Smith's Hill High School

Promoting excellence in a spirit of trust and co-operation

STUDENT NAME / BOS NUMBER:_____

TEACHER:_____

Year 2022
HSC
Assessment Task 4

Chemistry

General Instructions

- Reading time – 5 Minutes
- Working time – 3 hours
- Write using black pen
- Write your name and / or student number at the top of every page
- Show all relevant working
- NESA approved calculators may be used

Total Marks - 100

Section I
20 Marks
- Attempt Questions 1-20
- Allow about 35 mins for this section

Section II
80 Marks
- Attempt Questions 21-35
- Allow about 2 hours 25 mins for this section

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Student Number/Name: …….

Section I – 20 marks
Attempt Questions 1-20
Allow about 35 minutes for this part

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

1. The best description of the effect of a catalyst on a chemical reaction is that it

(A) increases the activation energy of the forward and reverse reactions by the same amount.
(B) lowers the activation energy of both the forward and reverse reactions by the same amount.
(C) lowers the activation energy of the forward reaction and raises the activation energy of the reverse reaction.
(D) lowers the activation energy of the reverse reaction without changing the activation energy of the forward reaction.

2. Methanoic acid and ethanoic acid are both weak acids with the following acid dissociation constants K_a at 25°C:
   - methanoic acid (HCOOH) = 1.82×10^{-4}
   - ethanoic acid (CH_3COOH) = 1.74×10^{-5}

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

(A) CH_3COOH in the ethanoic acid solution
(B) CH_3COO^- in the ethanoic acid solution
(C) HCOOH in the methanoic acid solution
(D) $HCOO^-$ in the methanoic acid solution

3. Some solid copper sulfate crystals were added to a beaker of water, stirred to dissolve the solid, covered to prevent evaporation and left to stand.

   After 1 day, solid crystals were still present in the beaker. More solid copper sulfate, which contained radioactive atoms, was then added to the beaker. The beaker was then covered and left to stand for a second day. Assume that temperature has remained constant.
   Which of the following statements is/are correct after the 2-day period?

   I – the solution will contain radioactive atoms as some of the radioactive solid will have dissolved.
   II – there will be more solid remaining in the beaker than was present before the radioactive solid was added.
   III – the final solution of copper sulfate will be more concentrated than it was after 1 day.

(A) I only
(B) II only
(C) I and II only
(D) I, II and III

4. A sample of an unknown solution is tested with the indicator bromothymol blue. The solution turns yellow on the addition of this indicator. What would the solution be?

(A) 1.0M CH_3COOK

(B) 1.0M LiCl

(C) 1.0M Na_2SO_4

(D) 1.0M NH_4NO_3

5. When two moles of an organic compound are burnt in oxygen, eight moles of carbon dioxide gas are formed. In a second test, when a few drops of bromine are added to the compound and shaken, the bromine rapidly decolourises. The formula of the compound could be

(A) C_4H_8

(B) C_4H_{10}

(C) C_8H_{16}

(D) C_8H_{18}

6. The molecule $HOCH_2CH_2CH_2COOH$ (molar mass = 104 g mol^{-1}) forms a condensation polymer in which the average polymer molecule contains 1000 monomer units. The approximate molar mass of the polymer, in g mol^{-1}, is

(A) 68000
(B) 86000
(C) 95000
(D) 104000

7. Which of the following solutions, upon mixing will produce the solutions with the highest temperature change?

(A) 50mL of 0.050M HNO_3 + 100mL of 0.4M NaOH

(B) 200mL of 0.05M CH_3COOH + 100mL of 0.01M NaOH

(C) 100mL of 0.1M H_2SO_4 + 50mL of 0.4M KOH

(D) 50mL of 0.2M HCl + 100mL of 0.025 $Ba(OH)_2$

8. Which of the following is not an amphiprotic species?

(A) HCO_3^-

(B) CO_3^{2-}

(C) HPO_4^{2-}

(D) $H_2PO_4^-$

9. What are the two Bronsted-Lowry acids in the following reaction?

$$HNO_2(aq) + H_2O \rightleftharpoons H_3O^+(aq) + NO_2^-(aq)$$

(A) HNO_2 and H_3O^+

(B) H_2O and HNO_2

(C) H_2O and H_3O^+

(D) H_2O and NO_2^-

10. Which of the following compounds is the most basic?

(A) $CH_3CH_2CH_2CH_2OH$

(B) $CH_3CH_2CH_2CH_2NH_2$

(C) $CH_3CH_2COOCH_2CH_3$

(D) $CH_3CH_2CH_2CH_2CONH_2$

11. Limestone ($CaCO_3$) can be eroded by acids. What volume (in mL) of 11.5 mol/L nitric acid (HNO_3) is required for complete reaction with 24.7 g of limestone?

(A) 42.9 mL

(B) 21.5 mL

(C) 11.5 mL

(D) 10.7 mL

12. Which of the following changes takes place when 500 mL of water is added to 500 mL of 1 mol/L acetic acid?

(A) pH increases, percentage ionisation increases

(B) pH increases, percentage ionisation does not change

(C) pH decreases, percentage ionisation does not change

(D) pH decreases, percentage ionisation decreases

13. A solution is prepared by mixing 100.0 mL of 0.1 mol/L of $NaNO_3$ with 200.0 mL of 0.100 mol/L HCl and then adding sufficient water to give it a final volume of 500 mL. What is the pH of the solution?

(A) 1.00

(B) 1.12

(C) 1.40

(D) 1.70

14. At 25°C, solutions of barium ions (Ba^{2+}) and hydroxide ions (OH^-) are mixed so that the following concentrations are initially present. $[Ba^{2+}] = 0.030$ M and $[OH^-] = 0.065$ M.
Which of the following identifies the correct ionic product and whether the precipitation occurs for this reaction?

	Ionic Product	***Precipitation***
(A)	1.27×10^{-4}	Yes
(B)	1.95×10^{-3}	No
(C)	1.27×10^{-4}	No
(D)	5.85×10^{-5}	Yes

15. The data sheet lists the Ksp value for lead iodide, PbI_2 as 9.8×10^{-9}.
If the concentration of lead ions in a sample solution is 5.0×10^{-5} mol/L, then what is the maximum concentration of iodide ions in the same solution?

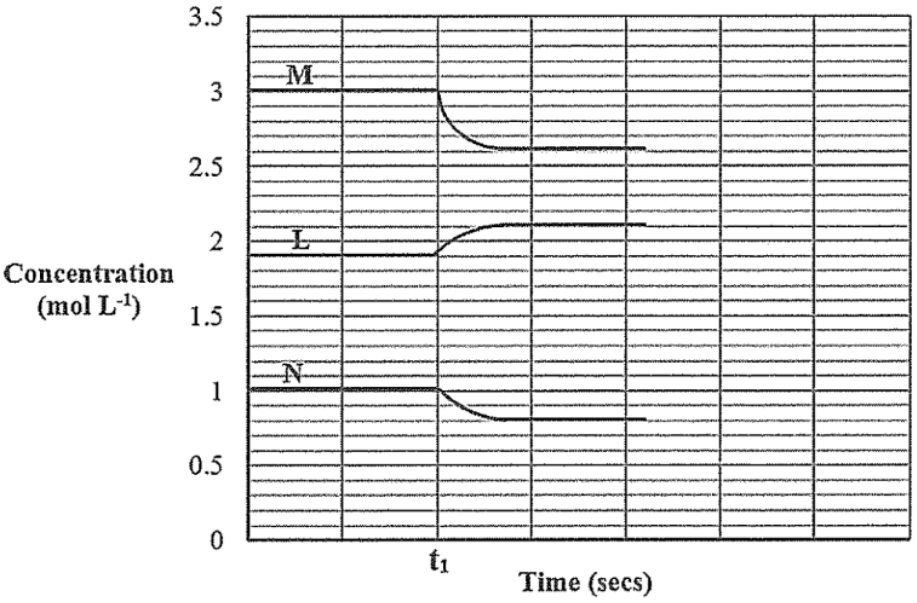
(A) 1.1×10^{-2} mol/L

(B) 1.4×10^{-2} mol/L

(C) 2.3×10^{-1} mol/L

(D) $1.5 \times 10^{+2}$ mol/L

16. Three gasses L, M and N in a sealed 5.0 L container react to form an equilibrium. The graph shows how the concentration of these gasses changes at time t_1 when the mixture is heated.



Which is correct of the reaction in this graph?

(A) $L(g) \rightleftharpoons 2M(g) + N(g)$ and the forward reaction is exothermic

(B) $2M(g) \rightleftharpoons L(g) + N(g)$ and the forward reaction is endothermic

(C) $2M(g) + N(g) \rightleftharpoons L(g)$ and the forward reaction is exothermic

(D) $L(g) + 2M(g) \rightleftharpoons N(g)$ and the forward reaction is endothermic

17. The organic compound ethylene (C_2H_4) can be reacted with water to make ethanol. The equation for this reaction is:

$$C_2H_4 + H_2O \rightarrow C_2H_5OH$$

A reaction uses 18.4 g of ethylene but only produces 27.6 g of ethanol at the end of the reaction pathway.
What is the percentage yield for this reaction?

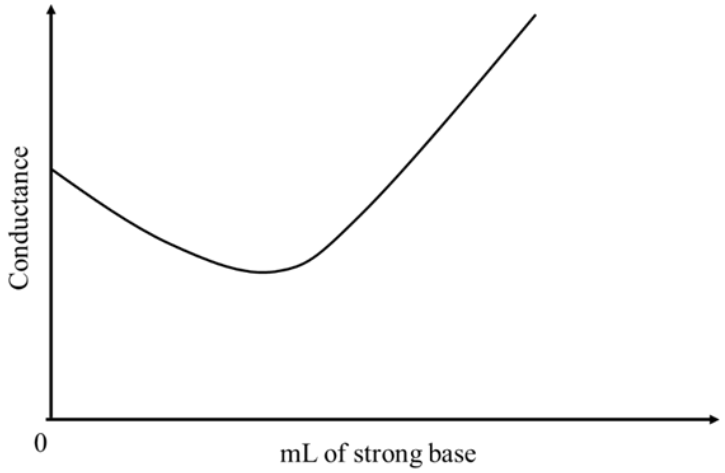
(A) 43%

(B) 61%

(C) 67%

(D) 91%

18. This conductivity graph represents a reaction between two reactants.



What are the two reactants?

(A) HNO_3 and NH_3
(B) HCl and $Ca(OH)_2$
(C) H_3PO_4 and $NaHCO_3$
(D) CH_3COOH and KOH

19. Which of the following pairs of compounds are NOT isomers?

(A) hexan-2-ol and 2,2-dimethylbutan-1-ol
(B) methyl ethanoate and propanoic acid
(C) butane and cyclobutane
(D) butan-2-one and 2-methylpropanal

20. The following table shows the value of the ionisation constant of pure water at various temperatures and at a constant pressure.

Temperature of water (℃)	**0**	**25**	**50**	**75**
K_w	**1.1×10^{-15}**	**1.0×10^{-14}**	**5.5×10^{-14}**	**2.0×10^{-13}**

Given this data, which one of the following statements about pure water is correct?

(A) The $[OH^-]$ will decrease with increasing temperature
(B) The $[H_3O^+]$ will increase with increasing temperature
(C) Its pH will increase with increasing temperature.
(D) Its pH will always be exactly 7 at any temperature.

Section II

80 marks

Attempt questions 21 – 35

Allow about 2 hours and 25 minutes for this section

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

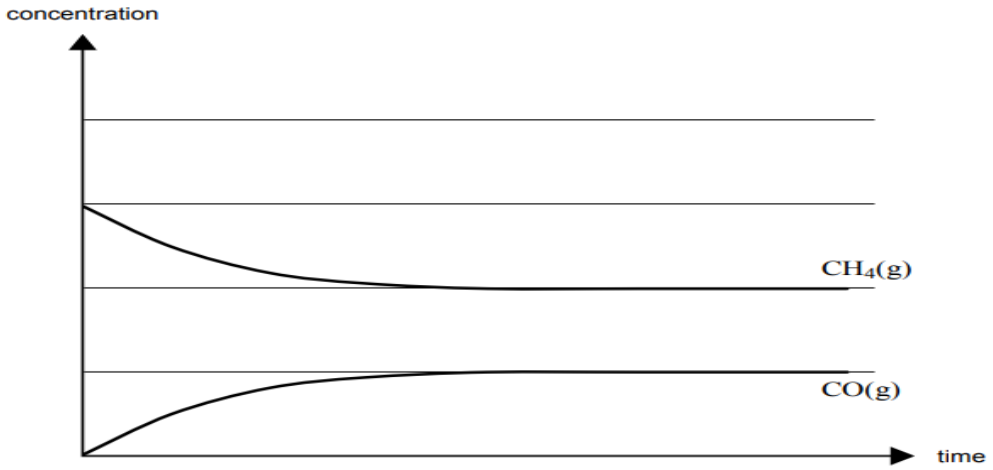
Show all relevant working in questions involving calculations.

Question 21 (4 marks)

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

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

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



a) On the graph above, draw a line to predict the change in concentration of hydrogen gas as the reaction progresses. Label this line. Explain why you have drawn the line in this position. **(2 marks)**

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b) On the graph above, draw a line to show how the formation of carbon monoxide would differ over time in the presence of a catalyst. Label this line. Explain why you have drawn the line in this position. **(2 marks)**

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Question 22 (6 marks)

a) Lead (II) chloride is sparingly soluble in water, and this equilibrium is set up between the solid and its ions in solution. Given its *Ksp* = 1.7 x 10^{-5}, determine the solubility of Lead (II) chloride. **(3 marks)**

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b) Calculate and compare the solubility of the lead chloride when dissolved in 0.35mol/L of NaCl. **(3 marks)**

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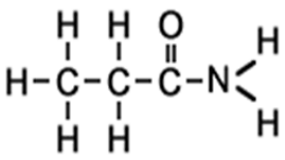
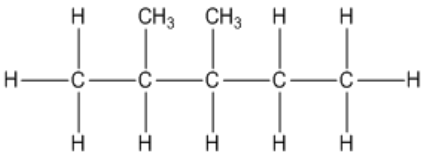
Question 23 (8 marks)

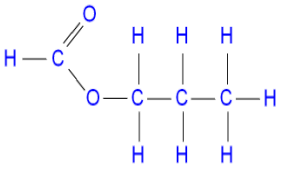
a) Using IUPAC nomenclature, name the compounds shown below. **(3 marks)**



Compound 1



Compound 2



Compound 3

Compound 1 ……

Compound 2 ……

Compound 3 ……

Question 23 continues on the next page

b) Compare the intermolecular forces in the molecules from part a) and predict the order of boiling points (lowest to highest) of these molecules. Explain your prediction. **(5 marks)**

Question 24 (10 marks)

The table shows acid dissociation constants at 25ºC.

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

a) Identify the weakest acid in the table and determine the pK_a value for this acid at 25°C. **(2 marks)**

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

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

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Question 24 continues on the next page

d) A buffer solution is prepared by combining 100 mL of 0.010 M nitrous acid and 80 mL of 0.010 M $NaNO_2$.

Calculate the pH of this buffer solution and explain the classification of the solution as a buffer.

(4 marks)

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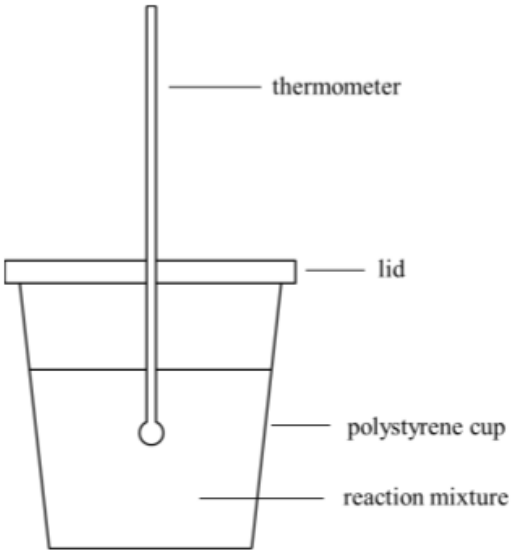
Question 25 (4 marks)

A student conducts an investigation to measure the enthalpy of neutralisation, setting up the apparatus as shown in the diagram.



The reaction mixture consisted of 50.0 mL of diluted potassium hydroxide solution and 50.0 mL of a 1.5 mol L-1 solution of nitric acid. The student noticed that the temperature rose from 23°C to a maximum of 32°C.

Determine the enthalpy of neutralisation for this reaction. **(4 marks)**

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Question 26 (8 marks)

Compounds A and B are isomers with a molecular formula C_3H_7Cl. Samples of compounds A and B are heated separately with sodium hydroxide to produce compounds C and D respectively. A student used samples of compound C in a series of reactions to produce propyl propanoate, a volatile compound with a strong, pungent but sweet pineapple-like smell.

a) Identify all compounds and construct a flow chart to outline a series of reactions that the student could use to produce propyl propanoate using compound C. In your flow chart identify the types of reactions that are carried out and the reagents required for each step. **(4 marks)**

b) Draw the structural formula of the compound that reacted with compound C to produce propyl propanoate. What qualitative results would identify that the reaction from compound C to synthesise that which you have drawn has occurred? **(2 marks)**

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c) Identify ONE risk associated with carrying out the reaction that formed propyl propanoate in a school laboratory and state how this risk can be minimized. **(2 marks)**

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Question 27 (3 marks)

Outline the use of solubility equilibria by Aboriginal and Torres Strait Islander Peoples when removing toxicity from foods.

(3 marks)

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Question 28 (7 marks)

High strength aspirin ($C_9H_8O_4$) tablets were purchased overseas by the school's chemistry teacher. Puzzled by the low cost, he encouraged his students to perform a chemical analysis on the concentration of aspirin in each tablet.
Students were given 6 tablets each and were instructed to use sodium hydroxide solution with an approximate concentration of 0.1 mol/L, which was standardised using oxalic acid $(COOH)_2$.

a) Three 25.00 mL samples of a 0.1034 mol/L solution of oxalic acid were titrated to standardise the NaOH solution according to the following equation:

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

The average volume required for neutralisation was 25.75 mL. Calculate the molarity of the NaOH solution. **(3 marks)**

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Question 28 continues on the next page

b) Four flasks were prepared each containing a mixture of 25 mL of water and 10 mL of ethanol. Two aspirin tablets were dissolved in each flask. The aspirin in each solution was titrated with the standardised NaOH solution according to the following equation:

$$C_9H_8O_4\ (aq) + NaOH\ (aq) \rightarrow C_9H_7O_4Na\ (aq) + H_2O\ (l)$$

The students achieved the following titration results:

Trial	Volume (mL)
1	16.55
2	16.75
3	16.60
4	16.50

The packaging claims the tablets contain 350 mg of aspirin per tablet.

Using the information provided, calculate the mass (mg) of aspirin per tablet, and justify whether the claim is true. **(4 marks)**

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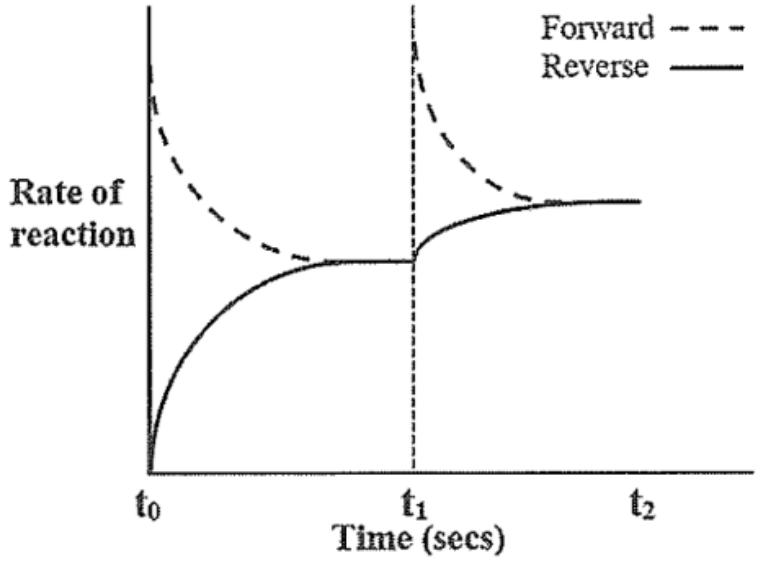
Question 29 (3 marks)

A graph of the rate of reaction versus time for a particular chemical reaction is shown. At time t_1 the reactant concentration is increased.



Account for the shape of the graphs between t_0 and t_1 and between t_1 and t_2 in terms of collision theory.
(3 marks)

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Question 30 (3 marks)

With the use of at least ONE diagram, explain the action of soaps in emulsifying oils. **(3 marks)**

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Question 31 (3 marks)

Initially a 2.00 litre glass vessel contains a mixture of 1.00 mole of hydrogen gas and 1.00 mole of iodine gas. The gases react as follows:

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

At 400℃ equilibrium is achieved and the concentration of hydrogen iodide gas is 0.760 mol/L. Calculate the equilibrium constant for this reaction and discuss what the value indicates about the reaction. Show all working. **(3 marks)**

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Question 32 (5 marks)

A solution is thought to contain sodium salts of hydroxide, chloride and sulfate ions. Using only test solutions of $Ba(NO_3)_2$, $Pb(NO_3)_2$ and $Mg(NO_3)_2$, suggest a procedure that could be used to identify and extract each anion. Include expected observations and a balanced chemical equation in your answer.

(5 marks)

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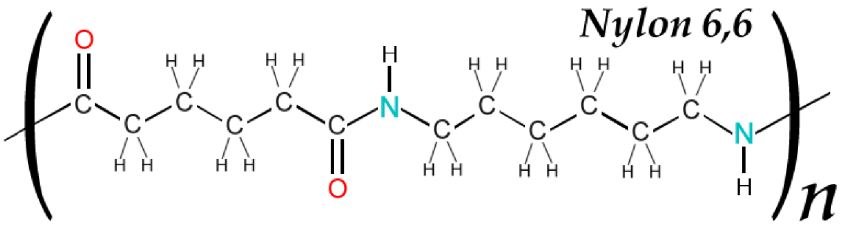
Question 33 (4 marks)

The diagram below shows the structure of the condensation polymer Nylon – 6,6.



a) Explain what is meant by a 'condensation polymer'. **(2 marks)**

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b) Contrast the process of condensation polymerisation with that of addition polymerisation.

(2 marks)

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Question 34 (4 marks)

Heptane is a clear, odourless liquid hydrocarbon. Its high flammability gives it properties necessary in many industries, including use as a fuel.

Species	$O_2(g)$	$CO_2(g)$	$H_2O(l)$	$C_7H_{16}(l)$
Enthalpy of Formation (kJ mol^{-1})	0	-393	-285	-224
Entropy (J K^{-1} mol^{-1})	+205	+214	+70	+329

Use the data in the table to determine whether the combustion of heptane at 298 K is spontaneous.

(4 marks)

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Question 35 (8 marks)

Diesel is a common fuel used in vehicles. Biodiesel, first commercially developed in 1991, is now readily available as an alternative fuel. A biofuels manufacturing facility, Shoalhaven Pty Ltd, in Nowra NSW, uses waste plant products from sugar and wheat processing and canola oil to produce biodiesel.

Discuss advantages and disadvantages of producing and/or using biodiesel as a sustainable fuel for transport and describe THREE significant factors that may have been considered when building the Shoalhaven biofuels facility. **(8 marks)**

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2022

TRIAL
EXAMINATION
Multiple Choice Answer Sheet

Chemistry

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

2022 Year 12 Chemistry Trial examination. Marking Guidelines and Model Answers.

Section I Multiple Choice

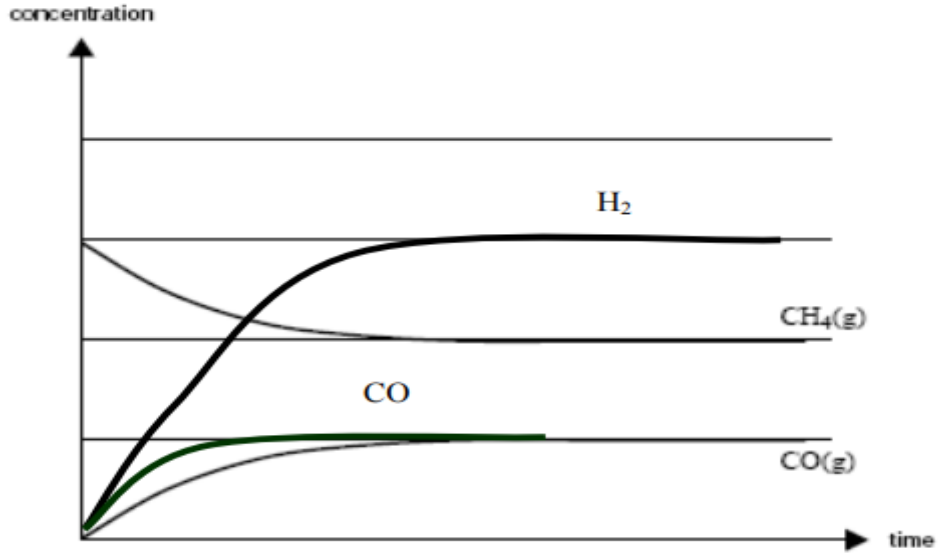
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
B	B	C	D	A	B	C	B	A	B	A	A	C	A	B	A	D	D	C	B

Section II

Question 21 (4 marks)
21 (a) (2 marks)

Criteria	Marks
● Draws a line labelled (a) above AND ● Explains that 3 moles of hydrogen are formed when 1 mole of CO forms	2
● Draws a line labelled (a) above OR ● Explains that 3 moles of hydrogen are formed when 1 mole of CO forms	1

Sample answer



Because of the mole ratio in the equation, the amount of H_2 produced must be 3 x the amount of CO produced. The line should show the $[H_2]$ reaching equilibrium at the same elapsed time as CO and CH_4 gases.

21 (b) (2 marks)

Criteria	Marks
● Draws a line labelled (b) above AND ● Explains that the rate of formation of CO is faster when a catalyst is present but the same amount of CO is formed	2

● Draws a line labelled (b) above OR ● Explains that the rate of formation of CO is faster when a catalyst is present but the same amount of CO is formed	1

Sample answer

The line drawn (b) should show a steeper slope / faster rate of reaction when a catalyst is present but the same amount of CO should be formed as for the uncatalysed reaction.
(Note that both backward and forward reaction rates would have increased – not just that of the CO production.)

Question 22a (3 marks)

Criteria	***Marks***
● Correct equilibrium expression ● Working out ● Correct concentration of solution with units	3
● Omitting <u>one</u> to <u>two</u> of the criteria above	1-2

Sample answer

$PbCl_2\ (s) \rightleftharpoons Pb^{2+}\ (aq) + 2Cl^-\ (aq)$

$K_{sp} = [Pb^{2+}][Cl^-]^2$
$1.7 \times 10^{-5} = s \times (2s)^2$
$1.7 \times 10^{-5} = 4s^3$
$s^3 = 4.25 \times 10^{-6}$
$s = 1.6 \times 10^{-2}$

The solubility of $PbCl_2$ is 1.6×10^{-2} $molL^{-1}$

Question 22b (3 marks)

Criteria	***Marks***
● Correct concentration of Cl^- ● Correct final concentration of $PbCl_2$ ● Makes a justified comparison on solubility	3
● Omitting <u>one</u> to <u>two</u> of the criteria above	1-2

Sample answer

	$PbCl_2\ (s) \rightleftharpoons$	$Pb^{2+}\ (aq)$	$+ 2Cl^-\ (aq)$
I		0	0.35
C		+s	+2s
E		s	0.35 + 2s
			~ 0.35

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

$1.7 \times 10^{-5} = s \times 0.35^2$

$1.7 \times 10^{-5} = s \times 0.1225$

$s = 1.3877551 \times 10^{-4}$

Solubility of $PbCl_2$ is 1.39×10^{-4} $molL^{-1}$ in 0.35 $molL^{-1}$ NaCl

$PbCl_2$ is 115 times more soluble in water

Question 23 (8 marks)

23 (a) (3 marks)

Criteria	Marks
● Names THREE compounds correctly	3
● Names TWO compounds correctly	2
● Names ONE compound correctly	1

Sample answer

Compound 1 = propanamide
Compound 2 = 2,3-dimethylpentane
Compound 3 = 1-propyl methanoate

Markers notes: need to review IUPAC naming. Use commas to separate numbers and dashes to separate numbers and words. Make it very clear when there is meant to be a space and when there is not. Spelling matter when naming compounds.
Amides are terminal (at the end of the carbon chain) and thus do not require a number.
Too many messing up naming the ester. Alcohol comes before the acid. Acid chain came from the side with C=O.

23 (b) (5 marks)

Criteria	Marks
● Predicts the correct order of boiling points (Compound 2, Compound 3, Compound 1) ● Explains the impact of the different intermolecular forces ● Identifies that Compound 1 has very strong hydrogen bonding ● Identifies that Compound 2 has dispersion (temporary dipole-dipole) forces only ● Identifies that Compound 3 has dipole-dipole bonding	5
● Predicts the correct order of boiling points (Compound 2, Compound 3, Compound 1) ● Describes the impact of the different intermolecular forces ● Identifies that Compound 1 has very strong hydrogen bonding ● Identifies that Compound 2 has dispersion (temporary dipole-dipole) forces only ● Identifies that Compound 3 has dipole-dipole bonding	4
● Predicts the correct order of boiling points ● Identifies the intermolecular forces in 3 of the 3 compounds	3
● TWO of:	2

• Predicts the correct order of boiling points • Describes the impact of the different intermolecular forces • Identifies the intermolecular forces in 2 of the 3 compounds	
• ONE of: • Predicts the correct order of boiling points • Describes the impact of the different intermolecular forces • Identifies the intermolecular forces in 1 of the 3 compounds	1

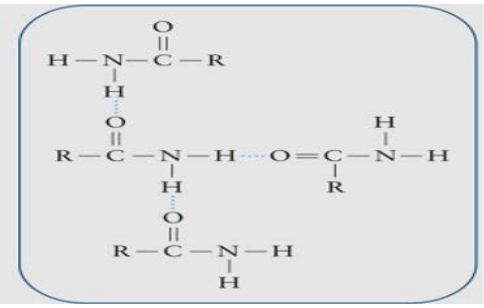
Sample answer

The order of increasing boiling points is Compound 2, Compound 3, Compound 1.

The stronger the intermolecular forces, the higher the boiling point, as greater energy is needed to separate the liquid molecules to form a gas.

Compound 2 is non-polar and has only weak intermolecular forces (dispersion or temporary dipole-dipole forces) caused by the electrical interaction of molecules as they collide (protons from 1 molecule being attracted to electrons from the other as the molecules are temporarily distorted on collision). (Boiling point 58°C)

Compound 1 is polar and would experience very strong hydrogen bonding forces, as well as weaker temporary and permanent dipolar forces) as molecules interact. These are strong intermolecular forces as hydrogen bonds can also form between the oxygen of 1 molecule and the hydrogen of the $-NH_2$ group. The geometry of the molecules allows more than 1 H-bond per molecule at any instant. Propanamide has a boiling point of 213°C and is a solid at room temperature. This boiling point is higher than that of Compound 3, an ester which does not exhibit hydrogen bonding between neighbouring molecules.



Compound 3 is an ester. It is a polar molecule with dipole-dipole interactions but has no hydrogen bonding. (Boiling point 102°C)

Hence the intermolecular forces and thus boiling points are highest in Compound 1 and lowest in Compound 2.

Markers notes: boiling point is a physical property and thus linked to intermolecular interactions (i.e. dispersion forces, dipole-dipole, hydrogen bonds)... NOT double or single bonds. Many attempted to identify forces and boiling point trends without any explanation. Others stated stronger forces mean higher boiling points, but failed to link stronger forces to greater **energy** requirements to separate molecules. Better answers also included whether polarity occurred in molecules, thus causing dipoles and described the distinction between dipole-dipole and H-bonding.

Question 24 (10 marks)

24 (a) (2 marks)

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

Sample answer

hydrocyanic acid

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

Markers notes: weakest acid = lowest ionisation = smallest K_a. If the wrong acid was identified, it was still possible to demonstrate a correct pK_a calculation and achieve 1 mark.

24 (b) (2 marks)

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

Sample answer

$HClO_2$ (chlorous acid) forms the chlorite ion (ClO_2^-) as its conjugate base.
The strongest acid forms the weakest base.
For a conjugate acid-base pair:
$pK_b = 14 - pK_a = 14.00 - 1.96 = 12.04$
OR
$K_w = K_a.K_b$
$K_b = K_w/K_a$
$pK_b = -\log(K_b)$

Markers notes: many didn't read the questions properly. Identify the **weakest base formed** from these acids. Therefore, the correct answer was the conjugate base of the strongest acid. Again, if the wrong base was identified, it was still possible to demonstrate a correct pK_b calculation and achieve 1 mark.

24 (c) (2 marks)

Criteria	Marks

● Calculates the pH with correct working and reasoning	2
● Shows some correct working	1

Sample answer

$CH_3CH_2COOH\ (aq)\ +\ H_2O\ (l) \rightleftharpoons CH_3CH_2COO^-\ (aq)\ +\ H_3O^+\ (aq)$

$$K_a\ CH_3CH_2COOH = \frac{[CH_3CH_2COO^-]\,[H_3O^+]}{[CH_3CH_2COOH]} = 1.34 \times 10^{-5}$$

Let x moles of CH_3CH_2COOH ionise, forming x moles of H_3O^+

$$K_a\ CH_3CH_2COOH = \frac{[x]\,[x]}{[0.010 - x]} = 1.34 \times 10^{-5}$$

Assume x will be small by comparison with 0.010
Hence $[x]^2 = 1.34 \times 10^{-5} \times 0.010 = 1.34 \times 10^{-7}$
$[H_3O^+] = \sqrt{(1.34 \times 10^{-7})} = 0.000366$ mol/L
Hence pH $= -\log_{10}(0.000366) = 3.44$

24 (d) (4 marks)

Criteria	Marks
● Calculates the pH ● Explains why this mixture is classified as a buffer	4
● Calculates the pH with correct steps but mathematical error ● Explains why this mixture is classified as a buffer	3
● Determines the $[H_3O^+]$ in the buffer AND explains why this mixture is classified as a buffer	2
● Shows some relevant working OR explains why this mixture is classified as a buffer	1

Sample answer

$HNO_2\ (aq)\ +\ H_2O\ (l) \rightleftharpoons NO_2^-\ (aq)\ +\ H_3O^+\ (aq)$

$$K_a\ HNO_2 = \frac{[NO_2^-]\,[H_3O^+]}{[HNO_2]} = 7.2 \times 10^{-4}$$

Initial $[HNO_2] = 0.010$ mol/L
Initial $[NO_2^-] = 0.010$ mol/L
On mixing, the volume is increased to 180 mL
After mixing, $[HNO_2] = 0.010 \times 100/180 = 0.00555$ mol/L
After mixing, $[NO_2^-] = 0.010 \times 80/180$ mol/L $= 0.00444$ mol/L

Let x mol/L HNO_2 ionise at equilibrium.

At equilibrium
$[HNO_2] = (0.00555 - x)$ mol/L
$[NO_2^-] = (0.00444 + x)$ mol/L
$[H_3O^+] = x$ mol/L

K_a HNO_2 = $\frac{[NO_2^-][H_3O^+]}{[HNO_2]}$ = 7.2×10^{-4} = $\frac{(0.00444 + x)(x)}{(0.00555 - x)}$

Assume x is small by comparison with 0.00555 and with 0.00444 mol/L

K_a HNO_2 = $\frac{[NO_2^-][H_3O^+]}{[HNO_2]}$ = 7.2×10^{-4} = $\frac{(0.00444)(x)}{(0.00555)}$

$[H_3O^+] = x = 7.2 \times 10^{-4} \times 0.00555/0.00444 = 0.00090$ mol/L

pH = 3.05

A buffer solution is one which will maintain an almost constant pH, even if small quantities of strong acid or base are added to it. As long as there are close to equal moles of equal concentration solutions making up the buffer mixture, and the acid and base are both only moderately strong as acids and bases, the solution will stay at close to the pH value 3.05, as calculated above. By Le Chatelier's Principle, if [x] is small by comparison with the concentrations of the acid and base, if the concentration of H^+ in the buffer mixture changes slightly, the proportions of HNO_2 and NO_2^- will change to keep the pH close to 3.05.

Question 25 (4 mark)

Criteria	***Mark***
• Calculates enthalpy of neutralisation (ΔH_{neut})	4
• Calculates quantity of heat (q) • Calculates moles of nitric acid	3
• Calculates quantity of heat (q)	2
• Provides correct balanced chemical equation OR • Calculates temperature change (ΔT)	1

Sample answer

$KOH(aq) + HNO_3(aq) \rightarrow KNO_3(aq) + H_2O(l)$

$\Delta T = 32 - 23$

$\Delta T = 9°C$

$q = mC\Delta T$

$q = 100 \times 4.18 \times 9$

$q = 3762$ J

$q = 3.762$ kJ

$n(HNO_3) = cV$

$n(HNO_3) = 1.5 \times 0.05$

$n(HNO_3) = 0.075$ mol

$n(H_2O) = n(HNO_3)$ as 1:1 ratio

$n(H_2O) = 0.075$ mol

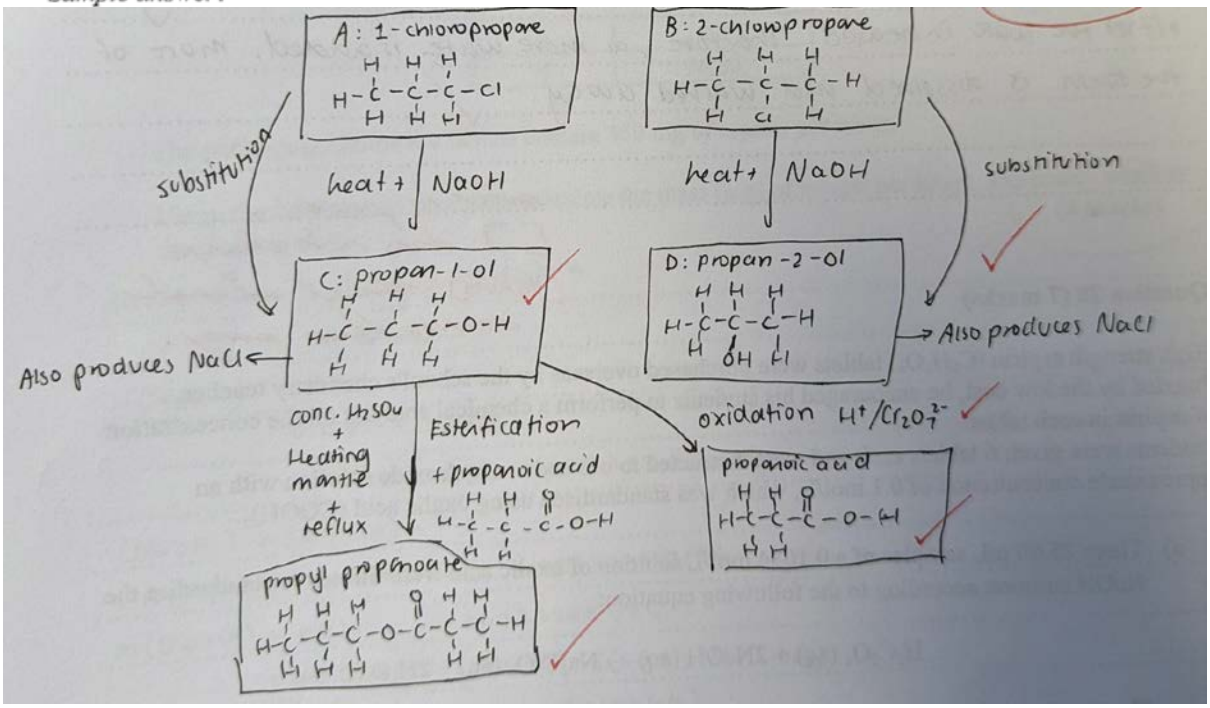
$\Delta H_{neut} = -50.16$ kJ mol^{-1}

Question 26a (4 marks)

Question 26(a)

Criteria	Mark
• Constructs a suitable flow diagram to show the steps required to produce propyl propanoate from propanol • Correctly identifies all relevant organic compounds, types of reactions and other reagents required	4
• Constructs a suitable flow diagram to show the steps required to produce propyl propanoate from propanol • Correctly identifies all relevant organic compounds	2–3
• Constructs a suitable and relevant flow diagram that identifies some relevant organic compounds, types of reaction and/or other reagents required	1

Sample answer:



Question 26b (2 marks)

Criteria	*Marks*
• correctly draws the structural formula for propanoic acid • identifies the correct colour change for the oxidising agent used	2
• correctly states ONE of the above	1

Question 26c (2 marks)

Criteria	*Marks*
• explicitly identifies ONE risk **linked** to an appropriate control measure	2
• identifies ONE risk OR • identifies ONE control measure	1

Question 27 (3 marks)

Criteria	*Marks*
• Refers to dissolution of toxins • Describes link to solubility equilibria (i.e. running water/multiple rinses) • Describes link to LCP (i.e.reducing toxicity over time)	3
• Address **TWO** of the above criteria	2
• Any relevant information	1

Sample answer

Although the formal idea of chemical equilibria is relatively recent, communities have exploited these principles for tens of thousands of years.

An example of this is the highly toxic cycad fruit. ATSI needed a way to reduce toxicity so that it could be a dietary staple. One method was to cut the fruit open and leave it in a running stream. This achieved the solubility equilibria of toxins (s) ⇋ toxins (aq). Overtime, the aqueous toxin dissolves into the water and its concentration will decrease.

By LCP, the equilibrium will shift to the right as the aqueous toxins are swept away (conc. Is lowered) since there is a constant water source. Thus, the longer ATSI wait, the less toxic the fruit will be.

Question 28a (3 marks)

Criteria	*Marks*
● Correctly calculates NaOH molarity to **4 sig figs**	3
● Correctly calculates NaOH molarity	2
● Calculates [NaOH] with ONE error OR ● Calculates moles of $H_2C_2O_4$ or NaOH	1

Sample answer

$H_2C_2O_4$ (aq) + 2NaOH (aq) □ $Na_2C_2O_4$ (aq) + $2H_2O$ (l)

$n(H_2C_2O_4) = cv$
$= 0.1034 \text{ mol/L} \times 0.025 \text{ L}$
$= 2.585 \times 10^{-3} \text{ mol}$
$= n(NaOH) \times 2$
$n(NaOH) = 0.00517 \text{ mol (1:2 ratio)}$

$c(NaOH) = \frac{n}{v} = \frac{0.00517 \text{ mol}}{0.02575 \text{ L}}$
$= 0.2008 \text{ mol L}^{-1} \text{ (to 4sf)}$

Question 28b (4 marks)

Criteria	*Marks*
● Correctly calculates the mass of aspirin (average) ● Justifies that the claim is false	3-4
● Calculates mass of aspirin with ONE error OR ● Calculates moles of NaOH/$C_9H_8O_4$ and molar mass aspirin	2
● Calculates moles of NaOH/ $C_9H_8O_4$ OR ● Calculates molar mass aspirin $C_9H_8O_4$	1

Sample answer

Avg. vol. = 16.55 mL (trial 2 is an outlier)

n(NaOH) = cv

= 0.2008 mol/L x 0.01655 L

= 0.00332324 mol

= n($C_9H_8O_4$) (1:1 ratio)

m($C_9H_8O_4$) = n x MM

= 0.00332324 mol x 180.154 *(9×12.01+8×1.008+4×16.00)* g/mol

= 0.5986 g

= 598.6 mg

$$m(C_9H_8O_4)\text{ Per tablet} = \frac{}{2}$$

= 299.3 mg

The claim about the table is false.

Question 29 (3 marks)

Criteria	Mark
• Gives reasons for the shape of both the forward and reverse reaction rate graphs between t_0 and t_1 in terms of collision theory • Gives reasons for the shape of both the forward and reverse reaction rate graphs between t_1 and t_2 in terms of collision theory	3
• Gives reasons for the shape of both the forward and reverse reaction rate graphs between t_0 and t_1 in terms of collision theory OR • Gives reasons for the shape of both the forward and reverse reaction rate graphs between t_1 and t_2 in terms of collision theory	2
• Provides some correct information about the shape of a graph in terms of collision theory	1

Sample answer: At the start of the reaction (t_0) the reactants are at their highest concentration and no products have formed. When a chemical reaction first occurs the chances of more successful collisions is therefore greater, and the forward reaction is relatively fast. As the reaction proceeds, the reactants become less concentrated, and the chances of successful collisions decreases. As the products become more concentrated, collisions become more successful, and the rate of the reverse reaction now increases. This continues until the forward reaction rate equals the reverse reaction rate and the system is now said to be in equilibrium.

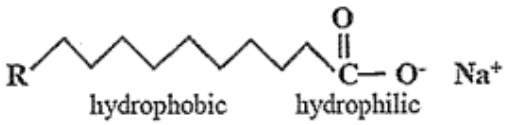
At t_1 more reactant(s) are added. This increases the reactant concentration and causes an immediate spike in the rate of the forward reaction. However, as before, as the reaction proceeds, the reactants become less concentrated, and the chances of successful collisions decreases. The forward reaction rate therefore decreases gradually until equilibrium is again re-established just before t_2. At the same time the reverse reaction rate will gradually increase because reactant particles have become product particles. An increase in concentration of either the reactants or the products will result in both the forward and reverse reaction rates being higher once equilibrium is re-established as more particles are present after t_1.

Markers notes: The question specifies to account for the shape. Many students ignored this. The better answers identified the 'spike' at T2, or the 'plateau', or any of the 'curves'. Better answers would consistently refer to collision theory throughout their answer, explicitly linking to each section of the graph (T_0-T_1 and T_1-T_0). Important note: collisions MUST be successful (expected) rather than just 'collisions'.

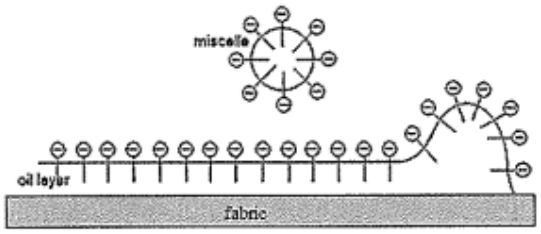
Question 30 (3 marks)

Criteria	Mark
• Thoroughly explains, with the use of a suitable diagram(s), the action of soaps in emulsifying oils in terms of the structure of the soap anions	3
• Explains, with the use of a suitable diagram, the action of soaps in interacting with oils in terms of the structure of the soap anions	2
• Describes the structure of the soap anions OR • Describes the interaction of soaps with water and oils (in words OR as a diagram)	1

Sample answer: Soaps are soluble salts of long chain fatty acids with a typical formula $CH_3(CH_2)_{16}COO^-Na^+$. When dissolved in water the soap loses its cation leaving an anion that has a negatively charged carboxylate "head" at one end and a non-polar hydrocarbon "tail" at the other. The charged head is hydrophilic and so is soluble in water, while the non-polar tail is hydrophobic, so it is insoluble in water but soluble in oils. In a water and oil mixture, the soap anions will line up along the water/oil interface with the charged head end in water and the non-polar tail in the oil, as shown in the diagram.



Agitation will cause droplets of oil to break off and become completely surrounded by soap anions forming micelles. The charge surrounding each micelle repels other micelles, keeping them separated. The oil broken up into droplets in this way is said to be emulsified in the water.



Markers notes: Not answered well overall. Answers were either vague or too broad. MUST be specific and LABEL diagrams thoroughly! The structure of soaps is poorly represented (no ANIONS labelled or identified). The 'emulsifying' action was also poorly explained. It is the REPULSION of all the anions (heads of each soap molecule) surrounding the oil in the micelle formation to cause the 'even spreading' of the oil particles throughout the water.

Question 31 (3 marks)

Criteria	Mark
• Shows working to calculate the value of the equilibrium constant, K_{eq} • Makes a correct statement(s) about what the K_{eq} indicates	3
• Shows working to calculate the value of the equilibrium constant, K_{eq}	2
• Provides a correct calculation process or some correct information about K_{eq}	1

Sample answer: Initial concentrations: $[H_2] = 0.5$ mol L^{-1} $[I_2] = 0.5$ mol L^{-1} $[HI] = 0.0$ mol L^{-1}

	$[H_2]$	$[I_2]$	$[HI]$
Initial	0.5	0.5	0.0
Change	–0.38	–0.38	+0.76
Equilibrium	0.12	0.12	0.76

Now $K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = (0.76)^2/(0.12) \times (0.12) = 40.1$

This moderately large number indicates that the equilibrium position is on the right side. The products are favoured in this equilibrium reaction.

Markers notes: Many did not READ the question properly and missed the 'DISCUSS' what the value indicates (losing 1 mark). Many did not realise that the vessel was 2.00L…and the concentrations of the reactants were in mol/L… again they did not READ the question properly! RICE tables need revision for many students!

Question 32 (5 Marks)

Marking Guidelines	Marks
• Describes a sequence of steps in the correct order that distinguish between the three anions • Each step identifies that filtration, excess cation is added, and correct ppt colour • Provides one correct equation (adjusted for error in question)	**5**
• Describes a sequence of steps in the correct order that distinguish between the three anions • Each step identifies that filtration • Provides one correct equation (adjusted for error in question)	**4**
• Identifies the three correct cations to ppt with each anion, may not be in order • Provides one correct equation (adjusted for error in question)	**3**
• Identifies three correct cation tests, may not be in order and an incorrect equation OR • Identifies two tests and provides one substantially correct equation (adjusted for error in question)	**2**
• Identifies any correct cation test to identify one anion OR • provides one substantially correct equation (adjusted for error in question)	**1**

Add cations to the solution in this order:

Step 1(or 2)- Add excess Mg^{2+}. This will form a white precipitate with the OH^-. Filter out the $Mg(OH)_2$ solid.

Step 2 (or 1)- Add excess Ba^{2+}. This will form a white precipitate with the SO_4^{2-}. Filter out the $BaSO_4$ solid.

Step 3 - Add excess Pb^{2+}. (MUST be last as lead will form a ppt with sulfate). This will form a white precipitate with the Cl^-. Filter out the $Pb(Cl)_2$ solid.

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

Markers notes: some students didn't interpret the question correctly, and misinterpreted that all three anions were in the one solution. Therefore it is essential that the cations are added in a specific order so that each anion precipitates with only the one cation. If Lead is added before Ba or Mg ions, it would not be clear whether the sulfate or the chloride ions would ppt out. Either Ba or Mg ions could be used first.

Any balance equation was accepted due to the formula errors in the question.

NOTE: Formulas should have been $Ba(NO_3)_2$, $Pb(NO_3)_2$, $Mg(NO_3)_2$

Question 33 (4 marks)

33(a) (2 marks)

Marking Guidelines	Marks
● Identifies that condensation polymerisation involves functional groups on the monomer units reacting AND the elimination of a small molecule (water).	**2**
● Identifies that condensation polymerisation involves functional groups on the monomer units reacting OR the elimination of a small molecule (water).	**1**

Sample answer:
A condensation polymer is a polymer that forms when functional groups on the monomer units react to produce the polymer with the elimination of a small molecule (usually water).

Markers notes: poor understanding of condensation polymerisation - very few mentioned the functional groups and there is a small molecule eliminated (not always water…but is mostly)

33(b) (2 marks)

Marking Guidelines	Marks
● Identifies TWO differences between the processes of addition polymerisation and condensation polymerisation.	**2**
● Identifies ONE difference between the processes of addition polymerisation and condensation polymerisation.	**1**

Sample answer:
Addition polymerisation involves the opening of the double bond in the monomer unit to form the polymer, while condensation polymerisation involves functional groups on the monomer units reacting to form the polymer. In addition polymerisation, the polymer forms without the loss of any atoms, while in condensation polymerisation the polymer forms with the elimination of a small molecule (usually water).

Markers notes: not well answered - as students did not always identify the key mechanism of the addition into a double bond which is broken in addition polymerisation…with no loss of atoms. Whereas condensation polymerisation loses a small molecule and involves functional groups on the monomer units.

Question 34 (4 marks)

Marking Guidelines	Marks
● Provides balanced chemical equation for combustion of heptane ● Converts ΔS to kJ K-1 mol-1 ● Calculates ΔH, ΔS and ΔG ● Writes statement about spontaneity	**4**
● · Provides balanced chemical equation for combustion of heptane ● · Calculates ΔH, ΔS and ΔG ● · Writes statement about spontaneity ● OR ● · Provides balanced chemical equation for combustion of heptane ● · Converts ΔS to kJ K-1 mol-1 ● · Calculates ΔH OR ΔS	**3**
● Provides balanced chemical equation for combustion of heptane ● Calculates ΔH OR ΔS OR ● Calculates ΔH OR ΔS ● Writes spontaneity statement	**2**
● Provides some relevant calculation OR ● Provides balanced chemical equation for combustion of heptane	**1**

Sample answer:

$C_7H_{16}(l) + 11O_2(g) \rightarrow 7CO_2(g) + 8H_2O(l)$

$\Delta H = [(7 \times -393) + (8 \times -285)] – [(1 \times -224) + [11 \times 0)]$

$\Delta H = (-2751 – 2280) – (-224)$

$\Delta H = -5031 + 224$

$\Delta H = -4807$ kJ mol-1

$\Delta S = [(7 \times 214) + (8 \times 70)] – [(1 \times 329) + (11 \times 205)]$

$\Delta S = (1498 + 560) – (329 + 2255)$

$\Delta S = 2058 – 2584$

$\Delta S = -526$ J K-1 mol-1

$\Delta S = -0.526$ kJ K-1 mol-1

$\Delta G = \Delta H – T\Delta S$

$\Delta G = -4807 – (298 \times -0.526)$

$\Delta G = -4807 – (-156.748)$

$\Delta G = -4650.25$ kJ mol-1

The reaction is spontaneous at 298 K as the value for ΔG is negative.

Markers notes: poor use of units! A statement must be include the relative value of ΔG.

Question 35 (8 marks)

Marking Guidelines	Marks
• Discusses at least TWO significant advantages and TWO significant disadvantages of using biodiesel (any biofuel in general terms) as a sustainable fuel • Identifies at least THREE significant factors that would have been considered when building the biofuels plant • Describes the characteristics of EACH of these factors that would make them relevant to building the biofuels plant	**8**
• As above but ONE aspect missing OR • ONE aspect may be outlined (not discussed or described))	**7**
• As above but TWO aspects missing OR • ONE/TWO aspects may be outlined (not discussed or described)	**6**
• As above but THREE aspects missing OR • TWO/THREE aspects may be outlined (not discussed)	**5**
• As above but FOUR aspects missing OR • TWO/THREE aspects may be outlined (not discussed)	**4**
• As above but FIVE aspects missing OR • THREE/FOUR aspects may be outlined (not discussed)	**3**
• As above but SIX aspects missing OR • FOUR/FIVE aspects may be outlined (not discussed)	**2**
• Any relevant information	**1**

Marks awarded for general biofuels advantages and disadvantages and/or specific to biodiesel. These may include:

Advantages:

- **Biofuels are made from crops or biowaste, which are renewable (fossil fuels are are finite resource)**
- **fewer harmful emissions - especially greenhouse gases (eg, CO, CO2 etc)**

- **There is some claim that biofuels are carbon neutral as they take in the CO2 through crop growth**

Disadvantages:

- **Biofuels are relatively expensive to produce compared to fossil fuels**
- **the production could use arable land, otherwise used for food production**
- **not yet suitable to use in many engines, therefore incurring extra costs or potential damage**
- **biodiesel causes corrosion of some metals**
- **large amounts of water required which impacts the environment**

The main factors considered when building the biofuel plant would be:

- Availability of raw materials and reagents
- Reaction conditions
- Yield and purity
- Markets and their location
- Availability of cheap energy
- Availability of a workforce
- Suitability of waste disposal sites and environmental controls

The Shoalhaven biofuel plant is conveniently located where its main raw material is located, that is, wheat for starch and canola crops for canola oil. The main reaction involved in producing biodiesel is an equilibrium and the conditions of temperature, pressure, concentration and the use of a catalyst would need to be considered in order to maximise the yield of biodiesel and in a realistic time frame.

Purity would need to be monitored so that contaminants did not affect the reaction process. Regulations need to be enforced for waste treatment. Wastes would need to be properly disposed of, recycled and/or sold for reprocessing for other uses such as fertilisers or added to road base.

The market for biofuels is increasing internationally and recent government policy has required that the fuel industry meets targets for the sale of bio-based fuels. A by-product of the production of biodiesel is glycerol which is sold for use in other industries like soap making and solvents.

The town of Shoalhaven is found near a large city (Nowra) and in an area that has access to relatively cheap energy to power the plant, a large local workforce for the production process and good transport options (rail, road, shipping and airport) to distribute the fuel to markets.

The production of biodiesel has impacts on the environment. A large amount of land and water is required and the use of monocultures (e.g., wheat and canola) affects biodiversity. The combustion of biodiesel produces significant greenhouse gases. Many believe that growing crops for biofuels will offset greenhouse gas emissions from their combustion but this depends on the methods used to produce the feedstock and process the fuel. Some studies have shown significant emissions reductions compared to fossil fuels plants that base their main energy source on non-renewables.
(NB: only 3 factors required)

Markers notes: Mostly well answered. Discuss and Describe verbs are still not well adhered to.