IB HL Redox 1

1 Define *oxidation* and *reduction* in terms of electrons.

2 Define *oxidation* and *reduction* in terms of loss/gain of hydrogen/oxygen.

3 Define *oxidation* and *reduction* in terms of oxidation state (oxidation number).

4 Determine the oxidation states of all elements in the following species:

P_4	SO_2	SO_3	SO_4^{2-}	HCl	$HClO_3$	ClO_4^-	$KMnO_4$	C_2H_5Cl
Ca	CrO_4^{2-}	$Cr_2O_7^{2-}$	H_2O_2	BaO_2	LiH	$LiAlH_4$	$Na_2S_2O_3$	$S_4O_6^{2-}$

5 Name the following molecules/ions/compounds using oxidation states/numbers:

SO_2	SO_3	$Cr_2O_7^{2-}$	$FeCl_2$	$CuSO_4$	$KMnO_4$	$NaClO_4$	Cu_2O	$Fe_2(SO_4)_3$

6 Explain whether each of the following involves oxidation, reduction or neither:

$2Cl^- \rightarrow Cl_2 + 2e^-$

$Cu^{2+} + 2e^- \rightarrow Cu$

The conversion of Mn_2O_3 to MnO_2

The conversion of CH_3CH_2OH to CH_3CHO

The conversion of CH_3CH_2CHO to CH_3CH_2COOH

7 Explain which of the following equations represent Redox reactions

$I_2(s) + 2OH^-(aq) \rightarrow I^-(aq) + OI^-(aq) + H_2O(l)$

$SO_4^{2-}(aq) + H_2O(l) \rightarrow HSO_4^-(aq) + OH^-(aq)$

$Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$

$C_2H_2 + 2H_2 \rightarrow C_2H_6$

$2CrO_4^{2-} + 2H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O$

8 Balance the following half-equations in neutral solution:

$Ni^{2+}(aq) + \quad e^- \rightarrow Ni(s)$

$Br^- \rightarrow Br_2$

$H_2O \rightarrow H_2 + OH^-$

9 Balance the following half-equations in acidic solution:

$Cr_2O_7^{2-} + H^+ + e^- \rightarrow Cr^{3+} + H_2O$

$MnO_4^- \rightarrow Mn^{2+}$

$CH_3CH_2OH \rightarrow CH_3CHO$

10 Write balanced redox reactions from each pair of half equations

$2IO_3^-(aq) + 12H^+(aq) + 10e^- \rightarrow I_2(aq) + 6H_2O(l)$

$2I^-(aq) \rightarrow I_2(aq) + 2e^-$

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

$CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$

11 Balance the following redox equations:

$MnO_4^-(aq) + H^+(aq) + Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + H_2O(l) + Fe^{3+}(aq)$

$MnO_4^-(aq) + H^+(aq) + C_2O_4^{2-}(aq) \rightarrow Mn^{2+}(aq) + H_2O(l) + CO_2(g)$

$I_2(aq) + S_2O_3^{2-}(aq) \rightarrow I^-(aq) + S_4O_6^{2-}(aq)$

12 Define the terms *oxidising agent* and *reducing agent*.

13 Identify the oxidising and reducing agents in the equations in 11.

14 Explain whether A or Q is more reactive given the equation $A(s) + Q^{2+}(aq) \rightarrow A^{2+}(aq) + Q(s)$

15 Complete the following table by predicting whether a 'reaction' or 'no reaction' will occur in each case and write an ionic equation for each ***reaction***.

	$ZnSO_4$(aq)	$MgCl_2$(aq)	$CuSO_4$(aq)
Zinc			
Magnesium			
copper			

16 Solve redox titration problems involving iron(II) and manganate(VII)

$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$

(a) 25.00 cm^3 of 1 mol dm^{-3} sulfuric acid was added to 25.00 cm^3 of a solution of iron(II) sulfate. This was then titrated against 0.02000 mol dm^{-3} potassium manganate(VII). 22.50 cm^3 of $KMnO_4$ was required to be added to the mixture to give the first permanent pink colour. Calculate the concentration of the original iron(II) sulfate solution.

(b) Five iron tablets are dissolved in about 100 cm^3 of 1.0 mol dm^{-3} sulfuric acid and the solution is made up to a total volume of 250 cm^3 with distilled water. 25.0 cm^3 of the iron(II) solution is titrated with 0.0100 mol dm^{-3} potassium manganate(VII) solution until the first permanent pink colour is seen. 11.60 cm^3 of $KMnO_4$ was required. Calculate the mass of iron (in mg) in 1 tablet.

17 Solve redox titration problems involving sodium thiosulfate and iodine

$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

(a) 25.00 cm^3 of iodine solution is pipetted into a conical flask. 0.100 mol dm^{-3} sodium thiosulfate solution is added until the mixture becomes pale yellow. Starch indicator is added and the titration continued until the reaction mixture becomes colourless. The total volume of sodium thiosulfate solution required was 21.50 cm^3. Calculate the concentration of the iodine solution.

(b) x g of potassium iodate(V) is dissolved in distilled water and made up to a total volume of 250.0 cm^3. 25.00 cm^3 of this solution is pipetted into a conical flask and 20 cm^3 of 1 mol dm^{-3} sulfuric acid added – this is excess. Excess potassium iodide solution is added to the reaction mixture and the liberated iodine titrated against sodium thiosulfate solution. 25.30 cm^3 of 0.100 mol dm^{-3} sodium thiosulfate is required for the titration. Determine the value of x.

$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$

18 Calculate BOD from titrations using the Winkler Method

$$2Mn(OH)_2(s) + O_2(aq) \rightarrow 2MnO(OH)_2(s)$$

$$MnO(OH)_2(s) + 4H^+(aq) \rightarrow Mn^{4+}(aq) + 3H_2O(l)$$

$$Mn^{4+}(aq) + 2I^-(aq) \rightarrow Mn^{2+}(aq) + I_2(aq)$$

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

(a) The Winkler method was used to measure the concentration of dissolved oxygen in a sample of water. Manganese(II) sulfate, sulfuric acid and potassium iodide were added to 50.0 cm^3 of the water. The iodine that was formed was titrated against a sodium thiosulfate solution with a concentration of 2.00×10^{-3} mol dm^{-3}. It was found that 17.40 cm^3 of sodium thiosulfate was required for the titration.

Another sample of water from the same source was incubated for 5 days at 20 °C. At the end of the incubation the Winkler method was used to determine concentration of dissolved oxygen. It was found that the concentration of dissolved oxygen in the sample was 3.50 ppm.

Calculate the concentration of dissolved oxygen (in ppm) in the original sample and the biochemical oxygen demand.

(b) The Winkler method was used to measure the concentration of dissolved oxygen in a sample of water. Manganese(II) sulfate, sulfuric acid and potassium iodide were added to 25.0 cm^3 of the water. The iodine that was formed was titrated against a sodium thiosulfate solution with a concentration of 1.00×10^{-3} mol dm^{-3}. It was found that 22.30 cm^3 of sodium thiosulfate was required for the titration.

Another sample of water from the same source was incubated for 5 days at 20 °C. At the end of the incubation the Winkler method was used to determine concentration of dissolved oxygen. It was found that the concentration of dissolved oxygen in the sample was 2.80 ppm.

Calculate the concentration of dissolved oxygen in the original sample and the biochemical oxygen demand.

19 Explain the connection between biochemical oxygen demand and the degree of pollution of a water sample.

20 (a) Draw a labelled diagram showing a voltaic (Galvanic) cell made up of Zn/Zn^{2+} and Cu/Cu^{2+} half-cells. Labelling should include the anode, cathode, positive and negative electrodes and show the direction of electron flow in the external circuit and the direction of ion flow in the solutions.

(b) Write half-equations for the reactions at each electrode

(c) Write the overall redox reaction that occurs in the cell.

(d) State whether the overall reaction that occurs is exothermic or endothermic.

21 Explain the purpose of the salt bridge in a voltaic (Galvanic) cell.

22 State the energy conversion that occurs in a voltaic cell.

23 Explain what is meant by the term *standard electrode potential* and *standard cell potential*

24 Describe, with the aid of a labelled diagram, the standard hydrogen electrode

25 Write the half-equation for the standard hydrogen electrode and state the value of the standard electrode potential.

26 Explain, with the aid of a diagram, how the standard electrode potential for Cu^{2+}/Cu could be measured

27 State the significance of the fact that the standard electrode potential for a Cu^{2+}/Cu half-cell is positive but that for a Zn^{2+}/Zn half-cell is negative.

28 For each of the following cells

- calculate the cell potential,
- write an overall equation for the reaction that goes on in the cell
- state which is the positive and which the negative electrode
- identify the anode and cathode
- state which way electrons flow in the external circuit
- state which way ions flow in the salt bridge

$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$ $Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ $Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$ $Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$ $Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$

29 For each of the cells in 28 write the cell diagram using the cell diagram convention

30 Explain using electrode potentials below whether the reactions below will be spontaneous or not

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6Fe^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 6Fe^{3+}(aq)$

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6Br^-(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 3Br_2(l)$

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6F^-(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 3F_2(g)$

31 Given the electrode potentials below select the strongest reducing agent and the strongest oxidising agent.

$U^{4+} + e^- \rightleftharpoons U^{3+}$ $E^\ominus = -0.61$ V

$Eu^{3+} + e^- \rightleftharpoons Eu^{2+}$ $E^\ominus = -0.43$ V

$Ho^{3+} + e^- \rightleftharpoons Ho$ $E^\ominus = -2.32$ V

$Ce^{4+} + e^- \rightleftharpoons Ce^{3+}$ $E^\ominus = +1.61$ V

$Pu^{4+} + e^- \rightleftharpoons Pu^{3+}$ $E^\ominus = +0.97$ V

32 Using the values in 31 explain whether the following are true or false:

(a) Eu^{3+} will oxidise Pu^{3+}

(b) U^{3+} will reduce Ce^{4+}

(c) Pu^{4+} will oxidise U^{3+}

33 For each of the following reactions calculate the cell potential and ΔG and predict whether the reaction is spontaneous.

(a) $Mn(s) + Sn^{2+}(aq) \rightarrow Mn^{2+}(aq) + Sn(s)$

(b) $\frac{1}{2}Br_2(l) + Fe^{2+}(aq) \rightarrow Br^-(aq) + Fe^{3+}(aq)$

(c) $Br_2(l) + 2Fe^{2+}(aq) \rightarrow 2Br^-(aq) + 2Fe^{3+}(aq)$

(d) $MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$

(e) $2MnO_4^-(aq) + 16H^+(aq) + 10F^-(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5F_2(g)$