2.12 Chemistry: Electrode Potentials and Transition Metals: 30-minute Pack

AQA 7405 · Calculator allowed · about 30 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 This question is about precipitation reactions of transition metal ions with aqueous sodium hydroxide.

(a) State the colour of the precipitate formed, and identify the species present, when aqueous sodium hydroxide is added separately to solutions of $Fe^{2+}(aq)$, $Fe^{3+}(aq)$, and $Cu^{2+}(aq)$. **(3)**

(b) Chromium(III) hydroxide, $Cr(OH)_3$, is described as amphoteric. Using ionic equations, explain what this means with reference to its reactions with excess sodium hydroxide and with a strong acid. **(3)**

(c) The green precipitate of $Fe(OH)_2$ slowly turns to a rust-orange colour on standing in air. Explain this observation, giving an equation. **(2)**

(Total for Question 1 is 8 marks)

© Revision Library | revisionlibrary.co.uk

2 A colorimeter is calibrated using standard solutions of hydrated copper(II) sulfate, plotting absorbance against concentration to give a straight-line calibration graph through the origin, with gradient (calibration constant) k = 42.5 dm3 mol-1 (absorbance = k x concentration). An unknown copper(II) sulfate solution gives an absorbance of 0.638 using the same colorimeter and filter.

(a) Explain, in terms of the colour of the solution, why a red/orange filter (rather than a blue filter) should be selected for this colorimeter measurement. **(2)**

(b) Using the calibration data given, calculate the concentration, in mol dm-3, of Cu^{2+} in the unknown solution. **(3)**

(c) This solution was prepared by diluting 10.0 cm^3 of the original stock solution to a total of 250 cm^3 with distilled water before measuring its absorbance. Calculate the concentration, in mol dm-3, of Cu^{2+} in the original (undiluted) stock solution. **(2)**

(Total for Question 2 is 7 marks)

© Revision Library | revisionlibrary.co.uk

3 This question uses practical techniques from the required practical on titration. $EDTA^{4-}$ forms a 1:1 complex ion with Ca^{2+}, [Ca(EDTA)]2-, and this reaction is used to determine the total hardness of a water sample. A 100.0 cm^3 sample of tap water is titrated with 0.0100 mol dm-3 EDTA solution, using an indicator that changes colour once all the free Ca^{2+} (and Mg^{2+}) has been complexed. The mean titre required is 24.60 cm^3.

(a) State the coordination number of Ca^{2+} in the [Ca(EDTA)]2- complex ion, and explain why $EDTA^{4-}$ can form this complex with only one $EDTA^{4-}$ ion per Ca^{2+} ion. **(2)**

(b) Describe the colour change that would be observed at the end point of this titration, in general terms, given that the indicator used binds to free Ca^{2+} (giving one colour) but is a different colour when it is not bound to a metal ion. **(2)**

(c) Calculate the amount, in mol, of $EDTA^{4-}$ used in the titration, and hence the concentration, in mol dm-3, of Ca^{2+} in the water sample. **(4)**

(d) Express this hardness as a concentration in mg dm-3 of $CaCO_3$ equivalent (Mr of $CaCO_3$ = 100.1), and use the scale below to classify this water sample: soft, less than 60 mg dm-3; moderately hard, 60 to 120 mg dm-3; hard, 120 to 180 mg dm-3; very hard, greater than 180 mg dm-3 (all as $CaCO_3$). **(3)**

(Total for Question 3 is 11 marks)

© Revision Library | revisionlibrary.co.uk

Mark scheme · 2.12 Chemistry: Electrode Potentials and Transition Metals: 30-minute Pack

Question 1

(a) $Fe^{2+}(aq)$: green precipitate of $Fe(OH)_2$ **B1**

(a) $Fe^{3+}(aq)$: orange-brown (rust-coloured) precipitate of $Fe(OH)_3$ **B1**

(a) $Cu^{2+}(aq)$: pale blue precipitate of $Cu(OH)_2$ **B1**

(a) Answer: Fe^{2+}: green $Fe(OH)_2$. Fe^{3+}: orange-brown $Fe(OH)_3$. Cu^{2+}: pale blue $Cu(OH)_2$.

(b) amphoteric means $Cr(OH)_3$ can react with both a base and an acid (oe) **B1**

(b) with excess $OH^-(aq)$: $Cr(OH)_3(s) + 3OH^-(aq) \rightarrow [Cr(OH)_6]^{3-}(aq)$, the precipitate dissolves to give a (dark) green solution **B1**

(b) with a strong acid: $Cr(OH)_3(s) + 3H^+(aq) \rightarrow Cr^{3+}(aq) + 3H_2O(l)$, the precipitate dissolves to give a green Cr^{3+} solution **B1**

(b) Answer: Amphoteric means it reacts with both acids and bases. With excess OH^-: $Cr(OH)_3 + 3OH^- \rightarrow [Cr(OH)_6]^{3-}$ (dissolves, green solution). With acid: $Cr(OH)_3 + 3H^+ \rightarrow Cr^{3+} + 3H_2O$ (dissolves, green solution).

(c) $Fe(OH)_2$ is oxidised by dissolved oxygen (and water) in the air to $Fe(OH)_3$, which is the rust-orange colour observed (oe) **B1**

(c) $4Fe(OH)_2(s) + O_2(g) + 2H_2O(l) \rightarrow 4Fe(OH)_3(s)$ **B1**

(c) Answer: $Fe(OH)_2$ is oxidised by atmospheric oxygen to $Fe(OH)_3$: $4Fe(OH)_2 + O_2 + 2H_2O \rightarrow 4Fe(OH)_3$.

Question 2

(a) aqueous Cu^{2+} solutions ($[Cu(H_2O)_6]^{2+}$) are pale blue, meaning they strongly absorb light from the complementary (red/orange) part of the visible spectrum (oe) **B1**

(a) using a red/orange filter means the light passing through the solution is strongly absorbed, giving the largest, most sensitive change in absorbance reading with concentration (oe) **B1**

(a) Answer: The blue solution strongly absorbs red/orange light (its complementary colour); using a red/orange filter means absorbance changes most sensitively with concentration.

(b) concentration = absorbance / k = 0.638 / 42.5 **M1**

(b) 0.0150 mol dm-3 cao (awrt 0.0150) **A1**

(b) correct rearrangement of absorbance = k x concentration shown **B1**

(b) Answer: 0.0150 mol dm-3

(c) c1 = c2 x V2 / V1 = 0.0150 x 250 / 10.0 **M1**

(c) 0.375 mol dm-3 cao ft from (b) **A1**

(c) Answer: 0.375 mol dm-3

Question 3

(a) coordination number = 6 **B1**

(a) because $EDTA^{4-}$ is hexadentate, providing all six donor atoms (bonds) needed by Ca^{2+}, so only one $EDTA^{4-}$ ion is required per Ca^{2+} ion (oe) **B1**

(a) Answer: Coordination number = 6; since $EDTA^{4-}$ is hexadentate it alone can supply all six dative bonds to Ca^{2+}, so a 1:1 complex forms.

(b) before the end point, free Ca^{2+} ions are still present in solution, bound to the indicator, giving the indicator's 'metal-bound' colour **B1**

(b) at the end point, the last free Ca^{2+} ions are complexed by $EDTA^{4-}$ (which binds Ca^{2+} more strongly than the indicator does), releasing the indicator, which changes to its own (free/uncomplexed) colour (oe) **B1**

(b) Answer: While free Ca^{2+} remains, the indicator stays bound to it, showing its metal-bound colour; at the end point, $EDTA^{4-}$ (which binds Ca^{2+} more strongly) displaces the last of the indicator from Ca^{2+}, and the colour changes to the indicator's free (unbound) colour.

(c) $n(EDTA^{4-}) = 0.0100 \times (24.60/1000) = 2.460 \times 10^{-4}$ mol **M1**

(c) $n(Ca^{2+}) = n(EDTA^{4-}) = 2.460 \times 10^{-4}$ mol (1:1 ratio) **M1**

(c) concentration = n/V = 2.460e-4 / 0.1000 **M1**

(c) 2.46×10^{-3} mol dm-3 cao (awrt 2.46e-3) **A1**

(c) Answer: 2.46×10^{-3} mol dm-3

(d) mass of $CaCO_3$ equivalent per dm3 = $2.460 \times 10^{-3} \times 100.1$ **M1**

(d) 246 mg dm-3 cao (awrt 246) **A1**

(d) classified as very hard water (since 246 mg dm-3 is greater than 180 mg dm-3) ft **B1**

(d) Answer: 246 mg dm-3 as $CaCO_3$; this is classified as very hard water.

© Revision Library | revisionlibrary.co.uk