24 Reactions of inorganic compounds in aqueous solutions Practice questions

Question number	Answer	Marks	Guidance
1 (a)	N in $Cu(NO_3)_2$ oxidation state: +5 N in NO_2 oxidation state: +4 Oxidation product: oxygen	1 1 1	You know Cu is +2 here since the formula of copper(II) nitrate is given to start. Since oxygen is normally −2 and in O_2 the oxygen is zero, then oxygen must have been oxidised.
1 (b)	$[Cu(H2O)_6]^{2+}$ octahedral	1 1	When a transition metal compound is added to water, a hexaaqua complex ion is formed.
1 (c)	$Cu(H_2O)_4(OH)_2$ **OR** $Cu(OH)_2$ $[Cu(H2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$	1 1	Accept: copper(II) hydroxide since the identity is asked for. Using two equations, this would be: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow$ $Cu(H_2O)_4(OH)_2 + 2H_2O$
1 (d)	$[Cu(NH_3)_4(H_2O)_2]^{2+}$ deep blue $Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow [Cu(NH_3)_4(H2O)_2]^{2+}$ $+ 2H_2O + 2OH^-$	1 1 1	This is an example of partial ligand substitution.
1 (e)	$[CuCl_4]^{2-}$ yellow-green tetrahedral	1 1 1	Learn the colours of these transition metal complexes.
1 (f) (i)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$	1	Remember the 4s electron is lost first.
1 (f) (ii)	a reducing agent	1	

2 (a)	Forms blue or pink precipitate.	1	This sometimes looks lilac.
	$Co(H_2O)_4(OH)_2$	1	Accept: $Co(OH)_2$.
	Precipitate dissolves in excess ammonia.	1	
	Forms yellow or pale brown 'straw' coloured solution.	1	
	$[Co(NH_3)_6]^{2+}$	1	
	Darkens on standing in air.	1	Accept turns brown.
	$[Co(NH_3)_6]^{3+}$ formed.	1	
	Due to oxidation by O_2 in air.	1	
2 (b)	Fe^{3+} has a larger charge and smaller size than Fe^{2+}. The Fe^{3+} polarises a ligand water molecule to a greater extent. The solution of Fe^{3+} contains more H+ ions. green precipitate with Fe^{2+} $FeCO_3$ brown or red/brown precipitate with Fe^{3+} $[Fe(H_2O)_3(OH)_3]$ Effervescence as carbon dioxide is evolved from the Fe^{3+} reaction.	9	Fe^{3+} has a higher charge/size ration scores two marks, or Fe^{3+} has a higher charge density scores two marks. However, if you refer to either atoms or molecules and not ions you lose both marks. Accept: more hydrolysis occurs, or Fe^{3+} weakens the OH bond more. If you give the hydrolysis equation, then you can get a mark for the equation and then a mark for stating that in Fe^{3+} the equilibrium lies further to the right. Fe^{3+} is more acidic in aqueous solution so it can react with carbonates and give off carbon dioxide (acid + carbonate → salt + water + carbon dioxide). The Fe^{2+} is not acidic enough to react in this way.

3 (a)	**Reaction 1** ammonia (NH_3) (solution) / NaOH $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Cu(H_2O)_4(OH)_2] + 2NH_4^+$ **OR** $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow [Cu(H_2O)_4(OH)_2] + 2H_2O$	1 2	**General principles in marking this question** Square brackets are not essential Penalise charges on individual ligands rather than on the whole complex Reagent and species can be extracted from the equation Ignore conditions such as dilute, concentrated, excess Reagent must be a compound NOT just an ion Equations must start from $[Cu(H_2O)_6]^{2+}$ except in 4(b) Mark reagent, species and equation independently Do not allow OH^- for reagent Product 1, balanced equation 1 Allow either equation for ammonia
3 (b)	**Reaction 2** Ammonia (conc/xs) $[Cu(H_2O)_4(OH)_2] + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 2H_2O + 2OH^-$	1 2	 Product 1, balanced equation 1 Note that the equation must start from the hydroxide $[Cu(H_2O)_4(OH)_2]$
3 (c)	**Reaction 3** Na_2CO_3 / any identified soluble carbonate / $NaHCO_3$ $[Cu(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CuCO_3 + 6H_2O$ OR $[Cu(H_2O)_6]^{2+} + Na_2CO_3 \rightarrow CuCO_3 + 6H_2O + 2Na^+$ OR $2[Cu(H_2O)_6]^{2+} + 2CO_3^{2-} \rightarrow Cu(OH)_2.CuCO_3 + 11H_2O + CO_2$ OR with $NaHCO_3$ $[Cu(H_2O)_6]^{2+} + HCO_3^- \rightarrow CuCO_3 + 6H_2O + H^+$	1 2	Do not allow $NaCO_3$ or any insoluble carbonate but mark on Product 1, balanced equation 1
3 (d)	**Reaction 4** HCl (conc/xs) / NaCl $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$	1 2	Allow any identified soluble chloride Product 1, balanced equation 1

4 (a)	W is $CuCl_4^{2-}$ Yellow-green/yellow/green $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow CuCl_4^{2-} + 6H_2O$	1 1 1	Not necessary to indicate solution Do not allow precipitate/solid Allow $+ 4HCl \rightarrow 4H^+$
4 (b)	X is $Cu(H_2O)_4(OH)_2$ Blue precipitate/solid $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$	1 1 1	Allow $Cu(OH)_2$/copper hydroxide Ignore shades Allow any balanced equation/equations leading to this hydroxide or $Cu(OH)_2$ But must use ammonia
4 (c)	Y is $[Cu(NH_3)_4(H_2O)_2]^{2+}$ Deep/dark/royal <u>blue solution</u> $Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^-$	1 1 1	 QoL Accept equation for formation from $Cu(OH)_2$
4 (d)	Z is $CuCO_3$ Green solid/precipitate $[Cu(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CuCO_3 + 6H_2O$	1 1 1	Allow copper carbonate Allow blue-green precipitate
4 (e) (i)	$Cu^{2+}(aq) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq)$ Blue Green	1 1 1	Allow hydrated ions State symbols not essential but penalise if wrong Do not allow description of solids Allow yellow/(red-brown/orange
4 (e) (ii)	Any two correct points about copper extraction from two of these three categories: Any relevant mention of lower energy consumption Any relevant mention of benefits of less mining (of copper ore) Less release of CO_2 (or CO) into the atmosphere	2	Do not allow reference to electricity alone or to temperature alone. Allow avoids depletion of (copper ore) resources Not just greenhouse gases. Must mention CO_2 or CO