
Student Number

NORTH SYDNEY GIRLS HIGH SCHOOL

2020

Higher School Certificate
Trial Examination

Chemistry

Total Marks – 100

General Instructions

- Reading Time – 5 minutes
- Working Time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet, data sheet and Periodic Table are provided
- Write your student number at the top of this booklet and on the multiple choice answer sheet.

Section I

20 Marks

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

Section II

80 Marks

- Attempt question 21 – 37
- Allow about 2 hours and 25 minutes for this part

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

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

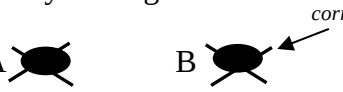
Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

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 ○

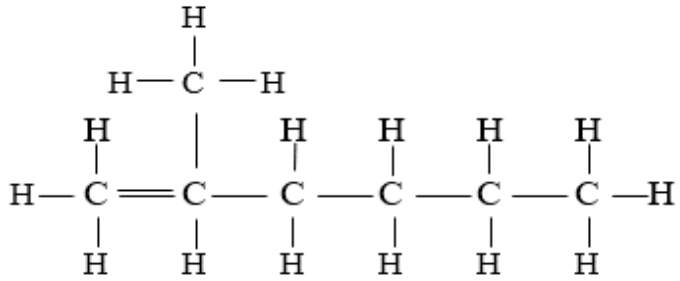
If you have changed your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows:



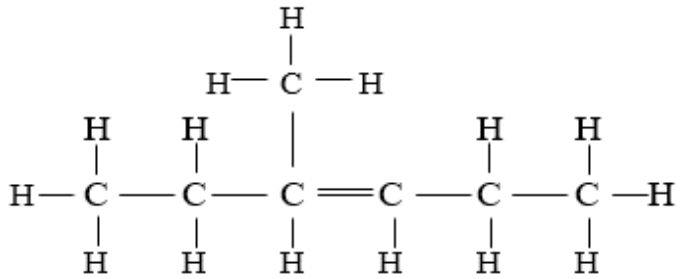
A ⊗ B ⊗ C ○ D ○

1. Which of the following structural formula for a hydrocarbon is correctly shown?

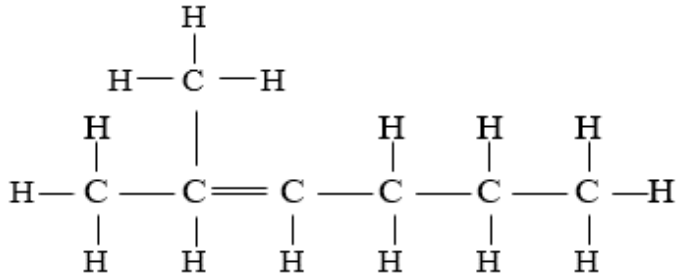
(A)



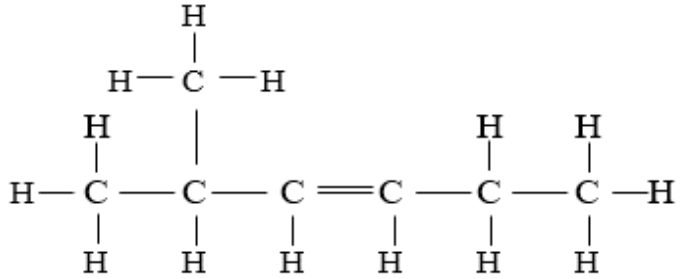
(B)



(C)



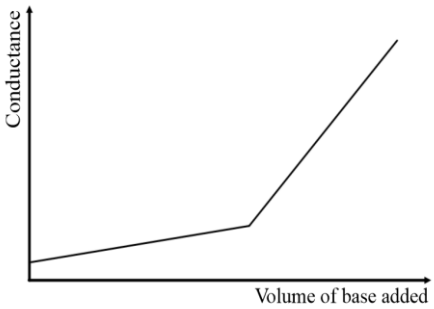
(D)



2. Which of the following conditions are required for a system to be in dynamic equilibrium?

	System	Forward rate of reaction
A.	Open	No longer occurring
B.	Open	Equal to the reverse rate of reaction
C.	Closed	No longer occurring
D.	Closed	Equal to the reverse rate of reaction

3. The following graph shows the conductivity curve for a titration as base is added.



Identify the type of titration which was carried out.

A. Strong Acid / Weak Base
B. Strong Acid / Strong Base
C. Weak Acid / Weak Base
D. Weak Acid / Strong Base

4. Which of the following formulae describes a ketone?

A. $CH_3(CH_2)_3CHO$
B. $CH_3CH_2COCH_3$
C. $CH_3CHOHCH_3$
D. CH_3COOCH_3

5. Acid X is 0.10 $molL^{-1}$ hydrochloric acid.
Acid Y is 0.10 $molL^{-1}$ acetic acid.

Each acid was titrated with 25 mL of a 0.10 $molL^{-1}$ sodium hydroxide solution.
Which of the following statements is correct?

A. More than 25mL of Y is needed to need to achieve the equivalence point in this titration.
B. 25mL of Y is needed to need to achieve the equivalence point in this titration.
C. Less than 25mL of Y is needed to need to achieve the equivalence point in this titration.
D. Less than 25mL of X is needed to need to achieve the equivalence point in this titration.

6. The diagram represents a test-tube containing a saturated solution of sodium chloride, with some crystals of sodium chloride at the bottom of the tube.

A few drops of concentrated hydrochloric acid are added to the solution. Which of the following would be observed?

A. bubbles of gas form
B. more precipitate is formed
C. some of the sodium chloride crystals dissolve
D. a change in the colour of the crystals

7. 0.1 $molL^{-1}$ solutions of various bases are made. Which number indicates the pH of the weakest base according to Arrhenius?

A. 12
B. 9
C. 7
D. 5

8. 25.0 mL of a 0.100 $molL^{-1}$ solution of HCl is added to 25.0 mL of a 0.180 $molL^{-1}$ solution of NaOH. What is the concentration (in $molL^{-1}$) of $OH^-(aq)$ remaining in the solution?

A. 0.0200
B. 0.0400
C. 0.0500
D. 0.0800

9. A student has a list of acids and is asked to classify them as organic or non-organic.

The list of acids to classify is: HCl, H_2SO_4, CH_3CH_2COOH, HCN, HOOCH, H_2CO_3

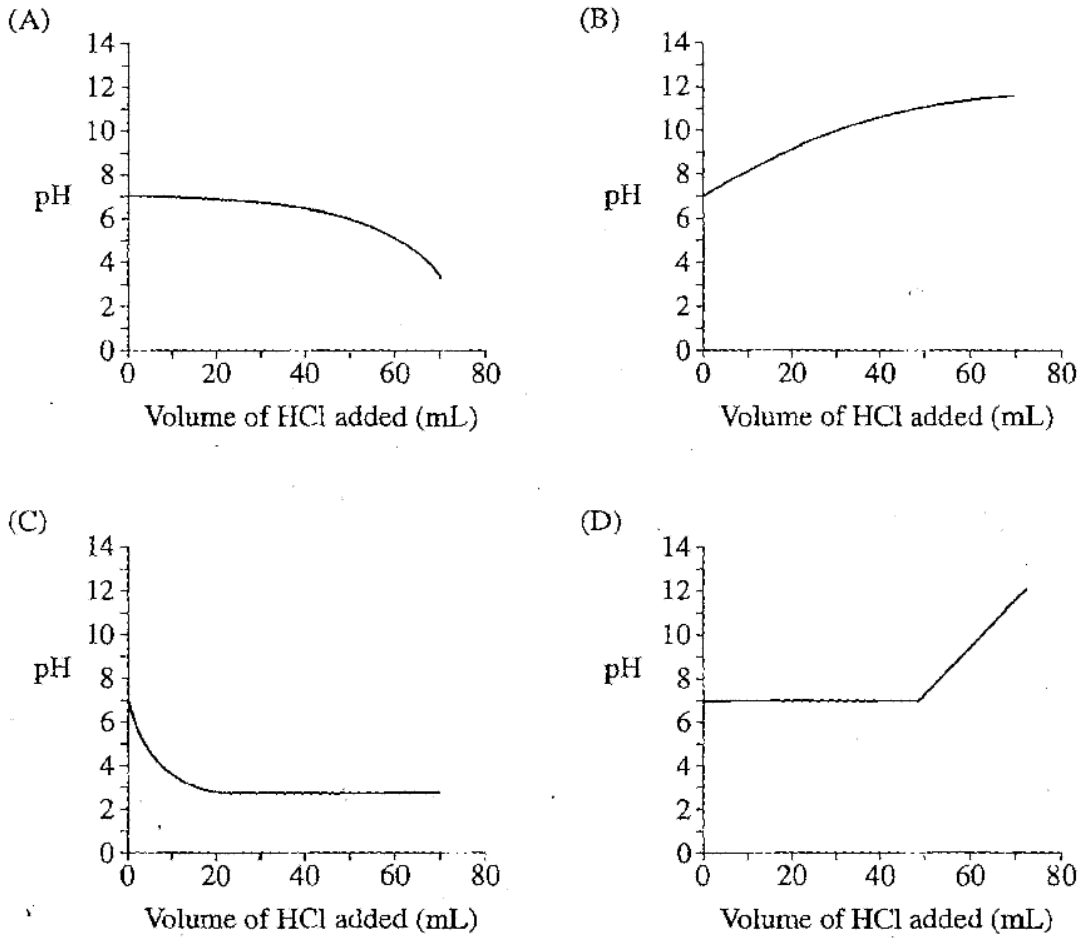
How many acids of the above acids would be classified as organic?

A. 2
B. 3
C. 4
D. 5

10. Which statement best describes the end point in a titration between a strong acid and a strong base?

A. The point at which the first permanent sign of a colour change occurs.
B. The point at which equal moles of acid and base are added together.
C. The point at which the rate of the forward reaction equals the rate of the reverse reaction.
D. The point at which equal moles of H^+ ions and OH^- ions have been added together.

11. Which of the following graphs best shows how pH will vary when dilute HCl is added to 100 mL of a buffer solution with an initial pH of 7.0?



12. Which of the following reagents would result in 1-bromopropane being produced from propene?

A. Br_2
B. HBr
C. NaBr
D. CH_3Br

13. Ethene and chlorine gases are mixed in the dark. Which of the following describes the speed of the reaction and a product?

A. A fast reaction producing chloroethane
B. A slow reaction producing 1,2 – dichloroethane
C. A slow reaction producing chloroethane
D. A fast reaction producing 1,2 – dichloroethane

14. Two solutions of hydrochloric acid are available. Solution **A** has a pH of 1 and solution **B** has a pH of 2. Equal volumes of the solutions are separately reacted with excess magnesium. Which statement about the volume of evolved hydrogen gas (at the same temperature and pressure) is correct?

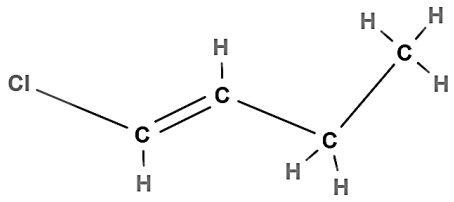
A. **B** produces twice as much volume as **A** produces
B. **A** produces twice as much volume as **B** produces
C. **A** produces ten times as much volume than **B** produces
D. **A** produces twenty times as much volume than **B** produces

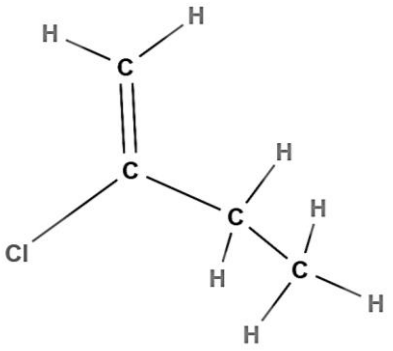
15. In a titration of sodium carbonate with hydrochloric acid what would be the pH at the equivalence point?

A. Less than 3
B. Between 3 and 6
C. Between 6.5 and 7.5
D. Between 8 and 10

16. Which of the following pairs are functional group isomers of each other?

A.





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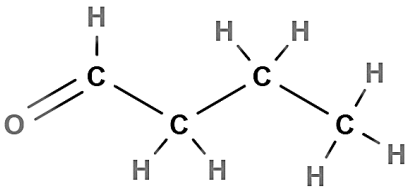

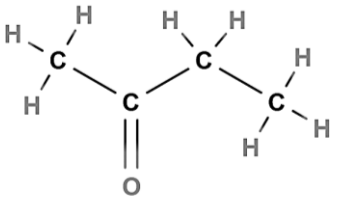

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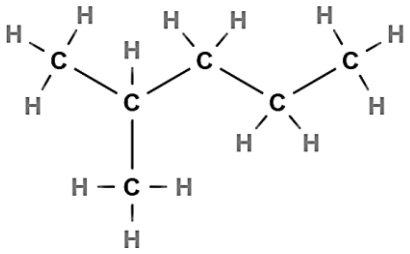
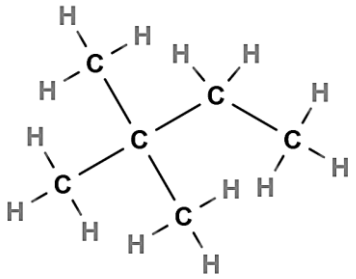
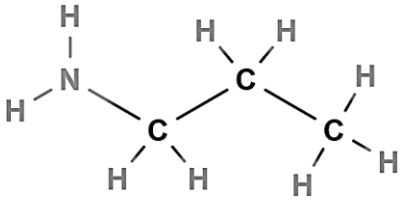
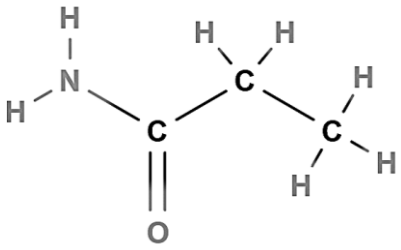




D.





17. A saturated solution of magnesium sulfate was placed in a beaker. Solid magnesium sulfate containing radioactive sulfur-35 was added to the solution. The beaker was left overnight and then the mixture was filtered.

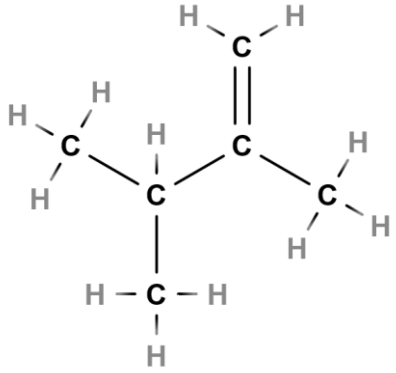
Radioactivity could reasonably be expected to be found in which of the following?

A. the residue only
B. the filtrate only
C. neither the residue nor the filtrate
D. both the mixture and filtrate

18. A catalyst is added to a system in equilibrium. Which of the following would correctly describe the effect of the catalyst on the system?

	Effect on activation energy required	Effect on equilibrium position	Effect on the forward rate of reaction
A.	No effect	No effect	decrease
B.	Lowered	No effect	No effect
C.	Lowered	No effect	Increase
D.	Lowered	Shifts to favour products	No effect

19. Name the following compound.



A. 1,1,2 -trimethylpropene
B. 3-methylbut-1-ene
C. 2,3-dimethylbut-1-ene
D. 2,3-dimethylbut-3-ene

20. 3.50 g of ethanol was refluxed with 5.75 g of methanoic acid. The mass of the product was found to be only 24 % of the expected result.

What was the mass of the product extracted?

A. 0.71g

B. 1.35g

C. 2.22g

D. 5.63g

Section II 80 Marks

Attempt Questions 21 - 37

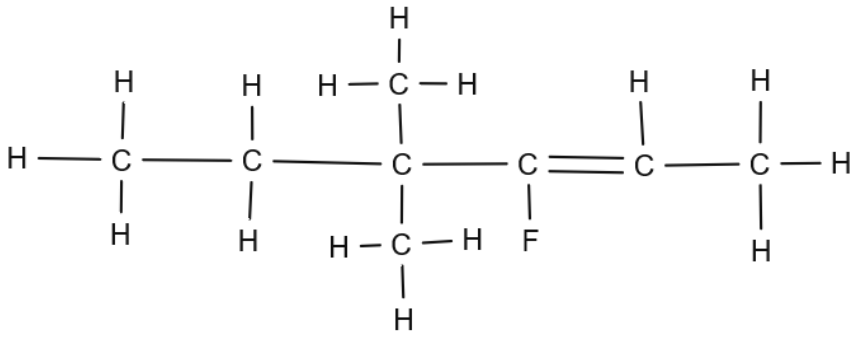
Allow about 2 hours and 25 minutes for this section.

Answer the questions in the space provided.

Show all relevant working for questions involving calculations.

Question 21 (1 Mark) **1**

What is the systematic name for the compound with this structure?



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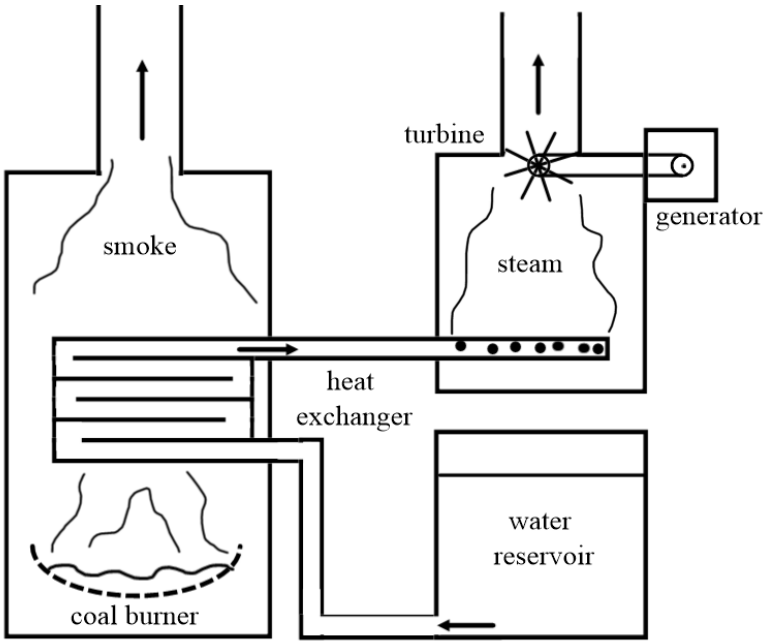
Question 22 (5 Marks)

A student has drawn a diagram showing the energy exchange that occurs in a coal burning power plant.



The coal ($C_{(s)}$) is crushed and fed into the coal burner where a fire, heavily oxygenated by fans, completely burns the fuel. The heat produced boils water via an array of pipes called a heat exchanger. The steam created in this heat exchanger is released across turbine fins which turn to generate electrical energy.

The heat of combustion of coal is -715 $kJmol^{-1}$

a) Determine the mass of coal needed to heat 1.00kg of water from 25ºC to 100ºC. **2**

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b) Describe the enthalpy and entropy changes that occur in the combustion of coal and use this to explain why this reaction is spontaneous. **3**

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Question 23 (3 Marks) **3**

What is the minimum volume of water that is necessary to completely dissolve 1.0g $PbSO_4$ at 25^oC?

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Question 24 (2 Marks) **2**

Write equations to show that potassium dihydrogen phosphate is an amphiprotic substance.

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Question 25 (4 Marks)

The Arrhenius theory of acids and bases could not explain why ammonia (NH_3) is basic when dissolved in water. The Brønsted –Lowry theory does explain the basic nature of an ammonia solution.

a) Describe the differences by which Arrhenius and Brønsted–Lowry defined a base. **2**

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b)

(i) Why wasn't Arrhenius able to explain the basic nature of NH_3 in water? **1**

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(ii) Brønsted –Lowry theory is able to explain this phenomena. Write an equation to illustrate this. **1**

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Question 26 (3 Marks) **3**

A student dissolved 1.25 g of calcium hydroxide in 1500 mL of water. Calculate the pH of the solution.

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Question 27 (4 Marks) **4**

Determine whether precipitation will occur when 100 mL of 2.0×10^{-3} $molL^{-1}$ calcium chloride solution and 100 mL of 4.0×10^{-3} $molL^{-1}$ sodium sulfate are mixed? Show all working.

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Question 28 (6 Marks)

Consider the following system involving nitrosyl chloride, nitrogen oxide and chlorine gas.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g) \qquad \Delta H = +128 kJmol^{-1}$$

5.00 mol of NOCl was placed in a 3.00L container at 400^{o}C. At equilibrium 28.0 % of the NOCl had decomposed.

a) Calculate the equilibrium constant for this reaction at 400^{o}C. **4**

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b) What is the effect on the equilibrium constant if the temperature of the system is lowered? Explain your answer in terms of Le Chatelier's Principle. **2**

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Question 29 (1 Marks) **1**

In order to maintain a suitable pH in swimming pools, a buffer such as sodium hydrogen carbonate / carbonic acid is added to the water. This keeps the pH range between 7.2 to 7.8.

Write an equation to demonstrate the buffering action of sodium hydrogen carbonate to control the swimming pool pH.

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Question 30 (3 Marks) **3**

What is the pH of a 1.0 $molL^{-1}$ hydrofluoric acid (HF) solution, given that the pKa of HF is 3.18?

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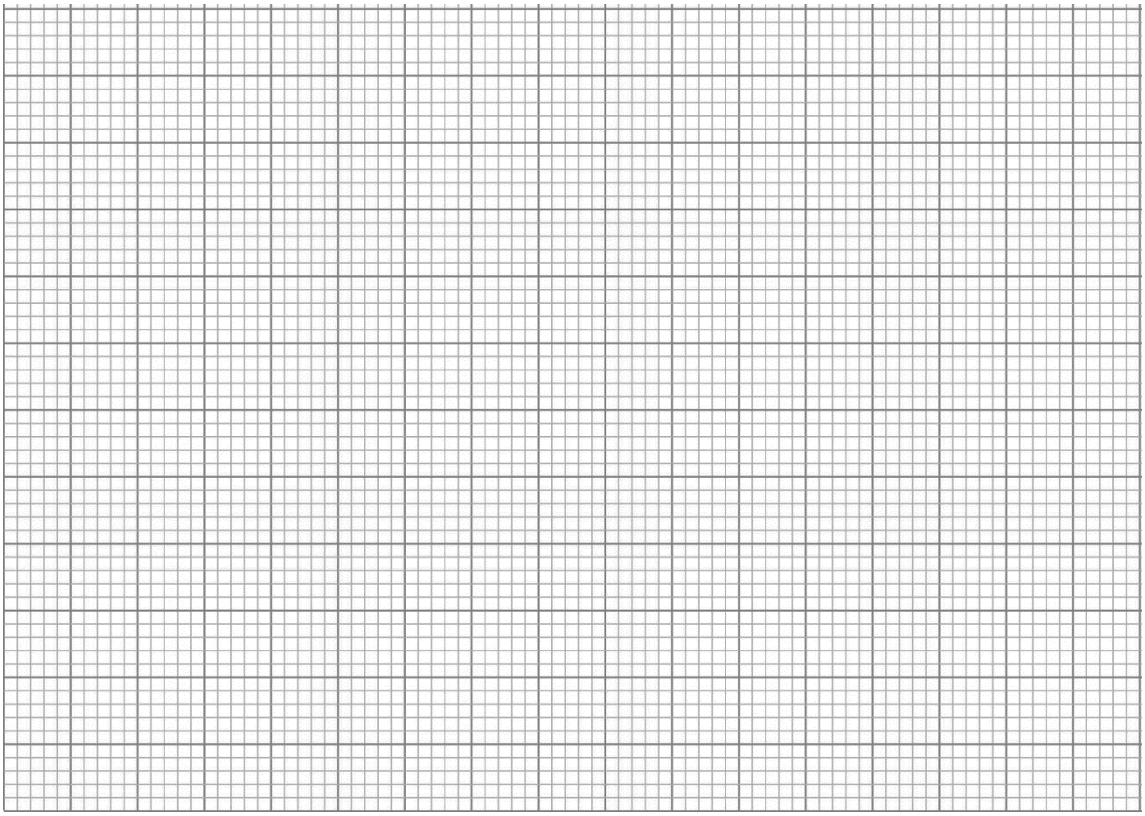
Question 31 (8 Marks)

A student conducted a titration of 0.15 $molL^{-1}$ sodium hydroxide against ethanoic acid. The table below shows the student's results as base was added to the 25 mL aliquot of ethanoic acid.

Volume Added (mL)	0.0	5.0	10.0	15.0	20.0	21.0	24.0	25.0	30.0	35.0	40.0
pH	3.8	4.0	4.5	4.8	5.0	5.4	10.8	10.9	11.2	11.3	11.4

a) Graph this data in the space provided. **4**



b) Determine the equivalence point. **1**

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c) Calculate the concentration of the ethanoic acid. **3**

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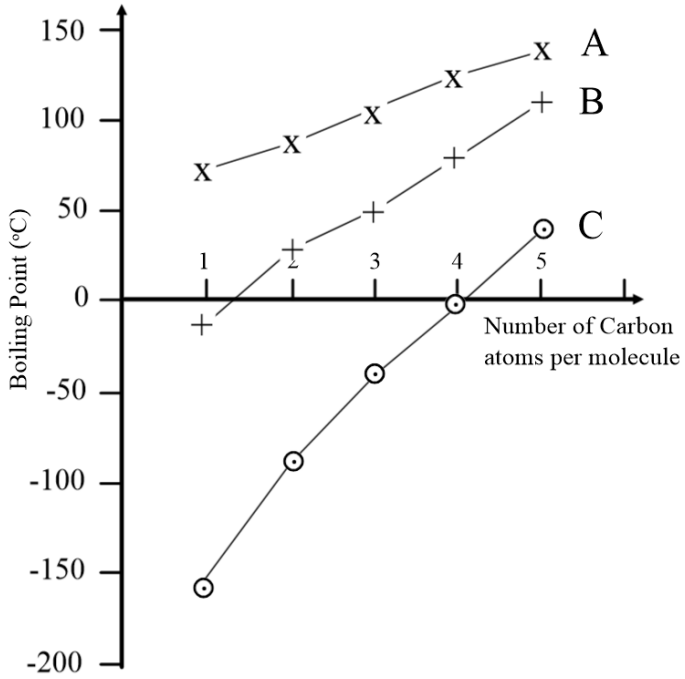
Question 32 (5 Marks)

The graph below shows the boiling points, in ^{o}C, of 3 homologous series, A, B and C for the first 5 carbons ($C_1 - C_5$). The three homologous series present are primary alkanols, alkanes and alkanols.



a) Identify the letter associated with each homologous series shown on the graph. **2**

(i) primary alkanols ☐

(ii) alkanes ☐

(iii) alkanals ☐

b) Explain the differences between the homologous series shown in the graph in terms of the intermolecular bonds. **3**

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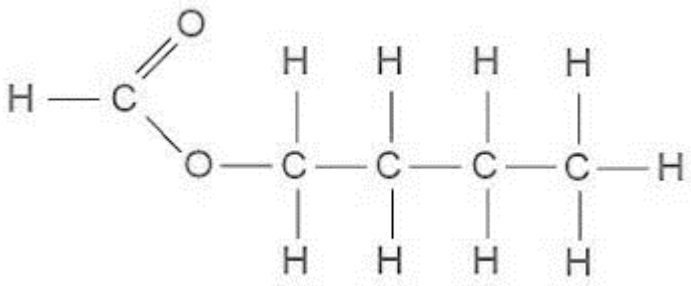
Question 33 (6 Marks)

The structure of an ester is shown below.



a) Name this ester. **1**

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b) Name the two reactants used to form this ester. **2**

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c) What other compound must be present for this reaction to proceed? **1**

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d) Two students decided to make this ester in the lab. Student one incorporated a reflux in her process, while student two did not.

Which student would have produced the highest yield of ester? Explain. **2**

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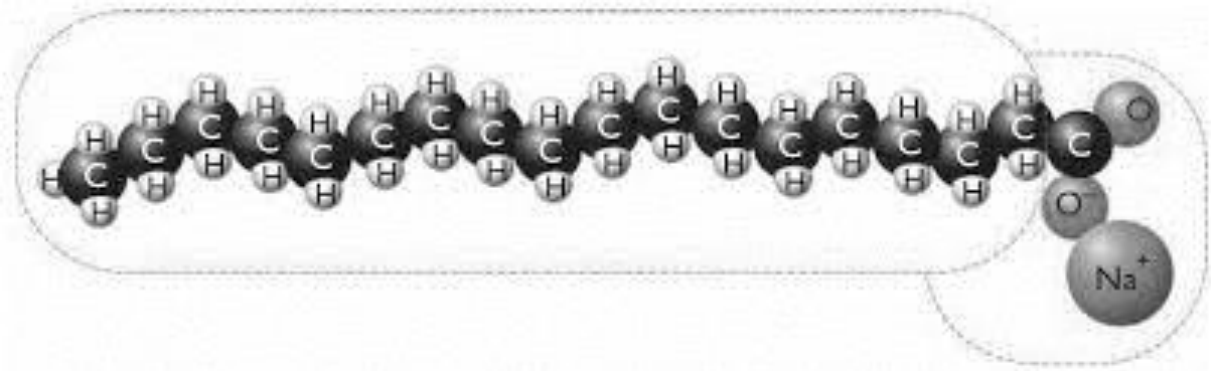
Question 34 (5 Marks)

An example of a soap molecule is shown below.



a) The tail (left hand end) of this molecule is often described as hydrophobic. What does this mean? **1**

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b) Using this molecule as a reference, identify and explain the chemical steps involved in the cleaning process such as the removal of an oil stain from a cotton shirt. **4**

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Question 35 (7 Marks)

Amines and amides are two carbon-based groups of compounds, both having nitrogen in their functional groups.

The general formula for an amine is $R\text{-}NH_2$, while the general formula for an amide is $R\text{-}CO\text{-}NH_2$.

When ethanamine is dissolved in water, an alkali solution is formed.

a) (i) Write the formula equation to show this chemical reaction. **1**

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(ii) Draw a labelled diagram to show the solubility of ethanamine in water. Label any significant bonds. **2**

b) (i) Ethanamide is also soluble in water. What would be the approximate pH of a water/ethanamide solution? **1**

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(ii) Would pentamide be more soluble, less soluble or have the same solubility in water as ethanamide? Explain your choice in terms of structure and bonding. **3**

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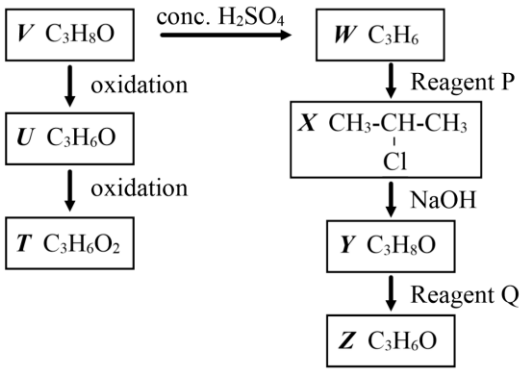
Question 36 (8 Marks) **8**

Assess the environmental implications of obtaining and using hydrocarbons from the Earth and contrast with a biofuel such as ethanol.

Question 37 (9 Marks) **9**

The diagram below shows two sequences of reactions starting with the alcohol labelled **V.**



Identify compounds T to Z and justify your answers with the reference to the information provided.

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Section II

80 Marks

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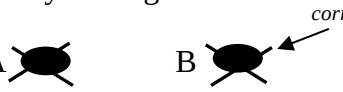
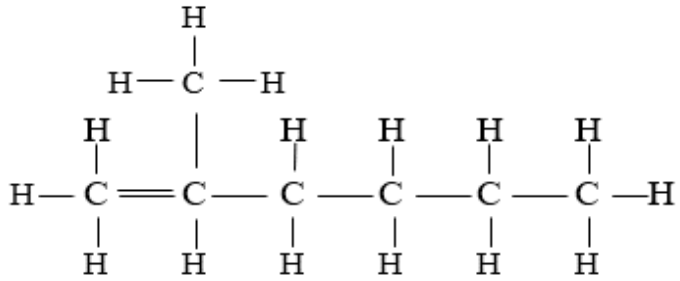


A ⊗ B ⊗ C ○ D ○

1. Which of the following structural formula for a hydrocarbon is correctly shown?

(A)



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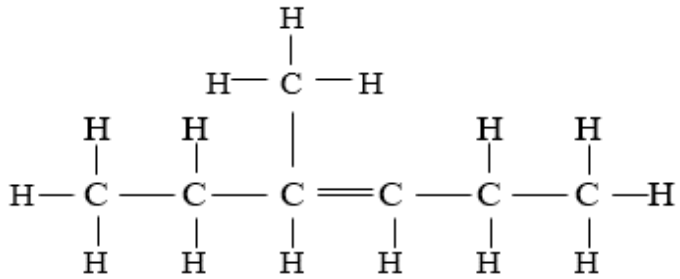
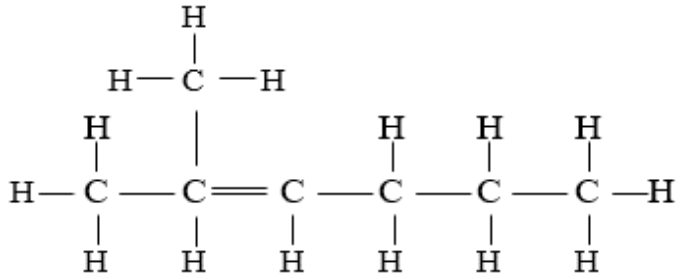
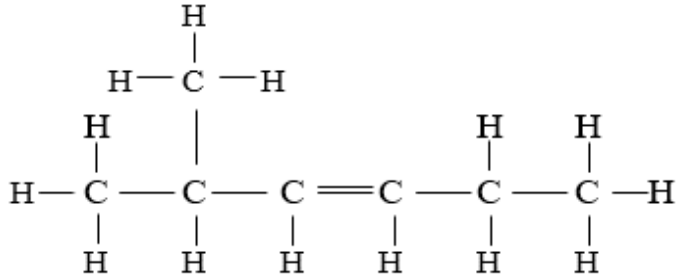


(C)



(D)

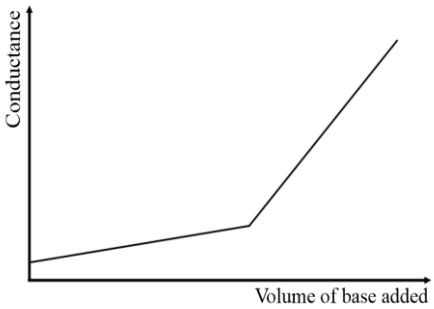


Answer D

2. Which of the following conditions are required for a system to be in dynamic equilibrium?

	System	Forward rate of reaction
A.	Open	No longer occurring
B.	Open	Equal to the reverse rate of reaction
C.	Closed	No longer occurring
D.	**Closed**	**Equal to the reverse rate of reaction**

3. The following graph shows the conductivity curve for a titration as base is added.



Identify the type of titration which was carried out.

A. Strong Acid / Weak Base
B. Strong Acid / Strong Base
C. Weak Acid / Weak Base
D. Weak Acid / Strong Base

4. Which of the following formulae describes a ketone?

A. $CH_3(CH_2)_3CHO$
B. $CH_3CH_2COCH_3$
C. $CH_3CHOHCH_3$
D. CH_3COOCH_3

5. Acid X is 0.10 molL^{-1} hydrochloric acid.
Acid Y is 0.10 molL^{-1} acetic acid.
Each acid was titrated with 25 mL of a 0.10 molL^{-1} sodium hydroxide solution.
Which of the following statements is correct?

A. More than 25mL of Y is needed to need to achieve the equivalence point in this titration.
B. 25mL of Y is needed to need to achieve the equivalence point in this titration.
C. Less than 25mL of Y is needed to need to achieve the equivalence point in this titration.
D. Less than 25mL of X is needed to need to achieve the equivalence point in this titration.

6. The diagram represents a test-tube containing a saturated solution of sodium chloride, with some crystals of sodium chloride at the bottom of the tube.

A few drops of concentrated hydrochloric acid are added to the solution. Which of the following would be observed?

A. bubbles of gas form
B. more precipitate is formed
C. some of the sodium chloride crystals dissolve
D. a change in the colour of the crystals

7. 0.1 molL^{-1} solutions of various bases are made. Which number indicates the pH of the weakest base according to Arrhenius?

A. 12
B. 9
C. 7
D. 5

8. 25.0 mL of a 0.100 molL^{-1} solution of HCl is added to 25.0 mL of a 0.180 molL^{-1} solution of NaOH. What is the concentration (in molL^{-1}) of OH^-(aq) remaining in the solution?

A. 0.0200
B. 0.0400
C. 0.0500
D. 0.0800

9. A student has a list of acids and is asked to classify them as organic or non-organic.

The list of acids to classify is: HCl, H_2SO_4, CH_3CH_2COOH, HCN, HOOCH, H_2CO_3

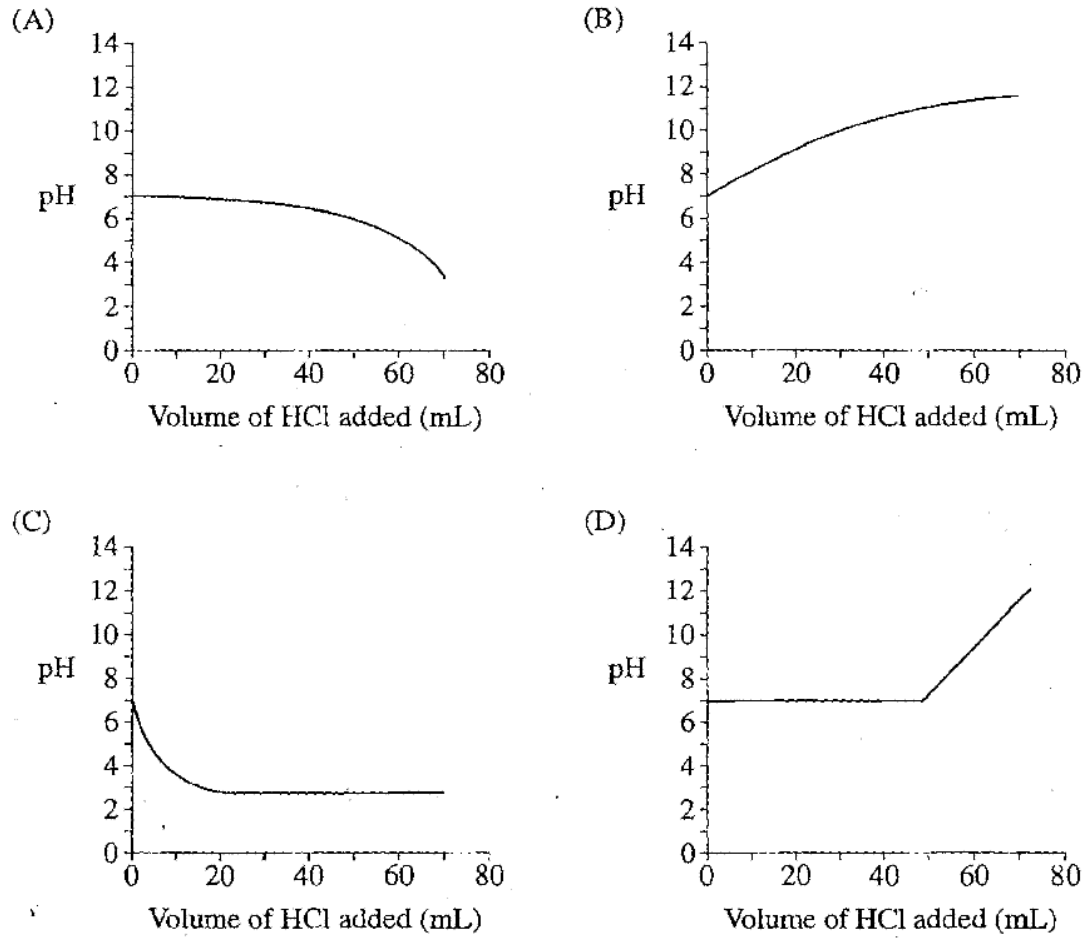
How many acids of the above acids would be classified as organic?

A. 2
B. 3
C. 4
D. 5

10. Which statement best describes the end point in a titration between a strong acid and a strong base?

A. The point at which the first permanent sign of a colour change occurs.
B. The point at which equal moles of acid and base are added together.
C. The point at which the rate of the forward reaction equals the rate of the reverse reaction.
D. The point at which equal moles of H^+ ions and OH^- ions have been added together.

11. Which of the following graphs best shows how pH will vary when dilute HCl is added to 100 mL of a buffer solution with an initial pH of 7.0?



Answer =A

12. Which of the following reagents would result in 1-bromopropane being produced from propene?

A. Br_2
B. **HBr**
C. NaBr
D. CH_3Br

13. Ethene and chlorine gases are mixed in the dark. Which of the following describes the speed of the reaction and a product?

A. A fast reaction producing chloroethane
B. A slow reaction producing 1,2 – dichloroethane
C. A slow reaction producing chloroethane
D. A fast reaction producing 1,2 – dichloroethane

14. Two solutions of hydrochloric acid are available. Solution **A** has a pH of 1 and solution **B** has a pH of 2. Equal volumes of the solutions are separately reacted with excess magnesium. Which statement about the volume of evolved hydrogen gas (at the same temperature and pressure) is correct?

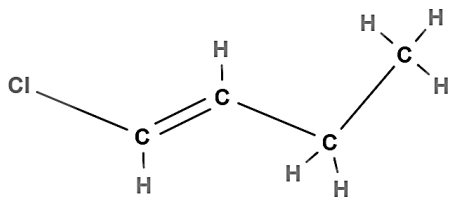
A. **B** produces twice as much volume that **A** produces
B. **A** produces twice as much volume that **B** produces
C. A produces ten times as much volume that B produces
D. **A** produces twenty times as much volume that **B** produces

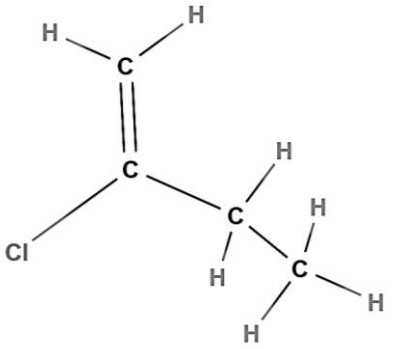
15. In a titration of sodium carbonate with hydrochloric acid what would be the pH at the equivalence point?

A. Less than 3
B. Between 3 and 6
C. Between 6.5 and 7.5
D. Between 8 and 10

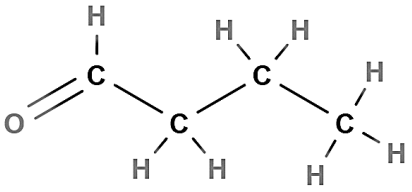
16. Which of the following pairs are functional group isomers of each other?

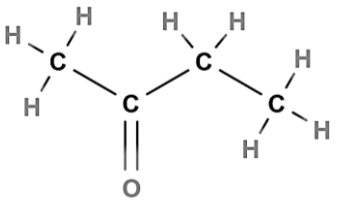
A.



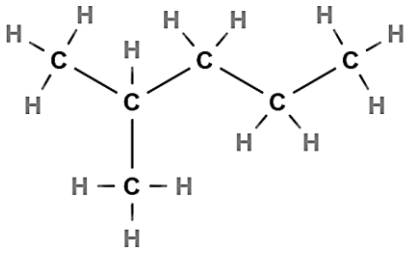


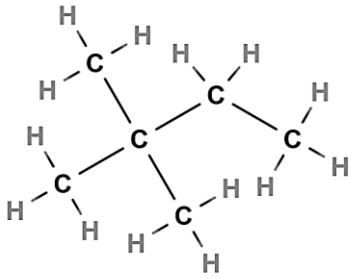
B.



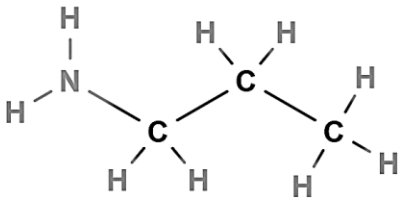


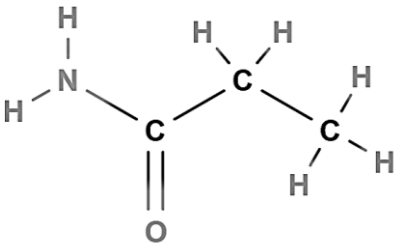
C.





D.





17. A saturated solution of magnesium sulfate was placed in a beaker. Solid magnesium sulfate containing radioactive sulfur-35 was added to the solution. The beaker was left overnight and then the mixture was filtered.

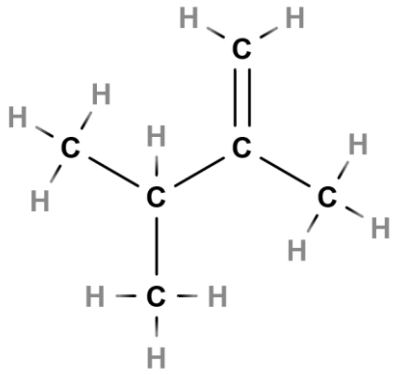
Radioactivity could reasonably be expected to be found in which of the following?

A. the residue only
B. the filtrate only
C. neither the residue nor the filtrate
D. both the mixture and filtrate

18. A catalyst is added to a system in equilibrium. Which of the following would correctly describe the effect of the catalyst on the system?

	Effect on activation energy required	Effect on equilibrium position	Effect on the forward rate of reaction
A.	No effect	No effect	decrease
B.	Lowered	No effect	No effect
C.	**Lowered**	**No effect**	**Increase**
D.	Lowered	Shifts to favour products	No effect

19. Name the following compound.



A. 1,1,2 -trimethylpropene
B. 3-methylbut-1-ene
C. 2,3-dimethylbut-1-ene
D. 2,3-dimethylbut-3-ene

20. 3.50 g of ethanol was refluxed with 5.75 g of methanoic acid. The mass of the product was found to be only 24 % of the expected result.

What was the mass of the product extracted?

A. 0.71g

B. 1.35g

C. 2.22g

D. 5.63g

Section II 80 Marks

Attempt Questions 21 - 37

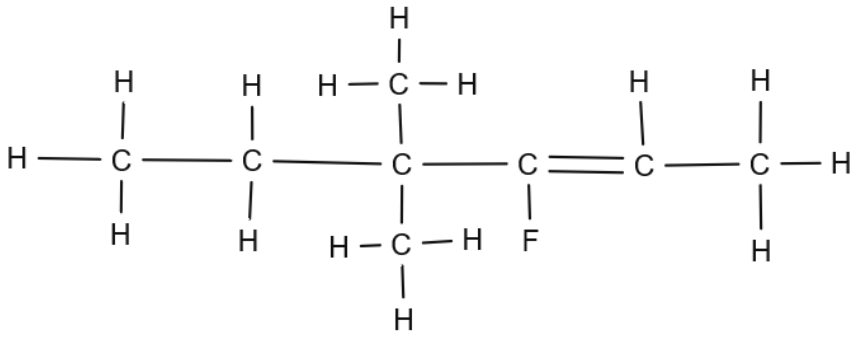
Allow about 2 hours and 25 minutes for this section.

Answer the questions in the space provided.

Show all relevant working for questions involving calculations.

Question 21 (1 Mark)

What is the systematic name for the compound with this structure?



3-fluoro-4,4-dimetylhex-2-ene

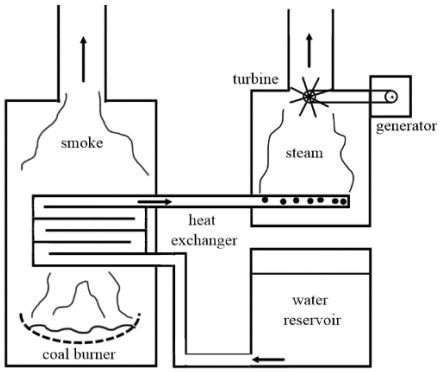
3-fluoro-4,4-dimetyl-2-hexene also accepted

Common mistakes for:

- **Missed the F all together**
- **Misspelled the "fluoro" as "fluro"**
- **Writing "hexan-2-ene" instead of "hex-2-ene"**
- **Dash between letters and numbers**
- **Comma between numbers**

Question 22 (5 Marks)

A student has drawn a diagram showing the energy exchange that occurs in a coal burning power plant.



The coal ($C_{(s)}$) is crushed and fed into the coal burner where a fire, heavily oxygenated by fans, completely burns the fuel. The heat produced boils water via an array of pipes called a heat exchanger. The steam created in this heat exchanger is released across turbine fins which turn to generate electrical energy.

The heat of combustion of coal is -715 $kJmol^{-1}$

a) Determine the mass of coal needed to heat 1.00kg of water from 25ºC to 100ºC. **2**

Energy needed = 1 x 4.18x 10^3 x 75 = 313.5 kJ 1 mk

Moles needed =313.5/715 = 0.438

Mass needed = 12g x 0.438 = 5.26g 1 mk

This section needs review across the grade! Fundamental misunderstanding on how to calculate the enthalpy of combustion and reverse process. Should not have been a descriminator! Check your answer is plausible, e.g. 63 000kg to heat 1L of water!!!!!

b) Describe the enthalpy and entropy changes that occur in the combustion of coal and use this to explain why this reaction is spontaneous. **3**

1 mark – Student describes components that enthalpy decreases as energy is released AND that entropy increases as solid to gas means more disorder. (NO half marks)

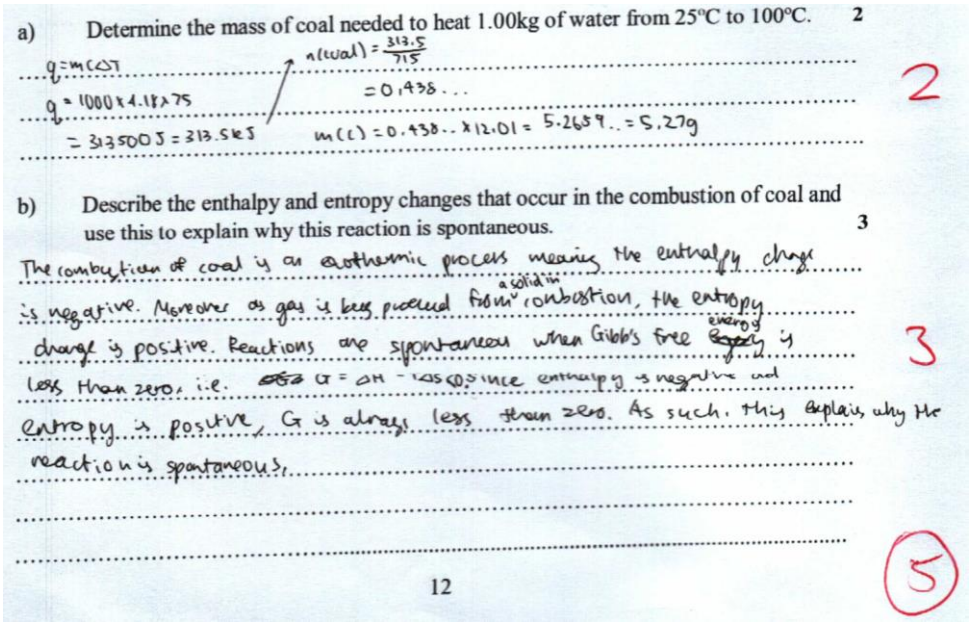
1 mark – Student states the requirements for Gibbs free energy (CAUSE)

1 mark – Student states that negative ΔG means this reaction is spontaneous (EFFECT).

Enthalpy is negative according to the data given (-715kJmol^{-1}). Entropy is positive as the reactants change from solid to gas. $\Delta G = \Delta H - T\Delta S$ so $-\Delta H - T\Delta S$ will always be negative and so combustion of coal will always be spontaneous.

Common mistakes were:

- **Students correctly stated that the mole ratio decreases to show order, however, mixed up the fact that this is for gases and not liquids and solids. To go from a solid to gas is far more entropic than gas mole ratios.**
- **Students stated that "entropy increases for all combustion reactions". Not true, when you combust a metal, entropy goes down.**
- **People stated that Gibbs Free Energy is therefore negative without referring to an equation or theory. Be careful of CAUSE and EFFECT.**



a) Determine the mass of coal needed to heat 1.00kg of water from 25°C to 100°C. 2

$q = mc\Delta T$

$q = 1000 \times 4.18 \times 75$

$= 313500\,J = 313.5\,kJ$

$n(coal) = \frac{313.5}{715}$

$= 0.438...$

$m(C) = 0.438.. \times 12.01 = 5.2659.. = 5.27g$

2

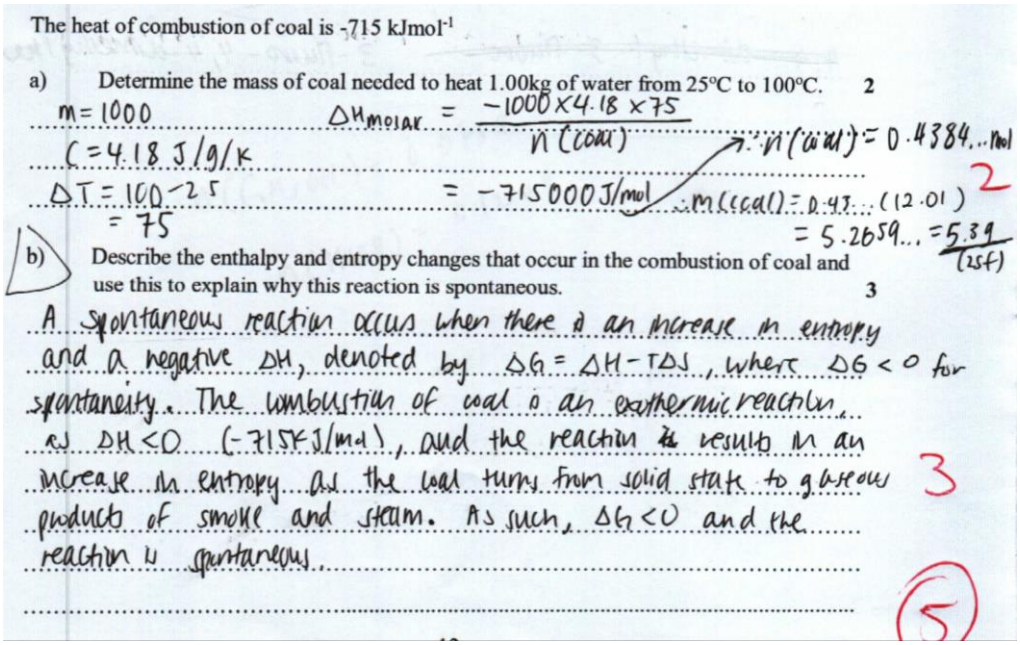
b) Describe the enthalpy and entropy changes that occur in the combustion of coal and use this to explain why this reaction is spontaneous. 3

The combustion of coal is an exothermic process meaning the enthalpy change is negative. Moreover as gas is being produced from a solid in combustion, the entropy change is positive. Reactions are spontaneous when Gibb's free energy is less than zero, i.e. ~~ΔG~~ $G = \Delta H - T\Delta S$ since enthalpy is negative and entropy is positive, G is always less than zero. As such, this explains why the reaction is spontaneous.

3

5

12


The heat of combustion of coal is -715 kJmol^{-1}

a) Determine the mass of coal needed to heat 1.00kg of water from 25°C to 100°C. 2

m = 1000
C = 4.18 J/g/K
ΔT = 100 − 25 = 75

$\Delta H_{molar} = \frac{-1000 \times 4.18 \times 75}{n(coal)}$

= −715000 J/mol

∴ n(coal) = 0.4384... mol

∴ m(coal) = 0.43... (12.01) = 5.2659... = 5.27 (2sf) 2

b) Describe the enthalpy and entropy changes that occur in the combustion of coal and use this to explain why this reaction is spontaneous. 3

A spontaneous reaction occurs when there is an increase in entropy and a negative ΔH, denoted by ΔG = ΔH − TΔS, where ΔG < 0 for spontaneity. The combustion of coal is an exothermic reaction, as ΔH < 0 (−715 kJ/mol), and the reaction is results in an increase in entropy as the coal turns from solid state to gaseous products of smoke and steam. As such, ΔG < 0 and the reaction is spontaneous. 3

5

Question 23 (3 Marks)

What is the minimum volume of water is necessary to completely dissolve 1.0g $PbSO_4$ at 25°C?

1 mark – Student correctly calculates the number of moles of $PbSO_4$ to be 3.297 x 10^{-3}.

1 mark – Student correctly states the ionic product equation for $PbSO_4$,

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

1 mark – Student correctly substitutes concentration and moles into volume formula,

V = n/c

Determine Ksp of $PbSO_4$ is 2.53 x 10^{-8}
Ksp =$[Pb^{2+}][SO4^{2-}]$
$x^2 = 2.53 \times 10^{-8}$
$x = 1.59 \times 10^{-4}$ molL^{-1} = $[PbSO_4]$
1.0g $PbSO_4$ = 1.00/303.27 = 0.003297 moles
Solve 0.003297 / volume = 1.59×10^{-4}
Volume = .003297/1.59×10^{-4} = 20.7L 1mk

Question 24 (2 Marks)

Write equations to show that potassium dihydrogen phosphate is an amphiprotic substance.

2 marks – Student shows that KH_2PO_4 can act as a B/L acid AND base in the presence of an acid & base respectively OR donates a proton in water and accepts a proton in water. Student must have correct chemistry in each of the two equations.

1 mark – Student shows one of the equations using correct chemistry.

$H_2PO_4^- + H_3O^+ \rightarrow H_2O + H_3PO_4$

$H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_20$

OR

$H_2PO_4^- + H_2O \rightarrow H_3O^+ + HPO_4^{2-}$

$H_2PO_4^- + H_2O \rightarrow OH^- + H_3PO_4$

ISSUES:

- **THERE IS NO SUCH COMPOUND AS $KH_3PO_4^+$!! This was the biggest discriminator when it was designed as a band 4 recount question. 80% of the grade need to go back to the Year 11 section on salts and revise the group 1 inert ions like Na^+ and K^+. Wow!**
- **Please note that we accepted water as the reactant but it is not good chemistry. Yes, Pearson does have it but better to show amphiprotic with a reactant of acid in one and base in the other.**

Question 25 (4 Marks)

The Arrhenius theory of acids and bases could not explain why ammonia (NH_3) is basic when dissolved in water. The Brønsted –Lowry theory does explain the basic nature of an ammonia solution.

a) Describe the differences by which Arrhenius and Brønsted–Lowry defined a base. **2**

Arrhenius: A base dissociates a hydroxide ion in solution. 1mk

Brønsted–Lowry: A base is a proton acceptor. 1mk

b)

(i) Why wasn't Arrhenius able to explain the basic nature of NH_3 in water? **1**

According to his theory no hydroxide ions present OR not taking into account action of water. 1 mk

(ii) Brønsted –Lowry theory is able to explain this phenomena. Write an equation to illustrate this. **1**

$NH_{3\,(aq)} + H_2O_{(l)} \rightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

STATES were marked here. -1mk for incorrect chemistry.

Also accepted reactions with acids to show basic nature.

The Arrhenius theory of acids and bases could not explain why ammonia (NH_3) is basic when dissolved in water. The Brønsted –Lowry theory does explain the basic nature of an ammonia solution.

a) Describe the differences by which Arrhenius and Brønsted–Lowry defined a base. **2**

aq soln. — proton acceptor

Arrhenius defined a base as containing an OH^- ion.

Whereas Brønsted-Lowry defined a base as a proton acceptor.

2

b) $NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_{4(aq)} + OH^-$

(i) Why wasn't Arrhenius able to explain the basic nature of NH_3 in water? **1**

$NH_{3(aq)}$ does not contain an OH^- ion.

1

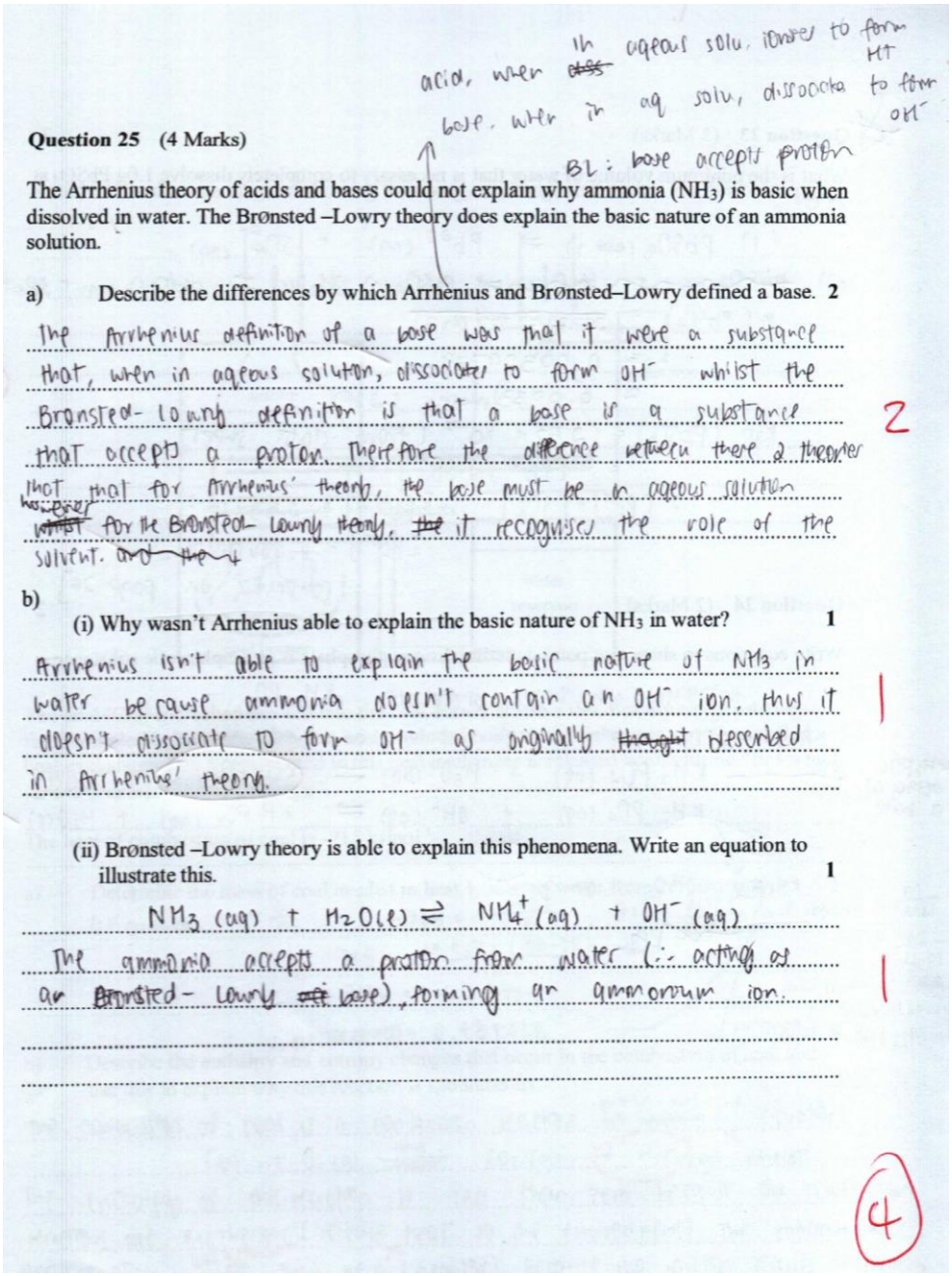
(ii) Brønsted –Lowry theory is able to explain this phenomena. Write an equation to illustrate this. **1**

H^+

$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-_{(aq)}$

1

4



acid, when in aqueous solu, ionises to form H^+

base, when in aq solu, dissociate to form OH^-

BL: base accepts proton

Question 25 (4 Marks)

The Arrhenius theory of acids and bases could not explain why ammonia (NH_3) is basic when dissolved in water. The Brønsted –Lowry theory does explain the basic nature of an ammonia solution.

a) Describe the differences by which Arrhenius and Brønsted–Lowry defined a base. **2**

The Arrhenius definition of a base was that it were a substance that, when in aqueous solution, dissociates to form OH^- whilst the Bronsted-Lowry definition is that a base is a substance that accepts a proton. Therefore the difference between these 2 theories is that for Arrhenius' theory, the base must be in aqueous solution whereas for the Brønsted-Lowry theory, it recognises the role of the solvent.

2

b)

(i) Why wasn't Arrhenius able to explain the basic nature of NH_3 in water? **1**

Arrhenius isn't able to explain the basic nature of NH_3 in water because ammonia doesn't contain an OH^- ion, thus it doesn't dissociate to form OH^- as originally described in Arrhenius' theory.

1

(ii) Brønsted –Lowry theory is able to explain this phenomena. Write an equation to illustrate this. **1**

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

The ammonia accepts a proton from water (∴ acting as a Brønsted-Lowry base), forming an ammonium ion.

1

4

Question 26 (3 Marks)

A student dissolved 1.25 g of calcium hydroxide in 1500 mL of water. Calculate the pH of the solution.

$Ca(OH)_2$ mw = 74.1

Moles OH^- = 2 x 1.25/74.1 = 0.022492 1 mk

pOH = 1.65 1 mk

pH =12.35 1 mk

Question 27 (4 Marks)

Determine whether precipitation will occur when 100 mL of 2.0 x 10^{-3} $molL^{-1}$ calcium chloride solution and 100 mL of 4.0 x 10^{-3} $molL^{-1}$ sodium sulfate are mixed? Show all working.

Ksp Calcium sulfate = 4.93 x 10^{-5}

[Ca^{2+}]= 1 x 10^{-3}, [SO_4^{2-}]= 2 x 10^{-3} 1 mk

Q = (1 x 10^{-3})(2 x 10^{-3}) = 2 x 10^{-6} 1 mk

State Q < known Ksp 1 mk

State precipitation will not occur 1 mk

Issues: Not all students realised that as the volume was doubled the concentration of ions was halved.
Some students tried to solve this question using the concept of limiting reactants, this approach is not valid as Ksp is based purely on concentration of ions in solution.

Question 28 (5 Marks)

Consider the following system involving nitrosyl chloride, nitrogen oxide and chlorine gas.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g) \qquad \Delta H = +128 kJmol^{-1}$$

5.00 mol of NOCl was placed in a 3.00L container at 400ºC. At equilibrium 28.0 % of the NOCl had decomposed.

a) Calculate the equilibrium constant for this reaction at 400ºC. **4**

K = $[NO]^2[Cl_2]/ [NOCl]^2$ **1 mk correct K expression**
Moles NO = 5.00 x 0.28 = 1.4
[NO]= 1.4/3 = 0.4666667
Moles NOCL at eqm. = 5.00 x .72 = 3.6 **2mks for correctly determining**
[NOCL]= 3.6 /3 = 1.2 **equilibrium concentrations**
Moles Cl_2 = 0.7 **using correct volume and**
[Cl_2]= 0.7/3 = 0.233333333 **stoichiometry**
K = $(0.4666667)^2$ x 0.2333333/1.44 = 0.035 **1 mk correct substitution**

b) What is the effect on the equilibrium constant if the temperature of the system is lowered? Explain your answer in terms of Le Chateliers Principle. **2**

As forward reaction is endothermic a reduction in temperature will cause the equilibrium position to favour the reactant side. 1 mk

As [Products] decreases and [Reactants] increases, K will decrease 1 mk

Question 29 (1 Marks)

Swimming pools can experience high alkalinity causing eye and skin irritations for bathers. In order to overcome this problem a buffer such as sodium hydrogen carbonate /carbonic acid buffer is used to maintain a pH range between 7.2 to 7.8.

Write an equation to demonstrate the buffering action of sodium hydrogen carbonate to control the swimming pool pH.

$HCO_3^- + H_3O^+ \leftrightarrow H_2CO_3 + H_2O$

This buffer consists of the weak carbonic acid and its conjugate base HCO_3^-, equation needs to show this relationship.
The sodium ions are only spectators.

Question 30 (3 Marks)

What is the pH of a 1.0 $molL^{-1}$ hydrofluoric acid (HF) solution, given that the pKa of HF is 3.17?

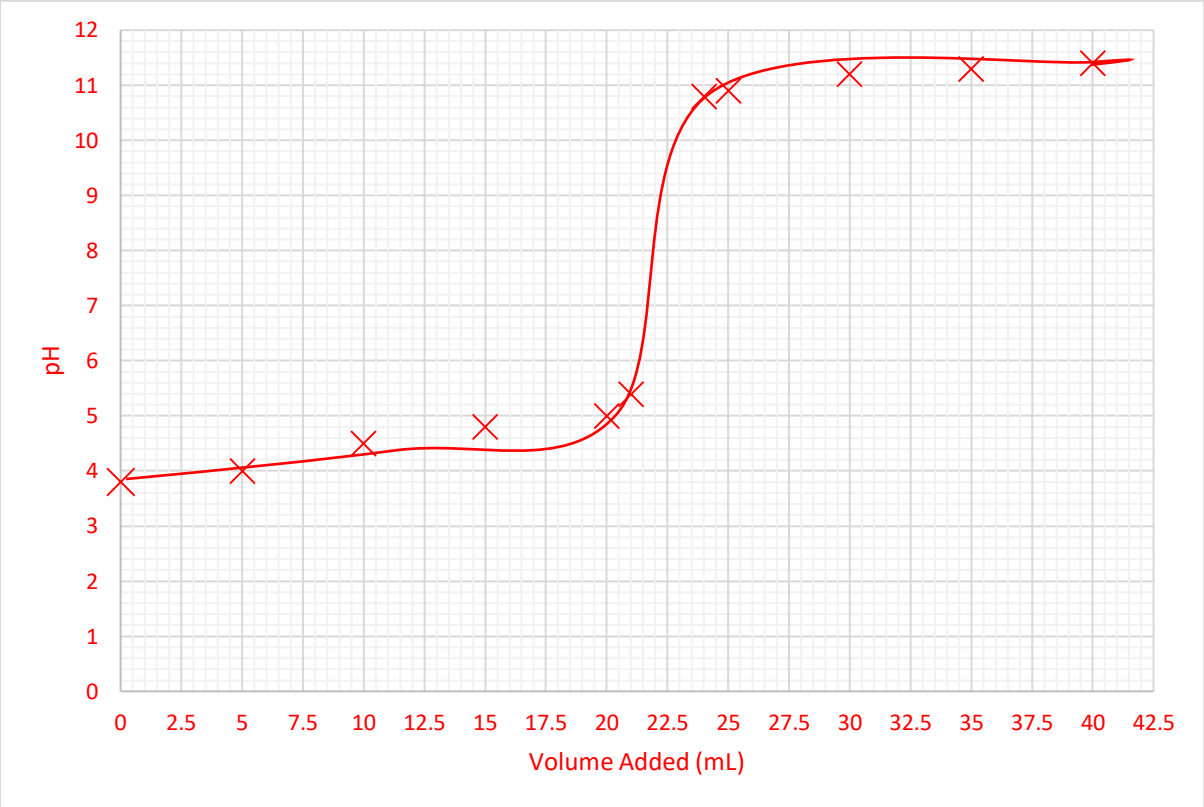
$[H^+][F^-]/1 = 10^{-3.18}$ 1 mk
$[H+] = \sqrt{10^{-3.18}} = 10^{-1.59}$ 1 mk
pH = 1.59 1 mk

Question 31 (8 Marks)

A student conducted a titration of 0.15 $molL^{-1}$ sodium hydroxide against acetic acid. The table below shows the student's results as base was added to the 25 mL aliquot of acetic acid.

Volume Added (mL)	0.0	5.0	10.0	15.0	20.0	21.0	24.0	25.0	30.0	35.0	40.0
pH	3.8	4.0	4.5	4.8	5.0	5.4	10.8	10.9	11.2	11.3	11.4

a) Graph this data in the space provided. **4**



b) Determine the equivalence point. **1**

1 mark correct pH or volume from graph.

c) Calculate the concentration of the acetic acid. **3**

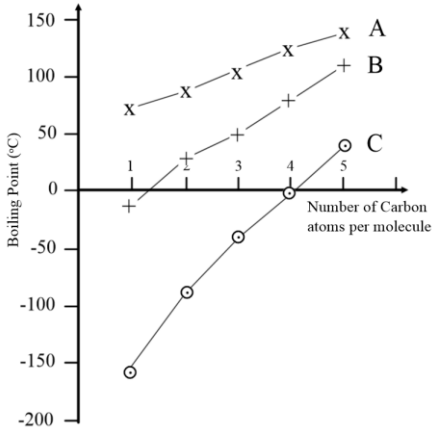
1 mk correct calculation moles of base

1 mk correct calculation conc of acid

1 mk units (for expressing conc. in $molL^{-1}$)

Question 32 (5 Marks)

The graph below shows the boiling points, in ^{o}C, of 3 homologous series, A, B and C for the first 5 carbons ($C_1 - C_5$). The three homologous series present are primary alkanols, alkanes and alkanols.



a) Identify the letter associated with each homologous series shown on the graph. **2**

(i) primary alkanols **A** ☐

(ii) alkanes **C** ☐

(iii) Alkanals **B** ☐

b) Explain the differences between the homologous series shown in the graph in terms of the intermolecular bonds. **3**

3 marks- correctly *explains* differences in boiling points of all 3 homologous series with reference to intermolecular bonds present.

2 marks- correctly *describes* differences in all 3, or correctly explains 2, or correctly explains all 3 with a mistake.

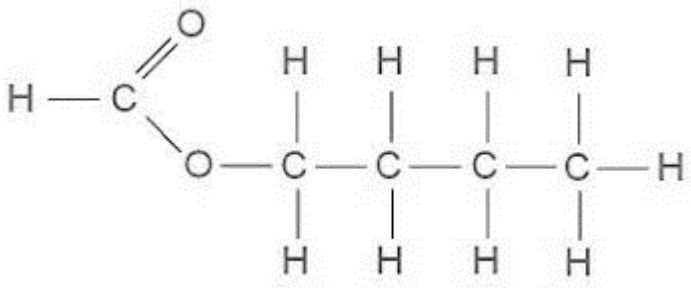
1 mark- provides correct information relating to question.

Markers comments- Hydrogen bonding is a form of dipole-dipole interaction. Therefore alcohols, for example, do not give rise to hydrogen bonding AND dipole interactions between their molecules.

Sample Answer;
Alkanes have the lowest boiling points as they are non-polar molecules and can only form weak dispersion forces between their molecules. These bonds require relatively little energy to overcome and so alkanes have the lowest boiling points. Alkanals have the next highest boiling point as the polar C=O bond allows for stronger dipole-dipole bonds to form. These require more energy to break. Finally, primary alkanols have the highest boiling points as the highly polar O-H functional group allows for strong hydrogen bonds to form between molecules. These require a lot more energy to overcome and so they have the highest boiling points.

Question 33 (6 Marks)

The structure of an ester is shown below.



a) Name this ester. **1**

butyl methanoate

b) Name the two reactants used to form this ester. **2**

butan-1-ol or 1-butanol (position must be given) and methanoic acid 1mk each

c) What other compound must be present for this reaction to proceed? **1**

Conc. Sulfuric acid (must specify conc.)

d) Two students decided to make this ester in the lab. Student one incorporated a reflux in her process, while student two did not.

Which student would have produced the highest yield of ester? Explain. **2**

The student who used the reflux process would have achieved the highest yield

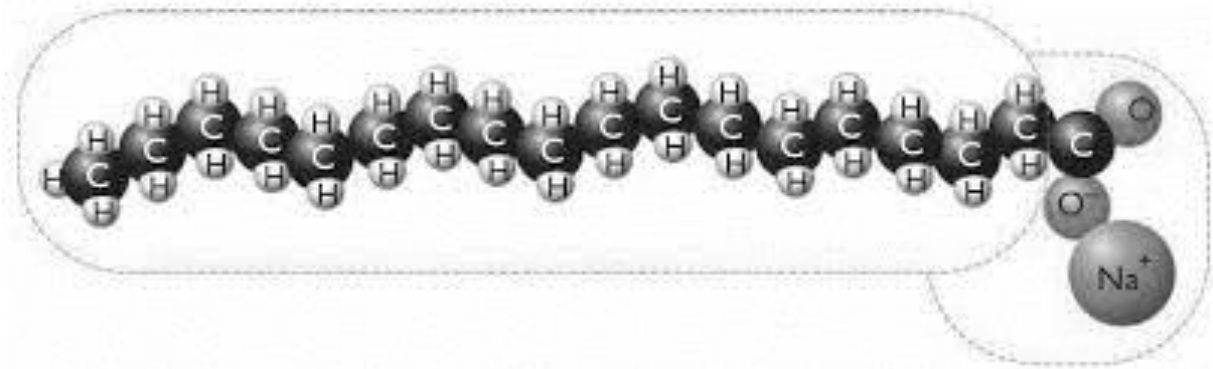
Esterification is a slow reaction. It requires heat to ensure a reasonable rate. Alkanols and esters are both volatile substances and therefore will vaporise on heating. (1 mark)

The reflux system uses a vertical water-cooled condenser attached to the reaction flask. As the volatile substances vaporise, they move up the condenser, cooling until they liquify and fall back into the reaction flask. An un-refluxed system would lose the alcohol before it had a chance of reacting to form the ester. Clearly refluxing results in a higher yield. (1 mark)

Note: higher rate of reaction does not produce a higher yield over time.

Question 34 (5 Marks)

An example of a soap molecule is shown below.



a) The tail (left hand end) of this molecule is often described as hydrophobic. What does this mean? **1**

Hydrophobic literally means a fear of water. In this context it means not attracted to water (1 mark)

b) Using this molecule as a reference, identify and explain the chemical steps involved in the cleaning process such as the removal of an oil stain from a cotton shirt. **4**

Soap dissociates to form alkanoate ion 1mk
Hydrophobic end of alkanoate ion attracted to oil particle 1 mk
Hydrophillic end attracted to water molecule 1 mk
Micelle formation 1 mk

Sample Answer

Soap consists of millions of molecules held together mainly by dispersion forces. When the soap molecule pictured is mixed with water, the sodium ion is released as it has a strong attraction to water molecules. This produces a soap anion which is the basis of the cleaning process.
The hydrophobic tail of the soap ion forms dispersion forces with the oil molecules which are also hydrophobic.
The charged end of the ion forms ion-dipole bonds with the water molecules.
With agitation, the oil is is removed as tiny droplets which become surrounded by the soap ions forming a micelle. This stops the oil droplets returning to the fabric. When the emulsified water is allowed to pass down the sink hole, the cleaning process is complete.

Question 35 (7 Marks)

Amines and amides are two carbon-based groups of compounds, both having nitrogen in their functional groups.

The general formula for an amine is R-NH_2, while the general formula for an amide is R-CO-NH_2.

When ethanamine is dissolved in water, an alkali solution is formed.

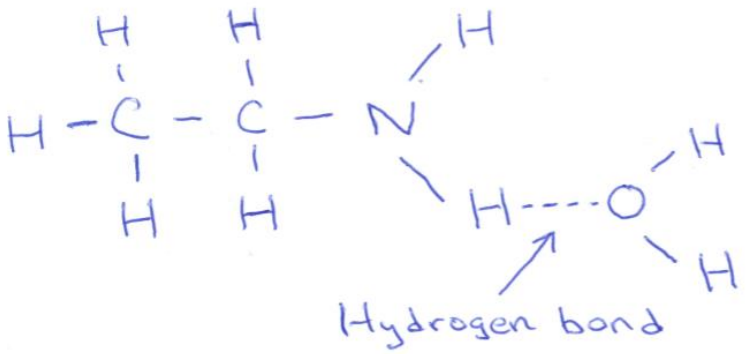
a) (i) Write the formula equation to show this chemical reaction. **1**

$R\text{-}NH_2 + H_2O \rightarrow R\text{-}NH_3^+ + OH^-$

(ii) Draw a labelled diagram to show the solubility of ethanamine in water. Label any significant bonds. **2**

Correct structures shown **1 mark**

Hydrogen bond labelled between water and amine **1 mark**



b) (i) Ethanamide is also soluble in water. What would be the approximate pH of a water/ethanamide solution?

Amides are neutral so pH will be 7

1

(ii) Would pentamanide be more soluble, less soluble or have the same solubility in water as ethanamide? Explain your choice in terms of structure and bonding. **3**

The pentanamide would be less soluble **1mark**

The pentanamide has a longer alkyl chain so it there would be more dispersion forces between these parts of the molecules. **1 mark**

This would reduce the significance of polar nature of molecule **1 mark**

Question 36 (8 Marks)
Assess the environmental implications of obtaining and using hydrocarbons from the Earth and contrast with a biofuel such as ethanol.

Marking Scheme	Mark
• Explanation showing comprehensive understanding of how obtaining AND using hydrocarbons from the earth has environmental implications • Explanation showing comprehensive understanding of how obtaining AND using biofuels has environmental implications • Explicit assessment of severity of environmental implications for BOTH hydrocarbons from the earth and biofuels	8
• Explanation showing understanding of how obtaining AND using hydrocarbons from the earth has environmental implications • Explanation showing understanding of how obtaining AND using biofuels has environmental implications • Explicit assessment of severity of environmental implications for both hydrocarbons from the earth and biofuels	7
• Description of how obtaining and/or using hydrocarbons from the earth has environmental implications • Description showing understanding of how obtaining and/or using biofuels has environmental implications • Simple assessment of severity of environmental implications for both hydrocarbons from the earth and biofuels • Some errors in terminology	5-6
• Attempts description of how obtaining and/or using hydrocarbons from the earth has environmental implications • Attempts description showing understanding of how obtaining and/or using biofuels has environmental implications • Minimal assessment of use of hydrocarbons from the earth and/or biofuels • Some errors in terminology	3-4
• Demonstrates basic understanding obtaining and/or using hydrocarbons from the earth and/or biofuels	2
• Some relevant information given	1

Question 36 (8 Marks)

Assess the environmental implications of obtaining and using hydrocarbons from the Earth and contrast with a biofuel such as ethanol. 8

HYDROCARBONS (OCTANE):

The main sources of hydrocarbons from the Earth are fossil fuels and crude oil. Octane is the main component of petrol and can be used as an example to assess the environmental implications of obtaining and using.

OBTAINING: the methods of extraction of hydrocarbons from the Earth include surface drilling for coal, mining for fossil fuels, and fracking for hydrocarbons. All these methods can contaminate soil and water, is by bringing heavy metal ions to the surface, and heavily degrade the environment.

USING: The combustion of hydrocarbons (such as octane) releases $CO_{2(g)}$ into the atmosphere:

$$C_8H_{18} + \frac{25}{2}O_{2(g)} \longrightarrow 8CO_{2(g)} + 9H_2O_{(l)}$$

This contributes to an enhanced greenhouse effect and causes a higher average global temperature, which leads to rising sea levels and dangerous flooding in some areas.

Due to the lack of oxygen in octane (C_8H_{18}), it is more likely to undergo incomplete combustion, releasing $C_{(s)}$ and $CO_{(g)}$ into the air and degrading air quality.

Acid rain, from nitrogen oxides (NO_x) cause the acidification of lakes and waterways, leading to defoliation of forests and harms to animal habitat and lifestyle.

Hydrocarbons are non-renewable resources as the rate of consumption is much higher than the rate of production of fossil fuels.

BIOFUELS / BIOETHANOL:

Biofuels, predominantly bioethanol, is made through hydrolysis of cellulose (from sugarcane) and fermentation of glucose, or the hydration of ethene.

8

well argued!

☆ CONT. on PG 26

CONT. Q36

(BIOETHANOL)

OBTAINING: Bioethanol is sourced from natural resources such as sugarcane for cellulose. These are renewable because the rate of production is higher than the rate of production. ✓

The process of fermentation of glucose is theoretically carbon neutral, meaning it does not harm the environment.

$$C_6H_{12}O_{6(aq)} \xrightarrow{\text{zymase}} 2C_2H_5OH_{(aq)} + 2CO_{2(g)}$$

USING: due to the presence of oxygen in ethanol (C_2H_5OH), it undergoes complete combustion and will not release harmful byproducts of $C_{(s)}$ and $CO_{(g)}$ into the air (like octane does).

However, the process is ultimately not carbon neutral, as intensive amounts of energy is used in the process and transportation of ethanol.

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If used as fuel in cars, an ethanol concentration of >10% would require engine modifications. ✓

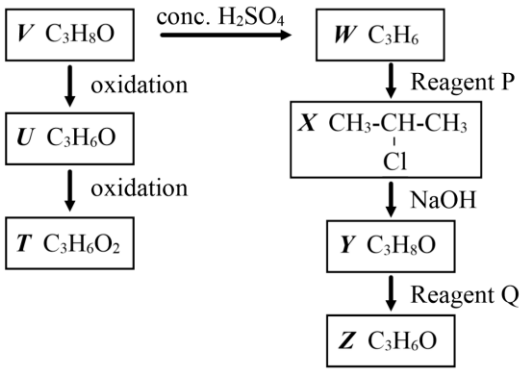
The low calorific value of combustion of bioethanol means that more fuel needs to be combusted to achieve the same amount of energy as less fuel containing octane.

Thus, considering the environmental implications of obtaining and using hydrocarbons from the Earth, in contrast to biofuels, such as bioethanol, we can conclude that hydrocarbons from the Earth are a serious detriment to the environment which accelerates climate change. ✓

Biofuels are a more environmentally viable solution. However, due to lack of research on biofuels, they are not an economically viable solution.

Question 37 (9 Marks)

The diagram below shows two sequences of reactions starting with the alcohol labelled **V.**



Identify compounds T to Z and justify your answers with the reference to the information provided.

Marking Scheme	**Marks**
Comprehensive justification with: • All compounds correctly identified • Justification of primary alcohol structure for V • Correct use of reaction names for processes to produce structures U-Z	**9**
1 error in above	**8**
2 errors in above	**7**
3 errors in above	**6**
4 errors in above	**5**
Multiple errors but shows understanding of naming and some processes	**4**
Some correct names given without justification	**3**
Some correct information provided	**2**
Some relevant information provided	

T is propanoic acid which was oxidised from propan-1-ol (**V**)

U is an intermediate step in this oxidation and so is an aldehyde (propanal)

V is dehydrated by conc. Sulfuric to produce propene (W)

The addition of HCl will lead to the formation of 2-chloropropane (X).

X undergoes an addition rn to form propan-2-ol (Y) which will oxidise to form propanone (Z).