Solutions

Each answer shows the steps, then the **result**.

2.1

- a d-block element that forms one or more stable ions with incomplete (partly filled) d orbitals

2.2

- variable oxidation state; catalytic behaviour; form complex ions; form coloured compounds

2.3

- Cr: $[\mathrm{Ar}]\,3d^5 4s^1$; Fe^{3+}: $[\mathrm{Ar}]\,3d^5$

2.4

- In iron the 4s and 3d sub-shells are very close in energy, so electrons can be removed from either for a similar energy cost, giving more than one stable ion; calcium has only 4s electrons available above a noble-gas core, and removing a third electron would break into that core, which costs far too much energy

2.5

- Its only stable ion is Sc^{3+}, which has an empty d sub-shell ($3d^0$) rather than a partially filled one

3.1 B

- Zn^{2+} is $3d^{10}$ (a full d sub-shell), so it is not a transition element

3.2 B

- The close energies of 3d and 4s allow different numbers of electrons to be removed

3.3

- they have more than one stable oxidation state; and vacant d orbitals that can form dative bonds with reactants, providing a surface/intermediate

3.4

- scandium's only stable ion is Sc^{3+}, which has an empty d sub-shell ($3d^0$), so it has no incomplete d orbitals

3.5

(a)

- A d-block element that forms at least one stable ion with a partially filled d sub-shell

(b)

- Cu atom $[\mathrm{Ar}]\,3d^{10}4s^1$; Cu^{2+} $[\mathrm{Ar}]\,3d^9$; Zn atom $[\mathrm{Ar}]\,3d^{10}4s^2$; Zn^{2+} $[\mathrm{Ar}]\,3d^{10}$

(c)

- The only stable zinc ion, Zn^{2+}, has a FULL d sub-shell; the definition requires a partially filled one, so zinc is excluded

(d)

- In the copper complex the ligands split the 3d orbitals into two energy levels; Cu^{2+} is $3d^9$, so there is a vacancy and an electron can absorb a photon of visible light to jump the gap; the transmitted light is the complementary colour, which is blue. Zn^{2+} is $3d^{10}$, so the sub-shell is full, no electron can be promoted, no visible light is absorbed and the solution is colourless

(e)

- Any two, each with its reason: catalytic activity, because variable oxidation states allow electrons to be accepted and donated in a redox cycle; complex ion formation, because the small, highly charged ion has vacant d orbitals that accept lone pairs from ligands