**Q1.**          (a)     **P** and **Q** are oxides of Period 3 elements.

Oxide **P** is a solid with a high melting point. It does not conduct electricity when solid but does conduct when molten or when dissolved in water. Oxide **P** reacts with water forming a solution with a high pH.

Oxide **Q** is a colourless gas at room temperature. It dissolves in water to give a solution with a low pH.

(i)      Identify **P**. State the type of bonding present in **P** and explain its electrical conductivity. Write an equation for the reaction of **P** with water.

(ii)     Identify **Q**. State the type of bonding present in **Q** and explain why it is a gas at room temperature. Write an equation for the reaction of **Q** with water.

**(9)**

(b)     **R** is a hydroxide of a Period 3 element. It is insoluble in water but dissolves in both aqueous sodium hydroxide and aqueous sulphuric acid.

(i)      Give the name used to describe this behaviour of the hydroxide.

(ii)     Write equations for the reactions occurring.

(iii)     Suggest why **R** is insoluble in water.

**(6)**

**(Total 15 marks)**

**Q2.**          (a)     The reaction between aqueous persulphate ions, , and iodide ions, I–(aq), is catalysed by Fe2+(aq) ions. Suggest why this reaction has a high activation energy.
Write equations to explain the catalytic action of Fe2+(aq) ions.
Suggest why V3+(aq) ions will also act as a catalyst for this reaction but Mg2+(aq) ions will not.

**(6)**

(b)     Outline a mechanism for the reaction between benzene and ethanoyl chloride and explain why AlCl3 acts as a Lewis acid catalyst for this reaction. Predict, with an explanation in each case, the suitability of FeCl3 and of NH4Cl to act as a catalyst for this reaction.

**(9)**

**(Total 15 marks)**

**Q3.**          The reaction scheme below shows the conversion of epoxyethane into sodium ethanedioate.

    Compound **X**    (COOH)2    Na2C2O4

(a)     Identify compound **X**. State the reagents and conditions required to convert **X** into ethanedioic acid. Draw the structure of the anion in sodium ethanedioate.

**(4)**

(b)     The addition of sodium ethanedioate to an aqueous solution containing [Co(H2O)6]2+ ions results in the formation of a more stable complex ion. Draw the structure of the complex ion formed and explain, in thermodynamic terms, why this substitution reaction occurs.

**(4)**

**(Total 8 marks)**

**Q4.**          (a)     State what is meant by the term *co-ordinate bond*.

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**(2)**

(b)     Define the terms *Brønsted–Lowry acid* and *Lewis acid*.

*Brønsted–Lowry acid* ...................................................................................

*Lewis acid* ....................................................................................................

**(2)**

(c)     State what is meant by the term *bidentate ligand*.

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**(2)**

(d)     State how the co-ordination number of cobalt(II) ions in aqueous solution changes when an excess of chloride ions is added. Give a reason for the change.

*Change in co-ordination number* ..................................................................

*Reason for change ..*.....................................................................................

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**(2)**

(e)     Suggest why the enthalpy change for the following reaction is close to zero.

[Co(NH3)6]2+  +  3NH2CH2CH2NH2  →  Co(NH2CH2CH2NH2)3]2+  +  6NH3

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**(2)**

(f)      Deduce the formula of the compound formed when ethane-1,2-diamine is treated with an excess of hydrochloric acid.

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**(1)**

**(Total 11 marks)**

**Q5.**          (a)     (i)      Write an equation to show why aqueous chromium(III) chloride is acidic.

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(ii)     Explain why aqueous chromium(III) chloride is more acidic than aqueous chromium(II) chloride.

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**(3)**

(b)     The addition of sodium hydroxide or of sodium carbonate to aqueous chromium(III) chloride results in the formation of the same green precipitate.

(i)      Identify this green precipitate.

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(ii)     State the role shown by both sodium hydroxide and sodium carbonate in the formation of this green precipitate.

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(iii)     Identify the gas evolved when carbonate ions react with aqueous chromium(III) ions and write an equation for the reaction occurring.

*Gas evolved* ........................................................................................

*Equation* ..............................................................................................

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**(4)**

(c)     State the reagents which could be used to convert aqueous chromium(III) ions into chromate(VI) ions.

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**(2)**

**(Total 9 marks)**

**Q6.**          Consider the reaction sequence below.



(a)     Identify the silver-containing species in **A**, give its shape and state a use for it in organic chemistry.

*Species …..*...................................................................................................

*Shape* ...........................................................................................................

*Use* ...............................................................................................................

**(3)**

(b)     (i)      Identify the cream precipitate **B** and the silver-containing species in **C**.

*Precipitate B* ................................................................................................

*Silver-containing species in* ***C*** ......................................................................

(ii)     Write an equation for the reaction in which the silver-containing species in **C** is formed from **B** and explain the use of this reaction in photographic processing.

*Equation* ..............................................................................................

*Explanation* .........................................................................................

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**(4)**

(c)     Identify the silver-containing species in **D**, and state **one** use of solutions containing this species.

*Species* ........................................................................................................

*Use …*...........................................................................................................

**(2)**

(d)     What can be deduced about the outer electronic configuration of silver in each of the species **A**, **C** and **D** from the fact that all the species are colourless?

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**(1)**

**(Total 10 marks)**

**Q7.**          (a)     State the origin of the colour of transition-metal complexes.

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**(2)**

(b)     Give **three** changes to a transition-metal complex which result in a change in colour.

*Change 1* ......................................................................................................

*Change 2* ......................................................................................................

*Change 3* …..................................................................................................

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**(3)**

(c)     You are provided with a 1.00 mol dm–3 solution of iron(III) ions and a visible-light spectrophotometer (colorimeter). Outline a plan for experiments using this solution and this apparatus which would enable you to determine the concentration of iron(III) ions in a solution of unknown concentration.

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**(5)**

**(Total 10 marks)**

**Q8.**          Large blocks of magnesium are bolted onto the hulls of iron ships in an attempt to prevent the iron being converted into iron(II), one of the steps in the rusting process.

Use the data below, where appropriate, to answer the questions which follow.

*E*/ V

                Mg2+(aq) + 2e–          Mg(s)                    –2.37

                Fe2+(aq) + 2e–          Fe(s)                    –0.44

     O2(g) + 2H2O(l) + 4e–          4OH–(aq)              +0.40

(a)     Calculate the e.m.f. of the cell represented by Mg(s)|Mg2+(aq)||Fe2+(aq)|Fe(s) under standard conditions. Write a half-equation for the reaction occurring at the negative electrode of this cell when a current is drawn.

*Cell e.m.f.* ....................................................................................................

*Half-equation* ................................................................................................

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**(2)**

(b)     Deduce how the e.m.f. of the cell Mg(s)|Mg2+(aq)||Fe2+(aq)|Fe(s) changes when the concentration of Mg2+ is decreased. Explain your answer.

*Change in e.m.f.* ..........................................................................................

*Explanation* ..................................................................................................

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**(3)**

(c)     Calculate a value for the e.m.f. of the cell represented by
Pt(s)|OH–(aq)|O2(g)||Fe2+(aq)|Fe(s) and use it to explain why iron corrodes when in contact with water which contains dissolved oxygen.

*Cell e.m.f.* ....................................................................................................

*Explanation* ..................................................................................................

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**(2)**

**(Total 7 marks)**

**Q9.**          (a)     The following reaction occurs in the high-temperature preparation of titanium(IV) chloride.

TiO2(s)  +  C(s)  +  2Cl2(g)  →  TiCl4(l)  +  CO2(g)

(i)      Use the data given below to calculate the standard enthalpy change and the standard entropy change for this reaction.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Substance | TiO2(s) | C(s) | Cl2(g) | TiCl4(l) | CO2(g) |
| ΔHf / kJ mol–1 | –940 | 0 | 0 | –804 | –394 |
| S/ J K–1mol–1 | 49.9 | 5.7 | 223 | 252 | 214 |

*Standard enthalpy change* ..................................................................

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*Standard entropy change* ....................................................................

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(ii)     Calculate the temperature at which this reaction ceases to be feasible.

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**(9)**

(b)     In the industrial extraction of titanium, TiCl4 is reduced to titanium in an inert atmosphere.

(i)      Write an equation for this reduction process.

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(ii)     Explain why it is essential to exclude air when this reduction takes place.

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**(3)**

(c)     Write an equation for the reaction of TiCl4 with water.

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**(1)**

**(Total 13 marks)**

**Q10.**          (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 Fe3+(aq) and Fe2+(aq) ions. You are provided with zinc, a standard solution of potassium dichromate(VI) and dilute sulphuric acid. Zinc can reduce Fe3+(aq) to Fe2+(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)**

**Q11.**          (a)     Give **one** example of a bidentate ligand.

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**(1)**

(b)     Give **one** example of a linear complex ion formed by a transition metal.

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**(1)**

(c)     Write an equation for a substitution reaction in which the complete replacement of ligands in a complex ion occurs with a change in **both** the co-ordination number and the overall charge of the complex ion.

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**(2)**

(d)     Write an equation for a substitution reaction in which the complete replacement of ligands in a complex ion occurs without a change in either the co-ordination number or the overall charge of the complex ion.

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**(2)**

(e)     When a solution containing [Co(H2O)6]2+ ions is treated with a solution containing EDTA4– ions, a more stable complex is formed.  Write an equation for this reaction and explain why the complex is more stable.

*Equation* ......................................................................................................

*Explanation* ..................................................................................................

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**(3)**

**(Total 9 marks)**

**Q12.**Use the standard electrode potential data in the table below to answer the questions which follow.

                                                                                                        *E*/ *V*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

                       Ce4**+**(aq) + e–          Ce3+(aq)                              +1.70

   MnO–(aq) + 8H+(aq)+ 5e–          Mn2+(aq) + 4H2O(l)               +1.51

                         Cl2(g) + 2e–          2Cl–(aq)                               +1.36

       VO2+(aq) +2H+(aq) + e–          VO2+(aq) + H2O(l)               +1.00

                       Fe3+(aq) + e–          Fe2+(aq)                               +0.77

   SO42–(aq) + 4H+(aq) + 2e–          H2SO3(aq) + H2O(l)            +0.17
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(a)     Name the standard reference electrode against which all other electrode potentials are measured.

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**(1)**

(b)     When the standard electrode potential for Fe3+(aq) / Fe2+(aq) is measured, a platinum electrode is required.

(i)      What is the function of the platinum electrode?

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(ii)     What are the standard conditions which apply to Fe3+(aq)/Fe2+(aq) when measuring this potential?

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**(3)**

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

Pt|H2SO3(aq), SO42–(aq)||MnO4–(aq), Mn2+(aq)|Pt

Calculate the e.m.f. of this cell and write an equation for the spontaneous cell reaction.

*Cell e.m.f.* ….................................................................................................

*Equation* .......................................................................................................

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**(3)**

(d)     (i)      Which one of the species given in the table is the strongest oxidising agent?

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(ii)     Which of the species in the table could convert Fe2+(aq) into Fe3+(aq) but could  not convert Mn2+(aq) into MnO4–(aq)?

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**(3)**

(e)     Use data from the table of standard electrode potentials to deduce the cell which would have a standard e.m.f. of 0.93 V. Represent this cell using the convention shown in part (c).

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**(2)**

**(Total 12 marks)**

**Q13.**          Use the data in the table below to answer the questions which follow.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Substance | Fe2O3(s) | Fe(s) | C(s) | CO(g) | CO2(g) |
| Δ*H*f/ kJ mol–1 | –824.2 | 0 | 0 | –110.5 | –393.5 |
| *S*/ J K–1 mol–1 | 87.4 | 27.3 | 5.7 | 197.6 | 213.6 |

(a)     The following equation shows one of the reactions which can occur in the extraction of iron.

Fe2O3(s)  +  3CO(g)  →  2Fe(s)  +  3CO2(g)

(i)      Calculate the standard enthalpy change and the standard entropy change for this reaction.

*Standard enthalpy change* ..................................................................

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*Standard entropy change* ....................................................................

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(ii)     Explain why this reaction is feasible at all temperatures.

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**(9)**

(b)     The reaction shown by the following equation can also occur in the extraction of iron.

Fe2O3(s)  +  3C(s)  →  2Fe(s)  +  3CO(g)          Δ*H* = +492.7 kJ mol–1

The standard entropy change, Δ*S*, for this reaction is +542.6 J K–1 mol–1

Use this information to calculate the temperature at which this reaction becomes feasible.

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**(3)**

(c)     Calculate the temperature at which the standard free-energy change, Δ*G* has the same value for the reactions in parts (a) and (b).

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**(3)**

**(Total 15 marks)**

**Q14.**          (a)     State what is observed when aqueous ammonia is added dropwise, until present in excess, to a solution of cobalt(II) chloride, and the mixture obtained is then left to stand in air.
Give the formula of each cobalt-containing species formed. Explain the change which occurs when the mixture is left to stand in air.

**(8)**

(b)     Explain why separate solutions of iron(II) sulphate and iron(III) sulphate of equal concentration have different pH values.
State what is observed when sodium carbonate is added separately to solutions of these two compounds. Give the formula of each iron-containing species formed.

**(9)**

**(Total 17 marks)**

**Q15.**          (a)     (i)      Draw a fully-labelled Born–Haber cycle for the formation of solid barium chloride, BaCl2, from its elements. Include state symbols for all species involved.

(ii)     Use your Born–Haber cycle and the standard enthalpy data given below to calculate a value for the electron affinity of chlorine.

         Enthalpy of atomisation of barium                        +180 kJ mol–1Enthalpy of atomisation of chlorine                       +122 kJ mol–1Enthalpy of formation of barium chloride              –859 kJ mol–1First ionisation enthalpy of barium                        +503 kJ mol–1Second ionisation enthalpy of barium                   +965 kJ mol–1Lattice formation enthalpy of barium chloride     –2056 kJ mol–1

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**(9)**

(b)     Use data from part (a)(ii) and the entropy data given below to calculate the lowest temperature at which the following reaction becomes feasible.

BaCl2(s)  →  Ba(s)  +  Cl2(g)

|  |  |  |  |
| --- | --- | --- | --- |
|   | BaCl2(s) | Ba(s) | Cl2(g) |
| *S* / J K–1 mol–1 | 124 | 63 | 223 |

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**(4)**

**(Total 13 marks)**

**Q16.**          (a)     The ion  can act as a bidentate ligand.

(i)      Explain the meaning of the term *bidentate ligand*.

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(ii)     Sketch the structure of the octahedral complex ion formed by Fe3+ ions which contains  as the only ligand. Include the overall charge on the complex ion.

**(5)**

(b)     Explain the meaning of the term *chelate effect*.

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**(2)**

(c)     The chloride ion can act as a monodentate ligand.

(i)      Deduce the formula of the linear complex formed when an excess of concentrated hydrochloric acid is added to silver chloride.

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(ii)     Explain why metal(II) ions do not usually form octahedral complexes when chloride ions are the only ligands.

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**(2)**

(d)     The concentration of  ions can be determined by titration in acidic solution using a standard solution of potassium manganate(VII). At room temperature, the reaction proceeds very slowly at first but becomes faster after some of the manganate(VII) ions have reacted.

(i)      Suggest why this reaction is very slow at first.

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(ii)     This is an example of an autocatalytic reaction. State the meaning of the term *autocatalytic* and identify the catalyst.

*Meaning of the term autocatalytic* ........................................................

*Catalyst* ................................................................................................

(iii)     Suggest how this catalyst might be involved in the reaction.

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**(5)**

**(Total 14 marks)**

**Q17.**          (a)     Identify a reagent, or mixture of reagents, necessary to carry out each of the following conversions.

(i)      [Cr(H2O)6]3+(aq)  →  (aq)

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(ii)     (aq)  →  [V(H2O)6]2+(aq)

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(iii)     [Ag(NH3)2]+(aq)  →  Ag(s)

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**(5)**

(b)     In an acidic solution, hydrogen peroxide, H2O2, is oxidised to oxygen by manganate(VII) ions, which are reduced to Mn2+ ions.

(i)      Write half-equations for the reactions occurring and use these to deduce the overall equation for this reaction.

*Half-equation for the oxidation of H2O2*

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*Half-equation for the reduction of manganate(VII) ions*

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*Overall equation*

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(ii)     20.0 cm3 of an acidified solution of H2O2 was found to react with exactly 15.7 cm3 of a 0.0180 mol dm–3 solution of potassium manganate(VII).
Calculate the concentration, in g dm–3, of the solution of hydrogen peroxide.
(If you have been unable to complete the overall equation in part (b)(i), assume that the mole ratio of manganate(VII) to H2O2 is 3:5. This is not the correct ratio.)

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**(7)**

**(Total 12 marks)**

**Q18.**          Consider the following oxides.

Na2O,   MgO,   Al2O3,   SiO2,   P4O10,   SO3

(a)     Identify one of the oxides from the above which

(i)      can form a solution with a pH less than 3 ............................................

(ii)     can form a solution with a pH greater than 12 ......................................

**(2)**

(b)     Write an equation for the reaction between

(i)      MgO and HNO3

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(ii)     SiO2 and NaOH

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(iii)     Na2O and H3PO4

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**(3)**

(c)     Explain, in terms of their type of structure and bonding, why P4O10 can be vaporised by gentle heat but SiO2 cannot.

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**(4)**

**(Total 9 marks)**

**Q19.**          Transition metals form complex ions. Using actual examples of complex ions formed by transition metal ions, give the formula of
•   a linear complex ion,
•   a tetrahedral complex ion and
•   an octahedral complex ion formed by using a bidentate ligand.

**(Total 4 marks)**

**Q20.**          (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  ions in this solution. When an excess of zinc was added to this solution, the  ions were reduced to V2+ ions and the zinc was oxidised to Zn2+ 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 cm3 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  to V2+ by zinc in acidic solution.

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

**(8)**

**(Total 15 marks)**

**Q21.**          (a)     Explain why complex ions with partially filled d sub-levels are usually coloured.

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......................................................................................................................

**(2)**

(b)     (i)      When aqueous ammonia was added to an aqueous solution of cobalt(II) sulphate, a blue precipitate **M** was formed. Identify the cobalt-containing species present in aqueous cobalt(II) sulphate and the precipitate **M**.

*Cobalt-containing species* ...................................................................

*Precipitate* ***M*** .......................................................................................

(ii)     Precipitate **M** dissolved when an excess of concentrated aqueous ammonia was added. The solution formed was pale brown due to the presence of the cobalt-containing species **P**. Identify **P**.

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(iii)     On standing in air, the colour of the solution containing **P** slowly darkened as the cobalt-containing species **Q** was formed. State the type of reaction occurring when **P** changes into **Q** and identify the reactant responsible for this change.

*Type of reaction* ...................................................................................

*Reactant responsible* ...........................................................................

(iv)    When potassium iodide was added to the solution containing **Q** and the mixture was acidified, a dark red-brown colour due to the presence of **R** was produced. On addition of starch solution the mixture turned blue-black.
Identify **R** and explain its formation.

*Identity of* ***R*** .........................................................................................

*Explanation .*.........................................................................................

**(7)**

**(Total 9 marks)**

**Q22.**          Use the data below, where appropriate, to answer the questions which follow.

|  |  |
| --- | --- |
| Standard electrode potentials | *E*/V |
|        2H+(aq)  +  2e–  →  H2(g) | 0.00 |
|             Br2(aq)  +  2e–  →  2Br–(aq) | +1.09 |
| (aq)  +  12H+(aq)  +  10e–  →  Br2(aq)  +  6H2O(l) | +1.52 |

Each of the above can be reversed under suitable conditions.

(a)     State the hydrogen ion concentration and the hydrogen gas pressure when, at 298 K, the potential of the hydrogen electrode is 0.00 V.

*Hydrogen ion concentration* .........................................................................

*Hydrogen gas pressure* ................................................................................

**(2)**

(b)     The electrode potential of a hydrogen electrode changes when the hydrogen ion concentration is reduced. Explain, using Le Chatelier’s principle, why this change occurs and state how the electrode potential of the hydrogen electrode changes.

*Explanation of change .*.................................................................................

*Change in electrode potential* .......................................................................

**(3)**

(c)     A diagram of a cell using platinum electrodes **X** and **Y** is shown below.



(i)      Use the data above to calculate the e.m.f. of the above cell under standard conditions.

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(ii)     Write a half-equation for the reaction occurring at electrode **X** and an overall equation for the cell reaction which occurs when electrodes **X** and **Y** are connected.

*Half-equation* ......................................................................................

*Overall equation* ..................................................................................

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**(4)**

**(Total 9 marks)**

**Q23.**          Chlorine is formed in a reversible reaction as shown by the equation

4HCl(g)  +  O2(g)    2Cl2(g)  +  2H2O(g)

(a)     Use the data below to calculate the standard enthalpy change, Δ*H*, and the standard entropy change, Δ*S*, for this reaction.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Substance | HCl(g) | O2(g) | Cl2(g) | H2O(g) |
| Δ*H*f/kJ mol–1 | –92 | 0 | 0 | –242 |
| *S*/ J K–1 mol–1 | 187 | 205 | 223 | 189 |

*Standard enthalpy change*, Δ*H* ................................................................

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*Standard entropy change*, Δ*S .*.................................................................

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**(6)**

(b)     The data below apply to a different gas phase reversible reaction.

Standard enthalpy change, Δ*H* = +208 kJ mol–1Standard entropy change, Δ*S* = +253 J K–1 mol–1

(i)      Deduce the effect of an increase in temperature on the position of the equilibrium in this reaction. Use Le Chatelier’s principle to explain your answer.

*Effect* ..................................................................................................

*Explanation* .........................................................................................

(ii)     Calculate the minimum temperature at which this reaction is feasible.

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**(7)**

**(Total 13 marks)**

**Q24.**          The following two-stage method was used to analyse a mixture containing the solids magnesium, magnesium oxide and sodium chloride.

**Stage 1**A weighed sample of the mixture was treated with an excess of dilute hydrochloric acid.
The sodium chloride dissolved in the acid. The magnesium oxide reacted to form a solution of magnesium chloride. The magnesium also reacted to form hydrogen gas and a solution of magnesium chloride. The hydrogen produced was collected.

(a)     Write equations for the two reactions involving hydrochloric acid.

(b)     State how you would collect the hydrogen. State the measurements that you would make in order to calculate the number of moles of hydrogen produced. Explain how your results could be used to determine the number of moles of magnesium metal in the sample.

**(8)**

**Stage 2**Sodium hydroxide solution was added to the solution formed in **Stage 1** until no further precipitation of magnesium hydroxide occurred. This precipitate was filtered off, collected, dried and heated strongly until it had decomposed completely into magnesium oxide. The oxide was weighed.

(c)     Write equations for the formation of magnesium hydroxide and for its decomposition into magnesium oxide.

(d)     When a 2.65 g sample of the mixture of the three solids was analysed as described above, the following results were obtained.

Hydrogen obtained in **Stage 1**                                              0.0528 mol

Mass of magnesium oxide obtained in **Stage 2**                   6.41 g

Use these results to calculate the number of moles of original magnesium oxide in 100 g of the mixture.

**(7)**

**(Total 15 marks)**

**Q25.**          (a)     The gaseous reactants **W** and **X** were sealed in a flask and the mixture left until the following equilibrium had been established.

2W(g)  +  X(g)    3Y(g)  +  2Z(g)        Δ*H* = –200 kJ mol–1

Write an expression for the equilibrium constant, *K*p, for this reaction.
State one change in the conditions which would both increase the rate of reaction and decrease the value of *K*p. Explain your answers.

**(7)**

(b)     Ethyl ethanoate can be prepared by the reactions shown below.

          **Reaction 1**CH3COOH(l) + C2H5OH(l)    CH3COOC2H5(l) + H2O(l)      ∆*H* = –2.0 kJ mol–1

**Reaction 2**CH3COCl(l) + C2H5OH(l) → CH3COOC2H5(l) + HCl(g)            ∆*H* = –21.6 kJ mol–1

(i)      Give one advantage and one disadvantage of preparing ethyl ethanoate by **Reaction 1** rather than by **Reaction 2**.

(ii)     Use the information given above and the data below to calculate values for the standard entropy change, ∆*S*, and the standard free-energy change, ∆*G*, for **Reaction 2** at 298 K.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | CH3COCl(l) | C2H5OH(l) | CH3COOC2H5(l) | HCl(g) |
| *S*/JK1mol1 | 201 | 161 | 259 | 187 |

**(8)**

**(Total 15 marks)**

**Q26.**          (a)     State what is meant by the term *homogeneous* as applied to a catalyst.

......................................................................................................................

**(1)**

(b)     (i)      State what is meant by the term *autocatalysis*.

.............................................................................................................

.............................................................................................................

(ii)     Identify the species which acts as an autocatalyst in the reaction between ethanedioate ions and manganate(VII) ions in acidic solution.

.............................................................................................................

**(2)**

(c)     When petrol is burned in a car engine, carbon monoxide, carbon dioxide, oxides of nitrogen and water are produced. Catalytic converters are used as part of car exhaust systems so that the emission of toxic gases is greatly reduced.

(i)      Write an equation for a reaction which occurs in a catalytic converter between two of the toxic gases. Identify the reducing agent in this reaction.

*Equation* ..............................................................................................

.............................................................................................................

*Reducing agent* ...................................................................................

(ii)     Identify a transition metal used in catalytic converters and state how the converter is constructed to maximise the effect of the catalyst.

*Transition metal* ...................................................................................

*How effect is maximised* ......................................................................

.............................................................................................................

**(5)**

(d)     The strength of the adsorption of reactants and products onto the surface of a transition metal helps to determine its activity as a heterogeneous catalyst.

(i)      Explain why transition metals which adsorb strongly are not usually good catalysts.

.............................................................................................................

(ii)     Explain why transition metals which adsorb weakly are not usually good catalysts.

.............................................................................................................

**(2)**

**(Total 10 marks)**

**Q27.**          (a)     State what is meant by each of the following terms.

(i)      *Ligand* ...................................................................................…………

.............................................................................................................

(ii)     *Complex* *ion* ........................................................................................

.............................................................................................................

(iii)     *Co-ordination number* ...........................................................…………

.............................................................................................................

**(3)**

(b)     Using complex ions formed by Co2+ with ligands selected from H2O, NH3, Cl–,  and EDTA4–, give an equation for each of the following.

(i)      A ligand substitution reaction which occurs with no change in either the co-ordination number or in the charge on the complex ion.

.............................................................................................................

(ii)     A ligand substitution reaction which occurs with both a change in the co-ordination number and in the charge on the complex ion.

.............................................................................................................

(iii)     A ligand substitution reaction which occurs with no change in the co-ordination number but a change in the charge on the complex ion.

.............................................................................................................

(iv)    A ligand substitution reaction in which there is a large change in entropy.

.............................................................................................................

**(8)**

(c)     An aqueous solution of iron(II) sulphate is a pale-green colour. When aqueous sodium hydroxide is added to this solution a green precipitate is formed. On standing in air, the green precipitate slowly turns brown.

(i)      Give the formula of the complex ion responsible for the pale-green colour.

.............................................................................................................

(ii)     Give the formula of the green precipitate.

.............................................................................................................

(iii)     Suggest an explanation for the change in the colour of the precipitate.

.............................................................................................................

.............................................................................................................

**(4)**

**(Total 15 marks)**

**Q28.**          Use the data below, where appropriate, to answer the following questions.

 Standard electrode potentials                                                        *E*/ V



(a)     State the colours of the following species in aqueous solution.

(i)      (aq) ........................................................................................

(ii)     Cr3+(aq) ...............................................................................................

(iii)     (aq) ...........................................................................................

**(3)**

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

......................................................................................................................

**(1)**

(c)     Deduce the oxidation state of

(i)      chromium in  ...........................................................................

(ii)     nitrogen in HNO2 .................................................................................

**(2)**

(d)     The concentration of iron(II) ions in aqueous solution can be determined by titrating the solution, after acidification, with a standard solution of potassium manganate(VII).

(i)      Explain, by reference to the data given in the table above, why hydrochloric acid should not be used to acidify the solution containing iron(II) ions.

.............................................................................................................

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(ii)     Explain, by reference to the data given in the table above, why nitric acid should not be used to acidify the solution containing iron(II) ions.

.............................................................................................................

.............................................................................................................

**(4)**

(e)     (i)      Calculate the e.m.f. of the cell represented by

Pt | Mn2+(aq), MnO(aq) || (aq), (aq) | Pt

.............................................................................................................

(ii)     Deduce an equation for the reaction which occurs when an excess of (aq) is added to an aqueous solution of Mn2+(aq) ions.

.............................................................................................................

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.............................................................................................................

**(3)**

**(Total 13 marks)**

**Q29.**          In the questions below, each of the three elements **X**, **Y** and **Z** is one of the Period 3 elements Na, Mg, Al, Si or P.

(a)     Both the chloride and the oxide of element **X** have high melting points. The oxide reacts readily with water. The chloride dissolves in water to form a neutral solution.

(i)      Deduce the type of bonding present in the chloride of element **X**.

.............................................................................................................

(ii)     Identify element **X**.

.............................................................................................................

(iii)     Write an equation for the reaction between water and the oxide of element **X**.

.............................................................................................................

**(3)**

(b)     Element **Y** has a chloride and an oxide which react vigorously with water to form solutions containing strong acids.

(i)      Deduce the type of bonding present in the oxide of element **Y**.

.............................................................................................................

(ii)     Identify element **Y**.

.............................................................................................................

(iii)     Identify an acid which is formed when **both** the oxide and the chloride of element **Y** react separately with water.

.............................................................................................................

**(3)**

(c)     The oxide of element **Z** is a crystalline solid with a very high melting point. This oxide is classified as an acidic oxide but it is not soluble in water.

(i)      Deduce the type of crystal shown by the oxide of element **Z**.

.............................................................................................................

(ii)     Identify element **Z**.

.............................................................................................................

(iii)     Write an equation for a reaction which illustrates the acidic nature of the oxide of element **Z**.

.............................................................................................................

**(4)**

**(Total 10 marks)**

**Q30.**          (a)     A Born–Haber cycle for the formation of magnesium(II) chloride is shown below.



Taking care to note the direction of the indicated enthalpy change and the number of moles of species involved, give each of the enthalpy changes (i) to (v) above.

*Enthalpy change (i)* ....................................................................................

*Enthalpy change (ii)* ...............................................................................….

*Enthalpy change (iii)* ...................................................................................

*Enthalpy change (iv)* ...................................................................................

*Enthalpy change (v) …..*...............................................................................

**(5)**

(b)     Write an equation for the decomposition of MgCl(s) into MgCl2(s) and Mg(s) and use the following data to calculate a value for the enthalpy change of this reaction.

∆*H*fMgCl(s) = –113 kJ mol–1

∆*H*fMgCl2(s) = –653 kJ mol–1

*Equation* ......................................................................................................

*Calculation* ...................................................................................................

......................................................................................................................

......................................................................................................................

......................................................................................................................

**(4)**

(c)     Use the data below to calculate a value for the molar enthalpy of a solution of MgCl2(s).

Lattice formation enthalpy of MgCl2(s)    = –2502 kJ mol–1

 of Mg2+(g)                              = –1920 kJ mol–1

 of Cl–(g)                                 = –364 kJ mol–1

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**(3)**

**(Total 12 marks)**

**Q31.**          (a)     In the Haber Process for the manufacture of ammonia, the following equilibrium is established in the presence of a heterogeneous catalyst.

N2(g) + 3H2(g)  2NH3(g)

Identify the heterogeneous catalyst used in this process and state what is meant by the term *heterogeneous*.

A heterogeneous catalyst can become poisoned by impurities in the reactants.
Give one substance which poisons the heterogeneous catalyst used in the Haber Process and explain how this substance poisons the catalyst.

**(5)**

(b)     State what is observed when an excess of aqueous ammonia reacts with an aqueous iron(II) salt. Write an equation for this reaction.

**(4)**

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**(Total 9 marks)**

**Q32.**          (a)     Octahedral and tetrahedral complex ions are produced by the reaction of transition metal ions with ligands which form co-ordinate bonds with the transition metal ion.
Define the term *ligand* and explain what is meant by the term *co*-*ordinate bond*.

**(3)**

(b)     (i)      Some complex ions can undergo a ligand substitution reaction in which both the co-ordination number of the metal and the colour change in the reaction.
Write an equation for one such reaction and state the colours of the complex ions involved.

(ii)     Bidentate ligands replace unidentate ligands in a metal complex by a ligand substitution reaction.
Write an equation for such a reaction and explain why this reaction occurs.

**(8)**

(c)     The frequency, *v*, of light absorbed by a transition metal complex ion can be determined using the relationship Δ*E* = *hv*. State what is meant by the symbols Δ*E* and *h*. Give **three** factors which result in a change in the frequency of light absorbed as a result of the reaction of a complex ion.

**(5)**

**(Total 16 marks)**

**Q33.**          (a)     Complete the electronic arrangement of the Co2+ ion.

[Ar] ...............................................................................................................

**(1)**

(b)     Give the formula of the cobalt complex present in an aqueous solution of cobalt(II) sulphate and state its colour.

*Formula of cobalt complex* ..........................................................................

*Colour of cobalt complex* .............................................................................

**(2)**

(c)     (i)      When a large excess of concentrated aqueous ammonia is added to an aqueous solution of cobalt(II) sulphate, a new cobalt(II) complex is formed.
Give the formula of the new cobalt(II) complex and state its colour.

*Formula of new cobalt(II) complex* ......................................................

*Colour of new cobalt(II) complex* .........................................................

(ii)     Write an equation for the formation of this new complex.

.............................................................................................................

**(3)**

(d)     When hydrogen peroxide is added to the mixture formed in part (c), the colour of the solution darkens due to the formation of a different cobalt complex. Identify this different cobalt complex and state the role of hydrogen peroxide in its formation.

*Cobalt complex formed*.................................................................................

*Role of hydrogen peroxide .*..........................................................................

**(2)**

**(Total 8 marks)**

**Q34.**         (a)     The Period 3 elements, Na, Mg, Al, Si, P and S, all form oxides when the elements are burned in an excess of oxygen.

(i)      Give the formula of an oxide of **one** of these elements in which the element is not in its highest oxidation state. Give the oxidation state of the element in this oxide.

*Formula of oxide .*................................................................................

*Oxidation state of element* ..................................................................

(ii)     Write an equation for the reaction in which phosphorus(V) oxide is formed from phosphorus and oxygen.

.............................................................................................................

**(3)**

(b)     The melting points of some of the oxides formed by Period 3 elements are given in a random order below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Oxide | **A** | **B** | **C** | **D** | **E** |
| *T*m/ °C | 2852 | –73 | 1610 | 1275 | 300 |

(i)      Using the letters **A** to **E**, give **two** oxides which have simple molecular structures.

Explain your answer.

*Oxide 1* ...............................................................................................

*Oxide 2* ...............................................................................................

*Explanation* .........................................................................................

.............................................................................................................

(ii)     Give a simple chemical test which could be used to show which of the oxides in the table is sodium oxide. State the observation you would make.

*Chemical test* .................................................................................…..

.............................................................................................................

*Observation* .........................................................................................

**(6)**

(c)     The pH curve for the titration of the weak diprotic acid H2SO3 with aqueous sodium hydroxide is shown below.



(i)      Identify the sodium salt formed from H2SO3 when *x* cm3 of NaOH have been added.

.............................................................................................................

(ii)     Write an equation for the reaction that occurs between the two end-points (equivalence points).

.............................................................................................................

(iii)     Name an indicator which could be used to determine the second end-point (equivalence point).

.............................................................................................................

**(3)**

**(Total 12 marks)**

**Q35.**         (a)     The Period 3 elements, Na, Mg, Al, Si, P and S, all form oxides when the elements are burned in an excess of oxygen.

(i)      Give the formula of an oxide of **one** of these elements in which the element is not in its highest oxidation state. Give the oxidation state of the element in this oxide.

*Formula of oxide .*................................................................................

*Oxidation state of element* ..................................................................

(ii)     Write an equation for the reaction in which phosphorus(V) oxide is formed from phosphorus and oxygen.

.............................................................................................................

**(3)**

(b)     The melting points of some of the oxides formed by Period 3 elements are given in a random order below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Oxide | **A** | **B** | **C** | **D** | **E** |
| *T*m/ °C | 2852 | –73 | 1610 | 1275 | 300 |

(i)      Using the letters **A** to **E**, give **two** oxides which have simple molecular structures.

Explain your answer.

*Oxide 1* ...............................................................................................

*Oxide 2* ...............................................................................................

*Explanation* .........................................................................................

.............................................................................................................

(ii)     Give a simple chemical test which could be used to show which of the oxides in the table is sodium oxide. State the observation you would make.

*Chemical test* .................................................................................…..

.............................................................................................................

*Observation* .........................................................................................

**(6)**

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(i)      Identify the sodium salt formed from H2SO3 when *x* cm3 of NaOH have been added.

.............................................................................................................

(ii)     Write an equation for the reaction that occurs between the two end-points (equivalence points).

.............................................................................................................

(iii)     Name an indicator which could be used to determine the second end-point (equivalence point).

.............................................................................................................

**(3)**

**(Total 12 marks)**

**M1.**          (a)     (i)      Deductions:

         Ionic **(1)**Ions not free to move in the solid state **(1)**Ions free to move when molten or in aqueous solution **(1)**Identity of **P**: Na2O or sodium oxide **(1)**

*N.B. If a formula given this must be correct*

         Equation: Na2O + H2O → 2 NaOH **(1)**

**5**

(ii)     Deductions:

         Covalent
Intermolecular forces are weak or van der Waals forces,
or dipole-dipole

*N.B. Any answer including a reference to hydrogen bonding is incorrect*

         Identity of **Q**: SO2 or sulphur dioxide **(1)**

         Equation: SO2 + H2O → H2 SO3**(1)**

*NB Allow max one for SO3*

**4**

(b)     (i)      Amphoteric **(1)**

(ii)     Equation with NaOH

         Al(OH)3 + NaOH → NaAl(OH)4

*OR Al(OH)3(H2O)3 + OH– → [Al(OH)4(H2O)2]– + H2O
OR Al(OH)3 + OH– → [Al(OH)4]–*

**R** identified as Al(OH)3 or Al(OH)3(H2O)3 **(1)**A balanced equation **(1)**

*N.B. Allow equation with six co-ordinate Aluminium and up to six OH– ligands
N.B. Allow equation mark if M(OH)3 given in a balanced equation*

         Equation with H2SO4

2Al(OH)3 + 3H2SO4 → Al2(SO4)3 + 6H2O

OR Al(OH)3(H2O)3 + H+ → [Al(OH)2(H2O)4+ + H2O

*NB Allow equations with six co-ordinate Aluminium and up to six H2O ligands NB Allow equation mark if M(OH)3 given in a balanced equation*

Correct Al species as product **(1)**A balanced equation **(1)**

(iii)     Large lattice energy
or strong covalent bonds
or ΔHsoln is very positive
or ΔG is positive
or sum of hydration energies less than covalent bond energies **(1)**

**6**

**[15]**

**M2.**          (a)     High *E*a: S2O82– repels I– **or** both ions negative **(1)**2Fe2+ + S2O82– → 2Fe3+ + 2SO42– **(1)**2Fe3+ + 2I– → 2Fe2+ + I2 **(1)**

*N.B. Ignore additional incorrect equations*

          Vanadium is a transition element **or** Magnesium is not a transition element **(1)**

          Vanadium has variable oxidation states **(1)**

          Magnesium only forms Mg2+, **or** has only one oxidation state **(1)**

*N.B. Score two marks for “Only vanadium has variable oxidation states”*

**6**

(b)     AlCl3 + Cl-COCH3 → AlCl4– + CH3CO+ **(1)
**H+ + AlCl4– → AlCl3 + HCl **(1)**Lewis acid: AlCl3 accepts electron pair

*N.B. penalise incorrect acyl chloride by one
N.B. penalise chloroethane by two marks i.e. first equation mark, attack on benzene mark*

          NH4Cl: Not a catalyst **(1)**

FeCl3: A catalyst **(1)**has a low energy vacant shell
or has spaces or vacancies in d shell
or has a partially filled d shell
or able to accept an electron pair
or can form FeCl4– **(1)**

**9**

**[15]**

**M3.**         (a)     Identity of **A**;
ethane-1,2-diol **or** 1,2 dihydroxyethane **or** ethylene glycol **or** formula **(1)**

*N.B. Do NOT allow OHCH2CH2OH unless a correct name is also given*

          K2Cr2O7 / dilute H2SO4 **or** dilute HCl **or** K2Cr2O7 / H+

*N.B. Oxidising agent must be a reagent
N.B. Do NOT allow concentrated H2SO4*

          Reflux **or** warm **or** heat **(1)**

*Ignore temperature if given
N.B. If a temperature given on its own it must be at or below 200°C*

          Anion:  **(1)**

*N.B. Do NOT allow C2O42–N.B. Ignore lone pairs of electrons*

**4**

(b)     Structure : 

*correct co-ordination (1)
bonding through six correct oxygen (1)*

*Score 2 or zero
N.B. Not essential to show double bonds i.e. C=O in structure*

Explanation:
Substitution produces more molecules or particles or more disorder **(1)**Entropy change is positive **(1)**

**4**

**[8]**

**M4.**          (a)     A shared electron pair or a covalent bond **(1)**Both electrons from one atom **(1)**

*OR when a Lewis base reacts with a Lewis acid
Mark points separately*

**2**

(b)     *Brønsted-Lowry acid*: A proton or H+ donor **(1)**

*Not H3O+*

          *Lewis acid*: A lone or electron pair acceptor **(1)**

**2**

(c)     Two atoms or two points of attachment **(1)**Each donating a lone electron pair **(1)**

*OR forms 2 (1) co-ordinate bonds (1)
OR donates two (1) pairs of electrons (1)*

**2**

(d)     *Change in co-ordination number*: 6 to 4 **(1)**

*Reason for change*: chloride ligands are larger than water ligands **(1)**

**2**

*OR greater repulsion between chloride ligands
DO NOT allow chlorine or Cl*

(e)     Same number **(1)**, and same type of bonds **(1)**, broken and made

**2**

(f)      ClNH3CH2CH2NH3Cl **(1)**

*OR (NH3CH2CH2NH3)2+ 2Cl–Allow C2H10N2Cl2 and NH3ClCH2CH2NH3Cl*

**1**

**[11]**

**M5.**          (a)     (i)      [Cr(H2O)6]3+ + H2O → [Cr(H2O)5(OH)]2+ + H3O+ **(1)**

*OR [Cr(H2O)6]3+ → [Cr(H2O)5(OH)]2+ + H+DO NOT allow reactions with bases other than water
Allow loss of up to 2 H+*

(ii)     Cr3+ is smaller than Cr2+ **(1)**

*OR Cr3+ has a greater charge density or charge to size ratio*

Cr3+ is more polarising **(1)**

*OR draws electron density from oxygen*

So more O—H bonds break (weakened) **(1)**

*Max 2 from three*

**3**

(b)     (i)      Cr(H2O)3(OH)3 **or** Cr(OH)3 **or** Cr(OH)3 x H2O, where x =, 1, 2 or 3 **(1)**

*OR name chromium (III) hydroxide*

(ii)     Base or electron pair donor or proton acceptor **(1)**

*NOT alkali, ignore nucleophile but penalise ‘ligand’*

(iii)     *Gas evolved*: CO2 or name **(1)***Equation*:

3CO32– + 2[Cr(H2O)6]3+ → 2[Cr(H2O)3(OH)3] + 3CO2 + 3H2O **(1)**

*N.B if separate equations for CO32– and Cr3+ (aq) given an
overall equation must be deduced*

**4**

(c)     H2O2 + NaOH (or KOH) score **(2)**H2O2 + anything else or on its own scores **(1)**NaOH alone scores zero
Na2O2 scores **(2)**

*Do not allow ‘alkaline’, or OH– or NH3*

**2**

**[9]**

**M6.**         (a)     *Species*: [Ag(NH3)2]+ **(1)***Shape*: Linear **(1)***Use*: To distinguish between (or identify) aldehydes and ketones

*OR Tollen’s reagent or in ‘silver mirror test’
Allow name but penalise contradictions
Mark species and shape separately*

**3**

(b)     (i)      *Precipitate B:* AgBr or name **(1)***Silver containing species in* ***C***: [Ag(S2O3)2]3– **(1)**

(ii)     *Equation*: AgBr + 2S2O32– → [Ag(S2O3)2]3– + Br– **(1)***Explanation*: Removes AgBr (AgI) **(1)**

*OR “fixer” or prevents AgX darkening or reacting with light*

**4**

(c)     *Species*: [Ag(CN)2]– **(1)***Use:* Electroplating **(1)**

*Mark use separately*

**2**

(d)     It has a full d shell or does not have a partially filled d shell **(1)**

*NOT ‘it has a full outer shell’
Ignore 3 if 3d stated*

**1**

**[10]**

**M7.**         (a)     Electron transitions/electrons excitedin d shell **(1) o**r d-d transition

*Do NOT allow charge transfer*

          (Energy in) visible range **(1)**

*(NOT emits in visible region)*

**2**

(b)     *Change 1*: (Different) oxidation states **(1)***Change 2* : (Different) ligands **(1)***Change 3*: (Different) co-ordination number **(1)**

*Do not allow shape as an answer*

**3**

(c)     Add an appropriate (or a given correct) ligand to intensify colour **(1)**e.g. thiocyanate (CNS)— or bipyridyl
Make up solutions of known concentration **(1)**Measure absorption or transmission **(1)**Plot graph of results or calibration curve **(1)**Measure absorption of unknown and **(1)**compare

*N.B.:  Allow concentration statement if included in graph statement
          Allow adsorption but circle the d
          Also*

**

**5**

**[10]**

**M8.**          (a)     *Cell* *e.m.f.*: 1.93 (v) CE if negative value given **(1)***Half equation*: Mg → Mg2+ + 2 e– **(1)**

*or *

*Ignore state symbols*

*Mark on after an AE*

**2**

(b)     *Change in e.m.f*.: increases **(1)**

*Mark on even if incorrect*

          *Explanation*: Equilibrium displaced to Mg2+ or to the left **(1)**

*cell reaction or overall reaction goes to the right
Electrode is more negative or E decreases
or gives more electron
or forms more Mg2+ ions
Mark separately*

**3**

(c)     *Cell e.m.f.* : –0.84 (V) **(1)**

          *Explanation*: Fe is giving electrons **or** forming Fe2+**or** reaction goes in the reverse direction **(1)**

*Mark on after AE*

*N.B. In (a) and (c) mark on if no value given,
but CE in both (a) and (c) if e.m.f. = 0*

**2**

**[7]**

**M9.**          (a)     (i)      *Standard enthalpy change*: ΔHR = ΣΔHf products – ΣΔHfreactants **(1)**ΔHR = (–804 – 394) – (–940) **(1) N.B: If answer wrong
statement worth 2**       = -258 (kJ mol–1; ignore units completely) **(1)**

*Allow +258 (2) marks*

*Standard entropy change*: ΔS = ΣS products – Σ reactants **(1)**

ΔS = (252 + 214) – (49.9 + 5.7 + [2 × 223]) **(1) N.B: If answer
wrong statement worth 2**

     = –35.6 (kJ mol–1; ignore units completely) **(1)**

*Allow +35.6 (2) marks
Mark –36 AE minus one
Allow max one for +187*

(ii)     T =  **or** T =  **(1)**

*Penalise wrong sign*

T =  = 7245 to 7250 **(1)**

*Ignore letter after value
Ignore  even if wrong way around*

*Mark answer conseq to ΔH and ΔS values from above*

*If negative temperature given max 2\**

*If °C used incorrectly max 2\**

*\*But only penalise one of these errors*

**9**

(b)     (i)      TiCl4 + 4Na **(or 2 Mg)** → 4NaCl **(or 2MgCl2)**+ Ti

*Note: CE if species incorrect*

*Correct species (1), balanced (1)
Penalise (aq) by one mark and ignore other state symbols*

(ii)     Ti reacts with oxygen or air, **or** Ti is oxidised, **or** an oxide is
formed **(1)
or** Ti reacts with nitrogen **or** nitride formed **or** formula of any
nitride **(allow any oxide) or** Na or Mg react with oxygen,
nitrogen or air **(1)**

*Do not allow hydrolysis
Penalise if other products given e.g. carbide*

**3**

(c)     TiCl4 + 2H2O → TiO2 + 4HCl (Ignore state symbols) **(1)**

*Allow Ti(OH)4 when 4 H2O needed
or Ti(OH)4(H2O)2 when 6 H2O needed
or TiO2 x H2O but must be balanced and x = 6 or less*

**1**

**[13]**

**M10.**          (a)     reactants brought together / increased concentration on surface
or increased collision frequency **(1)**reactants must be correctly orientated **(1)**reaction on the surface **(1)**products desorbed **(1)**example of a catalysed reaction (not a named process) **(1)**a suitable catalyst for this reaction **(1)**

*penalise incorrect second reactions and catalysts*

          If absorption too weak reactants not brought together **(1)**e.g. silver **(1)**If adsorption too strong products not desorbed **(1)**e.g. tungsten **(1)**

**max 8**

(b)     Equations:

          Cr2O72– +14 H+ + 6 Fe2+→ 6 Fe3+ + 2 Cr3+ + 7 H2O **(1)**Zn + 2 Fe3+ → Zn2+ +2 Fe2+ **(1)**

Method

Titrate measured volume solution against K2Cr2O7 **(1)**

Reduce same volume solution with zinc **(1)**

Filter off excess zinc **(1)**

Titrate total Fen+ using K2Cr2O7 **(1)**

Percentage Fe3+ = 100 × (titre2 ‑ titre1) / titre 2
or equivalent **(1)**

**7**

**[15]**

**M11.**          (a)     C2O42– or H2NCH2CH2NH2 **(1)**

**1**

(b)     [AgCl2]– or [Ag(CN)2]– or [Ag(NH3)2]+ **(1)**

**1**

(c)     e.g. [Co(H2O)6]2+ + 4Cl– → [CoCl4]2– + 6H2O
Correct complex species **(1),** Balanced **(1),** Only allow if species correct

**2**

(d)     e.g. [Co(H2O)6]2+ + 6NH3 → [Co(NH3)6]2+ + 6H2O
Correct complex species **(1),** Balanced **(1),** Only allow if species correct

**2**

(e)     *Equation:* [Co(H2O)6]2+ + EDTA4– → [Co(EDTA)]2– + 6H2O **(1)***Explanation:* More molecules on right hand side **(1)**Entropy increases **(1)**

**3**

**[9]**

**M12.**(a)     (Standard) hydrogen (electrode) **(1)**

**1**

(b)     (i)      To allow transfer of electrons / provide a reaction surface **(1)**

(ii)     298 K **(1)**Both F3+ (aq) and Fe2+ (aq) have a concentration of 1
mol dm–3 **(1)** (QoL)
OR [H+] = 1 mol dm–3

*NOT zero current or 100 kPa*

**3**

(c)     +1.34 V **(1)**2 MnO4– + 5 H2SO3 → 2 Mn2+ + 5 SO42– + 3 H2O +4 H+Correct species / order **(1)**Balanced and cancelled **(1)**

*Allow one for 2 MnO4– + 5 H2SO3 → 2 Mn2+ + 5 SO42–*

**3**

(d)     (i)      Ce4+ (aq) **(1)**

(ii)     VO2+ (aq) **(1)**; Cl2 **(1)**

*Penalise additional answers to zero*

**3**

(e)     Pt | Fe2+ (aq), Fe3+ (aq) || Ce4+(aq), Ce3+ (aq) | Pt
Correct species **(1)**Correct order **(1)**

*Deduct one mark for each error*

**2**

**[12]**

**M13.**          (a)     (i)      *Standard enthalpy change*:
ΔHR = ΣΔHf(products) - ΣΔHf(reactants) **(1)**

*or cycle*

ΔHR = ([2 × 0] + [3 × –393.5]) ‑ (-824.2 + [3 × -110.5]) **(1)**= -24.8 (kJ mol–1) **(1)**

*Allow + 24.8 max one*

         *Standard entropy change*: ΔS = ΣS(products) ‑ ΣS(reactants) **(1)**

         ΔS = ([2 × 27.3] + [3 × 213.6]) ‑ (87.4 + [3 × 197.6]) **(1)**     = (54.6 + 640.8) ‑ (87.4 + 592.8) **(1)**     = 15.2 (JK–1mol–1) **(1)**

*Allow -15.2 max one*

(ii)     ΔG = ΔH ‑ TΔS **(1)**ΔH negative and ‑TΔS is negative **(or ΔS positive or
or correct calc) (1)**Hence ΔG is always negative
**(or feasible when ΔG ** **0) (1)**

**9**

(b)     ΔG = O = ΔH ‑ TΔS  Hence ΔH = TΔS **(1)**T **=** ΔH / ΔS = 492.7 × 1000 / 542.6 **(1)**                 = 908 K **(1)**

*penalise missing 1000 by one mark*

**3**

(c)     ΔG (b) = ΔG (a)
(492.7 × 103 ‑ T × 542.6) = (-24.8 × 103 ‑ T × 15.2) **(1)**517.5 × 103 = 527.4 T **(1)**T = 981.2 K**(1)**

*Allow 980 ‑ 982
Penalise missing 1000 by one mark*

**3**

**[15]**

**M14.**          (a)     Forms blue or pink or blue / green percipitate **(1)**

*Not green*

         of Co(H2O)4(OH)2 etc **(1)**

          (Precipitate) dissolves or forms a solution (in excess ammonia) **(1)**

          Forms yellow or pale brown ‘straw’ (coloured solution) **(1)**

         Containing [Co(NH3)6]2+ **(1)**

          Darkens or goes brown on standing in air **(1)**

         as [Co(NH3)6]3+ formed **(1)**

          Due to oxidation (by O2 in air) or by reaction with oxygen (QoL) **(1)**

**8**

(b)     Fe3+ has a large charge **(1)**and smaller size than Fe2+ **(1)**

*NB    Fe3+ has a higher charge size ratio or higher surface density of charge or higher charge density scores (2)*

***NB    Lose these two marks if candidates refer to either atoms or molecules***

Greater polarisation (of water) by Fe3+ or more hydrolysis occurs
or Fe3+ weakens the O-H bond more

*Allow converse statements*

Fe2+ higher pH than Fe3+ or Fe3+ more acidic or solution of
Fe3+ contains more H+ **(1)**

***NB    Allow marks for correct hydrolysis equation i.e.***

***[Fe(H2O)6]3+  [Fe(H2O)5(OH)]2+ + H+***

***if accompanied by a statement that this equilibrium lies further to the right for Fe3+ than for Fe2+ (1) and more H+ produced/pH lower (1)
(Allow converse statement)***

**4**

Fe2+ with Na2CO3; green precipitate **(1)**of FeCO3 **(1)**

Fe3+ with Na2CO3; (rust)/brown or red/brown precipitate (Not red) **(1)**of [Fe(H2O)3(OH)3] etc

*Allow Fe2O3.xH2O but not Fe2O3* ***(1)***

          and allow (carbon dioxide) gas evolved **(1)**

**5**

**[17]**

**M15.**          (a)     (i)



*ONLY consider species involved in the step marked*

(ii)     Cycling clockwise about (\*)

*CE if step missing*

         ΔHaBa + 1st IEBa + 2nd IE Ba + 2ΔHaCl + 2EACl + LE – ΔHfBaCl2 = 0 **(1)**+180 + 503 + 965 + 2 × 122 + 2EA –2056 + 859 = 0 **(1)**EA = –695/2 = – (347 to 348) **(1)**

*Ignore units*

*Calculation –1 for each error*

*Mark conseq.*

*Notes: –695 scores* ***(2)****+(347 to 348) scores* ***(2)****–(286 to 287) scores* ***(2)****+(286 to 287) scores* ***(1)****–573 scores* ***(1)****+573 scores* ***(0)***

**9**

(b)     ΔS = ΣS products – ΣS reactants
      = (63 +223) – 124 = 162 **(1)**

ΔG = ΔH – TΔS     or      ΔH = TΔS or T = ΔH/ΔS **(1)**

*or used correctly*

          ΔH = 859 × 103 **(1)** = T × 162
T = (5 300 to 5304) K **(1)**

*Penalise if units °C*

*–1 for each error + mark conseq.*

**4**

**[13]**

**M16.**          (a)     (i)      Two **(1)** lone pair donor / electron pair donor **(1)** atoms
Allow:– forms two co-ordinate bonds **(1)**

*NOT atom with two lone pairs*

(ii)



*Correct ligand structure* ***(1) ***

*penalise any error*

*Six correct O–Fe bonds* ***(1)***

*Correct charge* ***(1)***

*N.B. Penalise the second mark if arrow from Fe shown*

*N.B. Ignore charges on atoms*

**5**

(b)     (Substitution of a monodentate ligand by a) bi or multidentate
ligand **(1)** giving a more stable complex **(1)** or with an increase
in entropy / disorder or forming a ring / cage complex / structure
(crab like)

**2**

(c)     (i)      [AgCl2]– or AgCl2– **(1)**

(ii)     Chloride or Cl– big or large or repel **(1)**

*NOT Cl2 or Cl+ or Cl*

*Allow ‘chlorine ion’*

**2**

(d)     (i)      (Both) ions are negative or ions repel or High Ea **(1)**

(ii)     *Meaning of the term autocatalytic:* A product of the reaction acts
as a catalyst **(1)**

*NOT a self catalysing reaction (0)*

*Catalyst*: Mn2+ or Mn3+ **(1)**

(iii)     Mn2+ converted into Mnn+ or Mn2+ oxidised **(1)**Mnn+/oxidised species then oxidises/reacts with C2O42– **(1)**

**5**

**[14]**

**M17.**          (a)     (i)      H2O2 **(1)** plus NaOH **(1)**

*only allow if H2O2 given*

*Alkaline H2O2 scores (1)*

*Na2O2 scores (2)*

(ii)     Zn **(1)** plus HCl/H2SO4 **(1)**

*only allow if Zn given*

*Ignore conc*

*Not HNO3*

(iii)     A named aldehyde or a correct formula clearly with an
aldehyde gropup **(1)**

or Cu → Mg

**5**

(b)     (i)      *Half-equation for the oxidation of H2O2*H2O2 → O2 + 2H+ + 2e– (or multiple) **(1)**

         *Half-equation for the reduction of manganate(VII) ions*MnO4– + 8H+ + 5e– → Mn2+ + 4H2O (or multiple) **(1)**

         *Overall equation*2MnO4– + 5H2O2 + 6H+ → 2Mn2+ + 5O2 + 8H2O **(1)**

*only allow this or multiple*

(ii)     Moles MnO4– = mv/1000 = (2.82 to 2.83) × 10–4 **(1)**Moles H2O2 = 2.826 × 10–4 × 5/2 **(1)** = (7.06 to 7.08) × 10–4

*mark conseq to equation in b(i)*

[H2O2] = 7.065 × 10–4 × 1000/20 **(1)** = (3.53 to 3.54) × 10–2

         Mass = moles × Mr = 3.53 × 10–2 × 34
                              = 1.2(0) **(1)**

*Ignore units*

*Max 3 if ratio 2/5 used. (Final answers 0.19)*

*N.B.     Using 3:5 ratio
     Moles MnO4– = (2.82 to 2.83) × 10–4* ***(1)****Moles [H2O2] = 2.826 × 10–4 × 5/3* ***(1)*** *= (4.70 to 4.72) × 10–4     [H2O2] = 4.71 × 10–4 × 1000/20* ***(1)*** *= (2.35 to 2.36) × 10–2     Mass = 0.8(0)* ***(1)*** *(i.e. 2 sig fig required)*

**7**

**[12]**

**M18.**          (a)     (i)      *can form a solution with pH less than 3*: P4O10 or SO3 **(1)**

(ii)     *can form a solution with with a pH greater than 12*: Na2O **(1)**

penalise any wrong answer to zero

**2**

(b)     (i)      MgO + 2HNO3 → Mg(NO3)2 + H2Oor an ionic equation **(1)**i.e. MgO + 2H+ → Mg2+ + H2O

*not O2– + 2H+ → H2O*

(ii)     2NaOH + SiO2 → Na2SiO3 + H2O or ionic equation **(1)**i.e. SiO2 + 2OH– → SiO32- + H2O

(iii)     3Na2O + 2H3PO4 → 2Na3PO4 + 3H2O etc or ionic equation **(1)**

*i.e. Na2O + 2H+ → 2Na+ + H2O*

**3**

(c)     P4O10 is a molecular (structure) or simple covalent **(1)**Weak intermolecular forces or van der Waals forces (between
molecules) **(1)**SiO2 is a macromolecule / giant covalent / giant molecule **(1)**

*Not giant lattice*

(Strong) covalent bonds (between atoms) must be broken **(1)**

**4**

**[9]**

**M19.**          Linear complex             e.g.        [Ag(NH3)2]+ **(1)**

          Tetrahedral complex     e.g.        [CoCl4]2– **(1)**

          Octahedral complex     e.g.        [Fe(H2NCH2CH2NH2)3]3+

*Species* ***(1)****Charge* ***(1)***

**[4]**

**M20.**          (a)     (i)      Heterogeneous:-    In a different phase to reactants **(1)**Catalyst:-               Increases reaction rate **(1)**                               Alternative route or route described **(1)**                               Lower *E*a **(1)** Unchanged at end of reaction **(1)**      Max 4

(ii)     Feature:- QoL        Variable oxidation states shown by vanadium **(1)**Equations               V2O5 + SO2 → V2O4 + SO3 **(1)**                               2V2O4 + O2 → 2V2O5 **(1)**

**7**

(b)     VO2+ + 4H+ + 3e– → V2+ (aq) + 2H2O **(1)**

            Zn → Zn2+ + 2e– (given)

2VO2+ + 8H+ + 3Zn → 3Zn2+ + 2V2+ (aq) + 4H2O **(1)**

**2**

Mol KMnO4 = mv/1000 = 0.0200 × 38.5/1000 = 7.70 × 10–4 **(1)**

Mole ratio MnO4– to V(II) = 3:5 deduced

or equation

         5V2+ + 3MnO4– + 4H+ → 2H2O + 3Mn2+ + 5VO2+ **(2)**

Mol V(II) = 7.70 × 10–4 × 5/3 **(1)** = 1.283 × 10–3

Mass V = 1.283 × 10–3 × 50.9 **(1)** = 0.0653 g

% V in sample = 0.06532 × 100/0.160 = 40.8 **(1)**

**6**

**[15]**

**M21.**          (a)     Electrons excited / transition from ground state to excited state **(1)**Energy absorbed from visible / light (spectrum) **(1)**

**2**

(b)     (i)      *Cobalt-containing species*: [Co(H2O)6]2+ **(1)**

*Precipitate* ***M***: Co(H2O)4(OH)2 or Co(OH)2 **(1)**

(ii)     [Co(NH3)6]2+ **(1)**

(iii)     *Type of reaction*: Co2+ oxidised to Co3+ **(1)**

*Reactant responsible*: Oxygen **(1)**

(iv)    *Identity of* ***R***: Iodine **(1)**

*Explanation*: I– oxidised (by Co3+ which is reduced to Co2+) **(1)**

**7**

**[9]**

**M22.**          (a)     *Hydrogen ion concentration*: 1.00 mol dm–3 **(1)**

*Hydrogen gas pressure*: 100 kPa **(1)**

**2**

(b)     *Explanation of change*: Equilibrium displaced to left **(1)**                                   to reduce constraint **(1)**

*Change in electrode potential*: Becomes negative or decreases **(1)**

*allow more negative*

**3**

(c)     (i)      0.43V **(1)**

(ii)     *Half-equation*: 2Br– → Br2 + 2e– **(1)**

*Overall equation*: 2BrO3– + 10Br– + 12H+ → 6Br2 + 6H2O **(2)**                  or BrO3– + 5Br– + 6H+ → 3Br2 + 3H2O

*species* ***(1)****balanced* ***(1)***

**4**

**[9]**

**M23.**          (a)     *Standard enthalpy change, ΔH*: Δ*HR* = ΣΔ*Hf*products - ΣΔ*Hf*reactants **(1)**                                                           or cycle

          Δ*HR* = (0 + [2 × –242]) – (4 × –92) **(1)**       = -484 + 368
       = –116 (kJ mol–1)

*Allow max 1 for +116*

          *Standard entropy change, ΔS*: ΔS = ΣΔHf products – ΣΔHf reactants

Δ*S*   = ([2 × 223] + [2 × 189]) - (205 + [4 × 187]) **(1)**

= 824 – 953

= –129 (J K–1 mol–1)

*allow max one for +129*

**6**

(b)     (i)      *Effect*: Equilibrium displaced to right / to products **(1)***Explanation*: Reaction is endothermic **(1)**                    Constraint reduced **(1)**

*mark separately*

(ii)     Feasible when Δ*G* 0 **(1)**

*ΔG* = Δ*H* – TΔ*S* **(1)**

         T = Δ*H*/Δ*S* = 208 × 1000 **(1)** / 253

= 822 K **(1)**

**7**

**[13]**

**M24.**          (a)     Mg + 2HCl → MgCl2 + H2

**1**

MgO + 2HCl → MgCl2 + H2O

*Allow ionic equations*

**1**

(b)     Hydrogen collection
Using a gas syringe or measuring cylinder/ graduated vessel over water

*Allow if shown in a diagram*

**1**

          Measurements                              (i) P 1
                                                      (ii) T 1
                                                      (iii) V 1

Use ideal gas equation to calculate mol hydrogen or mass/*M*r
Mol H2 = mol Mg (Mark consequentially to equation)

**2**

(c)     MgCl2 + 2NaOH → Mg(OH)2 + 2NaCl Species

**1**

          Balanced

**1**

*Allow an ionic equation*

          Mg(OH)2 → MgO + H2O

**1**

(d)     ***Allow 2 significant figures in these calculations and
ignore additional figures***

          EITHER

          Mol MgO obtained stage 2 = mass MgO/*M*rMgO

**1**

          = 6.41/ 40.(3)                     = 0.159 *Allow 0.16*

*Allow method mark if formula of magnesium oxide or Mr incorrect*

**1**

          Moles of Mg = moles of H2 hence

Mol original MgO = mol MgO from stage 2 - mol H2

**1**

= 0.159 – 0.0528 = 0.106 *Allow 0.11*

*Mark consequentially to moles of magnesium oxide determined above*

          OR

          Mass MgO formed from Mg = 0.0528 × *M*r MgO {or 40.(3)}             **(1)**

= 2.13 g

*Allow 2.1* ***(1)***

*Allow method mark if formula of magnesium oxide or Mr incorrect*

          Mass original MgO = total mass MgO - mass formed from Mg       **(1)**

                             = 6.41 – 2.13 = 4.28 g           *Allow 4.3*                 **(1)**

*Mark consequentially mass of magnesium oxide determined above*

**NB**

**As there is an error in part (d), the mass of sample should
have been 6.25 NOT 2.65, award full marks to any candidate
who has crossed out their correct first** **answer.**

**1**

**[15]**

**M25.**          (a)     *M1*    Kp = (PY)3. (PZ)2/ (PW)2.( PX)      *NB [ ] wrong*

**1**

*M2*    temperature

**1**

*M3*    increase

**1**

*M4*    particles have more energy or greater velocity/speed

**1**

*M5*    more collisions with E > Ea or more successful collisions

**1**

*M6*    Reaction exothermic or converse

**1**

*M7*    Equilibrium moves in the left

**1**

          Marks for other answers
*Increase in pressure or concentration*   *allow M1, M5, M6*         *Max 3
Addition of a catalyst;*                             *allow M1, M5, M6*         *Max 3
Decrease in temperature;*                      *allow M1, M2, M6*         *Max 3
Two or more changes made;*                 *allow M1, M6*                *Max 2*

(b)     (i)      Advantage; reaction goes to completion, not reversible
or faster

**1**

         Disadvantage; reaction vigorous/dangerous

*(exothermic must be qualified)*

          or HCl(g) evolved/toxic
or CH3COCl expensive

*NB     Allow converse answers
     Do not allow reactions with other reagents e.g. water
     or ease of separation*

**1**

(ii)     Δ*S* = ΣS products – ΣS reactants

**1**

Δ*S* = (259 + 187) – (201 + 161)

**1**

Δ*S* = 84 (JK–1 mol–1)     *(Ignore units)*

*Allow – 84 to score* ***(1)*** *mark*

**1**

Δ*G* = Δ*H* – *T*Δ*S*

**1**

      = – 21.6 – 298 × 84/1000
 = – 46.6 kJ mol–1 or – 46 600 J mol–1

**1**

*Allow* ***(2)*** *for – 46.6 without units*

*(Mark ΔG consequentially to incorrect ΔS)*

*(e.g. ΔS = –84 gives ΔG = +3.4 kJ mol–1)*

**1**

**[15]**

**M26.**          (a)     A catalyst in the same phase/phase as the reactants

**1**

(b)     (i)      A reaction in which a product acts as a catalyst

**1**

(ii)     Mn2+ or Mn3+*“Self-catalysing” not allowed*

**1**

(c)     (i)      2CO + 2NO → 2CO2 + N2

or      4CO + 2NO2 → 4CO2 + N2

*C not allowed as a product*

**1**

          Reducing agent CO

**1**

(ii)     Pt, Pd or Rh

**1**

         Deposited on a ceramic honeycomb or matrix or mesh or sponge

**1**

         To increase surface area of catalyst

**1**

(d)     (i)      Reactants cannot move on surface or products not desorbed or
Active sites blocked

**1**

(ii)     Reactants not brought together or
No increase in reactant concentration on catalyst surface or
Reactants not held long enough for a reaction to occur or
Reactant bonds not weakened

**1**

**[10]**

**M27.**          (a)     (i)      An atom, ion or molecule which can donate a lone electron pair

**1**

(ii)     A central metal ion/species surrounded by co-ordinately
bonded ligands or ion in which co-ordination number
exceeds oxidation state

**1**

(iii)     The number of co-ordinate bonds formed to a central metal ion
or number of electron pairs donated or donor atoms

**1**

(b)     (i)      *Allow the reverse of each substitution*

[Co(H2O)6]2+ + 6NH3 → [Co(NH3)6]2+ + 6H2O

Complex ions

**1**

Balanced

**1**

*Allow partial substitution*

(ii)     [Co(H2O)6]2+ + 4Cl– → CoCl + 6H2O

Complex ions

**1**

Balanced

*or H2O or NH3 or C2O by Cl–*

**1**

eg.     (iii)     

Complex ions

**1**

Balanced

**1**

*Allow all substitution except*

*(i) NH3 by H2O*

*(ii) more than 2Cl– substituted for NH3 or H2O*

eg.     (iv)    

Complex ions

**1**

Balanced

*or H2O or NH3 by  and  orby *

**1**

(c)     (i)      [Fe(H2O)6]2+

**1**

(ii)     Fe(OH)2 or Fe(OH)2(H2O)*x* where *x* = 0 to 4

**1**

(iii)     Fe2+ is oxidised to Fe3+ or Fe(OH)3

**1**

By oxygen in the air

**1**

**[15]**

**M28.**          (a)     (i)      Orange

**1**

(ii)     Red-violet/ruby/violet/ green

**1**

(ii)     Purple

**1**

(b)     Fe2+ or Fe(II)

**1**

(c)     (i)      6 or (VI)

**1**

(ii)     3 or (III)

**1**

(d)     (i)      MnO/Mn2+ has a more positive *E*~~ο~~ value than Cl2/Cl–                        or data used

**1**

and will oxidise Cl– or change Cl– to Cl2

*Allow converse answers*

**1**

(ii)      has a more positive *E*~~ο~~ value than Fe3+/Fe2+                        or data used

**1**

and will oxidise Fe2+ or change Fe2+ to Fe3+

**1**

(e)     (i)      0.5

**1**

(ii)     2Mn2+ + 8H2O + 5S2O → 10SO + 2MnO + 16H+

Both SO and MnO on right

**1**

Balanced

**1**

**[13]**

**M29.**          *Each section to be marked independently*

(a)     (i)      Ionic

**1**

(ii)     Sodium/Na

**1**

(iii)     Na2O + H2O → 2NaOH

*Ignore state symbols*

**1**

(b)     (i)      Covalent

**1**

(ii)     Phosphorus/P

**1**

(iii)     H3PO4 or other acid with P in oxidation state (V) or (III)

**1**

(c)     (i)      Macromolecular/giant covalent/giant molecular

**1**

(ii)     Silicon/Si

**1**

(iii)     e.g.     CaO + SiO2  CaSiO3 Base

**1**

         Balanced

**1**

**[10]**

**M30.**          (a)     (i)      Δ*H* atomisation/sublimation of magnesium

**1**

(ii)     Bond/dissociation enthalpy of Cl-Cl

OR 2 × *H* atomisation of chlorine

**1**

(iii)     Second ionisation enthalpy of magnesium

**1**

(iv)    2 × electron affinity of chlorine

**1**

(v)     Lattice formation enthalpy of MgCl2

**1**

(b)     Equation     2MgCl(s)  →  MgCl2(s) + Mg(s)

*State symbols not required but penalise if incorrect*

**1**

          Calculation    Δ*H* reaction = ΣΔ*H*f products – ΣΔ*H*f reactants

**1**

= – 653 – (2 × –133)

**1**

= – 427 (kJmol–1)

*Allow +427 to score (1) mark*

*Other answers; award (1) for a correct  H reaction expression*

**1**

(c)     Δ*H* soln MgCl2 = – Δ*H* Lat.form. + Δ*H* hyd.Mg2+ + 2Δ*H* hyd.Cl–

**1**

          or cycle
= 2502 – 1920 – (2 × 364)

**1**

= – 146 (kJmol–1)

*Allow + 146 to score (1) mark*

*Other answers; award (1) for a correct ΔH soln MgCl2 expression/cycle*

**1**

**[12]**

**M31.**          (a)     Iron

**1**

Heterogeneous; catalyst in a different phase from
that of the reactants

**1**

          Poison; a sulphur compound (allow sulphur)

**1**

Poison strongly adsorbed onto active sites/ blocked

**1**

Poison not desorbed or reactants not adsorbed or
catalyst surface area reduced

**1**

(b)     Pale green solution                                                                                          1

Green precipitate formed

**1**

Insoluble in excess ammonia

**1**

Equation:

 Species

**1**

Balance

**1**

*NB     Allow equations with H2O and OH – if reaction of H2O with NH3 also given*

**Max 4**

**[9]**

**M32.**          (a)     Ligand: -
atom, ion or molecules which can donate a pair of electrons to a metal ion.

**1**

co-ordinate bond:- a covalent bond

**1**

in which both electrons are donate by one atom

**1**

(b)     (i)      Two correct complex ions

**1**

Balanced equation

**1**

Two correct colours

**2**

(ii)     Complex with a bidentate ligand

**1**

Balanced equation

*NB en not allowed as a ligand unless structure also given*

**1**

         More molecules/ions formed

**1**

Increase in entropy

**1**

more stable complex formed

**1**

**Max 2**

(c)     Δ*E;* energy absorbed by electron, ground to excited state (QoL)

**1**

*h;* Planck’s constant or a constant

**1**

Change in

Oxidation state

**1**

Ligand

**1**

Co-ordination number

*Apply list principle to incorrect additional answers*

**1**

**[16]**

**M33.**         (a)     3d7

**1**

(b)     [Co(H2O)6]2+

**1**

Pink

**1**

(c)     (i)      [Co(NH3)6]2+

**1**

Pale brown or straw

**1**

(ii)     [Co(H2O)6]2+ + 6NH3  →  [Co(NH3)6]2+ + 6H2O

**1**

(d)     [Co(NH3)6]3+

**1**

An oxidising agent

**1**

**[8]**

**M34.**          (a)     (i)      SO2

**1**

+4

**1**

(ii)     4P + 5O2 → 2P2O5

or      P4 + 5O2 → P4O10

**1**

(b)     (i)      B

**1**

E

**1**

They have low melting points
or there are weak van der Waals forces between molecules

**1**

(ii)     Add water     or     heat in a flame

**1**

         Test pH           check flame colour

**1**

         13/14

yellow

**1**

(c)     (i)      NaHSO3

**1**

(ii)     NaHSO3 + NaOH → Na2SO3 + H2O

or      

**1**

(iii)     Phenolphthalein or alizarin yellow or thymol blue

**1**

**[12]**

**M35.**          (a)     (i)      SO2

**1**

+4

**1**

(ii)     4P + 5O2 → 2P2O5

or      P4 + 5O2 → P4O10

**1**

(b)     (i)      B

**1**

E

**1**

They have low melting points
or there are weak van der Waals forces between molecules

**1**

(ii)     Add water     or     heat in a flame

**1**

         Test pH           check flame colour

**1**

         13/14

yellow

**1**

(c)     (i)      NaHSO3

**1**

(ii)     NaHSO3 + NaOH → Na2SO3 + H2O

or      

**1**

(iii)     Phenolphthalein or alizarin yellow or thymol blue

**1**

**[12]**