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Examiners' report

CHEMISTRY A

H032

For first teaching in 2015

H032/01 Summer 2022 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 are 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.

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

Paper 1 series overview

H032/01 is one of the two examination components for the current AS Level examination for GCE Chemistry A.

H032/01 is worth 70 marks, is split into two sections and assesses content from all teaching modules, 1 to 4. Candidates answer all questions.

- Section A includes 20 multiple-choice questions that assess many different areas of the specification. This section of the paper is worth 20 marks.
- Section B includes short answer question styles (structured questions, problem solving, calculations, practical) and extended response questions. This section of the paper is worth 50 marks.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• demonstrated knowledge and understanding for determination of relative atomic mass: Question 22 (a); empirical formula determination from percentage compositions: Question 22 (c) • produced clear and concise responses for explanations of chemical knowledge and understanding, e.g. use of the Boltzmann distribution to explain the effect of changing the temperature on reaction rate: Question 25 (b) • performed calculations using the Ideal Gas Equation: Question 26 (b) • showed knowledge of key chemical concepts such an ionic bonding and structure: Question 23 (a) (i), (ii) and disproportionation: Question 24 (a) (i).	• found it difficult to apply what they had learnt in situations that are unfamiliar • produced responses that lacked depth and were often unnecessarily long, e.g. bonding and conductivity in calcium: Question 23 (c); halide tests and identification of unknowns: Question 24 (b) • did not clearly set out unstructured calculations, e.g. Determination of an enthalpy change from raw experimental data: Question 25 (a) (i); empirical formula determination: Question 22 (c) and Ideal gas equation: Question 26 (b) • did not use significant figures appropriately: Question 25 (a) (i) • did not precisely place curly arrows, correct charges and dipoles in reaction mechanisms, e.g. Electrophilic addition to alkenes: Question 21 (a) (i); Nucleophilic substitution of haloalkanes: Question 26 (a).

There was no evidence that any time constraints had led to a candidate underperforming or of scripts where there were no responses to many questions.

Note: We provide candidates with a fixed number of answer lines and an additional answer space for level of response questions. The additional answer space will be clearly labelled as additional and should only be used when required. We encourage teachers to keep reminding students about the importance of concise answers.

Section A overview

Section A includes 20 multiple-choice questions that assess many different areas of the specification. This section of the paper is worth 20 marks.

Question 1

1 Which substance has a giant covalent lattice structure in its solid state?

A potassium

B silicon

C sodium chloride

D water

Your answer ☐ **[1]**

Most candidates selected B (silicon) as the correct response. A and C featured more than D as the incorrect choice but there seemed to be no pattern.

Question 2

2 What is the meaning of the term electronegativity?

A The ability of an atom to attract the electrons in a covalent bond.

B The ability of an atom to gain an electron.

C The electrostatic attraction between a negative ion and a positive ion.

D The size of the charge on a negative ion.

Your answer ☐ **[1]**

Most candidates knew the concept of electronegativity well and selected A as the correct response.

Question 3

3 Which compound is an alkali?

A CH_3COOH

B CH_3OH

C HNO_3

D NH_3

Your answer ☐ **[1]**

Candidates were less successful with this question than Questions 1 and 2, and it appeared as if many candidates did not recognise that ammonia was an alkali. Most candidates rejected A but a significant number selected C, suggesting that they did not recognise HNO_3 as an acid or confused HNO_3 with NH_3.

Question 4

4 What is the number of paired orbitals in a sulfur atom?

A 4

B 6

C 7

D 8

Your answer ☐ **[1]**

This question was answered reasonably well. From the annotations on scripts many candidates wrote out the electron configuration of a sulfur atom. The successful candidates used electrons in a box notation so that they could visually see, and count, the paired orbitals. This is an excellent strategy to use in any similar questions.

Question 5

5 Which element has the lowest melting point?

A S

B P

C C*l*

D Ar

Your answer ☐ **[1]**

Candidates found this question difficult. Although argon looked to be the obvious choice, many candidates selected phosphorus (B) or chlorine (C). Candidate annotations alongside the question included atomic number and electron configurations suggesting that many find it difficult to link trends in melting point to the correct chemical concepts.

Question 6

6 The first four ionisation energies of a Period 3 element **X** are shown in the table.

Ionisation energy / kJ mol^{-1}			
1st	**2nd**	**3rd**	**4th**
738	1451	7733	10 541

Element **X** is reacted with chlorine.

What is the formula of the chloride formed?

A **X**C*l*

B **X**Cl_2

C **X**Cl_3

D **X**Cl_4

Your answer ☐ **[1]**

Although two steps were required to solve this problem, most candidates answered this question correctly. Candidate annotations showed that many identified element X as being in Group 2 and even as magnesium. The correct formula of XCl_2 (B) then usually followed.

Question 7

7 A sample of lead(II) sulfate (M = 303.3 g mol^{-1}) is decomposed by heat, as shown in the equation below.

$2PbSO_4(s) \rightarrow 2PbSO_3(s) + O_2(g)$

The reaction forms 2.40 g of $O_2(g)$.

What is the mass of lead(II) sulfate that has been heated? Assume a 100% yield.

A 22.7 g

B 30.3 g

C 45.5 g

D 60.7 g

Your answer ☐ **[1]**

Candidates often appear to find quantitative questions such as this one easier than questions involving interpretation of textual information. Most candidates selected the correct response and most scripts contained working including molar proportions alongside the question. This is an excellent strategy.

Question 8

8 Which volume of 18.0 mol dm^{-3} hydrochloric acid should be diluted to 250.0 cm^3 to prepare a 0.450 mol dm^{-3} solution of hydrochloric acid?

A 4.50 cm^3

B 6.25 cm^3

C 10.0 cm^3

D 32.4 cm^3

Your answer ☐ **[1]**

Candidates found this calculation more difficult than Question 7. From the annotations, most showed working using the relationship between moles, concentration and volume. Options A (18 × 250/1000) and C (18 × 250/1000 ÷ 0.450) were the main distractors.

Question 9

9 What is the number of **ions** in 4.00 mol of magnesium chloride, $MgCl_2$?

A 1.81×10^{24}

B 2.41×10^{24}

C 4.82×10^{24}

D 7.22×10^{24}

Your answer ☐ **[1]**

Candidates found this question very difficult. B was the main distractor, obtained by multiplying the number of moles (4) by the Avogadro constant. Only the highest-attaining candidates realised that the question asked for the number of **ions** and multiplied the answer to B by 3 to obtain option D. The lesson here is to consider carefully any bold text in the question (**ions**).

Question 10

10 What is the correct explanation for the trend in the boiling points of chlorine, bromine, and iodine down the group?

A Bond enthalpy increases.

B Chemical reactivity decreases.

C Electronegativity decreases.

D London forces increase.

Your answer ☐ **[1]**

This question was direct recall of specification content and most candidates selected D as the correct answer.

Question 11

11 Combustion of hydrazine, N_2H_4, produces NO_2 and H_2O as in the equation below.

$N_2H_4(l) + 3O_2(g) \rightarrow 2NO_2(g) + 2H_2O(l)$

The table shows standard enthalpy changes of formation, $\Delta_f H^{\ominus}$.

Substance	$\Delta_f H^{\ominus}$ / kJ mol^{-1}
$N_2H_4(l)$	+50.6
$O_2(g)$	0
$NO_2(g)$	+33.2
$H_2O(l)$	–285.8

What is the enthalpy change of combustion, in kJ mol^{-1}, for hydrazine, $N_2H_4(l)$?

A –555.8

B –303.2

C +303.2

D +555.8

Your answer ☐ **[1]**

Candidates answered this question reasonably well with most choosing either the correct option A, or the incorrect D (the same numerical value but with the wrong sign). Energy cycles and Hess' law seemed to be well known with most candidates drawing their cycle by the question. Candidates should take care with the direction of the arrows as these travel in different directions for formation and combustion problems. The incorrect option D was the result of arrows in the wrong direction.

Question 12

12 Which prediction can be made using le Chatelier's principle?

A The effect of a catalyst on the reaction rate.

B The effect of a catalyst on the equilibrium position.

C The effect of temperature on the reaction rate.

D The effect of concentration on the equilibrium position.

Your answer ☐ **[1]**

Candidates produced a variety of responses with just over half choosing the correct option D. Option C was the main distractor.

Question 13

13 Four equilibrium reactions are set up.

The concentration of each gas in the equilibrium mixtures is 0.1 mol dm^{-3}.

Which equilibrium has a numerical K_c value of 0.01?

A $CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$

B $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

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

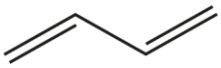
D $2NO_2(g) \rightleftharpoons N_2O_4(g)$

Your answer ☐ **[1]**

This question discriminated very well. Evidence from annotations showed that the successful candidates substituted the 0.1 mol dm^{-3} concentration into the K_c expression for each equilibrium and calculated K_c by calculator. This method should guarantee the correct answer.

Question 14

14 What is the number of σ-bonds in the molecule below?



A 1

B 3

C 7

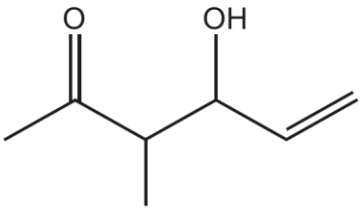
D 9

Your answer ☐ **[1]**

Candidates found this question difficult with very many choosing option B rather than the correct option D. Candidates are advised to draw out all bonds displayed when tackling such as question as the answer of B (3) results from considering just the three bonds shown in the skeletal formula and omitting the other 6 C–H bonds.

Question 15

15 What is the number of hydrogen atoms in **one** molecule of the compound below?



A 8

B 10

C 12

D 14

Your answer ☐ **[1]**

Most candidates selected the correct response. Where an error had been made, it was usually option B, the result of ignoring the two tertiary H atoms.

Question 16

16 Complete combustion of an alkane forms 30 cm^3 of carbon dioxide and 40 cm^3 of water vapour, under the same conditions of temperature and pressure.

Which alkane has undergone complete combustion?

A butane

B ethane

C heptane

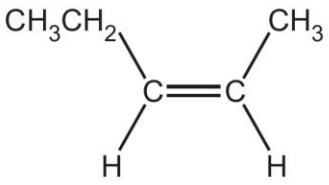
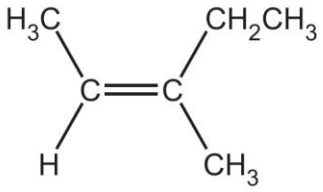
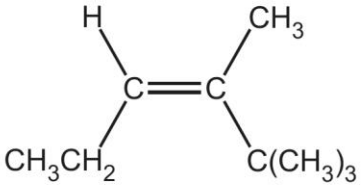
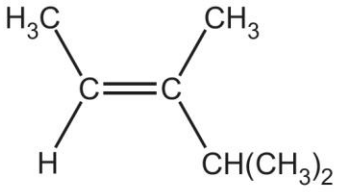
D propane

Your answer ☐ **[1]**

This question discriminated extremely well with most candidates choosing the correct option. Most candidates showed some working. The key to success was to identify the balanced equation that produced CO_2 and H_2O in a 3 : 4 molar ratio.

Question 17

17 Which alkene is an *E* stereoisomer?

A	
B	
C	
D	

Your answer [ ] **[1]**

This was a difficult question, requiring candidates to use CIP rules along carbon chains. Higher-attaining candidates rose to the challenge but a variety of responses were seen, suggesting that many candidates guessed.

Question 18

18 When heated with NaOH(aq), 1-chlorobutane is hydrolysed at a slower rate than 1-bromobutane.

Which statement explains the different rates?

A The C–Br bond enthalpy is greater than the C–Cl bond enthalpy.

B The C–Br bond enthalpy is less than the C–Cl bond enthalpy.

C The C–Br bond is less polar than the C–Cl bond.

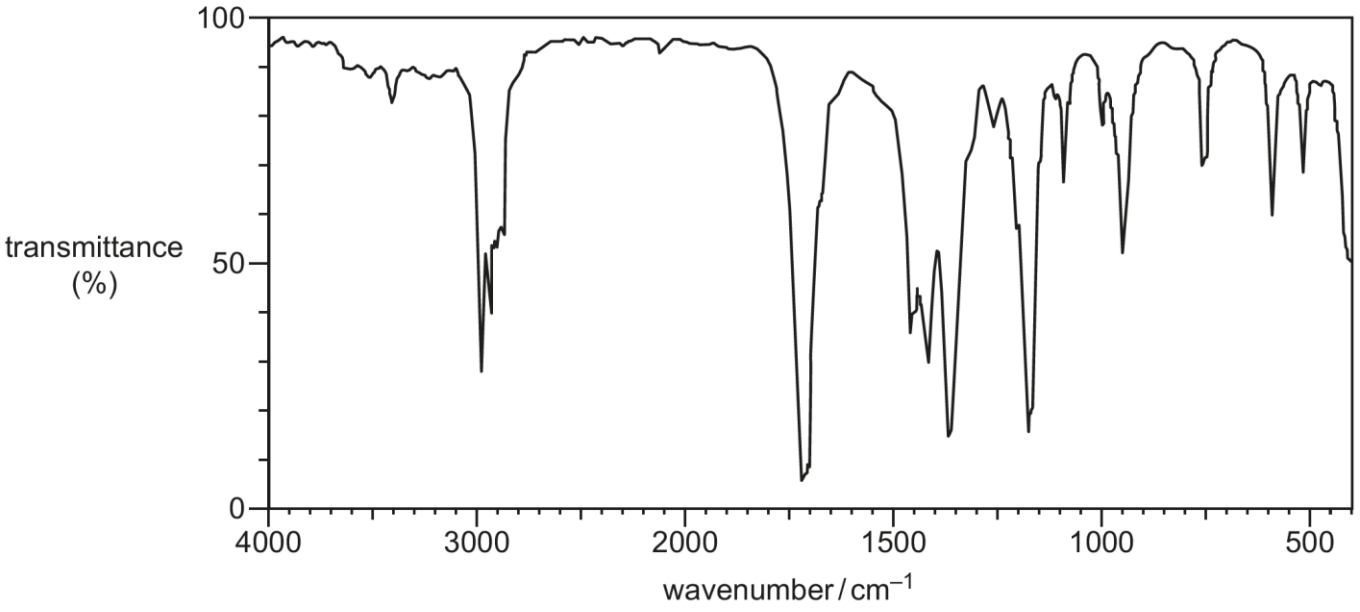
D The C–Br bond is more polar than the C–Cl bond.

Your answer ☐ **[1]**

Most candidates selected the correct option, B. The main distractors were A (confusing which C–X bond is stronger) and C (confusing which effect of bond strength and polarity is dominant for this reaction).

Question 19

19 Which organic compound could have produced the infrared spectrum below?



A $CH_3COCH_2CH_3$

B $CH_3CH_2CHOHCH_3$

C $CH_3COCH_2CH_2OH$

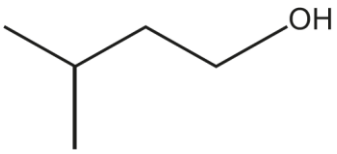
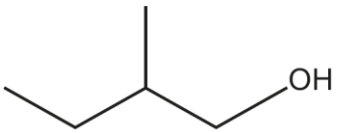
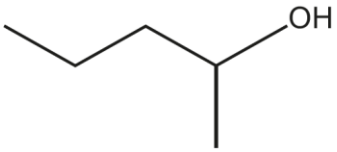
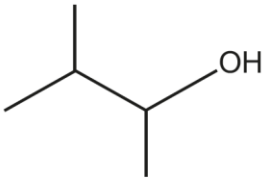
D CH_3CH_2COOH

Your answer [ ] **[1]**

Candidates found this question hard with many selecting C or D instead of the correct option, B. Candidates appeared to have assigned the C–H absorption at 3000 cm^{-1} to an O–H group (from an alcohol or carboxylic acid). Candidates should appreciate that this C–H absorption will be present in any organic compound possessing a C–H group (that is, nearly all organic compounds).

Question 20

20 Which alcohol is likely to have fragment ions at m/z = 15, 29 **and** 43 in its mass spectrum?

A	
B	
C	
D	

Your answer ☐ **[1]**

Compared to Question 19, candidates had more success with this question. Most drew out all the bonds in each structure, a good approach that should allow the candidate to identify the compound that would produce the three peaks.

Section B overview

Section B includes short answer question styles (structured questions, problem solving, calculations, practical) and extended response questions. This section of the paper is worth 50 marks.

Question 21 (a) (i)

21 The alkene, $(CH_3)_3CCH=CH_2$, is used to make some perfumes.

(a) (i) What is the systematic name for $(CH_3)_3CCH=CH_2$?

..... **[1]**

Candidates had difficulty in naming this compound correctly as 3,3-dimethylbut-1-ene. Many counted an incorrect number of carbons in the chain, numbered substituents from the wrong end (e.g. 1,1,1-) or used insufficient numbering (e.g. 3-dimethyl). Hex-1-ene was a common incorrect answer, presumably as there are six carbon atoms and one C=C double bond in the alkene.

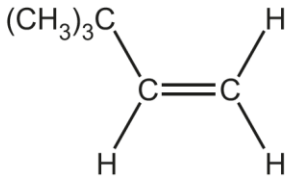
Question 21 (a) (ii)

(ii) $(CH_3)_3CCH=CH_2$ decolourises bromine.

Outline the reaction mechanism for the reaction of $(CH_3)_3CCH=CH_2$ and bromine.

The structure of $(CH_3)_3CCH=CH_2$ has been provided.

Include curly arrows and relevant dipoles, the structure of the product and the name of the mechanism.

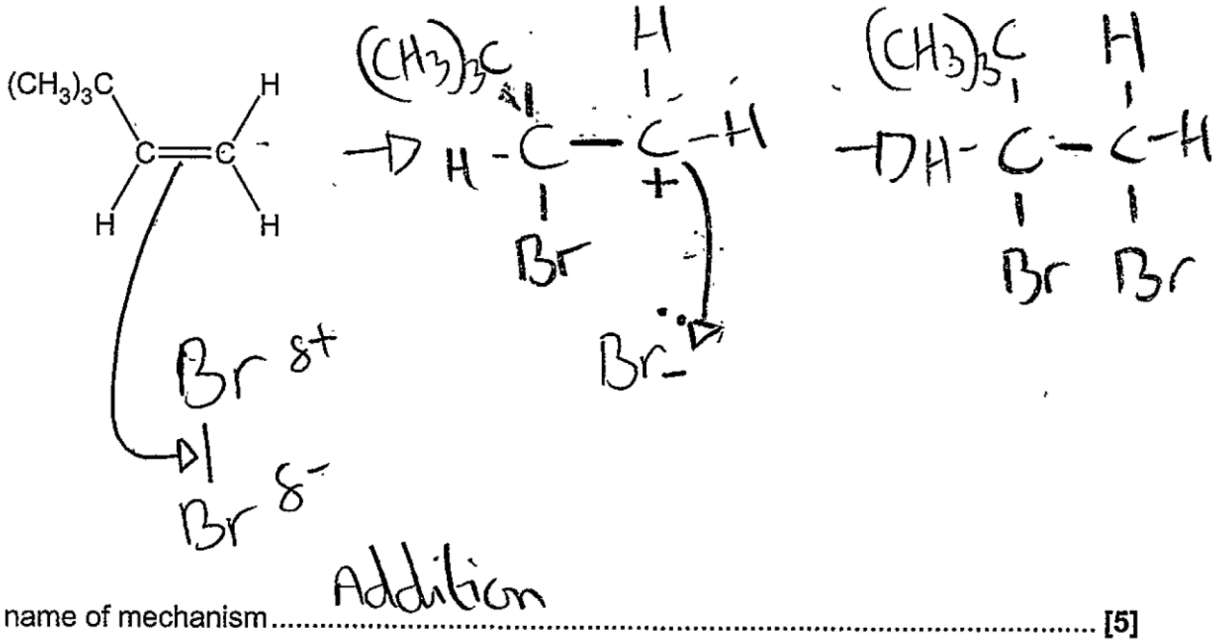


name of mechanism..... **[5]**

Many candidates answered the mechanism proficiently. However, many mistakes were seen with the direction of arrows, and confusing $\delta+$/ $\delta-$ and +/– charges. In the intermediate carbocation, the C=C was often left intact and $\delta-$ used on the bromide ion attacking the intermediate. Some less successful responses did not position curly arrows accurately.

One common error was showing one or more C atoms missing from the $(CH_3)C$ groups. Candidates should take great care when drawing organic structures to make sure that all groups have been drawn accurately.

Exemplar 1



name of mechanism ..... [5]

This exemplar has been included to emphasise the importance of accurately placed curly arrows and use of charges. It was only possible to award this response 1 out of 5 marks. With a few improvements, this response could easily have been 5/5.

The start of the first curly arrow has been placed accurately starting from the C=C double bond but the arrow should have finished at the $Br^{\delta+}$: 0 marks

The Br–Br dipole is correct but there is no curly arrow showing it breaking: 0 marks

The intermediate carbocation is correct but the curly arrow should have been shown from a lone pair on the Br^- ion to the + charge of the carbocation: 0 marks

The product is correct: 1 mark

The reaction type is addition but the name of the mechanism is electrophilic addition: 0 marks

Assessment for learning

Reactions mechanisms are the organic chemist's way of communicating electron transfers in organic chemistry. Candidates must use curly arrows, dipoles and charges appropriately and accurately. AS Chemistry includes three important reaction mechanisms: electrophilic addition, nucleophilic substitution and radical substitution. This paper includes two of these in Questions 21 (a) (i) and 26 (a). It is essential that candidates learn these three mechanism types.

Question 21 (b) (i)

(b) The alkene $(CH_3)_3CCH=CH_2$ can be polymerised to form a polymer.

(i) Draw **one** repeat unit for this polymer.

[1]

Most candidates drew out the correct repeat unit although some less successful responses showed the molecule instead of the polymer. Missing 'side' bonds were very few as were attempts to connect to the CH_3 group leaving the C=C intact. Where candidates made an error, it was often from missing out a C or a 3 from the side chain.

Question 21 (b) (ii)

(ii) State **one** advantage and **one** disadvantage of using combustion as a method for the disposal of a polymer after it has exceeded its useful life.

Advantage .....

.....

Disadvantage .....

.....

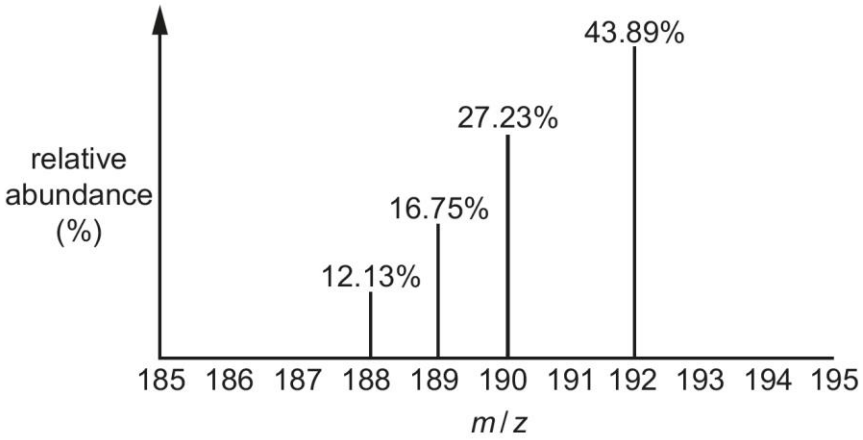
[1]

The responses to this question were highly variable. Many candidates correctly identified the disadvantage, usually in terms of CO_2 release and global warming, but an advantage was less frequently seen. When it was seen it was almost universally about releasing energy. General hazard comments such as 'harmless'; and 'dangerous' as too general and are never given marks at AS or A Level.

Question 22 (a)

22 This question is about atomic structure and formulae.

(a) The relative atomic mass of a sample of osmium can be determined from its mass spectrum, shown below.



Calculate the relative atomic mass of osmium in the sample.

Give your answer to **two** decimal places.

relative atomic mass = ... **[2]**

Candidates answered this question very successfully. Few candidates mis-wrote the numbers and even fewer gave answers to the incorrect number of decimal places. This type of question has featured on previous examinations and it was pleasing to see how well it was answered, even with more isotopes being included than in previous instances.

Question 22 (b)

(b) Complete the table for an atom and an ion of **two** different elements.

Element	Mass number	Protons	Neutrons	Electron configuration	Charge
.....	.....	28	34	.....	0
.....	33	.....	.....	$1s^2 2s^2 2p^6 3s^2 3p^6$	3–

[2]

This question produced many mixed responses. Most candidates correctly identified nickel. However, its electron configuration was frequently shown as $3d^{10}$ instead of $3d^8$ and some less successful responses gave nickel's relative atomic mass of 58.7 from the periodic table, instead of the mass number of the isotope provided.

Many candidates selected the incorrect element for phosphorus, with argon being a key distractor from the extra 3 electrons in the P^{3-} ion. The numbers of protons and neutrons were largely correct, although the wrong way round for many less successful responses.

Question 22 (c)

(c) Substance **A** is a hydrated salt with the following percentage composition by mass:

Zn, 21.99%; H, 4.04%; N, 9.41%; O, 64.56%.

- Determine the empirical formula of **A**.
- Write the formula of **A** showing the water of crystallisation.

empirical formula: .....

formula showing water of crystallisation: .....

[3]

Candidates processed the empirical formula data well to obtain the correct molar ratio of the elements, with many being able to convert this ratio into an empirical formula. This type of problem is common in chemistry and candidates were clearly well-versed in the method of its solution. The most common error was H:11 rather than H:12.

The third mark for water of crystallisation was far harder to obtain. Many candidates identified that $6H_2O$ was present, but the O was often missing in a formula shown as $ZnN_2 \cdot 6H_2O$, or 'included' with the water as $ZnN_2 \cdot 6H_2O_2$. Many candidates did not seem to know how to proceed here. The mark scheme allowed credit for both the preferred answer of $Zn(NO_3)_2 \cdot 6H_2O$ and for $ZnN_2O_6 \cdot 6H_2O$, as both had extracted the waters of crystallisation from the rest of the empirical formula.

A few candidates inverted the moles calculation, a strategy that could not be given marks.

Question 23 (a) (i)

23 This question is about different types of bonding.

(a) Ionic compounds have ionic bonding and exist in a giant ionic lattice structure.

(i) What is meant by **ionic bonding**?

.....

.....

..... **[1]**

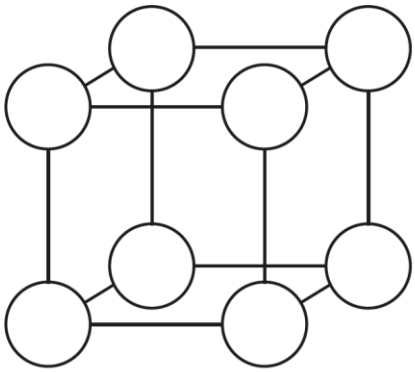
Candidates answered this question well. Where candidates had not been given marks, it was usually because they omitted the term 'ions' or did not state that an ionic bond is between metals and non-metals.

Question 23 (a) (ii)

(ii) Magnesium reacts with sulfur to form a compound which has a giant ionic lattice structure.

The diagram shows ions as circles in part of the lattice.

Complete the diagram by showing the symbols of the ions, including charges.



[2]

Most candidates correctly drew alternating Mg^{2+} and S^{2-} labels in the circles. Some candidates made errors, however, including 2+ and 2– without Mg and S, incorrect or omitted charges, and placing the ions in layers rather than alternating.

Question 23 (b)

(b) 'Oxyanions' are ions containing oxygen combined with atoms of other elements. Roman numerals are used to show the oxidation state of the element in the oxyanion.

Complete the table below for three oxyanions.
One row has been completed as an example.

Name of oxyanion	Ionic charge	Formula of oxyanion
.....	1–	BrO_2^-
Sulfate(VI)	2–	SO_4^{2-}
Phosphate(V)	3–	.....

[2]

Although this question included important clues within the table, these were usually ignored by candidates and this item did not score as well as expected. The bromate(III) was poorly identified, with many candidates missing the oxidation state of the bromine. Many candidates wrote bromide, bromate without (III), bromide (III), bromate (VI) and other oxidation numbers. The phosphate ion was more familiar with many candidates identifying its formula as PO_4^{3-}. A common error was the inclusion of the wrong number of oxygen atoms in the ion, such as PO_5 with various charges.

Question 23 (c)

(c) Describe the structure and bonding and electrical conductivity of calcium in the solid state. You may wish to include a labelled diagram in your answer.

.....

.....

.....

.....

.....

..... **[4]**

Many candidates answered this question well, with most identifying the model of metallic bonding as fixed positive ions and mobile delocalised electrons. The question did ask for bonding and structure and the **giant** feature of the structure was often omitted. Unfortunately, some candidates contradicted a correct metallic bonding statement by including descriptors of intermolecular forces, covalent bonding or attraction between electrons and the nucleus rather than with positive ions. Less successful responses demonstrated less understanding: some didn't realise that Ca is a metal and conductivity explanations were often given as ions moving in the molten and not in the solid state, clear confusion with ionic bonding. Full marks were only given for showing the correct charges on the Ca^{2+} cations (+ was insufficient) and for explaining conductivity in terms of electron movement, rather than the common 'the electrons carry charge' and 'the electrons are free'.

Overall, this relatively simple question discriminated very well and demonstrated how well the candidates understood metal bonding and structure.

Question 24 (a) (i)

24 This question is about halogens and practical tests.

(a) Chlorine gas reacts with dilute sodium hydroxide, NaOH(aq).

This is a disproportionation reaction. One of the products has the formula NaC*l*O.

(i) What is meant by the term **disproportionation**?

.....

..... **[1]**

Candidates answered this question well and most were given the mark. Where candidates didn't receive credit, it was mainly because they used the term 'same atom' instead of 'same element'. Some less successful responses responded with completely incorrect chemistry and had clearly not learnt this specification content.

Question 24 (a) (ii)

(ii) Construct the equation for the reaction of chlorine with dilute sodium hydroxide.

Use your equation to explain that disproportionation has taken place.

Equation .....

Explanation .....

.....

.....

.....

[3]

Candidates found the equation hard, despite this reaction being specification content and the inclusion in the earlier part of the stem of 'NaClO' as one product. The correct response required candidates to realise that NaCl would be a product and to balance the resulting equation. Some did not add the balancing '2' before NaOH, and many selected HCl as the second product, a compound that would react further with NaOH to produce NaCl.

The explanation worked the same whether NaCl or HCl had been identified as the second product. There were some excellent responses, providing the correct oxidation number changes, linking these to the species involved and identifying the changes as either oxidation or reduction. Two explanation marks were available with marks not being given for omission of one of the three features described above.

Exemplar 2

Equation $Cl_2 + NaOH \rightarrow NaClO + HCl$

Explanation The way I reason the disproportionation has taken place is because Cl has gone from 0 to +1 in NaClO and has gone from 0 to -1 in HCl (so it has been oxidised and reduced)

[3]

This exemplar has been included to emphasise the points made above. It was only possible to award this response 1/3 marks.

The equation shows the common error of the second chlorine-containing product being HCl and not NaCl: 0 marks

The candidate has identified the oxidation number changes and has linked these to the correct species. The last statement in brackets is correct but the candidate has not communicated which oxidation number change is oxidation and which is reduction: 1/2 marks

Question 24 (b)

(b) A student is supplied with aqueous solutions of ionic compounds **B** and **C**.

Compound **B** is a chloride, bromide or iodide of a Group 1 element.
Compound **C** is a chloride, bromide or iodide of a Group 2 element.

The molar masses of **B** and **C** are both in the range 100–115 g mol^{-1}.

Use this information and test-tube tests to show how the student could identify the halide present in **B** and **C** and the formulae of **B** and **C**.

Explain your reasoning.

In your answer, include observations, colours and equations.

.....

.....

.....

.....

.....

..... **[5]**

Candidates generally answered the first part of this question well. Most candidates were able to identify silver nitrate (or a halogen displacement method), to describe the expected observations, supported with mainly correct ionic equations. Candidates found it much harder to identify B and C as NaBr and $CaCl_2$. They could do this in various ways by matching possible formula with the provided molar mass ranges. The mark scheme did allow marks to be given when candidates described the identification process, although this was often very muddled, so, only the most able few candidates fully identified the unknown B and C.

Question 25 (a) (i)

25 This question is about enthalpy changes and reaction rates.

(a) Aqueous barium hydroxide, $Ba(OH)_2(aq)$, reacts with dilute nitric acid, $HNO_3(aq)$, as in **Equation 25.1**.

$Ba(OH)_2(aq) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + 2H_2O(l)$ **Equation 25.1**

A student carries out an experiment to determine the enthalpy change of this reaction, $\Delta_r H$.

The student measures out:

- $25.0\,cm^3$ of $2.00\,mol\,dm^{-3}$ $Ba(OH)_2(aq)$ and
- $50.0\,cm^3$ of $2.00\,mol\,dm^{-3}$ $HNO_3(aq)$.
  The temperature of each solution is the same.

The student mixes both solutions in a polystyrene cup, stirs the mixture and records the maximum temperature.

Temperature readings

Initial temperature	= 20.5 °C
Maximum temperature	= 39.0 °C

(i) Calculate $\Delta_r H$, in $kJ\,mol^{-1}$, for the reaction shown in **Equation 25.1**.

Give your answer to **3** significant figures.

Assume that the density and specific heat capacity, c, of the solutions are the same as for water.

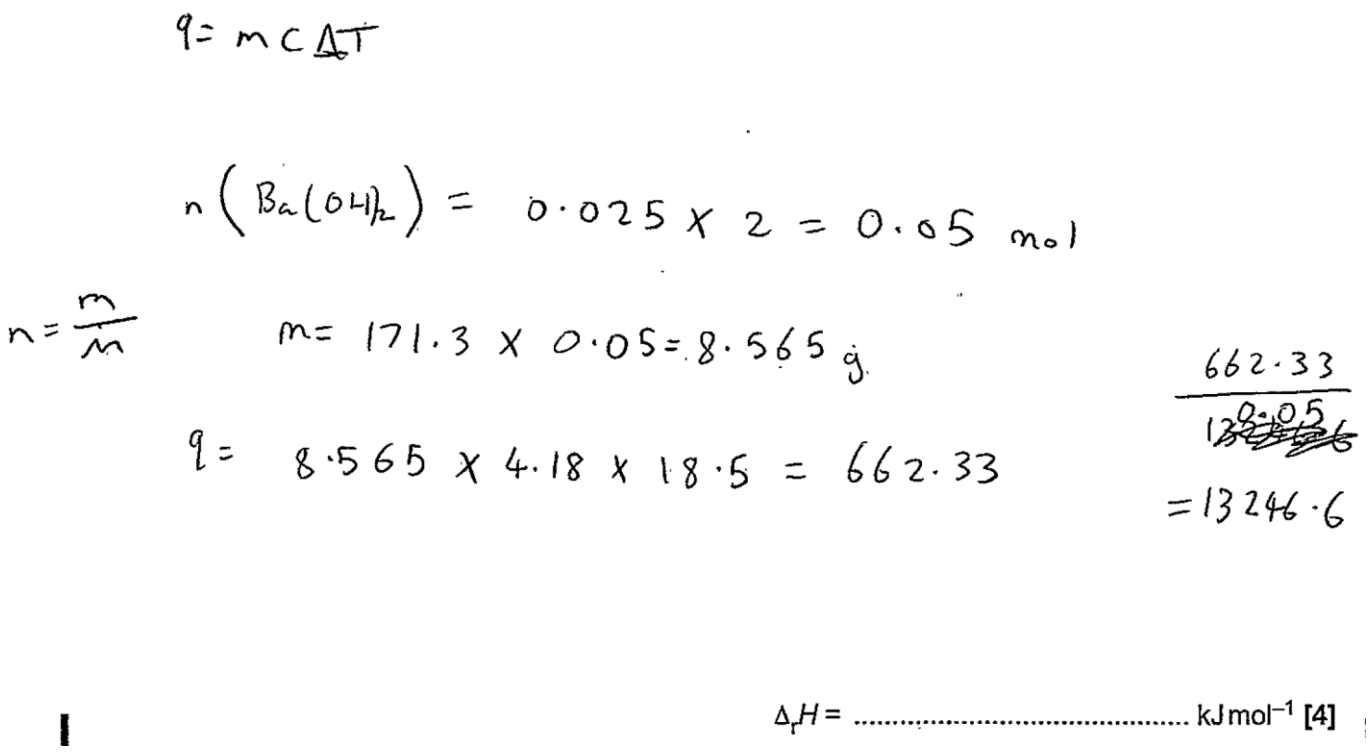
$\Delta_r H$ = ... $kJ\,mol^{-1}$ **[4]**

More successful candidates followed a well-rehearsed method for processing experimental enthalpy results to arrive at an enthalpy change. The result was usually the correct answer of –116 kJ mol^{-1}. Most candidates combined the 2 volumes (25 cm^3 and 50 cm^3) to give 75 cm^3 with m = 75 g and then calculated the correct energy change of 5799.75 J using $mc\Delta T$. Some candidates did not combine the volumes and used m = 25 g or 50 g instead. Most candidates worked out the amount in moles of $Ba(OH)_2$ and HNO_3.

Unfortunately, these calculations were often scattered across the page with no indication of what the calculated values applied to.

Some candidates incorrectly combined the moles (0.10 and 0.05) and divided this value (usually 0.15) into the energy change. The mark scheme accounted for these errors and allowed error carried forward marks to be allocated appropriately. Candidates are strongly advised to organise their calculation in a coherent way and to show what each calculated value applies to so that error carried forward can be applied for mistakes.

Exemplar 3



Exemplar 3 illustrates a common misconception of less successful responses when using of $mc\Delta T$: misunderstanding the meaning of m in the equation $q = mc\Delta T$, used for finding the energy change q from experimental results.

Misconception

In the equation $q = mc\Delta T$, mass m is the mass of the substance that changes temperature by ΔT. This substance has a specific heat capacity, c. Looking at the experimental results, the substance changing temperature is the mixture of the two solutions, which have volumes of 25 cm^3 and 50 cm^3. This is where the thermometer has been placed.

The information states that the density of the solutions is the same as for water, 1.00 g cm^{-3}. Therefore, the mass m that changes temperature ΔT is 75.0 g and the energy change is 75.0 × 4.18 × 18.5 J. This candidate has correctly calculated the moles of one of the reactants, $Ba(OH)_2$, as 0.0500 but has then calculated its mass as 75.0 × 4.18 × 18.5 J = 8.565 g and has used this in $mc\Delta T$.

So the key message is that m in $mc\Delta T$ is where the thermometer has been placed.

Question 25 (a) (ii)

(ii) The student looked back at **Equation 25.1** and noticed that the reaction was a neutralisation.
The student concluded that $\Delta_r H$ is the enthalpy change of neutralisation.

Explain why the student's conclusion is **incorrect** and determine the correct value for the enthalpy change of neutralisation.

.....

.....

.....

.....

enthalpy change of neutralisation = ... $kJ\,mol^{-1}$ **[2]**

Many candidates correctly identified that neutralisation is the formation of 1 mole of water, whereas this equation forms 2 moles of water. Significantly fewer were then able to use their answer to the calculation in Question 25 (a) (i) to determine a value for the neutralisation enthalpy as half of that that value.
This was a novel question, not used in previous examinations, and many candidates coped with the challenge admirably.

Question 25 (b)

(b) The Boltzmann distribution model can be used by chemists to explain how the rate of a reaction is affected by temperature.

Fig. 25.1 shows the Boltzmann distribution for a gas at room temperature.

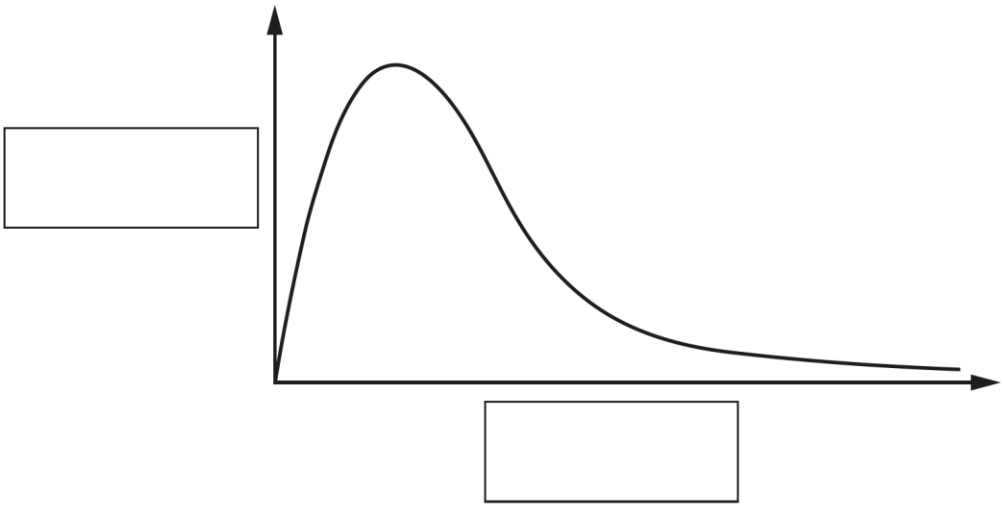


Fig. 25.1

Label the axes on **Fig. 25.1** and add a second curve to show the Boltzmann distribution of the gas at a higher temperature.

Explain why the Boltzmann distribution shows that the rate of a reaction is affected by temperature.

.....

.....

.....

..... **[3]**

Most candidates answered this question well. Most graphs were drawn with care but some peaks were shown at the same height as the provided curve or meeting this curve at high energy. Some candidates labelled what should have been 'energy' on the x axis as 'progress of reaction', or used 'atoms' rather than molecules for the y axis label. Many candidates were able to explain that more molecules exceed the activation energy at a higher temperature.

Question 26 (a)

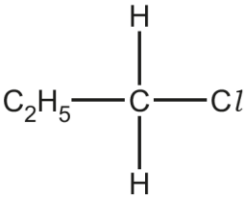
26 This question is about haloalkanes.

(a) 1-Chloropropane, $C_2H_5CH_2Cl$, can be hydrolysed with aqueous sodium hydroxide, NaOH.

Outline the mechanism for this reaction.

The structure of 1-chloropropane has been provided.

Show curly arrows, relevant dipoles and product(s).



[3]

Although a simpler mechanism than electrophilic addition in Question 21 (a) (ii), candidate responses here were less successful. Many candidates weren't able to identify the OH^- ion attacking the carbon atom and the curly arrow often did not originate from an O lone pair or the negative charge. Candidates often omitted the dipole on the C–Cl bond or did not include a curly arrow. Candidates were expected to show both the resulting alcohol and Cl^- as products. Many tried to incorporate Na into their organic structure.

Organic mechanisms are a key concept in organic chemistry and it is essential for candidates to learn all the mechanisms in preparation for examinations.

Assessment for learning

Reactions mechanisms are the organic chemist's way of communicating electron transfers in organic chemistry. It is essential that curly arrows, dipoles and charges are used appropriately and accurately. AS Chemistry includes three important reaction mechanisms: electrophilic addition, nucleophilic substitution and radical substitution. This paper includes two of these in Questions 21 (a) (i) and 26 (a). It is essential that candidates learn these three mechanism types.

Question 26 (b)

(b) A bromoalkane **D** is a liquid at room temperature and pressure but can easily be vaporised.

When vaporised, 0.330 g of **D** produces 74.0 cm^3 of gas at 1.01×10^5 Pa and 100 °C.

Determine the molar mass and molecular formula of bromoalkane **D**.

molar mass = ... $g\,mol^{-1}$

molecular formula = ...

[5]

In contrast with the mechanism in Question 26 (a), this ideal gas calculation was answered well by most candidates. Most had obviously learnt the method for successfully processing this type of calculation.

More candidates than in previous series were able to convert ºC into K and cm^3 into m^3 to obtain n = 0.00241 mol. Many candidates were then able to achieve the correct molar mass of 136.9 g mol^{-1} and molecular formula of C_4H_9Br.

Candidates with incorrect unit conversions could still collect method marks by error carried forwards. The most common error was to use $\times 10^{-3}$ instead of $\times 10^{-6}$ for the cm^3 conversion to m^3, unfortunately this error led to a molar mass of 0.1369 from which a molecular formula is impossible.

Notwithstanding the success of obtaining the correct answers, most calculations were unclearly presented, as in Question 25 (a) (i).

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