

Teacher Name \_\_\_\_\_ NESA Number \_\_\_\_\_



### **Merewether High School**

**2019**

#### **TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION**

# **Chemistry**

#### **General Instructions**

Reading time – 5 minutes

Working time – 3 hours

Write using black pen

Draw diagrams using pencil

Approved calculators may be used

A Periodic Table and Data Sheet are provided

Place your NESA sticker in the spaces provided

Write your class/teacher information in the spaces provided

When completing the paper, allocate time periods that are commensurate with the mark values of each question.

Total Marks – 100

**Section I** - pages 1 - 9

20 Multiple Choice Questions

20 marks

Allow about 35 minutes for this section

**Section II** – pages 10 - 30

Attempt Questions 21 – 35

Extended Response Questions

80 marks

Allow about 2 hour and 25 minutes for this section



## Section I

**20 marks**

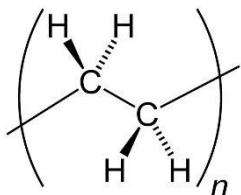
**Attempt Questions 1-20**

**Allow about 35 minutes for this section**

Use the multiple choice answer sheet.

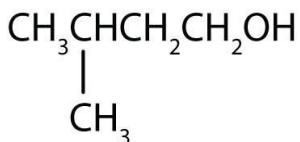
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1. Consider the polymer represented by the structure below:



Which alternative best names and describes this type of polymer?

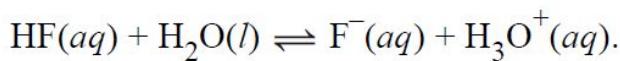
- A. Polyethylene, an addition polymer.
  - B. Polyethylene, a condensation polymer.
  - C. Polyethane, an addition polymer.
  - D. Polyethane, a condensation polymer.
2. What is the IUPAC name of the following compound?



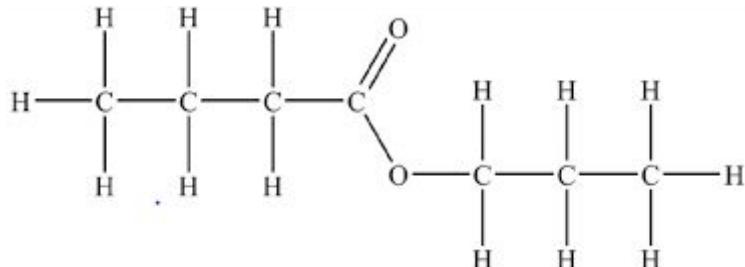
- A. 2-methylbutan-4-ol
  - B. 2,2-dimethylpropan-4-ol
  - C. 3-methylbutan-1-ol
  - D. 3,3-dimethylpropan-1-ol
3. Which of the following lists contains members of the same homologous series?

- A.  $\text{C}_2\text{H}_6$ ,  $\text{C}_4\text{H}_{10}$ ,  $\text{C}_6\text{H}_{14}$
- B.  $\text{C}_2\text{H}_2$ ,  $\text{C}_2\text{H}_4$ ,  $\text{C}_2\text{H}_6$

- C.  $\text{C}_2\text{H}_5\text{Cl}$ ,  $\text{C}_2\text{H}_5\text{OH}$ ,  $\text{C}_2\text{H}_5\text{NH}_2$   
D.  $\text{CH}_3\text{Cl}$ ,  $\text{CH}_2\text{Cl}_2$ ,  $\text{CHCl}_3$
4. Consider the system:



- Which of the following represents a conjugate acid–base pair present in this system?
- A.  $\text{HF}(aq)/\text{F}^-(aq)$   
B.  $\text{HF}(aq)/\text{H}_3\text{O}^+(aq)$   
C.  $\text{HF}(aq)/\text{H}_2\text{O}(l)$   
D.  $\text{F}^-(aq)/\text{H}_3\text{O}^+(aq)$
5. The structural formula of an ester is shown below:

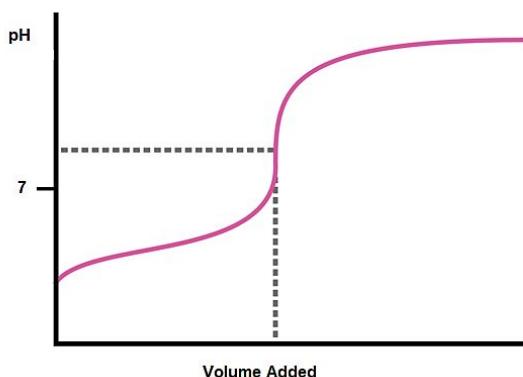


- To make this ester, a chemist would use:
- A. Propan-1-ol and propanoic acid.  
B. Propene and butanoic acid.  
C. Butan-1-ol and propanoic acid.  
D. Propan-1-ol and butanoic acid.
6. Which of the following is amphiprotic?

- A.  $\text{HCl}$   
B.  $\text{Cl}^-$   
C.  $\text{NH}_4^+$   
D.  $\text{HCO}_3^-$



7. A student used a pH probe to gather data whilst performing an acid-base titration. The data was plotted to create the titration curve below:

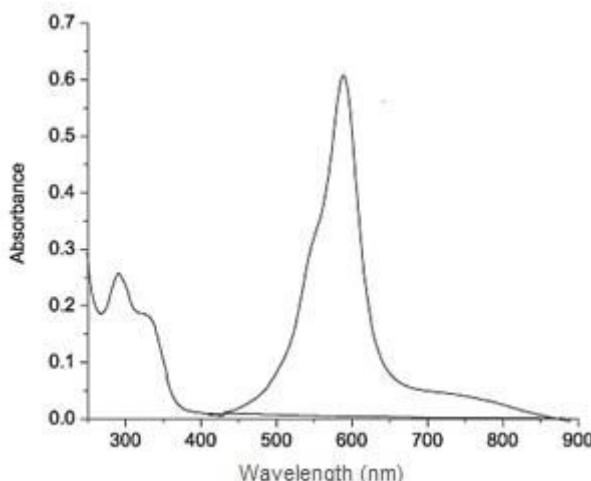


Identify a possible acid and base used by the student.

|    | <i>Analyte</i>       | <i>Titrant</i>       |
|----|----------------------|----------------------|
| A. | HCl                  | NH <sub>3</sub>      |
| B. | CH <sub>3</sub> COOH | NaOH                 |
| C. | NH <sub>3</sub>      | CH <sub>3</sub> COOH |
| D. | NaOH                 | HCl                  |

8. What mass of solid sodium hydrogen carbonate is required to make 250 mL of 0.28 mol L<sup>-1</sup> solution?
- A. 3.8 g  
B. 9.0 g  
C. 5.9 g  
D. 6.3 g

9. The UV-visible spectrum of a solution of a certain compound is shown below.



Consider the following statements about this compound and its UV-visible spectrum:

- I. The amount of light absorbed by a solution of this compound depends on its concentration.
- II. The amount of light absorbed by a solution of this compound depends on the wavelength of light used.
- III. The spectrum is a result of electrons falling back from higher to lower electronic energy levels.
- IV. The concentration of a solution of this compound can only be determined by UV-visible spectroscopy at 400 nm.

Which of the above statements are true?

- A. I and II
- B. II and III
- C. I, II and III
- D. I, II and IV

10. 1.0 mL of  $10 \text{ mol L}^{-1}$  nitric acid solution was diluted to 1 L with distilled water. A 100 mL of this resulting solution was then further diluted to 1 L using distilled water.

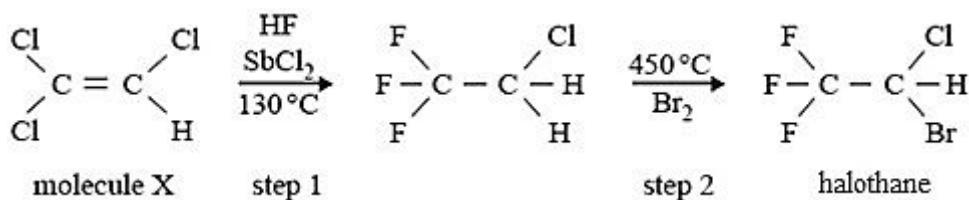
What pH is the final solution closest to?

- A. 1
- B. 2

C. 3

D. 4

11. Halothane is a general anaesthetic. The diagram below outlines the reaction pathway for the formation of halothane.



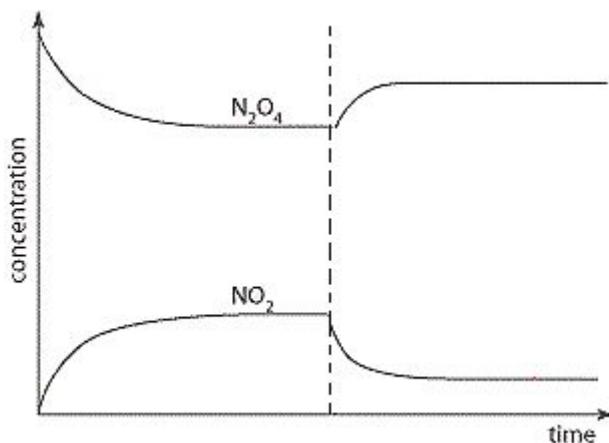
Which of the following correctly identifies the reaction at step 2 and correctly states the systematic name of molecule X?

| Type of Reaction in Step 2 | Systematic Name of Molecule X |
|----------------------------|-------------------------------|
| substitution               | 1,2,2-trichloroethane         |
| addition                   | 1,1,2- trichloroethene        |
| substitution               | 1,1,2- trichloroethene        |
| addition                   | 1,2,2- trichloroethane        |

12. Consider the following reaction taking place in a closed vessel:

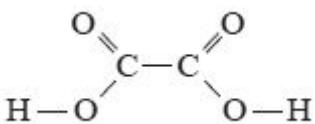


The concentration of gases in the vessel was monitored and the following graph was constructed:



What was the most likely change imposed at the time indicated by the dotted line?

- A. More  $\text{N}_2\text{O}_4$  was injected.
  - B. The temperature was decreased.
  - C. A catalyst was introduced.
  - D. The reaction vessel was opened to the atmosphere.
13. The structure of oxalic acid is shown below.



A 25.0 mL solution of oxalic acid reacts completely with 15.0 mL of 2.50 M NaOH. The concentration of the oxalic acid solution is:

- A.  $0.667 \text{ mol L}^{-1}$
  - B.  $0.750 \text{ mol L}^{-1}$
  - C.  $1.33 \text{ mol L}^{-1}$
  - D.  $1.50 \text{ mol L}^{-1}$
14. Hydrated aluminium chloride contains the complex ion  $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ . Which statement best describes the interaction between the  $\text{Al}^{3+}$  ion and the water molecules in the complex ion?
- A. An electrostatic force of attraction between the  $\text{Al}^{3+}$  ion and the polar water molecule forms ionic bonds.
  - B. Dispersion forces occur between the  $\text{Al}^{3+}$  ion and water molecules.
  - C. The greater electronegativity of aluminium ion results in the formation of polar covalent bonds between it and the water molecules.
  - D. Coordinate covalent bonds form as a result of the attraction between the lone pair of electrons on the water molecules and the  $\text{Al}^{3+}$ .
15. Soaps remove grease because:

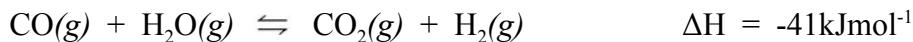
- A. The hydrophilic head of the soap molecule binds to grease particles
- B. The hydrophobic head of the soap molecule binds to grease particles
- C. The hydrophilic tail of the soap molecule binds to grease particles
- D. The hydrophobic tail of the soap molecule binds to grease particles

16. Magnesium reacts with dilute hydrochloric acid to liberate hydrogen gas.

What is the volume of hydrogen produced at 298.1 K and 100 kPa when 1.22 g of magnesium is reacted with excess dilute acid?

- A. 1140 mL
- B. 1240 mL
- C. 2270 mL
- D. 2450 mL

17. The reaction below is used in some industries to produce hydrogen gas.



The equilibrium constant at 200 °C for the above reaction is  $K_{\text{eq}} = 210$ .

In an experiment, carbon monoxide, water vapour, carbon dioxide and hydrogen were pumped into a sealed container that was maintained at a constant temperature of 200 °C. After 30 seconds, the concentration of gases in the sealed container was found to be:

$$[\text{CO}] = 0.1 \text{ M}, [\text{H}_2\text{O}] = 0.1 \text{ M}, [\text{H}_2] = 2.0 \text{ M}, [\text{CO}_2] = 2.0 \text{ M}.$$

Which one of the following statements about the relative rates of the forward reaction and the reverse reaction at 30 seconds is true?

- A. The rate of the forward reaction is greater than the rate of the reverse reaction.
- B. The rate of the forward reaction is equal to the rate of the reverse reaction.
- C. The rate of the forward reaction is less than the rate of the reverse reaction.
- D. There is insufficient data to allow a statement to be made about the relative rates of the forward and reverse reactions.

18. Which of the following pairs of compounds are NOT isomers?

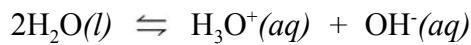
- A. Hexan-2-ol and 2,2-dimethylbutan-1-ol.
- B. Methyl ethanoate and propanoic acid.
- C. Butane and cyclobutane.
- D. Butan-2-one and 2-methylpropanal.

19. Hydrofluoric acid has a  $K_a = 6.2 \times 10^{-4}$ .

What is the pH of a  $0.5 \text{ mol L}^{-1}$  solution of the acid?

- A. 0.30
- B. 1.75
- C. 2.90
- D. 3.20

20. Water self-ionises as shown by the equation:



This ionisation is temperature dependent.

| <b>Temperature<br/>(°C)</b> | <b>Ionisation Constant<br/>(<math>K_w</math>)</b> |
|-----------------------------|---|
| 5                           | $1.9 \times 10^{-15}$                             |
| 15                          | $4.5 \times 10^{-15}$                             |
| 25                          | $1.0 \times 10^{-14}$                             |
| 35                          | $2.1 \times 10^{-14}$                             |

What can be inferred about this data?

- A. The pH of pure water at  $35^\circ\text{C}$  is less than 7.
- B. The ionisation of water is an endothermic process.
- C. The equilibrium position lies well to the right.
- D. In pure water at  $15^\circ\text{C}$   $[\text{OH}^-]$  is lower than  $[\text{H}_3\text{O}^+]$ .

## Section II

**80 marks**

## Attempt Questions 21 – 35

**Allow about 2 hours and 25 minutes for this section**

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

| Question 21 (9 marks)   | Marks |
|---|-------|
| The decomposition reaction of gaseous nitrosyl chloride, NOCl, forms the gases nitrogen monoxide and chlorine in equilibrium. |       |
| The reaction was performed in a sealed vessel with a moveable piston.   |       |
| a) Write the equation for this equilibrium reaction.  | 1     |

**Question 21 continues on the following page**

**Question 21 continued****Marks**

- c) The piston was moved to increase the volume of the vessel. Using Le Chatelier's Principle, explain what would happen to this system at equilibrium.

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- d) 1.00 moles of NOCl was placed into a sealed vessel with a fixed volume of 2.0 L. When the container was heated to 227°C, 0.056 mol of Cl<sub>2</sub> was formed at equilibrium.

Calculate  $K_{eq}$  for the reaction at this temperature.

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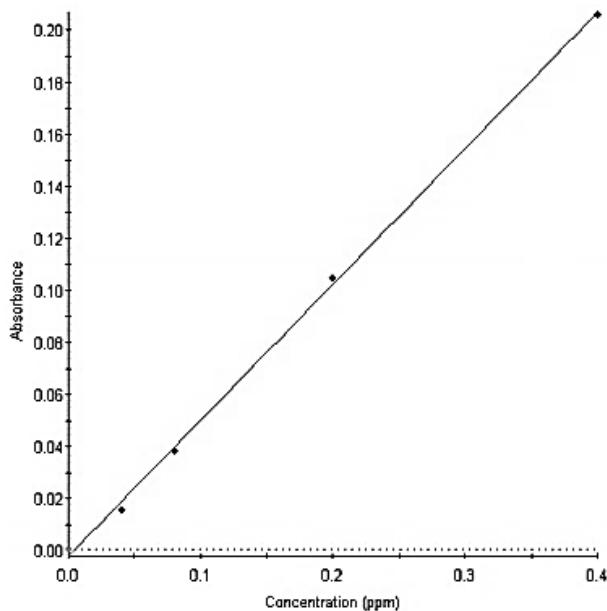
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**Question 22 (3 marks)****Marks**

A 10.0mL sample of pond water was analysed to determine its nitrate content using UV-VIS spectrophotometry. Suitable standard solutions were prepared and the following calibration curve was produced:



The sample produced an average absorbance reading of 0.125.

Calculate the nitrate concentration (in  $\text{mol L}^{-1}$ ) of the sample of pond water.

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**Question 23 (5 marks)****Marks**

For the salt silver chloride,  $\text{AgCl}$ , its  $K_{\text{sp}} = 1.77 \times 10^{-10}$  at 298K.

A 1.0 L mixture was formed from 0.25 mole of  $\text{AgNO}_3$  and 1.0 mole of  $\text{NaCl}$ .

- a) Write the expression for the  $K_{\text{sp}}$  for silver chloride.

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- b) Calculate the concentration of aqueous  $\text{Ag}^+$  ions at equilibrium in the mixture.

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- c) In a separate experiment, solid lead chromate was added to a 0.20M solution of lead nitrate. Outline the effect of the dissolved lead nitrate on the solubility of lead chromate.

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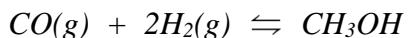
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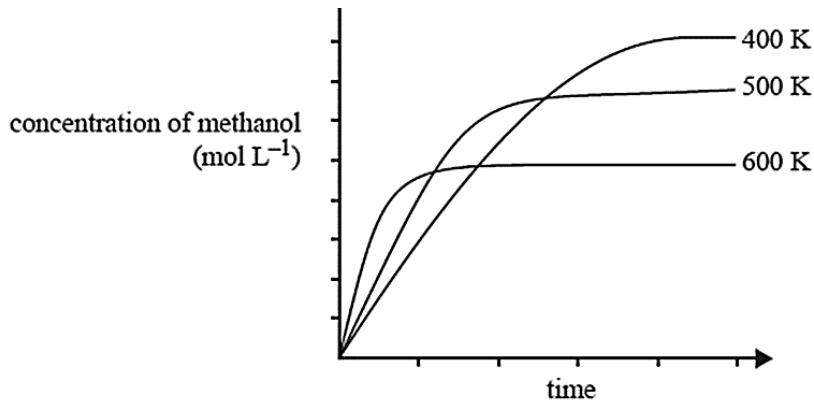
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**Question 24 (4 marks)****Marks**

Methanol is produced on an industrial scale by the catalytic conversion of a mixture of hydrogen and carbon monoxide gases at a temperature of 520 K. The reaction that occurs is:



Carbon monoxide gas and hydrogen gas were mixed in a reaction vessel and equilibrium was established. The graph below shows how the concentration of methanol in this vessel changes with time at three different temperatures. The pressure is the same at each temperature.



- a) Is the reaction exothermic or endothermic? Justify your answer. 2

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- b) Explain why a moderately high temperature of 520 K is used for this process. 2

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**Question 25 (7 marks)****Marks**

The following questions refer to the list of ionic compounds below:

- LiCH<sub>3</sub>COO
- Mg(NO<sub>3</sub>)<sub>2</sub>
- CaCl<sub>2</sub>
- Na<sub>2</sub>SO<sub>4</sub>
- NH<sub>4</sub>Cl
- KF
- Na<sub>2</sub>CO<sub>3</sub>
- NaCl

- a) From the list above, select ONE example of an acidic, neutral and basic salt to complete the table below.

| <i>Acidic Salt</i> | <i>Neutral Salt</i> | <i>Basic Salt</i> |
|--------------------|---------------------|-------------------|
|                    |                     |                   |

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- b) Explain, with the use of an equation, the acidic nature of the salt that was identified in the table above.

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- c) A white solid forms when gaseous ammonia and gaseous hydrogen chloride react.

The Bronsted-Lowry theory classifies this process as an *acid base reaction*, whereas the Arrhenius theory does not. Explain why.

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## **Question 26 (4 marks)**

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Carbonic acid is formed when carbon dioxide dissolves in water. Carbonic acid plays a major role in the buffering of human blood, which has a typical pH of 7.40.

- a) Calculate the typical hydrogen ion concentration in human blood.

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- b) Outline how the carbonic acid buffer system in human blood works. Include relevant equations to support your response.

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**Question 27 (4 marks)****Marks**

A student attempted to neutralise 10.5mL of 0.0355M hydrochloric acid, so they added enough 0.0288M sodium hydroxide to make a total volume of 50.0mL.

- a) Outline ONE practical method which could be used in the school laboratory to determine whether enough sodium hydroxide was added to form a neutral solution.

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- b) Calculate the final pH of the mixture.

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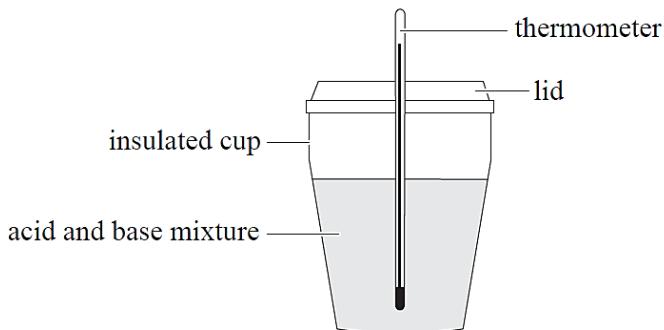
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**Question 28 (5 marks)****Marks**

The diagram shows a coffee cup calorimeter used by a student to measure the enthalpy of neutralisation of an acid–base reaction.



The student combined 120.0 mL of  $0.50 \text{ mol L}^{-1}$  sodium hydroxide and 60.0 mL of  $0.50 \text{ mol L}^{-1}$  sulfuric acid. Both solutions were initially at a temperature of  $24.2^\circ\text{C}$ . After mixing, the final temperature was  $26.3^\circ\text{C}$ .

- a) List TWO assumptions made by the student whilst performing this experiment. 1

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- b) Calculate the enthalpy change per mole of water formed in this reaction. 4

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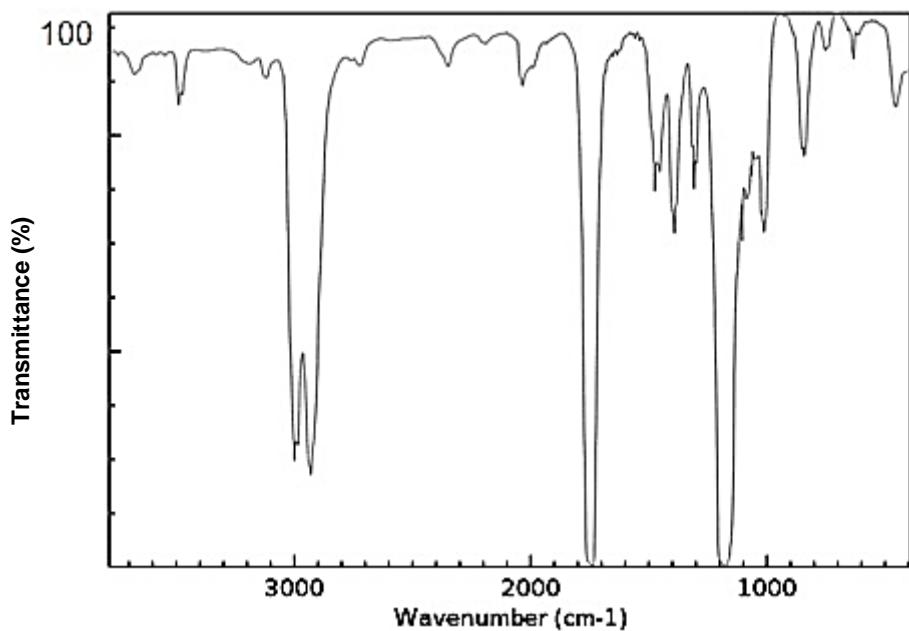
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**Question 29 (3 marks)****Marks**

A pure sample of an organic molecule has the molecular formula of  $C_3H_6O_2$ . The sample did not react with sodium hydrogen carbonate or decolourise an acidified permanganate solution. It produced the following infra-red spectrum:



Use the information provided to deduce all possible structures of the organic molecule.

Support your response with at least TWO pieces of evidence.

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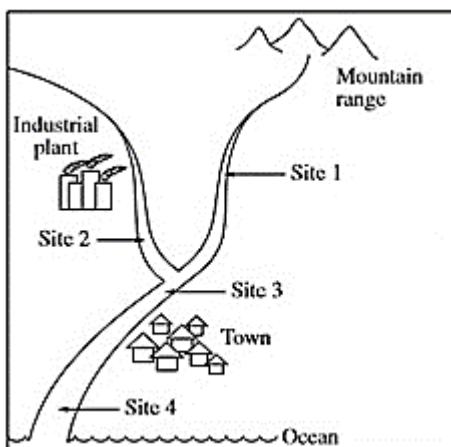
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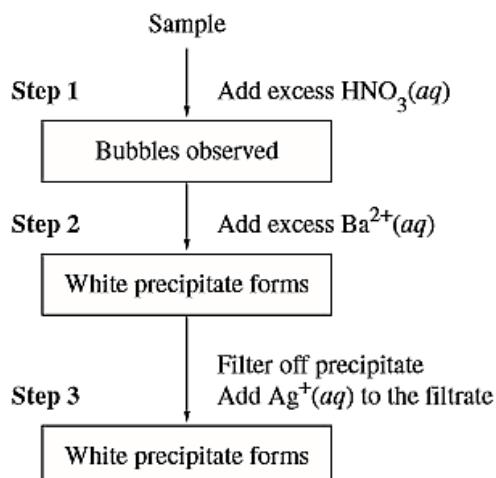
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**Question 30 (6 marks)****Marks**

The map below shows a water catchment area for a town.



The local water authority appointed an inexperienced analytical chemist to test the quality of the water in the river. Initially, he sampled the river water at Site 3 and performed a series of qualitative tests to assess the presence of carbonate, chloride and sulfate ions. The procedure he used is summarised below:



- a) Complete the table by naming the observed product formed at each step of the procedure.

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| <i>Step</i> | <i>Product Formed</i> |
|-------------|-----------------------|
| 1           |                       |
| 2           |                       |
| 3           |                       |

**Question 30 continues on the following page**

**Question 30 continued****Marks**

- b) The chemist was also asked to test for the presence of phosphate ions. He claimed that this was not possible, as phosphate ions and sulfate ions both form white precipitates when barium ions are added. Evaluate the chemist's statement.

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- c) The chemist suspected that the industrial plant was releasing high levels of  $\text{Fe}^{2+}$  ions into the river.

Outline a procedure that the chemist could use on location at Site 2 as a qualitative test to confirm this suspicion.

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**Question 31 (6 marks)****Marks**

The following data may be of use when answering this question.

| Name               | Formula                              | Solubility in Water<br>at 25°C<br>(g/100g water) |
|--------------------|--------------------------------------|--|
| Lead(II) ethanoate | Pb(CH <sub>3</sub> COO) <sub>2</sub> | 55   |
| Lead(II) iodide    | PbI <sub>2</sub>                     | 0.076  |
| Lead(II) nitrate   | Pb(NO <sub>3</sub> ) <sub>2</sub>    | 60   |
| Potassium iodide   | KI                                   | 142  |

Some brands of hair dye still contain lead(II) ions in an active ingredient, lead(II) ethanoate.

In an investigation to estimate the amount of lead(II) ions in a particular brand of dye, 10.0 g of the dye was measured. Enough solid potassium iodide is measured and dissolved in water to produce a 0.10 M solution of potassium iodide.

An excess of the 0.10 M potassium iodide was added to the dye sample. The precipitate that formed was filtered through pre-weighed filter paper and thoroughly washed in distilled water. The mass of the filter paper and precipitate was measured after repeated gentle heating in an incubator set at 30°C. The results are shown below.

| Measurement   | Mass<br>(g) |
|---|-------------|
| Mass of filter paper (g)  | 0.298       |
| Mass of filter paper + precipitate (g)<br><i>(after 1 period of heating)</i>  | 1.567       |
| Mass of filter paper + precipitate (g)<br><i>(after 2 periods of heating)</i> | 1.454       |
| Mass of filter paper + precipitate (g)<br><i>(after 3 periods of heating)</i> | 1.387       |
| Mass of filter paper + precipitate (g)<br><i>(after 4 periods of heating)</i> | 1.387       |

- a) Why is potassium iodide an appropriate reagent for this particular investigation?

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**Question 31 continues on the following page**

**Question 31 continued**

**Marks**

- b) How did the procedure of repeatedly heating and weighing the filter paper and precipitate increase the accuracy of the results?

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- c) Use the results of the investigation and the data provided to calculate the concentration of lead(II) ions (as a % w/w) in the dye sample.

Include an appropriate equation in your answer.

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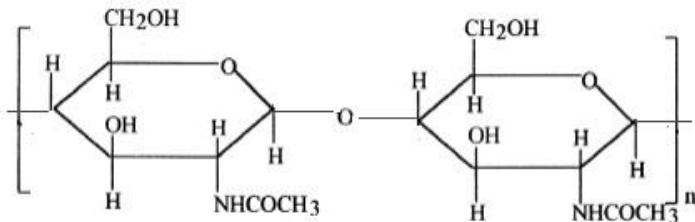
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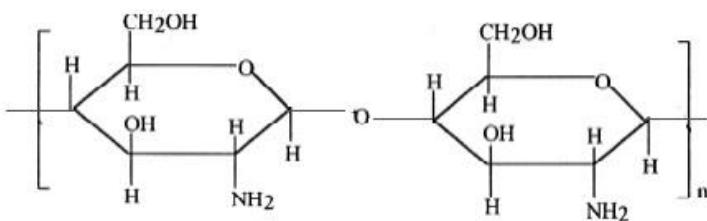
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**Question 32 (6 marks)****Marks**

Chitin is an insoluble polymer which forms the exoskeleton (shell) of many insects and crustaceans. It can be synthetically modified to produce chitosan, which is water-soluble.



Chitin,  $pK_a = 6.1$



Chitosan,  $pK_a = 6.5$

- a) Are chitin and chitosan examples of addition or condensation polymers? Justify your response.

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- b) Explain why the chemical structure of chitin imparts strength to the shells of insects.

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**Question 32 continues on the following page**

**Question 32 continued** **Marks**

- c) Would a 0.012M solution of chitosan be acidic or basic? Justify your response with an appropriate calculation.

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**Question 33 (7 marks)****Marks**

Refer to the following information for this question

***Engineered Cyanobacteria Turn Carbon Dioxide into Petrol Substitute***

*A strategy transforms wild photosynthetic organism into a system that could reduce humanity's reliance on fossil fuels.*

*Scientists in Sweden have engineered cyanobacteria that can photosynthesise the petrol substitute butanol out of carbon dioxide. The microorganisms could not only provide a way to make transportation fuels that don't depend on fossil fuels, but they could also remove carbon dioxide already present in the atmosphere.*

*(Adapted from Chemistry World 2019, Royal Society of Chemistry)*

- a) Use a table to compare and contrast the environmental impacts of synthesising butanol using butane sourced from natural gas, or using cyanobacteria as outlined above. **3**

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**Question 33 continues on the following page**

**Question 33 continued**

## Marks

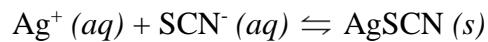
- b) Construct a flow chart which illustrates a reaction pathway to chemically synthesise butanol from butane. Your flowchart should include all systematic names, necessary reagents and conditions.

4

**Question 34 (4 marks)****Marks**

An excess of 0.072M silver nitrate solution was added to 30.0mL of a sodium phosphate solution of unknown concentration. The total volume of silver nitrate added was 60.0mL. The precipitate was then filtered out, rinsed thoroughly and the filtrate collected in a conical flask.

The filtrate was titrated with a 0.0531M potassium thiocyanate solution and an appropriate indicator according to the following equation:



An average titre of 15.03mL potassium thiocyanate was obtained.

Calculate the concentration of phosphate ions in the original solution.

**4**

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### **Question 35 (7 marks)**

## Marks

Evaluate the significance of carbon as the basis for organic chemistry by explaining its role in producing the wide diversity of properties seen in organic molecules.

7

**Continue response over the page**

Teacher's Name \_\_\_\_\_ NESA Number \_\_\_\_\_

End of Examination

**2019 Chemistry Trial Examination**  
**Marking Criteria and Markers' Comments**

**Section I**

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

**Section II**

**Question 21a**

| <b><i>MARKING CRITERIA</i></b>  |          |
|---|----------|
| • <i>Correct balanced equilibrium equation including states of matter</i> | <i>1</i> |

**Sample Answer**



**Marker's Comments**

The majority of candidates were able to gain full marks for the equation with 8 candidates receiving no marks due to:

- Not including all states of matter.
- Putting a charge on the products (usually NO).

**Question 21b**

| <b><i>MARKING CRITERIA</i></b>  |          |
|---|----------|
| <ul style="list-style-type: none"> <li>• <i>Thoroughly explains the effect on reaction equilibrium using collision theory in terms of:</i> <ul style="list-style-type: none"> <li>○ <i>Number of successful collisions between the products decreases resulting in a decrease in the rate of the reverse reaction</i></li> <li>○ <i>Number of successful collisions between the reactants increase (relative to the reverse reaction) resulting in an increase in the rate of the forward reaction.</i></li> <li>○ <i>Equilibrium shifts to the right.</i></li> </ul> </li> </ul> | <i>2</i> |
| <ul style="list-style-type: none"> <li>• <i>Outlines the effect on reaction equilibrium using collision theory</i><br/> <i>Or</i></li> <li>• <i>Any relevant information in reference to collision theory</i></li> </ul>  | <i>1</i> |

**Sample Answer**

Removing  $\text{Cl}_2$  gas from the system reduces its concentration. Applying collision theory, the number of collisions between the products will decrease as a result of the reduced  $[\text{Cl}_2]$ . As reaction rate is a measure of the number of ~~coll~~<sup>the</sup> successful collisions, the reduced number of collisions between the products will result in a reduced reverse reaction rate relative to the forward reaction. This ~~more~~<sup>relative</sup> increased forward reaction rate causes more products to be produced than reactants and hence shifts the equilibrium position to the right, to the products.

### Marker's Comments

This was considered to be a band 3-4 question; consequently, the majority of the cohort were able to achieve full marks. The way candidates expressed their response did vary significantly; however, as long as a response clearly addressed the above points, full marks were given. If an error was made by a candidate, it usually was due contradictory statements about collision theory and its effects on the reactions equilibrium.

### Question 21c

| MARKING CRITERIA  |   |
|---|---|
| <ul style="list-style-type: none"> <li>• Thoroughly explains the effect on reaction equilibrium using Le Chatelier's Principle in terms of           <ul style="list-style-type: none"> <li>○ An increase in volume will result in a decrease in pressure<br/>Or</li> <li>○ An increase in volume will result in a decrease in concentration</li> <li>○ Either of the above approaches will result in a shift in equilibrium to the right as a response to the change imposed on the system according to Le Chatelier's Principle.<br/>(i.e. in an attempt to increase pressure of the system or to increase the number of moles of gases present in the system)</li> </ul> </li> </ul> | 2 |
| <ul style="list-style-type: none"> <li>• Outlines the effect on reaction equilibrium using Le Chatelier's Principle<br/>Or</li> <li>• Any relevant information in reference to Le Chatelier's Principle</li> </ul>  | 1 |

### Sample Answer

Le Chatelier states that an equilibrium system will 'shift' the equilibrium point to counteract a change. Increasing volume would reduce the concentrations of all species, however have a greater reducing effect on the reactants due to their smaller stoichiometric ratio. Therefore to counteract this change, the equilibrium point will shift towards the reactants by Le Chatelier's principle.

By increasing the volume, the system's pressure has decreased. Le Chatelier principle states that when a system at equilibrium is disturbed (~~increased~~ decreased pressure) the system will attempt to reestablish equilibrium by counteracting the change (attempt to ~~decrease~~ increase pressure) by favouring the forward reaction as it produces ~~more~~ <sup>less</sup> moles of gas, reducing system pressure. 2

### Marker's Comments

Again, this was considered to be a band 3-4 question; pleasingly, the majority of the cohort achieved full marks. Like the previous question, candidate's responses varied in their explanation of the effect on equilibrium with candidates using changes in pressure or concentration. Both were appropriate as long as the candidate addressed the criteria for the question.

Some points to note:

- Candidates are advised to avoid referring to collision theory in their responses when the question asks for an explanation using Le Chatelier's Principle.
- Some candidates need to review their understanding of Le Chatelier's Principle as their logic was correct, however the conclusion they made about the shift in equilibrium was not.
- It is advised that candidates do not shorten Le Chatelier's Principle to LCP in their HSC responses.

### Question 21d

| MARKING CRITERIA  |   |
|---|---|
| <ul style="list-style-type: none"> <li>Write the expression for <math>K_{eq}</math></li> <li>Use an ICE or RICE table to determine the concentrations of ALL chemical species present at equilibrium for a 2L container (2 marks)</li> </ul> <p>Or</p> <p>Use an ICE or RICE table to determine the moles of ALL chemical species present at equilibrium and converts the values to concentrations for a 2L container (2 marks)</p> | 4 |
| • Correctly substitute values into the expression for $K_{eq}$ and correct calculated value for $K_{eq}$  |   |
| • ONE component of the above points not addressed   | 3 |
| • TWO components of the above points not addressed  | 2 |
| • THREE components of the above points not addressed  | 1 |

### Sample Answer

Examples of 2 different approaches to this question allowing for the 2L container at different times in the response. Additionally setting out was easy to follow.

$$K_{eq} = \frac{[NO]^2 [Cl_2]}{[NOCl]^2}$$

$$= \frac{[0.056]^2 [0.028]}{[0.444]^2}$$

$$= 0.0004454 \dots$$

∴  $K_{eq}$  for the decomposition of

$NOCl$  @  $227^\circ C$  is

$$0.00045 \quad (2sf)$$

Nice!

|   | $2NOCl$ | $2NO$ | $Cl_2$  |
|---|---------|-------|---------|
| I | 1       | 0     | 0       |
| C | $-2x$   | $+2x$ | $+x$    |
| E | $1-2x$  | $2x$  | $0.056$ |

$$x = 0.056 - 0$$

$$\therefore x = 0.056$$

At Equilibrium: (mols)

$$Cl_2 = x = 0.056$$

$$NO = 2x = 0.112$$

$$NOCl = 1-2x = 0.888$$

At Equilibrium: conc.

$$eq': c = \frac{n}{V} \quad (V=2\text{L})$$

$$Cl_2 = \frac{0.056}{2} = 0.028$$

$$NO = \frac{0.112}{2} = 0.056$$

$$NOCl = \frac{0.888}{2} = 0.444$$

| $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$ |             |             |  |
|--|-------------|-------------|--|
| I:   | 0.5 mol/L   | 0           | 0  |
| C:   | $-2x$       | $+2x$       | $+x$                                     |
| E:   | 0.444 mol/L | 0.056 mol/L | 0.028 mol/L                              |
|  |             |             | $\frac{NOCl}{1\text{mol}/2\text{L}}$     |
|  |             |             | 0.5 mol/L                                |
|  |             |             | $\frac{Cl_2}{0.056\text{mol}/2\text{L}}$ |
|  |             |             | 0.028 mol/L                              |

$$K_{eq} = \frac{[NO]^2 [Cl_2]}{[NOCl]^2}$$

$$= \frac{(0.056)^2 (0.028)}{(0.444)^2}$$

$$= 0.0004454 \dots$$

$$= 4.5 \times 10^{-4} \quad (2sf)$$

### Marker's Comments

Approximately, 60% of the cohort were able to gain full marks for this question. Despite a significant improvement in setting out, this was still an issue especially the ICE/RICE table. It is advised that candidates take the time to construct it correctly as it makes it easier to mark; additionally, make the table larger so all the appropriate information can be added easily. The main issues candidates had were:

- Errors in writing the expression for  $K_{eq}$  with the majority of candidates forgetting to square the values for NO and NOCl. The majority of candidates did not rewrite the chemical equation for this question and it is advised that this should be done. The candidates who used a RICE table did not have this problem.

- Candidates did not construct an ICE/RICE table and struggled with determining the equilibrium concentrations.
- Candidates did not allow for the 2L volume for the container or only calculated the initial concentration of the reactant and used mole values for the rest of the calculations.
- A few candidates transposed numbers incorrectly usually due to poor hand writing.

Some other points to note:

- Ticks do not equal marks.
- Carried errors were allowed for when calculating  $K_{eq}$ , except when the wrong expression was being used and no marks were awarded for the calculation.
- Although significant figures were not marked here, candidates MUST assume that they are and should take the time to write their final figure using appropriate sig figs.

## Question 22

| MARKING CRITERIA   |   |
|--|---|
| • Determines the nitrate concentration in ppm from the graph       | 3 |
| • Convert the nitrate concentration from ppm to $gL^{-1}$          |   |
| • Convert the nitrate concentration from $gL^{-1}$ to $mol L^{-1}$ |   |
| • ONE component of the above points not addressed                  | 2 |
| • TWO components of the above points not addressed                 | 1 |

### Sample Answer

Absorbance = 0.125

$\therefore$  concentration (ppm) = 0.225 ✓

$n = \frac{m}{MM}$

$= \frac{0.00235}{62.01} = 3.789 \times 10^{-6} \text{ mmol}$

$c = \frac{0.235 \text{ mg}}{1 \text{ L}}$

$\therefore c = 3.789 \times 10^{-6} \text{ M}$

$c = 3.79 \times 10^{-6} \text{ M (3)}$

$\therefore \text{fixed}$  ✓

$n = \frac{m}{MM}$

$m = 0.235 \text{ mg}$

$= 0.00235 \text{ g}$

$MM_{NO_3} = 14.01 + 16.00 \times 3 = 62.01 \text{ g}$

Well done!

12

### Marker's Comments

This question was not completed well by the majority of the cohort with only several candidates achieving full marks. Some issues were:

- Candidates tried to develop an equation for the line given on the graph. The concentration in ppm can be taken directly from the graph.
- Misreading the concentration value from the graph. Candidates should take more care at looking at the scale of axis when reading values from a graph.
- Many candidates did not know or apply the relationship of ppm = mg/L and this made it hard to continue with further calculation.
- Many candidates tried to calculate the sample size in their calculations and this either confused their calculations or meant that their final value for the concentration was out by a factor of 10 or 100 (in a lot of cases).

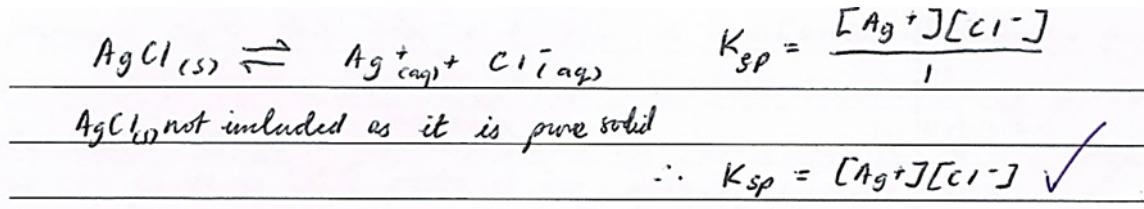
Note – the marker allowed different values for the concentration of nitrate ions take from the graph as long as they were reasonable (e.g. 2.4 – 2.5)

Again, it is advised for candidates to revise this aspect of the course since this could be asked again in the HSC exam.

### Question 23a

| MARKING CRITERIA                               |   |
|--|---|
| • Correctly writes the expression for $K_{sp}$ | 1 |

#### Sample Answer



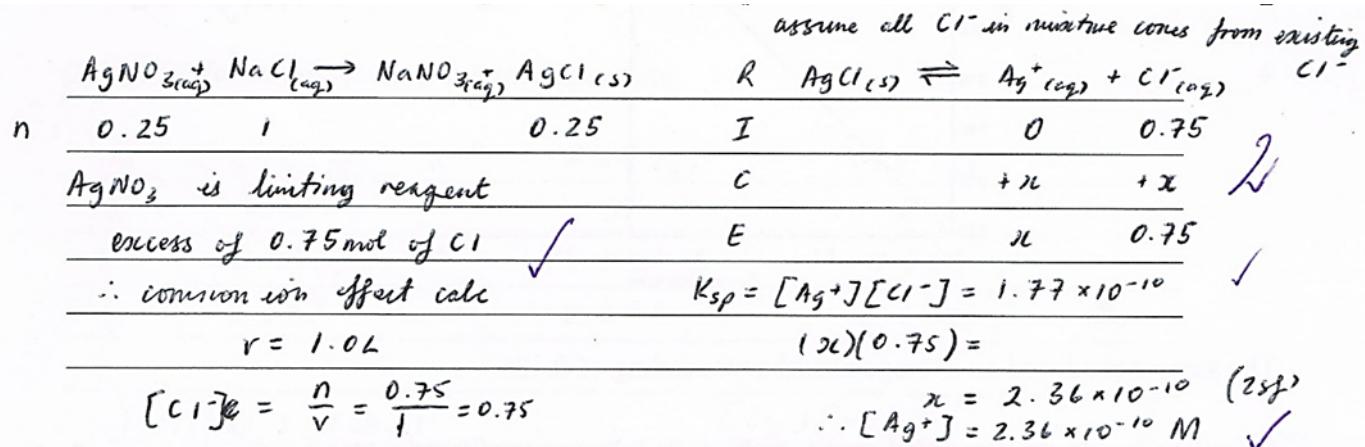
#### Marker's Comments

This was considered to be a band 3-4 question. Disappointingly, only 35% of the cohort was able to write the correct expression for the  $K_{sp}$  of silver chloride. Many candidates included solid silver chloride as a denominator in the expression, and since solids are assigned a value of 1 it is not necessary to include it. Other candidates included sodium and nitrate ions which had nothing to do with this expression. This question has exposed a weakness in many candidates understanding of  $K_{sp}$  or candidates just forgot about it as it was studied back in term 4 last year. It is recommended that this concept be reviewed.

### Question 23b

| MARKING CRITERIA  |   |
|---|---|
| • Determines that $\text{AgNO}_3$ is the limiting reagent for the reaction + calculates the $[\text{Cl}^-]$ that remain in solution | 2 |
| • Use the expression for $K_{sp}$ to calculate the $[\text{Ag}^+]$ present at equilibrium   |   |
| • ONE component of the above points not addressed   | 1 |

#### Sample Answer



### Marker's Comments

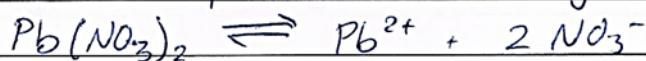
A more challenging question with a number of concepts that required to be considered. Only 1 candidate was able to get this question correct, with approximately 50% of the cohort calculating the concentration of silver ions if a saturated solution of silver chloride was made with water (i.e. molar solubility). Only a handful of candidates recognised that there was a limiting reagent in the reaction – silver nitrate – and there was excess chloride ions (i.e. 0.75 mole) left unreacted. This was an application of the common ion effect. Again, candidates should review this aspect of the course.

### Question 23c

| <b>MARKING CRITERIA</b>   |   |
|---|---|
| <ul style="list-style-type: none"> <li>• Outlines the effect of dissolved lead nitrate on the solubility of lead chromate in terms of:           <ul style="list-style-type: none"> <li>○ an example of the Common ion effect – <math>\text{Pb}^{2+}</math> already being present will decrease the solubility of lead chromate</li> <li>○ as equilibrium of the dissolution of lead chromate to form lead and chromate ions will be forced to the left in accordance to Le Chatelier's Principle or</li> <li>○ less lead ions from the addition of lead chromate are required for the system to reach equilibrium and form a saturated solution</li> </ul> </li> </ul> | 2 |
| <ul style="list-style-type: none"> <li>• ONE component of the above points not addressed</li> </ul>   | 1 |

### Sample Answer

The solution of lead nitrate means that less lead chromate will be able to dissolve in that solution than in pure water.  
The solution of lead nitrate is given by:



Adding solid lead chromate will add more  $\text{Pb}^{2+}$  ions. Since  $\text{Pb}$  ions are already present from the  $\text{Pb}(\text{NO}_3)_2$  dissociation, by Le Chatelier's principle, the equilibrium position will shift left to decrease the  $[\text{Pb}^{2+}]$  produced by the lead chromate. Hence less lead chromate will dissolve / it will become less soluble in a 0.20M  $\text{Pb}(\text{NO}_3)_2$  solution than pure water, as the  $\text{Pb}^{2+}$  ions also in solution shift its equilibrium position left. ✓

By adding the ~~more~~ lead chromate to a solution already containing lead ions, the solubility of the lead chromate would be reduced. Since the dissolution of lead chromate can be expressed as an equilibrium system, Le Chatelier's principle tells us that the presence of lead ions additional to those dissolved from the solid will push equilibrium to the left to offset this, resulting in more solid lead chromate at equilibrium, resulting in a reduced solubility.

#### Marker's Comments

The majority of candidates recognised that this question involved the common ion effect and was able to state that the solubility of the solid lead salt would decrease. Pleasingly, many candidates then went on to outline the reason for this conclusion based on Le Chatelier's Principle or the solution reaching equilibrium (for lead ions) quickly with less addition lead ions.

### Question 24a

| MARKING CRITERIA                                   |   |
|--|---|
| • States that the reaction is exothermic           | 2 |
| • Justifies this statement based on the data given |   |
| • ONE component of the above points not addressed  | 1 |

### Sample Answer

According to Le Chatelier's principle, heating an equilibrium mixture will favour the endothermic reaction as it attempts to counteract the initial disturbance. Since the yield of  $\text{CH}_3\text{OH}$  is decreased at higher temperatures, we know that the reverse reaction must be endothermic, and the forwards reaction is exothermic.

- b) Explain why a moderately high temperature of 520 K is used for this process.

As the temperature is increased, the yield of methanol decreases, suggesting that the addition of heat favouring the reverse reaction, hence which must be endothermic. Hence the forward reaction is exothermic. / 2

### Marker's Comments

This question was completed well by the cohort with the majority gaining full marks.

### Question 24b

| MARKING CRITERIA   |   |
|--|---|
| • Provides a thorough explanation for the use of moderate temperatures for the reaction  | 2 |
| • Provides a limited explanation for the use of moderate temperatures for the reaction<br>Or<br>• Any relevant information about the process | 1 |

### Sample Answer

A very high temperature will increase the rate of reaction by increasing the kinetic energy of the molecules. However, it will favour the reverse reaction of this equilibrium & thus lower the yield of  $\text{CH}_3\text{OH}$ . Conversely a low temperature will increase the yield of  $\text{CH}_3\text{OH}$  but will be a slower process as the particles have less kinetic energy. Hence a moderately high temperature of 520 K is used as it creates an effective compromise of a decent yield AND rate of reaction. ✓

From the graph, it is clear that increasing temperature reduces the amount of time required to reach equilibrium due to the increased rate of collisions between particles. Although 400°K has a roughly 30% higher yield than 520°K, it takes twice as long to produce a full yield due to it taking longer to reach equilibrium. Therefore it is more efficient to use a moderate temperature as a sizeable yield will be produced more often.

### Marker's Comments

This question was completed well by the cohort with the majority gaining full marks. They saw the link between rate and yield in the data.

### Question 25

a)

| Marking Criteria                       | Marks |
|--|-------|
| • All three salts identified correctly | 2     |
| • One-two salts identified correctly   | 1     |

### Markers Comments

Around 60% achieved full marks.

### Sample Answer

Acidic:

- NH<sub>4</sub>Cl

Neutral:

- Mg(NO<sub>3</sub>)<sub>2</sub>
- CaCl
- Na<sub>2</sub>SO<sub>4</sub>
- NaCl

Basic:

- LiCH<sub>3</sub>COO
- KF
- Na<sub>2</sub>CO<sub>3</sub>

b)

| Marking Criteria   | Marks |
|--|-------|
| Must include one of the following explanations <ul style="list-style-type: none"> <li>• It acts as a proton donor</li> <li>• It will form H<sup>+</sup> ions in water</li> <li>• It is the conjugate of a weak base</li> </ul> | 2     |

|   |   |
|---|---|
| And   |   |
| <ul style="list-style-type: none"> <li>• Equation that demonstrates the explanation</li> <li>• Explanation with no equation<br/>Or</li> <li>• Equation of it acting as an acid<br/>Or</li> <li>• It is the salt formed of a weak base and strong acid with an appropriate equation</li> </ul> | 1 |

### Markers Comments

To achieve full marks for students needed to explain that  $\text{NH}_4^+$  is a proton donor or that it forms  $\text{H}^+$  ions in water. This is the acid nature of a substance. They then needed to back this up with an equation showing it donating a proton or form  $\text{H}^+$  ions in water.

I accepted the explanation that ammonium is the conjugate acid of a weak base with an equation to demonstrate this, however, this does not explain its acidic nature, it does not show how it acts as an acid.

I did not accept that a strong acid and a weak base produce an acidic salt. This is often true but often not as well. In fact, I believe it only works for ammonia and a strong acid. All carbonates will give a neutral salt even though they are a weak base, group two metal hydroxides give a neutral salt and all weak conjugate bases of weak acids like  $\text{F}^-$  will not give a salt at all. You could still achieve 1 mark for this explanation.

Many students focus on the formation of the salt with a HCl and  $\text{NH}_3$ , suggesting the reaction wouldn't go to completion leaving some HCl remaining which was the result of the lower pH. This response has nothing to do with ammonium chloride being acidic, it is the remaining reactant HCl that is acidic. This response was wrong because the reaction of a strong acid and base will go to completion and the question asked about the acidic nature of the ammonium chloride, all by itself. You needed to show how it acts as an acid.

### Sample Answer

b) Explain, with the use of an equation, the acidic nature of the salt that was identified in the table above.

*in the presence of a base,  $\text{NH}_4^+$  can be curtailed and donate a proton.*

$\text{NH}_4\text{Cl}_{(\text{aq})} + \text{NaOH}_{(\text{aq})} \rightarrow \text{NaCl}_{(\text{aq})} + \text{NH}_3_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})}$

2

c)

| Marking Criteria   | Marks |
|--|-------|
| <ul style="list-style-type: none"> <li>• Identifies BL acids/bases as proton donors/acceptors</li> <li>• Identifies Arrhenius acids/bases as those that produce <math>\text{H}^+/\text{OH}^-</math> when dissolved in <b>water</b>.</li> <li>• Explains that this reaction is an acid base reaction according to BL because HCl donates a proton and <math>\text{NH}_3</math> accepts, but is not for Arrhenius because it does not occur in aqueous phase.</li> </ul> | 3     |
| Any two of the following <ul style="list-style-type: none"> <li>• Identifies BL acids/bases as proton donors/acceptors</li> </ul>  | 2     |

|  |   |
|--|---|
| <ul style="list-style-type: none"> <li>Identifies Arrhenius acids/bases as those that produce <math>H^+/OH^-</math> when dissolved in <b>water</b>.</li> <li>HCl donates and proton and <math>NH_3</math> accepts</li> </ul>   |   |
| Any one of the following <ul style="list-style-type: none"> <li>Identifies BL acids/bases as proton donars/acceptors</li> <li>Identifies Arrhenius acids/bases as those that produce <math>H^+/OH^-</math> when dissolved in <b>water</b>.</li> <li>HCl donates and proton and <math>NH_3</math> accepts</li> <li>•</li> </ul> | 1 |

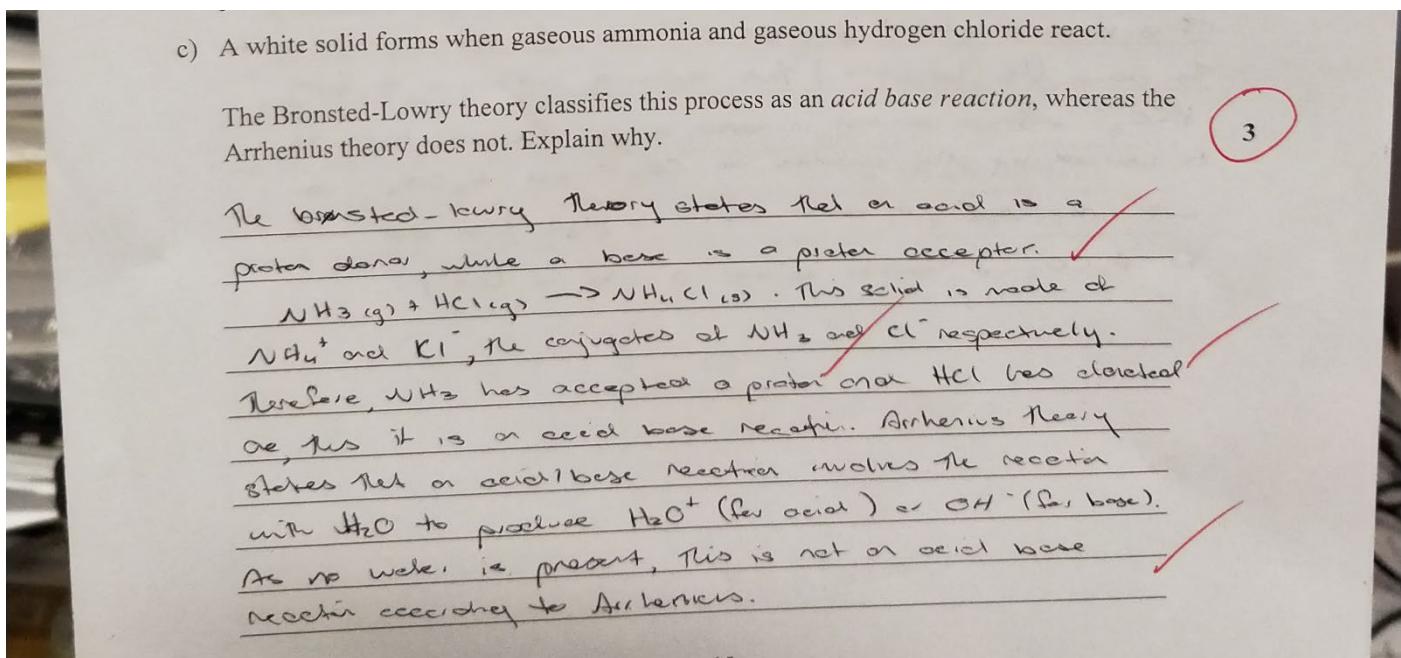
### Markers Comments

Most students were able to answer the BL part of the question without any trouble, however, you needed to be specific about what species was the donor/acceptor.

Most students did not know what Arrhenius classified as an acid/base. They need to form  $H^+/OH^-$  when dissolved in water. This theory is actually just as important as the BL theory of acids as it what we base to concept of pH on.

I was also disappointed by the number of students that could not figure out that the product was solid ammonium chloride based on the information given in the question.

### Sample Answer



### Question 26

a)

| Marking Criteria   | Marks |
|--|-------|
| <ul style="list-style-type: none"> <li>Correct answer of <ul style="list-style-type: none"> <li><math>4.0 \times 10^{-8} \text{ mol/L}</math> (correct sig figs)</li> <li><math>3.98... \times 10^{-8} \text{ mol/L}</math> (incorrect sig figs)</li> </ul> </li> <li>-1/2 marks for no units</li> </ul> | 1     |

### Markers Comments

Well done by most students. Quite a lot of students did not round correctly giving an answer of  $3.9 \times 10^{-8} \text{ mol/L}$ .

Also, remember that sig figs for pH is different, it is the number of decimal places, therefore, a pH of 7.40 is 2 sig figs and that's what your answer should be too.

b)

| Marking Criteria  | Marks |
|---|-------|
| <ul style="list-style-type: none"><li>Correct equation(s) and correct explanation of how the addition of <math>H^+</math> and <math>OH^-</math> will significantly alter the pH.</li></ul> <p>Or</p> <ul style="list-style-type: none"><li>Identifies that pH change is resisted</li><li>Includes relevant equation(s) to show the effect of adding of <math>H^+</math> and <math>OH^-</math></li><li>Identifies that buffers are made of a weak acid/base and their conjugate.</li></ul> | 3     |
| Two of the following <ul style="list-style-type: none"><li>Identifies that pH change is resisted</li><li>Includes relevant equation(s) to show the effect of adding of <math>H^+</math> and <math>OH^-</math></li><li>Identifies that buffers are made of a weak acid/base and their conjugate.</li></ul>   | 2     |
| • Relevant information  | 1     |

#### Markers Comments

The carbonic acid buffer system is made up of carbonic acid and conjugate base, hydrogen carbonate. Many students did not use these exact two but used hydrogen carbonate and carbonate or some other combination. I allowed that so long as it was an acid and its conjugate, but it should be carbonic acid and hydrogen carbonate.

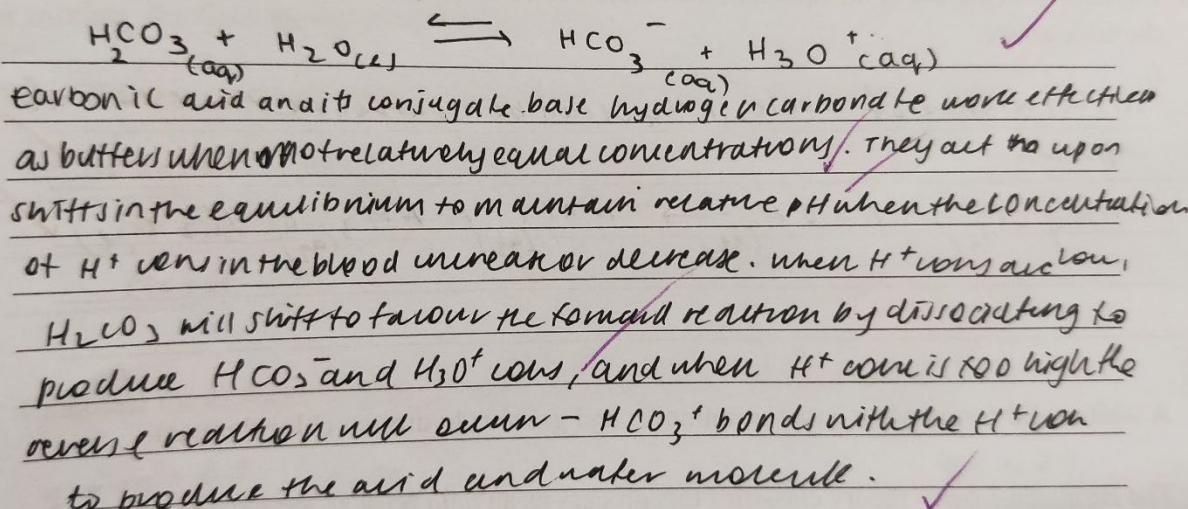
The key to this question was that you needed to show how the addition of a strong acid and a strong base would not significantly affect pH. The easiest way to do this is to have the carbonic acid neutralising hydroxide and hydrogen carbonate neutralising hydrogen ions.

Many students answered with an equilibrium shift, which is fine if done correctly, however, some got confused and had it shifting one way and then back which took them back to where they started and did not show any resistance to a pH change. Once a disturbance to the equilibrium has occurred and it has shifted to counteracted this, that shift doesn't cause another shift and so on like a bouncing spring.

Better answers identified that buffers must be made of a weak acid/base and its conjugate.

#### Sample Answer

- b) Outline how the carbonic acid buffer system in human blood works. Include relevant equations to support your response.



3

3

### Question 27

a)

| Marking Criteria   | Marks |
|--|-------|
| • Outline a correct procedure that would definitively determine if the pH of the solution was 7. | 1     |

### Markers Comments

The straightforward answer to this question was to use a pH probe and confirm that the pH was 7. Universal indicator was accepted too if it was used to conform a pH of 7.

If the response did not outline how a pH of 7 could be confirmed then it was marked incorrect.

Titration was a poor choice for this question.

### Sample Answer

- a) Outline ONE practical method which could be used in the school laboratory to determine whether enough sodium hydroxide was added to form a neutral solution.

1

Use an electronic pH meter - if the pH of the solution is  $\geq 7$ , then the hydrochloric acid has been completely neutralised; however, if it is in fact  $> \text{pH } 7$  then too much was added and the NaOH will need to be neutralised....

b)

| Marking Criteria                            | Marks |
|---|-------|
| • Calculate number of moles of HCl and NaOH | 3     |
| • Calculate concentration of excess NaOH    |       |
| • Calculate pH                              |       |
| • 2 of the above                            | 2     |

### Markers Comments

Generally, well done. Common mistakes were

- Using the number of moles of excess  $\text{OH}^-$  in the pOH calculation instead of concentration
- Rounding before the end
- Working out pOH but not converting to pH

Once again, remember sig figs are different for pH. The answer should be to 3 sig figs which is pH= 12.185.

### Sample Answer

b) Calculate the final pH of the mixture. (3)

$$\begin{aligned} n_{\text{HCl}} &= \cancel{CV} = 0.0355 \times 10.5 \times 10^{-3} \\ &= 3.7275 \times 10^{-4} \text{ mol L}^{-1} \\ n_{\text{NaOH}} &= CV = 0.0288 \times (50 - 10.5) \times 10^{-3} \\ &= 0.0011376 \text{ mol/L} = 1.1376 \times 10^{-3} \text{ mol/L} \\ \text{HCl}_{(\text{aq})} + \text{NaOH}_{(\text{aq})} &\rightarrow \text{H}_2\text{O}_{(\text{l})} + \text{Na}^{+}_{(\text{aq})} + \text{Cl}^{-}_{(\text{aq})} \\ 1 : 1 &: 1 : 1 : 1 : 1 \\ \text{NaOH is in excess by } &1.1376 \times 10^{-3} - 3.7275 \times 10^{-4} \\ &= 7.6485 \times 10^{-4} \text{ mol} \\ \therefore \text{the OH}^- \text{ concentration is } &c = \frac{n}{V} = \frac{7.6485 \times 10^{-4}}{0.0500} \\ &= 0.015297 \dots \\ \therefore \text{pOH} &= -\log_{10} [\text{OH}^-] = 1.81539 \dots \\ \therefore \text{pH} &= 14 - 1.81539 \dots = 12.1846 \dots \\ &\approx 12.185 \quad (3 \text{ sig figs/d.p.}) \end{aligned}$$

### Question 28

a)

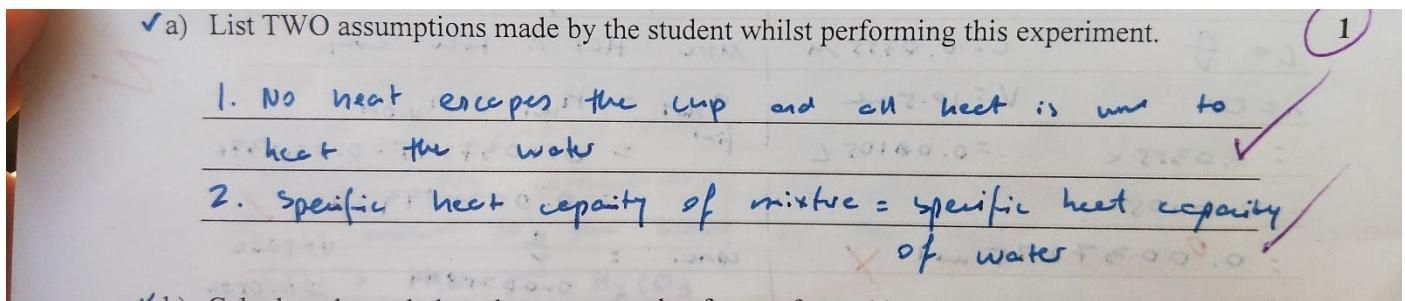
| Marking Criteria          | Marks         |
|---------------------------|---------------|
| • Two correct assumptions | 1             |
| • One correct assumption  | $\frac{1}{2}$ |

### Markers Comments

I considered only assumptions that are definitely not true, like the specific heat capacity of the solution is the same as water or that all the energy released by the reaction stayed in the water, to be correct. Otherwise you could say any part of the experiment was based on an assumption, like the solvent used was water or the volumes were accurate.

I did not accept that the reaction went to completion. A strong acid and strong base will always go to completion. I did not accept that molar amounts of each had to be in their correct ratios as the calculations will allow for one being in excess.

### Sample Answer



b)

| Marking Criteria  | Marks |
|---|-------|
| • Calculates $q$  | 4     |
| • Calculates number of moles of $H_2O$                                    |       |
| • Calculates $\Delta H$ (-½ if positive) (-½ if missing units)            |       |
| • 3 significant figures   |       |
| • Three of the above  | 3     |
| • Two of the above  | 2     |
| • Selects appropriate equation<br>Or<br>• Gives correct chemical equation | 1     |

### Markers Comments

60% of students achieved 3-4.

### Common mistakes

- Many students had the mass in  $q=mC\Delta T$  as the water produced by the reaction. This is the mass of the overall water/solution 180g
- Incorrect sig figs
- Positive enthalpy for an exothermic reaction
- Incorrect/missing units
- Rounding too early
- Mixing up  $q$  and  $\Delta H$
- Incorrect moles of water

### Sample Answer

b) Calculate the enthalpy change per mole of water formed in this reaction.

$$q = m \cdot c \cdot \Delta T$$

$$\Delta T = 2.1$$

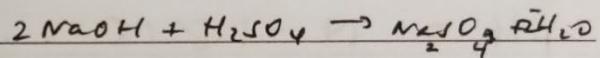
$$= 0.180 \times 4.18 \times 10^3 \times 2.1$$

$$m = 180 \text{ g}$$

$$= 1580.04 \text{ J}$$

$$c = 4.18 \times 10^3$$

$$= 1.58004 \text{ kJ}$$



molar ratio NaOH : H<sub>2</sub>O = 1:1

$$\Delta H = \frac{-q}{n}$$

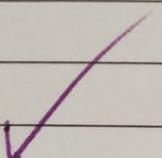
$$\therefore \text{mol of H}_2\text{O} = 0.500 \times 0.120$$

$$= -1.58004$$

$$= 0.06 \text{ mol}$$

$$0.06$$

$$\Delta H = -26.3 \text{ kJ/mol}$$



## Question 29

### Marking Criteria

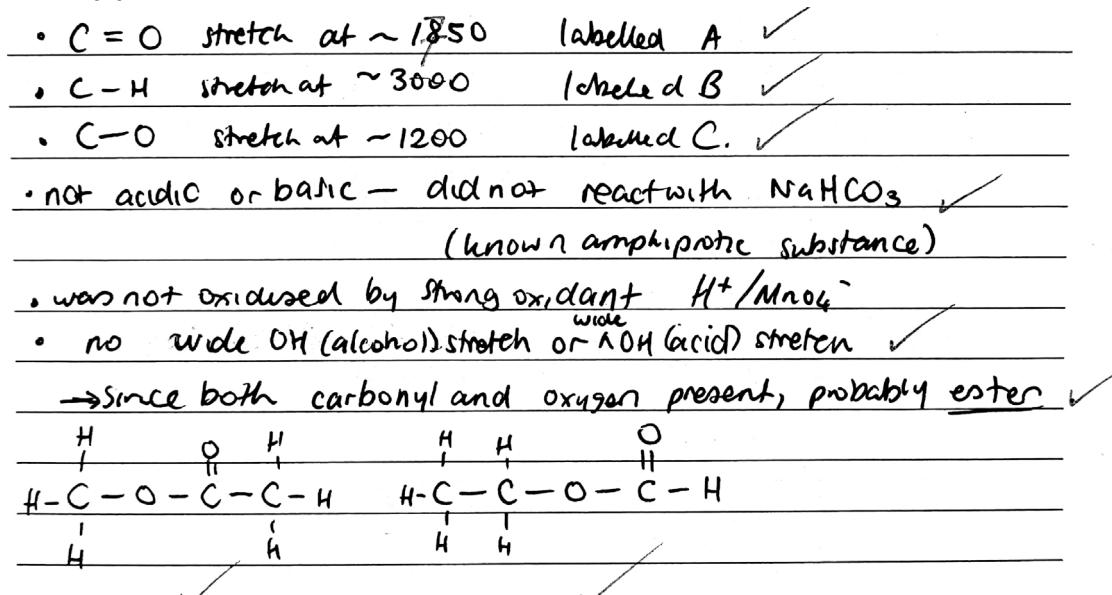
| Criteria  | Mark |
|---|------|
| Identifies the two possible esters correctly, supported with conclusive evidence  | 3    |
| Identifies two possible esters correctly, with inconclusive evidence OR Incorrectly identifies the structures, with detailed evidence | 2    |
| Supplies some evidence  | 1    |

### Marker's Comments

Students took many approaches to tackling this question (see samples below), which is really a logic puzzle using your understanding of organic chemistry. You did not need to state every piece of evidence, but your answer needed to narrow down the possible structures conclusively. Better answers drew support from the IR spectrum, the chemical test data and the molecular formula.

- The ABSENCE of evidence (doesn't react, doesn't decolourise, missing peaks) can provide good supporting evidence for eliminating some options.
- A few students made errors involving the valency of carbon, which permitted them to draw structures which were consistent with the evidence but impossible, e.g. a diketone.
- A few students confused the terms carboxyl (-COOH) and carbonyl (-C=O) – these are very different functional groups and it is most important that the terms are not misused.
- Some students identified the peak in the 3000 region as a hydroxyl peak. This is not possible due to its shape – hydroxyl peaks are always broad (alcohol) or very broad (carboxylic acid).
- Note: 2 ½ marks were awarded to students with conclusive evidence who identified only one isomer of the ester.

### Sample Answer(s)



The IR spectrum at 3000 shows C-H stretching indicating organic molecule, the transmittance at 1680-1750 shows absorption of C=O, indicating that a C double bonded to O is present and so has to be a carboxylic acid, aldehyde, ester, however no transmittance after 3000 which indicates there is no O-H present, thus can't be carboxylic acid (and also doesn't react with NaHCO<sub>3</sub>, so isn't an acid). Also the acidified permanganate is an oxidising agent and so if aldehydes oxide, produce carboxylic acids which would decolourise permanganate and so can't be aldehydes. There is also a spike between 1000-1300 which could indicate possible C-O bond which could mean organic molecule is an ester which supports molecular formula of C<sub>3</sub>H<sub>6</sub>O<sub>2</sub>. So possible structures could include methyl ethanoate and ethyl methanoate

$$\begin{array}{c} \text{H}-\text{C}-\text{O}-\text{C}-\text{H} \\ | \qquad | \\ \text{H} \qquad \text{H} \end{array}$$

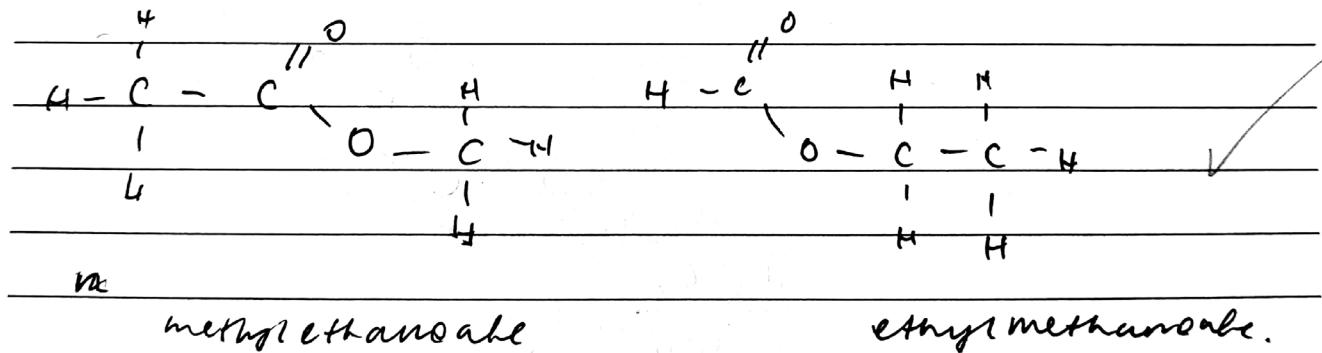
$$\begin{array}{c} \text{O}-\text{C}-\text{C}-\text{O}-\text{C}-\text{H} \\ | \qquad | \\ \text{H} \qquad \text{H} \end{array}$$

$\begin{array}{c} \text{O} \\ || \\ \text{C}-\text{O}-\text{C} \\ | \\ \text{C}-\text{O}-\text{C} \\ || \\ \text{C}-\text{O}-\text{C} \end{array}$ 
 $\begin{array}{c} \text{O} \\ || \\ \text{C}-\text{C}-\text{O} \\ | \\ \text{C}-\text{C}-\text{O} \end{array}$

Through stoichiometry, the molecular formula C<sub>3</sub>H<sub>6</sub>O<sub>2</sub> can form propanoic acid or the esters methyl ethanoate or ethyl methanoate as they have a fixed number of atoms. Using the infrared spectrum, we can see that there are peaks of at wavenumbers of roughly 3000, 1750 and 1200. The molecule is likely not propanoic acid as it lacks the characteristic 'hairy band' and the peak corresponding O-H bond peaks from 2500-3000. Further support for the molecule being an ester comes from the high levels of saturation in C-H bond at 3000, high peak at 1750, indicative of a C=O bond and the most significant indicator of a strong peak at an ester with the peak of 1200 indicative of a C-O bond. Hence it can be deduced that the organic molecule is the ester methyl ethanoate or ethyl methanoate.

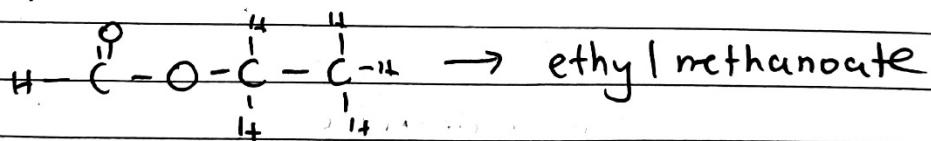
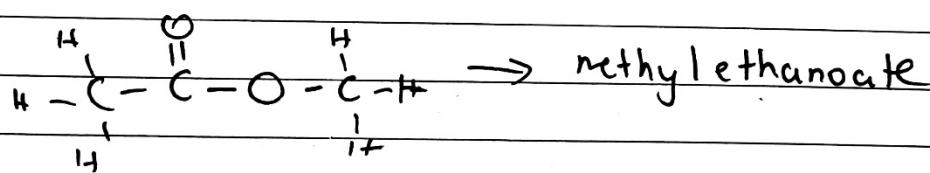
The sample did not react with carbonate ∴ not a carboxylic acid.

The spectrum shows that a C-H bond (2850-3300),  
C=O bond (1680-1750) and a C-O bond (1000-1300)  
are present. It cannot be a ketone or aldehyde as a  
C=O bond is present. Therefore it must be an ester.



Since it did not react w/  $\text{NaHCO}_3$  or decolorise ~~acidified~~  ~~$\text{H}_2\text{O}_2$~~  permanganate solution, it must not be a carboxylic acid or an alcohol.

Sharp dip in transmittance at  $\sim 1750\text{ cm}^{-1}$  indicates a C=O bond. A <sup>clear</sup> dip at  $\sim 1200$  indicates a C-O bond.



## Question 30(a)

### Marking Criteria

| Criteria   | Mark |
|--|------|
| Identifies two of the products formed at the correct steps ( $\text{CO}_2$ , $\text{BaSO}_4$ , $\text{AgCl}$ ) | 2    |
| Identifies the product formed at one step  | 1    |

### Marker's Comments

- This was marked VERY leniently with only two out of three correct responses required to score full marks. This would not always be the case for a question like this, so take note if you were one of the “lucky ones” this time!
- Surprisingly, the most common error was to misidentify the first product: acid + carbonate always forms carbon dioxide gas (the OBSERVED product in this case).
- Technically, this question asked you to *name* (NOT *state the formula* for) the product. I accepted formulae as well, but again, this may not always be the case.

### Sample Answer(s)

| Step | Product Formed      |
|------|---------------------|
| 1    | Carbon dioxide      |
| 2    | Barium sulfate      |
| 3    | Silver (I) chloride |

## Question 30(b)

### Marking Criteria

| Criteria   | Mark |
|--|------|
| Acknowledges that both sulfate and phosphate form white pptes with barium OR<br>that the chemist's statement is false, AND<br>Suggests a valid method to distinguish phosphate | 2    |
| Acknowledges that both sulfate and phosphate form white pptes with barium  | 1    |

### Marker's Comments

- Many students did not reference the chemist's statement in their response. For an evaluation, this should be done – if it was clearly implied, it was accepted in this instance.
- Most students who suggested a mean of distinguishing phosphate did so in the context of the question. Whilst both ions do form white precipitates with barium, the best method is to alter the pH – sulfate will still precipitate at low pH and can be filtered off, then the pH can be made alkaline and more barium added – this will precipitate any barium phosphate. This method relies on  $K_a(H_2SO_4) \gg K_a(H_3PO_4)$ . Adding acid ( $H^+$ ) has a major effect on the amount of free phosphate ions, but not on sulfate ions.
- Some alternate methods involved the ammonium molybdate test for phosphate (specific) or distinguishing via less conventional precipitations ( $Fe^{3+}$ ,  $Cu^{2+}$ ) – these were accepted.

### Sample Answer(s)

This is not correct. As the solution was acidified with the addition of  $HNO_3$ , adding  $Ba^{2+}$  would not have formed a precipitate with  $PO_4^{3-}$ , and so by ~~reducing~~ filtering precipitate out and making the solution alkali the presence of phosphate would have formed a white precipitate with  $Ba^{2+}$ .

This statement is ~~incorrect~~<sup>incorrect</sup>. Phosphate and sulfate  
can be distinguished by first acidifying the solution, looking  
for phosphate  $\rightarrow \text{H}_3\text{PO}_4$ , and then adding barium. If  
a white precipitate forms sulfate is present. The solution  
can then be ~~another~~<sup>filtered, until</sup> alkaline, and more barium  
added. If another white precipitate forms, ~~phosphate~~<sup>phosphate</sup> is present.

### Question 30(c)

#### Marking Criteria

| Criteria  | Mark |
|---|------|
| Outlines a valid procedure suitable for use on-site AND Identifies expected result  | 2    |
| Outlines a valid procedure suitable for use off-site AND Identifies expected result,<br>OR<br>Outlines a valid procedure suitable for use on-site which identifies $\text{Fe}^{3+}$ or is non-specific for oxidation state of iron AND Identifies expected result | 1    |

#### Marker's Comments

- Accepted answers (test – accepted result) included:
  - Acidified  $\text{MnO}_4^-$  - decolourises
  - $\text{OH}^-$  or  $\text{NH}_3$  – green to reddish-brown ppt
  - $\text{Cl}^-$  - pale green solution
  - $\text{PO}_4^{3-}$  - brown ppt
- Detail on dealing with other ions possibly present was not required.
- Note that flame tests / AAS are not suitable on-site methods. Filtration can be done on a small scale, but is not ideal here.
- Thiocyanate is a diagnostic test for  $\text{Fe}^{3+}$ , not  $\text{Fe}^{2+}$

#### Sample Answer(s)

The chemist could take a sample of the river-water at Site 2 and add it to a solution of acidified potassium permanganate ( $\text{MnO}_4^-/\text{H}^+$ ). If the sample decolorises the  $\text{MnO}_4^-/\text{H}^+$  solution, turning it from purple to colourless, this is a qualitative, positive test for the presence of  $\text{Fe}^{2+}$  ions in the river.

He could add  $\text{OH}^-$  ions. A green precipitate would possibly indicate the presence of  $\text{Fe}^{2+}$ . To further confirm this he could see how ~~an~~ a sample of water reacts with an acidified permanganate solution. If the permanganate solution is decolourised, the presence of  $\text{Fe}^{2+}$  is confirmed.

### Question 31(a)

#### Marking Criteria

| Criteria   | Mark |
|--|------|
| Any of: <ul style="list-style-type: none"><li>• KI is highly soluble</li><li>• <math>\text{KCH}_3\text{COO}</math> is highly soluble</li><li>• <math>\text{PbI}_2</math> has very low solubility / will form a precipitate</li></ul> | 1    |

#### Marker's Comments

Most students got this entry level question, which was generously marked.

#### Sample Answer(s)

Potassium iodide is an appropriate reagent as it is ~~insoluble~~<sup>very soluble</sup> in water. ~~This forms a precipitate.~~ However, in a reaction with lead, lead (II) iodide is formed, which is insoluble in water and is a precipitate that can be washed.

repeatedly heating allowed water in filter paper to evaporate away, leaving the only mass measured to be the filter paper (mass known ∴ can be subtracted) & the ppte, giving a more accurate weight of ppte & hence more accurate results. repeatedly = allowed seeing when water stopped evaporating.

## Question 31(b)

### Marking Criteria

| Criteria   | Mark |
|--|------|
| Explains how the heating to constant mass procedure increases accuracy of the results: <ul style="list-style-type: none"><li>• Heating removes excess water</li><li>• Repeating the process until consistent mass is obtained ensures all water is gone</li><li>• Produces a mass closer to the true value</li></ul> | 2    |
| One of the above points  | 1    |

### Marker's Comments

It was relatively easy to get the first mark, but considerably more difficult to get the second.

- A few students are confused by the term “accuracy” – this refers to the closeness of the experimental result to the true value. Experimental design (effective control of variables, testing the aim) are key in achieving this.
- Many students referred to the removal of excess “solution” or “substances”. As the filter paper was thoroughly rinsed, only water would remain with the precipitate.

### Sample Answer(s)

Heating and weighing shows that most of the excess water to be removed from the precipitate! Allowing the measured weight to be closer to the true value! Therefore increasing the accuracy of the results. The last two measurements are equal confirming that all water has evaporated making the weight as accurate as possible. ✓

### Question 31(c)

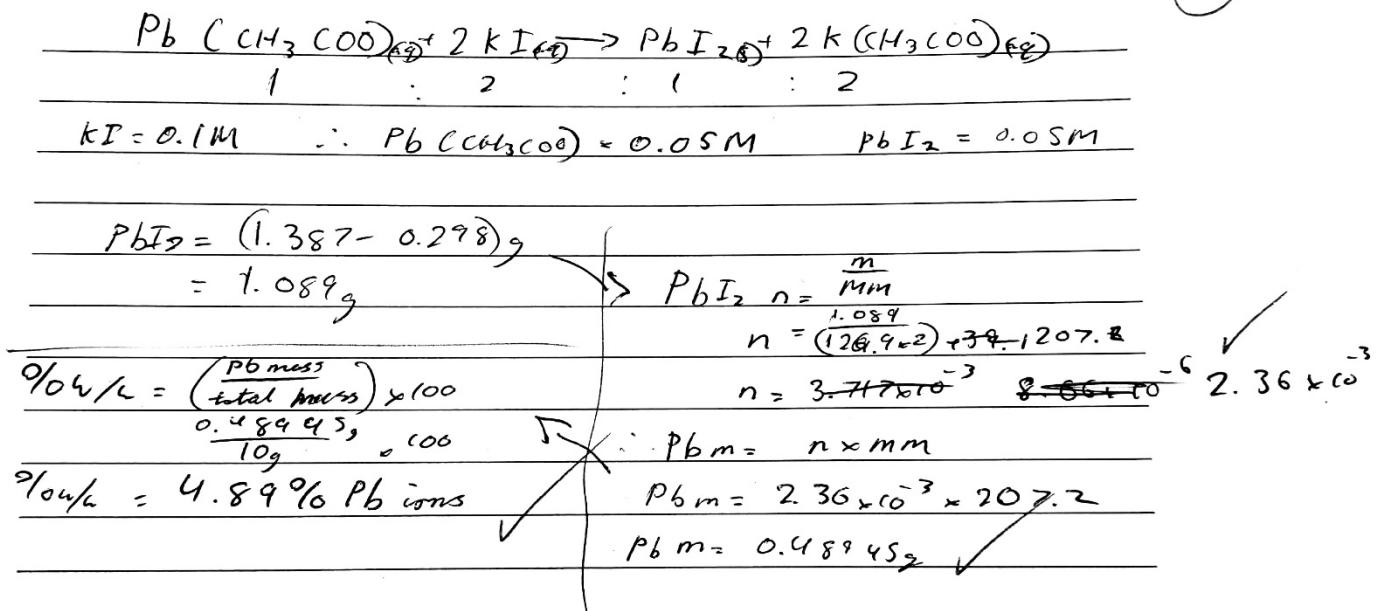
#### Marking Criteria

| Criteria  | Mark |
|---|------|
| <ul style="list-style-type: none"> <li>Calculates number of moles of lead iodide precipitate formed</li> <li>Calculates the mass of lead ions in the precipitate</li> <li>Calculates the concentration (%w/w) of lead ions in the hair dye</li> </ul> | 3    |
| Two of the above  | 2    |
| One of the above  | 1    |

#### Marker's Comments

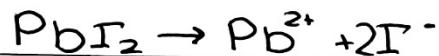
- Many students answered this question quite well, including setting out.
- Two or three students used an unconventional method which did not fit the marking criteria above – they achieved full marks as their method was stoichiometric and the answer was correct.
- Some students became tangled in an attempt to use the concentration of KI solution. As KI was in excess, it cannot be used as a part of a mole ratio.
- A few students forgot to subtract the mass of the filter paper.
- Technically this question should be answered to 3 sig figs as the concentration of KI (2 sf) was not used in the calculation.

#### Sample Answer(s)



Include an appropriate equation in your answer.

You already  
know it's data  
time babe4444  
3



$$n(\text{PbI}_2) = \frac{m}{MM}$$

$$= \frac{1.089}{461} = 0.00236\dots$$

$$n(\text{PbI}_2) = n(\text{Pb}^{2+}) \rightarrow 1:1 \text{ mole ratio}$$

$$\therefore m(\text{Pb}^{2+}) = 0.00236 \cdot 207.2 \\ = 0.4894\dots \text{g}$$

$$= \frac{0.4894}{10} \times 100 \\ = 4.9\%$$

3 s.f.

$$M_{(\text{O}_2)} = 10.0 \text{ g}$$

$$C_{(\text{KI})} = 0.10 \text{ M}$$

$$M_{(\text{PbI}_2)} = 1.387 - 0.298 \\ = 1.089 \text{ g}$$

$$m(\text{Pb}^{2+}) = ?$$

$$MM_{(\text{PbI}_2)} = 207.2 + (2 \times 126.9) \\ = 461$$

## Question 32(a)

### Marking Criteria

| Criteria  | Mark |
|---|------|
| Identifies the polymers as condensation type because: <ul style="list-style-type: none"> <li>• A glycosidic (oxygen) link is present between monomers</li> <li>• There is no end site which could have been unsaturated</li> <li>• Each monomer has two functional groups</li> <li>• Chitin is a naturally occurring polymer</li> </ul> | 1    |

### Marker's Comments

- Although it is true that all naturally occurring polymers are condensation polymers, this is the weakest of the above justifications.
- Many students attempted to predict what the functional groups that had reacted to eliminate a small molecule may have been – this was risky and not necessary.
- Some students believed that the polymers must be addition as the monomers were the same. Condensation and addition polymers may have monomers that are the identical or different in a repeating pattern.

### Sample Answer(s)

Both are forms of condensation polymers. The -o- bond between monomers negates the possibility of an addition reaction across a double bond.

condensation - both ends of the molecule are sites of <sup>reaction</sup> ~~addition~~ & removal of a small particle (in this case likely  $\text{H}_2\text{O}$ )

~~Addition~~ Condensation, as there is no extra bonding room for the end carbons to have a double bond with any other carbon

## Question 32(b)

### Marking Criteria

| Criteria   | Mark |
|--|------|
| <ul style="list-style-type: none"><li>Identifies the sources (both hydroxyl and amide groups) and describes the role of hydrogen bonding between polymer chains in strengthening chitin</li></ul> <p>OR</p> <ul style="list-style-type: none"><li>Describes the role of intermolecular forces in more general terms, AND describes the effect of close packing of chains in strengthening chitin</li></ul> | 2    |
| Describes one important factor in determining the strength of chitin   | 1    |

### Marker's Comments

- This question was not particularly well answered.
- Few students identified the amide group, which is very important here, although many identified the important role of the hydroxyl groups.
- Many students referred to dipole-dipole forces but not hydrogen bonding.
- Some students argued that ring structures imparted strength (some misidentifying the ring as a benzene ring). Many natural polymers contain similar ring structures but are not strong e.g. starch. The key is what is occurring BETWEEN polymer chains.
- A few students tried to describe a chain stiffening effect caused by side chains – these side chains are not large enough to cause rigidity in the chain.

### Sample Answer(s)

Polymer like Chitin are not able to form long chains of compound that are stuck on top of each other to form dense, strong exterior material. Furthermore, the presence of O-H groups in chitin, means that Hydrogen bond the polymer amide group bond with itself, increasing the ~~strength of~~ intermolecular forces between molecules and therefore the strength of the material.

amide ( $\text{NHCOCH}_3$ )

Chitin contains many highly polar bonds in its structure such as that found in the  $-\text{OH}$  group,  $\text{NH}$  group. The polar bonds form dipoles. These dipoles form interactions between polymer chitin chains and exert intermolecular bonding forces which are strong such as dipole-dipole interactions and the very strong hydrogen bonding forces as well as dispersion forces. As the sum of these intermolecular forces is high between adjacent chains, chitin is very strong and gives strength to chain shells of insects.

The  $\text{O}^{\delta^-}\text{-H}^{\delta^+}$ ,  $\text{N}^{\delta^-}\text{-H}^{\delta^+}$  and  $\text{C}=\text{O}^{\delta^+}$  bonds allow for relatively strong dipole-dipole forces and hydrogen bonds to occur between the polymer chains, allowing the polymer to have strength, functioning as an effective shell.

### Question 32(c)

#### Marking Criteria

| Criteria   | Mark |
|--|------|
| Justifies the chitosan solution as acidic with an appropriate calculation  | 3    |
| Reasonable attempt to justify the chitosan solution as acidic with an appropriate calculation, OR  |      |
| Justifies the chitosan solution as basic (due to one error) with an appropriate calculation  | 2    |
| Calculates $K_a$ , OR<br>Justifies the chitosan solution as acidic with a descriptive answer, OR<br>Reasonable attempt to justify the chitosan solution as basic with an appropriate calculation | 1    |

#### Marker's Comments

- Some students tackled this question very competently, using  $pK_a$  to calculate  $K_a$ , using a K expression and the solution concentration of chitosan to calculate  $[H^+]$ , then calculating pH; others stumbled around in the dark!
- Some students assumed a chitosan solution must be basic as it contains amino groups. Although it qualifies as an organic base broadly speaking, this is only a guide to its probable behaviour in water. Its  $pK_a$  suggests it is acidic, although quite weakly. The calculation of pH demonstrates this (see sample answer).
- Most students assumed chitosan was monoprotic; better answers stated this assumption.
- Most successful students used the approximation of substituting initial concentration of chitosan for equilibrium concentration of chitosan due to its small  $K_a$ ; some used a quadratic method. Both methods were acceptable as numerical support for the acidic nature of chitosan, although the quadratic method was unnecessarily complex here.

#### Sample Answer(s)

For chitosan

$$K_a = 6.5$$

$$-\log_{10} [K_a] = 6.5$$

$$K_a = 10^{-6.5}$$

$$= 3.16 \times 10^{-7}$$

$$K_a = \frac{[H_3O^+] [Chitosan^-]}{[Chitosan]}$$

$$As this is clearly highly weak we can let$$

$\{Chitosan\} = \text{the initial}$   
 $i.e. 3.16 \times 10^{-7} = \frac{[H_3O^+]^2}{0.012}$   
 $[H_3O^+] = 3.16 \times 10^{-7} \times 0.012$   
 $= 3.16 \times 10^{-9} [H_3O^+] = 6.1 \times 10^{-5}$   
 $\text{now } pH = -\log_{10} [H_3O^+]$   
 $= -\log \{3.16 \times 10^{-9}\} / \{6.1 \times 10^{-5}\}$   
 $= 4.210... - 8.42 + 3...$   
 $= 4.210... - 8.42 + 3...$   
 $pH > 7 \therefore \text{basic}$   
 $pH < 7 \therefore \text{acidic}$

### Question 33 a)

| <b>MARKING CRITERIA</b>  |   |
|--|---|
| <ul style="list-style-type: none"><li>Constructs a suitable table with 3 columns showing the feature being contrasted/compared<br/><i>OR</i></li></ul> | 3 |
| <ul style="list-style-type: none"><li>2 columns where the features being contrasted/compared "marry - up"<br/><i>AND</i></li></ul>                     |   |
| <ul style="list-style-type: none"><li>Clearly shows 2 direct comparisons of the <b>synthesis</b> process</li></ul>                                     |   |
| <ul style="list-style-type: none"><li>As above but only ONE suitable feature compared</li></ul>  | 2 |
| <ul style="list-style-type: none"><li>One feature compared<br/><i>OR</i></li></ul>   | 1 |
| <ul style="list-style-type: none"><li>Table provided</li></ul>   |   |

### Marker's Comments

#### Problems encountered:

- Poorly constructed tables
- Students just repeating information provided in the Q ... eg Removal of CO<sub>2</sub> ..... No need to transport the fuel ... (mis-reading the reference to "transport fuels")
- Addressing the combustion of the fuel instead of the synthesis of the fuel
- Very general statements made ...eg. good/bad for the environment etc (not explaining the how or why)
- Not making it clear whether the CO<sub>2</sub> produced is referring to the synthesis of its combustion
- Some "quite weak" ..... like Yr 7 standard features were regularly offered
- NO-ONE made reference to whether butanol is a viable fuel alternative for internal combustion engines. (They would require major modification in order to become efficient ..... even ethanol can only be used if it is mixed as an "additive" of 10% with gasoline.

**Question 33 b)**

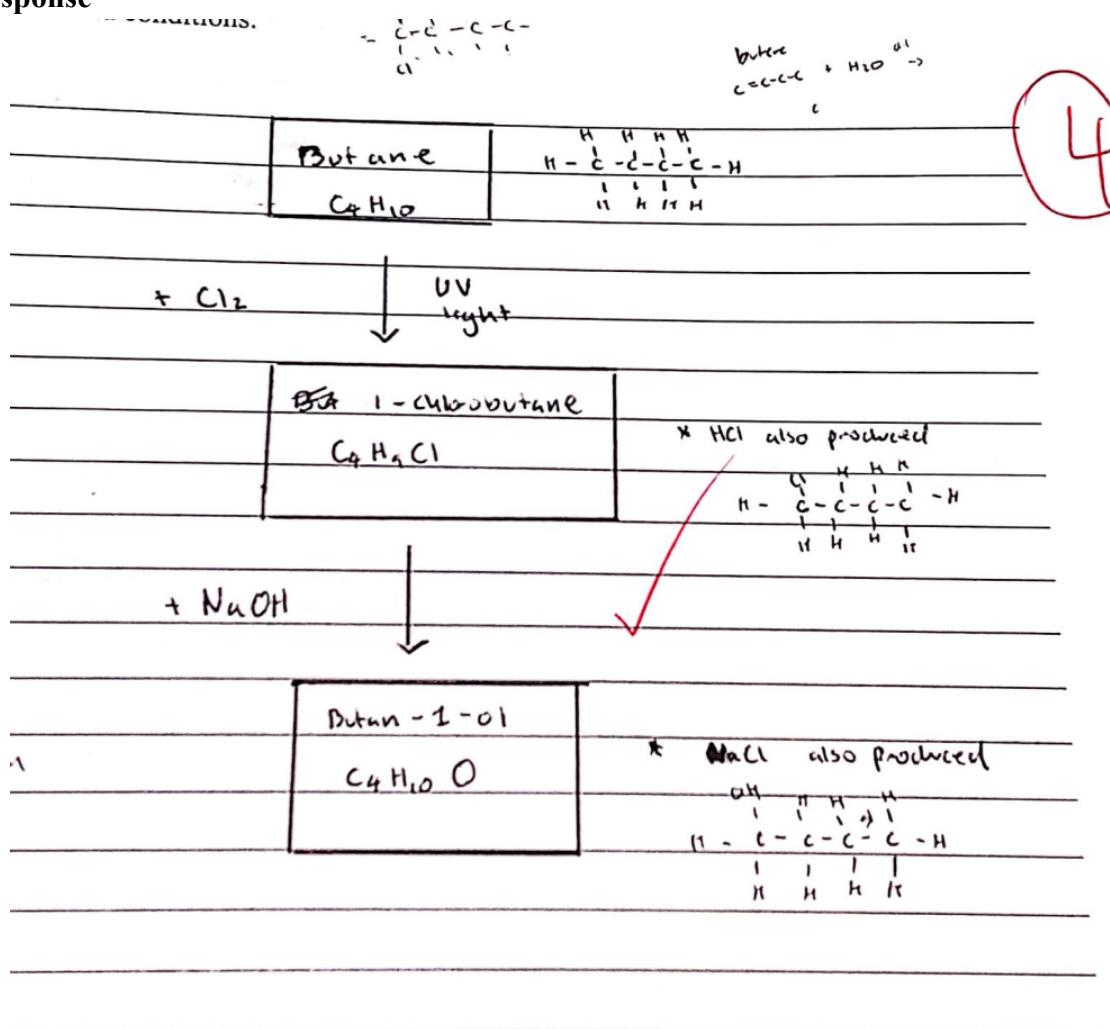
| <b>MARKING CRITERIA</b>                              |                   |
|--|-------------------|
| • Provides a suitable flow-chart/reaction pathway    | (1 mark)          |
| • Correct reagents & conditions for first step ..... | (1 mark)          |
| • Correct reagents & conditions for second step ...  | (1 mark)          |
| • Correct systematic names for substances produced   | (2 x 1/2 mark ea) |

**Marker's Comments**

Mostly well answered, though some students wanted the halogenate the alkane with HBr in the presence of UV light, which will not work

- A few students confused the term "systematic name". I believe they have confused this term with "generic" name

**Sample response**



### Question 34

| <b>MARKING CRITERIA</b>   |   |
|---|---|
| • Determines the moles of $\text{Ag}^+$ ions titrated<br>$(7.981 \times 10^{-4})$ (1/2 mark)  |   |
| • Calculates the TOTAL moles of $\text{Ag}^+$ ions used<br>$(4.32 \times 10^{-3})$ (1/2 mark)   |   |
| • Determines the amount of $\text{Ag}^+$ ions reacted with the phosphate<br>$(3.522 \times 10^{-3})$ (1 mark)   | 4 |
| • Correctly applies the molar ratio to determine the moles $\text{PO}_4^{3-}$ ions that reacted<br>$(1.174 \times 10^{-3})$ (1 mark)  |   |
| • Correctly calculates $[\text{PO}_4^{3-}]$ ( $0.039 \text{ mol L}^{-1}$ ) (1 mark)   |   |
| • NB. Carried errors were possible to be awarded ... <b>PROVIDED</b> ..... your working is set out AND I could follow what you are doing  |   |
| • A half mark could be awarded for the final answer ..... provided that the carried error took into account the correct molar ratio AND the concentration was calculated on a volume of 30 mL |   |

#### Marker's Comments

Many students did not realise that this was a “Back Titration” question, so it was imperative that the amount of  $\text{Ag}^+$  ions involved with the titration were subtracted from the TOTAL  $\text{Ag}^+$  ions used.

Poor setting out is a major issue and will need to be addressed BEFORE your HSC

Many students did not attempt this Q.

Calculate the concentration of phosphate ions in the original solution.

(4)

$$n = CV$$

$$n = 0.06 \times 0.072$$

$$n = 0.00432 \text{ mol}$$

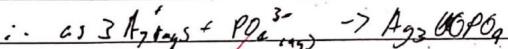
$$n = CV$$

$$n = 0.01503 \times 0.0531$$

$$n = 0.000798093 \text{ mol} \checkmark$$

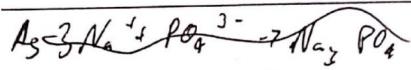
∴ 0.000798093 moles of  $\text{Ag}^+$  in solution after sodium phosphate added & reacted.

$$0.00432 - 0.00079... = 0.003521907 \text{ moles reacted}$$



3:1 mol ratio

$$\frac{0.00352...}{3} = 0.001173... \text{ moles of phosphate ions}$$



1:1

$$0.001173... =$$

$$\therefore 0.001173... \text{ moles of Na}_2\text{PO}_4$$

28

C = n/V

$$C = \frac{0.001173...}{0.03}$$

$$C = 0.03913... \text{ M}$$

$$= 0.039$$

$$= 3.9 \times 10^{-2} \text{ M } \text{Na}_2\text{PO}_4^-$$

Calculate the concentration of phosphate ions in the original solution.

(4)

SCN

$$V = 0.01503$$

$$V = 0.06$$

$$C = 0.0531$$

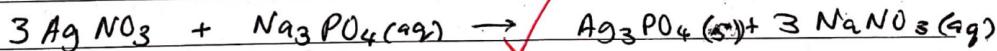
$$C = 0.072$$

$$n = CV$$

$$n = 0.00432 \text{ mol}$$

$$n = 0.000798... \text{ (A)} \checkmark$$

$$0.00432 - 0.000798... = \text{amount used by Na}_2\text{PO}_4 \text{ of Ag}^+ \\ = 0.003521... \text{ mol (B)}$$



$$\frac{B}{3} = n \text{ PO}_4$$

$$n = 0.00117... \text{ mol PO}_4 \text{ (C)}$$

$$\frac{n}{V} = C$$

$$\frac{0.00117...}{0.03} = C$$

$$0.03$$

$$C = 0.0391... \text{ mol L}^{-1}$$

$$= 0.039 \text{ mol L}^{-1}$$

## Question 35

| <b>MARKING CRITERIA</b>  |   |
|--|---|
| <p><i>A comprehensive response without errors that addresses:</i></p> <ul style="list-style-type: none"><li>• <b>Explains</b> how valence of the carbon atom allows a huge range of bonding possibilities by addressing <b>in detail</b>:<br/>- the types of covalent bonds (eg single, double, triple) AND the types structures possible (chains, branched chains, rings, aromatic etc) etc</li></ul> <p><i>AND</i></p> <ul style="list-style-type: none"><li>• Provides examples of at least 3 <b>different functional groups or types of compounds</b></li></ul>  |   |
| <p><i>AND</i></p> <ul style="list-style-type: none"><li>• Accurately describes the physical properties of at least 2 different compounds AND <b>explains</b> how these properties arise in terms of their intermolecular bonding OR</li><li>• Accurately describes the chemical properties of at least 2 different compounds AND <b>explains</b> how these properties arise in terms of the typical reactions they undergo</li><li>• </li></ul>  | 7 |
| <ul style="list-style-type: none"><li>• As above BUT contains minor errors/inconsistencies which DO NOT contradict the information provided<br/><i>OR</i></li><li>• <b>Explains</b> how valence of the carbon atom allows a huge range of bonding possibilities by addressing <b>in detail</b>:<br/>- the types of bonds (eg single, double, triple) AND the types structures possible (chains, branched chains, rings, aromatic etc) etc</li></ul> <p><i>AND</i></p> <ul style="list-style-type: none"><li>• Provides examples of at least 2 <b>different functional groups or types of compounds</b></li></ul> |   |
| <p><i>AND</i></p> <ul style="list-style-type: none"><li>• Describes the physical properties of at least 2 different compounds AND <b>relates/infers</b> how these properties arise in terms of their intermolecular bonding OR</li><li>• Accurately describes the chemical properties of at least 2 different compounds AND <b>relates</b> how these properties arise in terms of the typical reactions they undergo</li></ul>   | 6 |
| <ul style="list-style-type: none"><li>• <b>Relates</b> how valence of the carbon atom allows a huge range of bonding possibilities by addressing:</li></ul>  | 5 |

|  |   |
|--|---|
| <p>- the range of bonds carbon can form <b>AND/OR</b> identifies the <b>range</b> possible types of carbon backbone structures possible</p> <p><b>AND</b></p> <ul style="list-style-type: none"> <li>• Provides examples of only <b>2 different types of compounds</b></li> </ul> <p><b>AND</b></p> <ul style="list-style-type: none"> <li>• <b>Indicates how the physical or chemical properties of at least 2 different compounds are determined</b></li> </ul>  |   |
| <ul style="list-style-type: none"> <li>• Provides <b>accurate</b> details of at least <b>3 different compounds &amp; accounts</b> for their properties in terms of their <b>bonding &amp;/or structure</b></li> </ul> <p><b>OR</b></p> <ul style="list-style-type: none"> <li>• <b>Identifies that the carbon atom can form a huge range of bonding possibilities by addressing:</b></li> </ul> <p>- the types of bonds <b>OR</b> the types structures possible</p> <p><b>AND</b></p> <ul style="list-style-type: none"> <li>• Provides examples of only <b>2 different functional groups/types of compounds</b></li> </ul> <p><b>OR</b></p> <ul style="list-style-type: none"> <li>• <b>Identifies the physical or chemical properties of at least 2 different compounds AND accounts</b> for these properties</li> </ul> | 4 |
| <p>Response addresses <b>TWO</b> of the following</p> <ul style="list-style-type: none"> <li>• <b>Identifies two features of the carbon atom</b></li> </ul> <p><b>AND/OR</b></p> <ul style="list-style-type: none"> <li>• Provides examples of <b>2 compounds AND accounts</b> for their properties</li> </ul> <p><b>OR</b></p> <ul style="list-style-type: none"> <li>• Describes how <b>TWO</b> properties result from intermolecular bonding</li> </ul>   | 3 |
| <ul style="list-style-type: none"> <li>• <b>Identifies two features of the carbon atom</b></li> </ul> <p><b>OR</b></p> <ul style="list-style-type: none"> <li>• Provides examples of <b>2 compounds</b></li> </ul> <p><b>OR</b></p> <ul style="list-style-type: none"> <li>• <b>accounts</b> for their properties</li> </ul>   | 2 |
| <ul style="list-style-type: none"> <li>• Some relevant information</li> </ul>  | 1 |

### Marker's Comments

It was evident that students who planned their response were able to score better marks than those who just started “spewing” everything they knew about different organic compounds. As a result there were several students who scored full marks and many who scored low marks. It seemed that there were few who missed the point of the Q and failed to realise the importance of the features of the carbon atom itself. Yes it has a valence of 4 (as many students quoted) .... but ..... why is this so important???????

### A few common problems:

- Carbon can bond (covalently) with up to 4 other atoms ..... not 4 other molecules

- Carbon has a valence of 4 ..... not  $4^+$  or  $4^-$
- Be careful about saying that “the dispersion forces become stronger” as the carbon chain becomes longer. This could be considered controversial since it is debatable whether the actual forces become larger ..... but what does happen is that the overall cumulative effect is greater.
- Quantity does not relate to quality. Many students repeated the same “argument” over and over again.
- Many weaker responses generalised. Saying things like the “chain length ..... functional groups .... would “**affect**” the properties of the compounds without going into detail of what the effect was or how it came about.

#### Sample Response

Evaluate the significance of carbon as the basis for organic chemistry by explaining its role in producing the wide diversity of properties seen in organic molecules.

(7)

T EEE C : T: organic chemistry, diversity of properties  
C properties relate to intermolecular forces & ability of carbon to bond with many things E: alkane → alkene → carboxylic acid → amide w/ properties & link to carbon C: - carbon important.

T: Organic chemistry is defined as carbon-based chemistry, that is the study of carbon-based compounds. The wide range of properties seen in organic molecules refers to the wide range of component elements (from carbon & hydrogen to nitrogen & oxygen) and how they input inter- and intra-molecular forces

E: Carbon has 4 valence electrons, and as such can bond with up to four other atoms directly. This allows it to form long, hydrogen-rich single chains like decane, which is highly flammable, or to bond to three elements in a specific way, as in a carboxylic acid.

E: The sheer number of possibilities; that is of different molecules being formed around a carbon backbone leading directly to the wide diversity of properties seen in organic molecules. Note: due to carbon and hydrogen having a near-identical pull <sup>electronegativity values</sup> for electrons, carbon-hydrogen only compounds are by nature non-polar, but this can be changed by the addition of functional groups.

Continue response over the page

E: This is evident by the ability to produce both carbon-bond acids and bases, as outlined below.

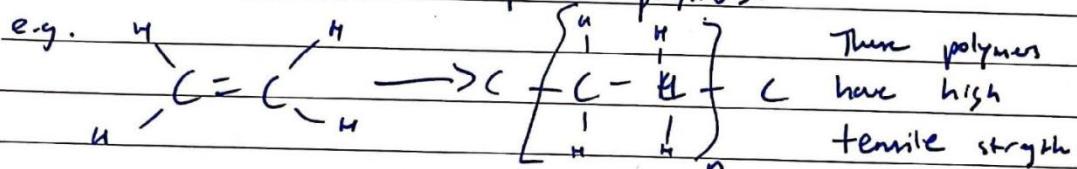
Carboxylic acid via the creation of functional groups

$\text{C}=\text{C}$  The valency of the carbon allows it to attach to both a  $=\text{O}$  and  $\text{O}-\text{H}$ , causing the H to become easily removable & thus forming an acid

### Amines

$\text{C}-\text{N}$  The ability of carbon to attach to a nitrogen allows for the nitrogen to have exposed a free pair of electrons, allowing co-ordinate covalent bonding to occur with  $\text{H}^+$  ion, and thus acting as a base.

In addition, carbon-carbon double bonds can be broken & used to form polymers.



e.g. polyethylene and can be produced easily, another different set of properties.

The ability of oxygen to double-bond to either an end or middle carbon in the chain also presents more diversity of properties; ketones cannot be oxidized, whereas alkenols can.

Due to the presence of polar groups, haloalkanes and alkenols are soluble in water, whereas non-polar substances like alkanes are not. Carbon-bond compounds can be both polar and non-polar, as in the case of soaps, where a long non-polar carbon tail attaches to a polar head.

### End of Examination

C: Thus it is clear that carbon is the most significant molecule in the study of organic chemistry, as from it (quite literally) "all things are made" and their unique & diverse properties determined by its interaction with other elements in the functional group.