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Mark Scheme (Results)

Summer 2016

Pearson Edexcel
International Advanced Level
in Chemistry (WCH05) Paper 01
General Principles of Chemistry II

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Summer 2016
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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Section A (multiple choice)

Question Number	Correct Answer	Reject	Mark
1	D		**(1)**

Question Number	Correct Answer	Reject	Mark
2	B		**(1)**

Question Number	Correct Answer	Reject	Mark
3(a)	B		**(1)**

Question Number	Correct Answer	Reject	Mark
3(b)	D		**(1)**

Question Number	Correct Answer	Reject	Mark
4(a)	C		**(1)**

Question Number	Correct Answer	Reject	Mark
4(b)	D		**(1)**

Question Number	Correct Answer	Reject	Mark
5	C		**(1)**

Question Number	Correct Answer	Reject	Mark
6	C		**(1)**

Question Number	Correct Answer	Reject	Mark
7	C		**(1)**

Question Number	Correct Answer	Reject	Mark
8	A		**(1)**

Question Number	Correct Answer	Reject	Mark
9	D		**(1)**

Question Number	Correct Answer	Reject	Mark
10	A		**(1)**

Question Number	Correct Answer	Reject	Mark
11	C		**(1)**

Question Number	Correct Answer	Reject	Mark
12	B		**(1)**

Question Number	Correct Answer	Reject	Mark
13	A		**(1)**

Question Number	Correct Answer	Reject	Mark
14	B		**(1)**

Question Number	Correct Answer	Reject	Mark
15	A		**(1)**

Question Number	Correct Answer	Reject	Mark
16	A		**(1)**

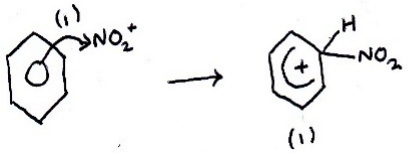
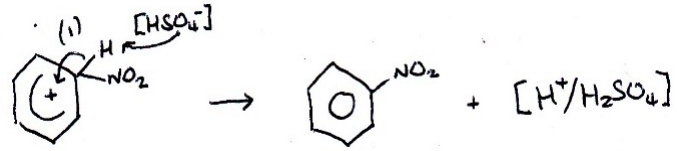
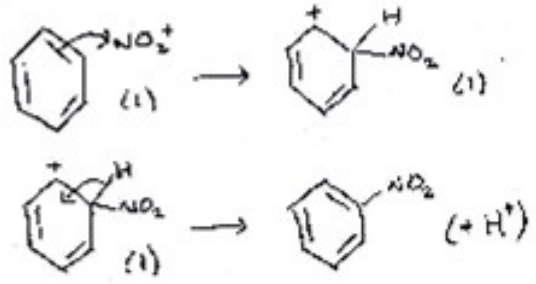
Question Number	Correct Answer	Reject	Mark
17	C		**(1)**

Question Number	Correct Answer	Reject	Mark
18	A		**(1)**

Section B

Question Number	Acceptable Answers	Reject	Mark
19*(a)	ALLOW reverse arguments for Kekule structure Any **three** points from **Type of reaction** Benzene reacts by (mostly electrophilic) substitution OR does not react by (electrophilic) addition OR Benzene does not react like alkenes / does not decolourise bromine water ALLOW Other suitable reactions / benzene needs a catalyst /halogen carrier to react with bromine **(1)** **Di-substitution** There are only 3 isomers of di-substituted compounds (not 4) OR Some di-substituted compounds are the same, e.g. 1,2 and 1,6 **(1)** **Thermochemical** Benzene's (standard) enthalpy (change) of **hydrogenation** is less exothermic than if it had (three localised C=C) double bonds / is not three times the value for three (localised C=C) double bonds ALLOW Benzene is more stable by ~150 kJ mol^{-1} OR stated enthalpies (of hydrogenation) −205 to −210 kJ mol^{-1} for benzene and −360 kJ mol^{-1} for 3 (localised C=C) double bonds OR (Standard) enthalpy (change) of combustion is less exothermic than if it had three (localised C=C) double bonds	Additional incorrect points Nucleophilic substitution Lower / just 'different' hydration Lower / just 'different' Just "less"	**(3)**

	ALLOW (Standard) enthalpy (change) of formation of benzene is less endothermic than that of "cyclohexa-1,3,5-triene" **(1)** IGNORE Just 'thermodynamically more stable' **X-ray diffraction** – does not need to be mentioned The C-C bond lengths in benzene are mid-way between that of a single bond and a double bond / are all the same length OR Benzene is a regular hexagon (and Kekule structure is not) **(1)** IGNORE Bond angles are the same **Infrared** The infrared spectrum for benzene has a peak for an aromatic C=C at a different wavenumber / absorption / frequency to an alkene C=C OR Benzene has peaks at 1600, 1580, 1500, 1450 (cm−1) rather than 1669 – 1645 (cm−1) ALLOW Benzene has no peak for alkene C=C / 1669 – 1645 (cm−1) **(1)** IGNORE different C-H absorptions / just 'different peaks to alkenes' IGNORE References to NMR **Electron density map** Benzene shows an even spread of electrons **(1)**	C-H bond	

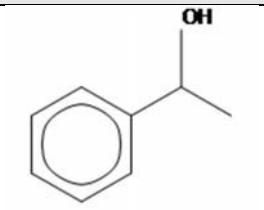
Question Number	Acceptable Answers	Reject	Mark
19(b)(i)	$H_2SO_4 + HNO_3 \rightarrow NO_2^+ + H_2O + HSO_4^-$ OR $H_2SO_4 + HNO_3 \rightarrow H_2NO_3^+ + HSO_4^-$ **and** $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$ OR $2H_2SO_4 + HNO_3 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$ IGNORE state symbols, even if incorrect **(1)**		**(4)**
	 Curly arrow from on or within the circle to N of NO_2^+ ALLOW curly arrow from anywhere **within** the hexagon ALLOW curly arrow towards any part of the NO_2^+, including to the + charge **(1)**	Half arrow heads Curly arrow on or outside the hexagon	
	 Intermediate structure including charge with horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon **and** some part of the positive charge must be within the horseshoe **(1)**	Dotted bonds to H and NO2 unless as part of a 3D structure	
	Curly arrow from C-H bond to anywhere in the hexagon reforming the delocalised structure **(1)**	Curly arrow from H	
	Correct Kekulé structures score full marks 		

Question Number	Acceptable Answers	Reject	Mark
19(b)(ii)	Higher temperature causes multiple substitution of NO_2 groups / formation of dinitrobenzene / formation of trinitrobenzene ALLOW further nitration / substitution **(1)** IGNORE decomposition of benzene / nitrobenzene / addition of NO_2 groups At lower temperature reaction is (too) slow **(1)** IGNORE References to activation energy / reaction does not occur at low temperature	Different isomers of nitrobenzene	**(2)**

Question Number	Acceptable Answers	Reject	Mark
19(c)(i)	 Formula of organic product **(1)** Rest of equation correct **(1)** ALLOW Br on any 3 carbon atoms ALLOW $C_6H_5OH + 3Br_2 \rightarrow C_6H_2(OH)Br_3 + 3HBr$ for both marks, allow $C_6H_2(Br_3)OH$, ignore missing brackets ALLOW correct balanced equations to form mono or di substituted product for 1 mark ALLOW Kekulé structures IGNORE position of bond to OH if vertically above or below the ring / name of product / state symbol	OH-C of benzene on lhs or rhs	**(2)**

Question Number	Acceptable Answers	Reject	Mark
***19(c)(ii)**	**MP1** **Lone pair of electrons on oxygen** (may be shown on a diagram) **and** EITHER Overlaps with pi cloud /delocalised electrons / delocalised system OR Feeds into / donates into / interacts with (benzene) ring /delocalised electrons / delocalised system OR Increases the electron density of the (benzene) ring **(1)** **MP2** (Increased electron density) makes the ring more susceptible to electrophilic attack ALLOW phenol is a better nucleophile **(1)**	More electro-negative	**2**

Question Number	Acceptable Answers	Reject	Mark
19(d)(i)	If name and formula are given, both must be correct Ethanoyl chloride / CH_3COCl **(1)** aluminium chloride / $AlCl_3$ / iron(III) chloride / $FeCl_3$ Conditional on correct reagent or a 'near miss' eg acyl chloride ALLOW corresponding bromides **(1)** NOTE Reagent and catalyst in either order and they do not need to state which they are IGNORE Friedel-Crafts catalyst / Lewis acid catalyst / any solvent mentioned	Just aluminium or iron Additional reagents	**(2)**

Question Number	Acceptable Answers	Reject	Mark
19(d)(ii)	 ALLOW skeletal **/** displayed / structural formulae or any combination of these e.g. $C_6H_5CH(OH)CH_3$		**(1)**

Question Number	Acceptable Answers	Reject	Mark
19(d)(iii)	If name and formula are given both must be correct Lithium aluminium hydride / $LiAlH_4$ / lithium tetrahydridoaluminate((III)) / sodium borohydride / sodium tetrahydridoborate / $NaBH_4$ IGNORE solvents / temperature, even if incorrect	Hydrogen with or without any catalyst Water, if $LiAlH_4$	**(1)**

Question Number	Acceptable Answers	Reject	Mark
19(d)(iv)	If name and formula are given, both must be correct Phosphorus(V) chloride / phosphorus pentachloride / PCl_5 / phosphorus(III) chloride / phosphorus trichloride / PCl_3 / phosphorus and chlorine / P and Cl_2 thionyl chloride /$SOCl_2$ / conc hydrochloric acid / HCl **and** zinc chloride / $ZnCl_2$ / zinc / Zn No TE on 19(d)(ii)	Just (Conc.) hydrochloric acid / HCl	**(1)**

(Total for Question 19 =18 marks)

Question Number	Acceptable Answers		Reject	Mark
20(a)	$MnO_4^-(aq) + e^- \rightleftharpoons MnO_4^{2-}(aq)$	+0.56	Missing +	**(1)**
	$MnO_4^{2-}(aq) + 2H_2O(l) + 2e^- \rightleftharpoons MnO_2(s) + 4OH^-(aq)$	+0.59		
	Both correct for the mark			

Question Number	Acceptable Answers	Reject	Mark
20(b)	If name and formula are given, both must be correct **A** (Salt bridge containing a solution of) potassium nitrate / KNO_3 ALLOW potassium chloride / KCl / sodium chloride / NaCl /sodium nitrate / $NaNO_3$ **(1)** **B** (Electrode made of) platinum /Pt **(1)** **C** (Solution containing) manganese(II) **and** manganese(III) ions /Mn^{2+} **and** Mn^{3+} ions ALLOW Soluble salts of manganese(II) and manganese(III) ions **(1)** (Essential condition) **stand alone mark** 1 mol dm^{-3} ALLOW this if written in **C** ALLOW '1 molar' / 1M / equal concentrations of Mn^{2+} **and** Mn^{3+} / manganese(II) **and** manganese(III) ions **(1)** IGNORE any temperature or pressure	KI NaI Incorrect unit eg mol dm^3	**(4)**

Question Number	Acceptable Answers	Reject	Mark
20(c)(i)	$2Mn^{2+} + 5BiO_3^- + 14H^+ \rightarrow 2MnO_4^- + 5Bi^{3+} + 7H_2O$ All correct formulae on both sides ALLOW ⇌ **(1)** Balancing correct formulae Conditional on all formulae correct ALLOW multiples **(1)** IGNORE state symbols, even if incorrect IGNORE other equations as working before final equation IGNORE electrons left in if they have been crossed through **Note:** Balanced equation with uncancelled electrons or uncancelled H^+ ions / H_2O scores **(1)**		**(2)**

Question Number	Acceptable Answers	Reject	Mark
20(c)(ii)	(E^o_{cell} = 1.60 – 1.51 =) +0.09 V Sign, value and unit required TE on incorrect starting oxidation state of manganese For Mn^{2+} to Mn^{3+} (E^o_{cell} = 1.60 – 1.49 =) +0.11 V For MnO_2 to MnO_4^{2-} (E^o_{cell} = 1.60 – 0.59 =) +1.01 V For MnO_4^{2-} to MnO_4^- (E^o_{cell} = 1.60 – 0.56 =) +1.04 V	+0.1 V	**(1)**

Question Number	Acceptable Answers	Reject	Mark
20*(d)	NOTE This calculation involves 8 individual mathematical operations (see 1 to 8 below), 4 on each titration and an additional subtraction. The first mark is awarded for the first operation finding the number of moles of Fe^{2+} ions from one of the titrations. The second mark is awarded after three further operations and then each subsequent mark for every other operation. The subtractions scores 1 mark on its own. One possible suggested solution is as follows For the original solution of **A** 1. Moles of MnO_4^- which reacts with 25 cm^3 of original solution **A** $= \frac{16.80 \times 0.0195}{1000}$ $= 3.276 \times 10^{-4}$ (mol) **(1)** 2. Moles of Fe^{2+} in original solution = Answer to 1 x 5 $= 1.638 \times 10^{-3}$ (mol) AND 3. Moles of Fe^{2+} in 500 cm^3 of original solution **A** = Answer to 2 x 20 $= 3.276 \times 10^{-2}$ (mol) AND 4. Mass of Fe2+ in 500 cm^3 of original solution **A** = Answer to 3 x 55.8 = 1.828 (g) **(1)** ALLOW The three operations (x 5, x 20 and x 55.8) in any order. A_r Fe = 56 (instead of 55.8)		**(5)**

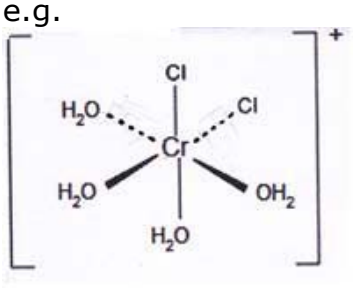
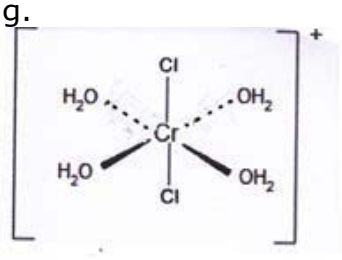
	For the fully reduced solution of **A** 5. Moles of MnO_4^- which reacts with 25 cm^3 of reduced solution $= \frac{18.20 \times 0.0195}{1000}$ = 3.549 x 10-4 (mol) AND 6. Moles of Fe^{2+} in the fully reduced solution **A** = Answer to 1 x 5 = 1.7745 x 10-3 (mol) **(1)** 7. Moles of Fe^{2+} in 500 cm3 of the fully reduced solution **A** = Answer to 6 x 20 = 3.549 x 10-2 (mol) AND 8. Mass of Fe^{2+} in 500 cm^3 of reduced solution Y = Answer to 7 x 55.8 = 1.980342 (g) **(1)** Mass of Fe^{3+} in original solution = Answer to 8 - Answer to 7 = 0.15288 (g) **(1)** ALLOW The three operations (x 5, x 20 and x 55.8) in any order. A_r Fe = 56 (instead of 55.8) ALLOW other methods IGNORE SF except 1SF		**(5)**

(Total for Question 20 = 13 marks)

Question Number	Acceptable Answers	Reject	Mark
21(a)	Transition metals form at least one **ion** with an incomplete **d**-subshell / partially filled d orbital(s) ALLOW forms an **ion** with unpaired **d** electron(s) OR Scandium **only** forms an **ion** with an empty **d**-subshell / all **d** orbital**s** are empty OR Scandium does not form an **ion** with an incomplete **d**-subshell / partially filled d orbital(s) **(1)** Scandium (only) forms Sc^{3+} ALLOW Sc only has one oxidation state (in compounds) **(1)** Sc^{3+} is [Ar] OR Sc is $[Ar]3d^{1}4s^{2}$ / $[Ar]4s^{2}3d^{1}$ **and** loses all three outer electrons ALLOW [Ar] written out as $1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}$ **(1)**	d shell sub-shell / orbital other than 3d	**(3)**

Question Number	Acceptable Answers	Reject	Mark
21(b)	$[Cr(H_2O)_6]^{3+}$ + **3**NH_3 → $Cr(OH)_3$ + $3H_2O$ + $3NH_4^+$ OR $[Cr(H_2O)_6]^{3+}$ + **3**NH_3 → $[Cr(OH)_3(H2O)_3]$ + $3NH_4^+$ Correct formula of chromium(III) hydroxide ALLOW $[Cr(H_2O)_3(OH)_3]$ **(1)** IGNORE square brackets Rest of equation and balancing Conditional on correct formula of chromium(III) hydroxide **(1)** IGNORE state symbols even if incorrect	Any equation where NH_3 replaces water ligands	**(2)**

Question Number	Acceptable Answers	Reject	Mark
21(c)	ALLOW oxidation numbers written by formulae in equations **First mark** **Reaction 1** is a redox reaction as chromium decreases / changes in oxidation number from (+)6 / VI to (+)3 / III **(1)** **Second mark** **Reaction 2** is not a redox reaction as chromium has oxidation number (+)6(+) / VI in CrO_4^{2-} and $Cr_2O_7^{2-}$ / reactant and product / both species **(1)** IGNORE change in oxidation number of iron		**(2)**

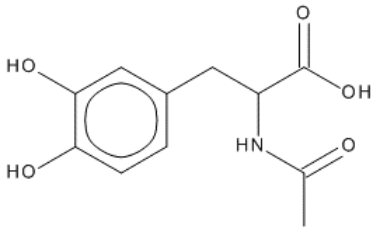
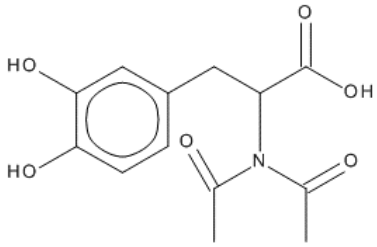
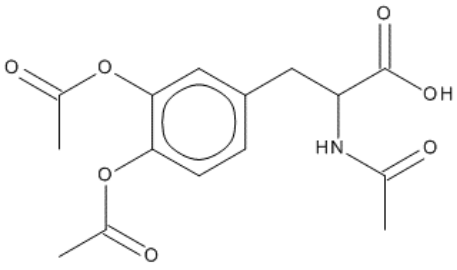
Question Number	Acceptable Answers	Reject	Mark
21(d)(i)	In both complexes: IGNORE charges on ions (Cl^- or Cr^{3+}) inside the brackets IGNORE exact position of dative bond from the water Any complex ion showing the two chloride ligands in the 'cis' positions where Cl-Cr-Cl bond angle is 90^o e.g.  **(1)** Any complex ion showing the two chloride ligands in the 'trans' positions where Cl-Cr-Cl bond angle is 180^o e.g.  **(1)** ALLOW for one mark two diagrams with correct chlorine, but no water OR two diagrams with correct water, but no chlorines ALLOW for one mark two diagrams with Cl_2 instead of Cl		**(2)**

Question Number	Acceptable Answers	Reject	Mark
21(d)(ii)	dative(covalent) ALLOW co-ordinate (covalent/ bonding) **(1)** (formed from) the lone pair (of electrons) on the oxygen / chloride ion / ligand / water (to the chromium ion) **(1)** ALLOW "pair of electrons" for "lone pair" IGNORE element / molecule / atom		**2**

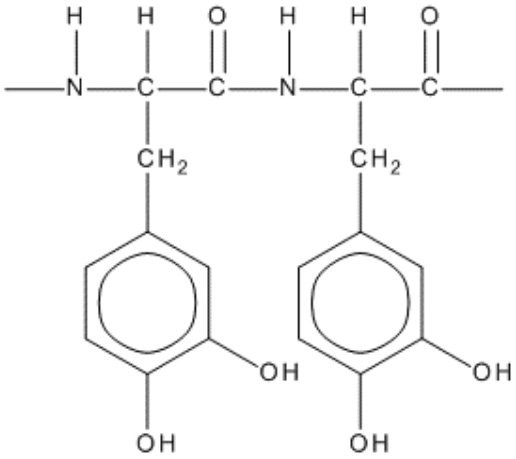
Question Number	Acceptable Answers	Reject	Mark
21(d)(iii)	Working is essential mol of AgCl = 3.44/143.4 = 0.023989 **(1)** ratio Cr^{3+}: (free Cl^{-}) (= 0.012: 0.023989) = 1 : 2 ALLOW this written in words **(1)** so, $[CrCl(H2O)5]^{2+}$ / (ion) **Y** (is formed) **(1)** ALLOW structure of **Y** drawn IGNORE SF except 1SF ALLOW for two marks **Y** if 178.8 used for M_r **X** if 107.8 / 82.5 used for M_r If no other mark is awarded: ALLOW 1 mark for just $[CrCl(H_2O)_5]^{2+}$ / (ion) **Y** (is formed)	No TE on incorrect moles	**3**

(Total for Question 21 = 14 marks)

Question Number	Acceptable Answers	Reject	Mark
22(a)	$C_9H_{11}NO_4$ ALLOW any order eg $C_9H_{11}O_4N$ IGNORE any additional structural formulae as working		**(1)**

Question Number	Acceptable Answers	Reject	Mark
22(b)	Must have N linked to CH_3CO  OR  OR CH_3CO linked to N and Os on benzene ring e.g.  ALLOW any combination of skeletal, displayed or structural formulae IGNORE bond angles	Ethanoyl group joined to COOH group to form an anhydride	**(1)**

Question Number	Acceptable Answers	Reject	Mark
22(c)	In each pair, the observation is conditional on a correct or 'near miss' reagent Any matching pair from: Sodium carbonate / Na_2CO_3 / sodium hydrogencarbonate / $NaHCO_3$ ALLOW other (metal) carbonates **(1)** Effervescence/ fizzing/ bubbles Gas turns lime-water cloudy **(1)** IGNORE "gas given off" OR Add ethanol/ alcohol **and** H_2SO_4/ strong acid **(1)** Fruity smell/ pear drops / "glue smell" **(1)** ALLOW 1 mark for sodium/ Na **and** fizzing ALLOW 1 mark for phosphorus(V) chloride/PCl_5 **and** steamy white fumes IGNORE equations, even if incorrect IGNORE indicators	Incorrect formulae Additional incorrect tests Incorrect gas eg hydrogen	**(2)**

Question Number	Acceptable Answers	Reject	Mark
22(d)	 amide group (CONH) **(1)** extension bonds (can be solid or dotted) **and** rest of structure correct with OH groups on carbon atoms 3 and 4 relative to the CH_2 **(1)** ALLOW any combination of displayed/ skeletal / structural formulae ALLOW Kekulé structures IGNORE bond angles / brackets and n	Additional O in amide group One repeat unit / more than 2 repeat units	**(2)**

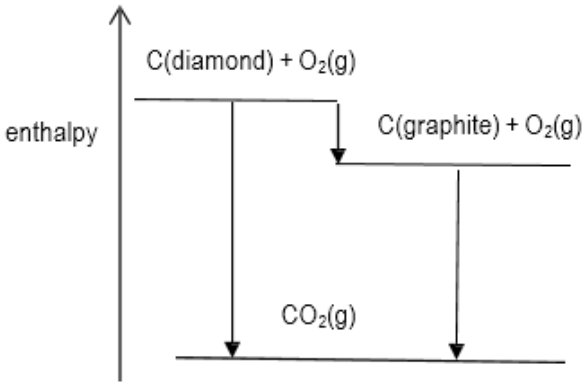
(Total for Question 22 = 6 marks)

Section C

Question Number	Acceptable Answers	Reject	Mark
23(a)(i)	**First mark** d-subshell splits / d-orbital**s** split (in energy) / d energy level(s) split(s) (by the ligands) **(1)** **Second mark** Electron(s) promoted / excited (from lower) to higher energy levels / electron(s)move (from lower) to higher energy d orbitals ALLOW d-d transitions **(1)** **Third mark** Absorbing photons / energy of a certain frequency (in visible region) ALLOW absorbing light **(1)** **Fourth mark** Transmitted / remaining light is coloured ALLOW complementary colour is seen ALLOW reflected / transmitted / remaining light is seen **(1)** IGNORE "opposite" colour / reference to electrons relaxing / dropping to the ground state	Penalise omission of (3)d once only. d-**orbital**/d-**shell** splits d-d splitting Just 'absorbing photons/energy' Emitted	**(4)**

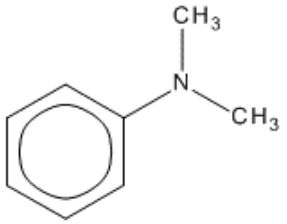
Question Number	Acceptable Answers	Reject	Mark
23(a)(ii)	Sapphires / rubies / they contain different (metal) ions OR Electron transfer between different metal ions OR The colour is caused by charge transfer ALLOW some of the aluminium ions / Al^{3+} have been replaced by chromium(III) ions / Cr^{3+} ALLOW d-orbitals are split with a different energy gap ALLOW different number of electrons in d- subshell ALLOW different oxidation states (of chromium) have different colours IGNORE Different ligands	Different oxidation states of aluminium	**(1)**

Question Number	Acceptable Answers	Reject	Mark
***23(b)**	**First mark** – diamond In diamond each carbon atom is **covalently** bonded to four other carbon atoms (in 3 dimensions) ALLOW diamond exists as a giant covalent structure with a tetrahedral arrangement **(1)** Second mark - graphite Graphite has London / dispersion / van der Waals' forces **between the layers** **(1)** Third mark - comparison The (covalent) bonds in diamond are stronger than the (London / dispersion / van der Waals' / (intermolecular) forces in graphite OR Reverse argument **(1)** ALLOW these marks on labelled diagrams	Ionic / metallic bonding / any intermolecular forces Hydrogen bonding London forces in diamond	**(3)**

Question Number	Acceptable Answers	Reject	Mark
23(c)(i)	ΔH_r C(diamond) → C(graphite) +O2(g) +O2(g) -395.4 -393.5 CO2(g) $\Delta H = -395.4 - (-393.5)$ $= -1.9$ (kJ mol^{-1}) ALLOW O2(g) missing from cycle Correct answer, with or without cycle **(1)** Diagram must be consistent with sign in calculation One enthalpy level diagram  Both combustions to CO2 **and** graphite below diamond **(1)** IGNORE missing enthalpy label and axis / O_2 / state symbols IGNORE activation energy curve	-2 (kJ mol^{-1}) Incorrect units Two energy diagrams	**(2)**

Question Number	Acceptable Answers	Reject	Mark
23(c)(ii)	ΔS_{system} needed to give ΔS_{total} (which must be positive) ALLOW ΔS_{system} and ΔS_{total} needed ALLOW If ΔS_{total} is positive, reaction is (thermodynamically) feasible IGNORE references to activation energy / kinetic inertness		**(1)**

Question Number	Acceptable Answers	Reject	Mark
23(d)(i)	sodium nitrite / sodium nitrate(III) / $NaNO_2$ **and** hydrochloric acid / HCl / sulfuric acid / H_2SO_4 ALLOW nitrous acid / HNO_2 (and hydrochloric acid / HCl) **(1)** IGNORE concentration of hydrochloric acid at 5 ^{o}C/ between 0 and 10 ^{o}C. Conditional on correct or 'near miss' reagents ALLOW any temperature or range of temperatures within range /ice bath / less than 5/10^{o}C **(1)**	Just sodium nitrate HNO_3 Incorrect formula with correct name or vice versa Conc H_2SO_4	**(2)**

Question Number	Acceptable Answers	Reject	Mark
23(d)(ii)	 ALLOW skeletal formula	Missing 'ring' Structure including OH	**(1)**

Question Number	Acceptable Answers	Reject	Mark
23(d)(iii)	**Note** First mark can only be awarded if there is a partial justification Strong acid-weak alkali ALLOW strong acid-strong alkali / named suitable acids and alkalis e.g. hydrochloric acid and (aqueous) ammonia ALLOW base for alkali **(1)** Conditional on M1 pK_{in} (for methyl red) is 5.1 / pH range (for methyl red) is 4.2-6.3 **and** this lies (wholly) within the vertical part of the titration curve ALLOW pH at the end / equivalence point corresponds with the pH range (for methyl red) ALLOW pK_{in} corresponds with the pH at the equivalence /end point (of the titration) / is in the middle of the vertical part of the titration curve ALLOW Indicator changes colour (entirely) within vertical part of the titration curve **(1)**		**(2)**

Question Number	Acceptable Answers	Reject	Mark
23(e)(i)	$[Fe(H_2O)_6]^{2+} + 6CN^- \rightarrow [Fe(CN)_6]^{4-} + 6H_2O$ OR $[Fe(H_2O)_6]^{2+} + 6KCN \rightarrow [Fe(CN)_6]^{4-} + 6K^+ + 6H_2O$ OR $[Fe(H_2O)_6]^{2+} + 6KCN \rightarrow K_4[Fe(CN)_6] + 2K^+ + 6H_2O$ OR $Fe^{2+} + 6CN^- \rightarrow [Fe(CN)_6]^{4-}$ OR $Fe^{2+} + 6KCN \rightarrow K_4[Fe(CN)_6] + 2K^+$ **(1)** IGNORE missing square brackets on complexes / state symbols Ligand exchange / ligand substitution / ligand replacement **(1)** Mark independently		**(2)**

Question Number	Acceptable Answers	Reject	Mark
23(e)(ii)	(+)3 / 3+ / III / iron(III) ALLOW Fe^{3+}		**(1)**

(Total for Question 23 = 19 marks)

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