www.dynamicpapers.com

CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

This examination paper provided a difficult challenge to the candidates. The highest score achieved by one of the low number of candidates was 31 marks out of 40, this was a very good performance. The statistics for individual questions suggest that candidates had sufficient time to complete the paper.

The mean mark was 14 / 40, the median mark was 13 / 40. The four modes were 9, 10, 12 and 13 / 40. As these modal values suggest, the majority of candidates scored between 9 and 13 marks.

Very few questions can be said to have been found to be easier, however 40 per cent or more of candidates chose the correct response to each of **Questions 2**, **5**, **7**, **12**, **13**, **17**, **19**, **20**, **22**, **26**, **27**, **30**, **31** and **36**. Six questions can be said to have been found to be particularly difficult. Less than 23 per cent of candidates chose the correct response to each of **Questions 1**, **9**, **11**, **23**, **28** and **29**. The questions that were found to be particularly difficult will now be looked at in greater detail.

Comments on specific questions

Question 1

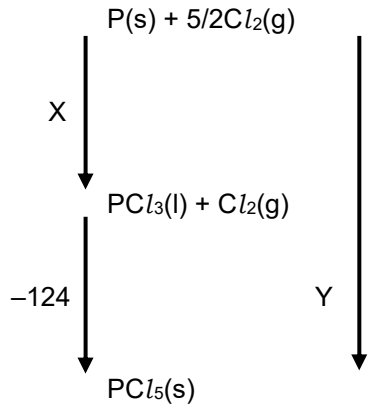
20 per cent of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**. 49 per cent of candidates chose this answer. 35.5 g of chlorine contains 0.50 mol of chlorine molecules. 16 g of sulfur contains 0.50 mol of sulfur atoms. 23 g of sodium contains 1.0 mol of sodium atoms. 74.5 g of potassium chloride contains 2.0 mol of ions. 88 g of carbon dioxide contains 2.0 mol of molecules. The answer is therefore **A**.

© 2022

www.dynamicpapers.com

Question 9

15 per cent of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **B**. 44 per cent of candidates chose this answer. The question was best approached by an energy level diagram.



It can be seen that $\Delta H_{reaction}$, which is –124, is less negative than $\Delta H_f(PCl_5)$, which is Y, so statement 1 is correct for **A** and **C**.

It can be seen that $\Delta H_{reaction}$ can be calculated from the enthalpies of formation, X and Y, without using the Cl_2 bond energy, so statement 1 is correct for **C** and **D**.

The correct answer is therefore **C**.

Question 11

17 per cent of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **B**. 51 per cent of candidates chose this answer. The oxidation state of N in NH_4^+ is –3. The oxidation state of N in NO_3^- is +5. The change in oxidation state, from –3 to +5, is +8.

Question 23

20 per cent of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**. 39 per cent of candidates chose this answer. **A** is incorrect because ammonia is formed when ammonium ions react with an alkali, not when they react with an acid. **C** is correct because both an ammonium ion and a methane molecule contain ten electrons.

Question 28

22 per cent of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**. 32 per cent of candidates chose this answer. The oxidation state of bromine in Br_2 is zero, the oxidation state of bromine in 1,2-dibromopropane is –1. Bromine is reduced in this reaction, so **A** is a redox reaction. In reaction **B** the propan-1-ol is dehydrated, producing water. The oxidation state of oxygen is –2 in propan-1-ol and in water, the oxidation state of hydrogen is +1 in propan-1-ol and in water, so **B** is not a redox reaction.

Question 29

15 per cent of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**. 34 per cent of candidates chose this answer. When santonin is treated with warm dilute H_2SO_4 the ester link is hydrolysed, producing an –OH group and a –COOH group. When treated with cold dilute acidified $KMnO_4$ each double bond is oxidised to two –OH groups. This makes a total of six OH groups, so six atoms of hydrogen will react with sodium.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

This examination paper provided a suitable challenge to the candidates. 13 candidates scored 40 marks out of 40, this was an excellent performance. The statistics for individual questions suggest that candidates had sufficient time to complete the paper.

The mean mark was 18 / 40, the median mark was 17 / 40. The mode was 15 / 40.

Ten questions can be said to have been found to be easier. 60 per cent or more of candidates chose the correct response to each of **Questions 1**, **2**, **3**, **7**, **10**, **11**, **12**, **22**, **26** and **32**. Six questions can be said to have been found to be particularly difficult. Less than 30 per cent of candidates chose the correct response to each of **Questions 5**, **13**, **15**, **16**, **29** and **35**. The questions that were found to be particularly difficult will now be looked at in greater detail.

Comments on specific questions

Question 5

22 per cent of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **B**. 30 per cent of candidates chose this answer. The one mole of Zn described in the question has lost two moles of electrons in becoming Zn^{2+}. The two moles of VO_2^+ have gained these two moles of electrons, so the oxidation state of vanadium has decreased by one from +5 to +4. VO^{2+} is the only ion with vanadium in a +4 oxidation state, so the correct answer is **C**.

© 2022

www.dynamicpapers.com

Question 13

26 per cent of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**. 33 per cent of candidates chose this answer. There are three electron pairs around the 'central' oxygen atom, so we might expect the bond angle to be close to 120°. However the three electron pairs consist of two bond pairs and one lone pair. The lone pair exerts a slightly greater repulsion than the two bond pairs, causing a bond angle close to 117°.

Question 15

27 per cent of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **A**. 42 per cent of candidates chose this answer. At constant temperature the relation between the pressure and the volume of an ideal gas is $P \propto 1/V$ (P is proportional to 1 / V), the answer is therefore **D**.

Question 16

23 per cent of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**. 30 per cent of candidates chose this answer. The C–H bond energy can be deduced to be +412 from the information that the ΔH for the change $CH_4(g) \rightarrow C(g) + 4\,H(g)$ is +1648 kJ mol^{-1}. The enthalpy change for the reaction given in the question is therefore $((6 \times -412) + -350)$ which is –2822.

Question 29

28 per cent of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**. 33 per cent of candidates chose this answer. Candidates who chose **C** had failed to appreciate that a bromine atom will substitute for an –OH group when an alcohol is warmed with an excess of HBr.

Question 35

29 per cent of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**. 33 per cent of candidates chose this answer. Compound 1 is ethanal. This will give a positive result with alkaline $I_2(aq)$, with Fehling's reagent and with Tollens' reagent. Compound 2 is propanone. This will give a positive result with alkaline $I_2(aq)$, but as it is a ketone it will give a negative result with Fehling's reagent and with Tollens' reagent. Compound 3 is pentan-3-one. This will give a negative result with alkaline $I_2(aq)$, with Fehling's reagent and with Tollens' reagent. The correct answer is therefore **A** – all three rows of the table are correct.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/13
Multiple Choice

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

General comments

This examination paper provided a suitable challenge to the candidates. One candidate scored 40 marks out of 40, this was an excellent performance. The statistics for individual questions suggest that candidates had sufficient time to complete the paper.

The mean mark was 23 / 40, the median mark was 22 / 40. The mode was 17 and 18 / 40, however the distribution of marks was quite 'flat' from 14 to 31 marks.

Ten questions can be said to have been found to be easier. 70 per cent or more of candidates chose the correct response to each of **Questions 2**, **5**, **7**, **8**, **12**, **13**, **14**, **16**, **26** and **34**. Six questions can be said to have been found to be particularly difficult. Less than 40 per cent of candidates chose the correct response to each of **Questions 1**, **9**, **25**, **28**, **29** and **35**. The questions that were found to be particularly difficult will now be looked at in greater detail.

Comments on specific questions

Question 1

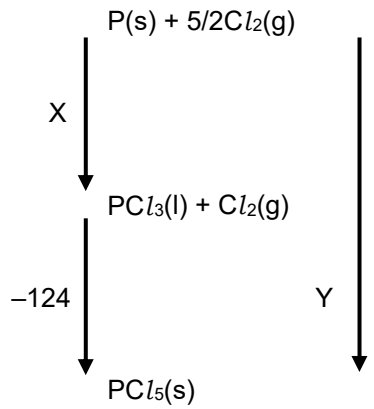
34 per cent of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**. 48 per cent of candidates chose this answer. 35.5 g of chlorine contains 0.50 mol of chlorine molecules. 16 g of sulfur contains 0.50 mol of sulfur atoms. 23 g of sodium contains 1.0 mol of sodium atoms. 74.5 g of potassium chloride contains 2.0 mol of ions. 88 g of carbon dioxide contains 2.0 mol of molecules. The answer is therefore **A**.

© 2022

www.dynamicpapers.com

Question 9

39 per cent of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**. 28 per cent of candidates chose this answer. The question was best approached by an energy level diagram.



It can be seen that $\Delta H_{reaction}$, which is –124, is less negative than ΔH_f(PCl_5), which is Y, so statement 1 is correct for **A** and **C**.

It can be seen that $\Delta H_{reaction}$ can be calculated from the enthalpies of formation, X and Y, without using the Cl_2 bond energy, so statement 1 is correct for **C** and **D**.

The correct answer is therefore **C**.

Question 25

16 per cent of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **C**. 41 per cent of candidates chose this answer. The value of Q is four – white solids will be seen when MgO, Al_2O_3, SiO_2 and SiCl_4 are added to water. The value of R is also four – white solids will be seen when an excess of NaOH(aq) is added to the tubes that originally contained MgO, SiO_2, MgCl_2 and SiCl_4. The correct answer is therefore **D**.

Question 28

32 per cent of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**. 27 per cent of candidates chose this answer. The oxidation state of bromine in Br_2 is zero, the oxidation state of bromine in 1,2-dibromopropane is –1. Bromine is reduced in this reaction, so **A** is a redox reaction. In reaction **B** the propan-1-ol is dehydrated, producing water. The oxidation state of oxygen is –2 in propan-1-ol and in water, the oxidation state of hydrogen is +1 in propan-1-ol and in water, so **B** is not a redox reaction.

Question 29

29 per cent of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**. 26 per cent of candidates chose this answer. When santonin is treated with warm dilute H_2SO_4 the ester link is hydrolysed, producing an –OH group and a –COOH group. When treated with cold dilute acidified $KMnO_4$ each double bond is oxidised to two –OH groups. This makes a total of six OH groups, so six atoms of hydrogen will react with sodium.

Question 35

24 per cent of candidates chose the correct answer, **C**. The most commonly chosen incorrect answers were **A**, chosen by 31 per cent of candidates, and **B**, chosen by 32 per cent of candidates. There are seven isomeric compounds : –

- *cis*-HOOC–CH=CH–CH_2–COOH
- *trans*-HOOC–CH=CH–CH_2–COOH
- HOOC–C(=CH_2)–CH_2–COOH
- *cis*-HOOC–C(CH_3)=CH–COOH
- *trans*-HOOC–C(CH_3)=CH–COOH
- HOOC–C(=CH–CH_3)–COOH
- HOOC–CH(CH=CH_2)–COOH

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/21
AS Structured Questions

General comments

Candidates do appear to have some weaknesses in the fundamental knowledge that is assumed to have been covered pre-AS level Chemistry.

Comments on specific questions

Question 1

(a) (i) Many answers gave the correct number of protons, neutrons and electrons for the two isotopes of Gallium, ^{69}Ga and ^{71}Ga.

(ii) The definition of relative atomic mass often attracted vague answers with the phrases 'average mass' and '1/12th of the mass of an **atom** of C-12' frequently omitted. The answers presented rarely included a comparison with the 'atomic mass unit, amu'.

(iii) The calculation of the percentage abundance of the gallium isotope, ^{69}Ga, was well answered by many candidates. The given A_r, 69.723, and the expression for the average of the two gallium isotopes, ^{69}Ga and ^{71}Ga, were used to determine the percentage abundance of the ^{69}Ga isotope.

Common errors included determining the average of the relative isotopic masses of the individual isotopes, assuming an abundance of 1:1 and giving answers to less than four significant figures, as required by the question.

(b) (i) Both isotopes of potassium have the same number of electrons allowing them to have the same chemical properties.

Many correct answers were seen, with the most common errors being answers which mentioned that the two isotopes had the same number of valence electrons or the same number of protons.

(ii) The full electronic configuration of an atom of potassium was correctly answered by most candidates. The most common error was to state $3d^1$ rather than $4s^1$ for the valence shell electron.

(iii) Most candidates were able to identify that the large increase in the given values of the ionisation energies between the first and second values, was indicative of the first electron removed being in a singly occupied outer shell. However, very few answers then went on to explain that the large values of the second and third IE's represented electrons removed from inner shells that were closer to the nucleus.

Question 2

(a) The representations of the bonding in magnesium metal were frequently poorly drawn and inadequately labelled. Unlabelled drawings with circles containing only a +ve charge were seen and the electrons were often drawn as a –ve sign but not labelled as 'delocalised electrons'.

(b) (i) The products from the separate reactions of HCl(aq) with magnesium and $MgCO_3$, were generally well recognised as hydrogen, and carbon dioxide plus water. Some candidates omitted the production of water in the second reaction or incorrectly gave the product here as H_2CO_3.

© 2022

www.dynamicpapers.com

(ii) When $MgCl_2$ was reacted with $Ca(OH)_2$ a precipitate of $Mg(OH)_2$ is formed. However, when the reaction was repeated but using $BaCl_2$ and $Ca(OH)_2$ no precipitate is formed because the product, $Ba(OH)_2$, is soluble and so no precipitate is observed.

Very few candidates gained any credit here. The concept of the solubilities of Group 2 hydroxides rarely featured. Many answers focused on the relative reactivities of barium and calcium or displacement reactions of the metals/metal ions.

(iii) The heating of $MgCO_3$ to form MgO was correctly identified as a *thermal decomposition* reaction by many candidates. The most common errors described the reaction as a redox reaction or a combustion reaction.

(c) The answers to the observations when $AgNO_3(aq)$ was added to $MgCl_2(aq)$ followed by dilute $NH_3(aq)$ were frequently awarded both marks. The common errors, seen on occasions, involved observations of gas production, or of the formation of a yellow insoluble precipitate, for $AgCl$.

(d) Very few candidates answered this question which required an explanation for the observation that a solution remains orange when $Br_2(aq)$ was added to $MgCl_2(aq)$. The focus of the answer should have been on the redox behaviour of $Br_2(aq)$ with the $Cl^-(aq)$ ion in $MgCl_2$.

$Br_2(aq)$ is a weak oxidising agent and is unable to oxidise the Cl^- ion (in $MgCl_2(aq)$) to Cl_2; hence the solution remains orange because the bromine has not reacted.

Many answers referred to the relative reactivities/relative oxidising abilities of Br_2 and Cl_2 but did not apply this specifically to this question and there were many vague statements referring to displacement reactions.

Question 3

(a) (i) The chlorides of Period 3 elements that are giant ionic structures include $NaCl$ and $MgCl_2$. This question was well answered with both species often given.

(ii) Strongly acidic solutions are formed when $AlCl_3$, $SiCl_4$ and PCl_5 are separately added to water. The answers were not usually given credit as all three species were seldom given. $AlCl_3$ was often omitted and considered to react with water to form a neutral solution.

(iii) $NaCl$ was often correctly identified as the chloride that dissolves in water to form a neutral solution. $AlCl_3$ was a common error.

(iv) $SiCl_4$ was often identified as the chloride formed from the element with the highest melting point.

(b) In addition to $NaCl$, water and sodium chlorate(I) are formed as the other products from the reaction of cold dilute NaOH(aq) with chlorine gas.

Many candidates correctly identified $NaOCl$ and H_2O as the other products; water was sometimes omitted and several incorrect answers commonly identified HCl, O_2 and $HClO$ as products.

(c) (i) The type of reaction when PCl_5 reacts with alcohols was correctly identified by many candidates as a substitution reaction.

(ii) Many answers correctly presented 1,3-dichlorobutane as the product formed from a reaction of excess PCl_5 with butane-1,3-diol.

(d) (i) In the question, SCl_2 was described as a liquid that reacts vigorously with water to form an acidic solution. This information identifies the bonding as covalent because it is hydrolysed by the reaction with water; it further identifies the structure as simple/molecular with weak IMFs because the melting point is low (as it is a liquid).

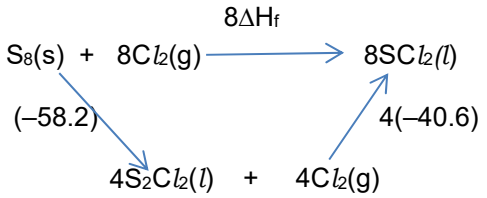
Very few candidates were awarded full credit here; most often answers included the identification of a simple structure with covalent bonding present. This was usually not linked to a correct explanation for full credit to be given.

© 2022

www.dynamicpapers.com

(ii) Many candidates found this question challenging. Sulfur was represented as S_8 in an enthalpy change of formation calculation. Several answers gained some credit for the use of the correct enthalpy values in the correct direction in an energy cycle, if present, as was suggested in the question. An example is given below.

Answers containing the correct use of stoichiometry were less common.



$(–58.2 + 4(–40.6) = 8\Delta H_f)$; $\Delta H_f = (–220.6 \div 8) = – 27.6\,kJ\ mol^{–1}$

(iii) The equilibrium, in reaction 2 was represented by the equation:

$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l)$$

Any change in pressure will only affect the gaseous Cl_2 in this equation; a decrease in pressure will cause the equilibrium to shift to the left-hand-side to create more molecules of gas. The remaining two species in this equation are liquid.

Many candidates did not consider the physical state of reactants and products and frequently answers concluded that there was no change in the position of equilibrium as there were equal number of moles or reactants and products.

(iv) Overall, the definition of the term structural *isomer* was quite well answered with many candidates recognising that structural isomers have the same molecular formula but different structural formulae.

(v) Some candidates were able to correctly deduce the Cl-S-S bond angle around the central Group 16 sulfur atom, in isomer I of S_2Cl_2, from the two bonding pairs and two lone pairs of electrons in the outer shell.

However, explanations of the *repulsion effect* of the two lone pairs causing the bond angle to shrink to less than 108°, were rarely seen.

A common incorrect answer stated the molecule to be linear with 180° bond angle and with no lone pairs present.

(vi) The diagram in the question of isomer II, S_2Cl_2, showed the central S atom bonded to two Cl atoms by single bonds and to another S atom by a double bond.

The bonding pairs were usually identified correctly. A common omission, however, involved an incorrect number of the remaining electrons around the S atoms; often the lone pair on the central S was absent.

Question 4

(a) This question tested a cross section of Organic chemistry where reagents were required to distinguish between four separate pairs of organic compounds via positive observations. The first pair separately contained an ester and a secondary alcohol; many correctly chose acidified $K_2Cr_2O_7$ to identify the secondary alcohol by the potassium dichromate turning from orange to green during the test.

The second pair contained a ketone and ester respectively. 2,4-dinitrophenylhydrazine, 2,4-DNPH reagent, was the reagent favoured by many candidates; it identified the ketone with the formation of an orange precipitate.

© 2022

www.dynamicpapers.com

The third pair comprised a cycloalkane and a separate alkene; the latter was easily distinguishable by the decolourisation of Br_2(aq) from orange to colourless.

One of the fourth pair contained primary and secondary alcohol groups whilst the second compound contained a primary alcohol and a carboxylic acid functional group.

Many candidates found a distinguishing test challenging for this pair. Often acidified $K_2Cr_2O_7$ or $KMnO_4$ were given as answers together with 2,4-DNPH reagent without appreciating that the oxidising agent would give a positive result with both compounds in the pair, and there is no carbonyl group present to give a result with the 2,4-DNPH reagent.

Many candidates gave positive results for chemical tests but did not identify which of the pair was responsible for the positive result.

(b) This question was generally well answered with many answers stating that the cycloalkane has a low melting and boiling point because of 'weak' intermolecular forces of attraction, IMF, between the molecules. These intermolecular forces of attraction were often correctly identified as instantaneous dipole – induced dipole/London dispersion forces.

(c) The structures for the cis isomer of hex-2-ene **(C2)**, were generally correctly drawn.

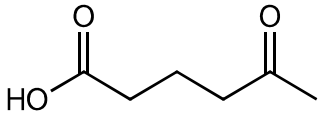
(d) (i) The type of polymer formed when using hex-2-ene (**C2**), is an addition polymer. Many candidates elected to name the polymer rather than the type of polymer.

(ii) The attempts to draw one repeat unit of the polymer formed from **C2**, hex-2-ene, were generally quite well answered.

Common errors included diagrams with multiple repeat units or incorrect carbon backbones.

Question 5

(a) (i) The oxidation of 1-methylcyclopentene, **M**, using hot concentrated acidified $KMnO_4$, yielded

N, 

Many candidates correctly identified compound **N**. Some candidates identified the carboxylic acid group correctly but the ketone group was incorrectly given as an aldehyde group.

(ii) The question required the construction of an equation, using molecular formula, for the reduction of **N** to 5-hydroxyhexanoic acid, where the reducing agent was represented as [H], given in the question.

The molecular formula of **N** was given in the stem of this question but was regularly ignored by many candidates; the use of [H] to represent the hydrogen atoms from the reducing agent was also generally overlooked.

Overall, a poorly answered question, due in part to candidates not using the information given in the question.

(iii) Very few answers gained any credit here. The question referred to the reduction of **N**, containing a ketone and carboxylic acid functional groups, by $NaBH_4$ to form 5-hydroxyhexanoic acid, via a nucleophilic addition reaction.

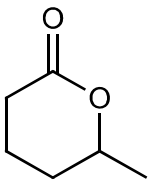
The recognised mechanism of nucleophilic addition of the H^- ion to a carbonyl group, allows attack of the planar carbonyl group, in N, from either side of the plane to form a mixture of two stereoisomers.

Many answers suggested that the $NaBH_4$ reduced both the keto and carboxylic acid groups to form different products. Several candidates also considered the reaction to involve secondary or tertiary carbocation intermediates, which would generate different products.

© 2022

www.dynamicpapers.com

(iv) The removal of a water molecule from a reaction involving 5-hydroxyhexanoic acid **l**eads to a lactone, a cyclic ester, by the method outlined if equation **1**, in the stem of the question:



Candidates found the lactone difficult to draw. A common mistake was to omit the methyl branch from the ring structure or place it at an incorrect position on the six-membered ring. Other errors included ring structures with an incorrect number of carbon atoms.

(b) The keto-carboxylic acid, N, and the 5-hydroxyhexanoic acid are difficult to distinguish using infrared spectroscopy because of the similarity of the functional groups which will give similar absorptions in the infrared spectrum.

This question was not well answered with many answers containing vague statements regarding C-H, C-O and O-H bonds. Credit was given to answers that stated that that both molecules contained a C=O group and gave the correct the absorption range from a table of data given in the question.

(c) The question required the use of the data given in a table of the abundances of the M^+ and M + 1 peaks for *m/e*'s of 72 and 73, using the expression:

$\frac{M+}{M+1} = \frac{100}{n \times 1.1}$ to calculate n, the number of carbon atoms in lactone, Q.

The mass of this number of carbon atoms plus the mass of the two oxygen atoms, from the lactone, cyclic ester, can then be subtracted from 72 to give a molecular formula of $C_3H_4O_2$.

Some candidates were able to calculate the number of carbon atoms and then draw a correct structure. Many incorrectly gave non-cyclic structures or did not give any response to this question.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/22
AS Structured Questions

Key messages

Candidates should be encouraged to use chemical related vocabulary with precision and in appropriate contexts e.g. the inappropriate use of the terms 'atoms' for 'molecules' and/or 'ions' and 'halogens' with 'halides'.

Candidates are reminded that their working in calculations should be shown to ensure that due credit can be awarded.

General comments

Candidates performed less well in organic chemistry questions than those involving physical and inorganic topics.

Candidates knowledge of structure and bonding was generally weak. Confusion of key details relating to intramolecular bonds, metallic, covalent and ionic bonds and the identification of specific intermolecular forces was seen regularly.

Comments on specific questions

Question 1

(a) The species electrostatically attracted to one another in ionic bonds was described by many candidates. Knowledge of the species involved in a covalent bond was less well known. Only a small minority of candidates described the attraction between two nuclei and a shared pair of electrons.

(b) Use of relative atomic mass rather than proton number for the elements was the most common error. Correct application of the relationship between the number of protons and the number of electrons in these different ions was often seen.

(c) (i) The majority of candidates gave an appropriate definition. Some answers were imprecise and described the behaviour of a Bronsted-Lowry acid in terms of the '*release of protons'* rather than '*donation of protons*'.

(ii) This reaction did not appear to be well known, equations with incorrect species were seen frequently.

(iii) Appropriate shapes for the s and p orbitals were common. The correct orientation of the p_x orbital in the correct position on the axis was less well known.

(d) (i) Inclusion of the appropriate roman numeral, to denote the oxidation number of phosphorus in the anion, occurred rarely.

(ii) Clear logical working was seen in many answers. Occasionally there was misunderstanding of the term 'molecules of water of crystallisation', as a result some candidates calculated the actual number of water molecules present in 1 mole of struvite.

© 2022

www.dynamicpapers.com

(e) (i) Some excellent diagrams for this mechanism were produced, curly arrows were clearly positioned to show the transfer of a pair of electrons, either in a bond or from a lone pair of electrons when a specific bond is broken or made.

(ii) Clear understanding of the term tertiary bromoalkane was seen in answers which focused on the presence of three different alkyl groups bonded to a carbon atom which is covalently bonded to the bromine atom. Some responses were imprecise, for example '*when a halogenoalkane is attached to three alkyl groups'*. There was also inappropriate use of the term '*compound*' instead of '*alkyl group'* and '*is surrounded by'* instead of '*is bonded to'*.

(iii) Many candidates did not appreciate that, under the conditions described, an alkene rather than an alcohol would be made. Of those who attempted to represent **M** as an alkene some represented the structure of prop-1-ene or showed a structure with an incorrect number of hydrogen atoms present on the correct carbon skeleton.

Question 2

(a) The bonding in the Period 3 chlorides was generally well known. A common incorrect answer described $SiCl_4$ as a giant structure. The majority knew the oxidation states of the Period 3 chlorides stated in the syllabus and correctly deduced the oxidation numbers of PCl_3 and SCl_2.

(b) Equations which represented the dissolving of sodium chloride were uncommon; many answers described the production of hydrochloric acid and sodium hydroxide.

The formation of H_3PO_4 on addition of PCl_5 to water was seen more frequently. Equations were not always balanced. Incorrect state symbols for at least one of the species was relatively common.

(c) (i) Good, clear diagrams which distinguished between the relevant dative bonds and covalent bonds in the structure of Al_2Cl_6 were seen. The weakest diagrams showed the two aluminium atoms bonded together.

(ii) When a change occurs to an equilibrium mixture the reaction, by definition, may proceed in either direction. To reduce ambiguity candidates should be encouraged to refer to 'forward reaction' or 'backward reaction' rather than just 'the reaction'.

(d) This question was generally well answered. Common errors involved inappropriate unit conversion and incorrect relationships between mass and mol. Sometimes the formula of the chloride deduced from the molecular mass calculated was not a Period 3 chloride.

(e) (i) Very few candidates recognised that no reaction occurs between chloride ions and bromine. Some explained this lack of reaction in terms of no displacement between the two species. The best answers used appropriate vocabulary for the relevant halogen and halide to explain that bromine was unable to oxidise the chloride ions.

(ii) Excellent answers described the presence of stronger permanent dipoles due to the greater electronegativity difference in SCl_2 molecules.

Many misconceptions regarding intermolecular forces were highlighted in a significant proportion of answers. Ambiguity arose when the term 'van der Waals' was used to describe 'instantaneous dipole induced dipole attractions' rather than as the generic term for all intermolecular forces. For example, when the increased strength of van der Waals in SCl_2 was attributed to the number of electrons present in a molecule. Contradictions included linking the difference in the physical state to the strength of bonds between the atoms rather than intermolecular forces. The weakest answers explained why the melting or boiling point of SBr_2 is higher even though the question states that it is a gas and SCl_2 is a liquid at room temperature.

(f) (i) Clear labelled diagrams which described the presence of cations surrounded by delocalised electrons were seen. Many diagrams were not labelled appropriately.

(ii) Answers regularly gave the correct identification of the structure and bonding present. Explanations tended to restate the information given in the question rather than draw conclusions from the

© 2022

www.dynamicpapers.com

observations. Reference to a low melting point for bismuth chloride was seen more regularly than identification of a hydrolysis reaction when it was added to water.

Question 3

(a) (i) This question proved challenging. Some excellent answers clearly identified suitable reagents with appropriate observations for one of each pair of compounds. Distinguishing **D2** from **D1** using bromine was a common correct answer. Many described the addition of 2,4-DNPH to the two ketones **B1** and **B2**.

(ii) Definitions of structural isomers was well known.

(iii) The correct systematic name for **B2** was relatively uncommon. Some answers gave the correct basic stem and identified the wrong number to indicate the position of the C=O group on the chain. Others used 'prop' instead of 'pent'. Incorrect spelling or position of the number within the name was also seen.

(iv) Interpretation of the skeletal formula of the cyclic structure of **D1** proved challenging. Many answers did not give a molecular formula as their answer.

(b) (i) Some answers described the functional group present in the polymer rather than the type of polymer made.

(ii) Very few answers showed a structure with one repeat unit. Appropriate identification of the side chains around the -C-C- backbone of the repeat unit proved most challenging.

(c) (i) Identification of the alkene or C=C functional group present in **E**, with appropriate reference to a specific absorption in its infrared spectrum was relatively common.

(ii) Identification of **F** with a hydroxyl functional group and appropriate reference to a specific absorption in its infrared spectrum was seen less often. Some answers did not refer to the spectrum and gave an explanation in terms of the formation of a diol on addition of cold dilute acidified $KMnO_4$.

(iii) Some answers used the mass spectra details provided to deduce that **E** contains a bromine atom. Not all of these went on to deduce the relative molecular mass of **E** based on the approximately equal proportion of the two isotopes of bromine which occur naturally.

(iv) Some answers used some of the information given to describe structures of **E** as an alkene, made of 3 carbon atoms. A much smaller proportion of candidates used the information in **(c)(iii)** to deduce that the compound was an alkene with three carbon atoms and a bromine atom.

(v) Appropriate equations using [O] as the oxidising agent for the reaction of a 3-carbon alkene to form a 3-carbon diol were seen infrequently.

(d) Different methods were used to describe the synthesis of **C2** from **A1** in a multi-step process. Many answers were incomplete. Common omissions included no reference to either conditions or the identity of organic product at each step in the synthesis. Some answers focused on the conversion of **A1** to either an alcohol or a carboxylic acid.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/23
AS Structured Questions

General comments

Candidates do appear to have some weaknesses in the fundamental knowledge that is assumed to have been covered pre-AS level Chemistry.

Comments on specific questions

Question 1

(a) (i) Many answers gave the correct number of protons, neutrons and electrons for the two isotopes of Gallium, ^{69}Ga and ^{71}Ga.

(ii) The definition of relative atomic mass often attracted vague answers with the phrases 'average mass' and '1/12th of the mass of an **atom** of C-12' frequently omitted. The answers presented rarely included a comparison with the 'atomic mass unit, amu'.

(iii) The calculation of the percentage abundance of the gallium isotope, ^{69}Ga, was well answered by many candidates. The given A_r, 69.723, and the expression for the average of the two gallium isotopes, ^{69}Ga and ^{71}Ga, were used to determine the percentage abundance of the ^{69}Ga isotope.

Common errors included determining the average of the relative isotopic masses of the individual isotopes, assuming an abundance of 1:1 and giving answers to less than four significant figures, as required by the question.

(b) (i) Both isotopes of potassium have the same number of electrons allowing them to have the same chemical properties.

Many correct answers were seen, with the most common errors being answers which mentioned that the two isotopes had the same number of valence electrons or the same number of protons.

(ii) The full electronic configuration of an atom of potassium was correctly answered by most candidates. The most common error was to state $3d^1$ rather than $4s^1$ for the valence shell electron.

(iii) Most candidates were able to identify that the large increase in the given values of the ionisation energies between the first and second values, was indicative of the first electron removed being in a singly occupied outer shell. However, very few answers then went on to explain that the large values of the second and third IE's represented electrons removed from inner shells that were closer to the nucleus.

Question 2

(a) The representations of the bonding in magnesium metal were frequently poorly drawn and inadequately labelled. Unlabelled drawings with circles containing only a +ve charge were seen and the electrons were often drawn as a –ve sign but not labelled as 'delocalised electrons'.

(b) (i) The products from the separate reactions of HC*l*(aq) with magnesium and $MgCO_3$, were generally well recognised as hydrogen, and carbon dioxide plus water. Some candidates omitted the production of water in the second reaction or incorrectly gave the product here as H_2CO_3.

© 2022

www.dynamicpapers.com

(ii) When $MgCl_2$ was reacted with $Ca(OH)_2$ a precipitate of $Mg(OH)_2$ is formed. However, when the reaction was repeated but using $BaCl_2$ and $Ca(OH)_2$ no precipitate is formed because the product, $Ba(OH)_2$, is soluble and so no precipitate is observed.

Very few candidates gained any credit here. The concept of the solubilities of Group 2 hydroxides rarely featured. Many answers focused on the relative reactivities of barium and calcium or displacement reactions of the metals/metal ions.

(iii) The heating of $MgCO_3$ to form MgO was correctly identified as a *thermal decomposition* reaction by many candidates. The most common errors described the reaction as a redox reaction or a combustion reaction.

(c) The answers to the observations when $AgNO_3(aq)$ was added to $MgCl_2(aq)$ followed by dilute $NH_3(aq)$ were frequently awarded both marks. The common errors, seen on occasions, involved observations of gas production, or of the formation of a yellow insoluble precipitate, for $AgCl$.

(d) Very few candidates answered this question which required an explanation for the observation that a solution remains orange when $Br_2(aq)$ was added to $MgCl_2(aq)$. The focus of the answer should have been on the redox behaviour of $Br_2(aq)$ with the $Cl^-(aq)$ ion in $MgCl_2$.

$Br_2(aq)$ is a weak oxidising agent and is unable to oxidise the Cl^- ion (in $MgCl_2(aq)$) to Cl_2; hence the solution remains orange because the bromine has not reacted.

Many answers referred to the relative reactivities/relative oxidising abilities of Br_2 and Cl_2 but did not apply this specifically to this question and there were many vague statements referring to displacement reactions.

Question 3

(a) (i) The chlorides of Period 3 elements that are giant ionic structures include $NaCl$ and $MgCl_2$. This question was well answered with both species often given.

(ii) Strongly acidic solutions are formed when $AlCl_3$, $SiCl_4$ and PCl_5 are separately added to water. The answers were not usually given credit as all three species were seldom given. $AlCl_3$ was often omitted and considered to react with water to form a neutral solution.

(iii) $NaCl$ was often correctly identified as the chloride that dissolves in water to form a neutral solution. $AlCl_3$ was a common error.

(iv) $SiCl_4$ was often identified as the chloride formed from the element with the highest melting point.

(b) In addition to $NaCl$, water and sodium chlorate(I) are formed as the other products from the reaction of cold dilute NaOH(aq) with chlorine gas.

Many candidates correctly identified $NaOCl$ and H_2O as the other products; water was sometimes omitted and several incorrect answers commonly identified HCl, O_2 and $HClO$ as products.

(c) (i) The type of reaction when PCl_5 reacts with alcohols was correctly identified by many candidates as a substitution reaction.

(ii) Many answers correctly presented 1,3-dichlorobutane as the product formed from a reaction of excess PCl_5 with butane-1,3-diol.

(d) (i) In the question, SCl_2 was described as a liquid that reacts vigorously with water to form an acidic solution. This information identifies the bonding as covalent because it is hydrolysed by the reaction with water; it further identifies the structure as simple/molecular with weak IMFs because the melting point is low (as it is a liquid).

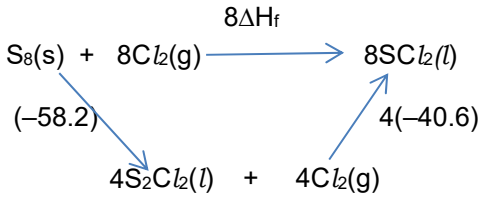
Very few candidates were awarded full credit here; most often answers included the identification of a simple structure with covalent bonding present. This was usually not linked to a correct explanation for full credit to be given.

© 2022

www.dynamicpapers.com

(ii) Many candidates found this question challenging. Sulfur was represented as S_8 in an enthalpy change of formation calculation. Several answers gained some credit for the use of the correct enthalpy values in the correct direction in an energy cycle, if present, as was suggested in the question. An example is given below.

Answers containing the correct use of stoichiometry were less common.



$(–58.2 + 4(–40.6) = 8\Delta H_f)$; $\Delta H_f = (–220.6 \div 8) = – 27.6\,kJ\ mol^{–1}$

(iii) The equilibrium, in reaction 2 was represented by the equation:

$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l)$$

Any change in pressure will only affect the gaseous Cl_2 in this equation; a decrease in pressure will cause the equilibrium to shift to the left-hand-side to create more molecules of gas. The remaining two species in this equation are liquid.

Many candidates did not consider the physical state of reactants and products and frequently answers concluded that there was no change in the position of equilibrium as there were equal number of moles or reactants and products.

(iv) Overall, the definition of the term structural *isomer* was quite well answered with many candidates recognising that structural isomers have the same molecular formula but different structural formulae.

(v) Some candidates were able to correctly deduce the Cl-S-S bond angle around the central Group 16 sulfur atom, in isomer I of S_2Cl_2, from the two bonding pairs and two lone pairs of electrons in the outer shell.

However, explanations of the *repulsion effect* of the two lone pairs causing the bond angle to shrink to less than 108°, were rarely seen.

A common incorrect answer stated the molecule to be linear with 180° bond angle and with no lone pairs present.

(vi) The diagram in the question of isomer II, S_2Cl_2, showed the central S atom bonded to two Cl atoms by single bonds and to another S atom by a double bond.

The bonding pairs were usually identified correctly. A common omission, however, involved an incorrect number of the remaining electrons around the S atoms; often the lone pair on the central S was absent.

Question 4

(a) This question tested a cross section of Organic chemistry where reagents were required to distinguish between four separate pairs of organic compounds via positive observations. The first pair separately contained an ester and a secondary alcohol; many correctly chose acidified $K_2Cr_2O_7$ to identify the secondary alcohol by the potassium dichromate turning from orange to green during the test.

The second pair contained a ketone and ester respectively. 2,4-dinitrophenylhydrazine, 2,4-DNPH reagent, was the reagent favoured by many candidates; it identified the ketone with the formation of an orange precipitate.

© 2022

www.dynamicpapers.com

The third pair comprised a cycloalkane and a separate alkene; the latter was easily distinguishable by the decolourisation of Br_2(aq) from orange to colourless.

One of the fourth pair contained primary and secondary alcohol groups whilst the second compound contained a primary alcohol and a carboxylic acid functional group.

Many candidates found a distinguishing test challenging for this pair. Often acidified $K_2Cr_2O_7$ or $KMnO_4$ were given as answers together with 2,4-DNPH reagent without appreciating that the oxidising agent would give a positive result with both compounds in the pair, and there is no carbonyl group present to give a result with the 2,4-DNPH reagent.

Many candidates gave positive results for chemical tests but did not identify which of the pair was responsible for the positive result.

(b) This question was generally well answered with many answers stating that the cycloalkane has a low melting and boiling point because of 'weak' intermolecular forces of attraction, IMF, between the molecules. These intermolecular forces of attraction were often correctly identified as instantaneous dipole – induced dipole/London dispersion forces.

(c) The structures for the cis isomer of hex-2-ene **(C2)**, were generally correctly drawn.

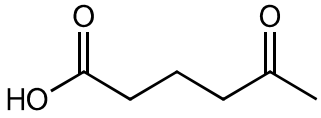
(d) (i) The type of polymer formed when using hex-2-ene (**C2**), is an addition polymer. Many candidates elected to name the polymer rather than the type of polymer.

(ii) The attempts to draw one repeat unit of the polymer formed from **C2**, hex-2-ene, were generally quite well answered.

Common errors included diagrams with multiple repeat units or incorrect carbon backbones.

Question 5

(a) (i) The oxidation of 1-methylcyclopentene, **M**, using hot concentrated acidified $KMnO_4$, yielded

N, 

Many candidates correctly identified compound **N**. Some candidates identified the carboxylic acid group correctly but the ketone group was incorrectly given as an aldehyde group.

(ii) The question required the construction of an equation, using molecular formula, for the reduction of **N** to 5-hydroxyhexanoic acid, where the reducing agent was represented as [H], given in the question.

The molecular formula of **N** was given in the stem of this question but was regularly ignored by many candidates; the use of [H] to represent the hydrogen atoms from the reducing agent was also generally overlooked.

Overall, a poorly answered question, due in part to candidates not using the information given in the question.

(iii) Very few answers gained any credit here. The question referred to the reduction of **N**, containing a ketone and carboxylic acid functional groups, by $NaBH_4$ to form 5-hydroxyhexanoic acid, via a nucleophilic addition reaction.

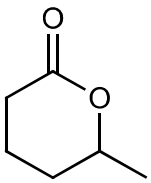
The recognised mechanism of nucleophilic addition of the H^- ion to a carbonyl group, allows attack of the planar carbonyl group, in N, from either side of the plane to form a mixture of two stereoisomers.

Many answers suggested that the $NaBH_4$ reduced both the keto and carboxylic acid groups to form different products. Several candidates also considered the reaction to involve secondary or tertiary carbocation intermediates, which would generate different products.

© 2022

www.dynamicpapers.com

(iv) The removal of a water molecule from a reaction involving 5-hydroxyhexanoic acid **l**eads to a lactone, a cyclic ester, by the method outlined if equation **1**, in the stem of the question:



Candidates found the lactone difficult to draw. A common mistake was to omit the methyl branch from the ring structure or place it at an incorrect position on the six-membered ring. Other errors included ring structures with an incorrect number of carbon atoms.

(b) The keto-carboxylic acid, N, and the 5-hydroxyhexanoic acid are difficult to distinguish using infrared spectroscopy because of the similarity of the functional groups which will give similar absorptions in the infrared spectrum.

This question was not well answered with many answers containing vague statements regarding C-H, C-O and O-H bonds. Credit was given to answers that stated that that both molecules contained a C=O group and gave the correct the absorption range from a table of data given in the question.

(c) The question required the use of the data given in a table of the abundances of the M^+ and M + 1 peaks for *m/e*'s of 72 and 73, using the expression:

$\frac{M+}{M+1} = \frac{100}{n \times 1.1}$ to calculate n, the number of carbon atoms in lactone, Q.

The mass of this number of carbon atoms plus the mass of the two oxygen atoms, from the lactone, cyclic ester, can then be subtracted from 72 to give a molecular formula of $C_3H_4O_2$.

Some candidates were able to calculate the number of carbon atoms and then draw a correct structure. Many incorrectly gave non-cyclic structures or did not give any response to this question.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

Key messages

- Introductory notes are present in the quantitative and qualitative analysis sections. Candidates should be encouraged to read and apply them.
- Candidates should be encouraged to read the questions carefully to ensure they provide suitable responses.
- Candidates should be given the opportunity to discuss errors arising in the different methods and possible improvements to the method.
- When recording observations in qualitative analysis questions, candidates should ensure accuracy of description with respect to changes in colour and state.
- Supervisors should carry out and record all practical parts of the **qualitative** analysis question as well as all the practical parts of the quantitative analysis questions as stated in the Confidential Instructions.

General comments

Almost all candidates completed the paper in the time allocated.

Candidates should be advised to write their answers in black or dark blue ink as some answers in pencil were very difficult to decipher

In a few cases insufficient data was supplied for **Questions 1(a)** and **2(a)** as some Supervisors failed to record the essential readings needed.

Supervisors should record in their reports, the use of any chemicals supplied to candidates that differ from those specified in the Confidential Instructions otherwise their candidates may be disadvantaged. This also applies to the alternatives suggested by Cambridge International.

Centres should avoid using 4 decimal place balances as these are inappropriate for use in practical work at this level. The syllabus specifies the use of 2 dp balances as being suitable though 3 dp balances are also acceptable.

Comments on specific questions

Question 1

Most candidates appeared well-prepared for titration exercises. Their performance in the subsequent calculations however varied greatly.

A small minority of Supervisor results appeared inappropriate by comparison with those of the candidates in their centre. A candidate-derived mean was used when awarding accuracy marks in cases where candidate agreement varied greatly from that of the Supervisor.

(a) Most candidates gained at least 4 of the 7 marks available.
Some candidates omitted burette readings for the rough titre. It is acceptable for these to be included in the main table of results even though space is provided in the method for the values to be recorded.
Many candidates gained the mark for suitable headings and units though this tended to be centre-dependent.
Most candidates gave their burette readings to the expected #.#0 or #.#5.

© 2022

www.dynamicpapers.com

Most candidates gained at least 1 mark for accuracy with a small minority gaining all 3.

(b) Most candidates gained the mark for a suitable mean titre to use in their calculations. Some did not show working and some did not provide an answer correctly rounded to 2 decimal places (dp).

(c) (i) Candidates are expected to give their answers to 3 or 4 significant figures (sf) in calculations arising from most titration exercises. This mirrors the accuracy with which the solutions have been prepared and the precision of the apparatus used. Candidates should not ignore 'trailing zeros', for example, 2.6975×10^{-3} should be given as 2.70×10^{-3} and not 2.7×10^{-3}.

(ii) Almost all candidates were successful in calculating the amount of MnO_4^- in their mean titre.

(iii) While most candidates recognised their answer to **(c)(ii)** should be multiplied by 5/2 (from the mole ratio given in the equation) only the more able candidates gained the mark for correctly using the dilution factor given in the question.

(iv) Most candidates realised that they needed to use the 10.14 g given in the introduction to the question. An error carried forward from **(iii)** was credited.

(v) The error carried forward principle applied to **(v)** even though the appropriate use of the relative formula mass calculation from **(iv)** gave an incorrect identity for **M**.

(d) This mark was gained by only the most able. It was necessary to recognise that more H^+ was provided and that this allowed the reaction to proceed. It was insufficient merely to say that acid was added.

Question 2

A large majority of candidates performed well in the practical tasks set. While some gained most of the marks for the question others had problems with the calculations.

(a) Most candidates wrote all the required data in the results section.
Almost all calculated the mass of **FA 4** and the reduction in temperature correctly. The most common error was to give the thermometer readings as integers. Thermometers are calibrated at 1 ºC so should be read to ##.0 or ##.5.

(b) (i) The main errors seen were the use of the mass of solid, adding 273 to the change in temperature or giving the answer to 5 or more significant figures. Almost all candidates correctly used the value for the specific heat capacity of water given in the data section of page 15.

(ii) Whist most candidates correctly calculated the amount of $CuSO_4 \cdot 5H_2O$ some used the relative molecular mass of the anhydrous compound or an incorrect relative molecular mass.

(iii) While many divided their answer to **(b)(i)** by **(b)(ii)** not all gave the correct sign in the answer.

(c) Many gained the mark by showing correct calculations and with the temperature rise in **(c)** being greater than the temperature fall in **(a)**.

(d) (i) Similar errors were seen as in **(b)(i).**

(ii) Answers based on the use of Hess's cycle or addition of relevant equations were accepted but it was necessary to show some working.

(e) This part was only answered correctly by the most able candidates. Most merely made vague statements about the apparatus or the method being similar.

Question 3

Candidates found parts of this question the very challenging. The introduction to the Qualitative analysis question gives a useful prompt on how to detail observations and what further tests may be necessary.

© 2022

www.dynamicpapers.com

(a) (i) Test 1

Most candidates stated that a white precipitate was formed and many went on to say that the precipitate was soluble in excess sodium hydroxide. Very few gave the observation that heating the resultant solution had no effect.

Test 2

For this mark it was necessary to note the effervescence **and** the identity of or a test for ammonia.

Test 3

Many candidates reported the formation of a coloured solution but a precipitate was not accepted.

(ii)/(iii) Many candidates correctly identified the two cations and also suggested a test to distinguish between them.

(iv)/(v) These parts however were much less well answered. Nitrate, nitrite, bromide or iodide were accepted and many chose the addition of potassium manganate(VII) to distinguish between them. Some confusion was evident since this reagent will react with halides and nitrite.

(b)(i), (ii) and (iii)

Possibly because there is little information in the notes in the question paper these parts were very poorly answered.

Many seemed to realise that the 'no change' result in **Test 1** had some significance with respect to −OH but a number stated it showed that −OH was present.

Very few candidates apparently recognised the triiodomethane reaction as **Test 2** and although some reported the decolouration of potassium manganate(Vll) in **Test 3** few deduced the group/groups present.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key messages

Introductory notes are present in the quantitative and qualitative analysis sections. Candidates should be encouraged to read and apply them.

Candidates should be encouraged to read the questions carefully to ensure they provide suitable responses.

Candidates should be given the opportunity to discuss errors arising in the different methods and possible improvements for these.

When recording observations in qualitative analysis questions candidates should ensure accuracy of description with respect to changes in colour and state.

Supervisors should carry out and record all practical parts of the qualitative analysis question as well as all the practical parts of the quantitative analysis questions as given in the Confidential Instructions.

General comments

Almost all candidates completed the paper in the time allowed.

Candidates should be encouraged to write answers in black or dark blue ink as some answers in pencil were very difficult to decipher.

In a small number of cases, insufficient data was supplied for **Questions 1(a)** and **2(a)** as some Supervisors failed to record the essential readings needed.

A small number of centres supplied candidates with iron(II) ammonium sulfate for **Question 3(a)** instead of iron(III). If centres cannot supply the appropriate chemicals they should follow the instructions given in the current syllabus and contact Cambridge International for acceptable alternatives.

Supervisors should record in their reports the use of any chemicals supplied to candidates that differ from those specified in the Confidential Instructions otherwise their candidates may be disadvantaged. This also applies to the alternatives suggested by Cambridge International.

Centres should avoid using 4 decimal place balances as these are inappropriate for use in practical work at this level. The syllabus specifies the use of 2 dp balances as being suitable though 3 dp balances are also acceptable.

Comments on specific questions

Question 1

Most candidates appeared well-prepared for titration exercises. Their performance in the subsequent calculations varied. The section that caused the most problems was in identifying the effect of errors and in assumptions made when calculating the percentage by mass of iron in **FA 1**.

© 2022

www.dynamicpapers.com

(a) Almost all candidates gained the mark for recording the balance readings and the mass of **FA 1** used to make solution **FA 4**.
Some candidates omitted burette readings for the rough titre. It is acceptable for these to be included in the main table of results even though space is provided in the method for the values to be recorded.
Many candidates gained the mark for suitable headings and units though this tended to be centre-dependent.
Most candidates gave their burette readings to the expected #.#0 or #.#5.
Due to candidates having to prepare their own solution for titration the boundaries for the accuracy marks were more generous than usual. Most candidates gained at least 1 mark for accuracy with a minority gaining all 3. Some Supervisors' results differed considerably from those of their candidates and allowance for this was made where possible.

(b) Most candidates gained the mark for a suitable mean titre to use in their calculations. Some did not show working and some did not provide an answer correctly rounded to 2 decimal places (dp).

(c) (i) Candidates are expected to give their answers to 3 or 4 significant figures (sf) in calculations arising from most titration exercises. This mirrors the accuracy with which the solutions have been prepared and the precision of the apparatus used. Candidates should not ignore 'trailing zeros', for example, 2.6975×10^{-3} should be given as 2.70×10^{-3} and not 2.7×10^{-3}.

(ii) Almost all candidates were successful in calculating the amount of $KMnO_4$ in their mean titre.

(iii) Almost all candidates used the stoichiometry of the equation correctly to calculate the amount of Fe^{2+} in $25\,cm^3$ of **FA 4**. However, the question required the amount of Fe^{2+} in **FA 1** and few candidates multiplied by 10 to find the amount of Fe^{2+} in the weighed sample.

(iv) Most candidates used their answer to **(c)(iii)** and 55.8 correctly, often from an error carried forward (ecf), and many gained both marks.

(d) Answers such as 'it would give the wrong mass' lacked the necessary detail. The apparent increase in mass of **FA 1** had to be linked to a decreased percentage of Fe^{2+} calculated.

(e) Few candidates gained both marks for this question and many did not score either mark. Some of the answers were inappropriate such as 'the A_r values were correct' or 'the end-point was reached in the titration'. Few considered that some of the iron could have been present as Fe^{3+} or that **FA 1** may have contained impurities which could be oxidised by the acidified aqueous potassium manganate(VII).

Question 2

A few Centres did not provide their candidates with Bunsen burners or gas burners for this gravimetric exercise. As stated in the current syllabus spirit burners are not suitable as the flame temperature is too low to drive off water or carbon dioxide from many of the compounds that are used in these exercises.

(a) Most candidates gave all the data in the space provided. T
The main error in the headings was to refer to the mass of residue as '**FA 5** after heating'. **FA 5** is the pure hydrated salt and heating should have driven off all the water.
Almost all candidates were consistent in the decimal place recorded for their balance readings.
Some confused the mass of **FA 5** used with the mass of residue and more confused the mass of water driven off with the mass of residue.
There was generally good agreement in the ratio of mass of **FA 5**/mass of H_2O and most gained at least 1 mark for accuracy.

(b) (i) The majority of candidates gained this mark though a few gave the answer to an inappropriate number of significant figures.

(ii) Fewer candidates were successful in this part. One error was to ignore the mole ratio of water to Mg**X** given in the question. Some incorrectly calculated the ratio of mass of residue/mass of **FA 5**.

(c) Some candidates did not read the question sufficiently carefully as they answered along the lines of how to improve the accuracy of the procedure or suggested that **FA 5** contained impurities. The

© 2022

www.dynamicpapers.com

correct assumption seen most frequently was that all the water was lost on heating. More able candidates also suggested that the residue was assumed to be thermally stable.

Question 3

Candidates were awarded a wide range of marks in this question though few scored all the marks available. Some candidates would have benefitted from consulting the Qualitative analysis notes given on pages 14 and 15 of the paper. Correct terminology was required for full marks to be available.

(a) (i) Almost all candidates correctly selected aqueous sodium hydroxide as a suitable reagent. Most correctly reported a red-brown precipitate with many adding that the ppt was insoluble in excess reagent. Far fewer continued by warming this mixture and testing the gas evolved with (damp) red litmus paper. As the ppt formed with NaOH(aq) indicated the presence of Fe^{3+}(aq) in **FA 6** there was no need to test the solution with aqueous ammonia. Some candidates incorrectly claimed a differently coloured ppt was formed with NH_3(aq): this contradicted the observation with NaOH(aq).

(ii) Most candidates noted that **FA 6** contained either the sulfate ion or the sulfite ion so selected either an aqueous barium salt or acidified aqueous potassium manganate(VII). Those writing Ba^{2+}, $BaCl$ or $BaNO_3$ could not be credited as the salt had to be named or a correct formula given. A minority of candidates selected sulfuric acid to add to the white ppt formed with their chosen barium compound. This was not appropriate given they were testing for SO_4^{2-} or SO_3^{2-} ions.

(iii) Many candidates were able to identify Fe^{3+} and SO_4^{2-} as they had some evidence for each ion. Far fewer identified NH_4^+ though some claimed it was present even though no relevant test had been attempted so could not be credited.

(b) Very few candidates gained both marks in this part. In Test 1 the colour of the solution should have changed from pale yellow to a shade of red. The complex formed with the sulfite is broken down by the addition of acid and the diluted Fe^{3+}(aq) should have appeared pale yellow again or colourless owing to dilution. At no point in this test should a ppt have been observed. In Test 2 few noted the pale yellow solution became a darker yellow on addition of the KI(aq). Again, no ppt should have been observed. Most candidates correctly reported a blue-black colouration when starch solution was added.

(c) (i) As candidates were informed that the anions present were carbonate, chloride and bromide it would have helped some to add $AgNO_3$(aq) to each of **FA 7**, **FA 8** and **FA 9** alongside each other and then compare colours of ppts. 'Milky solution' is not acceptable for 'white ppt'. 'The solution is clear' on adding NH_3(aq) does not indicate the solubility of the ppt formed. However, there were many candidates who achieved all 3 marks for this part.

(ii) Successful candidates tested 1, 2 or all 3 of the solutions with a named dilute acid and noted effervescence with **FA 8**. 'Gas produced' is not an observation so could not be credited. Centres should note that describing the white ppt formed with limewater as 'milky' or 'cloudy white' is no longer credited. Other valid tests such as using aqueous barium chloride or barium nitrate were also awarded the mark for a white ppt forming with **FA 8**. Those who had positively identified the anions in **(c)(i)** could have written 'No further test is necessary.' or words to that effect.

(iii) Many candidates were successful in this part. However, some could not match their conclusions to their observations in **(c)(i)** and **(c)(ii)**.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key messages

- Introductory notes are present in the quantitative and qualitative analysis sections. Candidates should be encouraged to read and apply them.
- Candidates should be encouraged to read the questions carefully to ensure they provide appropriate responses.
- When recording observations in qualitative analysis questions candidates should ensure accuracy of description with respect to changes in colour and state.
- Supervisors should carry out and record all practical parts of the **qualitative** analysis question as well as all the practical parts of the quantitative analysis questions as stated in the Confidential Instructions.

General comments

Almost all candidates completed the paper in the time allocated.

Candidates should be advised to write their answers in black or dark blue ink as some answers in pencil were very difficult to decipher.

In a few cases insufficient data was supplied for **Questions 1(a)** and **2(a)** as some Supervisors failed to record the essential readings needed.

Supervisors should record in their Reports the use of any chemicals or equipment supplied to candidates that differ from those specified in the Confidential Instructions.

A small number of centres appeared to use balances reading to only 1 decimal place (dp) which may disadvantage candidates. Centres should also avoid using 4 dp balances as these are inappropriate for use in practical work at this level. The syllabus specifies the use of 2 dp balances as being suitable though 3 dp balances are also acceptable.

For **Question 1**, the results for a small number of candidates either showed an increase in temperature throughout the 9 minutes or reported a very small temperature change on adding **FB 2**. In such cases, allowances may be made when awarding marks for accuracy but it is essential that the Supervisor provides a full set of results and comments on any difficulties in the Supervisor Report.

Comments on specific questions

Question 1

Almost all candidates successfully completed the experiment, plotted a graph of their results and attempted at least the first parts of the calculation.

(a) Most candidates scored at least 1 of the 2 accuracy marks.
A sizable minority of candidates did not record thermometer readings to .0 and .5 °C.
A very small number of candidates did not read the instructions and added zinc at time = 0 minutes.

(b) (i) Most candidates labelled the axes but some did not include units. Not all candidates considered their scales carefully: some started the *y*-axis scale at 0 which usually meant that they did not score

© 2022

www.dynamicpapers.com

the mark for appropriate scale as their plotted points did not cover more than half the available length. Other candidates did not allow for the extra 5 ºC.

(ii) Many candidates were able to draw the 3 lines required successfully. Some gave the temperature at the point of intersection of the lines rather than the temperature difference. Others did not report the temperature rise with sufficient precision (1 dp).

(c) (i) The vast majority of candidates successfully answered this question.

(ii) Whilst correct calculations were often seen, some candidates did not compare the moles of zinc with the moles of Cu^{2+}.

(iii) A large minority of candidates failed to score this mark, usually by using the mass of zinc instead of the volume of solution. The density of solutions is always taken as 1.0 g cm^{-3} in practical papers unless otherwise specified.

(iv) Only a small number of candidates gained this mark. The errors made include failing to covert to kJ, omitting or giving the wrong sign and using too many significant figures.

(d) Candidates found this question extremely challenging and only a very few were able to gain both marks. A substantial number of candidates gained one mark for ticking the correct box and attempting an explanation even if it was not fully correct.

Question 2

It appeared that a few centres did not provide their candidates with Bunsen burners or gas burners for this gravimetric exercise. As stated in the current syllabus spirit burners are not suitable as the flame temperature is too low to drive off water or carbon dioxide from many of the compounds that are used in these exercises.

(a) Most candidates gave all the data in the space provided.
The main error in the headings was to refer to the mass of residue as 'mass of **FB 3** after heating' rather than as 'mass of residue' or 'mass of contents after heating.'
Almost all candidates were consistent in the dp recorded for their balance readings. Some confused mass of carbon dioxide driven off with the mass of residue. Almost all candidates weighed out the correct mass of **FB 3**.
There was good agreement in the ratio of mass of **FB 3**/mass of residue and most candidates gained at least 1 mark for accuracy.
A few candidates recorded impossible balance readings, e.g. an increase in mass after heating, and need to consider their experimental data carefully before continuing with a question.

(b) (i) The majority of candidates gained this mark by a correct calculation including clearly showing their use of the correct formula mass for copper(II) oxide.

(ii) There was more than once approach to answering the second part of this question and answers which gave the amount of CO_2 as equal to amount of CuO calculated in **(b)(i)** or the correctly calculated moles of $CuCO_3$ were credited.

(iii) Fewer candidates scored this mark as they did not follow the instruction to use their answers to **(b)(i)** and **(b)(ii)**. Others incorrectly added the numbers of moles of CuO and CO_2 together. Candidates who used mole ratios to answer the second part of **(b)(ii)** were often unable to score this mark.

(c) This proved to be a very demanding question, even though basic carbonates have often featured in gravimetric questions on these papers in the past.

(d) (i) Most candidates were aware that they needed to heat again, however, many failed to state that they were looking for a constant mass after heating to show that the reaction was complete.

(ii) Very few candidates gained both marks here. Writing 'acid' alone is not enough to gain a mark: a reagent must be fully named or the correct formula given. A large number of candidates chose to use limewater but this would not indicate whether **FB 3** had decomposed completely without first adding acid. Of the many candidates who reported whether the residue fizzed with acid, far fewer

© 2022

www.dynamicpapers.com

offered a suitable conclusion so could not be awarded the second mark. Centres are reminded that 'white precipitate' with lime water is now the only observation which is credited as a positive test for carbon dioxide.

Question 3

Candidates were awarded a wide range of marks in this question though very few, if any, scored all the marks available. Some candidates would have benefitted from consulting the Qualitative analysis notes given on pages 14 and 15 of the paper.

(a) (i) Marks for this question part were poor. In **Test 1**, most candidates failed to record the two stages of observation with ammonia, even though these are clearly stated in the Qualitative analysis notes. When adding EDTA in **Test 2**, observations were not precise enough and the slight darkening of colour was rarely noticed. Many candidates incorrectly recorded a precipitate with NaOH, perhaps because they used too much alkali having not read the instructions carefully enough. Only strong candidates reported the correct precipitate colour at the end of the sequence. **Test 3** observations were more accurate but few candidates recorded the change in colour of the solution.

(ii) The question required candidates to record their observations 'in a suitable form' and a simple table was expected. Most candidates did report their results in a table but a few failed to provide suitable headings. Most candidates correctly used a barium salt but some did not specify nitrate or chloride. Some candidates did not carry out a test to distinguish between sulfate and sulfite ions.

(iii) The majority of candidates gained this mark.

(iv) This mark was rarely awarded. Even when formulae were correct, errors in state symbols were common.

(b) (i)(ii) These question parts were often answered successfully but with a minority gaining all 4 marks. Some candidates reported a brown precipitate in **Test 1**, which was not awarded a mark, and may suggest that insufficient ammonia was added when preparing the Tollens' solution. Candidates are advised to read instructions very carefully.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key messages

- Introductory notes are present in the quantitative and qualitative analysis sections. Candidates should be encouraged to read and apply them.
- Candidates should be encouraged to read the questions carefully to ensure they provide suitable responses.
- Candidates should be given the opportunity to discuss errors arising in the different methods and possible improvements to the method.
- When recording observations in qualitative analysis questions, candidates should ensure accuracy of description with respect to changes in colour and state.
- Supervisors should carry out and record all practical parts of the **qualitative** analysis question as well as all the practical parts of the quantitative analysis questions as stated in the Confidential Instructions.

General comments

Almost all candidates completed the paper in the time allocated.

Candidates should be advised to write their answers in black or dark blue ink as some answers in pencil were very difficult to decipher

In a few cases insufficient data was supplied for **Questions 1(a)** and **2(a)** as some Supervisors failed to record the essential readings needed.

Supervisors should record in their reports, the use of any chemicals supplied to candidates that differ from those specified in the Confidential Instructions otherwise their candidates may be disadvantaged. This also applies to the alternatives suggested by Cambridge International.

Centres should avoid using 4 decimal place balances as these are inappropriate for use in practical work at this level. The syllabus specifies the use of 2 dp balances as being suitable though 3 dp balances are also acceptable.

Comments on specific questions

Question 1

Most candidates appeared well-prepared for titration exercises. Their performance in the subsequent calculations however varied greatly.

A small minority of Supervisor results appeared inappropriate by comparison with those of the candidates in their centre. A candidate-derived mean was used when awarding accuracy marks in cases where candidate agreement varied greatly from that of the Supervisor.

(a) Most candidates gained at least 4 of the 7 marks available.
Some candidates omitted burette readings for the rough titre. It is acceptable for these to be included in the main table of results even though space is provided in the method for the values to be recorded.
Many candidates gained the mark for suitable headings and units though this tended to be centre-dependent.
Most candidates gave their burette readings to the expected #.#0 or #.#5.

© 2022

www.dynamicpapers.com

Most candidates gained at least 1 mark for accuracy with a small minority gaining all 3.

(b) Most candidates gained the mark for a suitable mean titre to use in their calculations. Some did not show working and some did not provide an answer correctly rounded to 2 decimal places (dp).

(c) (i) Candidates are expected to give their answers to 3 or 4 significant figures (sf) in calculations arising from most titration exercises. This mirrors the accuracy with which the solutions have been prepared and the precision of the apparatus used. Candidates should not ignore 'trailing zeros', for example, 2.6975×10^{-3} should be given as 2.70×10^{-3} and not 2.7×10^{-3}.

(ii) Almost all candidates were successful in calculating the amount of MnO_4^- in their mean titre.

(iii) While most candidates recognised their answer to **(c)(ii)** should be multiplied by 5/2 (from the mole ratio given in the equation) only the more able candidates gained the mark for correctly using the dilution factor given in the question.

(iv) Most candidates realised that they needed to use the 10.14 g given in the introduction to the question. An error carried forward from **(iii)** was credited.

(v) The error carried forward principle applied to **(v)** even though the appropriate use of the relative formula mass calculation from **(iv)** gave an incorrect identity for **M**.

(d) This mark was gained by only the most able. It was necessary to recognise that more H^+ was provided and that this allowed the reaction to proceed. It was insufficient merely to say that acid was added.

Question 2

A large majority of candidates performed well in the practical tasks set. While some gained most of the marks for the question others had problems with the calculations.

(a) Most candidates wrote all the required data in the results section.
Almost all calculated the mass of **FA 4** and the reduction in temperature correctly. The most common error was to give the thermometer readings as integers. Thermometers are calibrated at 1 ºC so should be read to ##.0 or ##.5.

(b) (i) The main errors seen were the use of the mass of solid, adding 273 to the change in temperature or giving the answer to 5 or more significant figures. Almost all candidates correctly used the value for the specific heat capacity of water given in the data section of page 15.

(ii) Whist most candidates correctly calculated the amount of $CuSO_4 \cdot 5H_2O$ some used the relative molecular mass of the anhydrous compound or an incorrect relative molecular mass.

(iii) While many divided their answer to **(b)(i)** by **(b)(ii)** not all gave the correct sign in the answer.

(c) Many gained the mark by showing correct calculations and with the temperature rise in **(c)** being greater than the temperature fall in **(a)**.

(d) (i) Similar errors were seen as in **(b)(i).**

(ii) Answers based on the use of Hess's cycle or addition of relevant equations were accepted but it was necessary to show some working.

(e) This part was only answered correctly by the most able candidates. Most merely made vague statements about the apparatus or the method being similar.

Question 3

Candidates found parts of this question the very challenging. The introduction to the Qualitative analysis question gives a useful prompt on how to detail observations and what further tests may be necessary.

© 2022

www.dynamicpapers.com

(a) (i) Test 1

Most candidates stated that a white precipitate was formed and many went on to say that the precipitate was soluble in excess sodium hydroxide. Very few gave the observation that heating the resultant solution had no effect.

Test 2

For this mark it was necessary to note the effervescence **and** the identity of or a test for ammonia.

Test 3

Many candidates reported the formation of a coloured solution but a precipitate was not accepted.

(ii)/(iii) Many candidates correctly identified the two cations and also suggested a test to distinguish between them.

(iv)/(v) These parts however were much less well answered. Nitrate, nitrite, bromide or iodide were accepted and many chose the addition of potassium manganate(VII) to distinguish between them. Some confusion was evident since this reagent will react with halides and nitrite.

(b)(i), (ii) and (iii)

Possibly because there is little information in the notes in the question paper these parts were very poorly answered.

Many seemed to realise that the 'no change' result in **Test 1** had some significance with respect to −OH but a number stated it showed that −OH was present.

Very few candidates apparently recognised the triiodomethane reaction as **Test 2** and although some reported the decolouration of potassium manganate(Vll) in **Test 3** few deduced the group/groups present.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/36
Advanced Practical Skills 2

Key messages

- Introductory notes are present in the quantitative and qualitative analysis sections. Candidates should be encouraged to read and apply them.
- Candidates should be encouraged to read the questions carefully to ensure they provide suitable responses.
- Candidates should be given the opportunity to discuss errors arising in the different methods and possible improvements to the method.
- When recording observations in qualitative analysis questions candidates should ensure accuracy of description with respect to changes in colour and state.
- Supervisors should carry out and record all practical parts of the **qualitative** analysis question as well as all the practical parts of the quantitative analysis questions as given in the Confidential Instructions.

General comments

Almost all candidates completed the paper in the time allowed.

Candidates should be encouraged to write answers in black or dark blue ink as some answers in pencil were very difficult to decipher.

In a small number of cases, insufficient data was supplied for **Questions 1(a)** and **2(a)** as some Supervisors failed to record the essential readings needed.

Supervisors should record in their reports the use of any chemicals supplied to candidates that differ from those specified in the Confidential Instructions otherwise their candidates may be disadvantaged. This also applies to the alternatives suggested by Cambridge International.

Centres should avoid using 4 decimal place balances as these are inappropriate for use in practical work at this level. The syllabus specifies the use of 2 dp balances as being suitable though 3 dp balances are also acceptable.

Comments on specific questions

Question 1

Most candidates appeared well-prepared for titration exercises. Their performance in the subsequent calculation varied markedly. The section causing most problems was in identifying the effect of errors on the titre and how to rectify errors that have been made. Some Supervisor results differed appreciably from those of their candidates. In this case a candidate-derived mean was used when awarding accuracy marks in cases of candidate agreement.

(a) Most candidates gained at least 4 of the 7 marks available.
Some candidates omitted burette readings for the rough titre. It is acceptable for these to be included in the main table of results even though space is provided in the method for the values to be recorded.
Many candidates gained the mark for suitable headings and units though this tended to be centre-dependent.
Most candidates gave their burette readings to the expected #.#0 or #.#5.
Most candidates gained at least 1 mark for accuracy with a minority gaining all 3.

© 2022

www.dynamicpapers.com

(b) Most candidates gained the mark for a suitable mean titre to use in their calculations. Some did not show working and some did not provide an answer correctly rounded to 2 decimal places (dp).

(c) (i) Candidates are expected to give their answers to 3 or 4 significant figures (sf) in calculations arising from most titration exercises. This mirrors the accuracy with which the solutions have been prepared and the precision of the apparatus used. Candidates should not ignore 'trailing zeros', for example, 2.6975×10^{-3} should be given as 2.70×10^{-3} and not 2.7×10^{-3}.

(ii) Almost all candidates were successful in calculating the amount of K_2CO_3 in their mean titre.

(iii) Many lost this mark through omitting state symbols or by including KC*l*(aq) as a product.

(iv) While most candidates recognised their answer to **(c)(ii)** should be multiplied by 2 (from the mole ratio given in the equation) far fewer used their mean titre calculated in **(b)**.

(v) Only the more able candidates gained the mark for correctly using the dilution factor given in the question. Some candidates attempted a restart but most of these neglected to use their mean titre value in the calculation.

(d) The majority of candidates correctly stated the titre would be smaller if the hydrated salt was used. However, not all went on to give a reason in terms of amount or concentration of K_2CO_3 in the 25.0 cm^3 pipetted.

(e) There were several ways of gaining this mark and all were seen. However, only the more able candidates were successful. Others realised that the volume of **FB 2** needed to be increased but failed to state by how much.

Question 2

A large majority of candidates performed well in the practical tasks set. Some candidates gained most of the marks for the question but others had problems with the calculations.

(a) Most candidates wrote all the required data in the results section.
Almost all calculated the mass of **FB 5** and the reduction in temperature correctly.
There was generally good agreement in the ratio of temperature change/mass of **FB 5** with many gaining both marks for accuracy.

(b) (i) The main errors seen were use of the mass of solid, adding 273 to the change in temperature or giving the answer to 5 or more sf. Almost all candidates correctly used the value for the specific heat capacity of water given in the data section on page 11.

(ii) This part was well-answered with most candidates gaining the mark.

(iii) While many divided their answer from **(b)(i)** by **(b)(ii)** not all gave the correct sign in the answer.

(c) Some candidates appeared to be confusing heat with temperature. The heat energy absorbed would be the same in both cases but the temperature change would be halved with double the volume. The errors arising in measuring this temperature change compared with that in **2(a)** far outweighed the errors in measuring the volumes. A few candidates gained the mark for the alternative answer involving acid spray.

(d) Many candidates gained all 3 marks.
The most common error was to give the thermometer readings as integers. Thermometers are calibrated at 1 ºC so should be read to ##.0 or ##.5.

(e) (i) Similar mistakes to **(b)(i)** were seen but some also omitted converting J to kJ. However, many of the candidates attempting this question gained at least 1 of the 2 marks available.

(ii) Candidates found this part difficult with many mistakenly subtracting **2(e)(ii)** from **2(b)(iii)**. The equation for the reaction was restated so that candidates could use downward arrows (or other methods) to keep track of their values and direction of change required.

© 2022

www.dynamicpapers.com

Question 3

Candidates found this question the most challenging. The introduction to the Qualitative analysis question gives a useful prompt on how to detail observations and what further tests may be necessary.

(a) (i) The change in colour of the reagent should have been reported but some candidates gave the original colour as that of **FB 7** which was colourless so could not access the mark.

(ii) Many candidates gained marks in this part. Common errors were to give incorrect formulae of the reagents, e.g. Ag^{+} and $BaNO_3$, or not to state which acid was used to differentiate between sulfate and sulfite ppts. Some candidates selected the use of sulfuric acid to add to the white ppt with the aqueous barium salt indicating a lack of understanding of the test. Other candidates mistakenly reused acidified aqueous potassium manganate(VII) even though **(a)(i)** had a positive outcome. The use of the latter meant incorrectly identifying one of the anions as SO_3^{2-}. Some candidates gave the colour of ppt with $AgNO_3$(aq) as white or yellow instead of off-white or cream and wrote Cl^{-} or I^{-}: the lack of solubility of the ppt in aqueous ammonia helped to eliminate the presence of a chloride ion.

(b) (i) While many candidates noted the change of colour to yellow when **FB 8** was heated not all gave the colour when cool again. Few noted the condensation at the mouth of the test-tube and very few attempted to test any gas being evolved with limewater. However, those who attempted the test in **(b)(ii)** were awarded the marks here. Centres should note that describing the white ppt formed with limewater as 'milky' or 'cloudy white' is no longer credited.

(ii) Nearly all candidates noted bubbling or effervescence, but few candidates gave more than one observation. A few candidates gained the mark by stating that the reaction was rapid. Gases should be identified by a suitable test and changes in state should be noted. Some candidates reported a white ppt suggesting they added more solid than specified and possibly did not understand that it was unreacted **FB 8** and not a precipitate.

(iii) Some candidates did not take the acidic nature of the solution tested into consideration so added insufficient aqueous ammonia to dissolve the white ppt. Some only tested with aqueous sodium hydroxide and then concluded the cation was Al^{3+}.

(iv) Although candidates were required to give the formula of **FB 8** some wrote Zn^{2+} instead of $ZnCO_3$.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/41
A Level Structured Questions

Key messages

- Candidates must ensure their handwriting is legible. Handwriting that is too small often becomes illegible.
- Candidates should never attempt to write over the top of a previous answer if they wish to change their answer. The original answer should be clearly crossed through, and a new answer should be written in available space.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- In organic reaction mechanisms, the starting and finishing points of curly arrows is a key part in the description of the mechanisms. Curly arrows should always start in a precise place and should be pointing towards a precise place.

General comments

The paper enabled candidates to demonstrate their knowledge and understanding of a wide range of chemistry topics.

Many candidates were able to work through to the end of the paper, suggesting they had sufficient time.

Comments on specific questions

Question 1

(a) This was generally well answered, many candidates correctly identified the species. The completion of the energy cycle was found to be more challenging.

(b) Candidates performed well on this question. Common errors included –2284 (only one Cl^- used) and –1610 (one sign error). Weaker candidates omitted –364 in their calculation and scored no credit.

(c) Many candidates were able to identify that Mg^{2+} has a greater ionic charge and smaller ionic radii or larger charge density. However, some did not clearly state that this would lead to greater attraction between the ions in $MgCl_2$.

(d) (i)(ii) This was generally answered well. Some definitions lacked precision and some candidates incorrectly suggested that the enthalpy of atomisation formed one mole of gaseous ions (instead of gaseous atoms) from its elements.

(e) (i) This definition was well known.

(ii) This was found to be difficult. Many candidates correctly stated that the entropy change was positive but did not give an adequate explanation. A common error was an explanation in terms of melting instead of dissolving.

(iii) Candidates often gave the correct answer here.

© 2022

www.dynamicpapers.com

Question 2

(a) (i) Most candidates gave the correct answer.

(ii) This proved difficult for candidates. Many were unable to recall the equations describing the mechanism for a Fe^{2+} catalysed reaction between iodide ions and peroxodisulfate ions.
equation 1 $S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$
equation 2 $2I^- + 2Fe^{3+} \rightarrow 2Fe^{2+} + I_2$

(iii) This was generally well answered.

(b) (i) Most candidates gave a correct answer. Use of [O] or [NO_2] were common errors.

(ii) This answer was usually correct.

(c) (i) This answer was usually correct.

(ii) Most candidates answered this question well. Weaker candidates were unable to recall the equation $t\frac{1}{2} = \ln 2 / k$ for use in this question.

(iii) Due to an issue with the final concentration of $Pt(NH_3)_2Cl_2$ given in this question, candidates were awarded the full two marks so they were not disadvantaged.

Question 3

(a) (i) This answer was usually correct.

(ii) Candidates generally answered this question well. Some common errors were:
- use of a Sn electrode instead of Pt in the Sn^{4+} / Sn^{2+} half-cell
- use of $H^+(aq)$ in the Sn^{4+} / Sn^{2+} half-cell
- use of $Sn^{4+}(aq)$ in one half-cell and $Sn^{2+}(aq)$ in the other half-cell.

(iii) This proved difficult for candidates. Some could use the electrode potentials to predict the feasibility of this redox reaction. However, some incorrectly combined the correct $E^\ominus$ values to give a positive E_{cell}.

(iv) Many candidates found it difficult to construct this equation. Error carried forward was given for an incorrect balanced redox equation involving Sn^{2+} and VO^{2+}.

(b) Many good answers were seen. Most candidates calculated the moles of Sn, but either did not convert to the moles of Al correctly or multiplied by the M_r of Al_2O_3.

Question 4

(a) (i) Most candidates answered this question well. Weaker candidates omitted to reference to an equilibrium.

(ii) Many correct answers were seen. Some errors included:
- 121.8 cm^3 (from 3.50 = (1.62 / V) ÷ (0.38 / 100)) or
- 66.5 cm^3 (from 3.50 = (2.00 / 100) ÷ (0.38 / V)).

(b) (i) Most candidates knew the definition in the syllabus. Some did not give a precise definition, stating the pH would remain unchanged or stay constant.

(ii) Many candidates found this question challenging. Some managed to identify an inorganic compound (normally NaOH) that could be added to butanoic acid to form a buffer. However, a correct organic compound was rare.

(c) (i) Most candidates gave a correct expression for the K_{sp}, of aluminium hydroxide.

(ii) This was answered well by many candidates. The commonest error was 3.72×10^{-35}.

© 2022

www.dynamicpapers.com

Question 5

(a) This question was generally well answered. A common error was drawing the lobes along two different axes in $3d_{xy}$.

(b) (i) Candidates performed well on this question. The splitting of d orbitals; the absorption of photons of visible light; the excitation of electrons and the observed colour being complementary to the colour absorbed were all described clearly. Some omitted the reason for the difference in colours of the complexes.

(ii) Many accurately drawn correct answers, using correct conventions for the three-dimensional bonds, were seen.

(iii) Candidates often gave the correct answer here.

(c) This was generally well answered. A common error was stating that Fe^{2+} had a smaller charge density or larger ionic radii.

(d) (i) This was not well known. Most candidates gave the colour change as purple to colourless.

(ii) Many candidates calculated the correct percentage by mass of iron. A common error was 2.98 (omitted $\times$ 5).

Question 6

(a) (i) This was generally well answered. Common errors were $[Cu(OH)_2(H_2O)_4]^{2+}$ and Na instead of $[Cu(OH)_2(H_2O)_4]$ and Na^+ respectfully.

(ii) Some good answers were seen but many gave equations that were unbalanced with charge, stating H_2 was formed instead of $4H^+$.

(b) (i) Candidates performed well on this question. Common errors included use of O_2H (for OH_2) or drawing the same isomer twice.

(ii) Most managed to identify the cis isomer as polar and the trans as non-polar.

(c) (i) This definition was generally well answered. Some did not identify *K*stab as an equilibrium constant.

(ii) Most candidates were able to identify that $[Cu(NH_3)_4(H_2O)_2]^{2+}$ is more stable and correctly explain in terms of its large K_{stab}.

(iii) Candidates often gave the correct answer here. Common errors included inclusion of $(H_2O)6$ or having the charge of the complex ion outside their outer brackets in their expression.

(iv) This answer was usually correct.

(d) Candidates had to write the formula of two unfamiliar complexes using the information. Some good answers were seen but common errors included $[Ru(C_{12}H_8N_2)_2(C_2O_4)_2]^-$, $[Ru(C_{12}H_8N_2)_2Cl_4]^{3+}$ and $[Fe(C_2O_4)_6]^{9-}$.

Question 7

(a) (i) Most candidates gave the correct answer.

(ii) This proved difficult for some candidates. Many were able to state the plane of polarised light would be rotated in both isomers. However, it was less well known that light would be rotated by **equal** amounts in **opposite** directions.

(b) (i) Candidates generally answered this question well. The commonest error was using ethanoic acid with water as the other product.

© 2022

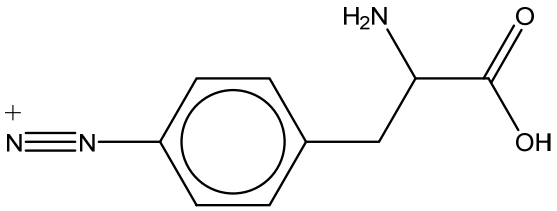
www.dynamicpapers.com

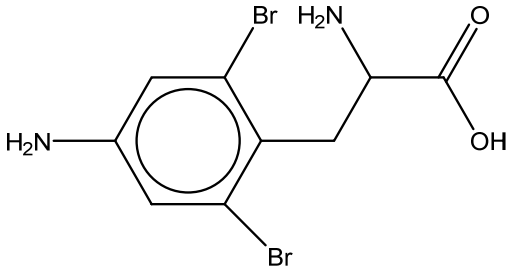
(ii) Most candidates were able to identify methanol as one of the products. The product from the reduction of the ester (to the primary alcohol) and the amide (to the secondary amine) were less frequently awarded.

(iii) Many candidates found this challenging. Answers were often not sufficiently detailed. For each substance a clear statement linked to the ability of the lone pair of electrons on the N to accept a proton was required. Many candidates recognised that the alkyl group is an electron donating group and the lone pair on the N of NH_2 is delocalised into the benzene ring. However, the relatively low basicity of amides was less well known. A common error was answers in terms of the N-H bond strength, a clear confusion with acidic strength.

(c) (i) Most candidates were able to identify the correct reagents and conditions.

(ii) This was generally answered well. The most common errors are shown.





(d) (i) This was generally answered well. However, some definitions omitted a reference to pH.

(ii) This proved difficult for many candidates. Common errors for this question included:
- omission of the identity of the repeat unit
- an incorrect linkage bond such as –COO–NH
- inclusion of a trivalent carbon or omitting a carbon atom.

Question 8

(a) Candidates often gave the correct answer here.

(b) (i) This question was usually fully credited.

(ii) Those who had learned the electrophilic substitution mechanism found this to be accessible. Common errors included:
- an incorrect structure of the intermediate – the partly delocalised ring should <u>not</u> include the sp^3 carbon, and positive charge should <u>not</u> be on the sp^3 carbon
- the curly arrow in the intermediate starting on the H <u>not</u> on the C-H bond
- no H^+ ion was shown at the end of the mechanism.

(c) (i) This mark was rarely scored here. Many candidates incorrectly suggested NaOH(aq) or NH_3(aq).

(ii) Many candidates gained credit by ecf from **(c)(i)** using an appropriate nucleophile in their equation.

(iii) Most candidates found this question difficult and did not give both points why chlorobenzene does not undergo hydrolysis.

Question 9

(a) (i) This was generally answered well. Most candidates identified a suitable substance for the mobile phase however the stationary phase was less well known.

(ii) This definition was well known.

(iii) Candidates performed well on this question. The mathematical approach using areas was more commonly seen.

© 2022

www.dynamicpapers.com

(b) Many candidates gained credit here. The most common error seen was stating that $CH_3CH_2CO_2CH_2CH_3$ would give 3 or 4 peaks.

(c) This was generally answered well. Many candidates correctly identified the correct number of peaks. However, fewer were able to state the splitting patterns that would be seen. Commonest error was stating a hextet (instead of a multiplet) would be seen.

(d)(i) This was usually answered well. Many identifying the correct structures of **D** and **E**. Two common errors are $CH_3CH_2CH_2CO_2CH_3$ (for D) and $CH_3CO_2CH(CH_3)_2$ (for E).

(ii)(iii) This proved difficult for many candidates. Many gave the correct reasoning but either they labelled the incorrect protons in their structures in **(d)(i)** or did not label the protons **F** for **(d)(ii)** / **G** for **(d)(iii)**.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/42
A Level Structured Questions

Key messages

Many candidates are still using general wordings and imprecise terminology.

Candidates must ensure their handwriting is legible. Handwriting that is too small often becomes illegible.

Candidates should never attempt to write over the top of a previous answer if they wish to change their answer. The original answer should be clearly crossed through and a new answer should be written in available space.

Chemical equations, ionic equations and half-equations should always be balanced for substances and charges.

In a calculation that involves two or more stages the full number should be left on the calculator after each stage. The final answer should be rounded to the appropriate number of significant figures.

The correct convention is needed when writing the formulae of substances. For example, Potassium manganate(VII) should be written $KMnO_4$ and not $kmno_4$, $KmNO_4$ or KMNo4.

General comments

The paper enabled candidates to demonstrate their knowledge of chemistry and their ability to apply that knowledge in new contexts. Many very good scripts, and a significant number of excellent ones, were seen, with precise and detailed answers that explained the chemistry well.

The majority of candidates were able to work through to the end of the paper, suggesting that they had sufficient time.

Comments on specific questions

Question 1

(a) Candidates who lost this mark usually omitted either ‘one mole’ or ‘gaseous ions’.

(b) Many candidates did not appreciate that one or both of the data values 121 and 364 had to be multiplied by two.

(c) Some candidates wrote about the difference between the Br and C*l* atoms without stating clearly that Br is an atom with a larger atomic radius.

(d) (i) It was important for candidates to state clearly that both changes involve dissolving (in water).

(ii) Some candidates lost marks by using incorrect data, e.g. their answer to **Question 1b**, others lost one mark by failing to divide by two, giving their final answer as –670.

(e) (i) Many imprecise answers were seen here. Many candidates did not state the key fact that gas molecules are used up in this reaction.

(ii) Candidates found this question to be very difficult. However, there were some excellent, clear answers which used the Gibbs equation as the basis for a logical explanation. A candidate who

© 2022

www.dynamicpapers.com

had stated in **Question 1(e) (i)** that the entropy change is negative should have stated here either that $T\Delta S$ becomes more negative, or that $-T\Delta S$ becomes more positive, as temperature increases.

Question 2

(a) (i) This question was usually answered correctly, although a minority of candidates used the concentrations of the products in their rate equation, and some used neither k nor 11500.

(ii) Correct rounding is important when performing calculations. We accepted answers rounded to 1.7×10^{-8} and 1.66×10^{-8} but not rounded to 1.6×10^{-8}.

(iii) This question was found to be difficult by many candidates. A reaction only has a constant half-life if it is overall first order. The reaction described is overall second order so it does not have a constant half-life.

(b) (i) This was generally answered correctly.

(ii) This was answered correctly by most candidates.

(iii) It is important for candidates to make it clear exactly which species they are referring to in different parts of their answer. The question included a chemical equation so that candidates could refer to substances by name or formula. This could have been used to write clear, unambiguous answers.

- The initial adsorption phase involves the **reactant**, N_2O, forming temporary bonds with the surface of the catalyst, Pt. Imprecise terms such as 'gas' did not score – there are three gases involved in this reaction as either the reactant or as one of the products.
- The bond weakening that occurs involves the bonds **within** the N_2O molecules, not bonds between N_2O molecules.
- The final desorption phase involves the **products**, N_2 and O_2, leaving the catalyst surface.

(iv) This mark was rarely awarded.

Question 3

(a) (i) Most candidates were able to make a good attempt at this question, the commonest errors were the use of 'cell' instead of 'electrode' or 'half-cell' and errors in units e.g. 101 Pa or 101 atm.

(ii) Many candidates gave a good answer. The commonest error was the omission of H^+. A minority of candidates were unable to draw an electrochemical cell.

(iii) This discriminated well.

(iv) Most candidates scored the mark here.

(v) This equation was produced correctly by many candidates.

(vi) This was found to be very difficult. Candidates' answers sometimes included an attempt to predict what happens to the E of $Mg^{2+} + 2e^- \rightleftharpoons Mg$ but without including a comment on the cell reaction as a whole.

It should be noted that there are **two** voltages that will be changed by the dilution, the E of $Mg^{2+} + 2e^- \rightleftharpoons Mg$ and the overall E_{cell}. It was very important for candidates' explanations to make it clear which voltage they were referring to. The dilution makes the E of $Mg^{2+} + 2e^- \rightleftharpoons Mg$ more negative but it makes the overall E_{cell} more positive.

(b) This calculation was usually performed well. A significant number of candidates lost one mark because their calculation was based on Mg^+ not Mg^{2+}.

Question 4

(a) (i) This was found to be difficult. A significant number of candidates lost the mark after writing $3^3 = 9$.

© 2022

www.dynamicpapers.com

(ii) This was found to be very difficult.

(iii) Most candidates scored the mark here.

(b) (i) Many candidates did not know this definition well. The majority of answers could just as well have applied to CH_3COOH and NH_3 – i.e. any acid and any base – rather than specifically describing a conjugate acid/conjugate base pair. However, it was pleasing to read a number of clear correct answers such as 'The difference between a conjugate acid and its conjugate base is a single proton'.

(ii) This discriminated well.

(iii) Some candidates did not appreciate that (HBrO) = 4×10^{-2} mol dm^{-3}. Others worked through the calculation using the method to find the pH of a strong acid and did not use the K_a expression.

(iv) This mark was rarely awarded. Many candidates failed to see that (HBrO) = (BrO^-) so pH = pK_a.

Question 5

(a) This discriminated well.

(b) (i) This was answered well.

(ii) Good answers included clear statements about the energies of the orbitals involved.

(iii) This was usually answered well, although marks were lost on many scripts for the use of imprecise language, such as 'energy gap', rather than a more precise phrase such as 'energy gap ΔE between split d-orbitals'

(c) (i) This mark was scored by many candidates.

(ii) Many poor diagrams were seen, including a large number of answers where the ethanedioate ion was monodentate. Ethanedioate is clearly described as bidentate at the start of **Question 7(c)**.

(iii) Many candidates knew that the isomerism shown would be optical and geometric. A small number of answers were seen in which the diagrams in **Question 7(c)(ii)** were perfect, and the isomeric pairs were correctly identified in **Question 7(c)(iii)**.

(d) Three marks were available here, it was pleasing to see many good, well explained answers that scored either two or three marks. However, it should be emphasised that many, quite detailed calculations, scored fewer marks because it was impossible to know what each step of the calculation actually meant. The following labels were very welcome.

- Moles of ethanedioate ions in 3.70 g =
- Moles of ethanedioate ions in 25.0 cm^3 of solution =
- Moles of manganate(VII) ions required for full oxidation =
- Volume of 0.0100 mol dm^{-3} $KMnO_4$ required =

These labels made it much easier to award marks on the scripts where they were seen.

(e) Some candidates answered as if they had been asked to describe the trend in stability of the nitrates of the Group 2 elements. Such answers could score a maximum of one mark. For two marks it was necessary to suggest Cu^{2+} has a smaller ionic radius than Ba^{2+}, and to explain the different polarising effects these two ions will have on the nitrate ions.

Question 6

(a) (i) Good answers showed an appreciation that the four states commonly encountered in practical chemistry are solid, liquid, gas and aqueous. In the situations described in the question the states are solid and aqueous.

© 2022

www.dynamicpapers.com

(a) (ii) and (a) (iii) Errors seen included:

- unbalanced equations, for example forgetting to include the displaced water ligands in the products
- species with incorrect charges, for example $CoCl_4^-$, or Na.

(b) (i) The candidates who scored the mark did so because they had learnt the precise wording required.

(ii) Although some excellent answers were seen some candidates are still failing to put ionic charges inside the last set of square brackets used. $[(Co(NH_3)_6)^{2+}]$ is correct, $[Co(NH_3)_6]^{2+}$ is incorrect, when used in a K_{stab} expression. This is because the terms in a K_{stab} expression are **concentration** terms.

(iii) This discriminated well.

(iv) Candidates scored this mark for a correct calculation using the K_{stab} they had written in **Question 6(b)(ii)**, providing they used all the data given in the question.

Question 7

(a) Many candidates scored the first mark for the order C-A-B.

The second mark was awarded less often, but many good explanations were seen of the effect of the electronegative chlorine atom in weakening the O–H bond, or stabilising the anion formed. This chlorine atom is present in C but not in A.

The third mark was rarely awarded. Many candidates wanted to describe the delocalisation of the lone pair on the phenol group of B into the benzene ring. However, this tends to make a phenol a stronger acid (when compared to an alcohol), but the explanation required here is why the phenol B is a **weaker** acid than the carboxylic acid A. A correct explanation for this relative acidity focuses on how the electronegative C=O group in the carboxylic acid weakens the O–H bond, or stabilises the anion formed.

(b) (i) This was answered well

(ii) This was answered well.

(iii) Answers here were highly varied. However, many excellent answers were seen. On some scripts the starting and finishing places of the curly arrows, and the directions of the curly arrows were not carefully drawn so marks were lost.

(iv) The reagent $KMnO_4$ was well known but many unbalanced equations were seen.

(v) This was generally answered well, although a significant proportion of candidates did not understand the importance of the directing effects of the $–CH_3$ and –COOH groups.

(c) (i) This discriminated well.

(ii) This discriminated well.

(iii) This question was found to be difficult by many candidates. The dye molecule Y was often wrongly shown with –N≡N– or without all necessary substituents on the two rings. The conditions should be alkaline and below 10 °C, otherwise the diazonium ion will react to form a phenol (as in **7(c)(ii)**) rather than couple to form dye molecule Y.

Question 8

(a) This question was found to be more difficult than was anticipated. The instruction was not read by all candidates and so C* was not labelled on many scripts.

© 2022

www.dynamicpapers.com

(b) (i) No data table was given because it was intended that candidates would base their deductions on the splitting patterns. R is the only compound that gives a singlet, quartet and triplet in addition to the aryl proton peak at $\delta = 7.2$.

(ii) It was good to see a clear and accurate explanation, in terms of no protons on neighbouring carbon atoms, on many scripts.

(c) (i) This discriminated well.

(ii) This discriminated well.

(d) This piece of factual recall was known by many candidates.

(e) A minority of candidates stated that the two spectra would be the same and gave a correct reason.

(f) Deciding which carbon atoms are in identical environments was found difficult by some candidates.

Question 9

(a) This question was found to be very difficult. It was hoped that candidates would start by considering pH 9.47. Since this is the isoelectric pH, the zwitterion should be drawn at this pH. We accepted either of the two $–NH_2$ groups could be protonated at pH 9.47. Candidates could then deduce that:

- at pH 12, a significantly more alkaline pH than 9.47, the zwitterion will have lost a proton, forming an ion with a single negative charge
- at pH 7, a significantly more acidic pH than 9.47, the zwitterion will have gained one or two protons, forming an ion with a single positive charge, or an ion with two positive charges.

(b) The mark for D was most frequently awarded. It was important for candidates to read the question carefully and to use the following information:

- E has an ester linkage, F does not
- E and F are isomers of each other.

(c) This was found to be difficult.

- The first structure should have two bromine atoms substituted for hydrogen atoms in the ring. These bromine atoms should be at the 2 and 6 positions relative to the –OH group. The instruction to ignore the directing effect of the other substituent was not always followed.
- The second structure should have both acidic protons neutralised by the alkali, producing one $–O^-Na^+$ group and one $–COO^-Na^+$ group. Candidates were allowed to omit the Na^+ ions providing the minus charges were shown i.e. $–O^-$ and $–COO^-$.
- The third structure should have one or two nitro groups substituted for hydrogen atoms in the ring at either or both the 2 and 6 positions relative to the –OH group.

(d) (i) Most candidates were able to make a reasonable attempt at this question but not all who did so scored the mark. Careful, accurate description was essential – for example the answer had to make it clear which distance is divided by which distance. Candidates who chose to sketch a labelled diagram at the bottom of the page made it easier for them to address this.

(iii This question was found to be difficult by many candidates. A lot of imprecise answers such as 'different solubility' were seen. The data that candidates were asked to explain shows that lysine has a much smaller R_f value than tyrosine. It was therefore possible to suggest that tyrosine is more soluble in the mobile phase, or that lysine is more attracted to the stationary phase.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/43
A Level Structured Questions

Key messages

- Candidates must ensure their handwriting is legible. Handwriting that is too small often becomes illegible.
- Candidates should never attempt to write over the top of a previous answer if they wish to change their answer. The original answer should be clearly crossed through, and a new answer should be written in available space.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- In organic reaction mechanisms, the starting and finishing points of curly arrows is a key part in the description of the mechanisms. Curly arrows should always start in a precise place and should be pointing towards a precise place.

General comments

The paper enabled candidates to demonstrate their knowledge and understanding of a wide range of chemistry topics.

Many candidates were able to work through to the end of the paper, suggesting they had sufficient time.

Comments on specific questions

Question 1

(a) This was generally well answered, many candidates correctly identified the species. The completion of the energy cycle was found to be more challenging.

(b) Candidates performed well on this question. Common errors included –2284 (only one Cl^- used) and –1610 (one sign error). Weaker candidates omitted –364 in their calculation and scored no credit.

(c) Many candidates were able to identify that Mg^{2+} has a greater ionic charge and smaller ionic radii or larger charge density. However, some did not clearly state that this would lead to greater attraction between the ions in $MgCl_2$.

(d) (i)(ii) This was generally answered well. Some definitions lacked precision and some candidates incorrectly suggested that the enthalpy of atomisation formed one mole of gaseous ions (instead of gaseous atoms) from its elements.

(e) (i) This definition was well known.

(ii) This was found to be difficult. Many candidates correctly stated that the entropy change was positive but did not give an adequate explanation. A common error was an explanation in terms of melting instead of dissolving.

(iii) Candidates often gave the correct answer here.

© 2022

www.dynamicpapers.com

Question 2

(a) (i) Most candidates gave the correct answer.

(ii) This proved difficult for candidates. Many were unable to recall the equations describing the mechanism for a Fe^{2+} catalysed reaction between iodide ions and peroxodisulfate ions.
equation 1 $S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$
equation 2 $2I^- + 2Fe^{3+} \rightarrow 2Fe^{2+} + I_2$

(iii) This was generally well answered.

(b) (i) Most candidates gave a correct answer. Use of [O] or [NO_2] were common errors.

(ii) This answer was usually correct.

(c) (i) This answer was usually correct.

(ii) Most candidates answered this question well. Weaker candidates were unable to recall the equation $t\frac{1}{2} = \ln 2 / k$ for use in this question.

(iii) Due to an issue with the final concentration of $Pt(NH_3)_2Cl_2$ given in this question, candidates were awarded the full two marks so they were not disadvantaged.

Question 3

(a) (i) This answer was usually correct.

(ii) Candidates generally answered this question well. Some common errors were:
- use of a Sn electrode instead of Pt in the Sn^{4+} / Sn^{2+} half-cell
- use of $H^+(aq)$ in the Sn^{4+} / Sn^{2+} half-cell
- use of $Sn^{4+}(aq)$ in one half-cell and $Sn^{2+}(aq)$ in the other half-cell.

(iii) This proved difficult for candidates. Some could use the electrode potentials to predict the feasibility of this redox reaction. However, some incorrectly combined the correct $E^\ominus$ values to give a positive E_{cell}.

(iv) Many candidates found it difficult to construct this equation. Error carried forward was given for an incorrect balanced redox equation involving Sn^{2+} and VO^{2+}.

(b) Many good answers were seen. Most candidates calculated the moles of Sn, but either did not convert to the moles of Al correctly or multiplied by the M_r of Al_2O_3.

Question 4

(a) (i) Most candidates answered this question well. Weaker candidates omitted to reference to an equilibrium.

(ii) Many correct answers were seen. Some errors included:
- 121.8 cm^3 (from 3.50 = (1.62 / V) ÷ (0.38 / 100)) or
- 66.5 cm^3 (from 3.50 = (2.00 / 100) ÷ (0.38 / V)).

(b) (i) Most candidates knew the definition in the syllabus. Some did not give a precise definition, stating the pH would remain unchanged or stay constant.

(ii) Many candidates found this question challenging. Some managed to identify an inorganic compound (normally NaOH) that could be added to butanoic acid to form a buffer. However, a correct organic compound was rare.

(c) (i) Most candidates gave a correct expression for the K_{sp}, of aluminium hydroxide.

(ii) This was answered well by many candidates. The commonest error was 3.72×10^{-35}.

© 2022

www.dynamicpapers.com

Question 5

(a) This question was generally well answered. A common error was drawing the lobes along two different axes in $3d_{xy}$.

(b) (i) Candidates performed well on this question. The splitting of d orbitals; the absorption of photons of visible light; the excitation of electrons and the observed colour being complementary to the colour absorbed were all described clearly. Some omitted the reason for the difference in colours of the complexes.

(ii) Many accurately drawn correct answers, using correct conventions for the three-dimensional bonds, were seen.

(iii) Candidates often gave the correct answer here.

(c) This was generally well answered. A common error was stating that Fe^{2+} had a smaller charge density or larger ionic radii.

(d) (i) This was not well known. Most candidates gave the colour change as purple to colourless.

(ii) Many candidates calculated the correct percentage by mass of iron. A common error was 2.98 (omitted $\times$ 5).

Question 6

(a) (i) This was generally well answered. Common errors were $[Cu(OH)_2(H_2O)_4]^{2+}$ and Na instead of $[Cu(OH)_2(H_2O)_4]$ and Na^+ respectfully.

(ii) Some good answers were seen but many gave equations that were unbalanced with charge, stating H_2 was formed instead of $4H^+$.

(b) (i) Candidates performed well on this question. Common errors included use of O_2H (for OH_2) or drawing the same isomer twice.

(ii) Most managed to identify the cis isomer as polar and the trans as non-polar.

(c) (i) This definition was generally well answered. Some did not identify *K*stab as an equilibrium constant.

(ii) Most candidates were able to identify that $[Cu(NH_3)_4(H_2O)_2]^{2+}$ is more stable and correctly explain in terms of its large K_{stab}.

(iii) Candidates often gave the correct answer here. Common errors included inclusion of $(H_2O)6$ or having the charge of the complex ion outside their outer brackets in their expression.

(iv) This answer was usually correct.

(d) Candidates had to write the formula of two unfamiliar complexes using the information. Some good answers were seen but common errors included $[Ru(C_{12}H_8N_2)_2(C_2O_4)_2]^-$, $[Ru(C_{12}H_8N_2)_2Cl_4]^{3+}$ and $[Fe(C_2O_4)_6]^{9-}$.

Question 7

(a) (i) Most candidates gave the correct answer.

(ii) This proved difficult for some candidates. Many were able to state the plane of polarised light would be rotated in both isomers. However, it was less well known that light would be rotated by **equal** amounts in **opposite** directions.

(b) (i) Candidates generally answered this question well. The commonest error was using ethanoic acid with water as the other product.

© 2022

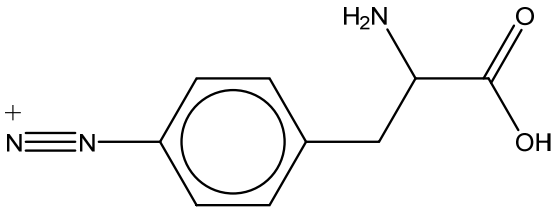
www.dynamicpapers.com

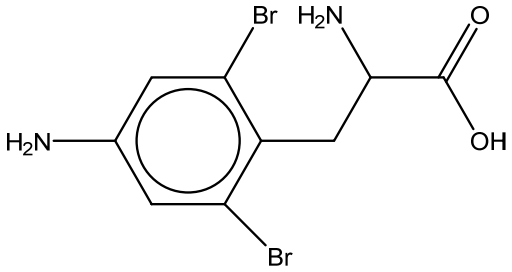
(ii) Most candidates were able to identify methanol as one of the products. The product from the reduction of the ester (to the primary alcohol) and the amide (to the secondary amine) were less frequently awarded.

(iii) Many candidates found this challenging. Answers were often not sufficiently detailed. For each substance a clear statement linked to the ability of the lone pair of electrons on the N to accept a proton was required. Many candidates recognised that the alkyl group is an electron donating group and the lone pair on the N of NH_2 is delocalised into the benzene ring. However, the relatively low basicity of amides was less well known. A common error was answers in terms of the N-H bond strength, a clear confusion with acidic strength.

(c) (i) Most candidates were able to identify the correct reagents and conditions.

(ii) This was generally answered well. The most common errors are shown.





(d) (i) This was generally answered well. However, some definitions omitted a reference to pH.

(ii) This proved difficult for many candidates. Common errors for this question included:
- omission of the identity of the repeat unit
- an incorrect linkage bond such as –COO–NH
- inclusion of a trivalent carbon or omitting a carbon atom.

Question 8

(a) Candidates often gave the correct answer here.

(b) (i) This question was usually fully credited.

(ii) Those who had learned the electrophilic substitution mechanism found this to be accessible. Common errors included:
- an incorrect structure of the intermediate – the partly delocalised ring should <u>not</u> include the sp^3 carbon, and positive charge should <u>not</u> be on the sp^3 carbon
- the curly arrow in the intermediate starting on the H <u>not</u> on the C-H bond
- no H^+ ion was shown at the end of the mechanism.

(c) (i) This mark was rarely scored here. Many candidates incorrectly suggested NaOH(aq) or NH_3(aq).

(ii) Many candidates gained credit by ecf from **(c)(i)** using an appropriate nucleophile in their equation.

(iii) Most candidates found this question difficult and did not give both points why chlorobenzene does not undergo hydrolysis.

Question 9

(a) (i) This was generally answered well. Most candidates identified a suitable substance for the mobile phase however the stationary phase was less well known.

(ii) This definition was well known.

(iii) Candidates performed well on this question. The mathematical approach using areas was more commonly seen.

© 2022

www.dynamicpapers.com

(b) Many candidates gained credit here. The most common error seen was stating that $CH_3CH_2CO_2CH_2CH_3$ would give 3 or 4 peaks.

(c) This was generally answered well. Many candidates correctly identified the correct number of peaks. However, fewer were able to state the splitting patterns that would be seen. Commonest error was stating a hextet (instead of a multiplet) would be seen.

(d)(i) This was usually answered well. Many identifying the correct structures of **D** and **E**. Two common errors are $CH_3CH_2CH_2CO_2CH_3$ (for D) and $CH_3CO_2CH(CH_3)_2$ (for E).

(ii)(iii) This proved difficult for many candidates. Many gave the correct reasoning but either they labelled the incorrect protons in their structures in **(d)(i)** or did not label the protons **F** for **(d)(ii)** / **G** for **(d)(iii)**.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

Key Messages

It is vital that candidates analyse the question carefully to determine the type of response required.

Candidates must demonstrate their understanding of reliability related to the specific experiment under examination in their response. General answers such as 'Repeat the experiment and average' are not worthy of a mark.

Use of appropriate vocabulary, terminology and conventions is key to good communication in science.

General comments

Many candidates produced well-structured responses, illustrating excellent understanding of the methods and concepts covered.

Comments on specific questions

Question 1

(a) (i) The majority of candidates successfully completed this calculation, clearly showing the two-steps of working involved. The most common incorrect answer (0.0159) was obtained by dividing the mass of the solid mixture by the relative formula mass of magnesium chloride.

(ii) This calculation was performed correctly by most candidates. A small, but significant number of candidates incorrectly used 1.5g (in place of 1.52g) in their calculation of percentage by mass.

Although the working shown by candidates for both parts of **1(a)** was clear, completion of each two-step calculation caused a number to struggle with the use of significant figures and rounding.

In a multi-step calculation involving multiplication or division, the number of significant figures in the final answer should equal the least number of significant figures in any of the data used; in this case three.

When carrying out multi-step calculations, it is recommended to keep at least one more significant figure in intermediate values than is needed in the final answer.

If intermediate values are rounded to only three figures and used in subsequent steps, information contained in the fourth figure is discarded so the ***third*** digit of the final answer might be incorrect.

(b) (i) Almost all candidates' responses to this question showed an excellent understanding of how the rate of dissolving could be increased. Some candidates, unnecessarily, gave more than one correct method. A small number suggested stirring or heating the solid, which was not credited.

(ii) Most candidates addressed the need to remove something from the precipitate and many identified magnesium nitrate and/or silver nitrate. More general descriptions, such as solid, substance, residue or impurities, needed to be qualified by 'soluble' in order to gain the mark. Other common responses included 'Increasing the purity of the precipitate.' which is too vague and 'To prevent further reaction.' which is not correct.

A few candidates misinterpreted the question and incorrectly suggested that the washing was to ensure that all the precipitate would be transferred.

© 2022

www.dynamicpapers.com

(iii) Careful examination of this question reveals that the candidate needed to explain why an oven is used (rather than a Bunsen burner), and key phrases such as 'to avoid' or 'to prevent' often began a credit worthy response. Thermal decomposition and melting of the precipitate were the predominant processes to be avoided. 'To ensure the precipitate dried uniformly' or 'The oven heats evenly' were common erroneous responses.

(c) (i) A great proportion of candidates included the full working required for this mark. The uncertainty in a balance reading is estimated as half the smallest scale division. i.e. ±0.005 g. The mass of the sample is calculated as the difference between two balance readings. Therefore, the absolute uncertainty in the mass of the sample is (2 × ±0.005 cm^3) = ±0.010 cm^3. In this case, the

percentage error = $\frac{2 \times 0.005}{1.52}$ × 100 = 0.658 per cent.

(ii) Most candidates understood the necessity to increase the mass of the sample of solid. A small number of candidates misinterpreted the question and suggested repeating the weighing, weighing by difference, or using a larger beaker.

A small number of candidates used 'weight' instead of 'mass' in their answer and therefore failed to gain the mark.

(iii) The principle of continuing to dry (in the oven) until the mass of the precipitate is constant was commonly described, particularly by high scoring candidates. Simply drying for a longer period without re-weighing would not confirm that the precipitate was completely dry. The use of an absorbent material, such as tissue or paper towel, to dry the precipitate was a popular incorrect response.

(d) There were some excellent explanations given for the increase of the calculated percentage mass of magnesium chloride. These followed the reasoning; the apparent mass and calculated amount of AgCl would increase, and, consequently, the amount and mass of $MgCl_2$ in the sample would appear larger.

A small number of candidates misinterpreted the question, citing the effect on percentage error in their response.

Question 2

(a) Candidates were informed that 'hydrogen peroxide is corrosive to skin', indicating that **chemical resistant** gloves are the most appropriate safety precaution. The protective nature of the gloves had to be specified to gain the mark.

(b) (i) Candidates are expected to be able to describe the arrangement of apparatus using labelled diagrams. Suitable diagrams should be neatly drawn using a ruler, fully labelled and follow the usual conventions for representing apparatus.

Most candidates achieved the first mark by drawing leak-proof apparatus capable of delivering a sample of gas collected over water. Extension of the delivery tube into the reaction vessel contents, failure to seal the reaction vessel, and passing the delivery tube through the side wall of the trough or the collection vessel were common mistakes.

The second mark was awarded for the collection of the gas in a correctly positioned and appropriate vessel. A small number of candidates used an unsuitable vessel, such as beaker, test-tube, boiling tube or an unidentifiable piece of apparatus, and did not gain this mark.

The use of a gas syringe is not a valid way to collect the oxygen gas over water.

(ii) This mark was awarded rarely. The reaction vessel and delivery tube are full of air when the reaction begins. Therefore, the first bubbles of gas produced would be air and should not be collected.

© 2022

www.dynamicpapers.com

Testing the gas using a glowing splint merely confirms the presence of oxygen. Use of a chemical filter to remove other gases would be ineffective as the oxygen produced by the reaction is pure. The use of a vacuum to remove air from the flask is impractical.

(c) (i) The data points plotted easily on the grid provided and were accurately located by all but a few candidates. The line of best fit, which should be a straight line passing as close to non-anomalous data points as possible with roughly the same number of points on each side of the line, was drawn well by most candidates. A significant number of candidates drew a straight line between the first and last points, which was clearly not a good line of best fit.

(ii) The selection and recording of co-ordinates from the line of best fit, and calculation of the gradient to 3 significant figures, was done very well in most cases. It was disappointing to see some candidates, who clearly knew how to complete the gradient calculation, losing one or both marks by:

- using table values, which did not fall on the line of best fit as co-ordinates
- using two points that were not more than half of the length of the axes apart
- not quoting the answer to three significant figures.

(d) (i) Nearly all candidates were able to identify the anomalous point.

(ii) Unfortunately, relatively few candidates were able to suggest a possible explanation for the anomaly identified in **(d)(i).**

A comparison of the 'actual value' with the 'recorded value' for either temperature **or** volume of oxygen was required. For example, 'The actual temperature was higher than the recorded temperature' **or** 'The actual volume of oxygen was lower than the recorded volume'. The vague assertion that a value was recorded too early or too late was not awarded a mark.

(e) (i) Identification of the independent variable was done correctly by nearly all candidates.

(ii) This question proved extremely difficult for candidates. Many candidates suggested the superficial 'repeat the experiment and find a mean' which is not worthy of credit. Repeating the experiment does not make it more reliable and this type of general answer must be avoided.

Candidates should think carefully about the requirements of the particular experiment under consideration. To make this experiment more reliable, it is necessary to take more volume measurements at various temperatures and use these to identify and eliminate anomalies.

(f) The stem of this question makes it clear that candidates must use the ideal gas equation in their answer. This means that their response must include an expression for the gradient of the graph derived from the ideal gas equation, as well as stating the effect of using a smaller initial volume of gas. Some candidates understood how and why the gradient changed and produced excellent answers, whilst others gave confused responses, including contradictions and omissions.

Question 3

(a) (i) Many candidates suggested stopping the clock when the first orange colour of bromine appears. Since bromine is produced almost instantaneously in this reaction, this does not offer an effective method of judging the end-point of the reaction.

The best approach is to use a method in which the time taken for the formation of a fixed amount of bromine is measured using an appropriate end-point.

This could be achieved by measuring the time taken for the intensity of the orange colour to reach a fixed value, using a colorimeter or light sensor. A suitable alternative is a 'clock reaction' using a small amount of a substance, such as phenol in this case, to remove the first fixed amount of bromine produced before the colour then appears (the end point). Description of a viable disappearing cross method was also credited.

(ii) The majority of candidates gained both marks here, reflecting their ability to use the experimental data to determine the order of reaction for each reactant.

© 2022

www.dynamicpapers.com

(b) Mixture A required a volume of 5.0 cm^3 to be measured. Volumetric apparatus must be used to achieve this level of precision, a burette being the most suitable. Some candidates suggested using a measuring cylinder, a beaker, a boiling tube or a test-tube, all of which lack the necessary precision.

(c) This question proved to be challenging for many candidates. This experiment is designed to examine the effect of changing the concentration of the reactants in turn. The temperature is a variable that needs to be controlled. Having different starting temperatures for individual mixtures would affect the rate of reaction.

(d) This question required candidates to describe making a solution of a particular concentration by dilution of a more concentrated solution.

The description of the procedure used for dilution of the 1 mol dm^{-3} sulfuric acid required for the first mark was largely well recalled. This standard procedure includes, using volumetric apparatus, for example a burette, to measure a known volume into a volumetric flask and then adding distilled water to make up to the graduation mark. The most common error in otherwise correct responses was failure to specify a suitable piece of apparatus to measure the specified volume of acid to be added to the volumetric flask.

A significant number of candidates described rinsing the burette (or indeed pipette) into the volumetric flask, which incorrect procedure would introduce unnecessary inaccuracy.

Fewer candidates gained the second mark by specifying both the volume of 1 mol dm^{-3} sulfuric acid to be used and the correct corresponding total volume of the diluted solution to be produced.

There were some excellent concise and precise answers which gained both marks such as:

'Use a burette to transfer 37.50 cm^3 of 1 mol dm^{-3} sulfuric acid into a 250 cm^3 volumetric flask and make up to the graduation mark with distilled water.'

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key messages

Candidates should read through the methodology of the experiment upon which the questions are based. Many candidates gave responses which suggested they had not appreciated the aim of the experiment being asked about.

Candidates need to be made aware that offering lists of answers beyond the number of responses asked for, will most likely incur a penalty if any of the additional answers are incorrect.

State and explain questions require a **statement** of the answer followed by an **explanation** of the answer.

General comments

In general, candidates were well prepared for this exam.

Centres should include as much practical work as possible during their course so that candidates are familiar with common experimental techniques and types of apparatus seen in this paper.

In calculation work, candidates should be encouraged to show full working. In multi-step calculations, candidates should avoid early rounding as this invariably produces an incorrect final answer.

Candidates should be aware of the need to use an appropriate number of significant figures in numerical answers even when a question does not specify an exact number of significant figures. One significant figure will usually be insufficient at A level.

Comments on specific questions

Question 1

(a) Although many candidates recognised the need to warm to a constant mass, many weaker candidates suggested using cobalt(II) chloride paper, dabbing with tissue paper and other similar methods.

(ii) The question asked candidates to state and to explain and many did not do both. The eggshell is made into a powder to increase its surface area, although a significant minority thought that it decreased it. The explanation was that this increases the rate of reaction.

Simply saying it made it dissolve/react 'more easily' was insufficient.

(iii) Here we were looking for the idea that the reaction between the calcium carbonate and the hydrochloric acid would go to completion. Answers that suggested that all the eggshell would have reacted/dissolved did not get the mark since the undissolved parts were filtered out later in the method.

(b) (i) Neary all candidates correctly subtracted initial burette readings from final burette readings but occasionally this answer was not given to the second decimal place. Only titres within 0.10 cm^3 of each other should be averaged to calculate a mean titre, a skill many were unaware of. Many candidates averaged all three titres, thus including non-concordant titres, and some even included the rough titre in their averaging.

© 2022

www.dynamicpapers.com

(ii) Although the idea of a back titration only applied to **(b)(iii)**, this seems to have confused many candidates here. The calculation of the number of moles of unreacted HCl in 25.0 cm^3 involved the use of the mean titre from **(b)(i)**. Many weaker candidates did not use the mean titre. Of those who did, only a minority were able to multiply their answer by 10 to obtain the number of moles in 250 cm^3.

(iii) This multi-step calculation involved calculating:

- the number of mol of HCl which had reacted by subtracting the answer to **(b)(ii)** from 0.200 mol, which was the total number of mol of HCl added to the eggshell
- the number of mol of $CaCO_3$ in the eggshell (which was half of the number of mol of HCl which had reacted)
- the mass of $CaCO_3$ in the eggshell by multiplying the mol by 100.1
- the mass of $CaCO_3$ as a percentage of the total mass of the eggshell by dividing by 2.136.

More able candidates scored all three marks.

Common errors included:

- failing to subtract the answer to **(b)(ii)** from 0.200 and using the answer to **(b)(ii)** in step 2 which subsequently led to a percentage greater than 100 in the final answer
- early rounding leading to an incorrect final answer
- using 100 as the molar mass of $CaCO_3$.

(c) Nearly all candidates realised that a (25.00 cm^3 volumetric) pipette was needed, although a burette was also accepted.

(d) Most candidates clearly showed how they derive their answer. If the mass was 2.136g then the balance must have intervals of 0.001g. A 3 decimal place balance may have a maximum error of 0.0005g. Furthermore, there needs to be two readings made so the expected working was:

$$\frac{(0.0005 \times 2)}{2.136} \times 100$$

$\frac{0.001}{2.136} \times 100$ was not accepted.

(e) This was another state and explain question. The calculated percentage by mass of $CaCO_3$ in the eggshell would be less because **either** the actual mass of the eggshell was less than 2.136 g as some of it was water **or** the actual mass would be more than 2.136 g because water was present in addition to the eggshell.

(f) Many candidates appear not to have understood this question. Few answers had the idea that the volume of NaOH needed was far more than a (50 cm^3) burette could hold or that the burette would need filling several times. Those who calculated the actual volume or increase in volume were also credited. Weaker responses focused on it taking more time.

Question 2

(a) Most candidates plotted the points correctly, with the most common error being the omission of the 0,0 point. Most also made a good attempt at a quite difficult line of best fit and were awarded the mark. However, a significant number drew straight lines starting at the origin, which was not the best line when the points were clearly curving.

(b) (i)/(ii) The anomalous point was easily spotted. The explanation of the anomalous point required candidates to say that the diameter was measured early/before 3 minutes/before 18 minutes or that the diameter was measured smaller than it was. A 'direction' is always required. Vague statements such as the time or diameter were measured incorrectly will never get the mark. Some candidates forgot that it was a continuous experiment and gave answers such as 'timing started too early', which would affect all the results, not just one.

© 2022

www.dynamicpapers.com

(c) Most candidates could draw a good tangent at the correct point on the curve. Similarly, most could correctly read two pairs of co-ordinates on the tangent. A separation of at least 2.0 units on the y-axis was expected. Please note that due to an issue with this question, the third mark was awarded to all candidates to make sure that no candidates were disadvantaged.

(d) The average rate of diffusion required the calculation of a mean over the first 30 minutes, whilst the diameter was getting larger, although over 36 minutes, the full time of measurement, was also allowed.

(e) Most candidates correctly identified time as the independent variable. Time intervals was the most common incorrect answer.

(f) The best way to increase the reliability of results is to repeat the experiment until consistent results are obtained, as with concordant titres in a titration. Repeating and discarding anomalous results is also acceptable but repeating and averaging alone is not enough.

(g) (i) The question asked candidates to predict and explain and again many did not fully address the question. The prediction was that the graph would be less steep, although this could be expressed in many ways. The 'explain' was that the M_r for potassium dichromate(VI) was higher so the 'particles' would diffuse/move more slowly. Again, this could be expressed in many ways.

(ii) This was a challenging question and only the better candidates realised that the concentrations of the two solutions was the variable that must be kept constant. Many chose volume but as the hole was always the same stated size, it was assumed that the volume would be the same.

(h) (i) Some idea of chemically resistant gloves was needed here. Answers such as 'protective gloves' were accepted, but gloves alone were insufficient.

(ii) This was a challenging question. Candidates were required to apply their knowledge of diffusion in solutions to this novel situation. The marking points were the idea that solids would only diffuse slowly or not at all, that they first needed to dissolve which would be slow if at all and that it would be difficult to get even contact between the crystals and the gel. A wide range of answers covering these ideas were accepted. A common misconception was that it was the actual crystals that were moving through the gel.

© 2022

www.dynamicpapers.com

CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation

Key Messages

It is vital that candidates analyse the question carefully to determine the type of response required.

Candidates must demonstrate their understanding of reliability related to the specific experiment under examination in their response. General answers such as 'Repeat the experiment and average' are not worthy of a mark.

Use of appropriate vocabulary, terminology and conventions is key to good communication in science.

General comments

Many candidates produced well-structured responses, illustrating excellent understanding of the methods and concepts covered.

Comments on specific questions

Question 1

(a) (i) The majority of candidates successfully completed this calculation, clearly showing the two-steps of working involved. The most common incorrect answer (0.0159) was obtained by dividing the mass of the solid mixture by the relative formula mass of magnesium chloride.

(ii) This calculation was performed correctly by most candidates. A small, but significant number of candidates incorrectly used 1.5g (in place of 1.52g) in their calculation of percentage by mass.

Although the working shown by candidates for both parts of **1(a)** was clear, completion of each two-step calculation caused a number to struggle with the use of significant figures and rounding.

In a multi-step calculation involving multiplication or division, the number of significant figures in the final answer should equal the least number of significant figures in any of the data used; in this case three.

When carrying out multi-step calculations, it is recommended to keep at least one more significant figure in intermediate values than is needed in the final answer.

If intermediate values are rounded to only three figures and used in subsequent steps, information contained in the fourth figure is discarded so the ***third*** digit of the final answer might be incorrect.

(b) (i) Almost all candidates' responses to this question showed an excellent understanding of how the rate of dissolving could be increased. Some candidates, unnecessarily, gave more than one correct method. A small number suggested stirring or heating the solid, which was not credited.

(ii) Most candidates addressed the need to remove something from the precipitate and many identified magnesium nitrate and/or silver nitrate. More general descriptions, such as solid, substance, residue or impurities, needed to be qualified by 'soluble' in order to gain the mark. Other common responses included 'Increasing the purity of the precipitate.' which is too vague and 'To prevent further reaction.' which is not correct.

A few candidates misinterpreted the question and incorrectly suggested that the washing was to ensure that all the precipitate would be transferred.

© 2022

www.dynamicpapers.com

(iii) Careful examination of this question reveals that the candidate needed to explain why an oven is used (rather than a Bunsen burner), and key phrases such as 'to avoid' or 'to prevent' often began a credit worthy response. Thermal decomposition and melting of the precipitate were the predominant processes to be avoided. 'To ensure the precipitate dried uniformly' or 'The oven heats evenly' were common erroneous responses.

(c) (i) A great proportion of candidates included the full working required for this mark. The uncertainty in a balance reading is estimated as half the smallest scale division. i.e. ±0.005 g. The mass of the sample is calculated as the difference between two balance readings. Therefore, the absolute uncertainty in the mass of the sample is (2 × ±0.005 cm^3) = ±0.010 cm^3. In this case, the

percentage error = $\frac{2 \times 0.005}{1.52}$ × 100 = 0.658 per cent.

(ii) Most candidates understood the necessity to increase the mass of the sample of solid. A small number of candidates misinterpreted the question and suggested repeating the weighing, weighing by difference, or using a larger beaker.

A small number of candidates used 'weight' instead of 'mass' in their answer and therefore failed to gain the mark.

(iii) The principle of continuing to dry (in the oven) until the mass of the precipitate is constant was commonly described, particularly by high scoring candidates. Simply drying for a longer period without re-weighing would not confirm that the precipitate was completely dry. The use of an absorbent material, such as tissue or paper towel, to dry the precipitate was a popular incorrect response.

(d) There were some excellent explanations given for the increase of the calculated percentage mass of magnesium chloride. These followed the reasoning; the apparent mass and calculated amount of AgCl would increase, and, consequently, the amount and mass of $MgCl_2$ in the sample would appear larger.

A small number of candidates misinterpreted the question, citing the effect on percentage error in their response.

Question 2

(a) Candidates were informed that 'hydrogen peroxide is corrosive to skin', indicating that **chemical resistant** gloves are the most appropriate safety precaution. The protective nature of the gloves had to be specified to gain the mark.

(b) (i) Candidates are expected to be able to describe the arrangement of apparatus using labelled diagrams. Suitable diagrams should be neatly drawn using a ruler, fully labelled and follow the usual conventions for representing apparatus.

Most candidates achieved the first mark by drawing leak-proof apparatus capable of delivering a sample of gas collected over water. Extension of the delivery tube into the reaction vessel contents, failure to seal the reaction vessel, and passing the delivery tube through the side wall of the trough or the collection vessel were common mistakes.

The second mark was awarded for the collection of the gas in a correctly positioned and appropriate vessel. A small number of candidates used an unsuitable vessel, such as beaker, test-tube, boiling tube or an unidentifiable piece of apparatus, and did not gain this mark.

The use of a gas syringe is not a valid way to collect the oxygen gas over water.

(ii) This mark was awarded rarely. The reaction vessel and delivery tube are full of air when the reaction begins. Therefore, the first bubbles of gas produced would be air and should not be collected.

© 2022

www.dynamicpapers.com

Testing the gas using a glowing splint merely confirms the presence of oxygen. Use of a chemical filter to remove other gases would be ineffective as the oxygen produced by the reaction is pure. The use of a vacuum to remove air from the flask is impractical.

(c) (i) The data points plotted easily on the grid provided and were accurately located by all but a few candidates. The line of best fit, which should be a straight line passing as close to non-anomalous data points as possible with roughly the same number of points on each side of the line, was drawn well by most candidates. A significant number of candidates drew a straight line between the first and last points, which was clearly not a good line of best fit.

(ii) The selection and recording of co-ordinates from the line of best fit, and calculation of the gradient to 3 significant figures, was done very well in most cases. It was disappointing to see some candidates, who clearly knew how to complete the gradient calculation, losing one or both marks by:

- using table values, which did not fall on the line of best fit as co-ordinates
- using two points that were not more than half of the length of the axes apart
- not quoting the answer to three significant figures.

(d) (i) Nearly all candidates were able to identify the anomalous point.

(ii) Unfortunately, relatively few candidates were able to suggest a possible explanation for the anomaly identified in **(d)(i).**

A comparison of the 'actual value' with the 'recorded value' for either temperature **or** volume of oxygen was required. For example, 'The actual temperature was higher than the recorded temperature' **or** 'The actual volume of oxygen was lower than the recorded volume'. The vague assertion that a value was recorded too early or too late was not awarded a mark.

(e) (i) Identification of the independent variable was done correctly by nearly all candidates.

(ii) This question proved extremely difficult for candidates. Many candidates suggested the superficial 'repeat the experiment and find a mean' which is not worthy of credit. Repeating the experiment does not make it more reliable and this type of general answer must be avoided.

Candidates should think carefully about the requirements of the particular experiment under consideration. To make this experiment more reliable, it is necessary to take more volume measurements at various temperatures and use these to identify and eliminate anomalies.

(f) The stem of this question makes it clear that candidates must use the ideal gas equation in their answer. This means that their response must include an expression for the gradient of the graph derived from the ideal gas equation, as well as stating the effect of using a smaller initial volume of gas. Some candidates understood how and why the gradient changed and produced excellent answers, whilst others gave confused responses, including contradictions and omissions.

Question 3

(a) (i) Many candidates suggested stopping the clock when the first orange colour of bromine appears. Since bromine is produced almost instantaneously in this reaction, this does not offer an effective method of judging the end-point of the reaction.

The best approach is to use a method in which the time taken for the formation of a fixed amount of bromine is measured using an appropriate end-point.

This could be achieved by measuring the time taken for the intensity of the orange colour to reach a fixed value, using a colorimeter or light sensor. A suitable alternative is a 'clock reaction' using a small amount of a substance, such as phenol in this case, to remove the first fixed amount of bromine produced before the colour then appears (the end point). Description of a viable disappearing cross method was also credited.

(ii) The majority of candidates gained both marks here, reflecting their ability to use the experimental data to determine the order of reaction for each reactant.

© 2022

www.dynamicpapers.com

(b) Mixture A required a volume of 5.0 cm^3 to be measured. Volumetric apparatus must be used to achieve this level of precision, a burette being the most suitable. Some candidates suggested using a measuring cylinder, a beaker, a boiling tube or a test-tube, all of which lack the necessary precision.

(c) This question proved to be challenging for many candidates. This experiment is designed to examine the effect of changing the concentration of the reactants in turn. The temperature is a variable that needs to be controlled. Having different starting temperatures for individual mixtures would affect the rate of reaction.

(d) This question required candidates to describe making a solution of a particular concentration by dilution of a more concentrated solution.

The description of the procedure used for dilution of the 1 mol dm^{-3} sulfuric acid required for the first mark was largely well recalled. This standard procedure includes, using volumetric apparatus, for example a burette, to measure a known volume into a volumetric flask and then adding distilled water to make up to the graduation mark. The most common error in otherwise correct responses was failure to specify a suitable piece of apparatus to measure the specified volume of acid to be added to the volumetric flask.

A significant number of candidates described rinsing the burette (or indeed pipette) into the volumetric flask, which incorrect procedure would introduce unnecessary inaccuracy.

Fewer candidates gained the second mark by specifying both the volume of 1 mol dm^{-3} sulfuric acid to be used and the correct corresponding total volume of the diluted solution to be produced.

There were some excellent concise and precise answers which gained both marks such as:

'Use a burette to transfer 37.50 cm^3 of 1 mol dm^{-3} sulfuric acid into a 250 cm^3 volumetric flask and make up to the graduation mark with distilled water.'

© 2022