Problem 2 25% of total	Question	2.1	2.2	2.3	2.4	2.5	2.6	2.7	Total
	Points	1	1	1	2	3	2	1	11

Problem 2: See You

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Copper is a ubiquitous element, especially in general chemistry. With its versatility, it is no wonder that it is found with many applications in our lives.

2.1) **State** the electronic configuration of Cu in spdf notation.

While copper(I) and copper(II) compounds are commonly known, copper(III) and copper(IV) compounds are much rarer. A well-known copper(III) compound is potassium cuprate(III), a dark blue solid. The sodium equivalent, $NaCuO_2$, can also be synthesised as follows:

Step 1: NaOH is added to $CuSO_4$.
Step 2: The resultant precipitate from step 1 was reacted with NaOH and NaClO, yielding $NaCuO_2$, NaCl and H_2O.

2.2) **Write** balanced equations for steps 1 and 2.

However, cuprates(III) are unstable in water, oxidising water when they are placed in it.

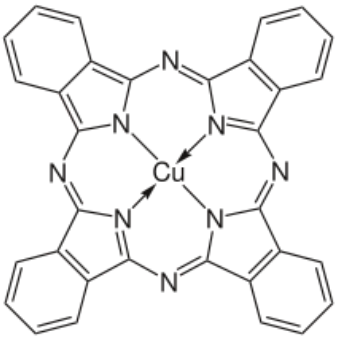
2.3) Given that hydroxide ions (OH^-) are formed in the oxidation reaction, **write** the balanced ionic equation for the reduction of CuO_2^- ions in water.

Although copper(III) compounds are very rare, copper(IV) compounds are even rarer. However, caesium hexafluorocuprate(IV) is one example of a copper(IV) compound which has been synthesised. The unbalanced reaction is shown below:

$$CsCuCl_3 + CsF + F_2 \rightarrow Cs_2CuF_6 + Cl_2$$

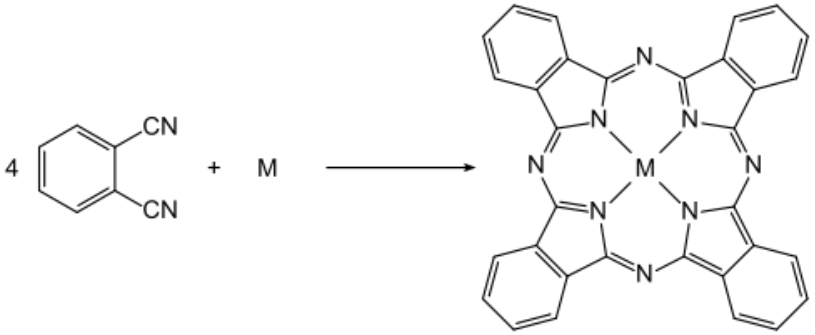
2.4) **Write** the balanced equation for the above reaction.

Copper is also used in the making of dyes. One example is copper phthalocyanine, a bright, crystalline, synthetic blue pigment from the group of phthalocyanine dyes. Its structure is shown below:



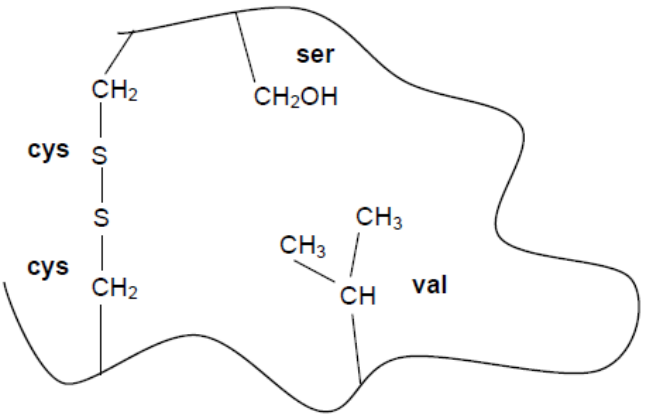
2.5) **State** the oxidation state of Cu in copper phthalocyanine.

A common method of synthesising copper phthalocyanine is by heating phthalic anhydride with copper(I) chloride, as shown below, where M = Cu:



2.6) With reference to your answer in part **2.5** and the structure above, **explain** why copper(I) chloride should be used, instead of copper(II) chloride.

Copper(I) chloride was used in the above synthesis, but copper(I) ions, Cu^{+} (aq), are highly toxic to humans due to their effects on proteins.



2.7) With reference to the receptor site shown above, **suggest** how copper(I) ions may affect the protein's ability to act as receptor site.

Problem 2: Solution

2.1) **State** the electronic configuration of Cu in spdf notation.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$, or [Ar] $3d^{10}\ 4s^1$

1 point for correct electronic configuration.
0 points for [Ar] $3d^9\ 4s^2$.

2.2) **Write** balanced equations for steps 1 and 2.

Step 1: $2\ NaOH + CuSO_4 \rightarrow Cu(OH)_2 \downarrow + Na_2SO_4$
Step 2: $2\ Cu(OH)_2 + 2NaOH + NaClO \rightarrow 2\ NaCuO_2 + NaCl + 3\ H_2O$

1 point for correct step 1 with correct balancing of equations.
2 points for correct step 2 with correct balancing of equations.
-0.5 points for each wrong coefficient, capped at 0 points overall.

2.3) Given that hydroxide ions (OH^-) are formed in the oxidation reaction, **write** the balanced ionic equation for the reduction of CuO_2^- ions in water.

$4\ CuO_2^- + 2\ H_2O \rightarrow 4\ CuO + O_2 \uparrow + 4\ OH^-$

1 point for correct products of the reaction. (O_2 gas instead of H_2 gas)
1 point for correct coefficients.
-0.5 points for each wrong coefficient, capped at 0 points overall.

2.4) **Write** the balanced equation for the above reaction.

$2\ CsCuCl_3 + 2\ CsF + 5\ F_2 \rightarrow 2\ Cs_2CuF_6 + 3\ Cl_2$

1 point for correct coefficients.
-0.5 points for each wrong coefficient, capped at 0 points overall.

2.5) **State** the oxidation state of Cu in copper phthalocyanine.

The pyrrole nitrogens each are negatively charged. The oxidation state of Cu is +2.

1 point for correct answer.

2.6) With reference to your answer in part **2.2** and the structure above, **<u>explain</u>** why copper(I) chloride should be used, instead of copper(II) chloride.

The macrocycle needs to be reduced (e.g. nitrile is reduced to imine groups), so copper(I) chloride must be used as a reducing agent to form the complex, whilst being oxidised to Cu^{2+} in the process.

1 point for mentioning reducing agents.

2.7) With reference to the receptor site shown above, **<u>suggest</u>** how copper(I) ions may affect the protein's ability to act as receptor site.

Cu^{+} ions act as reducing agents to denature protein by breaking the disulfide bond, hence breaking the tertiary structure of the protein and resulting in its loss of ability to act as receptor site.

1 point for identification of Cu^{+} being a reducing agent.
1 point for identification of it breaking the tertiary structure of the protein.