Student Number: ……

Teacher's Name: ……

2020

Task 4: Trial Examination

Weighting: 30%

HSC Chemistry Booklet 1

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 data sheet, formulae sheets and Periodic Table are provided at the back of this paper
- For questions in Section II, show all relevant working in questions involving calculations
- This paper MUST NOT be removed from the examination room

Subject Teachers: Ms Disney, Mr Weeding, Ms Dreesbeimdieke, Mrs Goddard, Mr Nunan, Mr Pimentel

Total marks - 100

Section I - 20 marks (Booklet 1)

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

Section II - PART - 80 marks

- Attempt Questions 21-27 (Booklet 2)
- Attempt Questions 28-34 (Booklet 3)
- Allow about 2 hours 25 minutes for this section

EXTRA BOOKLETS USED: **(please circle)** YES / NO

IF EXTRA BOOKLETS USED - HOW MANY BOOKLETS USED? (please circle)

1 2 3 4 5 or write number here.....

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

1. Indigenous Australians detoxify seeds of various plants so they are safe to eat. To do this the seeds are crushed and then soaked in water.

   The property of the toxins that enables this to be achieved is:

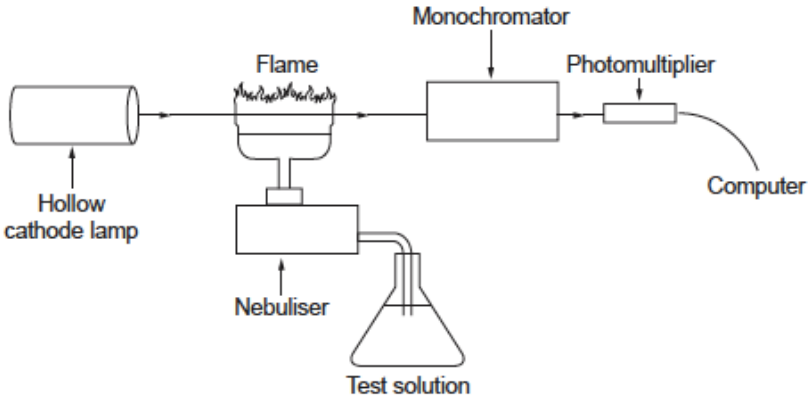
   A. the solubility of the toxin in water.

   B. the fermentation of the toxin in water.

   C. the reactivity of the toxin with water.

   D. the different density of the toxin in water.

2. A diagram of an atomic absorption spectrophotometer is shown.



   What is the purpose of the flame in Atomic Absorption Spectroscopy?

   A. To atomise the sample.

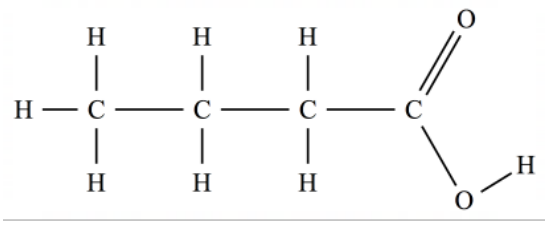
   B. To split the beam into two.

   C. To burn off unwanted components.

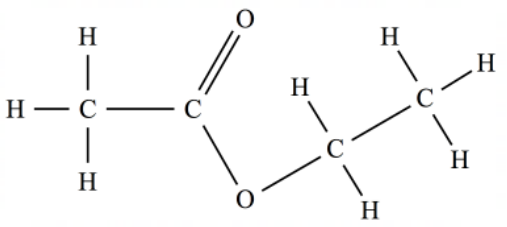
   D. To select a wavelength to measure.

3. Four compounds W, X, Y and Z are represented below.

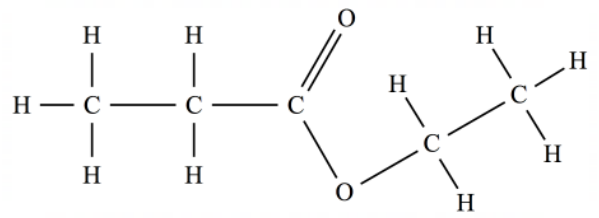
Compound W



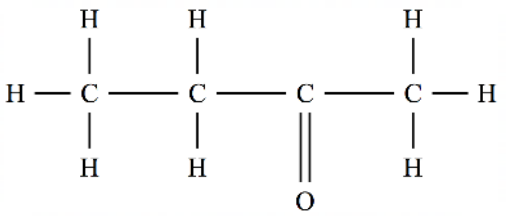
Compound X



Compound Y



Compound Z



Which of the following is a pair of isomers?

A. W and X

B. W and Y

C. X and Y

D. Y and Z

4. Which of the following represents a conjugate acid–base pair?

A. H^+ / OH^-

B. H_2SO_4 / SO_4^{2-}

C. CO_2 / HCO_3^-

D. NH_4^+ / NH_3

5. Cyclohexane was used to compare alkane and alkene reactivity when reacted with bromine water. Part of the warning label on the bottle of cyclohexane is shown below.

Which of the following shows the safest list of precautions that should be followed when using cyclohexane to achieve the aim of this experiment in a school laboratory?

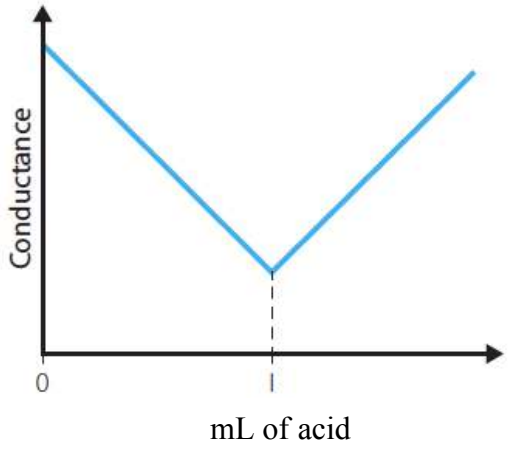
A. Use stoppered micro test tubes, and dispose of the contents in a labelled waste container.

B. Use small amounts in a dimple tile and dispose the contents in a labelled waste container.

C. Use small amounts in micro test tubes and dispose of the contents in a labelled waste container.

D. Use small amounts in micro test tubes in a fume hood, and dispose of the contents in a labelled waste container.

6. The conductivity graph of an acid base titration is shown below.



The graph above shows how the conductivity changes when:

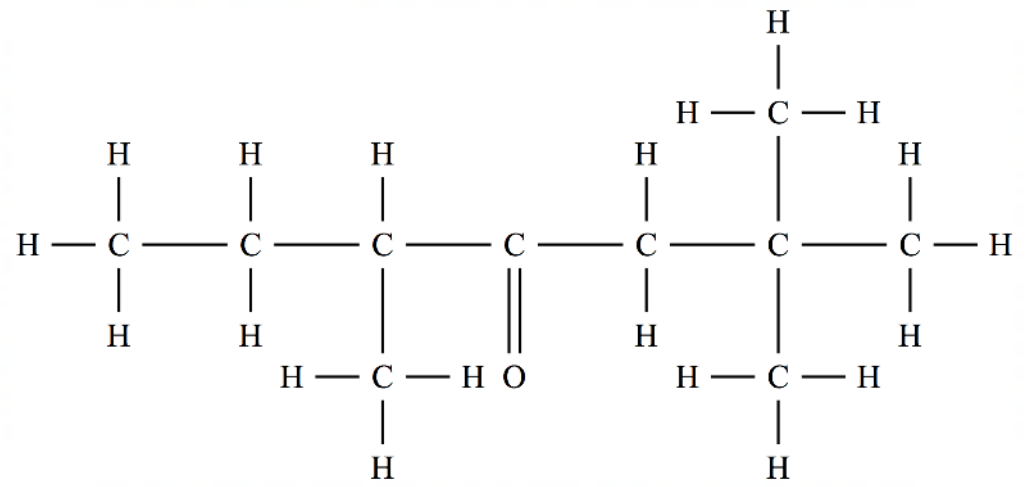
A. a strong acid is added to a strong base.

B. a weak base is added to a strong acid.

C. a weak acid is added to a strong base.

D. a weak base is added to a weak acid.

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



A. 1,1,4-trimethyl-4-heptanone

B. 2,2,5-trimethyl-4-heptanal

C. 3,6,6-trimethyl-4-heptanone

D. 2,2,5-trimethyl-4-heptanone

8. Esterification involves the use of concentrated sulfuric acid. The purpose of adding the acid to the reaction mixture is to:

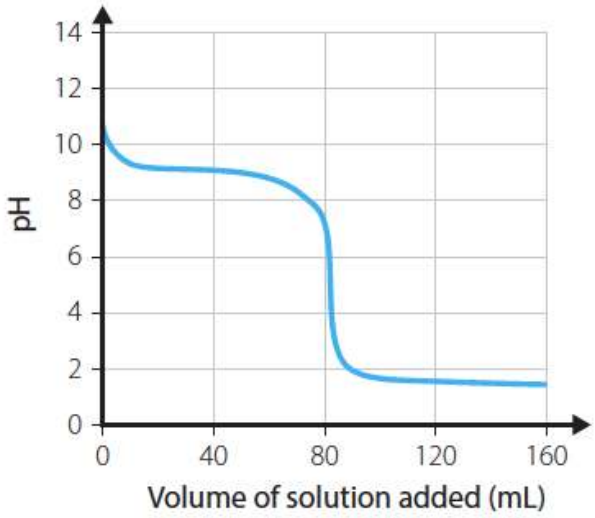
A. increase the rate of reaction by acting as a catalyst.

B. increase the yield by providing more hydrogen to react with the alcohol.

C. increase the rate and yield by acting as a catalyst and a dehydrating agent.

D. increase the yield by providing an alternative pathway for the reaction to occur.

9. The following graph represents the pH changes during an acid–base titration.



Listed below are four indicators and the pH range at which they change colour. Which one is the best to use for identifying the end point of the above titration?

A. Phenol red (pH range 6.8–8.4)

B. Methyl orange (pH range 3.1–4.4)

C. Phenolphthalein (pH range 8.3–10)

D. Bromocresol green (pH range 3.8–5.4)

10. A student performed an experiment to determine the mass changes that occur when glucose undergoes fermentation. The student's results are given in the table below:

Initial mass of reactant flask and contents (g)	223.92
Final mass of reactant flask and contents (g)	214.30

Based on the student's results, the volume of carbon dioxide gas produced at 0^oC and 100kPa is closest to:

A. 4.96 L

B. 5.42 L

C. 218.5 L

D. 238.5 L

11. A solution of hydrochloric acid is diluted by adding enough water to change the pH from 2 to 4. What is the ratio of $\frac{initial\ volume}{final\ volume}$ of the solutions?

A. 0.010

B. 0.25

C. 2

D. 100

12. Nitrogen dioxide, a brown gas, and dinitrogen tetroxide, a colourless gas form an equilibrium according to the equation:

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

An equilibrium mixture of the two gases at room temperature is light brown but at higher temperatures the colour becomes a much deeper brown. From this observation it can be concluded that:

A. the reverse reaction in the above equation is endothermic.

B. the forward reaction in the above equation is endothermic.

C. the brown colour is due to the strong nitrogen-oxygen bonds in NO_2.

D. the equilibrium concentration of N_2O_4 is not dependent on temperature.

13. It is suspected that a stream is contaminated with metal ions. A sample of water from the stream was analysed. The results of some tests on the sample are recorded in the table below.

Test	**Result**
Add dilute HCl	White precipitate forms
Add Na_2SO_4 solution	White precipitate forms
Add KI solution	Yellow precipitate forms

What is the most likely contaminant in the water?

A. Ba^{2+}

B. Ca^{2+}

C. Fe^{3+}

D. Pb^{2+}

14. Consider the following reaction:

$$2ICl(g) \rightleftharpoons I_2(g) + Cl_2(g) \qquad Keq = 4.8 \times 10^{-6} \text{ at } 25°C$$

Which of the following statements is true?

A. At 25°C, there will be much less I_2 and Cl_2 than ICl

B. At 25°C there will be twice as much ICl as I_2 present

C. At 25°C, there will be much more I_2 and Cl_2 than ICl

D. At 25°C, the pressures of I_2, Cl_2 and ICl will be the same

15. A student titrated a strong base with a strong acid using the procedure outlined below to determine the concentration of the acid:

1. A burette was rinsed with the acid, emptied and then filled with the solution of the acid.
2. A conical flask was rinsed with water.
3. A pipette was rinsed with water and then used to transfer a volume of the standard base solution to the conical flask.
4. An indicator was added to the solution of the base and then the acid was added from the burette until the indicator changed colour.

The student then calculates the concentration of the acid. Which of the following statements about his value is correct?

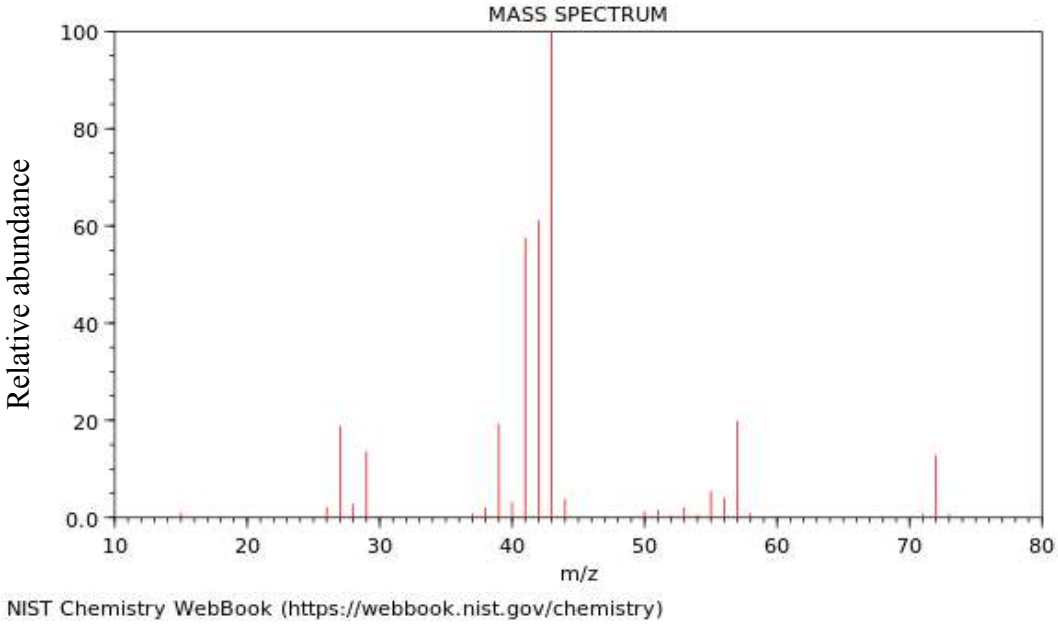
A. His acid concentration will be correct.

B. His acid concentration will be too low.

C. His acid concentration will be too high.

D. It is not possible to reach a conclusion about the acid concentration since his technique was faulty.

16. The mass spectrum of an alkane is shown below.



Which one of the following alkanes could have the spectrum shown above?

	Peak (m/z)	Fragment	Alkane name
A.	43	$CH_2CH_3^+$	Pentane
B.	29	$CH_3CH_2^+$	Propane
C.	43	$CH_2CH_2CH_3^+$	Pentane
D.	29	$CH_2CH_2CH_3^+$	Propane

17. When 1-butene is added to water, and propene is added to HCl there are two possible products.

Which of the following options is correct?

	1-butene + water		Propene + HCl	
	Main product	**Minor product**	**Main product**	**Minor product**
A.	1-butanol	2-butanol	1-chloropropane	2-chloropropane
B.	1-butanol	2-butanol	2-chloropropane	1-chloropropane
C.	2-butanol	1-butanol	1-chloropropane	2-chloropropane
D.	2-butanol	1-butanol	2-chloropropane	1-chloropropane

18. The compounds $H_2NCH_2CH_2NH_2$ and $HOOCCH_2COOH$ react to form a polymer. What is the structure of the repeating unit of the polymer?

A. $\leftarrow OCCH_2CONHCH_2NHCO \rightarrow$

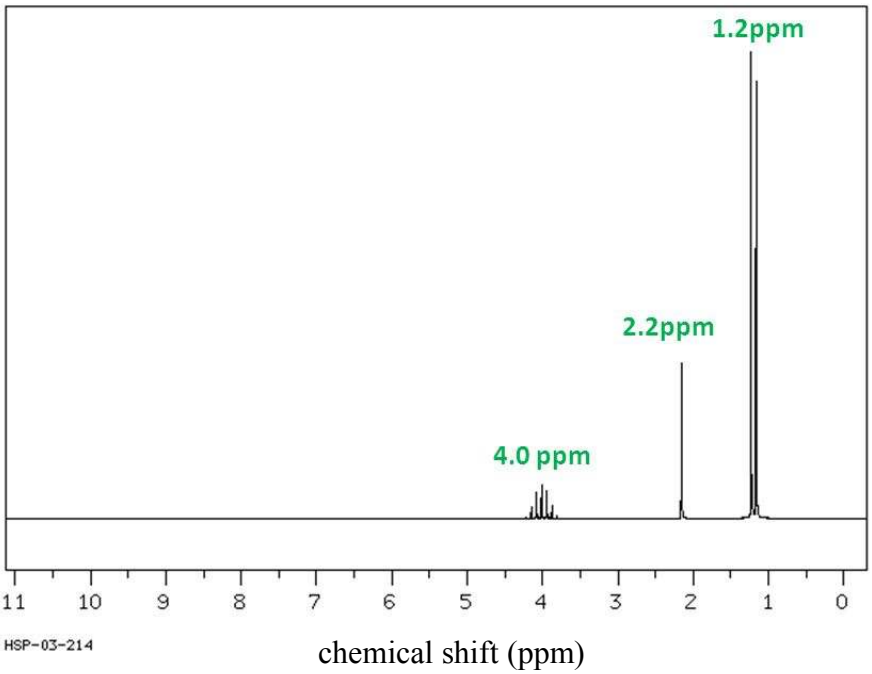
B. $\leftarrow HNCH_2CH_2NHCOCH_2NH \rightarrow$

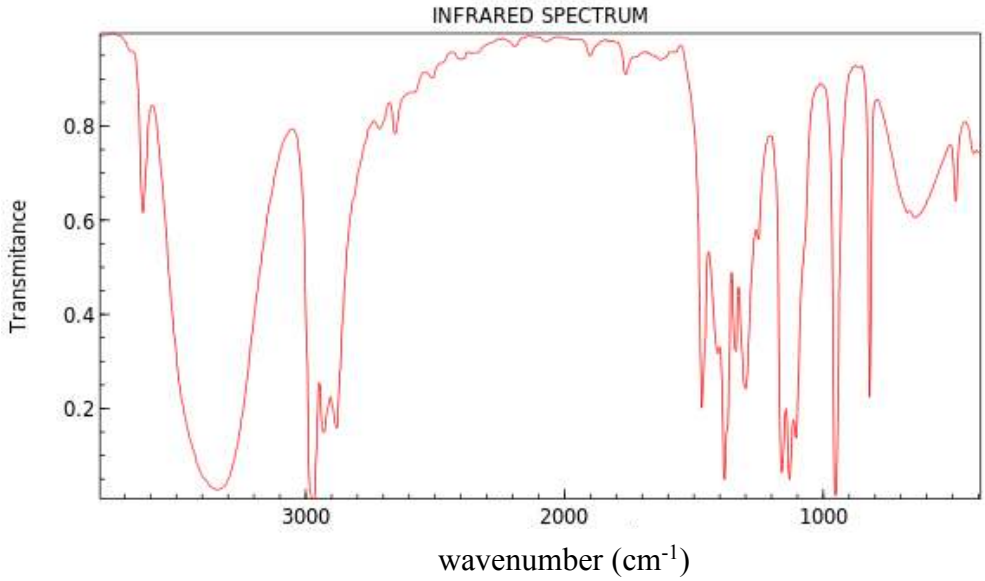
C. $\leftarrow HNCH_2CH_2NHCOCH_2CO \rightarrow$

D. $\leftarrow HNCH_2CONHCH_2CH_2NHCO \rightarrow$

19. The following ^{1}H proton NMR spectrum and infra-red spectrum were obtained for an organic compound containing carbon, hydrogen and oxygen.

^{1}H proton NMR





The compound is most likely to be:

A. 1-propanol

B. 2-propanol

C. 2-butanone

D. butanoic acid

20. Hydrogen peroxide solution is commonly used as an antibacterial agent to clean wounds. On standing, hydrogen peroxide slowly decomposes according to the equation:

$$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$$

A pharmacist was concerned that some stock of hydrogen peroxide solution had decomposed in this way. The extent of the decomposition was checked by using the following procedure:

- A 20.0 mL sample of the hydrogen peroxide solution was acidified and titrated against a 0.200 mol L^{-1} potassium permanganate solution.
- 35.3 mL of the permanganate solution from the burette was required to reach the end-point.

The equation for the titration is shown below:

$$2MnO_4^-(aq) + 5H_2O_2(l) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$$

Calculate the concentration of hydrogen peroxide in g L^{-1}, and identify the colour change that occurs in the conical flask at the endpoint of the solution.

	Concentration (g L^{-1})	**Colour change**
A.	4.8	purple to colourless
B.	30	purple to colourless
C.	4.8	colourless to purple
D.	30	colourless to purple

Student Number: ……

Teacher's Name: ……

2020

Task 4: Trial Examination

HSC Chemistry Booklet 2

BOOKLET 2

Section II

- Attempt Questions 21-27

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 booklets are available upon request. If you use a booklet, clearly indicate which question you are answering and indicate in this paper that a booklet has been used.

Use a new booklet for each question.

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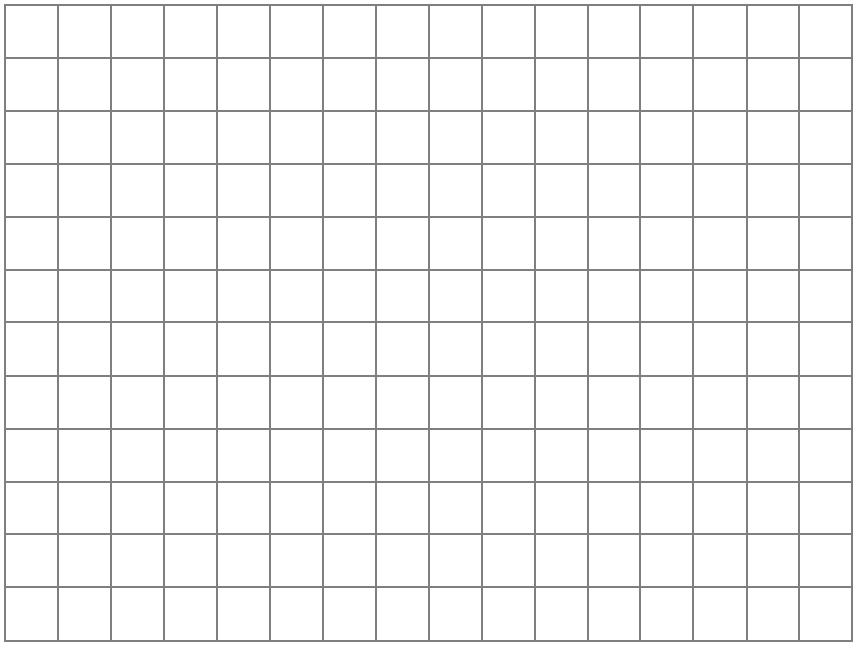
Question 21 (6 marks)

To determine the iron content in a sports drink a 10.0 mL sample was diluted to 100.0 mL.

The absorption of the diluted solution and several standard solutions were measured using AAS. The results are shown in the table below.

Solution concentration (ppm)	**Absorption**
0	0.004
1.00	0.16
2.00	0.30
3.00	0.43
4.00	0.57
Sample	0.33

(a) Use the grid below to create a calibration curve **3**



(b) Use the calibration curve to calculate the mass of iron present in a 250 g serving of the undiluted drink. **3**

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Question 22 (5 marks)

An experiment is carried out to measure the enthalpy of combustion for methanol. Some methanol is placed in a spirit burner, ignited and used to heat a known mass of water in a conical flask. The results obtained are tabulated below:

Mass of water used…….100.0 g
Initial temperature of water……19.0 ^{o}C
Final temperature of water……..56.0 ^{0}C
Mass of fuel combusted……..1.44 g

(a) Calculate the enthalpy of combustion of methanol in kJ/mol. **3**

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(b) The accepted value for the enthalpy of combustion of methanol is -725 kJ mol^{-1}. Account for the difference between the calculated and accepted values. **2**

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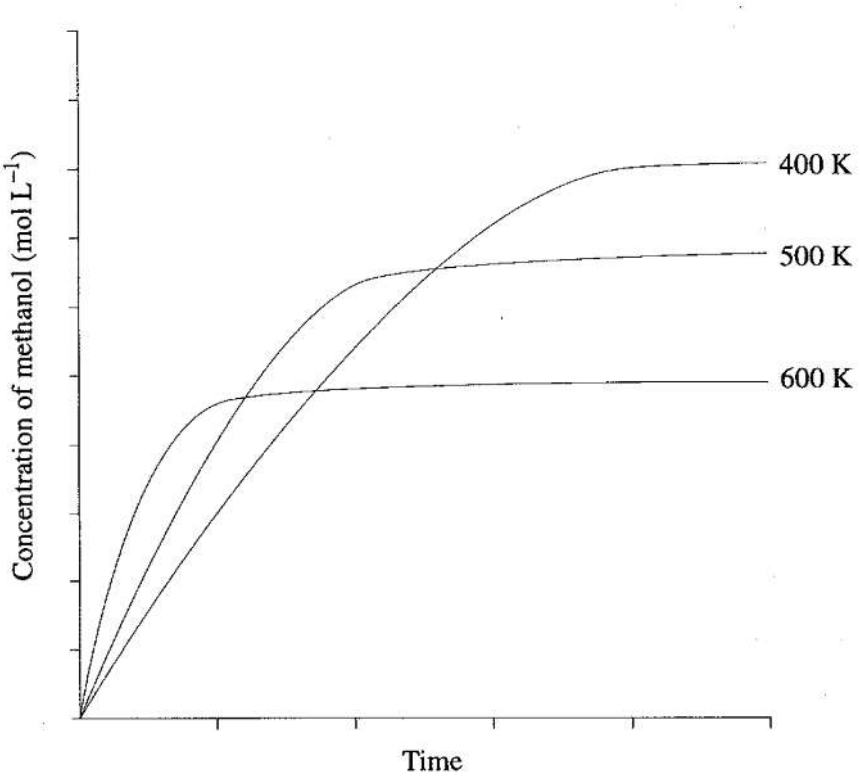
Question 23 (7 marks)

Methanol as a gas can be prepared by reacting carbon monoxide gas with hydrogen gas in an equilibrium reaction.

The graph below shows the formation of methanol at three different temperatures.



(a) By referring to a balanced chemical equation, explain why the curves are initially steep. **3**

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(b) At 500K, the K_{eq} is 14.5. By making reference to whether this reaction is endothermic or exothermic, how would this value change at 600K? **4**

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Question 24 (5 marks)

Two students were given the following solutions to mix in a lab to determine if the pH of the two final solutions would be the same.

In beaker A, 50 mL of 1.0 mol L^{-1} HCl is reacted with 30 mL of 0.70 mol L^{-1} NaOH.

In beaker B, 50 mL of 1.0 mol L^{-1} CH_3COOH is reacted with 30 mL of 0.70 mol L^{-1} NaOH.

(Ka of $CH_3COOH = 1.7 \times 10^{-5}$)

Student 1 gave an answer of 'yes they will be the same'.

Student 2 gave an answer of 'no they will be different'.

Which student is correct? Support your choice with calculations showing the final pH of the solution in each beaker. **5**

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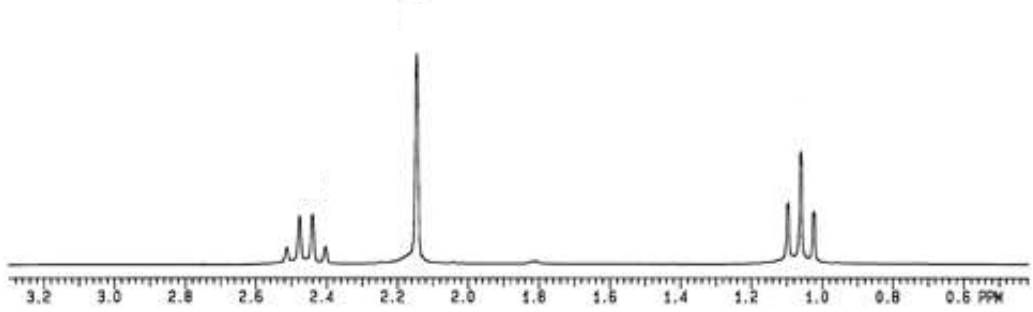
Question 25 (6 marks)

Several organic compounds have the molecular formula C_4H_8O. One of these is an aldehyde; another a ketone.

(a) The ^{1}H-NMR spectrum below was produced by ONE of the two compounds described above.



Justify the identity of this compound.

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(b) Outline a chemical test that could be used to distinguish between the aldehyde and ketone isomers and, using an equation, state the expected results. **3**

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Question 26 (6 marks)

The solubility of magnesium hydroxide can change, depending on the substance it is being dissolved in.

(a) Use Le Chatelier's Principle to account for the increased solubility of magnesium hydroxide when dissolved in water, compared to being dissolved in 0.10 mol L^{-1} NaOH solution at 25°C. **2**

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(b) Quantitatively compare the solubility of magnesium hydroxide in water with its solubility in 0.10 mol L^{-1} NaOH at 25°C. **4**

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Question 27 (5 marks)

Two monoprotic acids, HA and HB, were investigated by a student. **5**

Into a beaker, the student placed a dilute solution of the acid HA. Into another beaker he placed a concentrated solution of HA.

This was repeated in two more beakers for a dilute and concentrated solution of the acid HB.

Using the information in the table below, rank the FOUR acid solutions in order of decreasing pH and justify your answer.

Acid solution	Concentration of acid (mol/L)	Relative Conductivity
HA1	0.05	High
HA2	0.10	Very high
HB1	0.10	Low
HB2	0.30	Moderate

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END OF BOOKLET 2

Student Number: ……

Teacher's Name: ……

2020

Task 4: Trial Examination

HSC Chemistry Booklet 3

BOOKLET 3

Section II

- Attempt Questions 28-34

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 booklets are available upon request. If you use a booklet, clearly indicate which question you are answering and indicate in this paper that a booklet has been used.

Use a new booklet for each question.

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Question 28 (6 marks)

During the World Wars, there was a shortage of animal and vegetable fats and oils that were used in making soap. Chemists had to use other raw materials instead, which produced chemicals that are known today as "detergents." One benefit of using detergents includes improved performance in hard water when compared to natural soaps.

Account for this benefit with reference to the structure and cleaning action of soaps and anionic detergents. **6**

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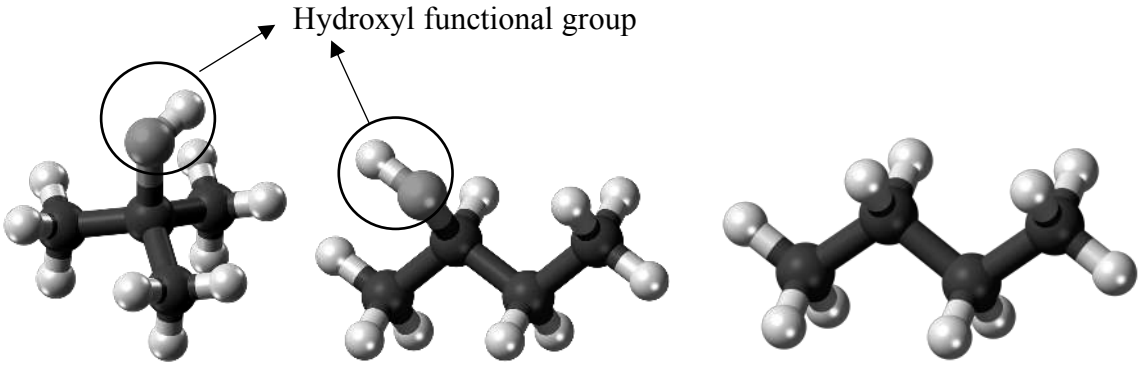
Question 29 (7 marks)

A student was asked by her teacher to demonstrate an understanding of isomerism and how physical properties are influenced by molecular structure. She constructed the following molecules using black carbon, white hydrogen and red oxygen atoms from a model kit.



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Assess the use of the models she constructed to demonstrate the concepts asked by the teacher.

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Question 30 (4 marks)

A patient is admitted to hospital and is observed to be hyperventilating (breathing rapidly and shallowly so that her oxygen intake increases).

The patient's blood pH is measured and found to be 7.15. Blood normally has a pH of 7.4.

An equilibrium reaction involving haemoglobin (HbH^+) and hydronium ions in the blood is:

$$HbH^+(aq) + 4O_2(g) + H_2O(l) \rightleftharpoons Hb(O_2)_4(aq) + H_3O^+(aq) \quad \ldots \text{Equation 1}$$

(a) Explain the pH changes that have occurred in the patient's blood. **2**

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(b) One of the major buffering reactions in the blood is: **2**

$$CO_2(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H^+(aq) \quad \ldots \text{Equation 2}$$

The doctor decides to inject the patient with a solution of hydrogen carbonate (HCO_3^-) ions.

Explain how this will help return the patient's blood pH back to normal levels.

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Question 31 (6 marks)

Consider the following data for the dissociation of ammonium nitrate at 298K.

	$NH_4NO_{3(s)}$	$NH_4^+{}_{(aq)}$	$NO_3^-{}_{(aq)}$
Enthalpy of formation (kJ mol^{-1})	-356.56	-132.51	-205.0
Entropy ($JK^{-1}mol^{-1}$)	151.08	113.4	146.4

(a) With the use of a balanced chemical equation, qualitatively justify the change in entropy in the system when solid ammonium nitrate is dissolved in water. **2**

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(b) By using appropriate calculations, demonstrate that despite opposing reaction drivers, the dissociation of ammonium chloride is spontaneous. **4**

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Question 32 (4 marks)

Outline the development of the acid base definition by showing how Bronsted-Lowry addressed the limitations of Arrhenius' theory. **4**

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Question 33 (4 marks)

A student is given FOUR unknown solutions (A, B, C, D). The four solutions are known to be:

- sodium carbonate
- magnesium chloride
- barium chloride
- sodium phosphate

Outline a series of steps that could be used to identify A, B, C and D. To ensure correct identification of the samples, use confirmation tests where possible. **4**

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Question 34 (9 marks)

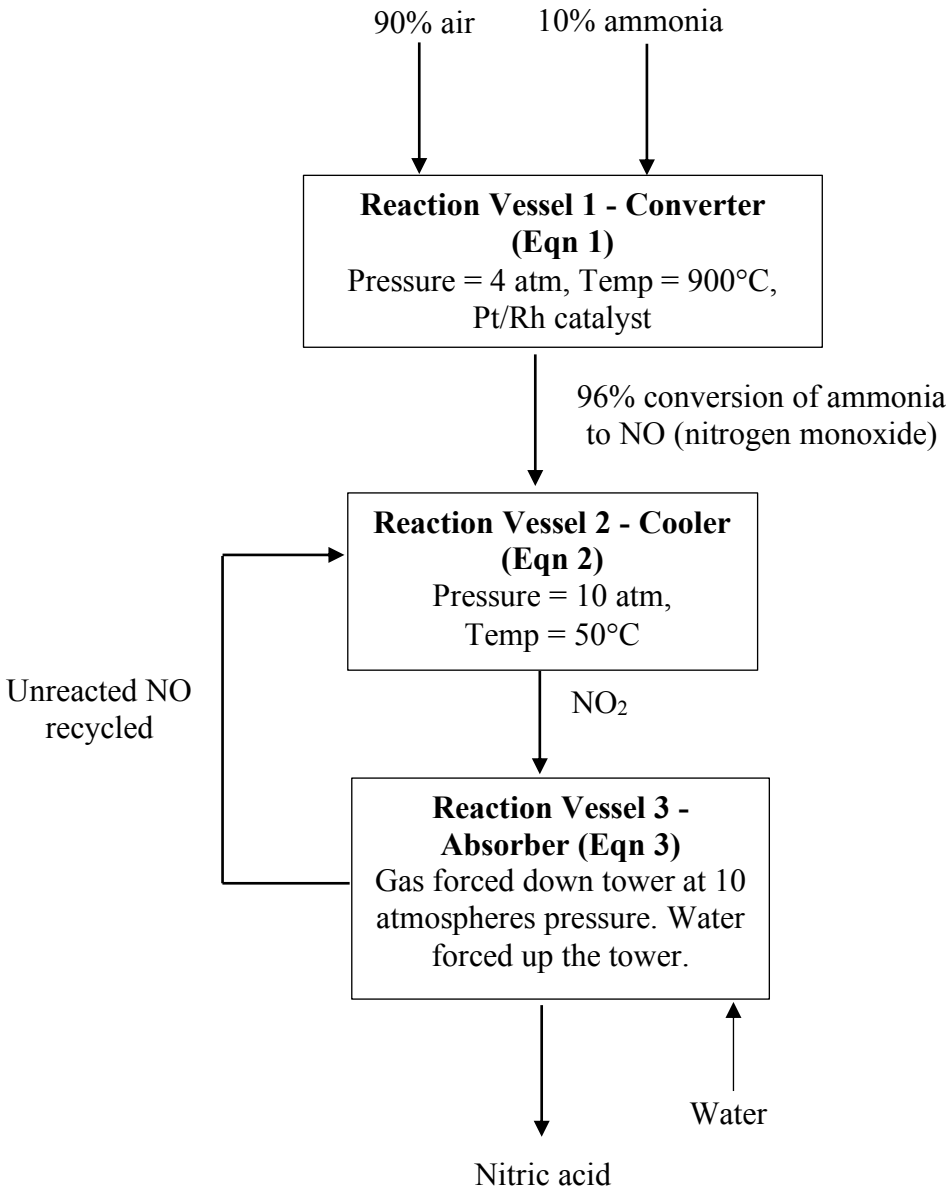
An efficient industrial process is one that gives the most yield of product, in the shortest possible time, with the least cost, minimising any environmental impact.

The flowchart and equations below show the industrial production of nitric acid by the Goddard Corporation. The equations below represent the major steps in the process.

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ $\Delta H = -909$ kJ mol^{-1} Equation 1

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ $\Delta H = -114$ kJ mol^{-1} Equation 2

$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$ $\Delta H = -117$ kJ mol^{-1} Equation 3



Analyse the Goddard Corporation's production of nitric acid in terms of economic, safety, social and environmental issues. **9**

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END OF BOOKLET 3
END OF EXAMINATION

Year 12 Chemistry 2020 Knox Trial Marking Guideline.

MCQ:

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

Qu 21: (G Nunan) Banded 2-6

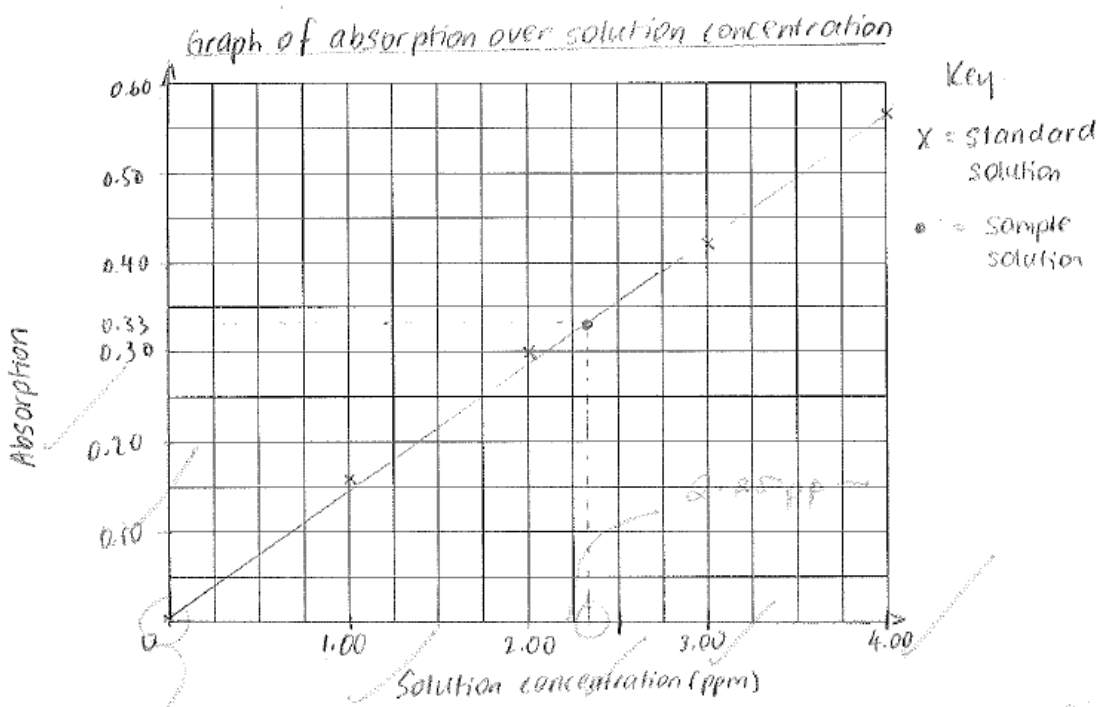
(a)

Criteria	Marks
Correct graph drawn with all points plotted accurately, usable scale (preferably 2, 4 and 5 units NOT 3 units) and axes labelled. Title should be displayed; Line of best fit drawn correctly with numbers of points above, on and below the line considered. the LOBF should not pass through the origin.	3
Substantially correct graph with minor error	2
Some correct features of graph present or multiple errors	1

Suggested answer Refer to attachment and Zoom video for plotted graph and annotations

Marker Comments

- Allowed three-unit grid - this can be an issue with plotting points and should be avoided;
- Students must show interpolation on graph grid;
- Title in this case was not considered but should be shown;
- When plotting points be aware of accuracy aligning to both x and y axes;
- Interpolation should be shown via dotted line from y-axis to LOBF to x-axis.



3

(b)

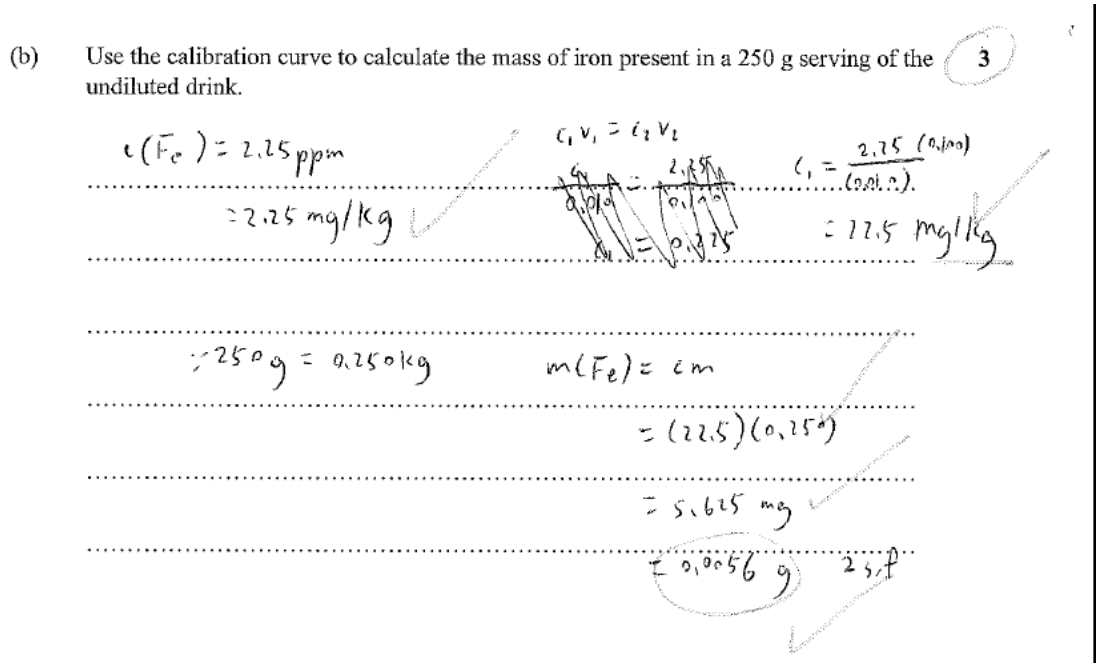
Criteria	Marks
Interpolation clearly shown on graph and correct value read (within accepted range) and used in calculation showing appropriate units; Mass of iron calculated with full working shown, including all dilution factors and unit conversion justifications via unit analysis made	3
Substantially correct answer with minor error or omission of key step or clear unit analysis.	2
A correct step using interpolated concentration in ppm in determining the mass of iron shown OR uses interpolated value with the correct alternate unit (mg/kg) that allows the next step to be made.	1

Suggested answer (alternate approaches can be used but must be clear with justifications)
Please note the importance of using unit analysis…...units fall out throughout calculation
From interpolation on graph (Absorbance 0.33 = concentration of 2.30 ppm)

In 100 mL sample of sports drink:
c (Fe) = 2.30 ppm = 2.30 mg/L

c(Fe) = 2.30 mg/L x 0.10 L = 0.230 mg
c(Fe) in undiluted drink = 0.230 mg / 0.01 L = 23 mg/L

In 250 g serving of undiluted drink (note mg/L = mg/kg)
m(Fe) = 23 mg/kg x (250/1000) kg = 5.75 mg (tolerance allowed depending on calibration curve)
Final answer can be stated on g or mg.



Qu 22: (G Nunan) Banded 2-4

(a)

Criteria	Marks
Enthalpy of combustion of methanol calculated showing negative value and correct units	3
Substantially correct calculation with minor error	2
One correct step in calculation shown or significant error/omission	1

Suggested Answer
Need to show all working/key steps:

Data
Change in temperature = 56 – 19 = 37 degrees Celsius (or Kelvin)
Mass of water = 100 g
Molar mass of methanol = (12.01 + 4(1.008) + 16.00) = 32.042 g/mol
Mass of fuel consumed = 1.44 g

q (heat content) = mCpΔT = 100g x 4.18J/g degrees C x 37 degrees celcius = 15.466 kJ
ΔH = - q/n = - 15.466 kJ / (1.44g/32.042 g/mol) = - 344 kJ/mol (3 sig figs)

(a) Calculate the enthalpy of combustion of methanol in kJ/mol. **3**

$\Delta H = \frac{-q}{n}$ $\Delta T = T_f - T_i$ $n = \frac{m}{MM}$

$= -\frac{m C \Delta T}{n}$

$= -\frac{0.1\text{kg} \times 4.18 \times 10^3 \text{J kg}^{-1}\text{K}^{-1} \times (56.0 - 19.0)\text{K}}{\frac{1.44\text{g}}{(12.01 + 4(1.008))\text{g mol}^{-1}}}$

$= -344139.9806 \text{ J mol}^{-1}$

$= -344.1399806 \text{ kJ mol}^{-1}$

$= -3.44 \times 10^2 \text{ kJ mol}^{-1}$

Good to show separate working!

(b)

Criteria	Marks
Accounts for differences in accepted and calculated values of enthalpy change for methanol with a description of heat loss to surroundings or relevant reason.	2
Identification of heat loss to surroundings as reason (or incomplete combustion of methanol). No account provided for difference in values.	1

Suggested Answer

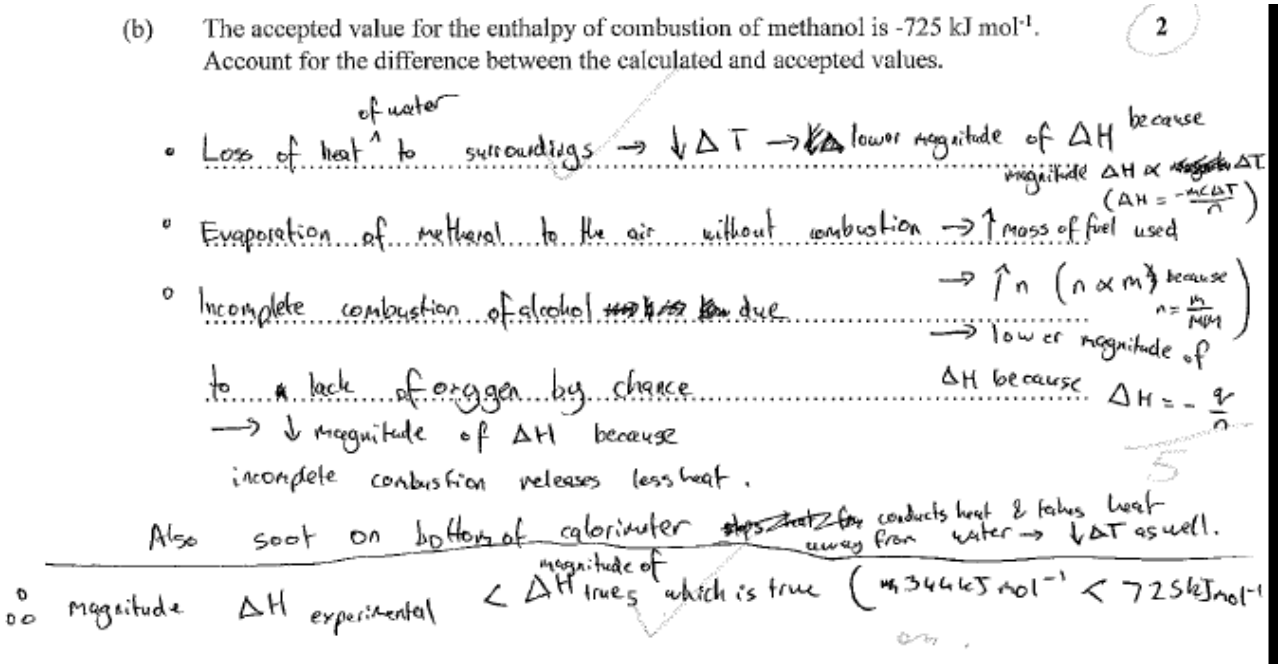
The accepted value is almost twice as large as the calculated value (or words to this effect).

Possible show a percentage difference

Incomplete combustion of the fuel occurs/loss of heat to the surroundings that includes the air and the conical flask.

Marker comments:

- A number of students did not read the question and address the verb 'account.' To score full marks, comment must be provided with respect to the difference between the accepted/true/data book value and the calculated/experimental value. Best approach was to show the quantitative difference or state the accepted value is almost twice as large or higher than the calculated value.

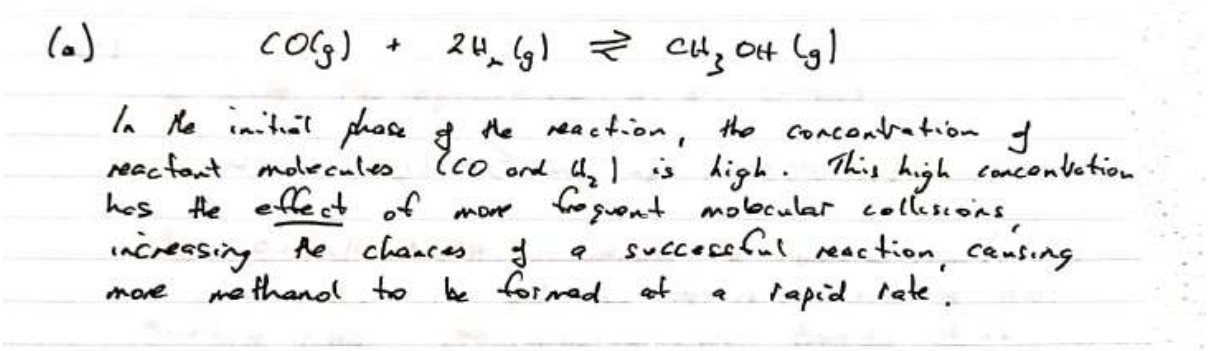


Qu 23:

(a)

Criteria	Mark
● Provides a correctly balanced equation with states ● Explains why the curves are initially steep	3
● Provides a mostly correct balanced equation ● Provides a correct reason for the shape of the curves	2
● Provides some relevant information	1

Markers notes:
Read the question! This is not about the effect of temperature on rate or reaction
Many boys stated that due to Le Chatelier's principle, the forward reaction was favoured. LCP refers to a system at equilibrium – this system is not initially at equilibrium.
Most equations were quite well done and included states – good job.


(a) $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

In the initial phase of the reaction, the concentration of reactant molecules (CO and H_2) is high. This high concentration has the effect of more frequent molecular collisions, increasing the chances of a successful reaction, causing more methanol to be formed at a rapid rate.

(b) Band 2-6

Criteria	Mark
● Extensively explains the exothermic nature of the reaction (must use stimulus) ● Demonstrates an understanding of an equilibrium constant to show the K will be less than 14.5	4
● Thoroughly explains the exothermic nature of the reaction ● Demonstrates K will be less than 14.5 OR ● Identifies that the reaction is exothermic ● Thoroughly demonstrates an understanding of an equilibrium constant and uses Le Chatelier's principle to show that K will be less than 14.5	3
● Demonstrates an understanding of LCP in reference to the reaction OR ● Shows some analysis of the equilibrium constant	2
● Provides some correct information	1

Markers notes:
You needed to use the information in the graph to work out that the forward reaction was exothermic
You needed to use LCP to either show why the forward reaction was exothermic or explain why, with an increase in temp, the reverse reaction was favoured.

Put chemicals in your K expression (not just products/reactants)
When analysing K, you need to refer to both the reactants and the products (not just one!)
Band 2-6 – so needed an extensive answer. Not just statements.

- From the graphs, yield decreases as temperature increases.
Thus
- the equilibrium $CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$
favours the product in lower temperatures. ✓
- By Le Chatelier's Principle, if the temperature is lowered, there is less energy, so then the equilibrium will shift as to counteract the change, i.e., release heat. This is done by favouring the exothermic reaction, ✓ which releases heat.
- As lower temperatures favour both the exothermic reaction and the forward reaction, it must be exothermic. ✓
- Thus, $K_{eq} = \frac{[CH_3OH_{(g)}]}{[CO_{(g)}][H_{2(g)}]^2_{eq}}$ will decrease at a higher temperature (600K compared to 509K): an increase in heat would favour the endothermic (reverse) reaction, so ✓
$[CH_3OH_{(g)}] \downarrow$ and $[CO_{(g)}], [H_{2(g)}] \uparrow$.

Qu 24: Band 2-6

Marking Criteria	Marks
Correct calculation showing all working, balanced chemical equations and correct sig fig	5
Substantially correct calculation showing working and a balanced chemical equation	4
Mostly correct calculation	3
Shows some correct steps in calculation	2
Provides some relevant information	1

Marker's Comments:

- a few students still forget to **convert moles to concentration**, before substituting into the following formulas: pH = -log[H^+] and the K_a expression,

$$K_a = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$$

- use an **ICE table** to determine the moles/concentrations of the reactants and products at equilibrium, e.g.

	$[CH_3COOH]$	$[CH_3COO^-]$	$[H_3O^+]$
Initial	0.3625	0	0
Change	-x	+x	+x
Equil.	0.3625 – x	x	x

- you need to specify that **'x' is very small** (for acids with very small K_a values) and thus the approximate concentration of $[CH_3COOH]_{eq} = [CH_3COOH]_{init}$. Quite a few boys that could have scored full marks omitted this information.

- must include **balanced chemical equations** for all chemical reactions to clearly show the mole ratio used in calculations (even if it is 1:1 mol ratio e.g. HCl : NaOH and CH_3COOH : NaOH)

- know when to use a one-way arrow and when to use an equilibrium arrow.

- reminder to only round at the very end.

- include the correct decimal places for pH values.

Done well: Most students showed all working in their calculation (with units); it was therefore easy for the marker to follow - Well done.

Question 24 (5 marks)

Two students were given the following solutions to mix in a lab to determine if the pH of the two final solutions would be the same.

In beaker A, 50 mL of 1.0 mol L^{-1} HCl is reacted with 30 mL of 0.70 mol L^{-1} NaOH.

In beaker B, 50 mL of 1.0 mol L^{-1} CH_3COOH is reacted with 30 mL of 0.70 mol L^{-1} NaOH.

(Ka of $CH_3COOH = 1.7 \times 10^{-5}$)

Student 1 gave an answer of 'yes they will be the same'.

Student 2 gave an answer of 'no they will be different'.

Which student is correct? Support your choice with calculations showing the final pH of the solution in each beaker.

5

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$ ✓

A: $n(HCl) = 0.05 \times 1 = 0.05$ mol $n(NaOH) = 0.03 \times 0.7 = 0.021$ mol ✓

$n(HCl) > n(NaOH)$ ∴ in excess

$n(HCl)_{excess} = 0.05 - 0.021 = 0.029$ mol ✓

$HCl_{(aq)} + H_2O_{(l)} \rightarrow Cl^-_{(aq)} + H_3O^+_{(aq)}$

∴ $n(H^+) = 0.029$ mol

$[H^+] = \frac{0.029}{0.08} = 0.3625$ M ✓

$pH = -\log 0.3625 = 0.44$ (2dp) ✓

Conclusion:

- Student 2 is correct: ph of 0.44 vs 2.16
  - Due to non-complete ionisation of CH_3COOH

B:

$n(CH_3COOH) = 0.05 \times 1 = 0.05$ mol

$n(NaOH) = 0.021$ mol (already calculated)

$n(CH_3COOH)_{Buss} = n(HCl)_{excess} = 0.029$ mol

not complete ionisation ✓

$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

$[CH_3COOH] = 0.3625$ M

$1.7 \times 10^{-5} = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$ ✓

$= \frac{x^2}{0.3625 - x}$ ✓ but x is really small ✓

$= \frac{x^2}{0.3625}$

$x = [H^+] = 0.0068481$

$pH = -\log 0.0068481$

$= 2.1644 = 2.16$ (2dp) ✓

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Qu 25: Band 2-5
(a)

Marking Criteria	Marks
● Correctly identifies the compound and provides a thorough justification (using the proton NMR spectrum) that may include: number of H environments, splitting patterns of peaks, intensity of signal that shows number of protons of that type	3
● Correctly identifies the compound and provides a sound justification	2
● Incorrectly identifies the compound but provides some relevant and correct analysis	1

Marker's comment:

- As the molecular formula was provided, you need to identify/name the compound that produces the H^1 - NMR, i.e. **butanone**.

- Make reference to BOTH the ketone and aldehyde to clearly show why the given H^1 - NMR is that of butanone and not that of butanal, i.e.

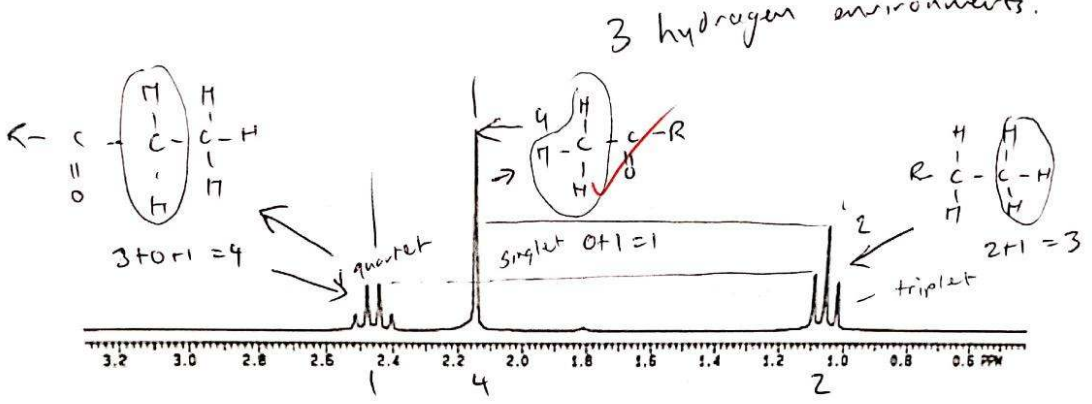
(1) H^1 - NMR for **butanone** has 3 different H environments whereas **butanal** has 4 H environments.
(2) Single peak (at approx. 2.15 ppm) in H^1 - NMR for butanone is due to the methyl group that is attached to the adjacent group (i.e. C=O) with no hydrogens. Whereas, butanal has no single peaks in its H^1 - NMR spectrum as all hydrogens are coupled to Hydrogens that are attached to adjacent carbons.

Note: *As the question was targeted at Band 2-5, it was sufficient to only consider the ketone and* ***one*** *aldehyde.*
(A third compound that fits the molecular formula is 2-methyl propanal; it has 3 H- environments like butanone but the splitting pattern is different to butanone.)

Question 25 (6 marks)

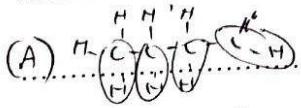
Several organic compounds have the molecular formula C_4H_8O. One of these is an aldehyde another a ketone.

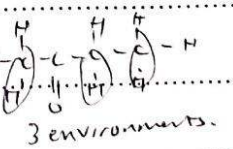
(a) The ^{1}H-NMR spectrum below was produced by ONE of the two compounds described above.



Justify the identity of this compound.

The compound is butanone. There are 3 peaks, indicating 3 hydrogen environments. In the aldehyde (A) there are 4, but only 3 in the ketone (B):

(A)  4 environments.

(B)  3 environments.

- Additionally, the presence of a singlet peak indicates there is a carbon without hydrogens bonded. This is only present in the ketone. good.

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(b) Band 4 - 6

Marking Criteria	Marks
● Correctly outlines a thorough chemical test (that includes a Risk Assessment and is qualitative and quantitative via appropriate and realistic volumes and conditions) that distinguishes between an aldehyde and a ketone and clearly states expected results; ● Uses a correct and relevant equation that displays the result	3
● Correctly outlines a sound chemical test that attempts to distinguish between an aldehyde and a ketone but displays an error or omits a correct and relevant equation that shows outcome.	2
● Basic outline of a possible chemical test that displays some relevant chemistry OR shows a correct and relevant equation	1

Marker's Comments:

- Only a handful of students provided a **risk assessment** – and of those, only one student included a risk assessment of the organic compounds used in this test. (Note: Module 7 **syllabus outcome**: '*describe the procedures required to safely handle and dispose of organic substances')*

- '**outlines a test**' – again only a handful of students provided a quantitative method using appropriate and realistic volumes and conditions; e.g. 3 mL of organic liquid and 1 mL of acidified permanganate/dichromate solution. Reminder that the oxidising agent (OA) has to be the LR otherwise the colour change may not be observed.

- You must explicitly identify the colour **change**. Also, know that it is the OA that produces the colour change and <u>not</u> the organic liquids.

- Include a **structural formula equation for the oxidation** reaction of the aldehyde.

- **Note:** adding sodium carbonate to show production of gas bubbles to confirm the presence of carboxylic acid (produced by oxidation of aldehyde) will <u>not</u> allow you to distinguish between the ketone and aldehyde, as **acidified** OA was used in both the ketone and aldehyde tests.

Example of risk assessment:
Identify: aldehyde (butanal) and ketone (butanone)
Assess: highly flammable organic liquids and vapor, toxic; irritants
Control: dispose of into organic waste beaker, fume cupboard, gloves
(Also: sodium dichromate is toxic when inhaled, avoid inhalation of vapours by working in a fume cupboard, use gloves. Do not dispose of any material down the sink; use waste bottle.

butenal

(b) Outline a chemical test that could be used to distinguish between the aldehyde and ketone isomers and, using an equation, state the expected results.

butenal

Oxidation of aldehyde

~~[illegible]~~ **Risks** → strong acidified oxidising agents are toxic, hence if disposed into the sink, it will damage the ecosystem and waterways. To control this, use a waste bottle to collect the waste. Risks of aldehyde + ketone?

Method

1) Take 2 clean dry ~~[illegible]~~ test tubes, to each add 5mL of the tested aldehyde and ketone.

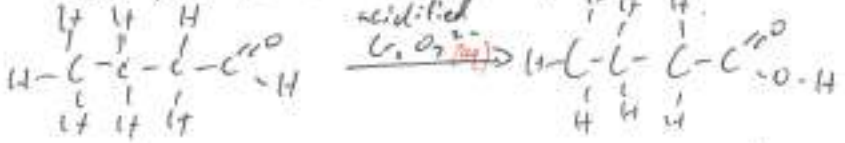
2) Add 2mL of the acidified $Cr_2O_7^{2-}$ ions to each test tube

3) Record the observations.

solution

~~[illegible]~~ Results

When ~~[illegible]~~ we adding an acidified strong oxidising agent to an aldehyde, it will initiate an oxidation reaction, changing the aldehyde to a carboxylic acid!



butenal — butenoic acid.

This will result in a colour change as: $\frac{1}{2}Cr_2O_7^{2-}_{(aq)} + 7H^+_{(aq)} + 3e^- \rightleftharpoons Cr^{3+}_{(aq)} + \frac{7}{2}H_2O_{(l)}$

i.e. solution changes colour from orange to green. However, when this reagent is added to a ketone, no reaction takes place as the colour remains orange. Therefore, we can distinguish between the two.

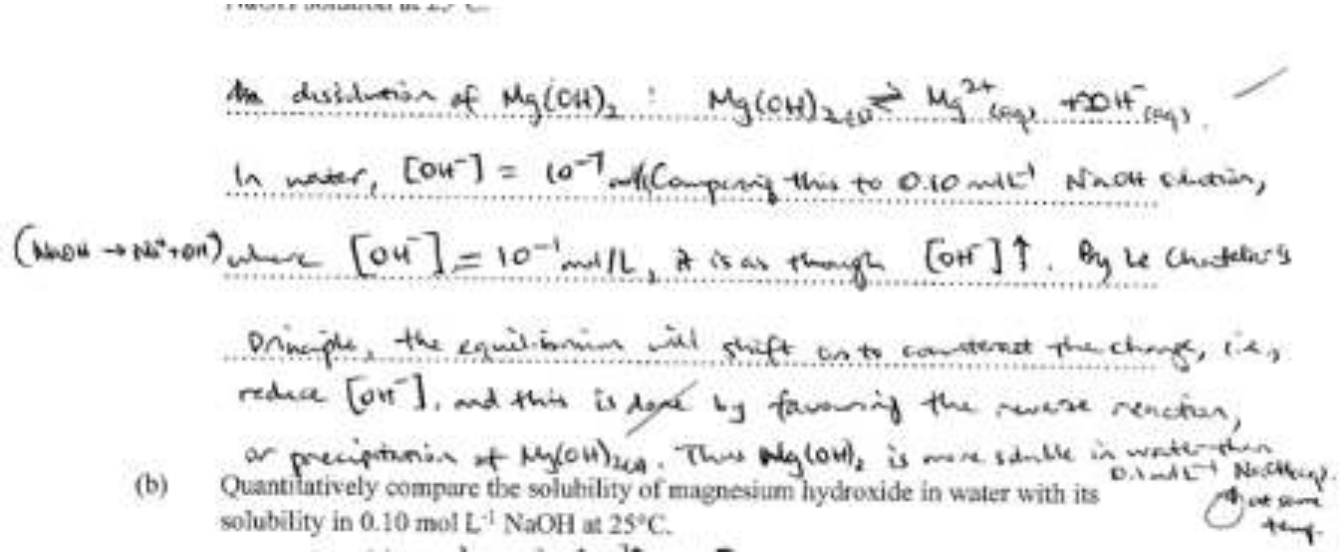
Qu 26

a)

Criteria	Mark
● Account for the increased solubility of magnesium hydroxide in water than in 0.10 mol L^{-1} NaOH solution at 25°C ● Includes a correct chemical equation	2
● Provides some relevant information	1

Markers notes:

- solids do not have a concentration!
- Many people tried to write a reaction with NaOH and $Mg(OH)_2$ instead of showing them dissociating.
- If this was a Band 6 qu, most wouldn't have got 2/2

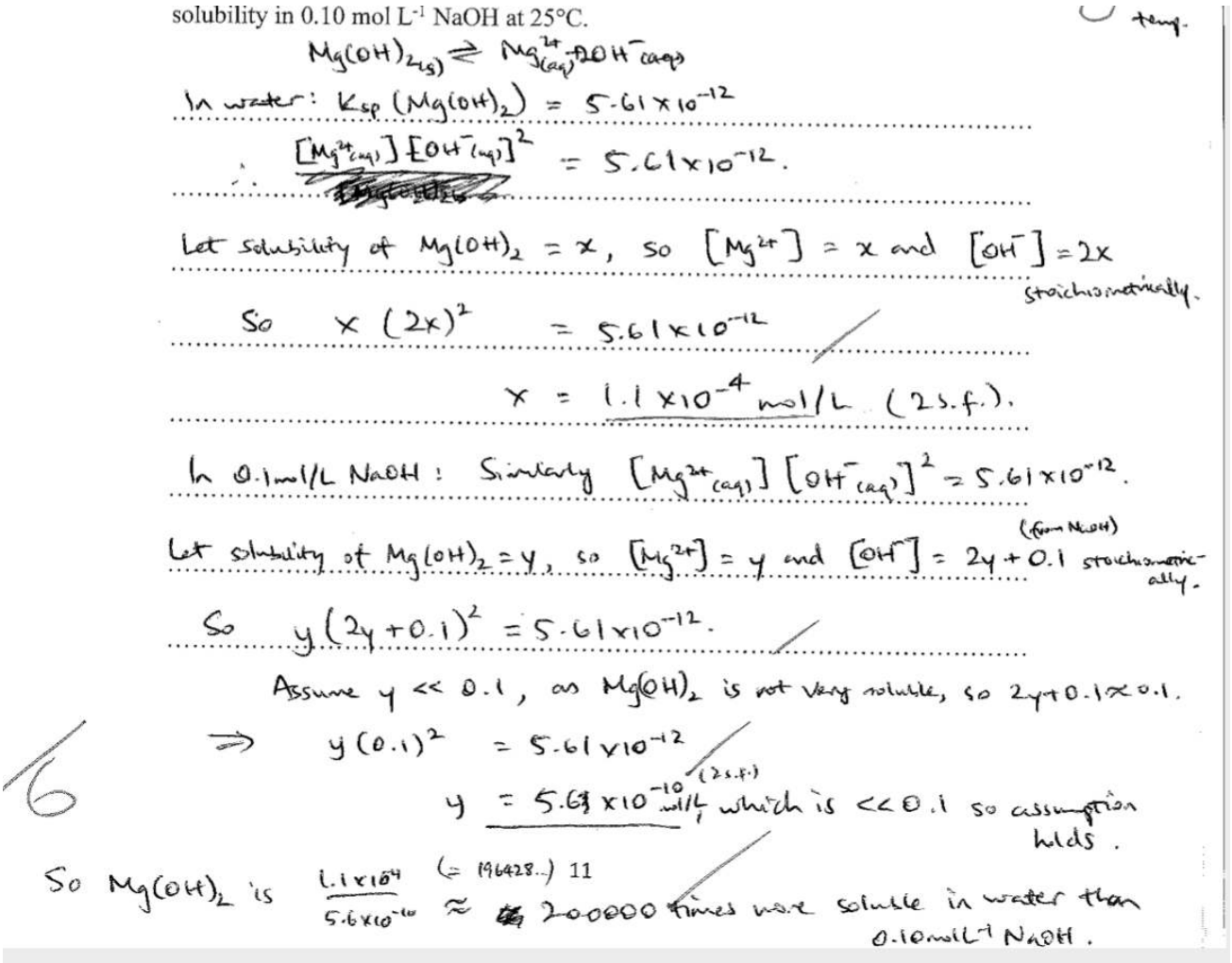


b)

Criteria	Mark
● Correctly calculates the solubility of magnesium hydroxide in water and 0.1M NaOH ● Uses the data to show the difference in solubility	4
● Mostly correctly calculation of the solubility of magnesium hydroxide in water and 0.1M NaOH ● Refers to the difference in solubility	3
● Mostly some correct calculation of the solubility of magnesium hydroxide in water and/or 0.1M NaOH	2
● Provides some correct information	1

Markers notes:

- Most either knew how to do common ion effect, or didn't.
- Many people forgot to square the concentration of hydroxide ion in the sodium hydroxide solution (always refer back to the K expression) and remember a 1:2 ratio of ions ALWAYS leads to $K_{sp} = 4x^3$
- Many that knew how to calculate the difference in OH^- concentration, did not then quantitatively show the difference. (Text book questions had very very similar qu!)



solubility in 0.10 mol L^{-1} NaOH at 25°C.

$Mg(OH)_{2(s)} \rightleftharpoons Mg^{2+}_{(aq)} + 2OH^-_{(aq)}$ ✓ temp.

In water: $K_{sp}(Mg(OH)_2) = 5.61 \times 10^{-12}$

$\therefore [Mg^{2+}_{(aq)}][OH^-_{(aq)}]^2 = 5.61 \times 10^{-12}$.

Let solubility of $Mg(OH)_2 = x$, so $[Mg^{2+}] = x$ and $[OH^-] = 2x$ stoichiometrically.

So $x(2x)^2 = 5.61 \times 10^{-12}$ ✓

$x = 1.1 \times 10^{-4}$ mol/L (2s.f.).

In 0.1mol/L NaOH: Similarly $[Mg^{2+}_{(aq)}][OH^-_{(aq)}]^2 = 5.61 \times 10^{-12}$.

Let solubility of $Mg(OH)_2 = y$, so $[Mg^{2+}] = y$ and $[OH^-] = 2y + 0.1$ (from NaOH) stoichiometrically.

So $y(2y+0.1)^2 = 5.61 \times 10^{-12}$. ✓

Assume $y \ll 0.1$, as $Mg(OH)_2$ is not very soluble, so $2y + 0.1 \approx 0.1$.

$\Rightarrow y(0.1)^2 = 5.61 \times 10^{-12}$ ✓

$y = 5.61 \times 10^{-10}$ mol/L (2s.f.) which is $\ll 0.1$ so assumption holds.

6

So $Mg(OH)_2$ is $\frac{1.1 \times 10^{-4}}{5.6 \times 10^{-10}}$ (= 196428...) 11 ≈ 200000 times more soluble in water than 0.10molL^{-1} NaOH.

Qu 27:

Criteria	Mark
● Ranks the four acids in order of decreasing pH correctly ● Justifies the ranking of the four acids extensively	5
● Ranks the four acids in order of decreasing pH correctly ● Justifies the ranking of the four acids thoroughly	4
● Sound justification for ranking the four acids however produces an incorrect order of decreasing pH	3
● Provides reasonable justifications with some errors.	2
● Provides some correct information	1

Markers notes:
For an extensive answer, you needed to show the links between

- Acid and ionisation of H+ or H_3O^+
- H+ and conductivity
- H+ to pH

- Terminology! Acids ionise (not dissociate)
- Be careful to not get caught up on defining the acids as weak or strong in this qu – was not the point. Many people assumed HA was strong as it ionisesd more than HB – but it may just have had a higher % ionisation.
- Some people are confused about strong vs concentrated and weak vs dilute (e.g. X acid is more dilute therefore it ionises less – please review definitions!)
- Both concentration AND strength affect pH

Decreasing order of pH for acids (high pH to low pH):

HB1 HB2….HA2 HA1

Equation: Acids form hydronium/hydrogen ions according to: $HA + H_2O \rightarrow H_3O^+ + A^-$. In the same way HB acids form hydronium ion and B^-.

Hydronium ions are excellent conductors of electricity due to excellent ion mobility in solution as a result solution high concentration of H_3O^+ ions will result in high relative conductivity and low H_3O^+ ion conc results in low conductivity as water molecules are relatively higher in mass and electrically neutral and so are poor conductors.

High H_3O^+ conc also relates to low pH and low conc H_3O^+ relates to high pH ($pH = -\log [H_3O^+]$. As a consequence HA1 must contain the highest conc of H_3O^+ due to very high conductivity and so will have the lowest pH whilst HB1 the lowest conc of H_3O^+ due to lowest conductivity and so the highest pH.

HB2 with mod conductivity has mod H_3O^+ conc so second highest pH and HA2 with high conductivity has higher H_3O^+ conc to HB2 but lower than HB1 and so third highest pH.

Acid solution	Concentration of acid (mol/L)	Relative Conductivity
HA1	0.05	High
HA2	0.10	Very high
HB1	0.10	Low
HB2	0.30	Moderate

- Generally, $HA \rightleftharpoons H^+ + A^-$ and $HB \rightleftharpoons H^+ + B^-$. These are the only ions in solution. (and OH^- ions only)
- H^+ ions are good conductors, whereas A^- and B^- are poor conductors.
- Thus, the effect on conductivity is negligible for A^- and B^- and based mainly on $[H^+]$.
- As conductivity of each solution is ranked (from lowest to highest) as "Low" "Moderate" "High" "Very High" HB1 < HB2 < HA1 < HA2, we know this is also the ranking of $[H^+]$ in each solution
- $pH = -\log[H^+]$. If $[H^+] \uparrow$, then $\log[H^+] \uparrow$, then $-\log[H^+] \downarrow$ $\Rightarrow pH \downarrow$.
- Thus the order of increasing $[H^+]$ is also the order of decreasing pH.

$\Rightarrow$ order is: HB1, HB2, HA1, HA2, which is supported by the information that HA2 is more concentrated than HA1 and HB2 is more concentrated than HB1, so $[H^+]$ in HA2 > HA1 and HB2 > HB1, which agrees with this order.

Great answer!

END OF BOOKLET 2

Qu 28: Band 4-6

Criteria	Marks
• Demonstrates thorough knowledge and understanding of the relationship between structure and uses of soaps and anionic detergents • Accounts for the effectiveness of anionic detergents in hard water compared to soap • Uses correct and relevant chemistry • Demonstrates coherence and logical progression and includes correct use of scientific principles and ideas	6
• Demonstrates sound knowledge and understanding of relationship between structure and uses of soap and anionic detergents • Describes the effectiveness of anionic detergents in hard water compared to soap • Uses some correct and relevant chemistry • Communicates some scientific principles and ideas in a clear manner with minor error(s)	4-5
• Demonstrates a basic knowledge and understanding of soaps and detergents and their uses AND/OR • Identifies some factors relating to the anionic detergents and hard water • Communicates ideas in a basic form using general scientific terms with error(s)	2-3
• Demonstrates a limited knowledge and understanding of soaps and/or detergents and their uses and/or structures	1

Marker's comments:
Recommend that students review text/powerpoint on soaps and detergents (Module 7 Part 5) since many found it difficult to recall and draw the structures of soaps and detergents.
Use the terms hydrophobic and hydrophilic to describe the tail and head, respectively, of these structures to elevate your answer. Also, use structural formulas and not just a 'tadpole sketch'.
Describing and drawing a micelle to address the action of soaps and detergents was generally well done, although be careful to not confuse the role of soaps in forming emulsions with them acting as a surfactant.
Better answers used IMF correctly such as the hydrophilic head forming ion-dipole forces with water and weak dispersion forces between the hydrophobic tails and non-polar grease/oil.
The presence of Ca^{2+} and/or Mg^{2+} in hard water that will form an insoluble solid with soap (scum) but not with detergent had to be addressed. Strong answers mentioned the use of phosphates in anionic detergents to remove these ions to improve its effectiveness.

Question 28 (6 marks)

During the World Wars, there was a shortage of animal and vegetable fats and oils that were used in making soap. Chemists had to use other raw materials instead, which produced chemicals that are known today as "detergents." One benefit of using detergents includes improved performance in hard water when compared to natural soaps.

Account for this benefit with reference to the structure and cleaning action of soaps and anionic detergents.

6

5

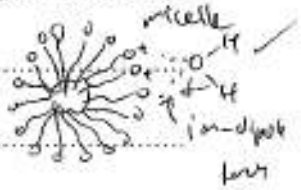
polar ionic (hydrophilic) long hydrocarbon tail (hydrophobic)

Soaps: $(Na^+)O^-$ ~~~~~ Soaps are substances which are the salts of fatty acid anions and contain an ionic head and an extremely long, non-polar hydrocarbon tail. Typically it can clean grease from a solution of water:

similar to detergent action

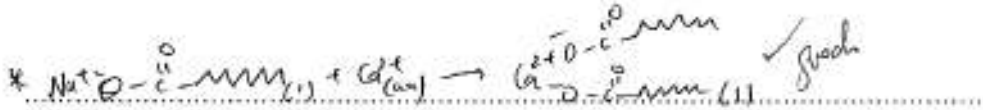
* The long hydrocarbon tail form dispersion forces with the grease and are attracted to the grease molecule. The ionic head sticks out and is attracted to water molecules, forming ion-dipole forces with the water

* Eventually, the soap completely surrounds the grease and is able to remove it from the surface, creating a micelle that can be removed and washed away with the water.



Hard Water

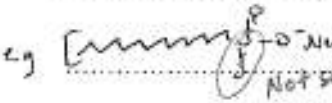
Hard water is water that has high concentrations of cation ions, such as $Ca^{2+}_{(aq)}$ and Mg^{2+} this is problematic for the action of soaps as soaps will react with these ions to form an insoluble precipitate called scum. good formula?

*  ✓ good

This reduces the soaping effectiveness ✓ as soap molecules are being precipitated out through its inability to attach to grease molecules and form micelles

Anionic Detergents

Anionic detergents help alleviate this problem

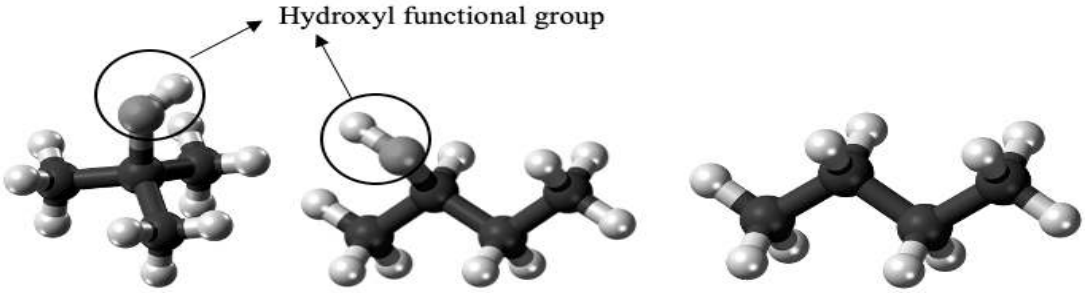
eg  Not so classic. These detergents still however do not precipitate when they come into contact with Ca^{2+} and Mg^{2+} ions which means that they will not form scum. However, they can still react with the ions so their effectiveness is also reduced in hard water, but more stable than natural soaps. Since added phosphates eliminate these ions in Colombia

* Occasionally, these detergents come with products such as phosphate builders which react with free Ca^{2+} and Mg^{2+} ions ✓ ✗ good. first and then allows the detergents to function normally within the presence of hard water.

Important you address cleaning action of detergents.

Question 29 (7 marks)

A student was asked by her teacher to demonstrate an understanding of isomerism and how physical properties are influenced by molecular structure. She constructed the following molecules using black carbon, white hydrogen and red oxygen atoms from a model kit.



7

Assess the use of the models she constructed to demonstrate the concepts asked by the teacher.

Criteria	Mark
● Demonstrates an extensive knowledge and understanding of isomerism and physical properties and incorporates this throughout the answer with reference to the models ● Thoroughly assesses the benefits and limitations of using the models to demonstrate named isomerism ● Thoroughly assesses the benefits and limitations of using the models to demonstrate physical properties ● Judgement related to overall use of models	6-7
● Demonstrates a thorough knowledge and understanding of isomerism and physical properties and incorporates this throughout the answer with reference to the models ● Provides thorough examples of the benefits and limitations of using the models to demonstrate named isomerism AND/OR physical properties ● Judgement related to overall use of models	5
● Provides a sound example of the benefit(s) and limitation(s) of using the models to demonstrate isomerism ● Provides a sound example of the benefit(s) and limitation(s) of using the models to demonstrate physical properties ● Judgement related to overall use of models OR ● Provides a thorough example of the benefit and limitation of using the models to demonstrate isomerism AND/OR physical properties	4
● Provides a thorough example of a benefit OR limitation of using the models to demonstrate isomerism AND/OR physical properties OR ● Provides a sound example of the benefit AND limitation of using the models to demonstrate isomerism OR physical properties OR ● Provides a sound example of the benefit OR limitation of using the models to demonstrate isomerism AND physical properties	3
● Provides a basic example of the benefit AND/OR limitation of using the models to demonstrate isomerism AND/OR physical properties	2

● Provides relevant information	1

- explore and distinguish the different types of structural isomers, including saturated and unsaturated hydrocarbons, including: (ACSCH035)
  - chain isomers
  - position isomers
  - functional group isomers

Syllabus p55

Markers Comments

- There has been a significant improvement in students attempting to go beyond the general ideas to incorporate specific reasoning using the stimulus provided, in this case the three models.
- The majority of students need to review how they approach a question with the 'assess' verb. The answer doesn't just require a list of benefits and limitations and a judgement, even though this is important. Student must demonstrate an extensive understanding of the theory underpinning the examples provides, in this case the models. A strong introduction that establishes an understanding of the key concepts is important. Students who did this well showed a solid understanding of isomerism and physical properties and then applied it to the 3 models.
- Students are reminded about the use of the term 'stronger dispersion forces'. The term 'the net strength of the dispersion forces' or number of dispersion forces is more applicable.
- Students must not use throw away lines such as the models are poor/ineffective/invalid. This shows a shallow consideration of the information presented, especially in an 'assess' question.

	Benefits	Limitations
Isomerism Identifies that A and B (only) are (chain) isomers	● Can visualise the same molecular formula but a different chain length in Model A and B ● Can count the atoms of each type to confirm the same molecular formula ● The colours enable you to easily distinguish the oxygen, hydrogen and carbon atom to easily recognise the position of the functional group remains constant for A and B, and as the chain length has changed it is therefore a chain isomer ● You can break and make bonds to see how many possible isomers there can be ● 3 dimensions show geometry of atoms and bonds – helps understand that the functional group in this case can occupy 2 different places on the one carbon (in model B)	● In terms of the three models, Model 3 is not an isomer of 1 and 2.
Physical Properties	● All three models shown can help demonstrate the atoms involved in contributing to IMF's which contribute to physical properties ● Comparison between the alcohols and the hydrocarbon can be visualised through setting up molecules where the functional groups are facing each other and therefore imf's can be inferred ● Model A and B – can look at how the position of the -OH group will determine how accessible or exposed it is to other molecule's -OH groups, affecting the hydrogen bonds	● Multiple models of the one structure need to be made to show interaction between atoms on different molecules ● Imf's cannot be seen ● Dipoles cannot be seen ● Doesn't show the movement of the molecules to show interaction between them

Qu 30:

Question 30 (4 marks)

A patient is admitted to hospital and is observed to be hyperventilating (breathing rapidly and shallowly so that her oxygen intake increases).

The patient's blood pH is measured and found to be 7.15. Blood normally has a pH of 7.4.

The equilibrium reaction involving haemoglobin (HbH^+) and hydronium ions that balances the blood pH is:

$$HbH^+(aq) + 4O_2(g) + H_2O(l) \rightleftharpoons Hb(O_2)_4(aq) + H_3O^+(aq) \quad \text{... Equation 1}$$

(a) Explain the pH changes that have occurred in the patient's blood. **2**

Criteria	Mark
● Thoroughly explains the explicit pH changes that occurred in the patient's blood with reference to H^+ ion concentration	2
● Provides some relevant information	1

When the patient hyperventilates, they are drawing in and exhaling air at a more rapid pace, increasing the concentration of $O_2(g)$ intake on the left-hand side of the equation. According to Le Chatelier's Principle, the forward reaction will be favoured to consume O_2, increasing $[H_3O^+]$, and since pH decreases with $\uparrow[H_3O^+]$, the patient's blood's pH will decrease from 7.0 to 7.1 2

One of the major buffering reactions in the blood is:

$$CO_2(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H^+(aq) \quad \text{... Equation 2}$$

The doctor decides to inject the patient with a solution of hydrogen carbonate (HCO_3^-)

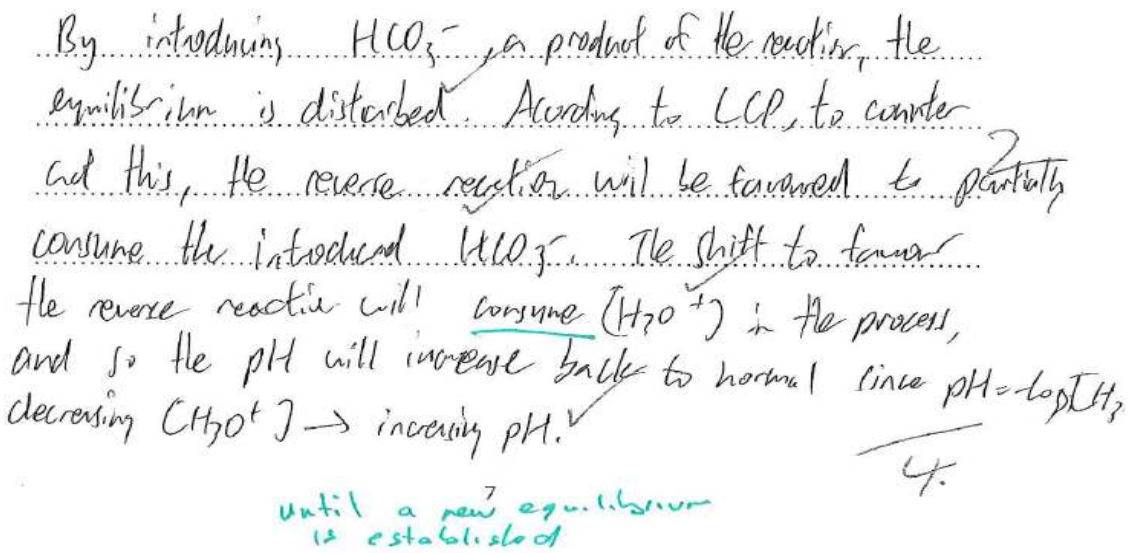
(b) One of the major buffering reactions in the blood is: **2**

$$CO_2(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H^+(aq) \quad \text{... Equation 2}$$

The doctor decides to inject the patient with a solution of hydrogen carbonate (HCO_3^-) ions.

Explain how this will help return the patient's blood pH back to normal levels.

Criteria	Mark
● Thoroughly explains explicit pH changes that occurred in the patient's blood with reference to H^+ ion concentration	2
● Provides some relevant information	1



Markers Comments

- Generally done well, though there is significant fine tuning to do prior to the HSC
- Students need to be aware that this was targeted at Band 2-4. If it was targeted higher most would have missed out on the 2 marks as the WHY in addressing shifts in equilibrium was not adequately done. Always consider the use of a verb to address the shift. In this case, the reaction is shifting to absorb some of the O_2 that was imposed on the system and disturbed the equilibrium.
- In terms of wording, don't say the equilibrium is moving in a direction. Equilibrium that is demonstrated with features (constant concentration, equal forward and reverse rates, constant macroscopic properties) is a process – say the reaction moves in a particular direction until the new equilibrium is established.

Qu 31: Band 2-5

(a)

Criteria	Mark
● Uses a correctly balanced equation to qualitatively justify the change in entropy in the system when solid ammonium nitrate is dissolved in water	2
● Provides a mostly correct equation OR ● Provides some relevant information	1

Marker's comments.
Generally well done.
Main error was that students either quantitatively justified change in entropy (not asked for) or made a simple statement that changing a solid to aqueous (not liquid) increases entropy. This is simply restating the chemical equation.

(b)

Criteria	Mark
● Correctly calculates ⊗H, ⊗S and ⊗G ● Correctly refers to enthalpy and entropy drivers in demonstrating the spontaneous reaction	4
● Provides mostly correct calculations for ⊗H, ⊗S and ⊗G ● Uses some calculations to show an understanding the reaction is spontaneous	3
● Provides some (partially correct) calculations for ⊗H, or ⊗S or ⊗G OR ● Shows an understanding the reaction is spontaneous	2
● Provides some correct information	1

Marker's Comment:
Many students did not address the opposition of the enthalpy driver (not favourable and 'weaker') and entropy driver (favourable and 'stronger') which resulted in a spontaneous reaction since ⊗G < 0.
Too many students are still forgetting to convert their entropy value to kJ before entering into the formula to calculate ⊗G.

(a) With the use of a balanced chemical equation, qualitatively justify the change in entropy in the system when solid ammonium nitrate is dissolved in water. (2)

$NH_4NO_{3(s)} \rightarrow NH_{4(aq)}^+ + NO_{3(aq)}^-$

No need here

$\Delta S = S^\circ_F - S^\circ_I = (113.4 + 146.4) - (151.08) = +108.72$ J/K/mol.

Entropy has increased. good

This is justified as the aqueous ions NH_4^+ and NO_3^- can exist in more potential states than solid $NH_4NO_{3(s)}$, increasing the randomness of the system

(b) By using appropriate calculations, demonstrate that despite opposing reaction drivers, the dissociation of ammonium chloride is spontaneous. (4)

$\Delta H = \Delta H^\circ_f$ (Products) $- \Delta H^\circ_f$ (reactants)

$= (-132.5) + (-205.0)) - (-357.56)$

$\Delta H = +19.5$ kJ/mol - The dissociation is endothermic. ∴ The energy drive is in the reverse direction as the system wants to move to a lower energy state. Very well presented

$\Delta S^\circ = +108.72$ J/K/mol $= +0.10872$ kJ/K/mol ∴ The entropy drive is forward to increase chaos, opposing the enthalpy drive.

$\Delta G = \Delta H - T\Delta S$

$= 19.5 - 298(0.10872)$

$\Delta G = -12.898...$ kJ/mol

< 0 kJ/mol, ∴ The dissociation is spontaneous at 298 K.

6

8

Qu 32: Band 2-5

Marking Criteria	Marks
● Correctly and thoroughly outlines the development of the acid base definitions via the Bronsted-Lowry theory and how it addressed the limitations of Arrhenius theory of acids and bases	4
● Thoroughly outlines the development of the acid base definitions via the Bronsted-Lowry theory and how it addressed the limitations of Arrhenius theory of acids and bases with a minor omission OR incorrect detail	3
● Sound outline of the development of the acid base definition via the Bronsted-Lowry theory and how it addressed a limitation of Arrhenius theory of acids and bases with a minor omission OR incorrect details with contradictions	2
● Limited outline with some correct detail	1

Marker's comments:
Recommend to structure your answer in this type of question: Define Arrhenius and Bronsted-Lowry Theories, then list at least TWO limitations of the Arrhenius Theory and then state how the B-L theory addressed these limitations.
This is an area of work that could do with more revision by many students, especially with identifying the limitations and how it was addressed by B-L theory.

Question 32 (4 marks)

Outline the development of the acid base definition by showing how Bronsted-Lowry addressed the limitations of Arrhenius' theory.

great work.

Arrhenius' theory of acids and bases proposed that all acids should dissociate in solution to form hydrogen ions and all bases should form hydroxide ions in solution. ✓

Bronsted-Lowry developed his model to state that all acids are proton donor and all bases are proton acceptor ✓ which explained many limitations of Arrhenius, namely:

① The basic nature of ammonia, NH_3. As it didn't have a hydroxide ion, this would not be explained by Arrhenius but now we know: $NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-_{(aq)}$ ✓ where NH_3 accepts a proton and water donates a proton which forms OH^- ions in solution

② Amphiprotic substances: These could not be explained by Arrhenius as you cannot simultaneously produce hydroxide and hydrogen ions.

HCO_3^- acting as a base: $HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$ ✓

HCO_3^- acting as an acid: $HCO_3^- + H_2O \rightleftharpoons CO_3^{2-} + H_3O^+$ ✓

Though Bronsted Lowry's definition, an substance can act as both an acid and a base

4

③ Hydrogen / Hydronium ions did not exist very long in solution. Bronsted Lowry conveyed the importance of the solvent and introduced the hydronium ion

e.g. $HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$

Qu 33:

Marking Criteria	Marks
• Extensively outlines ALL key steps (appropriate reagents used) required to identify correctly solutions A, B, C and D • Shows at least ONE relevant chemical equations to support identification • At least ONE confirmation test used	4
• Thorough outline of MOST key steps (appropriate reagents used) required to identify at least three solutions	3
• Sound outline of MOST key steps (appropriate reagents used) required to identify at least two solutions	2
• Limited outline with some correct detail	1

Markers Comments:

TABLE 4.1 Solubility of common ionic substances

SOLUBLE ANIONS	EXCEPTIONS	INSOLUBLE ANIONS	EXCEPTIONS
NO_3^-	None	OH^-	Group 1, NH_4^+, Ba^{2+}, Sr^{2+} soluble; Ca^{2+} slightly soluble
CH_3COO^-	Ag^+ slightly soluble	O^{2-}	Group 1, NH_4^+, Ba^{2+}, Sr^{2+}, Ca^{2+} soluble
Cl^-	Ag^+ insoluble Pb^{2+} slightly soluble	S^{2-}	Groups 1 and 2, NH_4^+ soluble
Br^-	Ag^+ insoluble Pb^{2+} slightly soluble	CO_3^{2-}	Group 1, NH_4^+ soluble
I^-	Ag^+, Pb^{2+} insoluble	SO_3^{2-}	Group 1, NH_4^+ soluble
SO_4^{2-}	Ba^{2+}, Pb^{2+}, Sr^{2+} insoluble Ag^+, Ca^{2+} slightly soluble	PO_4^{3-}	Group 1, NH_4^+ soluble

- Extremely wide range of possible answers/combinations:
  - sodium carbonate - react with acid to form bubbles of CO_2 / ppt with almost anything other than group 1 elements - confirmation test either yellow/orange flame test / bubble gas formed through limewater which will turn milky
  - magnesium chloride - ppt with hydroxide ions to form white magnesium hydroxide / ppt with silver ions to form white silver chloride that darkens in sunlight or dissolves in dilute ammonia
  - barium chloride - ppt with sulfate ions to form white barium sulfate / ppt with silver ions to form white silver chloride that darkens in sunlight or dissolves in dilute ammonia
  - sodium phosphate - any test below / ppt with almost any metal ion solution other than group 1 elements

Phosphate (PO_4^{3-})	1 Addition of ammonia followed by $Ba(NO_3)_2$ produces a white precipitate. 2 Addition of Mg^{2+} in an ammonia/ammonium nitrate buffer produces a white precipitate, $Mg(NH_4)PO_4$. 3 Acidification with HNO_3 followed by addition of ammonium molybdate solution ($(NH_4)_2MoO_4$) produces a yellow precipitate; warming the mixture for a few minutes may be necessary.

Key to logical answer:

- selecting tests that had one possible outcome to eliminate a substance (for example acid will eliminate/identify the sodium carbonate) - many students added silver ions to solutions to identify one possibility except silver would precipitate three of the solutions given

- using a flowchart rather than paragraphs of text - best answers were in flowchart form
- all solutions needed to be identified - cannot have "X is leftover so must be....".

Confirmation tests vs ppt tests

- Syllabus suggests through multiple references in two different modules to precipiates that it is something important in the course - flame tests are mentioned once
- Flame tests are CONFIRMATION TESTS - too many students used them as initial tests and provided no other form of testing for some ions. Use ppt tests THEN flame tests.

General comments:

- Too many students just identified "a white ppt will form so the solution must be barium chloride" - all ppts should have been given a colour (preferably) and a NAME
- Too many students used no equations in their whole answer - for a question that could have been answered almost entirely by equations and a flowchart, this was not demonstrating Band 6 answers.
- You cannot add "sulfate ions" to a solution - you need to add sodium sulfate or potassium sulfate. "X ion" solutions don't exist, you need to have actual solutions.
- Too many students did not know the correct colours for ppts or for flame tests - review and learn - essential details

Question 33 (4 marks)

A student is given FOUR unknown solutions (A, B, C, D). The four solutions are known to be:

- sodium carbonate
- magnesium chloride
- barium chloride
- sodium phosphate

Outline a series of steps that could be used to identify A, B, C and D. To ensure correct identification of the samples, use confirmation tests where possible. 4

Place 2 mL of all four solutions into four seperate sample tubes

Add 2 mL NH_3 NO_3 and 2 mL $Ba(NO_3)_2$ to each tube

white ppt — no ppt

Add 2 mL NH_4^+ NO_3^- to each tube remaining

Add 2 mL NaOH to each tube remaining

No bubbles ∴ Na_3PO_4

Bubbles means that it is Na_2CO_3

white ppt

No ppt

$Mg^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Mg(OH)_{2(s)}$

$BaCl$

Ca formation test, add Pb^{2+} to observe a white ppt.

$3Pb^{2+}_{(aq)} + PO_4^{3-}_{(aq)} \rightarrow Pb_3(PO_4)_{2(s)}$

ideally a ppt Pale green flame test.

flame test.

4

Question 33 (4 marks)

A student is given FOUR unknown solutions (A, B, C, D). The four solutions are known to be:

- sodium carbonate
- magnesium chloride
- barium chloride
- sodium phosphate

Outline a series of steps that could be used to identify A, B, C and D. To ensure correct identification of the samples, use confirmation tests where possible. 4

① Add $HNO_{3(aq)}$ to each of the solutions and if bubbles form, then it is Na_2CO_3

$2HNO_{3(aq)} + Na_2CO_{3(aq)} \rightarrow CO_{2(g)} + H_2O_{(l)} + 2NaNO_{3(aq)}$

The bubbles formed indicate the presence of $CO_{2(g)}$ and confirm the $CO_3^{2-}{}_{(aq)}$ ion

② Add $Na_2SO_{4(aq)}$ to the remaining three solutions. If a white precipitate forms, then the solution is $BaCl_2$

Ba^{2+} reacts with SO_4^{2-} to form a white precipitate

$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_{4(s)}$ (both $MgSO_4$ and Na_2SO_4 are soluble)

To confirm it is barium, a flame test could be used which should give a pale green flame

③ Add $NaOH_{(aq)}$ to the remaining two solutions

If a white precipitate forms, then the solution is $MgCl_2$, as Mg^{2+} reacts with OH^- to form $Mg(OH)_2$

$Mg^{2+} + 2OH^-_{(aq)} \rightarrow Mg(OH)_{2(s)}$ (this is confirmatory test for Mg^{2+})

The other solution contains Na_3PO_4, which could be confirmed by adding $Ca(NO_3)_{2(aq)}$, as a white ppt. should form

$3Ca^{2+}{}_{(aq)} + 2PO_4^{3-}{}_{(aq)} \rightarrow Ca_3(PO_4)_{2(s)}$

Qu 34:

Criteria (Band 2 – 6)	**Marks**
Extensive discussion of all FOUR factors, including relevant chemistry and multiple examples Answer is well structured and provides extensive levels of detail.	9
Thorough discussion of all FOUR factors, including relevant chemistry, and multiple examples. Answer is well structured, provides very good levels of detail but not all links clear.	8
Thorough discussion of THREE factors, including some relevant chemistry, and use of examples. Answer provides good to very good levels of detail.	6-7
Thorough discussion of TWO factors, including some relevant chemistry, use of examples and excellent detail. OR Sound discussion of FOUR factors, including some chemistry, and use of some examples.	5
Sound discussion of THREE factors, including some chemistry, and use of some examples. OR Thorough discussion of TWO factors, including some relevant chemistry, use of examples and good detail.	4
Sound discussion of TWO factors, including some chemistry, and use of some examples. OR Thorough discussion of ONE factor, including some relevant chemistry, use of examples and good detail. OR Limited discussion of THREE factors, including some chemistry, and use of some examples.	3
Limited discussion of ONE-TWO factors.	2
Includes some relevant information	1

Markers Comments:

- Structure was the key issue with students needing to analyse each of the four factors (note: "social and environmental" should have been "social" and "environmental" - separate factors).

- Reading the question was also key - the qustion started with the sentence:
- *"An efficient industrial process is one that gives the most yield of product, in the shortest possible time, with the least cost, minimising any environmental impact."*
- The sentence gave you several clues about features that needed to be included:
    - with two equilibrium equations, yield meant Le Chatelier's principle (heat and pressure)
    - shortest possible time, meant reaction rates, also indicated by use of a catalyst in the process
- The vast majority of students had very little (or no) chemistry of this nature in their response at all.
- Many other students just made statements about heat and yield, or pressure and yield, or heat and reaction rates but without any chemistry justification.

- This is a chemistry exam - if you write an answer that contains no chemistry, think again!

- For a 9 mark question, it is recommended that you try to find more than one example for a section/factor.
- It is also recommended that you analyse where your energy is best spent. Some students had more information for social than for the economic/environment sections combined. Analyse which sections contain the most chemistry, seem like they are the focus, are the key points of the syllabus!

- Realism was an issue for a lot of students. The following ideas need further thought....
    - use of water would decimate the drinking water and agricultural areas for the surrounding area (sure they will use water, but effectively cutting a town/region off from water? unlikely)
    - workers exposed to toxic gases and corrosive acids everyday and experiencing long term health issues (not sure what you think happens in an industrial plant, but you don't just have gases and acids floating and flowing freely throughout the facility... they are always contained)
    - every day tons of NO, HNO_3 and highly contaminated water is pumped out into surrounding areas causing widespread environmental destruction and death to wildlife and humans (again, not sure what you think happens.... maybe a leak or accident might do this once, but laws suggest most plants would be safer and less polluting than this)
    - this process produced no pollutants (does the heat come from burning fossil fuels? that might produce some pollutant mentioned extensively in a syllabus point from Module 7 about using and obtaining hydrocarbons??)

Suggested points (Note: a wide variety of ideas were given credit, but often ideas were simple, unlikely to happen, or unrealistic):

ECONOMIC:
- Reactor 1 - discussion of yield due to pressure and temperature by LCP, use of a catalyst to increase reaction rates, the 96% yield, use of air which is cheap and easily available, high temperature on rates, 4 atm pressure (note this means 4 x atmospheric pressure and is not exactly "non-existent" nor very easy to achieve).
- Reactor 2 - higher pressure and effect on rates and equilibrium by LCP, lower temperature and effect on rates and equilibrium
- Reactor 3 - recycling of NO to save cost of producing more, use of high pressure (10 atm = not low), use of water which is cheap and easily available
- Overall factors - cost involved in providing fuel to heat/cool various stages, need for high pressure and high temperature vessels/reactors which adds to costs, cost of purchasing reactants like ammonia or catalysts

ENVIRONMENTAL (again a range of factors considered - but had to elaborate on impacts for higher marks):
- emission of carbon dioxide due to burning of fossil fuels to provide heat and other processes - contributes to greenhouse effect and climate change (ocean acidification, increased global temperature etc) - PLEASE DO NOT USE THE TERM "global warming" - and you are instructed to forget the ozone layer exists. Don't write about it, don't link it with the greenhouse effect (fastest way to annoy a marker massively!!) and don't include it ANYWHERE in your chem exam.

- possible leaks of $NO/NO_2/HNO_3$ due to accidents or issues with transportation or storage - impacts wildlife, human health etc
- NO as a greenhouse gas (see CO_2 point above)
- possible contaminated water from reactor vessel 3 could cause some pollution of waterways

SAFETY:
- use of high temperature and high pressure reactor vessels - if not maintained could cause accidents
- some contact with gases/acids (note, this doesn't happen a lot, if at all) - use of appropriate PPE would be required
- preventing leaks/spills etc

SOCIAL (this needs to focus on PEOPLE!):
- any discussion of how PEOPLE are affected/impacted in either a positive or negative way

Economic: by maximising the efficiency of the production of NO_2, the corporation is able to maximise economical income and benefits. To do so, the production of nitric acid must have a high yield percentage of the amount of reactants used, to minimise waste of reactants, as well as achieved in a short time period. These criterias are achieved through the ajustment of reaction conditions. Equation 1:

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO_2(g) + 6H_2O(g) \quad -ve\ \Delta H,$$ ∴ exothermic.

To maximise yield, the reaction should be shifted as much to the right as possible. This is achieved through lowering the pressure of the system. According to LCP, the reaction will shift to counteract this change by producing more gas molecules by favouring the forward reaction to produce 10 gas molecules and consuming 9, which increases the yield. However, the temperature of the system is very high (900°), which will increase the rate of reaction so that the products can be produced in the shortest amount of time. However, by doing so, the reverse reaction is favoured since its the endothermic direction,

and is favored to decrease the temperature of the system by consuming heat energy. This will result in a lower % yield since reverse reaction is favoured. This is a major economic issue the corporation has to consider: the balance between % yield and the rate of production. Similarly, in equation two, the pressure is kept low to ensure yield by favouring the forward reaction to produce more moles of gas, (2 → 3), but the temperature is kept low (50°), this means although the rate of reaction is slow, the yield is higher. Furthermore, NO is recycled from vessel 3 to 2, decreasing wastage of reactants, safety. Nitric acid is extremely corrosive and NO(g) gas is toxic to humans. The production of these substances has many associated risks, such as spills from the reaction vessels or leakage of gas, resulting in the endangering of workers and the local area. To address these risks, the company must ensure that areas that

are responsible for the storage and transport of concentrated nitric acid and nitrogen monoxide gas is secure and does not have any leakages. This ensures that the issue of safety is addressed and no leakage accidents can occur, a major risk to the safety of the system

[Social]

The corporation must ensure that the system is closed and secure, and does not leak into the local environment, which could lead to environmental damages that lower the job opportunities in the local area and brings distress to the local people.