3**

$$NH_4^+ (aq) + H_2O (l) \rightleftharpoons NH_3 (aq) + H_3O^+ (aq)$$

Assuming negligible measurable change in the ammonium concentration, determine the value for K_{eq} for the equilibrium reaction as written.

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(b) (i) The decomposition of hydrogen sulfide may be represented as: **1**

$$2 H_2S (g) \rightleftharpoons 2 H_2 (g) + S_2 (g)$$

Write the equilibrium expression for this reaction.

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(ii) At 2000 K, K_{eq} is 1.6×10^{-2} for this reaction. A mixture of these gases was placed in a 2.00 L vessel and allowed to reach equilibrium. The equilibrium mixture was found to have equal amounts of H_2S and H_2. How many moles of S_2 were in the vessel? **2**

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Question 24 continues on page 17

(iii) At 1400 K, K_{eq} is 2.2×10^{-4}. State whether the reaction is endothermic or exothermic, giving a suitable reason. 1

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Question 25 (2 marks)

The solubility of substances may be defined as follows. 2

Solubility level	Insoluble	Very slightly to slightly soluble	Sparingly soluble	Soluble
Mass of solute per litre of water (at 25°C)	Less than 0.1 g	0.1 g to 10.0 g	10.0 g to 33.3 g	Greater than 33.3 g

At 25°C, the K_{sp} value of silver nitrite ($AgNO_2$) is 6.0×10^{-4}.

Show that the solubility level of silver nitrite at this temperature is in the "Very slightly to slightly soluble" range.

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Question 26 (5 marks)

The definition of acids has changed over time. Discuss the Arrhenius and Lowry-Bronsted theories of acids and, with the aid of equations, explain a limitation for each theory. **5**

Question 27 (3 marks)

Acyl chlorides, sometimes called acid chlorides, are organic compounds that are very reactive.

The term acyl chloride describes a functional group containing a carbonyl group (C=O) and a chlorine atom (Cl).

Molecules containing this functional group, such as ethanoyl chloride, CH_3COCl, can be used in a strongly exothermic reaction to produce an ester.

(a) Write the equation for the reaction between ethanoyl chloride and propan-1-ol. **1**

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(b) Suggest TWO disadvantages for using an acyl chloride rather than a carboxylic acid to produce an ester. **2**

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Question 28 (4 marks)

Buffers are a fundamental part of the natural environment. Our understanding of buffers in nature has become increasingly important when considering our impact on the environment. **4**

Name a buffer that occurs in a natural system. Explain the importance of this buffer in your named natural system.

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Question 29 (3 marks)

(a) Two unknown acids were found to have different pK_a values: **1**

Acid X had a pK_a of 4.76
Acid Y had a pK_a of -6.3

State, with a reason, which acid is the stronger acid.

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(b) Suggest, with a reason, a possible structure for acid X and acid Y. **2**

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Question 30 (3 marks)

A solution of 0.001 M lactic acid, $CH_3CH(OH)COOH$, has a pH of 4.2. Determine the K_a for lactic acid. 3

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Question 31 (4 marks)

A factory is situated near a stream that ends in a pond. An environmental scientist wants to identify if any copper(II) ions are present in the pond. 4

Outline how the scientist could carry out a flame test on the water, what they would expect to observe and discuss limitations of using this technique for the scientist's aim.

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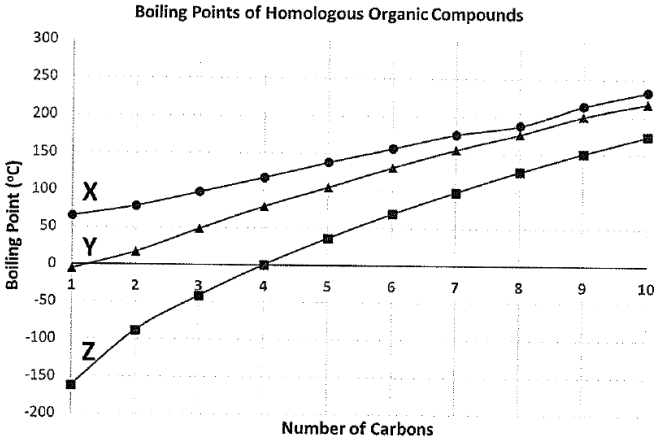
Question 32 (7 marks)

The graph below shows the boiling points of a homologous series for three organic compounds. 7



Use the data from the graph to identify X, Y and Z as alkanes, alcohols or amines. Explain the trends in the data provided.

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Question 32 continues on page 23

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Question 33 (7 marks)

A group of students conducted an investigation to identify different polymers.

The students placed samples of plastic into solutions of known density to identify the polymers.

The following solutions of known density were used to test the polymers.

Solution	Density(g/cm^3)
1	0.79
2	0.91
3	0.94
4	1.00
5	1.15
6	1.38

The polymers were taken from common household items. Samples were cut into 5 mm squares and tested with each solution to determine which plastics would float and which ones would sink.

For samples that sink, a letter S was recorded in the results table below.

Source of Polymer	Sink/Float					
	1	2	3	4	5	6
Food packaging trays	S	S	S	S	–	–
Lemonade bottle	S	S	S	S	S	S
Margarine tub	S	–	–	–	–	–
Motor oil container	S	S	S	–	–	–
Shampoo bottle	S	S	S	S	S	–
Tomato sauce container	S	S	–	–	–	–

Question 33 continues on page 25

(a) Use these results to complete the table and **predict** the density of each polymer. 2

Source of Polymer	Density (g/cm^3)
Food packaging trays	
Lemonade bottle	
Margarine tub	
Motor oil container	
Shampoo bottle	
Tomato sauce container	

(b) During this course you have studied addition polymers of ethylene. Compare TWO addition polymers of ethylene, with respect to their structure, properties and uses. 5

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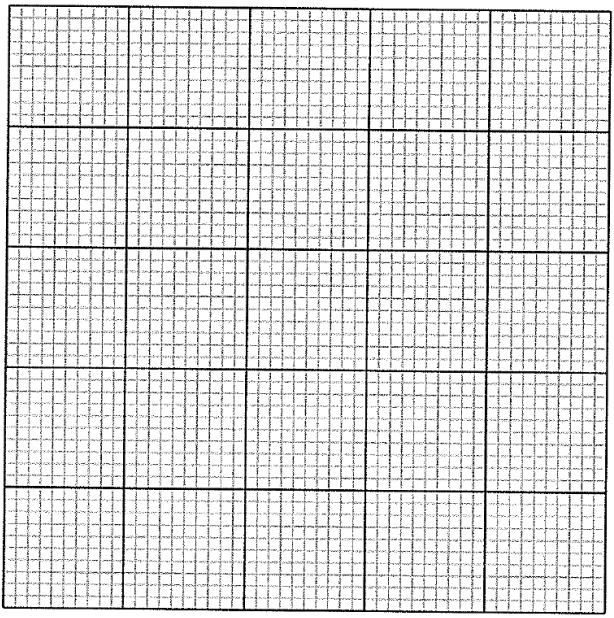
Question 34 (4 marks)

An environmental scientist wants to identify if any lead(II) ions are present in a body of water located near a smelting plant by using AAS. The absorbance of a sample of this water was found to be 0.42. From the following measurements and using the grid, determine the concentration of lead(II) ions in the body of water. Give the concentration in mol L^{-1}. **4**



Concentration of lead(II) [ppm]	Absorbance
0.1	0.18
0.2	0.34
0.3	0.49
0.4	0.66
0.5	0.81

Question 34 continues on page 27

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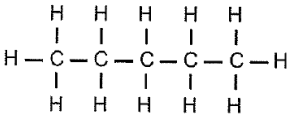
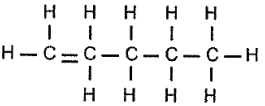
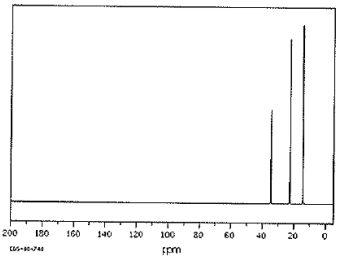
Question 35 (4 marks)

A chemist has prepared two compounds pent-1-ene and pentane. **4**

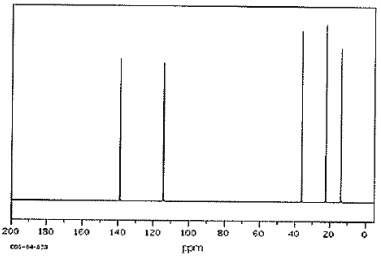
The chemist performs ^{13}C-NMR spectroscopic analysis on the compounds, resulting in the following spectra.

pentane	pent-1-ene
	

Spectrum 1



Spectrum 2



Graphic reference: https://sdbs.db.aist.go.jp

In the graphs above, note which compound each spectrum corresponds to. Justify your reasoning for how you assigned each spectrum.

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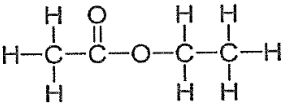
Question 36 (8 marks)

Mass spectrometry is a very useful technique in organic chemistry. Using ethyl ethanoate as an example, discuss how mass spectroscopy is used in the analysis of organic substances. Include an appropriate graph as part of your response. 8



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Section II extra writing space

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EXAMINERS

Ernst Smeets (Convenor)	Kincoppal - Rose Bay School, Rose Bay
Cassandra Aitken	Kincoppal - Rose Bay School, Rose Bay
Andrew Eaton	Wollondily Anglican College, Tahmoor
Andrea Arkstrom	Monte Saint Angelo, Sydney
Mora Soliman	MLC School, Burwood
Scott Tibbey	The Scots College, Bellevue Hill

Additional Disclaimer

Users of CSSA Trial HSC Exams are advised that due to changing NESA examination policies it cannot be assumed that CSSA Exams and NESA Exams will from year to year always fully align with respect to either or both the format and content of examination questions. Candidates for HSC exams and their teacher should anticipate a dynamic assessment environment.

Section I
20 marks

Questions 1-20 (1 mark each)

Question	Answer	Outcomes Assessed	Targeted Performance Band
1	D	CH 12-12	2-3
2	D	CH12-14	2-3
3	A	CH12-13	2-3
4	B	CH12-13	2-3
5	C	CH11/12-6	2-3
6	B	CH11/12-5	2-3
7	B	CH12-12	3-4
8	B	CH12-12	3-4
9	A	CH12-13	3-4
10	D	CH12-13	3-4
11	C	CH12-13	3-4
12	A	CH12-6, CH12-15	3-4
13	C	CH12-6, CH12-15	3-4
14	D	CH12-13	4-5
15	B	CH12-15	4-5
16	C	CH11/12-6, CH12-12	4-5
17	C	CH12-6, CH12-14	4-6
18	A	CH12-6	4-6
19	B	CH11/12-4	5-6
20	A	CH12-14	5-6

Section II

80 marks
Question 21 (5 marks)
(a) (3 marks)
Outcomes Assessed: CH12-12
Targeted Performance Bands: 2-5

Criteria	Marks
• Identifies TWO structural features of EACH molecule that allow the molecules to be soluble in water	3
• Identifies ONE structural feature of EACH molecule that allows them to be soluble in water	2
• Identifies that either compound is soluble in water	1

Sample Answer:

Leaching involves submerging the ground powder from the cycad seed inside a reed bag in running water for up to 4 weeks, depending on type of cycad. Each of the molecules is polar, due to the OH and azo functional groups in cycasin, and the OH, COOH and NH_2 functional groups in BBMA, hence they are water soluble. Grinding the seed increases the surface area available for the water to pass through. The remaining carbohydrate is insoluble and can then be cooked to make bread.

(b) (2 marks)
Outcomes Assessed: CH11/12-2, CH12-12
Targeted Performance Bands: 3-5

Criteria	Marks
• Outlines a method for distinguishing between the samples	2
• Names a method that can distinguish between the samples	1

Sample Answer:

There are several methods that could be used, such as HPLC, mass spectrometry, and NMR spectroscopy.

The simplest would be to use universal indicator and add 3 drops to a small sample of each. The BBMA has a COOH group which is acidic, so UI will turn red.

OR

^{13}C NMR spectroscopy would distinghuish between the samples. Production of the spectrum is achieved by placing small volumes of each into a sample tube and spinning it inside a strong magnetic field. Exposure to pulsed radiowaves results in spectrum showing the number of different Carbon atom environments. Cycasin will show more peaks than BMMA.

Question 22 (5 marks)
(a) (1 mark)
Outcomes Assessed: CH12-12
Targeted Performance Bands: 2-3

Criteria	Mark
• Correct equation	1

Sample Answer:

$CuCl_2\ (s) \rightleftharpoons Cu^{2+}\ (aq) + 2\ Cl^-\ (aq)$

(b) (2 marks)
Outcomes Assessed: CH11/12-4, CH11/12-5, CH11/12-6, CH12-12
Targeted Performance Bands: 3-4

Criteria	Mark
• Correctly identifies which compound is more soluble AND that both compounds have low solubility	2
• Correctly identifies which compound is more soluble OR that both compounds have low solubility	1

Sample Answer:

From the data sheet, lead(II) hydroxide has a K_{sp} value of 1.43×10^{-15} and lead(II) phosphate has a K_{sp} value of 8.0×10^{-43}. Both of these K_{sp} values are very small, indicating that they both have low solubility. However, lead(II) phosphate has a significantly lower K_{sp} value, so would be less soluble than lead(II) hydroxide.

(c) (2 marks)

Outcomes Assessed: CH11/12-6, CH12-12

Targeted Performance Bands: 4-6

Criteria	Mark
• Correctly identifies both chemical equations, both K_{sp} expressions AND identifies the correct precipitate	2
• Correctly identifies both chemical equations and both K_{sp} expressions OR correctly identifies which compound precipitates first	1

Sample Answer:

For calcium chloride:

$CaCl_2\ (s) \rightleftharpoons Ca^{2+}\ (aq) + 2\ Cl^-\ (aq)$

$K_{sp} = [Ca^{2+}]\ [Cl^-]^2$

If the calcium chloride concentration were x, then $K_{sp} = 4x^3$.

$x = 6.71$ mol L^{-1}

For aluminium nitrate:

$Al(NO_3)_3\ (s) \rightleftharpoons Al^{3+}\ (aq) + 3\ NO_3^-\ (aq)$

$K_{sp} = [Al^{3+}]\ [NO_3^-]^3$

If the aluminium nitrate concentration were x, then $K_{sp} = 27x^4$.

By trial and error, $x = 2.99$ mol L^{-1}

Hence, **aluminium nitrate** precipitates first (lower concentration).

Question 23 (9 marks)
(a) (6 marks)
Outcomes Assessed: CH11/12-2
Targeted Performance Bands: 3-6

Criteria	Marks
• Thorough justification, including standardisation of sodium hydroxide by titration against oxalic acid using appropriate and correctly cleaned glassware AND • Uses a valid method to conduct the titrations to achieve reliable results for ascorbic acid concentration	5-6
• Relevant procedures described, but no justification	3-4
• Briefly describes titration process.	1-2

Sample Answer:

NaOH needs to be standardised.

Dried oxalic acid was carefully weighed and transferred to a clean beaker containing a small volume of distilled water and dissolved. The solution was transferred to a clean 250.0 mL volumetric flask and made up to 250.0 mL with distilled water.

As a primary standard, oxalic acid is soluble and has a relatively high molar mass, reducing weighing errors, and reacts completely with basic sodium hydroxide.
Distilled water contains no contaminants so concentration of an unknown can be accurately determined.

Phenolphthalein indicator has a clear and distinct colour change close to the equivalence point, making its use appropriate.

Titrations:
The burette (accurate to +/- 0.5 mL) and pipette (accurate to +/- 0.1 mL) were washed and finally rinsed with the solutions to be used in them. Sodium hydroxide was transferred to the burette using a funnel and the initial volume recorded. For the standardising of sodium hydroxide titration 20.0 mL aliquots of oxalic acid were pipetted into clean conical flasks and 3 drops of phenolphthalein added. Sodium hydroxide was titrated against the oxalic acid solution until the endpoint was reached. The final volume was recorded and the procedure was repeated until concordance was achieved.

The ascorbic acid was then titrated against the standardised sodium hydroxide solution using phenolphthalein (the pH at the equivalence point will be similar to that of the endpoint, hence it is a suitable indicator).

(b) (3 marks)
Outcomes Assessed: CH11/12-5
Targeted Performance Bands: 3-6

Criteria	Marks
• Correct answer, with full working out	3
• Mole ratio shown, and correct working with one error	2
• Correct mole ratio	1

Sample Answer:

[NaOH] = 0.150 mol L^{-1}
V_{av} NaOH = 0.01165 mL (trial 1 and trial 3 are outliers)
mol NaOH = 0.001748 mol

mol ratio = 2:1 (mol ascorbic acid = ½ mol NaOH)

mol ascorbic acid = 0.0008740 mol
V_{asc} = 0.0150 L
[ascorbic acid] = 0.0583 mol L^{-1} in diluted sample
Therefore concentration in Kakadu plum = 0.0583 x 5 = 0.291 mol L^{-1}

Question 24 (7 marks)
(a) (3 marks)
Outcomes Assessed: CH11/12-5, CH12-6, CH12-12
Targeted Performance Bands: 3-5

Criteria	Marks
• Correct calculation with working AND equilibrium expression is shown	3
• Correct calculation with one error OR • Inverse of K is calculated	2
• Concentration of H^+ is calculated correctly or correct equilibrium expression is shown	1

Sample Answer:

$[H^+] = 10^{-pH} = 10^{-4.38}$
From the equation, $[NH_3] = [H^+] = 10^{-4.38}$

Assuming that the change in ammonium ion concentration is negligible, then $[NH_4^+] = 0.11$ mol/L

$$K_{eq} = \frac{[NH_3][H_3O^+]}{[NH_4^+]}$$

$$K_{eq} = \frac{10^{-4.38}\ X\ 10^{-4.38}}{0.11}$$

$$K_{eq} = 1.6 \times 10^{-8}$$

(b) (i) (1 mark)
Outcomes Assessed: CH11/12-5, CH12-12
Targeted Performance Bands: 2-3

Criteria	Mark
• Correctly identifies K expression	1

Sample Answer: $K = \frac{[H_2]^2[S_2]}{[H_2S]^2}$

(b) (ii) (2 marks)
Outcomes Assessed: CH11/12-5, CH11/12-6, CH12-12
Targeted Performance Bands: 4-5

Criteria	Marks
• Correctly calculates the number of moles of S_2 with no errors	2
• Calculates the concentration of S_2 OR calculates the number of moles of S_2 using an incorrect $[S_2]$	1

Sample Answer:

Let x be the concentration of H_2 and H_2S.

Using Part (a),

$$K = \frac{[H_2]^2[S_2]}{[H_2S]^2}$$

$$1.6 \times 10^{-2} = \frac{[x]^2[S_2]}{[x]^2}$$

$[S_2] = 1.6 \times 10^{-2}$ mol/L

Using $n = c \times V$

$n = 1.6 \times 10^{-2}$ mol/L x 2.0 L $= 3.2 \times 10^{-2}$ mol

(b) (iii) (1 mark)
Outcomes Assessed: CH11/12-5, CH11/12-6, CH12-12
Targeted Performance Bands: 3-4

Criteria	Mark
• Correctly identifies equilibrium as endothermic	1

Sample Answer:

K decreases as the temperature decreases. Therefore, the concentration of products must be decreasing as temperature decreases, indicating a shift to the LHS. Thus the equilibrium must be endothermic as written.

Question 25 (2 marks)
Outcomes Assessed: CH11/12-5, CH11/12-6, CH12-12
Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculates the mass of solute per litre of water	2
• Correctly identifies K expression	1

Sample Answer:

$AgNO_2$ (s) ⇌ Ag^+ (aq) + NO_2^- (aq)

$K_{sp} = [Ag^+][NO_2^-] = 6.0 \times 10^{-4}$

If $[Ag^+] = [NO_2^-] = x$, then

$x^2 = 6.0 \times 10^{-4}$

$x = 0.024495$ mol/L

So per litre, $m = n \times MM = 0.024495 \times 153.91$ g/mol = 3.85 g (3sf)

Question 26 (5 marks)
Outcomes Assessed: CH11/12-7, CH12-12
Targeted Performance Bands: 2-5

Criteria	Marks
• Discusses features of both Arrhenius and LB theories of acids AND • explains the limitation for each theory AND • shows correct equations	4-5
• As above, but limitations lack detail OR • Discusses Arrhenius OR • LB theories of acids AND • explains the limitation for the theory AND • shows correct equation	3
• Discusses Arrhenius OR • LB theories AND • explains the limitation for it	2
• States Arrhenius OR • LB theory	1

Sample Answer:

Arrhenius acid theory is that an acid will dissociate/ionise in water to produce aqueous hydrogen ions and bases dissociate to produce hydroxide ions. Neutralisation involves the reaction of hydrogen and hydroxide ions to produce water.

$$H^+ (aq) + OH^- (aq) \rightarrow H_2O (l)$$

Limitation: Unable to explain the reaction of ammonia with hydrochloric acid as there is no hydroxide ion. Eg. $NH_3 (aq) + HCl (aq) \rightarrow NH_4Cl (aq)$ or similar equation.
(note: some of the NH_3 reacts with water to form OH^-, but it is only a very small proportion – most of the reaction is directly between the molecules of ammonia with the HCl).

Bronsted-Lowry theory is that acids are proton donors and bases are proton acceptors.
For example, hydrogen ions form coordinate covalent bonds with water to produce hydronium ions, H_3O^+. These can then donate a proton to OH^- in neutralisation reactions.

$$H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l)$$

However, BL theory does not require water to be the solvent - if a proton donor and acceptor are present, an acid-base reaction can occur.

Limitation: (Can be any of the following).
BL theory cannot explain the reaction of acidic oxides with bases or of basic oxides with acids. Eg. $CaO(s)+SO_3(g) \rightarrow CaSO_4(s)$

OR BL theory cannot explain the acidic nature of chlorides such as aluminium chloride, which does not have a proton to donate.

Question 27 (3 marks)
(a) (1 mark)
Outcomes Assessed: CH12-6, CH12-14
Targeted Performance Bands: 3-4

Criteria	Mark
• Correctly identifies the reactants and products using an equation	1

Sample Answer:

$CH_3COCl (l) + C_3H_7OH (l) \rightarrow CH_3COCH_3H_7 (l) + HCl (l)$

(b) (2 marks)
Outcomes Assessed: CH12-6
Targeted Performance Bands: 4-6

Criteria	Marks
• Suggests 2 appropriate disadvantages	2
• Suggests 1 appropriate disadvantage	1

Sample Answer:

Acyl chloride is highly reactive, therefore can be dangerous. HCl produced as a product rather than water vapour, which can be irritating to the eye. The reaction is highly exothermic, so the HCl is easily vaporised.

Question 28 (4 marks)
Outcomes Assessed: CH12-5, CH12-13
Targeted Performance Bands: 3-6

Criteria	Marks
• Thorough explanation of how a named buffer works in a natural system, including relevant equations	3-4
• Outlines how a named buffer works in a natural system, including relevant equations	2
• Names a buffer	1

Sample Answer:

The carbonic acid/hydrogen carbonate ion buffer in blood is vital in maintaining blood pH. A buffer resists changes in pH when extra H^+ or OH^- is added to, or H^+ is removed from, a system.
CO_2 (g) dissolves in blood and reacts with H_2O (l) to form H_2CO_3 (aq):

CO_2 (g) + H_2O (l) ⇌ H_2CO_3 (aq).

This forms an equilibrium solution containing HCO_3^- (aq) and H_3O^+ (aq).

H_2CO_3 (aq) + H_2O (l) ⇌ HCO_3^- (aq) + H_3O^+ (aq)

In a buffered solution the concentrations of CO_2 (aq) and HCO_3^- (aq) are large compared to extra H^+ added from exercise or normal activities. If metabolic processes do add more H^+ then the equilibrium shifts to the left, maintaining a relatively constant $[H_3O^+]$ and hence pH, as $pH = -\log_{10}[H^+]$.

If extra OH^- (aq) is added it reacts with H_3O^+ (aq):

OH^- (aq) + H_3O^+ (aq) → $2H_2O$ (l)

The equilibrium reactions for this system shift to the right as there is sufficient CO_2 (aq) to form more H_2CO_3 (aq), which ionises to form more H_3O^+ (aq), hence maintaining a relatively constant $[H_3O^+]$ and hence pH.

Question 29 (3 marks)
(a) (1 mark)
Outcomes Assessed: CH12-6, CH12-14
Targeted Performance Bands: 3-4

Criteria	Mark
• Identifies the stronger acid	1

Sample Answer:

Acid Y is the stronger acid as it has a lower pK_a.

(b) (2 marks)
Outcomes Assessed: CH12-6, CH12-13
Targeted Performance Bands: 3-4

Criteria	Marks
• Identifies correct structure for both acids	2
• Identifies correct structure for 1 acid	1

Sample Answer:
Acid X – R-COOH as it is a weak acid according to its pK_a

Acid Y – HCl, H_2SO_4, as acid Y is a strong acid according to its pK_a

Question 30 (3 marks)
Outcomes Assessed: CH11, CH12-5
Targeted Performance Bands: 4-6

Criteria	Marks
• Correct equation and solution	3
• Correct equation and solution with one error	2
• Correct expression for K	1

Sample Answer:

$pH = 10^{-4.2}$

$[H^+] = 0.000063 \text{ mol } L^{-1}$

	$C_3H_6O_3$	$C_3H_5O_3^-$	H^+ (or H_3O^+)
I	0.001	0	0
C	-s	+s	+s
E	0.001 -s	s	s

$s = 0.000063 \text{ mol } L^{-1}$

$K_a = [0.000063][0.000063]/ [0.001 - 0.000063]$

$= 4.2 \times 10^{-6}$

Question 31 (4 marks)
Outcomes Assessed: CH11/12-2, CH11/12-4, CH12-7
Targeted Performance Bands: 3-5

Criteria	Marks
• Gives a correct method for carrying out a flame test with a solution • Correctly states the expected results • Gives TWO correct limitations to using this technique for the identification of one metal in a very dilute sample	4
• Gives THREE of the above criterion	3
• Gives TWO of the above criterion	2
• Gives ONE of the above criterion	1

Sample Answer: Method:

1. A nichrome wire loop should be placed in a sample of the water.

2. The wire loop is placed in the blue flame of a Bunsen burner and the colour produced observed.

A blue/green flame should be produced.

The limitations of using this method to identify the presence of copper(II) ions include:

1. other metal ions may in the sample so that the colour of the flame will not give accurate results that can be used to identify the presence of copper(II) ions

2. the amount of copper(II) ions in the sample may be too dilute to be identified using this method.

Question 32 (7 marks)
Outcomes Assessed: CH12-5, CH12-6, CH12-14
Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly identifies X, Y and Z • Explains general trend in increasing b.p • Discussion of ALL structures AND compares structures AND shows clear correlation to data	6-7
• Correctly identifies X, Y and Z • Explains general trend in increasing b.p • Discusses some structures AND compares structures AND shows clear correlation to data	4-5
• Correctly identifies X, Y and Z • Identifies some structural features	3
• Correctly identifies X, Y and Z	2
• Provides relevant information	1

Sample Answer:

All structures show an increase in boiling point as the number of carbons increase. A longer carbon chain means there are more dispersion forces between molecules, therefore a greater amount of energy is required to break these weak intermolecular forces. Hence, boiling point increases with increasing chain length. However, alcohols and amines also have a functional group attached, leading to extra intermolecular forces between their chains.

X – alcohols

Y – amines

Z – alkanes

Alkanes are non-polar molecules and are held together by weak dispersion forces – this is why they have the lowest boiling point.

Both alcohols and amines are polar molecules, and both have dispersion forces and stronger hydrogen bonding. The stronger hydrogen bonds mean more energy is required to break the intermolecular forces meaning that both amines and alcohols will have higher boiling points than alkanes.

The H-bonds between amine molecules are weaker than those between alcohol molecules because there is only one lone pair of electrons on the nitrogen atom, but two on the oxygen of the alcohol. This means that less energy is required to break the intermolecular forces in amines than in alcohols – resulting in lower boiling points than similar sized alcohols.

Question 33 (7 marks)
(a) (2 marks)
Outcomes Assessed: CH12-5, CH12-6
Targeted Performance Bands: 3-4

Criteria	Marks
• Correct density ranges for at least 5 polymers	2
• Correct ranges for less than 5 polymers OR provides "greater than" readings only	1

Sample Answer:

Source of Polymer	Sink/Float						Density (g/cm^3)
	1	2	3	4	5	6	
Food packaging trays	S	S	S	S	–	–	1.00 – 1.15
Lemonade bottle	S	S	S	S	S	S	>1.38
Margarine tub	S	–	–	–	–	–	0.79 – 0.91
Motor oil container	S	S	S	–	–	–	0.94 – 1.00
Shampoo bottle	S	S	S	S	S	–	1.15 – 1.38
Tomato sauce container	S	S	–	–	–	–	0.91 – 0.94

(b) (5 marks)
Outcomes Assessed: CH12-5, CH12-6, CH12-14
Targeted Performance Bands: 4-6

Criteria	Marks
• Compares two addition polymers of ethylene with respect to structures, properties and uses, demonstrating similarities and/or differences between them	5
• Identifies two addition polymers and their structures, properties and uses and makes some comparison	4
• Identifies either two uses OR two properties OR two structures of at least one addition polymer of ethylene	3
• Identifies one use AND one property AND?OR one structure fo an addition polymer of ethylene	2
• Provides relevant information	1

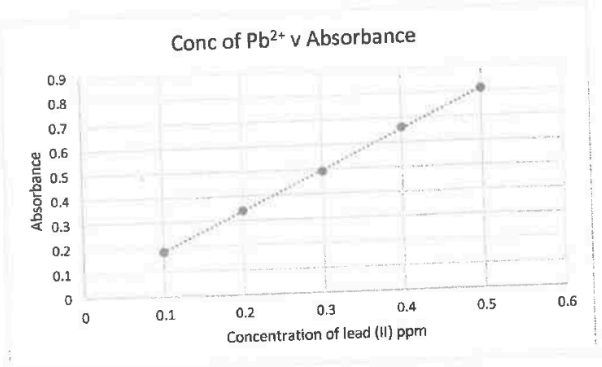
Sample answer:

HDPE (0.94 – 1.00g/cm^3) was found to be more dense than LDPE (0.91-0.94g/cm^3) LDPE has branched chains which cannot be packed together as tightly therefore they are less dense than polymers with linear molecules such as HPDE. LDPE is a flexible polymer and is used for tomato sauce bottles as it can be easily squeezed. HDPE has linear molecules which can pack closely together, making it more dense than LDPE. It is stronger and less flexible than LDPE and is suitable for use as a motor oil container which will prevent the oil from leaking.

Question 34 (4 marks)
Outcomes Assessed: CH12-5, CH12-6, CH12-7
Targeted Performance Bands: 3-6

Criteria	Marks
• Correct graph **used** to find conc. Pb (II) converted from ppm to mol L^{-1} to calculate $[Pb^{2+}]$ in mol L^{-1}. Lose 1 mark for an error	3-4
• Pb (II) in ppm is used as $[Pb^{2+}]$ in mol L^{-1} to calculate $[Pb^{2+}]$using graph OR graph is correct	2
• Graph is on incorrect axes	1

Sample answer:



Absorbance of 0.42 is approximately 0.25 ppm of Pb^{2+}

$$0.25\ ppm = 0.25\ mg/L$$

$$= 2.5 \times 10^{-4}\ g/L$$

$$= \frac{2.5 \times 10^{-4}}{207.2}\ mol/L$$

$$= 1.2 \times 10^{-6}\ mol/L^{-1}$$

Question 35 (4 marks)
Outcomes Assessed: CH12-5, CH12-6, CH12-14
Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly determines which spectrum corresponds with the correct molecule • Correctly justifies their selection for both molecules in terms of the number of the signals and the chemical shifts	4
• Correctly determines which spectrum corresponds with the correct molecule • Correctly justifies their selection for both molecules with some relevant information about both 13C NMR spectra OR • Correctly determines which spectrum corresponds with the correct molecule • Correctly justifies their selection for one molecule with in terms of the number of the signals and the chemical shifts OR • Incorrectly determines which spectrum corresponds with the correct molecule • Correctly justifies the appearance of the 13C NMR spectra for both molecules in terms of the number of the signals and the chemical shifts	3
• Correctly determines which spectrum corresponds with the correct molecule • Correctly justifies their selection for one molecule with some relevant information about one of the 13C NMR spectra OR • Incorrectly determines which spectrum corresponds with the correct molecule • Provides gives some relevant information about both 13C NMR spectra	2
• Gives one piece of correct information	1

Sample Answer:

Spectrum 1: pentane

Spectrum 2: pent-1-ene

Pentane has 5 carbon atoms and is a symmetrical molecule with only C-H bonds and 3 different chemical environments. Therefore, its spectrum shows 3 signals with chemical shifts in the range δ=5-40 ppm. Pent-1-ene also has 5 carbon atoms, but is not a symmetrical molecule and has a C=C bond present. Therefore, its spectrum shows 5 different signals, 2 signals in the range δ=90-150 ppm and 3 signals in the range δ=5-40 ppm.

Question 36 (8 marks)
Outcomes Assessed: CH12-5, CH12-6, CH12-14
Targeted Performance Bands: 3-6

Criteria	Marks
• Gives an accurate and detailed account of the use of mass spectrometry in organic analysis • Gives an accurate and detailed account of the process of how a mass spectrometer works • Gives an accurate and detailed account of the process of fragmentation • Gives an overview of isotopic patterns in mass spectra (maybe absent for 8 marks) • Gives an accurate and detailed account of the mass spectrum of ethyl ethanoate • Identifies how the information from the mass spectrum informs the identification of ethyl ethanoate • A sketch of a mass spectrum of ethyl ethanoate that should be correctly labelled for intensity (%) on y axis and m/z on x axis and correctly shows the molecular ion peak and shows at least two other peaks (intensity is not important)	8
• Gives a mostly accurate overview of the use of mass spectrometry in organic analysis • Gives a mostly accurate overview of the process of how a mass spectrometer works • Gives a mostly accurate overview of the process of fragmentation AND • Gives an accurate and detailed account of the mass spectrum of ethyl ethanoate. • A sketch of a mass spectrum of ethyl ethanoate that includes some of the following: correctly labelled for intensity (%) on y axis and m/z on x axis and correctly shows the molecular ion peak and shows at least two other peaks (intensity is not important). OR • Gives an accurate and detailed account of the mass spectrum of ethyl ethanoate. • Identifies how the information from the mass spectrum informs the identification of ethyl ethanoate. OR • A sketch of a mass spectrum of ethyl ethanoate that includes most of the following: correctly labelled for intensity (%) on y axis and m/z on x axis and correctly shows the molecular ion peak and shows at least two other peaks (intensity is not important). • Identifies how the information from the mass spectrum informs the identification of ethyl ethanoate	6-7
Shows at least TWO of the following: • some correct information about the use of mass spectrometry in organic analysis • some correct information about the process of how a mass spectrometer works • some correct information about the process of fragmentation AND • an mostly accurate outline of the mass spectrum of ethyl ethanoate OR • a sketch of a mass spectrum of ethyl ethanoate that includes some of the following: correctly labelled for intensity (%) on y axis and m/z on x axis and correctly shows the molecular ion peak and shows at least two other peaks (intensity is not important) OR	4-5

• Shows at least TWO of the following: • a mostly accurate overview of the use of mass spectrometry in organic analysis • a mostly accurate overview of the process of how a mass spectrometer works • a mostly accurate overview of the process of fragmentation • an accurate and detailed account of the mass spectrum of ethyl ethanoate • a sketch of a mass spectrum of ethyl ethanoate that includes most of the following: correctly labelled for intensity (%) on *y* axis and *m/z* on *x* axis and correctly shows the molecular ion peak and shows at least two other peaks (intensity is not important)	
Shows at least TWO of the following: • some correct information about the use of mass spectrometry in organic analysis • some correct information about the process of how a mass spectrometer works • some correct information about the process of fragmentation • some correct information about the mass spectrum of ethyl ethanoate • a sketch of a mass spectrum of ethyl ethanoate with some of the following: correctly labelled for intensity (%) on *y* axis and *m/z* on *x* axis and correctly shows the molecular ion peak and shows at least two other peaks (intensity is not important)	2-3
• Some relevant information is given	1

Sample Answer:

Mass spectrometry is a very useful technique in organic chemistry. Mass spectrometry can determine the mass of a molecule or atom very accurately. It can also determine the masses of parts of a broken down organic molecule to help identify its structure. The uses of mass spectrometry include identifying and measuring the abundance of isotopes and determining the structure of organic molecules.

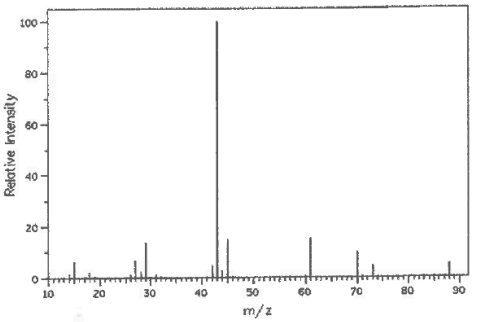
In mass spectrometry, molecules (or atoms) are bombarded with electrons to form ions. These ions pass through a magnetic field and the mass of the formed ions is detected. In the analysis of organic molecules, the sample is bombarded with high-velocity electrons. Initially, an electron is removed from the molecule itself, which forms the molecular ion (or parent ion) $[M]^{+\bullet}$. The molecular ion and the most stable fragments are detected by their charge to mass ratio *m/z* (most ions formed have a single positive charge, so the *m/z* value is equal to the mass of the ion).

Due the constant bombardment of electrons, the molecule begins to break down in a process called fragmentation to produce smaller ions that are called fragments and are made up of pieces of the molecule. During fragmentation, C-C and C-O bonds break, and C-H and C=O bonds rarely break. Therefore, different functional groups break up in different ways, which can be used for the identification of the molecule. Common fragments used for identification can include: CH_3^+ at m/z = 15, $CH_3CH_2^+$ at m/z = 29, CH_3CO^+ and $CH_3CH_2CH_2^+$ at m/z = 43 and $CH_3CH_2CO^+$ and $CH_3CH_2CH_2CH_2^+$ at m/z = 57. The *m/z* values of the fragment ions are detected and are shown as peaks in the mass spectrum.

When molecules in the sample contain isotopes of any atom, additional fragment peaks occur in the mass spectrum. Any fragments containing the isotope will have a "shadow" isotope peak. Fragments containing an carbon atom produce a small m/z+1 peak, caused by the presence of the ^{13}C nucleus. Naturally occurring carbon isotopes appear in an abundance of approximately 99% for the ^{12}C

isotope and 1% for the ^{13}C isotope. All organic molecules will show these isotope peaks in ratio of the heights of the M and $M+1$ peaks of 99:1.

The mass spectrum of ethyl ethanoate would have the molecular ion peak at $m/z = 88$, which corresponds to its molecular mass of 88.11. The ethyl ethanoate molecule fragments by breaking C-C and the C-O bonds. This results in the $CH_3C{=}O^+$ and $CH_3CH_2O^+$ fragments when the C-O bond breaks. Also the C-C bond in the $CH_3CH_2O^+$ fragment can beak, leading to the CH_2O^+ and CH_3^+ fragments. Therefore, peaks could include CH_3^+ at $m/z = 15$, $CH_3CH_2^+$ and CH_2O^+ at $m/z = 29$, $CH_3C{=}O^+$ at $m/z = 43$ and $CH_3CH_2O^+$ $m/z = 45$. For these signals, very small shadow peaks for fragments containing the ^{13}C isotope could be seen.



Graphic reference: https://sdbs.db.aist.go.jp

Therefore, mass spectrometry can be used to identify the molecular mass of the ethyl ethanoate molecule and it can be used to identify common fragments, such as the $CH_3C{=}O^+$ fragment, in the molecule, which will indicate the presence of a functional group that contains a carbonyl group, such as an ester.