Vanadium redox and variable oxidation states

AQA Chemistry (7405) · Full A level

Show your working where needed.

Name _____ Date _____

1. Read the species

Give the vanadium oxidation state and solution colour for VO_2^+, VO^{2+}, V^{3+} and V^{2+} in acid. Explain the difference between the first two formulae.

2. Combine with zinc

In acidic solution VO^{2+} is reduced to V^{3+} by zinc. Write a balanced vanadium half-equation and combine it with the zinc half-equation to give the ionic equation.

3. Change one condition

In acid the reduction half-equation is $VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$.

Predict how increasing the pH changes the tendency for reduction, with the concentrations of the vanadium ions held fixed. Explain using the half-equation.

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4. Where does reduction stop?

E° values in V are VO_2^+/VO^{2+} +1.00, VO^{2+}/V^{3+} +0.34, V^{3+}/V^{2+} −0.26 and Sn^{4+}/Sn^{2+} +0.15.

What is the lowest V oxidation state predicted with excess Sn^{2+}? Show the deciding E°cell values.

5. Calculate a minimum mass

An acidified sample contains 2.40×10^{-3} mol of vanadium in oxidation state +5. Calculate the minimum mass of zinc needed to reduce all the vanadium to +2, assuming no side reactions. $A_r(Zn) = 65.4$.

6. A sample exposed to air

Can dissolved O_2 oxidise V^{2+} to V^{3+} in acid under standard conditions? Use $E°(V^{3+}/V^{2+}) = -0.26$ V and $E°(O_2/H_2O) = +1.23$ V. Write the ionic equation.

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7. Change the ligand

At fixed pH, the metal(III)/metal(II) potential is +0.82 V with L and +0.48 V with M. The Fe^{3+}/Fe^{2+} potential is +0.77 V. Which ligand allows reduction by Fe^{2+}? Explain the ligand effect.

8. An ethanedioate determination

An acidified 25.0 cm^3 sample of $C_2O_4^{2-}$ reacts with 16.25 cm^3 of 0.0160 mol dm^{-3} MnO_4^-. Manganese goes from +7 to +2 and the carbon forms CO_2. Find the mole ratio and concentration of $C_2O_4^{2-}$.

9. Extra challenge · Work out a mixture from electron transfer

20.00 cm^3 contains V^{3+} and VO^{2+}, with total vanadium concentration 0.0750 mol dm^{-3}. In acid, 24.00 cm^3 of 0.0200 mol dm^{-3} MnO_4^- oxidises all vanadium to VO_2^+. Each MnO_4^- accepts five electrons.

Find the percentage of vanadium initially at oxidation state +3. Explain why the average number of electrons transferred per vanadium ion is between one and two.

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