NESA Number _____

HIGHER SCHOOL CERTIFICATE
TRIAL EXAMINATION 2020

Chemistry

SECTION	TOTALS	MARKS
Part A	20	
Part B	80	
TOTAL	100	

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- Use the Data Sheet and Periodic Table provided
- Use the multiple-choice answer sheet provided
- Write your NESA Number at the top of this page and on the multiple-choice answer sheet

Total marks – 100

100 marks
This section has two parts, Part A and Part B

Part A – 20 marks
- Attempt Questions 1-20
- Allow about 35 minutes for this part

Part B – 80 marks
- Attempt Questions 21-35
- Allow about 2 hours and 25 minutes for this part

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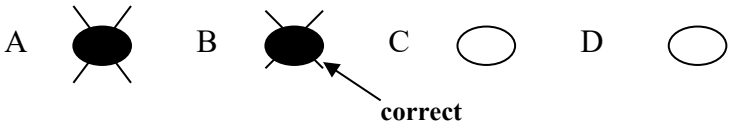
Use the multiple-choice answer sheet.

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.



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Part A

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

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

1 Which pair of compounds represents an acid and its conjugate base?

	Acid	*Conjugate base*
A.	H_2SO_4	SO_4^{2-}
B.	CH_3COO^-	CH_3COOH
C.	CH_3NH_2	$CH_3NH_3^+$
D.	$HCrO_4^-$	CrO_4^{2-}

2 Which of the following most accurately describes how Aboriginal and Torres Strait Islander peoples use solubility principles in the preparation of food sources, such as the fruits of cycads?

A. The starch in the fruits of cycads is more soluble than the toxins found in these fruits.

B. The toxins in the ground-up fruits are soluble in running water.

C. Placing the cycad fruits in water removes hard to digest food products such as fibre.

D. The skins of the cycad fruits easily dissolve in water leaving essential nutrients.

3 Ammonia can be produced by the reaction of hydrogen and nitrogen. When this reaction takes place in a sealed container of fixed volume, an equilibrium system is established.

The equation for the reaction is:

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

If the pressure and volume remain constant when the temperature is increased, the forward reaction rate will

A. increase and the $[NH_3]$ will decrease.

B. increase and the $[NH_3]$ will increase.

C. decrease and the $[NH_3]$ will decrease.

D. decrease and the $[NH_3]$ will remain the same.

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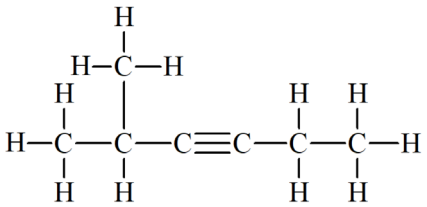
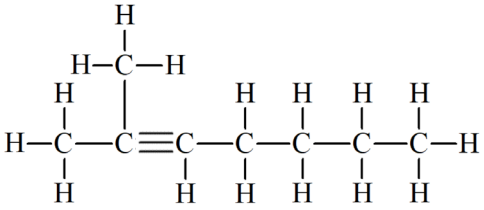
4 The structural formula representing 2-methyl-3-heptyne is:

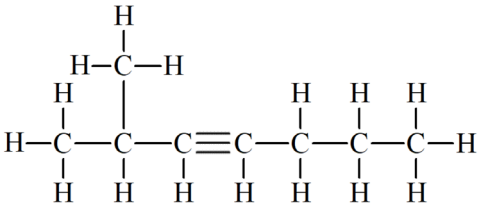
A.



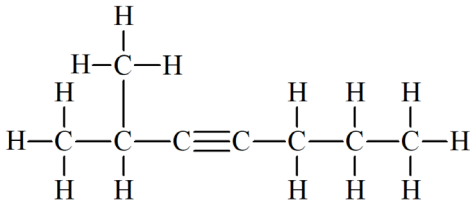
B.



C.



D.



5 Which alternative most correctly represents the chemical reaction for the equilibrium expression shown below?

$$\frac{[Ni(CO)_4]}{[CO]^4}$$

A. $Ni(CO)_4(g) \rightleftharpoons 4CO(g)$

B. $Ni(CO)_4(g) \rightleftharpoons Ni(g) + 4CO(g)$

C. $Ni(s) + 4CO(g) \rightleftharpoons Ni(CO)_4(g)$

D. $4Ni(s) + 4CO(g) \rightleftharpoons 4\ Ni(CO)(g)$

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6 An isomer of butanoic acid is

A. CH_3CH_2COOH

B. $CH_3CH_2COOCH_3$

C. $CH_3COCH_2CH_3$

D. $CH_3CH_2CH_2CHO$

7 The following table shows the colour changes and pH ranges of three indicators:

Indicator	*Colour change (low pH to high pH)*	*pH range*
bromophenol blue	yellow to blue	3.0–4.5
methyl red	red to yellow	4.5–6.3
alizarin	yellow to red	10.2–12.0

The indicators were used to test a liquid. The following table shows the final colours of the liquid:

Indicator	*Final colour*
bromophenol blue	blue
methyl red	yellow
alizarin	yellow

A. vinegar (pH 2.1)

B. rain water (pH 5.2)

C. distilled water (pH 7.0)

D. bleach (pH 12.1)

8 What is the concentration of barium ions in a saturated solution of barium carbonate?

A. 5.08×10^{-5} mol L^{-1}

B. 1.60×10^{-3} mol L^{-1}

C. 1.16×10^{-3} mol L^{-1}

D. 0.005 mol L^{-1}

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9 Which of the following organic compounds is classified as an organic base?

A. Propane

B. Propanol

C. Propanamide

D. Propanamine

10 Consider the reaction

$Br_2\ (g) + I_2\ (g) \rightleftharpoons 2IBr\ (g)$ $\quad K_c = 1.2 \times 10^2$ at 150°C

What is the K_c for the reaction shown below, at 150°C?

$4IBr\ (g) \rightleftharpoons 2Br_2\ (g) + 2I_2\ (g)$

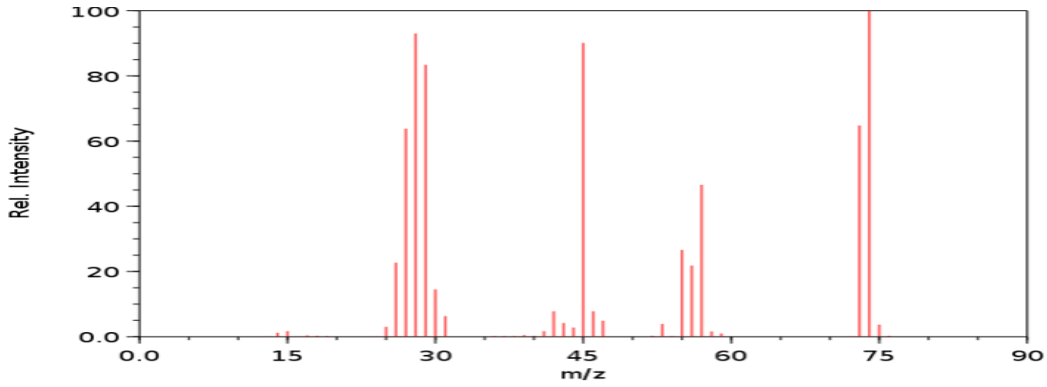
A. 1.6×10^{-2}

B. 4.1×10^{-3}

C. 6.9×10^{-5}

D. 8.03×10^{-5}

11 The diagram below shows the mass spectrum for an organic compound.



The compound is

A. ethanoic acid

B. ethanol

C. propanol

D. propanoic acid

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12 The pH of a 0.01 mol L^{-1} solution of a monoprotic acid was measured by a student and found to be 4.

What proportion of the acid molecules has been converted to ions?

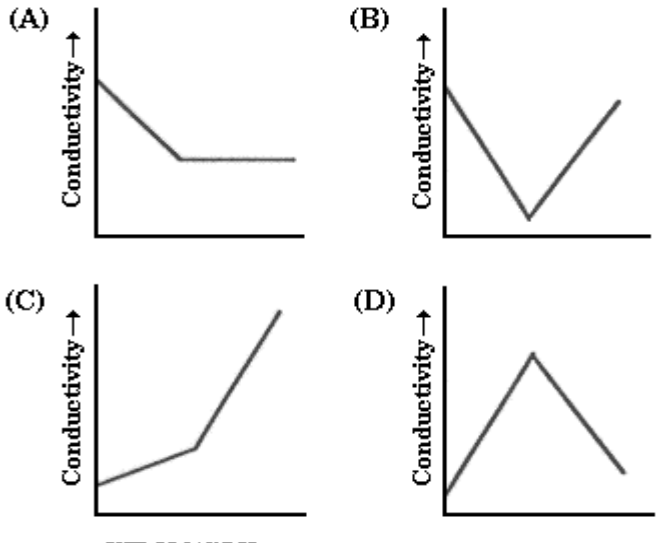
A. 0%

B. 1%

C. 90%

D. 100%

13 Which graph best represents the electrical conductivity changes that occur when an aqueous solution of sulfuric acid is titrated with an aqueous solution of barium hydroxide?



14 During a precipitation titration investigation, a 10.0 mL sample of a solution containing chloride ions was titrated with 23.5 mL of 0.125 mol L^{-1} $AgNO_3$ to reach the end-point. Calculate the mass of chloride ions present in the original sample.

A. 0.00294 g

B. 0.0520 g

C. 0.104 g

D. 0.208 g

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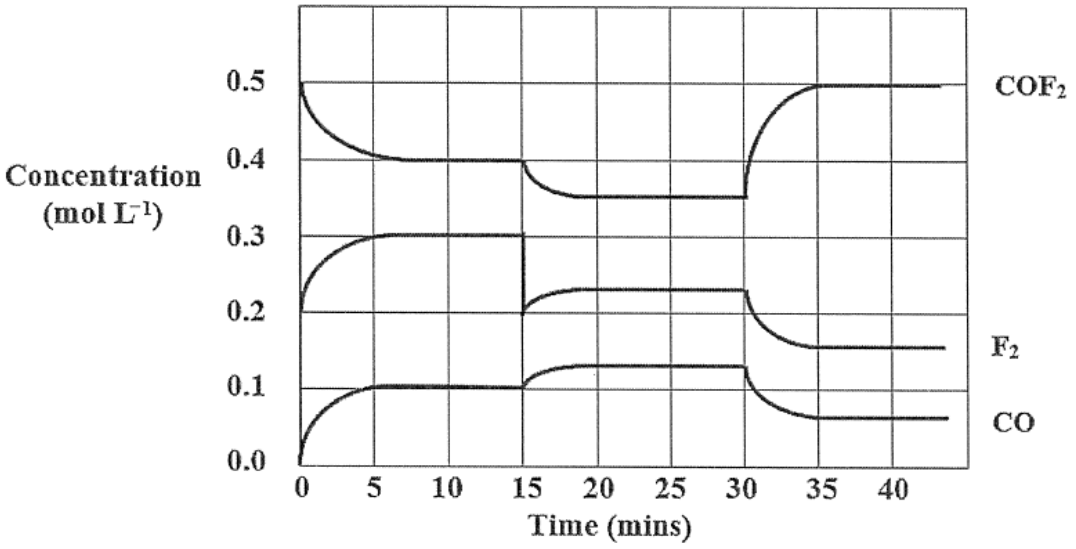
15 The gas carbon monoxide reacts with fluorine gas to form the gas carbonyl difluoride, COF_2. The reaction is exothermic.

$$CO\ (g) + F_2\ (g) \rightleftharpoons COF_2\ (g)$$

Scientists studying this reaction measured the concentration of each of these gases in a sealed 2.0 L reaction vessel over a period of time. The results are shown below.



What changes were imposed on this equilibrium at 15 minutes and 30 minutes?

	Change at 15 min	*Change at 30 min*
A.	Fluorine gas was removed from the vessel	The temperature of the vessel was decreased
B.	Fluorine gas was removed from the vessel	The temperature of the vessel was increased
C.	The temperature of the vessel was decreased	Carbonyl difluoride gas was added to the vessel
D.	The temperature of the vessel was increased	Carbonyl difluoride gas was added to the vessel

16 A sample of Teflon, polytetrafluorethene, was found to have a molecular mass of 1.9×10^4 g mol^{-1}.

On average, how many monomer units are there in this polymer?

A. 190

B. 186

C. 258

D. 212

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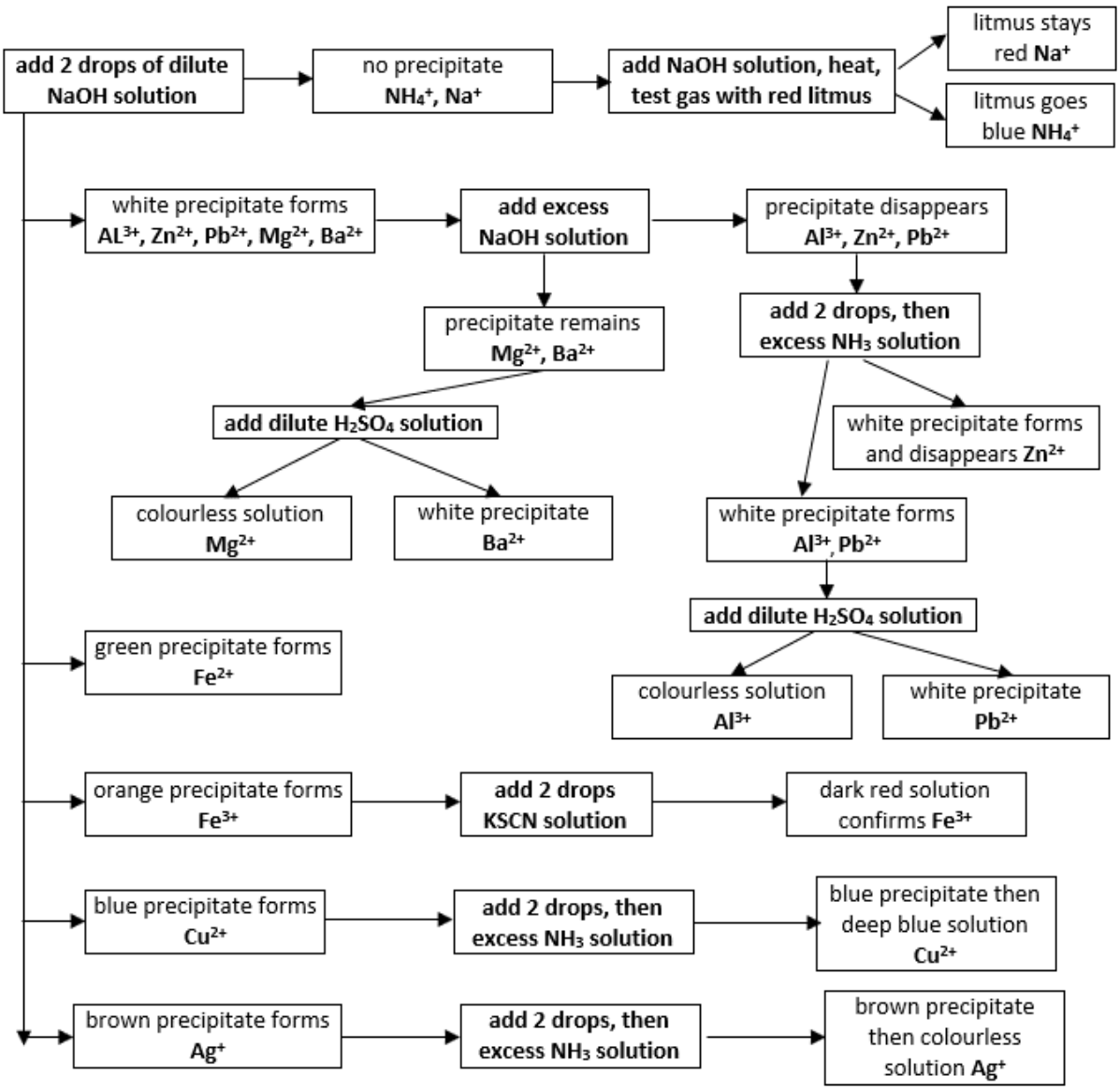
17 Consider the flowchart and the following information:



I When 2 drops of NaOH solution was added to a sample, a white precipitate was formed.
II After excess NaOH solution was added the precipitate disappeared.
III When 2 drops, then excess NH_3 solution was added, a white precipitate appeared.
IV After dilute H_2SO_4 solution was added, the result was a colourless solution.

The ion present in the solution is:

A. Pb^{2+}

B. Al^{3+}

C. Mg^{2+}

D. Zn^{2+}

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18 A student wishes to distinguish between samples of pentan-1-ol and pentanoic acid. Which of the following tests would NOT allow the 2 compounds to be identified?

A. Adding bromine water to both

B. Adding an acidified solution of potassium permanganate to both

C. Testing the pH of solutions of both

D. Adding sodium carbonate solution to both

19 An organic compound of formula C_4H_8O

I – could be an alkanal or an alkanone
II – could be formed by oxidation of an alkanol
III – could be formed by reduction of an alkanoic acid
IV – could react with an alkanoic acid to form an ester

Which of the above statements are correct?

A. I, and IV only

B. I, II and III

C. I and III only

D. III and IV only

20 Three chemical formulas are shown below.

Compound A: $CH_3(CH_2)_{15}COONa$

Compound B: $CH_3(CH_2)_5CONH_2$

Compound C: $CH_3(CH_2)_3COCH_3$

What are the names of the chemical families to which these compounds belong?

	Compound A	*Compound B*	*Compound C*
A.	carboxylic acid	amide	aldehyde
B.	soap	amine	aldehyde
C.	ester	amine	ketone
D.	soap	amide	ketone

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Part B

80 marks
Attempt Questions 21-35
Allow about 2 hours and 25 minutes for this section

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

Show all relevant working in questions involving calculations.

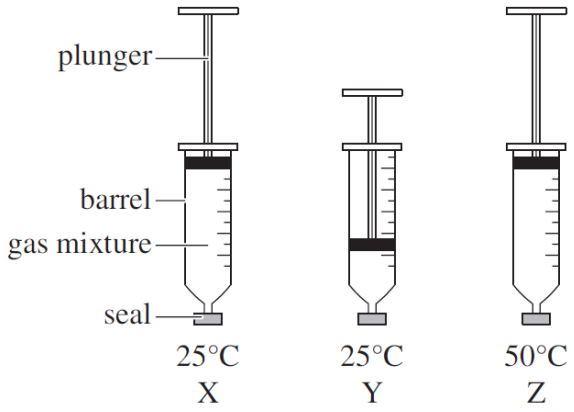
Extra writing space is provided on pages 29 to 32. If you use this space, clearly indicate which question you are answering.

Question 21 (6 marks)

Nitrogen dioxide is brown and dinitrogen tetroxide is colourless. They form an equilibrium mixture as shown by the following equation: **6**

$$2NO_2\,(g) \rightleftharpoons N_2O_4\,(g) \qquad \Delta H = -58 \text{ kJ mol}^{-1}$$

A sealed gas syringe can be used to investigate the properties of a fixed mass of gas. An equimolar mixture of nitrogen oxide and dinitrogen tetroxide was set up as shown in X in the following diagram. The conditions were then varied as shown in Y and Z.



Complete the table by describing the colour of the gas mixtures in X, Y and Z. Include any comparisons to the initial colour of X and justify your answers.

	Colour	*Justification*
X		
Y		
Z		

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Question 22 (5 marks)

A student makes up a 200.0 mL solution of barium hydroxide. The final solution is found to have a pH of 12. The student then adds 0.20 mol L^{-1} hydrochloric acid solution to neutralise the barium hydroxide solution.

(a) Write the balanced equation for the neutralisation reaction. **1**

(b) Calculate the concentration (in mol L^{-1}) of hydroxide ions in the original solution. **2**

(c) Calculate the volume of hydrochloric acid required to complete the neutralisation reaction. **2**

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Question 23 (6 marks)

The reaction to produce hydrogen from carbon monoxide and steam is shown.

$$H_2O\ (g) + CO\ (g) \rightleftharpoons CO_2\ (g) + H_2\ (g)$$

Use the data supplied in the table to answer the following questions.

	ΔH_f° $kJ\ mol^{-1}$	S° $J\ K^{-1}\ mol^{-1}$
$CO_{(g)}$	-111	198
$H_2O_{(g)}$	-242	189
$CO_{2(g)}$	-393	214
$H_{2(g)}$	0	131

(a) Calculate the enthalpy change for this reaction. **1**

(b) Calculate the entropy change for this reaction. **1**

(c) Determine whether this reaction is spontaneous at 600K under standard conditions. **2**

(d) Given that when a reaction has reached equilibrium $\Delta G = 0$, calculate the minimum temperature required for this reaction to reach equilibrium under standard conditions AND state when the reaction will be spontaneous. **2**

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Question 24 (8 marks)

A solution of hydrochloric acid was standardised by titration against a sodium carbonate solution using the following procedure.

- All glassware was rinsed correctly to remove possible contaminants.
- Hydrochloric acid was placed in the burette.
- 25.0 mL of sodium carbonate solution was pipetted into the conical flask.

The titration was performed and the hydrochloric acid was found to be 0.200 mol L^{-1}.

(a) Identify the substance used to rinse the conical flask and justify your answer. **2**

(b) Explain why sodium carbonate solution, rather than sodium hydroxide solution, is used to standardise the hydrochloric acid solution. **2**

Question 24 continues on the next page

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(c) Seashells contain a mixture of carbonate compounds, including $CaCO_3$. **4**

The standardised hydrochloric acid was used to determine the percentage by mass of carbonate ions in a seashell using the following procedure.

- A 0.145 g sample of the seashell was placed in a conical flask.
- 50.0 mL of the standardised hydrochloric acid was added to the conical flask.
- At the completion of the reaction, the mixture in the conical flask was titrated with 0.250 mol L^{-1} sodium hydroxide.

The volume of sodium hydroxide used in the titration was 29.5 mL.

Calculate the percentage by mass of carbonate ions in the sample of the seashell.

End of Question 24

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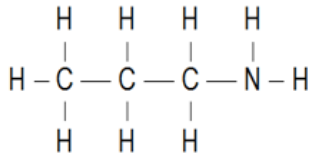
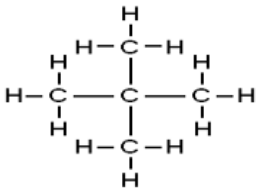
Question 25 (7 marks)

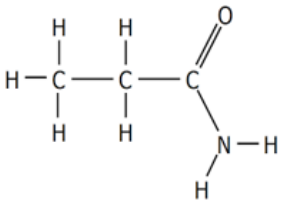
(a) Using IUPAC nomenclature, name the compounds shown below. **3**



Compound 1



Compound 2



Compound 3

Compound 1:

Compound 2:

Compound 3:

(b) Compare the intermolecular forces in the above 3 molecules and predict the order of boiling points (lowest to highest) of these molecules. Explain your prediction. **4**

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Question 26 (4 marks)

Compare Arrhenius' theory of acids and bases with the Brønsted-Lowry theory. **4**

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Question 27 (4 marks)

50.0 mL of a solution of 0.300 mol L^{-1} NaOH was added to a 50.0 mL solution of 0.250 mol L^{-1} HNO_3 in a styrofoam cup.

The initial temperature of both solutions was 21.0°C. The final temperature of the resulting solution was 22.5°C.

(a) Calculate the experimental heat of neutralisation from these results. **3**

(b) Suggest ONE change to the experimental design used above that would improve the accuracy of the investigation. **1**

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Question 28 (4 marks)

Hydrofluoric acid (HF) ionises in water to give a dissociation constant (K_a) value of 6.9×10^{-4} at 25°C.

(a) Write an equation for the ionisation of hydrofluoric acid in water. **1**

(b) Calculate the pK_a value for the ionisation of hydrofluoric acid. **1**

(c) Dissociation pK_a values at 25°C for some common acids are listed below. **2**

Acid	pK_a
ammonium ion (NH_4^+)	9.25
carbonic acid (H_2CO_3)	6.35
ethanoic acid (CH_3COOH)	4.75
phosphoric acid (H_3PO_4)	2.15
sulphurous acid (H_2SO_3)	1.82

Discuss the relative strength of hydrofluoric acid.

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Question 29 (3 marks)

Quantitatively compare the solubility of lead(II) sulfate in water with its solubility in a 0.10 mol L^{-1} solution of sodium sulfate, 25°C. **3**

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Question 30 (4 marks)

An equimolar solution of carbonic acid and hydrogen carbonate ions has reached equilibrium with a pH of 6.4. **4**

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

Explain how the addition of both a small volume of dilute acid and base can result in no change in the overall pH of this solution.

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Question 31 (4 marks)

Explain how the surfactant properties of the sodium salts of long chain fatty acids help to clean grease from dirty dishes. Use a diagram to support your answer. **4**

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Question 32 (4 marks)

In an addition reaction, 3-hexene is reacted with water and dilute sulfuric acid under heated conditions.

(a) Name the product formed and draw its structural formula. **2**

(b) Name and draw the structural formula for all possible products of the reaction between hydrogen chloride and propene. **2**

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Question 33 (8 marks)

Yeast was added to a 150 mL solution of glucose and water in a conical flask and the apparatus weighed.

(a) Describe the optimal conditions required for fermentation. **2**

(b) Write a balanced chemical equation for the fermentation of glucose. **1**

(c) The mixture was left under these optimal conditions for 24 hours. When weighed again, the mass of the mixture had reduced by 2.38 g. **2**

What was the mass of ethanol produced?

(d) Discuss the benefits and limitations of using ethanol obtained by the fermentation of sugars as an alternative liquid fuel. **3**

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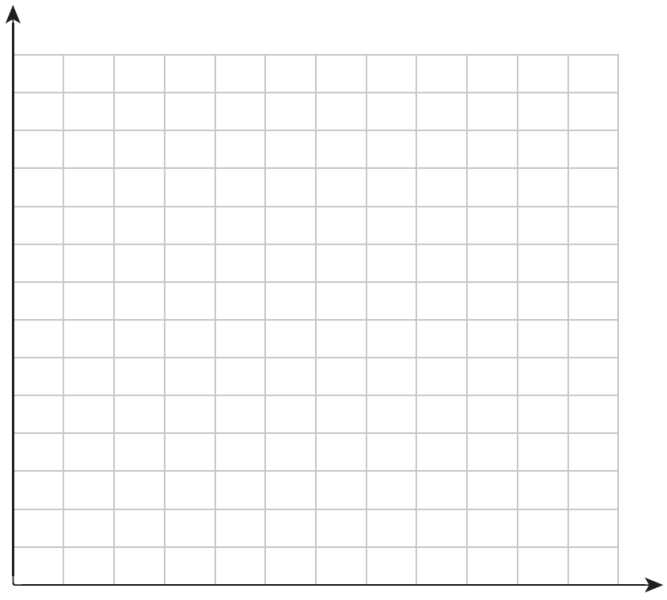
Question 34 (8 marks)

Brass is an alloy of copper and zinc.

To determine the percentage of copper in a particular sample of brass, an analyst prepared a number of standard solutions of copper(II) ions and measured their absorbance using an atomic absorption spectrometer (AAS). The results are given in the table.

Cu^{2+} concentration ($mg\ L^{-1}$)	*Absorbance*
0	0
50.00	0.060
100.0	0.120
200.0	0.240
300.0	0.360
400.0	0.480
500.0	0.600

(a) Draw and label the absorbance versus concentration calibration curve for Cu^{2+}. **3**



Question 34 continues on the next page

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Question 34 (continued)

A 19.8 mg sample of the brass was dissolved in acid, and the solution was made up to 100 mL in a volumetric flask. The absorbance of this test solution was found to be 0.150.

(b) Calculate the percentage by mass of copper in the brass sample. **3**

(c) When using AAS techniques, the presence of Zn^{2+} in the sample does not affect the measurement of Cu^{2+} in the sample. **2**

Explain this observation.

End of Question 34

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Question 35 (5 marks)

To determine the sulfate content of a sample of fertiliser by gravimetric analysis requires the sample to be dissolved and the sulfate ions precipitated with an appropriate cation before being filtered, dried and then weighed.

Several assumptions have to be made at particular steps in the process.

(a) Identify any *two* assumptions made in this process and outline how these assumptions may affect the final result. **2**

(b) From an initial sample of fertiliser weighing 4.27 g, a dried precipitate of $BaSO_4$*(s)* weighed 3.12 g. **3**

Calculate the percentage sulfate content of this fertiliser sample.

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2020 Higher School Certificate
Chemistry Trial Examination
Marking Criteria

Part A

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

Part B – 80 marks

Question 21 (6 marks)

Criteria	Marks
• Correctly completes all SIX cells of the table	6
• Correctly completes FIVE cells of the table	5
• Correctly completes FOUR cells of the table	4
• Correctly completes THREE cells of the table	3
• Correctly completes TWO cells of the table	2
• Correctly completes ONE cell of the table	1

Sample answer

	Colour	*Justification*
X	light brown	A mixture of colourless N_2O_4 and brown NO_2 gives a light brown equilibrium mixture.
Y	lighter brown (lighter than *X*) NOT Completely Colourless	The system has shifted to the right (fewer gas molecules), decreasing the amount of brown NO_2 in the resulting equilibrium mixture (Le Châtelier's principle).
Z	brown (darker than *X*)	The forward reaction is exothermic. Increasing temperature shifts the reaction to the left, increasing the amount of brown NO_2 in the resulting equilibrium mixture.

Marker comments

In equilibrium, both reactants and products exist so a shift to N_2O_4 does not make the system colourless, only lighter brown.

Question 22 (5 marks)
22 (a) (1 mark)

Criteria	Marks
• Writes a correctly balanced equation	1

Sample answer

$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$

22 (b) (2 marks)

Criteria	Marks
• Correctly calculates the pOH of the solution • Correctly calculates the hydroxide ion concentration	2
• Correctly calculates the pOH of the solution	1

Sample answer

pOH + pH = 14
$\therefore$ pOH = 14 – 12 = 2
$\therefore [OH^-] = 10^{-2} = 0.01 \text{ mol } L^{-1}$

22 (c) (2 marks)

Criteria	Marks
• Correctly calculates the volume of acid required	2
• Substitutes values into the correct formula	1

Sample answer

$C_1V_1 = C_2V_2$
0.01 x 0.2 = 0.2 x V_2
$\therefore V_2$ = 0.01 L (10.0 mL of acid)

Marker comments

$Ba(OH)_2$ produces 2 moles of OH^- ions per mole.

Question 23 (6 marks)

23 (a) (1 mark)

Criteria	Marks
• Calculates the enthalpy change correctly	1

Sample answer

$\Delta H = (-393 + 0) - (-242 + -111) = -393 + 353$
$\Delta H = -40 \text{ kJ mol}^{-1}$

23 (b) (1 mark)

Criteria	Marks
• Calculates the entropy change correctly	1

Sample answer

$\Delta S = (214 + 131) - (198 + 189)$
$\Delta S = -42 \text{ J K}^{-1} \text{ mol}^{-1}$

23 (c) (2 marks)

Criteria	Marks
• Calculates ΔG correctly and states that the reaction is spontaneous at 600 K with evidence	2
• Calculates ΔG correctly	1

Sample answer

$\Delta G = \Delta H - T\Delta S$
$= -40 - (600 \times -0.042)$
$= -14.8 \text{ kJ mol}^{-1}$

Yes, the reaction is spontaneous at 600 K as $\Delta G < 0$

23 (d) (2 marks)

Criteria	Marks
• Correctly calculates the minimum temperature for reaction to reach equilibrium • States a criterion for the reaction to be spontaneous	2
• Correctly calculates the minimum temperature for reaction to reach equilibrium OR • States a criterion for the reaction to be spontaneous	1

Sample answer

When $\Delta G = 0$
$T = \Delta H / \Delta S$
$T = -40 / -0.042$
$= 952.38 \text{ K}$
The reaction will be spontaneous when the reaction temperature is below 952.38 K (when Gibbs Free energy change is negative)

Marker comments

Entropy change is in Joules so must be converted to kJ so must be changed to 0.042 kJ in part "c". Since $\Delta G = \Delta H - T\Delta S$ a higher temperature will make ΔG less.

Question 24 (8 marks)
24 (a) (2 marks)

Criteria	Marks
• Identifies deionised water as the substance used to rinse the conical flask AND justifies the answer	2
• Identifies deionised water as the substance used to rinse the conical flask	1

Sample answer

Standard sodium carbonate is the solution to be placed in the flask. The flask must be cleaned and then rinsed with deionised water. If water remains in the flask, it will not change the number of moles of sodium carbonate in the flask. If either hydrochloric acid or sodium carbonate were used, the moles of the wash remaining in the flask would alter the titration results and hence make the calculation invalid.

24 (b) (2 marks)

Criteria	Marks
• Explains, giving at least 2 valid reasons, why sodium carbonate is used rather than sodium hydroxide as a standard	2
• Outlines one valid reason	1

Sample answer

A primary standard solution is one that can be used as the starting point in a series of titrations to determine the concentration of other solutions. The primary standard used to make the primary standard solution is normally a crystalline solid, which can be weighed out accurately (will not absorb water or carbon dioxide from the atmosphere) and has a relatively high molar mass (so that errors in transferring the solid are minimised in terms of moles). Sodium carbonate is suitable as it can be obtained pure, as crystals, can be weighed out accurately without absorbing water or reacting with carbon dioxide from the air and has a higher molar mass (106 g/mol) than NaOH (40 g/mol). Sodium hydroxide is not obtainable as pure crystals (lumps, which absorb water and react with CO_2).

24 (c) (4 marks)

Criteria	Marks
• Calculates correctly the percentage by mass of carbonate ions in the seashell	4
• Determines the mass of carbonate ions in the seashell	3
• Determines the moles of HCl in excess	2
• Determines the moles of HCl added to the flask	1

Sample answer

There were 4 steps in the process:

- The sample (0.145 g) was placed in a conical flask.
- 50.0 mL of standard hydrochloric acid (0.200 mol/L) was pipetted into the flask
- The excess HCl was titrated with NaOH to determine the no. of moles of HCl in excess and hence the no. of moles and mass of carbonate ions
- The percentage of carbonate ions, by mass, was determined

CO_3^{2-} (in the seashell) + 2HCl (aq) $\rightarrow$ $2Cl^-$ (aq) + CO_2 (g) + H_2O (l)

Moles HCl added initially to react and dissolve carbonate ions
= cV = 0.200 x 0.050 = 0.0100 mol

Moles NaOH required for titration excess HCl = 0.0295 x 0.250 = 0.007375 mol

Hence moles of excess HCl = 0.007375 (as NaOH and HCl react in 1:1 ratio)

Moles of HCl which had reacted with seashell = 0.0100 – 0.00738 = 0.00262 mol

Moles CO_3^{2-} = ½ moles HCl (from balanced equation)

Hence moles CO_3^{2-} in seashell = 0.00131 mol

Mass of CO_3^{2-} in seashell = n x M = 0.00131 x 60.01 = 0.0786 g (3 s.f.)

% CO_3^{2-} in seashell = 0.0786/0.145 x 100 = 54.2%

Marker comments

This final answer required the correct significant figures. A lot of students used the molar mass of calcium carbonate rather than carbonate (CO_3^{2-}).

Question 25 (7 marks)
25 (a) (3 marks)

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

Sample answer

Compound 1 = propan-1-amine
Compound 2 = 2,2-dimethylpropane
Compound 3 = propanamide

25 (b) (4 marks)

Criteria	Marks
• Predicts the correct order of boiling points • Explains thoroughly the impact of the different intermolecular forces • Identifies that Compound 1 has hydrogen bonding as the strongest intermolecular force • Identifies that Compound 2 has dispersion (temporary dipole-dipole forces) only • Identifies that Compound 3 has hydrogen bonding (2 hydrogen bonds form between adjacent molecules) and forms dimers	4
• Predicts the correct order of boiling points • Explains thoroughly the impact of the different intermolecular forces • Identifies the intermolecular forces in 2 of the 3 compounds	3

• TWO of:
  • Predicts the correct order of boiling points
  • Explains thoroughly the impact of the different intermolecular forces
  • Identifies the intermolecular forces in 2 of the 3 compounds
	2

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

Sample answer

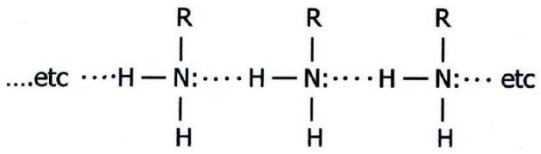
The order of increasing boiling points is Compound 2, Compound 1, Compound 3.

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

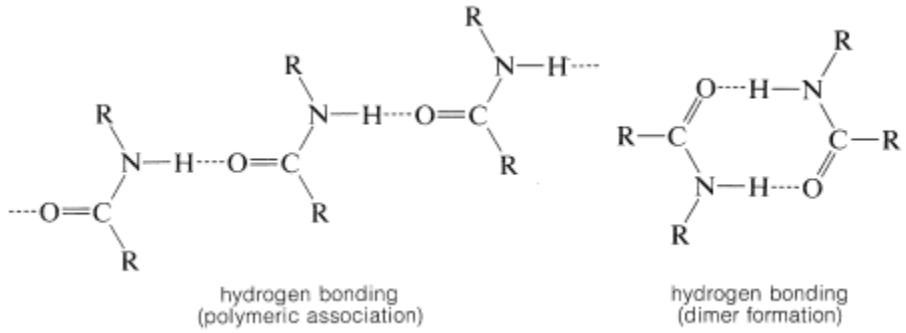
Compound 2 is non-polar and has only weak intermolecular forces (dispersion or temporary dipole-dipole forces) caused by the electrical interaction of molecules as they collide (protons from 1 molecule being attracted to electrons from the other as the molecules are temporarily distorted on collision).

Compound 1 is polar and would experience hydrogen bonding forces, as well as weaker temporary and permanent dipolar forces) as molecules interact. These are strong intermolecular forces where the electronegativity of the nitrogen results in a very polar bond

with hydrogen in the N–H group. This hydrogen is attracted to the nitrogen of a neighbouring amine molecule. The geometry of the molecule only allows 1 H-bond per pair of molecules at any instant.



Compound 3 is an amide and has the very polar – CONH functional group. The hydrogen atom of the –CONH can form a hydrogen bond with an oxygen of the neighbouring amide molecule. The planar nature of this –CONH group allows 2 H-bonds per pair of molecules. Hence the intermolecular forces and thus boiling points are highest in Compound 3 and lowest in Compound 2.



Marker comments

Boiling point depends on inter-molecular forces such as dispersion forces (weakest), dipole-dipole interaction and Hydrogen bonding (strongest). No covalent bonds are broken when a molecule changes state only the inter-molecular forces.

Question 26 (4 marks)

Criteria	Marks
• Explains in detail similarities and differences between Arrhenius definition of acids and bases and Brønsted- Lowry • Supports answer with clear, well-chosen examples	4
• Explains similarities and differences between Arrhenius definition of acids and bases and Brønsted- Lowry • Supports answer with examples	3
• Explains at least one similarity and one difference between Arrhenius definition of acids and bases and Brønsted- Lowry	2
• Gives either a similarities OR differences between Arrhenius definition of acids and bases and Brønsted- Lowry	1

Sample answer

Svante Arrhenius theorised that acids were compounds that produced hydrogen ions in water. Strong acids ionised completely while weak acids only ionised slightly. He said bases were substances which produced hydroxide ions in solution. This definition failed to take into account the basic nature of metal oxides and ammonia. The concept of acid was further developed by two chemists, Johannes Brønsted and Thomas Lowry, who said that acids are chemical species that transferred a proton to another species. This included the same acid compounds as the Arrhenius definition. The Brønsted- Lowry definition of bases as species which accept protons included the basic compounds excluded by the Arrhenius definition.

Marker comments

It is always better to use equations to illustrate your answer. E.g. Arrhenius
$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

Question 27 (4 marks)
27 (a) (3 marks)

Criteria	Marks
• Heat energy produced in reaction is calculated • Number of moles H_2O produced is calculated • Heat of neutralisation subsequently calculated correctly	3
• Two of the above steps correct	2
• One step correct	1

Sample answer

$q = mc\Delta T$
$= 100 \times 4.18 \times (22.5 - 21.0)$
$= 627$ J
$= 0.627$ kJ

No. moles H_2O produced = c x v for HNO_3 (limiting reagent)
$= 0.250 \times 0.0500$
$= 1.25 \times 10^{-2}$ mol

Heat of neutralisation $= 0.627 \text{ kJ} / 1.25 \times 10^{-2}$
$= 50.2$ kJ

Marker comments

This is a limiting reagent question. Only 0.0125 moles of acid and base can react.

27 (b) (1 mark)

Criteria	Marks
• A change suggested that would improve the accuracy	1

Sample answer

e.g. Use larger quantities; use a calorimeter with closed lid; etc

Question 28 (4 marks)

28 (a) (1 mark)

Criteria	Marks
• Writes a correctly balanced equation for the ionisation of HF	1

Sample answer

$HF(aq) + H_2O(l) \leftrightharpoons H_3O^+(aq) + F^-(aq)$

Marker comments

One-way arrows were not penalised, however, better answers identified that HF was a weak acid and therefore a two-way arrow was appropriate.

28 (b) (1 mark)

Criteria	Marks
• Calculates the pK_a value for the ionisation of HF	1

Sample answer

$pK_a = -\log_{10}(K_a) = -\log_{10}(6.9 \times 10^{-4}) = 3.16$

Marker comments

Some misconception around significant figures (did not affect mark) – similar to pH values, only the decimal places in pK_a are significant, therefore 3.16 has 2 sig. figs.

28 (c) (2 marks)

Criteria	Marks
• Associates a lower pKa value with stronger acids • Compares strength of HF with acids listed in the table	2
• Makes a relevant statement about the relative strength of HF	1

Sample answer

The pK_a value for HF lies between ethanoic acid and phosphoric acid. As the values for pK_a decrease the strength of the acid increases. Therefore, hydrofluoric acid is a stronger acid than ethanoic acid but is a weaker acid than phosphoric acid.

Marker comments

Additional information provided by students (not marked) showed some misconceptions regarding value of pK_a associated with strong acids. Note that none of the listed acids are strong; all are varying levels of weak (strong acids have negative pK_a values (typically < -2)). Also, being polyprotic is irrelevant to strength of an acid, e.g. sulfuric acid is diprotic and strong, whereas citric acid is triprotic and very weak.

Question 29 (3 marks)

Criteria	Marks
• Correctly calculates solubility in water and in 0.10 M Na_2SO_4 • Compares the two solubilities	3
• Calculates solubility in water and in 0.10 M Na_2SO_4 with one error AND • Compares the two solubilities	2
• Provides some relevant steps to calculating solubility AND/OR • Qualitatively explains that solubility will be lower in solution of a common ion	1

Sample answer

K_{sp} $PbSO_4 = [Pb^{2+}]\,[SO_4^{2-}] = 2.53x10^{-8}$

The solubility of $PbSO_4$ in water $= [Pb^{2+}] = [SO_4^{2-}] = \text{sqrt(Ksp)} = \sqrt{(2.53x10^{-8})}$
$=$ **1.59×10^{-4} mol/L**

Let the solubility of $PbSO_4$ in a 0.10 mol/L solution of sodium sulfate = s
K_{sp} $PbSO_4 = [Pb^{2+}]\,[SO_4^{2-}] = (s)\,(0.10 + s) = 2.53 \times 10^{-8}$
Since s is small by comparison with 0.10,
K_{sp} $PbSO_4 = [Pb^{2+}]\,[SO_4^{2-}] = (s)\,(0.10) = 2.53 \times 10^{-8}$
$s = 2.53 \times 10^{-8} / (0.10) = 2.53 \times 10^{-7}$ mol/L

The solubility of $PbSO_4$ in 0.10 M SO_4^{2-} $=$ **2.53×10^{-7} mol/L**

Hence $PbSO_4$ is much less soluble in a 0.10 mol/L common ion solution of sulfate ion than in water.

Marker comments

Many students didn't conduct any calculations and only qualitatively compared solubility. There was also a lot of confusion around the distinction between solubility and K_{sp}, as many students incorrectly assumed the terms are interchangeable.

Question 30 (4 marks)

Criteria	Marks
• Identifies the solution H_2CO_3/HCO_3^- as a buffer • Explains in detail how the addition of a small amount of acid or base can shift the equilibrium of the system to absorb the changes and maintain the pH	4
• Identifies the solution H_2CO_3/HCO_3^- as a buffer • Explains how the addition of a small amount of acid or base can shift the equilibrium of the system to absorb the changes and maintain the pH	3
• Identifies the solution is a buffer • Refers to LCP/equilibrium shift to maintain pH	2
• Identifies the solution is a buffer	1

Sample answer

An equimolar solution of H_2CO_3/HCO_3^- is a buffer. This is a solution consisting of a weak acid and its conjugate base.

If a small amount of acid such as HCl is added to this buffer then the equilibrium will shift to the left as the increase in hydrogen ions will cause the reaction to shift in such a way as to counteract the change. The additional H^+ will react with the $HCO_3^-{}_{(aq)}$ to form $H_2CO_{3(aq)}$ and the pH will remain constant.

$$H_2CO_{3(aq)} + H_2O_{(l)} \leftarrow HCO_3^-{}_{(aq)} + H_3O^+_{(aq)}$$

If a small amount of base such as NaOH is added to this buffer then the equilibrium will shift to the right as the increase in hydroxide will cause the reaction to shift in such a way as to counteract the change. The additional OH^- will react with the H_3O^+ to form water and the H_2CO_3 will produce more $HCO_3^-{}_{(aq)}$ and the pH will remain constant.

$$H_2CO_{3(aq)} + H_2O_{(l)} \rightarrow HCO_3^-{}_{(aq)} + H_3O^+_{(aq)}$$

Marker comments

Writing an equation was not required, however reference must have been made to the specific reaction given, and better answers used an equation to describe the neutralisation of added OH^-.

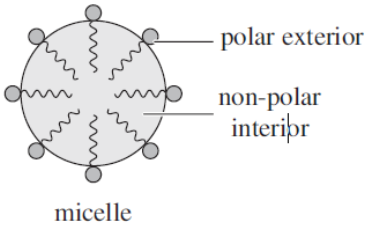
Question 31 (4 marks)

Criteria	Marks
• Provides a detailed description of the structure of a soap molecule • Correctly outlines how soap molecules interact with both water and grease • Refers specifically to the formation of micelles • Includes an appropriate, labelled diagram	4
• Most of the above	3
• Some of the above	2
• Provides some relevant information	1

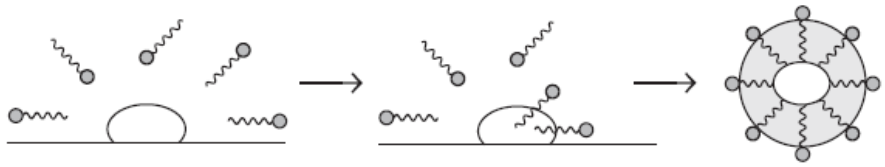
Sample answer

The sodium salts of long chain fatty acids consist of a non-polar hydrophobic 'tail' and a polar, hydrophilic, negatively charged 'head' consisting of the anionic carboxylate group.

A micelle forms when soap molecules assemble so that the long hydrophobic tails all point inwards and the polar heads all sit on the outside of the micelle.



When in contact with grease, the hydrophobic tails interact via dispersion forces, while the anionic heads remain in contact with the water via ion-dipole forces. With agitation, the soap molecules surround particles of grease to lift them off surfaces and trap them within micelles which become suspended in the water. The anionic heads from adjacent micelles repel each other so the grease cannot recombine and are easily rinsed away.



Marker comments

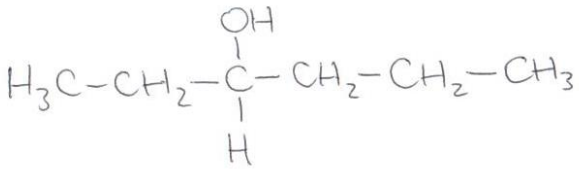
Any one diagram was acceptable as long as it was accurate and labelled.
Better answers referred to dispersion forces and ion-dipole forces as the forces behind the interaction of the soap molecules with both water and grease.

Question 32 (4 marks)
32 (a) (2 marks)

Criteria	Marks
• Correct name supplied • Correct structural formula drawn	2
• One of the above OR • Identifies hexanol is produced	1

Sample answer

3-hexanol (or hexan-3-ol)

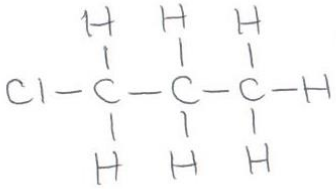


32 (b) (2 marks)

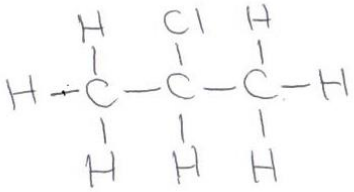
Criteria	Marks
• Correct name and structural formula given with no incorrect additional products or duplication	2
• Either correct name OR structural formula provided OR • Correct answer but with extra incorrect additional products	1

Sample answer

1-chloropropane:



2-chloropropane:



Question 33 (8 marks)

33 (a) (2 marks)

Criteria	Marks
• Two conditions, including anaerobic, identified	2
• Any one condition identified	1

Sample answer

Anaerobic (stop air getting in); warm (around 25−35°C); sugar dissolved in water.

33 (b) (1 mark)

Criteria	Marks
• Appropriate balanced equation written	1

Sample answer

$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

33 (c) (2 marks)

Criteria	Marks
• Correct answer given	2
• An appropriate calculation performed but error or omission made	1

Sample answer

Assume mass loss = $CO_2(g)$ liberated
n (CO_2) = 2.38 g/44.01 g mol^{-1} = 0.05408 mol
n (CO_2) = n (C_2H_5OH)
mass (C_2H_5OH) = 0.05408 x 46.068 = 2.49 g

Marker comments

Many students didn't attribute mass loss to amount of gas formed and instead assumed it was equal to mass of glucose reacted.

33 (d) (3 marks)

Criteria	Marks
• At least three benefits and limitations (including at least one of each) of the use of ethanol as an alternative fuel discussed • Response shows evidence of good understanding of the issue	3
• A benefit and a limitation of the use of ethanol as an alternative fuel discussed	2
• A benefit or a limitation is described	1

Sample answer

Sugars for fermentation to produce ethanol are obtained from plant material or biomass. In many cases, the plant material is sourced from a crop that would otherwise be used as a food (e.g. rice or corn), thus increasing the price of the food, having a detrimental effect for poor populations. The distillation of the fermentation mixture to obtain pure ethanol is energy intensive, however burning waste biomass is often used for this. The biomass grown for

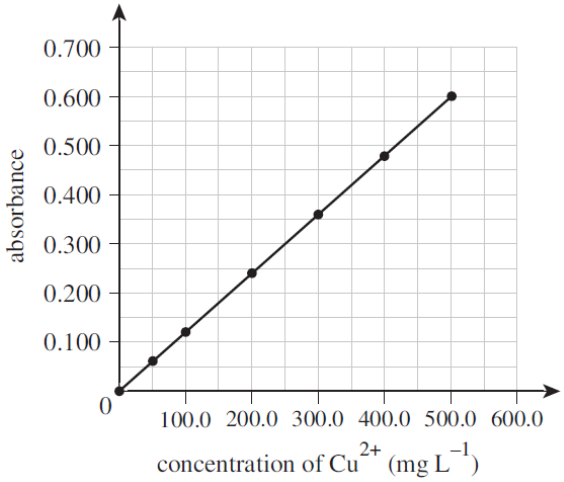
ethanol consumes CO_2 from the atmosphere, recycling that CO_2 released upon the combustion of the ethanol, making it less carbon emitting overall than fossil fuel liquids such as petrol or diesel.

Question 34 (8 marks)

34 (a) (3 marks)

Criteria	Marks
• Plots points correctly • Labels axes and uses appropriate scale • Draws appropriate line of best fit	3
• One error or omission from the above	2
• More than one error or omission from the above	1

Sample answer



34 (b) (3 marks)

Criteria	Marks
• Accurately reads graph to provide concentration (between 115-135 mg L^{-1} is acceptable) • Correctly determines mass of Cu in sample • Correctly determines %Cu in sample	3
• Determines mass of Cu in the sample based on an incorrect reading of the graph	2
• Provides some relevant calculations	1

Sample answer

From the graph, an absorbance of 0.150 gives a concentration of 120 mg L^{-1}.

The brass sample was dissolved in 100 mL; hence, it contains 12.0 mg of Cu(II).

% of Cu = mass of Cu/mass of sample x 100
= 12.0/19.8 x 100
= 60.6%

Marker comments

A number of students struggled with the conversion of mg/L to mg/100 mL and tried using more complex routes, not always successfully.

34 (c) (2 marks)

Criteria	Marks
• Provides a detailed explanation	2
• Provides some relevant information	1

Sample answer

The hollow cathode lamp that is used in the atomic absorption spectrometer (AAS) analysis of copper contains a copper cathode that produces wavelengths of light uniquely characteristic for copper. Zinc does not absorb light at the same wavelengths as copper.

Marker comments

There was some confusion between the different analysis techniques – many students described colourimetry instead of AAS. AAS is more robust than colourimetry, the metal does not need to give a visible colour to be able to be analysed by AAS.

For two marks, students had to state the principle involved (unique absorption spectra for different cations) AND how AAS achieves this (use of a cathode lamp containing the analyte to produce the characteristic spectrum).

Question 35 (5 marks)
35 (a) (2 marks)

Criteria	Marks
• Two assumptions identified • For each assumption, how the final result is affected is outlined correctly	2
• At least one assumption identified • For one assumption, how the result is affect is outlined correctly	1

Sample answer

Assumption 1: All the SO_4^{2-} ions are precipitated out of the solution. This has the effect of obtaining a result lower than the actual result for the % of SO_4^{2-} in the fertiliser.

Assumption 2: All the precipitate is filtered out of the solution. In effect, some precipitate may pass through the filter paper used, so the assumption again has the effect of causing the result to be lower than the actual content of SO_4^{2-} in the fertiliser.

Marker comments

Some students were vague in the effect of the assumption – "affects the accuracy of the result" is not sufficient – would the measured value be *higher or lower* than the true value? NOTE: water fully evaporated as an assumption was marked correct, but students are advised to not use this as an example in future since it can be avoided by 'drying to constant mass' (this can be used as an example of a potential *source of error* in the method).

35 (b) (3 marks)

Criteria	Marks
• Correct answer calculated	3
• Answer calculated but with an error made or an omission	2
• A correct step or steps made towards solving the question	1

Sample answer

$$\text{n } BaSO_4 = \frac{3.12}{137.3 + 32.06 + 4 \times 16.00}$$
$$= 0.01337 \text{ mol}$$

$\therefore$ mass SO_4^{2-} = 0.01337 x (32.06 + 4 x 16.00)
= 1.284 g

% SO_4^{2-} = (1.284/4.27) x 100%
= 30.1 % (3 sig figs)

Marker comments

Many students calculated % in precipitate, rather than % in the original sample. Students are reminded to not round off their interim values in multistep calculations. Only round at the end. This question was not marked on sig. figs., but students should note that the final answer should not have more significant figures than the value with least significant figures used in the calculation.

Part A

Question	Marks	Content	Syllabus Outcomes	Targeted Performance Bands
1	1	Mod 6: Properties of Acids and Bases	CH12-13	
2	1	Mod 5: Solution Equilibria	CH12–12	3-4
3	1	Mod 5: Factors that Affect Equilibrium	CH12–5, CH12–12	4-5
4	1	Mod 7: Hydrocarbons	CH12–4, CH12–13	3-4
5	1	Mod 5: Calculating the Equilibrium Constant	CH12–4, CH12–12	
6	1	Mod 7: Nomenclature	CH12–4, CH12–14	3-4
7	1	Mod 6: Properties of Acids and Bases	CH12–6, CH12–13	4
8	1	Mod 5: Solution Equilibria	CH12–6, CH12–12	
9	1	Mod 7: Analysis of Organic Acids and Bases	CH12–5, CH12–14	3-4
10	1	Mod 5: Calculating the Equilibrium Constant	CH12–4, CH12–12	3-4
11	1	Mod 8: Analysis of Organic Substances	CH12–5, CH12–15	3-4
12	1	Mod 6: Quantitative Analysis	CH12–5, CH12–13	3-4
13	1	Mod 6: Quantitative Analysis	CH12–5, CH12–13	3-4
14	1	Mod 8: Analysis of Inorganic Substances	CH12–6, CH12–15	3-4
15	1	Mod 5: Factors that Affect Equilibrium	CH12–5, CH12–6, CH12–12	4-5
16	1	Mod 7: Polymers	CH12–6, CH12–14	4-5
17	1	Mod 8: Analysis of Inorganic Substances	CH12–6, CH12–14	4-5
18	1	Mod 8: Analysis of Organic Substances	CH12–5, CH12–15	4-5
19	1	Mod 7: Nomenclature, Alcohols and Reactions of Organic Acids and Bases	CH12–6, CH12–14	5-6
20	1	Mod 7: Nomenclature	CH12–14	4-6

Part B

Question	Marks	Content	Syllabus Outcomes	Targeted Performance Bands
21	6	Mod 5: Factors that Affect Equilibrium	CH12–5, CH12–6, CH12–13	5
22 (a)	1	Mod 6: Properties of Acids and Bases	CH12–13	2-3
22 (b)	2	Mod 6: Using the Brønsted-Lowry Theory	CH12–6, CH12–13	3-4
22 (c)	2	Mod 6: Using the Brønsted-Lowry Theory	CH12–6, CH12–13	4
23 (a)	1	Mod 5: Static and Dynamic Equilibrium	CH12–12	
23 (b)	1	Mod 5: Static and Dynamic Equilibrium	CH12–12	
23 (c)	2	Mod 5: Factors that Affect Equilibrium	CH12–5, CH12–12	
23 (d)	2	Mod 5: Calculating the Equilibrium Constant	CH12–12	
24 (a)	2	Mod 6: Quantitative Analysis	CH12–2, CH12–3, CH12–7, CH12–13	3-4
24 (b)	2	Mod 6: Quantitative Analysis	CH12–2, CH12–3, CH12–7, CH12–13	3-4
24 (c)	4	Mod 6: Quantitative Analysis	CH12–5, CH12–6, CH12–13	2-5
25 (a)	3	Mod 7: Nomenclature	CH12–4, CH12–7, CH12–14	3-5
25 (b)	4	Mod 7: Hydrocarbons, Reactions of Organic Acids and Bases	CH12–5, CH12–7, CH12–14	3-6
26	4	Mod 6: Properties of Acids and Bases	CH12–6, CH12–13	
27 (a)	3	Mod 6: Properties of Acids and Bases	CH12–4, CH12–5, CH12–13	3-6
27 (b)	1	Mod 6: Properties of Acids and Bases	CH12–4, CH12–5, CH12–13	3-6
28 (a)	1	Mod 6: Quantitative Analysis	CH12–13	2-3
28 (b)	1	Mod 6: Quantitative Analysis	CH12–6, CH12–13	3-4
28 (c)	2	Mod 6: Quantitative Analysis	CH12–7, CH12–13	4-5
29	3	Mod 5: Solution Equilibria	CH12–4, CH12–6, CH12–12	3-6
30	4	Mod 6: Quantitative Analysis	CH12–2, CH12–13	
31	4	Mod 7: Reactions of Organic Acids and Bases	CH12–6, CH12–7, CH12–13	4
32 (a)	2	Mod 7: Products of reactions Involving Hydrocarbons	CH12–7, CH12–14	2-5

32 (b)	2	Mod 7: Products of reactions Involving Hydrocarbons	CH12–7, CH12–14	2-5
33 (a)	2	Mod 7: Alcohols	CH12–3, CH12–4, CH12–14	2-6
33 (b)	1	Mod 7: Alcohols	CH12–3, CH12–4, CH12–14	2-6
33 (c)	2	Mod 7: Alcohols	CH12–3, CH12–4, CH12–14	2-6
33 (d)	3	Mod 7: Alcohols	CH12–3, CH12–4, CH12–14	2-6
34 (a)	3	Mod 8: Analysis of Inorganic Substances	CH12–1, CH12–4, CH12–5, CH12–6, CH12–7, CH12–15	3-4
34 (b)	3	Mod 8: Analysis of Inorganic Substances	CH12–1, CH12–4, CH12–5, CH12–6, CH12–7, CH12–15	3
34 (c)	2	Mod 8: Analysis of Inorganic Substances	CH12–2, CH12–4, CH12–6, CH12–15	4-5
35 (a)	2	Mod 8: Analysis of Inorganic Substances	CH12–3, CH12–4, CH12–6, CH12–15	2-6
35 (b)	3	Mod 8: Analysis of Inorganic Substances	CH12–3, CH12–4, CH12–6, CH12–15	2-6