Q1. When vanadium reacts with chlorine at 400°C, a brown compound is obtained. When an aqueous solution containing 0.193 g of this compound was treated with aqueous silver nitrate all the chlorine in the compound was precipitated as silver chloride. The mass of silver chloride (AgCl) produced was 0.574 g. Which one of the following could be the formula of the brown compound?

A VCl

B VCl_2

C VCl_3

D VCl_4

(Total 1 mark)

Q2. The oxidation of ethanedioate (*oxalate*) ions by manganate(VII) ions can be represented by the half equations:

$$C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$$

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

What volume (in cm^3) of 0.02 M $KMnO_4$ is required to oxidise completely a solution containing 0.02 mol of ethanedioate ions?

A 25

B 40

C 250

D 400

(Total 1 mark)

Q3. Which one of the following can act as an oxidising agent but not as a reducing agent?

A CH_3CHO

B Fe^{2+}

C I^-

D MnO_4^-

(Total 1 mark)

Q4. In which one of the following reactions does the metal species undergo reduction?

A $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

B $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$

C $CrO_7^{2-} + 2OH^- \rightarrow 2CrO_4^{2-} + H_2O$

D $TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$

(Total 1 mark)

Q5. The percentage of iron in a sample of impure iron(II) sulphate crystals can be determined by titrating solutions, made from separate weighed samples acidified with dilute sulphuric acid, against a standard solution of potassium manganate(VII).

Which one of the following would lead to the greatest error in the calculation of the percentage of iron(II) in the sample?

A an error of 0.005 g made when weighing out a sample of mass 0.987 g

B an end-point error of 0.1 cm^3 in 25.0 cm^3

C an error of 5 cm^3 when measuring out 25.0 cm^3 of dilute sulphuric acid

D using the average of the titration values 25.4, 25.7 and 25.9 when the correct value is 25.5 cm^3

(Total 1 mark)

Q6. The percentage of iron in a sample of impure iron(II) sulphate crystals can be determined by titrating solutions, made from separate weighed samples acidified with dilute sulphuric acid, against a standard solution of potassium manganate(VII).

Which one of the following would lead to an inaccurate result?

A transferring the weighed sample of iron(II) sulphate into a wet conical flask

B failing to measure accurately the volume of water used to dissolve each weighed sample of iron(II) sulphate

C transferring the standard solution of potassium manganate(VII) from its original container to the burette using a wet beaker

D failing to measure accurately the volume of dilute sulphuric acid added to the

mixture before titration

(Total 1 mark)

Q7. Aqueous $C_2O_4^{2-}$ ions react with MnO_4^- ions in acidic solution according to the equation

$$5\ C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

Under the same conditions Fe^{2+} ions also react with MnO_4^- ions. How many moles of MnO_4^- ions are required to react exactly with one mole of $Fe(C_2O_4).2H_2O$?

A 0.4

B 0.6

C 2.5

D 7.5

(Total 1 mark)

Q8. The percentage of iron in a sample of impure iron(II) sulphate crystals can be determined by titrating solutions, made from separate weighed samples acidified with dilute sulphuric acid, against a standard solution of potassium manganate(VII).

Which one of the following statements explains why dilute hydrochloric acid is unsuitable for use in this titration?

A HCl will oxidise Fe^{2+} to Fe^{3+}

B Cl^- will reduce Fe^{3+} to Fe^{2+}

C Cl^- will reduce MnO_4^-

D HCl is a strong acid

(Total 1 mark)

Q9. Which one of the following statements about the reaction below is **false**?

$$[Cu(H_2O)_6]^{2+} + EDTA^{4-} \rightleftharpoons [Cu(EDTA)]^{2-} + 6H_2O$$

A $[Cu(EDTA)]^{2-}$ is a more stable complex than $[Cu(H_2O)_6]^{2+}$

B Both $[Cu(H_2O)_6]^{2+}$ and $[Cu(EDTA)]^{2-}$ are octahedral complexes.

C There is an increase in entropy when the reaction occurs.

D There is a redox reaction.

(Total 1 mark)

Q10. Where appropriate, use the standard electrode potential data in the table below to answer the questions which follow.

							$E^{\ominus}/V$
$Zn^{2+}(aq)$	+	$2e^-$	→	$Zn(s)$			–0.76
$V^{3+}(aq)$	+	e^-	→	$V^{2+}(aq)$			–0.26
$SO_4^{2-}(aq) + 2H^+(aq)$	+	$2e^-$	→	$SO_3^{2-}(aq)$	+	$H_2O(l)$	+0.17
$VO^{2+}(aq) + 2H^+(aq)$	+	e^-	→	$V^{3+}(aq)$	+	$H_2O(l)$	+0.34
$Fe^{3+}(aq)$	+	e^-	→	$Fe^{2+}(aq)$			+0.77
$VO_2^+(aq) + 2H^+(aq)$	+	e^-	→	$VO^{2+}(aq)$	+	$H_2O(l)$	+1.00
$Cl_2(aq)$	+	$2e^-$	→	$2Cl^-(aq)$			+1.36

(a) From the table above select the species which is the most powerful reducing agent.

.....

(1)

(b) From the table above select

(i) a species which, in acidic solution, will reduce $VO_2^+(aq)$ to $VO^{2+}(aq)$ but will **not** reduce $VO^{2+}(aq)$ to $V^{3+}(aq)$,

.....

(ii) a species which, in acidic solution, will oxidise $VO^{2+}(aq)$ to $VO_2^+(aq)$.

.....

(2)

(c) The cell represented below was set up under standard conditions.

$Pt|Fe^{2+}(aq), Fe^{3+}(aq)||Tl^{3+}(aq), Tl^{+}(aq)|Pt$ Cell e.m.f. = + 0.48 V

(i) Deduce the standard electrode potential for the following half-reaction.

$Tl^{3+}(aq) + 2e^{-} \rightarrow Tl^{+}(aq)$

.....

.....

(ii) Write an equation for the spontaneous cell reaction.

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(3)

(d) After acidification, 25.0 cm^3 of a solution of hydrogen peroxide reacted exactly with 16.2 cm^3 of a 0.0200 mol dm^{-3} solution of potassium manganate(VII). The overall equation for the reaction is given below.

$2MnO_4^- + 6H^+ + 5H_2O_2 \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

(i) Use the equation for this reaction to determine the concentration, in g dm^{-3}, of the hydrogen peroxide solution.

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(ii) Calculate the maximum volume of oxygen, measured at a pressure of 98 kPa and a temperature of 298 K, which would be evolved in this reaction.

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(8)
(Total 14 marks)

Q11. Which one of the following would **not** reduce an acidified aqueous solution of potassium dichromate(VI)?

A CH_3COOH

B Zn

C CH_3CHO

D $Fe^{2+}(aq)$

(Total 1 mark)

Q12. (a) "The strength of adsorption onto the active sites on the surface of a heterogeneous catalyst helps to determine the activity of the catalyst."

Explain how heterogeneous catalysts work, give **one** example of a reaction catalysed in this way and discuss why different catalysts have different activities.

(8)

(b) Outline a plan of an experiment to determine the percentage of iron present as iron(III) in a solution containing $Fe^{3+}(aq)$ and $Fe^{2+}(aq)$ ions. You are provided with zinc, a standard solution of potassium dichromate(VI) and dilute sulphuric acid. Zinc can reduce $Fe^{3+}(aq)$ to $Fe^{2+}(aq)$.

Write equations for all the reactions that occur. Explain how you would use the zinc and how you would calculate the final answer.

(7)
(Total 15 marks)

Q13. Use your knowledge of the chemistry of transition metals to predict which of the following will convert $[Mn(H_2O)_6]^{2+}$ into MnO_4^{2-}

A an acid and a reducing agent

B an acid and an oxidising agent

C an alkali and a reducing agent

D an alkali and an oxidising agent

(Total 1 mark)

Q14. A 0.0720 g sample of reducing agent **R** was dissolved in water and acidified with an excess of dilute H_2SO_4. The resulting solution was found to react with exactly 18.0 cm^3 of a 0.0200 mol dm^{-3} solution of $KMnO_4$.

In this reaction, 5 mol of **R** react with 3 mol of $KMnO_4$. The M_r of **R** is

A 120

B 167

C 240

D 333

(Total 1 mark)

Q15. (a) Vanadium(V) oxide is used as a heterogeneous catalyst in the Contact Process.

Explain what is meant by the terms *heterogeneous* and *catalyst* and state, in general terms, how a catalyst works.

State the essential feature of vanadium chemistry which enables vanadium(V) oxide to function as a catalyst and, by means of equations, suggest how it might be involved in the Contact Process.

(7)

(b) The following method was used to determine the percentage by mass of vanadium in a sample of ammonium vanadate(V).

A solution was made up by dissolving 0.160 g of ammonium vanadate(V) in dilute sulphuric acid. The ammonium vanadate(V) formed VO_2^+ ions in this solution. When an excess of zinc was added to this solution, the VO_2^+ ions were reduced to V^{2+} ions and the zinc was oxidised to Zn^{2+} ions.

After the unreacted zinc had been removed, the solution was titrated against a 0.0200 mol dm^{-3} solution of potassium manganate(VII). In the titration, 38.5 cm^3 of potassium manganate(VII) solution were required to oxidise all vanadium(II) ions to vanadium(V) ions.

Using half-equations, construct an overall equation for the reduction of VO_2^+ to V^{2+} by zinc in acidic solution.

Calculate the percentage by mass of vanadium in the sample of ammonium vanadate(V).

(8)
(Total 15 marks)

Q16. The vanadium does **not** have an oxidation state of +3 in

A $[V(H_2O)_6]^{3+}$

B $[V(C_2O_4)_3]^{3-}$

C $[V(OH)_3(H_2O)_3]$

D $[VCl_4]^{3-}$

(Total 1 mark)