Year 12 Chemistry **Topic Test #5 (Electrochemistry) - 2013**

Name: **ANSWERS** Mark = _____ / 42

Part One: Multiple Choice Section **10 marks**

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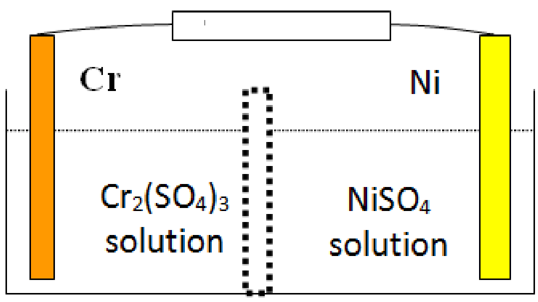
1. **D** 2. **C** 3. **A** 4. **D** 5. **D** 6. **A** 7. **D** 8. **A** 9. **A** 10. **D**

Part Two: Short Answer Section **32 marks**

Question 11 **(10 marks)**

The following diagram represents an electrochemical cell based on chromium and nickel.
A porous barrier separates the two half-cells but allows ions to migrate between them.

anode



(a) Write the equation for the overall reaction that occurs.

$2\ Cr(s) + 3\ Ni^{2+}(aq) \rightarrow 2\ Cr^{3+}(aq) + 3\ Ni(s)$ ✓✓

(2 marks)

(b) On the diagram, label the electrode that is the anode. ✓

(1 mark)

(c) Draw an arrow in the box provided to show the direction of the electron flow in the wire. ✓

(1 mark)

(d) What emf (voltage) will be generated under standard conditions?

$E°_{cell} = E°_{ox} + E°_{red} = +0.74 + (-0.24) = \underline{+0.50\ V}$ ✓

(1 mark)

(e) Which metal cations will migrate through the porous barrier? **$Cr^{3+}(aq)$** ✓

(1 mark)

(f) List a change that would occur in each half-cell as the cell operates.

Cr/Cr^{3+} half-cell: solution colour becomes more intense green *or* Cr electrode loses mass✓
Ni/Ni^{2+} half-cell: solution colour becomes more pale green *or* Ni electrode gains mass ✓

(2 marks)

(g) Apart from the colour change in the solution, what other changes would be expected in the cell if the porous barrier was removed and the solutions became mixed?

$E°_{cell}$ decreases to zero ✓
because the oxidant and reductant are no longer physically sperated ✓

(2 marks)

Question 12 **(8 marks)**

A method for determining the manganese content in steel is to convert all the manganese to the deeply coloured permanganate ion and then to measure how much light is absorbed by the solution.

Step 1: A sample of steel is dissolved in sulfuric acid, producing the manganese(II) ion and sulfur dioxide gas.

Step 2: This solution is then reacted with an acidified solution of periodate (IO_4^-) ions, producing the permanganate and iodate (IO_3^-) ions.

Write the oxidation and reduction half equations and then the fully balanced chemical equations for each of these steps.

Step 1

Oxidation: $\mathbf{Mn(s) \rightarrow Mn^{2+}(aq) + 2\,e^-}$ ✓

Reduction: $\mathbf{SO_4^{2-}(aq) + 4\,H^+(aq) + 2\,e^- \rightarrow SO_2(g) + 2\,H_2O(\ell)}$ ✓

Full equation: $\mathbf{Mn(s) + SO_4^{2-}(aq) + 4\,H^+(aq) \rightarrow Mn^{2+}(aq) + SO_2(g) + 2\,H_2O(\ell)}$ ✓✓

(4 marks)

Step 2

Oxidation: $\mathbf{Mn^{2+}(aq) + 4\,H_2O(\ell) \rightarrow MnO_4^-(aq) + 8\,H^+(aq) + 5\,e^-}$ ✓ **(x2)**

Reduction: $\mathbf{IO_4^-(aq) + 2\,H^+(aq) + 2\,e^- \rightarrow IO_3^-(aq) + H_2O(\ell)}$ ✓ **(x5)**

Full equation: $\mathbf{2\,Mn^{2+}(aq) + 5\,IO_4^-(aq) + 3\,H_2O(\ell) \rightarrow 2\,MnO_4^-(aq) + 5\,IO_3^-(aq) + 6\,H^+(aq)}$ ✓✓

(4 marks)

Question 13 **(3 marks)**

The owner of an aluminium trailer carelessly stored a leaking bag of herbicide in the trailer in the open air over winter. The herbicide contained a solid soluble copper(II) compound. When the owner returned much later, a hole had appeared in the trailer underneath the fertiliser bag. Using equations, explain what happened.

Once the herbicide dissolves, a spontaneous metal displacement reaction can occur:

$\mathbf{Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)}$	$\mathbf{E°_{red} = +0.34\ V}$
$\mathbf{A\ell(s) \rightarrow A\ell^{3+}(aq) + 3\,e^-}$	$\mathbf{\underline{E°_{ox} = +1.68\ V}}$
	$\mathbf{E°_{cell} = +2.02\ V}$

Question 14 **(5 marks)**

The inside surface of copper frying pans used for cooking foods such as eggs can develop a black coating due to the formation of copper(II) sulfide. These blackened pans can be restored by adding an electrolyte solution such as sodium chloride and placing aluminium foil in the pan. The copper(II) sulfide is reduced to copper metal and aqueous sulfide ions. The aluminium is oxidised. This method does not remove any of the copper from the pan. The equation for the reduction reaction is:

$$CuS(s) + 2\,e^- \rightarrow Cu(s) + S^{2-}(aq)$$

The by-product of this process is aluminium sulfide.

(a) Write the full equation for the reaction.

$\mathbf{3\,CuS(s) + 2\,A\ell(s) \rightarrow 3\,Cu(s) + A\ell_2S_3(s)}$ ✓✓

$\mathbf{(3\,CuS(s) + 2\,A\ell(s) \rightarrow 3\,Cu(s) + 2\,A\ell^{3+}(aq) + 3\,S^{2-}(aq)}$ **✓)**

(2 marks)

(b) A frying pan has a 0.0525 g coating of copper(II) sulfide. What mass of aluminium sulfide will be formed as the copper is restored?

n(CuS) = m/M = 0.0525/95.61 = 0.0005491 mol ✓

n($A\ell_2S_3$) = 1/3.n(CuS) = 0.0001831 mol ✓

m($A\ell_2S_3$) = n.M = 0.0001831 x 150.14 = <u>0.0275 g</u> ✓

(3 marks)

Question 15 **(6 marks)**

A jar containing a pale pink powder is labelled *commercial grade manganese(II) sulfate $MnSO_4$*. A chemist needed to know its purity in term of percentage by mass. He decides to analyse it by utilising the reaction between hydrogen peroxide and manganese(II) ions. The manganese(II) ions are converted into a black precipitate of manganese(III) oxide. The black oxide quickly settles to the bottom of the conical flask. The equation for the reaction is:

$$H_2O_2(aq) + 2\,Mn^{2+}(aq) + H_2O(\ell) \rightarrow Mn_2O_3(s) + 4\,H^+(aq)$$

The end point is taken to be when the final drop of hydrogen peroxide no longer produced a black precipitate.

The chemist dissolved 2.00 g sample of the impure manganese(II) sulfate in water in a 100 mL volumetric flask. He then pipetted 25.00 mL of this solution and diluted it to 250 mL in another volumetric flask. Next, he titrated 20.0 mL aliquots of the diluted manganese(II) sulfate solution against 0.00221 mol L^{-1} hydrogen peroxide solution. The average titre required was 46.55 mL.

What was the percentage purity of the commercial manganese(II) sulfate?

$n(H_2O_2)$ = c.V = 0.00221 x 0.04655 = 0.0001029 mol ✓

$n(Mn^{2+})_{20mL\ dilute}$ = 2.$n(H_2O_2)$ = 0.0002058 mol ✓

$n(Mn^{2+})_{250mL\ dilute}$ = $n(Mn^{2+})_{20mL\ dilute}$ x 250/20 = 0.002573 mol ✓

$n(Mn^{2+})_{25mL\ conc}$ = $n(Mn^{2+})_{250mL\ dilute}$ = 0.002573 mol

$n(MnSO_4)$ = $n(Mn^{2+})_{100mL\ conc}$ = $n(Mn^{2+})_{25mL\ conc}$ x 100/25 = 0.01029 mol ✓

$m(MnSO_4)$ = n.M = 0.01029 x 151 = 1.554 g ✓

%(Mn) = 1.554/2.00 x 100 = <u>77.7%</u> ✓

End of Test