InkChemistry

ANSWER BOOK

Variable oxidation states: vanadium, chromium and manganate(VII) titrations

Transition metals · Unit C14

AQA 3.2.5.5 · OCR A 5.3.1

18 questions · 57 marks

NAVY EDITION

Every question in this book has a code beside its number.
Type inklearning.co.uk/q/ followed by the code to open that question online.
© 2026 Ink Learning Ltd. All rights reserved.
inklearning.co.uk/chemistry/

SECTION A · Short, 1 to 2 marks

A1 VO-Q3

M1 E°_{cell} = E°(couple reduced) - E°(couple oxidised) = -0.26 - (-0.76). **A1** E°_{cell} = +0.50 V, to two significant figures. [2]

A2 VO-Q12

B1 MnO_4^- is deep purple but the Mn^{2+} it forms is almost colourless. **B1** after the end point the first excess drop of MnO_4^- stays unreacted and gives a permanent pale pink colour. [2]

A3 VO-Q18

M1 E°_{cell} = E°(couple reduced) - E°(couple oxidised) = +0.40 - (-0.56). **A1** E°_{cell} = +0.96 V, to two decimal places as the data. [2]

A4 VO-Q20

B1 chromium(III) hydroxide is amphoteric, so it reacts with hydroxide ions as an acid, giving soluble $[Cr(OH)_6]^{3-}$. **B1** iron(III) hydroxide is not amphoteric; it reacts only as a base, so no soluble complex forms with excess hydroxide. [2]

SECTION B · Standard, 3 to 5 marks

B1 VO-Q9

M1 moles of MnO_4^- = 0.0200 × 23.50 ÷ 1000 = 4.70×10^{-4} mol. **M1** moles of $C_2O_4^{2-}$ in 25.0 cm^3 = $4.70 \times 10^{-4} \times 5 \div 2 = 1.175 \times 10^{-3}$ mol. **M1** moles in 250.0 cm^3 = 1.175×10^{-2} mol. **M1** mass of $Na_2C_2O_4$ = $1.175 \times 10^{-2} \times 134.0$ = 1.5745 g. **A1** percentage purity = 1.5745 ÷ 2.00 × 100 = 78.7%, to three significant figures. [5]

B2 VO-Q10

B1 dilute sulfuric acid supplies the H^+ that the reduction of MnO_4^- to Mn^{2+} needs, and is not itself oxidised. **B1** manganate(VII) oxidises the chloride ions of hydrochloric acid to chlorine. **B1** so extra manganate(VII) is used and the titre is too large. **B1** ethanoic acid is a weak acid and does not supply enough H^+ ions. **B1** MnO_4^- is then reduced only to manganese(IV) oxide, a brown precipitate, so the 1 : 5 ratio no longer holds. [5]

B3 VO-Q1

B1 +5 is VO_2^+, a yellow solution. **B1** +4 is VO^{2+}, a blue solution. **B1** +3 is V^{3+}, a green solution. **B1** +2 is V^{2+}, a violet solution. [4]

B4 VO-Q2

B1 the products are Zn^{2+}, V^{3+} and H_2O. **B1** balanced as $Zn + 2VO^{2+} + 4H^+ \rightarrow Zn^{2+} + 2V^{3+} + 2H_2O$; allow multiples. **B1** the first green appears while some yellow VO_2^+ remains and some blue VO^{2+} has formed. **B1** yellow and blue together look green, so this green is a mixture and not V^{3+}. [4]

© 2026 Ink Learning Ltd. All rights reserved.

B5 VO-Q22 **M1** $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$, manganese falling from +7 to +2. **M1** $C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$, each carbon rising from +3 to +4, two electrons for each ion. **M1** ten electrons is the lowest common multiple, so the manganate half-equation is doubled and the ethanedioate one multiplied by five, which gives the 2 : 5 ratio. **A1** $2MnO_4^-(aq) + 16H^+(aq) + 5C_2O_4^{2-}(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 10CO_2(g)$; ignore state symbols. [4]

B6 VO-Q4 **B1** for VO^{2+} to V^{3+}, $E^\circ cell = +0.34 - (-0.14) = +0.48$ V, which is positive, so the reduction is feasible. **B1** for V^{3+} to V^{2+}, $E^\circ cell = -0.26 - (-0.14) = -0.12$ V. **B1** this is negative, because the V^{3+}/V^{2+} couple is more negative than tin's, so the reduction is not feasible. [3]

B7 VO-Q6 **B1** excess sodium hydroxide is added to give $[Cr(OH)_6]^{3-}$, a green solution. **B1** hydrogen peroxide is added and the mixture is warmed. **B1** a yellow solution of CrO_4^{2-} forms. [3]

B8 VO-Q7 **B1** the half-equation for reducing $Cr_2O_7^{2-}$ to Cr^{3+} uses fourteen H^+ ions. **B1** in acid the high H^+ concentration makes chromium(VI) a strong oxidising agent, so chromium(III) is the stable state and is hard to oxidise. **B1** in alkali there is little H^+, so chromium(VI) is a weak oxidising agent and chromium(III) is easily oxidised. [3]

B9 VO-Q8 **M1** moles of $MnO_4^- = 0.0180 \times 23.20 \div 1000 = 4.176 \times 10^{-4}$ mol. **M1** moles of $Fe^{2+} = 5 \times 4.176 \times 10^{-4} = 2.088 \times 10^{-3}$ mol, in 0.0250 dm^3. **A1** concentration = 0.0835 mol dm^{-3}, to three significant figures. [3]

B10 VO-Q14 **B1** in both, zinc reduces the metal one stage at a time to its +2 state. **B1** chromium goes from orange $Cr_2O_7^{2-}$ (+6) to green Cr^{3+} (+3) to blue Cr^{2+} (+2); vanadium goes from yellow (+5) through blue (+4) and green (+3) to violet (+2). **B1** both Cr^{2+} and V^{2+} are oxidised by air, so the flask must be closed or plugged to keep air out. [3]

B11 VO-Q15 **B1** the green precipitate is iron(II) hydroxide, and the orange-brown solid is iron(III) hydroxide. **B1** oxygen in the air oxidises iron(II) to iron(III). **B1** the electrode potential for iron(III)/iron(II) is much less positive in alkaline conditions, so iron(II) is oxidised more easily at high pH. [3]

B12 VO-Q16 **B1** Tollens' reagent contains $[Ag(NH_3)_2]^+$, with silver in the +1 oxidation state. **B1** an aldehyde reduces silver(I) to silver metal, oxidation state 0, seen as a silver mirror, and is itself oxidised. **B1** a ketone is not oxidised, so the silver stays as +1 and no mirror forms. [3]

© 2026 Ink Learning Ltd. All rights reserved.

B13 VO-Q17

B1 a grey-green precipitate of chromium(III) hydroxide forms. **B1** $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow [Cr(H_2O)_3(OH)_3] + 3H_2O$; allow $Cr(OH)_3$ as the product. **B1** in excess the precipitate dissolves to a dark green solution of $[Cr(OH)_6]^{3-}$. [3]

B14 VO-Q19

B1 Mn^{2+} gives a light brown precipitate (off-white at first) that darkens on standing in air. **B1** Cr^{3+} gives a grey-green precipitate. **B1** in excess sodium hydroxide the chromium precipitate dissolves to a dark green solution while the manganese precipitate does not. [3]

© 2026 Ink Learning Ltd. All rights reserved.

THIS BOOK ONLINE

Scan the code, or type the address, to open the questions in this book online:

inklearning.co.uk/chemistry/practise/questions/variable-oxidation-states/

© 2026 Ink Learning Ltd. All rights reserved.