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Examiners' report

CHEMISTRY B (SALTERS)

H033

For first teaching in 2015

H033/02 Summer 2023 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Paper 2 series overview

Candidates scored lower on this paper compared to 2019. Calculation questions used in the paper generally differentiated candidates at different grades well. The difficulty level of the paper was normal; however, some candidates found the questions challenging with a number of candidates misunderstanding observations and requirements of the practical aspects of the paper. Candidates did not appear to be short on time, with omitted responses usually appearing to be due to a lack of knowledge.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• understood the practical aspects of chemistry • could complete calculation questions with confidence • are able to balance equations including ionic equations • can relate periodicity trends to reasons for reactivity • understand the requirements of dynamic equilibrium.	• showed misconceptions when describing practical results and requirements • did not attempt the calculation questions or did not convert/determine values correctly • did not balance equations or misunderstood the charges of common ions • struggled to relate the presence of intermolecular bonds to boiling point or identify the intermolecular bonds present in specific compounds • mistook enthalpy diagrams for Boltzmann distribution curves.

Question 1 (a)

1 This question is about Group 2 compounds.

Group 2 hydroxides can be used to neutralise acidity in a variety of contexts. Magnesium hydroxide may be used to neutralise excess stomach acidity and calcium hydroxide may be used to neutralise acidity in soils.

The hydroxides are formed when the oxides react with water.

(a) Write an equation to show the ions formed when calcium oxide reacts with water.

[1]

Many candidates did not answer the question using ions and, when they were able to, the wrong charges were used by candidates or incorrect balancing was seen. Only a small number of candidates scored the mark on this question.

Question 1 (b)

(b) A student shakes a small amount of magnesium oxide in a test tube with water. A white suspension is formed.

The student then adds dilute hydrochloric acid, drop by drop with shaking, until no further changes are seen.

Describe how the **appearance** of the contents of the test tube changes during the addition of the acid.

....

....

....

.... **[2]**

A large number of candidates were able to score 1 mark on this question, identifying that the solution became clear or colourless. However, some candidates had the misconception that the solution would begin to fizz, and most candidates did not identify that the white precipitate disappears. Some candidates stated the solid would dissolve, but this is a deduction rather than an observation.

Question 1 (c)

(c) Barium chloride solution is used to test for the presence of sulfate ions in solution.

Write an **ionic** equation for this test.

Include state symbols.

[2]

Candidates did not score well on this question, with many not using an ionic equation. Many candidates included chloride ions in their equations and therefore lost the mark. When ionic equations were used, there was a level of misconception shown with candidates showing an incorrect charge for barium ions or identifying barium sulfate as an aqueous solution rather than a solid. Only a small portion of candidates scored full marks on this question.

Question 1 (d)

(d) A student is provided with a solid sample of an unknown Group 2 hydroxide, **X**$(OH)_2$.

The student describes how 250 cm^3 of a solution of this solid is made up in a volumetric flask.

Step 1 The mass of a weighing boat is measured and recorded.
Step 2 Solid is added to the boat and the new mass measured and recorded.
Step 3 The contents of the boat are tipped into a beaker.
Step 4 Deionised water is added.
Step 5 The mixture is stirred using a glass rod until all of the solid is dissolved.
Step 6 The glass rod is removed.
Step 7 The solution is poured through a funnel into the volumetric flask.
Step 8 The solution is made up to the mark with deionised water.
Step 9 The flask is stoppered and inverted several times.
Step 10 The concentration of the solution is calculated.

Describe **two** errors in this practical procedure made by the student and state the effect of each error on the concentration of the solution.

Error ....

....

Effect on concentration ....

....

Error ....

....

Effect on concentration ....

....
[4]

Candidates were able to score well on this question, with most candidates scoring 2 or 4 marks. A large number of candidates were able to identify that equipment had not been rinsed during the preparation of the standard solution, resulting in the final solution being a lower concentration than expected.

Question 1 (e)*

(e)* A student uses a titration to identify the unknown Group 2 metal **X** in a sample of **X**$(OH)_2$.

The student records the following data.

Mass of weighing boat + **X**$(OH)_2$ = 4.64 ± 0.005 g
Mass of weighing boat = 4.44 ± 0.005 g

The sample of **X**$(OH)_2$ is dissolved and made up to 250 cm^3 of solution in a volumetric flask.

The student titrates this solution with 0.0250 mol dm^{-3} HC*l*.

The student calculates correctly that the concentration of **X**$(OH)_2$ is 0.0106 mol dm^{-3}.

Use this data to calculate the M_r for **X**$(OH)_2$ and use this to identify the metal **X**.

Given that the percentage uncertainty is greatest for the mass, apply this percentage to the value of M_r when quoting your result. **[6]**

Most candidates were able to complete the calculation and determine that metal X was calcium. However, few candidates annotated their calculations to show the steps they were taking. Some candidates attempted the percentage uncertainty part of the question, but a large number ignored this, or did not identify that the percentage uncertainty needed to be multiplied by 2. Candidates tended to score a Level 2 response on this question due to this omission, with a portion of candidates omitting the question entirely or misunderstanding the requirements of the calculation.

Exemplar 1

A student uses a titration to identify the unknown Group 2 metal **X** in a sample of **X**$(OH)_2$.

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Given that the percentage uncertainty is greatest for the mass, apply this percentage to the value of M_r when quoting your result. **[6]**

$4.64 - 4.44 = 0.2g \pm 0.01$

0.2g of $X(OH)_2$ in 250 cm^3

$X(OH)_2 + 2HCl \rightarrow XCl + 2H_2O$

$0.0106 \times \frac{250}{1000} = 2.65 \times 10^{-3}$ mol $X(OH)_2$

$2.65 \times 10^{-3} = \frac{m}{M_r}$

$\frac{0.2}{2.65 \times 10^{-3}} = M_r$

79.245
71.698

$75.47 = M_r \pm 3.77 - 5\%$ percentage uncertainty

$(OH)_2 = 16 + 1 + 16 + 1$

$75 - 34 = \sim 41$ (percentage uncertainty) 5%

Ca = 40 so X = Ca.

$X(OH)_2 = Ca(OH)_2$

The candidate has shown a clear sequence for the calculation, including annotations to show which calculation is being used and what they expect to find from this. The percentage uncertainty has been correctly used to determine the range which the molecular mass of the compound could have. This sequence has allowed them to determine calcium as the unknown metal. The calculation is set out in a clear and logical format and consequently achieves the higher Level 3 mark.

Question 2 (a)

2 Bromine can be extracted from sea water.

(a) Describe the appearance and physical state of bromine at room temperature.

.... **[1]**

Misconception

?

A large number of candidates identified bromine as orange rather than red/brown. A smaller portion identified bromine as a solid or a gas rather than a liquid at room temperature.

Question 2 (b) (i)

(b) Sea water contains some bromide ions and these can be displaced as aqueous bromine by reaction with the more reactive halogen chlorine, as shown in **Equation 2.1**.

$2Br^-(aq) + Cl_2(aq) \rightarrow Br_2(aq) + 2Cl^-(aq)$ **Equation 2.1**

(i) Explain, in terms of electrons, why chlorine is more reactive than bromine.

....

....

....

....

....

.... **[3]**

Misconception

?

This was another question where candidates showed misconceptions in their understanding. When discussing reactivity, candidates referenced electrons being lost from the outer shell rather than being gained. Most candidates could identify that chlorine atoms were smaller than bromine atoms, but some referenced chlorine ions rather than atoms.

Question 2 (b) (ii)

(ii) Identify the oxidising agent and reducing agent in **Equation 2.1**.

Oxidising agent ....

Reducing agent .... **[1]**

This was a question where candidates scored lower than expected, with a large portion scoring 0 on this question. This was largely due to candidates identifying bromine as the reducing agent, rather than bromide.

Question 2 (c)

(c) A student adds aqueous silver nitrate to an aqueous sodium halide. A precipitate forms but the student is unsure whether it is silver bromide or silver iodide.

Explain what the student can do to confirm the identity of the precipitate.

....

....

....

.... **[2]**

Assessment for learning

Candidates tended to answer this question with reference to the colour of the halide precipitate rather than with a further test to easily identify the halide. Some candidates were able to identify the use of ammonia, with some using this to determine between bromide and iodide ions. Some candidates were able to clarify this with the different observations of concentrated and dilute ammonia.

Candidates should see this in action and identify unknown ions using this method.

Question 2 (d) (i)

(d) Silver bromide is light-sensitive and is used in photography.

Light causes the addition of electrons to the silver ions.

(i) Write a half-equation for the reaction that occurs in the presence of light.

[1]

High scoring candidates were able to identify that the silver ions are reduced and show the relevant half-equation for this. However, some candidates gave the incorrect ionic charge for silver and lost the mark here.

Question 2 (d) (ii)

(ii) Explain, in terms of electrons, whether silver ions are oxidised or reduced in this reaction.

....

.... **[1]**

This was a well answered question with a large portion of candidates identifying that the ions are reduced and gain electrons.

Question 2 (e)

(e) The remaining silver bromide is removed by a developer, such as hydroquinone, $C_6H_4(OH)_2$.

This reacts with silver ions as shown:

..........Ag^+ + ...$C_6H_4(OH)_2$ $\rightarrow$ ....Ag + ...$C_6H_4O_2$ + ...H^+ **Equation 2.2**

Balance **Equation 2.2**. **[1]**

Only a small portion of candidates were able to balance the equation correctly.

Question 2 (f)

(f) A student adds concentrated phosphoric acid to an unknown solid sodium halide in a test tube. When the test tube is warmed, a colourless gas is given off.

When a red-hot inert wire is held in the mouth of the test tube, a purple colouration is seen around the hot wire.

Explain what is happening in the test tube and identify the sodium halide.

....

....

....

....

....

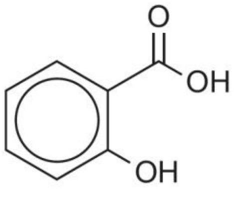
.... **[4]**

Most candidates were able to identify the halide correctly as sodium iodide, with a portion of these showing an understanding of the purple colouration being iodine. However, most candidates could not make the link between the colourless gas being a hydrogen halide or the reason why the purple colouration appeared around the red-hot wire. Only candidates with a clear understanding of the practical aspects of chemistry were able to score 3 or 4 marks on this question.

Quest ion 3 (a)

3 Aspirin, $CH_3COOC_6H_4COOH$, is a medicine that is made by an esterification reaction. It is conventionally made in the laboratory by refluxing a mixture of 2-hydroxybenzoic acid with ethanoic anhydride in the presence of a catalyst of concentrated sulfuric acid.

(a) The structure of 2-hydroxybenzoic acid is shown below.



2-hydroxybenzoic acid

Give the name of the –OH functional group attached directly to the benzene ring.

.... **[1]**

Misconception

A large number of candidates mistook the functional group for a hydroxyl group rather than a phenol group. The presence of the carboxylic acid group on the benzene ring could have caused this misconception to occur.

Question 3 (b) (i)

(b) The crude product from the esterification reaction requires purification.

Aspirin is soluble in hot water but insoluble in cold water. A student begins by adding a large volume of hot water to the crude product. The student then allows the hot solution to cool to room temperature. However, very little product recrystallises.

(i) Describe and explain how the student should modify this part of their technique in order to obtain more recrystallised product.

....

....

....

.... **[2]**

Assessment for learning

A large number of candidates did not understand the requirement for a minimum amount of hot solvent being required to improve yield. Some candidates referenced that the product should be cooled slowly to increase yield. Those candidates that could identify the need for a minimum amount of hot solvent did not always identify that this would form a saturated solution.

This could be incorporated into a wider investigation on how yield is increased on a larger scale in industrial reactions and its wider applications.

Question 3 (b) (ii)

(ii) Name a practical technique that the student could use to check the purity of a recrystallised product.

.... **[1]**

Candidates showed a mixed response on this question with half of the candidates correctly identifying that the melting point could be determined or that thin layer chromatography could be used.

Question 3 (c) (i)

(c) The equation below shows the reaction for the preparation of aspirin.

$$HOC_6H_4COOH + (CH_3CO)_2O \rightarrow CH_3COOC_6H_4COOH + CH_3COOH$$

2-hydroxybenzoic acid	**ethanoic anhydride**	**aspirin**	**ethanoic acid**

A student prepares 3.06 g of aspirin having started with 3.45 g of 2-hydroxybenzoic acid and excess ethanoic anhydride.

(i) Calculate the percentage yield of aspirin in this preparation.

percentage yield = ... % **[3]**

Candidates tended to score all 3 marks or no marks on this question depending on their approach to the question. Some candidates incorrectly determined the M_r for 2-hydroxybenzoic acid and/or aspirin, but this was considered and an ECF given where this was identified. Some candidates used an alternate method for the calculation, but again this was given marks appropriately.

Question 3 (b) (ii)

(ii) Calculate the atom economy of this preparation of aspirin.

atom economy = ... % **[1]**

Some candidates gained an ECF mark on this question from part 3(b)(i), but generally most candidates were able to understand how the atom economy calculation is completed.

Question 3 (d) (i)

(d) Aromatic alcohols, such as phenylethanol, $C_6H_5CH_2CH_2OH$, have many of the properties of aliphatic alcohols.

(i) When $C_6H_5CH_2CH_2OH$ is oxidised with acidified potassium dichromate(VI), an aldehyde and a carboxylic acid are formed.

Name the practical technique that should be used to allow the formation of more aldehyde and less carboxylic acid.

.... **[1]**

Misconception

Half of the candidates were able to identify the need to distil the mixture in order to obtain the aldehyde rather than the carboxylic acid, with the other half of mistakenly identifying that reflux should take place.

Question 3 (d) (ii)

(ii) Classify $C_6H_5CH_2CH_2OH$ as a primary, secondary or tertiary alcohol.

.... **[1]**

Most candidates were able to identify that the alcohol is a primary alcohol, with a small portion of candidates incorrectly identifying the alcohol as secondary or tertiary.

Question 3 (d) (iii)

(iii) Give the structural formula of the ester formed when $C_6H_5CH_2CH_2OH$ reacts with ethanoic acid.

.... **[1]**

Assessment for learning

Candidates found this question challenging, with a number of candidates showing the structural formula for the carboxylic acid rather than the ester. Some candidates that identified that an ester was produced showed the carbonyl group on the incorrect carbon. Candidates that drew the ester before showing the structural formula tended to score on this question.

Question 3 (d) (iv)

(iv) $C_6H_5CH_2CH_2OH$ undergoes a dehydration reaction when heated with concentrated sulfuric acid. However, phenylmethanol, $C_6H_5CH_2OH$, does **not** undergo this reaction.

- Use structural formulae to write an equation for the dehydration of $C_6H_5CH_2CH_2OH$.
- Name the **type** of reaction that occurs.
- Explain why this same reaction **cannot** occur in $C_6H_5CH_2OH$.

Equation

Type of reaction ....

Explanation ....

....

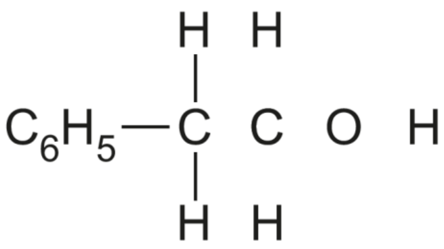
.... **[3]**

Candidates who scored marks on this question were able to identify the type of reaction that took place. A smaller portion of candidates were able to show the equation for the elimination reaction and express the formation of the alkene. Few candidates were able to explain the reason why phenylmethanol could not undergo this reaction.

Question 3 (e)

(e) Electron 'dot-and-cross' diagrams can be used to show the arrangements of electrons in molecules.

Add dots and crosses to the diagram of phenylethanol below (where bonds are not shown), and use this diagram to state and explain the C–O–H bond angle.



C–O–H bond angle = ...°

Explanation ....

....

....

....

....

.... **[5]**

This question showed a range of candidate understanding, with most candidates identifying the presence of the electrons in phenylethanol. However, some candidates did not identify the lone pairs of electrons on the oxygen atom. Not all candidates understood that the C-O-H is a bent shape with a bond angle of 104.5°. However most candidates, when they showed the correct formation of electrons in the phenylethanol, could identify the number of lone pairs versus bonding pairs, with some of these identifying that the lone pairs repel more and a small portion identifying the reason for this.

Question 3 (f)*

(f)* Three small aliphatic molecules are methanol, CH_3OH, methanal, HCHO, and methane, CH_4.

....

....

....

....

.... **[6]**

Misconception

Candidates showed a mixed response to this question, with a number of candidates incorrectly identifying the intermolecular bonds present in each compound. Some candidates incorrectly identified methanal as having hydrogen bonding and others showed the incorrect order for boiling points.

Where candidates were able to identify the correct intermolecular bonds and order for boiling point, they were not always clear on how these intermolecular bonds are formed and this limited the level and the marks gained on this question.

Exemplar 2

use your explanations to deduce their relative boiling points.

H–C(H)(H)–OH methanol H–C(=O)–H methanal H–C(H)(H)–H methane.

Methanol has a polar -OH group due to oxygen being much more electronegative than hydrogen, so has δ^-O and δ^+H. This means that it can form very strong hydrogen bonds with adjacent methanol molecules, the δ^+H bonding attracted to ~~the~~ a lone pair on another oxygen in another CH_3OH molecule. It also forms instantaneous dipole induced dipole interactions (IDID).

Methanal has a very polar C=O bond which means it has a permanent dipole ($C=\delta^+$ / $O=\delta^-$) so it can form permanent dipole-dipole interactions as well as IDIDs.

Methane has no permanent dipole due to there being no significant difference in the electronegativities **[6]**

Additional answer space if required

of C/H therefore can only form IDID interactions between molecules from the instantaneous dipole created by the movement of electrons in the C-H bonds (thus inducing a dipole in another molecule of CH_4)

Therefore, CH_3OH has the highest boiling point as more energy is required to break hydrogen bonds than permanent dipole dipole extra space→

interactions, Then it is ~~HCOH~~ HCHO, and methane CH_4 has the lowest boiling point as ID-ID interactions are the weakest intermolecular forces so require the least amount of energy to break.

The structures of the three compounds have been drawn and this has enabled the candidate to picture the types of intermolecular bonds that would occur for each one. Details have been given to explain how each intermolecular bond arises, with clear links to the structure of the compound and the relative boiling point of each one. These have been directly compared and a clear reasoning for the order of the boiling points has been articulated.

Question 4 (a)

4 Ammonia, NH_3, is an important gas that is made industrially on a very large scale. It has a wide range of uses such as the production of synthetic fertilisers like ammonium nitrate.

The manufacture of ammonia occurs in the Haber process as shown in **Equation 4.1**.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ **Equation 4.1**

This reaction is an example of a dynamic equilibrium.

(a) A student says:

- When a reaction is in dynamic equilibrium, the forward and reverse reactions have stopped.
- This means that the concentrations of reactants and products remain constant.

Comment on the student's statements, correcting any errors.

....

....

....

....

....

.... **[3]**

This was a well answered question. A large portion of candidates were able to achieve full marks, showing a clear understanding of dynamic equilibrium.

Question 4 (b)

(b) For the equilibrium in **Equation 4.1**:

$$K_c = \frac{[NH_3]^2}{[N_2]\,[H_2]^3}$$

At a temperature of 472 K, this equilibrium constant has a numerical value of 0.105.

In an equilibrium mixture at this temperature, the concentration of N_2 is 4.02×10^{-2} mol dm^{-3} and the concentration of H_2 is 1.27×10^{-1} mol dm^{-3}.

Calculate the concentration of NH_3 in the mixture (in mol dm^{-3}) at the same temperature.

Give your answer to an **appropriate** number of significant figures.

concentration of NH_3 = ... mol dm^{-3} **[3]**

As with other calculation questions, candidates tended to score full marks or 0 to 1 marks for this question. Candidates were able to rearrange the equation and input the correct values to determine $[NH_3]$, with candidates losing marks for either significant figures or value errors in the initial part of the calculation.

Question 4 (c)

(c) Some of the ammonia produced in the Haber process is oxidised in the first step of a different process to make nitric acid, as shown in **Equation 4.2**.

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ **Equation 4.2**

Calculate the minimum mass of oxygen (in kg) required to react with 4.8×10^7 cm^3 of ammonia at 5.0×10^2 kPa and 900 K.

minimum mass of O_2 = ... kg **[4]**

The candidates showed a wide distribution of marks on this question, with higher attaining candidates scoring 3 or 4 marks. Some candidates mistakenly converted pressure and/or volume in the question, with very few candidates failing to correctly rearrange the ideal gas equation.

Question 4 (d)

(d) Ammonia can be converted into the fertiliser ammonium nitrate by reaction with nitric acid, as shown in **Equation 4.3**.

$NH_3 + HNO_3 \rightarrow NH_4NO_3$ **Equation 4.3**

Calculate the mass of ammonia (in kg) required to produce 1.00 tonne of ammonium nitrate.

mass of ammonia = ... kg **[2]**

Candidates tended to score well on this question, with candidates scoring either the full marks available or none. Candidates who scored 1 mark generally did so for incorrectly converting between g and kg.

Question 4 (e) (i)

(e) **Equation 4.1** is repeated below:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ **Equation 4.1**

The Haber process (**Equation 4.1**) uses an iron catalyst.

(i) What **type** of catalyst is iron in the Haber process?

.... **[1]**

This was a well answered question with a large portion of candidates identifying the catalyst as heterogeneous.

Question 4 (e) (ii)

(ii) Complete the following stages that describe the function of the iron in the Haber process.

Stage 1 nitrogen and hydrogen are adsorbed onto the surface of the iron

Stage 2 ....

Stage 3 ....

Stage 4 ammonia is desorbed from the surface of the iron

[1]

Half of the candidates were able to identify the process of how catalysts work, with the process of reactant bonds breaking and then product bonds being formed. Candidates who did not score on this question did not identify the breaking/making sequence.

Question 4 (f)

(f) Draw a labelled Boltzmann distribution curve for a reaction.

Mark the activation enthalpies when a catalyst is used and when it is not used.

[2]

A large portion of candidates incorrectly drew enthalpy profile diagrams here rather than Boltzmann distribution curves. Candidates who identified the need to draw the distribution curve at times showed the curve showing the change in temperature rather than the use of a catalyst.

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