Student Number:_____

Chemistry

2019 TRIAL HSC EXAMINATION

General Instructions

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

Total marks: 100

Section I – 20 marks (pages 3–9)

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

Section II – 80 marks in Booklet A and B

- Attempt Questions 21–35
- Allow about 2 hours and 25 minutes for section II in Booklet A and B

Section I
20 marks

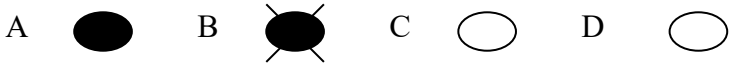
Attempt Questions 1-20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet.

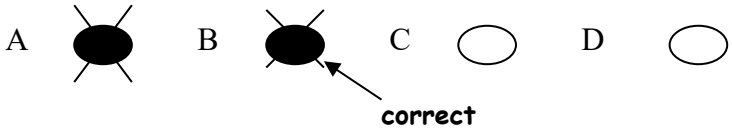
Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

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

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



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.



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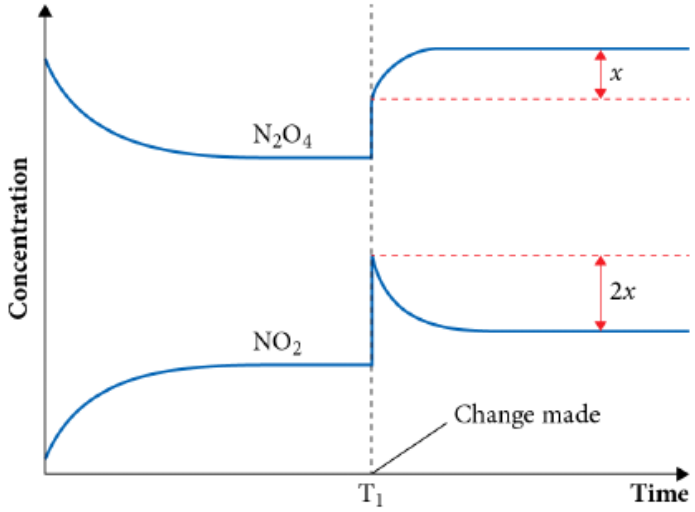
1. Consider the reaction: $2NO_2(g) \rightleftharpoons N_2O_4(g)$
The imposed change at T1 is most likely to be:



(A) an addition of NO_2.

(B) an addition of N_2O_4.

(C) an increase in the volume of the container.

(D) a decrease in the volume of the container.

2. Which of the following statements about acids and bases is FALSE?

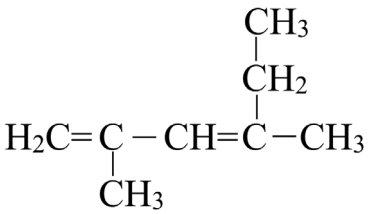
(A) Acids are able to produce hydrogen ions in solutions.

(B) A hydrogen ion attached to water forms a hydronium ion.

(C) Bases are able to produce hydroxide ions in solution.

(D) All oxides are basic.

3. The structural formula represents a compound. The IUPAC systematic name for this compound is:



(A) 3,5-dimethyl-3,5-hexane.

(B) 2,4-dimethyl-1,3-hexadiene.

(C) 2-methyl-4-ethyl-1,3-pentadiene.

(D) 2-ethyl-4-methyl-2,4-pentadiene.

4. Which of following alcohols have been classified correctly?

	Names of alcohols and their classification		
	Primary, 1º	**Secondary, 2º**	**Tertiary, 3º**
(A)	Propan-1-ol	Pentan-3-ol	2-methylpropan-2-ol
(B)	Butan-2-ol	2-methylpropan-1-ol	2-methylpropan-2-ol
(C)	2,2-dimethylpropan-1-ol	Butan-1,4-diol	Ethanol
(D)	Propan-2-ol	Butan-2-ol	Pentan-3-ol

5. The equilibrium expression for the K_{sp} of $CaCO_3$ is:

(A) $[Ca^{2+}][CO_3^{2-}]/[CaCO_3]$

(B) $1/[Ca^{2+}][CO_3^{2-}]$

(C) $[Ca^{2+}][CO_3^{2-}]$

(D) $[CaCO_3] /[Ca^{2+}][CO_3^{2-}]$

6. For a given weak acid, HA, the numerical value of K_a:

(A) will change with the pH

(B) will change with the temperature

(C) cannot be less than 10^{-7}

(D) cannot be greater than 10^{-7}

7. Which of the following hydrocarbons have the molecular formula $C_5H_{10}O$?

(I) Pentanoic Acid
(II) Pentan-3-ol
(III) Pentanal
(IV) Pentan-3-one

(A) I, II and III.

(B) I, III and IV.

(C) IV only.

(D) III and IV.

8. The purpose of the flame in the flame atomic absorption spectroscopy is to:

(A) desolvate and atomise the analyte atoms in a sample.

(B) purify the sample.

(C) ionise the analyte atoms.

(D) excite the analyte atoms.

9. The equation describes an equilibrium reaction occurring in a closed system.

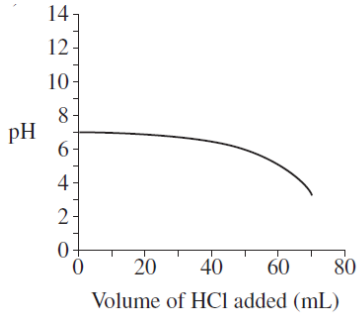
$$X(g) + Y(g) \rightleftharpoons 4Z(g); \qquad \Delta H = +58 \text{ kJ}$$

Under which set of conditions would the highest yield of $Z(g)$ be obtained?

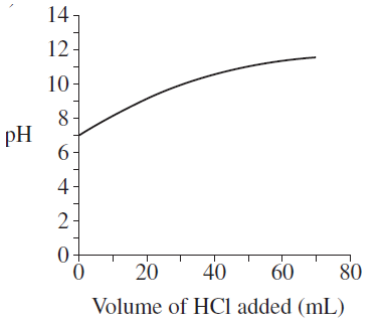
	Temperature (°C)	***Pressure (kPa)***
(A)	50	100
(B)	50	200
(C)	300	100
(D)	300	200

10. Which of the following graphs shows how pH will vary when dilute HCl is added to 100 mL of dilute natural buffer solution with an initial pH of 7.0?

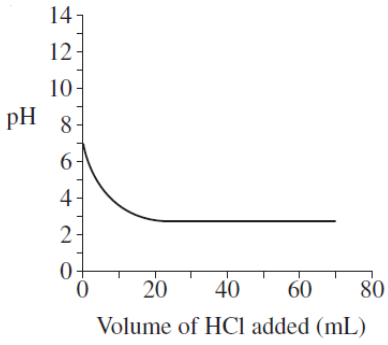
(A)



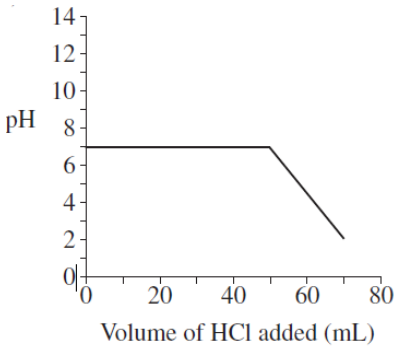
(B)



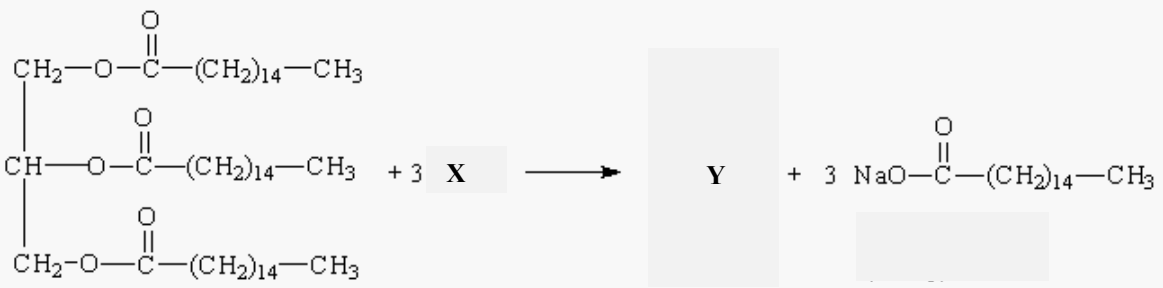
(C)



(D)



11. The general equation below represents the saponification reaction for the manufacture of soaps. Identify Reagent X and Product Y.



	Reagent X	Product Y
(A)	sodium hydroxide	glycine
(B)	sodium hydroxide	glycerol
(C)	sodium glyceride	triglyceride
(D)	sodium hydroxide	propan-1,2-diol

12. Which of the following statements regarding mass spectroscopy is incorrect?

(A) Only cations can be detected by a normal mass spectrometer.

(B) Molecular ion peaks always have an even-numbered values of mass charge ratio (*m/z*).

(C) In a normal mass spectrometer, electron impact causes a molecule to lose an electron an become a molecular radical cation which decomposes into fragment cations and radicals.

(D) A compound whose molecules contain just one bromine atom shows two molecular peaks of similar intensity, one at +1 and one and -1 of the average *m/z* value.

13. The solubility product expression for tin (II) hydroxide is:

(A) $[Sn^{2+}][OH^-]$

(B) $[Sn^{2+}]^2[OH^-]$

(C) $[Sn^{2+}][OH^-]^2$

(D) $[Sn^{2+}]^3[OH^-]$

14. Bromine, Br_2, dissolves in unsaturated hydrocarbons and reacts immediately.

Which of the following is the best description of this process?

(A) Bromine is polar and reacts by adding bromine atoms across the double bond.

(B) Bromine is polar and reacts by substituting hydrogen atoms with bromine atoms.

(C) Bromine is non-polar and reacts by substituting hydrogen atoms with bromine atoms.

(D) Bromine is non-polar and reacts by adding bromine atoms across the double bond.

15. A student uses their data table to find out that the heat of combustion of 1-propanol is 2021 kJ mol^{-1}. What value would the student calculate for the heat of combustion of 1-propanol in kJ g^{-1}?

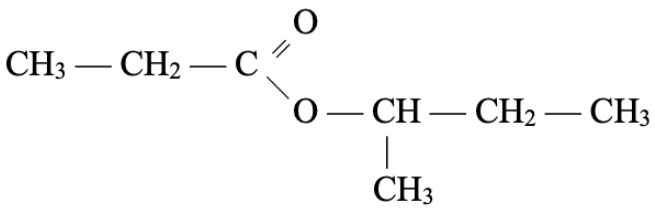
(A) 23.0

(B) 27.3

(C) 33.7

(D) 43.9

16. A compound has the structure shown below:



Hydrolysis of this compound will produce:

(A) butan-2-ol and propanoic acid.

(B) propan-1-ol and butanoic acid.

(C) propan-1-ol and 2-methylbutanoic acid.

(D) butan-1-ol and propanoic acid.

17. Nitric acid completely dissociates in aqueous solutions. 1.0 mL of 10 mol L^{-1} solution was diluted to 1 L with distilled water. 100 mL of this resulting solution was then further diluted to 1 L using distilled water.

What pH is the final solution closest to?

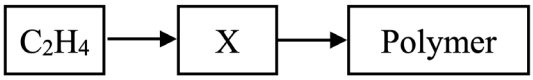
(A) 1

(B) 2

(C) 3

(D) 4

18. Which of the following compounds is represented by X in the flow chart?



(A) Cellulose

(B) Styrene

(C) Glucose

(D) Ethanol

19. A student determines the percentage of sodium chloride in a food sample by the following procedure. The food sample is dissolved in water and the chloride ion is precipitated by adding an excess of silver nitrate solution. The precipitate is washed and dried. If the food sample had a mass of 20.0 g and the final precipitate a mass of 0.376 g.

What is the percentage of sodium chloride in the food?

(A) 0.220%

(B) 0.465%

(C) 0.767%

(D) 1.88%

20. The equilibrium constant for the reaction below has an equilibrium constant K_1.

$$H_2\,(g) + I_2\,(g) \rightleftharpoons 2HI\,(g) \quad K_1 = 159 \text{ at } 500K$$

At the same conditions of temperature and pressure, what is the equilibrium constant for the reaction:

$$HI\,(g) \rightleftharpoons \tfrac{1}{2}\,H_2\,(g) + \tfrac{1}{2}I_2\,(g)$$

(A) 0.00629

(B) 0.0793

(C) 12.6

(D) 79.5

Student number

Chemistry

2019 TRIAL EXAMINATION

Section II – Booklet A
80 marks

Attempt Questions 21-37
Allow about 2 hour and 25 minutes for this part

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

Question 21 (3 marks)

Consider the following mixture of gases in a closed 3.0L vessel at 730°C.

Gas	*Quantity (mol)*
CH_4	2.00
H_2O	1.25
CO	0.75
H_2	0.75

The following reaction occurs:

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \triangle H = +206 \text{ kJ}$$

The equilibrium constant, K, is 0.26 at 1003K.

Determine whether the system is at equilibrium. **3**

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Question 22 (2 marks)

Models are often used to help explain complex concepts.

You performed a first-hand investigation to model a dynamic equilibrium reaction.

Outline the procedure used and the results you obtained.

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Question 23 (8 marks)

A student is investigating the following reaction system.

$$\underset{\text{brown}}{2NO_2(g)} \rightleftharpoons \underset{\text{colourless}}{N_2O_4(g)} \qquad \Delta H < 0$$

The reaction system can be observed in a sealed test tube, which allows the student to investigate the impact of temperature on the equilibrium position of the reaction.

(a) State the colour change expected when the student places the sealed test tube of the gas mixture in a beaker of hot water. Explain why this colour change occurs. **3**

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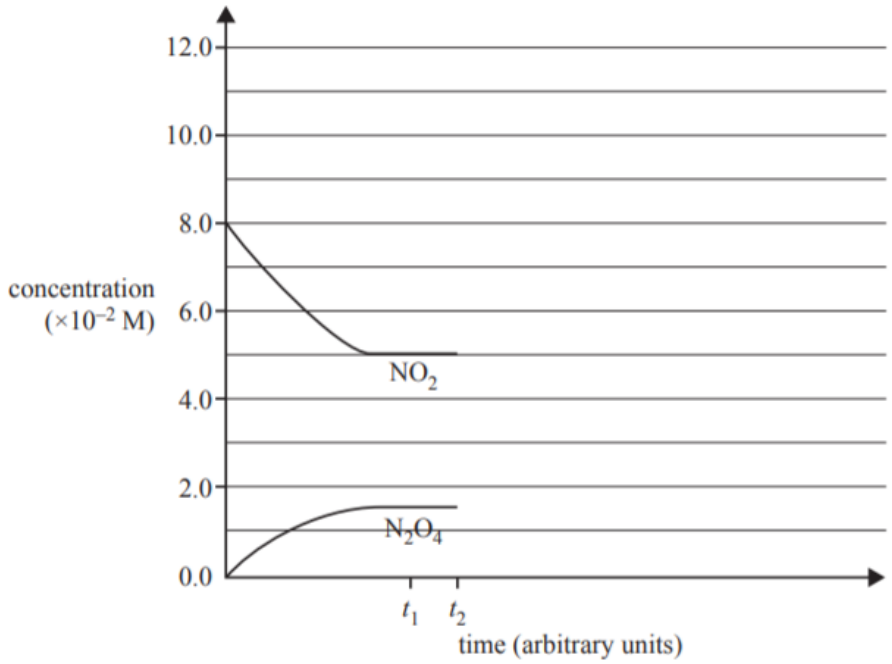
(b) Below is the concentration versus time graph for the reaction system. The graph was produced using secondary data at a temperature of 22°C.



i) Time t_1 is shown on the graph above.
Calculate the equilibrium constant at time t_1. **2**

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ii) At time t_2 the volume of the system was halved, keeping the temperature at 22°C. **3**

Continue the graph to show how this change would affect the reaction system and how the system would respond to this change until equilibrium was restored. Exact concentration of the gases at the new equilibrium are not required.

Question 24 (7 marks)

(a) Lead (II) chloride is sparingly soluble in water, and this equilibrium is set up between the solid and its ions in solution. Calculate the concentration of Pb^{2+} and Cl^- in the solution at 25°C.

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(b) Calculate and compare the solubility of the lead chloride when dissolved in 0.25 mol L^{-1} of NaCl.

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Question 25 (4 marks)

A green solution was made containing a weak acid, *HA* (which is a yellow molecule) and its conjugate base, A^- (which is blue).

(a) Write an equation for the reaction which occurs when a strong base such as sodium hydroxide is added to this solution. **1**

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(b) Write an equation for the reaction which occurs when a strong acid such as hydrochloric acid is added to this solution. **1**

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(c) Use your equations from part (a) and (b) to explain why this solution can act as an indicator. **2**

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Question 26 (3 marks)

Outline the differences between condensation and addition polymerisation, using an example of each polymerisation process, **3**

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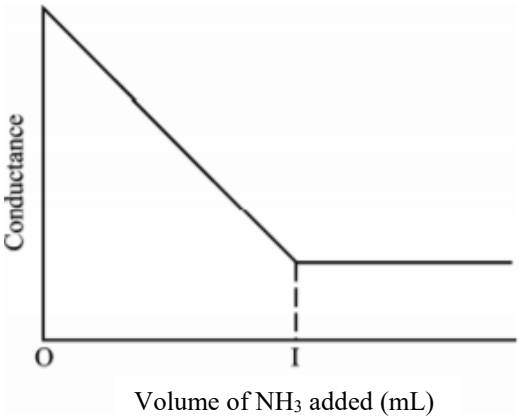
Question 27 (4 marks)

The figure below shows the conductivity graph for a reaction between sulfuric acid and ammonia solution.



(a) What does the point labelled " I " on the x-axis signify? **1**

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(b) Explain the shape of the conductivity curve. **3**

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Question 28 (4 marks)

Calculate the pOH of 0.20 M H_2CO_3. (K_a = 4.3 x 10^{-7}).

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Question 29 (8 marks)

Acids are defined as having a pH of less than 7 and a base of having a pH greater than 7 in an aqueous solution. **8**

Explain the role of water in solutions of both acids and bases.

Section II continues in Booklet B

Student Number: ……

SYDNEY BOYS HIGH SCHOOL

CHEMISTRY
2019 TRIAL HSC EXAMINATION

Section II - Booklet B
Answer questions 30-35

Part B Total:

Question 30 (5 marks)

The boiling points and molar masses of there compounds are shown:

Compound	***Boiling point (^oC)***	***Molar mass ($g\ mol^{-1}$)***
Ethanoic acid	118	60
Butan-1-ol	117	74
Butyl ethanoate	116	116

Discuss why ethanoic acid, butan-1-ol and butyl ethanoate have very similar boiling points but different molar masses.

5

Question 31 (5 marks)

During a school camp, a student uses a spirit burner which contains C_2H_5OH as a source of energy to boil his drinking water.

(a) Write a balanced equation for the complete combustion of ethanol. **1**

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(b) Calculate the amount of energy released when 1.0 g of ethanol is completely burnt in excess oxygen. Assume the enthalpy of combustion of ethanol is 1364 kJ mol^{-1}. **1**

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(c) A camping stove that uses ethanol as its fuel source heats a kettle containing 950 ml of water at 12ºC. What mass of ethanol must be burnt to heat the water to its normal boiling temperature? Assume only 40% of the energy provided by the combustion reaction of the ethanol is used to heat the water. **3**

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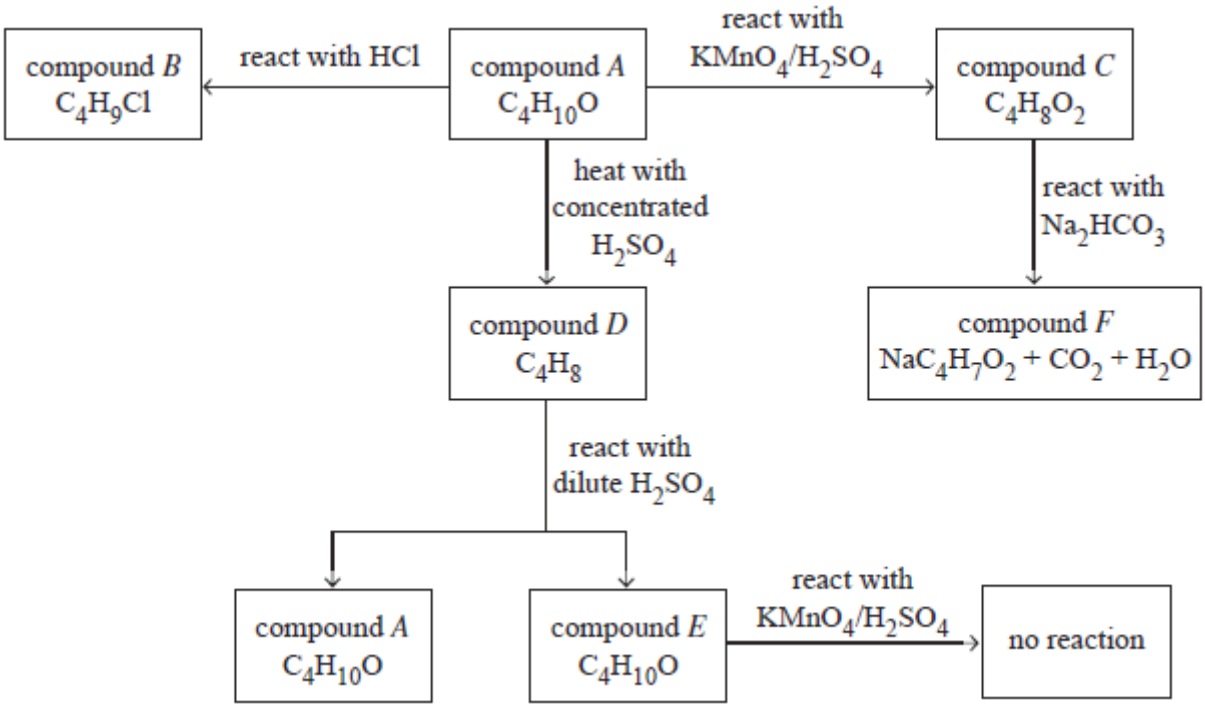
Question 32 (7 marks)

The flow chart shows the reactions of six different organic compounds.



(a) Complete the table by drawing the structural formulae for the compounds and justifying your answers with reference to the information provided. **6**

Compound	*Structural formula*	*Justification*
Compound *A* $C_4H_{10}O$		
Compound *B* C_4H_9Cl		

Question 32 continues on page 23

Question 32 Continued

Compound	*Structural formula*	*Justification*
Compound *C* $C_4H_8O_2$		
Compound *D* C_4H_8		
Compound *E* $C_4H_{10}O$		
Compound *F* $NaC_4H_7O_2$		

(b) Identify the systematic name of compound E. **1**

Compound E:……

Question 33 (9 marks)

An unknown organic compound with a molecular formula $C_4H_8O_2$ was supplied to a laboratory spectroscopist for identification.

An infrared absorption spectrum (Image A), mass spectrum (Image B) and a C-13 NMR spectra (Image C) for the compound were produced.

These are shown below.

Image A

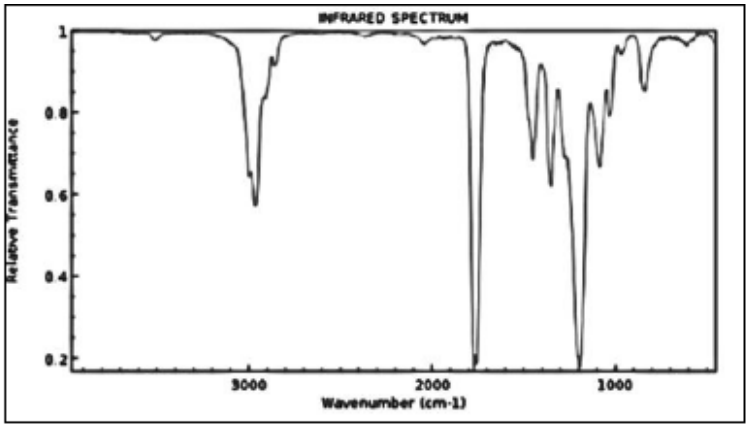


Image B

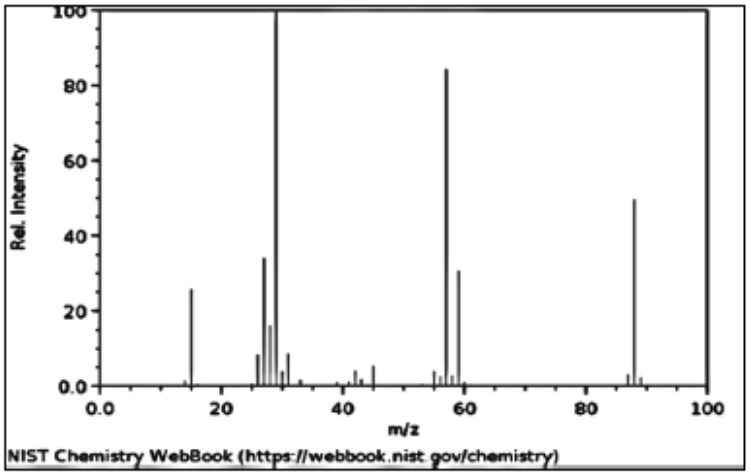
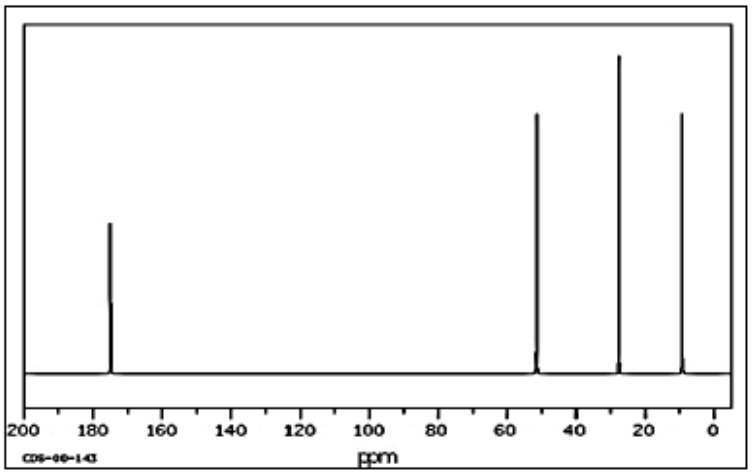


Image C



Question 33 continues on page 25

Question 33 (continued)

The analytical chemist concluded that the compound was *methyl propanoate* using various characteristics of each spectra produced in the analysis.

(a) Draw the structural formula of methyl propanoate in the box below **1**

(b) Complete the table below and explain how information from each spectrum supports the conclusion that the compound is methyl propanoate. **6**

Spectroscopic technique	Information from spectrum which supports the identification as methyl propanoate
IR spectra	
Mass spectra	
C-13 Nuclear Magnetic Resonance Spectra	

Question 33 (continued)

(c) A sample of the same compound was decomposed into its constituent elements and found to contain 54.5% carbon, 9.1% hydrogen, the remainder being oxygen, by mass. **2**

Does this data support the chemist's conclusion that the compound is methyl propanoate? Justify your answer.

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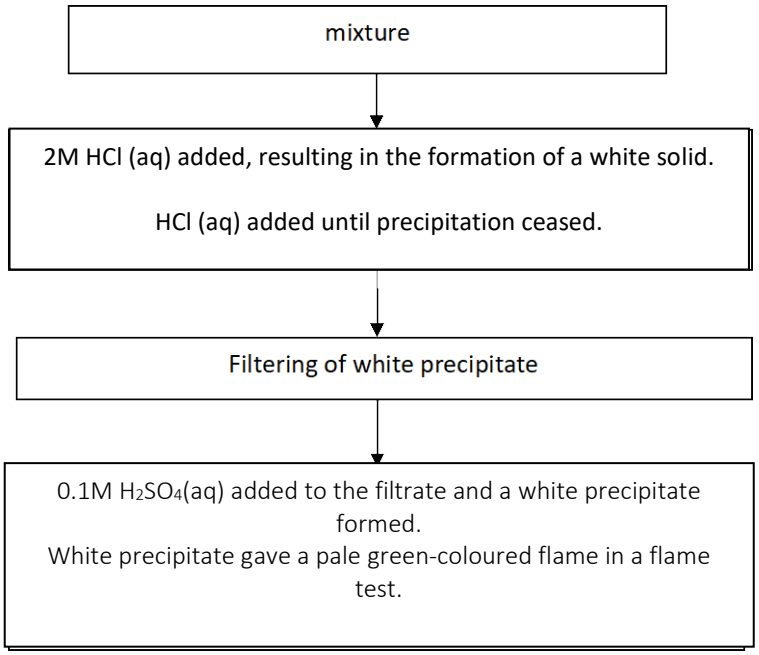
Section II continues on page 27

Question 34 (5 marks)

An aqueous solution was known to contain two of the following cations: Ca^{2+}; Ba^{2+}; Cu^{2+}; Pb^{2+}; Fe^{2+}.

The procedure a student used to identify the two cations is shown in the following flowchart.



(a) Identify the cation responsible for the white precipitate formed upon addition of HCl.

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(b) Write a net ionic equation for the reaction which produced the white precipitate upon addition of H_2SO_4.

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(c) Justify the procedure used to identify the two unknown cations.

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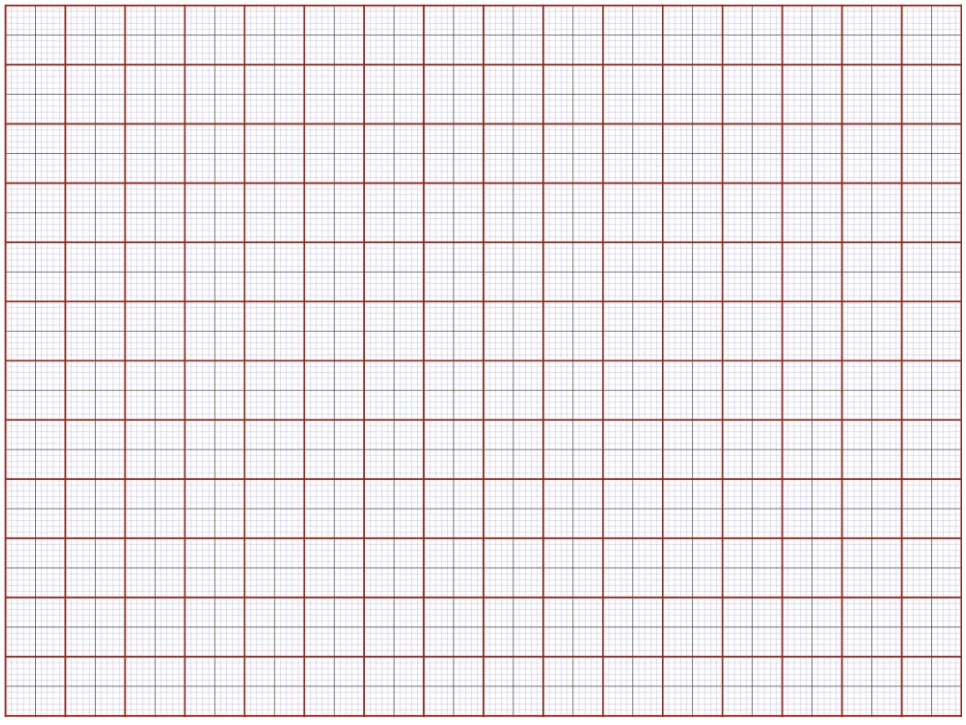
Question 35 (6 marks)

In monitoring the effect of discharge effluent on river quality, a chemist uses *atomic absorption spectroscopy* to compare the sodium ion concentrations above and below the discharge point in the Lachlan River. The table below shows the absorption values at a wavelength of 589 nm, for water samples, and also for a range of standard solutions.

Solution	***Na^+ concentration (mg L^{-1})***	***Absorbance at 589 nm (%)***
Standard	10	16
Standard	20	34
Standard	40	63
Standard	60	98
Up river sample 1		4
Up river sample 2		5
Down river sample 1		54
Down river sample 2		43

(a) Plot the standards on the grid below. (Label axes) **3**



(b) Complete the entries for Na^+ concentrations of water samples **in the table above.** **2**

Question 35 continues on page 29

Question 35 (continued)

(c) Assess the downstream water quality for the fresh water organisms, considering the tolerance limit for sodium ion concentration is 100 ppm. **1**

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End of Section II

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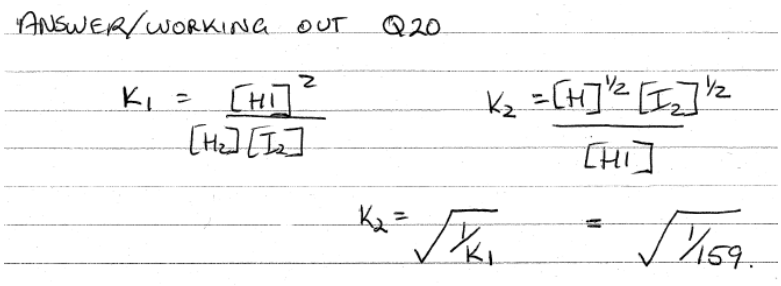
2019 Chemistry Trial – Marking Criteria

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



21

Sample Answer

To determine if the system is at equilibrium it is necessary to calculate Q, the reaction quotient, and see if it is the same as K.

$Q = [CO][H_2]^3 / [CH_4][H_2O]$

$= (0.25)(0.25)^3 / (0.667)(0.4167)$

$Q = 0.0141$

$K = 0.26$

$Q \neq K$

$[CH_4] = 2.00/3 = 0.667$

$[H_2O] = 1.25/3 = 0.4167$

$[CO] = 0.75/3 = 0.25$

$[H_2] = 0.75/3 = 0.25.$

Therefore, the system is not at equilibrium

Note: **Many forgot to divide the number of moles by 3 before substituting into the equilibrium expression. Water is included as it isn't a solvent.**

22

Possible Answer:

Two identical measuring cylinders are filled with different volumes of water. Water is transferred backwards and forwards from each cylinder using two differently sized pipettes until the volume of water in each cylinder remains constant (but at different levels).

- There are many models that could 'physically' model equilibrium in a closed system(that are 'non-chemical')
- Diagrams can be included

Note:

What's wrong with the model we used in class?

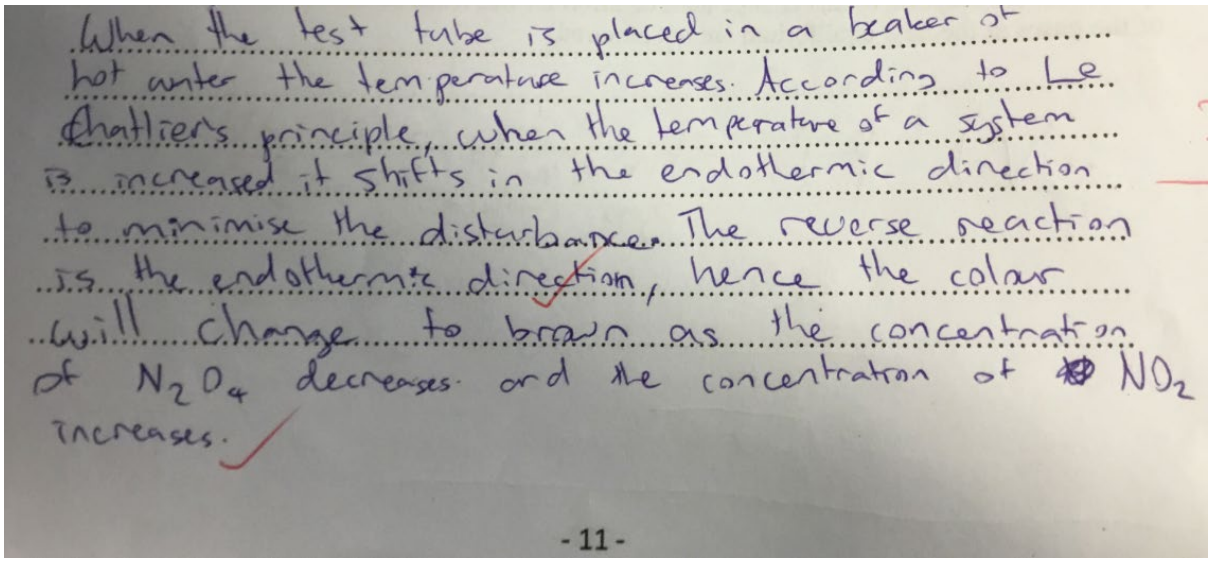
Make sure you are transferring different quantities each time.

The questions says "You performed a 1st hand investigation….." this marker knows which one you did…

Modelling equilibrium not manipulating a reaction that is at equilibrium.

23a.

Sample Answer


When the test tube is placed in a beaker of hot water the temperature increases. According to Le Chatliers principle, when the temperature of a system is increased it shifts in the endothermic direction to minimise the disturbance. The reverse reaction is the endothermic direction, hence the colour will change to brown as the concentration of N_2O_4 decreases and the concentration of NO_2 increases.

- 11 -

- The gas mixture goes darker brown.
- The forward reaction is exothermic ($\Delta H < 0$), hence the reverse reaction is favoured at higher temperatures.
- As the reverse reaction is favoured, [NO_2] increases and so the equilibrium mixture is darker at higher temperature.

Markers Notes

This question was generally answered well. Some students interpreted $\Delta H < 0$ to mean that the forward reaction was endothermic and argued consequently that the colour would go a lighter brown. Such responses, if coherent, could access partial marks. Statements such as the colour of the gas mixture turns brown, becomes brown, changes from colourless to brown, etc., were not acceptable because the initial equilibrium mixture contains both the brown NO_2 and the colourless N_2O_4.

Some students correctly noted that increasing the temperature at constant volume would increase the pressure in the sealed tube. They then tried to argue, using Le Chatelier's principle, that the system would favour the forward reaction to try to decrease the pressure. This argument is invalid since the concentration fraction is initially unaffected by the change. The system is out of equilibrium because the increased temperature has decreased the value of the equilibrium constant and hence it is no longer equal to the concentration fraction. The system favours the back reaction in order to decrease the concentration fraction. Le Chatelier's principle only applies to a pressure change if it is a result of a change to the volume of the system.

Some very verbose answers. You don't need to restate Le Chatelier's Principle, just use/apply it.

23bi

Sample Answer:

$K = [N_2O_4] / [NO_2]^2$

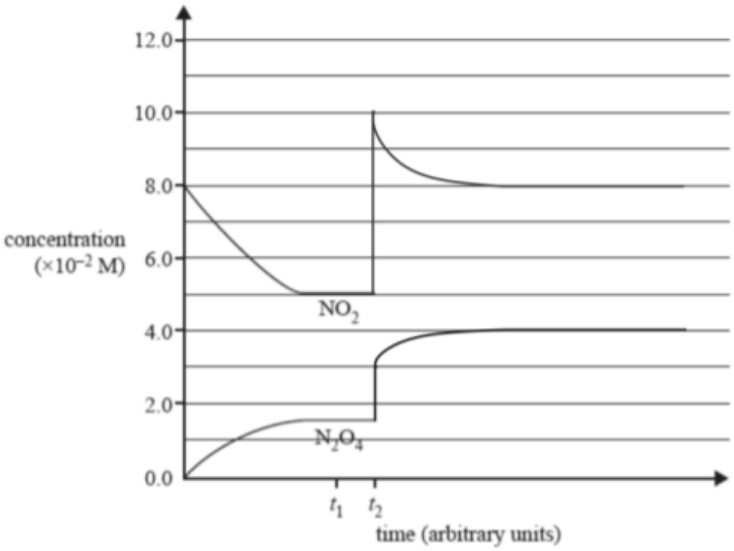
$= 1.5 \times 10^{-2}/(5.0 \times 10^{-2})^2$

$= 6.0$

Markers Note:

Most students identified the equilibrium law but many either misread the concentrations from the graph or did not include the appropriate unit for the value of the equilibrium constant. The ability to read graphical data accurately is a fundamental skill.

23bii



Students were awarded one mark each for:

- showing $[NO_2]$ doubled to $10.0(\times 10^{-2})$ M and $[N_2O_4]$ doubled to $3.0(\times 10^{-2})$ M
- showing subsequent adjustments in correct directions, NO_2 decrease and N_2O_4 increase
- showing change in $[NO_2]$ double that of N_2O_4 during return to equilibrium.

Students were not expected to determine the exact concentrations at which the system returned to equilibrium.

24. a.

Sample answer

$PbCl_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Cl^-_{(aq)}$ $\quad K_{sp} = 1.7 \times 10^{-5}$

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

$1.7 \times 10^{-5} = s \times (2s)^2$

$= 4s^3$

$s^3 = 4.25 \times 10^{-6}$

$s = 1.6 \times 10^{-2}$

$\therefore [Pb^{2+}] = 1.6 \times 10^{-2}$ molL^{-1} $\quad [Cl^-] = 2 \times 1.6 \times 10^{-2}$

$= 3.2 \times 10^{-2}$ molL^{-1}

24. b.

Sample answer

$PbCl_{2(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2Cl^-_{(aq)}$

I	0	0.25	
C	+s	+2s	
E	s	0.25+2s	$[Cl^-] \approx 0.25$

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

$1.7 \times 10^{-5} = s \times 0.25^2$

$s = 2.7 \times 10^{-4}$

$\therefore$ Solubility of $PbCl_2$ in 0.25 molL^{-1} NaCl is 2.7×10^{-4} molL^{-1}

$PbCl_2$ is approximately 59x more soluble in H_2O.

This question was answered very badly.

You were too compare the solubility of $PbCl_2$ in water to its solubility in 0.25M NaCl. Two separate calculations and then compare your answers. Too many student substituted the concentrations determined in Part a into Part b.

The use of scientific notation was poor.

This was a common ion effect question. 1 mark was given for recognising this.

25. a.

Marking guidelines	Marks
• Correct equation	1

Sample answer

$OH^-(aq) + HA(aq) \rightarrow H_2O(l) + A^-(aq)$
Blue

25. b.

Marking guidelines	Marks
• Correct equation	1

Sample answer

$H_3O^+(aq) + A^-(aq) \rightarrow H_2O(l) + HA(aq)$
yellow

25. c.

Sample answer

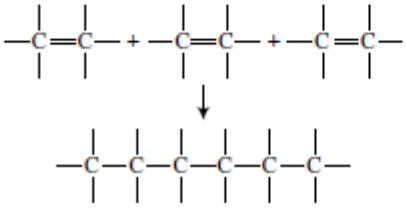
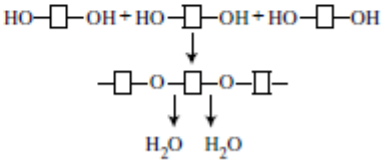
The solution is a green equilibrium mixture of HA (yellow) and A^- (blue).
The equilibrium in the solution can be represented:
$HA(aq) + H_2O(l) \Leftrightarrow A^-(aq) + H_3O^+(aq)$
yellow *blue*

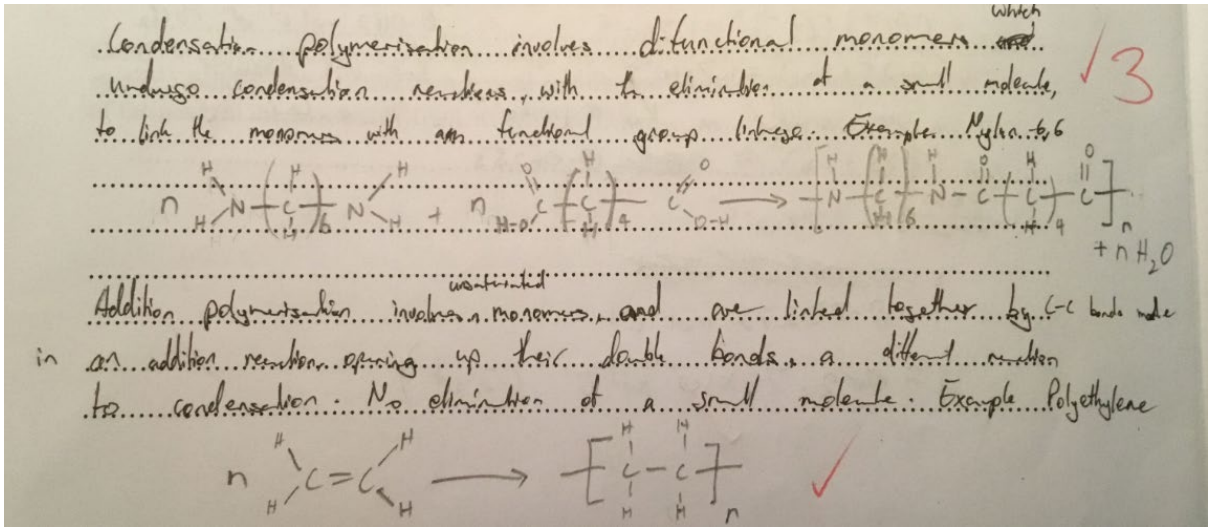
When a strong base is added, the reaction in (a) occurs and the indicator solution turns blue. Considering the equilibrium reaction above, the green solution turns blue, as the concentration of H_3O^+ decreases and the indicator equilibrium shifts to the right.
When a strong acid is added, the reaction in (b) occurs. Considering the equilibrium reaction above, the green solution turns yellow, as the equilibrium shifts to the left as the concentration of H_3O^+ increases.
Hence the green solution can act as an indicator as it is a different colour in acidic and basic solutions; i.e. in solutions of different pH.

** NB 1 mark for both equations a) and b) if the equations were written in equilibrium AS THEY ARE NOT IN EQUILIBRIUM

26

Answers could include:

	Polymerisation of ethylene	*Polymerisation of glucose*
Type of reaction	Addition	Condensation
Feature of reaction	Breaking double bonds	Releases a water molecule for each glucose unit added
Equation		



27a

Answer: Equivalence point (End point was accepted – but it is not the answer)

27b

Sample answer:

There is a high initial conductivity because of the high concentration of H^+ ions.

Conductivity decreases as H^+ ions react with NH_3 molecules and are replaced by NH_4^+ ions which have a lower conductivity.

The equivalence point occurs at the point on the graph when the lowest conductivity is first reached, after which the conductivity remains constant.

Conductivity does not change as more NH_3 solution is added after the equivalence point, because NH_3 is a weak base and is only dissociated to a very small extent.

28.

Sample answer

$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$

I	0.2	0	0
C	$-x$	$+x$	$+x$
E	$0.2-x$	x	x

$[H_2CO_3] \approx 0.2$

$K_a = \frac{[HCO_3^-][H_3O^+]}{[H_2CO_3]}$

$4.3 \times 10^{-7} = \frac{x^2}{0.2}$

$x^2 = 8.6 \times 10^{-8}$

$x = 2.93 \times 10^{-4}$ mol L^{-1}

$pH = -\log[H_3O^+]$

$= -\log(2.93 \times 10^{-4})$

$= 3.53$

$pH + pOH = 14.00$

$3.53 + pOH = 14.00$

$pOH = 10.47$

1MARK for the following incorrect response/working out-

- NB For polyprotic weak acids – one proton at a time dissociates from the acid molecule. The first dissociation differs by several orders of magnitude, and therefore we neglect subsequent dissociations.

$H_2CO_3 \rightleftharpoons 2H^+ + CO_3^{2-}$

$K_a = \frac{[CO_3^{2-}][H^+]^2}{[H_2CO_3]}$

$4.3 \times 10^{-7} = \frac{(2x)^2(x)}{0.2}$

Question 29*Sample answer*:

The definition of acids and bases, like all concepts in science has developed over time. In 1884, Arrhenius stated that all acidic solutions are formed when acids dissociate to produce hydrogen ions in water. Acids were strong were strong if they dissociate completely (hydrochloric, nitric) and weak if they ionised only slightly (acetic, formic). Arrhenius defined a base as a substance that dissolved in water to produce hydroxide ions.

Examples of ***Arrhenius acids:***

$$HCl(g) \rightarrow H^+(aq) + Cl^-(aq)$$

$$H_2SO_4(l) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

Examples of ***Arrhenius bases:***

$$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$$

$$Ba(OH)_2(s) \rightarrow Ba^{2+}(aq) + 2OH^-(aq)$$

Arrhenius proposed that when an acid neutralises a base, it is the hydrogen ions and hydroxide ions that react to form neutral water. Arrhenius' definitions of acids and base plains many properties of common acids and bases.

For Arrhenius acids and bases water was the solvent and for strong bases such as metal hydroxides it can be explained by the polarity of water and its ability to form strong ion dipoles with OH^- and cations such as Na^+ and thus hydrate the OH^- and the cation such as Na^+. Arrhenius acids show water behaving in a similar manner, ie a simple dissolution of an ionic substance, but in fact it is not the case.

Arrhenius failed to account for all the observations made about the behaviour of some substances. Such as – Why are metallic oxides and carbonates basic? Why are solutions of various salts acidic or basic rather than neutral?

To solve these problems the Bronsted-Lowry (B/L) proposed a new theory/ definition of acids and bases. Bronsted and Lowry defined acids and bases as:

- Acids are proton donors
- Bases are proton acceptors

The B/L definition focused on the role of water as an ionising solvent, it participated in a reaction where water behaved as a proton donor or acceptor:

When an acid is placed in water, water behaved as a base – proton acceptor:

For a strong acid which ionised completely, the reaction is-

$$\underset{\text{proton donor}}{HCl(g)} + \underset{\text{proton acceptor}}{H_2O(l)} \rightarrow H_3O^+(aq) + Cl^-(aq)$$

For a weak acid which ionised incompletely, the reaction is-

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

When a base is placed in water, water behaved as an acid – proton donor:

For a strong base which ionised completely, the reaction is-

$$Na_2O + H_2O \rightarrow 2NaOH$$

For a weak base which ionised incompletely, the reaction is-

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$$

The reason why many salts are not neutral in aqueous solutions is that many anion and cations can act as acids (proton donors) or bases (proton acceptors) in a hydrolysis reaction with water.

According to the B/L definition water is seen to have a dual nature and the self- ionisation of water can be understood in terms of the B/L definition:

$$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

proton acceptor proton donor

The term 'pH' stands for 'HYDROGEN POWER' it is based on the hydrogen ion concentration in water. **H** is written for convenience, what really happens is that the hydrogen ion attach to a lone pair of electrons on the polar water molecule, form a coordinate covalent bond and thus creating a hydronium ion- $\mathbf{H_3O^+}$. The pH scale was developed to quantitively measure the acidity of a solution. It is based on a logarithmic scale which made it more convenient as the [H_3O^+] are very small. Thus, pH is defined as:

$$pH = -\log [\ H_3O^+]$$

The pH scale generally extends from 0-14, although there are values outside this range. The lower the pH the more acidic the solution is; the higher the solution the more basic the solution is. Therefore, at 25^{o}C acids have a pH of less that 7 and bases have a pH of greater than 7, and a substance with a pH of 7 is neutral.

The pH scale is useful for comparing the acidity and basicity of household substances, soils, aquariums, swimming pools, rivers, industrial effluents, laboratory chemicals and in medicine. It can be measured using a pH meter, indicator solutions or indicator paper, all require the substance to be in liquid or aqueous form. If using a pH meter, the electrode must be calibrated with known buffers and if this is done correctly the measurement made is accurate within 0.01 pH units. Indicators are a convenient way of determining the acidity or basicity of substances, and it is based on a colour change when added to acidic or basic solutions. The actual range over which indicators change colour varies from one indicator to another and so cannot achieve the same accuracy as a well calibrated pH meter.

30.

Sample answer

Despite having different molar masses, all three molecules have similar boiling points due to the different structures and resulting intermolecular forces.

Butyl acetate has the largest molar mass and therefore greatest dispersion forces but is only slightly polar and has no hydrogen bonding.

Butan-1-ol has lower molar mass than butyl acetate and therefor smaller dispersion forces but it is polar and contains a hydrogen bound to an oxygen. Therefore, it exhibits hydrogen bonding resulting in strong intermolecular forces.

Acetic acid has the lowest molar mass and so the weakest dispersion force, but it is polar and contains a hydrogen bound to an oxygen allowing the formation of hydrogen bonds between molecules. The presence of a second oxygen in acetic acid increases the hydrogen bonding compared with butan-1-ol.

Therefore all three molecules have similar total strength of intermolecular forces and similar boiling points.

NB

31.a.

Marking Guidelines	Marks
• Correct balanced equation with states	1

Sample answer

$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

31.b.

Marking Guidelines	Marks
• Correct heat released with units and 2 significant figures	1

Sample answer

$n(C_2H_5OH) = \frac{1\,g}{46.068\,g\,mol^{-1}}$

$= 0.0217\ mol$

Heat released for 1.0 g $= 0.0217 \times 1364$

$= 30\ kJ$ (2sf)

31.c.

Sample answer

$Q = mc\Delta T$

$= 950 \times 4.18 \times (100 - 12)$

$= 349\,448\ J$

$= 349\ kJ$ @ 40%

Energy from combustion $= \frac{349\ kJ}{40} \times 100$

$= 874\ kJ$

$n(C_2H_5OH) = \frac{874\ kJ}{1364\ kJ\ mol^{-1}}$

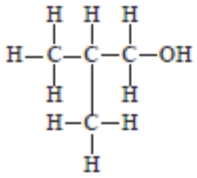
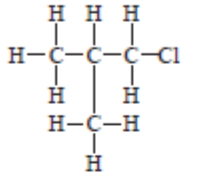
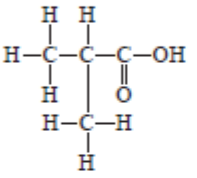
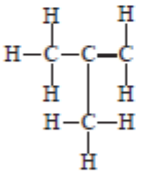
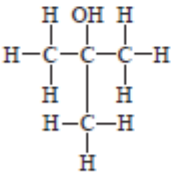
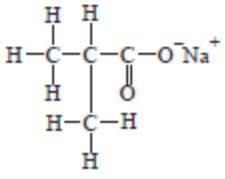
$= 0.6405\ mol$

$m(C_2H_5OH) = 0.6405\ mol \times 46.068\ g\ mol^{-1}$

$= 29.5\ g$

$= 30\ g\ (2sf)$

Question 32a

	Structural formula	*Justification*
A	 2-methylpropan-1-ol	Compound *A* is a primary alcohol as oxidation of compound *A* produces an acid, compound *C*. The branched structure is indicated by the formation of the tertiary alcohol, compound *E*.
B	 1-chloro-2-methylpropane	Compound *B* is a chloroalkane formed by the replacement of OH with Cl in compound *A*.
C	 2-methylpropanoic acid	Compound *C* is the acid produced by the oxidation of compound *A*. This is confirmed by the production of CO_2 when reacted with carbonate ion.
D	 2-methylpropene	Compound *D* is the alkene produced from compound *A* through the dehydration reaction, which removes the OH and another H atom to form the double bond.
E	 2-methylpropan-2-ol	Compound *E* is a tertiary alcohol as compound *E* is not oxidised with strong oxidants.
F	 sodium 2-methylpropanoate	Compound *F* is the sodium salt of the acid.

Note: Once you have Identified and Justified compound A being a branched molecule you don't have to repeat this in your justification for the other compounds.

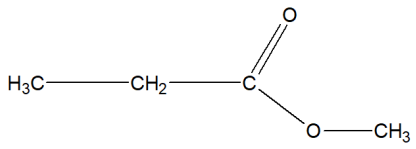
32b

Criteria	**Marks**
Identifies Compound E as 2-methylpropan-2-ol (or methylpropan-2-ol)	1

33a

Criteria	Marks
Draws the correct structure	1

Answer:



33b

Spectroscopic technique	Information from spectrum that justifies the identification
IR spectra	The IR spectrum shows a medium absorbance at 3000 cm^{-1} due to C-H bonds, and a strong absorbance band at 1700cm^{-1} due to the carbonyl bond (C=O). The molecular formula of the chemical being tested is $C_4H_8O_2$ (which matches the general formula $C_nH_{2n}O_2$) which can represent alkanoic acids and alkyl alkanoates. The fact that there is no broad band from 2700-3600 cm^{-1}, which corresponds to -OH bond, suggests the molecule is not an alkanoic acid. This suggests the unknown could be an alkyl alkanoate, which is consistent with the unknown being methyl propanoate ($CH_3O_2CH_2CH_2CH_3$).
Mass spectra (88, 57,29,15).	The molecular mass of methyl propanoate is 88, and the ion peak in the mass spectra of the unknown is at 88 amu, another piece of evidence the molecule may be methyl propanoate or an isomer of the compound (eg ethyl ethanoate). One peak on the spectrum is at 15amu, consistent with a CH_3 group fragment that could be broken off the methyl propanoate molecule
C-13 Nuclear Magnetic Resonance Spectra	The four shifts in the C-13NMR spectrum for the unknown suggests it contains 4 different carbon environments, with the peak around 175 consistent with the carbon in the carbonyl group. Four different carbon environments would be consistent with the structure of methyl propanoate, shown below.

33.c

Using the mass percentages given, in 100g of the compound:

Element	Mass %	Mass of element (g)	Moles
Carbon	54.5	54.5	54.5 / 12.01 = 4.5
Hydrogen	9.1	9.1	9.1 / 1.008 = 9.1
Oxygen	100 - 54.5 - 9.1 = 36.4	36.4	36.4 / 16.00 = 2.3

Simplest ratio: C: 4.5/2.3 = 1.95 H: 9.1/2.3= 3.96 O = 2.3/2.3 = 1
EF= C_2H_4O which is consistent with the empirical formula of methyl propanoate (MF = $C_4H_8O_2$ / EF = C_2H_4O).

Another way to use the data to support the conclusion is to calculate Mass % for methyl propanoate and compare to given data. (This was done by more students).

34a

Marking Guidelines	Marks
• Correctly identifies Pb^{2+}	1

34b

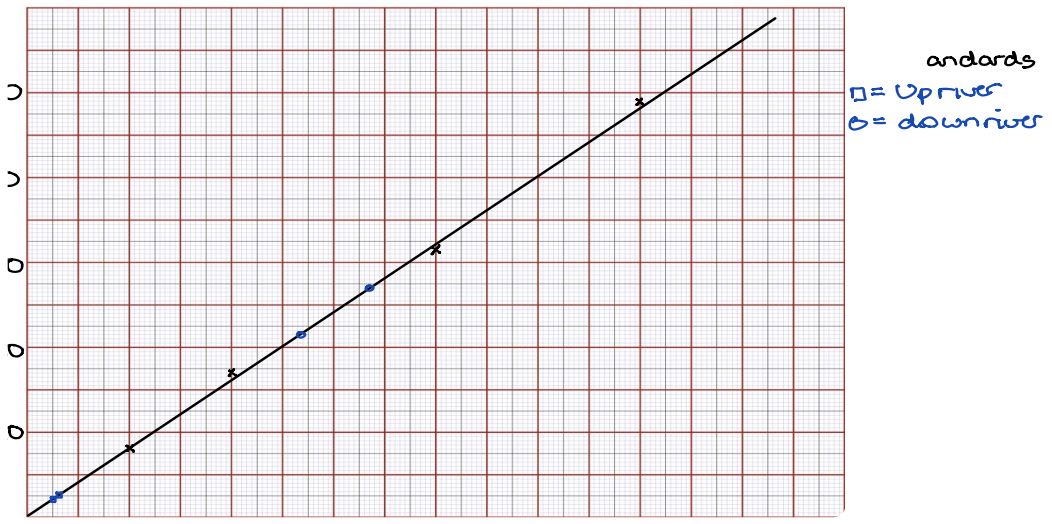
Marking Guidelines	Marks
• Correct ionic equation including correct states	1

Sample answer
$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

34c

Sample answer
The student knew there were two cations. The HCl was added first because from the list of possible cations, it precipitates only Pb^{2+}. If he had added H_2SO_4 first, it would have precipitated both the Pb^{2+} and the Ba^{2+} and there would have been no way of telling that both cations were in the ppt. HCl was added until ppt of the Pb^{2+} ceased in order to prevent remaining Pb^{2+} from precipitating with SO_4^{2-}, which would have provided a false positive in the sulfate precipitation test. The Pb^{2+} had to be removed to ensure that any precipitate in the sulfate test was not Pb^{2+}, but rather Ba^{2+}.

35a



35b

Sample answer
Refer to individual students graphs.

35c

Sample answer

The concentration of sodium ions downriver are within safe limits for fresh water organisms.