Chemguide – answers

TRANSITION METALS: VANADIUM

1. $SO_2 + V_2O_5 \longrightarrow SO_3 + V_2O_4$

$V_2O_4 + \frac{1}{2}O_2 \longrightarrow V_2O_5$

2. a) VO_2^+: +5 (x + 2(-2) = +1)

$V(H_2O)_6^{3+}$: +3 (The neutral molecule water has no overall oxidation state, and so vanadium's oxidation state is simply the charge on the ion.)

$V(H_2O)_6^{2+}$: +2 (as above)

VO^{2+}: +4 (x + (-2) = +2)

b) B: a mixture of VO_2^+ and VO^{2+}

C: VO^{2+}

D: $V(H_2O)_6^{3+}$

E: $V(H_2O)_6^{2+}$

c) The solution turns green as it is oxidised by the air to $V(H_2O)_6^{3+}$. If left a very long time, it will eventually turn blue as it is further oxidised by the air to VO^{2+}.

3. a) When you couple together two of these equilibria, the one with the more positive redox potential moves to the right, and the one with the more negative redox potential moves to the left. If you start with VO_2^+ ions that equilibrium *can* move to the left and, starting with zinc, that one *can* move to the right – so there is a reaction.

b) $2 \times (VO_2^+{}_{(aq)} + 2H^+{}_{(aq)} + e^- \longrightarrow VO^{2+}{}_{(aq)} + H_2O_{(l)})$

$Zn_{(s)} \longrightarrow Zn^{2+}{}_{(aq)} + 2e^-$

$2VO_2^+{}_{(aq)} + 4H^+{}_{(aq)} + Zn_{(s)} \longrightarrow 2VO^{2+}{}_{(aq)} + 2H_2O_{(l)} + Zn^{2+}{}_{(aq)}$

4. The final solution would be green, containing the $V(H_2O)_6^{3+}$ ion.

This equilibrium

$VO_2^+{}_{(aq)} + 2H^+{}_{(aq)} + e^- \rightleftharpoons VO^{2+}{}_{(aq)} + H_2O_{(l)} \quad E^0 = +1.00\text{ v}$

will move right because it has a more positive E^0 than the H_2SO_3 equilibrium, and so VO^{2+} ions are formed in the first instance.

The next equilibrium

$$VO^{2+}_{(aq)} + 2H^+_{(aq)} + e^- \rightleftharpoons V^{3+}_{(aq)} + H_2O_{(l)} \quad E^0 = +0.34\ v$$

will also move right because the E^0 value is still more positive than the H_2SO_3 equilibrium, and so V^{3+} ions are formed.

But the final equilibrium

$$V^{3+}_{(aq)} + e^- \rightleftharpoons V^{2+}_{(aq)} \quad E^0 = -0.26\ v$$

has a more negative E^0 value than the H_2SO_3 equilibrium, and so would want to move to the left – but that is where it is already. There therefore can't be any reaction.

(You could, of course, equally well describe this from the point of view of the H_2SO_3 equilibrium. In order for a reaction to occur, that has to move to the left – in which case, it has to have the more negative (or less positive) E^0 value.

It is less positive than the first vanadium equilibrium, and also than the second one – so both of those reactions can occur. But is more positive than the last one, and therefore would want to move to the right. But it is already on the right, and so no reaction is possible.)