Question Number	Answer	Mark
12	**The only correct answer is C** ($[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$) *A is not correct because this is the ionic equation describing the deprotonation when ammonia is not in excess* *B is not correct because four water ligands are exchanged by ammine ligands when ammonia is in excess* *D is not correct because four water ligands are exchanged by ammine ligands when ammonia is in excess*	**(1)** **Computer**

Question Number	Answer	Mark
5(a)	**The only correct answer is D** ($[Ar]\ 3d^{10}\ 4s^1$ $[Ar]\ 3d^{10}$ $[Ar]\ 3d^9$) *A is incorrect because the copper atom has the structure $[Ar]3d^{10}4s^1$ and Cu^+ is $[Ar]3d^{10}$* *B is incorrect because the copper atom has the structure $[Ar]3d^{10}4s^1$ and Cu^+ is $[Ar]3d^{10}$ and Cu^{2+} is $[Ar]3d^9$* *C is incorrect because Cu^+ has the structure $[Ar]3d^{10}$ and Cu^{2+} is $[Ar]3d^9$*	**(1)**

Question Number	Answer	Mark
5(b)	**The only correct answer is C** (T S P) *A is incorrect because T is the only Cu(0) present in the scheme* *B is incorrect because T is the only Cu(0) present in the scheme* *D is incorrect because S is the only Cu(I) in the scheme other than Cu(I) in copper(I) iodide*	**(1)**

Question Number	Answer	Mark
5(c)	**The only correct answer is D** (NH_3) *A is incorrect because aqueous ammonia is needed to convert $Cu(OH)_2$ to $[Cu(NH_3)_4(H_2O)_2]^{2+}$* *B is incorrect because aqueous ammonia is needed to convert $Cu(OH)_2$ to $[Cu(NH_3)_4(H_2O)_2]^{2+}$* *C is incorrect because aqueous ammonia is needed to convert $Cu(OH)_2$ to $[Cu(NH_3)_4(H_2O)_2]^{2+}$*	**(1)**

Question Number	Answer	Mark
5	**The only correct answer is C** (purple) *A is incorrect because this is the colour of a VO^{2+} ion* *B is incorrect because this is the colour of a V^{3+} ion* *D is incorrect because this is the colour of a VO_2^+ ion*	**(1)**

Question Number	Answer	Mark
5	**The only correct answer is D** (strong acid and strong alkali) *A is incorrect because chromium(III) hydroxide is insoluble in water* *B is incorrect because chromium(III) hydroxide also dissolves in strong alkalis* *C is incorrect because chromium(III) hydroxide also dissolves in strong acids*	**(1)**

Question Number	Answer	Mark
13	**The only correct answer is A** ($[Zn(OH)_4]^{2-} + 2H_3O^+ \rightarrow [Zn(H_2O)_4(OH)_2]$) ***B*** *is not correct because* $[Zn(OH)_4]^{2-}$ *is a soluble complex ion* ***C*** *is not correct because* $[Cr(H_2O)_6]^{3+}$ *is a soluble complex ion* ***D*** *is not correct because* $[Cr(OH)_6]^{3-}$ *is a soluble complex ion*	**(1)** **Computer**

Question number	Answer	Mark
4	**The only correct answer is C** (Ni^{2+}) ***A*** *is incorrect because* Cu^{2+} *gives a blue precipitate with aqueous sodium hydroxide and with aqueous ammonia* ***B*** *is incorrect because the precipitate formed with* Fe^{2+} *and aqueous ammonia is insoluble in excess ammonia* ***D*** *is incorrect because* V^{2+} *is a purple solution*	**(1)**

C *is in*

D *is in*

Question Number	Answer
7	**The only correct answer is C** (tetrahedral and square planar) ***A*** *is incorrect because* $[CuCl_4]^{2-}$ *is tetrahedral* ***B*** *is incorrect because* $[CuCl_4]^{2-}$ *is tetrahedral and* $Pt(NH_3)_2Cl_2$ *is square planar* ***D*** *is incorrect because* $Pt(NH_3)_2Cl_2$ *is square planar*

Question number	Answer	Mark
3	**The only correct answer is A** ($[Al(H_2O)_6]^{3+}$) ***B*** *is incorrect because* $[Cu(H_2O)_6]^{2+}$ *gives a blue solution* ***C*** *is incorrect because* $[Fe(H_2O)_6]^{3+}$ *gives an orange / brown solution* ***D*** *is incorrect because* $[Ni(H_2O)_6]^{2+}$ *gives a green solution*	**(1)**

Question Number	Answer	Mark
3	**The only correct answer is C** (36.4 %) ***A*** *is incorrect because this is the percentage of only one chlorine in the complex ion* ***B*** *is incorrect because this is the percentage of two chlorines in the compound and not the complex ion* ***D*** *is incorrect because this is the total percentage of chlorine in the compound and not the complex ion*	**(1)**

Question number	Answer	Mark
2	**The only correct answer is C** ($SO_2 \rightarrow SO_3$, $+5 \rightarrow +4 \rightarrow +5$) ***A*** *is incorrect because this is not the step catalysed* ***B*** *is incorrect because the vanadium is reduced* ***D*** *is incorrect because this is not the step catalysed and the vanadium is reduced*	**(1)**

Question number	Answer	Mark
5	**The only correct answer is B** ($[Zn(H_2O)_6]^{2+} + 2NH_3 \rightarrow Zn(OH)_2(H_2O)_4 + 2NH_4^+$) ***A*** *is incorrect because the precipitate should not have a positive charge and the charges do not balance* ***C*** *is incorrect because* $[Zn(NH_3)_4(H_2O)_2]^{2+}$ *is formed when the precipitate dissolves in excess aqueous ammonia* ***D*** *is incorrect because* $Zn(NH_3)_4(H_2O)_2$ *should have a 2+ charge and the equation is not balanced*	**(1)**

Question Number	Answer	Ma
4	**The only correct answer is A** (blue) ***B*** *is incorrect because the* VO^{2+} *ion is blue not green* ***C*** *is incorrect because the* VO^{2+} *ion is blue not violet* ***D*** *is incorrect because the* VO^{2+} *ion is blue not yellow*	(1

Question Number	Answer	Mark
6	**The only correct answer is D** (Cu $[Ar]3d^{10}4s^1$) ***A*** *is not correct because the 4s electrons are removed before the 3d electrons* ***B*** *is not correct because the electronic configuration of chromium is* $[Ar]3d^5 4s^1$ ***C*** *is not correct because the 4s electrons are removed before the 3d electrons*	**(1)** **Computer**

Question Number	Answer	Mark
2	**The only correct answer is B** (Ni^{2+}) ***A*** *is incorrect because all the 3d orbitals are fully occupied in this ion* ***C*** *is incorrect because none of the 3d orbitals is occupied in this ion* ***D*** *is incorrect because all the 3d orbitals are fully occupied in this ion*	**(1)**

Question number	Answer	Mark
1	**The only correct answer is B** (green) ***A*** *is incorrect because this is the colour of vanadium(IV)* ***C*** *is incorrect because this is the colour of vanadium(II)* ***D*** *is incorrect because this is the colour of vanadium(V)*	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(a)(i)	An answer that makes reference to the following points: • the presence of chloride ligands / change in ligands / different ligands results in a different energy gap between (lower and higher energy) d-orbitals / result in a different splitting in the d-subshell **(1)** • (colour results from the absorption of light by electrons) as they are promoted between d-orbitals / move from lower energy to higher energy (d-orbitals) / move to a higher energy level (d-orbital) **(1)** • so different wavelengths / frequencies (of light) are absorbed / transmitted / reflected (resulting in different colours) **(1)**	Penalise incorrect use of orbital rather than orbitals once only Allow different numbers of chloride ligands results in a different energy gap between the lower and higher energy d-orbitals Allow different ligands result in different splitting of the d-orbitals Allow different ligands give different d-d splitting Do not award the number of ligands is different Do not award the charge on the chromium ion is different Do not award they have different shapes Allow d-d transitions as long as the splitting of the d-orbitals has been stated Do not award d-orbital Do not award d-block electrons Allow different energies of light Allow colour absorbed? Do not award emitted	**(3)**

Question Number	Answer	Additional Guidance	Mark
17(a)(ii)	An explanation that makes reference to the following points: Reagent • use silver nitrate solution (which reacts with free chloride ions) to give a precipitate **(1)** Practical technique • use equal volumes of each solution of the three isomers (because they are equimolar solutions) **(1)** • add an excess of silver nitrate solution **(1)** • collect the precipitate / silver chloride by filtration / centrifuge **and** dry the precipitate **(1)** • weigh the silver chloride **and** calculate the number of moles (of silver chloride / chloride ions / silver ions and so find the ratio) or weigh the silver chloride for each isomer **and** find the ratio **(1)**	 May be shown with an equation Ignore presence / absence of dilute nitric acid Do not award if other reagents are added but allow other marks to be scored Allow an appropriate titrimetric method Allow the same amount of solution Allow prepare solutions using the same mass of isomer Allow add until no more precipitate is produced Do not award decant Allow centrifuge (MP4) followed by measure the height of the precipitate (in the tube) **and** calculate ratio heights (MP5)	**(5)**

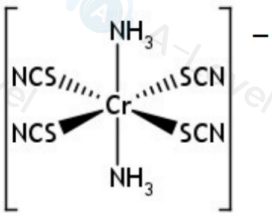
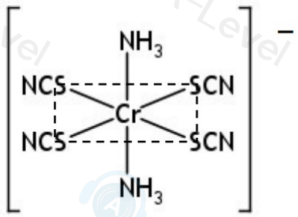
Question Number	Answer	Additional Guidance	Mark
17(b)(i)	An answer that makes reference to the following point: • correct equation	$[Pt(NH_3)_2Cl_2] + H_2O \rightarrow [Pt(NH_3)_2(H_2O)Cl]^+ + Cl^-$ Allow ligands in any order Allow displayed formula but ignore incorrect shapes Ignore state symbols even if incorrect Ignore omission of square brackets Do not award products without charges	(1)

Question Number	Answer	Additional Guidance	Mark
17(b)(ii)	An answer that makes reference to the following point: • a **lone pair / pair of electrons** on nitrogen is donated to / forms a coordinate bond / forms a dative (covalent) bond (with platinum ion)	Allow a lone pair is attached (to the platinum ion) Allow oxygen Do not award long pair Ignore just guanine/adenine/it has a lone pair Ignore ligand exchange	(1)

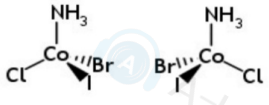
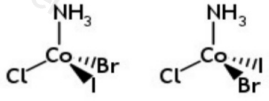
Question Number	Answer	Additional Guidance	Mark
17(b)(iii)	An answer that makes reference to the following points: • the second chloride is too far from / on the opposite side to the DNA strand **(1)** • to bind with a second guanine / adenine is too difficult / not possible **(1)**	Ignore just the chloride is on the opposite side Ignore the chloride is on the opposite side of the trans-platin Allow so trans-platin can only form one bond with DNA (while cis-platin can form two)	(2)

Question Number	Answer	Additional Guidance	Mark
17(c)(i)	• calculation of the moles of Cr, S, O and N **(1)** • calculation of the ratio of moles **(1)** • calculation of x, y and z **(1)**	Example of calculation: Award correct formula for Reinecke's salt given Ignore any attempts to calculate C or H Correct values with some working scores (3) If no other mark is awarded 3 correct ratio of moles (and one incorrect) scores 1	**(3)**

	Cr	S	O	N
$\div A_r$	14.67 ÷ 52.0 = 0.28212	36.23 ÷ 32.1 = 1.1287	4.51 ÷ 16 = 0.28188	27.65 ÷ 14 = 1.975
÷ 0.28188	1	4	1	7
so		x = 4	z = 1	y = 7 – 5 = 2

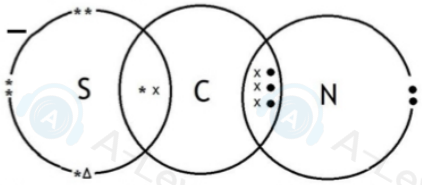
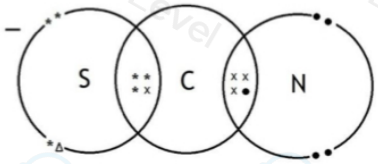
Question Number	Answer	Additional Guidance	Mark
17(c)(ii)	An answer that makes reference to the following points: • ammine ligands trans (180°) to each other in an octahedral complex **(1)** • the rest of the ion correct including charge and at least one dot bond and one wedge bond **(1)** or the rest of the ion correct including four ligands joined to show them in plane	Examples of diagram   Allow charge anywhere Allow structure lines with no bracket Ignore connectivity of ligands A cis- structure scores 1 for the octahedral shape and charge on the ion	**(2)**

Question Number	Answer	Additional Guidance	Mark
17(d)(i)	An answer that makes reference to the following points: • cobalt / central metal ion has four different groups / ligands attached to it **(1)** • giving (two) non-superimposable mirror images **(1)**	Allow cobalt is a chiral centre Allow Co is bonded to four different atoms / four different ligands Ignore rotation of plane polarised light	**(2)**

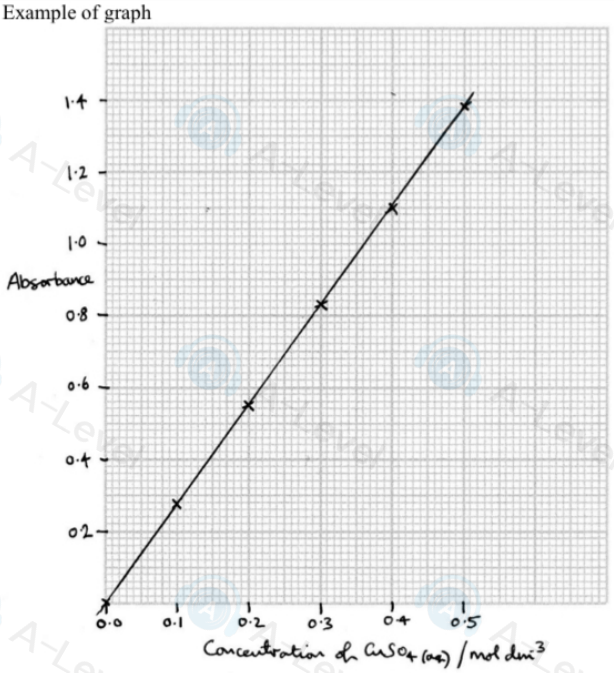
Question Number	Answer	Additional Guidance	Mark
17(d)(ii)	An answer that makes reference to the following points: • two structures drawn as mirror images or two structures drawn with two ligands swapped	Examples of diagram Correct answers must contain at least one dotted line and one wedged line   Accept second molecule in any correct orientation e.g. (compared to the molecule on the left in the	**(1)**

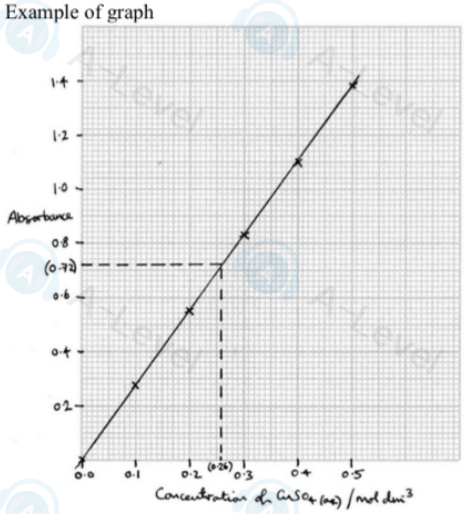
Question Number	Answer	Additional Guidance	Mark
18(a)(i)	An explanation that makes reference to the following points: • splitting in energy of d sub-shell/ d orbitals by water ligands **(1)** • absorption of light/photon/ (electromagnetic) radiation/energy **and** **electron**ic transition **(1)** • origin of observed colour of complex ion **(1)**	water/ligands **and** split the energy of the d-subshell/d-orbitals Do not award d orbital (singular) Allow degenerate d orbitals split into non-degenerate d orbitals by water ligands (visible) light/photon/(electromagnetic) radiation/energy is absorbed **and** promoting **electron**s from lower to higher energy Allow light etc causes d-d **electron** transitions Ignore colour absorbed Do not award reference to electron de-excitation colour due to reflected/transmitted light Allow due to wavelengths/frequencies of light that are not absorbed Allow complementary colour observed Do not award reference to emission/release of light	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(a)(ii)	An answer that makes reference to two of the following points: • the oxidation number of the iron is different in the two complexes **(1)** • (which results in a) different energy gap (due to different splitting of d orbitals) **(1)** • (and so) different wavelength/frequency of light required/ absorbed (to promote electron(s)) **(1)**	Allow reference to the charge on the iron ion is different but ignore just stating formulae Allow reference to the number of d orbital electrons is different Ignore reference to just number of electrons unless qualified Ignore reference to splitting of a singular d orbital Do not award an energy gap between 4s and 3d Ignore references to detailed explanations of colours even if incorrect as this is addressed in (i) Ignore reference to energy Ignore just reflection of colour Penalise once only reference to different ligands	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(b)(i)	• eight electrons around the S and the N using appropriate symbols with the triangle on the S **(1)** • eight electrons around the C using appropriate symbols **(1)**	Examples of diagram:  Allow one mark for a diagram with all dots/ all crosses/all triangles Accept the pairs to be vertical Allow electrons not in pairs Allow(2) for the alternative shown with two dative covalent bonds  	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(b)(ii)	An answer that makes reference to the following points: • (formula) $[Fe(H_2O)_5SCN]^{2+}$ **(1)** (justification) • calculation of moles of Fe^{3+} and calculation of moles of SCN^- **(1)** • 1:1 ratio (indicates one thiocyanate ion in octahedral complex which has six ligands so gives 5 water molecules) **(1)**	Allow missing square brackets Ignore any drawing if formula given, even if incorrect $n(Fe^{3+}) = 0.0128 \times 0.05 = 6.4 \times 10^{-4} / 0.00064$ (mol) $n(SCN^-) = 0.008 \times 0.08 = 6.4 \times 10^{-4} / 0.00064$ (mol) Ignore SF Allow evidence of division to get a value of 1	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(c)(i)	• labelled axes with unit **(1)** • all points plotted accurately **and** line of best fit including (0,0) **(1)** • scale to ensure points cover over half the graph paper in both directions **(1)**	Example of graph 	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(c)(ii)	• use of graph to determine concentration from 0.72 absorbance **(1)** • calculation of original concentration **(1)**	Example of graph  Allow answers in the range from 0.255 – 0.265 (mol dm^{-3}) Do not award M1 if working absent from graph Scaling up from diluted concentration =0.26 x (250 ÷ 50) = 1.3 (mol dm^{-3}) Allow answers in the range 1.275 – 1.325 (mol dm^{-3}) from 0.255 – 0.265 Ignore SF except 1SF TE from incorrect graphical reading	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(c)(iii)	An answer that makes reference to the following point • graph may not be linear above 0.50 mol dm^{-3} / unknown extrapolation above 0.50 mol dm^{-3}	Accept only values between 0 and 0.50 mol dm^{-3} are known Allow references to the limited solubility of copper(II) sulfate/solution may be saturated Allow absorbance is on a log scale and so absorbance above about 2 becomes hard to measure	(1)

Question Number	Answer	Additional Guidance	Mark
18(d)(i)	An answer that makes reference to the following point • increase in the number of moles **and** so a positive entropy (of the system)	Accept 4 moles to 7 moles for increase in the number of moles Allow particles for moles Allow positive total entropy/greater disorder Allow entropy increases Do not award references to endothermic/exothermic/enthalpy	(1)

Question Number	Answer	Additional Guidance	Mark
18(d)(ii)	An explanation that makes reference to two of the following points: • each nitrogen (atom) has one lone pair (of electrons) **(1)** • so both form dative covalent bonds/two dative bonds can form **(1)** • (and) the lone pairs of electrons being far enough apart **(1)**	Diagrams can give evidence for marking points Allow each ethane-1,2-diamine has two lone pairs (of electrons) Accept coordinate bonds for dative covalent bonds Do not award if carbon/CH_2 group forms dative bonds Allow reference to a four atom chain is the minimum (length) needed for a stable bidentate attachment to the central metal ion	(2)

Question Number	Answer	Additional Guidance	Mark
18(d)(iii)	An explanation that makes reference to the following points: • in ethane-1,2-diamine the angles are 107(°) because there are three bond pairs and one lone pair **(1)** • (because) in the complex ion the bond angle is 109.5(°) **(1)** • (the lone pair becomes a bonded pair with reduced repulsion and) therefore there are four pairs of bonded electrons around the nitrogen in the complex ion **(1)**	Standalone mark If no other mark awarded then award (1) for bond angle increases because lone pair now bonded	(3)

(Total for Question 18 = 22 marks)

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16 Iron is generally prescribed when a person is suffering from anaemia. Many people find it easier to take medicine in liquid form rather than solid tablets.

An iron solution, advertised for this purpose, contains iron as Fe^{2+}.
An adult is advised to take 90.0 mg of iron daily.

A 25.0 cm^3 sample of the solution was made up to 100.0 cm^3 using sulfuric acid and deionised water.
25.0 cm^3 samples of the diluted iron(II) solution were titrated with a 0.0125 mol dm^{-3} potassium manganate(VII) solution.
The mean titre was 16.20 cm^3.

The reaction is shown.

$$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

Calculate the volume of iron solution required to obtain a 90.0 mg dose of iron.
Give your answer to an appropriate number of significant figures.

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Volume required by an adult to obtain a 90.0 mg dose ..... cm^3

(Total for Question 16 = 6 marks)

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68%

Question Number	Answer		Additional Guidance	Mark
16			Example of calculation:	(6)
	• (M1) calculation of moles of manganate(VII)	(1)	$n(MnO_4^-)$ =(0.0125 x 0.01620)= 2.025 x 10^{-4}/0.0002025 (mol)	
	• (M2) calculation of moles of iron(II) from titre	(1)	$n(Fe^{2+})$ =(2.025 x 10^{-4} x 5=) 1.0125x 10^{-3} / 0.0010125 (mol)	
	• (M3) calculation of moles of iron(II) in flask	(1)	$n(Fe^{2+})$ =(1.0125 x 10^{-3} x 4=) 4.05 x 10^{-3} / 0.00405 (mol)	
	Either			
	• (M4) calculation of mass of iron in g	(1)	$m(Fe^{2+})$ =(4.05 x 10^{-3} x 55.8=) 0.22599 / 2.2599 x 10^{-1} (g)	
	(M5) calculation of mass of iron in mg in 25 cm^3	(1)	$m(Fe^{2+})$ =(0.22599 x 1000 =) 225.99 (mg)	
	• (M6) volume required for a 90 mg dose to 2/3 SF	(1)	$V(Fe^{2+})$ = (90 ÷ 225.99 x 25 =) = 10 / 9.96 (cm^3)	
	Or			
	• (M4) conversion of mass to mg	(1)	90 x 10^{-3} / 0.090 (g)	
	• (M5) calculation of moles of iron in advised dose	(1)	$n(Fe^{2+})$ =(0.090 ÷ 55.8 =) 1.6129 x 10^{-3}/0.0016129 (mol)	
	• (M6) volume required for a 90 mg dose to 2/3 SF	(1)	$V(Fe^{2+})$ =(0.0016129 ÷ 0.00405 x 25 =) 10 / 9.96 (cm^3)	
			Correct answer with some working scores (6) Ignore SF in M1 to M5 TE at each stage Intermediate acceptable rounding gives 9.94 (cm^3) for (6) Use of Fe = 56 gives 9.92 (cm^3) for (6) Ignore any errors in units during calculation	

(Total for Question 16 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
*17(a)	This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5-4 / 3 3-2 / 2 1 / 1 0 / 0 The following table shows how the marks should be awarded for structure and lines of reasoning Number of marks awarded for structure of answer and sustained lines of reasoning Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout / 2 Answer is partially structured	Guidance on how the mark scheme should be applied. The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks 3 or 4 indicative points would get 1 reasoning mark 0, 1 or 2 indicative points would get zero reasoning marks If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). **Comment**: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning	(6)