STUDENT NUMBER: _____

Pymble Ladies' College

2023 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 – 32
- Allow about 2 hours and 25 minutes for this section

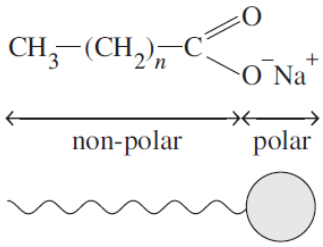
THIS PAGE HAS BEEN LEFT BLANK

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. Consider the diagram.



What structure does this diagram represents?

A. soap molecule.
B. hydrocarbon.
C. cationic detergent molecule.
D. anionic detergent molecule.

2. What is the conjugate base of HSO_4^- ?

A. H^+
B. SO_4^-
C. H_2SO_4
D. SO_4^{2-}

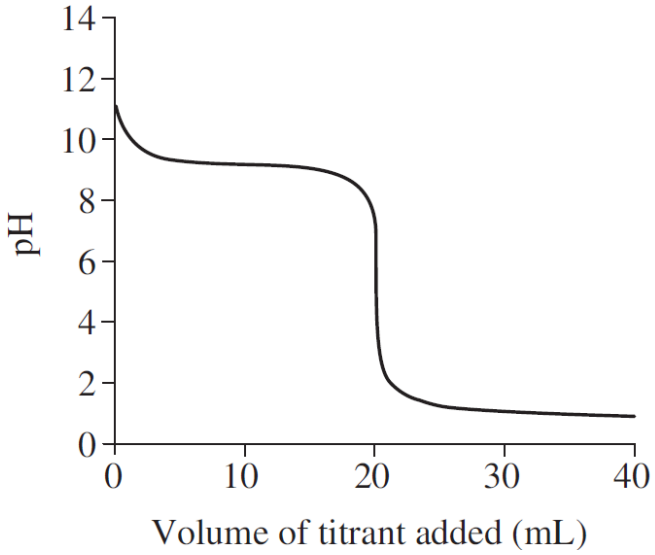
3. Which option is the correct equation for the incomplete combustion of ethanol?

A. $C_2H_5OH(l) + ½\ O_2(g) \rightarrow 2CO(g) + 3H_2(g)$
B. $C_2H_5OH(l) + 3/2\ O_2(g) \rightarrow 2CO_2(g) + 3H_2(g)$
C. $C_2H_5OH(l) + 2O_2(g) \rightarrow 2CO(g) + 3H_2O(l)$
D. $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

4. Which of the following statements about activation energy, *E*a, and equilibrium is correct?

A. Lowering the *E*a will cause a reaction to reach equilibrium faster.
B. Lowering the *E*a will shift the position of equilibrium to increase product yield.
C. *E*a affects only exothermic equilibrium reactions.
D. *E*a does not apply to equilibrium reactions.

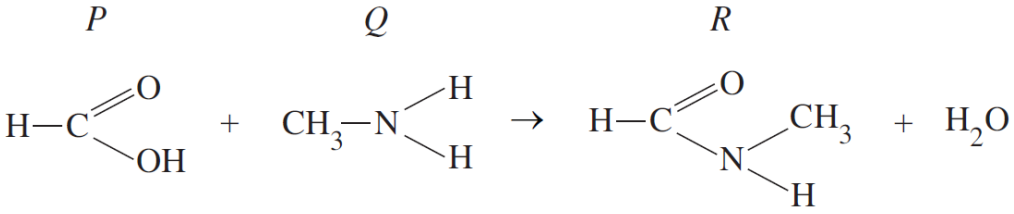
5. Consider the titration curve.



Based on the curve, what can be concluded about the titration?

A. A strong acid was added to a strong base.
B. A strong acid was added to a weak base.
C. A strong base was added to a weak acid.
D. A weak acid was added to a weak base.

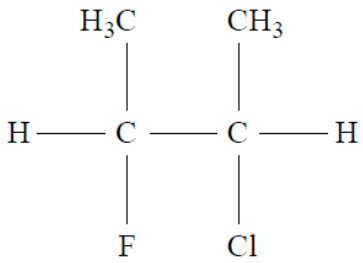
6. The diagram shows molecules *P* and *Q* reacting to form molecule *R* and water.



Which row of the table identifies the molecule types?

	P	**Q**	**R**
A.	alcohol	amine	ester
B.	carboxylic acid	amide	amine
C.	carboxylic acid	amine	amide
D.	aldehyde	amide	ketone

7. What is the IUPAC name of the molecule below?



A. 2-chloro-3-fluorobutane
B. 2-fluoro-3-chlorobutane
C. 2-dimethyl-1-chloro-2-fluoroethane
D. 1,2-dimethyl-1-fluoro-2-chloroethane

8. How many isomers does the formula $C_2H_4Br_2$ have?

A. 1
B. 2
C. 3
D. 4

9. 100 mL of 0.4 M nitric acid, HNO_3, is added to 100 mL of 0.1 M barium hydroxide, $Ba(OH)_2$. What is the pH of the resulting solution?

A. 0.3
B. 0.7
C. 0.8
D. 1.0

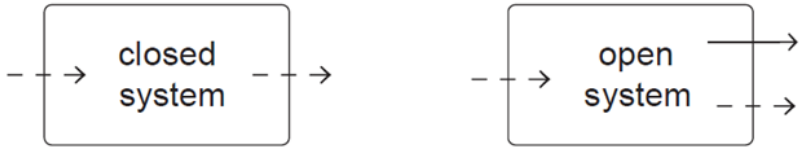
10. What mass of silver chloride (*MM* = 143.4) will dissolve in 1.00 L of water? The K_{sp} of AgCl is 1.8×10^{-10}.

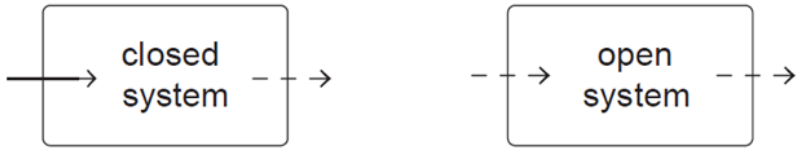
A. 1.4 mg
B. 1.9 mg
C. 2.9 mg
D. 3.8 mg

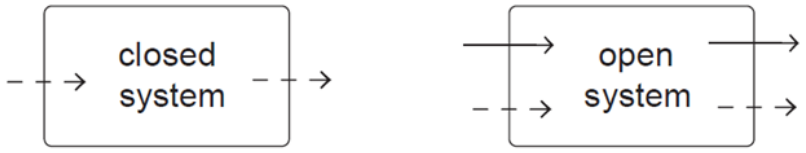
11. A student drew a diagram that illustrated the flow of matter and energy in closed and open systems. They used the following key.

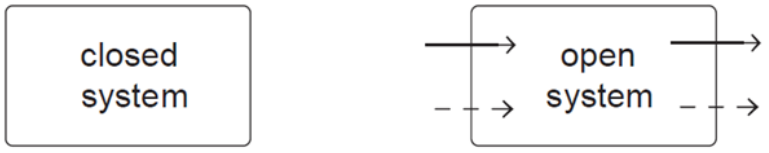
KEY
⟶ exchange of matter with the surroundings
- - → exchange of energy with the surroundings

Which of the following could be the student's diagram?

A.


B.


C.


D.


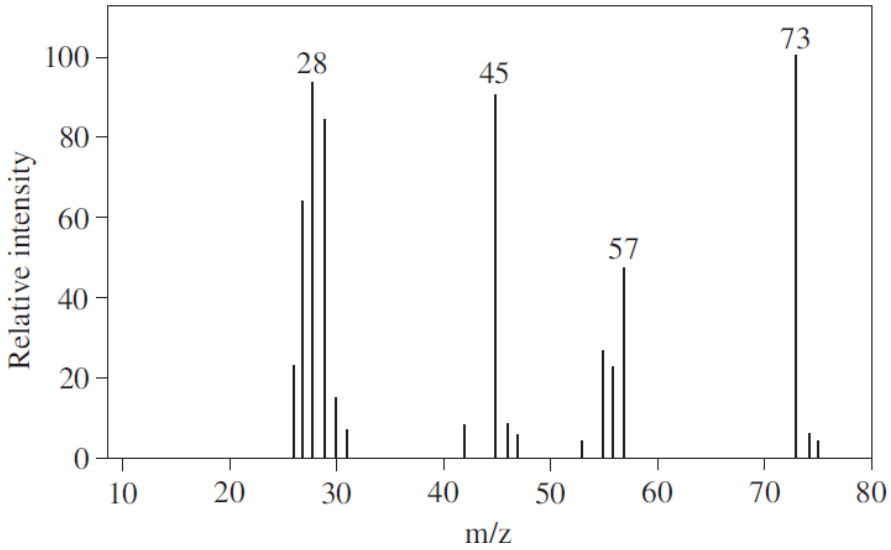
12. The production of hydrogen occurs by the reaction of methane with steam. The reaction mixture reaches a state of dynamic equilibrium.

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

Which of the following shows how the equilibrium yield of hydrogen and the value of the equilibrium constant are affected by the changes shown?

	Change	**Effect on equilibrium yield of $H_2(g)$**	**Effect on value of Keq**
A.	Increase pressure	decrease	decrease
B.	Add a catalyst	increase	no effect
C.	Increase temperature	increase	increase
D.	Remove CO(g) as formed	increase	increase

13. A simplified mass spectrum of butanoic acid is shown.



What does the peak with the mass-to-charge ratio, m/z, of 73 represent?

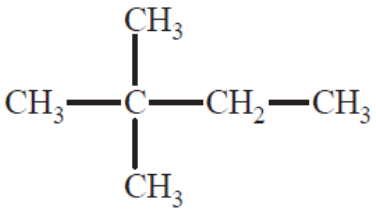
A. The greatest mass-to-charge ratio.

B. The species $CH_2CH_2COOH^-$

C. The species CH_2CH_2COOH

D. The species $CH_2CH_2COOH^+$

14. The structure of 2,2-dimethylbutane (C_6H_{14}) is shown below.
In a particular chlorination reaction, a single hydrogen atom of 2,2-dimethylbutane is replaced by one chlorine atom. More than one compound with the formula $C_6H_{13}Cl$ can be formed.



How many different compounds could be formed in this monosubstitution reaction?

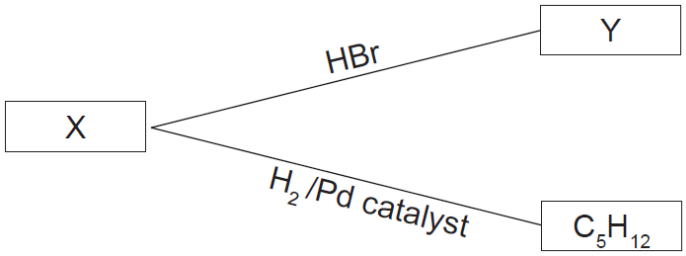
A. 2

B. 3

C. 4

D. 5

15. The diagram shows two reactions.
Determine the molecular formulae of substances **X** and **Y**.



	X	**Y**
A.	C_5H_{12}	$C_5H_{13}Br$
B.	C_5H_{10}	$C_5H_{11}Br$
C.	C_5H_{10}	$C_5H_{10}Br_2$
D.	C_5H_8	C_5H_9Br

16. Iron (III) forms a variety of coloured complex ions. One such example is that produced by the reaction with salicylic acid ($C_7H_6O_3$):

$$\underset{\text{(pale yellow)}}{Fe^{3+}(aq)} + C_7H_6O_3(s) \rightleftharpoons \underset{\text{(violet)}}{Fe(C_7H_5O_3)^{2+}(aq)} + H^+(aq)$$

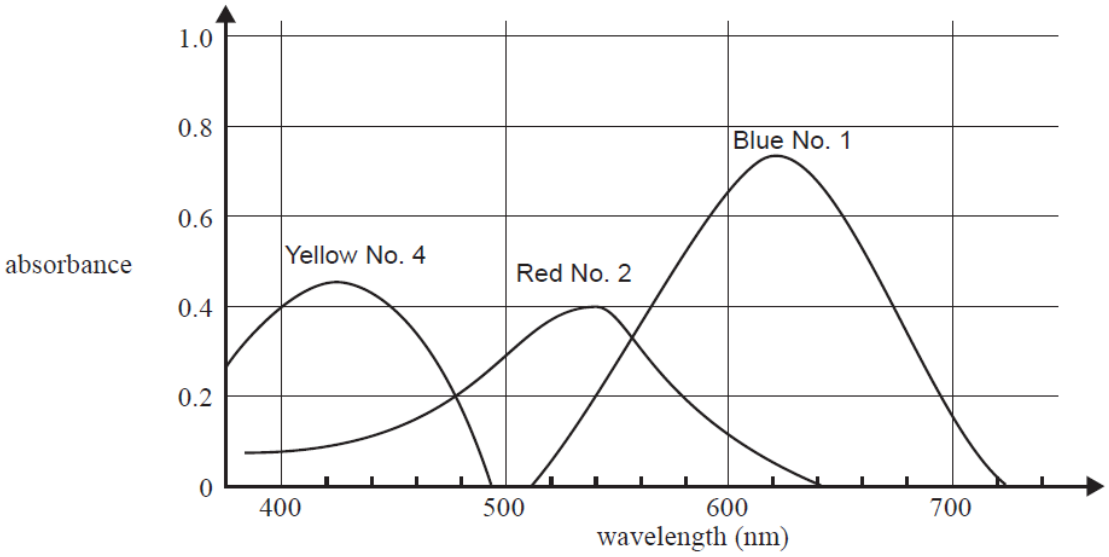
Which of the following will decrease the yield of the violet complex, $Fe(C_7H_5O_3)^{2+}$?

A. Lowering the pH of the solution
B. Raising the pH of the solution
C. Adding $C_7H_6O_3(s)$ to the solution
D. Adding Fe^{3+} ions to the solution

17. Which of the following combinations of solutions will form the most effective buffer solution?

A. 20 mL of 0.3 mol L^{-1} CH_3COOH and 10 mL of 0.2 mol $^{-1}$ $NaCH_3COO$
B. 10 mL of 0.3 mol L^{-1} H_2O and 20 mL of 0.2 mol L^{-1} H_3O^+
C. 20 mL of 0.3 mol L^{-1} NaOH and 10 mL of 0.3 mol L^{-1} $NaCH_3COO$
D. 20 mL of 0.3 mol $^{-1}$ H_2CO_3 and 20 mL of 0.3 mol L^{-1} $NaHCO_3$

18. The graph shows the absorption spectra of three food dyes: Blue No. 1, Red No. 2 and Yellow No. 4.



Which one of the following is the best wavelength to determine the concentration of Red No.2 dye in a solution containing a mixture of all three dyes?

A. 430 nm

B. 500 nm

C. 540 nm

D. 620 nm

19. The equation shows the reaction of HF with water.

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

A 0.13M solution of HF has a pH of 2.05.

What is the pK_b of F^- ?

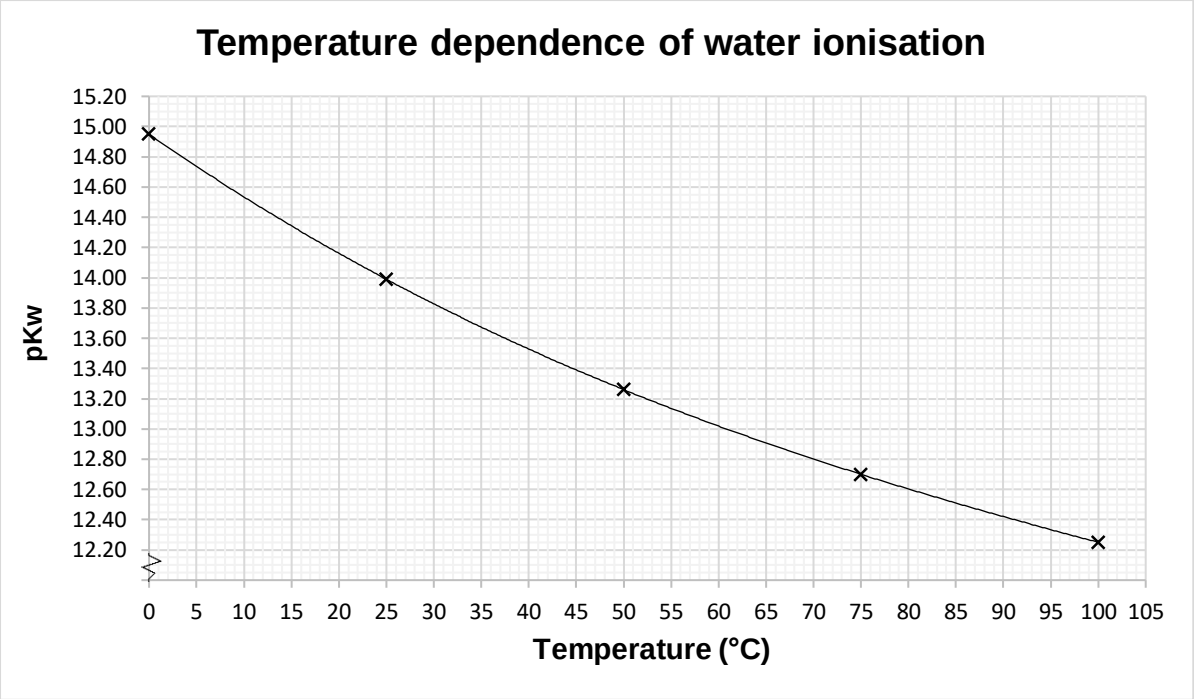
A. 11.81

B. 2.19

C. 3.21

D. 10.79

20. Temperature can affect the value of the equilibrium constant for the ionisation of water (Kw). The graph below shows values for pKw for temperatures between 0°C and 100°C.



A student placed solutions in a water bath at 60 °C to determine if temperature affected the resulting pH of the following reaction.

10.0mL of 0.15 mol L^{-1} KOH was added to 5mL of distilled water. Predict the final pH of the solution at 60 °C.

A. 10.50

B. 12.00

C. 13.00

D. 13.17

Chemistry

Section II
Answer Booklet

80 marks
Attempt Questions 21 – 32
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

BLANK PAGE

Question 21 (5 marks)

Molecules of propan-2-ol and propanone each contain three carbon atoms.

(a) Complete **Table 1** to suggest the shape around the central C atom in a molecule of each compound. **2**

Table 1

Compound	Propan-2-ol $CH_3CH(OH)CH_3$	Propanone CH_3COCH_3
Shape around central C atom		

(b) Explain why propanone has a lower boiling point than propan-2-ol. **3**

……

……

……

……

……

……

Question 22 (4 marks)

Consider the equilibrium reaction:

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

(a) Predict which reaction (forward or reverse) favours maximum entropy. Explain your answer. **2**

……

……

……

……

(b) Predict whether the forward reaction is exothermic or endothermic. Explain your answer. **2**

……

……

……

……

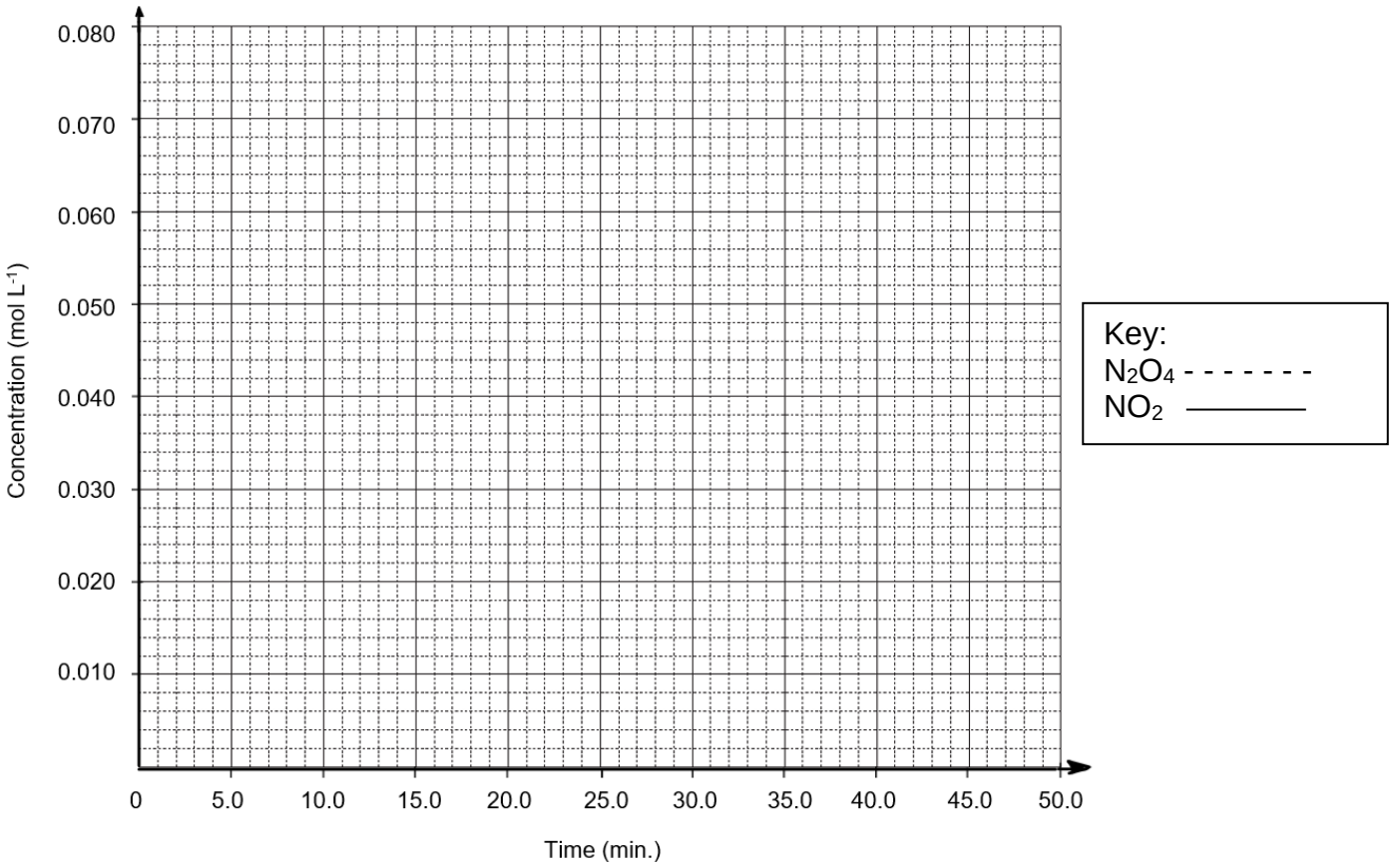
Question 23 (6 marks)

Consider the following equilibrium reaction:

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

A 2.0 L container is filled with 0.070 mol of N_2O_4. Equilibrium is reached after 20.0 minutes at which time there is 0.040 mol N_2O_4 and 0.060 mol of NO_2.

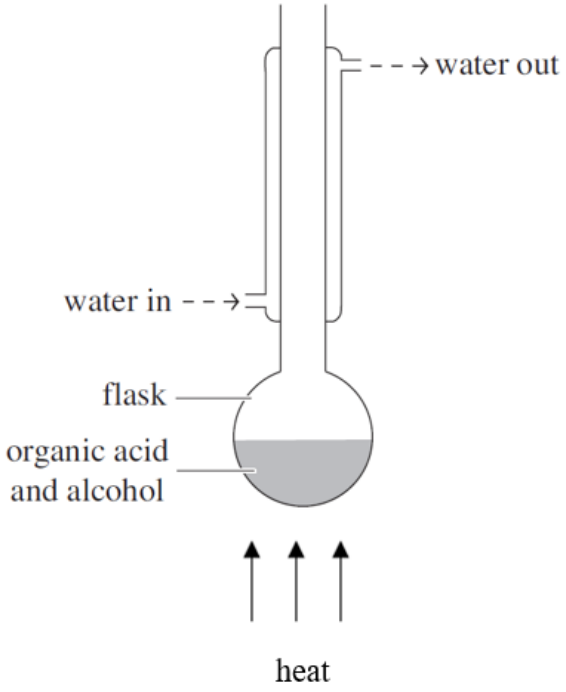
(a) Sketch and label a graph below for the changes in concentrations of N_2O_4 and NO_2 for the time period 0 to 30.0 minutes. **3**



(b) At time 30.0 minutes a malfunction with the equipment causes the volume to double and the equilibrium is disturbed. Equilibrium is reached after 10 minutes. Sketch and label a graph above for the changes in concentrations of N_2O_4 and NO_2 for the time period 30.0 to 50.0 minutes. **3**

Question 24 (8 marks)

Propan-1-ol can react with methanoic acid to produce an organic molecule. The diagram below shows the apparatus used for this reaction.



(a) Identify the type of reaction. **1**

……

(b) Write a balanced structural chemical equation for the reaction. **2**

(c) Identify an appropriate source of heat. Justify your answer. **2**

……

……

……

……

Question 24 continues on page 16

Question 24 (continued)

(d) You have performed this experiment in your study of Chemistry. Explain two steps you used to purify your product in the science laboratory. Refer to reagents and equipment used. **3**

……

……

……

……

……

……

Question 25 (8 marks)

A student was given 4 colourless liquids that were labelled **A**, **B**, **C** and **D**. They were known to be ethanol, ethanoic acid, pentane and hex-3-ene, but the exact identity of each liquid was unknown.
The student tested the properties of each liquid and obtained the following results.

	A	**B**	**C**	**D**
Solubility in water	insoluble	soluble	soluble	insoluble
Addition of red-coloured bromine solution *(aq)* (absence of UV light)	colour disappears	no immediate reaction	no immediate reaction	no immediate reaction
Addition of sodium carbonate solution *(aq)*	no reaction	gas evolved	no reaction	no reaction

(a) Identify each of the liquids. **2**

A = …….. **C** = ……..……..

B = …….. **D** = ……...

(b) Identify the type of reaction occurring between compound **A** and bromine solution **and** write a balanced structural equation. **3**

……..

……..

……..

……..

……..

……..

(c) Discuss the different solubilities of the 4 compounds in water. **3**

……..

……..

……..

……..

……..

……..

Question 26 (8 marks)

A student was investigating the properties of acids and constructed the following table.

Acid	**Concentration (**mol L^{-1})	**Type of acid**	**Available protons**	**pH at 25**°C
Hydrocyanic acid (HCN)	0.50	weak	monoprotic	4.72
Hydrochloric acid (HCl)	0.50		monoprotic	

(a)

(i) Complete the table. **1**

(ii) Calculate the Ka of Hydrocyanic acid. **3**

……..

……..

……..

……..

……..

……..

(b) A buffer solution is prepared by combining 100 mL of 0.010 M hypochlorous acid acid (HClO) and 0.107 g of solid NaClO. K_a HClO = 3.0 x 10^{-8}.

Calculate the pH of this buffer solution and explain the classification of the solution as a buffer using appropriate equation/s in your answer. **4**

……..

……..

……..

……..

……..

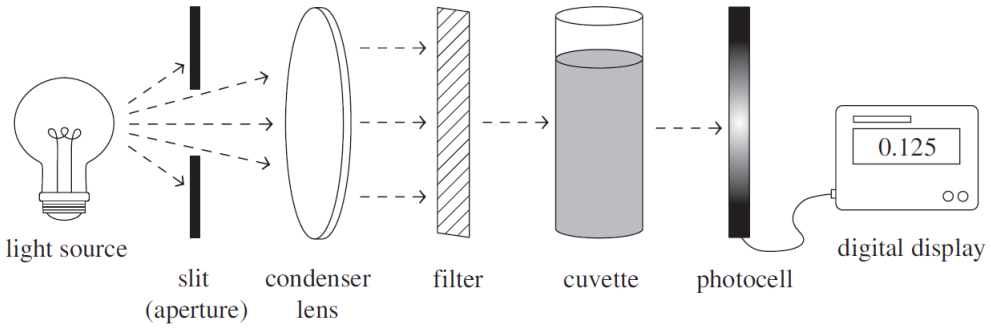
……..

……..

……..

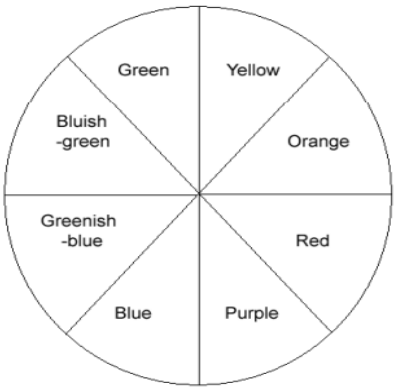
Question 27 (11 marks)

The diagram shows the major components of a colourimeter.



The concentration of phosphate in a water sample can be determined using a colorimeter. Phosphate is colourless, it can be reacted with ammonium molybdate and ascorbic acid in the presence of sulfuric acid to form a blue complex.

An analytical chemist used a colour wheel to select a suitable filter to determine the phosphate concentration of an industrial effluent water sample.



(a) Identify the most appropriate colour for the filter in the colorimeter for this analysis. **1**

……..

……..

Question 27 continues on page 20

Question 27 (continued)

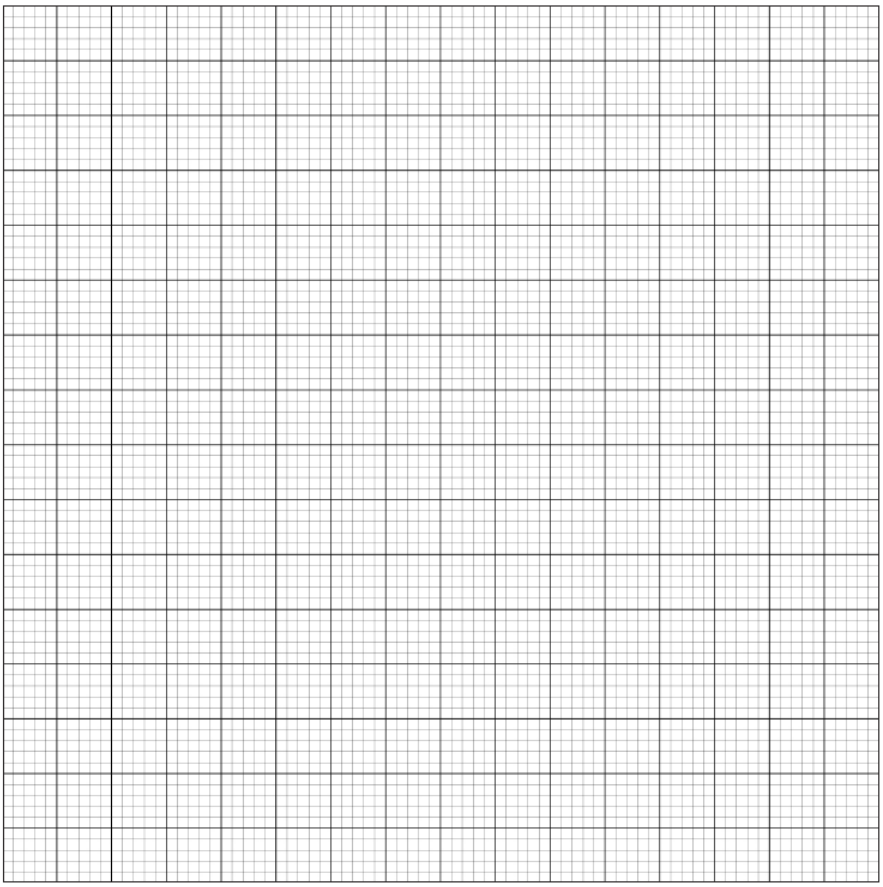
Solutions of known phosphate concentration were used to calibrate the colourimeter, so that absorbance was known for the concentrations shown in the table below.

(b) Graph the data given in Table 1 using the grid below. Draw a straight line of best fit. **3**

Table 1
Absorbance values for phosphate solutions of known concentration

Concentration mg/L	Absorbance
0.00	0.003
0.15	0.095
0.30	0.194
0.45	0.290
0.60	0.378
0.90	0.573
1.20	0.745

Calibration Curve of Phosphate Concentrations vs Absorbance



Question 27 continues on page 21

Question 27 (continued)

Environment Protection Authority (EPA) recommends that effluent from industrial sites entering a waterway should have a limit of 5.0×10^{-7} mol L^{-1} of phosphate to avoid algae growth.

10 mL of a filtered effluent sample was placed in a 100 mL volumetric flask and made up to the mark with distilled water. This sample was tested using the colourimeter. The absorbance value for this solution was 0.4440.

(c) Use the graphed data to determine the concentration of phosphate in the effluent and determine if the effluent water complies with EPA recommendations. **3**

……..

……..

……..

……..

(d) As a precaution, phosphate can be reduced in effluent wastewater before it enters waterways using precipitation.

In the research laboratory 100 mL of the wastewater containing 2.1×10^{-4} mol L^{-1} of phosphate ions is tested.

Will a precipitate of calcium phosphate form when the wastewater sample is added to 200 mL of 5×10^{-2} mol L^{-1} of calcium chloride?

Justify your answer. **4**

……..

……..

……..

……..

……..

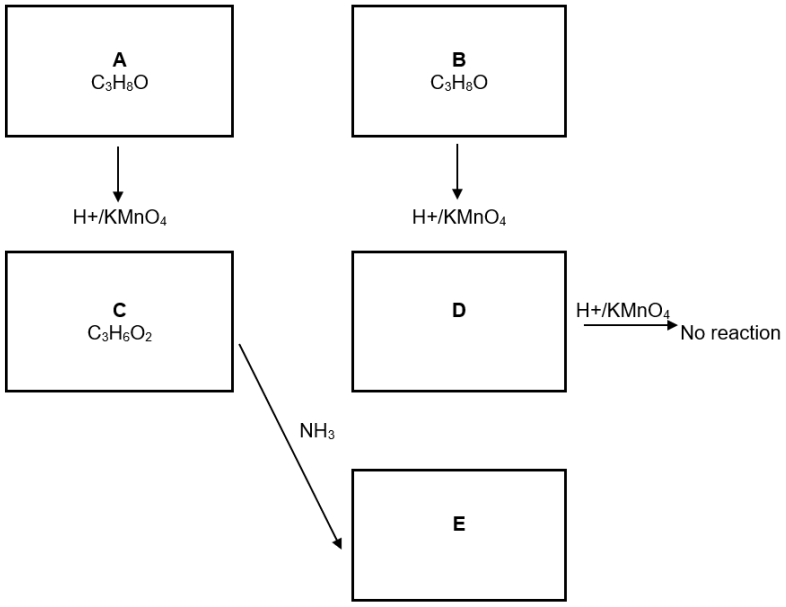
……..

……..

Question 28 (5 marks)

Two different compounds A and B are isomers with the molecular formula C_3H_8O.

A and B undergo a series of reactions as shown below.



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

A	B
C	D
	E

Question 29 (6 marks)

Consider the following equilibrium reaction:

$$O_2(g) + 2SO_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -197 \text{ kJ mol}^{-1}$$

(a) 2.0 moles of oxygen was heated with 0.89 moles of sulfur dioxide in a 2.0 L sealed container at 25°C. When equilibrium was established 0.80 moles of sulfur trioxide was present.

Calculate K_{eq} at 25°C. **3**

……

……

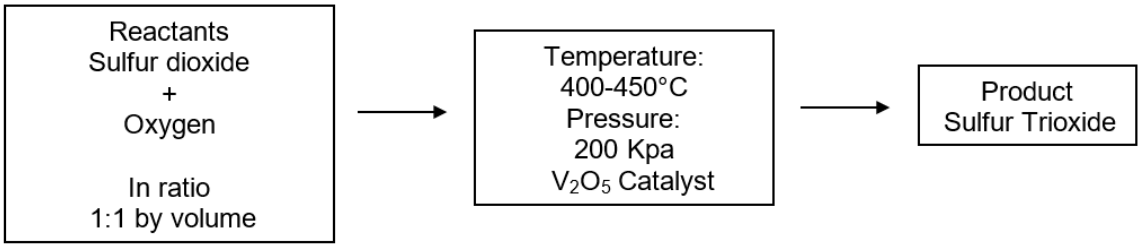
……

……

……

……

In the industrial process used to produce sulfur trioxide the conditions shown below are used.



(b) Analyse the conditions chosen by Engineers for this chemical synthesis process. **3**

……

……

……

……

……

……

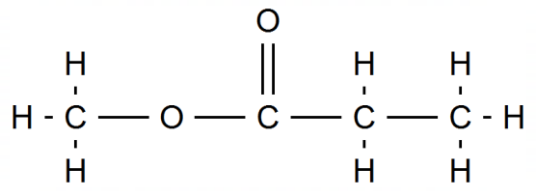
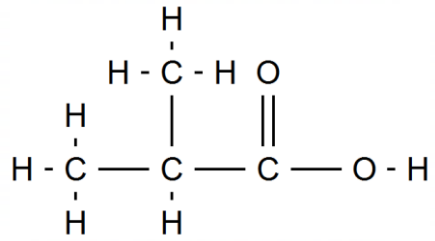
……

……

……

Question 30 (8 marks)

The formulae of two isomers, labelled compounds J and K, are shown below:

Compound J	Compound K
	

(a) Identify the type of isomer shown above. **1**

……..

A student was provided the mass spec, IR and ^{13}C NMR for both compounds.

(b) Identify the spectra that belongs to compound J and K in the title section on the following page (page 25). **1**

(c) Explain your reasoning referencing all spectra data on the following page. **6**

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

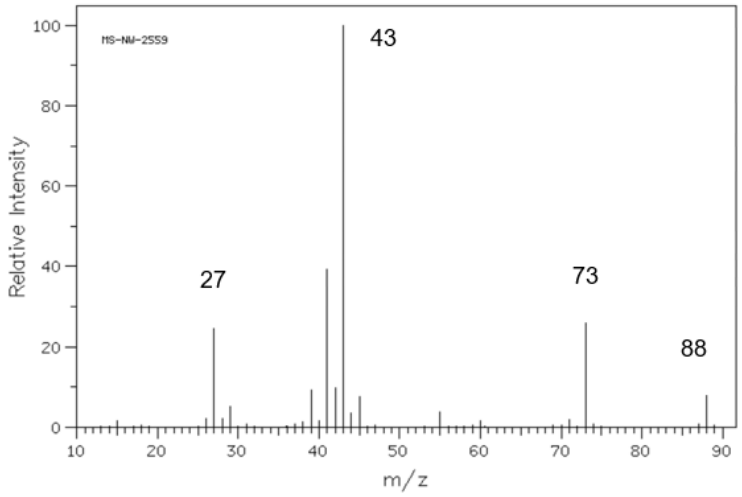
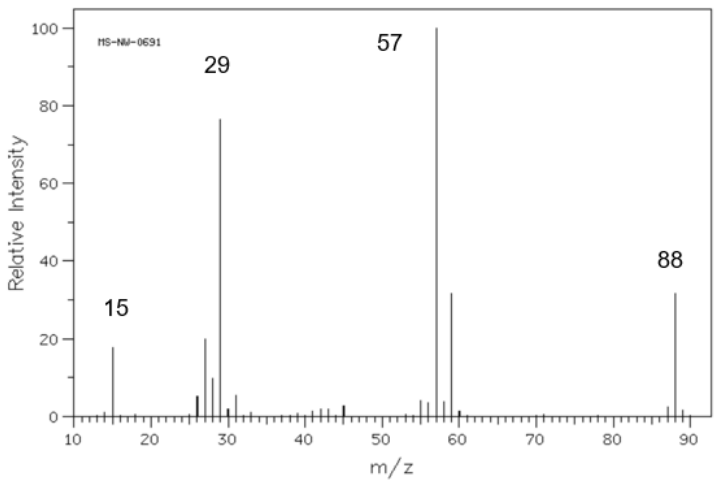
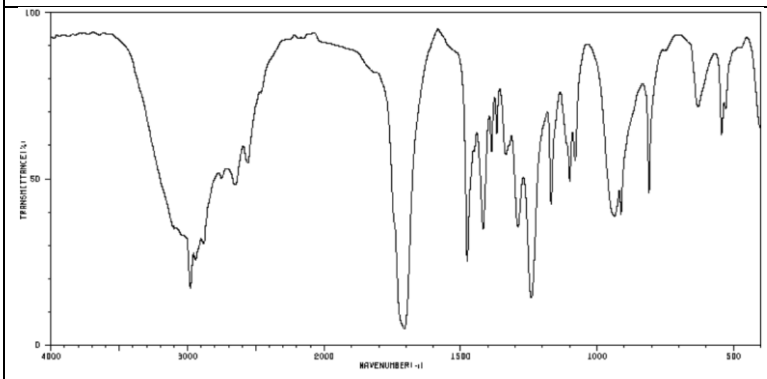
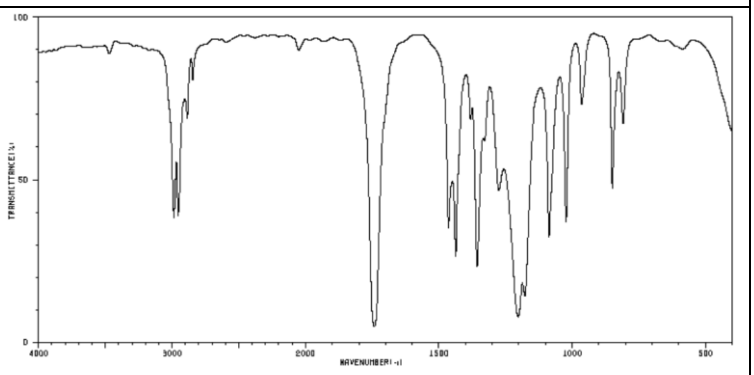
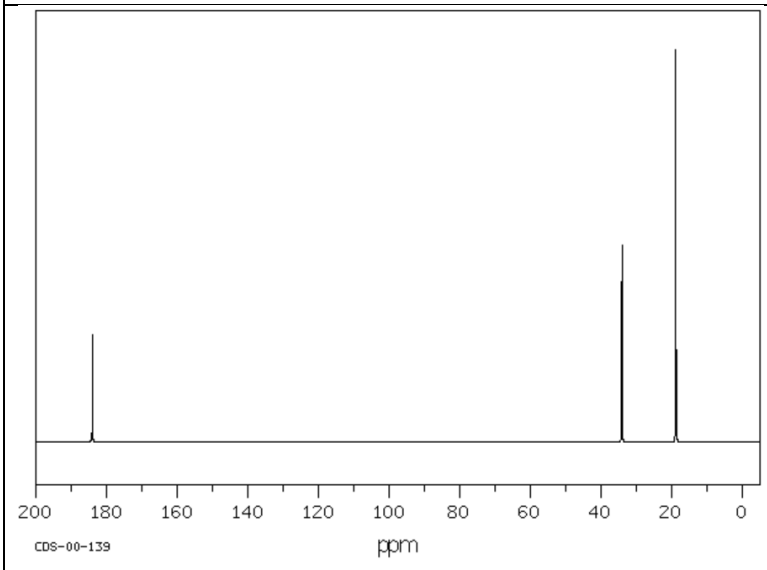
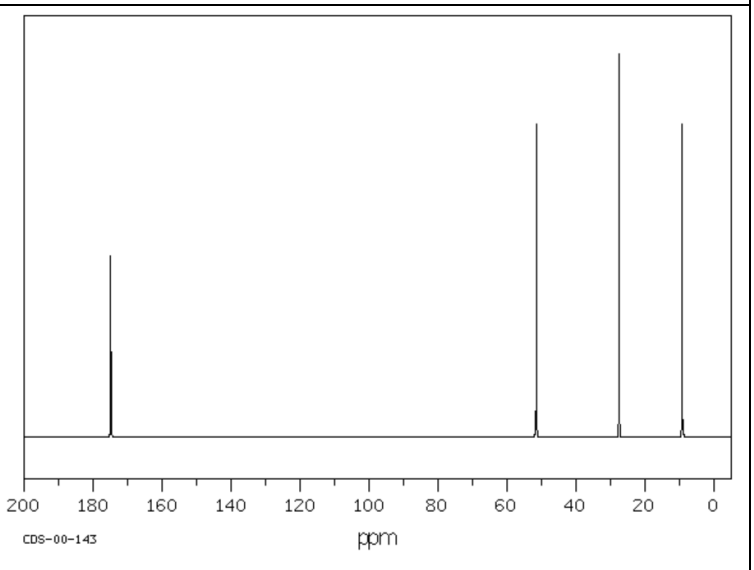
……..

……..

……..

……..

……..

Compound _____	**Compound** _____
Mass Spectroscopy	
	
Infra Red Spectroscopy	
	
C13 NMR	
	

Question 31 (5 marks)

Some thermochemical data relating to potassium hydroxide is shown below.

$$KOH(s) \rightarrow K^+(aq) + OH^-(aq) \qquad \Delta H = -57.6 \text{ kJ mol}^{-1}$$

$$KOH(s) + \frac{1}{2}H_2SO_4(aq) \rightarrow \frac{1}{2}K_2SO_4(aq) + H_2O(l) \qquad \Delta H = -59.1 \text{ kJ mol}^{-1}$$

An 80.0 mL sample of 0.50 mol L^{-1} H_2SO_4 was poured into a poly styrofoam cup. A temperature probe placed into the acid recorded an initial temperature of 24.3°C.

5.00 g of KOH was then added to the acid and completely dissolved in it. The probe was used to determine the highest temperature reached upon this dissolution.

(a) Show by calculation which is the limiting reagent in the reaction between potassium hydroxide and sulfuric acid. **2**

……

……

……

……

(b) Calculate the highest theoretical temperature which could be measured by the probe. Assuming no energy loss to the environment. **3**

……

……

……

……

……

……

Question 32 (6 marks)

Evaluate the following statement. Refer to provided data and use appropriate chemical equations.

"Biofuels are a better option than traditional fossil fuels as an energy source."

Fuel	Formula	$\Delta H°_c$ kJ/g
Octane (petrol)	C_8H_{18}	48
Diesel	$C_{12}H_{26}$	44
Biodiesel	$C_{11}H_{26}O_2$ – $C_{19}H_{34}O_2$	40 – 48*
Ethanol	C_2H_5OH	29.78

* NOTE: Biodiesel can have varying chain lengths.

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

……..

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.

THIS PAGE HAS BEEN LEFT BLANK

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 ⬭

2023 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
	A	D	C	A	B	C	A	B	D	B	C	C	D	B	B	A	D	B	D	B
Catch up					B		D	C				B								A

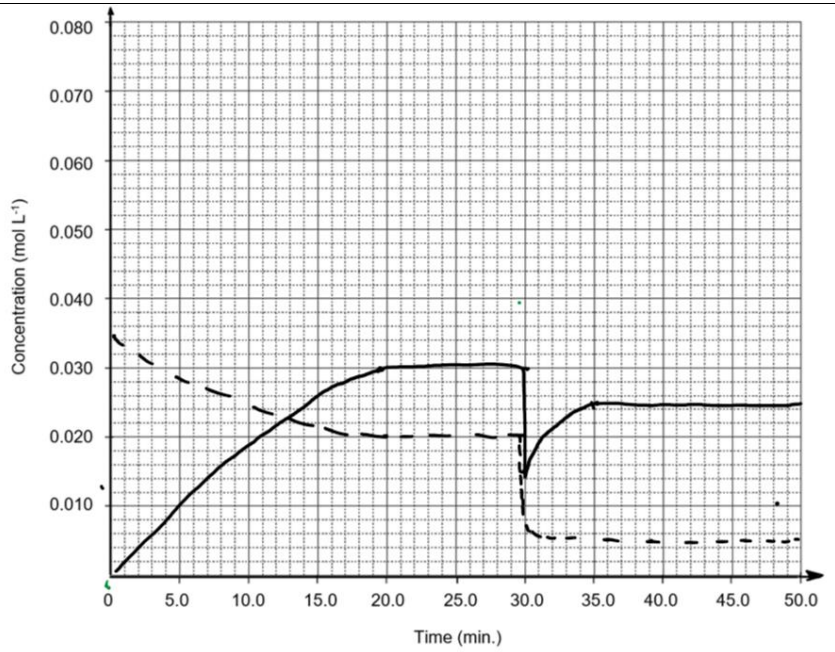
	Marking Guideline	**Suggested Answer**	
21 a)	Criteria / Marks • correct shape around central carbon identified for both molecules — 2 • 1 correct shape identified — 1	Propan-2-ol - tetrahedral Propanone – trigonal planar Must be named (not drawn)	Generally answered well. Some errors included drawing the structural formula, no marks were awarded for this. A few students left the question blank. If you identified propanone using trigonal this was not awarded as trigonal can be planar and pyramidal. Also a few students named them back to front, no marks were awarded in this case.
21 b)	Criteria / Marks • Provides thorough explanation of difference with reference to H-boning and dipole-dipole. — 3 • Provides some explanation — 2 • Some relevant information — 1	• Identifies most significant IMF for propanone and propan-2-ol • Explains difference in force strength. • Link to weaker force to less energy required to boil, or stronger force requires more energy to boil. The boiling points are determined by the intermolecular forces between their molecules. Both molecules have dispersion forces. However, propanone can form dipole-dipole forces due to the carbonyl group and propan-2-ol can form H-bonds due to the presence of hydroxyl group. As dipole-dipole is a weaker force compared to hydrogen bonding this results in propanone having a lower boiling point as therefore, less energy is required to overcome the attractive force.	Answered well across cohort. Some stated hydrogen bond between O-H in alcohol, note this is a covalent bond. Hydrogen bond is between the molecules. The O-H bond does not break, if you said this you lost marks. Other marks lost is no mention of dipole-diploe. Another error was indicating both molecules have hydrogen bonding, and the difference was due to dispersion forces. Note the MM of each molecule is very similar, and therefore the dispersion forces will be similar. It is important to discuss the most significant IMF

22 a)	Criteria	Marks		The forward reaction favours maximum entropy. The RHS has more moles of gas, hence there is more disorder on the RHS, and therefore more entropy.	Answered well across the cohort
	• Identifies correct direction. AND • Links increasing disorder with number of moles on each side of equation	2			
	• Identifies correct direction.	1			

<table>
<tr>
<td>22
b)</td>
<td>
<table>
<tr><td>Criteria</td><td>Marks</td></tr>
<tr><td>• Makes correct prediction.
AND
• Provides a correct reason related to Gibbs.</td><td>2</td></tr>
<tr><td>• Makes correct prediction.
OR
• Use Gibbs equation with wrong conclusion.</td><td>1</td></tr>
</table>
</td>
<td>Endothermic. Since the forward reaction favours maximum entropy, the reverse reaction must favour minimum enthalpy.

Needs to relate to Gibbs for two marks.
Or linking the concept or Gibbs/ spontaneity
Using words to explain:
e.g for an ⇌ reaction the driving force for one direction is entropy and the opposite direction would be enthalpy. So that ΔG can be zero for in both directions ⇌

Using equation to explain:
ΔG = ΔH- T ΔS
Therefore, as the driving force is a + entropy for the forward reaction the enthalpy must be positive i.e., endothermic.
OR
At equilibrium ΔG = 0
If ΔS is positive ΔH must also be positive for ΔG to equal 0</td>
<td>If answered endothermic and then went on to explain more energy absorbed in breaking bonds compared to energy released in making bonds. Did not award the second mark. You need data to calculate overall ΔH. You were not given this data.
The explanation needed to use Gibb's</td>
</tr>
<tr>
<td>23
a)</td>
<td></td>
<td></td>
<td>Some students did not account for the volume 2L. Initial moles and moles at equilibrium were provided.
Only penalised once if this was the case.
Other errors, not starting NO_2 at 0, not showing N_2O_4 decreasing slope, some used a straight line.</td>
</tr>
</table>

	Criteria / Marks • Correct concentrations for both reactants • Correct equilibrium concentration for both reactants • Equilibrium lines drawn constant concentration and correct time — 3 • 2 of above correct — 2 • 1 of above correct — 1		
23 b)	Criteria / Marks • Spike for N_2O_4 and NO_2 down • Spike drops by the correct amount. • 2 correct curves (i.e.[NO_2] rises after spike, and N_2O_4 drops). • line must not go above original level. • 1:2 ratio of change in concentrations — 3 • 3-4 of the above but must include. • Spike for N_2O_4 and NO_2 down • 2 correct curves (i.e.[NO_2] rises after spike, and N_2O_4 drops). — 2 • Shows some understanding of sketching equilibrium curves — 1	See diagram above from 30min	Part b was not answered as well as part a. Common error was not understanding the effect of volume change on concentrations or not showing the correct concentrations after the change. If the volume is doubled the concentration will halve. ECF was applied from part b as long as the concentrations decreased by half at 30 minutes. Some had both NO_2 and N_2O_4 shift in the same direction after disturbance. Other errors included the incorrect 2:1 ratio, the concentration of NO_2 higher than the original level and equilibrium not being re-established by 40 minutes.

24 a)

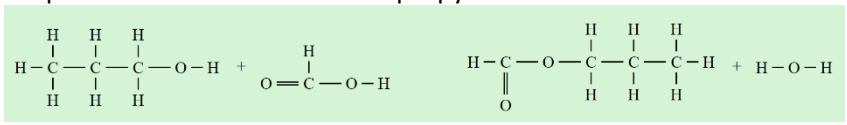
Criteria	Marks
• Identifies the type of reaction correctly	1

- Esterification
- Accept condensation

24 b)

Criteria	Marks
• Correct structural equation with equilibrium arrow	2
• Incorrect structure OR • No equilibrium arrow	1

Propan-1-ol + methanoic acid ↔ propyl methanoate + water



CH3CH2CH2OH + C(O)HCOH <--> C(O)HCH2CH2CH3 + H2O

Better answers included reaction conditions (reflux and conc. H_2SO_4)
Students should be using O-H rather than OH to show all the bonds I.e structure
Many are losing a mark for no equilibrium arrow. Many are forgetting to include water. (not enough marks to penalise for this and arrows, so 1 mark if forgot both)
Still the problem of "mid air" bonds to OH. The carbon has to be liked directly with the O, not between the O and H. Noted but marks not deducted.

24 c)

Criteria	Marks
• Identifies an appropriate source of heat • Justifies the answer – must relate to safety- flammable substances	2
• Identifies an appropriate source	1

A hot plate/ mantle is an appropriate source of heat.
This prevents overheating – avoiding risks of ignition or explosion because of the flammability of the products and reactants. .

Water bath was accepted however hot plate is better choice.
Need to be specific about what the safety risk is, not just a safety risk.
Many girls mention the flammability of alcohol. Esters are also highly flammable and volatile.

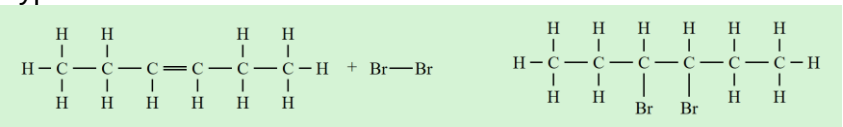
24 d)

Criteria	Marks
• Identifies two steps • Explains (including reason for the step) at least 1 step • Lists reagents/equipment	3
• Explains two steps without specific equipment	2

1. Using a separating funnel - Add water to separate the remaining soluble substances from the insoluble ester

2. Add sodium carbonate solution to the ester in a separating funnel to remove any remaining acid (sulfuric and organic)

Explanation of what the purpose of the steps was missing in many responses.
Many forgot to mention equipment (-1)
Several girls just described refluxing, not purifying

	• Or explains one steps with equipment • Explains one step OR lists equipment or names 2 processes. — 1	3. Distillation of mixture to separate lower boiling point ester from any further traces of water 4. Add calcium chloride (or another named dehydrating agent) to remove any traces of water	
25 a)	Criteria: — Marks • Identifies all four correctly — 2 • Identifies 2-3 correctly — 1	A- Hex-3-ene B- Ethanoic acid C- Ethanol D- Pentane	Very well answered
25 b)	Criteria: — Marks • Identify the type of reaction • Writes/ draws a correct structural equation — 3 • Identify the type of reaction • Write a mostly correct structural equation • OR correct equation with incorrect type of reaction — 2 • Identify the type of reaction • OR • Write a mostly correct structural equation — 1	Type of reaction – addition 	Halogenation /bromination not accepted as they are not unique to alkenes and can react with alkanes too. This reaction was able to identify the alkene due to its ability to ADD/ break the double bond
25 c)	Criteria: — Marks • Discusses the different water solubilities of all FOUR compounds. • Identifies the Correct IMF for each compound — 3	Alkanes and alkenes (A and D) are hydrocarbons. They are not generally soluble in water due to being non-polar Student then discusses either I) or ii) i) Weak dispersion forces are present only ii) no hydrogen bond interaction with the water. Ethanoic acid (B) is polar and soluble as it can form Hydrogen bonds between the acid molecule and water.	Well answered. Must indicate that hydrogen bonds form **with** water

	• Correctly discusses the different water solubilities of at least TWO compounds. • OR • Discusses polarity in detail without IMF — 2 • Correctly discusses the different water solubilities of at least ONE compound. — 1	Ethanol (C) is polar and so are soluble in water. Hydrogen bonds form between water and ethanol	
26 a) i	Criteria: — Marks • Correct calculation and identification of acid — 1	$pH = -\log_{10}(0.50)$ Concentration is 2sigfig so pH should be 2dp **Acid** | **Concentration (mol L^{-1})** | **Type of acid** | **Available protons** | **pH at 25°C** Hydrocyanic acid (HCN) | 0.50 | weak | monoprotic | 4.72 Hydrochloric acid (HCl) | 0.50 | STRONG | monoprotic | 0.30	Students should be using the pH Sig fig rule which would be 2 dp as concentration in 2 sigfigs.
26 a) ii	Criteria: — Marks • Writes the Ka expression • Substitutes correct numbers in (does not need an ice table) • Must make correct statement about negligible change in concentration for HCN — 3 • Provides main steps of the calculation does not show all working. — 2 • Provides some relevant steps of the calculation — 1	Writes Ka expression HCN] <-> H+ + CN- $K_a = [H^+][CN^-] /]HCN]$ HCN] | H+ | CN- R | 1 | 1 | 1 I | 0.5 | 0 | 0 C | $-10^{-4.72}$ | $+10^{-4.72}$ | $+10^{-4.72}$ E | $0.5 - 10^{-4.72}$ | $10^{-4.72}$ | $10^{-4.72}$ $K_a = (10^{-4.72})^2 / 0.5 - 10^{-4.72}$ OR $K_a = (10^{-4.72})^2 / 0.5 - 10^{-4.72}$ But student must say $10^{-4.72}$ is negligible or <5% cannot just be ignored $K_a = 7.26 \times 10^{-10}$	Many girls did not explain the approximation as it is a weak acid.

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>26
b)</td><td>
<table>
<tr><td>Criteria:</td><td>Marks</td></tr>
<tr><td>• Shows all working using Ka expression with correct substitutions to calculate H_3O^+
• to calculate correctly the concentration of [NaClO]
• Calculates the pH
• Define buffer using a correct equation</td><td>4</td></tr>
<tr><td>• 3 of the above
•</td><td>3</td></tr>
<tr><td>• 2 of the above or two mistakes
•</td><td>2</td></tr>
<tr><td>• Some relevant information/ calculation OR used some data.</td><td>1</td></tr>
</table>
</td><td>CALCULATE (3)
K_a = [ClO][H^+] / [HClO]
[H^+] = Ka x [HClO]. / [ClO]

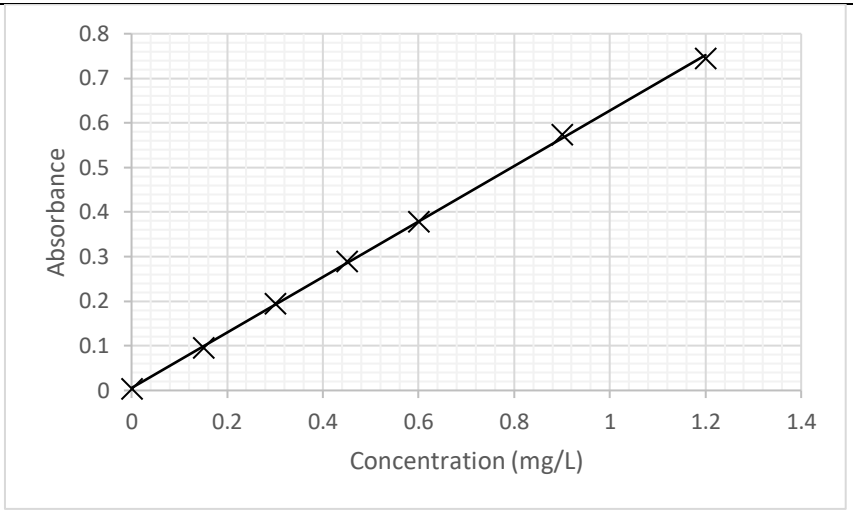
n(NaClO) = 0.107 g / (22.99+35.45+16) = 0.107 g / (74.44)= 0.001437..mol
[NaClO] = n/ V
0.001437..mol / 0.1L = 0.014374 M

[H^+] = 3.0 x $10^{-8.}$X 0.010 mol L^{-1} / 0.014374
2.08710171 x $10^{-8.}$
pH = -log [2.08710171 x 10^{-8} = 7.68
EXPLAIN (1)
Define buffer using a correct equation</td><td>Reasonably well done but major omission was showing detail in working. Concentration of Na Cl O was omitted t times. Two separate marks given. 3 and 1
Many omitted to say why solution was a buffer.
MANY girls did not read the question. It is hypochlorous acid so cant have an iodine in it!</td></tr>
<tr><td>27
a)</td><td>
<table>
<tr><td>Criteria:</td><td>Marks</td></tr>
<tr><td>• Identifies correct filter as yellow</td><td>1</td></tr>
</table>
</td><td>Must select yellow as most appropriate colour as yellow is directly opposite blue.

Must select blue as most appropriate colour as yellow is directly opposite yellow.</td><td>Very straightforward question – and very well done</td></tr>
</table>

27 b)

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



Very well done across cohort

27 c)

Criteria:	Marks
• Uses graph to find concentration at 0.444 • Correct calculation of concentration based on graph • Correct statement comparing calculated value with EPA recommended guidelines.	3
• Substantially correct	2
• Includes one correct calculation or process	1

From graph concentration is 0.7 mg/L

So concentration of sample is 7 mg/L (was diluted by 10 for absorption)

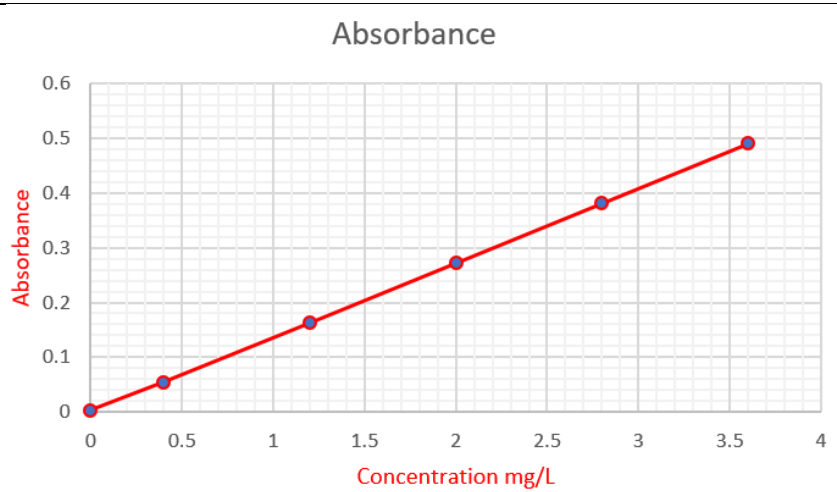
Which is 0.007g/L
MM PO_4^{3-} = 30.97 + (4x16) = 94.97 g/mol
0.007g/L / 94.97 g/mol = 7.37 $x10^{-5}$mol/L

Does not comply as concentration is greater than EPA limit 5.0 $x10^{-7}$ mol/L

Ideally add the interpolation dotted line
Many students struggled with the dilution

Lots of answers don't include information on what is being calculated, should say [PO_4^{3-}] = …

Some students forgot to consider the dilution



From graph concentration is 2.55 mg/L
Amount in 100 mL sample = 2.55 mg/L x 0.100 L = 0.255 mg

0.0255 mg in 10 mL sample

C= 0.0255 mg/0.010 L = 2.55 mg/L = 0.g/L
MM PO_4^{3-} = 30.97 + (4x16) = 94.97 g/mol
0.007g/L / 94.97 g/mol = 7.37 x10^{-5}mol/L

Does not comply as concentration is greater than EPA limit 5.0 x10^{-7} mol/L

27 d)

Criteria:	Marks
• Correct conclusion based on correct calculations • Must show working	4
• Correct conclusion based on calculations (minor error) OR • Insufficient working	3
• Provides main steps	2

$n(PO_4^{3-}) = 2.1 \times 10^{-4} \times 0.100 = 2.1 \times 10^{-5}$ moles
$n(Ca^{2+}) = 5 \times 10^{-2} \times 0.200 = 0.01$ moles

Total volume of solution 300 mL

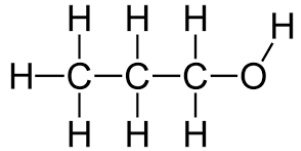
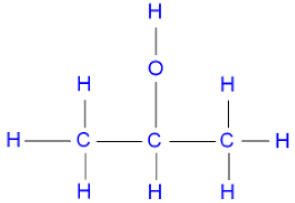
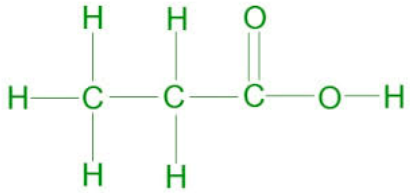
$[Ca^{2+}] = 0.01/0.3 =$ 0.033333… mol/L
$[PO_4^{3-}] = 2.1 \times 10^{-5} / 0.3 =$ 0.00007 mol/L

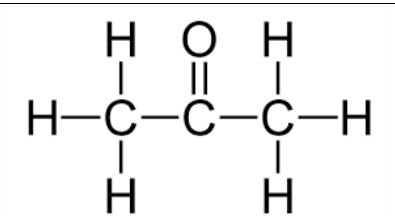
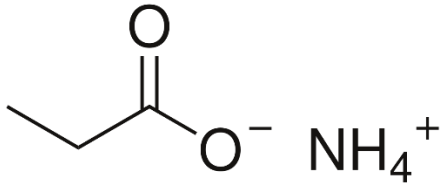
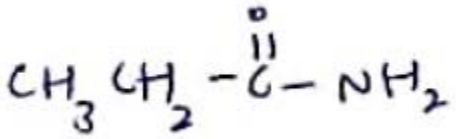
$Ksp = [Ca^{2+}]^3 [PO_4^{3-}]^2$

$Q = (0.033333\ldots)^3 \times (0.00007)^2$
$= 1.8148\ldots \times 10^{-13}$

Most students calculated
Number of moles (1 mark)
concentrations correctly (1 mark) – well done
Lots of errors in formulating correct Ksp expression – resulting from not knowing charge on a phosphate ion(1 mark lost)
Some students rounded correct concentration values in Ksp calculation (1 mark lost)

Hence, Qsp was calculated incorrectly
Most students demonstrated that if Qsp > Ksp a precipitation will form (1 mark)

			Since this product is greater than K_{sp} (2.07×10^{-29}), a precipitate will form. $n(PO_4^{3-}) = 5.0 \times 10^{-3} \times 0.100 = 5.0 \times 10^{-4}$ moles $n(Cu^{2+}) = 1.9 \times 10^{-5} \times 0.200 = 3.8 \times 10^{-6}$ moles Total volume of solution 300 mL $[Cu^{2+}] = 3.8 \times 10^{-6} / 0.3 = 1.266666 \times 10^{-5}$ mol/L $[PO_4^{3-}] = 5.0 \times 10^{-4} / 0.3 = 1.66666\ldots \times 10^{-3}$ mol/L $K_{sp} = [Cu^{2+}]^3 [PO_4^{3-}]^2$ $Q = (1.266666 \times 10^{-5})^3 \times (1.66666\ldots \times 10^{-3})^2$ $= 5.6 \times 10^{-21}$ Since this product is greater than K_{sp} (1.4×10^{-37}), a precipitate will form.	
	• Provides some relevant steps of the calculation	1		
28			A – propan-1-ol  B- propan-2-ol  C propanoic acid  D propanone	C – OH Please draw O-H with a bent bond (relates understanding of properties) Note that the propenamide would only occur with heat – no heat was shown, so that better answer is the acid/base
	Criteria:	Marks		
	All 5 drawings are correct with ALL bonds shown	5		
	Structures correct but not all bonds shown e.g OH OR One mistake	4		
	Two mistakes' OR One mistake and structures correct but not all bonds shown e.g OH	3		

	Three mistakes OR Two mistake and structures correct but not all bonds shown e.g OH	2	 E ammonium propanoate (acid base reaction)  propenamide (propanoic acid is heated and the ammonium salt dehydrates producing amide and water) 	
	Four mistakes OR three mistake and structures correct but not all bonds shown e.g OH	1		
29 a)	Criteria: • Writes the Keq expression OR • Substitutes correct numbers in to the Keq expressions • Uses ICE table and calculations from this to give correct answer	Marks 3	M / O_2 / SO_2 / SO_3 R / 1 / 2 / 2 I / 1.0 / 0.445 / 0 C / -0.20 / -0.40 / +0.40 E / 0.80 / 0.045 / 0.40 OR mol / O_2 / SO_2 / SO_3 R / 1 / 2 / 2 I / 2 / 0.89 / 0	Well done. A few girls forgot the 2 litres. Please be careful of your maths in calculations

	•		C	-0.4	-0.8	+0.8
	• Provides main steps of the calculation does not show all working.	2	E	1.6	0.09	0.8
	• Provides some relevant steps of the calculation e.g writes the correct Keq expression	1	[ ] = E/2	0.8	0.045	0.4

Keq = $[SO_3]^2/([SO_2]^2[O_2])$
= $(0.40)^2 / ((0.045)^2(0.8))$
= 98.77
= 98.8

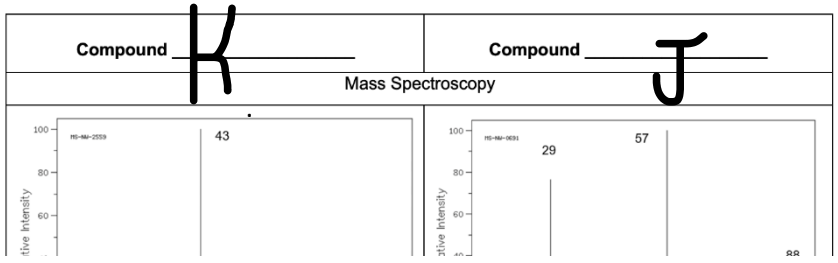
29 b)

Criteria:	Marks
• Thorough analysis of temperature and pressure can include catalyst but not needed • Ratio- forces equilibrium to the right • At LEAST two conditions are necessary and analysed in detail • Essential to talk about compromise for at least one condition • Uses data given. Temperature: • High temp related to ROR (collision) • Low temp related to LCP (yield) • Therefore compromise Pressure • LCP high pressure (yield)	3

This is a compromising conditions question AND must relate yield and equilibrium.
In industrial synthesis the aim is to maximise yield and reaction rate without compromising cost and safety .
At least 2 of the following:
Reactants are added in ratio 1:1 so excess oxygen is provided, reaction stoichiometry requires 1:2 ratio of O_2:SO_2 this will drive equilibrium to the right. Oxygen is also easier and safer to recycle (toxicity of SO2) and so this is the compromise situation.
.
High temperature of 400-450°C increases the energy of reacting particles and provides a greater chance for successful collisions hence increasing the rate. However as the reaction is exothermic the equilibrium would shift to the left so a compromise is needed. This temperature provides energy to reach Ea but a compromise exists between rate and equilibrium
Increase in pressure to 200 KPa would drive the equlibrium to the right and increase yield. Using pressures too high can be costly and dangerous, so must be balance with benefit/ safety- again a compromise is necessary. .
Using a V_2O_5 catalyst lowers the activitation energy for the reaction and increases the rate of reaction, however, yield is the same so the only way that it is an advantage is that it may become a less costly process.

There are 4 conditions mentioned so it is important that AT LEAST TWO are referred to in the analysis AND THAT THE COMPROMISE FOR AT LEAST ONE IS DISCUSSED.
The question requires analysis of the conditions that are used, and you should be justifying these conditions and it is essential you talk about the compromise necessary. It is not just looking at the conditions. NOTE THE AIM OF INDUSTRIAL SYNTHESIS!.
Many girls explained conditions but did not mention the need to compromise to get the best yield.
Many girls thought that 400oC was a LOW temperature.
Best answers mentioned the compromising situation in TWO factors, and referred to data.

Many answers contained LOTS of unnecessary information.
If you talk about catalyst, then you need to analyse why this is used and to what advantage. (and state that it has no effect on yield so really isnt fulfilling the aim of industrial synthesis completely.)

	• Low pressure chosen for safety OR cost reasons •			
	• Thorough analysis of temperature and/or pressure required • OR • TEMP/ PRESS less well analysed and no mention of compromise and catalyst	2		
	• Analysis of 1 relevant factor which includes: • Specific reference to flowchart data OR • Effect on rate and yield	1		
30 a	Criteria: Correctly identifies the type of isomerism. — Marks: 1		Functional group isomers	
30 b	Criteria: (blank) — marks: 1			

30

Criteria:	Marks
• Justifies the correct structure showing an extensive understanding of the interpretation of spectroscopic data • Refers explicitly to all 3 spectroscopic data diagrams	6
• Justifies the structure showing a thorough understanding of the interpretation of spectroscopic data • Refers to relevant spectroscopic data in 3 diagrams	5
• Shows a good understanding of the interpretation of spectroscopic data • Uses relevant information presented in the question to justify the structure of the compound •	4
• Demonstrates some understanding of the interpretation of spectroscopic data	2-3
• Provides some relevant information	1

For methyl propanoic acid
markers reference
Methyl propanoic acid

m/z value of [fragment]$^+$	73	55	45	44 ?	43	42	41	39	29	27
[molecular fragment]$^+$	$[C_3H_5O_2]^+$	$[C_3H_3O]^+$	$[COOH]^+$	$[CO_2]^+$	$[C_3H_7]^+$	$[C_3H_6]^+$	$[C_3H_5]^+$	$[C_3H_3]^+$	$[C_2H_5]^+$	$[C_2H_3]^+$

m/z value of [fragment]$^+$	87	59	58 ?	57	56	55
[molecular fragment]$^+$	$[C_4H_8O_2]^+$	$[C_2H_3O_2]^+$	$[C_3H_6O]^+$	$[C_3H_5O]^+$	$[C_3H_4O]^+$	$[C_3H_3O]^+$
m/z value of [fragment]$^+$	45 ?	31	29	27	26	15
[molecular fragment]$^+$	$[?]^+$	$[CH_3O]^+$	$[C_2H_5]^+$	$[C_2H_3]^+$	$[C_2H_2]^+$	$[CH_3]^+$

Methyl propanoate
3/6 was usually when there was a brief outline of each spectrum
4/6 was usually when there was a brief outline of each spectrum with a little more detail for CNMR or MS
5/6 was usually when there was comprehensive outline of each spectrum – explaining all peaks in each spectrum perhaps missing something like charges on the fragmentations of not referring to the CNMR peaks.

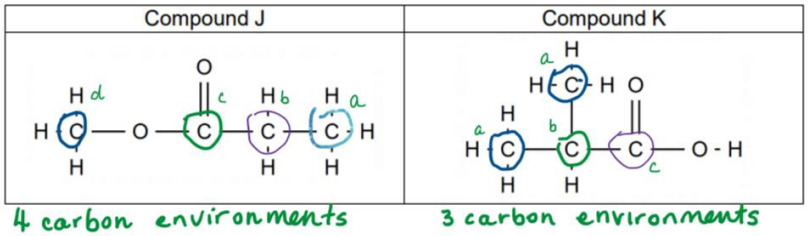
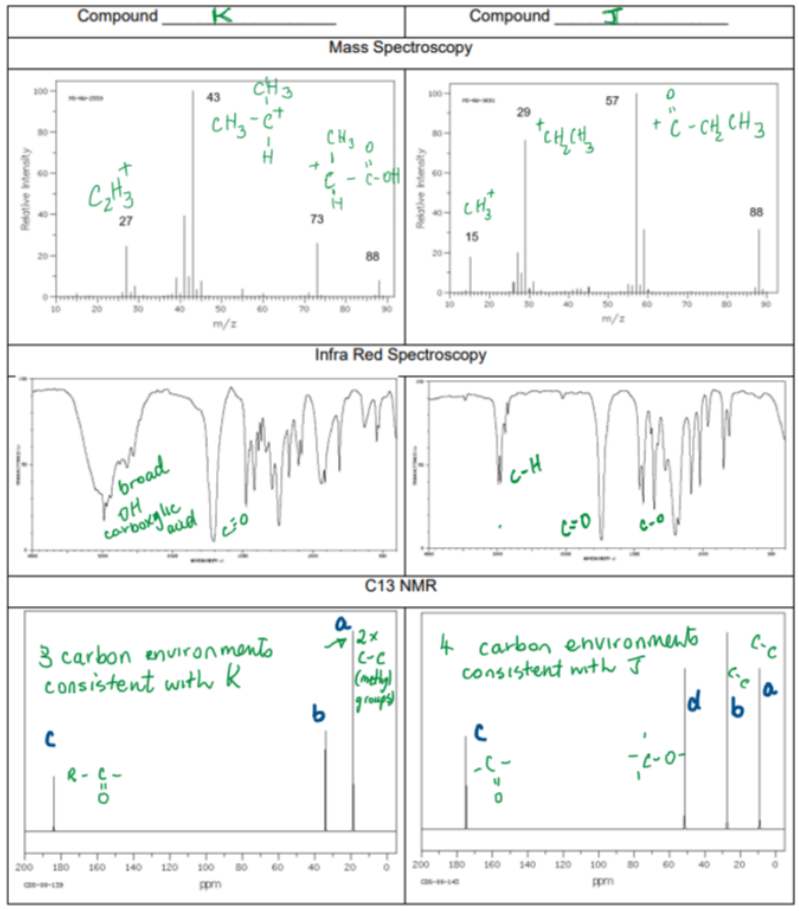
6/6 - To attain a thorough the students must have completed the following as a minimum.
IR – 3000 broad peak = OH from an acid / absence from the other spectrum; as a narrow peak indicative of a C-H was at 3000.
1700 – C=O which was in both

MS – needn't discuss the parent peak as already provided that they are isomers. Must have one unique peak per spectrum for each molecule identified what the fragment would be – WITH CORRECT CATION CHARGE
CNMR- labelled diagrams identifying the carbon environments.
Idea of symmetry to only give 3 peaks when there are 4 carbons
Each peak identified on the CNMR with relation to the data sheet or spins / electronegativity

Student should not just be doing process of elimination but using positive results/ reasons to why they made their choice. Students should be drawing/ labelling the environments if referring to them

Really good attempt by all just lacking a thorough explanation for ALL SPECTRA DATA – this includes explaining all relevant peaks- For the majority of students CNMR peaks were ignored and only the number of environments were addressed – you have this information on the data sheet so should be referring/ using it. Although this was a simple spectra to work out which compound belonged to which spectra – it was a 6 mark questions with 6 specta to be discussed. 6 marks you should spend minimum 10 mins. - detail was lacking to attain 5/6 and 6/6 marks for many – would not have spent 10 mins on this. Lots of students not including cation + charge on the fragmentations or putting – charges OR free radicals. Many students calling the –OH from the acid an alcohol group. Also, should be VERY BROAD PEAK.
Cannot just say broad peak at 3000 is an acid – it represents an OH group present within an acid.
Note for students – the 'dips' in IR spec are still referred to as peaks

Poorly done/ absent
WITH CORRECT CATION CHARGE

		 	*Each peak identified on the CNMR with relation to the data sheet or spins / electronegativity*

<table>
<tr>
<td>31 a)</td>
<td>
<table>
<tr><th>Criteria:</th><th>Marks</th></tr>
<tr><td>• Calculating moles of both reagents. With working –
• Comparing moles in the correct ratio to determine the limiting reagent</td><td>2</td></tr>
<tr><td>• Calculated the moles of both reagents correctly but failed to compare moles in correct ration OR made a mistake with one of the mole calculations but has compared in the ratio correctly with the incorrect moles.</td><td>1</td></tr>
</table>
</td>
<td>$2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$
n(KOH) = 5/ (39.1+16+1.008) = 0.08911385185 mol
$n(H_2SO4)$ = CV. 0.5 x 0.08 = 0.04mol
KOH : H_2SO_4
2:1
0.08 : 0.04
0.08 < 0.08911.. therefore KOH is in excess and H_2SO_4 is LR.
Calculating moles of both reagents. With working
0.08911385185 mol?</td>
<td>Mostly answered well - most students were able to calculate the moles of both reactants – there were a number of students that did not calculate the moles for both – the clue of Limiting reagent was even give to students. There needed to be a clear mole ratio step
Many students simply calculating the moles and then H2SO4 is the LR – without the mole ratio.

Stating the ratio clearly - examples
KOH : H_2SO_4
2:1
0.08911385185 > 2 x 0.04 YES
OR
0.08911385185 > 0.04 NO</td>
</tr>
<tr>
<td>31 b)</td>
<td></td>
<td>moles of H2O = 0.08 (from previous question or error carried forward)
ΔH = -59.1 X 0.08 = -4.728 kJ = -4728J
ΔH = -57.6 X 0.08911 = -5.132736 = -5132.736J
ΔH = - MC ΔT
ΔT = (-4728+5132.736)/ 80 X 4.18 = 29.48785 K

29.48785 + 24.3 = 53.8°C</td>
<td>Students really struggled with the question – which is rightly so: it was hard and the last maths question of the paper, so you expect it to be hard.
1/3 marks should have been accessible for all students
2/3 only a very small error
3/3 PERFECT – band 6 candidate

Note this question has been written in past examinations with an additional need to state any assumptions that were made during the calculation: Assuming....
1. the solution has the same heat capacity as water</td>
</tr>
</table>

	Criteria: / Marks • Shows working of both ΔHs • Substitutes correct number for ΔH = - MC ΔT • Adds change ΔT to initial temperature to correctly calculate the maximum temperature — 3 • Calculates a q value for one equation OR Missing one step from above or incorrectly completes one step above – all other steps correct — 2 • Provides some relevant calculations — 1		2. *the combined mass of water is 80g from the solution.* 3. *same density of water 1g=1mL* 4. *No heat loss to the surroundings or cup* 5. *the temperature increase will be dependent on the amount of energy released only*
32	Criteria: / Marks • Judgement statement • Thorough reference to data and links to argument • Extensive use of appropriate chemical equations — 6 • Judgement statement • Refers to data and links to argument • Good use of appropriate chemical equations — 4-5	**Biofuels** are derived from organic materials like plants and waste products. Biodiesel is a renewable fuel made from vegetable oils or animal fats.. Ethanol is a biofuel made from renewable sources such as corn or sugarcane using the fermentation process: $C_6H_{12}O_6 \rightarrow CO_2 + C_2H_5OH$ (yeast is used as the catalyst) (temperature 40 °C) They undergo combustion reactions to release energy in the form of heat and produce carbon dioxide and water as byproducts.	This was marked holistically on how well you developed your argument. Students needed to build their argument using the data ie formulae and heats of combustion with extensive reference to chemical equations to gain full marks. Students also supported their answer with discussion of - *Environmental/emissions/pollution:* (Acidification of oceans, greenhouse gas, Incomplete combustion Impurities of sulphur)

	• General statement • Some Reference to data and links to argument • Minimal use of appropriate chemical equations	3	For example biodiesel $2C_{11}H_{26}O_2 + 17O_2 \rightarrow 22CO_2 + 26H_2O$ This releases 40-48 kJ/g of heat which is comparable to diesel, both have long carbon chains. However, biodiesel has the advantage of containing oxygen which promotes complete combustion. This minimises production of carbon which can irritate the lungs and carbon monoxide which is toxic to humans. Ethanol has a lower energy content (29.78 kJ/g) compared to octane (48 kJ/g) or diesel (44 kJ/g), but it burns more cleanly, producing fewer pollutants. The disadvantage is needing more volume to produce the same energy output. However, being miscible with traditional petrol (mainly octane), can be used as an additive, and reduce the amount of fossil fuel used. $C_2H_5OH + O_2 \rightarrow 2CO_2 + 3H_2O$ The carbon dioxide released during biofuel combustion is part of the natural carbon cycle. Plants absorb carbon dioxide during their growth, and when biofuels are burned, the CO_2 released is reabsorbed by new plants, making biofuels potentially carbon-neutral. Chemical equation for photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ **Combustion of Fossil Fuels**: Fossil fuels, such as coal, oil, and natural gas, are derived from ancient organic matter that has undergone geological processes over millions of years. When fossil fuels are burned, they also undergo a combustion reaction: e.g. Octane $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ This releases 48 kJ/g of heat Being a long carbon chain may undergo incomplete combustion $2C_8H_{18} + 24O_2 \rightarrow 14CO_2 + 2CO + 2C + 18H_2O$ e.g. Diesel $2C_{12}H_{26} + 37O_2 \rightarrow 24CO_2 + 26H_2O$	- *Economic & Energy efficiency* - *Land use and* - *Infrastructure issues* - *Photosynthesis/ carbon neutral discussion* - *Fermentation of glucose to produce bioethanol* Only a handful of students indicated how biodiesel is made – this would have helped your argument supporting biofuels.
	• General relevant statements about fossil fuels and biofuels	2		
	• Relevant statement	1		

		Diesel releases more CO_2 than biodiesel, and unlike biofuels, fossil fuels release carbon dioxide that has been sequestered in the Earth's crust for millions of years. This contributes to an increase in atmospheric CO_2 levels, which is a major factor in climate change. Also supplies of fossil fuels are limited and may run out in the future Both biodiesel, diesel and octane release a similar amount of heat energy that can be utilised. Judgement: Biofuels are a better option than fossil fuels as an energy source.	