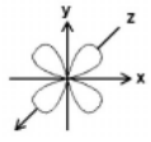
# 28. Chemistry of transition elements

## 28.3 Colour of complexes

## Paper 4

Marking Scheme

## Q1.

| | | |
|---|---|---|
| (b)(i) | orbitals of the same energy | 1 |
| (b)(ii) |   | 1 |

## Q2.

| | | |
|---|---|---|
| (c) | **M1** d orbital(s) of different energy / d-d splitting occurs<br>**M2** electron(s) promoted / excited<br>**M3** light is absorbed **AND** colour seen is complementary | 3 |

## Q3.

| | | |
|---|---|---|
| (c) | **M1** ($Ag^+$) d-subshell is full / complete **OR** $d^{10}$ **OR** d-orbitals are full<br>**M2** no d-$d^{(*)}$ transition **OR** no d electrons promoted/excited | 2 |

## Q4.

| | | |
|---|---|---|
| (f) | **M1** $\Delta E$ is different<br>**M2** different frequency (of light) is absorbed | 2 |

## Q5.

| | | |
|---|---|---|
| (f) | different $\Delta E$ **OR** different energy gap between d-orbitals [1]<br>absorption of different wavelength **OR** absorption of different frequency [1] | 2 |

## Q6.

| | | |
|---|---|---|
| (a) | • five 3d orbitals in the isolated $Fe^{2+}$ ion of same energy<br>• splitting two higher and three lower d orbitals<br>• energy of non-degenerate d orbitals in the complex more than degenerate d orbitals in isolated ion<br><br>two for one mark, three for two marks | 2 |

## Q7.

| | | |
|---|---|---|
| (c) | **M1** (in a complex / in the presence of ligands) the d-orbitals are split into two sets of orbitals<br><br>**M2** as an electron is excited / promoted<br><br>**M3** visible light is absorbed **AND** colour seen is complementary | **3** |

## Q8.

| | | |
|---|---|---|
| (b)(i) | • **d orbital(s)** of different energy / **d-d** splitting occurs<br>• **electron**(s) promoted / excited<br>• wavelength of visible light absorbed<br>**AND** complementary colour seen<br>• different energy gap / different $\Delta E$<br>**OR** different frequency/wavelength of light is absorbed | **4** |

## Q9.

| | | |
|---|---|---|
| (a) | a d-block element that forms one or more stable ions with incomplete d-orbitals | **1** |
| (b)(i) | <table><tr><th></th><th>geometry</th><th>CN</th><th>bond angle</th></tr><tr><td>$[Cu(H_2O)_6]^{2+}$</td><td>octahedral</td><td>6</td><td>90 or 180</td></tr><tr><td>$[CuCl_4]^{2-}$</td><td>tetrahedral</td><td>4</td><td>109 to 110</td></tr></table> | **3** |
| (b)(ii) | degenerate – of the same energy<br>non-degenerate – not of the same energy / different energy | **1** |
| (b)(iii) | different frequency / wavelength / photon absorbed | **1** |

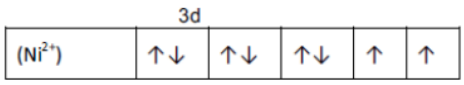
## Q10.

| | | |
|---|---|---|
| (c) | **M1:** $\Delta E$ is different **OR** energy gap between d-orbitals is different<br><br>**M2:** different frequency / wavelength is absorbed<br>**OR** different energy / light in visible region is absorbed | **2** |

## Q11.

| | | |
|---|---|---|
| (b)(i) | M1: **d-d orbital** splitting occurs [1]<br>M2: **electron**(s) promoted / excited [1]<br>M3: wavelength / frequency of light is **absorbed** [1]<br>M4: colour seen is complementary<br>**OR** wavelength / frequency of light **not** absorbed is seen [1] | **4** |
| (b)(ii) | (for $Cu^+$) $3d^{10}$ **OR** 3d subshell full [1] | **1** |

## Q12.

| | | |
|---|---|---|
| (a) |  | **1** |
| (b) | **M1** **d** orbitals **split** into **two levels/** lower and upper orbitals<br>**M2** **electron**(s) promoted / excited to a higher d–orbital<br>**M3** frequency of light **absorbed**<br>**M4** observed colour is complement of light absorbed | **4** |

## Q13.

| | | |
|---|---|---|
| (a)(i) | *K*stab = $[(Cu(NH_3)_4)^{2+}] / [(Cu(H_2O)_6)^{2+}] [NH_3]^4$ [1] | **1** |
| (a)(ii) | **deep / dark / royal** blue [1] | **1** |

| | | |
|---|---|---|
| (e) | **M1: d** orbitals splits into two sets of energy levels of different energy [1]<br>**M2:** wavelength / frequency / light / photon / hν **absorbed** [1]<br>**M3: electron**(s) promoted / excited [1]<br>**M4:** colour seen is complementary (to colour absorbed) [1]<br>**M5:** d–d energy gap / $\Delta E$ is different for **Y** and **Z**<br>**AND** so **different** frequency / wavelength of light absorbed • ✓ [1] | **5** |

## Q14.

| | | |
|---|---|---|
| (c)(iii) | **M1** (complexes have two sets of) **d orbital(s)** of different energy<br>**OR d** orbital(s)/d (sub)-shell splits<br>**OR (**inferred from a movement of an electron) from a **lower d** to **higher d orbital** [1]<br><br>**M2** wavelength / frequency / light / photon / hn **absorbed**<br>**OR** radiation / energy from visible (region) **absorbed** [1]<br><br>**M3 electron**(s) promoted / excited<br>**OR electron**(s) moves to higher (d-) orbital<br>**OR electron**(s) jumps up (to d-orbital) / jumps to higher (d-orbital) [1]<br><br>**M4** colour seen is complementary (to colour absorbed)<br>**OR** colour / light not absorbed is transmitted / reflected [1] | **4** |
| (c)(iv) | The gap between the d-orbitals / ΔE is different [1]<br>wavelength (**OR** photon, frequency) absorbed is different / changed etc 1] | **2** |

## Q15.

| | | |
|---|---|---|
| (a)(i) | $3s^2 3p^6 3d^9$ [1] | **1** |
| (a)(ii) | $[Cu(H_2O)_6]^{2+}$ (pale) blue<br>$CuCl_4^{2-}$ yellow **both** [1] | **1** |
| (a)(iii) | M1 energy gap / $\Delta E$ is **different** (for the ligands) [1]<br><br>M2 different frequency / wavelength of light **absorbed / transmitted / reflected** [1] | **2** |

## Q16.

| | | |
|---|---|---|
| (c) | • ligand exchange<br>• magnitude of d-orbital splitting changes / ΔE for d-orbitals changes / energy gap between d-orbitals changes<br>• change in colour / frequency / wavelength of light absorbed<br>• electrons are promoted/excited to higher d<br><br>Award 1 mark for two points, award 2 marks for three points, award 3 marks for all four points | **3** |