**A-LEVEL CHEMISTRY**

**PAPER 1**

**PRACTICE PAPER 8**

Answer all questions

Max 105 marks

2 hours

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|  | Name …………………………………………………………….. |  |
|  | Mark ……../105 ……....% Grade ……… |  |

**1.** The pigment ’Cobalt Yellow’ contains an octahedral complex of cobalt(III) and nitrate(III) ions (NO2–). Analysis shows that Cobalt Yellow contains 13.0% of cobalt, 18.6% of nitrogen and 25.9% of potassium by mass. The remainder is oxygen.

(a)     Use these data to calculate the empirical formula of Cobalt Yellow. Show your working.

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**(3)**

(b)     Deduce the structural formula of the cobalt-containing ion in Cobalt Yellow.

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**(1)**

**(Total 4 marks)**

**2.**         A 0.263 g sample of impure iron, containing an unreactive impurity, was reacted with an excess of hydrochloric acid. All of the iron in the sample reacted, evolving hydrogen gas and forming a solution of iron(II) chloride. The volume of hydrogen evolved was 102 cm3, measured at 298 K and 110 kPa.

The percentage, by mass, of iron in the sample can be determined using the volume of hydrogen produced.

    (i)      Write an equation for the reaction between iron and hydrochloric acid.

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(ii)     Calculate the number of moles of hydrogen produced in the reaction.

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(iii)     Use your answers to parts (a)(i) and (ii) to determine the number of moles of iron and the mass of iron in the original sample. (If you have been unable to complete part (a)(ii) you should assume the answer to be 4.25 × 10–3 mol. This is not the correct answer.)

*Moles of iron .*......................................................................................

*Mass of iron* ........................................................................................

(iv)    Calculate the percentage of iron in the original sample.

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**(7)**

**(Total 7 marks)**

**3.**      (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)

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

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**(4)**

**(Total 13 marks)**

**4.** In this question, give all values of pH to 2 decimal places.

(a)     The ionic product of water has the symbol *K*w

(i)      Write an expression for the ionic product of water.

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**(1)**

(ii)     At 42°C, the value of *K*w is 3.46 × 10−14 mol2 dm−6.

Calculate the pH of pure water at this temperature.

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**(2)**

(iii)    At 75 °C, a 0.0470 mol dm–3 solution of sodium hydroxide has a pH of 11.36.  
Calculate a value for *K*w at this temperature.

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**(2)**

(b)     Methanoic acid (HCOOH) dissociates slightly in aqueous solution.

(i)      Write an equation for this dissociation.

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**(1)**

(ii)     Write an expression for the acid dissociation constant *K*a for methanoic acid.

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**(1)**

(iii)    The value of *K*a for methanoic acid is 1.78 × 10−4 mol dm−3 at 25 °C.  
Calculate the pH of a 0.0560 mol dm−3 solution of methanoic acid.

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**(3)**

(iv)    The dissociation of methanoic acid in aqueous solution is endothermic.

Deduce whether the pH of a solution of methanoic acid will increase, decrease or stay the same if the solution is heated. Explain your answer.

Effect on pH .........................................................................................

Explanation ...........................................................................................

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**(3)**

(c)     The value of *K*a for methanoic acid is 1.78 × 10−4 mol dm−3 at 25°C.   
A buffer solution is prepared containing 2.35 × 10−2 mol of methanoic acid and 1.84 × 10−2 mol of sodium methanoate in 1.00 dm3 of solution.

(i)      Calculate the pH of this buffer solution at 25°C.

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**(3)**

(ii)     A 5.00 cm3 sample of 0.100 mol dm−3 hydrochloric acid is added to the buffer solution in part (c)(i).

Calculate the pH of the buffer solution after this addition.

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**(4)**

**(Total 20 marks)**

**5.** The table shows some electrode half-equations and the associated standard electrode potentials.

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| **Equation number** | **Electrode half-equation** | ***Eϴ / V*** |
| **1** | Cd(OH)2(s)  +  2e–   Cd(s)  +  2OH–(aq) | –0.88 |
| **2** | Zn2+(aq)  +  2e–   Zn(s) | –0.76 |
| **3** | NiO(OH)(s)   + H2O(I) + e–   Ni(OH)2(s) + OH–(aq) | +0.52 |
| **4** | MnO2(s)   + H2O(I) + e–   MnO(OH)(s) + OH–(aq) | +0.74 |
| **5** | O2(g)   + 4H+(aq) +4e–   2H2O(I) | +1.23 |

(a)     In terms of electrons, state the meaning of the term *oxidising agent*.

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**(1)**

(b)     Deduce the identity of the weakest oxidising agent in the table.  
Explain how *E*ϴ values can be used to make this deduction.

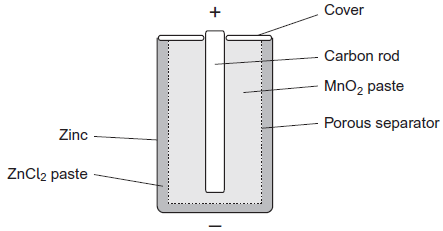
Weakest oxidising agent ...............................................................................

Explanation ....................................................................................................

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**(2)**

(c)     The diagram shows a non-rechargeable cell that can be used to power electronic devices. The relevant half-equations for this cell are equations **2** and **4** in the table above.



(i)      Calculate the e.m.f. of this cell.

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**(1)**

(ii)     Write an equation for the overall reaction that occurs when the cell discharges.

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**(1)**

(iii)     Deduce **one** essential property of the non-reactive porous separator labelled in the diagram.

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**(1)**

(iv)     Suggest the function of the carbon rod in the cell.

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**(1)**

(v)     The zinc electrode acts as a container for the cell and is protected from external damage. Suggest why a cell often leaks after being used for a long time.

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**(1)**

(d)      A rechargeable nickel–cadmium cell is an alternative to the cell shown in part (c).  
The relevant half-equations for this cell are equations **1** and **3** in the table above.

(i)      Deduce the oxidation state of the nickel in this cell after recharging is complete.  
Write an equation for the overall reaction that occurs when the cell is **recharged**.

Oxidation state ......................................................................................

Equation ................................................................................................

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**(3)**

(ii)     State **one** environmental advantage of this rechargeable cell compared with the non-rechargeable cell described in part (c).

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**(1)**

(e)     An ethanol–oxygen fuel cell may be an alternative to a hydrogen–oxygen fuel cell.  
When the cell operates, all of the carbon atoms in the ethanol molecules are converted into carbon dioxide.

(i)      Deduce the equation for the overall reaction that occurs in the ethanol–oxygen fuel cell.

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**(1)**

(ii)     Deduce a half-equation for the reaction at the ethanol electrode.  
In this half-equation, ethanol reacts with water to form carbon dioxide and hydrogen ions.

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**(1)**

(iii)     The e.m.f. of an ethanol–oxygen fuel cell is 1.00 V. Use data from the table above to calculate a value for the electrode potential of the ethanol electrode.

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**(1)**

(iv)     Suggest why ethanol can be considered to be a carbon-neutral fuel.

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**(2)**

**(Total 17 marks)**

**6.**    (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*.

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**(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.

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(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.

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**(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.

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**(5)**

**(Total 16 marks)**

**7.**      This question is about the use of transition metals as catalysts.

(a)     State how a catalyst speeds up a chemical reaction.

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**(2)**

(b)     State the characteristic property of transition metals that enables them to act as catalysts in redox reactions.

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**(1)**

(c)     In the Contact Process for the conversion of sulfur dioxide into sulfur trioxide, vanadium(V) oxide acts as a heterogeneous catalyst.

(i)      Write **two** equations to show how the catalyst is involved in this reaction.

Equation 1 …......................................................................................

Equation 2 ..........................................................................................

**(2)**

(ii)     Suggest **one** reason why poisoning reduces the effectiveness of a heterogeneous catalyst.

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**(1)**

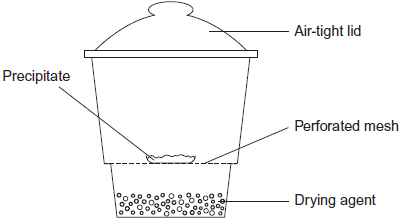
(iii)     Suggest how poisoning of a catalyst, used in an industrial process, can be minimised.

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**(1)**

**(Total 7 marks)**

**8.** A desiccator can be used to dry precipitates as shown in the diagram.



(a)     Explain briefly how the precipitate in the desiccator becomes dry.

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**(1)**

(b)     Anhydrous cobalt(II) chloride is blue. It is often added to the drying agent to indicate the amount of moisture in the drying agent.

State the colour change of this cobalt compound that you would observe as the drying process takes place.

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**(1)**

**(Total 2 marks)**

**9.** An experiment was carried out to determine the original concentration of iron(II) ions in a solution that had been stored in air. An excess of zinc and acid was added to this solution. The mixture was then filtered to remove the excess zinc before titration.

(a)     Suggest why the zinc and acid were added.

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**(1)**

(b)     Explain why it was necessary to remove the excess zinc.

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**(1)**

**(Total 2 marks)**

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

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

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

**(2)**

(b)     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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**(1)**

**(Total 3 marks)**

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| **11.** |  | |
|  | (a) |  |
|  | (b) |  |
|  | (c) |  |
|  | (d) |  |
|  | (e) |  |
|  | (f) |  |
|  | (g) |  |
|  | (h) |  |
|  | (i) |  |
|  | (j) | **(Total 14 marks)** |