STUDENT NUMBER: _____

Pymble Ladies' College

2022 Chemistry Trial 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 separately
- For questions in Section I, record your responses on the multiple choice answer sheet 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

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

Section II – 80 marks

- Attempt Questions 21 – 34
- Allow about 2 hours and 25 minutes for this section

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Section I

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

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

1. Which of the following substances would make the best primary standard?

	Substance	*Purity*	*Solubility*	*Formula mass*
A.	P	high	low	low
B.	Q	high	high	high
C.	R	high	low	high
D.	S	high	high	low

2. An acid is a substance that donates one or more protons"
Who first gave this definition of an acid?

A. Arrhenius

B. Brønsted-Lowry

C. Lewis

D. Lavoisier

3. The table below shows the pH range of four acid-base indicators

Indicator	**pH range**
W	3.3 - 4.3
X	6.2- 7.5
Y	7.8 -10.3
Z	8.1 - 9.8

Which indicator would be the best choice for a titration between potassium hydroxide and ethanoic acid?

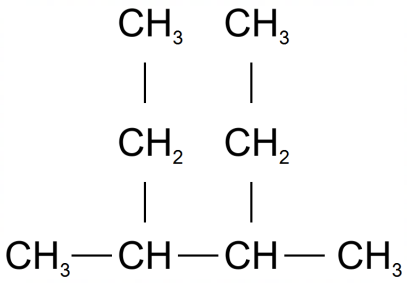
A. W

B. X

C. Y

D. Z

4. What is the correct systematic name for the following compound?



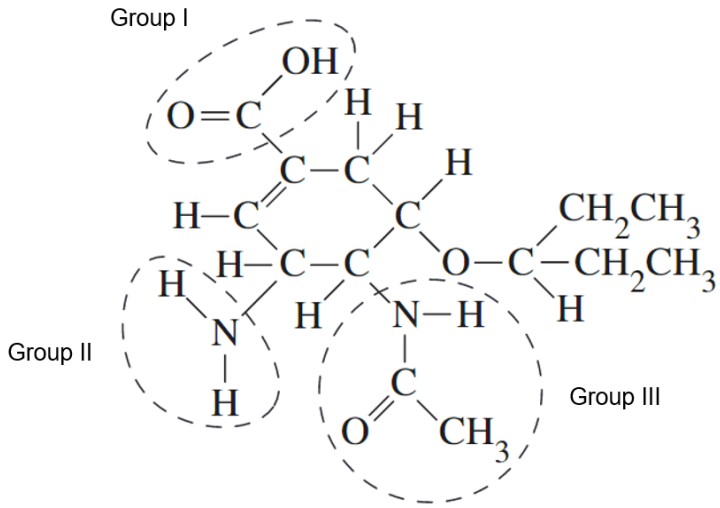
A. 2-ethyl-3-methylpentane

B. 3-methyl-4-ethylpentane

C. 3,4-dimethylhexane

D. 2,3-diethylbutane

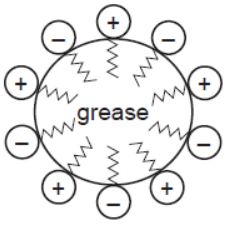
5. The structure of a compound is shown. It has been suggested that this molecule may be an effective drug for treating influenza.

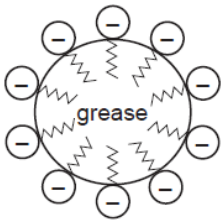


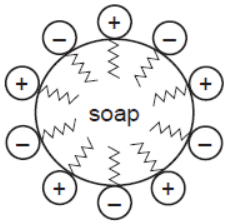
Which row of the table correctly names the functional groups labelled I, II and III?

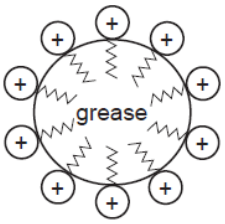
	Group I	***Group II***	***Group III***
A.	aldehyde	amide	ester
B.	carboxylic acid	amine	amide
C.	ketone	amine	carboxylic acid
D.	carboxylic acid	amide	amine

6. Which of the following diagrams represents a micelle that forms in water when soap is used to remove grease from dirty dishes?

A. 

B. 

C. 

D. 

7. How many structural isomers are there for the compound with molecular formula C_3H_6BrCl?

A. 4

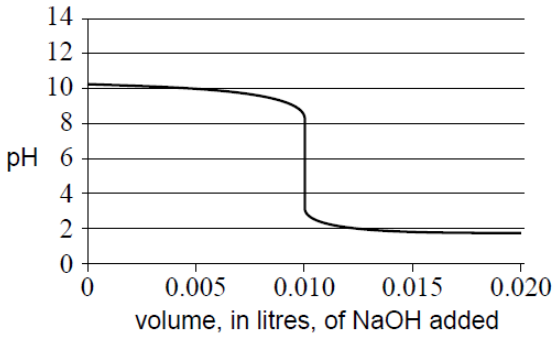
B. 5

C. 6

D. 7

8. Which titration curve best represents the change in pH as 0.100 M NaOH solution is added to a 10.0 mL aliquot of 0.100 M HCl solution?

A.



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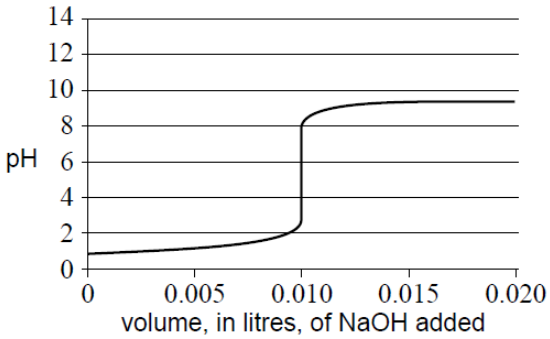
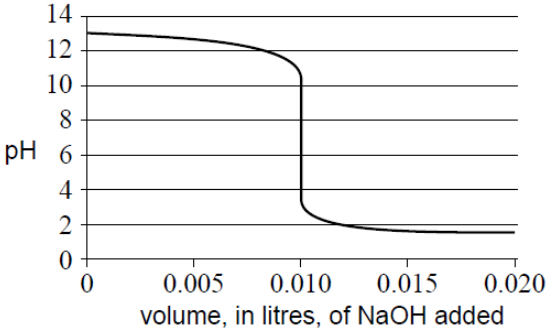
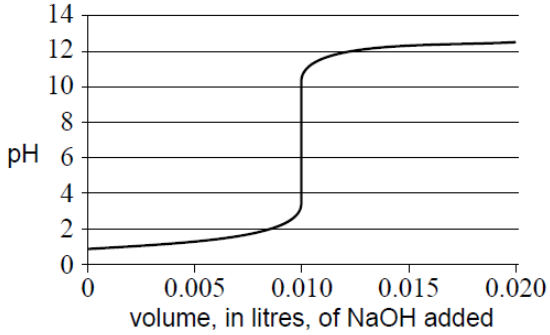


C.



D.



9. A 0.10 M solution of fluoride ions is gradually added to a solution containing Ba^{2+}, Ca^{2+} and Pb^{2+} ions, each at a concentration of 1×10^{-3} M. In what order, from first to last, will the precipitates of BaF_2, CaF_2 and PbF_2 form?

Solubility Product, Ksp	
BaF_2	1.8×10^{-7}
CaF_2	1.5×10^{-10}
PbF_2	7.1×10^{-7}

A. CaF_2, PbF_2, BaF_2

B. BaF_2, CaF_2, PbF_2

C. PbF_2, BaF_2, CaF_2

D. CaF_2, BaF_2, PbF_2

10. Methanoic acid and ethanoic acid are both weak acids with the following acid dissociation constants, K_a, at 25°C:

- methanoic acid (HCOOH) = 1.82×10^{-4}
- ethanoic acid (CH_3COOH) = 1.74×10^{-5}

Two separate solutions were prepared, one of 0.1 M methanoic acid and the other of 0.1 M ethanoic acid. Which one of the following would be present in the lowest concentration at 25°C?

A. CH_3COOH in the ethanoic acid solution

B. CH_3COO^- in the ethanoic acid solution

C. HCOOH in the methanoic acid solution

D. $HCOO^-$ in the methanoic acid solution

11. A solution contains an equilibrium mixture of two different cobalt (II) ions.

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

The solution contains pink $Co(H_2O)_6^{2+}$ ions and blue $CoCl_4^{2-}$ ions, and the solution has a purple colour.
10 mL of the purple solution was poured into a test tube.

Which one of the following changes would cause 10 mL of the purple cobalt (II) ion solution to turn blue?

A. the addition of a few drops of 10 M hydrochloric acid at a constant temperature

B. the addition of a few drops of 0.1 M silver nitrate at a constant temperature

C. the addition of a few drops of a catalyst at a constant temperature

D. the addition of a few drops of water at a constant temperature

12. One litre of an aqueous solution of potassium hydroxide (KOH) has a pH of 12.0 at 25°C.
How many moles of pure HCl gas must be added to the solution to lower the pH from pH 12.0 to 2.0?

A. 10

B. 2

C. 0.02

D. 0.01

13. Hydrogen iodide is produced by the reaction between hydrogen and iodine.

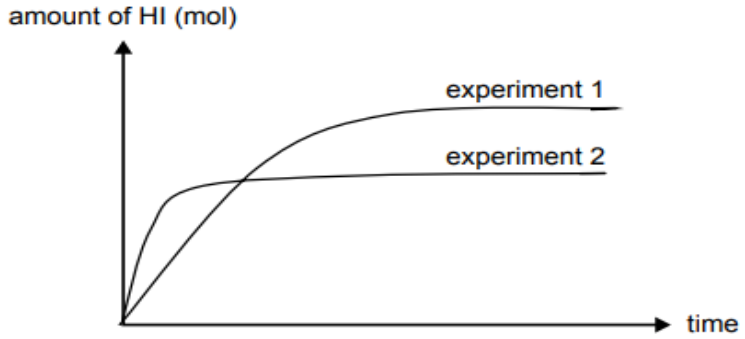
$$H_2\,(g) + I_2\,(g) \rightleftharpoons 2HI\,(g)$$

Two experiments were conducted.

Experiment 1: quantities of $H_2(g)$ and $I_2(g)$ were placed in a sealed vessel and the reaction allowed to proceed at constant temperature.

Experiment 2: experiment 1 was repeated, but at a different temperature.

The graph below shows the amount of hydrogen iodide produced over the course of experiments 1 and 2.



These results show that experiment 2 was conducted at a

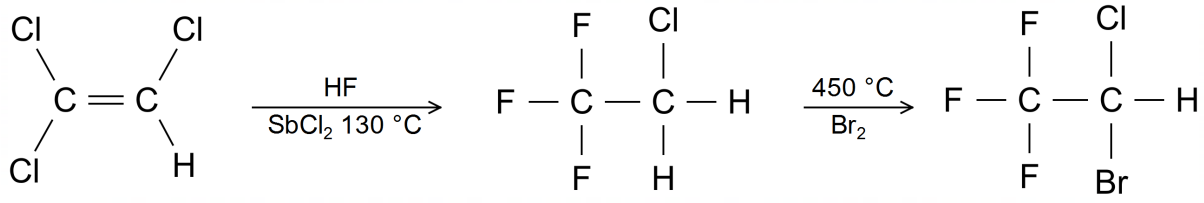
A. lower temperature than experiment 1 and the reaction is endothermic.
B. lower temperature than experiment 1 and the reaction is exothermic.
C. higher temperature than experiment 1 and the reaction is endothermic.
D. higher temperature than experiment 1 and the reaction is exothermic.

14. Which one of the following statements about 10.0 mL of 0.10 M HCl and 10.0 mL of 0.10 M CH_3COOH solutions is true?

A. Each solution will react completely with 10.0 mL of 0.10 M NaOH solution.
B. Each solution will have the same electrical conductivity.
C. Each solution will react at the same rate with 1.00 g of magnesium ribbon.
D. The concentration of H_3O^+ ions will be greater in the CH_3COOH solution.

15. Haloethane (1-bromo-1-chloro-2,2,2-trifluoroethane) is a general anaesthetic.

The following diagram represents the reaction pathway that produces haloethane.



molecule X *step 1* *step 2*

Which of the following correctly identifies molecule X and the type of reaction shown in step 2?

	*Molecule **X***	*Type of reaction in **step 2***
A	1,2,2-trichloroethane	Addition
B	1,1,2-trichloroethane	Substitution
C	1,1,2-trichloroethene	Substitution
D	1,1,2-trichloroethene	Addition

16. Four different equilibrium systems (I–IV) at standard pressure and temperature are shown.

I	$N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g)$	$\Delta H < 0$
II	$2NOBr(g) \leftrightharpoons 2NO(g) + Br_2(g)$	$\Delta H < 0$
III	$N_2(g) + 2O_2(g) \leftrightharpoons 2NO_2(g)$	$\Delta H > 0$
IV	$PCl_5(g) \leftrightharpoons PCl_3(g) + Cl_2(g)$	$\Delta H > 0$

In each system, the pressure was increased. Later, the temperature was decreased.
In which equilibrium system would BOTH changes result in a product yield increase?

A. I

B. II

C. III

D. IV

17. A student performed an experiment in which 250 mL of water was heated by burning methanol in a spirit burner. The enthalpy of combustion of methanol is -726 kJ mol^{-1}. Assume that all heat released by the process is absorbed by the water.

What is the maximum change in temperature of the water when 1.26 g of methanol is completely combusted?

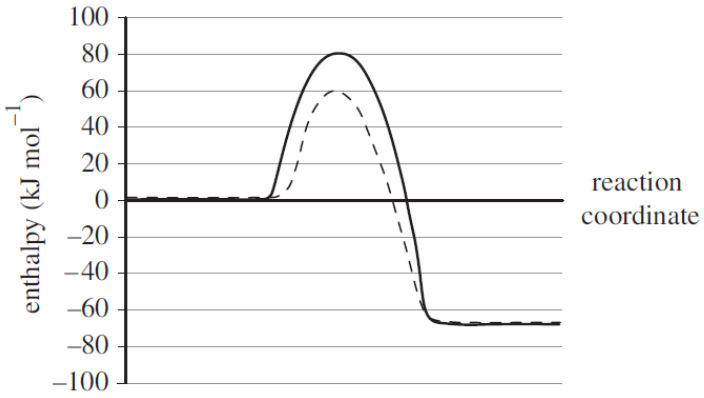
A. 0.434 °C

B. 3.66 °C

C. 27.3 °C

D. 36.3 °C

18. A particular reaction can occur with or without a catalyst. The energy profiles of this reaction, both catalysed and uncatalysed, are shown.



Which row of the table best matches the reactions as shown by the energy profiles?

	E_a of uncatalysed reaction (kJ mol^{-1})	ΔH of uncatalysed reaction (kJ mol^{-1})	E_a of catalysed reaction (kJ mol^{-1})	ΔH of catalysed reaction (kJ mol^{-1})
A.	-80	70	-60	70
B.	80	-150	80	60
C.	80	-70	60	-70
D.	20	80	150	-80

19. Consider this reaction, whose $K_{eq} = 33$

$$SO_2\ (g) + NO_2\ (g) \rightleftharpoons SO_3\ (g) + NO\ (g)$$

If 0.10 mol each of SO_2 and NO_2 are placed in a 1.0 L container, what is the concentration of SO_3 at equilibrium?

A. 0.0030 M

B. 0.015 M

C. 0.085 M

D. 0.097 M

20. An experiment is conducted in which 4-aminobutanoic acid, $H_2N(CH_2)_3COOH$, forms a polymer containing 100 monomer units.

What is the molar mass of this polymer?

A. 8.5×10^3 g mol^{-1}

B. 1.0×10^4 g mol^{-1}

C. 1.0×10^2 g mol^{-1}

D. 103 g mol^{-1}

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Chemistry

Section II
Answer Booklet

80 marks
Attempt Questions 21 – 34
Allow about 2 hours and 25 minutes for this section

Instructions

- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

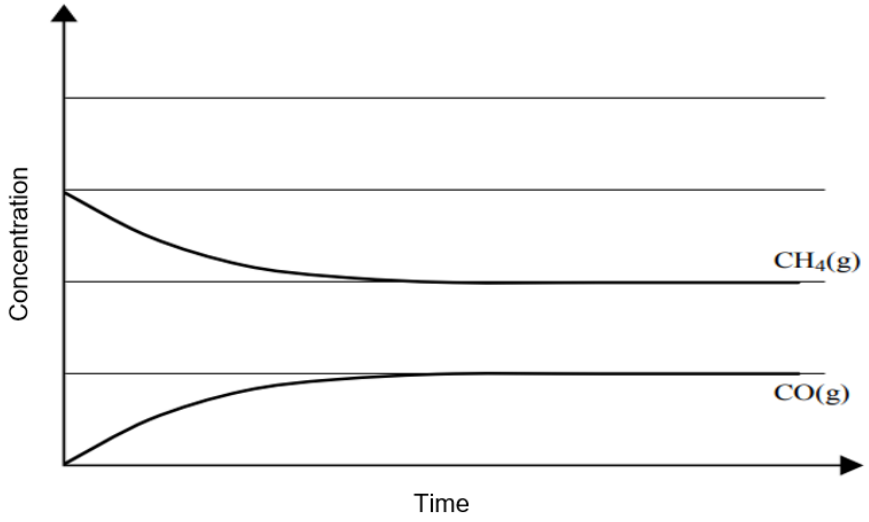
Please turn over

Question 21 (4 marks)

Carbon monoxide and hydrogen can be produced from the reaction of methane with steam, according to the equation:

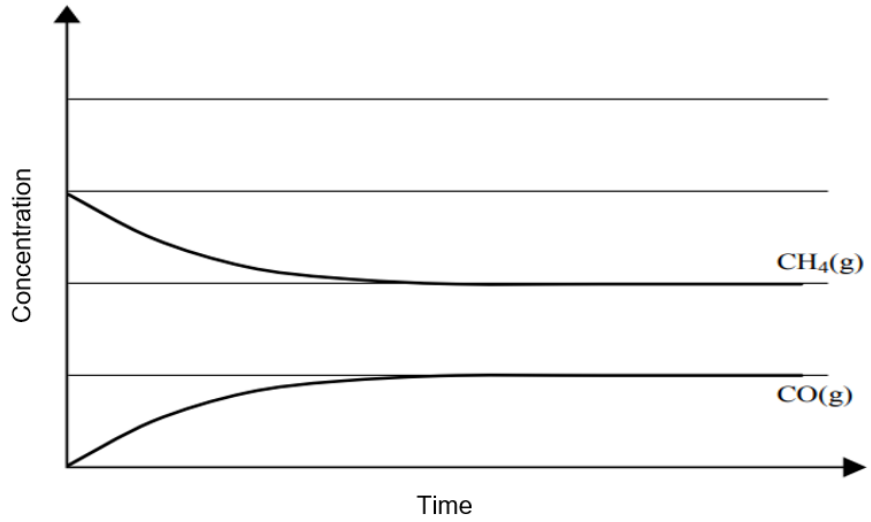
$$CH_4\ (g) + H_2O\ (g) \rightleftharpoons CO\ (g) + 3H_2\ (g) \qquad \Delta H = +206\ kJ\ mol^{-1}$$

Some methane and steam were placed in a closed container and allowed to react at a fixed temperature. The following graph shows the changes in concentration of methane and carbon monoxide as the reaction progresses.



(a) On the graph above, draw a line to predict the change in concentration of hydrogen gas as the reaction progresses. Label this line as 'H_2' **2**

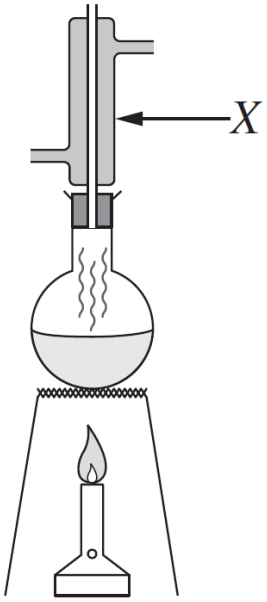
(b) On the graph below, draw a line to show how the formation of carbon monoxide would differ over time in the presence of a catalyst. **2**



Question 22 (4 marks)

A student conducted an experiment in the school laboratory to synthesise an ester.

Some of the equipment used is shown in the diagram below.



(a) Identify the risk associated with the students experimental set up in the diagram and suggest alternative equipment. **2**

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(b) Outline how the equipment piece labelled 'X' assisted in maximising the yield of the ester. **1**

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(c) Identify what else the student could do to maximise the yield of ester. **1**

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Question 23 (5 marks)

Industrially, ethanol, C_2H_5OH, is made by either of two methods.

One method uses ethene (ethylene), C_2H_4, which is derived from crude oil. The other method uses fermentation of a sugar such as glucose, $C_6H_{12}O_6$ or sucrose with yeast in an aqueous solution.

(a) Write a balanced equation to show the production of C_2H_5OH from $C_6H_{12}O_6$ and yeast. **1**

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(b) You carried out this fermentation reaction in the laboratory. What conditions were necessary for this fermentation to occur. **2**

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(c) Determine the mass, in grams, of pure C_2H_5OH that would be produced from 1.25 kg of $C_6H_{12}O_6$ dissolved in water. **2**

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Question 24 (3 marks)

Some salts display amphiprotic behaviour.
Using a suitable example, explain what is meant by ‘amphiprotic’. Support your answer using appropriate equations. **3**

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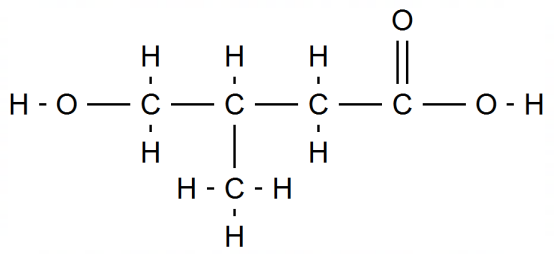
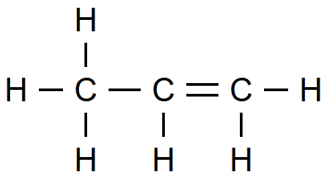
Question 25 (5 marks)

Polymers are important substances and have many practical applications.

Scientists have developed biopolymers to replace traditional polymers.

One example of this is polyhydroxybutyrate (PHB) that was developed as an alternative to polypropylene (PP)

Production	Produced in the cells of microorganisms such as *bacillus sp* using agricultural residue such as sugarcane bagasse, a dry pulpy material that remains after crushing sugarcane, as a carbon source.	Fractional distillation of crude oil. Fractions further thermally or catylitically cracked to produce the monomer.
Monomer structure		
Monomer name	hydroxybutyrate	Propylene

(a) Outline the advantage of using PHB as a replacement for PP. **1**

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(b) What type of polymerisation reaction produces PHB and PP? **2**

Polymer	Type of polymerisation reaction
polyhydroxybutyrate	
polypropylene	

Question 25 continues on page 19

Question 25 (continued)

(c) Draw three repeating units for each of the polymers made from the monomers. **2**

End of Question 25

Question 26 (5 marks)

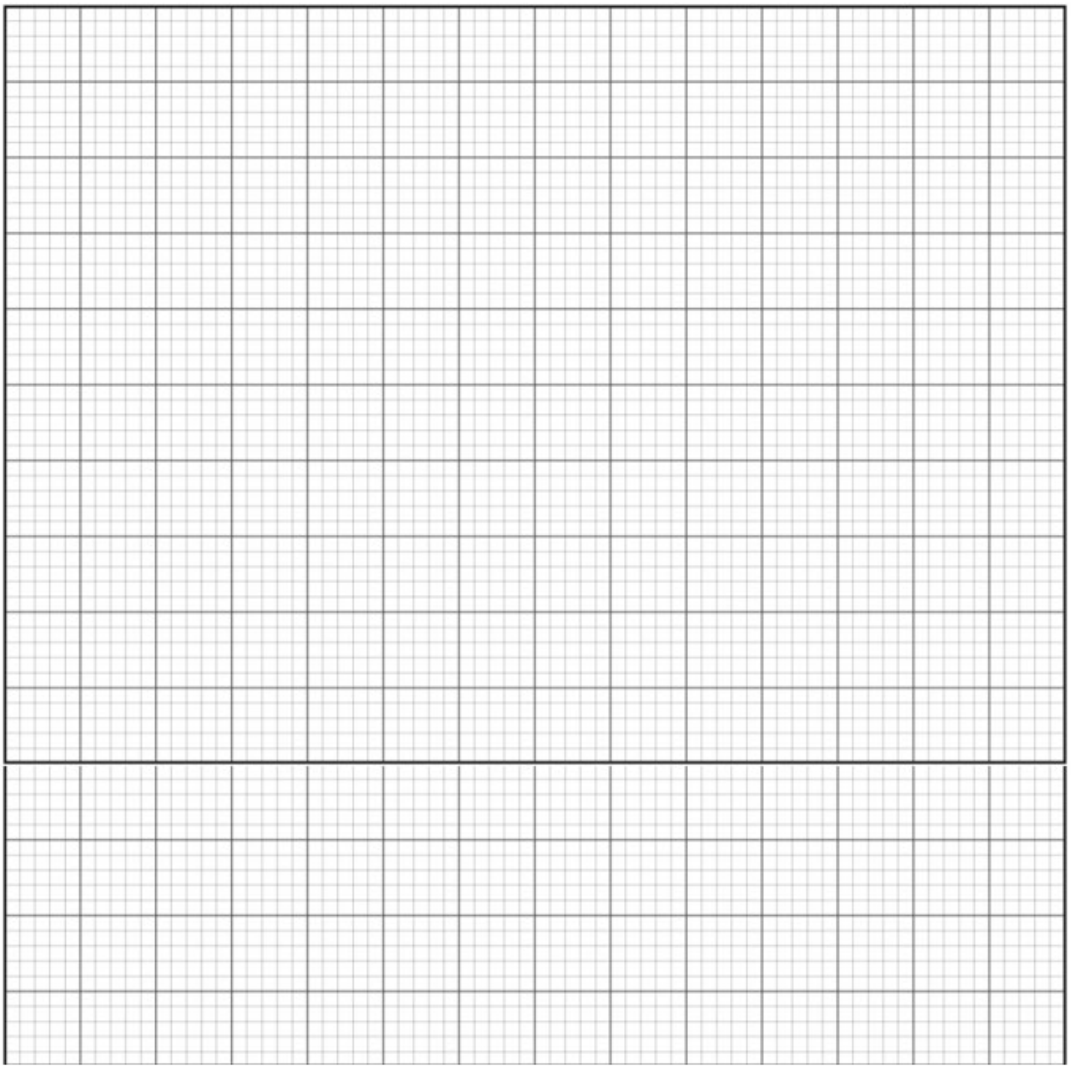
Nitric oxide is formed during lightning strikes as shown in the reaction below.

$$N_2\ (g) + O_2\ (g) \rightarrow 2NO\ (g) \quad \Delta H = +180.6\ kJ\ mol^{-1}$$

The table below shows the Gibbs Free Energy (ΔG) for this reaction at different temperatures.

Temperature (K)	ΔG ($kJ\ mol^{-1}$)
2000	131
4000	81
6000	31
8000	-19
10000	-69

a) Graph the provided data on the grid below. **3**



Question 26 continues on page 21

Question 26 (continued)

(b) Use the graph to estimate the minimum temperature in °C at which this reaction will become spontaneous. Justify your answer. **2**

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End of Question 26

Question 27 (6 marks)

Initially, a mixture has 0·400 mol each of CO_2 and H_2 in a 2·00 L vessel kept at 980°C.

The reaction is $CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$ $\Delta H = +41.2$ kJ mol^{-1}

and at this temperature the equilibrium concentration of CO is 0·110 mol L^{-1}.

(a) Write the equilibrium constant expression for this reaction. **1**

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(b) What is the equilibrium concentration of H_2? **2**

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(c) Calculate the equilibrium constant at 980°C. **1**

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(d) How would increasing the temperature affect the equilibrium constant? Explain your answer. **2**

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Question 28 (7 marks)

Lead (II) carbonate is a sparingly soluble salt.

(a) Calculate the molar solubility of lead (II) carbonate in water at 25°C.
Show all working. **2**

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(b) Quantitatively compare the solubility of lead (II) carbonate in water with its solubility in a 0.10 mol/L solution of lead (II) nitrate, at 25°C. **2**

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(c) 25 mL of 0.015 M lead (II) nitrate solution and 50 mL of 0.0030 M sodium carbonate solution are mixed. Does precipitation of lead (II) carbonate occur?

Support your answer with calculations **3**

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Question 29 (7 marks)

The solubility of highly soluble, thermally unstable salts such as ammonium chloride may be determined by back titration.

In one experiment a 5.00 mL saturated solution of ammonium chloride, NH_4Cl, at 20.0 °C, was diluted with distilled water to 250.0 mL in a volumetric flask.

A 20.0 mL aliquot of this solution was added to 10.0 mL of 0.400 M NaOH solution. The solution was heated to drive off the ammonia formed by this reaction.

When the flask had cooled, the excess hydroxide ions were neutralised by 14.7 mL of 0.125 M HCl solution. The molar mass of ammonium chloride is 53.5 g mol^{-1}.

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

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(b) Calculate the solubility, in g L^{-1}, of ammonium chloride in water at 20 °C. Show all relevant working. **4**

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(c) If the burette was rinsed with water instead of acid before the titration, how would the calculated solubility of ammonium chloride be affected?
Explain your answer. **2**

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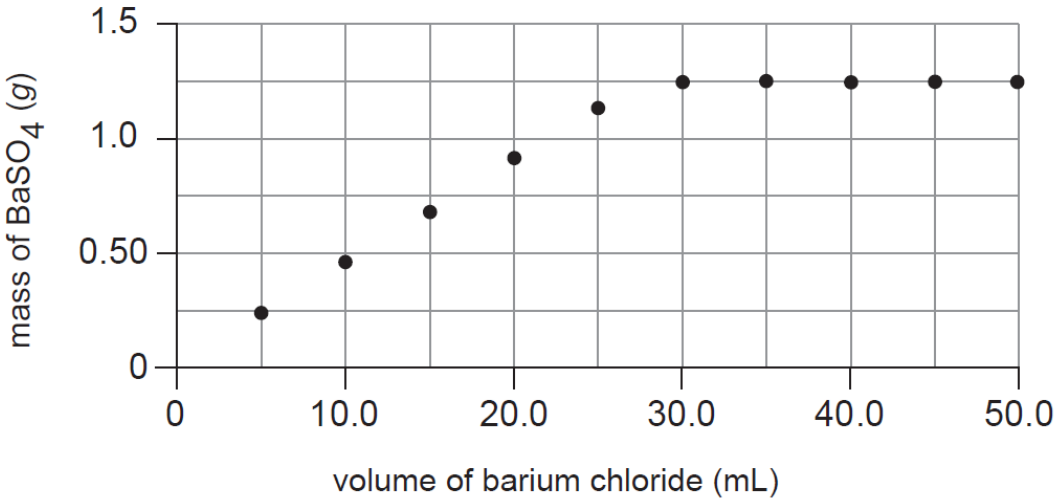
Question 30 (4 marks)

A gravimetric analysis was undertaken to determine the percentage, by mass, of sulfur in a sample of lawn fertiliser. A 10.4 g sample of fertiliser containing sulfate was dissolved into 250.0 mL of distilled water. This solution was then divided into ten equal 25.0 mL sub-samples.

Various volumes of barium chloride solution was added to each 25.0 mL sub-sample, and the resulting precipitate of barium sulfate was collected by filtration, dried and weighed. The graph shows the results of the gravimetric analysis.



Determine the percentage of sulfur, by mass, in the original sample of lawn fertiliser. Show all relevant working. **4**

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Question 31 (5 marks)

A student was given the organic compounds shown in the table below. **5**

Compound	*Molar mass (g mol $^{-1}$)*
but-1-ene	56
1-fluoropropane	62
propan-1-ol	60
ethanamide	59

Predict and explain the different water solubilities of these compounds. Support your answer with at least ONE labelled diagram using structural formulas.

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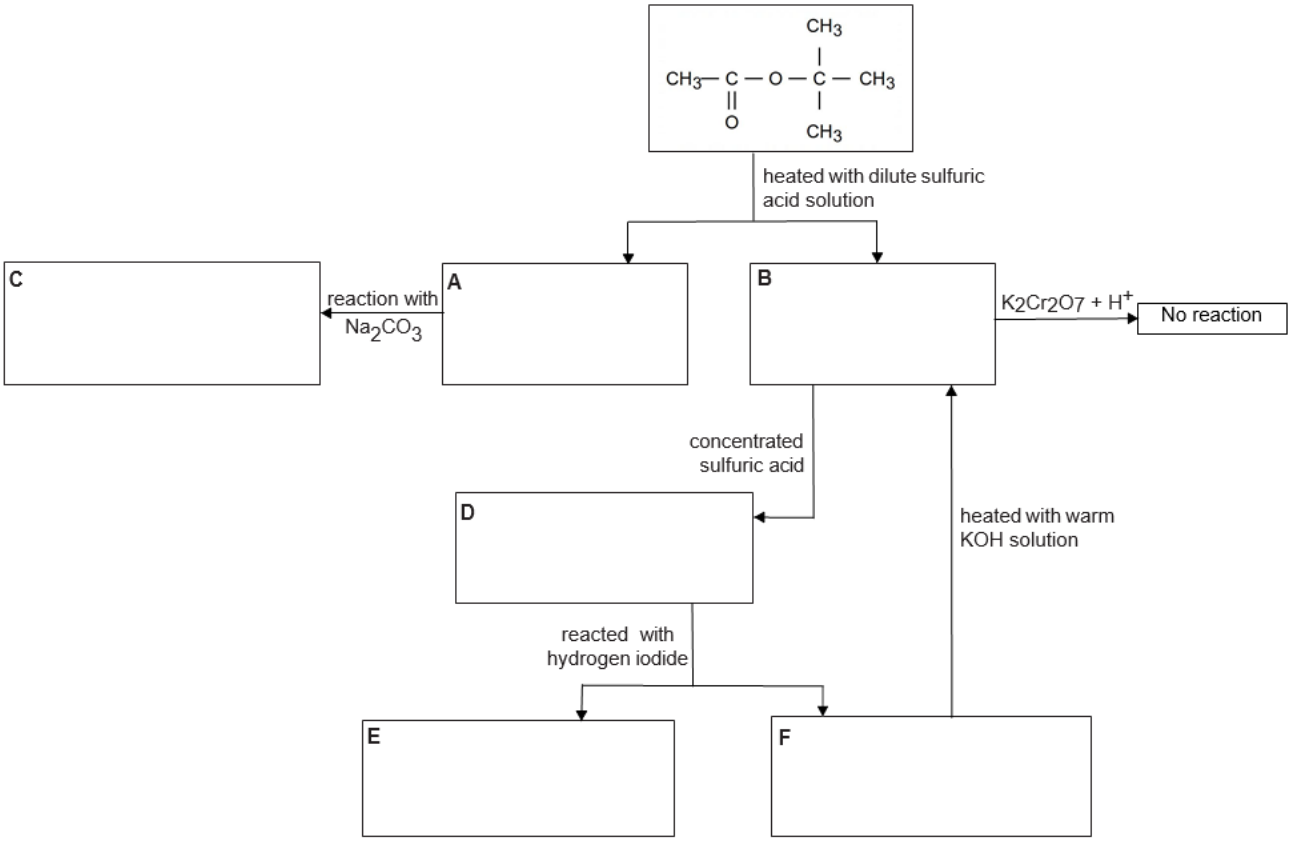
Question 32 (6 marks)

Esterification is a reversible reaction that can undergo hydrolysis when heated with dilute sulfuric acid solution to drive the reaction towards the reactants.

The flow chart shows reactions involving organic compounds, A to F



Draw the structure of each compound, A to F, in the corresponding space provided.

6

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

Question 33 (10 marks)

The table shows acid dissociation constants at 25ºC

Acid	Formula	K_a
Nitrous	HNO_2	7.2×10^{-4}
Hydrofluoric	HF	6.6×10^{-4}
Hydrocyanic	HCN	6.2×10^{-10}
Propanoic	CH_3CH_2COOH	1.34×10^{-5}
Chlorous	$HClO_2$	1.1×10^{-2}

(a) Identify the <u>weakest acid</u> in the table and determine the pK_a value for this acid at 25°C **2**

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(b) Identify the <u>weakest base</u> formed from these acids. What is the pK_b for this base at 25°C? **2**

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(c) Calculate the pH of a 0.010 M solution of propanoic acid at 25°C **2**

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Question 33 continues on page 29

Question 33 (continued)

(d) A buffer solution is prepared by combining 100 mL of 0.010 M nitrous acid and 80 mL of 0.010 M $NaNO_2$.
Calculate the pH of this buffer solution and explain the classification of the solution as a buffer. **4**

……

……

……

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End of Question 33

Question 34 (9 marks)

A series of chemical reactions can be used to distinguish between a variety of organic liquids.

(a) Draw a flowchart which could be used to distinguish between the following organic liquids. Include all reagents used and observations made. **4**

- HEX-1-ENE
- HEXANE
- PROPAN-1-OL
- PROPAN-2-OL

Question 34 continues on page 31

Question 34 (continued)

(b) Write balanced equations for TWO reactions used in your flowchart using structural formulae. **2**

……..

……..…

……..…

……..……

(c) Predict which of the 4 organic liquids would have the highest boiling point. Explain your prediction. **3**

……..

……..

……..

……..

……..

……..

End of paper

Section II extra writing space

If you use this space, clearly indicate which questions you are answering.

Section II extra writing space

If you use this space, clearly indicate which questions you are answering.

Section II extra writing space

If you use this space, clearly indicate which questions you are answering.

Student Number: ……

Chemistry Multiple Choice Answer Sheet

Select the alternative A, B, C or D that best answers the question.

Fill in the response space completely. 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 this by writing the word ***correct*** and drawing an arrow.

Start Here

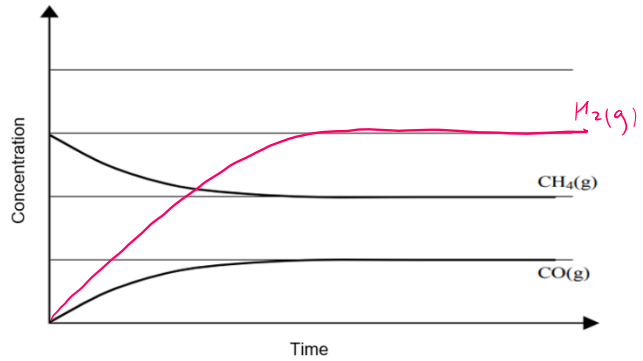
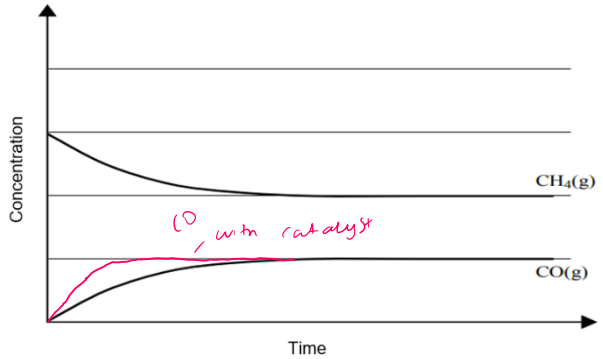
1.	A ⬭	B ⬭	C ⬭	D ⬭
2.	A ⬭	B ⬭	C ⬭	D ⬭
3.	A ⬭	B ⬭	C ⬭	D ⬭
4.	A ⬭	B ⬭	C ⬭	D ⬭
5.	A ⬭	B ⬭	C ⬭	D ⬭
6.	A ⬭	B ⬭	C ⬭	D ⬭
7.	A ⬭	B ⬭	C ⬭	D ⬭
8.	A ⬭	B ⬭	C ⬭	D ⬭
9.	A ⬭	B ⬭	C ⬭	D ⬭
10.	A ⬭	B ⬭	C ⬭	D ⬭
11.	A ⬭	B ⬭	C ⬭	D ⬭
12.	A ⬭	B ⬭	C ⬭	D ⬭
13.	A ⬭	B ⬭	C ⬭	D ⬭
14.	A ⬭	B ⬭	C ⬭	D ⬭
15.	A ⬭	B ⬭	C ⬭	D ⬭
16.	A ⬭	B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

2022 CHEMISTRY TRIAL MARKING GUIDELINES

MULTIPLE CHOICE

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

Q15 RE-mark

	Marking Guideline	Suggested Answer	
21 a)	Criteria / Marks • Correct direction from 0,0 **AND** Correct ratio at equilibrium — 2 • Correct direction from 0,0 **OR** Correct ratio at equilibrium — 1		
21 b)	Criteria / Marks • Correct slope from 0,0 **AND** Correct ratio at equilibrium — 2 • Correct slope from 0,0 **OR** Correct ratio at equilibrium — 1		CO needed to clearly have the a faster reaction
22 a)	Criteria / Marks • Identifies a relevant risk from the diagram **AND** Suggests a suitable piece of alternative equipment — 2	- Use of Bunsen burner with flammable liquids - Use hotplate	Most significant hazard Could not get full marks if flammable liquids and open flame was not identified. Only one mark allowed for any other risk correctly identified and controlled.

	• Identifies a relevant risk from the diagram **OR** • Suggests a suitable piece of alternative equipment — 1		
22 b)	Criteria — Marks • Correctly Outlines how 'X' maximises yield — 1	The water cooled condenser reduces loss of reactants and products to the atmosphere by condensing any vapourised components so that they return to reaction vessel as liquid.	Reflux was not accepted as not 'outline'
22 c)	Criteria — Marks • Identifies an appropriate strategy for increasing yield — 1	One of the following: - Add a small amount of concentrated H_2SO_4 will act as a dehydrating agent and drive reaction to the products - Add excess of one of the reacants to drive equilibrium to the right - Heat reactants on hot plate/heating mantle for an extended time	Ror = rate of reaction Rate of reaction reasons are not suitable as they do not related to yield but rate of yield. Needed to relate to LCP to increase forward reaction Marble chips not accepted as usually for a safety issue. Marble chips should not be used with conc. H2SO4 as stops the chips from working and causes a different reaction Must be concentration h2so4
23 a)	Criteria: — Marks • Correct equation — 1	$C6H12O6\ (s) \xrightarrow{yeast} 2\ C2H5OH(l)\ +\ 2\ CO2(g)$	State symbols not marked Zymase accepted

<table>
<tr>
<td>23
b)</td>
<td>
<table>
<tr><td>Criteria:</td><td>Marks</td></tr>
<tr><td>• 2 reasonable conditions</td><td>2</td></tr>
<tr><td>• 1 condition</td><td>1</td></tr>
</table>
</td>
<td>Any 2 of the following
Presence of yeast
Absence of oxygen-anaerobic
Temperature 37 °C (allow a range)
Aqueous solutions</td>
<td>‘warm conditions’ not accepted as not specific enough
Sunlight was not accepted</td>
</tr>
<tr>
<td>23
c)</td>
<td>
<table>
<tr><td>Criteria:</td><td>Marks</td></tr>
<tr><td>• Correct mass value and correct working shown</td><td>2</td></tr>
<tr><td>• One correct step</td><td>1</td></tr>
</table>
</td>
<td>MM $C_6H_{12}O_6$ = 180
1 mole glucose produced 2 moles ethanol
1250/180 = 6.6667 moles glucose
2x 6.6667 = 13.3333 moles ethanol
13.3333 x 46 = 613.33 g ethanol</td>
<td>Error carried forward from balanced equation

MM $C_6H_{12}O_6$ = 180.156
No rounding on MM for full marks
1 mole glucose produced 2 moles ethanol
1250/180.156 = 6.9384311 moles glucose
2x 6.9384311 = 13.87686 moles ethanol
13.87686 x 46.068 = 639.28g ethanol</td>
</tr>
<tr>
<td>24</td>
<td>
<table>
<tr><td>Criteria:</td><td>Marks</td></tr>
<tr><td>• Uses a suitable example
• Provides suitable equations.
• Gives a detailed explanation</td><td>3</td></tr>
<tr><td>• Uses a suitable example
• Provides at least ONE suitable equation.
• Gives an explanation</td><td>2</td></tr>
<tr><td>• Provides some relevant information</td><td>1</td></tr>
</table>
</td>
<td>A substance is amphiprotic if it can, in the right circumstances, lose a proton (hydrogen ion) to act as a Brønsted–Lowry acid and gain a proton to act as a Brønsted–Lowry base. An example of an amphiprotic substance is sodium hydrogen carbonate, commonly known as bicarbonate of soda.
The following reaction occurs when sodium hydrogen carbonate acts as an acid.
$HCO_3^-(aq) + OH^-(aq) \leftrightarrow CO_3^{2-}(aq) + H_2O(l)$
The following reaction occurs when sodium hydrogen carbonate acts as a base.
$HCO_3^-(aq) + H_3O(aq) \leftrightarrow H_2CO_3(aq) + H_2O(l)$</td>
<td>If students used two amphiprotic species they could not get full marks –</td>
</tr>
</table>

25 a)

Criteria:	Marks
• Outlines one appropriate advantage	1

Renewable
biodegradable

Important that you read the question, it asked what the advantage of using PHB was as a replacement for PP. Generally, well answered

25 b)

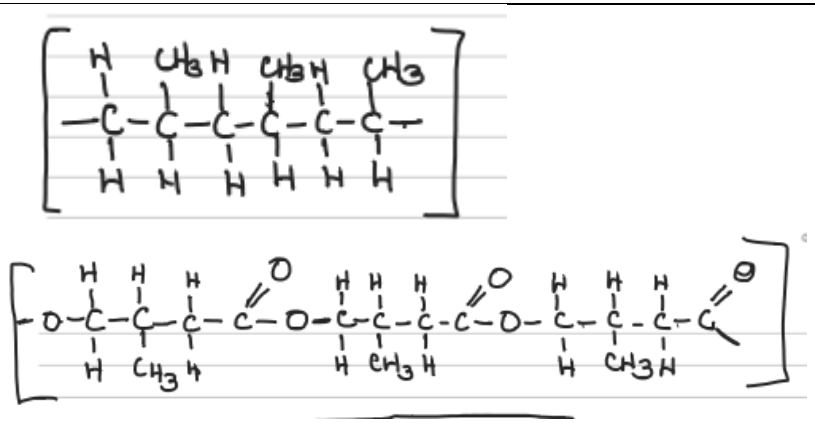
Criteria:	Marks
• Correctly identifies both polymer types	2
• Correctly identifies 1 polymer type	1

Polymer	Type of polymerisation
PHB	condensation
PP	addition

This was answered well across the cohort

25 c)

Criteria:	Marks
• Correctly draws both polymers with 3 repeating units	2
• Correctly draws at least 1 polymer with three repeating units OR • Draws 2 polymers with minor error	1



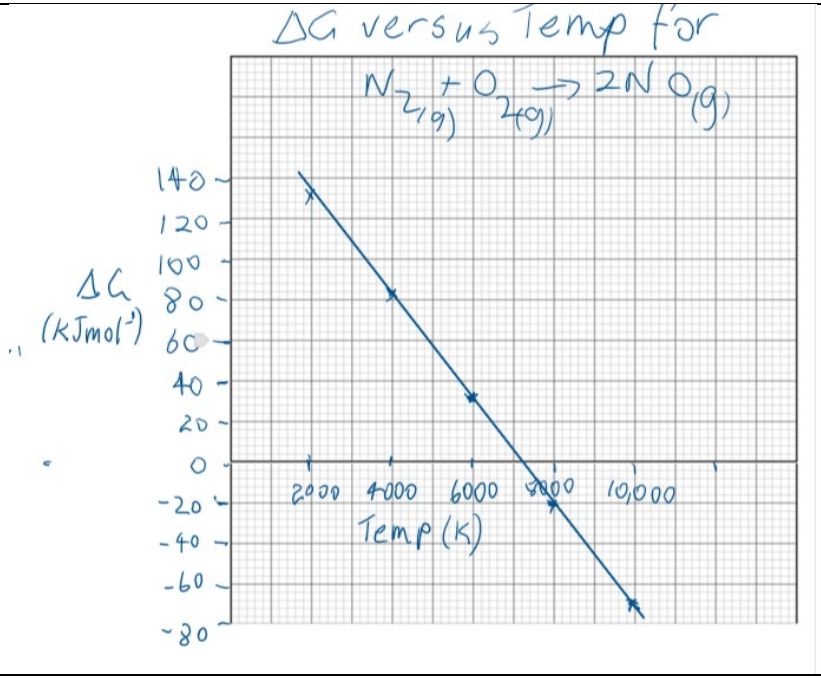
Very poorly answered many students got 0 for this question.

PP was the structure that most struggled with
PHB many omitted O where the monomers joined. Others included the OH at both ends. You needed to draw 3 units within the polymer as shown in the diagram.

If you drew the polymers correctly for both but did not indicate that they would continue, then 1 mark was deducted.

26 a)

Criteria:	Marks
• Labels axes correctly including units • Uses appropriate scale • Plots points correctly • Draws appropriate line of best fit	3
• Provides a substantially correct graph	2
• Includes one correct feature	1



Generally, very well answered.
Common errors here, not labelling axis or excluding units in the axis, incorrect plot points and no line of best fit.

Better to use X as a plot point rather than ●, no penalty for this

26 b)

Criteria:	Marks
• Correct estimate with correct units AND valid justification	2
• One correct statement	1

Temp (°C) ≈ 7200 – 273 = 6927
This is the temp at which $\Delta G < 0$, and as temp increases from from 6927 °C ΔG will become more negative which indicates a spontaneous reaction.

Very poorly answered, it is important to read the question.
You were asked to report in °C, most if the cohort left it in K.
Also, you needed to justify that the temperature for spontaneity was greater than 7200 K as when G is negative the reaction becomes spontaneous.
If you wrote ≤ 0 this was not awarded as when G=0 the reaction is at equilibrium

27 a)

Criteria:	Marks
• Correct equilibrium expression	1

$$Keq = \frac{[CO][H_2O]}{[CO_2][H_2]}$$

Common error here was not including the water.
All products and reactants are gaseous
ECF was applied to subsequent questions if the expression was incorrect

27 b)

Criteria:	Marks
• Correct concentration with units for H_2 **AND** • Calculation/working included in answer	2
• Correct concentration with units for H_2 **OR** • Partial Calculation/working included in answer	1

Initial $[CO_2]$ = 0.400/2 = 0.200 mol/L Initial $[H_2]$ = 0.400/2 = 0.200 mol/L

	CO_2	H_2	CO	H_2O
I	0.200	0.200	0	0
C	-0.110	-0.110	+0.110	+0.110
E	0.090	0.090	0.110	0.110

Equilibrium $[H_2]$ = 0.090 mol/L

Common error here was not converting the moles to concentration. Or leaving the moles and using concentration for CO.

It is really important that you are either working in moles then, adjusting for volume ie concentration at the end. Alternatively convert to concentration in the initial step.

Many lost marks for this reason

27 (c)

Criteria:	Marks
• Correct value for Keq (error carried forward from (b) or (c))	1

Keq = (0.110 x 0.110)/(0.090x0.090)
= 1.4938
Or 1.49

Again ECF applied here from the previous question as long as the process was correct

27 (d)

Criteria:	Marks
• Correct effect on Keq stated **AND** • Valid reason for affect	2
• One correct statement	1

Forward reaction is endothermic so concentration of products CO and H_2O would increase as equilibrium shifts to the right when temperature increases.
Therefore, Keq for the forward reaction would increase when temperature increases.

Well answered.
Again, you needed to answer the question

28 (a)

Criteria:	Marks
• Correct answer, with correct units, showing correct working/reasoning	2

Let the solubility of $PbCO_3$ be s.
Ksp $PbCO_3$ = 7.40×10^{-14} = $[Pb^{2+}]$ $[CO_3^{2-}]$ = (s)2
$s^2 = 7.40 \times 10^{-14}$
$s = 2.72 \times 10^{-7}$ mol/L

The solubility of $PbCO_3$ in water = 2.72×10^{-7} mol/L

Some students used the incorrect Ksp value and others the incorrect formula for $PbCO_3$
I even saw a few use the Kw value.
Careful when reading data from the data sheet, highlight or underlining may avoid transcription errors

	• Correct method and reasoning, with mathematical error — 1		
28 (b)	Criteria: / Marks • Correct conclusion based on correct calculations — 2 • Correct calculation for the solubility of PbCO3 in lead (II) nitrate solution — 1	Let the solubility of $PbCO_3$ in a 0.10 mol/L solution of lead (II) nitrate = x Ksp $PbCO_3 = [Pb^{2+}]\,[CO_3^{2-}] = (x + 0.10)(x) = 7.40 \times 10^{-14}$ Since x is small by comparison with 0.10 Ksp $PbCO_3 = [Pb^{2+}]\,[CO_3^{2-}] = (0.10)(x) = 7.40 \times 10^{-14}$ $x = 7.40 \times 10\text{-}14 / (0.10) = 7.4 \times 10^{-13}$ mol/L The solubility of $PbCO_3$ in 0.10 M $Pb^{2+} = 7.4 \times 10^{-13}$ mol/L The solubility of $PbCO_3$ in water $= 2.72 \times 10^{-7}$ mol/L (from part (a) above) Hence $PbCO_3$ is less soluble in a 0.10 mol/L solution of Pb^{2+} ion than in water.	Overall, well answered. You did need to answer both parts of the question and compare the solubilities. This was a common ion question. A significant portion of the cohort struggled.
28 (c)	Criteria: / Marks • Correct conclusion based on correct calculations — 3 • Correct calculation for the $[Pb^{2+}]\,[CO_3^{2-}]$ after mixing — 2 • Correct calculation of no. of moles of $Pb(NO_3)_2$ and Na_2CO_3 — 1	No. of moles $Pb(NO_3)_2 = 0.015 \times (25/1000) = 3.75 \times 10^{-4}$ no. of moles $Na_2CO_3 = 0.0030 \times (50/1000) = 1.5 \times 10^{-4}$ Total volume of solution = 75 mL $[Pb^{2+}] = 3.75 \times 10^{-4} / 0.075 = 5.0 \times 10^{-3}$ mol/L $[CO_3^{2-}] = 1.5 \times 10^{-4} / 0.075 = 2.0 \times 10^{-3}$ mol/L The product of the concentration of the ions is $[Pb^{2+}]\,[CO_3^{2-}] = 5.0 \times 10^{-3} \times 2.0 \times 10^{-3} = 1.0 \times 10^{-5}$ Since this product is greater than K_{sp} (7.40×10^{-14}), a precipitate will form.	The students who found 28b challenging did this well. It was familiar to most students. It was obvious that many had practiced this style of question. Common error here was not calculating the new concentrations. You also needed the correct statement based on the data produced.

<table>
<tr>
<td>29 a)</td>
<td>
<table>
<tr><td>Criteria:</td><td>Marks</td></tr>
<tr><td>• Writes appropriate balanced equation with states</td><td>1</td></tr>
</table>
</td>
<td>$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

OR

$OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$

$NH_4Cl + NaOH \rightarrow NH_3 + NaCl + H_2O$</td>
<td>Most girls, but not all wrote a correct equation. Remember water is a liquid. Some misinterpreted and wrote the equation for the other reaction. Remember to read and highlight the question before answering it.

Accepted both as the first reaction is also a neutralisation</td>
</tr>
<tr>
<td>29 b)</td>
<td>
<table>
<tr><td>Criteria:</td><td>Marks</td></tr>
<tr><td>• Performs correct calculations
• Reports to 3 significant figures</td><td>4</td></tr>
<tr><td>• Provides main steps of the calculation</td><td>3</td></tr>
<tr><td>• Provides some relevant steps of the calculation</td><td>2</td></tr>
<tr><td>• Provides some relevant information</td><td>1</td></tr>
</table>
</td>
<td>$n(NaOH) = 0.400 \times 10.0 \times 10^{-3} = 4.00 \times 10^{-3}$ (mol)

$n(NaOH)$ in excess = $n(HCl)$
$= 0.125 \times 14.7 \times 10^{-3}$ mol
$= 1.8375 \times 10^{-3}$ mol

$n(NH_4Cl)$ in 20.0 mL aliquot = $4.00 \times 10^{-3} - 1.84 \times 10^{-3}$
$= 2.1625 \times 10^{-3}$ mol

$n(NH_4Cl)$ in 5.00 mL saturated solution = $n(NH_4Cl)$ in 250 mL diluted solution
= ($n(NH_4Cl)$ in 20 mL diluted solution/20) × 250
$= (2.1625 \times 10^{-3} \div 20) \times 250$
= 0.02703125 mol

$n(NH_4Cl)$ in one litre = (0.02703125/5) × 1000
= 5.40625 mol

Alternative method
$n(NH_4Cl) = 2.1625 \times 10^{-3}$ mol

c NH_4Cl) diluted sample = 2.1625×10^{-3} mol/0.020 = 0.108125 mol/L
c(NH_4Cl) original sample= 0.108125 mol/L x 250/5(dilution factor) = 5.40625 mol/L

$m(NH_4Cl)$ in one litre = 5.40625 × 53.5
= 289 g
Solubility 289 g L^{-1} report to 3 significant figures</td>
<td>Reasonably well done but most students did not get 4 marks for this question. The dilution factor was often forgotten and there were lots of mathematical errors. Don't forget to highlight the figures you need in a response, so you don't forget them. The dilution factor was a little unusual so watch that you use this properly.</td>
</tr>
<tr>
<td>29 c)</td>
<td>
<table>
<tr><td>Criteria:</td><td>Marks</td></tr>
<tr><td>• Correctly identifies larger titre would result
• Appropriate explanation of how the increased titre</td><td>2</td></tr>
</table>
</td>
<td>Since the HCl(aq) in the burette was diluted, a larger $V(HCl)$ (titre) was required to react with the excess NaOH. Hence the $n(NaOH)$ in excess was calculated as higher than true, leading to a smaller calculated $n(NaOH)$ reacted with NH_4Cl and a lower calculated amount (solubility) of NH_4Cl.</td>
<td>This question required an explanation of higher or lower. The best responses showed how this dilution affected each step.</td>
</tr>
</table>

<table>
<tr>
<td></td>
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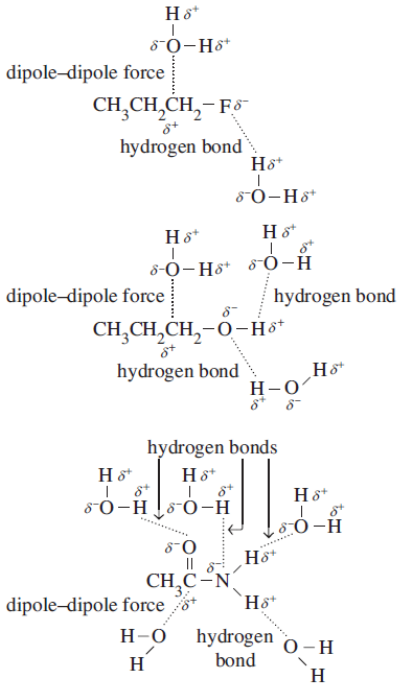
<table>
<tr><td>volume results in a lower calculated solubility</td><td></td></tr>
<tr><td>• Identifies larger titre volume AND/OR
• Limited explanation</td><td>1</td></tr>
</table>
</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>
<table>
<tr><td>Criteria:</td><td>Marks</td></tr>
<tr><td>• Determines the percentage of sulfur.
• Performs correct calculation.
• Shows all relevant working</td><td>4</td></tr>
<tr><td>• Provides main steps of the calculation</td><td>3</td></tr>
<tr><td>• Provides some relevant steps of the calculation</td><td>2</td></tr>
<tr><td>• Provides some relevant information</td><td>1</td></tr>
</table>
</td>
<td>The mass of fertiliser in each 25.0 mL sub-sample is 1.04 g.
From the graph, the maximum mass of $BaSO_4$ is 1.25 g.

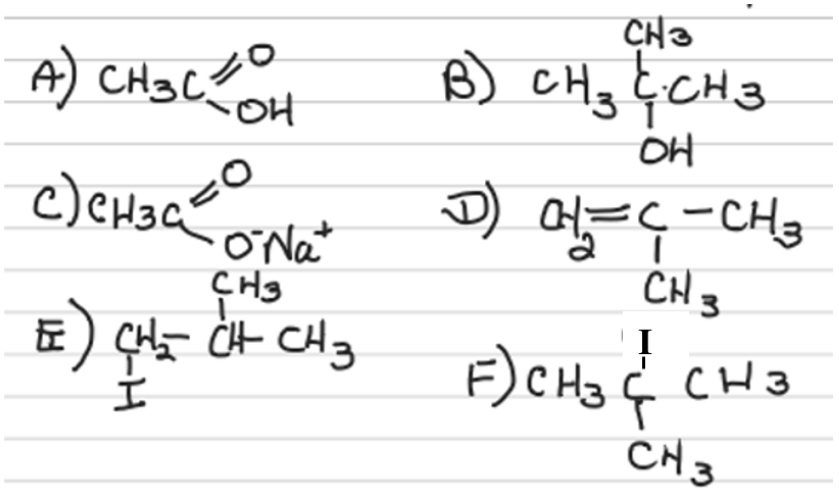
molar mass of $BaSO_4$ = 137.3 + 32.07 + 4x16.00 =233.4 g mol^{-}
n($BaSO_4$) = 1.25/233.4 = 0.00536 mol

n S = 0.00536 mol
mass of sulfur 0.00536 x 32.07 = 0.172 g
% of sulfur = 0.172/1.04 x100 = 16.5%</td>
<td>Many girls did not distinguish between sulfur and sulfate. Many also did not read correctly from the graph. Be careful about what the question is asking.</td>
</tr>
</table>

31	Criteria: • Explains the different water solubilities of all FOUR compounds. **AND** • Provides at least ONE appropriate, fully labelled diagram • Refer to DATA	Marks 5	Water can form hydrogen bonds and dipole–dipole forces with neutral molecules. All four compounds are neutral molecules that, being similar in size, form similarly sized dispersion forces. • But-1-ene is non-polar and cannot form hydrogen bonds with water. Therefore, but-1-ene is insoluble in water. • 1-fluoropropane is very polar and can form both one hydrogen bond with water. Therefore, it is slightly soluble in water. • Both propan-1-ol and ethanamide are very polar and can form hydrogen bonds and some dipole dipole with water. with water. Both can form many more hydrogen bonds with water than 1-fluoropropane, resulting in both compounds being much more water-soluble than 1-flouropropane.  	While lots of students were awarded 4/5 for this question, overall it was reasonably well done. The major mistake was NOT USING THE DATA given. (this was most students). Some comment about the fact that the substances have similar MM so dispersion forces were similar between water and all the substance. Many girls confused solubility with boiling points. It is important to remember in solubility that the force is with the water molecule. Also lots of girls had OH as an hydroxide (neg) as opposed to an hydroxyl group. Accurate drawings with labels are essential. NB. They were not asked to rank solubility. Also note the correct definition of a hydrogen bond.
	• Explains the different water solubilities of at least TWO compounds. AND • Provides at least ONE diagram.	3-4		
	• Explains the different water solubilities of at least ONE compound. OR • Outlines some intermolecular forces associated with functional groups	2		
	• Provides some relevant information	1		

32

Criteria	Marks
Identifies 6 compounds	6
Identifies 5 compounds	5
Identifies 4 compounds	4
Identifies 3 compounds	3
Identifies 2 compounds	2
Identifies 1 compound	1



A and B involved finding the carboxylic acid and alcohol formed from the ester

Very few students were able to correctly draw the structure of C

Some students had E and F reversed 1 mark only was awarded for this

Error carried forward was accepted if a structure was drawn correctly from an incorrect prior structure

33 a)

Criteria:	Marks
• Identifies hydrocyanic acid as the weakest acid AND determines the pK_a value for hydrocyanic acid	2
• Identifies hydrocyanic acid as the weakest acid OR determines the pK_a value for the identified acid	1

hydrocyanic acid

$pK_a = -\log_{10}(K_a) = -\log_{10}(6.2 \times 10^{-10}) = 9.21$ (2 s.f.)

Well done across the cohort

33 b)

Criteria:	Marks
• Identifies the ClO_2^- (chlorite ion) as the weakest base AND determines the pK_b for this base	2
• Identifies the ClO_2^- (chlorite ion) as the weakest base	1

$HClO_2$ (chlorous acid) forms the chlorite ion (ClO_2^-) as its conjugate base.

The strongest acid forms the weakest base.

For a conjugate acid-base pair:

$pK_a = -\log(K_a) = -\log(1.1 \times 10^{-2}) = 1.96$

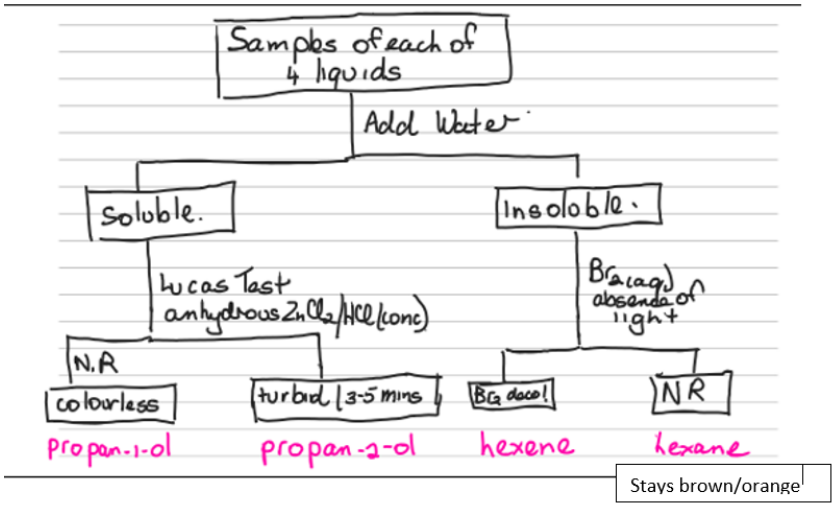
$pK_b = 14 - pK_a = 14.00 - 1.96 = 12.04$

Some students only mentioned Chlorous acid or $HClO_2$, a reminder to read the question carefully.

The weakest base which is ClO_2^- ion should be stated in answer

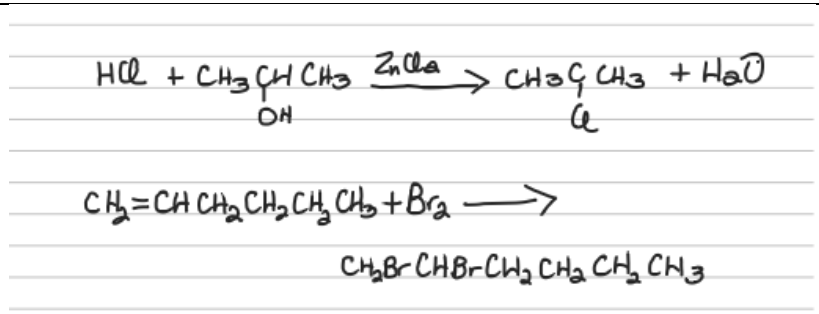
Most students calculated pK_b correctly

	OR determines the pK_b for the identified base		
33 c)	Criteria: / Marks • Calculates the correct pH — 2 • Shows some correct working and reasoning — 1	$CH_3CH_2COOH\ (aq) + H_2O\ (l) \rightleftharpoons CH_3CH_2COO^-\ (aq) + H_3O^+\ (aq)$ $K_a\ CH_3CH_2COOH = \frac{[CH_3CH_2COO^-]\,[H_3O^+]}{[CH_3CH_2COOH]} = 1.34 \times 10^{-5}$ Let x moles of CH_3CH_2COOH ionise, forming x moles of H_3O^+ $K_a\ CH_3CH_2COOH = \frac{[x]\,[x]}{[0.010 - x]} = 1.34 \times 10^{-5}$ Assume x will be small by comparison with 0.010 Hence $[x]^2 = 1.34 \times 10^{-5} \times 0.010 = 1.34 \times 10^{-7}$ $[H_3O^+] = \sqrt{(1.34 \times 10^{-7})} = 0.000366$ mol/L Hence pH $= -\log_{10}(0.000366) = 3.44$ (2 s.f.)	Most students answered this question well. Weaker answers calculated pH using the acid concentration given without considering Ka to determine how much acid dissociated/ionised to $[H_3O^+]$
33 d)	Criteria: / Marks • Calculates concentrations of $[NO_2^-]$ and $[HNO_2]$ • Uses equilibrium expression to calculate H_3O^+ • Calculates the pH • Explains why this mixture is classified as a buffer (2 points) — 4 • 3 of the above — 3 • 2 of the above — 2	$HNO_2\ (aq) + H_2O\ (l) \rightleftharpoons NO_2^-\ (aq) + H_3O^+\ (aq)$ $K_a\ HNO_2 = \frac{[NO_2^-]\,[H_3O^+]}{[HNO_2]} = 7.2 \times 10^{-4}$ Initial $[HNO_2] = 0.010$ mol/L Initial $[NO_2^-] = 0.010$ mol/L On mixing, the volume is increased to 180 mL After mixing, $[HNO_2] = 0.010 \times 100/180 = 0.00555$ mol/L After mixing, $[NO_2^-] = 0.010 \times 80/180$ mol/L $= 0.00444$ mol/L Let x mol/L HNO_2 ionise at equilibrium. At equilibrium $[HNO_2] = (0.00555 - x)$ mol/L $[NO_2^-] = (0.00444 + x)$ mol/L $[H_3O^+] = x$ mol/L $K_a\ HNO_2 = \frac{[NO_2^-]\,[H_3O^+]}{} = 7.2 \times 10^{-4} = \frac{(0.00444 + x)\,(x)}{}$	This question was poorly answered. Few students gained full mark for this question. Most students calculated pH by using the concentration of acid given which assumes full dissociation/ionisation, not correct. Equilibrium expression was needed to find $[H_3O^+]$ using the Ka value provided in data table. Also some students calculated the moles of each and subtracted to find excess – in this case error carried forward was used to award 1 mark for pH calculation using excess HNO_2

	• 1 of the above	1	$[HNO_2]$ $(0.00555 - x)$ Assume x is small by comparison with 0.00555 and with 0.00444 mol/L K_a HNO_2 $= \frac{[NO_2^-][H_3O^+]}{[HNO_2]} = 7.2 \times 10^{-4} = \frac{(0.00444)(x)}{(0.00555)}$ $[H_3O^+] = x = 7.2 \times 10^{-4} \times 0.00555/0.00444 = 0.00090$ mol/L pH = 3.05 A buffer solution is one which will maintain an almost constant pH, even if small quantities of strong acid or base are added to it. As long as there are close to equal moles of equal concentration solutions making up the buffer mixture, and the acid and base are both only moderately strong as acids and bases, the solution will stay at close to the pH value 3.05, as calculated above. By Le Chatelier's Principle, if [x] is small by comparison with the concentrations of the acid and base, if the concentration of H^+ in the buffer mixture changes slightly, the proportions of HNO_2 and NO_2^- will change to keep the pH close to 3.05.	For 1 mark for buffer explanation you needed at least 2 reasons
34 a)	**Criteria** / **Marks** • Draws a flowchart which correctly distinguishes the 4 compounds — 4 • Draws a flowchart which correctly distinguishes 3 compounds — 3 • Draws a flowchart which correctly distinguishes 2 compounds — 2 • Draws a flowchart which correctly distinguishes 1 compound — 1		Was well done. Problems here: Some students included an oxidation test with **acidified** $KMnO_4$ for distinguishing between the alcohols and used indicator or Na_2CO_3.Regardless of whether a carboxylic acid was formed or a ketone, there would be acid present. Testing with oxidation as the first step was a little tricky as hex-1-ene will oxidise as well as the alcohols.

34 b)

Criteria	Mark
2 correct reactions using structural formula	2
1 correct reaction or 2 partially correct	1



Most students were able to correctly write the addition reaction of Br_2 to hex-1-ene.

Students lost marks here for not using condensed structural or structural formula

Including a 'no reaction; for bromine with hexane was not accepted.

34 c)

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Criteria	Mark
Predicts that propan-1-ol the highest boiling point AND Differentiates between propan-1-ol and propan-2-ol (hydroxyl more exposed for hydrogen bonding) AND identifies the intermolecular forces in the other molecules and compares their strength	3
2 of the above	2
1 of the above	1

· propan-1-ol has the highest boiling point
AND
·propan-1-ol has the strongest intermolecular forces because hydrogen bonding as well as dispersion forces exist between the molecules. Hydrogen bonds are the strongest IMFs so it takes more energy to disrupt this force, so a higher BP.
Propan-2-ol also has hydrogen bonding because of the OH group, but this OH group is not as exposed so the IMF is less and so the BP is less .
AND
Hexene and hexane are both non polar so the only IMF that occurs between the molecules is dispersion, which is a weak force.

A lot of students were awarded full marks for this question.

Some issues here were:

- not including all the molecules
- not mentioning the types of IMF present for each molecule
- not comparing the strength of IMF