Student number

# Chemistry

## 2020 TRIAL HSC EXAMINATION

**General Instructions**

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper
- For questions in Section II, show all relevant working in questions involving calculations

**Total marks: 100**

**Section I – 20 marks (pages 3–10)**

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

**Section II – 80 marks in Booklet A and B (pages 12–30)**

- Attempt Questions 21–33
- Allow about 2 hours and 25 minutes for this section in Booklet A and B

## Section I

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

Use the multiple-choice answer sheet for Questions 1–20.

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**1.** The following equilibrium is set up in a sealed reaction vessel.

$N_2O_4(g) \rightleftharpoons 2NO_2(g)$; $\Delta H = +54.8 \text{ kJ mol}^{-1}$

Which of the following would INCREASE the yield of nitrogen dioxide?

A. Adding a catalyst to the reaction vessel.
B. Decreasing the volume of the reaction vessel.
C. Raising the temperature of the reaction vessel.
D. Increasing the pressure by adding argon to the reaction vessel.

**2.** At a certain temperature, the $K_{eq}$ for the following reaction is 75.

$$2O_3(g) \rightleftharpoons 3O_2(g)$$

0.3 mol of $O_3$ and 1.5 mol of $O_2$ were introduced to a 5L reaction vessel.

Which row of the table correctly identifies the direction of the equilibrium shift and the reason for the shift?

| | Direction favoured | Reason |
|---|---|---|
| A | Left | $Q < K_{eq}$ |
| B | Left | $Q > K_{eq}$ |
| C | Right | $Q < K_{eq}$ |
| D | Right | $Q > K_{eq}$ |

**3.** Arrange the following reactions in order of their increasing ability to reach completion.

| | | |
|---|---|---|
| I. | $Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)^{2+}$ | $K_{eq} = 1.6 \times 10^7$ |
| II. | $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ | $K_{eq} = 1.6 \times 10^{-3}$ |
| III. | $Br_2(aq) + Br^-(aq) \rightleftharpoons Br_3^-(aq)$ | $K_{eq} = 18$ |
| IV. | $I_2(g) \rightleftharpoons 2I^-(g)$ | $K_{eq} = 4 \times 10^{-5}$ |

(Note: Assume that each equilibrium constant was determined under their optimum conditions)

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

**4.** A 50.0 mL sample of a solution containing chloride ions was titrated with 27.3 mL of 0.150 mol/L $AgNO_3$ to reach the end-point, using potassium chromate as an indicator.

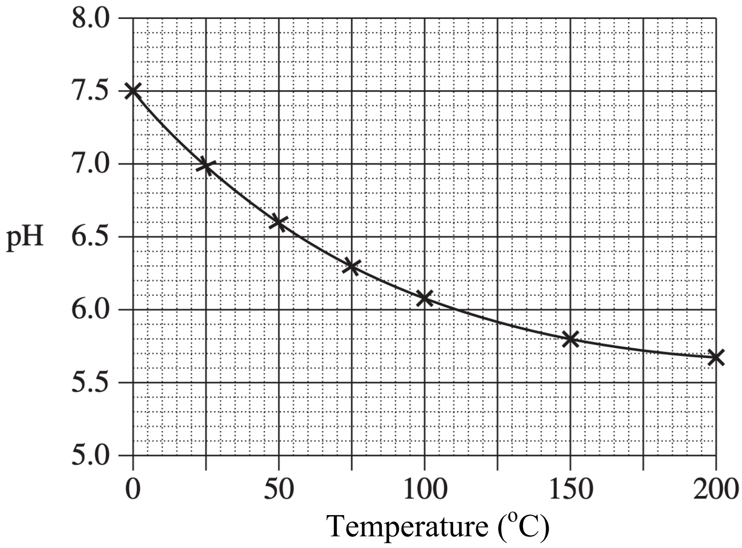
Calculate the mass of chloride ions in the original sample.

A. 0.00234 g
B. 0.0725 g
C. 0.1452 g
D. 0.2903 g

**5.** Arrhenius' theory of acids does not explain the acid-base behaviour of which reaction?

(A) $HNO_{3(aq)} + KOH_{(aq)} \rightarrow KNO_{3(aq)} + H_2O(l)$
(B) $CH_3COOH_{(aq)} \rightarrow CH_3COO^-_{(aq)} + H^+_{(aq)}$
(C) $2HCl_{(aq)} + CaCO_{3(s)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$
(D) $HF_{(aq)} + H_2O_{(l)} \rightarrow F^-_{(aq)} + H_3O^+_{(aq)}$

**6.** The graph shows the pH of a solution of a weak acid, HA, as a function of temperature.




What happens as the temperature increases?

A. HA becomes less ionised and the $H^+$ concentration increases.
B. HA becomes less ionised and the $H^+$ concentration decreases.
C. HA becomes more ionised and the $H^+$ concentration increases.
D. HA becomes more ionised and the $H^+$ concentration decreases.

**7.** Consider the system

$$HF(aq) + H_2O(l) \rightleftharpoons F^-(aq) + H_3O^+(aq).$$

Which of the following represents a conjugate acid–base pair present in this system?

A. $HF(aq)/F^-(aq)$
B. $HF(aq)/H_3O^+(aq)$
C. $HF(aq)/H_2O(l)$
D. $F^-(aq)/H_3O^+(aq)$

**8.** A titration is performed in which a 20.00 mL aliquot of 0.10 mol/L ethanoic acid solution is titrated with a 0.10 mol/L solution of sodium hydroxide. The pH of the solution in the conical flask is monitored and recorded throughout the titration. For this titration, the

A. equivalence point occurs when $n(CH_3COOH) = n(NaOH)$. The pH of the resulting solution is 7.
B. equivalence point occurs while $n(CH_3COOH)$ is less than $n(NaOH)$. The pH of the resulting solution is greater than 7.
C. equivalence point occurs while $n(CH_3COOH)$ is greater than $n(NaOH)$. The pH of the resulting solution is less than 7.

D. equivalence point occurs when $n(CH_3COOH) = n(NaOH)$. The pH of the resulting solution is greater than 7.

**9.** Rainwater has a pH of about 5, while seawater has a pH of about 8.

Which statement is correct concerning the *hydrogen ion concentrations* of rainwater and seawater?

A. The hydrogen ion concentration in rainwater is less by a factor of 5/8.
B. The hydrogen ion concentration in rainwater is less by a factor of 1000.
C. The hydrogen ion concentration in rainwater is greater by a factor of 3.
D. The hydrogen ion concentration in rainwater is greater by a factor of 1000.

**10**. Which of the following is an isomer of 1,4 dichloro-4-fluoro-2-butene?

A. 1–bromopropane
B. 1,2–dichloro-2-fluoropropane
C. 1,1–dichloro-3-fluoro-2-butane
D. 1,1 –dichloro-3-fluoro-2-butene

**11.** What type of reaction is represented by the conversion of hexan-3-ol to hexan-3-one?

A. addition
B. oxidation
C. elimination
D. substitution

**12.** In a first-hand investigation in a school laboratory, students were asked to distinguish between alkanes and alkenes, by reaction with bromine water.

The most suitable pair of chemicals to use in this experiment would be:

A. ethene and ethane.
B. cyclohexene and hex-1-ene.
C. cyclohexene and cyclohexane.
D. hex-1-ene and hex-2-ene.

**13.** The molar masses of 4 fuels are shown in the table below.

Each fuel is a liquid at room temperature.

| Fuel name | Molar mass ($gmol^{-1}$) |
|---|---|
| butane | 58.12 |
| 1-butanol | 74.12 |
| pentane | 72.146 |
| 1-pentanol | 88.146 |

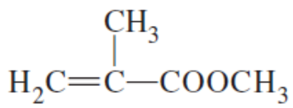
Fuel "X" is one of the fuels in the table above. It has a heat of combustion value of 3329 $kJmol^{-1}$.

Combustion of 0.44g of this fuel causes an increase in the temperature of 200.0g of water of 19.9$^{o}$C.

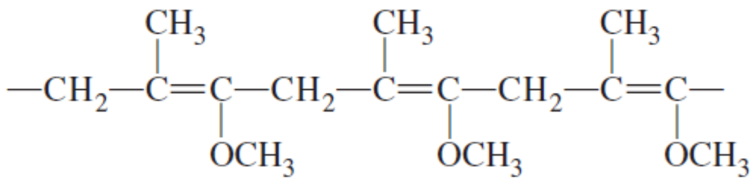
Assuming negligible heat loss to the environment outside of the water, which of the following identifies fuel "X"?

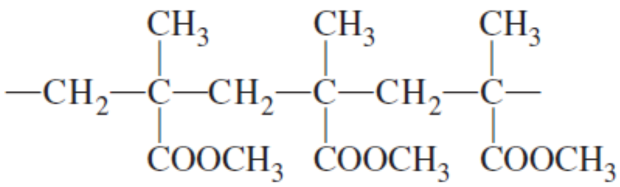
A. 1-butanol
B. butane
C. 1-pentanol
D. pentane

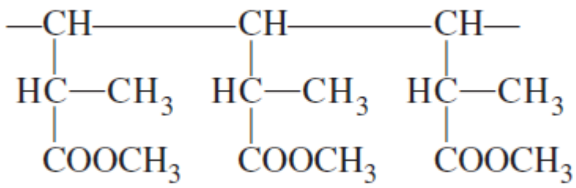
**14.** Which polymer is made by the polymerisation of methyl methacrylate?

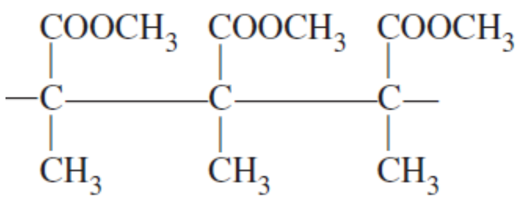


methyl methacrylate

A. 

B. 

C. 

D. 

**15.** Which of the following is the principle of atomic absorption spectroscopy?

A. Radiation is absorbed by non-excited atoms in vapour state and are excited to higher states of energy.
B. Medium absorbs radiation and transmitted radiation is measured.
C. Colour is measured.
D. Colour is simply observed.

**16.** An unknown solid was analysed by a number of tests, the results of which are described below.

- The solid did not react when $HNO_3(aq)$ was added to a sample.
- When $Ba(NO_3)_2(aq)$ was added to a solution of the solid, no observable change occurred.
- When $AgNO_3(aq)$ was added to a solution of the solid, a cream precipitate formed.
- The precipitate dissolved in excess nitric acid.
- When a small sample of the solid was placed into a Bunsen flame, a flash of red colour was observed.

Which one of the following chemicals would behave in a similar way when analysed with the same set of tests?

A. barium chloride
B. barium phosphate
C. calcium chloride
D. calcium phosphate

**17.** A lawn fertiliser lists the sulfate content as 38.5% (w/w).

What mass of barium sulfate precipitate would be expected to form if a 1.50 g sample of the fertiliser were analysed by reacting the sample with excess barium nitrate solution?

A. 0.238 g
B. 0.578 g
C. 1.40 g
D. 3.64 g

**18.** The increase in atmospheric carbon dioxide has been linked to the burning of fossil fuels.

The combustion of octane produces $1.554 \times 10^7$ kJ of energy per tonne of carbon dioxide produced.

Ethanol has been proposed as a more environmentally sound source of energy. The heat of combustion for ethanol is 1367 kJ $mol^{-1}$. The energy produced per tonne of carbon dioxide from the combustion of ethanol is

A. 8.311 kJ
B. $2.272 \times 10^4$ kJ
C. $1.553 \times 10^7$ kJ
D. $3.106 \times 10^7$ kJ

**19.** Select the statement that is TRUE about C-13 NMR Spectroscopy

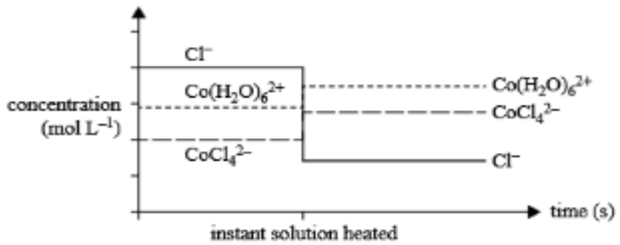
A. The standard used is dimethylpropane.
B. The chemical shift of the NMR peaks is affected strongly by electronegative atoms in functional groups.
C. The C-13 NMR spectrum of methane contains five peaks.
D. Carbon-carbon double bonds have chemical shifts between 5-40 ppm.

**20.** A solution contained an equilibrium mixture of two different cobalt (II) ions:

$$\underset{\text{pink}}{Co(H_2O)_6^{2+}\,(aq)} + 4Cl^-\,(aq) \rightleftharpoons \underset{\text{blue}}{CoCl_4^{2-}\,(aq)} + 6H_2O\,(l)$$

When the equilibrium system was heated, the colour changed from purple to blue. Which of the following graphs best represents this change?

A.

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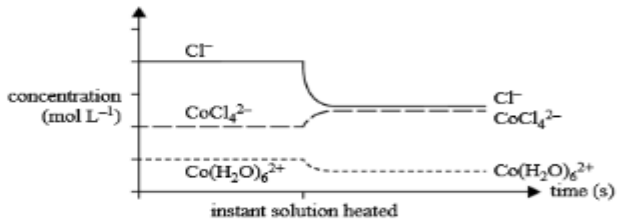


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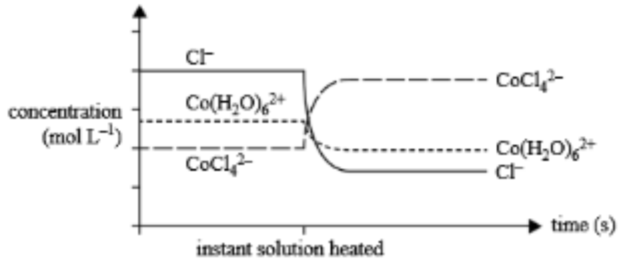


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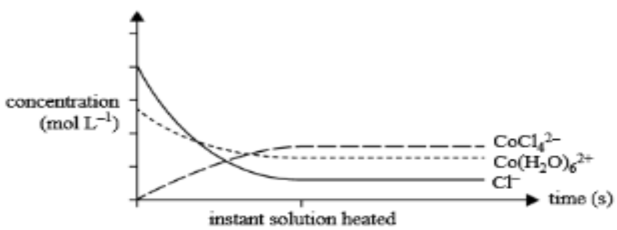

Student number

# Chemistry

## 2020 TRIAL EXAMINATION

**Section II**
**80 marks**

**Attempt Questions 21- 33**
**Allow about 2 hour and 25 minutes for this part**

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

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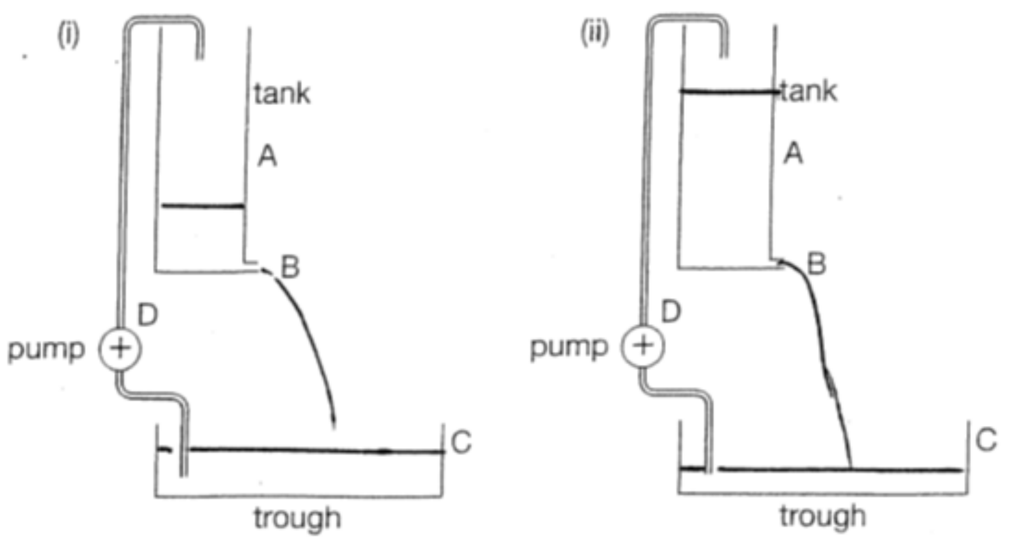
**Question 21** (6 marks)

Two students set up the experiment shown in (i) below. A tall tank A with an outlet B near the bottom was mounted above a long trough C; both tank and trough contained water. A small pump D was used to lift water from the trough into the tank. Water flowed back to the trough through outlet B. After a short time the water levels in the tank and trough became constant.




**Question 21 continues on page 13**

Question 21 (continued)

(a) How does this model relate to the essential features of a dynamic equilibrium reaction. **2**

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(b) The students then increased the speed of the pump. After a short time the system again settled down with constant water levels in tank and trough and with a greater flow rate from tank to trough as shown in (ii). **4**

By referring to the collision theory explain how this second experiment simulates the effect of temperature upon a chemical equilibrium.

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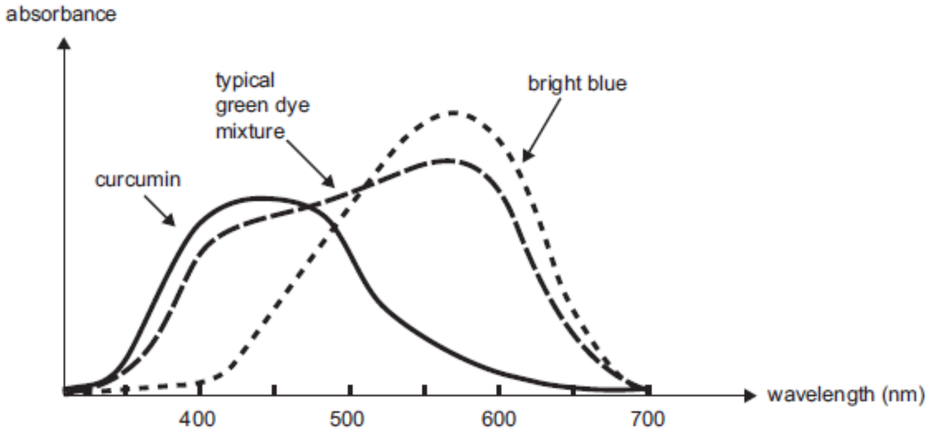
**Question 22** (6 marks)

A green dye used to colour tinned peas is made by mixing the yellow chemical, curcumin, with another colouring agent called bright blue. The individual spectra of curcumin, bright blue and a typical green dye are represented below.




UV-visible spectroscopy is used to analyse the curcumin content of tinned peas.

(a) Circle the wavelength below which would be best used for absorbance measurements to determine the curcumin content of the peas. **1**

400 nm 450 nm 500 nm 550 nm 600 nm 650 nm

(b) In one analysis, a stock solution of curcumin was prepared by dissolving 0.100 g of curcumin ($C_{21}H_{20}O_6$; molar mass = 368.0 g $mol^{-1}$) in 250.0 mL of water.
The stock solution was then diluted to make the following three standard solutions.

| standard solution | curcumin concentration in g $L^{-1}$ |
|---|---|
| standard 1 | $1.00 \times 10^{-3}$ |
| standard 2 | $5.00 \times 10^{-3}$ |
| standard 3 | $1.00 \times 10^{-2}$ |

(i) What volume of water must be added to 10.0 mL of the stock solution to make standard 3? Assume both solutions are of equal density. **2**

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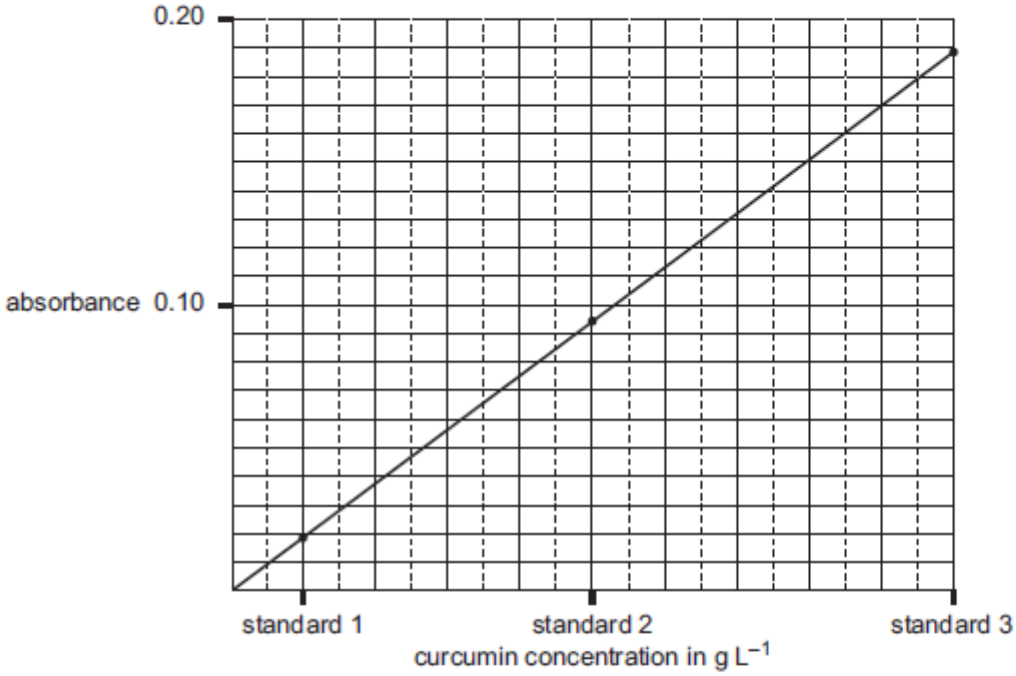
Question 22 (continued)

The absorbances of the standard solutions at the chosen wavelength were measured and the following calibration line was obtained.




(ii) The curcumin in a 9.780 g sample of peas was extracted into solution. The solution was filtered and made up to 100 mL in a volumetric flask. The absorbance of the solution at the wavelength used in the above calibration was found to be 0.170. **3**

Calculate the curcumin content of the peas in milligram per gram of peas.

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**Question 23** (11 marks)

When 20.0 mL of a solution of aqueous ammonia is titrated with 0.20 $molL^{-1}$ hydrochloric acid, 15.0 mL of the acid was needed to reach the equivalence point.

(a) What is the concentration of the aqueous ammonia? **2**

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(b) The $pK_a$ for the ammonium ion is 9.25. **5**

i. Calculate the pH of the solution at the start of the titration

ii. Calculate the pH of the solution at the equivalence point

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**Question 23 continues on page 17**

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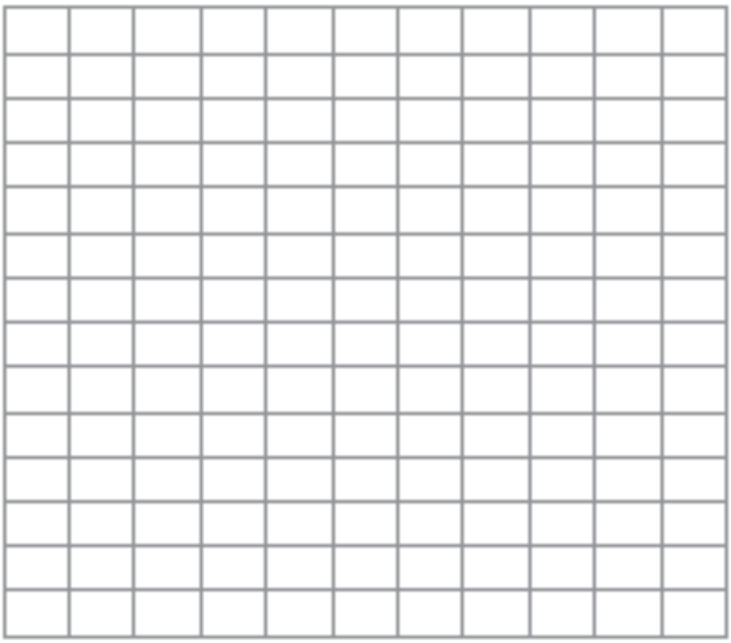
(c) Given these values, sketch the shape of the graph of pH against titre you would expect for this titration. **2**



(d) On the above grid, sketch the curve that you expect if the titration was carried out with aqueous sodium hydroxide of the same concentration as the ammonia. **2**

**Question 24** (4 marks)

A 50.0 mL solution of 2.00 x $10^{-4}$ mol/L sodium sulfate is added to a 200 mL solution of 2.00 x $10^{-4}$ mol/L lead (II) nitrate. Determine whether a precipitate of lead (II) sulfate will form. **4**

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**Question 25** (4 marks)

Explain the cleaning action of soaps and detergents. Include a labelled diagram. **4**

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**Section II continues in Booklet B**

**Question 26** (6 marks)

(a) Draw a flow chart for a procedure using chemical tests to distinguish and confirm between solutions of silver nitrate, lead nitrate and sodium carbonate. **4**

(b) Write ionic equations for 2 of the reactions in your flow chart. **2**

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**Question 27** (7 marks)

Hydrocarbons from the Earth are an important source of raw materials for many industrial processes. Analyse the impact of obtaining this resource on the environment and society. **7**

**Question 28** (3 marks)

Boric acid ($H_3BO_3$) is a weak acid. Its conjugate base, the borate ion, exists in water as $B(OH)_4^-$. A solution of pure sodium borate, $NaB(OH)_4$, is prepared in water at 25°C. The borate ion dissociates according to the equation

$$B(OH)_4^-(aq) \rightleftharpoons OH^-(aq) + H_3BO_3(aq)$$

At equilibrium in a particular solution of $NaB(OH)_4$, the concentration of $B(OH)_4^-$ is exactly 0.100 M and the pH is 11.11

(a) Calculate the hydrogen ion and hydroxide ion concentrations in the solution. **2**

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(b) Hence give the $H_3BO_3$ concentration in the solution. **1**

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**Question 29** (8 marks)

A small organic molecule has the molecular formula of the form $C_xH_yO_2Cl$.

The mass spectrum, infrared spectrum, $^1H$ NMR spectrum and $^{13}C$ NMR spectrum of this compound are provided on pages 26 and 27.

(a) On the infrared spectrum, label the peaks that correspond to the presence of two functional groups in this compound. **2**
Note: The peak due to the C-Cl stretch has been labelled.

(b) Use the data provided to determine the values of x and y in $C_xH_yO_2Cl$. **2**

x = y =

(c) i What specific information about the structure of the compound is provided by the splitting pattern in the $^1H$ NMR spectrum? **1**

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ii Draw the complete molecular structure for this molecule. **1**

(d) Give a reason why the mass spectrum shows two molecular ion peaks at m/z = 108 and 110, rather than just one. **1**

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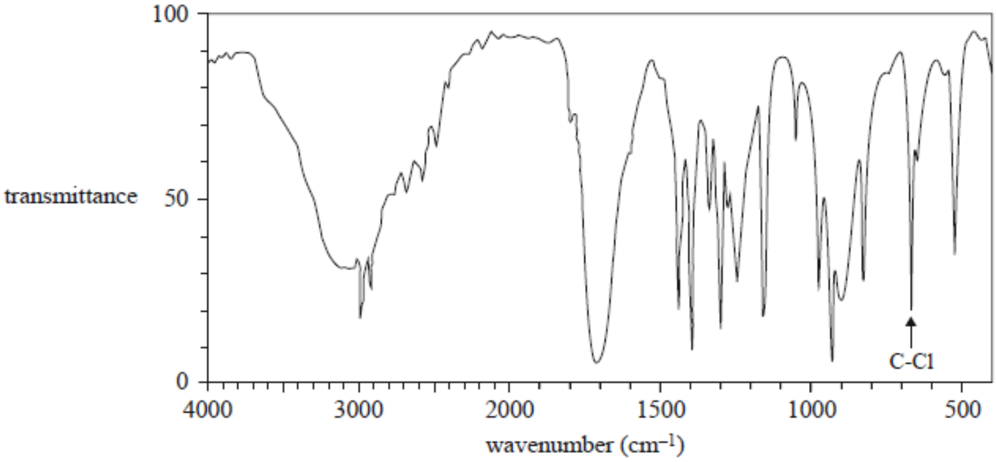
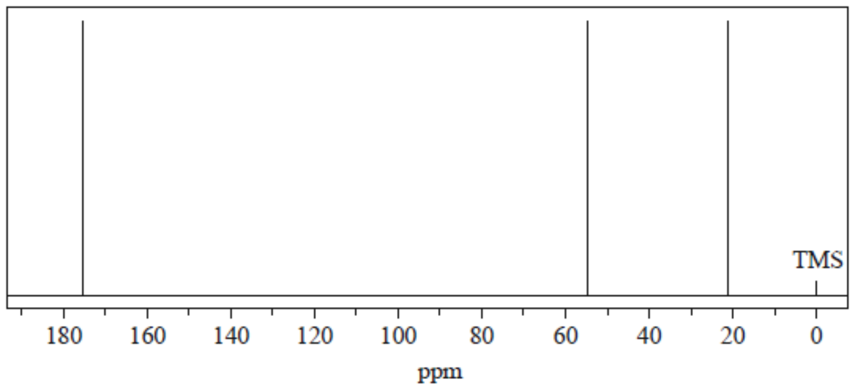
Question 29 (continued)

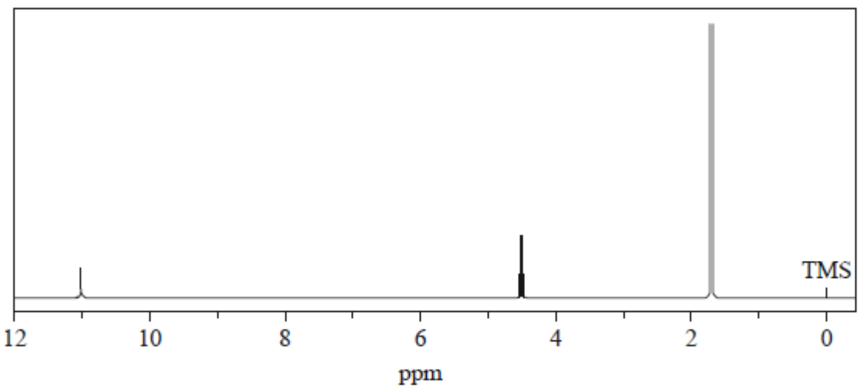
**IR spectrum**




**$^{13}$C NMR spectrum**



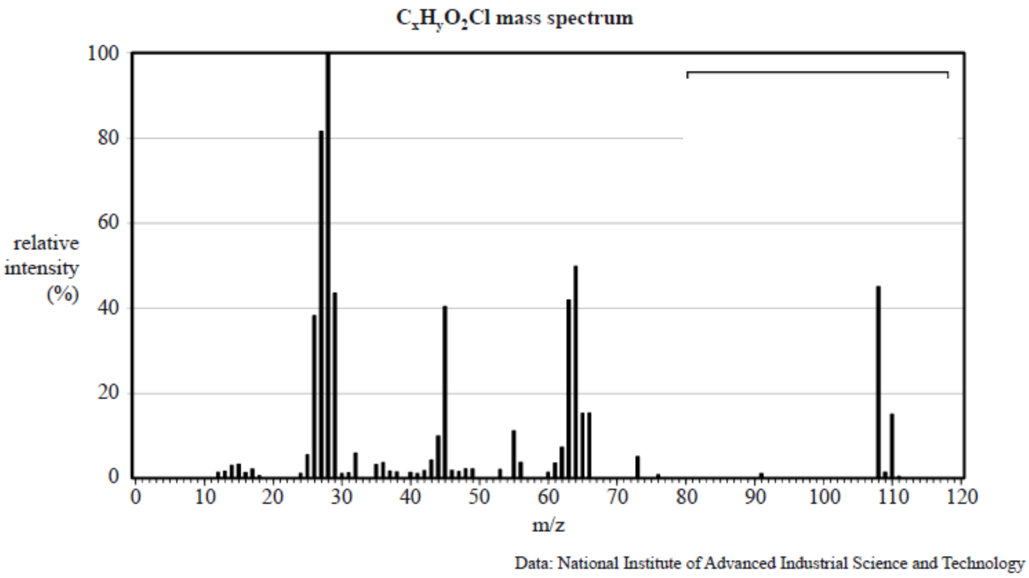

**$^{1}$H NMR spectrum**




**$^{1}$H NMR data**

| Chemical shift (ppm) | Peak splitting | Relative peak area |
|---|---|---|
| 1.7 | doublet (2 peaks) | 3 |
| 4.5 | quartet (4 peaks) | 1 |
| 11.2 | singlet (1 peak) | 1 |

All Spectral Data: National Institute of Advanced Industrial Science and Technology




(e) Identify the fragment that produces the base peak. **1**

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**Question 30** (4 marks)

Photosynthesis is an example of a non-equilibrium system.

(a) Write the balanced chemical equation for photosynthesis **1**

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(b) The following values occur for the photosynthesis reaction at 25°C

$\Delta H^o = +2803$ kJmol$^{-1}$
$\Delta S^o = -212$ Jmol$^{-1}$K$^{-1}$

**3**

Calculate the Gibbs free energy for photosynthesis at 25°C and explain the spontaneous or non-spontaneous nature of the reaction.

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**Question 31** (6 marks)

A class was set the task of conducting a chemical analysis of a common household substance for its acidity or basicity. **6**

Describe TWO different methods of how this analysis could be conducted. In your answer, include any advantages and disadvantages of the methods.

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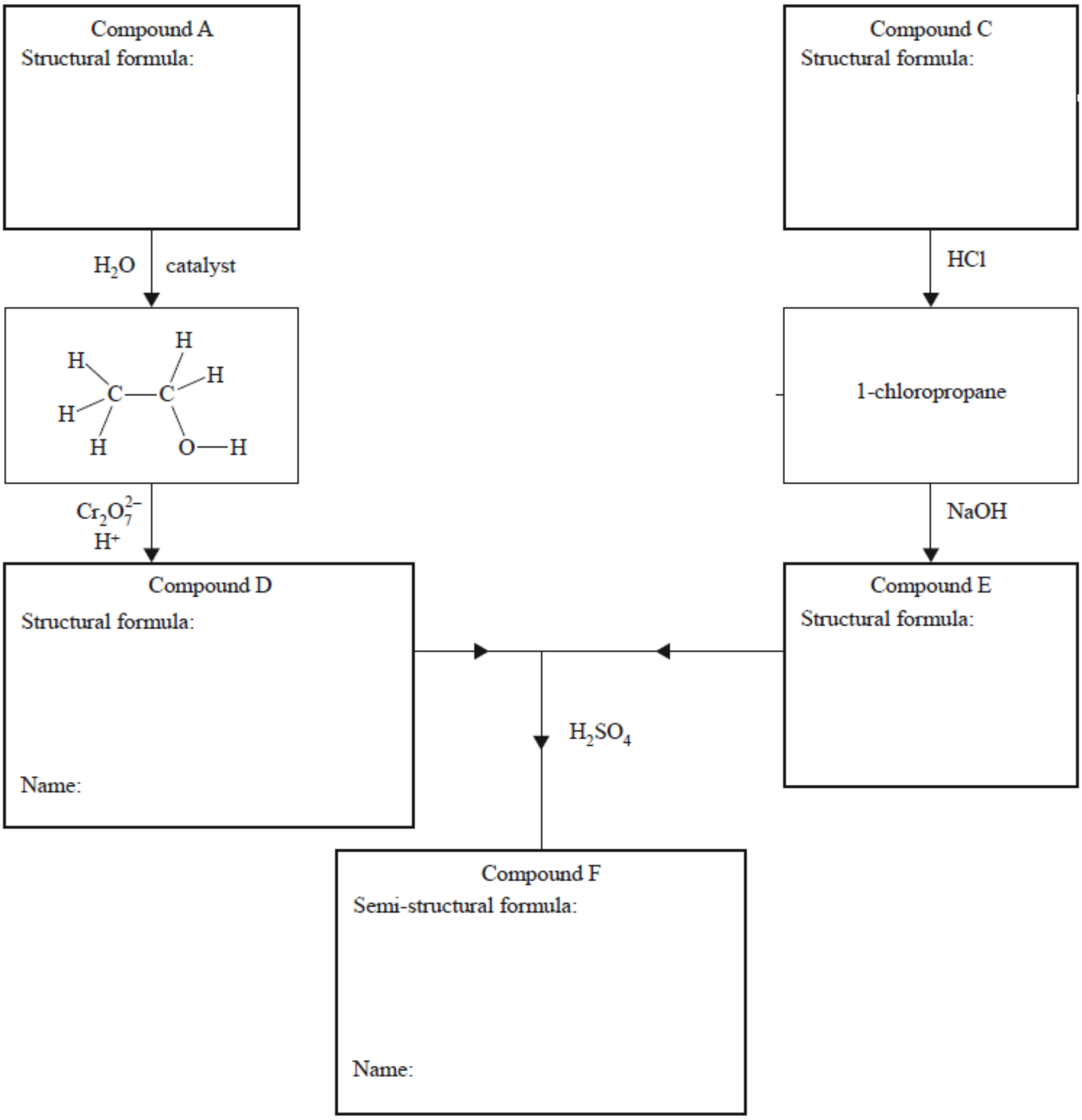
**Question 32** (9 marks)

The pathway below illustrates the processes involved in the synthesis of Compound F.




(a) Draw the structural formulas of Compounds A, C, D and E in the boxes provided. **4**

(b) Write the systematic name of Compound D in the appropriate box. **1**

(c) Insert the semi-structural formula and systematic name of Compound F in the box provided. **2**

(d) To synthesise Compound F in the laboratory heating under reflux is required. Justify the use of reflux. **2**

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**Question 33** (6 marks)

A student was supplied with the following chemicals to investigate the equilibrium between pink cobalt ions ($Co^{2+}$) and blue cobalt chloride ions ($CoCl_4^{2-}$) in an aqueous solution.

- 0.5 mol/$L^{-1}$ cobalt chloride solution ($CoCl_2$)
- Concentrated hydrochloric acid
- Distilled water

The coloured complexes exist together in equilibrium in solution in the presence of chloride ions:

$$\underset{\textit{pink}}{[Co(H_2O)_6]^{2+}}(aq) + 4Cl^-(aq) \rightleftharpoons \underset{\textit{blue}}{[CoCl_4]^{2-}}(aq) + 6H_2O(l)$$

Outline three experiments the student could perform, using all of the above solutions, to investigate the equilibrium between the hydrated and dehydrated cobalt complexes. Predict and explain the results of these experiments. **6**

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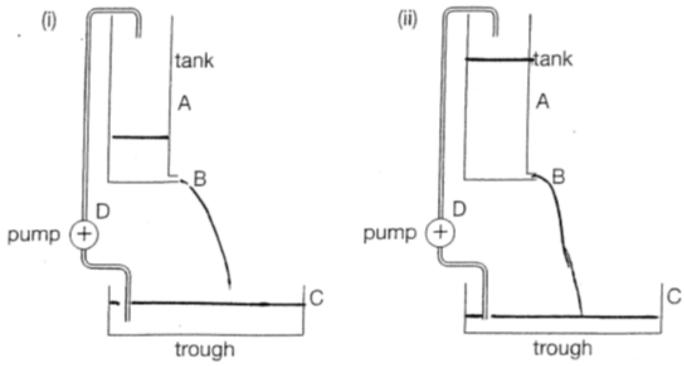
**End of Section II**

# SBHS Chemistry Trial 2020 – Marking Criteria

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

**Question 21**

Two students set up the experiment shown in (i) below. A tall tank A with an outlet B near the bottom was mounted above a long trough C; both tank and trough contained water. A small pump D was used to lift water from the trough into the tank. Water flowed back to the trough through outlet B. After a short time the water levels in the tank and trough became constant.\




**Question 21 (a)**
***Sample answer***
The pump pushing water from trough to tank represents the forward reaction and the flow of water from tank to trough the reverse reaction (or vice versa). The constant water levels in tank and trough represent constant equilibrium concentrations of products and reactants.

**Question 21(b)**

***Sample answer***
Temperature increases the rates of reactions. Increasing pump speed simulates increasing the rate of the forward reaction. As the temperature increases, the average kinetic energy of all particles increases. As the forward reaction is endothermic, its rate initially increases more than the rate of the reverse reaction. As the reactants react, there is will be an increase in the concentration of products (an increased height of water in the tank), and the concentration of the reactants decreases, the rate of forward reaction decreases. As the concentration of the products increases, the rate of the reverse reaction increases (flow of water out of the tank). Ultimately the rates of the forward and reverse reactions become equal and then the concentrations of products and reactants will again be constant (height of water in tank and trough again constant) and a new equilibrium is established.

## Question 22

A green dye used to colour tinned peas is made by mixing the yellow chemical, curcumin, with another colouring agent called bright blue. The individual spectra of curcumin, bright blue and a typical green dye are represented below.

UV-visible spectroscopy is used to analyse the curcumin content of tinned peas.

### Question 22 (a) (2 marks)

***Sample Answer***

400 nm

**Notes**

The absorbance used for the analysis of the curcumin content should be one at which curcumin absorbs strongly but the other colouring agent present, bright blue, does not. Curcumin absorbs most strongly between 400 nm and 500 nm. Of the wavelengths suggested within this span, bright blue would absorb least, and have less impact, at 400 nm.

### Question 22(b)(i) (2 marks)

***Sample Answer***

$$m(\text{curcumin}) \text{ in standard 3} = m(\text{curcumin}) \text{ in 10 mL stock solution}$$

$$= \left(\frac{0.400}{1000}\right) \times 10 \text{ or } \left(\frac{0.100}{250}\right) \times 10$$

$$= 4.00 \times 10^{-3} \text{ g}$$

$$c(\text{curcumin}) \text{ in standard 3} = 1.00 \times 10^{-2} \text{ g L}^{-1}$$

$$V(\text{stock solution}) = \frac{m(\text{curcumin})}{c(\text{curcumin})}$$

$$= \frac{4.00 \times 10^{-3} \text{ g}}{1.00 \times 10^{-2} \text{ g L}^{-1}}$$

$$= 0.400 \text{ L}$$

$$= 400 \text{ mL *}$$

$$V(\text{water}) = 400 - 10$$

$$= 390 \text{ mL *}$$

Alternatively; using $c_2V_2 = c_1V_1$:

$$c(\text{curcumin}) \text{ in standard 3} = \frac{1.00 \times 10^{-2} \text{ g L}^{-1}}{368 \text{ g mol}^{-1}}$$

$$= 2.72 \times 10^{-5} \text{ mol L}^{-1}$$

$$n(\text{curcumin}) \text{ in 'y' L of standard 3} = n(\text{curcumin}) \text{ in 10.0 mL of stock}$$

$$2.72 \times 10^{-5} \times \text{'y'} = 1.09 \times 10^{-3} \times 10.0 \times 10^{-3}$$

$$\text{'y'} = \left(\frac{1.09 \times 10^{-3} \times 10.0 \times 10^{-3}}{2.72 \times 10^{-5}}\right)$$

$$= 0.401 \text{ L}$$

$$= 401 \text{ mL *}$$

$$V(\text{water}) = 391 \text{ mL *}$$

**Question 22(b)(ii) (3 marks)**

***Sample Answer:***

From the graph, an absorbance of 0.170 corresponds to $c$(curcumin) = $9.00 \times 10^{-3}$ g $L^{-1}$ *
Since the curcumin from the peas was extracted into 100 mL of solution,
$m$(curcumin) in peas sample = 0.100 L * × $9.00 \times 10^{-3}$ g $L^{-1}$
= $9.00 \times 10^{-4}$ g
= (0.900 mg)

$$\text{curcumin content} = \frac{m(\text{curcumin})\ \text{in mg}}{m(\text{peas})\ \text{in g}}$$

$$= \frac{0.900}{9.780}$$

= 0.0920 * mg/g

Alternatively:
9.780 g peas in 100 mL is equivalent to 97.80 g peas in 1 L
$m$(curcumin) in 1 L = $9.00 \times 10^{-3}$ g → 9.00 mg

$$\text{curcumin content} = \frac{9.00}{97.80} \; *$$

= 0.0920 * mg/g

**Question 23** (11 marks)

**Sample answer:**

$NH_3 + HCl \rightarrow NH_4Cl$
n(HCl) = 0.20 x 0.015 = 0.003mol
$n(NH_3)$ = n(HCl)
= 0.003mol
$c(NH_3)$ = n/v
= 0.003/0.02
= 0.15M

**Question 23(b)**

**Sample answer**

pH at the start:

$pK_a = -\log K_a$

$K_a = 10^{-9.25}$

$= 5.623 \times 10^{-10}$

$K_a \times K_b = K_w$

$K_b = \frac{1.0 \times 10^{-14}}{5.623 \times 10^{-10}}$

$= 1.778 \times 10^{-5}.$

$K_b = \frac{[OH^-][NH_4^+]}{[NH_3]} = \frac{(x)(x)}{0.15 - x} = 1.778 \times 10^{-5}$

assume $x$ is v. small.

$Kb = \frac{x^2}{0.15} = 1.778 \times 10^{-5}$

$x^2 = 1.778 \times 10^{-5} \times 0.15$

$x = \sqrt{1.778 \times 10^{-5} \times 0.15}$

$= 1.633 \times 10^{-3}.$

$\therefore [OH^-] = 0.001633$

$pOH^- = -\log_{10} 0.001633$

$= 2.79.$

$\therefore pH = 14 - pOH$

$= 14 - 2.79$

$= 11.21.$

pH at Equivalence Point:

$[NH_4^+] = \frac{0.003}{0.035}$

$= 0.857$ Mol/L

$K_a = \frac{[H_3O^+][NH_3]}{[NH_4^+]} = 5.623 \times 10^{-10}$

$[H_3O^+] = \sqrt{5.623 \times 10^{-10} \times 0.857}$

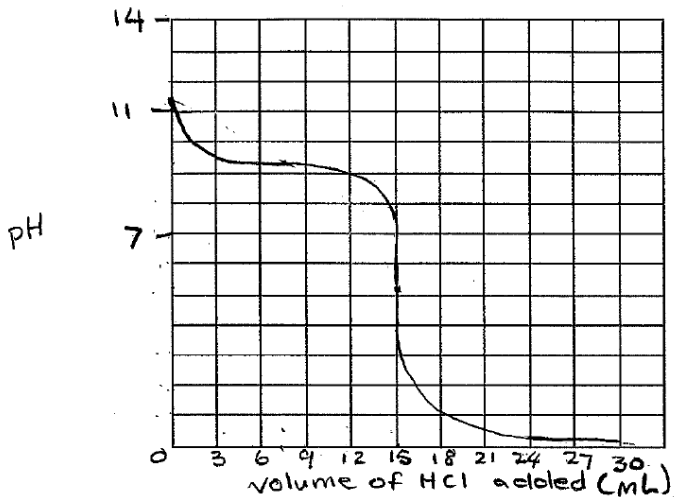
$= 6.942 \times 10^{-6}$

$\therefore pH = -\log_{10} 6.942 \times 10^{-6}.$

$= 6.16.$

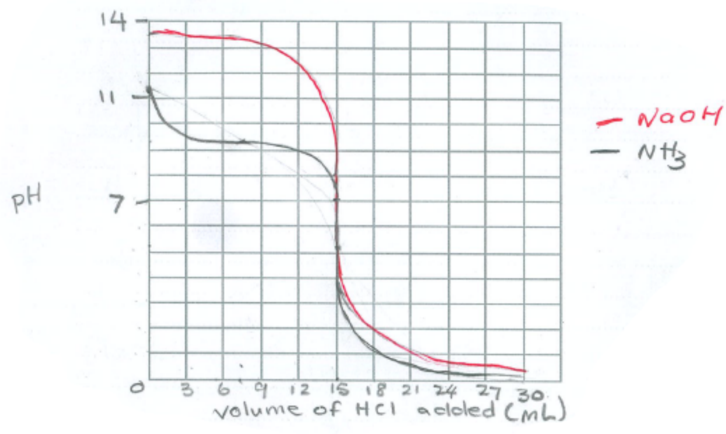
**Question 23(c)**

**Sample Answer:**




**Question 23(d)**

***Sample Answer:***




***Markers Note:***

**Question 24 (4 marks)**

***Sample answer***

$Na_2SO_4(aq) + Pb(NO_3)_2(aq) \rightleftharpoons PbSO_4(s) + 2NaNO_3(aq)$

$Ksp$ $PbSO_4 = [Pb^{2+}]\,[SO_4^{2-}]$

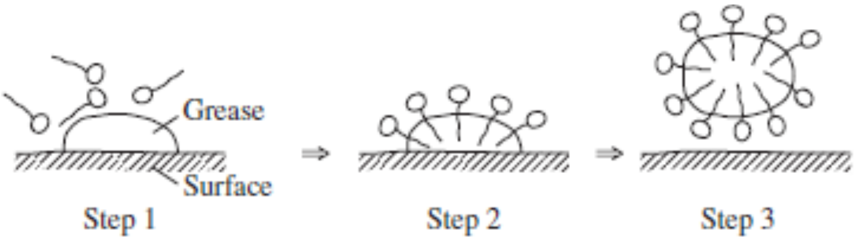
no. of moles $Na_2SO_4 = 2.00 \times 10^{-4} \times (50.0/1000) = 1.00 \times 10^{-5}$ mol
no. of moles $Pb(NO_3)_2 = 2.00 \times 10^{-4} \times (200/1000) = 4.00 \times 10^{-5}$ mol
Total volume of solution = 250 mL
$[SO_4^{2-}] = 1.00 \times 10^{-5} / 0.250 = 4.00 \times 10^{-5}$ mol/L
$[Pb^{2+}] = 4.00 \times 10^{-5} / 0.250 = 1.60 \times 10^{-4}$ mol/L

The product of the concentration of the ions is
$[Pb^{2+}]\,[SO_4^{2-}] = 1.60 \times 10^{-4} \times 4.00 \times 10^{-5} = 6.40 \times 10^{-9}$
Since this product is less than $K_{sp}$ ($2.0 \times 10^{-8}$), a precipitate will not form.

**Question 25 (4 marks)**

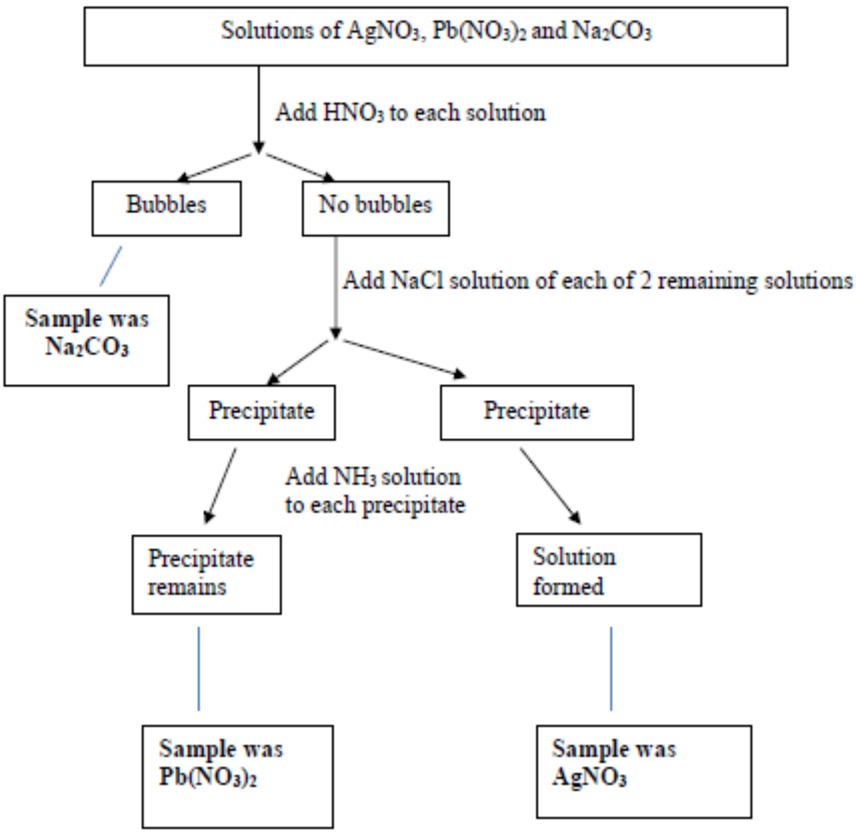
**Sample Answer**

Soap has a hydrophilic, negatively charged polar head and a long, hydrophobic non-polar tail. When a mixture of soap and water is added the non-polar tails of the soap will dissolve in the non-polar grease, fats, oils or dirt. The polar head groups stick out of the grease droplet and forms hydrogen bonds with water and repels grease. When enough soap has surrounded the grease, the particle is lifted off the surface and a micelle is formed keeping the grease molecules suspended (dispersed) throughout the water. The negatively charged heads of the soap prevent individual grease droplets recombining, effectively forming an emulsion of grease in water, allowing the grease to be removed from the surface and washed away.




**Question 26a (4 marks)**

*Sample answer*



## Question 26b (2 marks)

***Sample answer***

$CO_3^{2-}$ *(aq)* + $2H^+$ *(aq)* → $CO_2$ *(g)* + $H_2O$ *(l)*
$Ag^+$ *(aq)* + $Cl^-$ *(aq)* → AgCl *(s)*
AgCl *(s)* + $2NH_3$ *(aq)* → $[Ag(NH_3)_2]^+$ *(aq)* + $Cl^-$ *(aq)*
Diamine silver ion
$Pb^{2+}$ *(aq)* + $2Cl^-$ *(aq)* → $PbCl_2$ *(s)*

## Question 27 (7 marks)

## Sample Answer

Hydrocarbons obtained from fossil fuels are currently used as both fuels and as feedstocks for the production of polymers. For example, the fractional distillation of crude oil provides octane, which is used as motor vehicle fuel, releasing energy when it is combusted:
$C_8H_{18}(l) + O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$ + energy. The supply of octane is increased by cracking longer chain hydrocarbons, and this reaction also produces ethene, for example:
$C_{10}H_{22}(l) \rightarrow C_8H_{10}(l) + C_2H_4(g)$. The ethene produced in these cracking reactions is used to produce one of the most abundant polymers, polyethylene: $nC_2H_4(g) \rightarrow -(CH_2\text{-}CH_2)_n-$ . The use of hydrocarbons as fuels and in the production of polymers has serious environmental consequences but has also benefitted society in a number of ways.

Hydrocarbons as a fuel source have been extremely beneficial to modern society. Octane is combusted in engines which has allowed the use of motor vehicles for recreation and transport. This has improved our quality of life through being able to travel long distances quickly and allowing for consumable products to be moved around the country and overseas in a timely manner.

Burning hydrocarbons to produce energy also releases carbon dioxide into the atmosphere. There is global scientific consensus that the rising $CO_2$ concentration is causing large scale and very serious climatic change. Sea levels are rising, polar ice caps are melting, ocean currents are changing, the frequency and severity of droughts, bushfires, floods and hurricanes are increasing. These extreme weather events destroy habitat, cause water and air pollution – all devastating environmental impacts. Whole island nation states, for example the Marshall Islands in the Pacific Ocean are at risk of disappearing, which will bring large repatriation costs and serious negative impacts on these island societies. Extreme weather events also bring large clean-up and repair costs.

Polymers, such as polyethylene and PVC, produced from fossil fuels are inexpensive and abundant, but they are not biodegradable, and in global terms are not widely recycled. Societies all over the world have benefitted from affordable materials for plumbing, food preservation and safety equipment, but the environmental costs of using plastics outweighs these benefits. Non-biodegradable plastics have increased the need for landfill and they have resulted in large amounts of land and sea pollution, which has directly led to the large-scale death of large numbers of marine animals and birds which mistake them for food or become entangled in them.

Although the obtaining of hydrocarbons has produced many raw materials and subsequent useful products for society, the damage being done on the environment due our increasing use of them is a major concern.

**Question 28**

**Question 28a (2 marks)**

**Sample Answer**

$[H^+] = 10^{-11.11} = 7.76 \times 10^{-12}$ mol/L;

$[OH^-] = 10^{-14}/7.76 \times 10^{-12} = 1.29 \times 10^{-3}$ mol/L.

**Question 28b (1 mark)**
**Sample Answer**

$[H_3BO_3] = [OH^-] = 1.29 \times 10^{-3}$ mol/L.

**Question 29**

**Question 29a (2 marks)**

On the infrared spectrum, label the peaks that correspond to the presence of two functional groups in this compound.

**Note: Ensure arrow pointing to broad peak rather than sharp peak which is C-H.**

**Question 29b (2 marks)**

Use the data provided to determine the values of x and y in $C_xH_yO_2Cl$.

**Sample Answer**

$x = 3$, $y = 5$

The $^{13}C$ NMR spectrum showed three different carbon environments, the $^{1}H$ NMR spectrum showed three different hydrogen environments, and the molecule has a carboxyl –COOH functional group, and a chloro –Cl functional group. There is no evidence of a C=C on the IR spectrum. Also the mass spectrum suggests parent molecular ions at m/z = 108 and 110. All of this leads to the molecular formula $C_3H_5O_2Cl$.

Alternatively, subtracting the relative masses of COOH (45) and 35Cl (35) from m/z = 108 leaves a relative mass of 28, suggesting 2 'C' and 4 'H' atoms consistent with the molecular formula $C_3H_5O_2Cl$.

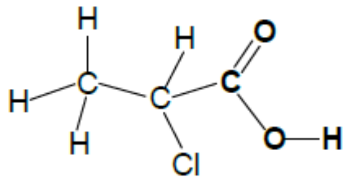
**Question 29ci and ii (2 marks)**

**Sample Answer**

**ci.**
Acceptable responses included (one of):

- there are three hydrogen environments on the molecule – one with three neighbouring H, one with one neighbouring H and one with no neighbouring H atoms
- two of the three hydrogen environments are $CH_3$ and CH (the third is COOH)
- the number of lines in the split signals is one more than the number of H atoms on the adjacent or neighbouring C atoms.

**cii.**
The correct structure was:




**Question 29d (1 marks)**

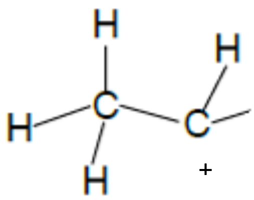
**Sample Answers:**

The presence of the two chlorine isotopes, $^{35}Cl$ and $^{37}Cl$
The two peaks are due to $[CH_3CH^{35}ClCOOH]^+$ and $[CH_3CH^{37}ClCOOH]^+$
The two chlorine isotopes have a mass difference of 2.

**Question 29e (1 marks)**

**Sample Answers:**

MW 28 = $[C_2H_4]^+$




## Question 30

**Question 30a (1 marks)**

Write the balanced chemical equation for photosynthesis

**Sample Answer**

$CO_2(g) + H_2O(l) \rightarrow C_6H_{12}O_6(aq) + O_2(g)$

**Question 30b (4 marks)**

### Sample Answer

$\Delta H° = +2803 kJmol^{-1}$
$\Delta S° = -212 J\ mol^{-1}K^{-1}$
$\Delta G° = \Delta H° - T\Delta S°$
$= +2803 - (298 \times -0.212)$
$= +2803 + 63.18$
$= +2866\ kJmol^{-1}$

Since ΔG is positive, this is a non-spontaneous system. It will only occur when a significant amount of energy is supplied or a catalyst is used with a lesser amount of energy being supplied. Photosynthesis occurs in green plants because they chlorophyll, a necessary catalyst for this reaction to occur. Photosynthesis also only occurs during the day when the UV light from the sun is readily available.

**Question 31 (6 marks)**
**The sample must be in aqueous solution. If supplied as a solid, it must be mixed with distilled/deionised water.**

One method is to use indicators. Indicators are chemicals that change colour over a specific pH range to help identify if a substance is acidic, neutral or basic.

For example, Litmus paper.

Place a small amount (about 5mL) of the substance (solution) in a clean test tube and place a small piece of red and blue litmus paper. Observe and record colour change. If the blue litmus changes pink, then the substance in acidic, and if the pink changes to blue, the substance is basic. If no colour change is observed then the substance is neutral.

The advantage of using indicators is that they are relatively cheap **and** easy to use. A disadvantage is that one must use an indicator with a colour change that matches the actual pH of the substance. If the substance being tested is itself coloured, this can obscure the result. The strength of the acid or base cannot be determined with LITMUS

The second method is to use electronic means such as pH metres, a pH probe or data loggers.

Firstly the probe must be calibrated using the buffer solutions provided to the specified pH values given.
Place a small amount (about 20mL) of the substance (solution) in a clean small beaker.
Then place the pH probe into the sample and record the pH value displayed. If the pH value is = 7, then the substance is neutral, if pH > 7, then the substance is basic and if pH < 7, the substance is acidic.

The advantage of using pH probe is that it is much more accurate and works over a larger pH range. A disadvantage is that they are more costly and more complex to operate. They have to be calibrated (set to an accurate value) using buffer solutions of known pH.

**Question 32**

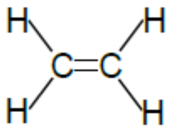
**Question 32a (4 marks)**

Draw the structural formulas of Compounds A, C, D and E in the boxes provided.

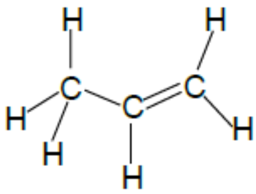
| Criteria | Marks |
|---|---|
| • 1 mark for each correct structural formulas | **4** |

**Sample Answer**

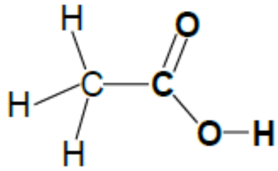
**Compound A**



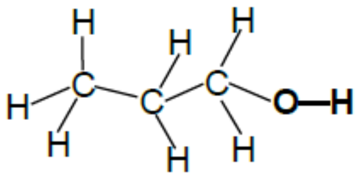
**Compound C**



**Compound D**



**Compound E**



***Markers Note:***

**Question 32b (1 marks)**

**Sample Answers**

Compound D: ethanoic acid

**Question 32c (2 marks)**

**Sample Answers**

Semi-structural formula: $CH_3COOCH_2CH_2CH_3$, $CH_3COO(CH_2)_2CH_3$ or $CH_3CH_2CH_2O.COCH_3$
Name: propylethanoate or 1-propylethanoate

**Question 32d (2 marks)**

**Sample Answers**

Heating under reflux increases the reaction rate (higher temperature) while preventing loss of reactants or products by vaporisation to outside.

**Question 33 (6 marks)**

Outline three experiments the student could perform, using all of the above solutions, to investigate the equilibrium between the hydrated and dehydrated cobalt complexes. Predict and explain the results of these experiments.

**Sample Answers**

Place approximately 5mL of the equilibrium mixture in 3 large test tubes. Label each test tube 1, 2, 3, and add :

1 – approximately 3mL of $CoCl_2$ solution.

2 – a few drops of concentrated HCl solution

3 - 5 mL of distilled water

The changes in colour indicate the direction which the system will shift and the explanations provided below are based on Le Chateliers Principle (LCP)

The addition of more cobalt(II) chloride to the purple cobalt(II) chloride solution will turn it blue. Adding a reactant ($Co^{2+}$ and $Cl^{-}$) according to LCP causes the reaction to move in the direction of the products to reduce the concentration of $Co^{2+}$ and $Cl^{-}$ ions and hence turns the solution blue as [$CoCl_4^{2-}$] increases.

If hydrochloric acid is added to the solution it will turn blue. This is due to the HCl raising the chloride ion ($Cl^{-}$) concentration on the left of the equation, so according to LCP the net forward reaction occurs and equilibrium moves to the right to reduce the concentration of $Cl^{-}$ ions. So more $[CoCl_4]^{2-}$(aq) forms and the colour of the solution will change to blue.

By adding water to the blue cobalt(II) chloride solution it increases the volume of the solution and this causes the concentration of all aqueous ions to reduce, so according to LCP the reaction will shift in the direction to increase the concentration of the aqueous ions, the net reverse reaction occurs and equilibrium moves to the left. More $[Co(H_2O)_6]^{2+}$(aq) is formed and the solution will change to pink in colour.