M1. (a) (i) $Fe + 2HCl \rightarrow FeCl_2 + H_2$

(allow ionic formulae)

or $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$

1

(ii) PV = nRT n = PV/RT

(allow either formula but penalise contradiction)

1

$$n = \frac{110000 \times 102 \times 10^{-6}}{8.31 \times 298}$$

1

= 4.53×10^{-3} (mol)

(answer must have at least 3 sig. figs. Ignore units)

1

(iii) Moles of iron = $4.5(3) \times 10^{-3}$ mol

(allow conseq on (a)(ii))

(or = $4.2(5) \times 10^{-3}$ if candidate uses given moles of hydrogen)

1

Mass of iron = $4.53 \times 10^{-3} \times 55.8 = 0.253$ g
(mark is for method mass = moles × A_r)
(Mass of iron can be 56)

1

(iv) 0.253 × 100/0.263 = 96.1 % (mark is for answer to 2 sig. figs.)

(allow conseq on mass of iron. E.g. = 90% from $4.2(5) \times 10^{-3}$ moles of H_2 and Fe)

(Do not allow answers greater than or equal to 100%)

1

(b) (i) $Fe^{2+} \rightarrow Fe^{3+} + e^-$

(ignore state symbols)

1

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

1

$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$

1

(ii) Moles of dichromate = moles Fe^{2+}/6

= $4.53 \times 10^{-3}/6 = 7.55 \times 10^{-4}$

(Allow conseq, mark is for method (a)(iii)/6)

1

Volume of dichromate = moles/concentration
(= $(7.55 \times 10^{-4} \times 1000)/0.0200$)

(mark is for this method)

1

V = 37.75 (cm^3)

(allow 37.7 to 37.8, allow no units but penalise wrong units)

(allow conseq on moles of dichromate)

(if value of 3.63×10^{-3} used answer is 30.2 to 30.3, otherwise ans = moles Fe^{2+}/0.00012)

(if mole ratio wrong and candidate does not divide by 6, max score is ONE for volume method)

1

(iii) ($KMnO_4$) will also oxidise (or react with) Cl^- (or chloride or HCl)

1

[14]

M2. (a) Ti(IV) [Ar]

Or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

1

Ti(III) [Ar]$3d^1$

Or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1$

1

Ti(III) has a d electron that can be excited to a higher level

Allow idea that d electrons can be excited to another level (or move between levels)

1

Absorbs one colour of light from white light

Allow idea that light is absorbed

1

Ti(IV) has no d electron so no electron transition with energy equal to that of visible light

Allow Ti(IV) has no d electrons

1

(b) $[Cu(NH_3)_4(H_2O)_2]^{2+}$

1

$[Cr(OH)_6]^{3-}$

1

$[CuCl_4]^{2-}$

1

(c) (i) Rapid determination of concentration

Or easy to get many readings

1

Does not use up any of the reagent/does not interfere with the reaction

Or possible to measure very low concentrations

1

(ii) Curve starts with small gradient (low rate)

1

Because negative ions collide so E_a high

1

Curve gets steeper

1

Because autocatalyst (Mn^{2+}) formed

1

Curve levels out approaching time axis

Can score this mark and next one ONLY with simple curve (that is curve with gradually decreasing gradient)

1

Because MnO_4^- ions used up

5 max

1

[15]

M3. (a) Species $[Co(H_2O)_6]^{2+}$

1

Precipitate $Co(H_2O)_4(OH)_2$ 1

(b) $[Co(NH_3)_6]^{2+}$ 1

(c) Reaction Oxidation 1

Reactant Oxygen in the air 1

(d) R Iodine 1

Explanation $[Co(H_2O)_6]^{3+}$ oxidises I^- to I_2 1

[7]

M4. (a) $FeCl_3$ accepts electron pairs from water 1

Hence acts as a Lewis acid 1

$[Fe(H_2O)_6]^{3+}$ donates protons 1

Hence acts as a Bronsted-Lowry acid 1

(b) The Fe^{2+} ion has a smaller charge to size ratio 1

Hence less polarising than Fe^{3+} or less weakening effect on O-H bonds 1

(c) (i) $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$

1

$V_2O_4 + O_2 \rightarrow V_2O_5$

1

(ii) Both ions are negative or ions repel

1

$2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ Species

1

Balanced

1

$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ Species

1

Balanced

1

[13]

M5. (a) $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$

1

(b) $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$

1

(c) Moles MnO_4^- in 19.6 cm^3
$= 19.6 \times 0.022 \times 10^{-3} = 4.312 \times 10^{-4}$

1

Moles Fe^{2+} in 25 cm^3
$= 5 \times 4.312 \times 10^{-4} = 2.156 \times 10^{-3}$

1

Moles Fe^{2+} in 250 cm^3
$= 10 \times 2.156 \times 10^{-3} = 2.156 \times 10^{-2}$

1

Mass Fe^{2+} = moles × A_r
A_r = 2.156 × 10^{-2} × 55.8 = 1.203 g

1

Percentage by mass of carbon
= (1.270 – 1.203) × 100/1.270
= 5.28%

1

(d) Repeat the titration and take an average of the concordant results

1

(e) Analyse several samples from different parts of the molten iron

1

[9]