
Student Number

Barker College

2019 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

AM THURSDAY 8TH AUGUST

100 copies

Section 1 – Multiple Choice
Choose the best response and fill in the response oval completely

Start Here →

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

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Student Number

Barker College

2019 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Staff Involved:

- AXC
- NJD
- DLM
- RJP*
- KMT

AM THURSDAY 8TH AUGUST

TIME: 3 hours

100 copies

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 separate Periodic Table and Data Sheet are provided with this paper
- For questions in Section II, show all relevant working in questions involving calculations

Total marks:
100

Section I – 20 marks (pages 3 - 10)

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

Section II – 80 marks (pages 11 - 32)

- Attempt Questions 21 - 32
- Allow about 2 hours and 25 minutes for this section

Section 1: Multiple Choice

20 marks
Attempt Questions 1 – 20
Allow about 35 minutes for this part
Use the multiple-choice answer sheet

Sample 2 + 4 = A 2 B 6 C 8 D 9

A ○ B ○ C ○ D ○

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

A ● B ⊗ C ○ D ○

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

correct ↓

A ● B ⊗ C ○ D ○

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1. Which ONE of the following is **not** a primary amine?

   A. CH_3NH_2

   B. $CH_3CH(NH_2)CH_3$

   C. CH_3NHCH_3

   D. $CH_3CH_2CH_2NH_2$

2. Hydrogen is produced on an industrial scale from methane. The equation for the reaction is

   $$2H_2O(g)+CH_4(g) \quad CO_2(g)+4H_2(g)$$

   The expression for the equilibrium constant for the reverse reaction is

   A. $K=\dfrac{[H_2O]^2[CH_4]}{[H_2]^4[CO_2]}$

   B. $K=\dfrac{[H_2]^4[CO_2]}{[H_2O]^2[CH_4]}$

   C. $K=\dfrac{[H_2O]\ [CH_4]}{[H_2]\ [CO_2]}$

   D. $K=\dfrac{4[H_2]\ [CO_2]}{2[H_2O]^4[CH_4]}$

3. A polymer which is produced by condensation reactions of monomers is

   A. polyethlylene

   B. polystyrene

   C. polyvinyl chloride

   D. polyester

4. The number of chain isomers of formula C_6H_{14} is

   A. 2

   B. 3

   C. 4

   D. 5

5. When nitrogen and hydrogen react, an equilibrium is established:

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g) \quad \Delta H = -92 \text{ kJ per mole of nitrogen } (g)$$

The equilibrium yield of ammonia can be increased by

A. using a suitable catalyst.

B. increasing the temperature.

C. increasing the volume of the container.

D. increasing the pressure.

6. Which of the following species is NOT amphiprotic?

A. H_2O

B. HCO_3^-

C. H_3PO_4

D. HSO_4^-

7. In which ONE of the following pairs is the second substance a stronger acid than the first?

A. $HCl \quad CH_3COOH$

B. $H_2PO_4^- \quad H_3PO_4$

C. $H_2SO_4 \quad H_2CO_3$

D. $H_2O \quad OH^-$

8. In a titration, a 25.00 mL titre of 1.00 mol L^{-1} hydrochloric acid neutralised a 20.00 mL aliquot of sodium hydroxide solution which was in a conical flask. In repeating the titration the titre would be

A. equal to 25.00 mL, if water was left in the conical flask after final rinsing.

B. less than 25.00 mL, if the final rinsing of the burette was with water rather than the acid.

C. greater than 25.00 mL, if the final rinsing of the 20.00 mL pipette was with water rather than the base.

D. greater than 25.00 mL, if the conical flask was rinsed with the acid prior to the addition of the aliquot.

9. Which of the following statements is INCORRECT?

A. The intermolecular attractions between hydrocarbon molecules are weak dispersion forces.

B. Neighbouring acetic acid molecules have strong hydrogen bonding between the molecules.

C. Propanone (acetone) is non-polar, so has only weak intermolecular forces.

D. The long-chain hydrocarbons have higher boiling points, in general, than those with shorter chains.

10. Ethanoic acid and ethanoate ions form an equilibrium as shown below:

$CH_3COOH\ (aq) + H_2O\ (l) \rightleftharpoons CH_3COO^-\ (aq) + H_3O^+\ (aq)$

Which solution would increase the concentration of the ethanoate ions, when added to the equilibrium mixture?

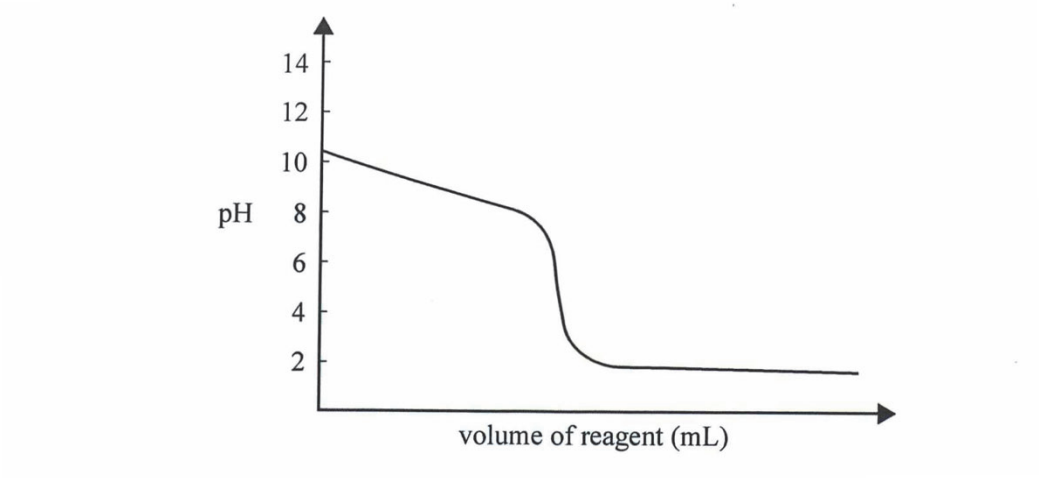
A. Sodium chloride

B. Hydrochloric acid

C. Sodium nitrate

D. Sodium hydroxide

11. The diagram below represents the titration curve for the reaction between a particular acid and a particular base.



The equation that best represents the reaction described by the titration curve is

A. $HCl_{(aq)} + NH_{3(aq)} \rightarrow NH_4Cl_{(aq)}$

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

C. $CH_3COOH_{(aq)} + NH_{3(aq)} \rightarrow CH_3COONH_{4(aq)}$

D. $CH_3COOH_{(aq)} + NaOH_{(aq)} \rightarrow CH_3COONa_{(aq)} + H_2O_{(l)}$

12. Consider the following statements related to methods of forming propan-2-ol:

I	Propan-2-ol is formed by a substitution reaction involving 2-chloropropane and sodium hydroxide solution
II	Propan-2-ol is formed by an addition reaction involving propene and water
III	Propan-2-ol is formed by oxidation of propanone, using acidified potassium dichromate solution

Which of the above statements is/are correct?

A. Statement I only

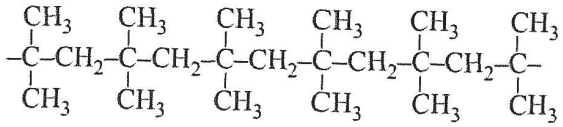
B. Statement II only

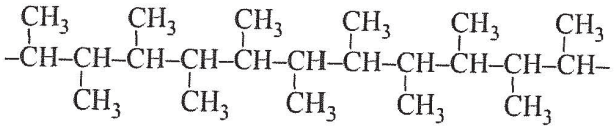
C. Statements I and II only

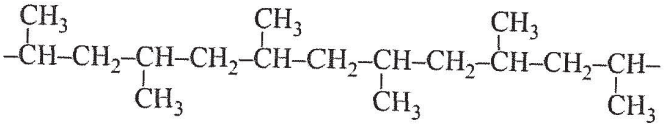
D. Statements I, II and III

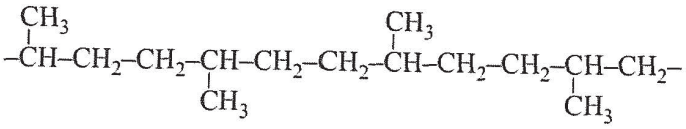
13. Consider the addition polymerisation of $CH_3CH{=}CHCH_3$.

The structure of the resulting polymer would be

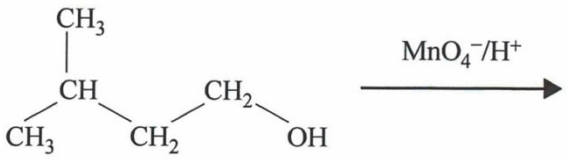
A. 

B. 

C. 

D. 

14. What is the systematic name for the product of the reaction below?



A. 2-methylpentanoic acid

B. 4-methylpentanoic acid

C. 2-methylbutanoic acid

D. 3-methylbutanoic acid

15. Which of the following will cause the greatest change in pH to a 100 mL sample of 0.1 mol L^{-1} HCl?

A. adding 1.0 g of calcium carbonate powder

B. adding 10 mL of 0.1 mol L^{-1} NaOH

C. adding 100 mL of 0.1 mol L^{-1} HC1

D. diluting the sample to 1000 mL

16. A student mixed 20.0 mL of 0.080 mol L^{-1} HC1 with 5.00 mL of 0.030 mol L^{-1} $Ba(OH)_2$.

What is the pH of the resulting solution?

A. 0.052

B. 0.58

C. 1.28

D. 2.24

17. Using the same 0.1 mol L^{-1} hydrochloric acid solution, a student carried out 2 titrations.

Titration 1: 25.0 mL of 0.1 mol L^{-1} sodium hydroxide solution
Titration 2: 25.0 mL of 0.1 mol L^{-1} ammonia solution

Which of the following summarises the CORRECT information about these TWO titrations?

	Titration 1		***Titration 2***	
	Volume of hydrochloric acid required to reach equivalence point	***pH at equivalence point***	***Volume of hydrochloric acid required to reach equivalence point***	***pH at equivalence point***
A.	25.0 mL	7	25.0 mL	> 7
B.	> 25.0 mL	> 7	> 25.0 mL	< 7
C.	25.0 mL	7	< 25.0 mL	7
D.	25.0 mL	7	25.0 mL	< 7

18. What mass of acetic acid (assuming 100% ionisation) will produce 2.5 L of solution having a pH of 5.50?

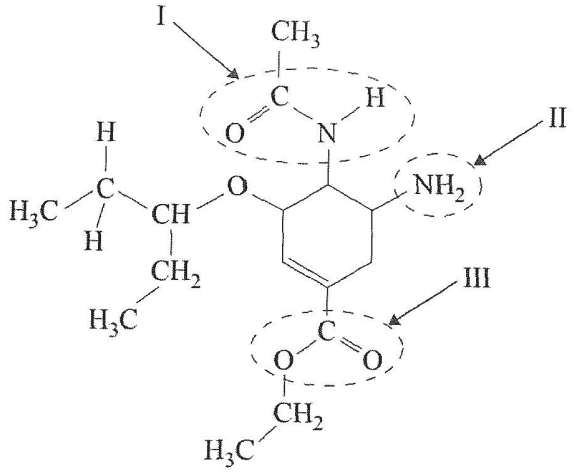
A. 0.11 g

B. $4.8 \times 10^{-4} g$

C. $1.9 \times 10^{-4} g$

D. $8.3 \times 10^{-5} g$

19. The structure of Tamiflu ®, an antiflu drug, is shown below.



The names of the function groups labelled I, II and III are:

	I	II	III
A.	amide	amino	carboxylic acid
B.	amino	amide	ester
C.	amide	amino	ester
D.	amino	amide	carboxylic acid

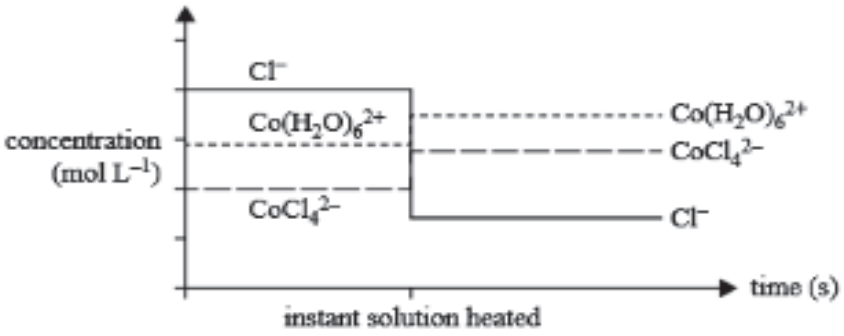
20. A solution contained an equilibrium mixture of two different cobalt (II) ions:

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

When the equilibrium system was heated, the color changed from purple to blue.

Which of the following graphs best represents this change?

A.



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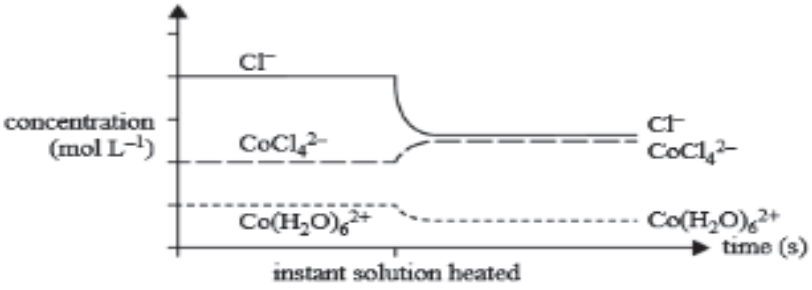
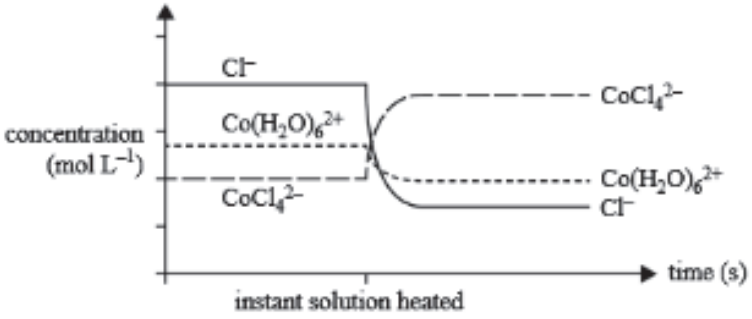
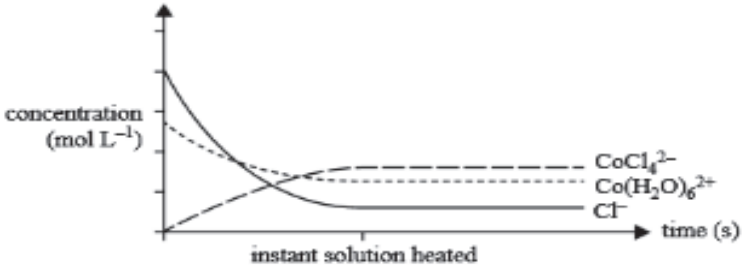


C.



D.



End of Section I

Student Number

2019 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Section II
Answer Booklet

80 marks
Attempt Questions 21 – 32
Allow about 2 hours and 25 minutes for this section.

Instructions

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

Student Number

Question 21 (18 marks)

Ethanol, C_2H_5OH, is made industrially by either of two methods:

- One method uses ethylene, C_2H_4, which is derived from crude oil.
- The other method uses a carbohydrate such as sucrose, $C_{12}H_{22}O_{11}$, and yeast, in aqueous solution.

The production of C_2H_5OH from $C_{12}H_{22}O_{11}$ and yeast proceeds according to the equation

$$C_{12}H_{22}O_{11}\ (aq) + H_2O\ (l) \rightarrow 4C_2H_5OH\ (aq) + 4CO_2\ (g)$$

(a) Determine the mass, in grams, of pure C_2H_5OH that could be produced from 1.250 kg of $C_{12}H_{22}O_{11}$ dissolved in water. **2**

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(b) Describe how ethanol can be formed from ethylene. Include an equation in your response and classify this type of reaction. **2**

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Question 21 continues on page 13

Student Number

Question 21 (continued)

(c) Ethanol can be converted into ethanoic acid. **2**

- Identify the reagent required to bring about this reaction.
- Outline what you would observe as the reaction occurs.
- Classify this type of reaction.

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(d) Ethanoic acid can be used in the manufacture of the ester, methyl ethanoate. **2**

Write a balanced equation for the reaction to form the ester, using structural formulae for the organic compounds.

Question 21 continues on page 14

Student Number

Question 21 (continued)

(e) Discuss the method used in the laboratory preparation of esters and their separation from the other species present in the reaction mixture. **5**

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Question 21 continues on page 15

Student Number

Question 21 (continued)

(f) The boiling points and molar masses of three compounds are shown:

Compound	*Boiling point (°C)*	*Molar mass, g mol^{-1}*
Acetic Acid	118	60
Butan-1-ol	117	74
Butyl acetate	116	116

Discuss why Acetic acid, butan-1-ol and butyl acetate have very similar boiling points but different molar masses. **5**

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End of Question 21

Student Number

Student Number

Question 22 (8 marks)

Sulfur trioxide, SO_3, is made by the reaction of sulfur dioxide, SO_2, and oxygen, O_2, in the presence of a catalyst.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \quad \Delta H < 0$$

In a closed system in the presence of a catalyst, the reaction quickly reaches equilibrium at 1000 K.

(a) A mixture of 2.00 mol of $SO_2(g)$ and 2.00 mol of $O_2(g)$ was placed in a 4.00 L evacuated, sealed vessel and kept at 1000 K until equilibrium was achieved. At equilibrium, the vessel was found to contain 1.66 mol of $SO_3(g)$. **3**

Calculate the equilibrium constant for the above equilibrium at 1000 K.

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(b) The manufacturer wanted to increase the yield of sulfur trioxide. What changes, if any, should be made in terms of the catalyst used, the temperature and the volume of the container? Justify your answer. **3**

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Question 22 continues on page 17

Student Number

Question 22 (continued)

(c) Explain, in terms of collision theory, why an increase in temperature of an equilibrium system always favours the endothermic reaction.
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End of Question 22

Student Number

Question 23 (8 marks)

(a) Write a net ionic equation for the reaction of solutions of lead (II) nitrate and sodium sulfate.

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(b) The solubility product constant for lead (II) sulfate at 25°C is 2.53×10^{-8}.

2

Calculate the concentrations of lead (II) ions and sulfate ions in a saturated solution of lead (II) sulfate at 25°C.

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(c) Would a precipitate of lead sulfate form if 50 mL of 2.0×10^{-4} mol/L sodium sulfate solution were added to 200 mL of a solution of 2.0×10^{-4} mol/L lead nitrate solution? Show all working. **3**

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Student Number

Questions 23 continues on page 19

Student Number

Question 23 (continued)

(d) A lump of solid lead (II) sulfate, which contained radioactive lead ions, was added to a saturated solution of lead (II) sulfate and left to stand for several hours. Predict the distribution of the radioactive lead (II) ions after some hours and explain your prediction. **2**

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End of Question 23

Student Number

Question 24 (3 marks)

(a) Write an equation for the gaseous reaction between ammonia and hydrogen chloride.
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(b) Explain why the reaction of ammonia and hydrogen chloride can be classed as an acid-base reaction by the Br□nsted-Lowry theory, but not by the Arrhenius theory.
2

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Student Number

Student Number

Question 25 (5 marks)

The table shows the acid dissociation constants at 25°C.

Phosphoric Acid	H_3PO_4	7.2×10^{-3}
Hydrofluoric Acid	HF	6.8×10^{-4}
Nitrous Acid	HNO_2	4.5×10^{-4}
Acetic Acid	CH_3COOH	1.8×10^{-5}
Ammonium ion	NH_4^+	5.6×10^{-10}
Water	H_2O	1.0×10^{-14}

(a) Identify the strongest acid in the table and determine the pK_a value for this acid. **2**

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(b) Calculate the pH of a 0.1M solution of ammonium nitrate. **3**

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Student Number

Question 26 (3 marks)

Aspirin is a weak monoprotic acid with a formula of $HC_9H_7O_4$.

3

To determine the amount of aspirin in a headache tablet, a chemist ground up the tablet and dissolved it in 25.0 mL of 0.125 mol/L sodium hydroxide solution. After complete reaction, the excess sodium hydroxide was titrated with 0.0975 mol/L hydrochloric acid. 11.6 mL was required.

Calculate the mass of the aspirin in the headache tablet. Assume a 1:1 ratio of aspirin to base.

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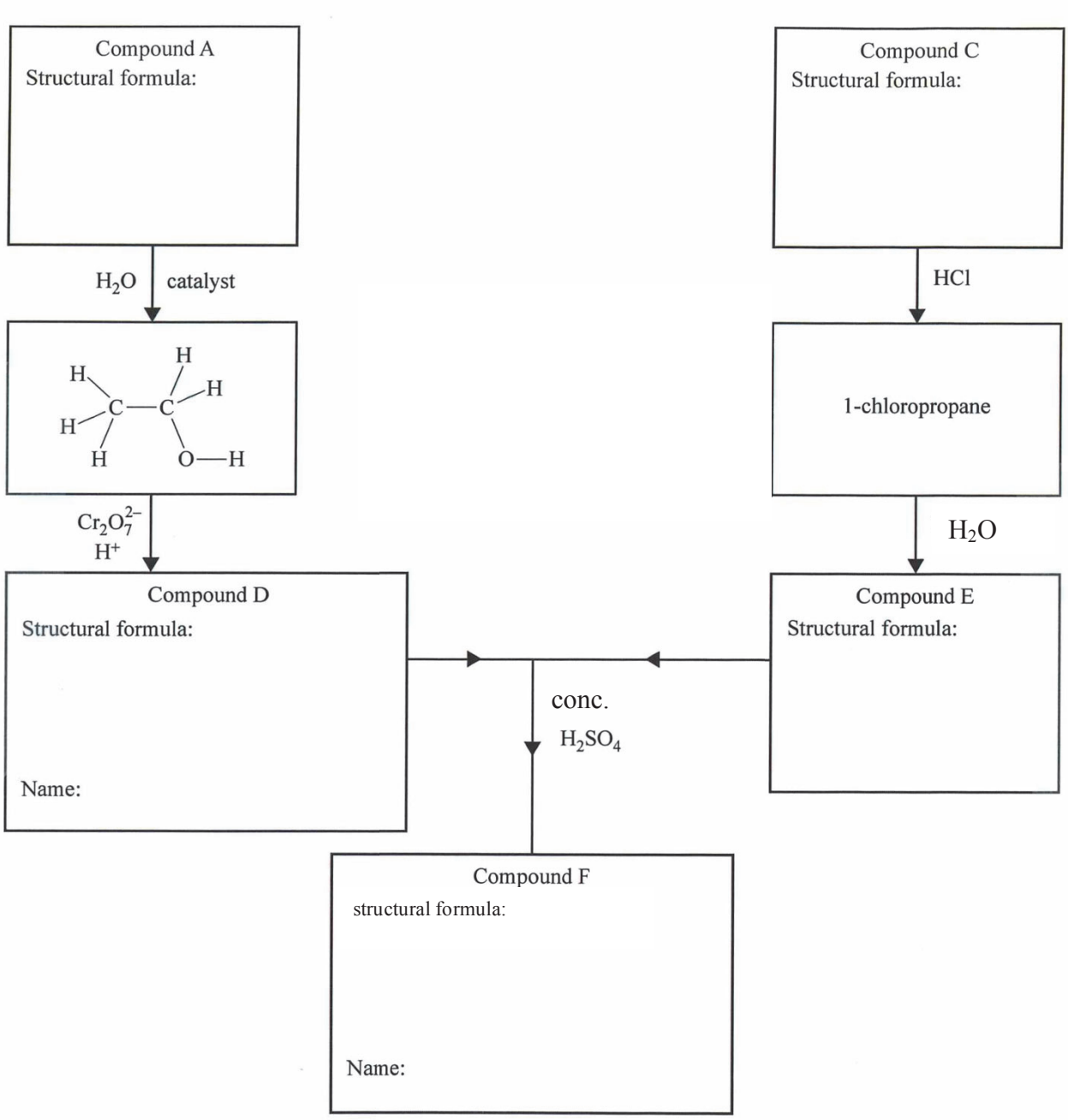
Student Number

Student Number

Question 27 (7 marks)

(a) Compound F may be synthesised as follows.



(a) Draw the structural formulas of Compounds A, C, D and E in the boxes provided. **4**

(b) Write the systematic **name** of Compound D in the appropriate box. **1**

(c) Insert the structural formula and systematic name of Compound F in the box provided. **2**

Student Number

Question 28 (7 marks)

(a) Draw the structural formula of the following compounds.

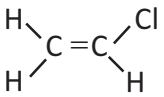
(i) 3-ethyl-2,3-dimethylhexane **1**

(ii) 4-methylpent-2-yne **1**

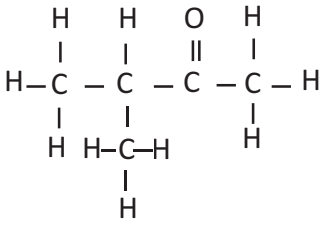
(iii) propanal **1**

(b) Write the systematic name for the following compounds. **4**

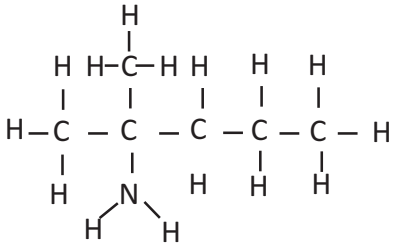
(i)



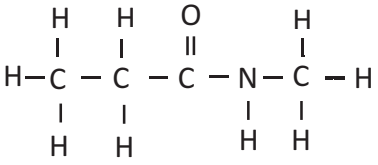
(ii)



(iii)



(iv)



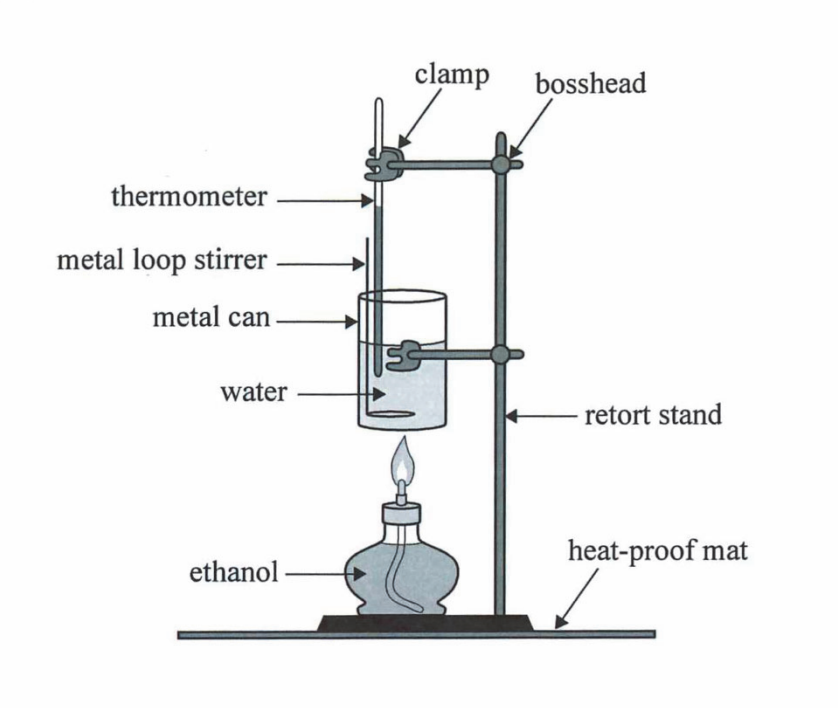
Student Number

Question 29 (5 marks)

The enthalpy for the combustion of ethanol is 1367 kJ.mol^{-1}. This combustion of ethanol is represented by the following equation.

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

A spirit burner used 1.80 g of ethanol raise the temperature of 100.0 g of water in a metal can from 25.0 °C to 40.0 °C.



Calculate the percentage of heat lost to the environment and to the apparatus. **5**

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Student Number

Question 30 (7 marks)

A 2% solution of glycolic acid (2-hydroxyethanoic acid), $CH_2(OH)COOH$, is used in some skincare products.

(a) Draw the structural formula of glycolic acid. **1**

(b) The equation for the ionisation of glycolic acid is

$$CH_2(OH)COOH_{(aq)} + H_2O_{(l)} \quad CH_2(OH)COO^-_{(aq)} + H_3O^+_{(aq)} \quad K_a = 1.48 \times 10^{-4}$$

Sodium glycolate, $CH_2(OH)COONa$, is a soluble salt of glycolic acid.

How does the pH of a solution of glycolic acid change when some solid sodium glycolate is dissolved in the solution ? Justify your answer. **2**

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(c) The solubility of glycolic acid is 1.0×10^6 mg per litre at 25°C.

Calculate the concentration, in mol L^{-1}, of a saturated solution of glycolic acid. The molar mass of glycolic acid is 76 g mol^{-1}. **1**

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Question 30 continues on page 27

Student Number

Question 30 (continued)

(d) 100 mL of the saturated solution of glycolic acid is spilt onto the floor.

What is the minimum mass of sodium carbonate that should be used to neutralise the spill? **2**

The equation for this reaction is shown below.

$$Na_2CO_{3(s)} + 2CH_2(OH)COOH_{(aq)} \rightarrow 2CH_2(OH)COONa_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

$\left(M(Na_2CO_3) = 106 \text{ g mol}^{-1}\right)$

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(e) The Material Safety Data Sheets (MSDS) for a concentrated solution of glycolic acid states that it is corrosive to the eyes, skin and respiratory system, and that is harmful if a concentrated solution of it is ingested or inhaled.

Outline ONE safety precaution, (other than lab coat or safety glasses) that should be taken when handling this compound. **1**

……

End of Question 30

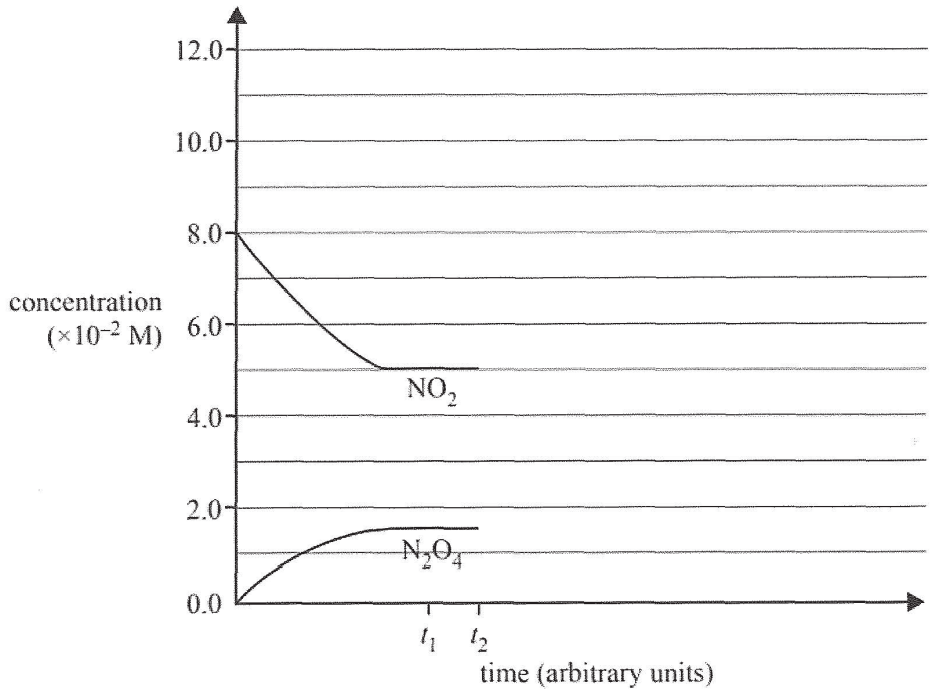
Student Number

Question 31 (4 marks)

Dinitrogen tetroxide can decompose into nitrogen dioxide according to the following equation:

$$N_2O_{4(g)} \qquad 2NO_{2(g)}$$

Below is the concentration versus time graph for the reaction system. The graph was produced using secondary data at a temperature 22°C.



(i) Time t_1 is shown on the graph above.

Calculate the equilibrium constant at time t_1.

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(ii) At time t_2 the volume of the system was halved, keeping the temperature at 22°C.

Continue the graph to show how this change would affect the reaction system and how the system would respond to this change until equilibrium is restored.

Student Number

Question 32 (5 marks)

A student investigated the effect of different catalysts on the molar enthalpy of the decomposition reaction of hydrogen peroxide. The student's report is provided below.

Report – Effect of different catalysts on the enthalpy of a reaction

Background:
Different catalysts, such as manganese dioxide, MnO_2, and iron(III) nitrate solution, $Fe(NO_3)_3$, will increase the rate of decomposition of hydrogen peroxide.

$$2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$$

Purpose:
This experiment investigated the effect of using different catalysts on the molar enthalpy of the decomposition of hydrogen peroxide.

Procedure:
The temperature change was measured when MnO_2 catalyst was added to a volume of hydrogen peroxide in a beaker. The procedure was repeated using $Fe(NO_3)_3$ solution as a catalyst.

Results:

	Trial 1	*Trial 2*
Volume H_2O_2	100 mL	200 mL
Concentration H_2O_2	2.0 M	4.0 M
Catalyst	0.5 g MnO_2	50 mL 0.1M $Fe(NO_3)_3$
Temperature change °C	3.0	10.1

Conclusion:
The change in temperature using the $Fe(NO_3)_3$ catalyst was greater than the change in temperature using the MnO_2 catalyst. This demonstrates that the molar enthalpy for the decomposition reaction depends on the catalyst used.

Question 32 continues on page 30

Student Number

Question 32 (continued)

The student's conclusion is not valid because the experimental design is flawed.

Critically review the student's experimental design. In your response, you should:

- identify and explain THREE improvements or modifications that you would make to the experimental design
- discuss the experimental outcomes you would expect regarding the effect of different catalysts on molar heats of reaction. Justify your expectations in terms of chemical ideas you have studied this year.

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End of Paper

Student Number

Section II Extra writing space
If you use this space, clearly indicate which question you are answering.

Student Number

2019 Chemistry Trial HSC Marking Guidelines and Feedback

Multiple choice

1	2	3	4	5	6	7	8	9	10
C	A	D	D	D	C	B	A	C	D

11	12	13	14	15	16	17	18	19	20
A	C	B	D	A	C	D	(B)	C	B

Question 21 (18 marks)

Ethanol, C_2H_5OH, is made industrially by either of two methods:

- One method uses ethylene, C_2H_4, which is derived from crude oil.
- The other method uses a carbohydrate such as sucrose, $C_{12}H_{22}O_{11}$, and yeast, in aqueous solution.

The production of C_2H_5OH from $C_{12}H_{22}O_{11}$ and yeast proceeds according to the equation

$$C_{12}H_{22}O_{11}\ (aq) + H_2O\ (l) \rightarrow 4C_2H_5OH\ (aq) + 4CO_2\ (g)$$

(a) Determine the mass, in grams, of pure C_2H_5OH that could be produced from 1.250 kg of $C_{12}H_{22}O_{11}$ dissolved in water. **2**

$n = \frac{m}{M_w} = 1250\,g / (12(12.01)+22(1.008)+11(16.00)) = 3.651810129\ mol$ (1)

(1 : 4 mol ratio) $\therefore n_{C_2H_5OH} = 4 \times 3.65....mol = 14.60724052\ mol$

$mass = n \times M_w \therefore 14.607... \times (2(12.01)+6(1.008)+16) = 672.9263561\,g$

$\therefore 672.9\,g$ — (1)

(b) Describe how ethanol can be formed from ethylene. Include an equation in your response and classify this type of reaction. **2**

(1) Ethanol can be formed from ethylene via a HYDRATION reaction with water and dilute H_2SO_4 catalyst.

$C_2H_{4(g)} + H_2O_{(l)} \xrightarrow[H_2SO_4]{dil.} C_2H_5OH_{(l)}$ — (1)

−1 for not including reaction condition (i.e dil. H_2SO_4 catalyst)

Question 21 continues on page 13

Question 21 (continued)

Student Number

(c) Ethanol can be converted into ethanoic acid. **2**

- Identify the reagent required to bring about this reaction.
- Outline what you would observe as the reaction occurs.
- Classify this type of reaction.

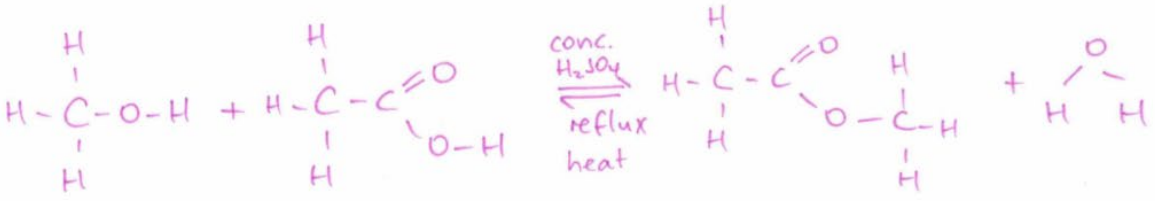
(1) (1) - must specify colour change

- Ethanol (1° alcohol) can be OXIDISED into ethanoic acid (via oxidation of the aldehyde, ethanal).
- oxidising agent e.g. dichromate ($Cr_2O_7^{2-}$) or permanganate (MnO_4^-)
- Colour change $Cr_2O_7^{2-}$ (orange) → Cr^{3+} (green)
  MnO_4^- (purple) → Mn^{2+} (clear, colourless)
- Oxidation of alcohol reaction.

(d) Ethanoic acid can be used in the manufacture of the ester, methyl ethanoate. **2**

Write a balanced equation for the reaction to form the ester, using structural formulae for the organic compounds.

methanol + ethanoic acid $\underset{\text{reflux}}{\overset{\text{conc. } H_2SO_4}{\rightleftharpoons}}$ methyl ethanoate + water



(1) correct structural formula/ equation

(1) reaction cond. (reflux or heat not necessary)

Question 21 continues on page 14

Q21 f) The boiling points and molar masses of three compounds are shown:

Compound	Boiling Point (°C)	Molar mass (g/mol)
Acetic acid	118	60
Butan-1-ol	117	74
Butyl acetate	116	116

Discuss why Acetic acid, butan-1-ol and butyl acetate have very similar boiling points but different molar masses.

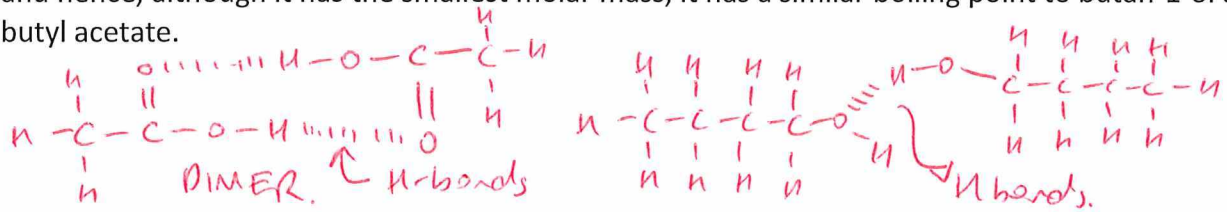
Criteria:

1 mark – State the regular expectation that larger molar mass leads to higher boiling point. Rest of the question goes on to explain why this is not the case in this situation.
1 mark – explain the bonding for acetic acid – hydrogen and dipole dipole (or two hydrogen bonds with acid forming dimers) meaning high energy to separate.
1 mark - explain the bonding for alcohol – hydrogen bonding, with larger molecular weight providing dispersion forces to make up for no additional dipole-dipole bonding.
1 mark - explain the bonding for ester – only dipole-dipole at the C=O, with larger molecular weight providing dispersion forces to make up for no additional hydrogen bonding.
1 mark – must have provided diagrams for all three molecules to get the full 5 marks (and shown all Hs)

Model answer

In comparing acetic acid, butan-1-ol and butyl acetate, the different molecular weights do not explain why these compounds have very similar boiling points. In general, the larger the molecular weight, the stronger the dispersion forces. It is the additional intermolecular forces in each substance which explain the similarity in boiling points.

Acetic acid contains a carboxylic acid functional group. This can form hydrogen bonds between molecules and in fact, dimers form where two hydrogen bonds exist between acetic acid molecules. This means that acetic acid has the strongest intermolecular forces between molecules and hence, although it has the smallest molar mass, it has a similar boiling point to butan-1-ol and butyl acetate.



Butan-1-ol contain the alcohol functional group. This means that butan-1-ol is capable of forming hydrogen bonds between molecules, however these are weaker than for acetic acid as the dimer structure does not exist. Butan-1-ol has a longer carbon chain and hence stronger dispersion forces between molecules, which makes the boiling point similar to acetic acid.

Butyl acetate is a polar molecule, as it contains the ester functional group. Thus molecule is capable of forming dipole-dipole forces between molecules but cannot form hydrogen bonds. These forces are weaker than the forces between acetic acid and 1-butanol molecules, but this ester has a larger molecular weight, and hence the relatively stronger dispersion forces means that the boiling point is very similar to acetic acid and butan-1-ol.

Q21 e) Discuss the method used in the laboratory preparation of esters and their separation from other species present in the reaction mixture.

Criteria:

1 mark – reflux required as esterification very slow at room temp therefore need to use sulfuric acid catalyst and high temps.
1 mark – reflux apparatus allows higher temps to be used whilst preventing volatile reactants and products from escaping.
1 mark – add some water to reaction mixture and use a separating funnel to separate the two resulting layers, with explanation of what is in each layer.
1 mark – add a base to neutralise any remaining acid (both catalyst and carboxylic acids), with explanation of how things move from organic to water layer for removal
1 mark – final distillation of ester to separate from any possible long chain alcohols.

Model answer

Esterification is slow at room temperature and hence sulfuric acid is required as a catalyst to increase the rate of the reaction, by decreasing the activation energy. Additionally, the reaction mixture should be heated to boiling to increase the rate of the reaction further. As the reaction mixture contains volatile reactants and products (alcohol, carboxylic acid and ester), a reflux apparatus is required as this allows the vapours to recondense back into the reaction flask, avoiding loss of reactants and products.

Once the reaction is complete, the reaction mixture is poured onto a saturated solution of sodium carbonate in a separating funnel. This creates two layers where the more dense aqueous layer sits below the organic layer. The sodium carbonate will neutralise both the sulfuric acid and the carboxylic acid, and the resulting salts will dissolve in the water layer. The ester, being polar but unable to form H-bonds with water will be insoluble in water and will be in the organic layer. Depending on the carbon chain length of the alcohol, this will either be water soluble or organic soluble, or appear in both layers. Short chain alcohols (methanol, ethanol) are soluble in water as they can form H-bonds with water molecules, however, longer chain alcohols will be less water soluble as they become more non-polar.

After separation of the two layers, the resulting ester may need further purification by distillation to remove any residual alcohol in the organic layer.

3	1	0	4	4	6	1

Student Number

Question 22 (8 marks)

Sulfur trioxide, SO_3, is made by the reaction of sulfur dioxide, SO_2, and oxygen, O_2, in the presence of a catalyst.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \quad \Delta H < 0$$

In a closed system in the presence of a catalyst, the reaction quickly reaches equilibrium at 1000 K.

(a) A mixture of 2.00 mol of $SO_2(g)$ and 2.00 mol of $O_2(g)$ was placed in a 4.00 L evacuated, sealed vessel and kept at 1000 K until equilibrium was achieved. At equilibrium, the vessel was found to contain 1.66 mol of $SO_3(g)$. 3

Calculate the equilibrium constant for the above equilibrium at 1000 K.

$K_{eq} = \dfrac{[SO_3]^2}{[SO_2]^2 \times [O_2]}$

	$2SO_{2(g)}$	+ $O_{2(g)}$	$\rightleftharpoons$ $2SO_{3(g)}$
R			
I	2.00 mol	2.00 mol	0
C	−1.66	−0.83	+1.66
E	$\frac{0.34\text{ mol}}{4}$ =	$\frac{1.17\text{ mol}}{4}$ =	$\frac{1.66\text{ mol}}{4}$ =
Conc.	0.085M	0.2925M	0.415M

$K_{eq} = \dfrac{0.415^2}{0.085^2 \times 0.2925}$

$= 81.49528$

$= 81.5$

(b) The manufacturer wanted to increase the yield of sulfur trioxide. What changes, if any, should be made in terms of the catalyst used, the temperature and the volume of the container? Justify your answer. 3

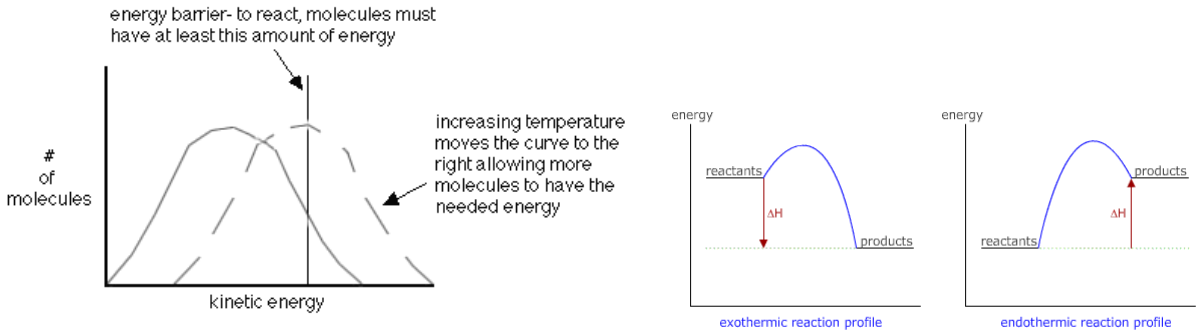
Changing the catalyst will have no effect on the yield of sulfur trioxide. To increase yield of sulfur trioxide the temperature of the system should be decreased to shift the equilibrium to favour the exothermic forward direction, hence increasing % SO_3 yield. Decreasing the volume of the reaction vessel will increase pressure and ∴ favour the production of sulfur trioxide due to the molar ratio of 3 : 2.

Question 22 continues on page 17

Q22c) Explain, in terms of collision theory, why an increase in temperature of an equilibrium system always favours the endothermic reaction. (2 marks)

Model answer:

Collision theory states that particles must collide with sufficient energy and in the correct orientation to overcome the activation energy barrier. When temperature is increased, the particles gain kinetic energy. For a chemical reaction, the activation energy barrier for the endothermic reaction is always greater than for the exothermic reaction. Hence, an increase in temperature will affect the percentage of particles able to overcome the endothermic activation energy barrier more than for the exothermic reaction. This will cause the equilibrium to shift in the endothermic direction when temperature is increased.



Q22 a)

1 mark - for stating ratio of demonstration application of ratio to amount of moles OTHER than just completing a rice table.

1 mark – correct calculations of equilibrium amounts

1 mark – correct expression and answer.

Q22 b)

1 mark – catalyst no change to yield

1 mark – decrease temp to move to right, exothermic direction, according to LCP

1 mark – decrease volume to move to right, less moles of gas, according to LCP

Q22 c)

Must mention activation energy to get even 1 mark.

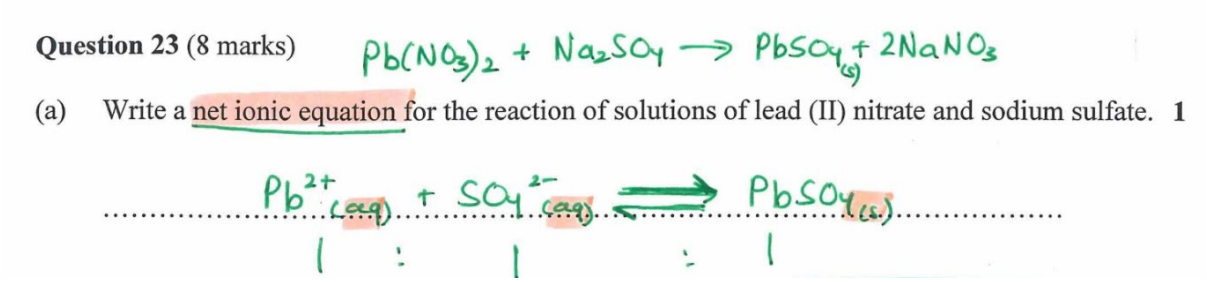
For two marks must discuss the increase in the percentage of molecules achieving Ea being greater for endo than exothermic reactions.

Many students just spoke about heat being a reactant for endo reactions so increasing temp move a reaction in endo direction according to LCP.

Q23.a

Criteria	Mark
Correct NET IONIC equation including states of matter	1

Sample answer:

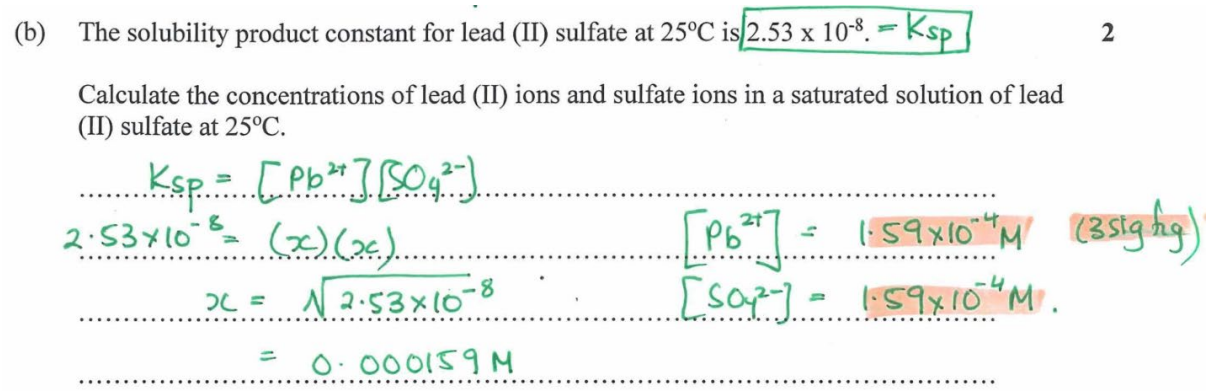


Feedback: Sadly, I could count the number of students that scored a mark on one hand. Many students did not read the question carefully and wrote a neutral species equation or a full ionic equation. Many students did not include states of matter which was required to receive the full mark.

Q23. b

Criteria	Mark
• Provides correct Ksp expression • Correctly calculates concentration of Pb2+ and SO42-, including units of measure.	2
1 of the above	1

Sample answer:



Feedback: Generally, very well answered by students. Many however lost marks for not including units of measure or just stating the value of 'x' without acknowledging was 'x' actually was referring to. Whilst no marks deducted for it in this case, I would advise students to go to the trouble of explicitly stating each ion and its calculated concentration. If you did not include units of measure I took a mark off (sorry…..).

Q23. c

Criteria	Mark
• Correctly determines concentration of Pb2+ and SO42- • Correctly determines Qsp • Identifies no precipitate forming	3
2 of the above	2
1 of the above	1

Sample answer:

(c) Would a precipitate of lead sulfate form if 50 mL of 2.0×10^{-4} mol/L sodium sulfate solution were added to 200 mL of a solution of 2.0×10^{-4} mol/L lead nitrate solution? Show all working. **3**

$n_{Na_2SO_4} = CV = (2.0 \times 10^{-4})(0.05) = 0.00001 mol = mol\ SO_4^{2-}$

$n_{Pb(NO_3)_2} = CV = (2.0 \times 10^{-4})(0.200) = 0.00004 mol = mol\ Pb^{2+}$

$C_{SO_4^{2-}} = \frac{n}{V} = \frac{0.00001}{0.250} = 0.00004 M$

$C_{Pb^{2+}} = \frac{n}{V} = \frac{0.00004}{0.250} = 0.00016 M$

$Qsp = [Pb^{2+}][SO_4^{2-}]$

$= (0.00016)(0.00004)$

$= 6.4 \times 10^{-9}$

$Qsp < Ksp \therefore$ no precipitate!

Feedback: Students were challenged by this question. Many were able to calculate the moles of SO42- and Pb2+ but did not go on to calculate the concentration of each ion. As such they incorrectly substituted number of moles, instead of concentration, into their Qsp expression. I allowed ECF for students that calculated an incorrect Qsp but could relate this to the given Ksp to determine if the reaction was spontaneous or not.

Q23. d

Criteria	Mark
• Correctly predicts the distribution of radioactive Pb^{2+} • Relates distribution of radioactive Pb^{2+} to an equilibrium between dissolution and recrystallisation/precipitation.	2
1 of the above	1

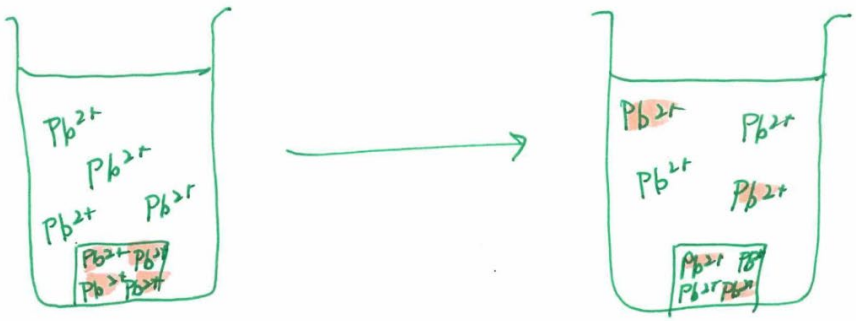
Sample answer:

Question 23 (continued)

(d) A lump of solid lead (II) sulfate, which contained radioactive lead ions, was added to a saturated solution of lead (II) sulfate and left to stand for several hours. Predict the distribution of the radioactive lead (II) ions after some hours and explain your prediction. **2**

$PbSO_{4(s)} \rightleftharpoons Pb^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$

A dynamic equilibrium exists in a saturated solution where the rate of the forward reaction (dissolution) is equal to the rate of the reverse reaction (recrystallisation). As such radioactive ions will be distributed both in solution (as they dissolve) and also in the solid (as they rejoin the crystal).



Pb^{2+}: Non-radioactive ions

Pb^{2+} : Radioactive ions

Feedback: A challenging question. Many incorrectly referred to the common ion effect, the decay of radioactive isotopes or Le Chatelier's Principle. A balanced chemical equation was not mandated in this marking scheme however better answers should have include this.

Q24. a

Criteria	Mark
• Correct equation including states of matter	1

Sample answer:

(a) Write an equation for the gaseous reaction between ammonia and hydrogen chloride. **1**

$NH_{3(g)} + HCl_{(g)} \longrightarrow NH_4Cl_{(s)}$

Feedback: Surprisingly this was the question where the overwhelming majority of students responded incorrectly. Students needed to recall the 'white smoke' example where gaseous HCl and NH3 travelled in a tube and formed the white solid, NH_4Cl at the interface (i.e. the white smoke). The majority of students either gave ions as products or incorrectly stated the state of NH_4Cl as a gas. This is an example of a static equilibrium and so equilibrium arrows should not have been used.

Q24. b

Criteria	Mark
• Outlines how stated reaction does not meet Arrhenius definition • Outlines how stated reaction meets Bronsted-Lowry definition	2
Some relevant information	1

Sample answer:

(b) Explain why the reaction of ammonia and hydrogen chloride can be classed as an acid-base reaction by the Brønsted-Lowry theory, but not by the Arrhenius theory. **2**

Arrhenius: Acid in solution generates H^+; base in solution generates OH^-. Reaction is not in solution and NH_3 does not produce OH^-

Bronsted-Lowry: Acid is a proton donor, base is a proton acceptor. HCl donates a proton which is accepted by NH_3.

Feedback: I was quite generous in my marking of this question. Many students struggled to explain Arrhenius' acid base theory clearly. Whilst not included in this marking scheme, the question does refer to the reaction in part a and so students should be explicit in relating each of the acid base theories to that reaction (i.e. identify HCl as being a proton donor and NH_3 as a proton receiver etc). If NESA is wanting you to use data supplied, then ensure if a question involves any stimulus that you explicitly refer to it.

Q25. a

Criteria	Mark
• Identifies strongest acid • Correctly determines pKa	2
• Identifies strongest acid	1

Sample answer:

The table shows the acid dissociation constants at 25°C.

Phosphoric Acid	H_3PO_4	7.2×10^{-3}
Hydrofluoric Acid	HF	6.8×10^{-4}
Nitrous Acid	HNO_2	4.5×10^{-4}
Acetic Acid	CH_3COOH	1.8×10^{-5}
Ammonium ion	NH_4^+	5.6×10^{-10}
Water	H_2O	1.0×10^{-14}

← strongest acid.

← Ka NH_4^+

(a) Identify the strongest acid in the table and determine the pK_a value for this acid. **2**

H_3PO_4 : $K_a = 7.2 \times 10^{-3}$

$pKa = -\log 10(K_a)$

$= -\log_{10}(7.2 \times 10^{-3}) = 2.14.$

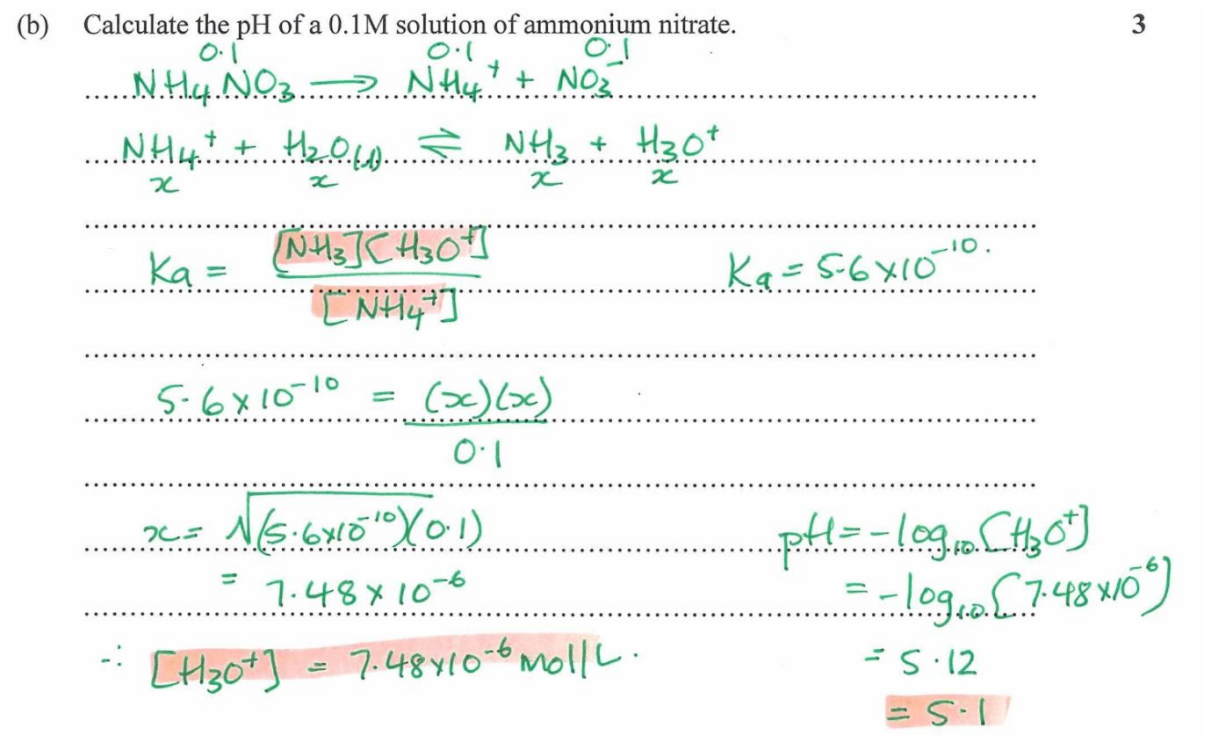
Feedback: Very well answered. Majority of students received full marks for this question. A few responded with very scant working. Please ensure you show FULL working.

Q25. b

Criteria	Mark
• Determines correct Ka expression • Correct calculation of [H3O+] • Correctly determines pH	3
2 of the above	2
1 of the above	1

Sample answer:

(b) Calculate the pH of a 0.1M solution of ammonium nitrate. **3**



Feedback: Another question that the vast majority of the cohort found challenging. Students were not able to recognise that NH_4NO_3 is a salt of a weak base and so is an acidic salt. When in water it ionises to produce NH_4+ which will donate a proton to the water and produce hydronium ions. There were about fifteen different variations on how students approached this question, with students using incorrect data from the table and substituting incorrect values to determine pOH and/or pH. Highly recommend a review of acidic and basic salts – not recognising this early in the question meant students were left floundering.

Question 26 (3 marks)

Aspirin is a weak monoprotic acid with a formula of $HC_9H_7O_4$. **3**

To determine the amount of aspirin in a headache tablet, a chemist ground up the tablet and dissolved it in 25.0 mL of 0.125 mol/L sodium hydroxide solution. After complete reaction, the excess sodium hydroxide was titrated with 0.0975 mol/L hydrochloric acid. 11.6 mL was required.

Calculate the mass of the aspirin in the headache tablet. Assume a 1:1 ratio of aspirin to base.

AMOUNT of $NaOH$ $n = cV$, $n = (0.125)(25.0 \times 10^{-3})$

INITAL $n_{NaOH} = 3.125 \times 10^{-3}$ mol. ✓

$NaOH + HCl \rightarrow NaCl + H_2O$

UNREACTED

$NaOH$ = moles of HCl titrated (1:1)

$= (0.0975)(11.6 \times 10^{-3})$

$= 1.131 \times 10^{-3}$ mol or 0.001131 mol.

∴ AMOUNT OF $NaOH$ reacted $= 3.125 \times 10^{-3} - 1.131 \times 10^{-3}$

$= 1.994 \times 10^{-3}$ mol ✓

As the reaction with ASPIRIN is 1:1

∴ 1.994×10^{-3} mol ASPIRIN

$m = n\,MM$ $\qquad MM_{HC_9H_7O_4}$

$= ?$ $\qquad MM = (1.008 \times 8) + (12.01 \times 9) + 16 \times 4$

$= (1.994 \times 10^{-3})(180.154)$ $\qquad = 180.154\ g.mol^{-1}$

$m = 0.359\ g$ of ASPIRIN. ✓

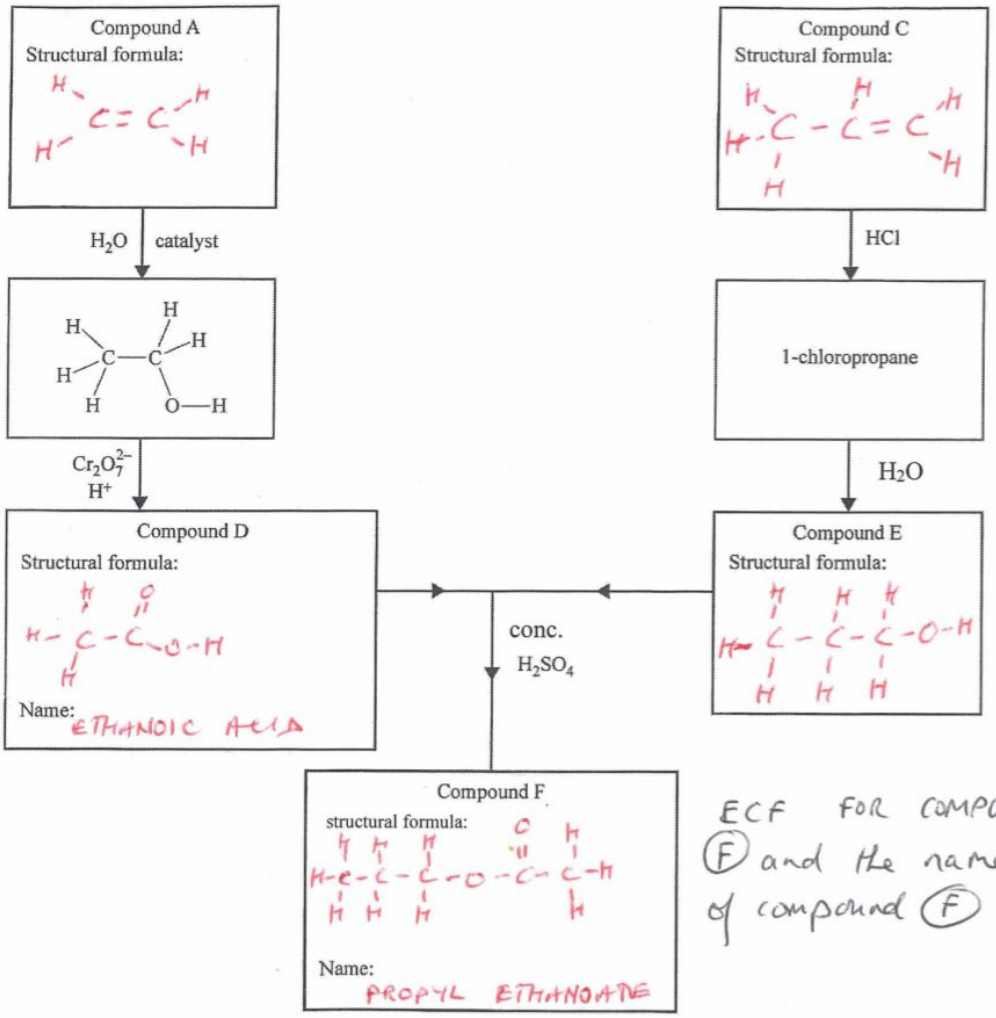
$HC_9H_7O_4 + NaOH \rightarrow NaC_9H_7O_4 + H_2O$

If they got the 0.359g out and had some relevant working out they got the 3 marks. Many FORGET UNITS like mol. They should always INCLUDE FORMULA ($n = cV$) and EQUATIONS.

Student Number

Question 27 (7 marks)

(a) Compound F may be synthesised as follows.



ECF FOR COMPOUNDS (F) and the name of compound (F)

(a) Draw the structural formulas of Compounds A, C, D and E in the boxes provided. **4**

(b) Write the systematic **name** of Compound D in the appropriate box. **1**

(c) Insert the structural formula and systematic name of Compound F in the box provided. **2**

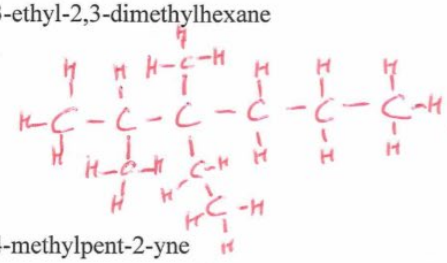
Remind students to SHOW the BOND in the HYDROXYL GROUP. If missing more than once they were penalised.

Student Number

Question 28 (7 marks)

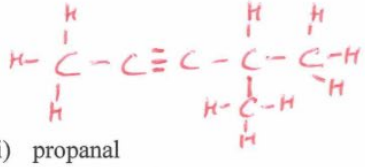
(a) Draw the structural formula of the following compounds.

(i) 3-ethyl-2,3-dimethylhexane **1**

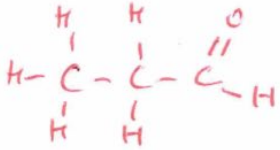


STUDENTS NEED TO SHOW ALL THE H's

(ii) 4-methylpent-2-yne **1**

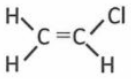


(iii) propanal **1**



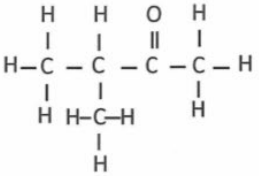
(b) Write the systematic name for the following compounds. **4**

(i)



CHLOROETHENE

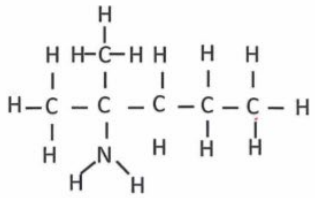
(ii)



~~But~~methylbutan-2-one

or 3-methylbutan-2-one

(iii)

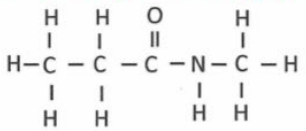


~~2-methylpentan-2-amine~~

2-methylpentan-2-amine

2-methyl-2-pentanamine

(iv)



N-methylpropanamide

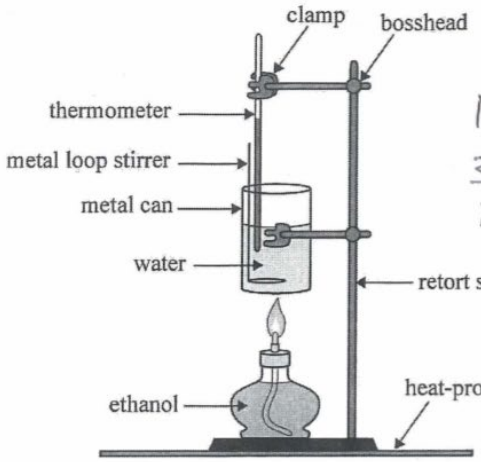
N-methylpropan-1-amide

Question 29 (5 marks)

The enthalpy for the combustion of ethanol is 1367 kJ.mol^{-1}. This combustion of ethanol is represented by the following equation.

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

A spirit burner used 1.80 g of ethanol raise the temperature of 100.0 g of water in a metal can from 25.0 °C to 40.0 °C.



NEEDED ANSWER TO 3 SIG. FIGS.
NEEDED RELEVANT WORKING OUT.
UNITS MISSING.

Calculate the percentage of heat lost to the environment and to the apparatus. **5**

$\Delta H = 1367\ kJ.mol^{-1}$, $MM_{C_2H_5OH} = 46.068\ g.mol^{-1}$

$q = mc\Delta T$

$q = (100)(4.18)(15)$

$q = 6270\ J$ ✓

$n_{C_2H_5OH} = \frac{m}{MM} = \frac{1.80}{46.068}$ ✓

$= 0.0390726\ mol$

THEORETICAL HEAT TRANSFERED

$\Delta H = \frac{q}{n}$, $q = (1367000)(0.0390726..)$

$q = 53412\ J$ ✓

OR $\Delta H = \frac{6270}{0.0390726..}$

$\Delta H = 160.47\ kJ.mol$

$\frac{160.47}{136.7} \times 100 = 11.7\%$

% heat transfered $= \frac{6270}{53412} \times 100$

$= 11.7\%$ ∴ heat lost $100 - 11.7\%$

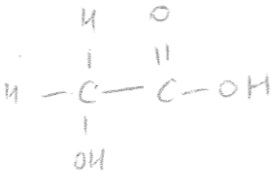
$= 88.3\%$ ✓

−1 SIG FIGS

Question 30 (7 marks)

A 2% solution of glycolic acid (2-hydroxyethanoic acid), $CH_2(OH)COOH$, is used in some skincare products.

(a) Draw the structural formula of glycolic acid. **1**



1 = correct structure

0 = one or more errors.

(b) The equation for the ionisation of glycolic acid is

$$CH_2(OH)COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_2(OH)COO^-_{(aq)} + H_3O^+_{(aq)} \quad K_a = 1.48\times10^{-4}$$

Sodium glycolate, $CH_2(OH)COONa$, is a soluble salt of glycolic acid.

How does the pH of a solution of glycolic acid change when some solid sodium glycolate is dissolved in the solution ? Justify your answer. **2**

2 - explain + justify
1 - some correct info

The pH of the solution would increase as conc. of H_3O^+ ions decreases. This is due to LCP, as additional glycolate ion will cause the equilibrium to shift to the reactant side, decreasing $[H_3O^+]$.

(c) The solubility of glycolic acid is 1.0×10^6 mg per litre at 25°C.

Calculate the concentration, in mol L^{-1}, of a saturated solution of glycolic acid. The molar mass of glycolic acid is 76 g mol^{-1}. **1**

1.0×10^6 mg/L = 1.0×10^3 g/L.

$n = \frac{m}{M}$ $n = \frac{1.0\times10^3}{76} = 13.16$ mol

$= 13$ mol/L.

1 = correct working

0 = incorrect

Question 30 (continued)

(d) 100 mL of the saturated solution of glycolic acid is spilt onto the floor.

What is the minimum mass of sodium carbonate that should be used to neutralise the spill? **2**

The equation for this reaction is shown below.

$$Na_2CO_{3(s)} + 2CH_2(OH)COOH_{(aq)} \rightarrow 2CH_2(OH)COONa_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

$(M(Na_2CO_3) = 106 \text{ g mol}^{-1})$

100mL of solution, $c = 13 \text{ mol/L}$. $n = cV$, $n = (13)(0.1)$

$n = 1.3 \text{ mol of acid.}$

acid : Na_2CO_3 = 2 : 1 ratio $\therefore n(Na_2CO_3) = 1.3 \div 2.$

$= 0.65 \text{ mol}$

$m = nM$, $m = (0.65)(2 \times 22.99 + 12.01 + 3 \times 16)$

$m = \cancel{54 \text{ g}}$ 68.9 g

(e) The Material Safety Data Sheets (MSDS) for a concentrated solution of glycolic acid states that it is corrosive to the eyes, skin and respiratory system, and that is harmful if a concentrated solution of it is ingested or inhaled.

Outline ONE safety precaution, (other than lab coat or safety glasses) that should be taken when handling this compound. **1**

use a fume hood

Additional notes:

- I did give error carried forward for Q30 d from part c.
- Q30 e, most got this mark. Student's did not get the mark if they suggested using a 'fume box' or some other incorrect word for a fume cupboard or fume hood. Others lost the mark for suggesting something which I thought would be very far down the list of reasonable safety precautions, e.g. 'ensure the lid is on the bottle when it isn't being used' or 'use a gas mask'.

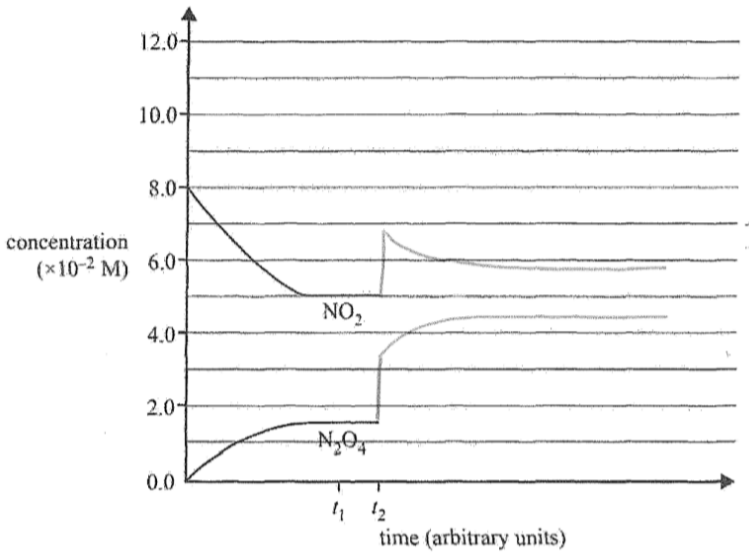
Question 31 (4 marks)

Student Number

Dinitrogen tetroxide can decompose into nitrogen dioxide according to the following equation:

$$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$$

Below is the concentration versus time graph for the reaction system. The graph was produced using secondary data at a temperature 22°C.



2 - spike and changes are correct

1 - spike or changes are correct.

(i) Time t_1 is shown on the graph above. (2)

Calculate the equilibrium constant at time t_1.

$K = \frac{[NO_2]^2}{[N_2O_4]}$ 2 - correct K expression and substitution

$K = \frac{(5)^2 \times 10^{-4}}{(1.5) \times 10^{-2}}$ 1 - 2 correct substitution

$K = 0.17$ 0 - K expression

(ii) At time t_2 the volume of the system was halved, keeping the temperature at 22°C.

Continue the graph to show how this change would affect the reaction system and how the system would respond to this change until equilibrium is restored. (2)

Question 32 Trial Exam 2019

Criteria	Marks
• Clear critical review of the student's experiment with specific examples • Explains at least three key modifications which would significantly improve the experimental design	5

• Accurate and detailed discussion of expected experimental outcomes	
• Explains at least two modifications which would improve the experimental design • Accurate and detailed discussion of expected experimental outcomes	4
• Explains one or two modifications which would improve the experimental design • Discusses the expected experimental outcome including at least one correct prediction	3
• Discusses one or two reasonable modifications OR Discusses one reasonable modification and a correct experimental outcome.	2
• Provides some relevant information	1

Suggested answer:

The student's conclusion is invalid because the experimental design is flawed. In the student's experiment, the independent variable is the type of catalyst and the dependant variable is the temperature change. All other variables should be controlled to ensure that this experiment is a fair test and the student has not done this.

Firstly, I would ensure that the concentration and volume of H_2O_2 and hence the moles of H_2O_2 are the same for each experiment. As concentration effects the rate of a reaction, this must be constant between the two experiments. In this experiment, the student has differing concentrations and volumes between trial 1 and trial 2. This means that more than one variable is effecting the temperature change and hence the experiment is invalid.

Secondly, there is no repetition applied to this experiment meaning that the reliability of the results cannot be determined. Even though the experiment is invalid, each trial should be repeated a minimum of three times to ensure reliability of the data.

Thirdly, the mole percentage of each catalyst to H_2O_2 should be the same to effectively compare these reactions. In this experiment, the final concentration of the catalyst is different as one is added as a solid and the other as a solution and both are added in different quantities. I would ensure that the final concentration of each catalyst is the same in each experiment, independent of what the catalyst is.

Additionally, the reactions are carried out in a beaker. Glass is not an insulating material and hence there will be significant heat loss to the surroundings. The temperature change will therefore be inaccurate and lead to an inaccurate calculated value for the enthalpy change. Instead, the student should have used a more insulating material, such as a polystyrene cup calorimeter to minimise this source of error and increase the accuracy of the experiment.

The student's experiment is not answering the aim, which is to compare the molar heat of combustion using different catalysts. The results table displays temperature change but there is no indication of whether this is a positive or negative temperature change. In addition, there are no calculations given for the quantity of heat (Q) and the experimental enthalpy of decomposition. Hence, no conclusion can be made about the difference in enthalpy values.

Theoretically, I would expect the enthalpy change to remain the same independent of the catalyst added. An effective catalyst will increase the reaction rate by decreasing the activation energy. This does not affect the enthalpy change of the reaction which will remain the same, independent of the reaction pathway between reactants and products. If this experiment was carried out as a fair test, the experimental values should be very close to each other. The values may be different due to experimental error but if all variables are controlled and sources of error are minimised then the results should be consistent between the two trials. I would expect the experimental values to be lower than the theoretical values because this method of measuring enthalpy change is inaccurate. Significant heat loss to the surroundings is likely to occur, resulting in experimental values which are lower than expected. Despite this, if the experiment is reliable then a valid comparison between the two catalysts should be possible.

3	1	0	4	4	7

Student Number

Question 32 (continued)

The student's conclusion is not valid because the experimental design is flawed.

Critically review the student's experimental design. In your response, you should:

- identify and explain THREE improvements or modifications that you would make to the experimental design
- discuss the experimental outcomes you would expect regarding the effect of different catalysts on molar heats of reaction. Justify your expectations in terms of chemical ideas you have studied this year.

Improvements / modifications

① The student conducted the experiment in a beaker, this allows a lot of the heat to escape into the surroundings. Instead the student should use ideally a bomb calorimeter or at least a well insulated container such as a styrofoam cup.

② The student used different amounts of H_2O_2 in the reaction with MnO_2 and $Fe(NO_3)_3$. With the MnO_2, $0.1 \times 2 = 0.2$ mol of H_2O_2 was used, whilst with the $Fe(NO_3)_3$, $0.2 \times 4 = 0.8$ mol of H_2O_2 was used. Additionally, different amounts of each catalyst were used, with the MnO_2 listed in grams and the $Fe(NO_3)_3$ in mL, making comprehension of the report difficult for any readers.

③ The student did not use any repetition in order to check the reliability of the results. Since there is a large amount of error associated with the experiment such as heat lost to surroundings, the student should take multiple readings and then average them. These experimental values can then be compared to literature values to check the accuracy of the experiment.

End of Paper

3	1	0	4	4	7	1	5

Student Number

Section II Extra writing space
If you use this space, clearly indicate which question you are answering.

(32) A catalyst works by lowering the activation energy to increase the rate of the reaction. Since enthalpy is the energy change due to the bonds being broken and/or formed, different catalysts should not affect the final change in enthalpy. Based off Hess' Law, the reaction pathway does not ~~matter~~ affect the resulting enthalpy change. However, in this experiment, the enthalpy is being measured using $\Delta H = \frac{-q}{n}$ where $q = mc\Delta T$, and the change in temp is measured. In an ideal calorimeter, the rate at which the temperature increases is irrelevant as no energy is being lost. However, in an experiment, since heat is being lost, a catalyst which causes the reaction to occur very quickly, before much heat can be lost, would register a greater change in temperature than a less effective catalyst. Therefore, whilst in theory the enthalpy should be the same, in an experiment it is likely that a more effective catalyst would register as causing a greater molar enthalpy.

5