Exam Choice

Student Number

2021 | TRIAL EXAMINATION

Chemistry

General Instructions
- Reading time – 5 minutes.
- Working time – 3 hours.
- Write using black pen.
- Draw diagrams using pencil.
- For questions in Section II, show all relevant working in questions involving calculations.
- NESA approved calculators may be used.

Total marks: 100

Section I – 20 marks (pages 3 – 13)

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

Section II – 80 marks (pages 14 – 31)

- Attempt questions 21 – 33
- Allow about 2 hours and 25 minutes for this section.

Section I – 20 marks

Attempt Questions 1-20

Allow about 35 minutes for this section

Use the multiple-choice answer sheet.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: $2 + 4 =$ (A) 2   (B) 6   (C) 8   (D) 9

A ◯   B ⬤   C ◯   D ◯

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ⬤   B ⨂   C ◯   D ◯

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.

A ⬤   B ⨂   C ◯   D ◯

correct

1. Which one of the following would be classed as a weak, diprotic acid?

    (A) $H_2SO_4(aq)$

    (B) $H_2CO_3(aq)$

    (C) $HCOOH(aq)$

    (D) $CH_2(OH)CH_2OH(aq)$

2. A student is told that an unlabelled solution may contain one or more nitrate salts of Mg^{2+}, Pb^{2+} and/or Ba^{2+}.

    They are required to determine which cation/s are present in the solution and are provided with several solid ionic compounds for this analysis.
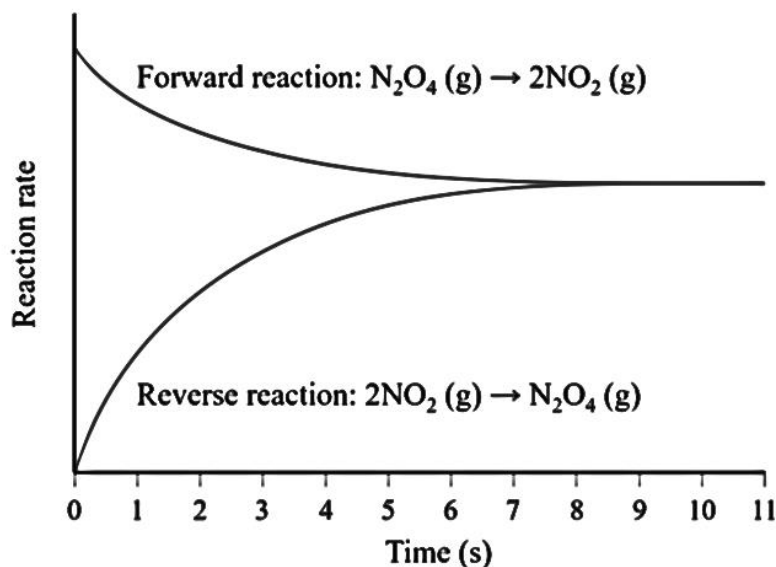
    Which compound below, when added to water, would form an effective reagent for the first step in this analysis?

    (A)   silver chloride

    (B)   potassium chloride

    (C)   lithium sulfate

    (D)   copper(II) sulfate

3. Which of the following organic compounds would you expect to have the highest K_b?

    (A) H_3C———CH_2——OH

    (B) HO——CH_2——CH_2——OH

    (C) H_3C———NH_2

    (D) H_3C———$\overset{\overset{\displaystyle O}{\|}}{C}$———$NH_2$
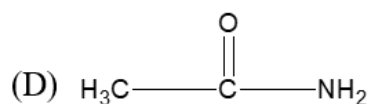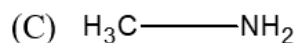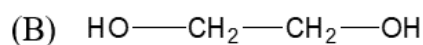
4. The graph below shows how the rates of the forward and reverse reactions, as shown by the balanced equations on the graph, change over time.

Forward reaction: N_2O_4 (g) → $2NO_2$ (g)

Reverse reaction: $2NO_2$ (g) → N_2O_4 (g)

(Reaction rate vs Time (s), axis 0 1 2 3 4 5 6 7 8 9 10 11)

Which of the following statements, from the data shown, is correct?

(A)   At equilibrium, the reverse reaction proceeds at its maximum rate.

(B)   After 10 s, the concentration of $NO_2(g)$ would be double that of $N_2O_4(g)$.

(C)   The pressure in the reaction vessel would decrease over the first 10 seconds.

(D)   After 10 s, any chemical reactions between the gases in the vessel have ceased.

5. '*Kevlar*' is a type of polymer used to manufacture bullet-proof material due its very high tensile strength.

The monomers which react to form '*Kevlar*' are shown below.
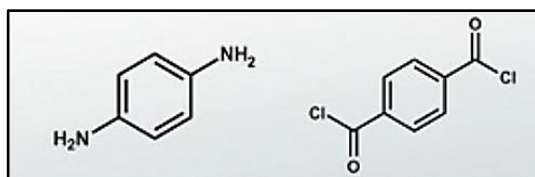
Which of the following best accounts for the particularly high tensile strength of '*Kevlar*'?

(A)   The ability of hydrogen bonds to form between the monomers.

(B)   The ability of the polymer strands to form cross-linking covalent bonds.

(C)   The strength of many of the bonds, such as C=O, within the polymer chain.

(D)   The strength of the intermolecular forces formed between the polymer strands.

6. The tetrachlorocopper(II) anion forms a green solution and reacts with water to form the blue hexaaquacopper(II) cation according to the following equation:

$$CuCl_4^{2-}(aq) + 6H_2O(l) \rightleftharpoons Cu(H_2O)_6^{2+}(aq) + 4Cl^-(aq) \quad \Delta H = \text{negative}$$
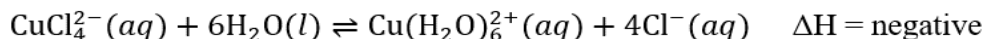
At a constant pressure and temperature, the appearance of a solution containing these ions remains pale blue.

Which alternative correctly predicts an identified change and its effect on the system?

(A) Adding water causes the solution to turn green.

(B) Increasing the temperature causes the solution to turn blue.

(C) Cooling the reaction vessel increases the rate of the reverse reaction.

(D) Adding concentrated hydrochloric acid causes the solution to turn green.

7. "X" is prepared from the reaction of "Y" and "Z" as described in the following equation.

$$Y(g) + Z(g) \rightleftharpoons 3X(g) \quad \Delta H = -50 \text{ kJ mol}^{-1}$$
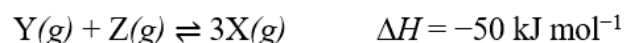
Which set of conditions would optimise the rate at which $X(g)$ is initially produced?

(A) High pressure, high temperature.

(B) Low pressure, low temperature.

(C) High pressure, low temperature.

(D) Low pressure, high temperature.

8. The structural formula of an organic compound is shown below.
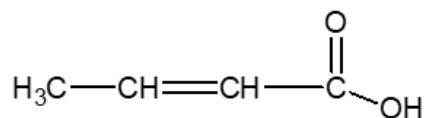
What mass of chlorine molecules would react with 0.250 moles of the compound?

(A) 8.86 g

(B) 17.73 g

(C) 26.59 g

(D) 35.45 g

9. The curve below shows the change in pH vs the volume of solution added from a burette during an acid-base titration.

Volume added from burette (mL)
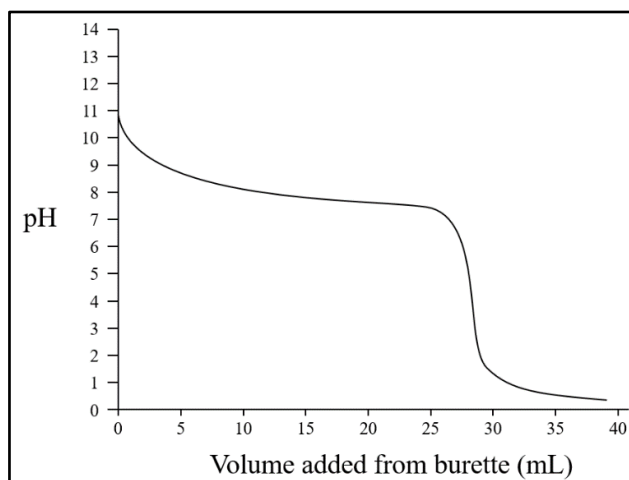
Which alternative identifies the type of solution present in the conical flask and burette during this titration.

	Solution in the conical flask	Solution in the burette
(A)	strong base	strong acid
(B)	weak base	strong acid
(C)	weak acid	weak base
(D)	strong acid	weak base

10. The diagram below is an example of a reaction known as transesterification.

A molecule such as the one labelled "A" is reacted with an alkanol, forming products B, C, D and E.
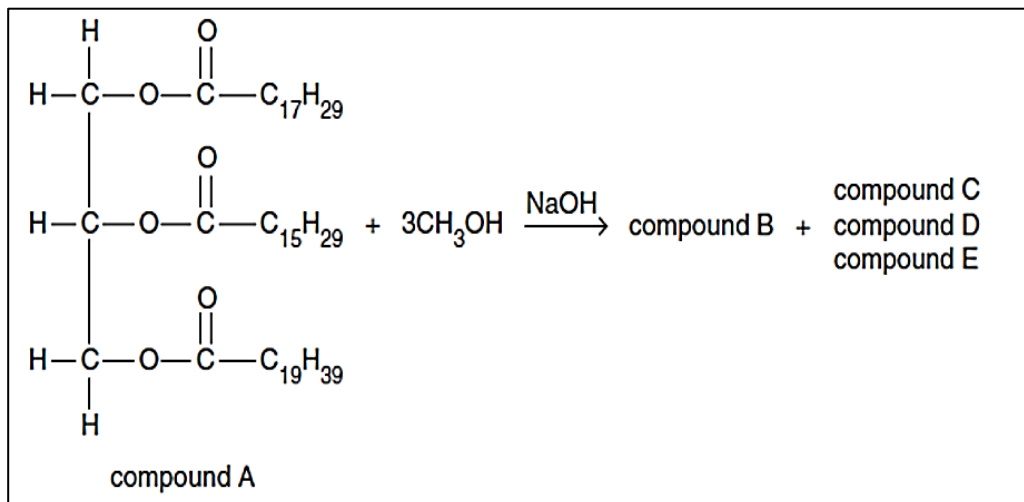
To which class of organic compound does "A" belong?

(A)   carboxylic acid

(B)   ester

(C)   fat

(D)   soap

11. Methane reacts with water vapour to produce carbon monoxide and hydrogen gas according to the following equation.

$$CH_4(g) + H_2O(l) \rightleftharpoons CO(g) + H_2(g)$$

The table below provides some data about this system.

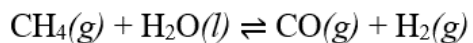| DH (kJ mol^{-1}) (forward reaction)	Activation Energy (kJ mol^{-1}) (forward reaction)	K_c at 1000°C
+206	250	4.68×10^{-2}

Which alternative below shows how these data would change if the reaction was carried out at 2000°C?

|	ΔH (kJ mol^{-1}) (forward reaction)	Activation Energy (kJ mol^{-1}) (forward reaction)	K_c at 2000°C
(A)	increase	increase	decrease
(B)	increase	no change	decrease
(C)	no change	increase	increase
(D)	no change	no change	increase

Questions 12 and 13 refer to the information below.

To test some urban creek water after early signs of algal blooms appeared, samples from two different sites in the creek were collected and analysed for their phosphate content using the principles of colourimetry. The basic steps followed in the analysis were:

- Preparation of four standard phosphate solutions (from 0.04, 0.15, 0.25 and 0.30 ppm)
- Addition of ammonium molybdate reagent to bind to the colourless phosphate ions, forming a yellow solution. This reagent was also added to the two test samples from the creek.
- Each standard sample was analysed in a UV-visible spectrometer and a calibration curve was constructed, showing the relative absorbance (of a wavelength specific for the coloured complex being analysed) vs concentration of the standards.
- Finally, the two unknown samples were tested using the same instrument.

A 'colour wheel' showing the main colours and their approximate wavelength is provided in the figure below.
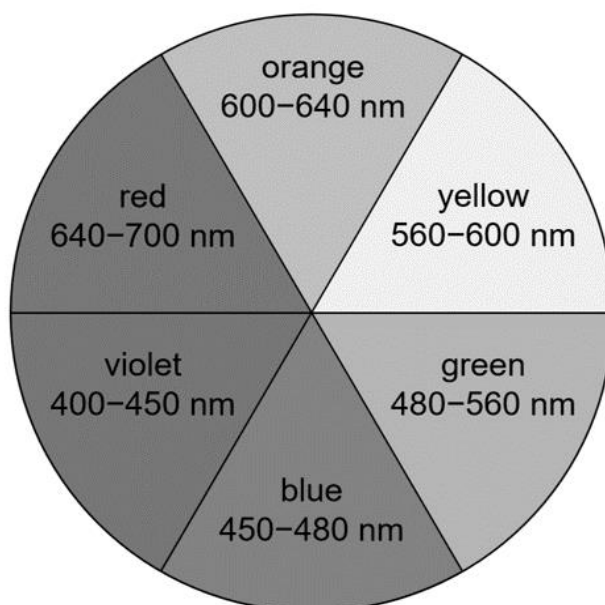
12. From the alternatives given, which wavelength of light would be the most effective to determine the level of absorbance through each of the samples?

(A) 440 nm

(B) 510 nm

(C) 580 nm

(D) 620 nm

13. The calibration curve below shows the absorbance of each standard phosphorus solution.

Measurement of absorbance of standard phosphorus solutions
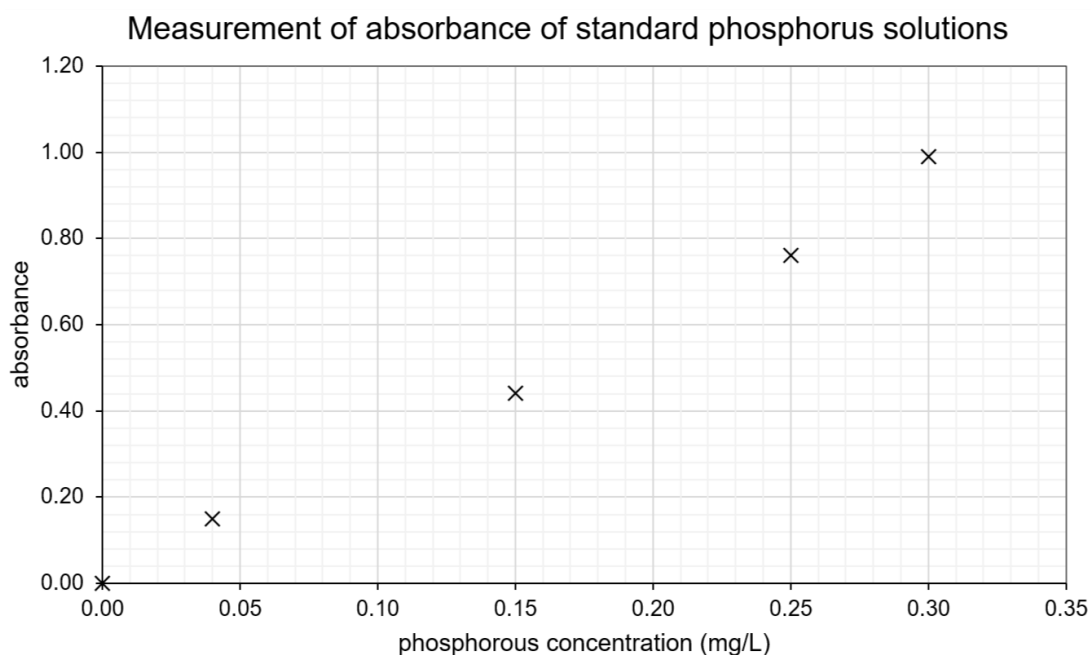
The absorbances of the two unknown creek samples are shown in the table below.

Sample	Absorbance
Creek Sample 1	0.32
Creek Sample 2	0.28

Sydney Water suggests phosphorus levels in unpolluted creeks should not exceed $60 \ \mu g \ L^{-1}$.

On the basis of these data, which statement below is correct?

(A)   Neither of the creek samples tested exceed Sydney Water's guidelines.

(B)   Creek Sample 1 is the only sample that exceeds Sydney Water's guidelines.

(C)   Creek Sample 2 is the only sample that exceeds Sydney Water's guidelines.

(D)   Both creek Samples exceed Sydney Water's guidelines.

14. The structural formulae of five organic compounds, labelled A-E, are shown below.

$H_3C-CH_2-C(=O)-O-CH_3$

A

$H_3C-C(=O)-O-CH_2-CH_3$

B

$H_3C-CH(CH_3)-C(=O)-OH$

C

$HC(=O)-O-CH_2-CH_2-CH_3$

D

$H_3C-CH_2-CH_2-C(=O)-OH$

E
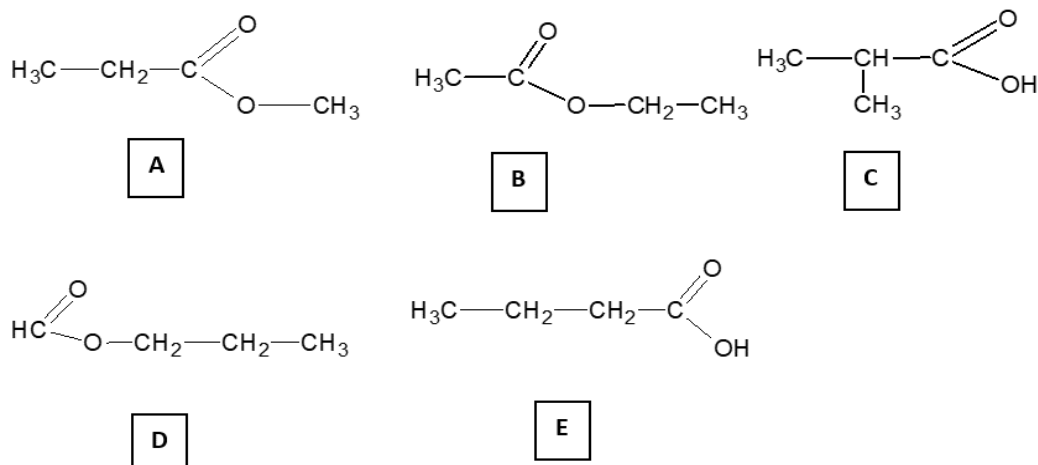
Which alternative below identifies a pair of these compounds which are examples of each type of structural isomer?

	Chain isomers	Functional group isomers	Position isomers
(A)	A and C	C and E	B and D
(B)	C and E	C and D	A and B
(C)	A and C	C and E	B and D
(D)	C and E	C and D	A and B

15. The following incomplete equation describes the oxidation of ethanol to ethanoic acid by potassium permanganate.

All coefficients shown are correct, but the coefficient for ethanoic acid has been replaced by the letter "X".

$$3C_2H_5OH(l) + 4KMnO_4(aq) \rightarrow X\ CH_3COOH(l) + 4MnO_2(s) + 4KOH(aq) + H_2O(l)$$

In a reaction carried out by an organic chemist, 5.0 g of ethanol yields 5.9 g of ethanoic acid.

What is the percentage yield for the above reaction, as predicted by the correctly balanced equation?

(A) 45%

(B) 77%

(C) 85%

(D) 91%

16. What is the order of increasing pH for the following substances of the same concentration, measured at the same temperature?

(A) $NH_4CH_3COO < NH_4Cl < NaCH_3COO < Na_2CO_3$

(B) $NH_4Cl < NaCl < NaCH_3COO < Na_2CO_3$

(C) $NaHCO_3 < NaCl < Na_2CO_3 < NaOH$

(D) $Na_2SO_4 < NaCl < NH_4Cl < NaOH$

17. What is the solubility of lead(II) carbonate in a 0.015 M solution of sodium carbonate at 25°C?

(A) 2.5×10^{-13} mol L^{-1}

(B) 4.9×10^{-12} mol L^{-1}

(C) 1.3×10^{-10} mol L^{-1}

(D) 1.8×10^{-6} mol L^{-1}

18. How many signals does the compound shown below produce in its ^{1}H NMR and ^{13}C NMR spectra?
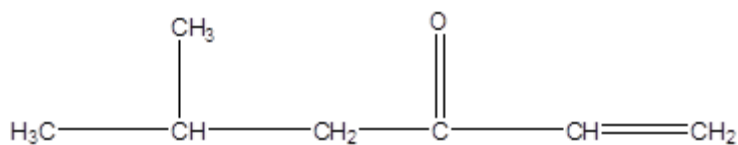
	^{1}H NMR signals	^{13}C NMR signals
(A)	5	6
(B)	6	6
(C)	6	7
(D)	5	7

19. At a point in a titration between 1.00 M sodium hydroxide and sulfuric acid (known by the teacher to be 2.00 M), 3.00 mL of the sulfuric acid had been added from the burette to 10.0 mL of sodium hydroxide in the conical flask.

If the pH of the mixture in the conical flask at this point was measured with a probe, what should the reading be?

(A)   0.81

(B)   2.25

(C)   2.70

(D)   5.71

20. The table below shows values of the ionisation constant of pure water, measured at various temperatures, but under constant pressure.

Temperature of water (°C)	0	25	50	75
K_W	1.1×10^{-15}	1.0×10^{-14}	5.5×10^{-14}	2.0×10^{-13}

Which one of the following statements regarding pure water is correct?

(A)   The reaction in which water molecules self-ionise releases energy.

(B)   Values of both the pH and the pOH of water at 5°C must exceed 7.0.

(C)   Water becomes slightly acidic at very hot temperatures, as its pH decreases.

(D)   Increasing temperature affects the K_w, but the pH of pure water remains at 7.0.

2021 | TRIAL EXAMINATION

Chemistry

Section II
Answer Booklet

80 marks

Attempt Questions 21 – 33

Allow about 2 hours and 25 minutes for this part

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

- Show all relevant working in questions involving calculations.

- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which questions you are answering.

Question 21 (4 marks)

Hydrogen iodide can be produced by the reversible reaction of hydrogen gas and iodine gas according to:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$
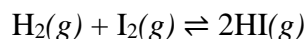
K_{eq} for this reaction is 2.25×10^3 at a temperature of 753°C.

(a) Calculate the concentration of HI in an equilibrium mixture if the concentration of H_2 is 0.15 M and the concentration of I_2 is 0.25 M. **2**

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(b) 2.4 moles of $H_2(g)$ and 1.5 moles of $I_2(g)$ were placed in a sealed 2.0 L vessel maintained at a temperature of 753°C. After 2 hours, the number of moles of each gas present were as follows.

Moles of $H_2(g)$	Moles of $I_2(g)$	Moles of $HI(g)$
1.7	0.8	1.4

Show by calculation whether the forward or reverse reaction must increase for the system to come to a state of dynamic equilibrium. **2**

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Question 22 (7 marks)

Buffers are solutions that resist changes in pH.

(a) Calculate the solubility (in mol L^{-1}) of lead(II) hydroxide in a solution that   **3**
     is buffered at pH = 8.45.

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(b) Blood must remain within a narrow pH range or death can result. Blood
     contains carbonic acid (H_2CO_3) and bicarbonate anions (HCO_3^-) which
     buffer blood so that its pH stays close to 7.4.

     Explain, using chemical equations, how these species work to resist   **4**
     changes in pH.

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Question 23 (7 marks)

Read the information below about the *Orica* ammonia plant in Newcastle.

The city of Newcastle is the second most populated area in the Australian state of New South Wales. Located at the mouth of the Hunter River, it is one of the largest coal exporting harbours in the world.

The company *Orica* is one of the world's largest providers of commercial explosives and innovative blasting systems to the mining, quarrying, oil and gas, and construction markets. The map below shows the location of *Orica*'s Newcastle Site.
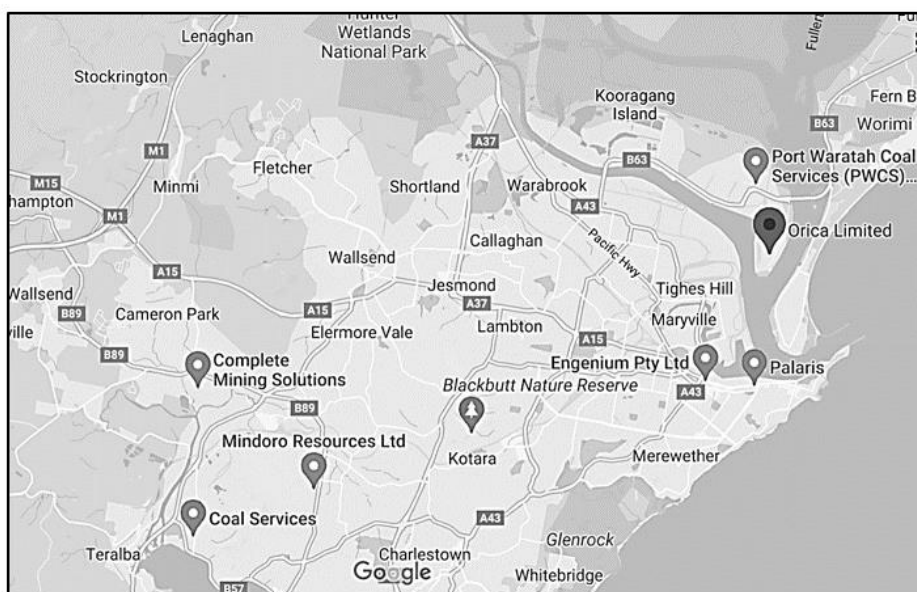
An ammonia-manufacturing plant operates on Kooragang Island.

Ammonia is used to make ammonium nitrate, a hazardous chemical used in the production of fertilisers and explosives. Large stockpiles of ammonium nitrate exist within the *Orica* site.

Last year, a major explosion in an overseas major city was due to the decomposition of large masses of ammonium nitrate.

A photograph of the container used to store ammonium nitrate at the plant.

Question 23 (continued)

(a)   At temperatures above 260°C, if confined, and when contaminated, ammonium nitrate pellets can decompose, forming dinitrogen oxide gas and water vapour.

Write a balanced chemical equation for the reaction described above.   **1**

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(b)   Given that the enthalpy of decomposition of ammonium nitrate is -454kJ/mol, calculate the energy released from the decomposition of 2.0kg of the solid.   **2**

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(c)   Discuss the location of Orica's ammonium nitrate storage facility, applying principles studied in the Year 12 Chemistry Course.   **4**

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Question 24 (4 marks)

A classroom activity to model dynamic equilibrium is carried out as follows.

Twenty-four coins are placed on a table with their heads side facing up.

Each minute, half the heads are flipped to tails, and one quarter of the tails are flipped back to heads.

Equilibrium is reached when there are 8 heads and 16 tails.

(a)   Describe a positive feature of this model.   **2**

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(b)   Describe a limitation of this model in modelling dynamic equilibrium in   **2**
        chemical systems.

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Question 25 (4 marks)

Acid X is monoprotic and has a K_a value of 1.64×10^{-5}.

(a)   Define the term "weak acid" and classify acid X as either strong or weak,   **2**
       giving a reason for your choice.

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(b)   Determine the pH of a 2.43×10^{-3} M solution of *acid X*.   **2**

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Question 26 (3 marks)

When ammonia gas (NH_3) is bubbled through water that contains a few drops of
phenolphthalein indicator, the water turns pink.

Explain how the Brønsted-Lowry theory of acids and bases can account for this   **3**
observation, supporting your response with a chemical equation.

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Question 27 (7 marks)

As a common pollutant in the marine environment, copper has been recognized as one of the three most toxic heavy metals to marine invertebrates, affecting their reproduction, growth, and abundance.

The levels of this heavy metal in marine ecosystems must be carefully monitored, and AAS is one spectroscopic technique that can be used to determine the concentration of copper, even at very low levels.

An analytical chemist given the task of measuring copper levels in some marine samples first produced a primary standard of copper(II) nitrate solution with a concentration of 100 ppm. This standard solution was then diluted using volumetric apparatus to make four standards.

The table below shows details of how the dilutions were carried out.

Standard Solution	Volume of stock 100 ppm standard withdrawn by pipette (mL)	Final volume of diluted solution upon addition of correct volume of distilled water (mL)
Original (100 ppm)	na	na
1	2	200
2	5	200
3	10	200
4	15	200

(a) Complete the table below by filling in the concentrations (in ppm) for the calibration standards 1–4 using data provided in the table above.   **2**

SAMPLE	BLANK	STANDARD 1	STANDARD 2	STANDARD 3	STANDARD 4
CONC. (PPM)	0	……….	………..	………	…….
ABSORBANCE	0.00	0.05	0.13	0.24	0.38

Question 27 (continues)

(b)   The marine sample was then analysed in the same instrument and its
       absorbance was measured at 0.42.

       Draw a scientifically formatted calibration curve from your table in part (a)   **3**
       that would allow the concentration of the marine sample to be accurately
       estimated.
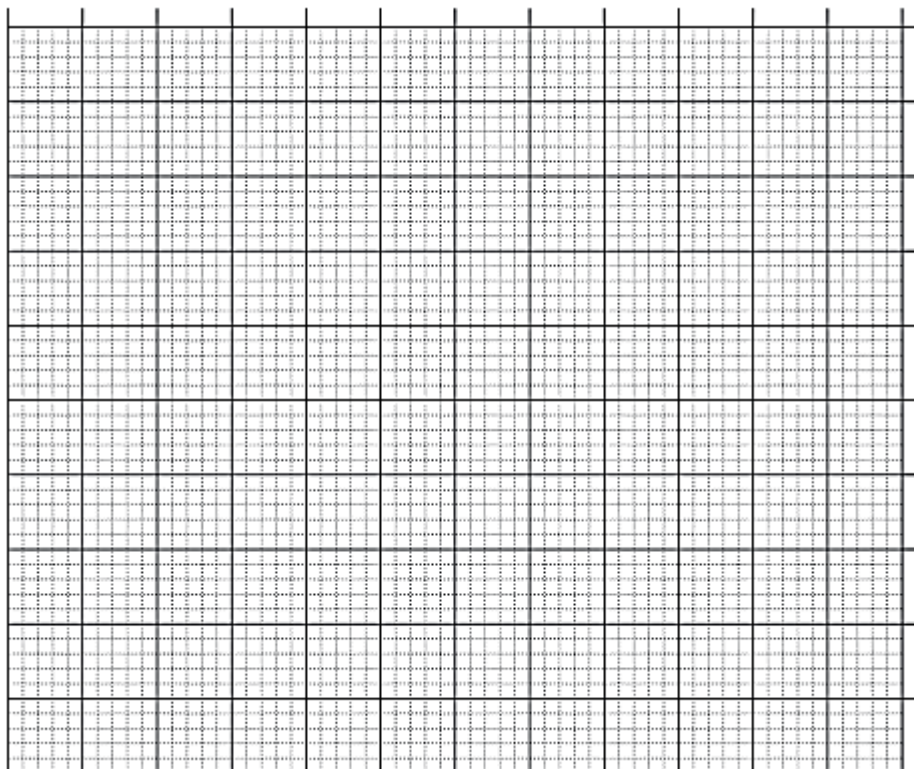
(c)   Use your graph to determine the concentration of copper(II) ions in the
       marine sample and express this in **ppm** and as a **molarity**.

       Show all working on the graph and in the space below.   **2**

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Question 28 (6 marks)

In an investigation to determine the solubility of NaCl in water, methanol and hexane, a student added 40.0 g of NaCl to 100.0 mL of each liquid maintained at a temperature of 25°C.

After 2 minutes of stirring each mixture, the mass of undissolved salt was determined through filtering the mixture and weighing the residue.

The results of the investigation are shown below.

Liquid	Mass of NaCl(s) recovered by filtration (g)
hexane	39.9
methanol	38.6
water	3.85

(a)   Place the liquids tested in order of their increasing solubility of NaCl.   **1**

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(b)   Explain the trend in solubility of NaCl in the three liquids using your   **5**
        knowledge of the process by which ionic solids dissolve and the
        intermolecular forces involved.

        Include at least one labelled diagram to support your explanation.

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Question 29 (3 marks)

Nitrogen dioxide (NO_2) gas forms an equilibrium system with nitric oxide (NO) gas and oxygen gas.

A syringe is used to inject 0.70 moles of nitrogen dioxide into an empty, sealed 2.0 L container maintained at a temperature of 185°C.

When the system has come to equilibrium, there are 7.8×10^{-3} moles of oxygen gas present in the container.

Calculate K_{eq} for the decomposition reaction of $NO_2(g)$. **3**

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Question 30 (17 marks)

2-butyl ethanoate (commonly known as sec butyl acetate) is an organic chemical used as a solvent in lacquers and enamels.

It is a clear flammable liquid with a sweet smell. Its structural diagram is shown below.
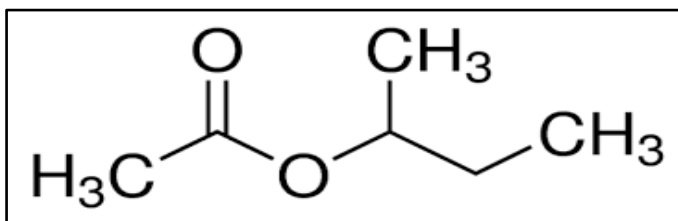
A small chemical plant aims to synthesise this chemical from two readily available petrochemicals, ethene and 2-butene.

(a)   Identify the class (family) of organic compound to which 2-butyl ethanoate   **1**
        belongs.

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(b)   Explain the chemical property of molecules, such as ethene and 2-butene,   **2**
        which makes them useful as starting materials in the synthesis of a range of
        organic chemicals.

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Question 30 (continued)

(c) Describe the series of reactions which could be followed to synthesise   **8**
     2-butyl ethanoate from ethene and 2-butene as the ***only*** organic starting
     compounds.

     Your description should:

     • identify a series of reactions which could be followed in the synthesis;
     • identify the reaction conditions, including any inorganic reagents, needed
        to optimise yield and rate of the main reactions identified;
     AND
     • include a series of relevant balanced chemical equations, using structural
        formula for all organic molecules.
     • Give the correct IUPAC names for each structure shown in your
        equations.

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Question 30 (continued)

(d) Periodically, a sample of the chemical produced at the plant is to be
analysed spectroscopically, to monitor for its purity.

Explain how analysis of spectra, produced from at least **two** identified   **6**
spectroscopic techniques, could be used to monitor for the purity of the
2-butyl ethanoate being produced.

You should include relevant labelled *sketches* of the type of spectra and
their features you may expect for 2-butyl ethanoate. These sketches do not
need to be drawn to scale.

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Question 31 (8 marks)

Acetylsalicylic acid is a pain relief medication also known as aspirin. The purity of an aspirin tablet was determined by titration against a basic standard.

First, the basic solution was standardised by titrating it with a standard solution of potassium hydrogen phthalate:

$$KHC_8H_4O_4(aq) + NaOH(aq) \rightarrow H_2O(l) + NaKC_8H_4O_4(aq)$$
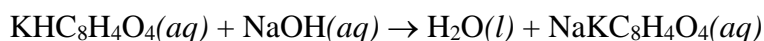
An average titre of 19.25 mL of the sodium hydroxide solution was required to reach equivalence with 25.0 mL of 0.0116 M potassium hydrogen phthalate.

One aspirin tablet was weighed and found to have a mass of 0.370 g.

It was dissolved in deionised water and made up to 250.0 mL in a volumetric flask.

The standardised NaOH solution was titrated against 25.0 mL of the aspirin solution:

$$C_9H_8O_4(aq) + NaOH(aq) \rightarrow H_2O(l) + NaC_9H_7O_4(aq)$$
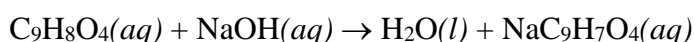
The average titre of NaOH that neutralised the aspirin solution was 13.20 mL.

(a)   Explain why dissolving a precisely known mass of solid NaOH and making the solution up to 250.0 mL in a volumetric flask is *not* an appropriate way to prepare a standard solution.   **2**

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(b)   Identify the most appropriate piece of equipment for collecting precisely 25.0 mL of the dissolved tablet solution.   **1**

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Question 31 (continued)

(c)   Calculate the concentration of the standardised NaOH solution.   **2**

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(d)   Given that the molecular mass of aspirin is 180.158 g mol^{-1}, calculate the   **3**
      purity of the tablet as %w/w.

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Question 32 (6 marks)

The graph shows the concentrations of three gas-phase species involved in a reversible decomposition reaction inside a closed container.

The decomposition reaction was known to be exothermic.
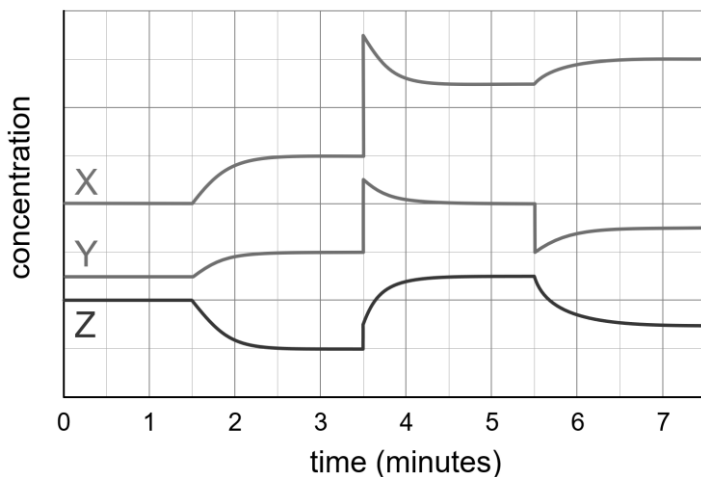
Infer from the data a possible balanced equation for the decomposition reaction, in terms of X, Y and Z, and explain the features of the graph in terms of:

6

• Le Chatelier's Principle,
• the enthalpy change of the reaction and
• any disturbances to the system made by experimenters at various times.

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Question 33 (4 marks)

A student adds 1 mL of oil to 5 mL of distilled water in a test tube labelled *X* which is stoppered and shaken for 10 seconds and allowed to settle.

The experiment is repeated, in a second test tube labelled *Y*. In addition to the oil and water, 5 drops of soap solution is added before the test tube is shaken.

(a)   Compare the appearance of the mixtures in test tubes *X* and *Y* after they   **1**
      have been shaken and allowed to settle for 10 seconds.

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(b)   Explain how the molecular structure of soap can account for the changes in   **3**
      appearance of the mixtures described in part (a).

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Section II extra writing space.

If you use this space indicate clearly which question you are answering.

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If you use this space indicate clearly which question you are answering.

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2021 Chemistry Trial Examination.

Marking Guidelines and Model Answers.

Section I   Multiple Choice

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

Section II

21.a.

Marking Criteria	Marks
● Correctly calculates the concentration of HI.	2
● Response contains one error.	1

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = 2.25 \times 10^3$$

$$[HI] = \sqrt{2.25 \times 10^3 \times 0.15 \times 0.25}$$

$$[HI] = 9.2 \text{ M}$$

21.b.

Marking Criteria	Marks
● Calculates Q for the system and compares Q to K to explain which reaction must proceed at a faster rate for the system to reach equilibrium.	2
● Calculates Q for the system OR ● Demonstrates an understanding of how comparing Q to K can determine which reaction (forward or reverse) must be higher in order for equilibrium to be reached.	1

$$Q = \frac{[HI]^2}{[H_2][I_2]}$$

[HI] = n/V = 1.4/2 = 0.7 molL^{-1}

[H$_2$] = n/V = 1.7/2 = 0.85 molL^{-1}

[I$_2$] = n/V = 0.8/2 = 0.4 molL^{-1}

$$Q = \frac{[0.7]^2}{[0.85][0.4]}$$

=1.44

Since Q<K, the system is not at equilibrium and the forward reaction must proceed at a higher rate than the reverse in order for the system to reach equilibrium.

22.a.

Marking Criteria	Marks
● Calculates the solubility (in mol L−1) of lead(II) hydroxide in a solution buffered at 8.45.	3
● Calculates the solubility (in mol L−1) of lead(II) hydroxide in a solution buffered at 8.45 with one error.	2
● Carries out one correct step in the calculation OR ● Writes a balanced equation for the dissolving of lead(II) hydroxide.	1

pOH = 14 – 8.45 = 5.55

$[OH^-] = 10^{-pOH} = 10^{-5.55} = 2.818... \times 10^{-6}$ mol L^{-1}

$Pb(OH)_2(s) \rightleftharpoons Pb^{2+}(aq) + 2OH^-(aq)$
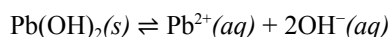
Upon addition of the solid compound to the solution, the buffer absorbs any extra OH$^-$ so its concentration remains fairly constant at 2.818×10^{-6} mol L^{-1}.

$K_{sp} = [Pb^{2+}] \times [OH^-]^2$

$[Pb^{2+}] = K_{sp} / [OH^-]^2$

$[Pb^{2+}] = \frac{1.43 \times 10^{-15}}{\left(2.818... \times 10^{-6}\right)^2} = 1.80 \times 10^{-4}$ which is the same as the number of moles of lead(II) hydroxide that dissolve per litre of water. Solubility is **1.80×10^{-4} mol L^{-1}**.

22.b.

Marking Criteria	Marks
● Explains, including the use of two correctly balanced equations, how the H2CO3/HCO3- buffer can resist changes in pH change when an increase in either [H+] or [OH-] occurs.	4
● Explains, including ONE correctly balanced equation, how the H2CO3/HCO3- buffer can resist changes in pH change when an increase in either [H+] or [OH-] occurs.	3
● Explains, including ONE correctly balanced equation, how the H2CO3/HCO3- buffer can resist changes in pH when either an increase in [H+] or [OH-] occurs. OR ● Outlines how buffers work to resist changes in pH.	2
● Some relevant information.	1

H_2CO_3 is the conjugate acid of HCO_3^-. They form an equilibrium system in water:

$$H_2CO_3 + H_2O \rightleftharpoons HCO_3^- + H_3O^+$$
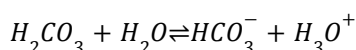
The pH of the blood depends on [H$_3$O$^+$]. If another substance causes an increase in this concentration, the position of equilibrium is shifted to the left to counteract this change (LCP). This leaves the [H$_3$O$^+$] and therefore the pH steady.

If a base, B is added to the blood, the [OH$^-$] would initially rise. The weak acid (H$_2$CO$_3$) would react and consume the majority of the extra OH$^-$, hence preventing the pH from rising significantly.

$$H_2CO_3 + OH^- \rightleftharpoons HCO_3^- + H_2O$$
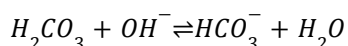
If an acid, A, is added to the blood, the [H$_3$O$^+$] would initially rise. The conjugate base in the buffer is strong enough to react with this and consume the majority of the extra H$_3$O$^+$, hence preventing the pH from falling significantly.

$$HCO_3^- + H_3O^+ \rightleftharpoons H_2CO_3 + H_2O$$
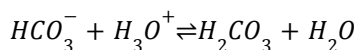
23.a.

Marking Criteria	Marks
● Writes the correct balanced chemical equation, including physical states.	**1**

NH_4NO_3 (s) □ N_2O (g) + $2H_2O$ (l)
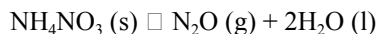
23.b.

Marking Criteria	Marks
● Calculates the energy released in the correct units.	**2**
● Completes one step in the calculation.	**1**

n(NH_4NO_3) = m/MM = 2000 / 80.052 = 24.98 moles

q released = ΔHxn = 454 x 24.98 = 1.13 x 10^4 kJ

23.c.

Marking Criteria	Marks
● Provides positive and negative aspects regarding the location of the ammonium nitrate storage facility, referring to the data provided in the question and knowledge of the factors considered when selecting a location for a chemical plant.	**4**
● Provides an advantage and issue regarding the location of the ammonium nitrate storage facility, referring to the data provided in the question and some knowledge of the factors considered when selecting a location for a chemical plant.	**3**
● Describes at least TWO factors considered when selecting a location for a chemical plant.	**2**
● Provides some relevant information.	**1**

The location of the ammonium nitrate storage facility has a number of benefits. It is close to the ammonia plant which is required for its production, reducing cost and energy requirements for transportation. Likewise, it is required to made explosives for the coal mining industry and fertilisers for agriculture, both industries being in close proximity to the storage facility. It is also close to a large city, with a workforce required to operate the plant. It is close to a port, so transport to other areas is economically advantageous. However, it is also relatively close to populous areas, and if an accident or terrorist incident etc occurred on the site and an explosion occurred, the potential for loss of life and damage to properties is definitely a negative aspect regarding its location. Hence a buffer area must surround it and the facility must be carefully monitored and protected.

24.a.

Marking Criteria	Marks
● Positive feature of model described in terms of its good ability to represent equilibrium systems	**2**
● Positive feature of model identified	**1**

Flipping the coins from heads to tails and back clearly represents the reaction proceeding to the right and back to the left, i.e. going from reactants to products and vice versa.
heads $\rightleftharpoons$ tails   represents   reactants $\rightleftharpoons$ products
Or, for example
The number of heads that "react" is proportional to the number of heads that are present.
Or, for example
At equilibrium there are still reactions occurring and the forward and reverse rates are equal.

24.b.

Marking Criteria	Marks
● Limitation that relates to dynamic equilibrium described.	**2**

	Marks
● Limitation identified, or ● Limitation that does not relate to dynamic equilibrium described	1

This model does not show how the position of equilibrium can be affected by temperature. One could re-do the experiment moving the coins around quickly between rounds (to model higher temperature) but the results would be the same – which is not how dynamic systems actually behave.

25.a.

Marking Criteria	Marks
● Defines "weak acid" and correctly classifies acid X, providing a reason for their choice.	2
● Defines "weak acid" or correctly classifies acid X	1

A weak acid is one that only dissociates partially in water [or some other solvent]. The magnitude of K is slow, indicating most of Acid X remains un-ionised. Therefore, Acid X is a weak acid.

25.b.

Marking Criteria	Marks
● Correctly calculates the pH	2
● Some correct working to find either [H+] (or [H3O+]) or pH	1

Acid X is monoprotic, so it follows this scheme: $HA + H_2O \rightleftharpoons H_3O^+ + A^-$

$$K_a = 1.64 \times 10^{-5} = \frac{[H_3O^+][A^-]}{[HA]} = \frac{x^2}{(2.43 \times 10^{-3} - x)}$$

Because Acid X has a small K_a we can approximate that x is small so $2.43 \times 10^{-3} - x \approx 2.43 \times 10^{-3}$

$$x^2 = (1.64 \times 10^{-5}) \times (2.43 \times 10^{-3}) = 3.9852... \times 10^{-8}$$

$$x = [H_3O^+] = \sqrt{3.9852... \times 10^{-8}} = 1.996... \times 10^{-4}$$

$$pH = -\log_{10}[H_3O^+] = -\log_{10}(1.996... \times 10^{-4}) = \mathbf{3.70}$$

26.

Marking Criteria	Marks
● Explains how the Bronsted-Lowry Theory explains the basic nature of ammonia, including a balanced equation, and relates this to a knowledge of the pH range of phenolphthalein.	3
● Explains how the Bronsted-Lowry Theory explains the basic nature of ammonia, including a balanced equation OR ● Explains how the Bronsted-Lowry Theory explains the basic nature of ammonia and relates this to a knowledge of the pH range of phenolphthalein.	2
● Provides some relevant information.	1

Phenolphthalein is an indicator that is colourless in acidic solutions and pink in basic solutions. According to the Bronsted-Lowry theory, bases accept protons from water. Therefore, bubbling ammonia through water causes the formation of OH⁻ ions according to the equation:

$NH_3(g) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$
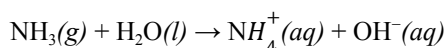
The excess OH⁻ ions increase the pH of the solution and this results in the phenolphthalein turning from colourless to pink.

27.a

Marking Criteria	Marks

SAMPLE		Completes the table by correctly determining the concentration of each standard solution from the dilution procedure outlined.			2	
		● Correctly determines the concentration of any ONE of the standard solution from the dilution procedure outlined OR ● Values for the concentration of the standard solutions shown in the table are incorrect but differ by same factor.			1	

SAMPLE	BLANK	STANDARD 1	STANDARD 2	STANDARD 3	STANDARD 4	
CONC. (PPM)	0	1	2.5	5	7.5	
ABSORBANCE	0.00	0.05	0.13	0.24	0.38	

27.b.

Marking Criteria	Marks
● Draws a correctly formatted graph to display the data shown in the table, including axes titles, units for concentration, variables plotted on correct axes, points plotted accurately, correctly drawn line-on-best-fit.	3
● Draws a well-formatted graph to display the data shown in the table, including most of the features identified above, with a major error or omission.	2
● Attempts to display the data provided in the form of a graph, with limited demonstration of formatting conventions.	1

Absorbance vs concentration of copper(II)
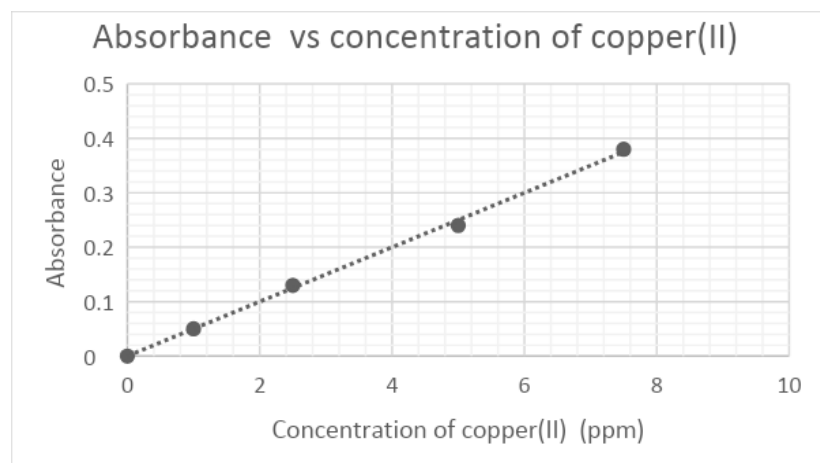
27.c.

Marking Criteria	Marks
● Calculates the concentration of copper(II) ions in ppm and as a molarity, showing working from their graph.	2
● Calculates the concentration of copper(II) ions in ppm OR as a molarity, showing working from their graph.	1

(i) From extrapolation, the concentration of Cu^{2+} = 8.4 ppm = 8.4 mgL^{-1}

(ii) $n (Cu^{2+})$ in 1L = m/MM = 0.0084 / 63.55 = 1.321 x 10^{-4} mol
$c (Cu^{2+})$ = 1.3 x 10^{-4} $molL^{-1}$

28.a.

Marking Criteria	Marks
● Identifies the correct trend in solubility of NaCl in the three liquids tested.	1

The trend in solubility of NaCl in the liquids tested is hexane<methanol<wáter

28.b

Marking Criteria	Marks
● Explains, using correct scientific terminology and at least one appropriately labelled diagram, the trend in solubility of NaCl in each liquid.	**5**
● Explains, using correct scientific terminology and an appropriately labelled diagram, the process by which ionic solids dissolve in water AND explains the relative solubility of NaCl in ONE of the other liquids.	**4**
● Explains, using correct scientific terminology and a diagram, the process by which ionic solids dissolve in water OR partially in ethanol.	**3**
● Outlines, using satisfactory scientific terminology, the process by which ionic solids dissolve in water or partially in methanol, OR explains the insolubility of salt in hexane.	**2**
● Provides some relevant information about how ionic solids dissolve in water or methanol but not in hexane.	**1**
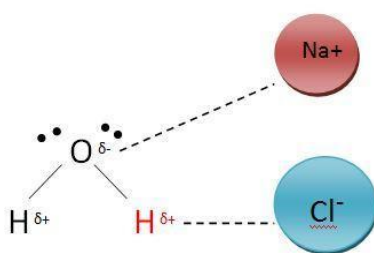
An ionic compound consists of a 3D array of oppositely charged ions attracted by electrostatic forces called ionic bonds. Water is a polar solvent that has a slightly negative oxygen end and a slightly positive hydrogen end due to differences in the electronegativities between oxygen and hydrogen. When an ionic salt is added to water, ion-dipole forces of attraction can be formed between the anions on the outer surface of the lattice and the hydrogen ends, and the cations and the oxygen ends. If these ion-dipole forces are strong enough to overcome the forces of attraction between the ions in the lattice, the ions dissociate, and some or all of the salt will dissolve.

Methanol is a relatively small polar solvent due to the hydroxy functional group. As such, ion-dipole forces can form between methanol molecules and the Na^+ and Cl^- ions, with the Na^+ being attracted to the O and Cl^- to the H atoms. These forces must not be as strong as those that can form in water, given the relatively low solubility of NaCl in methanol.
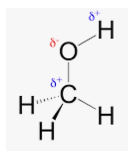
Hexane is a hydrocarbon which is non-polar, and since there are no strong interactions between this longer chained non-polar molecule and the Na^+ and Cl^- ions, the solubility of NaCl in hexane is negligible.

29.

Marking Criteria	Marks
● Correctly calculates Keq	3
● Calculation contains one error	2
● One correct step.	1

	$2NO_2$ $\rightleftharpoons$	$2NO$ +	O_2
I	0.70	0	0

C	−2 × 0.0078	+2 × 0.0078	+0.0078
E	0.6844	0.0156	0.0078
Conc.	0.3422	0.0078	0.0039

$$K_{eq} \frac{[NO]^2[O_2]}{[NO_2]^2} = \frac{0.0078^2 \times 0.0039}{0.3422^2} = 2.0 \times 10^{-6}$$

30.a.

Marking Criteria	Marks
● Identifies the class of organic compound shown.	1

Ester or alkyl alkanoate

30.b

Marking Criteria	Marks
● Explains a chemical property of short-chained alkenes that makes them useful starting materials for a range of organic compounds.	2
● Provides some relevant information.	1

All alkenes contain a reactive double bond which allows them to undergo addition reactions, where atoms from a reagent (eg Br2¬ or H¬2O) can add across the double bond, forming new products. Short-chained alkenes, especially ethene, are therefore industrially important starting materials in the petrochemical industry. Produced from the cracking of alkanes from either petroleum or natural gas, they are also readily available and relatively cheap.

30.c.

Marking Criteria	Marks
Describes a possible reaction pathway to synthesise the ester shown, including ● identification of the series of reactions which could be followed in the synthesis; ● identification of the reaction conditions, including any inorganic reagents, needed to optimise yield and rate of the main reactions identified; AND ● a series of relevant balanced chemical equations, using structural formula for all organic molecules. Give the correct IUPAC names for each structure shown in your equations.	8
Describes a possible reaction pathway to synthesise the ester shown, including ● identification of the series of reactions which could be followed in the synthesis; ● identification of the reaction conditions, including any inorganic reagents, needed to optimise yield and rate of the main reactions identified; AND ● a series of relevant balanced chemical equations, using structural formula for all organic molecules. Give the correct IUPAC names for each structure shown in your equations. But answer may contain an error or omission	6-7
Outlines some relevant reactions required to synthesise the ester shown, including some of the following criteria. ● identification of some reactions which could be followed in the synthesis; ● identification of some reaction conditions, including any inorganic reagents for the reactions shown AND ● at least two balanced chemical equations, using structural formula for all organic molecules.	4-5
Outlines TWO relevant reactions required to synthesise the ester shown, including: ● the identification of the reaction conditions, including any inorganic reagents for at least one of the reactions and	2-3

● a balanced chemical equation, using structural formula for all organic molecules.		
● Provides some relevant information.		1

The ester shown could be synthesised by the oxidation of ethene using a strong oxidising agent such as KMnO4¬, which would form ethanol as an intermediate and upon further oxidation ethanoic acid. This is one of the reagents needed to synthesise the ester.

The 2-butene could be r⸱ [H₂C=CH₂ →KMnO₄ H₃C—CH₂—OH] a catalyst to increase the reaction
rate. An addition reactio⸱ [ethene / ethanol] he double bond, forming 2-butanol.

The ethanoic aci⸱ [H₃C—CH=CH—CH₃ + H—OH →H₂SO₄ (dilute) H₃C—CH(OH)—CH₂—CH₃] uric acid added as as a
catalyst to increa⸱ [2-butene (but-2-ene) / 2-butanol (butan-2-ol)] the forward reaction in the
esterification re⸱

30.d.

[H₃C—C(=O)—OH + H₃C—CH(OH)—CH₂—CH₃ ⇌[H₂SO₄] / reflux H₃C—C(=O)—O—CH(CH₃)—CH₂—CH₃ + H₂O]

[ethanol / 2-butanol / 2-butyl ethanoate]

	Marks
● Sketc⸱ ⸱ed featur⸱ ● Clear explanation of how features of the molecule relate to features of each spectrum ● Explanation clarifies how impurities would be detected	6
As above but: ● explanations omit a relevant feature of a spectrum, or ● explanations omit relevant features of molecules, or ● sketched spectra are missing a key detail	4-5
● One technique clearly explained	2-3
● Provides some relevant information.	1

Mass spectrometry can be used to monitor purity. The molar mass of 2-butyl ethanoate is 116.16 g/mol, therefore the parent peak in the mass spectrum should appear at m/z = 116 and any peaks at higher values would indicate impurities caused by substances with greater molar mass. The intensity of the impurity peaks is a guide to how impure the sample is, but cannot be used definitively. Prominent fragment peaks may include 15 (CH3), 43 (CH3CO), and 57 (CH3CH2CHCH3) as well as peaks that differ in mass by one unit indicating the loss of hydrogen.
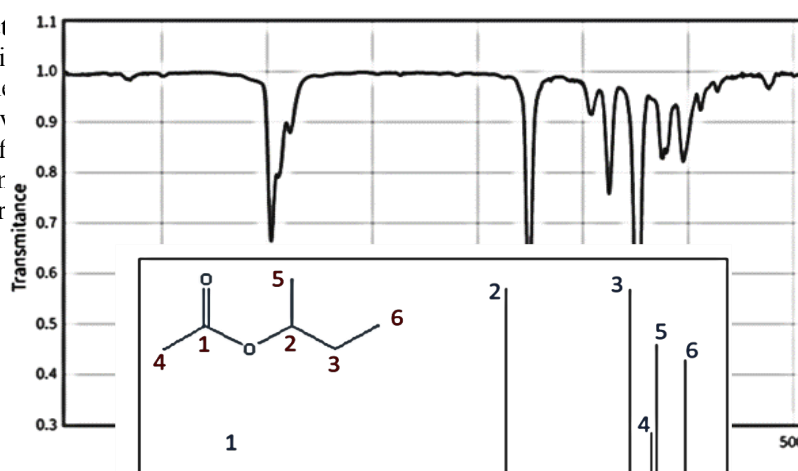
Infrared spectrosc⸱ ⸱al IR-active bonds. The
IR spectrum of the ⸱ gions, corresponding to
the listed bonds: C⸱)0 cm−1), and C—C
(750−1100 cm−1). ⸱ample, if the sample was
contaminated with ⸱ ⸱m−1 and 2220−2260
cm−1 correspondin⸱
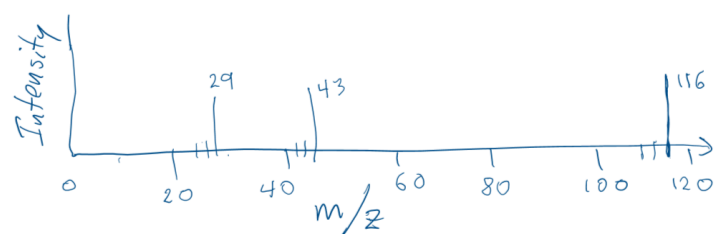
13C NMR spect⸱ ⸱n environments,
each of which gi⸱ ⸱ls are given on
the HSC data sh⸱ ⸱ numbered
carbon atoms giv⸱ ⸱ peaks in the
spectrum even if⸱ ⸱s. This is
because the cher⸱ ⸱egree on the
structure of the r⸱

Proton NMR can be used to detect impurities in a sample of 2-butyl ethanoate. The spectrum depends on the number of hydrogen atoms in each different chemical environment. There are five chemical environments for hydrogen, labelled a–e in the diagram. Each chemical environment results in a different chemical shift (δ, measured in ppm) in the spectrum.

The peaks produc⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯ the number of neighbouring
hydrogen atoms i⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯ d on the number of hydrogen atoms
in the environme⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯ a unique 1H NMR spectrum.
Impurities will b⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯ rent chemical shifts with different
splittings.

31.a.

	Marks
● Explai⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯ce a primary standa⋯	2
● Identifies ONE property of NaOH that make it unsuitable to produce a primary standard solution.	1

A primary standard solution is one which is made from weighing out a known mass of solid and transferring to a volumetric flask and adding sufficient distilled water such that the concentration of the solution is accurately known. Solid NaOH is not suitable for this purpose because it absorbs moisture from the air as well as reacts with CO2. Thus the mass weighed out contains fewer moles of pure NaOH, and thus the concentration of the solution calculated from the mass weighed out cannot be accurately known.

31.b.

Marking Criteria	Marks
● Identifies the correct piece of glassware.	1

A 25 mL volumetric pipette.

31.c.

Marking Criteria	Marks
● Calculates the concentration of the standardised NaOH.	2
● Completes one correct step in the calculation to determine the concentration of the standardised NaOH.	1

$n(KHC_8H_4O_4) = cV = 0.0116 \times 0.025 = 0.00029$ moles

$n(NaOH) = 0.00029$ moles (1:1 ratio)

$c(NaOH) = n/V = 0.00029 / 0.01925 = 0.0151$ $molL^{-1}$

31.d.

Marking Criteria	Marks
● Calculates the % purity of the aspirin to 3 significant figures.	3
● Calculates the correct % purity of the aspirin to incorrect number of significant figures OR ● Calculates the % purity of the aspirin, with one error, expressed to 3 significant figures.	2
● Completes one correct step in the calculation.	1

$n(NaOH) = cV = 0.0151 \times 0.0132 = 1.99 \times 10^{-4}$ moles

$n(C_9H_8O_4) = 1.99 \times 10^{-4}$ moles (1:1 ratio) (this number of moles present in 25mL of aspirin solution)

$n(C_9H_8O_4)$ in 250mL of solution $= 1.99 \times 10^{-4} \times 10 = 1.99 \times 10^{-3}$ moles

$m(C_9H_8O_4)$ in 250mL of solution $= n \times MM = 3591.99 \times 10^{-3} \times 180.158 = 0.359$ g

%purity of tablet = (0.359 / 0.370) x 100 = 97.1%

32.

Marking Criteria	Marks
Explains the major features of the graph in terms of: ● Le Chatelier's Principle ● correctly indentified stoichiometric ratios of the species shown by a balanced equation ● correctly identified enthalpy change of the reaction AND ● any disturbances to the system made by experimenters at various times.	**6**
Explains most major features of the graph in terms of at least 3 of the following: ● Le Chatelier's Principle ● correctly indentified stoichiometric ratios of the species shown by a balanced equation ● correctly identified enthalpy change of the reaction AND ● any disturbances to the system made by experimenters at various times.	**5**
Explains most major features of the graph in terms of at least 2 of the following: ● Le Chatelier's Principle ● correctly indentified stoichiometric ratios of the species ● correctly identified enthalpy change of the reaction AND ● any disturbances to the system made by experimenters at various times.	**4**
Explains TWO features of the graph in terms of one or more of the following ● Le Chatelier's Principle ● correctly indentified stoichiometric ratios of the species ● correctly identified enthalpy change of the reaction AND ● any disturbances to the system made by experimenters at various times.	**3**
Describes TWO features shown in the graph and demonstrates some understanding of any of the following: ● Le Chatelier's Principle ● correctly indentified stoichiometric ratios of the species ● correctly identified enthalpy change of the reaction AND ● any disturbances to the system made by experimenters at various times. ● to attempt to explain the features described	**2**
● Provides some relevant information.	**1**

Between t = 0 and 1.5 min the system is at equilibrium, as seen by the constant concentration of each gas in the system (rates of forward and reverse reactions must be equal for concentrations to remain constant).
At t = 1.5 min, a change in temperature occurred, as seen by the changing concentrations of all species. Since X and Y increase, but Z decreases, X and Y must be present on the same 'side' of the equation. As the equation is a decomposition reaction, the equation must be:
$Z(g) \rightleftharpoons X(g) + Y(g)$
Since the forward reaction was favoured, which is exothermic, the temperature must have been decreased at t=1.5, as cooling a system favours the exothermic reaction which released some heat energy, thereby minimising the effect of the disturbance imposed (as suggested by Le Chatelier's Principle).
At t=3.5 min, the concentrations of all species increase, suggesting the volume of the vessel decreased.
All concentrations increased by a factor of 1.5×, indicating that the volume was decreased to 2/3 of its original value.
When volume of the reaction vessel decreases, a shift to the side that produces less moles of gas occurs, to minimise the effect of the volume decrease. This is consistent with the change shown in the graph at 3.5 min, with the concentrations of X and Y decreasing (at different rates due to reaction stoichiometry), while the concentration of Z increases.
At t=5.5 min, the concentration of Y suddenly decreases, suggesting some of this product may have been removed at this time. According to Le Chatelier's Principle, removal of a product will shift the equilibrium to the side that minimises the effect of the removal ie to the right. This is consistent with the increases in concentration of both X and Y shown after the removal, and fall in that of Z.

33.a.

Marking Criteria	Marks

	Marking Criteria	Marks
●	Compares the appearance of the mixture in Test Tube X to Y after shaking and settling.	1

The contents of test tube X will form distinct layers, whereas a lather/froth will appear in Test Tube B, and the oil, water and soap solution will be mixed together, rather than appear as distinct layers.

33.b.

Marking Criteria	Marks
● Explains the difference in appearance of the test tubes by describing the molecular structure of soap and using this to account for its ability to form an emulsion between oil and water. Includes a labelled diagram of a micelle (or describes this in sufficient detail).	3
● Outlines the molecular structure of soap to write a satisfactory explanation for its ability to form an emulsion between oil and water. Answer may be supported with a basic diagram of a micelle.	2
● Provides some relevant information related to the question.	1

Soap molecules are sodium salts of long chained fatty acids. They have a water loving (hydrophilic) end, which is the charged end allowing it to interact and form attractions to the polar water molecules. They also have a long, non-polar hydrocarbon chain which allows this end to interact and form attractions to the non-polar oil molecules. In this way, the soap acts an emulsifying agent, allowing two chemicals which would normally be immiscible (like the oil and water in test tube X, which forms layers) to form a more homogeneous mixture, as seen in test tube Y. Micelles have formed which allow tiny oil droplets to disperse into the water.

11