Student number

PEM

Chemistry

2021 TRIAL EXAMINATION

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper
- For questions in Section II, show all relevant working in questions involving calculations

Total marks: 100

Section I – 20 marks (pages 3–10)

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

Section II – 80 marks (pages 11–25)

- Attempt Questions 21–37
- Allow about 2 hours and 25 minutes for this section

Section I
20 marks

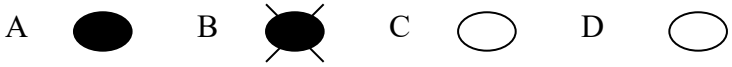
Attempt Questions 1-20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet.

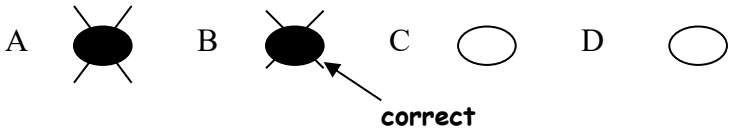
Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

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

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



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



Section I

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

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

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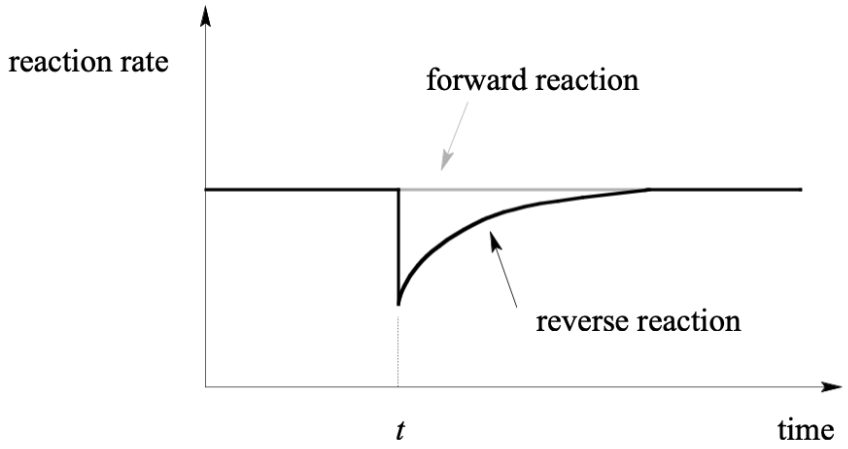
1. A small amount of solid lead iodide was added to a beaker of water, which was stirred. Most of the solid settled on the bottom of the beaker, but a little dissolved, establishing the equilibrium

$$PbI_2\ (s) \rightleftharpoons Pb^{2+}\ (aq) + 2I^-\ (aq)$$

The rates of the forward and reverse reactions were monitored over time, producing the graph shown below:



What happened at time *t*?

A. A small amount of solid $Pb(NO_3)_2$ was added to the beaker.
B. A small amount of solid KI was added to the beaker.
C. A small amount of solid PbI_2 was removed from the beaker.
D. A small amount of water was added to the beaker.

2. It is known that carbon monoxide reacts exothermically with hydrogen gas to form methanol at 400°C, in the presence of a catalyst.

$$CO\ (g) + 2H_2\ (g) \rightleftharpoons CH_3OH\ (g) \qquad \Delta H = \text{-ve}$$

A mixture of carbon monoxide, hydrogen gas and methanol placed under conditions described above achieves equilibrium in a closed container. If the reaction temperature is changed to 450°C, which of the following statements is correct?

A. The total number of molecules in the container decreases.
B. The reaction rates of both the forward and reverse reactions remain constant.
C. The average molecular mass of the gaseous mixture decreases.
D. Rate of formation of hydrogen decreases while the rate of decomposition of methanol increases.

3. A 0.1 mol L^{-1} solution of a weak acid HA is 5% dissociated at 25°C. Calculate the concentration of hydronium ions in the acid solution.

A. 0.50 mol L^{-1}.
B. 0.050 mol L^{-1}.
C. 0.0050 mol L^{-1}.
D. 2%.

4. The *K*sp for calcium fluoride is 3.2×10^{-11}. Determine the concentration of calcium ions in a saturated aqueous solution.

A. 2.0×10^{-4} mol L^{-1}.
B. 5.7×10^{-6} mol L^{-1}.
C. 3.2×10^{-4} mol L^{-1}.
D. 4.0×10^{-4} mol L^{-1}.

5. Consider the following weak acids with their associated *K*a values.

Acid	***K*a**
HClO	3.5×10^{-8}
$HClO_2$	1.2×10^{-2}
HCN	6.2×10^{-10}
$H_2PO_4^-$	6.2×10^{-8}

Which one of the following gives the correct order of increasing strength of the conjugate base of each acid?

A. ClO_2^-, ClO^-, HPO_4^{2-}, CN^-
B. ClO_2^-, HPO_4^{2-}, ClO^-, CN^-
C. CN^-, HPO_4^{2-}, ClO^-, ClO_2^-
D. CN^-, ClO^-, HPO_4^{2-}, ClO_2^-

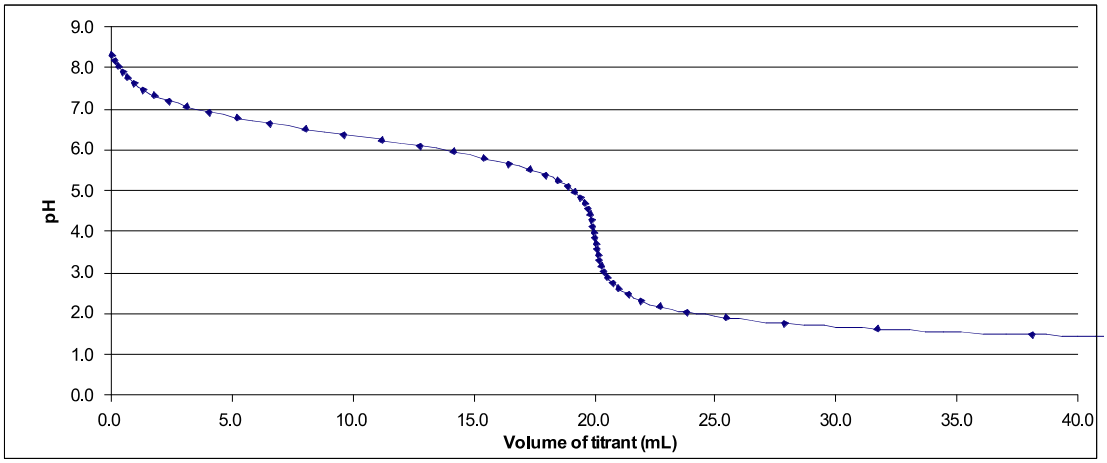
6. What will happen to the pH of a buffer solution when a small amount of a strong base is added?

A. it will increase slightly
B. it will decrease slightly
C. it will remain exactly the same
D. it will become 7.0

7. What is the p*H* of a 0.010 mol L^{-1} solution of a weak monoprotic acid that is 4.0% ionised?

A. 2.00
B. 2.40
C. 2.80
D. 3.40

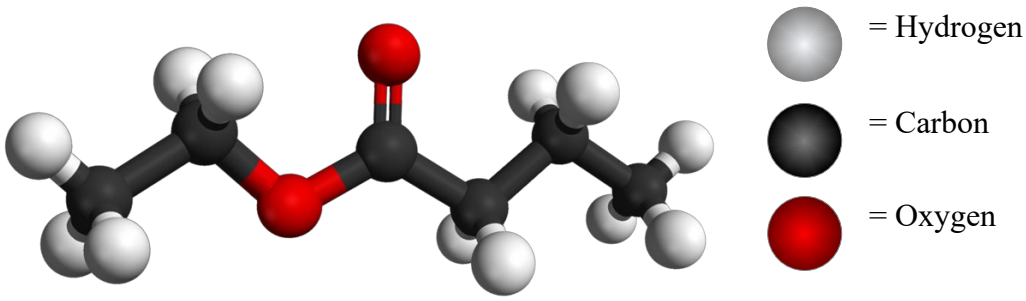
8. 20 mL of solution **X** was pipetted into a conical flask and titrated with solution **Y** from a burette. The pH was monitored with a pH meter throughout the experiment and was plotted against the volume of solution **Y** added to give the graph below.



Which one of the following alternatives is most likely the identity of solutions **X** and **Y**?

	X	**Y**
A.	KOH	CH_3COOH
B.	$NaHCO_3$	HBr
C.	CH_3COOH	$NaHCO_3$
D.	KOH	HBR

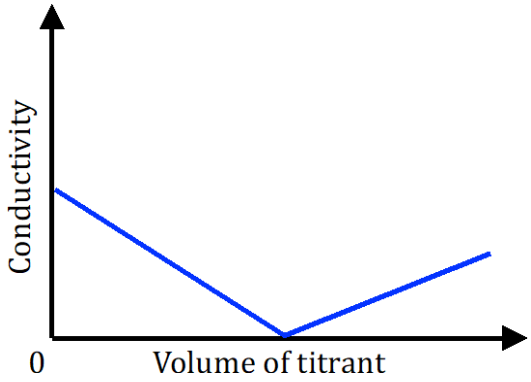
9. Which reactants could be used to form the compound below?



A. Butanoic acid and ethanol
B. Propanoic acid and ethanol
C. Ethanoic acid and propan-1-ol
D. Ethanoic acid and butan-1-ol

10. Which of the following conductivity curves correctly depicts the titration of hydrochloric acid against potassium hydroxide?

A.



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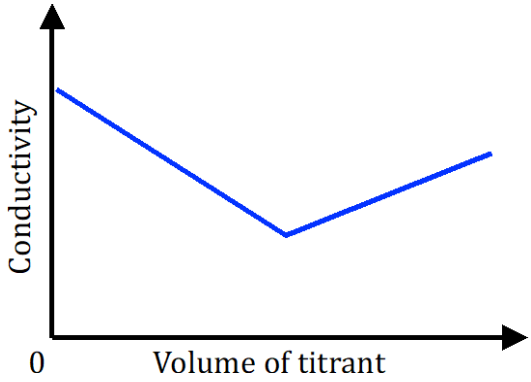
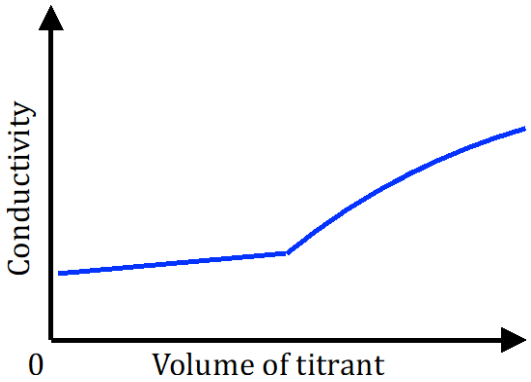
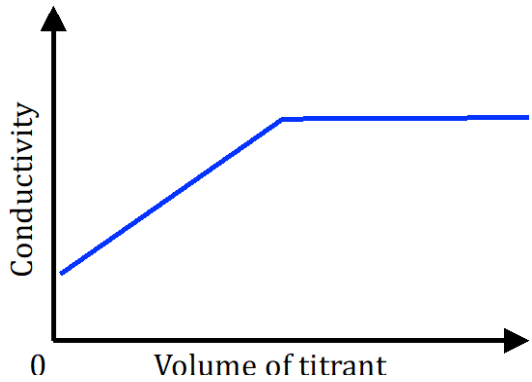


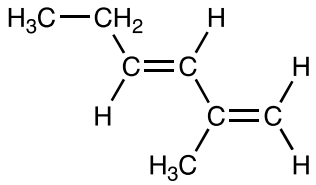
C.



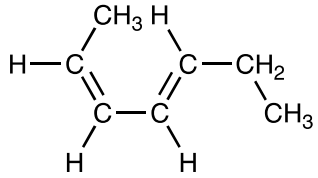
D.

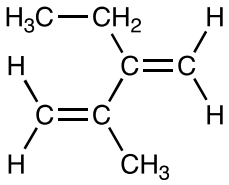


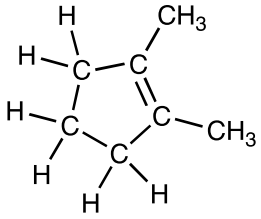
11. The molecule below represents 2-methy-1,3-hexadiene.

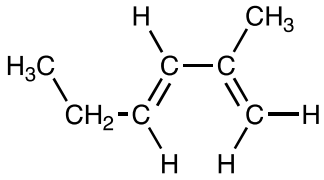


Which one of the following is **not** an isomer of the molecule depicted?

A. 

B. 

C. 

D. 

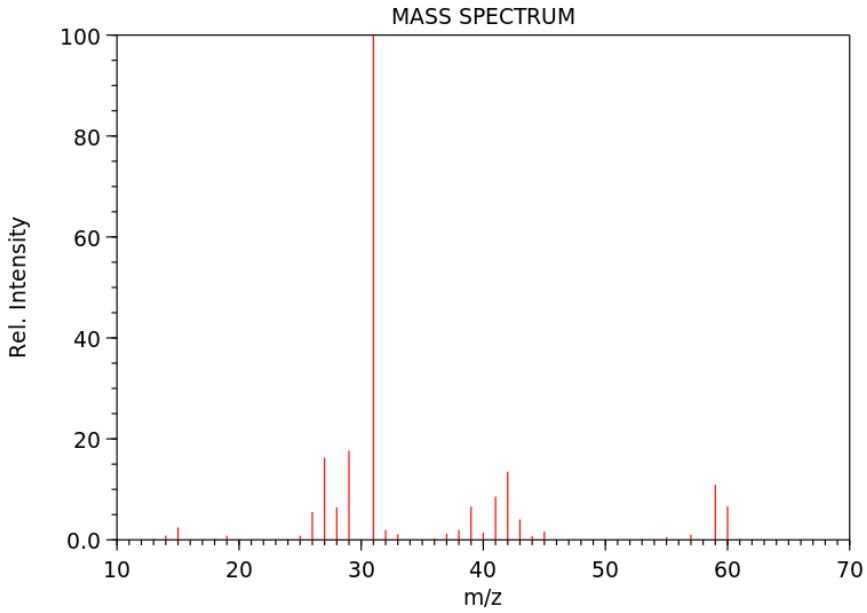
12. How many products are possible when 2-butene reacts with HCl?

A. one
B. two
C. three
D. four

13. Which row of the table below correctly matches the reaction type with its correct reactants, catalyst and products?

	Reaction Type	Reactants	Catalyst	Products
A.	Hydration	$H_2C = CH_2 + H_2O$	H_2SO_4	$HOCH_2CH_2OSO_3H$
B.	Hydration	$H_2C = CH_2$	concentrated H_2SO_4	CH_3CH_2OH
C.	Addition	$H_2C = CH_2 + H_2O + Br_2$	nil	$BrCH_2CH_2Br$
D.	Addition	$H_2C = CH_2 + H_2$	Nickel	CH_3CH_3

14. The mass spectrum for an alkanol is shown below.



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

A. methylpropanol
B. 1-propanol
C. 2-butanol
D. 1-butanol

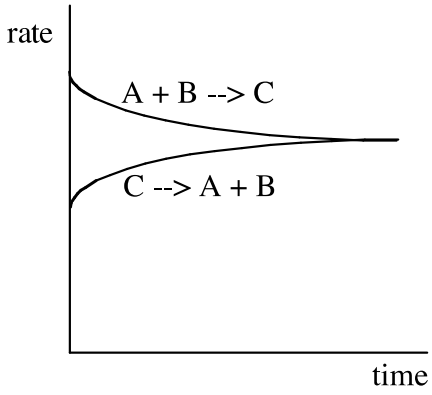
15. What brings about **emission** of visible and ultraviolet radiation from atoms?

A. electrons changing from lower to higher energy levels
B. the atoms condensing from a gas to a liquid or solid
C. electrons moving about the atoms within an orbital
D. electrons changing from higher to lower energy levels

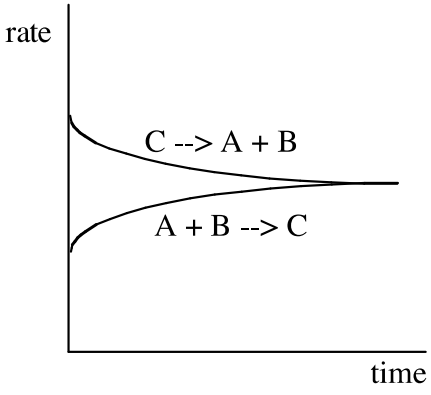
16. Consider an equilibrium system: A + B ⇌ C.

Which of the following graphs represent a system reaching equilibrium by *shifting the equilibrium position to the right*?

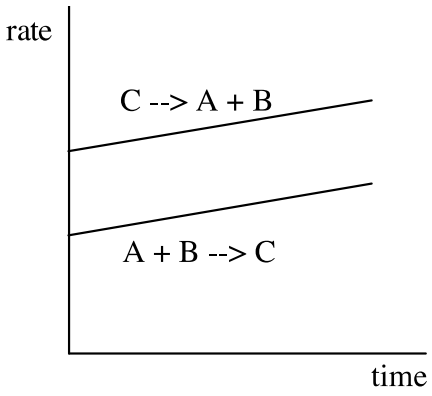
A.



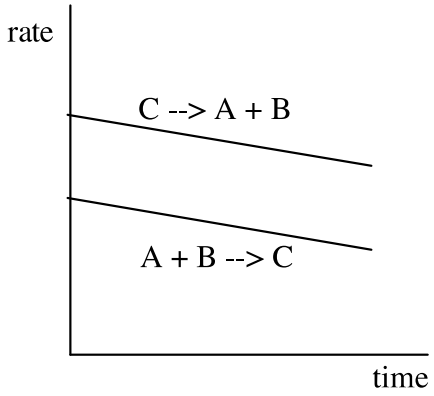
B.



C.



D.



17. When 1.27 g samples of the following substances are all treated with excess dilute hydrochloric acid, all give off carbon dioxide. Which gives off the greatest mass of carbon dioxide?

A. lithium carbonate
B. beryllium carbonate
C. sodium carbonate
D. magnesium carbonate

18. Pure water undergoes self-ionisation according to the equation below:

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

The equilibrium constant for the reaction is:

1.0×10^{-14} at 25°C and 5.5×10^{-13} at 100°C.

Which one of the following statements is correct?

A. At 100°C the p*H* of pure water is less than 7.0, but the $[H_3O^+] = [OH^-]$.
B. At 100°C the p*H* of pure water is less than 7.0, and therefore the $[H_3O^+] > [OH^-]$.
C. At 100°C the p*H* of pure water is greater than 7.0, and therefore the $[OH^-] > [H_3O^+]$.
D. At 100°C the p*H* of pure water must be 7.0 and the $[H_3O^+] = [OH^-]$.

19. Calcium carbonate is dissolved in 100 mL of water. This solution is mixed with 300 mL of 0.010 M Na_2SO_4. A faint precipitate of calcium sulfate is formed. Considering the *K*sp value of calcium sulfate is 2.4×10^{-5}, how much calcium nitrate was dissolved to make the initial solution?

A. 0.040 g
B. 0.21 g
C. 0.32 g
D. 0.63 g

20. The infrared spectrum of a pure compound showed a broad band between 3000 and 3200 cm^{-1}; a series of moderate bands at 2900, 2990 and 3200 cm^{-1}; an intense band at 1725 cm^{-1}; and numerous bands between 1640 and 750 cm^{-1}.

Which of the following compounds matches these absorbances?

A. ethene
B. ethanol
C. ethyl ethanoate
D. ethanoic acid

Student number

Chemistry

2021 TRIAL EXAMINATION

Section II
80 marks

Attempt Questions 21- 37
Allow about 2 hour and 25 minutes for this part

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 21 (4 marks**)**

A student was required to investigate the equilibrium between yellow chromate ions (CrO_4^{2-}) and orange dichromate ions ($Cr_2O_7^{2-}$) in an aqueous solution. They were supplied with:

- Solid Potassium Chromate
- Solid Potassium Dichromate
- 1 mol L^{-1} hydrochloric acid
- Water.

The equilibrium of the equation is:
$2CrO_4^{2-}\ (aq) + 2H^+\ (aq) \rightleftharpoons Cr_2O_7^{2-}\ (aq) + H_2O\ (l)$

Describe a series of experiments that could be performed to investigate the chromate / dichromate equilibrium. Predict the results of these experiments. ***4***

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Question 22 (4 marks**)**

At 448 °C the equilibrium constant *K*eq for the reaction:

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

is 50.5. Predict in which direction the reaction proceeds to reach equilibrium if we start with 2.0×10^{-2} mol of HI, 1.0×10^{-2} mol of H_2, and 3.0×10^{-2} mol of I_2 in a 2.00 L container. ***4***

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Question 23 (4 marks**)**

Determine whether silver sulfate will precipitate when 60 ml of 0.010 mol L^{-1} silver nitrate and 30 mL of 0.010 mol L^{-1} sodium sulfate are mixed at 25ºC.

The *K*sp (silver sulfate) = 1.20×10^{-5}. ***4***

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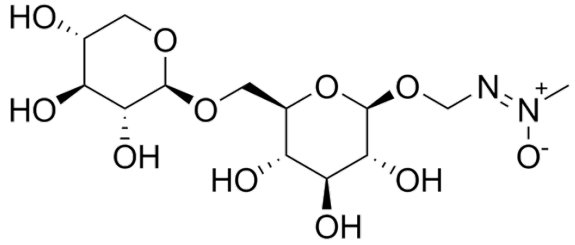
Question 24 (3 marks)

The seeds of cycad plants are used by Aboriginal and Torres Strait Islander peoples to make bread. However, these seeds contain toxins, TWO of which are illustrated below.



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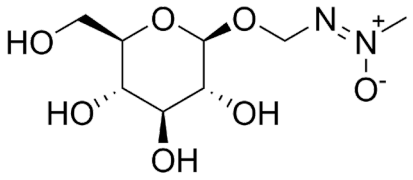

cycasin

Explain the process used to remove these toxins with reference to the features of each molecule. ***3***

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Question 25 (5 marks)

A sample of pure water is tested with phenol red indicator. The pH range and colour change for this indicator are 6.8 (yellow) to 8.4 (red).

(a) Predict the colour change of this indicator in pure water ***1***

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(b) A small quantity of a white solid is stirred into the water–phenol red mixture. The indicator turns red. Classify this solid as acidic, basic or neutral. ***1***

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(c) Citric acid crystals are added in excess to the solution in (b). The mixture is stirred. Describe the colour changes that would observe in this experiment ***3***

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Question 26 (4 marks**)**

Hydrazine (N_2H_4) is common to rocket fuel, spandex suits, power stations and car airbags. Like ammonia, it is classified as a Bronsted-Lowry base when it reacts with water. A 0.15 mol L^{-1} solution has a pH of 10.70. Calculate the *K*b for hydrazine. ***4***

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Question 27 (6 marks**)**

The maintenance of the pH of blood in the range 7.35 to 7.45 is a good example of a natural buffer system in operation and is represented below:

$$H_2CO_3\ (aq) + H_2O\ (l) \rightleftharpoons HCO_3^-\ (aq) + H_3O^+\ (aq)$$

Haemoglobin is the bluish-red iron-protein molecule that absorbs and transports oxygen in our blood. It is a complex molecule that contains four haem (Hb) groups bound to an iron (II) ion. Each haemoglobin molecule can bind four oxygen molecules. Haemoglobin is also a weak acid. It is a weak proton donor. The oxygenated form of haemoglobin is called *oxyhaemoglobin* which can be represented by the symbol $HHb_4(4O_2)$ or HHb_4O_8.

Oxyhaemoglobin is bright red in colour. The oxygenation of haemoglobin is a reversible equilibrium:

$$HHb_4 + H_2O\ (l) + 4O_2\ (aq) \rightleftharpoons Hb_4O_8^- + H_3O^+\ (aq)$$

A patient has untreated diabetes. She has a rapid pulse and her blood pH is 7.1.

(a) Her body reacts to the condition by hyperventilating (breathing faster or deeper than necessary). Why does this happen? ***3***

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(b) Her treatment involves an injection of hydrogen carbonate ions into the blood. Explain how this treatment will help her condition. ***3***

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Question 28 (5 marks)

Sodium hydrogencarbonate, $NaHCO_3$, is a common laboratory chemical. Explain why the Arrhenius acid/base definition is unable to account for the acid/base properties of this species, whereas the Bronsted-Lowry theory can. Include chemical equations to illustrate your explanation. ***5***

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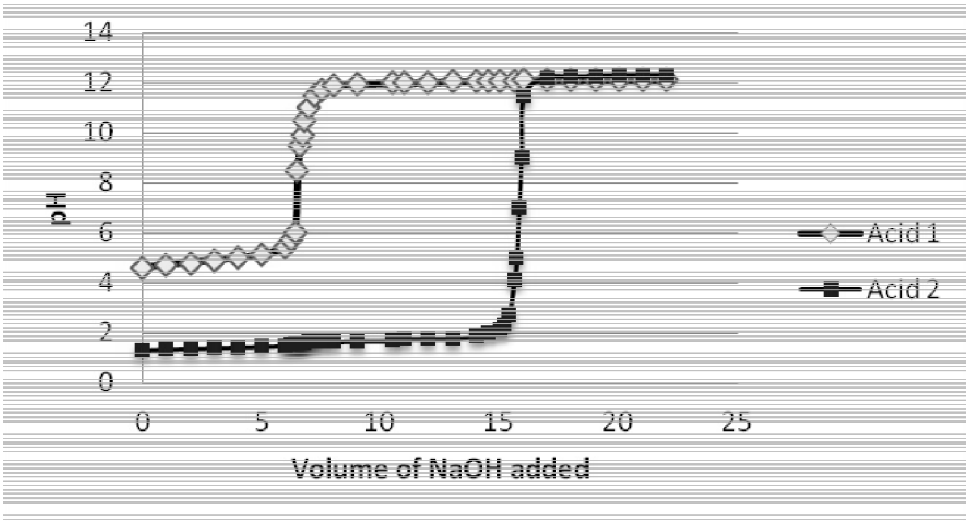
Question 29 (5 marks**)**

The graph shows changes in pH for the titrations of equal volumes of solutions of two monoprotic acids, *Acid 1* and *Acid 2*. The same sodium hydroxide solution was used for both titrations.



(a) Explain what is meant by a *monoprotic acid*. ***1***

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(b) Using the symbol HX for a monoprotic strong acid, write an equation for the ionisation of HX in water. ***1***

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(c) Using the symbol HY for a monoprotic weak acid, write an equation for the ionisation of HY in water. ***1***

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(d) Which of HX or HY is likely to be Acid 1 in the graph above? Justify your answer. ***2***

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Question 30 (5 marks**)**

The production of wine possesses strict regulations in which the content of volatile acid, mainly present as acetic acid, be no greater than 1.20 g L^{-1} for non-red wines. One technique to determine the volume of volatile acid is to distil a sample of the wine and then titrate the distillate with a solution of sodium hydroxide. It can be assumed that the only volatile acid present is acetic acid.

20.00 mL of this particular white wine is distilled, and the distillate made up to 100.00 mL in a volumetric flask. 10.00 mL of this solution is then titrated with approximately 20.0 mL sodium hydroxide. Using calculations, which of the following concentrations of NaOH is the most appropriate to use for the titration;

- 2.00×10^{-2} mol L^{-1}
- 2.00×10^{-3} mol L^{-1}
- 2.00×10^{-4} mol L^{-1}

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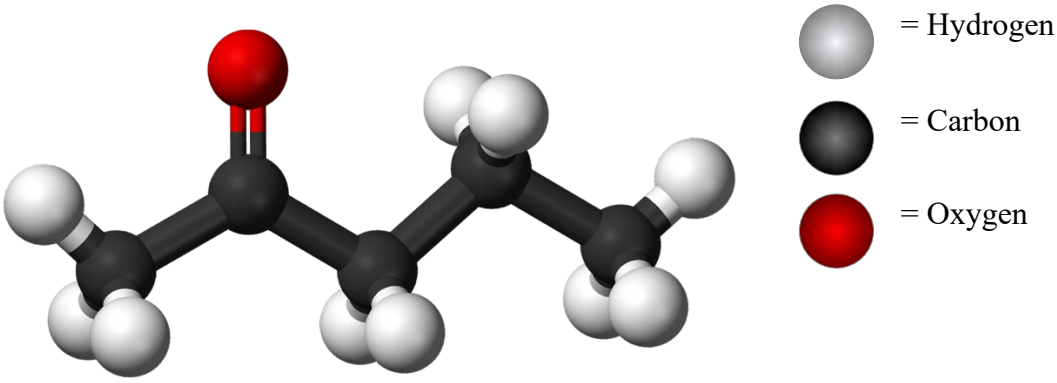
Question 31 (6 marks**)**

The image below represents a ball-and-stick model of an organic compound.



(a) Identify the name molecular formula of the molecule ***1***

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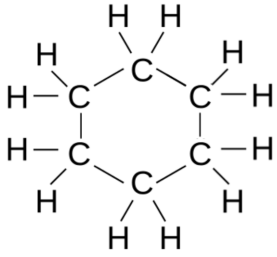
(b) Draw the structural formulas and name at least FIVE isomers of this molecule. ***5***

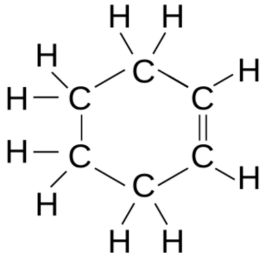
Structural Formula	**IUPAC Name**

Question 32 (6 marks**)**

A student carried out a first-hand investigation to distinguish between cyclohexane and cyclohexene. They are both colourless liquids that are insoluble and less dense than water.



Cyclohexane



Cyclohexene

(a) Justify a method that the student could use in their first-hand investigation. ***2***

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(b) Write the formula of possible products that will form when cyclohexene reacts with bromine water. ***1***

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(c) Explain the results that the student should have obtained. ***3***

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Question 33 (7 marks**)**

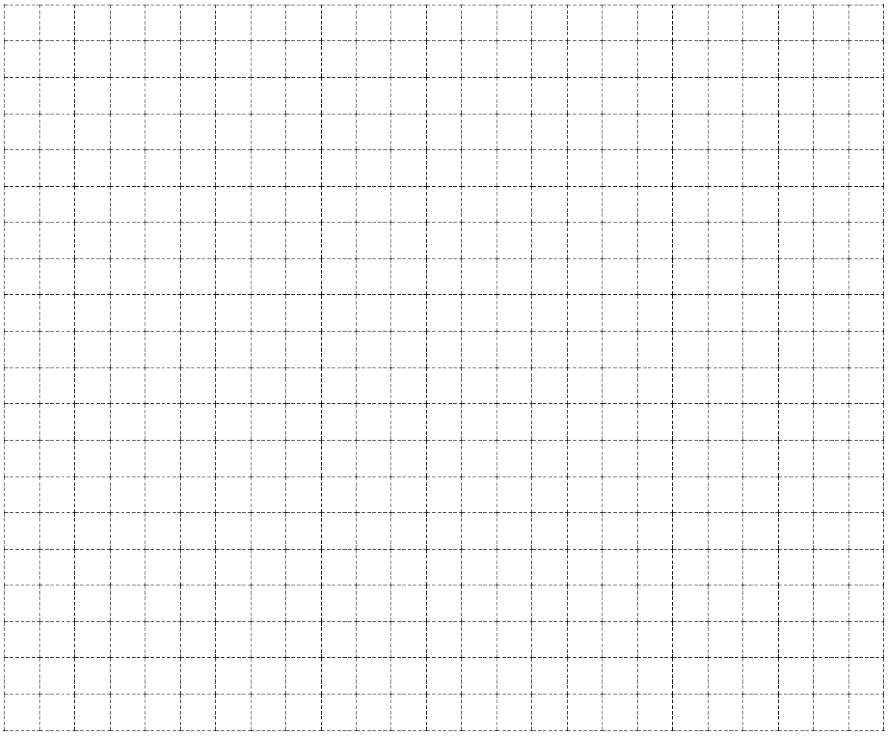
The tables below illustrate the boiling points of similar mass molecules from the alkenes, the aldehydes and the amines.

Alkene	Relative molecule mass (g mol^{-1})	Boiling Point (^{o}C)
Ethene	28.1	-104
Propene	42.1	-47
1-butene	56.1	-6
1-pentene	70.1	30

Aldehyde	Relative molecule mass (g mol^{-1})	Boiling Point (^{o}C)
Methanal	30.0	-21
Ethanal	44.1	21
Propanal	58.1	46
Butanal	72.1	75

Amines	Relative molecule mass (g mol^{-1})	Boiling Point (^{o}C)
Methylamine	31.1	-6
Ethylamine	45.1	17
1-Propylamine	59.1	49
1-butylamine	73.1	78

(a) Use the grid below to graph the boiling point against relative molecular mass for all the molecules in the 3 tables on the previous page. Draw a different line of best fit for each homologous series. ***3***



(b) Account for the differences in the boiling points within and between the homologous series. *4*

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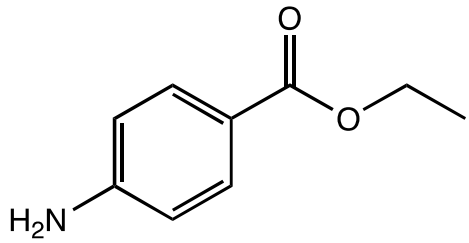
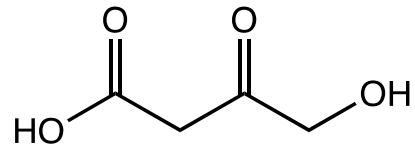
Question 34 (4 marks)

(a) Identify the name of the functional groups present in each of the following molecules below *3*

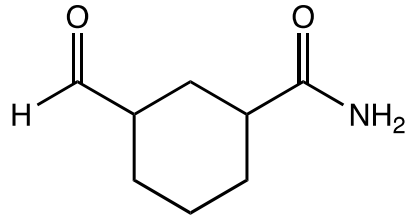
i.



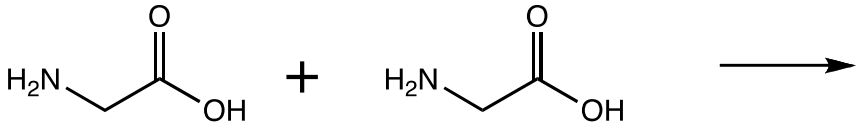
ii.



iii.



(b) Draw the possible product that could form when the two molecules are allowed to react. *1*



Question 35 (3 marks)

A student wanted to determine the phosphorus content in a certain brand of washing powder. The phosphorus was precipitated as $Ca_2P_2O_7$ and then filtered. An 8.84 g sample of washing powder resulted in a precipitate of mass 0.464 g.

(a) Identify TWO procedures that the student would need to perform, after filtration and before weighing, in order to increase the accuracy of the experiment. ***1***

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(b) Calculate the percentage of phosphorus, by mass, in the sample. ***2***

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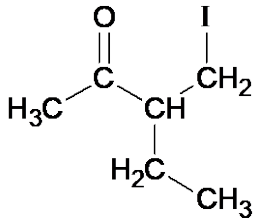
Question 36 (4 marks)

The following compound was analysed by mass spectrometry. Propose structures for each fragment corresponding to observed *m*/*z* peaks in the obtained spectrum.



m/*z* = 15	*m*/*z* = 29	*m*/*z* = 43	*m*/*z* = 127

4

Question 37 (5 marks)

An insoluble white solid X is dissolved in nitric acid. An odourless gas evolved and a colourless solution forms. Some of the gas is passed into a test tube containing universal indicator solution. The indicator turned pink. Some of the gas was passed into a solution of barium hydroxide and a faint white precipitate forms. The colourless solution was divided into three test tubes and tested with three reagents. The results are:

- Sodium iodide solution forms a bright precipitate.
- Sulfuric acid forms a thick white precipitate
- Sodium chloride solution forms a faint white precipitate that dissolved when the mixture is heated.

Analyse the information and identify the white solid X. ***5***

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End of paper

2021 Year 12 Chemistry Trial examination. Marking Guidelines and model Answers.

Section I Multiple Choice

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

Section II

Question 21

Marking guidelines	Marks
• Describes a method for testing the chromate ions with HCl and water • Describes a method for testing the dichromate ions with HCl and water • Predicts outcomes for BOTH species	4
• Describes methods for both species but provides no expected results OR • Provides a vague method with expected results	3
• Describes a method for one species AND provides the expected outcome.	2
• Describes a method for one species OR • Provides an expected outcome.	1

Question 22

Marking guidelines	Marks
• Calculates concentrations of species in moles per litre • Calculates Q • Compares magnitude of reaction quotient against equilibrium constant • Direction in which the reaction will proceed	4
• Provides THREE relevant steps OR has a one calculation error	3
• Provides TWO relevant step	2
• Provides any relevant information	1

Sample Answer

The initial concentrations are:

$[HI] = 2.0 \times 10^{-2}\ mol/2.00\ L = 1.0 \times 10^{-2}\ mol\ L^{-1}$

$[H_2] = 1.0 \times 10^{-2}\ mol/2.00\ L = 5.0 \times 10^{-3}\ mol\ L^{-1}$

$[I_2] = 3.0 \times 10^{-2}\ mol/2.00\ L = 1.5 \times 10^{-2}\ mol\ L^{-1}$

$$Q = \frac{[HI]_2}{[H_2][I_2]} = \frac{(0.01)^2}{0.005 \times 0.015} = 1.3$$

$\therefore Q < K$

The concentration of reactants will decrease, and the concentration of products will increase. Hence reaction will proceed in the forward direction.

Question 23

Marking guidelines	Marks
• Calculates the concentration of silver and sulfate ions • Provides equilibrium expression • Calculates ionic product • No precipitate is produced	4
• Provides THREE relevant steps	3
• Provides TWO relevant steps	2
• Any relevant information	1

Sample Answer

$n(Ag+) = cv$
$= 0.01 \times 0.06$
$= 0.0006 \text{ mol}$

$n(SO_4^{2-}) = cv$
$= 0.01 \times 0.03$
$= 0.0003$

Total volume of solution 30 mL + 60 mL = 90 mL

$$c(Ag+) = \frac{n}{v} = \frac{0.0006}{0.09} = 6.67 \times 10^{-3} \text{ mol L}^{-1}$$

$$c(SO_4^{2-}) = \frac{n}{v} = \frac{0.0003}{0.09} = 3.33 \times 10^{-3} \text{ mol L}^{-1}$$

$Ag_2SO_4 (s) \rightleftharpoons 2Ag^+ (aq) + SO_4^{2-} (aq)$

$\text{Ionic product} = [Ag^+]^2[SO_4^{2-}]$
$= (6.67 \times 10^{-3})^2 \times 3.33 \times 10^{-3}$
$= 1.48 \times 10^{-7}$

Ionic product < Ksp ∴ no precipitate will form.

Question 24

Marking guidelines	Marks
• Describes the process of leaching. AND • Explains structural features from each molecule that allows it to be soluble in water	3
• Describes the process of leaching. OR • Identifies structural features from each molecule that allows it to be soluble in water	2
• Identifies that either compound is soluble in water OR • Describes the process of leaching	1

Sample answer

Leaching involves submerging the grounded up powder from the cycad seeds inside a bag in running water for up to 4 weeks, depending on the type of seed. Each molecule is polar due to the OH functional groups, hence allow them to be soluble in water. Furthermore, grinding the seeds increases the surface area available for the water to pass through. The remaining carbohydrate is insoluble and can be cooked to make bread.

Question 25 (a)

Marking guidelines	Marks
● Yellow orange colour	1

Question 25 (b)

Marking guidelines	Marks
● basic	1

Question 25 (c)

Marking guidelines	Marks
● Refers to the solution becoming acidic ● Describes multiple colour changes ● Provides reason	3
● TWO of the above criteria	2
● ONE of the above criteria	1

Sample answer

The addition of a weak acid to basic solution will reduce the pH slightly below 7. This results in a red to orange to yellow as the solution turns from basic to neutral to slightly acidic.

Question 26

Marking guidelines	Marks
● Provides balanced equation ● Calculates concentration of [OH-] ● Provides *K*b expression ● Calculates *K*b	4
● Correctly addresses THREE of the above criteria OR ● Address ALL of the criteria with a calculation error	3
● Correctly addresses at least TWO of the above criteria	2
● Calculates $[H^+]$	1

Sample answer

$N_2H_4\ (aq) + H_2O\ (l) \rightleftharpoons N_2H_5\ (aq) + OH^-\ (aq)$

$$[H^+] = 10^{-pH}$$
$$= 10^{-10.70}$$
$$= 1.995 \times 10^{-11}$$

$$[H^+][OH^-] = 1.0 \times 10^{-14}$$
$$[OH^-] = \frac{1.0 \times 10^{-14}}{1.995 \times 10^{-11}}$$
$$= 5.0119 \times 10^{-4}$$

$$Kb = \frac{[N_2H_5][OH^-]}{[N_2H_5]}$$
$$= \frac{x^2}{0.15}$$
$$= \frac{(5.0119 \times 10^{-4})^2}{0.15}$$
$$= 1.67 \times 10^{-6}$$

Question 27 (a)

Marking guidelines	Marks
● Explains role of hyperventilating in relation to the equilibrium shift ● Refers to change in H_3O^+ concentration in increasing blood pH ● Refers to at least ONE equilibrium equation	3
● Outlines the role of hyperventilating in relation to the equilibrium shift ● Refers to change in H_3O^+ concentration in increasing blood pH	2
● Refers to the correct shift in equilibrium	1

Sample answer

The body hyperventilates to decrease the oxygen levels in the lungs and also in the blood. As less oxygen is now available to bind to the haemoglobin, the haemoglobin equilibrium shifts to the left as outlined below:

$$HHb_4 + H_2O\ (l) + 4O_2\ (aq) \rightleftharpoons Hb_4O_8^- + H_3O^+\ (aq)$$

This equilibrium shift reduces the levels of hydronium ions. Thus the blood pH will rise return to normal levels.

Question 27 (b)

Marking guidelines	Marks
● Outlines shift in hydrogen carbonate equilibrium ● Outlines shift in haemoglobin equilibrium ● Explains how treatment restores blood pH	3
● TWO of the above	2
● Any relevant information	1

Sample answer

Adding hydrogen carbonate ions to the blood will neutralise excess acidity and will favour the reverse reaction according to the equilibrium below:

$$H_2CO_3\ (aq) + H_2O\ (l) \rightleftharpoons HCO_3^-\ (aq) + H_3O^+\ (aq)$$

This results in a shift in the equilibrium towards oxyhaemoglobin; that is, to the right in the equilibrium

$$HHb_4 + H_2O\ (l) + 4O_2\ (aq) \rightleftharpoons Hb_4O_8^- + H_3O^+\ (aq)$$

Thus the normal balance is restored.

Question 28

Marking guidelines	Marks
• outlines the Arrhenius and Bronsted-Lowry definitions of acids and bases • explains why the Arrhenius definition cannot account for $NaHCO_3$ being a base • identifies that the Arrhenius definition cannot account for $NaHCO_3$ being amphiprotic • explains how the Bronsted-Lowry definition accounts for its amphiprotic behaviour • includes two or more correct, relevant chemical equations	5
• Correctly addresses THREE or FOUR of the above criteria	3-4
• Correctly addresses ONE or TWO of the above statements about the Arrhenius and Bronsted-Lowry definitions, relevant to $NaHCO_3$	1-2

Sample answer

The Arrhenius definition of acids/bases is that they ionise in water to give H^+ ions, and bases ionise in water to produce OH^- ions. This definition does not account for the behaviour of $NaHCO_3$:

- *it gives basic aqueous solutions even though it does not contain OH^- ions*
- *it reacts with both acids and bases*

The Bronsted-Lowry definition is that acids are proton donors and that bases are proton acceptors. $NaHCO_3$ can be classified as an acid or a base using this definition, depending on reaction conditions. Thus, it produces basic aqueous solutions because when it dissolves it ionises to give Na^+ ions and HCO_3^- ions. The hydrogen carbonate ions accept a proton from water, producing OH^- ions and hence a pH greater than 7: $HCO_3^- + H_2O$ □ $NaHCO_3 + OH^-$. In this case it is behaving like Bronsted-Lowry base.

However, in solutions of weak bases it can act as an acid, donating a proton: $HCO_3^- + PO_4^{3-}$ □ $HPO_4^{2-} + CO_3^{2-}$. Thus the Bronsted-Lowry definition can account for the basic and amphiprotic behaviour of $NaHCO_3$.

Question 29 (a)

Marking guidelines	Marks
• An acid that can donate only 1 proton	1

Question 29 (b)

Marking guidelines	Marks
• $HX\ (aq) + H_2O\ (l) \rightarrow H_3O^+\ (aq) + X^-\ (aq)$	1

Question 29 (c)

Marking guidelines	Marks
• $HY\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + Y^-\ (aq)$	1

Question 29 (d)

Marking guidelines	Marks
• Justifies that Acid 1 is HY in terms of initial pH AND pH at equivalence point	2
• Justifies that Acid 1 is HY in terms of initial pH OR pH at equivalence point	1

Sample answer

Acid 1 is likely to be HY, a weak acid, as the solution initially has a pH >4 and the equivalence point is at a pH >8. These values are typical of weak acids reacting with a strong base, such as NaOH solution. The salt formed at the equivalence point is basic (from a strong base and a weak acid) and reacts with water to form hydroxide ions. These make the pH at the equivalence point >7.

Question 30

Marking guidelines	Marks
● Converts mass of acetic acid into concentration ● Calculates diluted solution of acetic acid ● Calculates moles of acetic acid used in titration ● Calculates concentration of NaOH required in titration ● Identifies most appropriate concentration of NaOH to use.	5
● Provides FOUR relevant steps	4
● Provides THREE relevant steps	3
● Provides TWO relevant steps	2
● Any relevant information	1

Sample Answer

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

$c(CH_3COOH) = 1.2\ g\ L^{-1}$

$= \frac{1.30\ g}{(12.01\ x\ 2)+(1.008\ x\ 4)+(16\ x\ 2)}$

$= 1.998 \times 10^{-2}\ mol$

$\therefore c(CH_3COOH) = 1.998 \times 10^{-2}\ mol\ L^{-1}$

$c(CH_3COOH) = 3.997 \times 10^{-3}\ mol\ L^{-1}$ *(20 ml to 100 ml)*
"diluted"

$n = 3.997 \times 10^{-3}\ mol$ *in 100 ml*

$n(CH_3COOH) = 3.997 \times 10^{-3}\ mol \times 0.01\ L$
"in titration"

$= 3.997 \times 10^{-5}\ mol$

$\therefore c(NaOH) = \frac{n}{v}$
"required"

$c = \frac{3.997\ x\ 10-5\ mol}{0.02}$

$1.998 \times 10^{-3}\ mol\ L^{-1}$

The best concentration to use is $2.00 \times 10^{-2}\ mol\ L^{-1}$

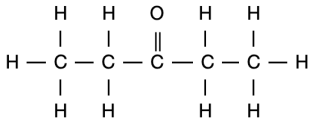
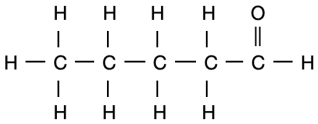
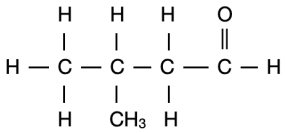
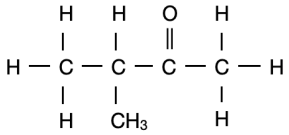
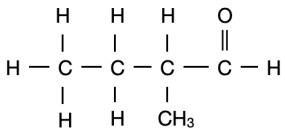
Question 31 (a)

Marking guidelines	Marks
● $C_5H_{10}O$	5

Question 31 (b)

Marking guidelines	Marks
● All FIVE correctly drawn AND named.	5
● FOUR correctly drawn AND named	
● THREE correctly drawn AND named	
● TWO correctly drawn AND named	
● One correctly drawn AND one named	

Sample Answer

Structural Formula	***IUPAC Name***
	*Pentan-3-one*
	*Pentanal*
	*3-methylbutanal*
	*3-methylbutane-2-one*
	*2-methylbutanal*

Question 32 (a)

Marking guidelines	Marks
● Provides reasons for the main listed steps of the investigation	2
● Provides reason for some of the main steps OR ● Writes a through method	1

Sample Answer

1. *5 mL of bromine water was added to 2 different test tubes*
   Justification: This is the coloured solution used to distinguish alkanes and alkenes (bromine water test)
2. *Performed in the absence of light*
   Justification: The distinguishing test requires no UV light to be present
3. *5 mL of cyclohexane and 5 mL of cyclohexene were added to the 2 different test tubes and shaken*
   Justification: These are the substances being tested
4. *Observe the differences in the colours and layers produced*
   Justification: The distinguishing test is qualitative

Question 32 (b)

Marking guidelines	Marks
● Correctly identifies both products	1

Sample Answer

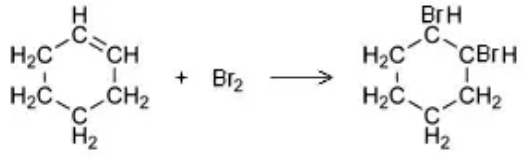
$C_6H_{10}Br_2$ (1,2-dibromocyclohexane)
$C6H_{10}BrOH$ (2-bromocyclohexan-1-ol)

Question 32 (c)

Marking guidelines	Marks
● Links the colour change of the alkene addition reaction with the reactive C=C bond and therefore no need for UV light. ● Links the lack of colour change of the alkane substitution reaction to the less reactive C-C bond, so only occurs if the energy input of UV light is provided. ● Equations included.	3
● Correctly addresses TWO of the above criteria	2
● Some relevant information	1

Sample Answer

Cyclohexene reacts with bromine water in an addition reaction to form the colourless 1,2-dibromcyclohexane as shown below.



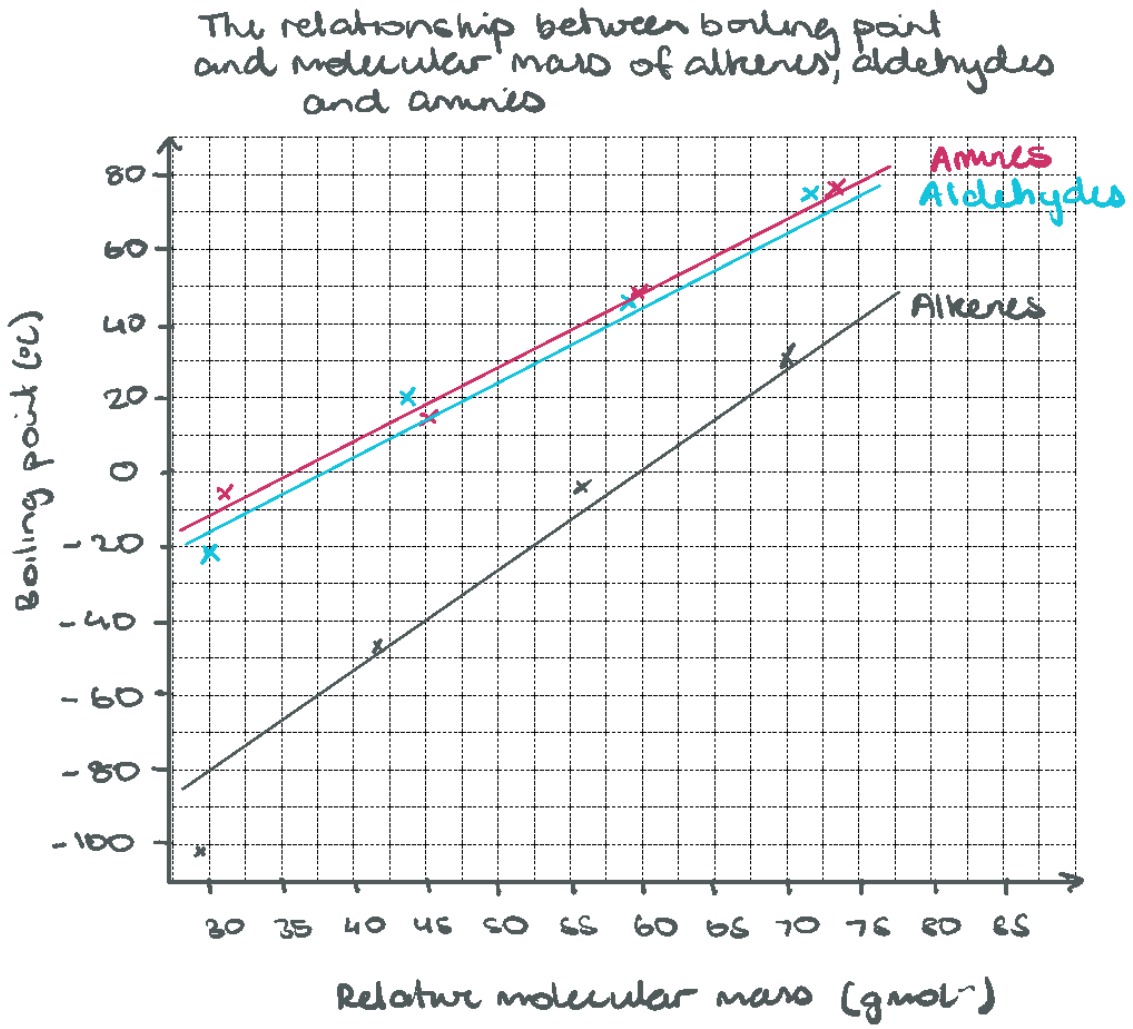
This does not require UV light due to the reactivity of the C=C double bond.

Cyclohexane contains the less reactive C-C single bond, so requires an input of UV light for the substitution reaction to occur. Hence, the reaction did not occur in the dark and the colour of the unreacted bromine water remained, allowing the alkane and the alkene to be distinguished.

Question 33 (a)

Marking guidelines	Marks
• Correctly formatted graph (labels, units, scale, title) with correctly plotted points and valid 3 curves drawn with a key provided	3
• Mostly correct	2
• Partially correct	1

Sample Answer



Question 33 (b)

Marking guidelines	Marks
● Provides correct reasons for the increasing boiling point in all three groups (dispersion forces) ● Provides correct reasons for the lowest values of the alkenes (dispersion force) ● Provides correct reasons for the higher values of the aldehydes (dipole-dipole force) ● Provides correct reasons for the highest values of the amines (hydrogen bond)	4
● Addresses THREE of the above criteria	3
● Addresses TWO of the above criteria	2
● Addresses ONE of the above criteria	1

Sample answer
Boiling point depends on the strength of the intermolecular forces between molecules. The increasing bp trend in all 3 groups is due to the increasing size of the dispersion forces due to more electrons as there are more atoms.

Alkenes have the lowest bp because they contain only non-polar C-C and C-H bonds. Therefore the only IMF between alkene molecules is dispersion forces which are the weakest so require the lowest amount of heat to break. Aldehydes and amines have similar boiling points, with amines slightly higher. The aldehydes possess the polar C=O bond. This permanent dipole means that it can form dipole-dipole attractions with other aldehydes which are stronger than dispersion forces, so more heat is required to separate these molecules. Amines possess the polar N-H bond. This gives rise to the strongest IMF of hydrogen bonding between amine molecules, requiring the most heat energy to break apart from each other.

Question 34 (a) i.

Marking guidelines	Marks
● Correctly identifies BOTH functional groups	1

Sample Answer
Amine and Ester

Question 34 (a) ii.

Marking guidelines	Marks
● Correctly identifies all THREE functional groups	1

Sample Answer
Carboxylic, ketone and alcohol

Question 34 (a) iii.

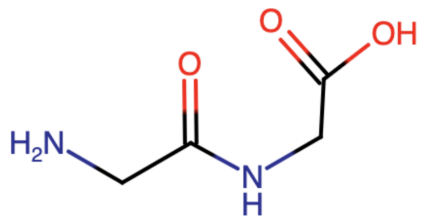
Marking guidelines	Marks
● Correctly identifies BOTH functional groups	1

Sample Answer
Aldehyde and amide

Question 34 (b)

Marking guidelines	Marks
• Draws molecule	1

Sample Answer



Question 35 (a)

Marking guidelines	Marks
• Identifies TWO correct procedures	1

Sample Answer

Wash the precipitate with distilled water to remove any soluble ions. Dry the precipitate thoroughly to remove any water.

(Both procedures will ensure that the mass is solely due to the $Ca_2P_2O_7$ (s).)

Question 35 (b)

Marking guidelines	Marks
• Correct Answer	2
• Calculates the correct no. of moles of phosphorus in the sample	1

Sample Answer

$$n(Ca_2P_2O_7) = \frac{0.464}{(40.08 \times 2) + (30.97 \times 2) + (16.00 \times 7)}$$

$$n(P) = 2 \times n(Ca_2P_2O_7)$$
$$= 0.00365 \text{ mol (2:1 ratio)}$$

$$m(P) \text{ in powder} = 0.00365 \times 30.97$$
$$= 0.113 \text{ g}$$

$$\%(P) \text{ in sample} = \frac{0.113}{8.84} \times 100$$
$$= 1.28\ \%$$

Question 36

Marking guidelines	Marks
• Correctly identifies all FOUR fragments with correct charge	4
• Correctly identifies all FOUR fragments with an incorrect charge	3
• Correctly identifies THREE fragments	2
• Correctly identifies TWO fragments	1

Sample Answer

m/z = 15 CH_3^+

m/z = 29 $CH_2CH_3^+$

m/z = 43 $COCH_3^+$

m/z = 127 I^+

Question 37

Marking guidelines	Marks
● Correctly identifies the white solid X as lead carbonate with supporting equations ● Analyses the reaction of the gas and nitric acid ● Analyses the reaction with barium hydroxide ● Analyses the reaction of the production of the bright precipitate ● Analyses the reaction of the production of the thick white precipitate ● Analyses the reaction of the production of the faint white precipitate	5
● Addresses ALL of the above without supporting equations OR ● Addresses FIVE of the above	4
● Addresses FOUR of the above	3
● Addresses THREE of the above	2
● Addresses TWO of the above	1

Sample Answer

The gas is acid as due to the pink colour change provided by the indicator. The gas produced is most likely carbon dioxide because it forms carbonic acid when dissolved in water. Therefore X is a carbonate.

Carbon dioxide reacts with barium hydroxide solution to form solid barium carbonate according to the reaction below:

$Ba(OH)_2\ (aq) + CO_2\ (g) \rightarrow BaCO_3\ (s) + H_2O\ (l)$

The cation in the solution is lead (II) ions. Lead (II) ions form a yellow precipitate when reacting with sodium iodide solution:

$Pb^{2+}\ (aq) + 2I^-\ (aq) \rightarrow PbI_2\ (s)$

Lead (II) ions form a white precipitate of $PbSO_4$ *when sulfuric acid is added:*

$Pb^{2+}\ (aq) + SO_4^{2-}\ (aq) \rightarrow PbSO_4\ (s)$

Lead (II) ions form a white faint precipitate $PbCl_2$ *when sodium chloride is added.* $PbCl_2$ *readily dissolves when the mixture is heated.*

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