2. (E) (a)  \[\text{Co}\left(\text{NH}_3\right)_6\]^{2+}  The coordination number of Co is 6; there are six monodentate NH\(_3\) ligands attached to Co. Since the NH\(_3\) ligand is neutral, the oxidation state of cobalt is +2, the same as the charge for the complex ion; hexaamminecobalt(II) ion.

(b)  \[\text{AlF}_6\]^{3−}  The coordination number of Al is 6; F\(^−\) is monodentate. Each F\(^−\) has a 1− charge; thus the oxidation state of Al is +3; hexafluoroaluminate(III) ion.

(c)  \[\text{Cu}\left(\text{CN}\right)_4\]^{2−}  The coordination number of Cu is 4; CN\(^−\) is monodentate. CN\(^−\) has a 1− charge; thus the oxidation state of Cu is +2; tetracyanocuprate(II) ion.

(d)  \[\text{CrBr}_2\left(\text{NH}_3\right)_2\]^+  The coordination number of Cr is 6; NH\(_3\) and Br\(^−\) are monodentate. NH\(_3\) has no charge; Br\(^−\) has a 1− charge. The oxidation state of chromium is +3; tetraamminedibromochromium(III) ion.

(e)  \[\text{Co}\left(\text{ox}\right)_3\]^{4−}  The coordination number of Co is 6; oxalate is bidentate. C\(_2\)O\(_4\)\(^2−\) (ox) has a 2− charge; thus the oxidation state of cobalt is +2; trioxalatocobaltate(II) ion.

(f)  \[\text{Ag}\left(\text{S}_2\text{O}_3\right)_2\]^{3−}  The coordination number of Ag is 2; S\(_2\)O\(_3\)\(^2−\) is monodentate. S\(_2\)O\(_3\)\(^2−\) has a 2− charge; thus the oxidation state of silver is +1; di(thio)sulfatoargentate(I) ion. (Although +1 is by far the most common oxidation state for silver in its compounds, stable silver(III) complexes are known. Thus, strictly speaking, silver is not a non-variable metal, and hence when naming silver compounds, the oxidation state(s) for the silver atom(s) should be specified).

11. (E) (a)  cis-trans isomerism cannot occur with tetrahedral structures because all of the ligands are separated by the same angular distance from each other. One ligand cannot be on the other side of the central atom from another.

(b)  Square planar structures can show cis-trans isomerism. Examples are drawn following, with the cis-isomer drawn on the left, and the trans-isomer drawn on the right.

```
      A    B
     / \  / \  
   M   M   M
  /   /   /   |
B   A  A   B  
```

cis-isomer trans-isomer

(c)  Linear structures do not display cis-trans isomerism; there is only one way to bond the two ligands to the central atom.

16. (M)  Complex ions (a) and (b) are identical; complex ions (a) and (d) are geometric isomers; complex ions (b) and (d) are geometric isomers; complex ion (c) is distinctly different from the other three complex ions (it has a different chemical formula).
21. **(M) (a)** Both of the central atoms have the same oxidation state, +3. We give the electron configuration of the central atom to the left, then the completed crystal field diagram in the center, and finally the number of unpaired electrons. The chloro ligand is a weak field ligand in the spectrochemical series.

\[
\text{Mo}^{3+} \quad [\text{Kr}] 4d^3 \quad \text{weak field} \quad \begin{array}{c|c}
\text{e}_g & \\
\text{t}_2g & \end{array} \quad 3 \text{ unpaired electrons; paramagnetic}
\]

The ethylenediamine ligand is a strong field ligand in the spectrochemical series.

\[
\text{Co}^{3+} \quad [\text{Ar}] 3d^6 \quad \text{strong field} \quad \begin{array}{c}
\text{e}_g & \\
\end{array} \quad \text{no unpaired electrons; diamagnetic}
\]

**22. (M) (a)** In \([\text{CoCl}_4]^{2-}\) the oxidation state of cobalt is 2+. Chloro is a weak field ligand. The electron configuration of Co\(^{2+}\) is \([\text{Ar}] 3d^7\) or \([\text{Ar}] 4010101\).

\[
\text{Co}^{2+} \quad [\text{Ar}] 3d^6 \quad \text{strong field} \quad \begin{array}{c|c|c}
\text{e}_g & \\
\text{t}_2g & \end{array} \quad \text{no unpaired electrons; diamagnetic}
\]

\[
\text{(b)} \quad \text{In } [\text{CoCl}_4]^{2-} \text{ the oxidation state of cobalt is } 2+. \text{ Chloro is a weak field ligand. The electron configuration of Co}^{2+} \text{ is } [\text{Ar}] 3d^7 \text{ or } [\text{Ar}] 4010101. \text{ The tetrahedral ligand field diagram is } weakness \quad \begin{array}{c|c|c}
\text{e}_g & \\
\text{t}_2g & \\
\end{array} \quad \text{weak field} \quad \begin{array}{c|c|c}
\text{e}_g & \\
\text{t}_2g & \\
\end{array} \quad \text{no unpaired electrons; diamagnetic}
\]

22. **(M) (a)** In \([\text{Cu(py)}_4]^{2+}\) the oxidation state of copper is +2. Pyridine is a strong field ligand. The electron configuration of Cu\(^{2+}\) is \([\text{Ar}] 3d^9\) or \([\text{Ar}] 4010101\).

\[
\text{Cu}^{2+} \quad [\text{Ar}] 3d^9 \quad \text{strong field} \quad \begin{array}{c|c}
\text{e}_g & \\
\text{t}_2g & \\
\end{array} \quad \text{no unpaired electrons; diamagnetic}
\]

**There is no possible way that an odd number of electrons can be paired up, without at least one electron being unpaired. [Cu(py)_4]^{2+} is paramagnetic.**

(b) In \([\text{Mn(CN)}_6]^{3-}\) the oxidation state of manganese is +3. Cyano is a strong field ligand. The electron configuration of Mn\(^{3+}\) is \([\text{Ar}] 3d^4\) or \([\text{Ar}] 4010101\).

\[
\text{Mn}^{3+} \quad [\text{Ar}] 3d^4 \quad \text{strong field} \quad \begin{array}{c|c|c|c|c|c|c}
\text{e}_g & \\
\text{t}_2g & \\
\end{array} \quad \text{weak field} \quad \begin{array}{c|c|c}
\text{e}_g & \\
\text{t}_2g & \\
\end{array} \quad \text{no unpaired electrons; diamagnetic}
\]

The ligand field diagram follows, on the left-hand side. In \([\text{FeCl}_4]^{-}\) the oxidation state of iron is +3. Chloro is a weak field ligand. The electron configuration of Fe\(^{3+}\) is \([\text{Ar}] 3d^5\) or \([\text{Ar}] 4010101\).

\[
\text{Fe}^{3+} \quad [\text{Ar}] 3d^5 \quad \text{weak field} \quad \begin{array}{c|c|c|c|c|c|c}
\text{e}_g & \\
\text{t}_2g & \\
\end{array} \quad \text{strong field} \quad \begin{array}{c|c|c|c|c|c|c}
\text{e}_g & \\
\text{t}_2g & \\
\end{array} \quad \text{5 unpaired electrons}
\]

The ligand field diagram follows, below.

**There are more unpaired electrons in [FeCl₄]⁻ than in [Mn(CN)₆]³⁻.**