

# Questions

## Module 8: Applying Chemical Ideas

Multiple-choice questions: 1 mark each

1. What is the purpose of the flame in atomic absorption spectroscopy (AAS)?

- (A) To ionise the sample
- (B) To produce a spectrum
- (C) To atomise the substance
- (D) To provide the absorption wavelength

2013 HSC Q2

2. Samples of a solution of barium nitrate were independently tested with chloride ions, with sulfate ions and also for flame colour.

Which row of the following table would represent the results?

	<i>Chloride</i>	<i>Sulfate</i>	<i>Flame test</i>
(A)	No precipitate	No precipitate	Red
(B)	No precipitate	Precipitate	Green
(C)	Precipitate	Precipitate	Green
(D)	Precipitate	No precipitate	Red

2012 HSC Q10

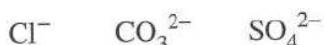
3. A chemist needed to determine the exact composition of chromium and nickel in a steel alloy to check on its quality. Which of these technologies would be used?

- |                           |                                    |
|---------------------------|------------------------------------|
| (A) Gravimetric Analysis  | (C) Proton NMR                     |
| (B) Infrared spectroscopy | (D) Atomic absorption spectroscopy |

4. Which of these chemical techniques is not a quantitative analysis?

- (A) Adding  $\text{AgNO}_3$  to  $\text{KCl}$  to form a white precipitate
- (B) A gravimetric analysis to determine the amount of fluoride in drinking water
- (C) An AAS analysis of the zinc content in the tailings dam of a mine
- (D) Using titration to find the vitamin C content in an orange juice drink

5. An aqueous sample containing the following anions is analysed.



In which order should the reagents be added to determine the amount of chloride in the sample?

	<i>Reagent 1</i>	<i>Reagent 2</i>	<i>Reagent 3</i>
(A)	$\text{AgNO}_3$	$\text{H}_2\text{SO}_4$	$\text{BaSO}_4$
(B)	$\text{HCl}$	$\text{Pb}(\text{NO}_3)_2$	$\text{AgNO}_3$
(C)	$\text{HNO}_3$	$\text{Ba}(\text{NO}_3)_2$	$\text{AgNO}_3$
(D)	$\text{Ba}(\text{NO}_3)_2$	$\text{AgNO}_3$	$\text{CH}_3\text{COOH}$

2011 HSC Q10

6. A sample of water from a stream, suspected to be contaminated with metal ions, was analysed.

The results of some tests on the water are recorded in the table.

<i>Test</i>	<i>Result</i>
Add dilute $\text{HCl}$	No change
Add $\text{Na}_2\text{SO}_4$ solution	White precipitate formed
Flame test	Pale green colour

What is the most likely contaminant in the water?

- |                      |                      |
|----------------------|----------------------|
| (A) $\text{Ba}^{2+}$ | (C) $\text{Cu}^{2+}$ |
| (B) $\text{Ca}^{2+}$ | (D) $\text{Fe}^{3+}$ |

2010 HSC Q10

7. All the lead ions present in a 50.0 mL solution were precipitated by reaction with excess chloride ions. The mass of the dried precipitate was 0.595 g.

What was the concentration of lead in the original solution?

- |                             |
|-----------------------------|
| (A) $8.87 \text{ g L}^{-1}$ |
| (B) $10.2 \text{ g L}^{-1}$ |
| (C) $11.9 \text{ g L}^{-1}$ |
| (D) $16.0 \text{ g L}^{-1}$ |

2012 HSC Q20

8. Solutions containing copper ions were analysed by AAS. A standard solution of 10 ppm copper had an AAS absorbance of 0.400. A second solution of unknown concentration was found to have an absorbance of 0.500.

100 mL of this second solution was reacted with excess sodium carbonate solution. The precipitate was then dried and weighed.

What mass of precipitate was formed?

- (A)  $1.25 \times 10^{-3}$  g
- (B)  $2.43 \times 10^{-3}$  g
- (C) 1.54 g
- (D) 2.43 g

*2010 HSC Q20*

9. Three separate colourless solutions each contain one cation,  $\text{Na}^+$ ,  $\text{Pb}^{2+}$  or  $\text{Ca}^{2+}$ .

Which of the following would be an appropriate reagent to unambiguously identify the solution containing  $\text{Pb}^{2+}$ ?

- (A) KI
- (B)  $\text{K}_2\text{CO}_3$
- (C)  $\text{K}_3\text{PO}_4$
- (D)  $\text{AgNO}_3$

*2009 HSC Q8*

10. A 2.45 g sample of lawn fertiliser was analysed for its sulfate content. After filtration and drying, 2.18 g of barium sulfate was recovered.

What is the % w/w of sulfate in the lawn fertiliser?

- (A) 16.8
- (B) 36.6
- (C) 46.2
- (D) 89.0

*2008 HSC Q15*

11. What flame colour is produced by barium ions in a flame test?

- (A) Red
- (B) Blue
- (C) Green
- (D) Orange

*2009 HSC Q4*

12. Which statement about Atomic Absorption Spectroscopy (AAS) is correct?

- (A) AAS is an effective qualitative technique but it cannot be used for quantitative analysis.
- (B) AAS measures the wavelengths of light emitted when electrons fall back to their ground state.
- (C) In AAS, white light is shone through a vaporised sample in order to observe which wavelengths are absorbed.
- (D) The wavelength of light used in AAS matches one of the spectral lines produced when the sample is analysed by a flame test.

2007 HSC Q14

13. What is a biofuel?

- (A) A non-renewable hydrocarbon that releases energy during its combustion.
- (B) An inorganic fuel such as bioethanol that releases energy during its combustion
- (C) An organic fuel derived from decayed plants, animals or microorganisms.
- (D) A fuel that is derived from inorganic material, such as grain crops or sugarcane.

14. What is the theoretical yield of a chemical reaction?

- (A) The mass of the reactants that are used up when the limiting reagent has completely reacted.
- (B) The mass of the products that are used up when the limiting reagent has completely reacted.
- (C) The mass of the product that would be formed if the limiting reagent was completely reacted.
- (D) The mass of the reactants that are formed when the limiting reagent has completely reacted.

15. Which of these statements does not involve a ‘green’ practice for chemical industries?

- (A) The methods used should not be harmful to the environment and the products made should be recyclable or biodegradable.
- (B) The processes used in the manufacture of the products should result in either no wastes, or wastes that can be recycled or are biodegradable.
- (C) The chemical process should utilise renewable resources rather than non-renewable resources, such as fossil fuels.
- (D) The chemical industry should use the most economical methods for the disposal of any waste, to ensure they make a profit.

- 16.** A scientist used atomic absorption spectroscopy (AAS) to analyse the concentration of iron in a sample of water. The scientist analysed the sample five times and obtained the absorbances shown in the table.

<i>Analysis</i>	<i>Absorbance</i>
1	0.390
2	0.392
3	0.249
4	0.387
5	0.394

The scientist needed an average absorbance to determine the concentration of iron from a calibration curve.

Which value should the scientist use?

- (A) 0.362
- (B) 0.3624
- (C) 0.39075
- (D) 0.391

2006 HSC Q14

- 17.** Which of the following substances is best analysed by atomic absorption spectroscopy (AAS)?

- (A) Calcium
- (B) Iodine
- (C) Nitrogen
- (D) Silicon

2005 HSC Q11

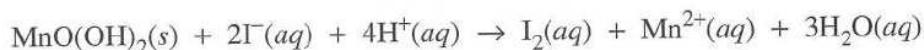
- 18.** Why is the effect of changes on a chemical equilibrium important for the chemical industry when designing a chemical synthesis process?

- (A) To achieve the optimum yield of reactants from the equilibrium reaction involved in the chemical synthesis process.
- (B) So that the reaction conditions used will obtain the optimum yield of products as efficiently as possible.
- (C) So that the temperature used will allow the chemical reactions to work in a reasonable timeframe.
- (D) So that the correct catalyst can be chosen for increasing the rate of the reaction and so obtain the maximum yield.

19. The Winkler method is used to determine the amount of dissolved oxygen in a sample. In this procedure, oxygen reacts with  $\text{Mn}^{2+}$  under alkaline conditions to produce a precipitate of  $\text{MnO(OH)}_2$ .



The precipitate is then dissolved in acid and reacted with iodide, forming iodine and  $\text{Mn}^{2+}$ .



Finally, the amount of iodine produced is determined by reaction with thiosulfate.



When a sample of water was analysed using the Winkler method, a total of 0.60 mol of thiosulfate was used in the reaction.

How many moles of oxygen were present in the original sample?

- (A) 0.15
- (B) 0.30
- (C) 0.60
- (D) 1.20

2005 HSC Q15

20. Four students were asked to test a solution for the presence of a cation by using various anions. The students obtained these results:

<i>Student</i>	<i>Chloride</i>	<i>Sulfate</i>	<i>Carbonate</i>
<i>A</i>	no precipitate	no precipitate	precipitate
<i>B</i>	precipitate	precipitate	no precipitate
<i>C</i>	precipitate	precipitate	precipitate
<i>D</i>	no precipitate	precipitate	no precipitate

Each student concluded that  $\text{Pb}^{2+}$  was present.

Which student had results consistent with this conclusion?

- (A) *A*
- (B) *B*
- (C) *C*
- (D) *D*

2001 HSC Q15

21. The table gives the results of chemical tests for some cations and anions.

(ppt = precipitate)

<i>Ion</i>	<i>Add cold 0.1 M HCl</i>	<i>Add 0.1 M KSCN</i>	<i>Add 0.1 M Na<sub>2</sub>CO<sub>3</sub></i>	<i>Add 0.1 M AgNO<sub>3</sub></i>
Ca <sup>2+</sup>	no change	no change	white ppt	no change
Fe <sup>3+</sup>	no change	red colour	brown ppt	no change
Ba <sup>2+</sup>	no change	no change	white ppt	no change
Pb <sup>2+</sup>	white ppt	no change	white ppt	no change
Cl <sup>-</sup>	no change	no change	no change	white ppt

When a group of students performed the above tests on an unknown solution they obtained the following results:

<i>Add cold 0.1 M HCl</i>	<i>Add 0.1 M KSCN</i>	<i>Add 0.1 M Na<sub>2</sub>CO<sub>3</sub></i>	<i>Add 0.1 M AgNO<sub>3</sub></i>
no change	no change	white ppt	white ppt

Which conclusion is consistent with these results?

- (A) The sample contained both CaCl<sub>2</sub> and BaCl<sub>2</sub>.
- (B) The sample contained both CaCl<sub>2</sub> and PbCl<sub>2</sub>.
- (C) The sample contained both FeCl<sub>3</sub> and PbCl<sub>2</sub>.
- (D) The sample contained both FeCl<sub>3</sub> and BaCl<sub>2</sub>.

2002 HSC Q15

22. The atomic absorption spectrophotometer was developed by Sir Alan Walsh and his team at CSIRO in the 1950s. Its development was one of the most significant in Australian chemical technology. What did it provide?
- (A) A rapid method to monitor chemical pollutants in water supplies
  - (B) The first method for determining the concentrations of metal ions in water supplies
  - (C) A method for determining the concentrations of hydrocarbons at very low concentrations
  - (D) A method for determining the concentrations of metal ions at very low concentrations

2001 HSC Q12

- 23.** Four students analysed a sample of fertiliser to determine its percentage of sulfate.

Each student:

- weighed an amount of fertiliser;
- dissolved this amount in 100 mL of water;
- added aqueous barium nitrate;
- filtered, dried and weighed the barium sulfate precipitate.

Their results and calculations are shown in the table.

Student	Mass of fertiliser used (g)	Mass of $BaSO_4$ weighed (g)	Percentage of sulfate in fertiliser (%)
A	11.6	19.5	69.2
B	10.4	16.9	66.9
C	10.268	22.612	90.6
D	11.1	18.2	67.5

The percentage of sulfate calculated by Student C was significantly higher than that of the other students. Which is the most likely reason for this?

- (A) Student C did not dry the sample for long enough.
- (B) Student C added more  $Ba(NO_3)_2$  solution than the other students.
- (C) Student C used a balance capable of measuring weight to more decimal places.
- (D) Student C waited longer than the other students for the  $Ba(NO_3)_2$  to react completely with the sulfate.

2001 HSC Q13

- 24.** Which part of the electromagnetic spectrum is used in NMR spectroscopy?

- (A) UV radiation
- (B) Radio waves
- (C) Visible light
- (D) Infrared radiation

- 25.** When acidified potassium permanganate is used to oxidise an organic compound, the colour change that occurs can help to identify the compound.

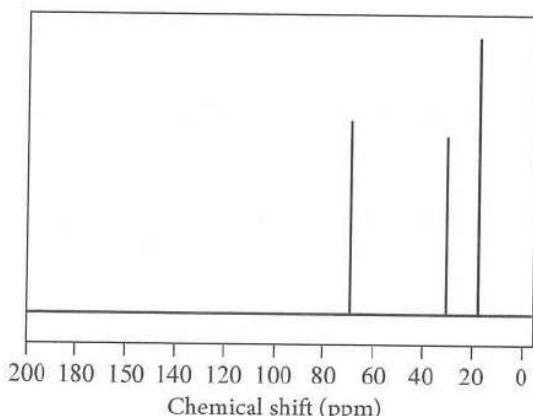
Which of these would be the correct result of such a test?

- (A) Brown to colourless with hexene
- (B) Orange to green with primary and secondary alcohols
- (C) Purple to colourless with primary and secondary alcohols
- (D) Colourless to purple with tertiary alcohols

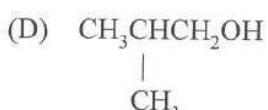
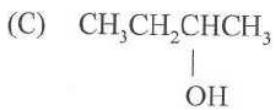
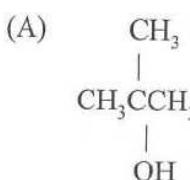


31. A chemist wanted to measure the concentration of copper ions in a solution of copper sulfate. Which of these technologies would be most suitable for doing this?
- (A) UV-visible spectroscopy  
(B) Mass spectroscopy  
(C) Proton NMR  
(D) Infrared spectroscopy
32. Which of these instruments would pass filtered light of a specific wavelength into a solution, then measure its absorbance to determine the concentration of a coloured compound in the solution?
- (A) Atomic absorption spectrometer  
(B) Colourimeter  
(C) Bunsen burner flame  
(D) IR spectrophotometer
33. In UV-visible spectrophotometry, what is a chromophore?
- (A) A chemical group in a substance that absorbs visible and UV radiation  
(B) A colourimeter that measures the absorbance of light by a chemical solution  
(C) The detecting device in a UV-visible spectrophotometer  
(D) The calibration curve for a known substance
34. The various spectroscopic techniques used for chemical analysis utilise different parts of the electromagnetic spectrum as an energy source. Which of these statements is incorrect about the region of the electromagnetic spectrum that is used?
- (A) Colourimetry, AAS and UV-vis spectroscopy use either visible or UV radiation  
(B) IR spectroscopy uses infrared radiation  
(C) Mass spectroscopy uses high-energy electrons  
(D) NMR uses radio waves
35. Which of the following organic molecules would display the greatest number of hydrogen environments when analysed using proton NMR spectroscopy?
- (A)  $\text{C}_2\text{H}_4\text{Br}$   
(B)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$   
(C)  $\text{CH}_3\text{COOH}$   
(D)  $\text{CH}_3\text{CH}_3$

36. The following C-13 NMR spectrum is for an alcohol.



The four alcohols shown below have the same molecular formula  $C_4H_{10}O$ . Which of these alcohols would produce the C-13 spectrum above?



37. There are a number of analysis techniques that chemists can use to determine the structure and identify an unknown organic compound.

Which of the following analysis techniques should be used to verify that an organic compound is an alcohol?

- (A) Mass spectroscopy  
(B) Infrared spectroscopy

- (C) Proton and C-13 NMR spectroscopy  
(D) All of the above

38. Which of these examples is *not* a qualitative chemical analysis?

- (A) Obtaining a red colour for calcium in a flame test  
(B) Observing flakes of paint containing lead in a soil sample  
(C) Identifying that a solution is basic due to litmus paper turning blue  
(D) Measuring the concentration of a transition metal in a solution

## Short-answer questions

**Question 39 (7 marks)**

A 20.72 g sample of solid lead was placed into 0.100 L of 1.00 mol L<sup>-1</sup> silver nitrate solution.

- (a) Complete the table. Show relevant calculations in the space below the table.

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<i>Chemical species</i>	Pb <sup>2+</sup> (aq)	Pb(s)	Ag <sup>+</sup> (aq)	Ag(s)	NO <sub>3</sub> <sup>-</sup> (aq)
<i>Moles in final mixture</i>					
<i>Balanced chemical equation</i>					

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- (b) With reference to only ONE species in the product mixture, explain why care must be taken in disposing of the final mixture.

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2013 HSC Q23

**Question 40 (5 marks)**

A laboratory assesses the amount of zinc in dietary supplement tablets.

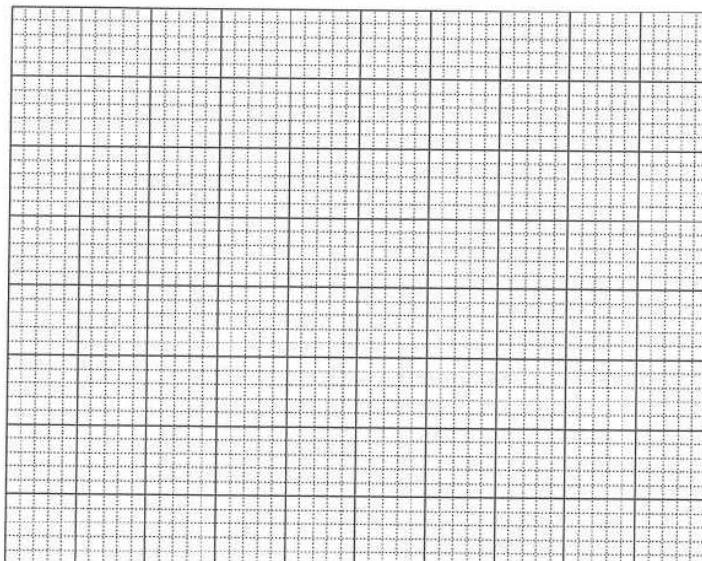
A chemist prepared 4 tablet samples for analysis by dissolving the tablets individually in 10% nitric acid. Each tablet solution was made up to a final volume of 100 mL. Five standard solutions of zinc were also prepared.

The absorbances of the standard and sample solutions were determined by atomic absorption spectroscopy at 213.9 nm.

The results are presented in the table.

<i>Standard zinc solutions (mg L<sup>-1</sup>)</i>	<i>Absorbance</i>
0.00	0.000
1.00	0.170
2.00	0.330
3.00	0.503
4.00	0.680
Tablet samples: mean absorbance	0.280

- (a) Plot a calibration curve for the standard zinc solutions on the grid. 3

**Question 40 continues**

## Question 40 (continued)

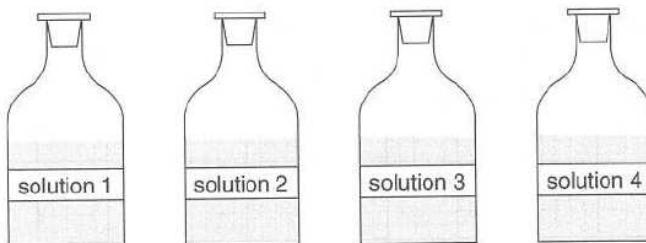
- (b) Using the mean absorbance of the tablet samples, calculate the mean amount of zinc per tablet in mg. 2

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**End of Question 40***2008 HSC Q19***Question 41 (4 marks)**

Each of the four bottles contains one of the following solutions:

- barium nitrate
- hydrochloric acid
- lead nitrate
- sodium carbonate.



A student mixed pairs of these solutions together and obtained the following results.

<i>Reactants</i>	<i>Observation</i>
solution 1 and solution 2	bubbles
solution 2 and solution 3	white precipitate
solution 2 and solution 4	no reaction
solution 1 and solution 3	white precipitate
solution 1 and solution 4	white precipitate

**Question 41 continues**

**Question 41 (continued)**

- (a) Write a correctly balanced equation to represent the reaction between solution 1 and solution 2. 1
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- (b) Use the information to identify the four solutions. 2

<i>Solution</i>	<i>Identity</i>
1	
2	
3	
4	

- (c) Why would it be inappropriate to use flame tests to identify these solutions? 1
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**End of Question 41**

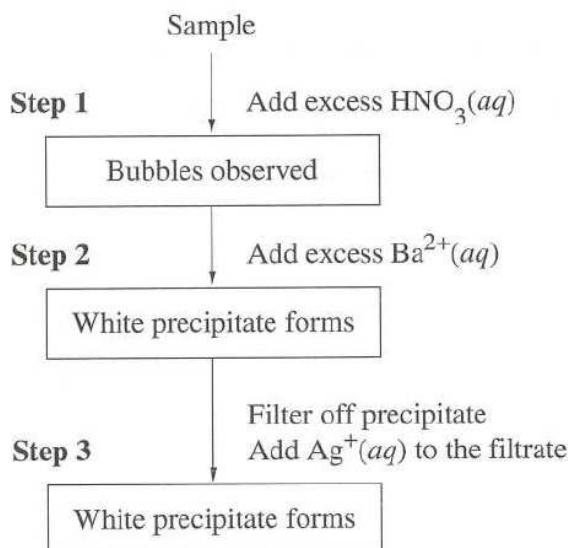
2007 HSC Q17

**Question 42 (3 marks)**

- An unknown carboxylic acid has an unbranched structure. Its mass spectrum has a molecular ion peak of  $m/z = 74$ . What is its molecular formula and IUPAC name? 3
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**Question 43 (4 marks)**

The flow diagram shows a series of tests that can be used to identify carbonate, chloride and sulfate ions present in a sample.



- (a) Identify the gas observed during Step 1.

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- (b) Explain why the analysis must be performed in the sequence given.

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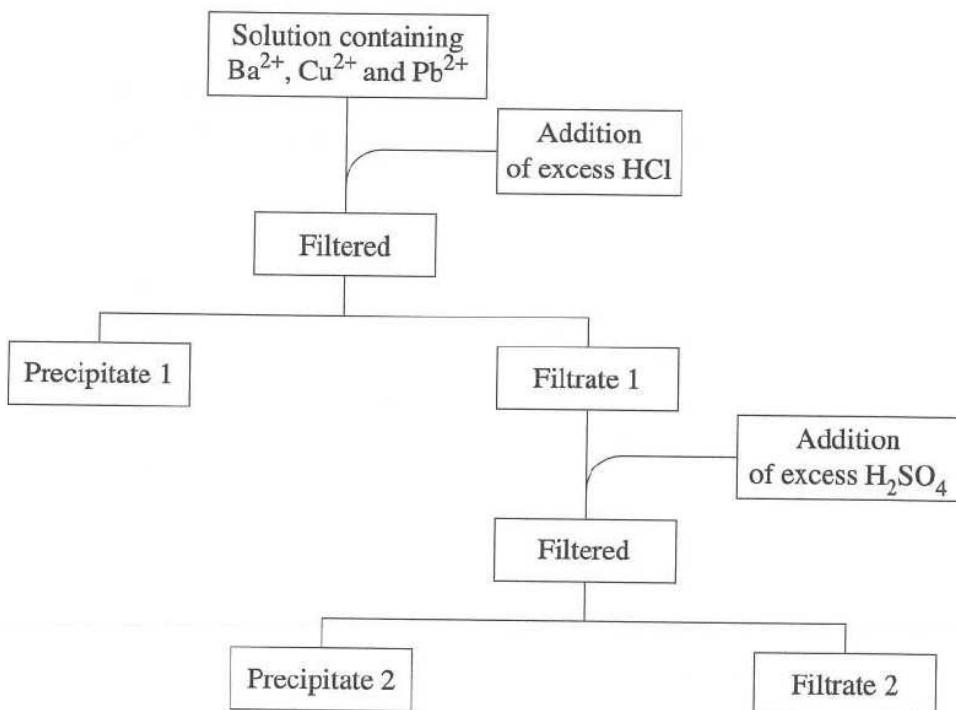
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2006 HSC Q26

**Question 44 (5 marks)**

A solution contains three cations,  $\text{Ba}^{2+}$ ,  $\text{Cu}^{2+}$  and  $\text{Pb}^{2+}$ . The flow chart indicates the plan used to confirm the identity of these cations.



- (a) Name Precipitate 2.

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- (b) Write a balanced net ionic equation for the formation of Precipitate 1.

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- (c) Suggest a test and the expected result that would confirm the identity of the metal cation remaining in Filtrate 2.

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2013 HSC Q22

**Question 45 (6 marks)**

The diagrams represent equipment used in an investigation to determine the chloride ion concentration in a water sample.

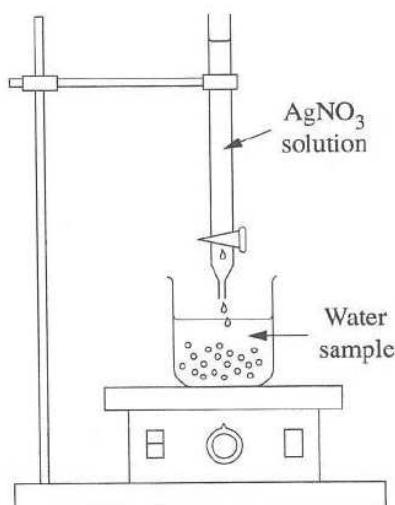


Figure 1

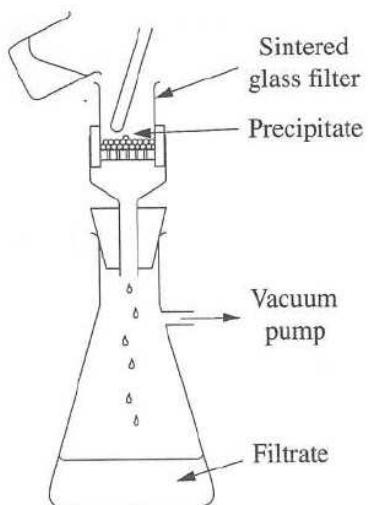


Figure 2

- (a) Describe how you could, using the equipment in the diagram, determine the chloride ion concentration in a water sample. Include a balanced equation. 3

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**Question 45 continues**

## Question 45 (continued)

- (b) If the volume of the water sample being tested is 50.0 mL and the mass of the dried precipitate obtained is 3.65 g, calculate the chloride ion concentration in the water sample in ppm.

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## End of Question 45

2007 HSC Q27(a) &amp; (b)

## Question 46 (5 marks)

Alkanes, alkenes, alcohols and carboxylic acids are four different classes of organic compounds.

- (a) Describe a simple test that would confirm that a compound is organic.

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- (b) Describe a sequence of tests that could be used to distinguish between any THREE of the classes of organic compounds named above.

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Adapted 2013 HSC Q36(d)(i) &amp; (ii)

**Question 47 (7 marks)**

With reference to the synthesis of a named chemical substance, outline how the reaction conditions are chosen to maximise yield, yet to minimise the environmental impact of the process.

7

**Question 48 (5 marks)**

During this course you conducted investigations, such as flame tests, to identify cations of the following metals: barium, calcium, magnesium lead(II), silver, copper(II), iron(II) and iron(III).

- (a) Outline a risk assessment for this investigation, and show how this would influence the experimental procedure.

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- (b) Provide a conclusion based on one set of observations from your first-hand investigation.

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*Adapted 2006 HSC Q33(a)(i) & (ii)*

**Question 49 (2 marks)**

Compare bioethanol as a source of energy compared to petrol, using the data in the table below.

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Fuel	Enthalpy of combustion (kJ g <sup>-1</sup> )	Mass of CO <sub>2</sub> produced per gram of fuel during combustion (g)
Petrol	47.9	3.1
Bioethanol	29.6	1.9

**Question 50 (5 marks)**

The table shows properties of some fuels.

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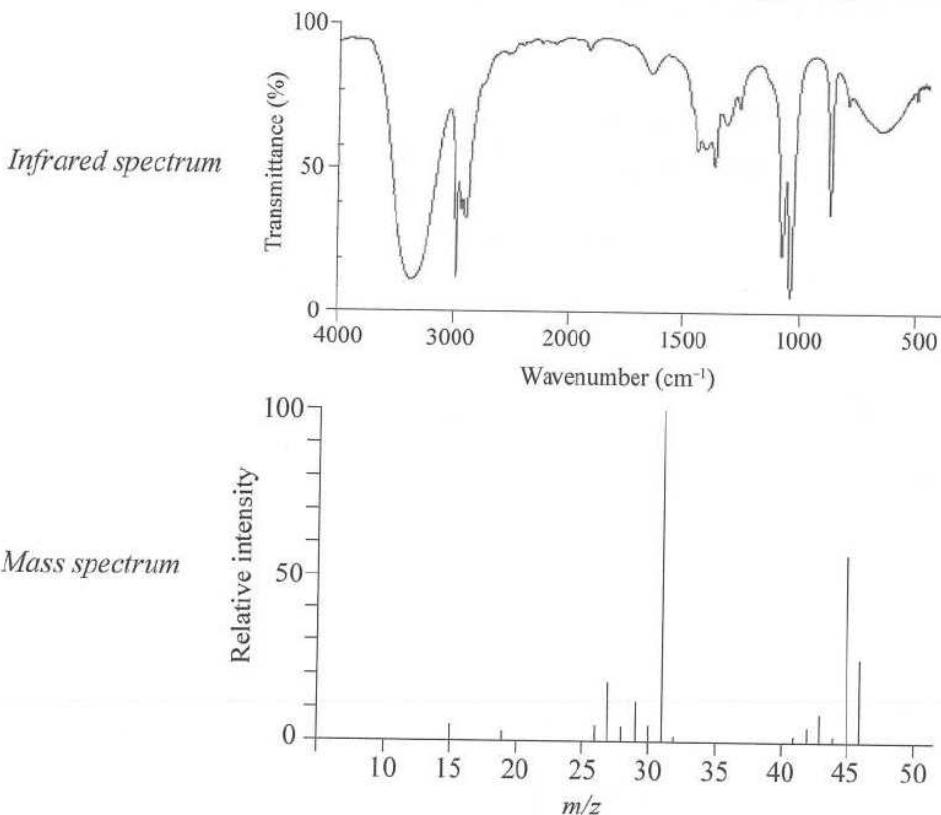
<i>Fuel</i>	<i>Main sources</i>	<i>Enthalpy of combustion (kJ g<sup>-1</sup>)</i>	<i>Boiling point (°C)</i>
Methane	• Petrochemical industry	55.6	-161.5
Propane	• Petrochemical industry • Natural gas	50.3	-42.1
Octane	• Refined from crude oil	47.9	125.7
Ethanol	• Hydration of ethene • Fermentation	29.7	78.3

Assess the potential of ethanol as an alternative fuel, making use of data from the table.

Adapted 2004 HSC O25

**Question 51 (6 marks)**

The infrared (IR) spectrum and mass spectrum below is for a liquid organic compound, *X*.



- (a) In the fragmentation pattern shown above for compound *X*, at what  $m/z$  value does the peak signal occur? Indicate what this signal represents. 2

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- (b) Suggest an organic compound that would match the data above for compound *X* and give its structural formula. Justify your choice. 4

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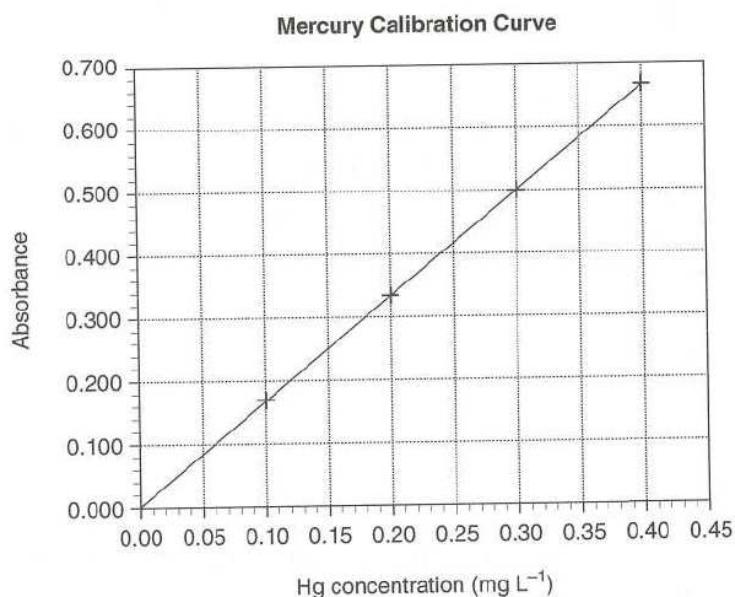
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**Question 52 (3 marks)**

The mercury concentration of a certain fish species was determined by atomic absorption spectroscopy. The sample data are:

Mass of fish (g)	18.6
Final sample volume (mL)	25.0
Absorbance (mean)	0.280



A consumer wants to avoid eating fish with a mercury concentration greater than 0.5 mg/kg of fish.

Calculate the concentration of mercury in the fish sample and state whether the consumer can eat this fish species.

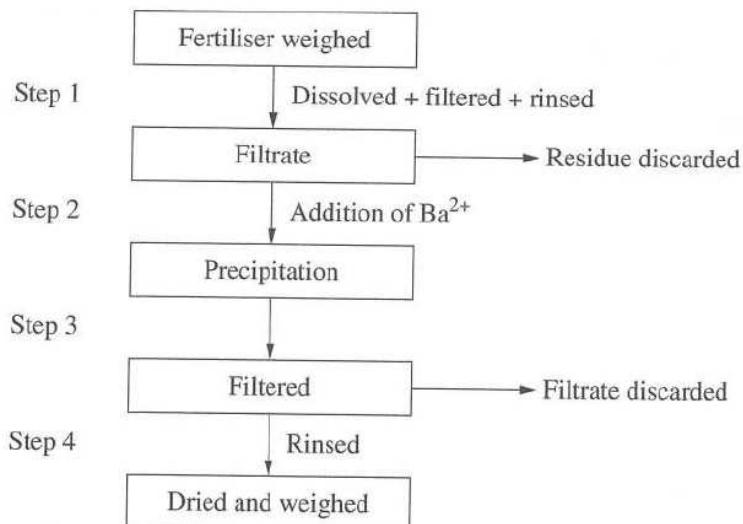
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204 STRIVE Chemistry 12 • Past HSC Q & A

2012 HSC Q32

**Question 53 (6 marks)**

The flowchart shown outlines the process used to determine the amount of sulfate present in a sample of lawn fertiliser.



- (a) What assumptions were made and how do these affect the validity of this process? 3

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- (b) It was found that a 4.25 g sample of the fertiliser had a sulfate content of 35%. 3

What is the mass of the dried precipitate at Step 4? Include a chemical equation in your answer.

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*Adapted 2010 HSC Q29*

**Question 54 (2 marks)**

A student collected a 250 mL sample of water from a local dam for analysis. It is suspected that the water in the dam has a high concentration of chloride ions.

2

Describe a chemical test that could be carried out on the water sample to determine the presence of chloride ions. Include an equation in your answer.

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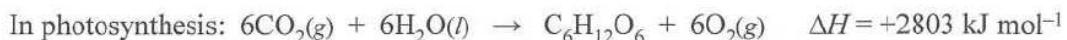
2010 HSC O31(b)

**Question 55 (5 marks)**

Explain how atomic absorption spectroscopy (AAS) is used in the environmental monitoring of a metal that is toxic to humans.

5

*Adapted 2009 HSC Q24*

**Question 56 (7 marks)**

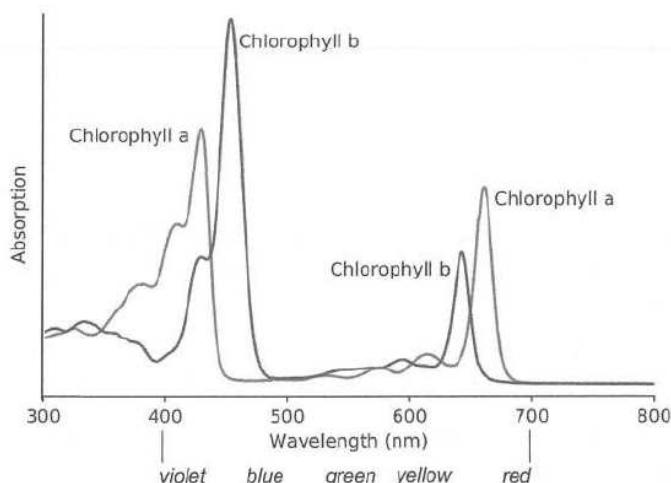
During photosynthesis, green chlorophyll *a* and *b* pigments enable plants such as algae to convert energy from the Sun via a complex series of reactions into glucose and oxygen.

- (a) (i) Name a specific analytical method apart from colourimetry that is used to determine the concentration of chlorophyll in solution prepared from algae
- 1
- .....

- (ii) What is the difference between transmittance and absorption, and which is tested for in this type of analysis?
- 2
- .....
- .....

- (iii) Which technique provides more accurate results for the concentration of a metal ion or salt in a solution – colourimetry or the technique named in (a)?
- 1
- .....

- (b) The absorption spectra of chlorophyll *a* and *b* in algae are shown below.



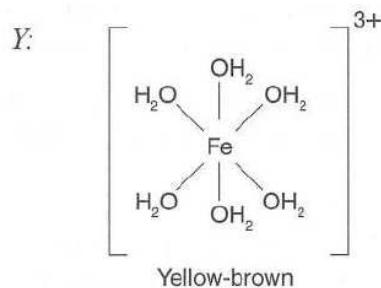
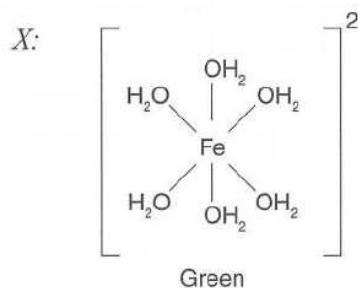
- (i) Which wavelength(s) enable the greatest absorbance for chlorophyll *b*?
- 1
- .....

- (ii) Which wavelength(s) are best to measure the chlorophyll *a* concentration?
- 1
- .....

- (c) When measuring the chlorophyll concentration in the algal solution, what is the relationship between its concentration and the light absorbed by the solution?
- 1
- .....
- .....

**Question 57 (9 marks)**

The structure of two complex ions  $X$  and  $Y$  are shown below.



- (a) Name the metal ion in each of these metal complexes. 2

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- (b) Outline the bonding that occurs between the central metal ion in  $X$  and its  $-\text{OH}_2$  ligands. 2

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- (c) How can a complex ion help to identify the metal ions in a salt? 1

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- (d) (i) A student had a solution that formed a yellow-brown precipitate when dilute NaOH was added. The student suspected that this solution contained  $\text{Fe}^{3+}$ , but knew that other metal ions can also produce a yellow-brown precipitate with NaOH. So potassium thiocyanate (KSCN) was then added and a blood-red colour was obtained. This confirmed that  $\text{Fe}^{3+}$  was present.

Is this method qualitative or quantitative? Justify your answer and explain the results obtained.

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**Question 58 (5 marks)**

A student carried out an investigation to analyse the sulfate content of lawn fertiliser. The student weighed out 1.0 g of fertiliser and dissolved it in water. 50 mL of  $0.25 \text{ mol L}^{-1}$  barium chloride solution was then added. A white precipitate of barium sulfate formed, which weighed 1.8 g.

- (a) Calculate the percentage by mass of sulfate in the fertiliser.

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- (b) Evaluate the reliability of the experimental procedure used.

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2003 HSC Q27

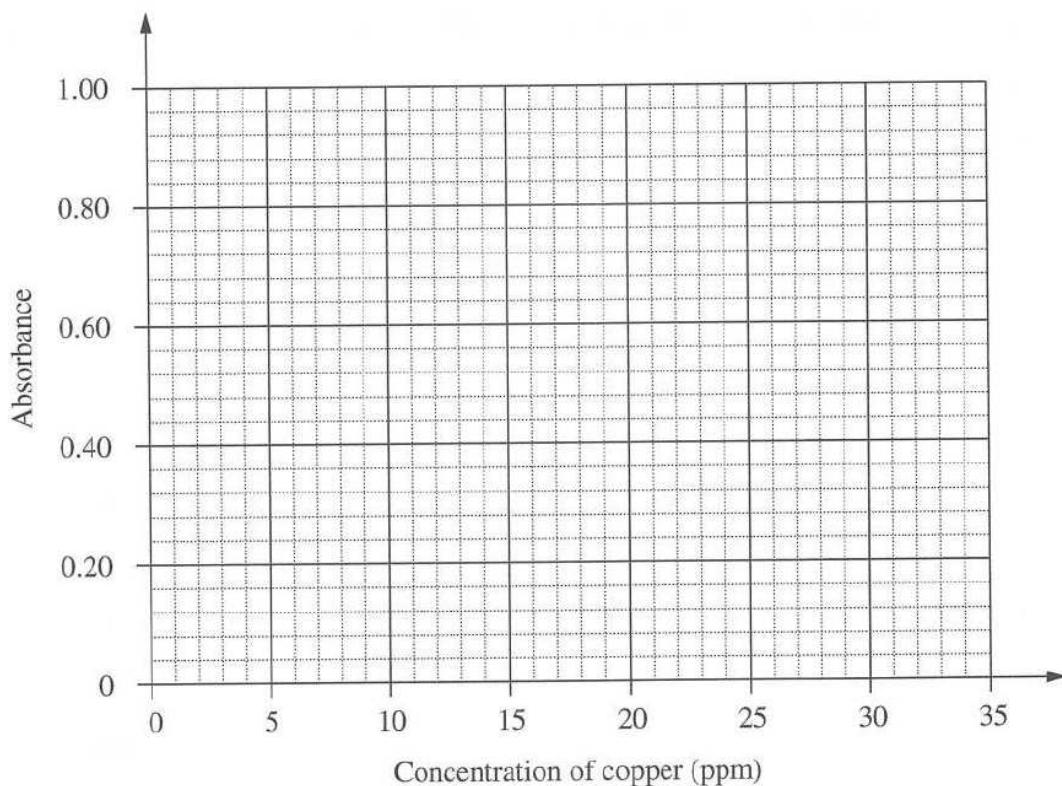
**Question 59 (5 marks)**

Atomic absorption spectroscopy was used to analyse a set of standard solutions of copper. The results are presented in the table.

<i>Concentration of copper (ppm)</i>	<i>Absorbance</i>
0	0
5	0.20
10	0.39
15	0.52
20	0.64
25	0.77

- (a) Draw an appropriate graph of the data.

2

**Question 59 continues**

**Question 59 (continued)**

- (b) An analysis of two samples containing copper was then performed. The results are given in the table. 3

<i>Sample</i>	<i>Absorbance</i>
1	0.44
2	0.90

Use your graph to estimate the concentration of copper present in the samples, and assess the validity of each of your estimates.

**End of Question 59**

2006 HSC Q25

**Question 60 (3 marks)**

Complete the following table to show how the anions listed can be identified.

Anion	Reagent	<i>Observations if anion is present</i>
$\text{Cl}^-$		
$\text{PO}_4^{3-}$		
$\text{SO}_4^{2-}$		

2004 HSC Q21(b)

**Question 61 (3 marks)**

The heavy metal, cadmium, has a toxic effect on living things. This metal has become a widely dispersed pollutant in the environment due to its mining and smelting, as well as from NiCd rechargeable batteries.

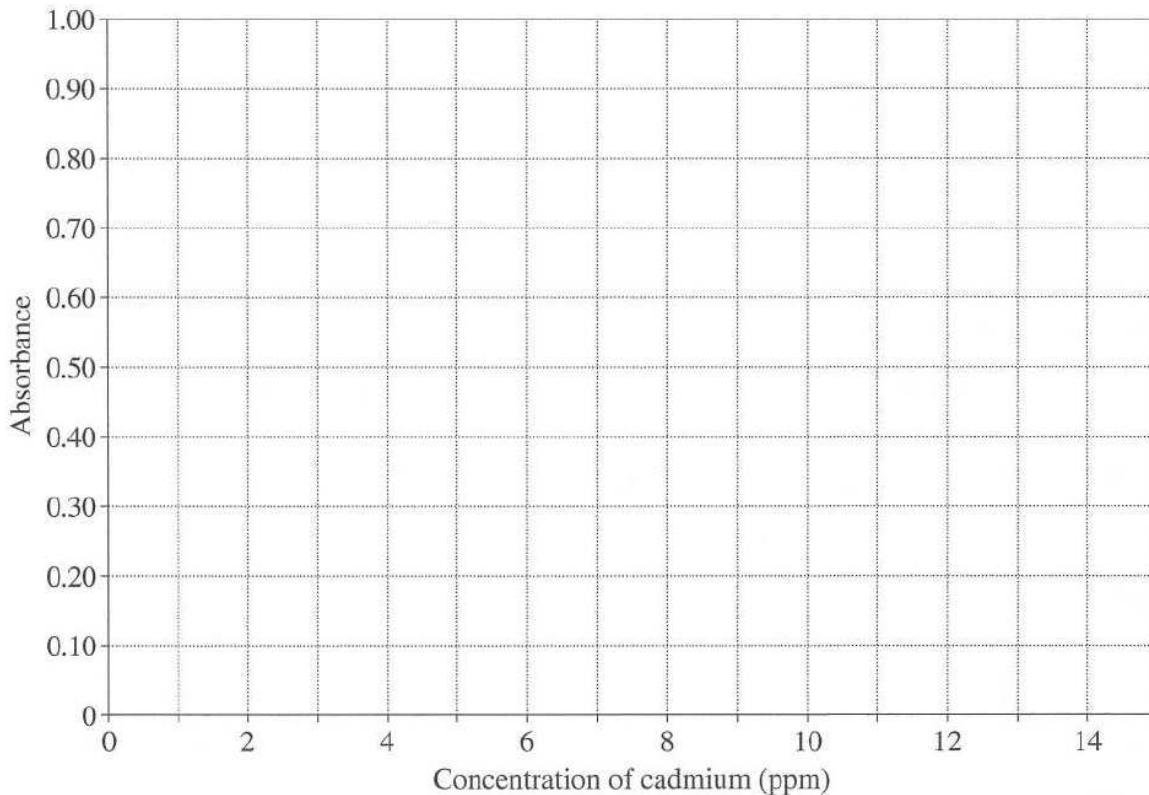
A river near a battery recycling plant was suspected of having cadmium pollution. So, some samples of fish from the river were tested using atomic absorption spectroscopy. The average absorbance reading obtained for the fish samples was 0.35.

A set of five standard cadmium solutions were also measured in a similar way. The results of analysis of the set of standard cadmium solutions are presented in the table.

<i>Concentration of cadmium standard solution (ppm)</i>	<i>Absorbance</i>
0	0.00
3	0.22
6	0.38
9	0.62
12	0.83

- (a) Draw an appropriate graph of the data.

2



**Question 61 continues**

## Question 61 (continued)

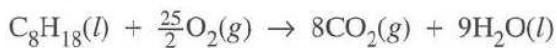
- (b) From the calibration curve you have drawn in (a), determine the concentration, 1  
in ppm, of cadmium in the fish.
- .....

**End of Question 61**

*New stimulus & new part (b)  
(a) is 2003 HSC Q28(a)*

**Question 62 (6 marks)**

When there is a plentiful supply of oxygen, octane undergoes incomplete combustion, 6  
according to the following equation:



Under conditions of low oxygen levels supply of oxygen, octane will undergo  
incomplete combustion, according to the following equation:



Using this data, explain the need for monitoring the reaction conditions in a chemical  
synthesis process with respect to combustion.

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*New question adapted from  
2001 HSC Q25 & 2014 HSC Q25(a)*

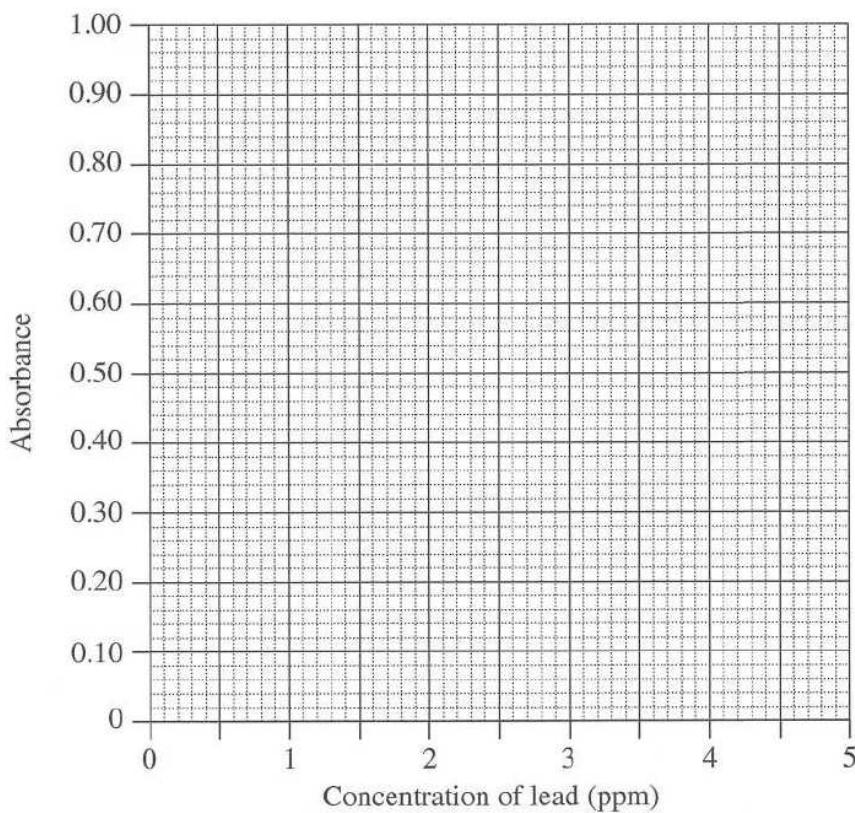
**Question 63 (2 marks)**

A university student decided to measure the concentration of lead (Pb) in the soil around his home. He prepared five standard lead solutions of known concentration. The absorbance of these solutions was measured. These results are shown in the table.

<i>Concentration of lead standard (ppm)</i>	<i>Absorbance</i>
0	0.00
1	0.15
2	0.31
3	0.44
4	0.59
5	0.75

- (a) Draw a line graph of these data.

1

**Question 63 continues**

## Question 63 (continued)

- (b) The student prepared solutions from four different soil samples around his home. These solutions were also analysed using the same method. The results are shown in the table.

1

<i>Solutions made from soil samples</i>	
<i>Area sampled</i>	<i>Absorbance</i>
Front garden bed	0.19
Back garden bed	0.09
Mail box	0.22
Back fence	0.11

Determine the highest concentration of lead in the soil around the home.

## End of Question 63

2001 HSC Q26(a) &amp; (b)

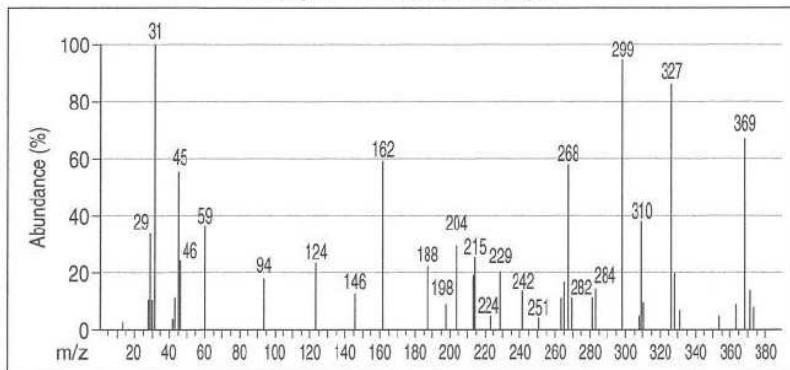
## Question 64 (2 marks)

Mass spectrometry can be used to identify other drugs in a blood sample.

2

Below is a spectrum obtained from the analysis of a blood sample.

Analysis of a blood sample



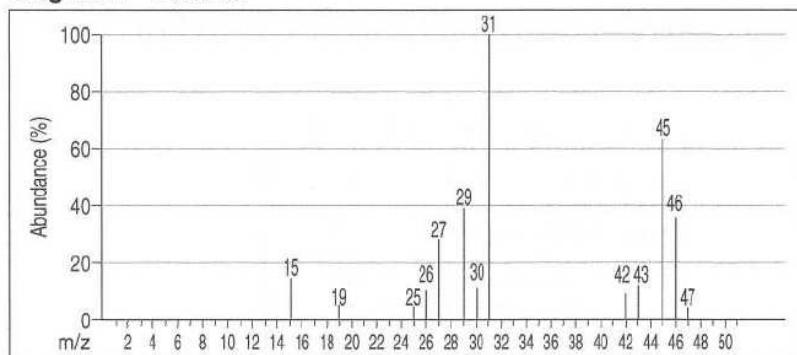
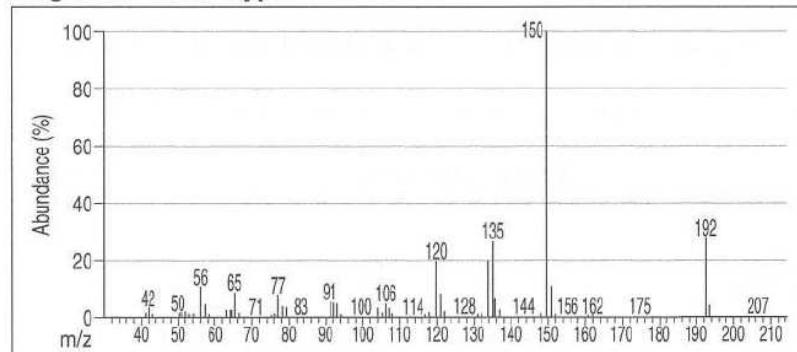
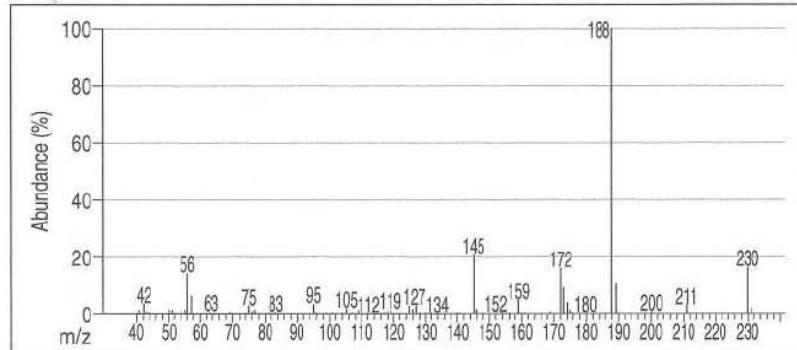
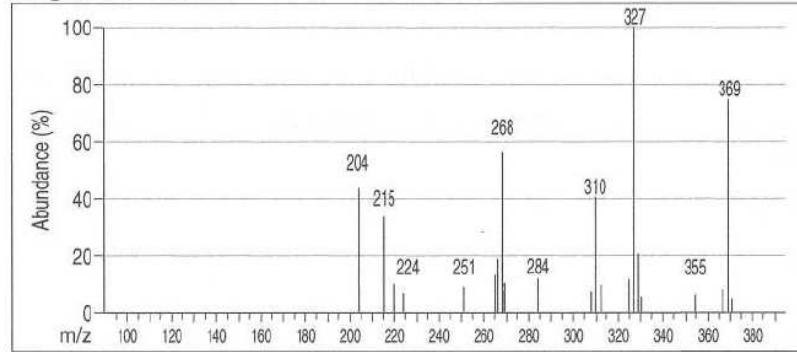
The mass spectra of four substances (Diagrams 1 to 4) are shown on the next page.

Using the diagrams, deduce which of the substances are present in the blood sample. Justify your answer.

## Question 64 continues

Adapted 2017 HSC Q35(c)(iii)

## Question 64 (continued)

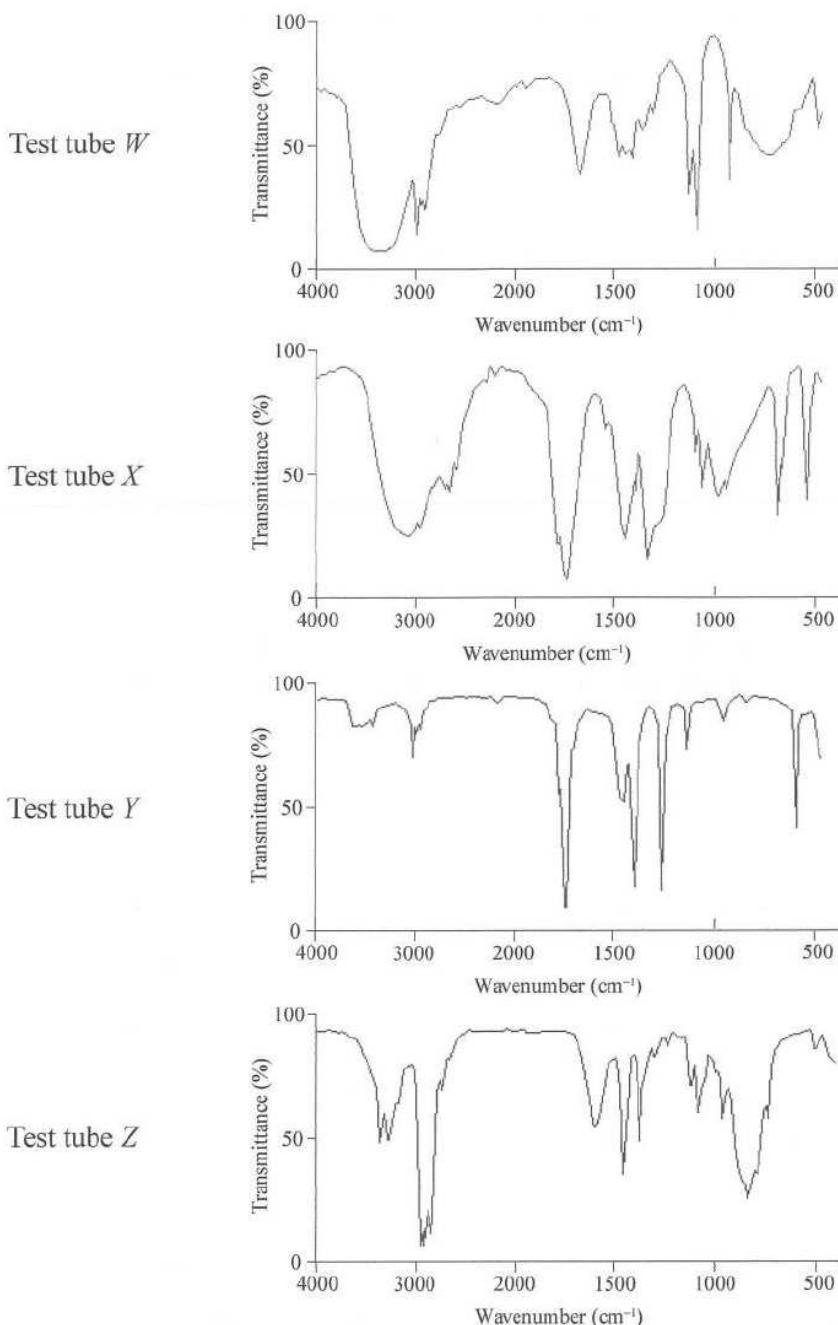
**Diagram 1 – Ethanol****Diagram 2 – Methoxyp.d****Diagram 3 – Trifluor.d****Diagram 4 – Heroin****End of Question 64**

**Question 65 (6 marks)**

Your chemistry teacher has asked you to identify the contents of four test tubes (labelled *W*, *X*, *Y* and *Z*), each containing a different organic compound. The four chemicals are ethanoic acid, 1-aminobutane, ethanol and propanone, and you have been provided with the IR spectra below for each of these four chemicals.

6

Determine which substance is in each of the test tubes, using the spectra below and the table of Infrared Absorption Data (in the Appendix of this book). Justify your choice.

**Question 65 continues**

**Question 65 (continued)**

**End of Question 65**

**Question 66 (3 marks)**

Describe how a first-hand investigation in the school laboratory could be undertaken to determine the presence of a particular metal in a water sample using a flame test. Give a reason why this method may not work.

3

2009 HSC Q30(d)(i)

**Question 67 (6 marks)**

Some chemistry students were setting up an experiment to measure the concentration of copper(II) sulfate in two blue copper(II) sulfate solutions (labelled *X* and *Y*) using a colourimeter.

- (a) The students chose to use an orange filter in the colourimeter.

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- (b) Outline how a copper(II) sulfate calibration curve would be obtained and how the students would have used it to determine the concentration of copper(II) sulfate in their unknown solutions.

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- (c) The absorbance values the students obtained were 0.868 for solution *X* and 0.608 for solution *Y*. Using the calibration curve that they obtained, they determined that the concentrations of the copper(II) sulfate solutions were 0.40 mol L<sup>-1</sup> for *X* and 0.24 mol L<sup>-1</sup> for *Y*.

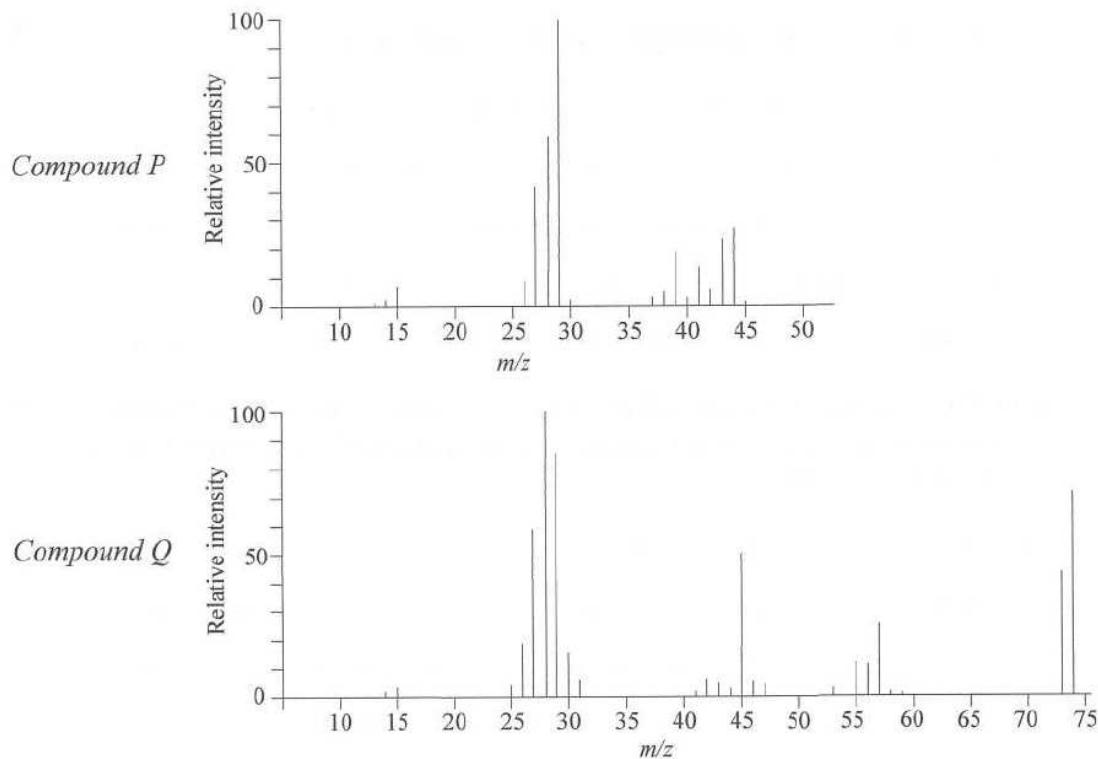
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Give a valid conclusion about the concentrations of *X* and *Y* that the students might have determined after obtaining these results.

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**Question 68 (5 marks)**

A mass spectrum can help to identify an unknown organic compound. The mass spectra of two unknown organic compounds is shown below. A chemical analysis has identified that Compound *P* as an alkane. Compound *Q* is its related carboxylic acid.



- (a) Identify Compound *P* and Compound *Q*. Justify your decision. 3

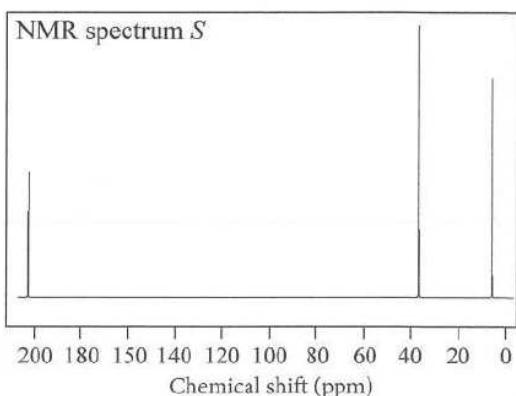
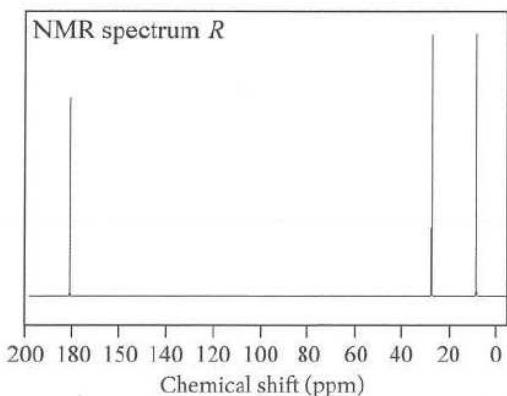
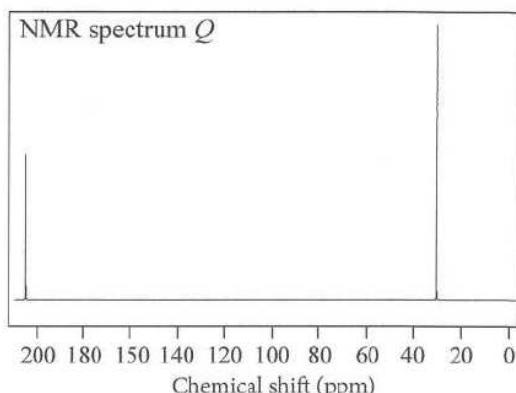
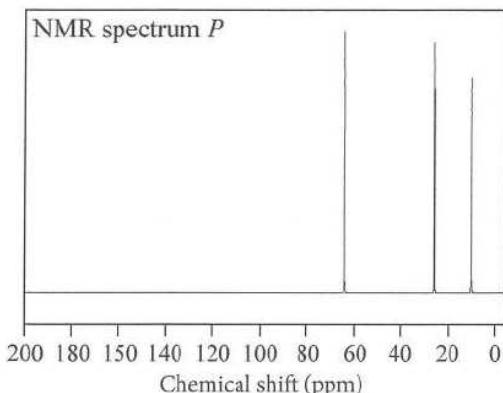
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- (b) Draw the molecular formulae for both Compound *P* and Compound *Q* and correctly name each compound with its IUPAC name. 2

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**Question 69 (5 marks)**

The four C-13 NMR spectra (*P*, *Q*, *R* and *S*) shown below are for four different organic compounds. 5



Using the Chemical Shift data table (in the Appendix), determine which of these compounds are represented by *P*, *Q*, *R* and *S*:

- propanone
- propanoic acid
- propan-1-ol
- propanal

Justify your decision with reference to the spectra used.

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**Question 69 continues**

**Question 69 (continued)**

End of Question 69

**Question 70 (4 marks)**

1-butene and 2-butene are isomers. Indicate why the C-13 NMR spectra and proton NMR spectra for these isomers would differ.

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**Question 71 (3 marks)**

An organic chemist will usually perform several instrumental analysis techniques when trying to identify an organic substance and to determine its structure. Account for this, making reference to some of the instrumental analytical techniques that are used.

**Question 72 (4 marks)**

- (a) Why is it important that the chemical industry carefully monitors the chemical processes they use with respect to the environment?

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- (b) Outline two ways in which the chemical industry could reduce its impact on the environment.

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# Answers

## Module 8: Applying Chemical Ideas

### Multiple choice

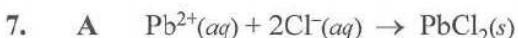
- |              |              |              |              |              |              |              |              |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| <b>1.</b> C  | <b>2.</b> B  | <b>3.</b> D  | <b>4.</b> A  | <b>5.</b> C  | <b>6.</b> A  | <b>7.</b> A  | <b>8.</b> B  |
| <b>9.</b> A  | <b>10.</b> B | <b>11.</b> C | <b>12.</b> D | <b>13.</b> C | <b>14.</b> C | <b>15.</b> D | <b>16.</b> D |
| <b>17.</b> A | <b>18.</b> B | <b>19.</b> A | <b>20.</b> C | <b>21.</b> A | <b>22.</b> D | <b>23.</b> A | <b>24.</b> B |
| <b>25.</b> C | <b>26.</b> D | <b>27.</b> A | <b>28.</b> C | <b>29.</b> D | <b>30.</b> C | <b>31.</b> A | <b>32.</b> B |
| <b>33.</b> A | <b>34.</b> C | <b>35.</b> B | <b>36.</b> D | <b>37.</b> D | <b>38.</b> D |              |              |

### Explanations

- C** In AAS, the compound being analysed must be broken up into free atoms. The flame atomises the compound. So (C) is the answer. AAS detects metal atoms in organic compounds as well as ionic compounds. So (A) is incorrect. A hollow metal cathode made of the metal being analysed (and not the flame) produces the appropriate spectrum to give absorption wavelengths that are characteristic of the metal atoms in the sample being analysed. So (B) and (D) are incorrect.
- B** Barium chloride is soluble and so chloride ions will not form a precipitate with barium nitrate solution. Barium sulfate is insoluble and so sulfate ions will form a precipitate with barium nitrate solution. Barium ions give a green flame test result. Only (B) has this combination.
- D** Atomic absorption spectroscopy (AAS) can be used to accurately identify and determine the concentration of most metals (including chromium and nickel) in samples of water and other substances. So (D) is the answer.
- A** You need to know the difference between ‘quantitative’ (able to be numerically measured) and ‘qualitative’ (observed, related to the characteristics or qualities, and not able to be measured). (A) is a precipitation reaction, which does not involve a measurement and so (A) is the answer. The other choices (B), (C) and (D) are quantitative as they involve a measurement being made.

5. C First, add dilute HNO<sub>3</sub> to react with CO<sub>3</sub><sup>2-</sup> and CO<sub>2</sub>(g) will be released. Second, add Ba(NO<sub>3</sub>)<sub>2</sub> solution to precipitate out SO<sub>4</sub><sup>2-</sup> as white barium sulfate. Third, add AgNO<sub>3</sub> solution to precipitate Cl<sup>-</sup> as white AgCl. So (C) is the answer. However, if AgNO<sub>3</sub> is used first, a mixed precipitate of AgCl and Ag<sub>2</sub>SO<sub>4</sub> will be produced, so (A) is incorrect. Adding HCl will add Cl<sup>-</sup> to the mixture and contaminate it, so (B) is incorrect. If Ba(NO<sub>3</sub>)<sub>2</sub> is used first, SO<sub>4</sub><sup>2-</sup> and most of the CO<sub>3</sub><sup>2-</sup> will precipitate, but some CO<sub>3</sub><sup>2-</sup> will be left and so when AgNO<sub>3</sub> is added, Ag<sub>2</sub>CO<sub>3</sub> will form and contaminate the AgCl precipitate. So (D) is incorrect.

6. A The four listed ions would not produce a reaction with HCl. Only Ba<sup>2+</sup> would definitely give a precipitate with Na<sub>2</sub>SO<sub>4</sub> as BaSO<sub>4</sub> is highly insoluble. Ca<sup>2+</sup> could also give a precipitate, if present in a high enough concentration to be considered a contaminant, as CaSO<sub>4</sub> is not very soluble. Cu<sup>2+</sup> and Fe<sup>3+</sup> do not form a precipitate with Na<sub>2</sub>SO<sub>4</sub>. Ba<sup>2+</sup> gives a pale green flame test while Ca<sup>2+</sup> gives a brick red flame. So (A) is the only possible answer.



$$\text{Molar mass, } M(\text{Pb}) = 207.2 \text{ g mol}^{-1}$$

$$\text{Molar mass, } M(\text{PbCl}_2) = 207.2 + (2 \times 35.45) = 278.1 \text{ g mol}^{-1}$$

$$\text{Mass Pb in sample} = 0.595 \times \frac{207.2}{278.1} = 0.4433 \text{ g}$$

$$\text{In 50 mL, } [\text{Pb}^{2+}] = \frac{0.4433}{50 \times 10^{-3}} = 8.866 \approx 8.87 \text{ g L}^{-1} \dots \text{as in (A).}$$

8. B Standard solution has 10 ppm [Cu<sup>2+</sup>]

$$\therefore \text{unknown sample} = \frac{0.500}{0.400} \times 10 = 12.5 \text{ ppm} = 0.0125 \text{ g L}^{-1}$$

$$\text{Molar mass, } M(\text{CuCO}_3) = 63.55 + 12.01 + (3 \times 16.00) = 123.56 \text{ g mol}^{-1}$$

$$\text{Molar mass, } M(\text{Cu}^{2+}) = 63.55 \text{ g mol}^{-1}$$

$$\therefore \text{mass CuCO}_3 = \frac{0.0125}{10} \text{ g/100 mL} \times \frac{123.56}{63.55} = 2.43 \times 10^{-3} \text{ g} \dots \text{as in (B)}$$

9. A KI solution would distinguish the Pb<sup>2+</sup> solution from the other solutions, as lead iodide forms a yellow precipitate, whereas calcium iodide and sodium iodide are both highly soluble in water. So (A) is the answer. Both K<sub>2</sub>CO<sub>3</sub> and K<sub>3</sub>PO<sub>4</sub> solutions would form white precipitates with both Pb<sup>2+</sup> and Ca<sup>2+</sup>, so would not distinguish them from each other. So (B) and (C) are incorrect. All nitrates are soluble, so AgNO<sub>3</sub> cannot be used to distinguish Pb<sup>2+</sup>. So (D) is incorrect.

[Note: Ag<sup>+</sup> in AgNO<sub>3</sub> may react with anions in the test solutions, as many silver compounds are insoluble.]

**10. B** Molar mass,  $M(\text{BaSO}_4) = 137.3 + 32.07 + (4 \times 16.00) = 233.37 \text{ g mol}^{-1}$

233.37 g of BaSO<sub>4</sub> contains 96.07 g SO<sub>4</sub><sup>2-</sup>

2.18 g of BaSO<sub>4</sub> contains  $\frac{96.07}{233.37} \times 2.18 = 0.897 \text{ g SO}_4^{2-}$

% w/w SO<sub>4</sub><sup>2-</sup> in lawn fertiliser =  $\frac{0.897}{2.45} \times 100 = 36.6\%$  ... as in (B).

**11. C** Barium ions give a pale green (apple green) flame test, so (C) is the answer. Lithium, calcium and strontium give red flame tests, copper gives a bluish-green test, while sodium and calcium give yellow/orange test results, so (A), (B) and (D) are incorrect.

**12. D** AAS uses a cathode containing the element being tested so the light produced matches the emission spectrum of that element which can also be seen in a flame test, so (D) is the answer. AAS does make quantitative determinations, so (A) is incorrect. AAS determines its results from the amount of light absorbed relative to a reference beam, so (B) is incorrect. The hollow cathode produces light specific to the element being tested and not white light, so (C) is incorrect.

**13. C** A biofuel is an organic fuel derived from biomass, such as decayed plants, animals, microorganisms, plants such as grain crops or sugarcane, etc. Examples of a biofuel include bioethanol and biodiesel. A biofuel is a renewable fuel, as opposed to a non-renewable hydrocarbon fuel, such as fossil fuels, e.g. coal, oil and natural gas. Hence (C) is the only correct answer.

**14. C** The yield of a chemical reaction is the amount of products (not reactants) formed. Hence the theoretical yield of a chemical reaction is the mass of the products (not reactants) that would be formed if the limiting reagent was completely reacted. So (C) is the answer, and (A) and (D) are incorrect. In a chemical reaction, reactants form products. The reactants are ‘used up’ to form the products, so the products do not get ‘used up’, but rather the products are ‘formed’. So (B) is incorrect.

**15. D** ‘Green’ chemistry aims to reduce or eliminate hazardous wastes from a chemical process in order to protect the environment. It incorporates all the principles mentioned in (A), (B) and (C). The only statement that does not involve a ‘green’ practice is (D), and so (D) is the answer.

- 16. D** The result of Analysis 3 is an outlier and should be ignored. The calculated average of the other four results gives 0.39075, as in (C) – but this needs to be rounded to three significant figures to 0.391. So (D) is the answer.
- 17. A** Although atomic absorption spectroscopy can measure very low concentrations of a wide variety of elements, it is particularly useful in doing this for metals. So (A) is the answer, as calcium is the only metal given.
- 18. B** Chemical engineers make a chemical synthesis process as safe and as efficient as possible. They design processes that maximise the yield and rate at which a desired product (not reactant) is produced. Hence the reaction conditions used are chosen to get an acceptable yield of products, in an acceptable time. So (B) is the answer, and (A) is incorrect. The reaction conditions include not only the temperature, but also the reactant concentration, volume/pressure, and whether a catalyst is used. So (C) is incorrect. Not all chemical processes need a catalyst and if needed, a catalyst increases the rate of reaction without affecting the yield. So (D) is incorrect.
- 19. A** From the last equation, 0.60 mol of thiosulfate reacts with 0.30 mol  $I_2$ . The previous equation shows that 0.30 mol  $I_2$  was produced from 0.30 mol  $MnO(OH)_2$ . The first equation shows that for 0.30 mol  $MnO(OH)_2$  to be formed, 0.15 mol  $O_2$  is needed. So (A) is the answer.
- 20. C** Lead(II) chloride ( $PbCl_2$ ) is only slightly soluble in water, and may or may not form a precipitate with chloride ions depending on the lead concentration.  $PbSO_4$  and  $PbCO_3$  are both insoluble in water, so  $Pb^{2+}$  will give a precipitate with both sulfate and carbonate ions. (C) is the only possible answer.
- 21. A**
- Addition of HCl produces no change – so no  $Pb^{2+}$ . (B) and (C) are incorrect.
  - Addition of KSCN produces no change – so no  $Fe^{3+}$ . (D) is incorrect.
  - Addition of  $Na_2CO_3$  produces a white precipitate – so  $Ca^{2+}$  or  $Ba^{2+}$  could be in solution. [Note:  $Pb^{2+}$  has been eliminated as a possibility above on the first bullet.]
  - Addition of  $AgNO_3$  produces a white precipitate – so  $Cl^-$  is in solution.
- A solution containing  $CaCl_2$  and  $BaCl_2$  is consistent with the results ... as in (A).
- 22. D** Atomic absorption spectroscopy is specific to metal ions and can measure very low metal ion concentrations, as in (D). Modern versions can determine concentrations below 1 ppm. Not all chemical pollutants are metals, so (A) is incorrect. Hydrocarbons are not metal ions, so (C) is incorrect. This method was preceded by other less accurate, more time-consuming methods, so (B) is incorrect.

- 23. A** A poorly dried precipitate will lead to a result that is too high. A precipitate must be filtered and dried until its mass is constant, to ensure that all water is removed. Since student C has a high value for the mass of  $\text{BaSO}_4$ , this is most likely due to not drying the sample properly. So (A) is the answer. (B) is incorrect, as once the sulfate is precipitated, excess  $\text{Ba}(\text{NO}_3)_2$  would have no further effect. (C) is incorrect, as a more accurate balance would enable the percentage of sulfate to be obtained more accurately, but would not significantly alter the value. The reaction is almost instantaneous, so waiting longer will not affect the result. So (D) is incorrect.
- 24. B** NMR spectroscopy uses radio waves, so (B) is the answer. UV radiation and visible light are used in UV-visible spectroscopy, visible light is also involved in colourimetry and flame tests, and infrared radiation is used in IR spectroscopy. So (A), (C) and (D) are incorrect.
- 25. C** An oxidising agent, e.g. acidified potassium permanganate, can be used to distinguish between different types of alcohols. With  $1^\circ$  and  $2^\circ$  alcohols, acidified potassium permanganate will change from purple to colourless, but does not change with  $3^\circ$  alcohols. So (C) is the answer, and (D) is incorrect. Alkenes undergo addition reactions across their double  $\text{C}=\text{C}$  bonds and so change bromine water from brown to colourless. However, this is an addition reaction and not an oxidation reaction. So (A) is incorrect. The colour change from orange to green will occur when primary and secondary alcohols are oxidised by acidified potassium dichromate (not acidified potassium permanganate). So (B) is incorrect.
- 26. D** Mass spectroscopy is the only technique listed that uses high-energy electrons to determine the molecular mass of a chemical. This method results in cations that are separated according to the mass/charge ratio ( $m/z$ ). Their relative abundance is then measured and the results are plotted as a mass spectrum versus the relative abundance. This can inform a chemist about the molar mass of a chemical and the elements present, as well as the isotopic abundances. So (D) is the answer.
- 27. A** In IR spectroscopy, ‘wavenumber’ is the number of waves (i.e. frequency) per cm. A high wavenumber means a high frequency, short wavelength and high energy. When molecules in a substance absorb IR radiation, their bonds become more energetic (i.e. more stretching or bending) as they move from one vibrational energy level to another. So (B), (C) and (D) are all true statements. The region from  $1100\text{--}750\text{ cm}^{-1}$  is the range for C–C bonds and is found in all hydrocarbons. Although this region does not identify any functional groups, it is part of the ‘fingerprint region’ below  $1400\text{ cm}^{-1}$  that is unique to a compound and so useful in identifying a substance. So (A) is not correct, and therefore the answer.

- 28. C** Propan-1-ol is an alcohol with the formula  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ . From the infrared absorption data (in HSC exam data sheet): the first broad band would be an O–H bond, the second broad band would be a C–H bond, the third broad band would be a C–O bond. So (C) is the answer. Propan-1-ol does not contain any N–H or C=O bonds, so (A) and (D) are incorrect. (B) is in the wrong order and so incorrect.
- 29. D** Heavy metals, such as mercury, lead and cadmium are highly poisonous (toxic) to organisms and biomagnify up a food chain. Hence these heavy metals are very harmful if they contaminate the environment. Magnesium is *not* a heavy metal, and is actually found in many foods that we eat. So (D) is the answer.
- [Note: There is no widely agreed definition of a heavy metal and so different meanings exist, depending on the context. However, this term usually applies to a metal with both a high density and over an atomic number of 20. Some heavy metals are either essential nutrients, e.g. Fe, Co and Zn, or are considered to be relatively harmless, e.g. Ag (although toxic in larger amounts or certain forms).]
- 30. C** In a flame test, many metal ions produce a very similar colour and so the accuracy of a flame test is limited as it is difficult to detect small differences in a colour. So (C) is the answer. It is not related to a Bunsen burner's temperature, so (B) is incorrect. No metal ions are inert, so (D) is incorrect. All metal ions emit energy when their electrons move from an excited state to the ground state, however only some metal ions emit this energy in the visible part of the electromagnetic spectrum. Hence not all metals will give a flame colour (e.g. silver, magnesium). So (A) is incorrect.
- [Note: Remember, a flame test cannot be used for identifying anions.]
- 31. A** UV-visible spectroscopy is suitable for determining the concentration of a metal ion which has colour, such as  $\text{Cu}^{2+}$  in a solution. Although not listed here, colourimetry can also be used to this, but is not as accurate as UV-visible spectroscopy. So (A) is the answer. UV-visible spectroscopy would be quicker and simpler to use, and therefore cheaper than using the other techniques listed. So (B), (C) and (D) are not the most suitable and therefore incorrect.
- 32. B** A colourimeter would be used to investigate the absorbance of a particular wavelength of light by a solution to determine the concentration of a coloured compound in it. So (B) is the answer. (A), (C) and (D) are incorrect. An atomic absorption spectrometer passes light from a lamp (made from the same element being tested) through a vaporised sample. A Bunsen burner is used for a flame test in which a sample of an element or compound is placed in the hot flame, so that it can be identified by its characteristic emission spectrum (colour). An IR spectrophotometer uses infrared radiation, not visible light.

- 33. A** A chromophore is the part of a molecule that absorbs visible or ultraviolet radiation, e.g. some chromophores (i.e. light-absorbing groups) are:  $-\text{C}-\text{H}$ ,  $-\text{C}-\text{C}$ ,  $-\text{C}=\text{C}$ ,  $-\text{C}\equiv\text{C}$ ,  $-\text{C}-\text{Cl}$ ,  $-\text{N}=\text{O}$ , etc. So (A) is the answer.
- 34. C** High-energy electrons used in mass spectroscopy are not part of the EM spectrum. So (C) is the answer as it is an incorrect statement. (A), (B) and (C) are all correct statements regarding the part of the EM spectrum used.
- 35. B**
- $\text{C}_2\text{H}_4\text{Br}$  (bromoethane) in (A) has 2 H environments.
  - $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$  (ethanol) in (B) has 3 H environments.
  - $\text{CH}_3\text{COOH}$  (ethanoic acid) in (C) has 2 H environments.
  - $\text{CH}_3\text{CH}_3$  (ethane) in (D) has 2 H environments.
- (B) has the greatest number of H environments and is therefore is the answer.
- 36. D** The C-13 NMR spectrum shows three different C environments. This question can actually be done without referring to a chemical shift table.  
 In (D), the two methyl groups are in the same environment as they are attached to the rest of the molecule in the same way and so would only produce one peak. The C-C is a second C environment, while the C-H is another C environment. Hence there are 3 C environments in (D), which accounts for the 3 peaks. So (D) is the alcohol that produced the C-13 NMR spectrum, and is therefore the answer. The alcohol in (A) has 2 different C environments, as all methyl groups are equivalent and so would produce 2 peaks. Both (B) and (C) have 4 different C environments, and so would produce 4 peaks. So (A), (B) and (C) are incorrect.
- 37. D** Each analysis technique listed provides different evidence, e.g. mass spectroscopy provides data to determine the molecular mass and hence the molar mass of an alcohol, and its elements. In IR spectroscopy, a strong, broad band around  $3350\text{ cm}^{-1}$  would indicate an alcohol, while proton NMR spectroscopy and carbon-13 NMR spectroscopy provide data about the number and type of the carbon and hydrogen nuclei present. When the data from each of these techniques is put together, it helps to better identify the structure of an organic compound being examined, rather than just using only one of the analysis techniques. If each spectrum has data that is consistent with the evidence from the other spectra, then the identity of an organic compound can be verified. So (D) is the best answer.
- 38. D** You need to know the difference between ‘quantitative’ (able to be numerically measured) and ‘qualitative’ (observed, related to the characteristics or qualities, and not able to be measured). (D) involves a measurement of concentration, and so (D) is the answer. The other choices (A), (B) and (C) are all observations, and so are qualitative.

## Short-answer questions

39. (a)

<i>Chemical species</i>	$\text{Pb}^{2+}(aq)$	$\text{Pb}(s)$	$\text{Ag}^+(aq)$	$\text{Ag}(s)$	$\text{NO}_3^-(aq)$
<i>Moles in final mixture</i>	0.05	0.05	0	0.1	0.1
<i>Balanced chemical equation</i>	$\text{Pb}(s) + 2\text{Ag}^+(aq) \rightarrow 2\text{Ag}(s) + \text{Pb}^{2+}(aq)$				

Molar mass,  $M(\text{Pb}) = 207.2 \text{ g mol}^{-1}$

$$\text{Moles, } n(\text{lead}) = \frac{20.72}{207.2} = 0.1 \text{ mol}$$

Initial  $[\text{Ag}^+(aq)] = [\text{NO}_3^-(aq)] = cV = 1.00 \times 0.100 = 0.1 \text{ mol} = \text{final } [\text{Ag}(s)]$

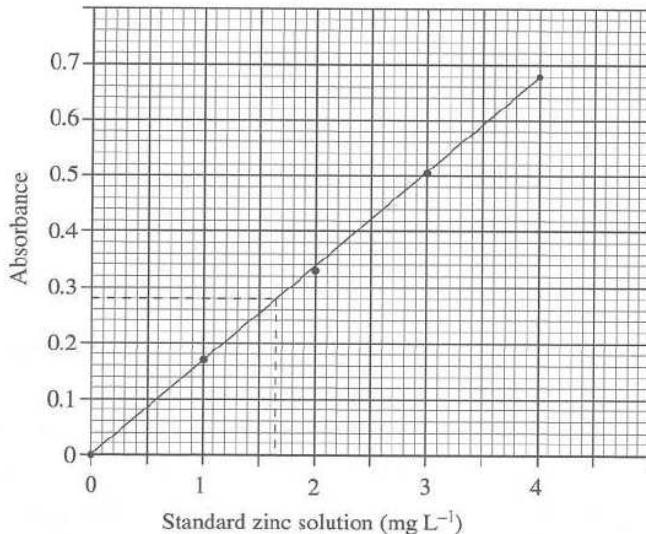
From equation, 1 mole  $\text{Pb}(s)$  reacts with 2 moles  $\text{AgNO}_3$

So 0.05 mol of  $\text{Pb}(s)$  reacts with 0.1 mole of  $\text{Ag}^+(aq)$ .

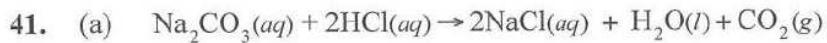
$\therefore$  0.05 mole  $\text{Pb}(s)$  is left in final solution.

- (b) The final mixture contains  $\text{Pb}^{2+}$  ions. Lead is a heavy metal and so toxic to animals, including humans, as it can cause neurological damage.

40. (a) *Calibration curve for the standard zinc solutions*



- (b) Mean absorbance = 0.280. From graph,  $[\text{Zn}] \equiv 1.65 \text{ mg L}^{-1}$   
 Concentration of zinc in tablet sample solution  $\equiv 1.65 \text{ mg L}^{-1}$   
 Each sample solution was made up to a volume of 100 mL, so the amount of zinc was 0.165 mg per 100 mL.  
 $\therefore$  amount of zinc per tablet = 0.165 mg.



<i>Solution</i>	<i>Identity</i>
1	sodium carbonate
2	hydrochloric acid
3	lead nitrate
4	barium nitrate

- (c) Although sodium and barium ions can be identified, lead ions are hard to detect and often not seen and hydrochloric acid does not give a flame test, so lead and hydrochloric acid cannot be positively identified.

[Note: School laboratory flame tests normally use powdered crystals, not solutions – although a suitable atomiser can be used to spray a solution into a flame to perform a flame test on a solution. Flame tests should always be done in a fume cupboard, as vapours such as lead are toxic.]

42. Since  $m/z = 74$ , the relative molecular mass = 74 and so its molar mass = 74

General formula for a carboxylic acid is  $\text{C}_n\text{H}_{2n}\text{O}_2$

$$\text{Molar mass, } M(\text{C}_n\text{H}_{2n}\text{O}_2) = (12n) + (1 \times 2n) + (16 \times 2) = 74 \text{ g mol}^{-1}$$

$$\therefore 14n + 32 = 74$$

$$14n = 46$$

$$n = 3.3$$

So molecular formula is  $\text{C}_3\text{H}_6\text{O}_2$  (or  $\text{CH}_3\text{CH}_2\text{COOH}$ )

and IUPAC name is propanoic acid.

43. (a) Carbon dioxide.

- (b) If the tests are done out of order, they will not identify each of the three ions as one anion can interfere with the test for another. Carbonates will form precipitates with many cations, so it is best to test the mixture first with an acid to remove all the carbonate by forming  $\text{CO}_2$ .  $\text{Ba}^{2+}$  will form a precipitate with both carbonates and sulfates, so testing for carbonates should be done before adding  $\text{Ba}^{2+}$ , then the  $\text{Ba}^{2+}$  is only testing for sulfates.  $\text{Ag}^+$  will form a precipitate with all three anions, so it needs to be the last test after any carbonate and sulfate have been identified and removed. Then it can be used to identify if chloride is present.

- 44.** (a) Barium sulfate.  
 (b)  $\text{Pb}^{2+}(aq) + 2\text{Cl}^-(aq) \rightarrow \text{PbCl}_2(s)$   
 (c) A flame test would be performed to identify the metal cation. This would result in a green/blue coloured flame, indicating the presence of  $\text{Cu}^{2+}$ .

- 45.** (a) An electronic balance is used to weigh a clean empty beaker, then to determine the mass of the water sample. Silver nitrate solution is then added in excess to the water sample to precipitate the chloride ions:  $\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl}(s)$ . This precipitate is transferred to the sintered glass filter, using a wash bottle to ensure that no precipitate remains in the beaker. After drying, the mass of  $\text{AgCl}(s)$  precipitate is measured and the  $[\text{Cl}^-]$  calculated.  
 (b) Molar mass,  $M(\text{AgCl}) = 107.9 + 35.45 = 143.35 \text{ g mol}^{-1}$   
 $\text{Mass of Cl}^- \text{ in precipitate} = \frac{35.45}{143.35} \times 3.65 = 0.9026 \text{ g}$   
 $\text{So } [\text{Cl}^-] = 0.9026 \text{ g in } 50.0 \text{ mL}$   
 $0.9026 \times \frac{1,000,000}{50} = 18,053 \text{ ppm} \approx 1.81 \times 10^4 \text{ ppm}$  (using 1 mL water  $\approx 1 \text{ g}$ )

[Note: ppm should be comparing the same quantity, i.e. mass of chloride ions compared to the mass of water sample, not its volume. ppm =  $\text{mg kg}^{-1}$ ]

- 46.** (a) A simple test is to heat a sample of the compound in air. Place a small amount of it on a metal spatula and heat it over an open flame in a fume cupboard. If it burns with a smoky flame leaving no residue, it is organic. If it melts without burning or produces white fumes or leaves a residue, it is inorganic.  
 (b) To distinguish between alkanes, alkenes and alcohols:
  - Add a few drops of bromine solution to each. The bromine will immediately be decolourised by the alkene. The alkane and alcohol will be brown due to the bromine solution.
  - Expose the two brown solutions to sunlight. The alkane solution will fade over a short period, while the alcohol solution will not react and so remain brown.

[Notes:

- (1) To distinguish the carboxylic acid from the other compounds, you could do either of the following:
  - Add a few drops of calcium carbonate solution – only carboxylic acid will react to produce  $\text{CO}_2(g)$ .
  - Add a piece of blue litmus – this will turn pink (red) with the acid, but not with the others.
- (2) An alcohol ( $1^\circ$  or  $2^\circ$ ) will undergo oxidation with acidified  $\text{KMnO}_4$  – this will change the colour from purple to colourless, however a  $3^\circ$  alcohol will not react. Acidified potassium dichromate will also oxidise  $1^\circ$  and  $2^\circ$  alcohols resulting in its colour changing from orange to green. These oxidation tests have to be done after confirming an alkene, as alkenes will also change their colour.]

47. (a) The reaction conditions of a chemical synthesis process affect its equilibrium and hence the product yield. It is important that the conditions are managed so the equilibrium lies to the far right, thus ensuring the maximum yield of products. When producing sulfuric acid, the reaction conditions are chosen to maximise yield and minimise environmental impact. A catalyst ( $V_2O_5$ ) is used to speed up the conversion of  $SO_2$  to  $SO_3$ :  $SO_2(g) + \frac{1}{2}O_2(g) \xrightarrow{\text{catalyst}} SO_3(g)$

In this combustion step, a high temperature is needed, but not too high as this would shift equilibrium to the left – so around 400–450°C is used to ensure the reaction rate is high enough. Excess oxygen and a high pressure around 1–2 atm are used (achieved by using large blower fans). This pushes the equilibrium to the right. Any higher pressure is too costly to achieve.

To minimise environmental impact, steam from roasting iron sulfide to form  $SO_2$

$$2FeS(s) + 3O_2(g) \rightarrow 2FeO(s) + 2SO_2(g)$$

is used to generate electricity for the smelter, rather than being released into the environment, where it can harm plants or animals.

48. (a) *Risk:* The chemicals used may be hazardous, e.g.  $BaCl_2$  is toxic, and the products may also be harmful or smell horrible.

*Effect on procedure:* The amount of chemical used was minimised and the tests were done in a fume cupboard with a well-ventilated lab to avoid any contact with the chemicals being used.

**Two other answers you could have given:**

- *Risk:* The conc HCl used on the platinum (or nichrome) wire may still be on the wire when heating and so may overheat and ‘spit’ causing it to go into the eyes or onto the skin.  
*Effect on procedure:* We wore safety goggles, gloves, covered footwear and protective clothing to avoid any contact with conc HCl
- *Risk:* A Bunsen burner involves hot metal and hot flame which cause burns if not careful (and can result in accidental gas release and ignition (explosion) and the blue flame is hard to see).  
*Effect on procedure:* The yellow ‘safety’ flame was used when not heating, or the Bunsen was turned off. The Bunsen was used on a heat-proof mat and was allowed to cool before moving.

- (b) CONCLUSION: Some metal ions emit a characteristic colour in flame tests as they produce a unique emission spectrum.

49. Bioethanol produces much less carbon dioxide (1.9 g per gram of fuel) than petrol (3.1 g per gram of fuel). However, bioethanol produces much less energy per gram ( $29.6 \text{ kJ g}^{-1}$ ) than petrol ( $47.9 \text{ kJ g}^{-1}$ ). This means that a much larger mass of bioethanol is required to provide the same amount of energy as petrol.

**50.** *Advantages:*

- Ethanol is a renewable resource when produced by fermentation and so is a possible alternative fuel to the other fuels in the table, which are all non-renewable.
- Being a liquid at room temperature, ethanol does not need to be stored under pressure like methane and propane.
- Ethanol burns more completely than octane as its molecule is smaller, and so releases less carbon monoxide and soot from combustion.

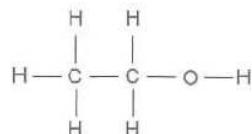
*Disadvantages:*

- Ethanol requires fossil fuels to produce the fertiliser that is used to grow plants to make it, and to produce the energy to distil it
- Ethanol has a lower boiling point than octane, so is more volatile. So car fuel systems using ethanol need to operate at a higher pressure than for octane to prevent evaporation of ethanol and this costs more.
- Ethanol's enthalpy of combustion is much less than octane and so its energy output is less, thus a greater amount of ethanol than octane would be needed to run a car.
- Growing crops to produce ethanol results in reduced land for food crops and requires much land clearing, which can lead to the loss of native forests.

*Judgement:* The advantages of using ethanol are still debatable, as most of these disadvantages are yet to be overcome. Also, clearing land to grow crops to produce ethanol often results in environmental problems to do with soil erosion, deforestation, fertiliser runoff and salinity, plus problems of disposal of fermentation wastes.

**51.** (a)  $m/z = 31$ . It is due to the ion with the greatest relative abundance, as it is the tallest (most intense) peak in the mass spectrum.

- (b)
- *IR spectrum* – this has a strong, broad band that maximises around  $3300\text{ cm}^{-1}$ , which is indicative of an O–H bond. This suggests an hydroxyl group might be present. It has an absorption band around  $2900\text{ cm}^{-1}$ , which matches data for the C–H bond. Since it does not have a band for a C=O bond around  $1680\text{--}1750\text{ cm}^{-1}$ , it is not an aldehyde, ketone or carboxylic acid.
  - *Mass spectrum* – this shows molecular mass is 46, so molar mass of  $X$  would be 46, as in ethanol.  
 $\therefore$  compound  $X$  would be ethanol (shown on right).



[Note: (1) Remember, the distinction between molar mass and molecular mass is important because relative molecular masses can be measured directly by mass spectroscopy, often to a precision of a few parts per million (ppm). This is accurate enough to directly determine the chemical formula of a molecule. (2) The peak with the highest  $m/z$  value in a mass spectrum usually (but not always) corresponds to the parent ion and so can usually be used to determine the molar mass of the molecule.]

- 52.** From the graph: when absorbance = 0.280,  $[Hg] = 0.17 \text{ mg L}^{-1}$

$$\text{Amount of mercury in } 25 \text{ mL sample} = 0.17 \times \frac{25.00}{1000} = 4.25 \times 10^{-3} \text{ mg}$$

So there is  $4.25 \times 10^{-3}$  mg of Hg in 18.6 g of fish

$$\therefore [Hg] \text{ in } 1 \text{ kg of fish} = 4.25 \times 10^{-3} \times \frac{1000}{18.6} = 0.228 \text{ mg/kg of fish}$$

$\therefore$  this fish is safe to eat, as the mercury level is less than 0.5 mg/kg of fish.

OR Sample volume = 25 mL and contains 18.6 g of fish.

So amount of fish in 1 L of this sample =  $40 \times 18.6 \text{ g} = 744 \text{ g}$

$$\therefore [Hg] \text{ in fish sample} = 0.17 \times \frac{1000}{744} = 0.228 \approx 0.23 \text{ mg/kg of fish}$$

$\therefore$  this fish is safe to eat, as the mercury level is less than 0.5 mg/kg of fish.

- 53.** (a) Any THREE of the following points:

- It assumes all sulfates in the fertiliser are dissolved. If not, they will get discarded in the residue and give a low sulfate value.
- It assumes no soluble phosphates or carbonates are present. These will precipitate with  $Ba^{2+}$  and give a high sulfate value.
- If the barium is not in excess, a low result will be obtained and so the process will be invalid.
- It assumes all  $BaSO_4$  precipitate is collected and no fine particles passed through the filter, causing a lower sulfate value.

[Note: Any changes to the sulfate value will affect the results and be an invalid process.]



$$\text{Molar mass, (M) of } SO_4^{2-} = 32.07 + (4 \times 16.00) = 96.07$$

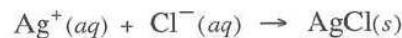
$$\text{Molar mass, (M) of } BaSO_4 = 137.3 + 32.07 + (4 \times 16.00) = 233.37$$

$$\text{Mass of sulfate} = 35\% \text{ of } 4.25 \text{ g} = 0.35 \times 4.25 \text{ g}$$

$$\text{Mass of dried } BaSO_4 = 0.35 \times 4.25 \times \frac{233.37}{96.07} = 3.61 \text{ g}$$

- 54.**  $AgNO_3(aq)$  could be added to the sample of dam water.

Formation of a white precipitate would indicate high  $[Cl^-]$ :



- 55.** AAS can detect and measure extremely low concentrations, e.g. in ppm, of metals in a wide range of substances, e.g. soil, water, blood, foods, paint, etc. Hence AAS can be used in environmental monitoring to accurately detect and monitor the concentration of a metal, e.g. mercury. To do this, AAS is performed using a lamp specific for the metal being monitored, then only those metal ions in the test sample will absorb the specific frequency, as each element has its own unique fingerprint. The light beam from this lamp is shone through a series of standard solutions that contain a known concentration of this metal ion to have their absorbance measured. Their absorbance readings are plotted versus their concentration to give a calibration curve. Then, the absorbance of each test sample would be measured. The concentration of the metal ions in these samples can then be determined by using the calibration curve and reading the corresponding concentrations for each of the absorbance values obtained. The greater the concentration of an element, the greater the intensity of absorbed light.

- 56.** (a) (i) UV-visible spectrophotometry  
 (ii) Transmittance refers to the wavelengths of light passing through a sample. Absorbance refers to the wavelengths of light *not* passing through a sample. This type of analysis tests for absorbance.  
 [Note: The wavelengths of light that are transmitted are NOT being used by the plant.]  
 (iii) UV-visible spectrophotometry  
 (b) (i) Around 450 nm and 640 nm  
 (ii) 430 nm is best, although 660 nm might also work (depending on the other pigments present in chlorophyll).  
 [Note: These wavelengths of light corresponds to the wavelengths that are most strongly absorbed by chlorophyll *a*.]  
 (c) The greater the amount of light absorbed by the algal solution, i.e. the higher its absorbance value, the greater the concentration of chlorophyll in that solution.

- 57.** (a) Complex *X* has  $\text{Fe}^{2+}$  and *Y* has  $\text{Fe}^{3+}$ .  
 (b) The lone pair of electrons on each oxygen atom in the  $-\text{OH}_2$  ligands can form a coordinate covalent bond with the central  $\text{Fe}^{2+}$  or  $\text{Fe}^{3+}$  ion.  
 (c) A complex ion has a characteristic colour that is often unique – the characteristic colour helps to identify which metal ion is present in a chemical reaction.

[Note: It is often possible to also identify the ligands as well from the colour.]

- (d) (i) Qualitative – as this only relies on the observation of colour changes and no numerical measurements were made.

The yellow-brown precipitate formed with NaOH would have been  $\text{Fe(OH)}_3(s)$ . Adding KSCN confirms that  $\text{Fe}^{3+}$  were in the original solution as this test formed the unique blood-red complex ion, iron(III) thiocyanate.

- (ii) Colourimetry OR UV-visible spectroscopy

- 58.** (a) Molar mass,  $M(\text{BaSO}_4) = 137.3 + 32.07 + (4 \times 16.00) = 233.37 \text{ g mol}^{-1}$

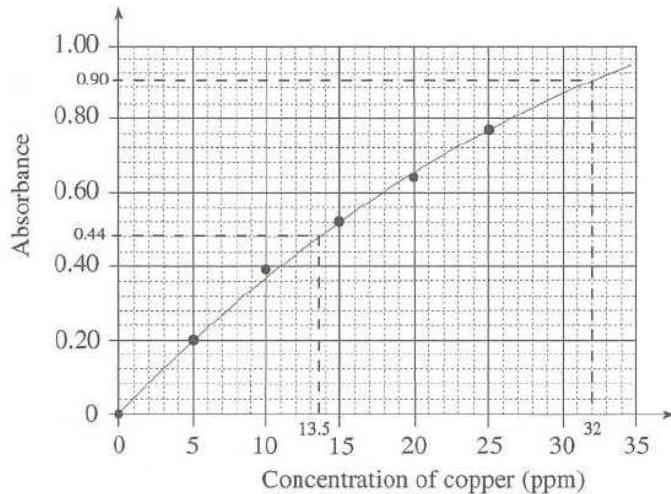
Mass of  $\text{SO}_4$  in 1 mol of  $\text{BaSO}_4 = 96.07 \text{ g}$

$$\therefore \text{mass of sulfate in } 1.8 \text{ g of BaSO}_4 = \frac{96.07}{233.37} \times 1.8 = 0.74 \text{ g}$$

$$\therefore \% \text{ mass sulfate in fertiliser} = \frac{0.74}{1.0} \times 100 = 74.0\%$$

- (b) Reliability refers to the reproducibility of a measurement – how easy it is to get the same answer from repeat measurements. Hence reliability depends on repetition of the procedure. This procedure was not reliable as it should have been repeated several times and the results averaged. Reliability also depends on how carefully the variables were controlled each time, e.g. if the fertiliser was completely soluble in the water, if the barium chloride was added in excess to ensure complete precipitation of the sulfate, if all insoluble material in the fertiliser was removed so it was not a part of the mass of precipitate, and if any other ions (e.g. carbonate) which also precipitate barium were removed.
- None of these steps are mentioned in the data and there is no repetition, so the reliability of the procedure is questionable.

- 59. (a)**



- (b) SAMPLE 1 – 13.3 ppm. SAMPLE 2 – 32 ppm.

The estimate for Sample 1 is valid because it can be obtained from the line of best fit within the range of the data collected. The estimate for Sample 2 is not valid because the absorbance and thus the concentration lies outside the measured range. It assumes that the line of best fit has the same trend for concentrations higher than 25 ppm and it may not. These results would be more valid if the absorbance had been measured at 30 and 35 ppm concentration of copper, to extend the range of the calibration curve.

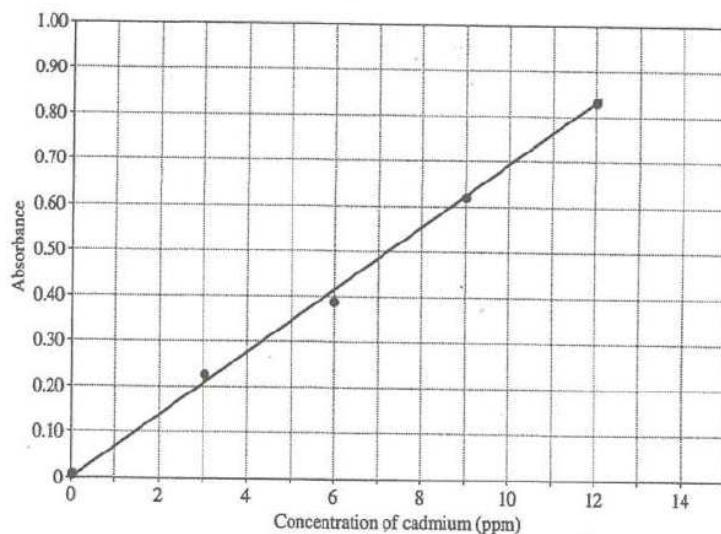
Also, there is no mention as to whether the conditions for the two samples were the same as for the standard solutions, e.g. same AAS equipment used, same lighting, same temperature, etc. All variables must be controlled for the results to be completely valid.

[Note: According to the Beer-Lambert Law, absorbance is proportional to concentration, and so you would expect this graph to be a straight line, and so you may have drawn a straight line of best fit, which would also be acceptable. In this case, your answer for Sample 1 would be about 13.5 ppm and Sample 2 would be about 27.5 ppm. In practice, AAS usually results in a curve rather than a straight line, as in this question, particularly at higher concentrations. Remember, your answers for the concentration of copper present in Samples 1 and 2 must match YOUR graph, and so could be slightly different to the values given here.]

60.

Anion	Reagent	Observations if anion is present
$\text{Cl}^-$	silver nitrate	A white precipitate forms which turns brown/purple in sunlight
$\text{PO}_4^{3-}$	silver nitrate	A yellow precipitate forms
$\text{SO}_4^{2-}$	barium chloride	A fine white precipitate forms

61. (a)

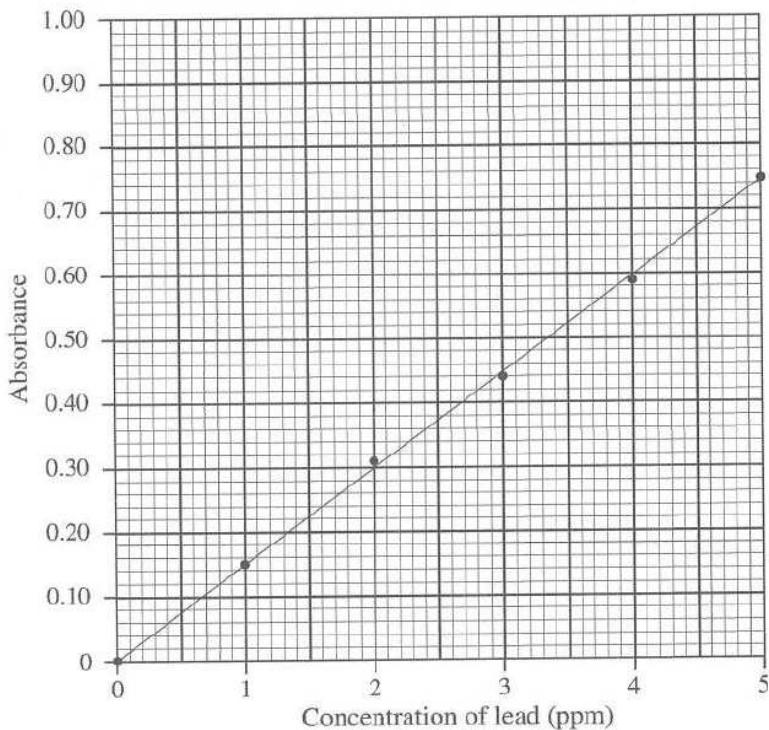


- (b) Cadmium concentration in fish is 5 ppm.

62. Monitoring reactions conditions ensures that maximum yield occurs in a reasonable timeframe, with minimal pollution, and does not risk damage to the environment or endanger people's health. Hence when the combustion of octane is used to provide energy for a chemical synthesis process, it is important to ensure an excess of oxygen. Hence complete combustion will occur and so only carbon dioxide and water are produced. Whereas carbon monoxide ( $\text{CO}$ ) and soot ( $\text{C}_{(s)}$ ) will be produced if there is a limited supply of oxygen as this results in incomplete combustion occurring. These products are more harmful to the environment and living things than carbon dioxide.  $\text{CO}$  is a poisonous gas and so is harmful to living things and can cause death. Soot contributes to respiratory problems, is carcinogenic and causes environmental pollution.

Monitoring oxygen levels also avoids wasting fuel energy, as less energy is released from incomplete combustion than complete combustion. Monitoring for water from combustion is also needed to prevent condensation on walls, ceilings, etc. as this may result in moulds that are harmful to humans, and could indicate ventilation problems.

63. (a)



- (b) The highest absorbance reading 0.22, so 1.5 ppm will be the highest lead concentration.

- 64.** Ethanol and heroin – as the blood sample has peaks in its mass spectrum that correspond to the major peaks for both ethanol and heroin, and not for the other two substances shown.

[Note: Although heroin is not a ‘simple organic compound’ like ethanol (as per the Chemistry syllabus), it is identified in exactly the same way – using its major peaks on the mass spectrum.]

- 65.** Test tubes *W* and *X* both have a strong, broad band around  $3000\text{--}3300\text{ cm}^{-1}$ . The band is higher in *W* than in *X*, suggesting that in *W* it is for an –O–H bond in an alcohol and in *X* it is for an –O–H bond in an acid. In *X* there is also has a strong band for a –C=O bond around  $1680\text{--}1750\text{ cm}^{-1}$ . This suggests *W* is ethanol and *X* is ethanoic acid.

Test tube *Y* does not have a band for an –O–H bond, but does have a band around  $1680\text{--}1750\text{ cm}^{-1}$  due to a –C=O bond. So *Y* would be propanone.

Test tube *Z* does not have a band for an –O–H bond, but does have an absorption band between  $3330\text{--}3500\text{ cm}^{-1}$  indicative of an –N–H bond. Since an amine contains the –NH<sub>2</sub> group, *Z* would be 1-aminobutane.

[Note: All organic compounds contain C–H bonds and C–C bonds. As expected, each test tube has an absorption band around  $2900\text{ cm}^{-1}$  (for C–H bonds), as well as band due C–C bond.]

- 66.** A flame test would involve using the loop of a clean platinum (or nichrome) wire that had been cleaned first by dipping it in conc HCl and then heating in the hottest part of the flame until no colour shows. Then, using the loop, a drop of the water sample would be heated in the hottest part of a Bunsen flame. Any metal cations present in the water sample will absorb the heat and so become excited. As excited electrons drop back to a lower energy level, they will emit energy. If this energy is in the visible region of the electromagnetic spectrum, a characteristic colour is observed that is specific to the metal cation producing it. Hence this test can be used to identify the presence of a metal cation that causes the colour.

Although all metals will emit energy after being heated in a flame test, not all metals will give a flame colour, as the energy emitted is not in the visible region of the electromagnetic spectrum. Also, some metals give a flame colour that is very similar to other metals, and so they are very difficult to differentiate in a flame test.

- 67. (a)** A blue solution allows blue light to pass through it, while all the other colours are absorbed. So, an orange filter that transmits blue light would be appropriate to use, as orange is absorbed by a blue solution. Also, this is actually the best choice of colour for the filter, as orange is the complementary colour to blue.

- (b) A series of copper (II) sulfate solutions of suitable, known concentrations would be placed in the colourimeter. Their absorbance reading would then be plotted versus their concentration to give a calibration curve.

The concentration of the unknown copper (II) sulfate solutions ( $X$  and  $Y$ ) can then be determined by using the calibration curve and reading the corresponding concentrations for the absorbance values obtained for  $X$  and  $Y$ .

- (c) The greater the amount of light absorbed by a solution, i.e. the higher its absorbance value, the greater the concentration of a solution.

- 68.** (a) Largest  $m/z$  ratio in  $P$  is 44, so molecular mass is 44.

General formula of alkanes:  $C_nH_{2n+2}$ .

Using C=12 and H=1, some molar masses for alkanes are:

- methane = 16, • ethane = 30, • propane = 44.

So  $P$  would be propane.

Its related carboxylic acid is propanoic acid, with a molar mass of 74.

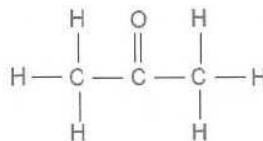
The largest  $m/z$  ratio shown for is  $Q$  74. So  $Q$  is propanoic acid.

(b)

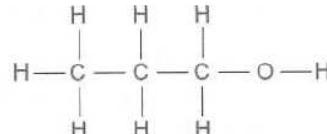


- 69.** Formulae are:

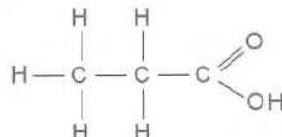
Propanone



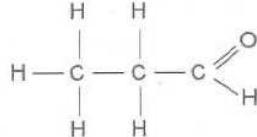
Propan-1-ol



Propanoic acid



Propanal



In spectra  $Q$  and  $S$ , the peaks over 200 ppm are indicative of a  $-C=O$  group, as in an aldehyde or ketone, e.g. propanal or propanone.

- propanal – its 3 carbons are in completely different environments, so its spectrum will have 3 peaks.

... continued on next page

- *propanone* – its 2 methyl groups are in the same environment, so produce one peak and the C=O group produces another peak, so its spectrum will have 2 peaks.  
 $\therefore S$  is propanal and  $Q$  is propanone.

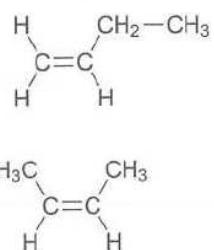
Spectrum  $R$  has a chemical shift around 180, which is indicative of a  $-\text{C}=\text{O}$  group in an acid, as in *propanoic acid*, which has 3 C environments.

$\therefore R$  is propanoic acid.

Hence  $P$  must be propan-1-ol. As expected, it has 3 peaks for its 3 C environments and the peak at about 65 ppm is indicative of a  $-\text{C}-\text{O}$  group, as in an alcohol.

70. Being isomers, 1-butene and 2-butene have the same general formula,  $\text{C}_4\text{H}_8$ . However, their C–13 and proton NMR spectra differ, as they have different numbers of H and C environments:

- 1-butene has 4 H environments and 4 C environments, so its C–13 NMR and proton NMR spectra would each have 4 peaks.
- 2-butene has 2 H environments and 2 C environments, so its C–13 NMR and proton NMR spectra would each have 2 peaks.



71. Each analytical test gives unique data, e.g. mass spectroscopy give molecular mass and isotopic abundance, NMR spectroscopy is useful for determining the C–H backbone of a molecule, and IR spectroscopy determines the type of bonds and functional groups present.

Hence using more than one test obtains much more information than just the one test. The information from several tests can be combined to give a more comprehensive understanding of a compound's identity and structure. Also, instrumental analytical tests are quick and accurate, and can detect and identify very small amount of complex substances.

72. (a) To ensure that no wastes or harmful substances from their chemical processes enter the environment, where they can contaminate resources in the atmosphere, soil and waterways and/or cause harm to plants and animals.
- (b) The chemical industry could adopt a more ‘green’ approach, by:
- minimising or eliminating the production of substances or wastes that are harmful to the environment, and
  - utilising renewable resources rather than using non-renewable resources, such as fossil fuels, to produce the energy for a chemical process or in the manufacture of a chemical, such as plastics.

Some other ‘green’ measures you could have given for the chemical industry are to:

- have measures in place to prevent chemical spills and accidents entering the environment and methods to contain such spills if an accident occurs.
- only produce products that are recyclable or biodegradable.
- monitor the concentrations of any harmful chemicals in the environment, e.g. in waterways, groundwater and the atmosphere and take the appropriate action to ensure they do not exceed the agreed acceptable level.]