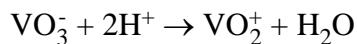


## Transition metal ions and redox

### Vanadium

When ammonium vanadate(V) is added to dilute hydrochloric acid, the dioxovanadium(V) ion forms:



white                      orange

If granulated zinc is added, this mixture is reduced over several minutes causing some colour changes.

The oxidation states, ions and colours formed are shown in the table on the right:

oxidation state	ion	colour
+4	$[\text{VO}(\text{H}_2\text{O})_5]^{2+}$	blue
+3	$[\text{VCl}_2(\text{H}_2\text{O})_4]^+$	green
+2	$[\text{V}(\text{H}_2\text{O})_6]^{2+}$	violet

Grey-blue  $[\text{V}(\text{H}_2\text{O})_6]^{3+}$  ions are produced at oxidation number +3 if sulphuric acid is used instead.

The reaction should be carried out in a stoppered flask to stop the  $[\text{V}(\text{H}_2\text{O})_6]^{2+}$  being oxidised by air.

### Chromium

The highest oxidation state of chromium is +6, found in chromate(VI),  $\text{CrO}_4^{2-}$ , and dichromate(VI),  $\text{Cr}_2\text{O}_7^{2-}$ . The dichromate ion is formed in acid solution:  $2\text{CrO}_4^{2-} + 2\text{H}^+ \rightleftharpoons \text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{O}$

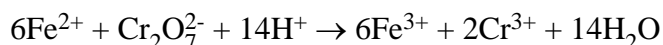
If granulated zinc is added, this mixture is reduced over several minutes causing some colour changes.

The oxidation states, ions and colours formed are shown in the table on the right:

oxidation state	ion	colour
+6	$\text{Cr}_2\text{O}_7^{2-}$	orange
+3	$[\text{CrCl}_2(\text{H}_2\text{O})_4]^+$	green
+2	$[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$	blue

The reaction should be carried out in a stoppered flask to stop the  $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$  being oxidised by air.

Dichromate(VI) ions can be used to estimate the concentration of iron(II) ions in solution by titration:



### Manganese

The highest oxidation state of manganese is +7, found in manganate(VII),  $\text{MnO}_4^-$ .

This is reduced by zinc, iron, or aqueous iron(II) ions to manganese(II) ions.

The oxidation states, ions and colours formed are shown in the table below:

oxidation state	ion	colour
+7	$\text{MnO}_4^-$	purple
+2	$[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$	colourless

The  $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$  ion is actually very pale pink, so it appears colourless in aqueous solution.

Manganate(VII) ions can be used to estimate the concentration of iron(II) ions in solution by titration:

