1 A titration using potassium manganate(VII) in dilute sulfuric acid can be used to determine the percentage of

☒ **A** aspirin in aspirin tablets.

☒ **B** chlorine in bleach.

☒ **C** copper in an alloy.

☒ **D** iron(II) sulfate in iron tablets.

(Total for Question = 1 mark)

2 Aqueous sodium hydroxide and aqueous ammonia are added to separate solutions of the same metal ion. The observations are shown in the table below.

Reagent added	A few drops	Excess
NaOH(aq)	green precipitate	green precipitate remains
NH_3(aq)	green precipitate	green precipitate dissolves to form a blue solution

The metal ion is

☒ **A** Cr^{3+}(aq).

☒ **B** Fe^{2+}(aq).

☒ **C** Fe^{3+}(aq).

☒ **D** Ni^{2+}(aq).

(Total for Question = 1 mark)

3 The reaction between cerium(IV) ions and thallium(I) ions is very slow.

$$2Ce^{4+}(aq) + Tl^{+}(aq) \rightarrow 2Ce^{3+}(aq) + Tl^{3+}(aq)$$

Which of these ions could catalyse this reaction?

☒ **A** Al^{3+}

☒ **B** Fe^{3+}

☒ **C** Na^{+}

☒ **D** Zn^{2+}

(Total for Question = 1 mark)

4 Which of these hydroxides is amphoteric?

☒ **A** $Cu(OH)_2$

☒ **B** $Mg(OH)_2$

☒ **C** $Ni(OH)_2$

☒ **D** $Zn(OH)_2$

(Total for Question = 1 mark)

5 The reaction

$$[Fe(H_2O)_6]^{2+} + H_2O \rightarrow [Fe(H_2O)_5(OH)]^{+} + H_3O^{+}$$

is an example of

☒ **A** oxidation.

☒ **B** reduction.

☒ **C** ligand exchange.

☒ **D** acid-base behaviour.

(Total for Question = 1 mark)

6 Hydrated crystals of a compound have the formula $CrCl_3(H_2O)_6$.
A solution containing one mole of the compound reacts with two moles of silver nitrate to form two moles of silver chloride.
The complex chromium ion in the compound is most likely to be

☒ **A** $[Cr(H_2O)_3Cl_3]^{3+}$

☒ **B** $[Cr(H_2O)_4Cl_2]^{+}$

☒ **C** $[Cr(H_2O)_5Cl]^{2+}$

☒ **D** $[Cr(H_2O)_6]^{3+}$

(Total for Question = 1 mark)

7 The reaction below can be catalysed by either Fe^{2+} ions or Fe^{3+} ions.

$$S_2O_8^{2-}(aq) + 2I^-(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$$

This is because

☒ **A** both reactants can react with Fe^{2+} ions.

☒ **B** both reactants can react with Fe^{3+} ions.

☒ **C** $S_2O_8^{2-}$ ions can be oxidized by Fe^{3+} ions and I^- ions can be reduced by Fe^{2+} ions.

☒ **D** $S_2O_8^{2-}$ ions can be reduced by Fe^{2+} ions and I^- ions can be oxidized by Fe^{3+} ions.

(Total for Question = 1 mark)

8 Copper metal is oxidized to Cu^{2+} by nitrate(V) ions which are reduced to nitrogen monoxide, NO.
By considering the changes to the oxidation numbers of copper and nitrogen, it can be deduced that in this reaction

☒ **A** 2 mol of copper reacts with 3 mol of nitrate(V) ions.

☒ **B** 2 mol of copper reacts with 5 mol of nitrate(V) ions.

☒ **C** 3 mol of copper reacts with 2 mol of nitrate(V) ions.

☒ **D** 5 mol of copper reacts with 2 mol of nitrate(V) ions.

(Total for Question = 1 mark)

9 The compound 1,2-diaminoethane, $H_2NCH_2CH_2NH_2$, is a bidentate ligand; in formulae, it is usually abbreviated to 'en'.

When 1,2-diaminoethane is added to $[Co(NH_3)_6]^{2+}$ in aqueous solution, $[Co(en)_3]^{2+}$ is formed. What is the **best** explanation for this?

☐ **A** There are much stronger bonds between the ligands and the cobalt(II) ion in $[Co(en)_3]^{2+}$ than in $[Co(NH_3)_6]^{2+}$.

☐ **B** When $[Co(en)_3]^{2+}$ is formed from $[Co(NH_3)_6]^{2+}$ the reaction is exothermic.

☐ **C** When $[Co(en)_3]^{2+}$ is formed from $[Co(NH_3)_6]^{2+}$ the total entropy change is positive.

☐ **D** When $[Co(en)_3]^{2+}$ is formed from $[Co(NH_3)_6]^{2+}$ the reaction has a low activation energy.

(Total for Question 9 = 1 mark)

10 When aqueous sodium hydroxide is added to an aqueous solution of a transition metal compound, a green precipitate is formed which dissolves in excess sodium hydroxide forming a green solution. The transition metal ion present in the original solution is

☒ **A** Cr^{3+}

☒ **B** Fe^{3+}

☒ **C** Fe^{2+}

☒ **D** Ni^{2+}

(Total for Question = 1 mark)

11 Sulfur dioxide reacts with hydrogen sulfide to form water and sulfur. By considering the changes in the oxidation numbers of sulfur, it can be deduced that, in this reaction

☒ **A** 1 mol of sulfur dioxide oxidizes 2 mol of hydrogen sulfide.

☒ **B** 1 mol of sulfur dioxide reduces 2 mol of hydrogen sulfide.

☒ **C** 2 mol of sulfur dioxide oxidizes 1 mol of hydrogen sulfide.

☒ **D** 2 mol of sulfur dioxide reduces 1 mol of hydrogen sulfide.

(Total for Question = 1 mark)

12 When EDTA is added to $[Cu(NH_3)_4]^{2+}$ in aqueous solution, the copper(II)-EDTA complex, $[Cu(EDTA)]^{2-}$, predominates in the resulting solution.

This is **best** explained by the fact that when $[Cu(EDTA)]^{2-}$ is formed from $[Cu(NH_3)_4]^{2+}$

☒ **A** there are much stronger bonds between the ligands and the copper(II) ion.

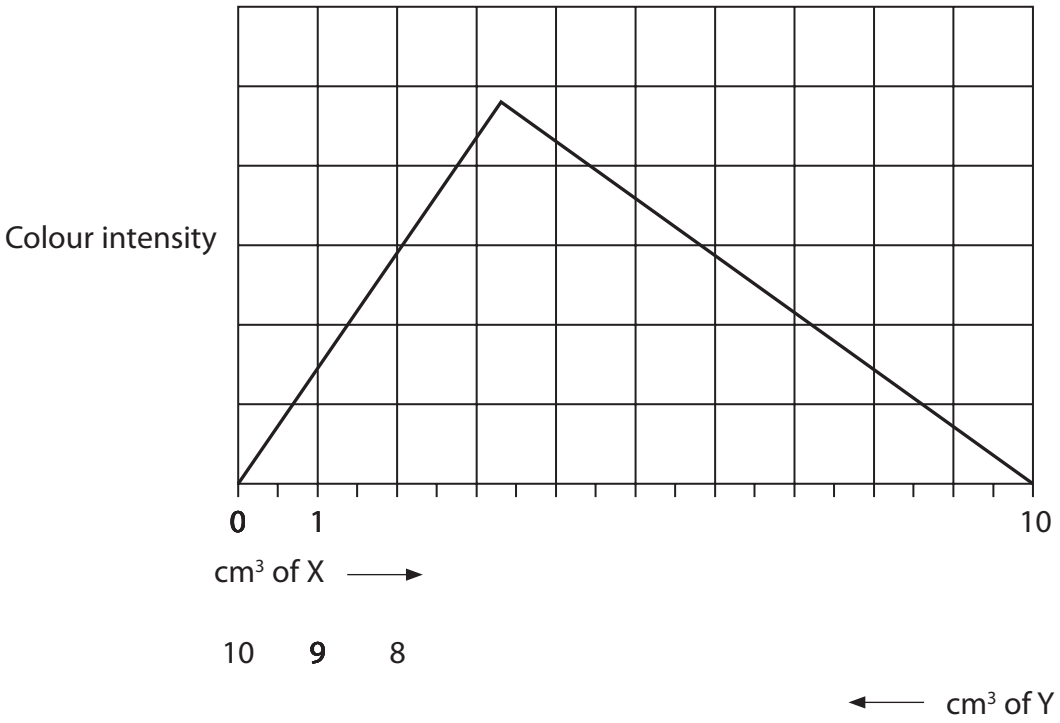
☒ **B** the reaction has a low activation energy.

☒ **C** the reaction is exothermic.

☒ **D** the total number of particles on the right-hand side of the equation is greater than on the left.

(Total for Question = 1 mark)

13 The graph below shows the variation in the colour intensity of different solutions formed by mixing a 0.05 mol dm^{-3} solution of a metal ion **X** and a 0.05 mol dm^{-3} solution of a complexing agent **Y**, in the proportions shown on the graph.



The most likely formula of the complex formed is

- ☒ **A** X_2Y
- ☒ **B** XY_2
- ☒ **C** XY_3
- ☒ **D** X_3Y

(Total for Question = 1 mark)

14 The hydrolysis of a transition metal cation can be represented by the following equation

$$[M(H_2O)_6]^{n+}(aq) + H_2O(l) \rightleftharpoons [M(H_2O)_5OH]^{(n-1)+}(aq) + H_3O^+(aq)$$

In this reaction

☒ **A** the solvent H_2O is acting as an acid by donating a proton to the metal cation.

☒ **B** the pH of the solution will be lower if the value of n is 2 instead of 3.

☒ **C** the equilibrium position lies further to the right if the value of n is 3 instead of 2.

☒ **D** the oxidation state of the metal in the cation has decreased from n to (n – 1).

(Total for Question = 1 mark)

15 Consider the equation below.

$$[Cu(H_2O)_6]^{2+}(aq) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq) + 6H_2O(l)$$

This reaction is best described as

☒ **A** acid-base.

☒ **B** redox.

☒ **C** addition.

☒ **D** ligand exchange.

(Total for Question = 1 mark)

16 In the manufacture of sulfuric acid, sulfur dioxide is converted to sulfur trioxide using a catalyst of vanadium(V) oxide:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The electronic configuration of vanadium is [Ar] $3d^3\ 4s^2$, so the mechanism for this reaction is most likely to involve a sequence in which vanadium(V) is converted to

☒ **A** vanadium(VI) by oxygen then back to vanadium(V) by sulfur dioxide.

☒ **B** vanadium(VI) by sulfur dioxide then back to vanadium(V) by oxygen.

☒ **C** vanadium(IV) by oxygen then back to vanadium(V) by sulfur dioxide.

☒ **D** vanadium(IV) by sulfur dioxide then back to vanadium(V) by oxygen.

(Total for Question = 1 mark)

17 All metal hydroxides dissolve in acid. When aqueous solutions of sodium hydroxide and ammonia are added separately to samples of chromium(III) hydroxide, in both cases the solid dissolves to form a green solution. How should these reactions be classified?

	sodium hydroxide	ammonia
☒ **A**	amphoteric	amphoteric
☒ **B**	amphoteric	ligand exchange
☒ **C**	ligand exchange	amphoteric
☒ **D**	ligand exchange	ligand exchange

(Total for Question = 1 mark)

18 This question is about a titration to determine the iron content of a tablet. The iron(II) ions in the tablet are oxidized to iron(III) ions by acidified manganate(VII) ions which are reduced to manganese(II) ions.

(a) The mole ratio of iron(II) to manganate(VII) ions in the reaction is

(1)

	Fe^{2+}	MnO_4
☒ **A**	1	5
☒ **B**	2	5
☒ **C**	5	2
☒ **D**	5	1

(b) A 0.200 g tablet is dissolved to make exactly 100 cm^3 of solution. 10 cm^3 of this solution is found to contain 5.38×10^{5} mol of iron(II) ions.

The percentage by mass of iron (A_r 55.8) in the tablet is

(1)

☒ **A** $\dfrac{5.38\times10^{-5}\times55.8}{0.200}\times\dfrac{100}{10}\times100\%$

☒ **B** $\dfrac{5.38\times10^{-5}}{55.8\times0.200}\times\dfrac{100}{10}\times100\%$

☒ **C** $\dfrac{5.38\times10^{-5}\times55.8}{0.200}\times\dfrac{10}{100}\times100\%$

☒ **D** $\dfrac{5.38\times10^{-5}\times0.200}{55.8}\times\dfrac{10}{100}\times100\%$

(Total for Question 2 marks)

19 In the first commonly used breathalyser, acidified potassium dichromate(VI) was used which was reduced to chromium(III) by alcohol.

The colour change seen when alcohol was present in a motorist's breath is from

☒ **A** orange to green.

☒ **B** orange to yellow.

☒ **C** yellow to green.

☒ **D** yellow to orange.

(Total for Question 1 mark)

20 Four reactions involving the transition elements copper and chromium are given below.

1 $Cu^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(s)$

2 $[Cu(H_2O)_4(OH)_2](s) + 4NH_3(aq) \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+}(aq) + 2OH^{-}(aq) + 2H_2O(l)$

3 $[Cr(H_2O)_3(OH)_3](s) + 3OH^{-}(aq) \rightarrow [Cr(OH)_6]^{3-}(aq) + 3H_2O(l)$

4 $[Cr(H_2O)_3(OH)_3](s) + 3H^{+}(aq) \rightarrow [Cr(H_2O)_6]^{3+}(aq)$

(a) Which reaction produces a dark blue solution?

(1)

☒ **A**

☒ **B** **2**

☒ **C** **3**

☒ **D** **4**

(b) Which two reactions show the amphoteric behaviour of a metal hydroxide?

(1)

☒ **A** **1** and **2**

☒ **B** **2** and **3**

☒ **C** **2** and **4**

☒ **D** **3** and **4**

(c) Predict, without calculation, which reaction has the most negative value for ΔS_{system}.

(1)

☒ **A**

☒ **B** **2**

☒ **C** **3**

☒ **D** **4**

(Total for Question 3 marks)

21 When a **few drops** of aqueous ammonia are added to a solution containing $[Cr(H_2O)_6]^{3+}$ ions the product formed will be

☒ **A** $[Cr(NH_3)_6]^{3+}$

☒ **B** $Cr(H_2O)_3(OH)_3$

☒ **C** $[Cr(NH_3)_4]^{3+}$

☒ **D** $[Cr(H_2O)_2(OH)_4]^-$

(Total for Question 1 mark)

22 In the reaction of manganate(VII) ions with reducing agents in strongly acidic solution, the half-reaction for the reduction is

☒ **A** $MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$

☒ **B** $MnO_4^- + 4H^+ + 5e^- \rightarrow Mn^{2+} + 2H_2O$

☒ **C** $MnO_4^- + 8H^+ + 3e^- \rightarrow Mn^{2+} + 4H_2O$

☒ **D** $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

(Total for Question = 1 mark)

23 Although platinum is very unreactive, it is used as a catalyst in catalytic converters in motor cars. Which of the following is true?

☒ **A** It converts nitrogen oxides and carbon monoxide to nitrogen and carbon dioxide by adsorbing the reactants on its surface so weakening their bonds.

☒ **B** It converts nitrogen oxides and carbon monoxide to nitrogen and carbon dioxide by being able to change its oxidation state.

☒ **C** It oxidizes unburnt fuel to carbon monoxide.

☒ **D** It oxidizes unburnt fuel to carbon dioxide.

(Total for Question = 1 mark)

24 When dichromate(VI) ions, $Cr_2O_7^{2-}$, react with iron(II) ions in acidic solution, the products are chromium(III) ions and iron(III) ions. In what ratio do the dichromate(VI) ions and the iron(II) ions react?

☒ **A** 1:6

☒ **B** 1:5

☒ **C** 2:5

☒ **D** 1:3

(Total for Question = 1 mark)

25 When concentrated ammonia solution is added to a green solution of chromium(III) sulfate, a green precipitate is formed which slowly dissolves in excess of the concentrated ammonia solution.

The chromium-containing species formed in these reactions are

	Green precipitate	Resulting solution
☒ **A**	$Cr(OH)_3$	$[Cr(OH)_6]^{3-}$
☒ **B**	$Cr(OH)_3$	$[Cr(NH_3)_6]^{3+}$
☒ **C**	$(NH_4)_2CrO_4$	$[Cr(OH)_6]^{3-}$
☒ **D**	$(NH_4)_2CrO_4$	$[Cr(NH_3)_6]^{3+}$

(Total for Question = 1 mark)

26 Which of the following reagents would enable you to separate iron(III) hydroxide from a mixture of iron(III) hydroxide and copper(II) hydroxide?

☒ **A** Dilute hydrochloric acid

☒ **B** Aqueous ammonia

☒ **C** Dilute nitric acid

☒ **D** Sodium hydroxide solution

(Total for Question 1 mark)

27 When a solution containing 0.10 mol of chromium(III) chloride, $CrCl_3.6H_2O$, is treated with excess silver nitrate solution, 0.20 mol of silver chloride, AgCl, is immediately precipitated. The formula of the complex ion in the solution is

☒ **A** $[Cr(OH)_6]^3$

☒ **B** $[Cr(H_2O)_6]^{3+}$

☒ **C** $[CrCl(H_2O)_5]^{2+}$

☒ **D** $[CrCl_2(H_2O)_4]^+$

(Total for Question 1 mark)