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FOREWORD

This booklet contains reports written by Examiners on the work of candidates in certain papers. **Its contents are primarily for the information of the subject teachers concerned**.

CHEMISTRY

GCE Advanced Level and GCE Advanced Subsidiary Level

Paper 9701/01

Multiple Choice

Question Number	Key	Question Number	Key
1	C	21	C
2	B	22	A
3	C	23	A
4	D	24	C
5	D	25	D
6	C	26	C
7	C	27	D
8	A	28	D
9	D	29	B
10	B	30	B
11	A	31	B
12	C	32	D
13	B	33	B
14	C	34	B
15	C	35	D
16	B	36	B
17	D	37	D
18	A	38	A
19	D	39	D
20	A	40	B

General comments

For this paper, the mean score was 22.9 (57.1%), a little below the targeted value, and the standard deviation of the scores was 7.07 (17.7%), indicating that the paper discriminated satisfactorily among candidates.

The first thirty questions were simple completion items: **Questions 31** to **40** were three-statement multiple completion items.

Comments on specific questions

Five questions had a high facility: **Question 3** on the pattern of ionization energies characteristic of a Group in the Periodic Table, **Question 4** on counting electrons and neutrons within an ion or atom, **Question 8** on the use of cryolite in aluminium production, **Question 9** an exercise in calculating oxidation numbers, and **Question 17** on the effect of acid rain. These clearly represent areas of the syllabus that are well understood.

Two questions required an interpretation of experimental results that were displayed diagrammatically – **Questions 32** and **34** – and both of these gave difficulty, presumably because candidates did not take all relevant factors into consideration. **Question 32** concerned the vapourisation of a solid within a closed vessel: 40% of candidates chose the distractor **B** rather than the key **D**, chosen by only 24%. The factor that was ignored here was that, within a closed vessel, pressure would increase with temperature. **Question 34** did not discriminate well between the various abilities of candidates, and there are signs that some candidates were guessing: one of the surprises here was that 39% of candidates concluded that removal of a product from a catalysed reaction that moves towards equilibrium would slow down its production.

In **Question 33** more candidates chose the distractor **C** (44%) rather than the key, **B** (23%): this was clearly a more taxing question about those enthalpy changes that can only be deduced by the use of Hess' Law. Here the surprise was that no less than 59% of candidates did not appreciate that the enthalpy change of combustion of glucose is obtained directly by calorimetric means.

Two questions failed to distinguish between the more able and less able candidates. In **Question 7** the enthalpy changes for two reactions were given: first that for the production of two moles of $ICl(s)$ from its elements, and then that for the production of $ICl_3(s)$ from $ICl(s)$. Some of the more able candidates gave a value corresponding to two moles of $ICl_3(s)$; a large proportion (42%) of candidates simply added the two enthalpy changes together, ignoring the factor of two in the number of moles of $ICl(s)$ in the two equations. These seem to be elementary matters in the handling of data. There were also unexpected results from **Question 39** in which the structure of a steroid containing both a cyclic ketone and secondary alcoholic groups was displayed. No less that 74% believed that a cyclic ketone would be ring-opened and oxidised by warm acidified potassium dichromate(VI) to generate a carboxylic acid, and 38% that it would react with Fehling's solution.

Two other questions, while performing satisfactorily, deserve comment. **Question 2** was about the production of nitrogen in car airbags, and like **Question 7** required the combination of two equations. 55% of candidates calculated the amount of nitrogen produced purely from the initial reaction, ignoring the further production from the reaction between Na and KNO_3 given in the second equation. **Question 13** indicated that a large proportion of candidates do not appreciate the way that a physical property such as electronegativity varies both across and up and down the Periodic Table.

> **Paper 9701/02**
>
> **Theory 1**

General comments

There were many candidates who made very good attempts to answer all of the questions, demonstrating sound knowledge and a good understanding of the chemistry examined in this paper. On the other hand, there is still a significant number of candidates whose knowledge, particularly of organic chemistry, is poor. Overall, however, the answers given showed a continuing improvement in the quality of candidates' performance with most candidates being able to demonstrate some positive achievement.

This paper contained a number of specific instructions such as "Give your answer to two decimal places." or "Draw displayed formulae for...". Such questions are intended to reflect how chemical information is presented by chemists to one another. Sadly, there were many instances of candidates failing to give their answers in the form required who were penalised as a result.

Comments on specific questions

Question 1

There were many good answers to this question which tested fundamental knowledge and understanding.

(a) Most candidates were able to explain clearly, in terms of proton number and nucleon number or equivalent phrases, the meaning of the term isotope.

(b) Almost all candidates gave correct answers to this question. Those candidates who made mistakes usually gave a wrong number of neutrons in the ^{59}Co atom.

(c)(i) Although it was clear that most candidates understood the meaning of the term relative atomic mass, there were many who could not express this clearly. Examiners expected candidates to compare the average mass of an atom of an element with $\frac{1}{12}$th the mass of one atom of ^{12}C. Many candidates omitted any reference to 'average mass'. Alternative answers which compared the mass of one mole of atoms of the element with 12 g of ^{12}C were accepted.

(ii) The majority of candidates were able to use the data in the question correctly and produce the following expression:

$$A_r = \frac{54 \times 5.84 + 56 \times 91.68 + 57 \times 2.17}{100}.$$

This gives A_r = 55.7 to three significant figures.

When the question was set, it was decided to omit any reference to the small amount, 0.31%, of the fourth isotope of iron. Candidates who used 99.69 instead of 100 as the denominator of the above expression, giving A_r = 55.9, gained full marks. However, candidates who failed to give their answer to three significant figures were penalised.
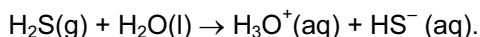
Question 2

There were many good answers to this question although a significant number of candidates struggled to explain themselves clearly in parts **(c)(iii)** and **(e)(i)**. Candidates are urged to use simple language when answering such questions.

(a) Many fully correct sequences of equations were seen by Examiners who accepted the following combinations:

S to SO_2, SO_2 to SO_3, and SO_3 to H_2SO_4

SO_2 to SO_3, SO_3 to $H_2S_2O_7$ and $H_2S_2O_7$ to H_2SO_4

A surprising number of candidates did not know that the conversion of SO_2 into SO_3 is the only reversible reaction in either sequence.

(b) This was generally well answered although not all candidates gave the correct oxidation state of vanadium in the vanadium(V) oxide catalyst.

(c)(i) The majority of candidates gave clear 'dot-and-cross' diagrams although a very small number gave an ionic structure despite the question referring to 'the H_2S molecule'.

(ii) While many candidates correctly described the shape of the H_2S molecule as 'bent' or 'non linear', a significant number incorrectly referred to it as 'pyramidal' or 'tetrahedral'. 'Tetrahedral' describes the arrangement of the bonding and non-bonding electrons around the S atom in H_2S but the shape of the molecule is determined only by the arrangement of the S and H atoms.

(iii) Candidates are expected to know that water molecules are held together by hydrogen bonds as well as by van der Waals' forces and that hydrogen bonds are stronger than van der Waals' forces. Examiners expected candidates to deduce that the forces between molecules in H_2S must be weaker than those between H_2O molecules because only van der Waals' forces are present. When discussing bonding of this type, candidates must avoid reference to the covalent bonding within molecules which is not broken when the compounds are melted or boiled.

(d)(i) The majority of candidates were able to give the correct equation.

(ii) While most candidates gave correct oxidation states, a surprising number gave +2 rather than –2 for the oxidation state of sulphur in H_2S.

(iii) There were many correct calculations of the volume of oxygen which was 9.13 dm^3 using 34.1 as the M_r of H_2S. Common mistakes were to:

- calculate incorrectly the number of moles of H_2S (0.254)
- fail to use the $2H_2S:3O_2$ ratio from the equation
- omit any reference to 24 dm^3 as the molar volume
- give the answer to two decimal places.

(e)(i) Most candidates stated clearly that a weak acid is only partially dissociated into ions. A small number stated that a solution of a weak acid has a low concentration of H^+ ions. Examiners did not accept this because it could refer to a very dilute solution of a strong acid.

(ii) Many candidates found this question difficult. A large number gave equations which contained the S^{2-} ion which Examiners did not accept because the question referred specifically to 'the *first* ionisation of H_2S'.

What was expected was an equation involving both H_2S and H_2O which produced HS^- ions. When state symbols are included this becomes the following:

$$H_2S(g) + H_2O(l) \rightarrow H_3O^+(aq) + HS^-(aq).$$

Question 3

This question was well answered by the majority of candidates.

(a) Most candidates were able to identify each of the compounds **A** to **F**. Some candidates struggled with formulae, notably $Mg(NO_3)_2$. A small number confused the oxidation number of Mg by giving, for example, $MgSO_4$ for **A** followed by $MgCl$ for **B**.

A few correctly identified a compound by name and then gave an incorrect formula. Such a contradictory answer received no credit.

The compounds to be identified were as follows:

A $MgSO_4$ **B** $MgCl_2$ **C** $MgCO_3$ **D** MgO **E** $Mg(OH)_2$ **F** $Mg(NO_3)_2$

(b)(i) There were many fully correct answers to this part. The most common error was in the third equation (for compound **F** to compound **D**) where the amount of oxygen was often unbalanced.

A small number of candidates added oxygen to both sides of the second equation (for compound **C** to compound **D**). The difference between heating a substance and causing its decomposition and burning a substance in air should be understood.

(ii) This was generally well answered.

Question 4

Parts **(a)** and **(b)** tested basic knowledge of the organic chemistry of the AS Syllabus in a slightly unusual manner. Many candidates struggled to state clearly the reagents and/or the conditions that would be used for each reaction. The knowledge required to answer a question such as this can only be acquired by a systematic process of learning the material.

(a)(i) Most candidates were able to state that chlorine in the presence of ultraviolet light would be required in stage I. It should be appreciated that if the mixture is heated further substitution of the $-CH_3$ group will occur.

Stage II involves the addition of a carbon atom which should automatically suggest to candidates that KCN is the reagent. The reaction is carried out by heating the reactants in ethanol. A number of candidates suggested HCN as the reagent. This will not work because the reaction involves the CN^- ion which is not present in HCN.

(ii) Fewer candidates answered this correctly, although in many cases they had previously given correct answers for stage I. The reaction is another free radical substitution of a hydrocarbon chain and requires bromine and ultraviolet light.

(b)   Many candidates appeared to understand that these two reactions are examples of hydrolysis but failed to pay sufficient attention to reagents used.

In stage IV a carboxylic acid is required and the reagent must be a dilute acid such as sulphuric acid. Examiners did not allow concentrated sulphuric acid as this behaves as a dehydrating agent and could behave in this manner here. Some candidates used NaOH(aq) in their hydrolysis. This will clearly work but will produce R–CHBrCO$_2$Na which is not the required product. When NaOH(aq) is used in such a hydrolysis, it must be followed by reacting the salt produced with dilute acid to form the free organic acid.

Stage V involved the hydrolysis of a halogenoalkane to form an alcohol. Here heating with NaOH(aq) is ideal. Some candidates stated that ethanol must be present and were penalised because this will produce an alkene via an elimination reaction.

(c)(i)   Most candidates understood the concept of chirality. The most common error was to describe the chiral centre as being surrounded by four different molecules. Examiners expected candidates to describe a chiral centre as being attached to four different atoms or groups of atoms.

(ii)   Fewer candidates were able to draw displayed formulae of a pair of isomers.

Many candidates, who drew a correct structural formula were penalised because in their formula the –CN or –CO$_2$H groups were not fully displayed.

Examiners expected candidates to draw two structures which clearly showed their three dimensional nature and in the mirror object/mirror image convention as shown below:

Full details of how Examiners expect candidates to draw structures of organic compounds are given in Syllabus Section 10.1.

Question 5

Part **(a)** was generally well answered, parts **(b)** and **(c)** were less well done and many candidates struggled with parts **(d)** and **(e)**. A significant number of candidates were penalised because their answers were considered by Examiners to be ambiguous.

(a)   Most candidates were able to calculate the empirical formula of **H** to be C$_4$H$_8$O. Fewer scored the second mark available for using M_r = 72 and showing the molecular formula to be the same as the empirical formula.

(b)(i)   Many candidates clearly appreciated that **H** was unsaturated because it contains a C=C bond. Those candidates who simply stated that '**H** contains a double bond' were not given any credit because this could refer to a C=O bond.

(ii)   Examiners expected candidates to state that **H** contained a carboxylic acid or alcohol group and many candidates did this.

(c)(i)   Many candidates stated correctly that **H** contained a carbonyl group.

(ii)   Few candidates fully understood that the group present in **H** that gave the results to tests 5 and 6 quoted in the question paper could only be a primary alcohol. Secondary alcohols would have given a positive result in test 6 while tertiary alcohols would have given a negative result in test 5.

Examiners regard it as important that candidates do not merely use the term 'hydroxy compound' when referring to alcohols because compounds other than alcohols contain this group.

(d)   Most candidates struggled to explain how *cis-trans* isomerism arises in an organic molecule. While there was a significant number who appreciated that restricted rotation around the C=C bond was important, there were others who referred to a 'lack of rotation of the molecule'. Examiners did not accept this answer which they regarded as ambiguous.

When it came to explaining the arrangement of atoms and groups around the C=C bond in *cis-trans* isomers, most candidates struggled to express themselves clearly. Examiners were looking for a statement such as 'on each side of the C=C bond there are two different atoms or groups'.

(e)   Few candidates deduced the correct structural formula of **H** which was as follows:
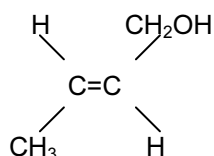
Few candidates were able to identify the *cis* and *trans* isomers correctly. The one drawn above is *trans* with the two hydrogen atoms diagonally opposite one another.

> **Paper 9701/03**
>
> **Practical Test**

General comments

Upon receipt of a packet of scripts, Examiners used the information supplied in the Report on the Examination, the seating plans and the Supervisor's Results to sort candidates into appropriate groups for the award of accuracy marks. Accuracy marks were awarded from a comparison of the candidate and Supervisor titres.

The Examiners again thank those Centres where all of the information above was provided and they were able to place each candidate in the correct session and laboratory within that session.

Centres who did not provide all of this information are again reminded of the wording in the Confidential Instructions.

Large volumes of solutions should not be bulked (thirty candidates maximum for any one solution).

Separate Supervisor results should be provided for *each Session and for each laboratory within that Session.*

Seating plans should be provided. (It is often possible to spot and resolve solution/titre problems for a small group of candidates in one part of a laboratory where the seating plan has been provided.)

Where inadequate information was supplied there was the risk that candidates were disadvantaged.

The Examiners noted that many candidates were proficient in the performance of titrations but were disappointed by many others who appeared to have little knowledge of the precision required in an AS and A Level titration.

The general recording of observations for the Cr^{3+} ion was disappointing. The Notes on Qualitative analysis only appeared to have been consulted at the "Evidence for ions" stage and not during the recording of actual observations. The *grey-green* colour of the precipitates with $NaOH(aq)$ and $NH_3(aq)$ were seldom recorded.

Comments on specific questions

Question 1

Titration

The Examiners checked the subtraction for all titres and the selection, by the candidate, of an appropriate "average" to use in the calculation.

Candidates are reminded of the guidance given in the syllabus:

- burettes should be read to the nearest ½ graduation – i.e. to the nearest 0.05 cm^3

- two titres within 0.10 cm^3 are sufficient.

7 accuracy marks were awarded for a titre value that was within 0.10 cm^3 of the value obtained by the Examiner, from the Supervisor's results. Accuracy marks decreased on a sliding scale, 4 marks being awarded for a difference of 0.20+ to 0.30 cm^3 and 1 mark for a difference of 0.60+ to 0.80 cm^3.

A deduction was made from the accuracy total for each of the following errors in recording the titration information. (There was a maximum deduction of 2 marks):

- final burette readings in Table 1.1 not recorded to 2 decimal places *or* "impossible" burette readings (e.g. 23.47 cm^3) recorded at any point in the table *or* initial and final burette readings transposed *or* 50 used as initial burette reading *or* final burette reading > 50.0 cm^3

- no two titres, as recorded by the candidate, within 0.1 cm^3

- an incorrect "average" calculated *or* no selection of at least two titres for the calculation of the "average" *(The candidate was allowed to tick the chosen titres or to show a calculation using two or more titres) or a* n error in subtraction in *any* accurate titration *or* the titre labelled rough if it was ticked and used in calculating the average.

Large numbers of candidates recorded at least one final burette reading to only 1 decimal place and/or failed to indicate the titres used in determining the "average".

It is recommended that candidates should be encouraged to record *all* burette readings to the nearest 0.05 cm^3.

A small number of candidates made a very poor selection of titres to be used in determining the "average" value. Any titres within a 0.20 cm^3 range were selected without penalty but as the range of titres selected increased so did the Spread Penalty applied.

Where there had been an error in subtraction in the titration table the Examiner selected the appropriate "average" on which accuracy marks were awarded.

Calculations

(b)   Most candidates divided 2.37 by 158 and multiplied by titre/1000 to gain both marks.

(c)   Most candidates correctly multiplied their answer to **(b)** by 2.5. A few multiplied by 0.4, the inverted mole ratio.

(d)   The majority of candidates multiplied their answer to **(c)** by 90 to gain the first mark. A significant but smaller number also multiplied by 1000/25 to gain the second mark.

Candidates who gained both of these marks were able to gain a third mark if the answer had been evaluated to within 1% of the answer calculated by the Examiner for the candidate's titre (titre x 0.135).

Candidates who rounded answers in **(b)**, **(c)** and **(d)** tended to obtain an answer outside the 1% deviation allowed.

(e) A large number of candidates correctly subtracted the answer to **(d)** from 5.00, but many others left this section blank. Where an error in earlier sections of the calculation resulted in an answer to **(d)** that was greater than 5.00, most subtracted 5.00 from their answer to **(d)** in this section but some did have the confidence to perform the correct calculation and end with a negative value!

(d) Very few candidates were able to complete this section. The majority who made an attempt at it calculated moles of water by dividing the answer to **(e)** by 18. Where candidates did calculate a value for **x**H_2O, a considerable number of methods were employed in the calculation.

Question 2

Observation and deduction

The solution provided contained chromium(III) chloride and barium nitrate. Observations for Cr^{3+} ions were generally poor – very few *grey-green* precipitates (see the qualitative analysis notes printed on the question paper) were recorded and the description of solubility/insolubility in excess was often missing or incorrect. Chromium was often recorded as an ion present and the evidence copied from the notes on page 6. Unfortunately it often did not match the observations recorded in the tests! Few retrospective observation marks were awarded for *completion* of observations in the evidence given.

(a) Most candidates observed the white precipitate after settling. Any initial reference to a green precipitate was ignored.

Very few candidates recorded any precipitate that was soluble in excess sodium hydroxide to give a *dark green* solution (the mark scoring observation).

The Examiners suspect that the test was not performed as instructed and that insufficient sodium hydroxide was added to see all of the changes. Where an answer stated "the white precipitate was not soluble in excess" the impression was that sodium hydroxide had been added to the precipitate formed in the first part of test **(a)**.

(b) Most candidates correctly described a positive *test* for ammonia. It was not sufficient to state that red litmus turned blue – it had to be clear that a gas had been tested.

This was an observation mark obtained retrospectively by some candidates where ammonia gas was referred to in the Evidence after red litmus turned blue in the observations.

(c) This was the test where candidates should have observed a grey-green precipitate insoluble in excess aqueous ammonia. Many green or dirty green precipitates were seen.

After the addition of potassium chromate(VI) to the filtrate most candidates recorded a yellow precipitate.

(d) Most candidates obtained the white precipitate with silver nitrate but failed to see the solubility of this precipitate in aqueous ammonia.

Identification of and Evidence for the ions present

Most candidates were able to identify and supply appropriate evidence for chloride, nitrate and barium (or lead(II)) ions. Many candidates in identifying nitrate ions eliminated nitrite as there was no NO/NO_2 with acid.

Comparatively few candidates gained the mark for chromium(III) as the evidence given did not match the observations that had been given.

> **Paper 9701/04**
>
> **Structured Questions**

General comments

The paper seemed of about the right length, and few candidates ran out of time. There were some excellent scripts seen by Examiners, and quite a number of candidates achieved scores in the 50s. At the other end of the spectrum, Examiners were disappointed at the significant number of candidates with scores of less than 10 out of 60. It was clear that many of these had not prepared for the paper sufficiently well. Candidates' performances on the Organic questions are still quite variable, with some showing a very patchy knowledge indeed. Questions based of practical techniques (such as **Questions 1 (a)** and **4 (b)**) often demonstrated a lack of practical experience on the part of the candidates. **Question 1** was designed to be a relatively easy "starter", and many candidates scored highly on it. **Question 3** was the other high-scorer. The other questions proved to be of roughly the same level of difficulty – all candidates were able to score some marks on all questions, but there were also some hard-to-obtain marks that differentiated between the able and the not-so-able.

Calculations were generally quite well carried out, with most candidates paying attention to the number of significant figures.

Comments on specific questions

Question 1

(a) This question clearly differentiated between those candidates who had had some experience of electrolysis in the laboratory, and those who had not.

    (i) There were several candidates who suggested that the missing items of equipment were to include salt bridges, internal diaphragms, voltmeters and extra batteries. Many scored full marks, however, for correctly suggesting that an ammeter (or galvanometer) and a stopclock were needed. Several also appreciated that a rheostat for controlling the current through the cell would be useful. Examiners ignored the additional upturned burette over the right hand electrode suggested by some candidates, but other incorrect apparatus was penalised.

    (ii) Marks were awarded for the hydrogen electrode being connected to the correct (negative) terminal, and for the ammeter connected in series in a complete circuit.

    (iii) The three essential measurements were the volume of the gas produced, the time over which it was produced, and the current passing during that time. Those candidates not familiar with the experiment incorrectly suggested variously the quantity of electricity, the coulombs, the voltage or the concentration of the solution.

(b)(i) Most candidates correctly stated F = Le, but weaker ones managed to mix up the order: L = Fe being a common error.

    (iii) Working needed to be shown for this mark, and the answer needed to be quoted to at least 2 significant figures.

Answer: **(b)(ii)** 6.02×10^{23}.

Question 2

(a) Perhaps allowing only one line for the answer to this question showed some optimism as to candidates' abilities to write concisely, although the mark could be obtained for the following: the order is the value of ^{a} in the equation: *rate = k[A]^a*. There were three essentials for the mark: the *power (or index)* to which the *concentration* of a reactant is raised *in the rate equation*. Many candidates failed to score due to the omission of one or more of these essential concepts.

(b)   Since all three parts of this question were connected, a policy of "error carried forward" was adopted for the allocation of marks.

(i)(ii)   The correct deduction was that the orders with respect to propanone, H^+ ions and CN^- are one, zero and one, respectively. The rate equation is thus: rate = k[propanone][CN^-]. Whilst many candidates made correct deductions here, there was a significant number who reckoned that the order with respect to H^+ ions was also one, or that the orders with respect to H^+ and CN^- were both zero.

(iii)   The answer to this part also depended on the deductions made in part **(i)**. If the correct rate equation was given (as above), full marks could have been obtained for suggesting that mechanism B was consistent, with its first step being rate determining, because since the order with respect to H^+ is zero, it cannot be involved either in the rate determining step or before it. If the orders in part **(i)** had been deduced as 1, 1, 0 respectively, mechanism A, with the first step being the slower, would have been the correct answer for part **(iii)**, and credit would have been given for it. If the orders in part **(i)** had been deduced as 1, 1, 1 respectively, *either* mechanism A *or* mechanism B would have fitted, and as long as it was clear that the *second* step was identified as the slow one, a mark could have been gained. For any other combinations of orders in part **(i)**, it was not possible to award any marks in part **(iii)**, since neither mechanism would fit.

Question 3

(a)(i)   The answers expected here were simply the general reasons why reactions are heated: that heat is needed because the reaction is endothermic (as deduced from the ΔH value given), and also to overcome the activation energy. Many candidates answered in terms of the trend in the temperatures of decomposition of Group II carbonates, virtually repeating what they wrote in answer to part **(ii)**.

(ii)   The three marks here were for stating that $MgCO_3$ would require a *lower* temperature, due to Mg^{2+} being a *smaller ion* that Ca^{2+}, and thus causing *more* polarisation of the bonds in the carbonate ion. Marks were sometimes lost by referring to the atoms rather than to the ions, and by stating the Mg^{2+} was the stronger polariser, but not saying what it polarised.

(b)   A surprisingly large number of candidates got this simple calculation wrong. All the possible ways of adding and subtracting the two ΔH values given were seen in answers, with +260 being very popular, followed by +96.

(c)   A mark was awarded for the correct M_r of dolomite (184.4). Many candidates scored this one. The second mark was often lost because candidates forgot that *two* moles of CO_2 are lost when one mole of dolomite decomposes. A small minority of candidates did not appreciate that this reaction was an example of the decomposition of a mixed carbonate, and formed oxygen, or magnesium metal, or magnesium peroxide, as products!

Answers: **(b)** –96 kJ mol^{-1}; **(c)** 47.7%.

Question 4

(a)   This part was very well answered, with most candidates scoring full marks. In **(i)** the contraction of the filled inner orbital arrangement to [Ar] was allowed, and the 3d and 4s orbitals could be written in either order.

(b)   This part was much less well answered. For part **(i)**, of the possible half equations involving MnO_4^- given in the Data Booklet, only that for the reduction to Mn^{2+} was accepted. The value of the Mn(VII) to Mn(VI) E^o is too small, and the Mn(VII) to Mn(IV) reduction does not occur in acidic solutions. Many candidates also seemed to make an arbitrary choice of which half equation involving Fe^{2+} to use. Some used MnO_4^- to *reduce* Fe^{2+} to Fe, and some used it to oxidise Fe to Fe^{2+}. In **(ii)** there was a mark for stating that $KMnO_4$ is purple in colour, and another for stating that the end point is the first permanent pink colour. As the purple $KMnO_4$ is added from the burette to the acidified Fe^{2+} solution in the conical flask, it decolourises. Only when all the Fe^{2+} has been oxidised, and there is one drop of $KMnO_4$ in excess, does the colour remain (very pale purple appearing as pink). It was clear that many candidates had not carried out this titration, or if they had, they had forgotten what the end point looked like. The most common erroneous answer was that the end point was from purple to colourless.

(c) Although many candidates scored well here, some answers were less than clear. The definition of a ligand needed to refer to a *lone pair* of electrons forming a *dative bond* (to a metal ion), whilst that of a complex ion was simply an ion surrounded by (or bonded to) ligands.

(d) Whilst most candidates knew that haemoglobin's role in the body is to transport oxygen in the blood from the lungs to the tissues, fewer could explain why carbon monoxide was poisonous. This is due to CO forming a stronger dative bond to the Fe^{2+} ion in haemoglobin than O_2. Thus a more stable complex is formed. This uses up the haemoglobin molecules, causing too few to be available for the transport of oxygen. Various incorrect alternatives were seen: CO reacting with oxygen to give CO_2, which is poisonous; CO dissolving in the blood to produce carbonate ions, which altered the pH.

(e) There is only one reagent that would readily distinguish methanol from ethanol, and that is aqueous alkaline iodine. Many candidates scored a mark here, but failed to score the second, by stating that it was the methanol, rather than the ethanol, that gave the pale yellow precipitate (of iodoform).

Answer: **(b)(i)** 0.75 V.

Question 5

(a) Many candidates scored a mark here. The most common incorrect answers were $K_a = [H^+]^2/[RCO_2H]$ *or* $K_a = [R^+][CO_2H^-]/[RCO_2H]$.

(b)(i) Merely stating that the K_a values increased with the addition of chlorine atoms was insufficient for the first mark here. The candidate had clearly to indicate that the *acid strength* was increasing. The other two marks were for stating that the increase in acid strength was due to the electron-withdrawing inductive effect of the C*l* atoms *either* weakening the O-H bond, *or* stabilising the anion, *or* spreading out the (−) charge more.

(ii)(iii) The conversion of $[H^+]$ into pH still causes difficulties for some candidates. Another common reason for not scoring the marks here was that some candidates confused the K_a values of the two chloro-substituted acids given in the table.

(c)(i) By analogy with the standard reaction of phenol with bromine water, it was expected that candidates would choose *chlorine water* (without A*l*C*l*$_3$ or other Lewis acids) for the reagent here. Few did.

(ii) Reaction I is an *electrophilic substitution* reaction, whilst reaction II is a *nucleophilic substitution* reaction (of the phenoxide ion on chloroethanoic acid). Most candidates scored the first mark, but few the second. The most common answer was *esterification* (although *etherification* could have been accepted, had it been seen).

(iii) There were many acceptable answers here. Positive tests for phenols, not shown by alcohols such as compound A, include aqueous (neutral) FeC*l*$_3$ (phenols give a violet/purple colour), aqueous bromine (phenol decolourise, forming a white precipitate), aqueous NaOH (phenols dissolve), universal indicator solution (phenols turn it yellow or orange), diazonium ions in alkaline solution (phenols give coloured dyes). Positive tests for alcohols such as compound A, not shown by phenols, include PC*l*$_5$ (ROH give steamy fumes), heating with CH_3CO_2H + conc sulphuric acid (ROH give fruity ester smells), warming with acidified $KMnO_4$ *or* $K_2Cr_2O_7$ (ROH cause a change of colour from purple to colourless, *or* from orange to green). Most candidates knew of a reagent that would allow then to distinguish between the two, but sometimes lost marks through incomplete descriptions of the reagents and conditions or of the observations. Two reagents that were not acceptable were sodium metal (which would react with both) and sodium carbonate (which would react with neither).

Answers: **(b)(ii)** 1.93, **(iii)** 1.26.

Question 6

(a)(i)   Most candidates scored the mark here, for *electrophilic substitution* or *nitration*.

(ii)   Most candidates scored a mark for the reagents, $HNO_3 + H_2SO_4$ (although some candidate thought the formula of nitric acid was HNO_2). The conditions are quite specific: both acids are concentrated, and the temperature should be kept between 50 and 60^oC.

(iii)   Many candidates knew that the electrophile is NO_2^+, but many lost a mark for the Wheland intermediate *either* because they included "+" charges on the H and/or the NO_2 as well as the ring, or their charge on the ring was more closely associated with the sp^3 carbon atom rather than the delocalised "horseshoe" of π electrons. The last box should have contained H^+.

(b)   Most candidates correctly identified reaction II as a *reduction* (no other term was accepted), but fewer stated the correct reagent: Sn + HC*l* is the preferred one, although Zn and Fe were accepted. H_2 + Ni or Pt was also accepted, but not LiA*l*H_4 – this tends not to reduce nitro compounds to amines, but produces azo, hydrazo and hydroxylamino compounds. Some candidates described the reaction as a nucleophilic substitution, with NH_3 as the nucleophile.

(c)   Most candidates correctly identified the reagent for reaction III as PC*l*$_5$ *or* SOC*l*$_2$. The most common incorrect reagents seen were A*l*C*l*$_3$ or HC*l*.

(d)(i)   The other functional group is an *amide* (*not* a peptide, as this is a special sort of amide group formed between two amino acids). Although many scored this mark, other candidates did not recognise the amide group, and stated *carbonyl, ketone, amine* or *methyl* as the other group.

(ii)   The reagents and conditions needed to hydrolyse amides are *either* aqueous sodium hydroxide under reflux *or* aqueous hydrochloric or sulphuric acids under reflux. A general proteolytic enzyme such as an amidase or a protease was accepted (in aqueous solution at no more than "warm" heat), but specific ones such as trypsin or pepsin were not. Their specificity would preclude their reacting with antifebrin.

> **Paper 9701/05**
>
> **Practical Test**

General comments

Upon receipt of a packet of scripts, Examiners used the information supplied in the Report on the Examination, the seating plans and the Supervisor's Results to sort candidates into appropriate groups for the award of accuracy marks. Accuracy marks were awarded in **Questions 1** and **2** from a comparison of the candidate and Supervisor results.

The Examiners again thank those Centres where all of the information above was provided and they were able to place each candidate in the correct session and laboratory within that session.

Centres who did not provide all of this information are again reminded of the wording in the Confidential Instructions:

> Large volumes of solutions should not be bulked (thirty candidates maximum for any one solution).
>
> Separate Supervisor results should be provided for *each Session and for each laboratory within that Session.*
>
> *Seating plans* should be provided. (It is often possible to spot and resolve solution problems for a small group of candidates in one part of a laboratory where the seating plan has been provided.)

Where inadequate information was supplied there was the risk that candidates were disadvantaged.

The practical work in **Question 1** was generally well performed resulting in good accuracy marks. Most candidates were able to complete the calculation.

Question 2 also produced good accuracy marks but many candidates did not appreciate what was required in the third (Δt) column of the table. The quality of graph work was generally disappointing. The calculation, using data obtained from the graph, was performed less well than the calculation in **Question 1**.

Question 3 was the most difficult for the candidates, some making no attempt at any part of the question. Most candidates attempted all or most sections of the question and answers suggested that they were in unfamiliar planning territory.

Comments on specific questions

Question 1

Nearly all candidates recorded weighings to 2 (or more) decimal places.

No penalty was applied for weighing the *flask + acid* and the *flask + solution after the reaction* to less than 2 decimal places as it was appreciated that some Centres did not have balances capable of reading higher masses with this precision.

Most candidates correctly calculated, in **(b)**, the mass of **FB 2** used but many were unable to correctly calculate in **(c)**, the mass of carbon dioxide evolved.

The most common answer to **(c)** was the straight difference between the masses in Table 1.2.

The Examiners corrected any error in **(b)** and **(c)**, then calculated the ratio $\dfrac{\text{mass of FB 2}}{\text{mass of carbon dioxide}}$ and compared this ratio with that obtained from the Supervisor's results. The theoretical ratio for the experiment was 2.41 but as some of the carbon dioxide dissolved in the acid ratios of 2.65 to 2.75 were more common. 3 accuracy marks were awarded for a difference within 0.10 reducing to 1 accuracy mark for a difference of 0.20+ to 0.50.

The calculations in **(d)** to **(f)** were generally well done – a few candidates losing the mark in **(f)** for including a unit (other than amu) in their final answer to either **(e)** or **(f)**.

Question 2

Candidates were asked to record the range and graduation of the thermometer used in this experiment. Most were able to do this but it was disappointing to see the number of candidates who were not familiar with the scales of a thermometer e.g. $-5^{\circ}C$ to $50^{\circ}C$ with graduations recorded at each $5^{\circ}C$.

Most candidates recorded all of their temperature readings to 1 decimal place. It is expected that all thermometers are read to the nearest half of a scale division, a thermometer graduated at $1^{\circ}C$ should therefore be read to the nearest $0.5^{\circ}C$.

It was noted that some candidates recorded 0 as the decimal place for all 17 thermometer readings. The Examiners consider this to be highly unlikely but no penalty was applied on this occasion.

A small number of candidates claimed to be able to read a thermometer graduated at $1^{\circ}C$ to 2 decimal places.

Candidates should be encouraged to consider the precision of equipment used and the realistic values that can be recorded, working from the general guideline that graduated equipment can be read to ½ of the smallest scale division.

Where solutions had been correctly prepared the Examiners expected to see a maximum temperature after the addition of 30-33 cm^3 of **FB 4**. 2 accuracy marks were awarded if the candidate and Supervisor recorded highest temperatures after addition of the same volume of acid. 1 accuracy mark was awarded if the volume of acid giving the maximum temperature was ±3 cm^3 when compared with the Supervisor.

A further 3 accuracy marks were awarded by comparing the maximum temperature rise achieved by the candidate and the Supervisor. 3 marks were awarded for a difference up to 0.5°C, 2 marks for a difference up to 1°C and 1 mark for a difference up to 1.5°C.

A small number of candidates recorded the maximum temperature after adding 15-18 cm^3 of **FB 4** and obtained the expected temperature rise. These candidates scored the second set of accuracy marks. They had pipetted 25.0 cm^3 of **FB 3** into the plastic cup rather than the 50.0 cm^3 specified in the instructions.

Many candidates did not understand the heading to column 3 of Table 1.3 and instead of recording the cumulative Δt they recorded successive values for each addition which resulted in –ve values after the maximum.

Graph

Most candidates plotted Δt on the *y*-axis and the volume of **FB 4** added on the *x*-axis. To gain the first mark the axes also needed to be labelled and the correct unit given. Most candidates gained this mark.

The plotting of three points around the maximum were checked and a second mark awarded to nearly all candidates.

The third mark for the graph was awarded to very few candidates. The Examiners were looking for *two smooth intersecting* curves from which the end-point could be read precisely.

The majority of candidates were not awarded this mark because they drew a single curve, rounded at the maximum value or rounded to a plotted point. Many graphs were not smooth – candidates joined each successive point.

In **(c)**, candidates were awarded the mark from intersecting curves, the rounded maximum or the mid-point of any plateau at the maximum value.

Candidates who had calculated successive Δt values were able to score the axes and plotting marks but not the third mark for the lines drawn or the mark in **(c)**.

About 50% of candidates were able to take their end-point from **(c)** and use it to calculate the concentration of the hydrochloric acid in section **(d)**.

Where the end-point was less than 25.0 cm^3 the calculated concentration was > 3.0 mol dm^{-3} which caused problems in the remainder of the calculation. The majority of candidates, having an end-point around 30 cm^3 should have obtained a concentration of approximately 2.5 mol dm^{-3}.

About 50% of candidates correctly subtracted their answer to **(d)** from 3.0 in **(e)**.

As there were two steps to the calculation in **(f)**, units in the final answer were not penalised. Many candidates failed to allow for the mole ratio in calculating the molecular mass of the carbonate.

There were a small number of Centres where the erratum notice had not been received and the hydrochloric acid provided did not produce a maximum temperature for neutralisation when added to the sodium hydroxide in the plastic cup. A modified mark scheme was applied, allowing candidates the same potential number of marks for the question.

Question 3

(a)   The Examiners were disappointed that few candidates realised the inherent error in reading any scale is half of the smallest scale division.

The most common answer seen gave the error as 1 complete scale division.

Many candidates gave answers based on the conditions of conducting the experiment, e.g. time delay between addition of acid from the burette and reading the thermometer.

(b)   Few candidates realised that the hydrochloric acid measured in **Question 1** was in excess.

Typical answers concentrated on the acid being weighed in the experiment, the measuring cylinder being accurately calibrated or a small percentage error in reading a full measuring cylinder.

(c)   The Examiners were looking for saturation of the acid in the flask with carbon dioxide in order that the all of the carbon dioxide given off during the main reaction would be collected.

Few candidates scored either of these marks. The most common answers seen were:

- the addition of sodium carbonate added reduces the initial fizzing so no solution will be lost through effervescence at the start of the reaction

- the carbon dioxide produced replaces that lost in the main reaction before the insertion of the bung into the flask.   (This was a possible E mark on page 10 and was awarded retrospectively, if required)

- the carbon dioxide produced displaced air from the flask and delivery tube

- the sodium carbonate added catalyses the reaction.

(d)   For each section the Examiners identified: **E**rror, **M**ethod and ex**P**lanation marks.

In answering this part most candidates gave rather vague answers. This was particularly the case when it came to describing the method for reducing the error and the explanation of how the method employed reduced the error.

Very often the Examiners had to combine the first and third statements to find the error mark.

The method mark was given for a *practical method* of reducing the error not for a qualitative statement such as raise the temperature.

To gain the explanation mark it had to be made clear how the method chosen would reduce the error.

Reference to the mark scheme will show a listing of errors/methods/explanations that scored marks.   The list was not exhaustive and on occasions an innovative method was seen and rewarded.

The best scoring combinations were the simplest, e.g.:

- carbon dioxide dissolves in water

- replace the collection apparatus with a gas syringe

- there is no water to dissolve carbon dioxide

- solubility of carbon dioxide in water varies with temperature change

- heat the water in the collection apparatus

- carbon dioxide is less soluble in hot water

- a measuring cylinder is not the best way to collect and measure the gas evolved

- replace with a gas syringe

- reference to the graduations on each piece of apparatus/the precision of measuring the volume of gas

- loss of carbon dioxide between adding the carbonate to the acid and inserting the stopper in the flask

- method involving the carbonate in a tube inside the stoppered flask or use of a divided flask

- apparatus is sealed before mixing the reagents.

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Comments on specific questions

Biochemistry

This proved to be a popular option, although candidates did not seem as well prepared as in recent examinations. In particular they seemed to find the chemical aspects of the option more difficult.

Question 1

Although candidates could identify the amino and carboxylic acid groups in part **(a)(i)**, a surprising number failed to correctly show the formation of the peptide bond in part **(a)(ii)**. In part **(b)** a significant number of candidates only showed ionisation of one of the amino or carboxylic acid groups in each structure. Part **(c)** was generally poorly done with little thought given to the effects on the various amino acids. Few candidates scored more than 2 marks out of a possible 6 here. The effect of heavy metal ions was very poorly understood, with a large number of candidates unsure of what constituted a 'heavy metal ion'.

Question 2

This question was much better answered than **Question 1**, with candidates using their biological knowledge in many cases. Marks were most commonly lost by imprecise answers. Part **(a)** was generally well answered, although a few candidates just gave ribose or sugar for **X**. In part **(b)** most candidates calculated the correct percentages. Part **(c)** produced some good answers, but too many candidates did not give sufficient detail to gain full marks.

Environmental Chemistry

Answers to this option were disappointing this session, with few candidates scoring more than 6 marks on either question. This was generally due to a lack of knowledge of the chemistry involved.

Question 3

Answers to part **(a)** were often vague and imprecise with surprisingly few candidates scoring both marks. In part **(b)** few candidates could write correct equations for the reactions of nitrogen monoxide with ozone and the subsequent regeneration of the nitrogen monoxide. In part **(c)(i)** although most candidates attempted to write an equation to show the formation of OH• few produced credible or balanced equations. The explanation in **(c)(ii)** was generally very weak, and despite their appearance in the equations given in the question, few candidates identified methanal or nitrogen dioxide as polluting gases.

Question 4

Most candidates quoted the correct equation in part **(a)**, although a significant number showed the reverse reaction. In part **(b)** although candidates seemed to know that the oxygen concentration and pH were significant, they had difficulty in stating what the significance was. Part **(c)** was poorly answered with candidates often having little idea of the effects on iron ions. In part **(d)** few candidates seemed to know that the reduction product of sulphate was hydrogen sulphide or sulphide ions, and rarely was more than 1 mark scored on this part.

Phase Equilibria

This option remains very popular, although candidates seemed to find it harder to score high marks on this paper. In some cases this seemed to be due to a lack of practice in answering numerical questions, with algebraic and arithmetical errors common.

Question 5

In part **(a)(i)** the definition was often imprecise, with candidates omitting to state that it applied for given volume of solvent at a particular temperature. The calculation of the mass of oxygen in part **(a)(ii)** was poorly tackled for such a simple calculation, and consequently the volume calculation in part **(a)(iii)** was similarly poor. In part **(b)**, few candidates appreciated that Henry's law would no longer apply and could explain why. The calculation in part **(c)(i)** was again poorly done and although candidates often knew that the gas was nitrogen in **(c)(ii)**, they often could not explain why.

Question 6

Parts **(a)** and **(b)** of this question were of a standard type as set in previous papers and were not expected to cause problems. Good candidates coped well with these, scoring 4 or 5 marks. Unfortunately, a significant number of candidates failed to label the axes in the phase diagram, or misread their own scales when plotting the points. Part **(c)** required a construction on the phase diagram followed by a simple calculation, and many failed to score any of the marks. Part **(d)** was a standard piece of knowledge, but it seemed that few candidates appreciated the way in which the lattice is affected by 'foreign' atoms in an alloy.

Spectroscopy

Although the least popular of the options, candidates who had studied spectroscopy appeared to be well prepared and scored better than average marks.

Question 7

In part **(a)** candidates needed to explain the processes leading to the absorption of energy in a transition metal complex. Although most knew that the ligands split the d orbitals producing two energy states, some confused absorption with emission and lost marks. In part **(b)** the prediction of colour from the uv/visible spectrum was generally successful, although again some treated it as an emission spectrum. In part **(c)** good candidates scored all of the marks, whilst those less well prepared often omitted two of the three possible transitions for ethanal.

Question 8

This question was well answered by almost all candidates. Most candidates were able to calculate that **Y** contained 15 carbon atoms, and from the n.m.r. spectrum that it contained 14 hydrogen atoms in two proton environments. From the M_r candidates determined that **Y** must also contain an oxygen atom. From there it was possible to work out the symmetrical structure, with a central C=O, confirming the structure using the i.r. spectrum and peaks in the mass spectrum.

Transition Metals

This remains a very popular option, although answers in this session scored somewhat lower than in recent sessions.

Question 9

Although many candidates knew that cobalt occurs in vitamin B12, a smaller proportion knew its role in the body. In part **(b)** candidates struggled with $E^\ominus$ values for reactions and lost marks in failing to choose the correct reactions or to use the $E^\ominus$ values correctly. A pleasing number of candidates managed to work out the equation for Co^{3+} ions reacting with Cr^{3+} ions and give the correct colour change for the solution. Many candidates knew that chromium was used to make stainless steel in part **(c)**, but the reaction in part **(d)** defeated all but the best candidates.

Question 10

Part **(a)** of this question was surprisingly poorly answered with few candidates showing detailed knowledge of the electrolytic purification of copper. The most common error was to state that the zinc was deposited in the anode sludge, rather than remaining in solution. In part **(b)** although many candidates knew that copper(II) ions were reduced by aldehydes, few could write an equation for the reaction, and not all realised that the product was Cu_2O. In part **(c)** good candidates successfully calculated the percentage of copper in the brass, but a surprisingly small percentage knew that the other major component was zinc.