Set 1. Oxidation and Reduction

Fill in the spaces for the following five reactions:

1. $4Na + O_2 \rightarrow 2Na_2O$

   Species Oxidised _____ Species reduced _____

   Oxidant _____ Reductant _____

2. $2Cr^{3+}(aq) + 3Zn(s) \rightarrow 6Cr(s) + 3Zn^{2+}(aq)$

   Species Oxidised _____ Species reduced _____

   Oxidant _____ Reductant _____

3. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

   Species Oxidised _____ Species reduced _____

   Oxidant _____ Reductant _____

4. $Cr_2O_7^{2-}(aq) + 3H_2S(g) + 8\ H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3S(s) + 7\ H_2O(l)$

   Species Oxidised _____ Species reduced _____

   Oxidant _____ Reductant _____

5. $H_2O_2(l) + H^+(aq) + Cl^-(aq) \rightarrow HClO(aq) + H_2O(l)$

   Species Oxidised _____ Species reduced _____

   Oxidant _____ Reductant _____

Write the oxidation numbers for each of the elements underlined here.

6. $\underline{Sn}Cl_4$ 7. $H_3\underline{P}O_4$ 8. $\underline{C}O_3^{2-}$ 9. H$\underline{C}$OOH 10. $\underline{Mn}O_4^-$

For the following reactions, state the elements that have been oxidised and reduced by, observing any change in oxidation numbers.

7. $2HBr + H_2SO_4 \rightarrow Br_2 + SO_2 + 2H_2O$

   Species Oxidised _____ Species reduced _____

8. $2SnCl_2 + 4HCl + O_2 \rightarrow 2SnCl_4 + 2H_2O$

   Species Oxidised _____ Species reduced _____

9. $Cr_2O_7^{2-} + 6Fe^{2+} + 14\ H^+ \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O.$

   Species Oxidised _____ Species reduced _____

10. $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$

    Species Oxidised _____ Species reduced _____

11. $Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$

    Species Oxidised _____ Species reduced _____

Set 2. Oxidation

Multiple Choice Questions

1. What are the oxidation numbers of hydrogen in the compounds LiH, MgH_2 and NH_3 respectively?

   (a) +1, +1, +1 (b) +1, +2, +3

   (c) +1, +1, -1 (d) -1, -1, +1

   (e) -1, -1, -1

2. What is the oxidation number of oxygen in hydrogen peroxide?

   (a) -2 (b) -1 (c) 0 (d) +1 (e) +2

3. What are the oxidation numbers of nitrogen in the compounds NO_2, N_2O, N_2O_4 respectively?

   (a) +2, +1, +4 (b) +2, +1, +2

   (c) +1, +2, +2 (d) +4, +1, +4

   (e) +4, +2, +4

4. Among the following reactions, the one involving oxidation as well as reduction is

   (a) $H^+ + OH^- \rightarrow H_2O$ (b) $Zn + 2H^+ \rightarrow Zn^{2+} + H_2$

   (c) $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ (d) $CuO + 2H^+ \rightarrow Cu^{2+} + H_2O$

   (e) $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

5. Given that the oxidation state of cyanide ion, CN^- is -1, in the compound $K_4Ni(CN)_4$ the oxidation state of Ni is

   (a) +4 (b) +2 (c) 0 (d) -2 (e) -4

6. Sulfur dioxide was passed through aqueous bromine solution. The solution changed from orange to colourless. During the reaction, the oxidation number of bromine has changed from

   (a) +4 to +6 (b) +4 to 0 (c) 0 to -1 (d) +6 to+4 (e) +6 to 0

7. During the reaction referred to in question 6 above, the oxidation number of sulfur has changed from

   (a) +4 to +6 (b) +4 to 0 (c) 0 to -1 (d) +6 to +4 (e) +6 to 0

8. Which of the following is not a redox reaction?

   (a) $2H^+ + Zn \rightleftharpoons Zn^{2+} + H_2$ (b) $H^+ + OH^- \rightleftharpoons H_2O$

   (c) $Cu^{2+} + Zn \rightleftharpoons Cu + Zn^{2+}$ (d) $2Fe^{3+} + S^{2-} \rightleftharpoons S + 2Fe^{2+}$

   (e) $Fe + S \rightleftharpoons FeS$

9. Iron (III) chloride is formed when chlorine is passed over heated iron because
   (a) chlorine is an oxidising agent (b) iron (III) chloride can sublime
   (c). chlorine is very reactive (d) iron is a transition element
   (e) iron (II) chloride is unstable at high temperature

10. Which substance involved in the following reaction has been oxidised?

$$2FeCl_2 + 2HCl + H_2O_2 \rightleftharpoons 2FeCl_3 + 2H_2O$$

   (a) $FeCl_2$ (b) HCl (c) H_2O_2 (d) HCl and H_2O_2
   (e) $FeCl_2$ and HCl

11. The oxidation number of iron in Fe_3O_4 is:
   (a) +2 (b) +3 (c) 0 (d) +4 (e) +2 and +3

12. The oxidation number of carbon in carbon monoxide CO is
   (a) +4 (b) +2 (c) 0 (d) -2 (e) -4

Written Questions

1. State the oxidation number of the species indicated in each:
   (a) S in Na_2SO_4 _____
   (b) Mn in $KMnO_4$ _____
   (c) N in $Ca(NO_3)_2$ _____
   (d) C in Na_2CO_3 _____
   (e) N in NO_2 _____
   (f) S in HSO_4^- _____
   (g) S in $H_2S_2O_7$ _____
   (h) S in Al_2S_3 _____

2. State the oxidation number of each of the elements in each species:
   (a) H_2S (b) P_4O_{10} (c) Na_3P
   (d) $Cr(OH)_4^-$ (e) SO_4^{2-} (f) $Ba(MnO_4)_2$
   (g) SO_2 (h) H_3O^+ (i) $AlCl_3$
   (j) KNO_3

3. (a) Which of these reactions will be spontaneous? (Yes/ No)
   (i) $Ni + I_2$ _____
   (ii) $Ag + Au^{3+}$ _____
   (iii) $Al + Cd^{2+}$ _____
   (iv) $Cl_2 + Br^-$ _____

(b) These are three metals and their ions used in an experiment:

A/A^+, B^{2+}/B^{3+} and C^{2+}/C^-.

Ion B^{3+} reacts with metal C. Ion B^{2+} does not react with ion C^{2+} but does react with metal ion A^+. Ion C^- does not react with any other metal or ion.

Place these metals and ions in order of reactivity: C^{2+}, A, B^{3+} from lowest to highest E^o values.

_____

4. In the following equations, state whether the substances underlined have been oxidised or reduced:

(a) $\underline{S}O_2 + 2H_2S \rightarrow 3S + 2H_2O$ _____

(b) $PbO_2 + 4H\underline{Cl} \rightarrow PbCl_2 + 2H_2O + Cl_2$ _____

(c) $H_2 + \underline{Cl_2} \rightarrow 2HCl$ _____

(d) $3\underline{Cu}O + 2NH_3 \rightarrow 3Cu + 3H_2O + N_2$ _____

5. State which of the following are redox reactions. For these reactions, identify the oxidising and the reducing agents. Balance the equations where necessary:

(a) $2H_2O_2 + MnO_4^- \rightarrow 3O_2 + Mn^{2+} + 2H_2O$

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_____

(b) $BaCl_2 + Na_2SO_4 \rightarrow 2NaCl + BaSO_4$

_____

_____

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

_____

_____

(d) $3H_2 + N_2 \rightarrow 2NH_3$

_____

_____

(e) $C + H_2O \rightarrow CO + H_2$

_____

_____

(f) $H^+ + NO_3^- + Fe^{2+} \rightarrow H_2O + NO_2 + Fe^{3+}$

_____

_____

(g) $3AgNO_3 + FeCl_3 \rightarrow AgCl + Fe(NO_3)_3$

_____

_____

(h) $Na_2S + AgNO_3 \rightarrow Ag_2S + NaNO_3$

(i) $2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$

(j) $NaClO + Na_2SO_3 \rightarrow NaCl + Na_2SO_4$

(k) $2CH_3OH + 2Na \rightarrow 2NaCH_3O + H_2$

(l) $SO_3 + H_2O \rightarrow H_2SO_4$

(m) $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

(n) $NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$

(o) $2NaCl + MnO_2 + H_2SO_4 \rightarrow MnSO_4 + Na_2SO_4 + H_2O + Cl_2$

(p) $2HBr + H_2SO_4 \rightarrow SO_2 + Br_2 + 2H_2O$

(q) $2HNO_3 + 2HCl \rightarrow 2NO_2 + Cl_2 + 2H_2O$

(r) $CuS + 2HNO_3 \rightarrow CuSO_4 + N_2O + H_2O$

6. Write partial ionic equations for the following reactions in acidic solution:

(a) $I_2 \rightarrow 2IO_3^-$

(b) $HClO \rightarrow Cl^-$

(c) $NO_3^- \rightarrow NO$

(d) $NO_3^- \rightarrow NO_2$

(e) $H_3PO_3 \rightarrow H_3PO_4$

(f) $MnO_4^- \rightarrow Mn^{2+}$

(g) $SO_2 \rightarrow SO_4^{2-}$

(h) $C_2O_4^{2-} \rightarrow 2CO_3^{2-}$

(i) $SO_3^{2-} \rightarrow SO_4^{2-}$

(j) $H_2O_2 \rightarrow O_2$

7. Balance the following equations and identify the elements that disproportionate in each reaction :

(a) $2H_2O_2 \rightarrow 2H_2O + O_2$ _____

(b) $3HNO_2 \rightarrow 2NO + NO_3^- + H_3O^+$ _____

(c) $3AuCl \rightarrow 2Au + AuCl$ _____

(d) $4KClO_3 \rightarrow KCl + 3KClO_4$ _____

(e) $Br_2 + H_2O \rightarrow HBr + HBrO$ _____

8. Write balanced equations for the following redox reactions:

(a) Producing chlorine by heating HCl gas and oxygen in the presence of a catalyst.

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_____

(b) The preparation of iron by passing hydrogen over hot solid iron (III) oxide.

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9. Predict the products of the reactions between Zn and O_2, Zn and H_2, Zn and I_2.

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_____

10. Gaseous chlorine is a good oxidant. Predict the products of the redox reactions between chlorine and:

(a) P (b) PCl_3 (c) CuCl (d) I^-

(a) _____ (b) _____

(c) _____ (d) _____

11. Identify the products of disproportionation reaction for the following species:

(a) Cu_2SO_4 (b) Hg_2Cl_2 (c) $NO_2 + H_2O$ (d) $Cl_2 + H_2O$

(a) _____

(b) _____

(c) _____

(d) _____

Set 3. Redox Reactions

Multiple Choice Questions

1. Which of the following statements about the rusting of iron is **not** true?
   (a) Rusting is accelerated by the presence of carbon dioxide.
   (b) Rusting is accelerated by the presence of an electrolyte.
   (c) Rusting slows down if an alkali is present.
   (d) Rusting is accelerated if iron is connected to another metal which is more reactive than iron.
   (e) Rusting is accelerated by the presence of sodium chloride solution.

2. Acidified potassium dichromate solution is a strong oxidising agent because:
   (a) There are seven oxygen atoms in the compound.
   (b) Oxygen atoms in the compound combine with hydrogen easily.
   (c) Chromium in the compound has a high oxidation number which can easily be reduced to a lower oxidation number.
   (d) Chromium metal is a good oxidising agent.
   (e) K^+ ions in the solution can easily be reduced.

3. Which of the following reactions show that hydrogen peroxide is a reducing agent?
   (a) $PbO_2 + H_2O_2 \rightarrow PbO + H_2O + O_2$
   (b) $H_2O_2 + dye \rightarrow H_2O + (dye + O)$
   (c) $H_2S + H_2O_2 \rightarrow S + 2H_2O$
   (d) $H_2SO_3 + H_2O_2 \rightarrow H_2SO_4 + H_2O$
   (e) $PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$

4. The following reagents can be used to oxidise iron (II) ions to iron (III) ions except:
   (a) chlorine water.
   (b) hydrogen peroxide.
   (c) hydrogen sulfide H_2S.
   (d) hypochlorous acid HClO.
   (e) acidified potassium dichromate.

5. Which of is a good way of preventing the rusting of steel?
   (a) Connect it to the positive terminal of a cell.
   (b) Keep it free from oil.
   (c) Keep it in a humid atmosphere.
   (d) Plate it with a coating of copper.
   (e) Remove oxygen from around the iron.

6. Acidified potassium permanganate solution is a strong oxidising agent because:
   (a) There are 7 oxygen atoms in the compound.
   (b) Oxygen atoms in the compound combine with hydrogen easily.
   (c) Manganese in the compound multiple oxidation states that can be formed.
   (d) Manganese metal is a good oxidant.
   (e) K^+ ions in the solution can easily be reduced.

7. Which of the following cannot be used to reduce iron (III) ions to iron (II) ions?
   (a) Fresh hydrogen.
   (b) Hydrogen sulfide.
   (c) Potassium iodide solution.
   (d) Oxalic acid ($H_2C_2O_4$) solution.
   (e) Manganese dioxide.

8. A metal X is dissolved in dilute nitric acid. The excess acid is neutralised by sodium hydroxide. On further addition of sodium hydroxide, a white precipitate is formed which soon redissolves in the excess sodium hydroxide. X is:

   (a) Mn (b) Mg (c) Al (d) Fe (e) Cu

9. Which of the following statements about the uses of aluminium is **not** true?

   (a) Used for galvanising iron.
   (b) Used as domestic cooking utensils.
   (c) Used for the thermite process.
   (d) Used for making alloys for aircraft bodies.
   (e) Used as sinker weights in fishing.

10. Metal C can displace the ion of metal B but metal A cannot displace metal C ion from solution. Metal C can displace metal B ion from solution.

    What is the order of these metals going from the best to the worst oxidant?

    (a) ABC (b) BCA (c) CAB (d) BAC (e) ACB

Calculations

1. In a titration experiment, a student was required to standardise an iron(II) sulfate solution. She found that 20.0 mL of the solution, when acidified, required 25.0 mL of a 0.10 mol L^{-1} potassium permanganate solution for complete reaction.

   (i) Write the reaction equation.

   _____

   _____

   (ii) Calculate the molar concentration of the iron (II) sulfate solution.

   _____

   _____

   _____

2. A student was determining the concentration of a commercial H_2O_2 solution. She prepared a dilute solution by adding 100.0 mL of distilled water to 10.0 mL of the solution. 20.0 mL of this dilute H_2O_2 solution, when acidified, reacted with 30.0 mL of 0.10 mol L^{-1} potassium dichromate solution. Determine the concentration of the H_2O_2 in the commercial solution.

   _____

   _____

   _____

   _____

   _____

   _____

3. A solution of oxalic acid was prepared by boiling some rhubarb leaves. A number of 20.0 mL portions of this solution were titrated against a standard 0.11 mol L^{-1} $KMnO_4$ solution. The average titre was 10.0 mL. Calculate the concentration of the oxalic acid solution using the normal half equations.

4. A 1.70 g of mineral sample containing chromium was analysed as follows. The chromium was first converted to sodium dichromate. 50.0 mL of a 0.20 mol L^{-1} standard iron (II) sulfate solution were required to titrate the dichromate solution to an end point. Determine the percentage of chromium in the mineral sample.

5. 12.6 g of crystalline oxalic acid was dissolved in distilled water and the solution made up to one litre. 20.0 mL of this solution, when acidified, reduced 25.0 mL of a potassium permanganate solution. Calculate the concentration of the permanganate solution.

6. 2.00 mL of a H_2O_2 solution when acidified required 40.0 mL of a 0.020 mol L^{-1} $KMnO_4$ solution for complete oxidation. Determine the concentration of the H_2O_2 solution and the volume of oxygen liberated at 35°C and 100.6 kPa pressure.

7. In standardising a solution of $KMnO_4$, 20.0 mL portions of a 0.110 mol L^{-1} oxalic acid solution, when acidified, were required to completely react with 9.00 mL of the $KMnO_4$ solution.

   Calculate the molar concentration of the $KMnO_4$ solution.

8. In standardising a $K_2Cr_2O_7$ solution, 20.0 mL portions of a 0.05 mol L^{-1} iron (II) sulfate solution, when acidified, reacted with 7.50 mL of the $K_2Cr_2O_7$ solution.

   Calculate the molarity of the dichromate solution.

9. In determining the iron (II) ion concentration of water, it was found that 50.0 mL samples of the water, when acidified, required 1.50 mL of a 0.0010 mol L^{-1} $KMnO_4$ solution for complete oxidation. Calculate the concentration of Fe^{2+} ions in water.

10. Acidified potassium dichromate will oxidise hydrogen peroxide according to the following unbalanced equation:

$$Cr_2O_7^{2-}(aq) + H_2O_2(aq) \rightarrow Cr^{3+}(aq) + O_2(g)$$

    (a) Balance the equation and determine the mass of potassium dichromate that is required for the complete oxidation of 1.0 g of hydrogen peroxide.

    (b) Calculate the volume of oxygen, measured at 0°C and 100 kPa pressure that will be produced in this reaction.

11. Three 25.0 mL samples of a potassium oxalate solution ($K_2C_2O_4$), when acidified with sulfuric acid, required the following titres: 24.48 mL, 24.54 mL and 24.47 mL of potassium permanganate solution of concentration 0.020 mol L^{-1} for complete reaction.

The relevant unbalanced equation is: $C_2O_4^{2-}(aq) + MnO_4^-(aq) \rightarrow Mn^{2+}(aq) + CO_2(g)$.

Determine:

(a) The average titre value of $KMnO_4$.

(b) The concentration of the potassium oxalate solution.

(c) The volume of carbon dioxide that could be collected at S.T.P by the reaction of potassium permanganate with 25.0 mL $K_2C_2O_4$.

12. A 4.00 g sample of iron ore was crushed and dissolved to produces only iron (II) ions. The resulting solution was acidified with dilute sulfuric acid and the volume made up to 500 mL in a volumetric flask, using distilled water. 25.0 mL portions of this dilute solution required an average titre of 20.0 mL of potassium permanganate of concentration 0.020 mol L^{-1} for complete reaction.

The relevant unbalanced equation is: $Fe^{2+}(aq) + MnO_4^-(aq) \rightarrow Fe^{3+}(aq) + Mn^{2+}(aq)$

Calculate the percentage of iron in the iron ore.

13. A 40.0 mL sample of a commercial hydrogen peroxide solution was transferred to a volumetric flask and the volume made up to 1000.0 mL with distilled water. Separate 20.00 mL samples of the solution acidified with sulfuric acid, required an average volume of 20.20 mL of 0.016 M potassium permanganate solution for a complete reaction. The unbalanced equation is:

$H_2O_{2(l)} + MnO_4^-{}_{(aq)} \rightarrow Mn^{2+}{}_{(aq)} + O_{2(g)}$

Determine:

(a) The concentration of the commercial hydrogen peroxide in mol L^{-1}

(b) The percentage by mass of hydrogen peroxide in the commercial solution. (Assume the density of the solution to be 1 g cm^{-3}.)

(c) The volume strength of the commercial solution (how many moles of oxygen 1 mole of solution produces).