## PERIODICITY AHL (HL only)

*Please ensure that you have also completed the Core (SL & HL) questions*

1. The chromium complex ion $[Cr(H_2O)_6]^{3+}$ is blue in colour.

(a) State how water behaves as a *ligand* in this complex ion.

[1]

water donates a pair of electrons / form a coordinate (dative) bond. ✓

(b) In terms of acid-base theory, what type of reaction is the formation of $[Cr(H_2O)_6]^{3+}$ from $Cr^{3+}$ and water? Explain your answer.

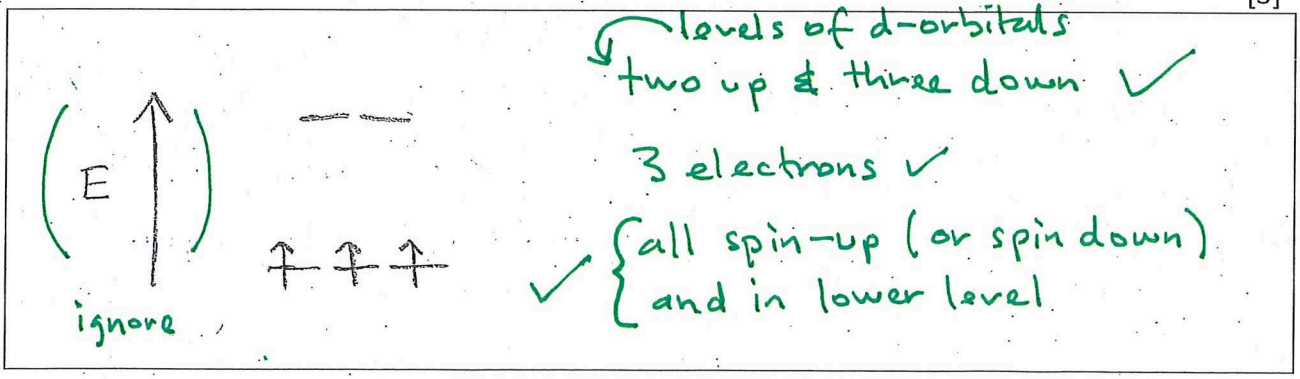
[2]

A Lewis (acid-base) reaction. ✓

$Cr^{3+}$ / chromium is behaving as a Lewis acid / $e^-$ pair acceptor and water is behaving as a Lewis base / $e^-$ pair donor. ✓

(c) Sketch a diagram to show the energy levels of the 3d-orbitals of chromium in $[Cr(H_2O)_6]^{3+}$. Complete the diagram by adding the d-electrons of chromium using arrows to represent electrons.

[3]




(d) Predict the type of magnetism that $[Cr(H_2O)_6]^{3+}$ might exhibit. Explain your answer.

[2]

Paramagnetism ✓

(As $Cr^{3+}$) has unpaired electrons. ✓

(e) Explain how the blue colour arises in this octahedral complex ion, you may refer to your diagram in (c).

[4]

The d-orbitals split in energy ✓

as the ligands approach in an octahedral complex. ✓

the energy gap / ΔE corresponds to visible light (in the electromagnetic spectrum) ✓

Light is absorbed as electrons are promoted / OWTTE (between d-orbitals) ✓

We see the complementary colour. ✓

ANY 4

(f) Using **section 15 and 17** of the data booklet, predict what would happen to the colour of $[Cr(H_2O)_6]^{3+}$ if some of the water ligands were replaced by hydroxide ligands ($OH^-$) using concentrated sodium hydroxide solution. Explain your answer.

[2]

($OH^-$ is a weaker ligand than water)

(ΔE)

So the energy gap will become smaller / light absorbed will be lower energy / higher wavelength ✓

Colour (observed) will go green ✓ or green-blue or colour with longer wavelength.

(g) Explain why Zinc compounds are colourless or white.

[2]

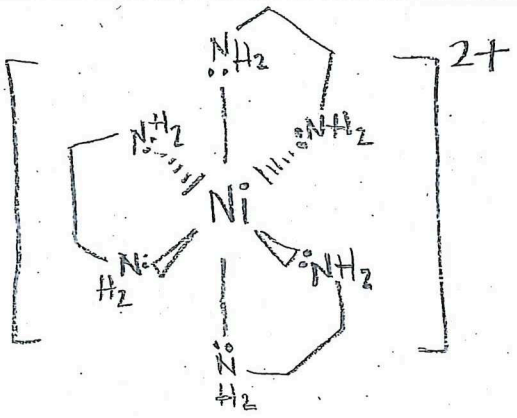
Zinc's d-orbitals are full of electrons / Zn has ([Ar]) $4s^0 3d^{10}$ in its only stable ion ($Zn^{2+}$) (for electron configuration) ✓

So electrons cannot move between the d-orbitals (in an octahedral complex) ✓

2. 1,2-ethanediamine (en) is a bidentate ligand shown in **section 16** of the data booklet.

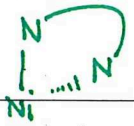
(a) Sketch the structure of $[Ni(en)_3]^{2+}$ showing the shape of the complex ion.

[2]



lone pair not required but N atom must be shown.

minimum:



3 en ligands and 6 bonds ✓

shape (octahedral) is clear ✓

e.g. minimum

(b) State the coordination number of the central nickel ion in $[Ni(en)_3]^{2+}$.

[1]

6 (6 coordinate bonds) ✓

(c) $Ni(en)_3]^{2+}$ is purple in colour. If drops of concentrated sodium hydroxide solution, NaOH (aq), are added the colour changes to blue.

Using **sections 15 and 17** of the data booklet suggest whether 1,2-ethanediamine (en) is a stronger or weaker ligand than $OH^-$. Explain your answer.

[1]

en is a stronger ligand than $OH^-$ and (because as we go from en to $OH^-$) the light absorbed yellow → orange / light seen violet → blue / ΔE gets smaller / wavelength of light increases. ✓

(d) Nickel is used as a catalyst in a number of reactions. State one reason why transition metals make good catalysts.

[1]

they have variable oxidation states / charges on ions (so may transfer electrons easily) ✓

OR substances can adsorb onto the metal surface.

Total marks 21 (32 minutes)