2020
Higher School Certificate
Trial Examination

Chemistry

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 a Periodic Table are provided
- Write your student number and/or name at the top of every page

Total marks – 100

Section I – Pages 2–12
20 marks
- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – Pages 13–31
80 marks
- Attempt Questions 21–37
- Allow about 2 hours and 25 minutes for this section

This paper MUST NOT be removed from the examination room

STUDENT NUMBER/NAME: .....

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Section I

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

Select the alternative A, B, C or D that best answers the question and indicate your choice with a cross (X) in the appropriate space on the grid below.

	A	B	C	D
1				
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	A	B	C	D
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1 Which of the following lists contains only addition polymers?

A. Polystyrene, polyvinyl chloride, nylon

B. Polytetrafluoroethylene, polyvinyl chloride, polyester

C. Polystyrene, polyvinyl chloride, polytetrafluoroethylene

D. Nylon, polyvinyl chloride, polyester

2 In Experiment *A*, 0.100 mol L^{-1} sodium sulfate is placed in a burette and titrated against 25.0 mL samples of 0.100 mol L^{-1} barium nitrate. The electrical conductivity of the mixture is measured.

In Experiment *B*, the light absorption of a mixture of $NO_2(g)$ and $N_2O_4(g)$ is recorded as the temperature is changed.

Which line in the table below correctly labels the variables in these experiments?

	Experiment *A*		Experiment *B*	
	Independent variable	Dependent variable	Independent variable	Dependent variable
A.	Electrical conductivity	Volume of Na_2SO_4	Temperature	Light absorption
B.	Electrical conductivity	Volume of Na_2SO_4	Light absorption	Temperature
C.	Volume of Na_2SO_4	Electrical conductivity	Temperature	Light absorption
D.	Volume of Na_2SO_4	Electrical conductivity	Light absorption	Temperature

3 How is solubility used by Aboriginal and Torres Strait Islander peoples in the preparation of food sources, such as the fruits of cycads?

A. Because the starch in the fruits of cycads is more soluble than the toxins found in these fruits.

B. The toxins in the ground-up fruits are soluble in running water.

C. Placing the cycad fruits in water removes hard to digest food products such as fibre.

D. The skins of the cycad fruits easily dissolve in water leaving essential nutrients.

4 Two separate closed systems involving gases are set up and allowed to reach equilibrium.

System 1: $2NO(g) \rightleftharpoons N_2(g) + O_2(g)$

System 2: $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$

What effect would there be on each of these systems, if the pressure of both systems were doubled?

	System 1	*System 2*
A.	No effect	Shift to the right
B.	No effect	Shift to the left
C.	Shift to the left	Shift to the right
D.	Shift to the right	Shift to the left

5 In a reaction vessel, carbon monoxide gas reacts with hydrogen gas to form the following equilibrium.

$$CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$$

At 10°C the equilibrium constant for this reaction is 0.71.

What is the equilibrium constant expression (K_{eq}) for this reaction and what does this information say about the relative concentrations of products compared to reactants?

A. $\dfrac{[CH_4]}{[CO][H_2]^3}$ Reactants are highly favoured

B. $\dfrac{[CH_4][H_2O]}{[CO][H_2]^3}$ Reactants are slightly favoured

C. $\dfrac{[CH_4]}{[CO][H_2]^3}$ Products are highly favoured

D. $\dfrac{[CH_4][H_2O]}{[CO][H_2]^3}$ Products are slightly favoured

6 The pKa for an acid is found to be –1.45.

What is the likely formula of this acid?

A. CaH_2

B. CH_3COOH

C. HSO_4^-

D. HNO_3

7 A sample of hydrochloric acid is found to have a pH of 1.5. 10.0 mL of this solution is made up to 1.0 L using distilled water.

What is the pH of the new solution closest to?

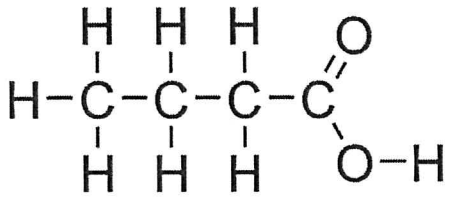
A. 2.0

B. 2.5

C. 3.0

D. 3.5

8 Examine the structural formula below.



Which of the following compounds is an isomer of this compound?

A. Butanone

B. Butanal

C. Propanoic acid

D. Methyl propanoate

9 In which of the following reactions is the dihydrogen phosphate ion ($H2PO4^-$) acting as an acid?

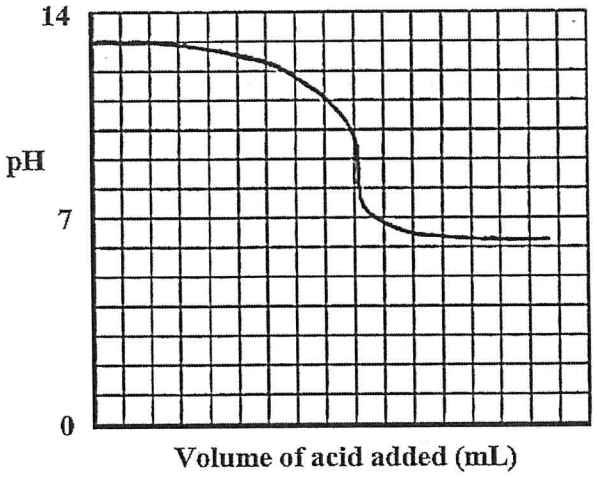
A. $H_2PO_4^- + NH_4^+ \rightarrow H_3PO_4 + NH_3$

B. $2H_2PO_4^- + Cu^{2+} \rightarrow Cu(H_2PO_4)_2$

C. $H_2PO_4^- + H_2O \rightarrow HPO_4^{2-} + H_3O^+$

D. $H_2PO_4^- + H_3O^+ \rightarrow H_2O + H_3PO_4$

10 The following titration curve was drawn from data collected when an acid was titrated against a 25.0 mL sample of a base.



What acid-base combination does this graph represent?

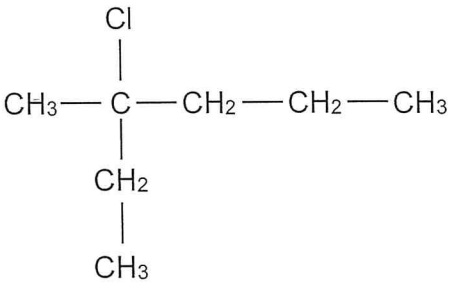
A. Strong base/weak acid

B. Strong acid/weak base

C. Strong base/strong acid

D. Weak acid/weak base

11 What is the correct IUPAC name for this haloalkane?



A. 2-chloro-2-ethylpentane

B. 3-chloro-3-methylhexane

C. 3-methyl-3-chlorohexane

D. 3-chloroheptane

12 The equation for the reaction of copper ions with aqueous ammonia is shown.

$$Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq)$$

Which of the following is a correct use for this reaction?

A. A Bronsted-Lowry reaction used to identify copper ions

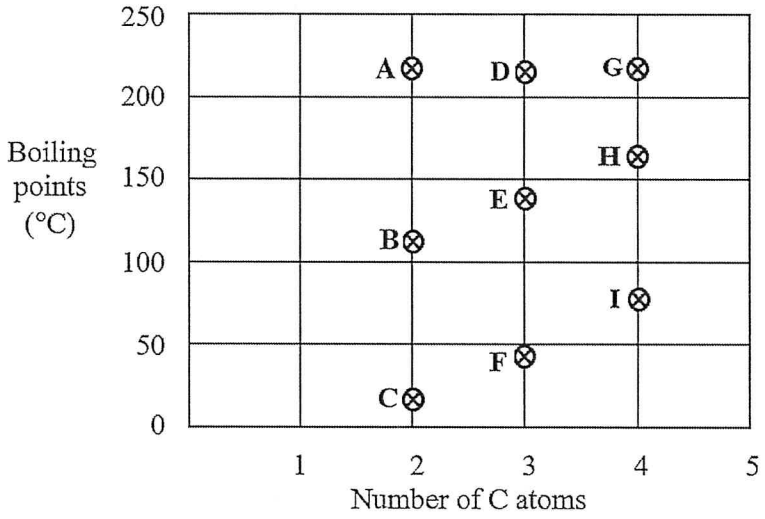
B. A complexation reaction used to identify copper ions

C. A precipitation reaction used to identify copper ions

D. A flame test

13 The graph below shows the boiling points and carbon chain lengths of nine different organic compounds that are represented by the letters A to I.

Three of these compounds are carboxylic acids, three are alkylamines and three are amides.



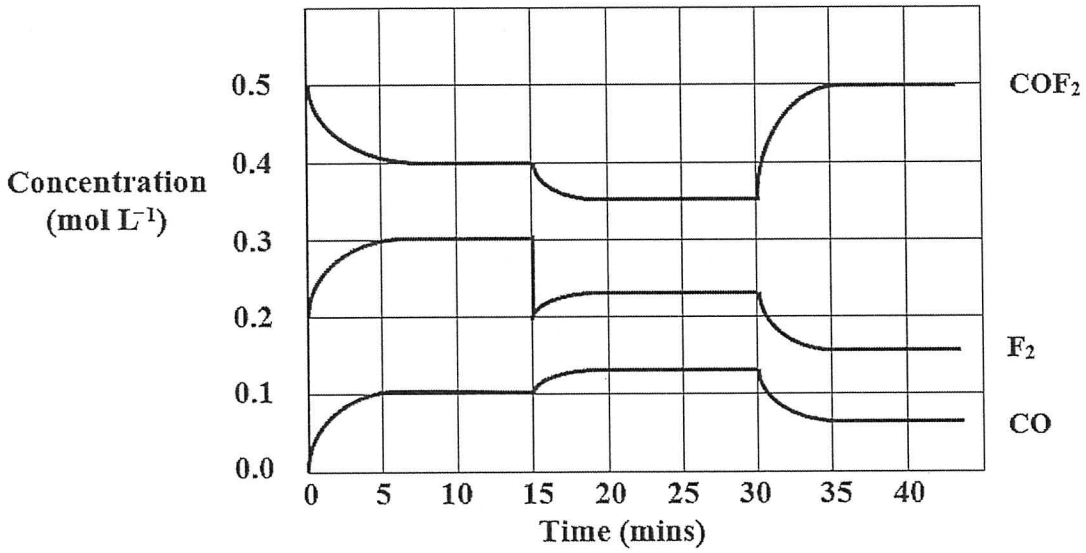
Which of the following correctly identifies the group to which each of the compounds (A to I) belongs?

	Carboxylic acid	*Alkylamine*	*Amide*
A.	D, E, F	A, B, C	G, H, I
B.	A, D, G	B, E, H	C, F, I
C.	B, E, H	C, F, I	A, D, G
D.	C, E, G	A, F, H	B, D, I

14 The gas carbon monoxide reacts with fluorine gas to form the gas carbonyl difluoride, COF_2. The reaction is exothermic.

$$CO(g) + F_2(g) \rightleftharpoons COF_2(g)$$

Scientists studying this reaction measured the concentration of each of these gases in a sealed 2.0 L reaction vessel over a period of time. The results are shown below.



What changes were imposed on this equilibrium at 15 minutes and 30 minutes?

	Change at 15 mins	*Change at 30 mins*
A.	Fluorine gas was removed from the vessel	The temperature of the vessel was decreased
B.	Fluorine gas was removed from the vessel	The temperature of the vessel was increased
C.	The temperature of the vessel was decreased	Carbonyl difluoride gas was added to the vessel
D.	The temperature of the vessel was increased	Carbonyl difluoride gas was added to the vessel

15 The organic compound butanal reacts with acidified potassium permanganate.

Which of the following is correct of this reaction?

	Product	*Oxidation or reduction*	*Colour change*
A.	Butanol	Oxidation	Purple to colourless
B.	Butanone	Reduction	Colourless to purple
C.	Butanoic acid	Oxidation	Colourless to purple
D.	Butanoic acid	Oxidation	Purple to colourless

16 The equation for the iron(III) thiocyanate equilibrium is shown.

$$Fe^{3+} + SCN^{-}(aq) \rightleftharpoons Fe(SCN)^{2+}(aq) \qquad K_{eq} = 110 \text{ at } 500°C$$

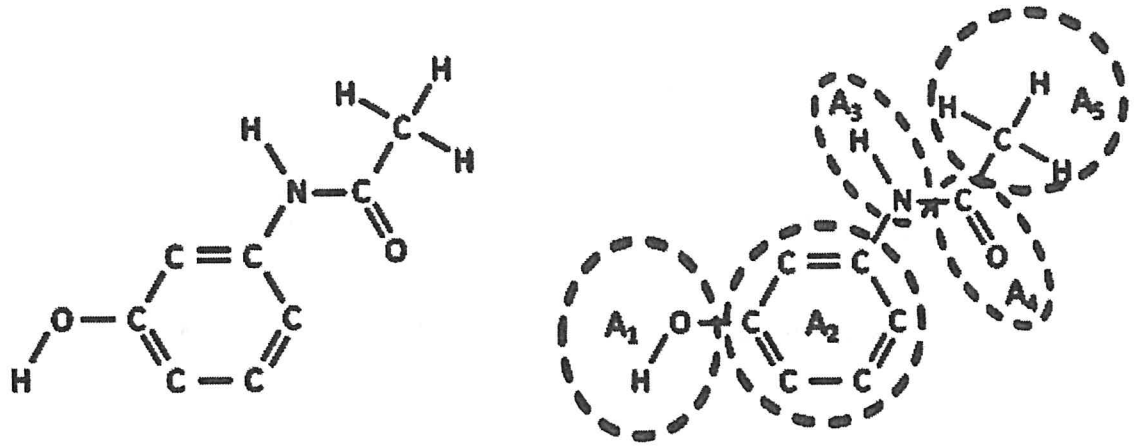
Which of the following is correct when this system is at equilibrium?

	Forward reaction rate	*Concentrations of reactants and product*	*Molecule collisions*
A.	Faster than the reverse reaction rate	Equal	Still occurring
B.	Equals the reverse reaction rate	Not equal	Stopped
C.	Equals the reverse reaction rate	Equal	Still occurring
D.	Equals the reverse reaction rate	Not equal	Still occurring

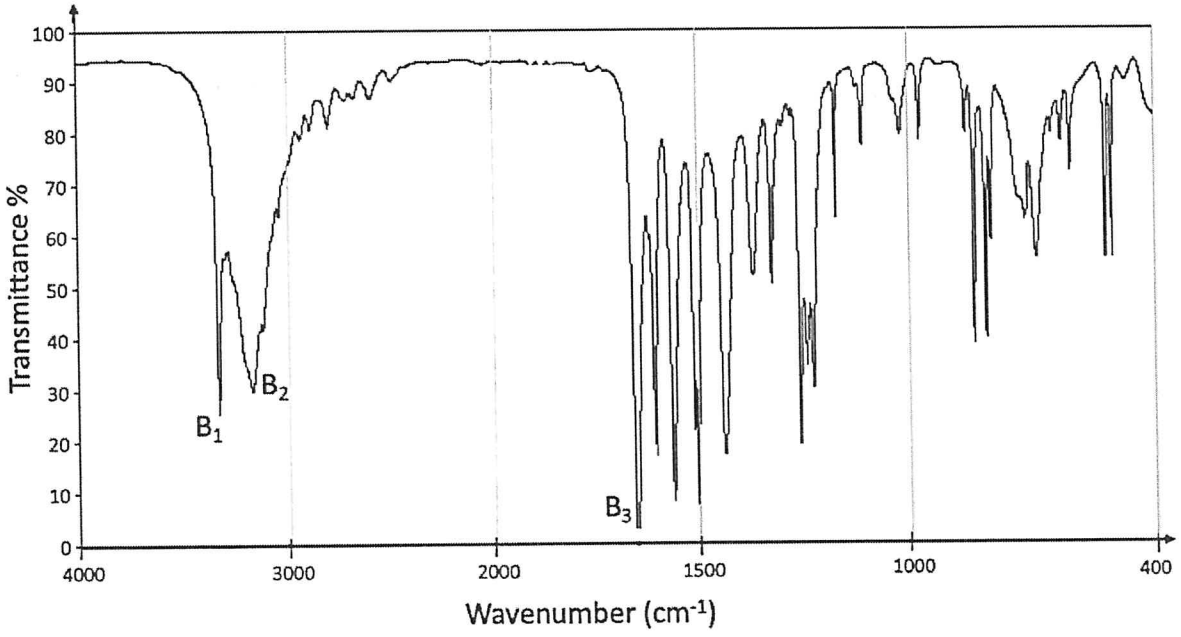
Refer to the following information to answer Questions 17 and 18.

The molecular structure of the medication paracetamol is shown below.

The first structure is unlabelled. The second structure highlights five different areas of the molecule: A_1, A_2, A_3, A_4 and A_5.



Three peaks on the infrared spectrum of paracetamol are labelled below:



17 Which of the areas of the molecule corresponds to peak B_1 in the graph above?

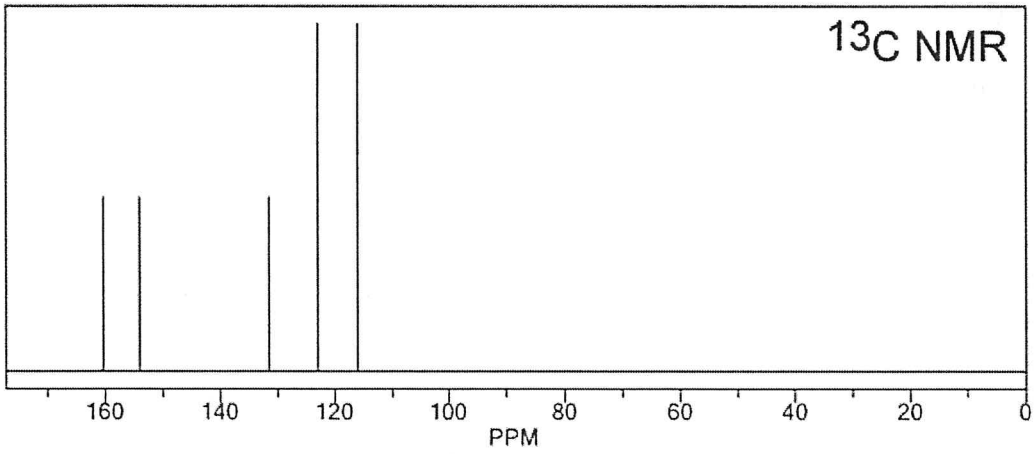
A. A_1

B. A_2

C. A_3

D. A_5

18 The ^{13}C NMR spectrum for paracetamol is shown.



Which of the areas of the molecule corresponds to the peaks in the graph above?

A. A_2

B. A_3

C. A_4

D. A_5

19 A 250.0 mL sample of 0.40 mol L^{-1} hydrochloric acid is added to 750.0 mL of 0.60 mol L^{-1} potassium hydroxide solution.

What is the final concentration of hydroxide ions?

A. 0.30 mol L^{-1}

B. 0.35 mol L^{-1}

C. 0.40 mol L^{-1}

D. 0.45 mol L^{-1}

20 Three chemical formulas are shown below.

Compound A: $CH_3(CH_2)_{15}COONa$

Compound B: $CH_3(CH_2)_5CONH_2$

Compound C: $CH_3(CH_2)_3COCH_3$

What are the names of the chemical groups to which these compounds belong?

	Compound A	*Compound B*	*Compound C*
A.	Soap	Amide	Ketone
B.	Soap	Amine	Aldehyde
C.	Ester	Amine	Ketone
D.	Carboxylic acid	Amide	Aldehyde

STUDENT NUMBER/NAME: .....

Section II

80 marks
Attempt Questions 21–37
Allow about 2 hours and 25 minutes for this section

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

Show all relevant working in questions involving calculations.

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

Question 21 (5 marks) **Marks**

A student makes up a 200.0 mL solution of barium hydroxide. The solution is found to have a pH of 12. The student then adds 0.20 mol L^{-1} hydrochloric acid solution to neutralise the barium hydroxide solution.

(a) Write a balanced equation for the neutralisation reaction. **1**

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(b) Calculate the concentration (in mol L^{-1}) of hydroxide ions in the original solution. **2**

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(c) Calculate the volume of hydrochloric acid required to complete the neutralisation reaction. **2**

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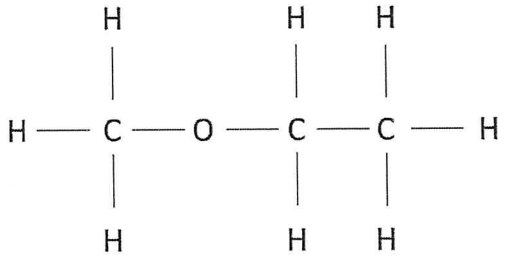
Question 22 (3 marks) **Marks**

The molecule below is named methoxyethane or ethyl methyl ether.



(a) Sketch a 'rectangle' around the ethyl functional group and a 'circle' around the methyl functional group on the above structural formula. **1**

(b) An isomer of methoxyethane is 1-propanol. **2**

Indicate which of these compounds, if any, would have the higher boiling point and justify your choice.

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STUDENT NUMBER/NAME: .....

Question 23 (4 marks) **Marks**

In 1815, the British chemist Sir Humphry Davy put forward the model of an acid as "a substance that contained replaceable hydrogen" while bases were substances that reacted with acids to form salts and water. **4**

The model was found to be too limiting and it was later extended by Svante Arrhenius (1884) and by Bronsted and Lowry (1923).

Compare the Davy model with the Arrhenius model and discuss the development of the Bronsted/Lowry model that is used today.

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Question 24 (5 marks) **Marks**

One litre aqueous solutions of two different acids, *HA* and *HB*, are prepared with each solution containing 1.0×10^{-2} moles of the acid. Upon investigation, the pH of *HA* is 2.0 while the pH of solution *HB* is 4.2.

(a) Describe a safety issue associated with the preparation of acid *HA*. **1**

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(b) Show how the pH of the acid solution *HA* could be mathematically calculated to be 2.0. **1**

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(c) Explain what the results of the pH analysis indicates about the properties of each acid and draw a diagram in the space below to model your explanation. **3**

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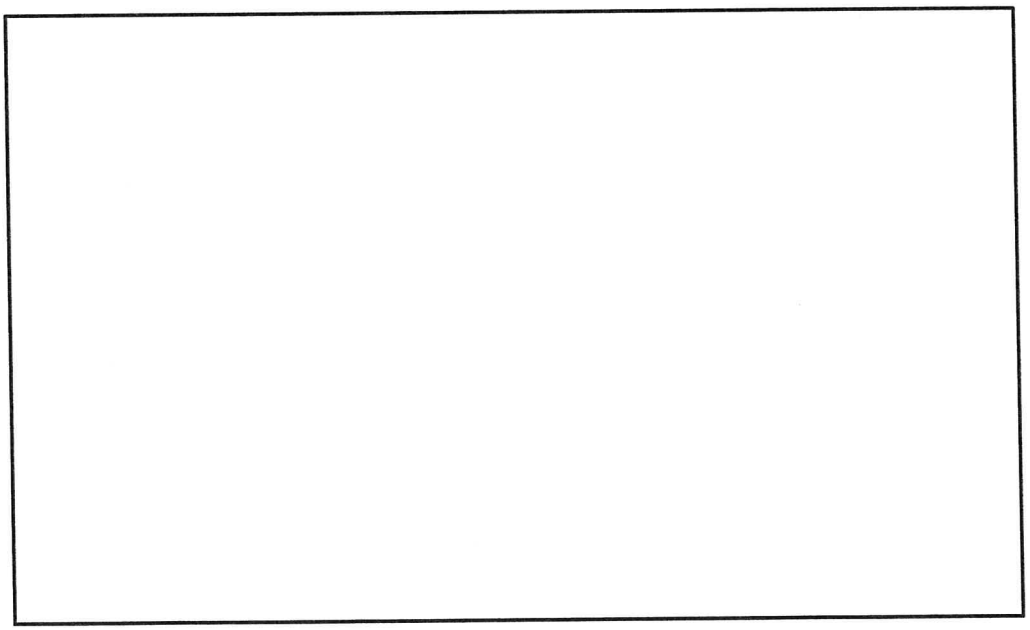

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Question 25 (4 marks) **Marks**

Hydrofluoric acid (HF) ionises in water to give a dissociation constant (K_a) value of 6.8×10^{-4} at 25°C.

(a) Write an equation for the ionisation of hydrofluoric acid in water. **1**

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(b) Calculate the pK_a value for the ionisation of hydrofluoric acid. **1**

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(c) Dissociation pK_a values at 25°C for some common acids are listed below. **2**

Acid	*pKa*
Ammonium ion NH_4^+	9.25
Carbonic acid H_2CO_3	6.35
Ethanoic acid CH_3COOH	4.75
Phosphoric acid H_3PO_4	2.15
Sulfurous acid H_2SO_3	1.82

Discuss the relative strength of hydrofluoric acid.

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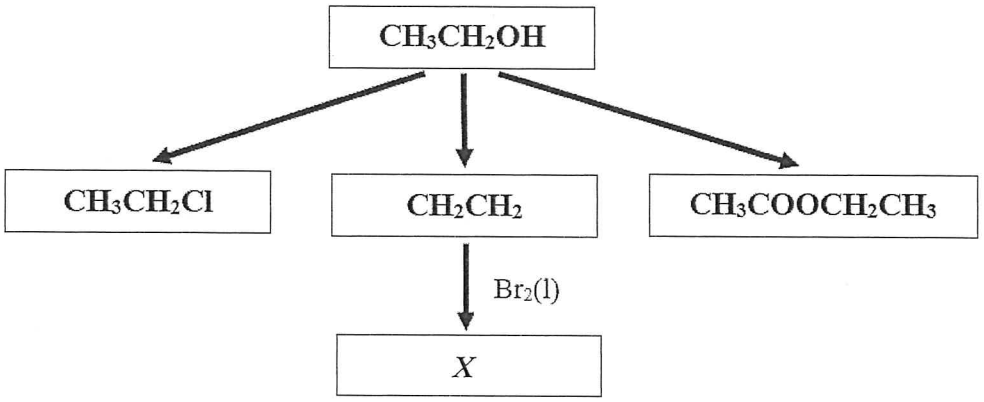
STUDENT NUMBER/NAME: .....

Question 26 (7 marks) **Marks**

The flow chart below shows the production of chloroethane, ethylene (ethene) and ethyl acetate (ethyl ethanoate) from ethanol. Compound X is produced in an additional reaction.



(a) Describe the arrangement of atoms in an ethylene molecule and its shape. **2**

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(b) Outline the reagents and conditions required for the production of chloroethane, ethylene (ethene) and ethyl acetate (ethyl ethanoate) from ethanol. **3**

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(c) Identify compound *X* and write an equation that represents its production. **2**

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STUDENT NUMBER/NAME: .....

Question 27 (5 marks) **Marks**

During the course, you conducted a practical investigation to collect primary data to compare the enthalpy of combustion for a range of alcohols.

(a) Describe the method followed, measurements and steps taken to ensure this investigation was valid. **3**

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(b) The enthalpy of combustion of methanol is -726 kJ mol^{-1}. **2**

Calculate the theoretical maximum mass of water that can be heated from 10°C to 25°C, using the combustion of 2.00 grams of methanol.

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STUDENT NUMBER/NAME: .....

Question 28 (5 marks) **Marks**

Hydrogen gas and iodine gas react to form an equilibrium with hydrogen iodide gas according to the following equation. The reaction is exothermic.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(a) A sample of 0.0123895 mol of hydrogen gas was inserted into a 1.0 L closed container of 0.0087805 mol of iodine gas at 458°C. After equilibrium was achieved, the concentration of hydrogen iodide was found to be 0.0154450 mol L^{-1}. **3**

Calculate the equilibrium constant for this reaction.

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(b) What effect would a decrease in temperature have on the equilibrium constant calculated in (a)? **1**

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(c) What effect would a decrease in pressure have on the equilibrium constant calculated in (a)? **1**

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STUDENT NUMBER/NAME: .....

Question 29 (7 marks) **Marks**

Ethanol can be produced by the fermentation of glucose.

(a) Write a balanced chemical equation for the fermentation of glucose. **1**

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(b) Identify and justify the experimental conditions required for the fermentation of glucose. **3**

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(c) Calculate the theoretical maximum mass of ethanol that can be produced by the fermentation of 5.00 grams of glucose. **2**

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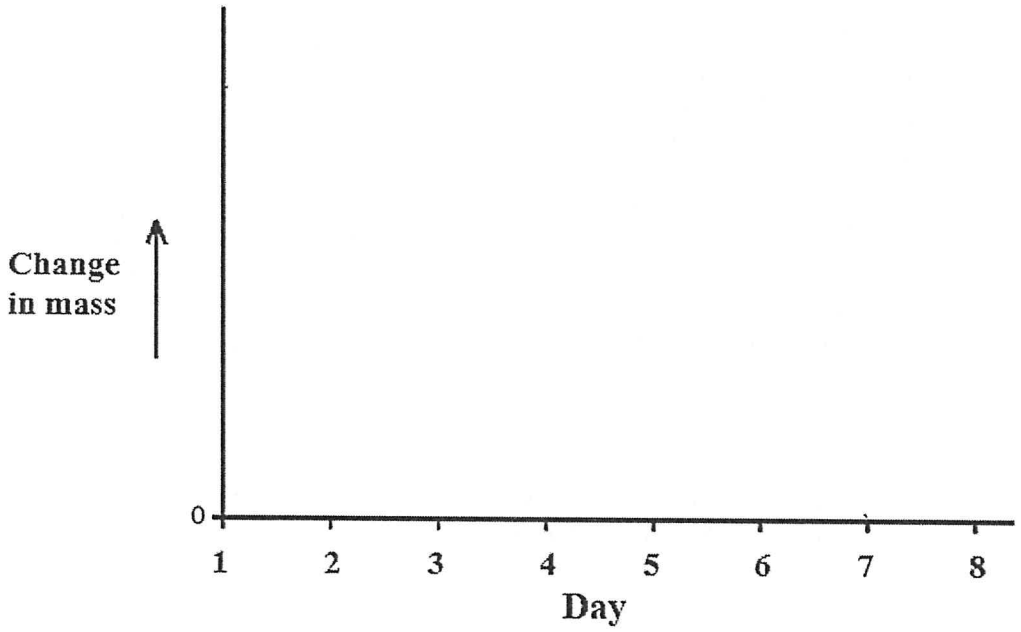
Question 29 continues on the next page

Question 29 continued

(d) An experiment was conducted to ferment the 5.00 g of glucose. **1**

The change in mass of the experimental apparatus was monitored each day for 8 days until it was determined that the fermentation process was complete.

On the axes provided, sketch a graph of the recorded change in mass that should have occurred over the 8 days of the experiment.



End of Question 29

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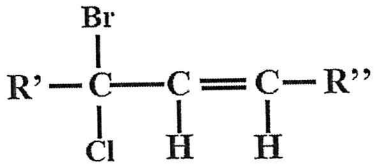
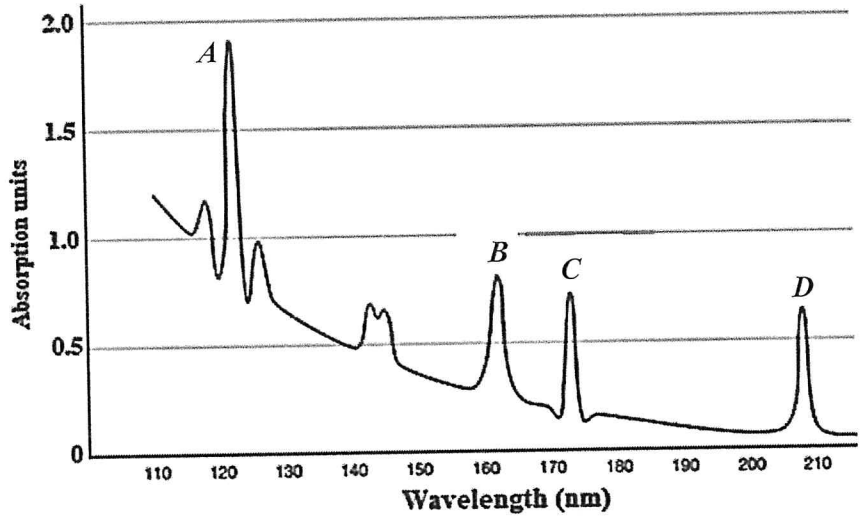
Question 30 (4 marks) **Marks**

The structural formula of a molecule of an organic compound is shown below. R' and R'' are unknown functional groups.



Part of the ultraviolet spectrum of this molecule is also shown.



(a) Using information supplied on your data sheet identify the chromophores represented by the peaks labelled *A*, *B*, *C* and *D* on this spectrum. **2**

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(b) Outline how a sample of this compound would be tested to determine its concentration in a solution. **2**

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Question 31 (5 marks) **Marks**

To avoid eye and skin irritations for bathers, swimming pools are maintained within a pH range of 7.2 to 7.8. To help achieve this pH range a chemical such as sodium hydrogen carbonate ($NaHCO_3$) may be added to the water.

(a) What physical property of sodium hydrogen carbonate makes it suitable for use in swimming pool water? **1**

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(b) Define the role of a "buffer" in an aqueous environment. **1**

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(c) Explain how sodium hydrogen carbonate would act as a suitable buffer in a swimming pool. Provide equations to support your answer. **3**

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Question 32 (7 marks) **Marks**

The following table shows the solubility of four salts.

Salt	*Formula*	*Solubility at 25°C (g/100 mL)*
Silver nitrate	$AgNO_3$	256
Magnesium nitrate	$Mg(NO_3)_2$	125
Magnesium chloride	$MgCl_2$	54.3
Silver chloride	AgCl	5.2×10^{-4}

(a) Write an equation, including states, that represents the dissociation of magnesium nitrate powder in water. **1**

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(b) Explain, in terms of bonding, the different solubilities of silver nitrate and sliver chloride. **2**

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(c) Write an equation, including states, that represents the reaction between solutions of magnesium chloride and silver nitrate. **1**

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(d) The K_{sp} of silver chloride is 1.8×10^{-10}. **3**

Use calculations to decide if a precipitate will form when 100 mL of 0.0012 mol $AgNO_3$ is reacted with 150 mL of 3.0×10^{-4} mol L^{-1} $MgCl_2$.

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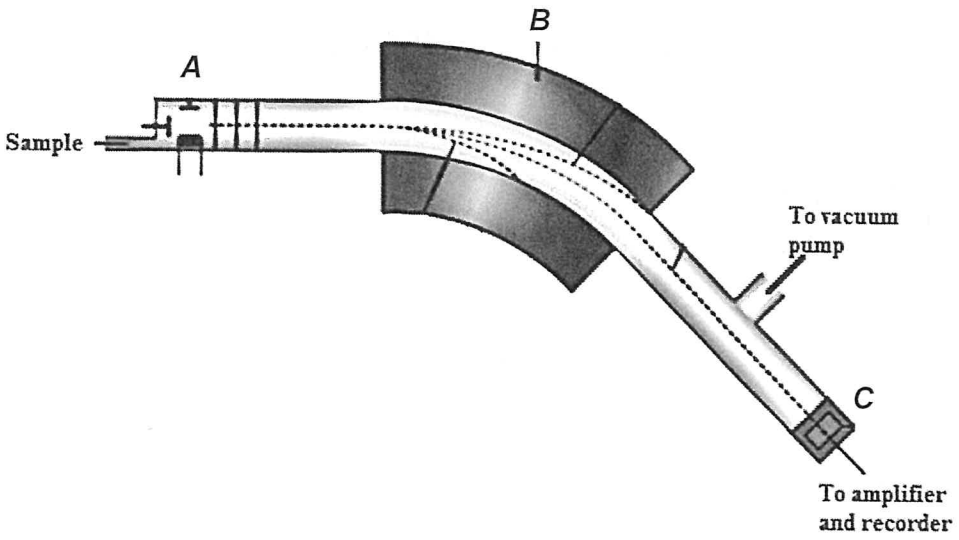
Question 33 (4 marks) **Marks**

The diagram below is a simplified representation of a mass spectrometer.



Identify parts *A*, *B* and *C* in this diagram and refer to their functions in explaining how a mass spectrometer can be used to analyse the structure of organic compounds. **4**

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Question 34 (3 marks) **Marks**

The combustion of magnesium using a Bunsen burner can be represented by the following equation.

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

(a) Explain in terms of entropy and enthalpy why this reaction is considered a non-equilibrium system. **2**

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(b) This reaction has a relatively high activation energy. **1**

Explain how this would affect the reaction's ability to reach equilibrium.

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STUDENT NUMBER/NAME: .....

Question 35 (4 marks) **Marks**

(a) Polyethylene is an addition polymer made from ethene monomers. **1**

Explain why, at room temperature, polyethylene is a solid while ethene is a gas.

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(b) Choose a DIFFERENT addition polymer to polyethylene and compare its structure and properties to a named condensation polymer. **3**

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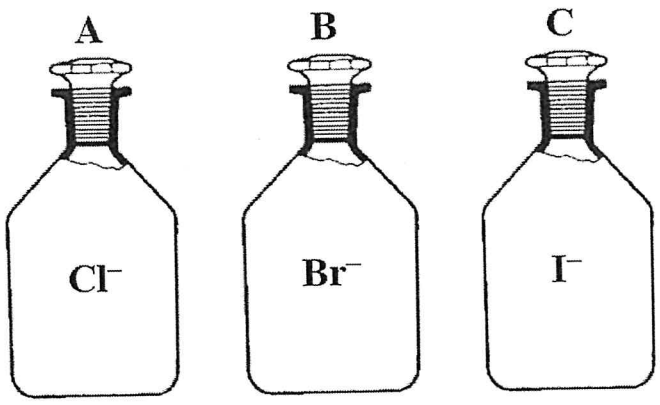
Question 36 (3 marks) **Marks**

Bottles A, B and C contain aqueous solutions of chloride (Cl^-), bromide (Br^-) and iodide (I^-) ions respectively. **3**



Describe chemical tests that could identify which bottle contains which anion.

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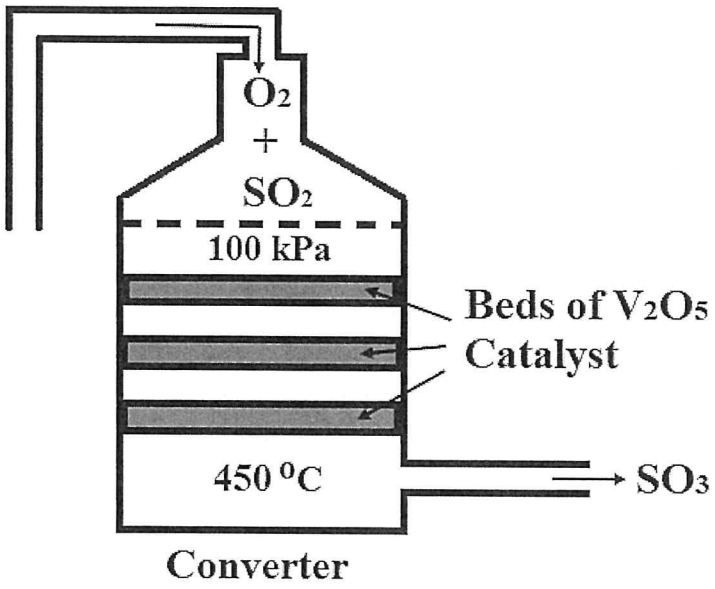
Question 37 (5 marks) **Marks**

Sulfur dioxide and oxygen react to form sulfur trioxide in a specially designed reaction vessel called a converter. **5**



The reaction between sulfur dioxide and oxygen that produces sulfur trioxide is exothermic and any unreacted gases are recycled.

The reaction conditions inside the vessel are a compromise between maximising the rate of production and maximising the equilibrium yield of sulfur trioxide.

Explain and evaluate the factors that have to be considered during the design of this synthesis reaction. Include a balanced chemical equation in your answer.

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Question 37 (continued)

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NSW INDEPENDENT TRIAL EXAMS – 2020
CHEMISTRY TRIAL HSC EXAMINATION
MARKING GUIDELINES

Section I

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

Section I

Question 21(a)

Criteria	Mark
• Writes a correctly balanced equation	1

Sample answer: $Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$

Question 21(b)

Criteria	Mark
• Correctly calculates the pOH of the solution • Correctly calculates the hydroxide ion concentration	2
• Correctly calculates the pOH of the solution	1

Sample answer:
$pOH + pH = 14$
$\therefore pOH = 14 - 12 = 2$
$\therefore [OH^-] = 10^{-2} = 0.01 \text{ mol } L^{-1}$

Question 21(c)

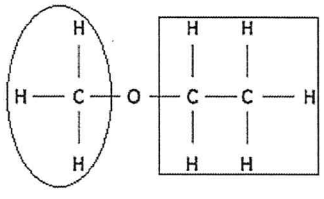
Criteria	Mark
• Correctly calculates the volume of acid required	2
• Substitutes values into the correct formula	1

Sample answer:
$c_1V_1 = c_2V_2$
$0.01 \times 0.2 = 0.2 \times V_2$
$\therefore V_2 = 0.01 \text{ L}$ (10.0 mL of acid)

Question 22(a)

Criteria	Mark
• Sketches a 'rectangle' around the ethyl functional group and a 'circle' around the methyl functional group on the structural formula of methoxyethane	1

Sample answer:



Question 22(b)

Criteria	Mark
• Indicates that 1-propanol has a higher boiling point than methoxyethane and correctly justifies this choice	2
• Indicates that 1-propanol has a higher boiling point than methoxyethane	1

Sample answer: 1-propanol has a hydroxyl functional group and is therefore capable of hydrogen bonding with itself. Methoxyethane has an ether functional group which cannot establish hydrogen bonds making its intermolecular bonds weaker. As a result, the boiling point of methoxyethane will be significantly lower than that of 1-propanol. (NB: Bp of 1-propanol is 97°C and 7.6°C for methoxyethane.)

Question 23

Criteria	Mark
• Outlines each of the models proposed by Davy and Arrhenius • Compares the Davy model with the Arrhenius model • Outlines the model proposed by Bronsted/Lowry • Provides a reason for the development of the Bronsted/Lowry model	4
• Outlines at least TWO of the models proposed by Davy, Arrhenius and Bronsted/ Lowry • Compares the Davy model with the Arrhenius model • Provides a reason for the development of the Bronsted/Lowry model OR • Outlines each of the models proposed by Davy, Arrhenius and Bronsted/Lowry • Compares the Davy model with the Arrhenius model OR provides a reason for the development of the Bronsted/Lowry model	3
• Makes a correct statement about TWO of the models and provides a reason for the development of the Bronsted/Lowry model	2
• Makes a correct statement about TWO of the models OR provides a reason for the development of the Bronsted/Lowry model	1

Sample answer: Davy had proposed that it was the hydrogen that gave the acid its properties. He proposed that an acid contained hydrogen that could be replaced by a metal.

Arrhenius explained that the property of an acid was determined by the way it behaved in aqueous solutions. He described that an acid ionised in solution to produce hydrogen ions while a base ionised in solution to produce hydroxide ions.

However, this model could not explain why ammonia was a base in aqueous solutions nor the fact that not all acids and bases reacted together to produce neutral solutions.

Bronsted/Lowry put forward the concept that an acid was a substance that could donate a proton while a base was a substance that could accept a proton. This overcame the limitations of the Davy and Arrhenius models of acids and bases in aqueous solutions.

Question 24(a)

Criteria	Mark
• Provides a relevant safety issue associated with acid HA	1

Sample answer: HA is a strong acid. When preparing acidic solutions, the acid is always added slowly to the water and not the other way around, so that the heat produced is dissipated slowly and there is no "spitting" of acid.

Question 24(b)

Criteria	Mark
• Shows a correct mathematical statement of how the pH was determined by using a formula	1

Sample answer: $pH = -\log_{10}[H^+] = -\log_{10}(10^{-2}) = 2$

Question 24(c)

Criteria	Mark
• Explains the results of the pH analysis and provides a suitable diagram	3
• Describes the results of the pH analysis and provides a suitable diagram	2
• Describes a result OR provides a suitable diagram	1

Sample answer: As both solutions contain the same number of moles of acid (1.0×10^{-2}), HA must have undergone a much greater ionisation with water to produce more hydronium ions and give a lower pH value compared to HB.

$HA + H_2O(l) \rightarrow H_3O^+(aq) + A^-(aq)$	$HB + H_2O(l) \rightleftharpoons H_3O^+(aq) + B^-(aq)$
H_3O^+ H_3O^+ A^- A^- H_3O^+ A^- H_3O^+ A^-	HB H_3O^+ HB H_3O^+ B^- HB HB B^-

Question 25(a)

Criteria	Mark
• Writes a correctly balanced equation for the ionisation of HF	1

Sample answer: $HF(aq) + H_2O(l) \rightarrow H_3O^+(aq) + F^-(aq)$

Question 25(b)

Criteria	Mark
• Calculates the pK_a value for the ionisation of HF	1

Sample answer: $pK_a = -\log_{10}(K_a) = -\log_{10}(6.8 \times 10^{-4}) = 3.17$

Question 25(c)

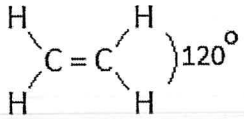
Criteria	Mark
• Discusses the relative strength of HF compared to other acids in the table	2
• Makes a relevant statement about the relative strength of HF	1

Sample answer: The pK_a value for HF lies between ethanoic acid and phosphoric acid. As the values for pK_a decrease the strength of the acid increases. Therefore, hydrofluoric acid is a stronger acid than ethanoic acid but is a weaker acid than phosphoric acid.

Question 26(a)

Criteria	Marks
• Correctly describes the arrangement of atoms in, and the planar shape of the ethylene molecule	2
• Correctly describes the arrangement of atoms in the ethylene molecule OR • Correctly describes the planar shape of the ethylene molecule	1

Sample answer: Ethylene is a planar molecule containing 2 carbon and 4 hydrogen atoms all in the same plane. There is a double covalent bond between the two carbon atoms. The H – C – H bond angle is approximately 120°.



Question 26(b)

Criteria	Marks
• Outlines the reagents and conditions required for the production of all THREE compounds	3
• Outlines the reagents and conditions required for the production of TWO of the compounds OR • Outlines the reagents required for the production of all THREE compounds	2
• Outlines the reagents and conditions required for the production of ONE of the compounds OR • Outlines the reagents required for the production of TWO of the compounds	1

Sample answer: The production of chloroethane requires ethanol to be heated with concentrated HCl in the presence of a catalyst (zinc chloride). The production of ethene requires ethanol to be heated in the presence of concentrated sulfuric acid. The production of ethyl acetate requires ethanol to be heated with acetic acid in the presence of concentrated sulfuric acid. *(Note* – other reactants and conditions may also be suitable for these reactions).

Question 26(c)

Criteria	Marks
• Identifies compound X as 1,2-dibromoethane and writes a correct equation that represents its production	2
• Identifies compound X as 1,2-dibromoethane OR writes a correct equation that represents its production	1

Answer: Compound X is 1,2-dibromoethane.

$C_2H_4(g) + Br_2(l) \rightarrow C_2H_4Br_2(l)$

Question 27(a)

Criteria	Marks
• Describes a complete method that includes: – Equipment used – Measurements made (amount of water heated, temperature change, mass of burner before and after) • Outlines at least THREE clear steps taken to ensure validity	3
• Describes a method that includes some equipment and measurements and outlines at least TWO steps to ensure validity	2
• Describes a method that includes some equipment OR measurements and makes a correct statement about validity	1

Sample answer: 200 mL of water was placed in a conical flask and heated by 10°C using a spirit burner containing an alcohol fuel. The mass of the spirit burner was recorded before and after burning to determine the mass of fuel combusted and the temperature of the water was recorded before and after heating using a thermometer. This process was repeated using the same fuel.

The mass of fuel required per degree of increased temperature was calculated to compare the enthalpies of combustion of the fuels.

The above method was then repeated using a number of different alcohol fuels.

Steps taken to ensure validity included:

- Using the same equipment for each experiment
- Always keeping the same distance between the spirit burner and the base of the conical flask
- Heating the same amount of water with each fuel
- In each step of the experiment using water with the same initial temperature
- Heating each water sample by the same amount (10°C increase)
- Repeating the experiment for each fuel to ensure reliability

Question 27(b)

Criteria	Marks
• Correctly calculates the theoretical maximum mass of water that can be heated	2
• Makes ONE correct calculation based on a formula	1

Answer:

n methanol (CH_3OH) = m/M = 2.0/(12.01 + 4.032 + 16) = 0.06241807627

$\therefore$ heat produced = 726 × 0.06241807627 = 45.31552338 kJ

$\Delta H = -mC\Delta T$

45 315.52338 J = m × 4.18 × 10^3 × 15

$\therefore$ m = 45 315.52338/62 700 = 0.723 kg (723 g)

Question 28(a)

Criteria	Mark
• Correctly calculates the equilibrium constant for the reaction to the correct number of significant figures	3
• Correctly calculates the equilibrium constant for the reaction	2
• Uses a correct calculation for the reaction	1

Answer:

	[H]	[I]	[HI]
I	0.0123895	0.0087805	0.0
C	–0.0077225	–0.0077225	+0.0154450
E	0.0046670	0.0010580	0.0154450

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.0154450)^2}{0.0046670 \times 0.0010580} = \frac{0.000238548}{00.0000049377} = 48.312$$

Question 28(b)

Criteria	Mark
• States a correct effect that a decrease in temperature would have on the equilibrium constant calculated in (a)	1

Answer: It would increase.

Question 28(c)

Criteria	Mark
• States a correct effect that a decrease in pressure would have on the equilibrium constant calculated in (a)	1

Answer: No effect

Question 29(a)

Criteria	Marks
• Writes a correct balanced equation for fermentation	1

Sample answer: $C_6H_{12}O_6(aq) \longrightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

Question 29(b)

Criteria	Marks
• Identifies and justifies at least THREE conditions required for fermentation	3
• Identifies and justifies at least TWO conditions required for fermentation	2
• Identifies and explains ONE condition required for fermentation OR • Identifies at least THREE conditions required for fermentation	1

Sample answer: (minimum of three required) …

1. Anaerobic conditions (no oxygen) to prevent the ethanol produced from undergoing further reactions.
2. The presence of yeast to supply the enzymes necessary to catalyse the fermentation reaction.
3. Warm temperatures (25–30°C depending on the yeast used). Yeast is a living organism that requires a particular temperature range for it to live and function efficiently.
4. Aqueous conditions. Yeast requires the glucose to be dissolved in water for fermentation to take place.

Question 29(c)

Criteria	Marks
• Correctly calculates the maximum mass of ethanol produced by the fermentation of 5.00 grams of glucose	2
• Calculates a mass of ethanol by applying at least one correct formula	1

Sample answer:

Formula of glucose is $C_6H_{12}O_6$

$n = m/M = 5.00/180.156 = 0.02775$ mol glucose

2 mol C_2H_5OH produced for every 1 mol glucose fermented

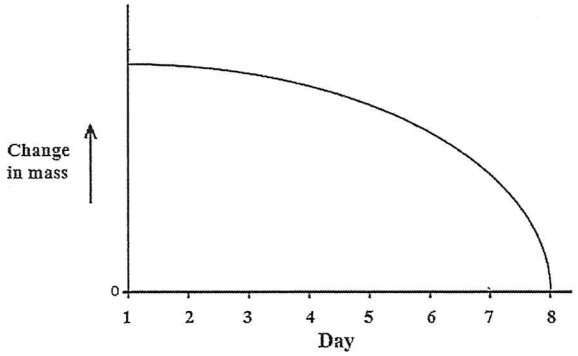
Therefore 0.05550 mol C_2H_5OH produced

$m = n \times M = 0.05550 \text{ mol} \times 46.068 \text{ g mol}^{-1} = 2.56$ g ethanol produced

Question 29(d)

Criteria	Marks
• Sketches a simple graph showing how the change in mass should have occurred over the 8 days of the experiment	1

Sample answer:



Question 30(a)

Criteria	Mark
• Correctly identifies the chromophores represented by the peaks labelled A, B, C and D on this spectrum	2
• Correctly identifies at least TWO of the chromophores represented by the peaks labelled A, B, C and D on this spectrum	1

Sample answer: Peak A is the C-H chromophore. Peak B is the C=C chromophore. Peak C is the C-Cl chromophore and peak D is the C-Br chromophore.

Question 30(b)

Criteria	Mark
• Identifies a suitable testing instrument for determining concentration • Outlines how the concentration of a sample of this compound would be determined by making at least THREE relevant points	2
• Identifies a suitable testing instrument for determining concentration OR • Outlines how the concentration of a sample of this compound would be determined by making at least TWO relevant points	1

Sample answer: A UV spectrum from a sample such as the compound indicated would normally be tested with a UV spectrophotometer or a colourimeter. An outline of the general process is:

1. Select a wavelength filter that corresponds to a wavelength of light that is most strongly absorbed by the sample.
2. Prepare and measure the absorbance of a series of 'standard' solutions of known concentration.
3. Plot a calibration curve of absorbance versus concentration for the standard solutions.
4. Place the sample into the spectrometer and measure its absorbance.
5. Use the calibration curve to determine its concentration.

Question 31(a)

Criteria	Mark
• Identifies a relevant physical property of $NaHCO_3$ for use in a pool	1

Sample answer: Sodium hydrogen carbonate is very soluble in water.

Question 31(b)

Criteria	Mark
• Correctly defines the role of a buffer in an aqueous environment	1

Sample answer: A buffer is a substance which resists a change in pH when a small amount of an acid or a base is added to an aqueous system. It allows for a relatively stable pH range.

Question 31(c)

Criteria	Mark
• Explains how sodium hydrogen carbonate acts as a buffer • Provides suitable equations	3
• Describes how sodium hydrogen carbonate acts as a buffer • Provides a suitable equation	2
• Describes how sodium hydrogen carbonate acts as a buffer OR • Provides a suitable equation	1

Sample answer: Buffers normally consist of a weak acid and its conjugate base. The sodium hydrogen carbonate dissolves in water to produce the hydrogen carbonate ion $HCO_3^-(aq)$. If the solution has an input of acid, the buffer reacts with the excess to increase the pH, based on Le Chatelier's principle.

$$H^+(aq) + HCO_3^-(aq) \rightarrow H_2CO_3(aq) \rightarrow H_2O(l) + CO_2(aq)$$

If the solution has an input of base, the buffer reacts with the excess to decrease the pH, based on Le Chatelier's principle.

$$OH^-(aq) + HCO_3^-(aq) \rightarrow H_2O(l) + CO_3^{2-}(aq)$$

Question 32(a)

Criteria	Mark
• Writes a correct equation, including states, that represents the dissociation of magnesium nitrate powder in water	1

Answer: $Mg(NO_3)_2(s) \rightarrow Mg^{2+}(aq) + 2NO_3^-(aq)$

Question 32(b)

Criteria	Mark
• Correctly explains, in terms of bonding, the different solubilities of silver nitrate and silver chloride	2
• Makes a correct statement, in terms of bonding, about the different solubilities of silver nitrate and silver chloride	1

Sample answer: Whether or not an ionic solute will dissolve in water depends on whether it can establish strong interactions with water molecules.

Silver nitrate is highly soluble because its ions establish strong ion–dipole forces with polar water molecules so that the ionic bonds in the solute's ionic lattice are broken.

Silver chloride is insoluble because even though its ions establish ion–dipole forces with polar water molecules, these forces are not strong enough to disrupt the solute's ionic lattice.

Question 32(c)

Criteria	Mark
• Write a correct equation, including states, that represents the reaction between magnesium chloride and silver nitrate	1

Answer: $MgCl_2(aq) + 2AgNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + 2AgCl(s)$

Question 32(d)

Criteria	Mark
• Uses correct and logical calculations to decide that a precipitate will form	3
• Uses some correct calculations and decides if a precipitate will form	2
• Makes a calculation(s) that indicates an understanding of Q_{sp} and/or K_{sp}	1

Answer:

n Ag^+ in AgCl = c × V = 0.0012 × 0.1 = 1.2×10^{-4}

∴ $[Ag^+]$ in mixture = $1.2 \times 10^{-4}/0.25 = 4.8 \times 10^{-4}$

n $MgCl_2$ = c × V = $3.0 \times 10^{-4} \times 0.15 = 4.5 \times 10^{-5}$

∴ n Cl^- = $4.5 \times 10^{-5} \times 2 = 9.0 \times 10^{-5}$

∴ $[Cl^-]$ in mixture = $9.0 \times 10^{-5}/0.25 = 3.6 \times 10^{-4}$

$Q_{sp} = [Ag^+] \times [Cl^-] = 4.8 \times 10^{-4} \times 3.6 \times 10^{-4} = 1.7 \times 10^{-7}$

$Q_{sp} > K_{sp}$

∴ A precipitate will form.

Question 33

Criteria	Mark
• Identifies parts A, B and C in the diagram • Indicates the functions of parts A, B and C in the diagram • Correctly explains how a mass spectrometer analyses the structure of organic compounds	4
• Identifies at least TWO of parts A, B and C in the diagram • Indicates the functions of at least two parts A, B and C in the diagram • Makes a correct statement about how the instrument works	2–3
• Names at least ONE of the parts A, B or C correctly and makes a correct statement about how the instrument works	1

Sample answer:
Part A is the ionisation chamber.
Part B is an electromagnet.
Part C is the ion detector.

A vaporised sample of the compound to be tested is injected into the ionisation chamber (A). The sample is exposed to high voltages and forms positive ions which are accelerated and pass through a magnetic field (B), where they are separated on the basis of their mass-to-charge ratio (m/z). The number of ions with different m/z values are measured by a detector (C), and the data is displayed as a mass spectrum.

Question 34(a)

Criteria	Mark
• Correctly explains in terms of entropy and enthalpy why this reaction is considered a non-equilibrium system	2
• Correctly explains in terms of entropy OR enthalpy why this reaction is considered a non-equilibrium system	1

Sample answer: This reaction is exothermic and has a high negative ΔH. Its entropy is negative (more ordered) because 3 moles react to form 2 moles. For a reaction to reach equilibrium ΔG must equal zero. In this case, the enthalpy change is considerably larger than $T\Delta S$ so that in the formula $\Delta G = \Delta H - T\Delta S$, ΔG will have a high negative value. An equilibrium will therefore, not form, especially in an open system.

Question 34(b)

Criteria	Mark
• Correctly explains how a high activation energy affects the reaction's ability to reach equilibrium	1

Sample answer: In a reversible reaction, the reactants must have enough energy to overcome the forward E_A and at the same time the product molecules must also have enough energy to overcome the reverse E_A. A reversible reaction is more likely to occur if the difference between the activation energies of the forward and reverse reactions is relatively small. In this reaction the difference is large.

Question 35(a)

Criteria	Marks
• Explains why, at room temperature, polyethylene is a solid while ethene is a gas by referring to intermolecular bonding	1

Sample answer: Polyethylene molecules are nonpolar but have a high to very high molecular mass. This creates relatively strong dispersion forces between molecules allowing it to be in a solid state at room temperature.

Ethene molecules are also non-polar but have a very low molecular mass. This creates weak dispersion forces between molecules and therefore it is found as a gas at room temperature.

Question 35(b)

Criteria	Marks
• Identifies an addition polymer (not polyethylene) and a condensation polymer and correctly compares their structure and properties	3
• Identifies an addition polymer (not polyethylene) and a condensation polymer and correctly compares their structure OR properties	2
• Identifies an addition polymer (not polyethylene) and a condensation polymer OR • Makes a correct statement that distinguishes addition polymerisation from condensation polymerisation	1

Sample answer: Polyvinyl chloride is an addition polymer. It has a linear backbone of carbon atoms but on every other carbon in the backbone chain, one of the hydrogen atoms is replaced with a chlorine atom.

These chlorine atoms add polarity to the molecule and so pure PVC tends to be a stiffer and less flexible plastic. It is very resistant to chemical attack.

Polyethylene terephthalate is a condensation polymer made from the esterification reaction between different monomers (terephthalic acid and ethanediol). It has a backbone of polar oxygen atoms between some of the carbon atoms due to the presence of ester groups. These oxygen atoms help strengthen this polyester plastic. It is a transparent polymer with elastic properties and a good resistance to attack by acids.

Question 36

Criteria	Mark
• Describes chemical tests that clearly identify the three separate anions	3
• Describes chemical tests that clearly identify TWO separate anions	2
• Describes a chemical test that clearly identifies an anion OR makes a correct statement about how the ions could be separately identified	1

Sample answer: Add a silver nitrate solution to each of the ions separately. All three anions form a precipitate with Ag(aq). Dilute nitric acid is then added separately to each precipitate. If the precipitate turns white the ion is Cl^-. If the precipitate turns off white (cream) the ion is Br^- and if the precipitate turns pale yellow the ion is I^-.

(*Note:* several other methods could be used, e.g. adding concentrated H_2SO_4 in a fume cupboard OR electrolysis and observing the colours produced).

Question 37

Criteria	Mark
• Evaluates at least three factors that have to be considered during the design of this reaction • Explains the relevance of Le Chatelier's principle in this reaction • Explains why a catalyst is used • Includes a relevant balanced chemical equation	4–5
• Evaluates at least TWO factors that have to be considered during the design of this reaction • Makes a relevant reference to Le Chatelier's principle AND • Explains why a catalyst is used OR • Includes a relevant balanced chemical equation	2–3
• Makes a correct statement about a factor that has to be considered during the design of this reaction OR • Includes a relevant balanced chemical equation	1

Sample answer: The equation for the reaction between sulfur dioxide and oxygen to produce sulfur trioxide is: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$.

Le Chatelier's principle indicates that if an equilibrium reaction is disturbed the reaction will proceed in the direction that minimises that disturbance. In this reaction, as there are more moles of gas on the reactant side of the equation, the production of sulfur trioxide is favoured by higher pressures. However, operating a reaction vessel above atmospheric pressure is potentially dangerous and expensive and so the reaction is carried out at 100 kPa.

Again, applying Le Chatelier's principle, as the reaction is exothermic, the equilibrium yield of sulfur trioxide is maximised at low temperatures. However, low temperatures result in a very slow rate of reaction. This is uneconomic, and so a compromise temperature of 450°C is used.

The large surface area of the beds of vanadium oxide catalyst is used to increase the rate of the reaction and also to balance the need for a lower temperature. Unreacted gases are recycled into the reaction vessel and this tends to increase the concentration of the reactants. Again, by Le Chatelier's principle this pushes the equilibrium further toward the right i.e. increasing the yield of sulfur trioxide. Ultimately, the design of this synthesis reaction produces a satisfactory yield.

NSW INDEPENDENT TRIAL EXAMS – 2020
CHEMISTRY TRIAL HSC EXAMINATION
MAPPING GRID

Question	Marks	Content	Syllabus Outcomes	Target performance bands
Section I				
1	**1**	Mod 7 Polymers	12-14	2-3
2	**1**	Mod 6 Properties of acids and bases Mod 6 Quantitative analysis	12-2, 12-4, 12-13	3-4
3	**1**	Mod 5 Solution equilibria	12-12	3-4
4	**1**	Mod 5 Factors that affect equilibrium	12-5, 12-6, 12-12	4
5	**1**	Mod 5 Calculating the equilibrium constant	12-1, 12-4, 12-12	3
6	**1**	Mod 6 Quantitative analysis	12-5, 12-13	3-5
7	**1**	Mod 6 Using Bronsted-Lowry theory	12-6, 12-13	4
8	**1**	Mod 7 Nomenclature	12-4, 12-14	3-4
9	**1**	Mod 6 Using Bronsted-Lowry theory	12-5, 12-13	3-4
10	**1**	Mod 6 Quantitative analysis	12-5, 12-13	3-4
11	**1**	Mod 7 Nomenclature	12-4, 12-7, 12-14	3-4
12	**1**	Mod 8 Analysis of inorganic substances	12-4, 12-15	5
13	**1**	Mod 7 Hydrocarbons Mod 7 Reactions of organic acids and bases	12-5, 12-14	4-5
14	**1**	Mod 5 Factors that affect equilibrium	12-5, 12-6, 12-12	4-5
15	**1**	Mod 7 Alcohols	12-4, 12-14	4-5
16	**1**	Mod 5 Factors that affect equilibrium	12-5, 12-6, 12-12	5
17	**1**	Mod 8 Analysis of organic substances	12-4, 12-15	3-5
18	**1**	Mod 8 Analysis of organic substances	12-4, 12-15	3-5
19	**1**	Mod 6 Using Bronsted-Lowry theory	12-6, 12-13	5-6
20	**1**	Mod 7 Nomenclature	12-14	4-6

NSW INDEPENDENT TRIAL EXAMS – 2020
CHEMISTRY TRIAL HSC EXAMINATION
MAPPING GRID - cont'd

Section II				
Question	**Marks**	**Content**	**Syllabus Outcomes**	**Target performance bands**
21(a)	1	Mod 6 Properties of acids and bases	12-13	2-3
21(b)	2	Mod 6 Using Bronsted-Lowry theory	12-6, 12-13	3-4
21(c)	2	Mod 6 Using Bronsted-Lowry theory	12-6, 12-13	4
22(a)	1	Mod 7 Nomenclature Mod 7 Hydrocarbons	12-6, 12-7, 12-14	2-3
22(b)	2	Mod 8 Analysis of organic substances	12-6, 12-7, 12-15	2-4
23	4	Mod 6 Properties of acids and bases	12-7, 12-13	4-5
24(a)	1	Mod 6 Quantitative analysis	12-13	2-4
24(b)	1	Mod 6 Quantitative analysis	12-4, 12-13	4-5
24(c)	3	Mod 6 Quantitative analysis	12-7, 12-13	4-5
25(a)	1	Mod 6 Quantitative analysis	12-13	2-3
25(b)	1	Mod 6 Quantitative analysis	12-6, 12-13	3-4
25(c)	2	Mod 6 Quantitative analysis	12-7, 12-13	4-5
26(a)	2	Mod 7 Hydrocarbons	12-7, 12-14	3-5
26(b)	3	Mod 7 Alcohols Mod 7 Reactions of organic acids and bases	12-14	3-5
26(c)	2	Mod 7 Products of reactions involving hydrocarbons	12-14	4
27(a)	3	Mod 7 Alcohols	12-2, 12-3, 12-14	3-5
27(b)	2	Mod 7 Alcohols	12-4, 12-6, 12-14	4-5
28(a)	3	Mod 5 Calculating the equilibrium constant	12-4, 12-12	5
28(b)	1	Mod 5 Calculating the equilibrium constant	12-5, 12-12	4-5
28(c)	1	Mod 5 Calculating the equilibrium constant	12-5, 12-12	4
29(a)	1	Mod 7 Alcohols	12-14	3-4
29(b)	3	Mod 7 Alcohols	12-2, 12-7, 12-14	3-5
29(c)	2	Mod 7 Alcohols	12-4, 12-14	3-5
29(d)	1	Mod 7 Alcohols	12-5, 12-14	4-5
30(a)	2	Mod 8 Analysis of inorganic substances Mod 8 Analysis of organic substances	12-4, 12-15	2-4
30(b)	2	Mod 8 Analysis of organic substances	12-6, 12-7, 12-15	2-4

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Question	Marks	Content	Syllabus Outcomes	Target performance bands
31(a)	1	Mod 6 Properties of acids and bases	12-13	2-3
31(b)	1	Mod 6 Quantitative analysis	12-13	3-4
31(c)	3	Mod 6 Quantitative analysis	12-7, 12-13	5-6
32(a)	1	Mod 5 Solution equilibria	12-12	2-3
32(b)	2	Mod 5 Solution equilibria	12-6, 12-7, 12-12	4-5
32(c)	1	Mod 5 Solution equilibria	12-12	4
32(d)	3	Mod 5 Solution equilibria	12-4, 12-12	6
33	4	Mod 8 Analysis of organic substances	12-5, 12-6, 12-7, 12-15	4-6
34(a)	2	Mod 5 Static and dynamic equilibrium	12-7, 12-12	5-6
34(b)	1	Mod 5 Factors that affect equilibrium	12-7, 12-12	5-6
35(a)	1	Mod 7 Polymers	12-6, 12-14	4-5
35(b)	3	Mod 7 Polymers	12-6, 12-7 12-14	4-6
36	3	Mod 8 Analysis of Inorganic Substances	12-6, 12-7, 12-15	4-6
37	5	Mod 8 Chemical synthesis and design	12-6, 12-7, 12-15	4-6