



Mark Scheme (Results)

October 2019

Pearson International Advanced Level
In Chemistry (WCH11)
Paper 01 Structure, Bonding and Introduction
to Organic Chemistry

Section A (Multiple Choice)

Question number	Answer	Mark
1	The only correct answer is C (iron) A is incorrect because argon is in the p-block B is incorrect because chlorine is in the p-block D is incorrect because sodium is in the s-block	(1)

Question number	Answer	Mark
2	The only correct answer is C ($\text{Al}^{2+}(\text{g}) \rightarrow \text{Al}^{3+}(\text{g}) + \text{e}^{-}$) A is incorrect because ionisation energies are successive so only one electron is lost at a time B is incorrect because the state symbols are incorrect and ionisation energies are successive so only one electron is lost at a time D is incorrect because the state symbols are incorrect	(1)

Question number	Answer	Mark
3	The only correct answer is B (6200) <i>A is incorrect because successive ionisation energies always increase</i> <i>C is incorrect because this is too big an increase</i> <i>D is incorrect because this very large value indicates a new quantum shell</i>	(1)

Question number	Answer	Mark
4	The only correct answer is B (600) <i>A is incorrect because the first ionisation energy of aluminium is greater than that of sodium</i> <i>C is incorrect because the first ionisation energy of aluminium is less than that of magnesium</i> <i>D is incorrect because the first ionisation energy of aluminium is less than that of magnesium</i>	(1)

Question number	Answer	Mark
5	The only correct answer is D (shielding of the outer electron from the nuclear charge) <i>A is incorrect because the force of attraction between the nucleus and outer electron decreases</i> <i>B is incorrect because neutrons do not affect ionisation energy</i> <i>C is incorrect because if this were the only reason, the ionisation energies would increase</i>	1

Question number	Answer	Mark
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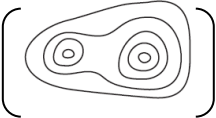
6	The only correct answer is D (392) A is incorrect because this does not include $6\text{H}_2\text{O}$ B is incorrect because this only includes one H_2O C is incorrect because this includes 6H_2 but only one O	(1)
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Question number	Answer	Mark
7	The only correct answer is D (3.612×10^{24}) A is incorrect because this is the number of molecules in 0.5 mol of water B is incorrect because this is the number of molecules of water C is incorrect because this is the answer if there are 2 atoms in a molecule	(1)

Question number	Answer	Mark
8	The only correct answer is A (sodium fluoride) B is incorrect because the strongest ionic bonding is between the smallest ions C is incorrect because the strongest ionic bonding is between the smallest ions D is incorrect because the strongest ionic bonding is between the smallest ions	(1)

Question number	Answer	Mark
9	The only correct answer is A (Ca²⁺ and S²⁻) <i>B is incorrect because K⁺ has 18 electrons and Br⁻ has 36 electrons</i> <i>C is incorrect because Li⁺ has 2 electrons and F⁻ has 10 electrons</i> <i>D is incorrect because Mg²⁺ has 10 electrons and Cl⁻ has 18 electrons</i>	(1)

Question number	Answer	Mark
10	The only correct answer is B (covalent and dative covalent bonding) <i>A is incorrect because there is a dative bond between the nitrogen atom and H⁺ ion</i> <i>C is incorrect because dative bonding is missing and ionic bonding is between ions, not within an ion</i> <i>D is incorrect because ionic bonding is between ions, not within an ion</i>	(1)

Question number	Answer	Mark
11	The only correct answer is C  <i>A is incorrect because this is the electron density map showing two ions</i> <i>B is incorrect because this is the electron density map with a polarised anion</i> <i>D is incorrect because this is the electron density map of a covalent molecule with two identical atoms</i>	(1)

Question number	Answer	Mark
12	The only correct answer is C (polar bond, non-polar molecule) <i>A is incorrect because the Al-Cl bond is polar</i> <i>B is incorrect because the Al-Cl bond is polar and the molecule is symmetrical so the bond polarities cancel</i> <i>D is incorrect because the molecule is symmetrical so the bond polarities cancel</i>	(1)

Question number	Answer	Mark
13	The only correct answer is B (45.8 %) <i>A is incorrect because the relative atomic mass of Fe on the right-hand side has not been multiplied by 2</i> <i>C is incorrect because the relative atomic mass of Fe has not been multiplied by 2 and the relative molecular mass of CO₂ has not been multiplied by 3</i> <i>D is incorrect because the relative molecular mass of CO₂ has not been multiplied by 3</i>	(1)

Question number	Answer	Mark
14	The only correct answer is A (8×10^{-2}) <i>B is incorrect because 2000 has been divided by 40 instead of 40 by 2000</i> <i>C is incorrect because 2 kg has not been converted to 2000 g</i> <i>D is incorrect because 2 kg has not been converted to 2000 g and 2 has been divided by 40</i>	(1)

Question number	Answer	Mark
15	The only correct answer is B (2)	(1)

	A is incorrect because the ratio of CaSO_4 to H_2O is the wrong way round C is incorrect because this is 3.405×0.900 to the nearest whole number and masses have not been converted to moles D is incorrect because this is $3.405 / 0.900$ to the nearest whole number and masses have not been converted to moles	
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Question number	Answer	Mark
16	The only correct answer is B (C_6H_{14}) A is incorrect because this would show the loss of two ethane molecules C is incorrect because this would show the loss of one ethane molecule D is incorrect because this would show the loss of one ethene molecule	(1)

Question number	Answer	Mark
17	The only correct answer is D (a pair of electrons from a bond to an atom, forming ions) A is incorrect because movement of an electron is represented by a curly arrow with a half arrow-head and ions are formed when a pair of electrons moves B is incorrect because movement of an electron is represented by a curly arrow with a half arrow-head C is incorrect because ions are formed when a pair of electrons moves	(1)

Question number	Answer	Mark
18	The only correct answer is C (9 σ bonds and 2 π bonds) A is incorrect because all single bonds are σ bonds, one of each double bond is a σ bond and one of	(1)

	<i>each double bond is a π bond</i> B <i>is incorrect because all single bonds are σ bonds, one of each double bond is a σ bond and one of each double bond is a π bond</i> D <i>is incorrect because all single bonds are σ bonds, one of each double bond is a σ bond and one of each double bond is a π bond</i>	
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Question number	Answer	Mark
19	The only correct answer is D (a secondary carbocation is more stable than a primary carbocation) A <i>is incorrect because the stability of the compound does not determine which product is formed</i> B <i>is incorrect because the stability of the compound does not determine which product is formed</i> C <i>is incorrect because the secondary carbocation is more stable</i>	(1)

Question number	Answer	Mark
20	The only correct answer is A (2.04 (g)) B <i>is incorrect because this is the mass when the yield is 100%</i> C <i>is incorrect because this is just the masses expressed as a percentage without converting them into moles</i> D <i>is incorrect because this is the mass of propene formed with the molar masses reversed</i>	(1)

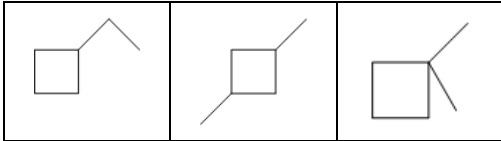
Section B

Question number	Answer	Additional guidance	Mark
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21(a)	2 correct skeletal formulae (1) - balanced equation (1)	Example of equation:  Ignore molecular, displayed or structural formulae as working for M1 Allow balanced equation using molecular, displayed or structural formulae e.g. $\text{C}_6\text{H}_{14} \rightarrow \text{C}_6\text{H}_{12} + \text{H}_2$ Allow TE on any other C_6H_{12} cycloalkane Ignore state symbols / conditions	(2)
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Question number	Answer	Additional guidance	Mark
21(b)(i)	1,3-dimethylcyclopentane	Allow 1,3 dimethylcyclopentane 1 3-dimethylcyclopentane 1 3 dimethylcyclopentane cyclopentane-1,3-dimethyl Allow methy / methly for methyl Do not award 1,3-dimethylpentane	(1)

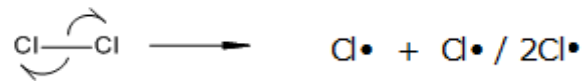
Question Number	Answer	Additional guidance	Mark
21(b)(ii)	C_7H_{14}	Allow $H_{14}C_7$ / C_7H_{14} / $H_{14}C_7$ Ignore any other symbols as working e.g. $CH_2CHCH_3CH_2CH_2CHCH_3$ Do not award superscripts e.g. C^7H^{14}	(1)

Question number	Answer	Additional guidance	Mark
21(c)	- All 3 correct (2) - Any 2 correct (1)	Examples of isomers:  Allow isomers in any order Allow CH_3 and C_2H_5 for side chains Ignore bond angles and bond lengths Do not award any structure with 2 or more rings	(2)

Question number	Answer	Additional guidance	Mark
21(d)	(E is) C₉H₁₈	Allow H ₁₈ C ₉ Allow large numbers Ignore working Do not award superscripts	(1)

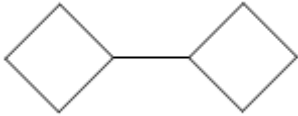
Question number	Answer	Additional guidance	Mark
21(e)	- calculation of volume of CO₂(g) and H₂O(g) (1) - calculation or working of volume of O₂(g) used (1) - calculation of volume of O₂(g) left (1)	Example of calculation: 25 cm³ of C₅H₁₀ produces $\frac{25 \times 10}{2} = 125$ (cm³) CO₂ and 125 (cm³) H₂O(g) 25 cm³ of C₅H₁₀ needs $\frac{25 \times 15}{2} = 187.5$ (cm³) O₂ Volume of O₂ left = 250 – 187.5 = 62.5 (cm³) TE on volume of O₂ reacted (volume of C₅H₁₀ = 0) Correct answers with no working scores (3) Allow volumes in dm³ provided unit is given Penalise rounding to 1 or 2 SF once only Penalise correct volumes not linked to specific gases once only Penalise incorrect units e.g. cm once only	(3)

Question number	Answer	Additional guidance	Mark
21(f)(i)	(free) radical (1) - substitution (1)	Allow words in either order Mark independently Ignore homolytic (fission) / initiation / propagation / termination / photochemical Do not award heterolytic / electrophilic / nucleophilic for M1 only Ignore halogenation / S_N1 / S_N2 Do not award addition / elimination for M2 only	(2)

Question number	Answer	Additional guidance	Mark
21(f)(ii)	- both curly half-arrows (1) - two chlorine (free) radicals with dot (1)	Example of equation:  Ignore two dots shown to represent electrons above and below the Cl-Cl bond Full arrow loses M1 only Penalise missing • once only in (f)(ii), (iii), (iv)	(2)

Question number	Answer	Additional guidance	Mark
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21(f)(iii)	• first propagation step • second propagation step	Example of equations: (1) $\text{C}_4\text{H}_8 + \text{Cl}\cdot \rightarrow \text{C}_4\text{H}_7\cdot + \text{HCl}$ (1) $\text{C}_4\text{H}_7\cdot + \text{Cl}_2 \rightarrow \text{C}_4\text{H}_7\text{Cl} + \text{Cl}\cdot$ Allow equations in either order Allow displayed or skeletal formulae Ignore curly arrows and state symbols, even if incorrect Do not award any equations involving $\text{H}\cdot$	(2)
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Question number	Answer	Additional guidance	Mark
21(f)(iv)	An explanation that makes reference to the following points: - correct skeletal formula (1) (two) $C_4H_7\cdot$ / cyclobutyl radicals join together (1)	Mark independently Example of skeletal formula:  Allow any 2 squares joined by a bond Ignore bond lengths and bond angles No TE on incorrect radicals Allow $2C_4H_7\cdot \rightarrow C_8H_{14}$ Allow cyclobutane / hydrocarbon radicals join together Ignore just '(two) radicals join together'	(2)

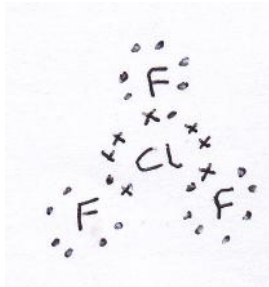
(Total for Question 21 = 18 marks)

Question number	Answer	Additional guidance	Mark
22(a)(i)	17 protons (1) 18 neutrons (1)	Any reference to electrons scores (1) for an answer that includes 17 protons and 18 neutrons	(2)

Question number	Answer	Additional guidance	Mark
22(a)(ii)	$(1s^2)2s^22p^63s^23p^6$	Allow $2p_x^22p_y^22p_z^2$ and/or $3p_x^23p_y^23p_z^2$ Allow numbers of electrons written as subscripts or large numbers Ignore repeated $1s^2$	(1)

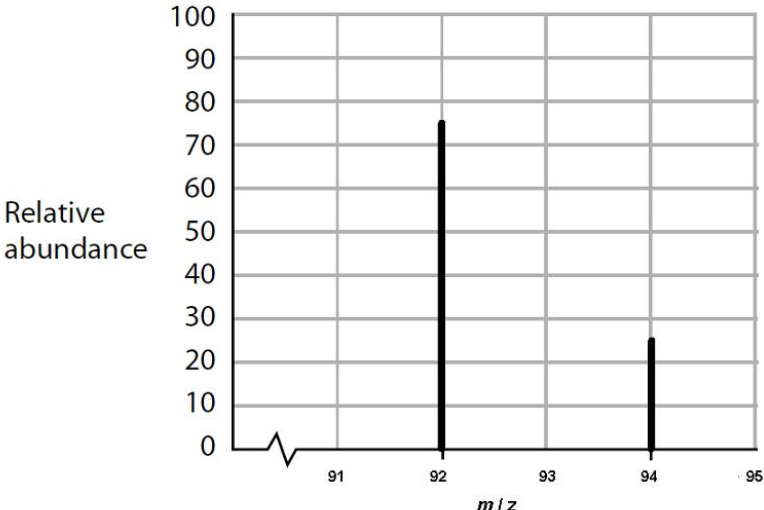
Question number	Answer	Additional guidance	Mark
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22(a)(iii)	- correct working (1) - answer given to 2 dp (1)	Example of calculation: $\frac{(35 \times 75.53) + (37 \times 24.47)}{100} (= 35.4894)$ or $(35 \times 0.7553) + (37 \times 0.2447) (= 35.4894)$ 35.49 TE on working involving two different species Correct answer to 2 dp with no working scores (2) 35.50 with no working scores (0) Ignore units, even if incorrect	(2)
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Question number	Answer	Additional guidance	Mark
22(b)(i)	- dot-and-cross diagram showing three pairs of electrons between one Cl and three F atoms (1) - rest of diagram correct conditional on M1 (1)	Example of dot-and-cross diagram:  Allow overlapping circles Allow all dots / all crosses Allow 4 non-bonded electrons on Cl shown as: 2 lone pairs together or 2 lone pairs between any two of the bonded pairs or 1 lone pair and 2 unpaired electrons or 3 electrons and 1 electron Ignore inner shell electrons / lines for bonds Penalise a charged species in M2 only	(2)

Question number	Answer	Additional guidance	Mark
22(b)(ii)	there are 10 electrons / 5 pairs of electrons in the outer / valence shell of chlorine	Allow there are more than 8 electrons in the outer / valence shell of chlorine Allow there are 3 bond pairs and 2 lone pairs (in the outer shell of chlorine) Allow chlorine has expanded its octet Allow chlorine does not have a noble gas electronic structure / does not have 8 electrons in the outer / valence shell Allow just 'chlorine has 10 electrons' / 'more than 8 electrons' Ignore chlorine is the central atom Ignore just 'chlorine has 2 lone pairs' Do not award incorrect numbers of electrons / orbitals	(1)

Question number	Answer	Additional guidance	Mark
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22(b)(iii)	• a peak at $m/z = 92$ (1) • a peak at $m/z = 94$ (1) • peaks at 92 and 94 are in the ratio 3:1 approximately (1)	Example of mass spectrum:  Relative abundance m/z Allow any 3:1 ratio for the peaks e.g. 100:33, 30:10 Ignore any labels on the peaks M3 is a stand alone mark for peaks at 92 and 94 only	(3)
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Question number	Answer	Additional guidance	Mark
22(b)(iv)	- conversion of temperature to K (1) - rearrangement of Ideal Gas Equation (1) - evaluation to give volume (1) - conversion of volume to cm³ and answer given to 2 or 3 SF (1)	Example of calculation: temperature = 60 + 273 = 333 K $V = \frac{nRT}{P}$ or $V = \frac{0.0200 \times 8.31 \times 333}{1.28 \times 10^5}$ V = 4.3238 x 10⁻⁴ (m³) TE on temperature volume = 4.3238 x 10⁻⁴ x 1 x 10⁶ = (432.38) = 432 / 430 / 4.32 x 10² / 4.3 x 10² (cm³) TE on volume in M3 Penalise rounding to 1SF once only in M1, M2 and M3 Correct answer with no working scores full marks	(4)

(Total for Question 22 = 15 marks)

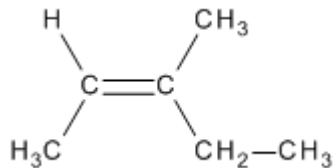
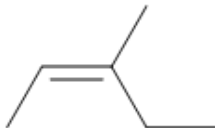
Question number	Answer	Additional guidance	Mark
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23(a)	A description that makes reference to the following points: (propane) yellow (solution) (1) (propene) colourless (solution) (1)	Allow brown or orange or any combination of yellow, orange and brown Allow no (colour) change / no change in bromine water / remains yellow / turns yellow Allow upper layer / both layers are yellow / orange / brown etc Ignore just 'no reaction' Do not award any mention of red Do not award lower layer is yellow / orange / brown etc Allow decolorises / colour disappears Allow (both) layers are colourless Ignore initial colour of red in M2 only Do not award remains colourless	(2)
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Question number	Answer	Additional guidance	Mark
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23(b)(i)	steam / H₂O(g) and acid (catalyst) / phosphoric acid / H₃PO₄	In (b)(i) and (ii) allow names or formulae for reagents but if both are given, both must be correct Allow water / H₂O and heat for steam Do not award steam and room temperature Allow name or formula of any strong acid (catalyst) / H⁺ Ignore concentration of acid / pressure	(1)
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Question number	Answer	Additional guidance	Mark
23(b)(ii)	potassium manganate(VII) (solution)/ KMnO₄ and sulfuric acid / H₂SO₄ / acid(ified) / H⁺ / sodium hydroxide / NaOH / potassium hydroxide / KOH / alkali(ne) / OH⁻	Allow potassium permanganate Do not award K₂MnO₄ Ignore heat / concentration of acid or alkali Allow (1) in (ii) if reagents and conditions for (i) and (ii) are interchanged If no other mark is awarded: Allow (1) in (ii) if reagents for both (i) and (ii) are correct but conditions are omitted / incorrect	(1)

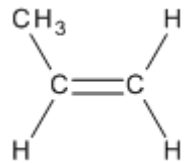
Question number	Answer	Additional guidance	Mark
23(c)	structure of Z-3-methylpent-2-ene	Examples of structure:  or  Allow C₂H₅ / displayed formula Ignore connectivity of methyl and ethyl groups Ignore bond lengths and bond angles on skeletal formula	(1)

Question number	Answer	Additional guidance	Mark
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23(d)	- calculation of number of moles of hydrogen or calculation of volume of alkene (1) - deduction of number of double bonds (1)	Example of calculation: $\frac{720}{24000} = 0.030 \text{ or } \frac{0.72}{24} = 0.030$ or volume of alkene = $0.01 \times 24000 = 240 \text{ (cm}^3\text{)}$ mole ratio alkene : hydrogen = $(0.01 : 0.03 \text{ or } 720/240) = 1 : 3$ so there are 3 double bonds TE on mol hydrogen Correct answer with no working scores (1)	(2)
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Question number	Answer	Additional guidance	Mark
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23(e)	- the dipole on the bromine (molecule) should be the other way around (1) - the arrow should go from the double / pi / π bond to the bromine / (pair of) electrons move from the double bond to the bromine or the curly arrow should go from C=C to Br$^{\delta+}$ (1) - the Br ion should have a negative charge (1)	Allow the changes in any order and they may be shown on the diagram Ignore references to lone pairs Allow the top bromine should be $\delta+$ / the bottom bromine should be $\delta-$ Allow the bromine (atom) should have a negative charge Ignore just 'Br is not positive' Do not award the bromine molecule should have a negative charge Do not award Br$^{\delta-}$	(3)
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Question number	Answer	Additional guidance	Mark
23(f)	structure of propene	Example of structure:  Allow any unambiguous structure of propene showing the double bond e.g. $\text{CH}_3\text{CH}=\text{CH}_2$ Ignore name, even if incorrect Ignore n / brackets Ignore connectivity of CH_3 group	(1)

(Total for Question 23 = 11 marks)

Question number	Answer	Additional guidance	Mark
24(a)(i)	correct electronic configuration	Example of electronic configuration: [Ne] ↑ ↓ 3s ↑ ↑ ↑ 3p Allow half-arrow heads Allow three arrows pointing downwards in 3p orbitals Ignore numbers in the boxes e.g. 2	(1)

Question number	Answer	Additional guidance	Mark
24(a)(ii)	An explanation that makes reference to the following points: Phosphorus - phosphorus has a half-filled p (sub)shell / one electron in each p orbital / the p orbitals are singly occupied (1) - more energy is required to remove an unpaired electron (than a paired electron) or an unpaired electron / electron removed has a lower energy (1) OR Sulfur - the outermost / 3p electron or the electron being removed in sulfur is paired (1) - less energy is required to remove a paired electron (than an unpaired electron) or repulsion between paired electrons (reduces the ionisation energy needed to remove it) or the paired electron has a higher energy (1)	Both marks must come from the same pair Allow 'electrons-in-boxes' / $3p_x3p_y3p_z$ to show electronic configurations Allow 'box' for orbital as this is in (i) Ignore references to shielding / nuclear charge / lone pairs Penalise 3 or more electrons in a p orbital once only Allow '(electron removed is from) a half-filled p orbital' Do not award just $3p^3$ Allow a half-filled subshell is (more) stable Allow sulfur is $3p^4$ Allow sulfur forms a half-filled p (sub)shell when it loses 1 electron Note – paired only needs to be mentioned once in M1 or M2 Do not award M2 if answer states more energy needed to remove electron in sulfur	(2)

Question number	Answer	Additional guidance	Mark
24(b)	An explanation that makes reference to the following points: - there are intermolecular forces between P₄ / phosphorus (molecules) or phosphorus is made up of small molecules / discrete molecules / is simple molecular (1) - there are covalent bonds between the silicon atoms or silicon is a giant (covalent) structure / giant lattice (1) (much) more energy is needed to break the (covalent) bonds in silicon than overcome the intermolecular forces in phosphorus or the (covalent) bonds in silicon are (much) stronger than the (intermolecular) forces in phosphorus (1)	Allow London / dispersion / van der Waals' forces for intermolecular forces Allow macromolecular / giant molecule Do not award ionic / metallic Do not award breaking bonds between phosphorus atoms	(3)

Question number	Answer	Additional guidance	Mark												
24(c)(i)	- number of bonding pairs and number of lone pairs - shape both bond angles	Example of table: <table><tr><td>Number of bonding pairs of electrons on phosphorus</td><td colspan="2">5</td></tr><tr><td>Number of lone pairs on electrons on phosphorus</td><td colspan="2">0</td></tr><tr><td>Shape of molecule</td><td colspan="2">trigonal bipyramidal</td></tr><tr><td>Cl-P-Cl bond angles</td><td>90°</td><td>120°</td></tr></table> Mark independently Allow bond angles in either order Ignore 180°	Number of bonding pairs of electrons on phosphorus	5		Number of lone pairs on electrons on phosphorus	0		Shape of molecule	trigonal bipyramidal		Cl-P-Cl bond angles	90°	120°	(3)
Number of bonding pairs of electrons on phosphorus	5														
Number of lone pairs on electrons on phosphorus	0														
Shape of molecule	trigonal bipyramidal														
Cl-P-Cl bond angles	90°	120°													

Question number	Answer	Additional guidance	Mark
24(c)(ii)	PCl_4^+ PCl_6^-	Ions can be in any order If no charges are shown or charges are incorrect, allow (1) for PCl_4 and PCl_6	(2)

Question number	Answer	Additional guidance	Mark
24(d)	- calculation of mol of H_3PO_4 and calculation of mol of NaOH (1) - mol ratio (1) - balanced equation (1)	Example of calculation: $\text{mol H}_3\text{PO}_4 = \frac{10.0 \times 0.100}{1000} = 0.00100 / 1.00 \times 10^{-3}$ and $\text{mol NaOH} = \frac{8.0 \times 0.250}{1000} = 0.00200 / 2.00 \times 10^{-3}$ mol ratio $\text{H}_3\text{PO}_4 : \text{NaOH} = 1 : 2$ Mol ratio mark can be awarded from equation TE on mol H_3PO_4 and NaOH Do not award M2 if the mol ratio in the balanced equation contradicts the mol ratio from the mol calculations $\text{H}_3\text{PO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{HPO}_4 + 2\text{H}_2\text{O}$ Allow HNa_2PO_4 Allow $\text{H}_3\text{PO}_4 + 2\text{OH}^- \rightarrow \text{HPO}_4^{2-} + 2\text{H}_2\text{O}$ Allow multiples Ignore state symbols, even if incorrect Equation TE on mol ratio provided it is 1:1 or 1:3 $\text{H}_3\text{PO}_4 + \text{NaOH} \rightarrow \text{NaH}_2\text{PO}_4 + \text{H}_2\text{O}$ $\text{H}_3\text{PO}_4 + 3\text{NaOH} \rightarrow \text{Na}_3\text{PO}_4 + 3\text{H}_2\text{O}$	(3)

Question number	Answer	Additional guidance	Mark
24(e)	- calculation of molar mass of hydrated magnesium phosphate (1) - calculation of y (1)	Examples of calculation: Method 1 molar mass = $262.9 \times \frac{100}{78.5} = 334.9$ (g) mass of water = $334.9 - 262.9 = 72$ moles of water = $\frac{72}{18} = 4$ so y = 4 Allow alternative methods, for example Method 2 in 100 g of salt: mol $\text{Mg}_3(\text{PO}_4)_2 = \frac{78.5}{262.9} = 0.29859$ (mol) and mol $\text{H}_2\text{O} = \frac{21.5}{18} = 1.1944$ (mol) (1) ratio $\text{Mg}_3(\text{PO}_4)_2 : \text{H}_2\text{O}$ = 0.29859 : 1.1944 = 1 : 4 so y = 4 (1) This could also be done using 0.785 g and 0.215 g Method 3 $\frac{262.9}{262.9 + 18y} = 0.785$ or $\frac{262.9}{262.9 + 18y} \times 100 = 78.5$ (1) $262.9 = 206.4 + 14.13 \text{ y}$ so y = 4 (1) Correct answer with no working or working that does not involve A_r or M_r or moles scores (0) Allow TE for y from correct working but an incorrect number used for one of the values	(2)

(Total for Question 24 = 16 marks)