STUDENT NUMBER: | | | | | |

Loreto Normanhurst
2019 HIGHER SCHOOL CERTIFICATE TRIAL EXAMINATION
Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours

- Write using black or blue pen

  Black pen is preferred
- Draw diagrams using pencil
- Board-approved calculators may be used
- A data sheet and Periodic Table are provided at the back of this paper
- Write your student number in the space(s) provided

Total marks – 100

Section I

20 marks

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

Section II

80 marks

- Attempt all Questions 21-35
- Allow about 2 hours and 25 minutes for this part

Section I

25 marks

Attempt Questions 1-20

Allow about 35 minutes for this part

Use the multiple-choice answer sheet provided for Questions 1-20

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

Sample: **2 + 4 =**

(A) 2 **(B)** 6 **(C)** 8 **(D)** 9

(A) ○ (B) ● (C) ○ (D) ○

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

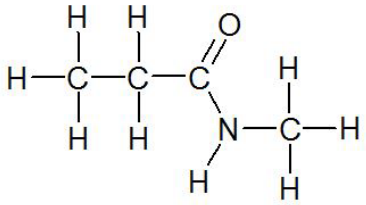
(A) ● (B) ⊗ (C) ○ (D) ○

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

correct ↙

(A) ⊗ (B) ⊗ (C) ○ (D) ○

1 What is the correct name of the following organic compound?



(A) Methyl propanoate

(B) Pentan-3-one

(C) N-methylpropanamine

(D) N-methylpropanamide

2 Which of the following is an isomer of 2,3,3-trimethylbutanoic acid?

(A) 2-ethylpentanal

(B) 3,4-dimethylheptan-2-one

(C) hexanoic acid

(D) ethyl pentanoate

3 Soaps and detergents are classified as emulsifiers because

(A) They reduce the hardness of water

(B) They reduce the surface tension of water

(C) They are non-polar fatty acids

(D) They are renewable and biodegradable

4 The table below shows pK_{ind}, the pH range, and the colour changes of three indicators. For a solution with a pH of 4, which option below correctly identifies the colour of the indicators in the solution?

Indicator	pK_{ind}	pH range	Colour at lower pH	Colour at higher pH
Bromophenol blue	4.0	3.0 - 4.6	Yellow	Blue
Methyl red	5.1	4.2 – 6.3	Red	Yellow
Phenolphthalein	9.3	8.3 – 10.0	Colourless	Red

	Bromophenol blue	Methyl red	Phenolphthalein
(A)	yellow	red	colourless
(B)	yellow	yellow	colourless
(C)	green	red	colourless
(D)	green	orange	colourless

5 Consider the following equilibrium expression.

$$\mathrm{K} = \frac{[L][M]^4}{[J]^6[K]}$$

The equation of the forward reaction for this equilibrium expression is

(A) $6J + K \rightleftharpoons L + 4M$

(B) $L + M_4 \rightleftharpoons J_6 + K$

(C) $J_6 + K \rightleftharpoons L + M_4$

(D) $L + 4M \rightleftharpoons 6J + K$

6 Pentanol, propyl acetate, pentanoic acid and ethyl propanoate all contain five carbon atoms. These four compounds are mixed in a flask and then separated by fractional distillation. Which compound would be most likely to remain in the flask?

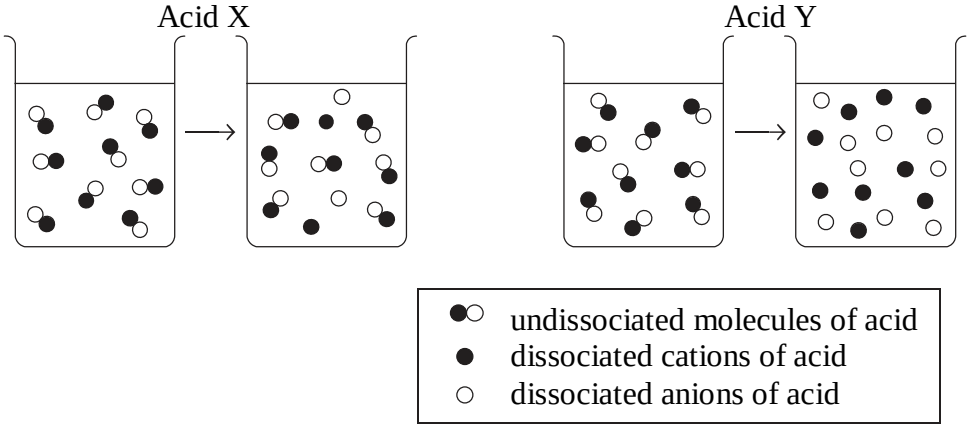
(A) Pentanol

(B) Propyl acetate

(C) Pentanoic acid

(D) Ethyl propanoate

7 The diagram shows the behaviour of two different acids when they are dissolved in distilled water.



Which row of the table correctly describes the two acids?

	Acid X	***Acid Y***
(A)	concentrated	dilute
(B)	dilute	concentrated
(C)	strong	weak
(D)	weak	strong

8 Choose the most correct statement to describe what occurs when a solution of sodium hydroxide is added to a saturated solution of magnesium hydroxide.

(A) The solubility of $Mg(OH)_2$ will be determined by the equilibrium constant, K_{sp}

(B) The molar solubility of $Mg(OH)_2$ will increase

(C) The total amount of Mg^{2+} in solution will increase

(D) The total amount of OH^- will be unchanged because it is saturated already.

9 Consider this system:

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

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

(A) HF(aq)/F^- (aq)

(B) HF(aq)/H_3O^+ (aq)

(C) HF(aq)/H_2O(l)

(D) F^- (aq)/H_3O^+(aq)

10 Water and chlorine, each at 1 atm pressure, are placed in a closed container at 375 K. The following reaction occurs.

$$\mathbf{2H_2O\ (g) + 2Cl_2\ (g) \rightleftharpoons 4HCl\ (g) + O_2\ (g)} \qquad \mathbf{\textit{K} = 5 \times 10^{-4}\ at\ 375\ K}$$

Which one of the following will be correct at equilibrium at this temperature?

(A) $[O_2] > ½[Cl_2]$

(B) $2[H_2O] = [HCl]$

(C) $[HCl] > 2[Cl_2]$

(D) $4[O_2] = [HCl]$

11 The pH of an alkaline solution is 8. Which of the following expressions is correct for this solution?

(A) $[OH^-] = 10^{-8}$

(B) $-\log_{10}[H^+] = 8$

(C) $-\log_{10}[OH^-] = 8$

(D) $[H^+] = 8$

12 In an experiment, 4-hydroxybutanoic acid [$HO(CH_2)_3COOH$] forms a polymer containing 10 monomer units.

Which of the following is closest to the approximate molar mass (in $gmol^{-1}$) of this sample of polymer?

(A) 8.78×10^2

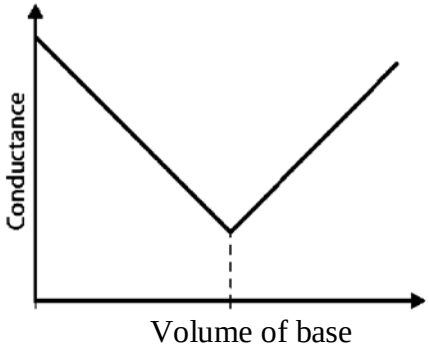
(B) 8.61×10^2

(C) 1.80×10^2

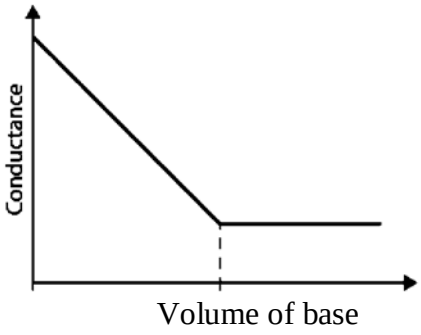
(D) 1.04×10^3

13 Which of the following conductivity graphs represent the titration of acetic acid and potassium hydroxide?

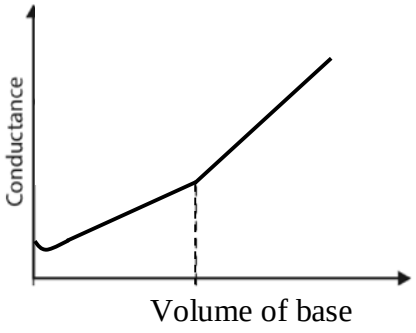
(A)



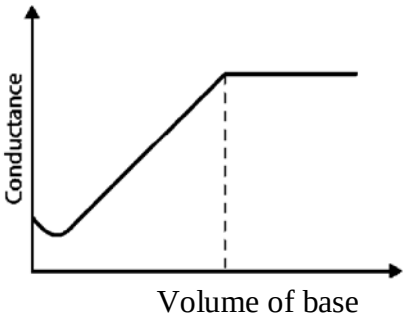
(B)



(C)



(D)



14 The pH of pure water at 50°C ($K_w = 5.5 \times 10^{-14}$) is:

(A) 2.35

(B) 6.63

(C) 7.00

(D) 7.37

15 Separate samples of hex-1-ene and hex-2-ene are reacted with bromine in the absence of light. Which of the following statements about these reactions is correct?

(A) The products will be 1,2-dibromohexane for both reactions.

(B) The products will be structural isomers of each other.

(C) The products will be isomeric dihaloalkenes.

(D) The products will be isomeric unsaturated compounds.

16 Oxides of nitrogen are formed in air at the high temperatures generated in lightning flashes. The equation and equilibrium constant for this reaction at 3000ºC is:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad K_1 = 5 \times 10^{-3} \text{ at } 3000^oC$$

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

$$4NO(g) \rightleftharpoons 2N_2(g) + 2O_2(g)$$

(A) 40000

(B) 100

(C) 0.01

(D) 0.005

17 When a sample of NO_2 (g) is placed in a container, the following equilibrium is rapidly established:

$$2NO_2\,(g) \rightleftharpoons N_2O_4\,(g)$$

If this equilibrium mixture is a darker colour at high temperatures and at low pressures, which of these statements about the reaction is correct?

(A) The reaction is exothermic and NO_2 is darker in colour than N_2O_4.

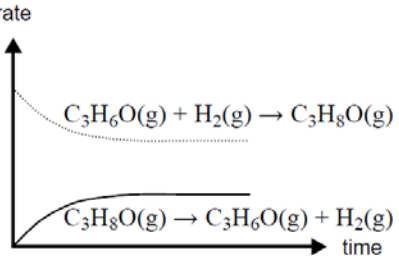
(B) The reaction is exothermic and N_2O_4 is darker in colour than NO_2.

(C) The reaction is endothermic and NO_2 is darker in colour than N_2O_4.

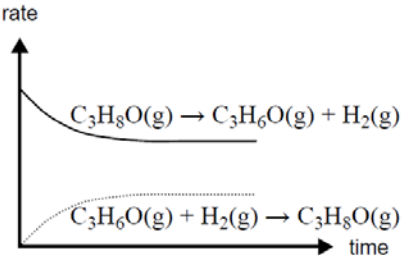
(D) The reaction is endothermic and N_2O_4 is darker in colour than NO_2.

18 Propan-2-ol reacts to form an equilibrium mixture with propanone and hydrogen. Which of the following best represents how the rates of the forward and back reactions change over time?

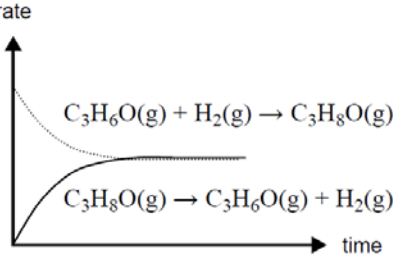
A.



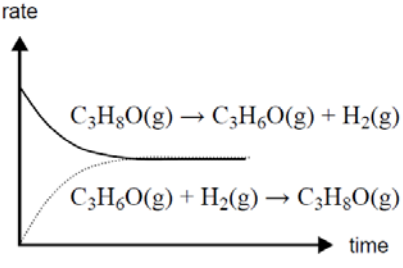
B.



C.

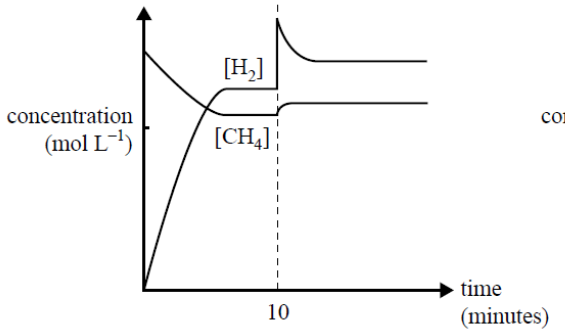


D.

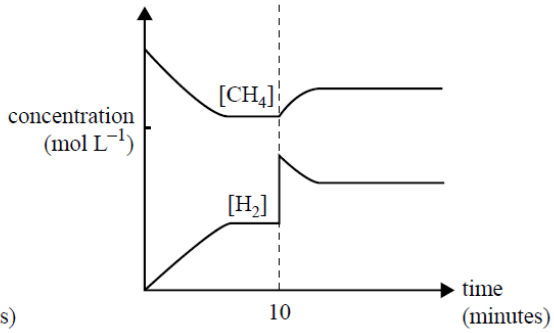


19 Carbon monoxide can be prepared by reacting gaseous methane and water. Equal amounts of $CH_4(g)$ and $H_2O(g)$ are added to a reaction vessel and allowed to react. After 10 minutes, equilibrium has been reached. At that time, some H_2 is added to the mixture and equilibrium is re-established. Which one of the following graphs best represents the changes in the amounts of CH_4 and H_2 in the reaction mixture?

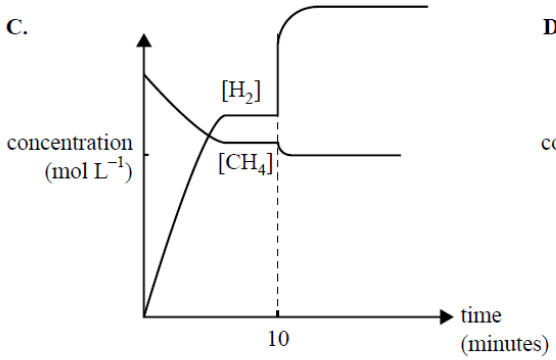
A.



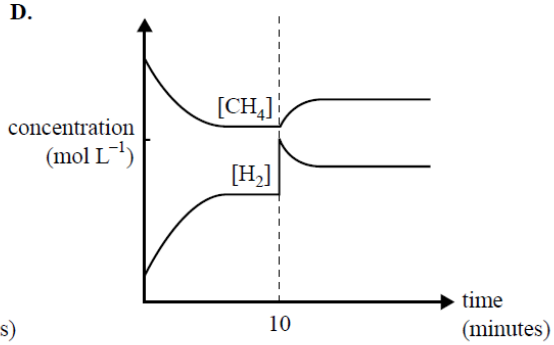
B.



C.



D.



20 Acetic acid, CH_3COOH, has a $K_a = 1.8\times10^{-5}$ and a molar mass of 60.052g/mol.
What mass of acetic acid should be used to form 2.5L of a solution with a pH of 5.50?

(A) 1.1×10^{-1} g

(B) 4.8×10^{-4} g

(C) 1.9×10^{-4} g

(D) 8.3×10^{-5} g

Section II

80 marks Attempt Questions 21-35

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.
Allow about 2 hours 25 minutes for this part

Question 21 (3 marks)

Consider the following mixture of gases in a closed 5.0 L 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:

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206.1 \text{ kJ}$$

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

Determine whether the system is at equilibrium.

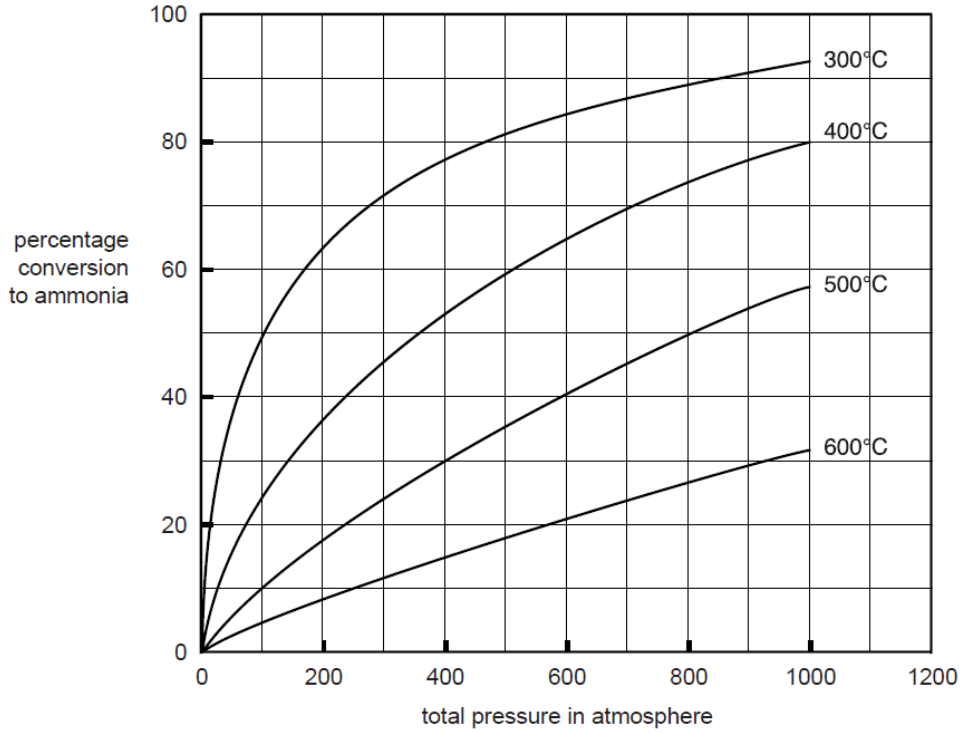
3

Question 22 (4 marks)

Ammonia is prepared industrially from hydrogen and nitrogen in the presence of a suitable catalyst according to the equation

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$$

The graph below shows the variation of the equilibrium yield of ammonia with pressure at different temperatures.



(a) A particular industrial plant uses a pressure of 300 atm and a temperature of 500ºC. From the graph, determine the percentage yield of ammonia under these conditions.

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1

(b) Deduce from the graph whether the production of ammonia from hydrogen and nitrogen is an exothermic or an endothermic reaction. Explain your reasoning.

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(c) Temperatures less than 400ºC are not used for this industrial reaction even though such temperatures give a greater equilibrium yield of ammonia. Give a possible reason for this.

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Question 23 (6 marks)

Lead (II) chloride is sparingly soluble in water, and an equilibrium is established between the solid and its ions in solution.

(a) Calculate the concentration of Pb^{2+} and Cl^- in the solution at 25°C.

3

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

3

Question 24 (9 marks)

(a) Calculate the pH of 0.20 M HNO_2. ($pK_a = 3.14$).

2

(b) The pH of a 0.10M HCN solution is 4.12. Compare the strength of HCN and HNO_2.

3

(c) Calculate the pH of the solution resulting when 85mL of the 0.20M HNO_2 is combined with 75mL of 0.12M $Mg(OH)_2$.

4

Question 25 (4 marks)

During a school camp, a student uses methylated spirits, which is mostly ethanol (C_2H_5OH), as a source of energy to boil their drinking water.

(a) Write a balanced equation for the reaction of methylated spirits with oxygen.

1

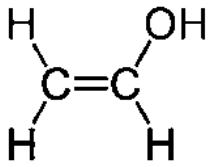
(b) A camping stove that uses methylated spirits as its fuel heats a kettle containing 950mL of water at 12ºC. Only 40% of the energy provided by the combustion reaction of the methylated spirits is used to heat the water.

What mass of methylated spirits must be burnt to heat the water to its normal boiling temperature? Assume the enthalpy of combustion of ethanol is 1364 kJ mol^{-1}.

3

Question 26 (3 marks)

Polyvinyl alcohol is a water-soluble addition polymer used in adhesives and paints. The monomer used has the following structure:



(a) Draw a structural formula for a 3–unit segment of the polymer.

1

(b) Explain the chemistry of how bromine water can be used to distinguish between a solution of the monomer and a solution of the polymer.

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2

Question 27 (4 marks)

Two students measured the pH of three solutions X, Y, Z with a pH probe. They stirred the solutions constantly and the measurements were all recorded at 25.0°C. Unfortunately, they did not label their beakers, but their teacher said they should be able to identify from the pH recorded. The measurements were:

Solution	pH
X	6.9
Y	8.7
Z	5.3

The solutions were sodium chloride, ammonium nitrate and sodium acetate.

(a) Identify each of the solutions X, Y and Z.

Solution	Identity of the solution
X	
Y	
Z	

2

(b) Explain the pH of the solution of ammonium nitrate.

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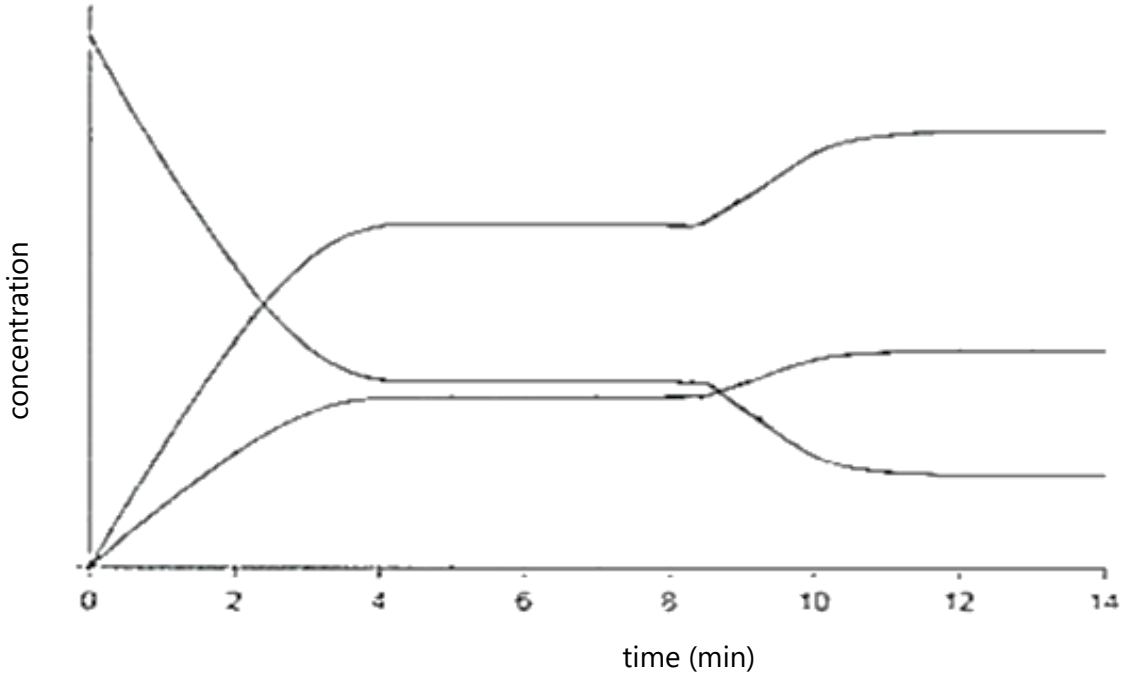
Question 28 (5 marks)

Nitrogen monoxide, chlorine and nitrosyl chloride (NOCl) form an equilibrium gaseous mixture:

$$Cl_2(g) + 2NO(g) \rightleftharpoons 2NOCl(g) \qquad \Delta H = -76kJ$$

The graph below shows the changes in concentration of the three species over time.



(a) Explain the change to the system that occurred at approximately t = 9 min.

3

(b) Compare the value of the equilibrium constant at t = 12 min and at t = 6 min? Justify your answer.

2

Question 29 (3 marks)

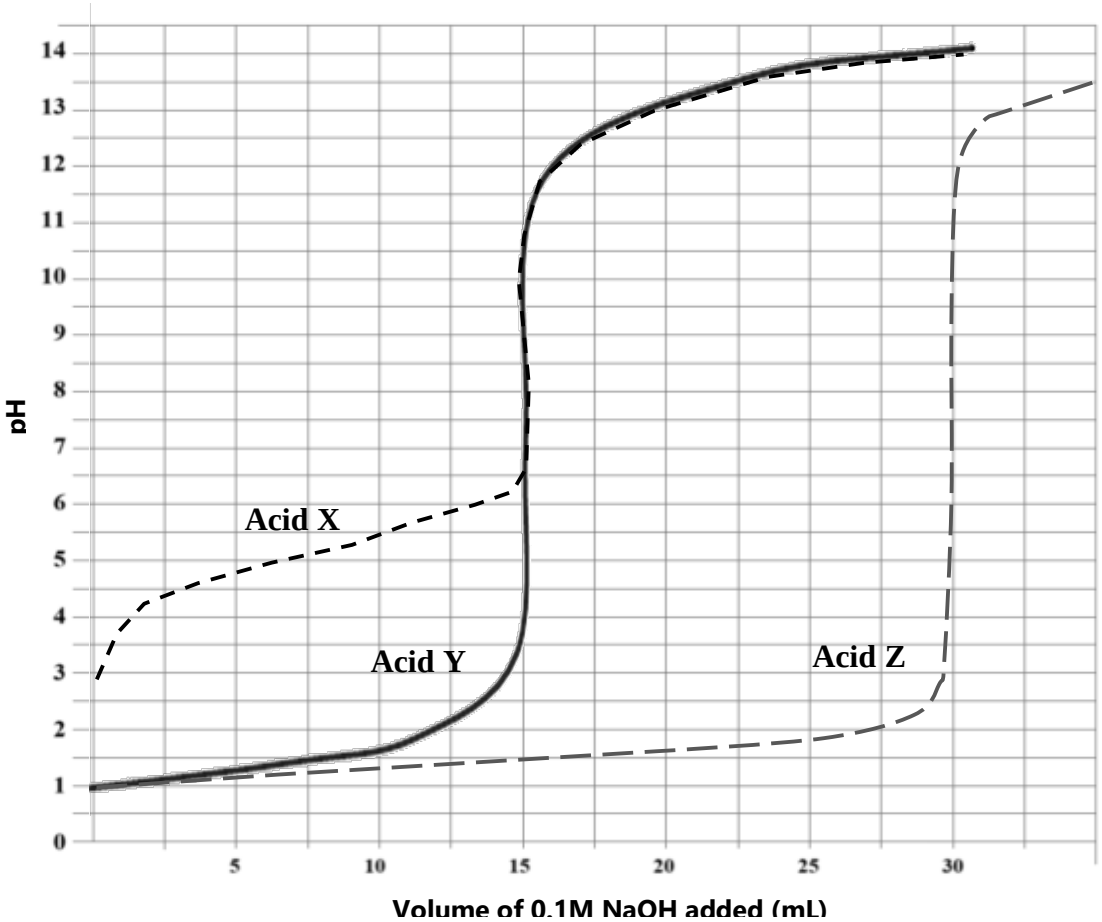
A buffer solution is prepared by combining 100 mL of 0.10 M HCOOH and 100 mL of 0.10 M NaHCOO. The K_a of formic acid, HCOOH, is 1.8×10^{-4}

Justify why this solution is classified as a buffer, explaining how it can resist changes in pH. Include relevant chemical equations in your response.

3

Question 30 (5 marks)

20.00 mL of three monoprotic acids were titrated against 0.1M sodium hydroxide. The titration curves resulting have been illustrated below.



(a) Calculate the concentration of the Acid Z.

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2

(b) Compare the concentration and strength of acids X and Y in comparison to Acid Z. Justify your response with reference to the graph.

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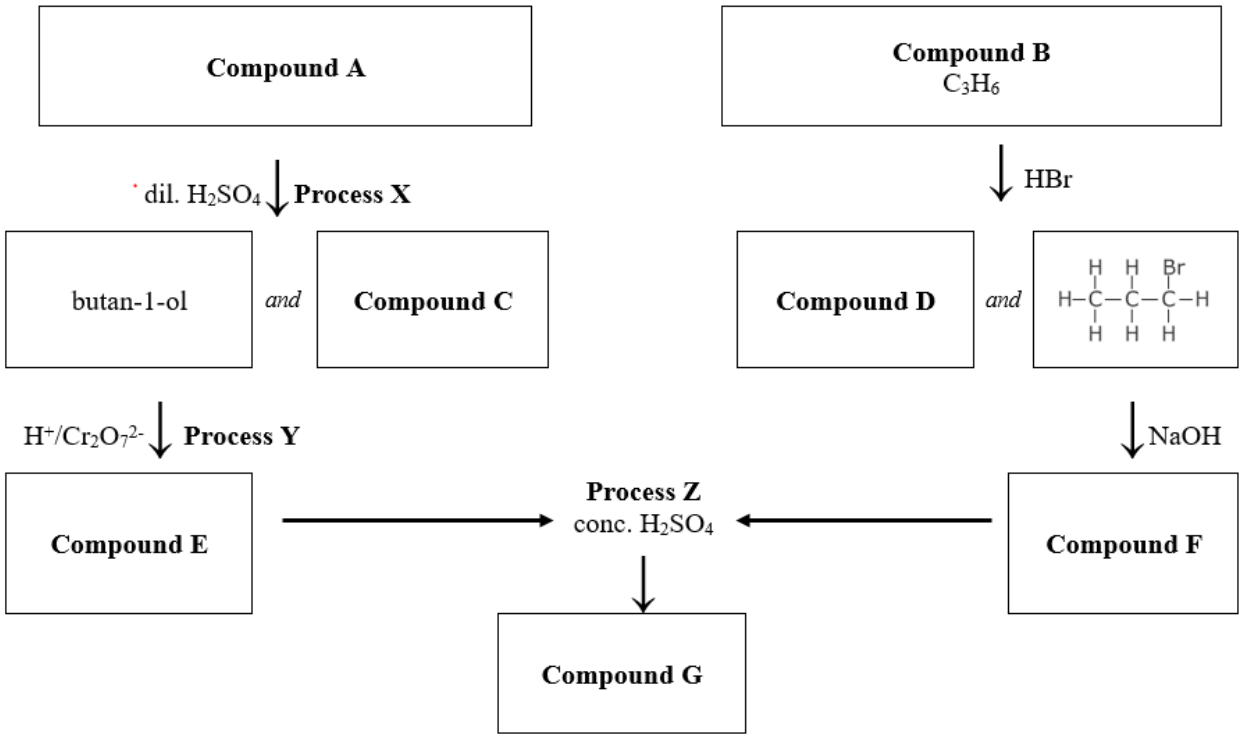
Question 31 (11 marks)

Compound G may be synthesised as follows:



(a) Name the following compounds from the flow chart: **6**

A		**B**	
C		**D**	
E		**F**	

(b) Draw the structural formula for Compound G from the flow chart: **1**

Question 31 continued on next page

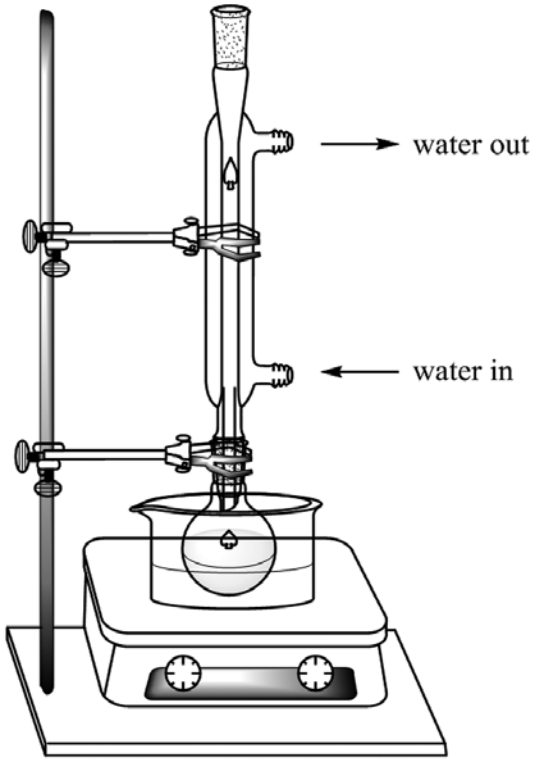
Question 31 (continued)

(c) Identify the type of reactions which occur for each of the following: **2**

(i) Process X: Compound A is converted to butan-1-ol: .....

(ii) Process Y: Butan-1-ol is converted to Compound E: .....

The image below shows the refluxing equipment that was used for Process Z.



(d) Explain why this equipment was chosen to carry out Process Z.

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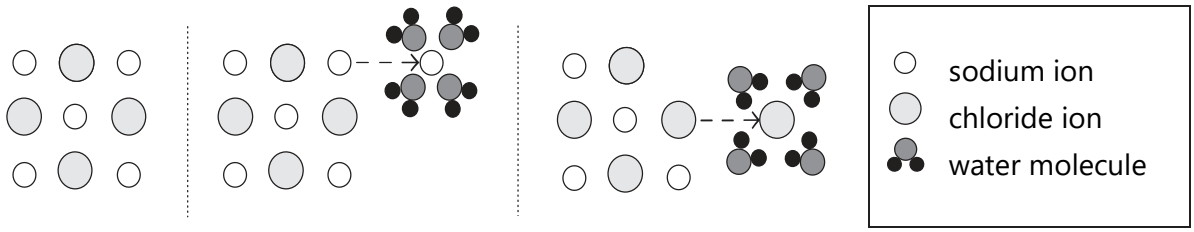
Question 32 (7 marks)

The diagram shows sodium chloride (common salt) dissolving in water.



(a) With reference to the diagram, describe the dissolution of sodium chloride in terms of bonding.

3

A mixture is formed from 0.14 mole of NaCl and 0.065 moles of $Pb(NO_3)_2$ in 4.0L of water.

(b) Determine whether a precipitate of lead (II) chloride will form.

4

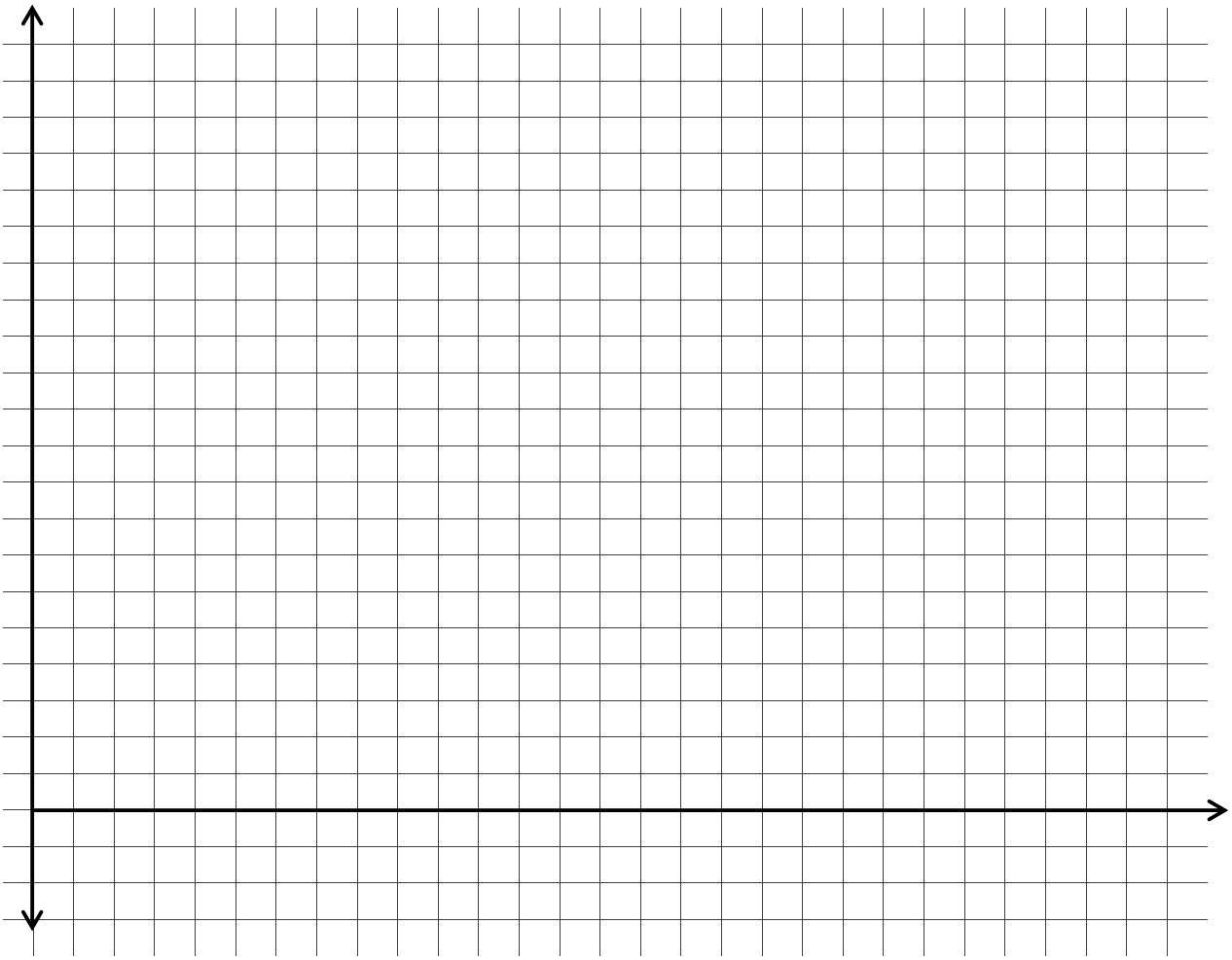
Question 33 (8 marks)

The boiling point of some organic compounds was measured. The results are shown in the table.

Number of carbon atoms	Carboxylic Acid	Boiling Point (°C)	Aldehyde	Boiling Point (°C)
1	Methanoic acid	100	Methanal	-21
2	Ethanoic acid	118	Ethanal	21
3	Propanoic acid	141	Propanal	49
4	Butanoic acid	163	Butanal	
5	Pentanoic acid	187	Pentanal	103
6	Hexanoic acid	205	Hexanal	129

(a) Using the data provided, construct a graph that shows the relationship between number of carbon atoms and boiling point for the carboxylic acids and the aldehydes.

3



Question 33 continued on next page….

Question 33 (continued)

(b) Use the graph to predict the of boiling point of butanal.

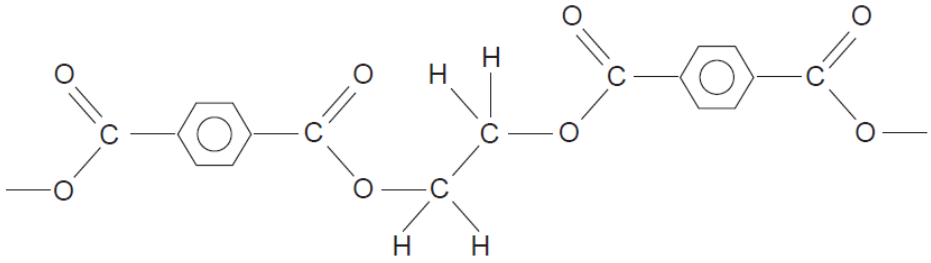
1

(c) Explain the trends that are evident in these data.

4

Question 34 (3 marks)

Polyethylene terephthalate, PET, is a plastic belonging to the polyester family and is a significant part of everyday life.



A section of a PET polymer

(a) Draw the monomers required to produce this polymer.

2

PET is typically referred to as *polyester* when used for fibres or fabrics, and called *PET* when used for soft drinks bottles, water bottles and other packaging applications

(b) Outline one property that makes polyethylene terephthalate suitable to be used in these applications.

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1

Question 35 (5 marks)

Pyrolusite, an ore of manganese, contains manganese in the form of MnO_2. A sample of pyrolusite from a newly discovered deposit is analysed to determine the degree of purity of the deposit.

To determine the amount of Mn in the pyrolusite sample, 1.25 g of dried pyrolusite was heated with 100 mL of 0.150 M oxalic acid ($H_2C_2O_4$).

The oxalic acid was in excess, so that all of the MnO_2 reacted according to

$$\mathbf{MnO_2(s) + H_2C_2O_4(aq) + 2H^+(aq) \rightarrow Mn^{2+}(aq) + 2CO_2(g) + 2H_2O(l)}$$

The resulting solution is then titrated with a solution of standardised NaOH

$$\mathbf{2NaOH(aq) + H_2C_2O_4(aq) \rightarrow Na_2C_2O_4(aq) + 2H_2O(l)}$$

22.80 mL of the 0.0510M NaOH was needed to react with the remaining oxalic acid.

(a) Calculate the number of moles of oxalic acid that was remaining in the 100 mL solution after reaction with the MnO_2.

2

(b) Calculate the number of moles of oxalic acid used to reduce the MnO_2.

1

(c) Calculate the percentage of Mn by mass present in the original 1.25 g of pyrolusite

2

END OF THE PAPER

2019 Year 12 Chemistry Trial examination.

Marking Guidelines and sample answers

Section I Multiple Choice

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

Section II

Q21.

Marking guidelines	Marks
• Correctly calculates the value of Q and states that the system is not at equilibrium	3
• Uses equilibrium expression in some form but gets incorrect answer	2
• States the equilibrium expression in some form	1

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.

$$Q = \frac{[CO][H_2]^3}{[CH_4][H_2O]}$$

$$= \frac{(0.15)(0.15)^3}{(0.4)(0.25)}$$

$$Q = 5.06 \times 10^{-3}$$

$$K = 0.26$$

$$Q \neq K.$$

$[CH_4] = 2.00/5 = 0.4$

$[H_2O] = 1.25/5 = 0.25$

$[CO] = 0.75/5 = 0.15$

$[H_2] = 0.75/5 = 0.15$

Therefore, the system is not at equilibrium…

Q<K thus equilibrium needs to shift to the RHS to reach equilibrium…

Students who got this wrong generally did not divide by 5L or didn't appreciate that these weren't initial concentrations and tried to apply an ICE table.

Better answers compared the value to K and stated that since Q≠K or Q<K, that this showed the reaction was not at equilibrium.

Q22.

(a)

Marking guidelines	Marks
• Correctly determines the yield of ammonia from the graph	1

Sample answer

25% yield

Several low estimates, suggesting that they thought each division was 5%

(b)

Marking guidelines	Marks
• Deduces that it is exothermic and explains this in terms of effect of increasing temperature on reaction	2
• Deduces that it is exothermic	1

Sample answer

The reaction is exothermic because an increase in temperature leads to a reduced yield of NH_3, indicating that the reverse reaction is favoured. In accordance with LCP, increased T favours endothermic reaction thus reverse reaction is endothermic (and forward is exothermic)

Students who dropped a mark did not express their response well and did not make good use of the data/refer to yield at different temperatures/promotion of the forward reaction at lower temps (vice versa)

(c)

Marking guidelines	Marks
• Provides a suitable reason	1

Sample answer

The reaction rate will be too slow to produce economical yield.

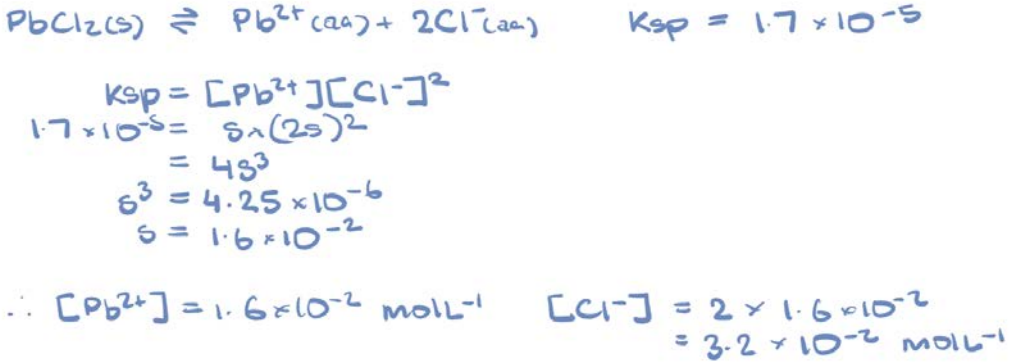
Students need to refer to daily yield and relate it to profit rather than simply the rate of the reaction.

Q23

(a)

Marking guidelines	Marks
• Provides correct balanced equation • Correctly calculates the value of the unknown using the K_{sp} expression • Calculates the concentration of Pb^{2+} in water and the concentration Cl^- in water	3
Correctly addresses TWO of the criteria above	2
Correctly addresses ONE of the criteria above	1

Sample answer



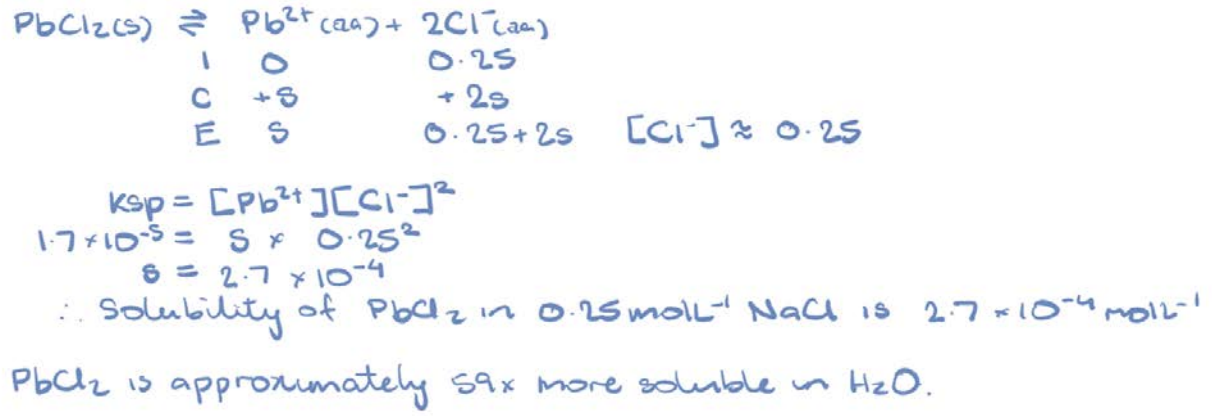
Let the solubility of $PbCl_2$ be s.
K_{sp} $PbCl_2$ = $[Pb^{2+}]$ $[Cl^-]^2$ = (s) $(2s)^2$ = $4s^3$ = 1.70 x 10^{-5}
s^3 = 4.25 x 10^{-6} mol/L
s = $(4.25 \times 10^{-6})^{1/3}$ = 1.62 x 10^{-2} mol/L
The solubility of $PbCl_2$ in water = 1.62 x 10^{-2} mol/L

This was poorly done by many students. Several of them got the Ksp expression, but did not substitute in the unknown correctly – i.e. had $[Cl^-]^2$ and $(x)^2$ rather than $(2x)^2$

(b)

Marking guidelines	Marks
• Provides assumption of $[Cl^-]$ • Correctly calculates the solubility of $PbCl_2$ • Qualitatively and quantitatively compares the differences in solubility	3
Correctly addresses TWO of the criteria above	2
Correctly addresses ONE of the criteria above	1

Sample answer



Only 2 students got this question completely correct, with another couple identifying that it was a common ion effect question.

Q24

(a)

Marking Guidelines	Marks
• pH of HNO_2 is correctly calculated	**2**
• Calculation is partially correct	**1**

Sample answer

$pK_a = 3.14$

$K_a = 10^{-3.14} = 7.244...x10^{-4}$

	HNO_2	H^+	NO_2^-
I	0.2	0	0
C	$-x$	$+x$	$+x$
E	0.2- x (x negligible)	x	x

$K_a = [H^+] \times [NO_2^-]/[HNO_2] = x^2/0.2 = 7.244...x10^{-4}$

thus:

$x = 0.01203... = [H^+]$

$pH = -\log[H^+] = 1.92$

pH of the 0.2M HNO_2 is 1.92

50% of students did this well; the other half did not apply an ICE table and the correct calculation.

(b)

Marking Guidelines	Marks
• Uses the data provided to correctly calculate the K_a of HCN and/or the pK_a of HCN OR • Calculates a comparative pH (eg) of 0.1M HNO_2 or 0.2M HCN AND • Makes a clear comparison of the values calculated (eg) $K_a(HNO_2) > K_a(HCN)$ OR $pK_a(HNO_2) < pK_a(HCN)$ OR $pH(HNO_2) < pH(HCN)$ • Uses the relative K_a/pK_a/pH to determine the relative strengths of the two acids	**3**
• Calculates a comparable value for the two acids (eg) pH of same concentration or K_a or pK_a	**2**
• Correctly completes a relevant calculation	**1**

Sample answer

pH =- 4.12 => $[H^+] = 10^{-4.12} = 7.585...x10^{-5}$

	HCN	H^+	CN^-
I	0.1	0	0
C	$-7.585...x10^{-5}$	$+7.585...x10^{-5}$	$+7.585...x10^{-5}$
E	0.0999...	$7.585...x10^{-5}$	$7.585...x10^{-5}$

$K_a = [H^+] \times [CN^-]/[HCN] = (7.585...x10^{-5})^2/0.0999... = 5.758...x\ 10^{-8}$

$pK_a = -\log K_a = 7.24$

Since the pK_a(HCN) is larger than the $pK_a(HNO_2)$ this means that HCN is the weaker acid.

Very few students used data to calculate pKa/Ka of the HCN, relying simply on a comparison of pH. This is a 3-mark question, which simply comparing pH would not lend itself to! The concentrations of the acids were not the same, so there was no simple way to compare them without repetition. NOTE: in the HSC, you wouldn't get this type of question as it requires the same skill to complete part a) and b); students get penalised twice when they can't do a)....

(c)

Marking Guidelines	Marks
ALL steps of the calculation have been accurately carried out • Balanced equation included or correct mole ratio of reacting species • Number of moles of the HNO_2 and of $Mg(OH)_2$ calculated • Limiting reagent and excess reagent identified • Number of moles of excess reagent calculated correctly • Total volume determined • Concentration of excess reagent correctly calculated • Concentration of excess species converted to pOH & pH	**4**
• 1 error in calculations	**3**
• 2-3 errors in the calculation OR • Calculation correct with the assumption that the acid is in excess.	**2**
• One relevant calculation is correctly completed	**1**

Sample answer

$2HNO_2$ + **$Mg(OH)_2$** → $Mg(NO_2)_2$ + $2H_2O$

$c_A = 0.2M$
$V_A = 0.085L$
$n_A = cV$
$= 0.017mol$
Limiting Reagent

Used up
0 moles left

$c_B = 0.12M$
$V_B = 0.075L$
$n_B = cV$
$= 0.009mol$
Excess

½ x (0.017) moles used
0.009-0.0085= 0.0005 moles left over

TOTAL VOLUME = 85+75
V = 160mL
V = 0.16L

$c(Mg(OH)_2)$ left = n/V
= 0.0005/0.16
= 0.003125 M

$[OH^-] = 2 \times c(Mg(OH)_2)$
$[OH^-] = 0.00625M$

$pOH = -\log[OH^-]$
= 2.204…

pH = 14-pOH
= 11.7958…
Final pH of solution is
pH=11.80

Common errors included failing to apply the mole ratio correctly and then making the assumption that the HNO_2 was in excess. This is a careless error that cost 2 marks.

Q25

(a)

Marking Guidelines	Marks
• Correct balanced equation ~~with states~~	**1**

Sample answer

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

This was done well – as it should be! Make sure that the states are correct (and included)

(c)

Marking Guidelines	Marks
Completely correct calculation: • Calculates energy (Q) required to heat the water ($Q=mc\Delta T$) • Makes appropriate correction to account for 40% transfer of heat. • Makes relevant conversion of units from joules to kilojoules • Calculates number of moles of ethanol that need to be combusted to provide this energy • Calculates mass of ethanol	**3**
• Calculation has some errors	**2**
• Correctly completes a relevant calculation	**1**

Sample answer

$Q = mc\Delta T$

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

$= 349\,448\ J$

$= 349\ kJ$ @ 40%

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

$= 874\ kJ$

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

$= 0.6405\ mol$

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

$= 29.5\ g$

$= 30\ g\ (2sf)$

Students often failed to …

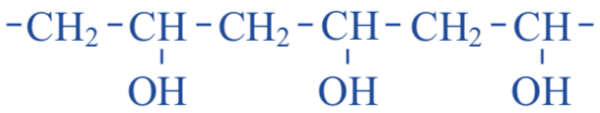
A few converted ΔT from C into K…not recognising that a CHANGE in temperature using either scale is the same i.e.

Q26

(a)

Marking Guidelines	Marks
• Correct structural formula	1

Sample answer



This was done quite well, although a few students retained the C=C or put H instead of OH

(b)

Marking Guidelines	Marks
• Explains how to distinguish between saturated and unsaturated hydrocarbons • Clearly outlines the colour change that occurs when $Br_2(aq)$ reacts • Relates the (addition) reaction to the C=C double bond	2
• Fails to mention that Bromine water reacts with double bond	1

Sample answer

Orange/yellow bromine water is decolourised instantly (to colourless) by the monomer. The Br_2 reacts readily with the C=C double bond via an addition reaction – UV light not required for reaction…
The polymer contains only single bonds and reacts very slowly in UV light or does not react at all (and orange colour remains).

This was done reasonably well, although the specific colour change was not mentioned. Also, lots of reference to alkene and alkane, rather than monomer (which is not an alkene!) and polymer (Which is not an alkane).

Q27

(a)

Marking Guidelines	Marks
• All 3 salts are correctly matched	2
• Only 1 salt is correctly identified	1

Sample answer

X	pH=6.9	sodium chloride
Y	pH=8.7	sodium acetate
Z	pH=5.3	ammonium nitrate

About 50% of students muddled Y and Z

(b)

Marking Guidelines	Marks
• Outlines the reaction of the NH_4^+ ion's reacting with H_2O to produce and excess of H_3O^+ • Excess H_3O^+ linked to low pH (acidic solution) • Relevant equation is included in answer	2
• One correct piece of information is provided (as long as it is not contradicted)	1

Sample answer

NH_4^+

NO_3^-	no reaction with H_2O:	NR
NH_4^+	cation reacts with H_2O:	$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$ Production of excess H_3O^+ results in pH<7

This was either done quite well or poorly.

Q28

(a)

Criteria	Mark
• Identifies that the temperature has been increased • Relates the temperature change to the direction in which the equilibrium shifts, including reference to the concentrations of reactant and product • Links the changes/shifts to Le Chatelier's Principle/minimising the change	3
• Identifies that a temperature change has increased AND • Relates the temperature change to the direction in which the equilibrium shifts/to the concentrations of reactant and product OR • Clearly links the temperature change to LCP	2
• Identifies that a temperature change has occurred	1

Sample answer

- An **increase in temperature** has occurred (concentrations changes with no addition or removal of reagents not an overall volume/pressure change).
- The change in temperature has caused a shift in the equilibrium **towards the left/favoured reverse reaction as this is endothermic** producing higher concentrations of chlorine and nitrogen monoxide and a lower concentration of NOCl
- Le Chatelier's Principle predicts that, if an equilibrium is disturbed, an increase in temperature favours the endothermic reaction.

Generally this was done quite well, but several students didn't refer to the concentrations or to LCP.

(b)

Criteria	Marks
• ~~Identifies that the equilibrium constants at t = 6 min and at t = 12 min differ~~ • Relates difference to the fact that the temperature has changed • Identifies the K value at t=6 is larger than at t=12	2
• Identifies that the equilibrium constants are different due to a temperature change	1

Sample answer

Equilibrium constants depend on temperature.
Temperature changed at t = 9 min thus the equilibrium constant at t = 6 min will differ from the equilibrium constant t = 12 min.
The reaction shifted in the reverse direction thus the K value will be smaller at t=12 compared to t=6.

Most students who lost the mark did not mention that K was temperature dependent.

Q29

Criteria	Marks
• Defines a buffer – including what constitutes a buffer solution • Relates the theory of buffers to the actual species present in this solution • Provides a clear explanation of the way in which a buffer works to minimise pH changes (ability to shift back and forth) using chemical equations • Refer to $[H^+]$ and/or $[OH^-]$ and pH	3
• Provides some relevant information OR • Explanation is not articulated clearly and correctly	2
• Provides one correct piece of relevant information	1

Sample Answer

- $HCOOH(aq) + H_2O(l) \rightleftharpoons HCOO^-(aq) + H_3O^+(aq)$
- A buffer is usually a roughly 1:1 mixture of a weak acid and its salt: HCOOH is a weak acid & NaHCOO is the salt of its conjugate. That is, roughly equal numbers of moles of both species are present in the system.
- Buffers resists changes in pH when acids or bases are added.
- It does this because added H^+ ion increase the H^+ concentration thus shifting the equilibrium to the side that consumes them (by reacting with the conjugate of the weak acid – which there is a decent amount of in the system)
- Added OH^- reacts with the H^+ ions thus effectively removing them from the system. System shifts to favour the reaction that produces more H^+ ions to minimise the change thus replenishing the H^+
- Therefore, the change in concentration of H^+ is minimised by the buffer system and hence pH change is also minimised.

Lots of students identified that it was a buffer due to weak acid/conjugate base. However, there were lots of incorrect equations, or lack of understanding of the effect of adding acid and base. Some students didn't cover both acid and *base.*

Q30

(a)

Marking Guidelines	Marks
• Concentration of Acid X is correctly calculated	2
• One relevant calculation is correctly performed	1

Sample answer

Acid Z is monoprotic – HZ => 1:1 ratio in the reaction

$$\underset{c_A = ?,\ V_A = 20mL = 0.02L}{HZ} + \underset{c_B = 0.1M,\ V_B = 30mL = 0.03L}{NaOH} \rightarrow NaZ + H_2O$$

$$\frac{c_A V_A}{1} = \frac{c_B V_B}{1}$$

$c_A = 0.15$ mol/L

Thus, concentration of Acid Z is 0.15M

Not done as well as expected as this was straight forward titration stuff.

(b)

Marking Guidelines	Marks
• Correctly compares the strength and concentration of of X and Y with each other and with Z • Justifies using data from the graph in terms of pH, equivalence point and volume of NaOH required (as applicable)	3
• Correct comparison of strength OR concentration of X **AND** Y with Z with correct justification	2
• Correctly compares the strength OR concentration of of X **AND** Y with Z OR • Correctly comparison of strength **OR** concentration of of X **OR** Y with Z with correct justification	1

Sample answer

Acid X and Acid Y are the same concentration as each other – and they are both half the concentration of Acid Z. This is determined by the fact that half the volume of NaOH is required to reach equivalence point for these acids (15mL instead of 30mL) - acids are all monoprotic and the NaOH being used is 0.1M in each case…

Acid Z is a strong acid – as seen by the starting pH of pH=1 on the graph and the equivalence point occurs at a neutral pH=7. This is also the case for Acid Y – hence it is also a strong acid.

Acid X is a weak acid. Its initial pH is higher (pH=2.5) than for Acid Y despite being the same concentration.

The equivalence point for the titration with Acid X also reaches equivalence point at a higher pH of about pH = 9 which is characteristic of titration between a weak acid and strong base (NaOH is a SB). The shape of the curve is also indicative of this being a weak acid.

Feature	X	Y	Z
Strength	**Weak**	**Strong**	**Strong**
Justification	• pH is around 3 • Initial pH is higher than for the other two acids Equivalence point or Salt pH is 8.5 (slightly basic) • Shape of curve is classic WA + SB	• pH is 1 • Equivalence point or Salt pH is 7 (neutral) • Shape of curve is classic SA + SB	• pH is 1 • Equivalence point or Salt pH is 7(neutral) • Shape of curve is classic SA + SB
Concentration	**Same as Y**	**Same as X**	**Double the others**
Justification	Same volume required	Same volume required	Double the volume of NaOH required

A lot of muddling up between concentration and strength…

Lots of students identified that Z was more dilute, rather than stronger (or more concentrated!)

Q31

(a)

Marking Guidelines	Marks
• Provides 6 correct names	6
• Provides 5 correct names	5
• Provides 4 correct names	4
• Provides 3 correct names	3
• Provides 2 correct names	2
• Provides 1 correct name	1

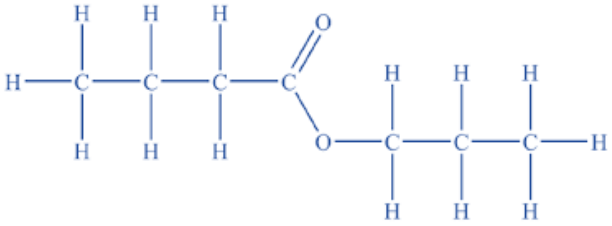
Sample answer

A	but-1-ene	**B**	propene
C	butan-2-ol	**D**	2-bromopropane
E	butanoic acid	**F**	propan-1-ol

(b)

Marking Guidelines	Marks
• Correct structure of G is drawn. Error carried forward if necessary.	1

Sample answer



(c)

Marking Guidelines	Marks
• Both processes have been correctly identified	2
• One process has been correctly identified	1

Sample answer

(i) Process X is Addition of water (also known as hydration)

(ii) Process Y is Oxidation

Lots of students used HYDROGENATION rather than hydration, which is not the same!

(d)

Marking Guidelines	Marks
• Explains TWO reasons for using the reflux technique	2
• Explains ONE reason for using the reflux technique	1

Sample answer

The reaction mixture is boiled under reflux, using an open condenser. This enables the reaction to be carried out at the boiling point, to maximise rate, without loss of reactants by vaporisation. The use of an open condenser avoids any hazardous build-up of pressure in the system.

The explanations provided lacked depth in the most part, with few students referring to the equilibrium. It was imperative to mention the volatility of reactants specifically and would have been better to link this to allowing the reaction to occur. High temperatures were not related to the reaction rate/Ea.

Q32

(a)

Criteria	Marks
• Describes the observations fully, by discussing the steps in the dissolution of ionic substances in water • Makes clear reference to the polar nature of water and charged nature of the ions • Specifies the interaction between the ions and the polar water molecules	3
• Partially explains the observations, by discussing some aspects of the steps in the dissolution of ionic substances in water	2
• Identifies some correct information about the observations OR the steps in dissolution	1

Sample answer

- Positive (Na^+) and negative (Cl^-) ions arranged in rigid lattice of solid NaCl
- Water molecules are polar with significantly negative (δ^-) Oxygen and a significantly positive (δ^+) Hydrogen end…giving rise to hydrogen bonding in the water
- Water molecules are in continuous motion and collide with the crystal lattice.
- The positively charged Na^+ cations in the crystal are attracted to the (δ^-) O ends of the water molecules.
- The negatively charged Cl^- anions in the crystal are attracted to the (δ^+) H ends of the water molecules.
- The strong ion-dipole interaction with the polar water molecules takes the crystal lattice apart, forming individual (solvated) sodium ions and chloride ions that are surrounded by water molecules.
- $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$

Students often referred to the oxygen in the water as O^{2-} and the hydrogens as H^+ - which they aren't; this suggests ionic bonding. $\delta^{+/-}$ is the required annotation for the polarity of the molecule. Better use of the diagram required.

(b)

Criteria	Marks
~~• Writes a balanced equation for the reaction occurring~~ ~~• Calculate [NaCl] or [Cl^-] and [$Pb(NO_3)_2$] or[Pb^{2+}] and~~ ~~• Write expression for K_{sp} of $PbCl_2$~~ • Calculates Q with given concentrations • Compares Q to K_{sp} • Identifies that Q>K_{sp} and hence a precipitate will form	4
• 1-2 errors in the above	3
• One correct and relevant calculation (eg) determining the [NaCl] AND • Balanced equation for precipitation occurring OR • Correct K_{sp} expression for $PbCl_2$	2
• One correct and relevant calculation (eg) determining the [NaCl] OR • Balanced equation for precipitation occurring OR • K_{sp} expression correct for $PbCl_2$	1

Sample answer

2NaCl	+	**$Pb(NO_3)_2$**	**$PbCl_2(s)$ + $2NaNO_3$**
n= 0.14mol		0.065mol	
V= 4L		V= 4L	
c = n/V		c = n/V	
c=0.035M		c=0.01625M	
[Cl^-]=[NaCl] = 0.035M		[Pb^{2+}]= [$Pb(NO_3)_2$] = 0.01625M	

From the data sheet
K_{sp} ($PbCl_2$) = 1.70×10^{-10}
K_{sp} ($PbCl_2$) = [Pb^{2+}] × [Cl^-]^2

Q = [Pb^{2+}] × [Cl^-]^2
Q =0.01625 x $(0.035)^2$ = 1.99…x 10^{-5}
Q>K_{sp}
Thus a precipitate of $PbCl_2$ will form

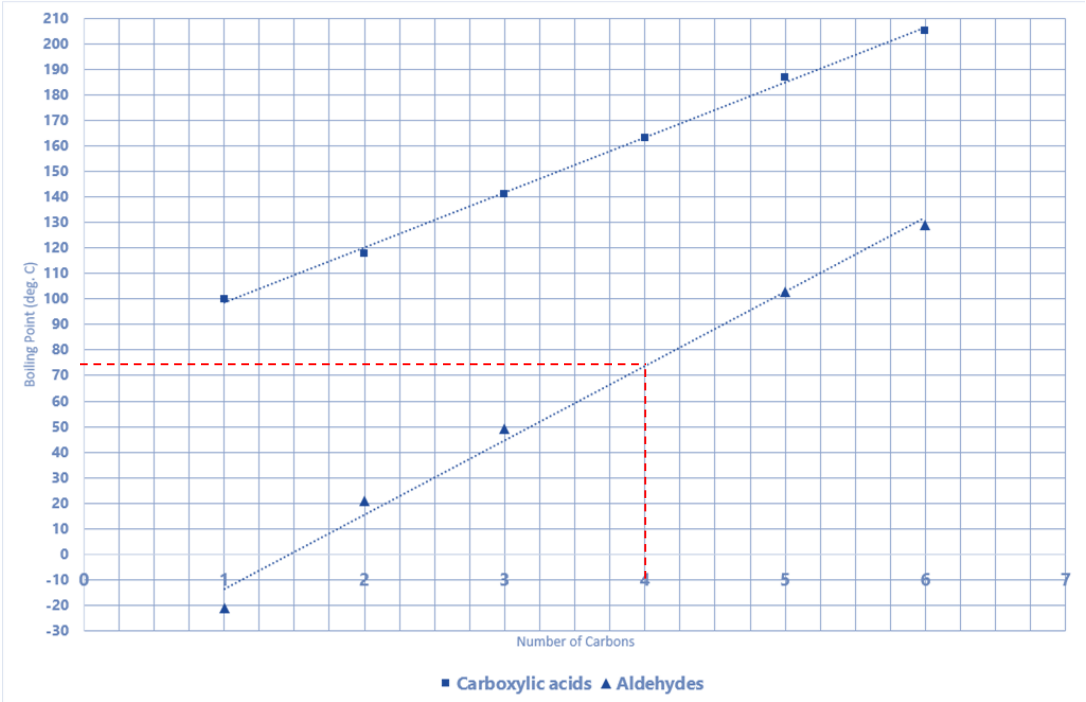
Students either did this correctly, or fairly poorly. There were a lot who calculated the relative concentrations of the solutions, but didn't seem to know what to do next.

Q33

(a)

Marking Guidelines	Marks
• Correct scale and label on vertical & horizontal axis • Points plotted correctly • Appropriate lines of best fit included • Clearly identified data sets – as carboxylic acid/aldehyde) • Used majority of the grid provided	3
• Most of the above with 1-2 errors and/or incomplete plotting	2
• Some attempt at plotting the data with errors in scale, plotting or axes allocation	1

Sample answer



There were lots of adequate graphs, but few scoring 3 marks. NOTES:

1. Only use multiples of 1, 2 and 5 for scales as this means that you can plot accurately and interpolate/read accurately

2. Use a ruler to draw the line of best fit

3. Ensure the line of best-fit passes through as many points as possible – don't join the top and bottom points…!

(b)

Marking Guidelines	Marks
• Correctly predicts the boiling point of butanal as determined by the graph.	1

Sample answer

75°C (see dotted red line on graph above)
(Data book answer is 74.8°C)

(c)

Marking Guidelines	Marks
• Identifies the **TWO** main trends shown in the graphed data. • Clearly explains the relationship between the increasing number of carbon atoms and the boiling point of both the carboxylic acids/aldehydes in terms of increasing strength of dispersion forces. • Justifies that, for same number of carbons, the carboxylic acid has a higher boiling point than the aldehyde as a result of stronger IMFs. • Comprehensively links IMFs of the two homologous series to the structure of the molecules.	4
• Identifies the **TWO** main trends shown in the graphed data. AND • Clearly explains ONE of the trends in terms of IMF and structure of the molecules OR • Addresses the TWO trends but answer is lacking in detail, clarity or accuracy	3
• Identifies the TWO main trends shown in the graphed data but explanations are limited OR • Identifies ONE trend with a clear explanation	2
• Identifies ONE of the trends.	1

Sample answer

Trends observed:

1. The boiling points of both series (carboxylic acids and aldehydes) increases with increasing number of carbons.
2. For a particular number of carbons, the carboxylic acids have higher a boiling point than the corresponding aldehyde.

Explanations of trends:

Stronger forces of attractions between adjacent molecules require more energy to overcome them during change of state – thus increasing boiling points.

1. As the number of carbons increases, the molecular mass of each molecule also increases. This in turn increases the dispersion forces between neighbouring molecules – for both homologous series.
2. The bp of the carboxylic acid is higher than the bp of corresponding aldehyde because the –COOH group on the acids gives rise to greater IMFS than the C=O group of the aldehydes. The polar $\delta+$C=O $\delta-$ carboxyl group gives rise to dipole-dipole forces between adjacent molecules. The additional, exceptionally polar $\delta-$O-H $\delta+$ hydroxy group on the carboxylic acid molecules gives rise to significantly stronger hydrogen bonding forces – thus accounting for the higher bp.

Diagrams are helpful here, but only if they are correct. Most students identified both trends, and lots explained the relationship between CH chain and BP referring to dispersion forces. There are lots of students who consider the C=O able to hydrogen bond in aldehydes, where it cannot (due to no O-H bond)…which is probably because H-bonding DOES exist between the O of the C=O and the H of the O-H in acids – but this is due to the presence of the OH bond.

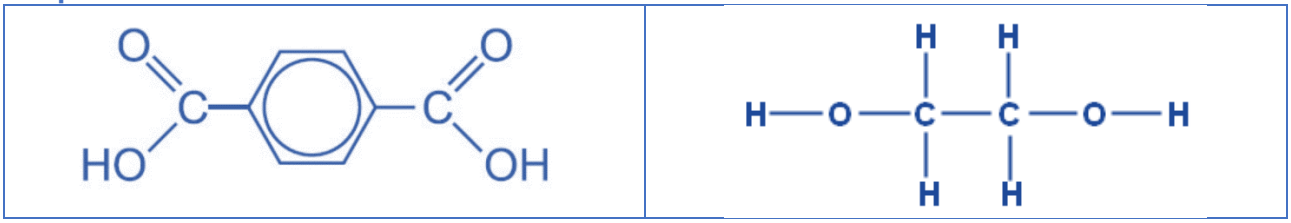
Students MUST refer to structure of the molecules.

Q34

(a)

Marking Guidelines	Marks
• Both monomer molecules drawn correctly	2
• One monomer molecule drawn correctly	1

Sample answer



Generally the 1,4-benzendicarboxylic acid was drawn correctly, but several student had it reacting with ethylene, rather than ethylene glycol. This is a CONDENSATION polymer, so no C=C bond present in the monomers.

(b)

Marking Guidelines	Marks
• Provides one relevant property of PET related to its use	1

Sample answer

Excellent water and moisture barrier - absorbs very little water
Hard, stiff, strong and stable material.
Good gas barrier properties
Good chemical resistance
Strong, flexible, and minimal wrinkles and shrinkage

This was marked very generously. The question asked for an OUTLINE, but identification of properties was awarded. SOLUBLE is not the same as waterproof.....NO plastic is soluble in water!

Q35

(a)

Criteria	Mark
• Correctly calculates the number of moles of oxalic acid that remained after reaction	2
• Partially correct calculation	1

Sample answer

$$\mathbf{2NaOH} \quad + \quad \mathbf{H_2C_2O_4} \quad \rightarrow \quad \mathbf{Na_2C_2O_4 + 2H_2O}$$

$c_B = 0.051M$ $\qquad$ n_A

$V_B = 22.8mL = 0.0228L$

$$\frac{c_B V_B}{2} = \frac{c_A V_A}{1} = \frac{n_A}{1}$$

$$\frac{0.051 \times 0.0228}{2} = \frac{n_A}{1}$$

$n_A = 5.814...x10^{-4}$ mol

OR

n(NaOH) = 0.051x0.0228 = 0.0011628 moles
n(oxalic acid) = n(NaOH)/2 *see the mole ratio in equation provided.*
n(oxalic acid) = $5.814...x10^{-4}$ mol

n(oxalic acid) left over from previous reaction = $5.81x10^{-4}$ mol (3 sf)

There were a lot of students getting this correct, or picking up a mark for calculating n(NaOH). Some students calculated n(oxalic acid) reacting with the pyrolusite, which was part b)….

(b)

Criteria	Marks
• Determines initial n(oxalic acid) and uses this to correctly calculate the n(oxalic acid) consumed in the reaction with the MnO_2 in the pyrolusite ore – with error carried from part (a)	1

Sample answer

n(oxalic acid) added initially to the pyrolusite= cV = 0.150 x 0.1= 0.015mol
n(oxalic acid) left over = $5.814...x10^{-4}$ mol
n(oxalic acid) used in reaction with the pyrolusite = 0.015 - $5.814...x10^{-4}$ = 0.0144186mol = 0.0144 mol (3sf)

This was done reasonably well for the students who didn't muddle a) and b) up….

(c)

Criteria	Mark
• Correctly calculates the number of moles of oxalic acid that remained after reaction	2
• Partially correct calculation	1

Sample answer

$n(MnO_2)$ = n(oxalic acid) = 0.0144186mol
n(Mn) in the ore = $n(MnO_2)$ = 0.0144186mol
m(Mn) = n x MM = 0.0144186 x 54.94 = 0.792…g

% Mn in pyrolusite ore = m(Mn)/m(ore sample) x 100 = 0.792…/1.25 x 100 = 63.4%

This was done ok, but a few students used the mass of MnO_2 rather than Mn, and some used Mg….
Errors were carried from a)/b) and for the incorrect mass.