



2019

HIGHER SCHOOL
CERTIFICATE

POST-TRIAL EXAMINATION

CHEMISTRY

GENERAL INSTRUCTIONS

- Reading time – 5 minutes.
- Working time – 3 hours.
- Write using black or blue pen. Black pen is preferred.
- Draw diagrams using pencil.
- Board-approved calculators may be used.
- A data sheet and periodic table is NOT provided – you may use your own. You may also use a ^1H NMR chemical shift table (not provided by N^ES_A).

TOTAL MARKS: 100

SECTION I Pages 2 to 7**20 marks**

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

SECTION II Pages 8 to 24**80 marks**

- Attempt Questions 21 – 34.
- Allow about 2 hours and 25 minutes for this section.

SECTION I

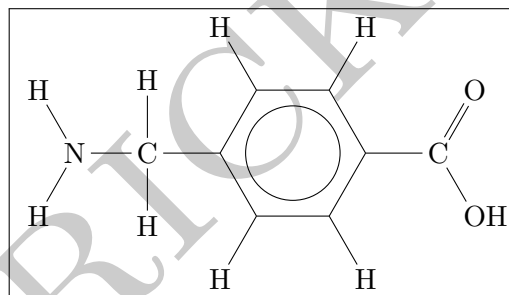
Question 1**1**

A common test to confirm the presence of an alcohol is to react the dehydrated alcohol with sodium metal. A student tests for ethanol using this method. Which of the following chemical equations represents the reaction of sodium metal and ethanol?

- A. $\text{CH}_3\text{CH}_2\text{OH}_{(\ell)} + \text{Na}_{(\text{s})} \longrightarrow \text{CH}_3\text{CH}_2\text{ONa}_{(\text{aq})} + \text{H}_{(\text{aq})}^+$
B. $\text{CH}_3\text{CH}_2\text{OH}_{(\ell)} + \text{Na}_{(\text{s})} + \text{H}_2\text{O}_{(\ell)} \longrightarrow \text{CH}_3\text{CH}_2\text{ONa}_{(\text{aq})} + \text{H}_3\text{O}_{(\text{aq})}^+$
C. $2\text{CH}_3\text{CH}_2\text{OH}_{(\ell)} + 2\text{Na}_{(\text{s})} \longrightarrow 2\text{CH}_3\text{CH}_2\text{ONa}_{(\text{aq})} + \text{H}_{2(\text{g})}$
D. $2\text{CH}_3\text{CH}_2\text{OH}_{(\ell)} + 2\text{Na}_{(\text{s})} \longrightarrow 2\text{CH}_3\text{CH}_2\text{ONa} + \text{H}_{2(\text{g})}$

Question 2**1**

How many ^1H environments does the following compound have?



- A. 4
B. 5
C. 7
D. 9

Question 3**1**

Which of the following reactions does NOT require a catalyst or any particularly special reaction conditions?

- A. Hydration of ethene
B. Substitution of ethane with HCl
C. Halogenation of ethene
D. Hydrogenation of ethene

Question 4

1

Which of the following is the least soluble?

- A. CaCO_3
- B. $\text{Ba}(\text{OH})_2$
- C. AgI
- D. $\text{Mg}_3(\text{PO}_4)_2$

Question 5

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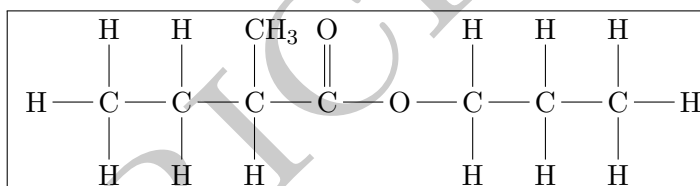
Which of the following is amphoteric?

- A. KOH
- B. $\text{Ba}(\text{OH})_2$
- C. LiOH
- D. $\text{Pb}(\text{OH})_2$

Question 6

1

An alcohol **X** is oxidised to produce a compound **Y**. **Y** reacts with CaCO_3 with effervescence being evident. Compound **Y** reacts with propan-1-ol to produce the following ester:



What are the systematic names of **X** and **Y**?

	X	Y
A.	Butan-1-ol	Butanoic acid
B.	2-methylbutan-1-ol	2-methylbutanoic acid
C.	Butan-1-ol	2-ethylpropanoic acid
D.	2-ethylpropan-1-ol	2-ethylpropanoic acid

Question 7

1

Which of the following organic compounds contains sp^3 -hybridised carbon atoms?

- A. Benzene, C_6H_6
- B. Cyclohexane, C_6H_{12}
- C. Ethene, C_2H_4
- D. Ethyne, C_2H_2

Question 8**1**

A compound with the molecular formula $C_4H_8O_2$ is analysed by 1H NMR. The following features on the 1H spectrum were noted:

- Singlet at 10.0 ppm
- Triplet at 2.0 ppm
- Triplet at 0.9 ppm
- Sextet at 1.5ppm

Which of the following properties is the compound most likely to exhibit?

- A. Acidic
- B. Basic
- C. Neither acidic nor basic
- D. Amphiprotic

Question 9**1**

10 mL of $\approx 10\%$ aqueous ethanamine ($CH_3CH_2NH_2$) is titrated with $1 \text{ mol L}^{-1} HNO_3$. The pK_a of $CH_3CH_2NH_3^+$ is 10.75. Which indicator is most useful for the titration?

	Indicator	pH at Colour Change(s)
A.	Thymol blue	1.2 – 2.8
B.	Bromocresol green	4.0 – 5.6
C.	Phenolphthalein	8.3 – 10.0
D.	Alizarin yellow	10.0 – 12.0

Question 10**1**

Which of the following is not a suitable use of atomic absorption spectroscopy as an instrumental technique?

- A. Determining the concentration of Pb^{2+} in a paint sample
- B. Determining the concentration of Cl^- in a solution by first precipitating Cl^- to excess with Ag^+ , determining the concentration of Ag^+ , then using molar calculations to determine $[Cl^-]$
- C. Determining the concentration of Fe^{2+} in a solution of Fe^{2+} that has been exposed to the air for a prolonged period of time
- D. Determining the Na^+ concentration of river water

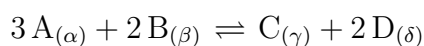
Question 11**1**

Which of the following techniques would be least useful in differentiating between butanoic acid and ethanoic acid?

- A. Mass spectrometry
- B. Infrared spectroscopy
- C. ^1H NMR spectroscopy
- D. ^{13}C NMR spectroscopy

Question 12**1**

An equilibrium reaction is represented by:



The equilibrium expression is given by:

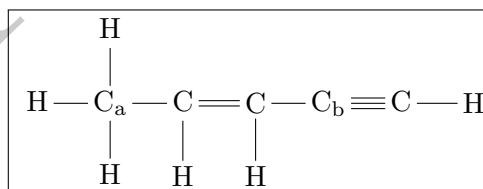
$$K_{\text{eq}} = \frac{[\text{D}]^2}{[\text{A}]^3}$$

Which of the following are the states represented by α , β , γ and δ ?

	α	β	γ	δ
A.	Aqueous	Liquid	Solid	Aqueous
B.	Liquid	Aqueous	Aqueous	Solid
C.	Solid	Gas	Gas	Solid
D.	Gas	Gas	Solid	Gas

Question 13**1**

Consider the following molecule:

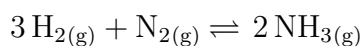


What is the geometry of the bonds on carbons C_a and C_b ?

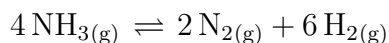
	C_a	C_b
A.	Planar	Linear
B.	Tetrahedral	Linear
C.	Linear	Linear
D.	Tetrahedral	Planar

Question 14**1**

The Haber Process is given by:



At 300 K, the K_p value is 2.7×10^8 . What is the K_p value of the following equilibrium?



- A. 5.4×10^8
- B. 1.9×10^{-9}
- C. 7.4×10^{-9}
- D. 1.4×10^{-17}

Question 15**1**

An organic compound is analysed using infrared spectroscopy. An absorption band from 3350 – 3370 nm was observed, as were several indistinguishable but narrow bands from 2850 – 3550 nm, and another absorbance band from 1700 – 1740 nm. Which of the following compounds best matches this spectrum?

- A. Propanamide
- B. Propan-1-ol
- C. Propanoic acid
- D. Propanal

Question 16**1**

If K_w is 2.9×10^{-15} at 308 K, what is the pH of pure water at this temperature?

- A. 6.72
- B. 7.00
- C. 7.27
- D. 7.53

Question 17**1**

A weak acid, of concentration 0.200 M, is 0.0320% ionised. Evaluate the K_a .

- A. 2.05×10^{-8}
- B. 2.12×10^{-4}
- C. 6.40×10^{-4}
- D. 2.56×10^{-5}

Question 18**1**

A student set up a fermentation apparatus, but forgot to put a lid or stopper on the conical flask. They measured the mass of the glucose solution (including yeast) in the conical flask before and after the fermentation.

Component	Mass (g)
Conical flask and solution before fermentation	232.10
Conical flask and solution after fermentation	229.40

You may assume that no oxidation of ethanol to ethanal and ethanoic acid occurred, no evaporation of water occurred, and ALL glucose had been fermented. How much glucose was present in the original solution, and how much ethanol was produced?

	Mass of Glucose Fermented (g)	Mass of Ethanol Produced (g)
A.	5.53	1.41
B.	5.53	2.83
C.	11.1	1.41
D.	11.1	2.83

Question 19**1**

The conjugate base of H_2 is:

- A. H_3^+
- B. H^+
- C. H^-
- D. H_2O

Question 20**1**

An unknown solution of a soluble salt is sprayed into a Bunsen burner, emitting a blue-green flame. Addition of NaOH leads to the formation of a deep blue precipitate. What is a possible salt?

- A. $\text{Ba}(\text{NO}_3)_2$
- B. BaCl_2
- C. $\text{Cu}_3(\text{PO}_4)_2$
- D. CuCl_2

————— **End of Section I** —————

SECTION II

Question 21**8**

The theoretical enthalpy of neutralisation when HNO_3 is reacted with KOH under standard laboratory conditions is -57 kJ mol^{-1} .

- (a) The temperatures of a HNO_3 solution and a KOH solution were recorded. 50.0 mL of 1.00 M HNO_3 was then combined with 40.0 mL of 1.00 M KOH in a styrofoam cup. The mixture was stirred, and the final temperature recorded. Calculate the enthalpy of combustion of the reaction using the values provided below.

(3)

Parameter	Value
Initial temperature of HNO_3 ($^{\circ}\text{C}$)	20.00
Initial temperature of KOH ($^{\circ}\text{C}$)	19.50
Final temperature of mixture ($^{\circ}\text{C}$)	24.50

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- (b) Outline TWO reasons why the experimentally obtained enthalpy of combustion differs from the literature value, and suggest an improvement to mitigate EACH of the two issues you have outlined. (2)

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- (c) Outline why the enthalpy of neutralisation of the reaction between CH_3COOH and NaOH is -56 kJ mol^{-1} . (1)

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- (d) A strong acid is often defined as an acid which “*completely ionises in water to produce H_3O^+ ions*”. You are given that the K_a of HCl under standard laboratory conditions is $\approx 1.00 \times 10^7$. Does this support the italicised definition? If not, suggest a new definition. Support your answer with reference to the K_a formula. (2)

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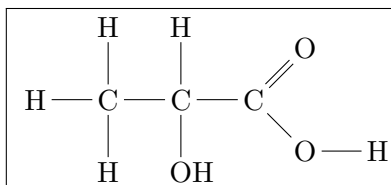
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Question 22

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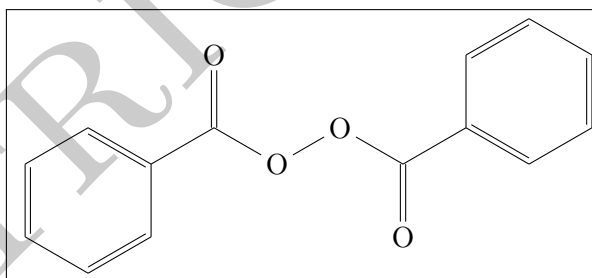
A polymer is produced from lactic acid, which is shown below:



- (a) Give the systematic name for lactic acid. (1)

- (b) Calculate the molar mass of a polymer containing 250 monomer units of lactic acid. (2)

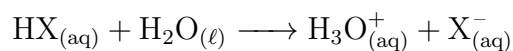
- (c) Benzoyl peroxide is a common organic peroxide used as an initiator for addition polymerisation. Its structure is shown below: (2)



Calculate the molar mass of a polyethylene polymer produced with a benzoyl peroxide initiator, assuming there are 250 monomer units.

Question 23**3**

The ionisation of a weak acid can be represented by:



(a) Derive the following result:

(2)

$$\text{pH} = \text{p}K_{\text{a}} + \log_{10} \frac{[\text{X}^-]}{[\text{HX}]} \quad (\text{Henderson-Hasselbalch Equation})$$

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(b) Under what conditions will a solution of acid have a pH equal to its $\text{p}K_{\text{a}}$?

(1)

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Question 24**5**

A Cu^{2+} ion reacts with Cl^- ions to produce a complex ion of coordination number 4.

(a) What is a complex ion?

(1)

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(b) Draw the structure of the complex ion described above, and provide its name.

(2)

- (c) In a separate beaker, some HCl was added to the solution of pH 11.0 prior to addition of $\text{Pb}(\text{OH})_2$. How does this affect the solubility of $\text{Pb}(\text{OH})_2$? Use a relevant chemical equation in your answer. (2)

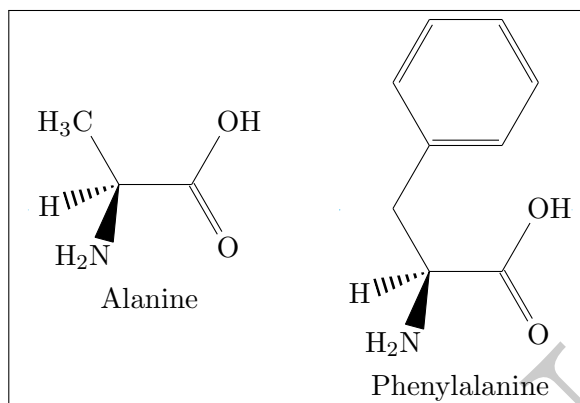
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- (d) A 50.0 mL of solution of $0.001 \text{ mol L}^{-1} \text{ Pb}(\text{NO}_3)_2$ was mixed with 25.0 mL of $0.0025 \text{ mol L}^{-1} \text{ NaOH}$ solution at 25°C . Determine whether a precipitate is formed. (2)

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Question 26**3**

The compounds alanine and phenylalanine react together to form a dipeptide.



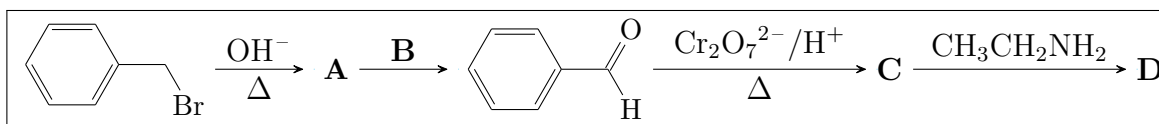
- (a) What class of compounds do alanine and phenylalanine belong to, and what type of polymerisation do they undertake? (1)
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- (b) Draw, using structural formulae, the products formed when alanine and phenylalanine react to produce a dipeptide. (2)



Question 27

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Consider the following reaction sequence:

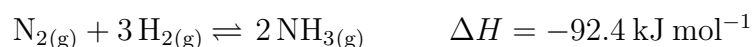


Give the reaction condition **B**, and draw the structures of organic compounds **A**, **C** and **D**. Additionally, provide the names for **A**, **C** and **D**. Show relevant working out demonstrating your thought process. You can exclude any by-products of reactions.

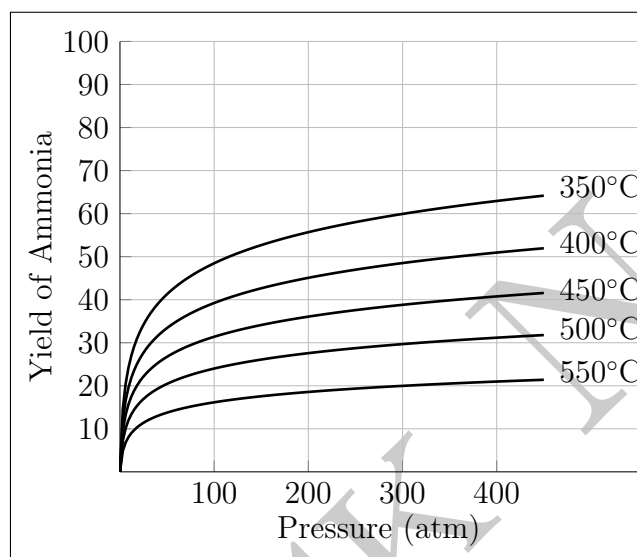


Question 28**7**

The Haber Process is given by:



A yield curve for the Haber Process is provided below:



- (a) Account for the trends shown in the graph.

(3)

- (b) Provide the range of values for the yield of NH_3 when temperatures of $400 - 450^\circ\text{C}$ and pressures of $200 - 250 \text{ atm}$ are used.

(1)

- (c) The initial yield of the Haber Process was approximated in part (b). However, yields of $\approx 98\%$ are common in industrial ammonia plants. Explain reasons for this discrepancy. (3)

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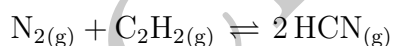
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Question 29**2**

Consider the equilibrium:



Initially, 0.75 mol of N_2 and 0.75 mol of C_2H_2 were introduced into a closed 5.00 L container at constant temperature and pressure. At equilibrium, K_{eq} was 63. Determine the equilibrium concentration of hydrogen cyanide.

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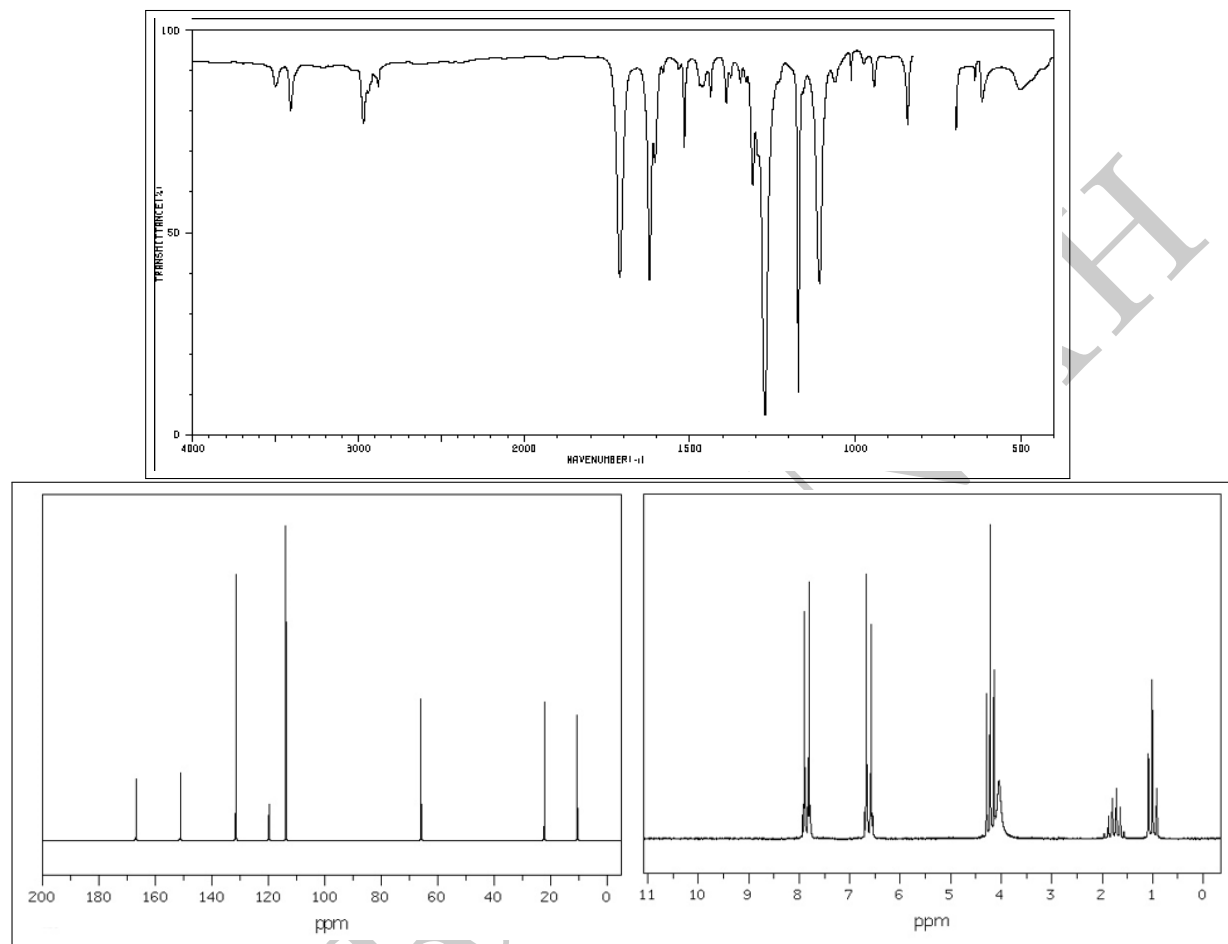
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Question 30

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A organic compound with molecular formula $C_{10}H_{13}NO_2$ produced the following spectra:



The following table details some information regarding the 1H NMR spectrum:

δ (ppm)	Integration	Multiplicity
1	3	Triplet
1.7	2	Sextet
4.05	2	?
4.2	2	?
6.6	2	?
7.9	2	?

Use the information above to determine the structural formula of the organic compound, and name the molecule. Briefly describe the information that can be obtained from each of the analytical techniques used. Use the space on the next page for your answer.

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Question 31

7

Ethanedioic acid is an acid commonly found to contain water of hydration. Hence, its formula can be written as $(\text{H}_2\text{C}_2\text{O}_4) \cdot k\text{H}_2\text{O}$, where k is a positive integer.

- (a) Draw the structural formula for ethanedioic acid and give its common name. Do NOT draw any water of hydration. (1)

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- (b) 5.00 g of ethanedioic acid (containing water of hydration) was dissolved in deionised water, and the solution made up to 500 mL. You may assume that ethanedioic acid is sufficiently soluble as to not form a precipitate. Part of this solution was placed in a burette, and 31.6 mL of ethanedioic acid was required to completely neutralise 50 mL of 0.1 mol L⁻¹ NaOH in the conical flask. Determine the value of k . (3)

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- (c) Evaluate why ethanedioic acid, despite its water of hydration, can be used as a primary standard, while other common acids and bases (such as HCl and NaOH) cannot be used as primary standards. (3)

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Question 32**7**

A sample of sodium ethanoate is dissolved in water. The solution is then distributed equally to 4 test tubes and tested with 4 different indicators. The results are shown below:

Indicator	pH for Colour Change	Colour Change	Sodium Ethanoate Solution Colour
Congo red	3.0 – 5.0	Blue to Red	Red
Bromothymol blue	6.0 – 7.6	Yellow to Blue	Blue
Litmus	5.5 – 8.2	Red to Blue	Blue
Thymol Blue	8.0 – 9.6	Yellow to Blue	Green

- (a) Determine the pH range for the solution of sodium ethanoate. (1)

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- (b) Explain why Brønsted-Lowry theory can account for the observation in part (a), whereas the Arrhenius theory cannot. Include a relevant chemical equation. (3)

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- (c) The reaction between gaseous ammonia and solid aluminium trichloride is classified as an acid-base reaction, but does not involve transfer of protons. Explain which acid-base theory accounts for this reaction, and draw the neutralisation reaction resulting in formation of an adduct. (3)

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Question 33

Calculate the pOH of a 0.10 M solution of H_2SO_4 , given that the K_a of HSO_4^- is 1.0×10^{-2} .

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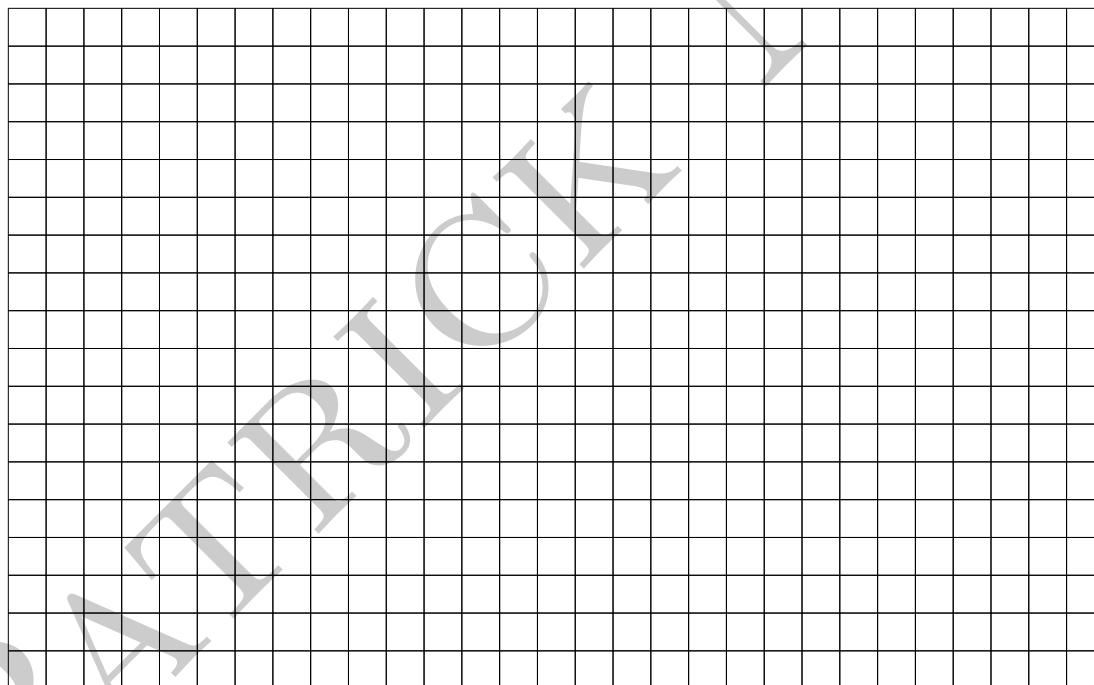
Question 34**7**

Lead(II) chloride is a sparingly soluble salt. A sample containing PbCl_2 was analysed with colourimetry and the results shown below.

Sample	Concentration of Pb^{2+} in sample (ppm)	Absorbance
Blank	0.000	0.000
Standard A	0.100	0.160
Standard B	0.200	0.330
Standard C	0.300	0.480
Standard D	0.400	0.650
Unknown X	?	0.740

- (a) Construct a calibration curve for the absorbances of the standard solutions.

(2)



- (b) Determine the mass of PbCl_2 in a 500 mL sample of solution **X**. (2)

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- (c) Is the concentration you obtained for **X** valid? Justify your answer. (1)

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- (d) Colourimeters can be quite inaccurate. Is the concentration of the solution you found in part (b) able to be produced without a precipitate forming? Justify your answer with reference to the K_{sp} value for PbCl_2 . (1)

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- (e) A $\text{Pb}(\text{NO}_3)_2$ solution is mixed with a AgNO_3 solution in equimolar amounts. Some HCl is added, and a precipitate eventually forms. Determine the precipitate. (1)

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————— **End of Section II** —————

————— **End of Examination** —————