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Examiners' report

CHEMISTRY B (SALTERS)

H433

For first teaching in 2015

H433/03 Summer 2024 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 3 series overview

The H433/03 component assesses content from across all teaching modules but places particular emphasis on practical skills.

Candidates are required to use knowledge and understanding of principles and concepts in the planning of experimental and investigative work and in the analysis and evaluation of data.

Chemical literacy is assessed through extended response questions as well as the comprehension of, and use of, data from a Practical Insert.

Generally speaking, Paper 3 performed well in this series, with the overall mean mark of this paper higher than in recent years.

There were fewer instances of candidates omitting to provide any response to certain questions this year, which was pleasing. There was no evidence that time was a problem on this paper.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• had sound knowledge of year 12 concepts and had good practical skills and knowledge • produced a clear, logical explanation of the chemistry involved in the two Level of Response Questions 2 (c) and 3 (b) – these candidates also addressed all three scientific points mentioned in the stem of these questions • scored highly in the calculation Questions 2 (e), 3 (d), 4 (c) (ii) and 4 (d) (ii) – calculations were clearly laid out allowing examiners to award ECF marks even where the final answer was wrong.	• did not lay out their calculation answers logically, making it difficult to award ECF marks • did not understand the difference between halide ions and parent halogens in Level of Response Question 3 (b) • confused intermolecular and intramolecular bonding, as well as the causes of electrical conductivity in molten compounds for Question 3.

Question 1 (a) (i)

1 This question is about electrochemical cells.

Table 1.1 shows some standard electrode potentials.

Table 1.1

Half-reaction	$E^{\ominus}$/V
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	–0.13
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$Ag_2O(s) + H_2O(l) + 2e^- \rightarrow 2Ag(s) + 2OH^-(aq)$	+0.34
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Cl_2(aq) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36

(a) The values in **Table 1.1** are described as **standard** electrode potentials.

(i) Name the electrode against which these values are measured.

.... **[1]**

Some candidates did not use the term 'standard' hydrogen electrode which was a requirement for the measurement of the standard electrode potentials in the table.

Question 1 (a) (ii)

(ii) What are the standard conditions at which these standard electrode potentials are measured?

....

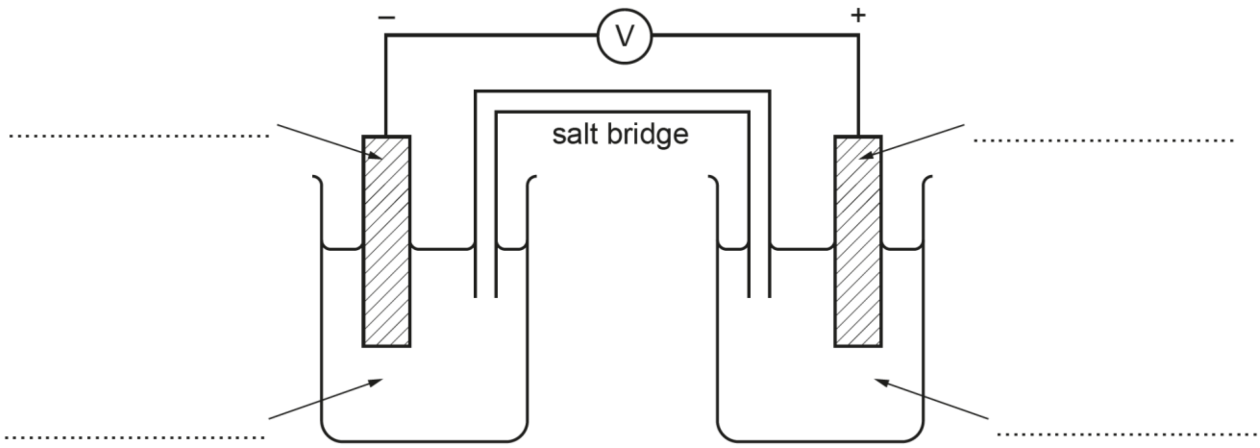
.... **[2]**

Candidates generally answered this question well.

Question 1 (b) (i)

(b)

(i) Some students set up the cell below. The cell consists of a copper/copper ion half-cell and a lead/lead ion half-cell. The left-hand electrode is negative.



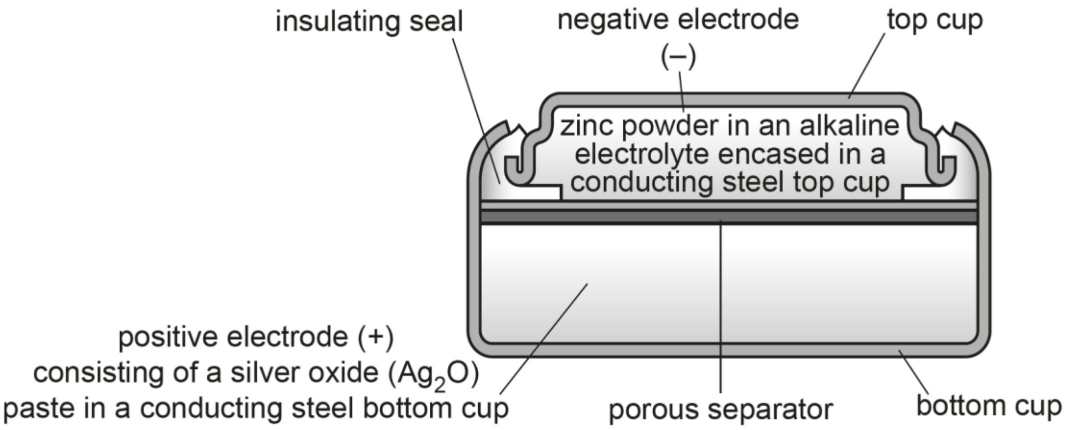
Identify the metals and ions by labelling the diagram with element symbols and ion formulae. Include state symbols. **[2]**

This question was generally well-answered. The most common error was a reversal of the electrodes, with the Cu/Cu^{2+} half-cell being labelled as the left-hand electrode.

Question 1 (c) (i)

(c) 'Button batteries' are small cells used where there is not much space, for example, in a watch or mobile phone.

The make-up of a silver oxide (Ag_2O) button battery is shown below.



(i) Use **Table 1.1** to write ion-electron half equations for the reactions happening at the negative and positive electrodes.

Then write the equation for the overall cell reaction.

Half-equation for the negative electrode:

Half-equation for the positive electrode:

Equation for the overall cell reaction:

[3]

Many candidates achieved full marks here with the most common error being the use of the Ag^+ half equation instead of the Ag_2O half equation.

Question 1 (c) (ii)

(ii) Suggest the purpose of the porous separator shown in the diagram.

....

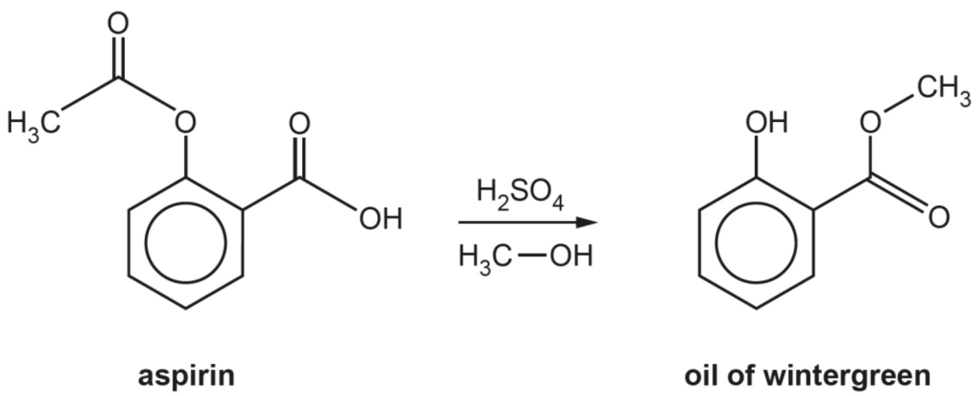
.... **[1]**

Examiners were looking for a realisation that this was acting as a salt bridge to allow the movement of ions between the half cells. A number of candidates suggested the porous separator was to prevent mixing of the chemical species in each part of the cell. This could have been achieved by a solid separator and was not therefore credited. A regularly seen incorrect answer was 'to let the electrons flow.'

Question 2 (a) (i)

2 'Oil of wintergreen' is used by athletes to warm their muscles. It can be synthesised in the laboratory from aspirin tablets.

The reaction is shown.



(a) Aspirin has a benzene ring and a carboxylic acid group.

(i) What term is used to describe compounds with benzene rings?

.... **[1]**

This was the best-answered question on the paper, with most candidates gaining the mark.

Question 2 (a) (ii)

(ii) Name the other functional group in aspirin.

.... **[1]**

Generally, well-answered.

Question 2 (b)

(b) Describe a simple test-tube test that could confirm the formation of oil of wintergreen.

....

....

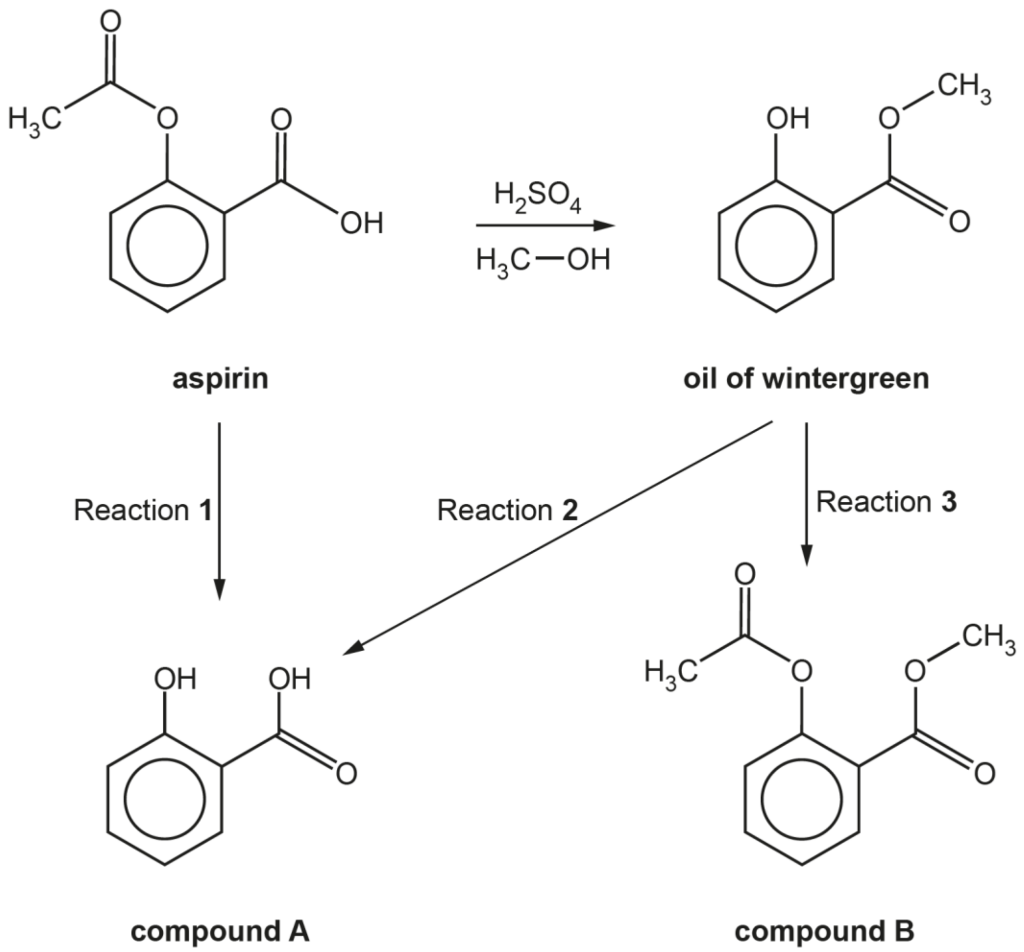
....

.... **[2]**

Many candidates realised that the addition of iron(II) chloride solution would result in a purple colour, confirming the presence of the phenol group in oil of wintergreen. Wrong answers included the use of Fehling's solution or the 'silver mirror' test.

Question 2 (c)*

(c)* Compound **A** can be made in one step from **both** aspirin and oil of wintergreen. Compound **B** can be made in one step from oil of wintergreen but not from aspirin. The reactions are numbered from 1 to 3 in the diagram below.



Explain why compound **B cannot** be made in one step from aspirin.

Give the reagents and conditions and show the **formulae** of other organic products in Reaction **1**, Reaction **2** and Reaction **3**.

State whether each reaction is **hydrolysis** or **condensation**. **[6]**

This question provided a wide range of answers. Most candidates recognised the types of reaction, however, the reagents, conditions and products suggested varied. A common error was suggesting ethanoic acid as a reactant for Reaction 3 instead of the anhydride or acyl chloride. Only a few candidates gave the correct response as to why compound B cannot be made in 1 step from aspirin, recognising that conditions of esterification would also hydrolyse the existing ester group.

Exemplar 1

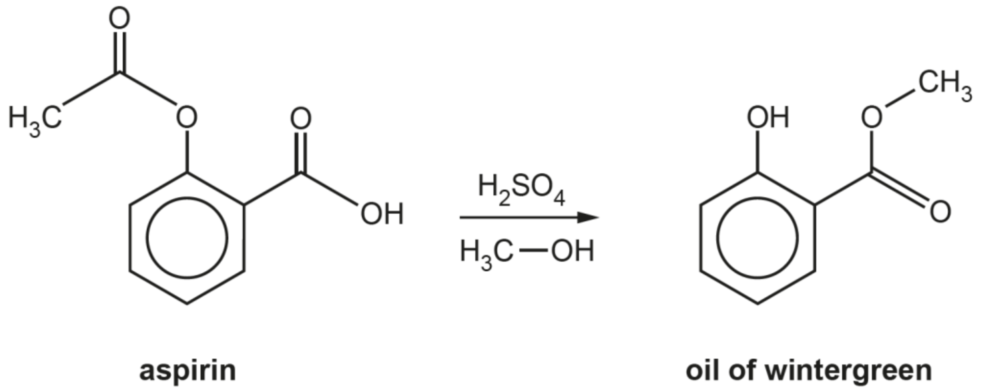
Reaction 1 is a hydrolysis reaction as aspirin has lost an ester and reformed the alcohol group = $H_3CCOO + H_2O \rightarrow H_3COOH$
Reaction 2 is a ~~condensation~~ hydrolysis reaction as the carboxylic acid ground is reformed from the ester $CH_3COO + H_2O \rightarrow CH_3COOH$. Reaction 3 is a condensation reaction as a molecule of water is formed $RCOH + RCOOH \rightarrow RCOO + H_2O$
Reagents for reaction 1 is $NaOH_{(aq)}$ + HUR
Reagents for reaction 2 is NaOH + HUR
Reagents for reaction 3 is ethanoic acid and heat under reflux

Extra answer space if required.

B cannot be made from aspirin in 1 step as position C=O bond swaps around therefore an intermediate must form first.

In this exemplar, the candidate has identified the reactions as hydrolysis or condensation correctly but uses incorrect reagents and does not correctly identify the other organic products. The reason why B cannot be made in one step from aspirin is also incorrect. Hence, the candidate only scores in Level 1.

Question 2 (d) (i)



(d) A group of students carry out a small-scale synthesis of oil of wintergreen. They add two crushed tablets of aspirin to 10 cm^3 of methanol and eight drops of concentrated sulfuric acid in a boiling tube.

They warm the tube in a hot water bath for about 5 minutes.

Two layers form, one of which contains oil of wintergreen.

(i) The students shake the impure product with sodium hydrogencarbonate solution in a separating funnel.

Which impurities are removed by doing this and what is seen during the process?

....

....

.... **[2]**

Many candidates recognised that the addition of the sodium hydrogencarbonate would remove acidic impurities and fizzing/bubbles would be seen.

Question 2 (d) (ii)

(ii) The students then add ether to the separating funnel.

Oil of wintergreen and aspirin are insoluble in cold water, but very soluble in ether.
The density of ether is 0.7 g cm^{-3}.

Which organic impurity would be left in the aqueous layer, and why is this the lower layer?

....

....

....

.... **[2]**

Only a minority of candidates knew that the organic impurity would be methanol. There was a lot of confusion about densities.

Question 2 (d) (iii)

(iii) Ether is volatile and very flammable.

How could oil of wintergreen be obtained from the ether layer?

....

.... **[1]**

There was very little knowledge of what to do with ether. Most candidates answered distillation or even reflux. Examiners were looking for gentle evaporation, for example, using a warm water bath.

Question 2 (e)

(e) The students start with 0.90 g aspirin with the other reactants in excess.

After the reaction, they collect 0.70 g of the purified oil of wintergreen.

Calculate the percentage yield of oil of wintergreen in this synthesis.

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

Most candidates answered this correctly, but a minority of candidates just used 0.7/0.9 x 100 as the percentage yield.

Question 3 (a)

3 The element chlorine is a powerful oxidising agent.

(a) Write an ion-electron half-equation to show what occurs when chlorine acts as an oxidising agent.

[1]

Most candidates got correct answers; if not, it was often because they had the equation in reverse.

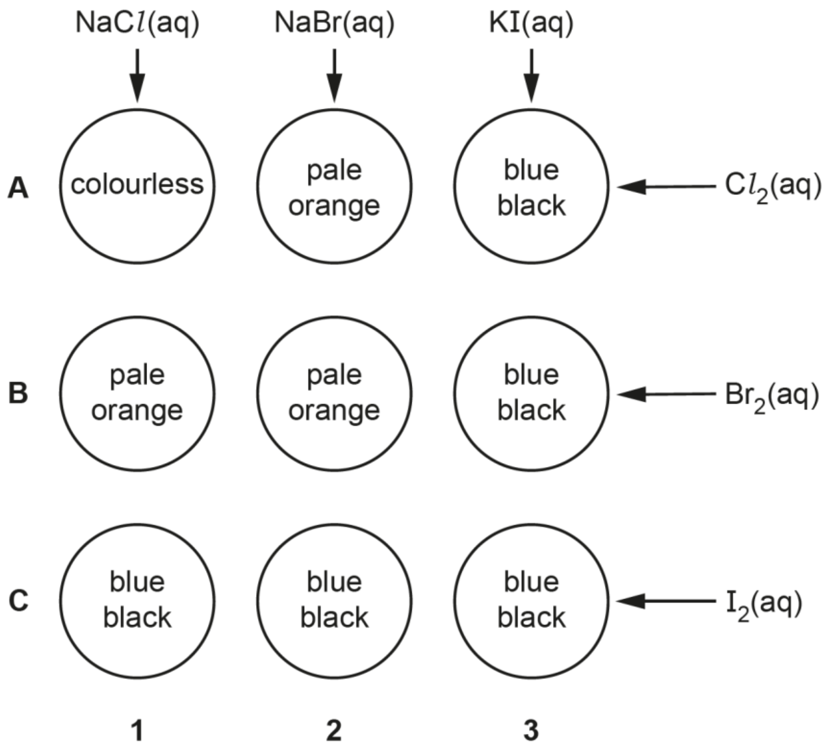
Question 3 (b)*

(b)* A student performs a microscale investigation on halogen displacement using a plate with nine small wells.

As shown in the diagram below, the student:

- adds two drops of starch solution to each well (**A1**, **B1**, **C1**, etc.)
- adds four drops of different sodium halide solutions to columns **1**, **2** and **3**
- adds four drops of dilute aqueous solutions of chlorine, bromine and iodine to rows **A**, **B** and **C**.

The colour (or lack of colour) of the resultant mixture in each well is described in the diagram.



Explain:

- the colour (or lack of colour) in each well
- any redox reactions that have taken place (include balanced equations)
- any patterns you see in the results.

[6]

This question was a good example of how common practicals can be placed in a microscale context. Although column 3 shows a potassium halide rather than a sodium halide, this did not affect candidates' ability to answer the question.

Misconception

A minority of candidates treated halide ions and halogen molecules as if their properties, e.g. colour, and their reactions, could be interconverted.

Exemplar 2

In C1, C2, C3 the colour is blue black because a reaction between starch and iodine will always form a blue black colour, hence why iodine is used to test for starch.
This is also a pattern. Because also in A3, B3, C3 there is blue black, due to the iodine in KI showing the Iodine is the most powerfull here,

Also, B1, B2 and A_2 are all pale orange due to bromine, this shows that bromine is stronger than chlorine but not as strong as the Iodine mixtures.

In this exemplar, the candidate confuses the cause of the blue/black colour suggesting both iodine and iodide are responsible. There is some suggestion that the presence of bromine is responsible for the orange colour in some wells, but no equations of any sort and only a tentative attempt at explaining any pattern in reactivity. One mark was given, mainly on the basis of the colour discussions.

Question 3 (c)

(c) The table shows some properties of two compounds of chlorine, $NaCl$ and PCl_3.

	$NaCl$	PCl_3
Melting point / K	1074	161
Electrical conductivity when molten	good	none

Use your knowledge and understanding of structure and bonding to explain the differences in melting points and electrical conductivity of $NaCl$ and PCl_3.

....

....

....

....

....

.... **[5]**

Many responses referred to molecules in ionic compounds or intermolecular forces. A minority seemed to think that ionic compounds conduct electricity due to their delocalised electrons.

Misconception

There were two misconceptions that were prevalent:

- Some candidates thought ionic bonds are stronger than covalent bonds. The problem here tends to be the lack of distinction between intermolecular bonding and intramolecular and corresponding link to melting point.
- Some candidates thought that electrical conduction in molten ionic compounds is due to delocalised electrons, as opposed to mobile ions.

Exemplar 3

NaCl ~~has~~ is a giant Lattice held together by strong intermolecular forces, meaning that they require lots of energy to be broken. It can conduct electricity when molten because it contains free electrons. PCl_3 has a simple molecular structure whichs bonds require less energy and therefore temperature to be broken. PCl_3 can't conduct electricity as there are no free electrons to carry charge.

This exemplar confuses the various terms, linking the NaCl lattice to intermolecular forces and suggesting the bonds in PCl_3 require little energy to break. Finally, the candidate explains the electrical conduction in terms of 'free' electrons. Only the simple molecular structure scores in this response.

Question 3 (d)

(d) The 'Dead Sea' is a lake that contains much more bromide than 'normal' sea water. Water from the Dead Sea is used to produce bromine.

Some data about water from the Dead Sea and 'normal' sea water are shown.

mass bromide concentration in water from the Dead Sea	$5.1\,g\,dm^{-3}$
average molar chloride concentration in normal sea water	$0.546\,mol\,dm^{-3}$
average molar bromide concentration in normal sea water	= average molar chloride concentration in normal sea water ÷ 650

Calculate the value of **X**, where:

$$\frac{\text{average molar bromide concentration in water from the Dead Sea}}{\text{average molar bromide concentration in normal sea water}} = \frac{\mathbf{X}}{1.0}$$

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

X = ... **[4]**

A minority of candidates got 4 out of 4, but a wide range of marks were able to be given using the idea of ECF (using 159.8 for the formula mass of Br^- was the most common error).

Question 4 (a)

4 This question refers to the **Practical Insert** that is provided with this paper.

(a) The students plot their results of temperature against time. They are told to **start the temperature axis from 13 °C**.

Show the students' plot below, labelling the axes. **[2]**

Most candidates' graphs scored both marks. The most common loss of a mark was due to the y axis not starting at 13^0C despite this being stated in the stem of the question.

Question 4 (b)

(b) What term describes a reaction where the temperature decreases?

.... **[1]**

Most candidates correctly identified that this would be an endothermic reaction.

Question 4 (c) (i)

(c)
(i) The students use the graph to allow for the warming that occurs from the surroundings during the dissolving process.

Draw lines on your graph in **(a)** to show what the students do and calculate the temperature decrease they obtain.

temperature decrease = ... °C **[2]**

Very few candidates realised the need to extrapolate the warming line back to t = 2mins so the majority got just 1 mark for the temperature rise (ECF).

Question 4 (c) (ii)

(ii) The students use the temperature decrease to calculate that the energy transferred in the experiment is 2200 J.

Calculate a value for the enthalpy change of solution of ammonium nitrate from this result.

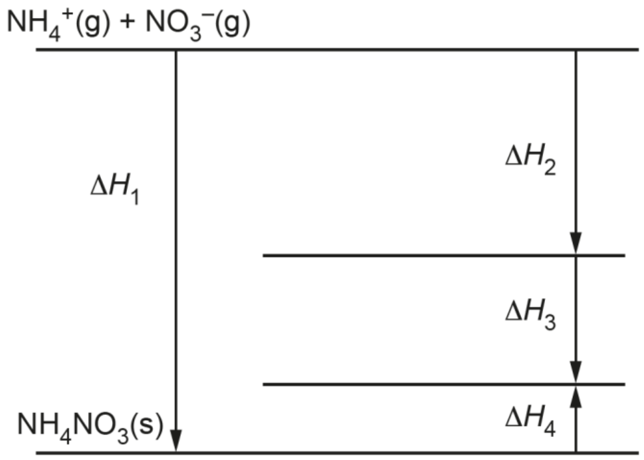
Give your answer in kJ mol^{-1}.

enthalpy change of solution = ... kJ mol^{-1} **[2]**

Most candidates got this calculation correct.

Question 4 (d) (i)

(d) The students, in their research, find the diagram below for the dissolving of ammonium nitrate.



They also find the following data table (**Table 4.1**).

Table 4.1

Enthalpy change / ΔH	**Value / $kJ\,mol^{-1}$**
Lattice enthalpy of NH_4NO_3 $\Delta_{LE}H$	–647
Hydration enthalpy of NH_4^+ $\Delta_{hyd}H\,(NH_4^+)$	–307
Hydration enthalpy of NO_3^- $\Delta_{hyd}H\,(NO_3^-)$	–314

(i) Use **Table 4.1** and your knowledge of ions in solution to **name** the enthalpy changes ΔH_1 to ΔH_4.

ΔH_1 ....

....

ΔH_2 ....

....

ΔH_3 ....

....

ΔH_4 ....

.... **[4]**

A minority of candidates got ΔH_2 and ΔH_3 the wrong way around, failing to spot on the diagram that ΔH_2 was the bigger of the two values.

Question 4 (d) (ii)

(ii) Use the data in **Table 4.1** to calculate ΔH_4.

Give the correct sign.

ΔH_4 = ... $kJ\,mol^{-1}$ **[2]**

This question was reasonably well answered, but a common error, despite the stem of the question, was not to give a sign for this enthalpy change.

Assessment for learning

Candidates should be reminded to always provide a sign for enthalpy change values.

Question 4 (d) (iii)

(iii) Suggest and explain the **two** enthalpy changes that occur when ions are hydrated, and explain why the overall process is always exothermic.

....

....

....

....

.... **[2]**

This was amongst the most challenging questions on the paper. Very few candidates realised that to hydrate the (already gaseous) ions requires breaking the H-bonds in water and forming ion-dipole bonds, consequently, the marks given were almost exclusively 2 (rare) or 0. A common error was to cite the lattice enthalpy as the endothermic process in ion hydration.

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