Year 12 Chemistry Oxidation and Reduction Chapter 18

**************************ANSWERS*******************************

Section 18.1 Industrial redox processes involving metals

IRON

1. hematite Fe_2O_3 gibbsite $Al_2O_3.3H_2O$
   malachite $CuCO_3.Cu(OH)_2$ galena PbS
   magnesite $MgCO_3$ barytes $BaSO_4$
2. mining – to extract the ore from the ground
   milling – to concentrate the ore (remove sand etc), usually a physical separation (eg; froth flotation for separating gold minerals from other crushed rock matter)
   smelting – to extract the impure metal from the ore, usually a chemical separation
   refining – to purify the impure metal
3. bauxite is approx 30% Al, the remainder mainly oxygen
4. iron ore is approx 69% Fe (high grade ore), the remainder mainly oxygen
5. <u>Fraction of Fe in Fe_2O_3</u> is (2xFe)/(2xFe+3xO)
   percentage is fraction x 100 = (2x55.8)/(2x55.8+3x16)x100 = 69
   <u>Fraction of Fe in $(Fe_2O_3)_2(H_2O)_3$</u> is (4xFe)/(4xFe+6xO+3x(2+16))
   percentage is fraction x 100 = (4x55.8)/(4x55.88+6x16+3x18)x100 = 59.8
   <u>Fraction of Fe in Fe_3O_4</u> is (3xFe)/(3xFe+4xO)
   percentage is fraction x 100 = (3x55.8)/(3x55.8+3x16)x100 = 72
6. <u>Fraction of Al in $Al_2O_3.3H_2O$</u> is (2xAl)/(2xAl+3xO+3x18)
   percentage is fraction x 100 = (2x27.0)/(2x27.0+3x16+3x18)x100 = 34.6
   <u>Fraction of Al in $Al(OH)_3$</u> is (Al)/(Al+3xOH)
   percentage is fraction x 100 = (27.0)/(27.0+3x17)x100 = 34.6
   <u>Fraction of Al in Al_2O_3</u> is (2xAl)/(2xAl+3xO)
   percentage is fraction x 100 = (2x27)/(2x27+3x16)x100 = 52.9

   > $Al(OH)_3$ is the another way of representing $Al_2O_3.3H_2O$

7. iron ore (hematite) coke (carbon)
   limestone (calcium carbonate) air (oxygen)
8. high temperature increases rate of combustion of the coke, which produces more heat
   recycles heat from the furnace gases

9. combustion $C + O_2 \rightarrow CO_2$

   formation of carbon monoxide $C + CO_2 \rightarrow 2\ CO$

10. carbon monoxide

    $Fe_2O_3(s) + 3\ CO(g) \rightleftarrows Fe(l) + 3\ CO_2(g)$

    Fe is being reduced (Fe^{3+} to Fe^0)

    C is being oxidized (+2 to +4)

11. $K = [CO_2]^3/[CO]^3$ (Fe_2O_3 and Fe are solids)

12. Large excess of CO (being continuously formed and blasted over the mixture – favours products – continuous shift to the right)

    The blast also continuously removes CO_2 (favours products – continuous shift to the right)

13. Decomposes to form CO_2 (which reacts with C to form the CO)

    $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

    The CaO formed reacts with, $CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$

    and so removes, sand impurity to form slag, which floats on top of the molten iron, and seals it off from the CO_2 (which could oxidize it back to Fe_2O_3)

14. Calcium silicate ($CaSiO_3$); in the furnace it is molten, like volcanic lava.

    Less dense than molten iron

    Acts as a seal preventing contact between molten iron and carbon dioxide

    Making cement; material for making roads; made into fibres for insulation (mineral wool)

15. Fe + C (about 4%) + small amounts of Mn, P, S and Si etc

    Brittle and difficult to weld

    Doesn't rust readily and expands as it solidifies, making it ideal for casting

    Water also expands as it freezes

16. $C(s) + O_2(g) \rightarrow CO_2(g)$ redox (C = 0 to +2; O = 0 to -2)

    $C(s) + CO_2(g) \rightarrow 2\ CO(g)$ redox (C_{1st} = 0 to +2; C_{2nd} = +4 to +2;oxygen no change)

    $Fe_2O_3(s) + 3\ CO \rightarrow 2\ Fe(l) + 3\ CO_2(g)$ redox

    $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ non-redox

    $CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$ non-redox

17. See text for properties and uses

18. Steel is iron that has been purified and mixed with other elements (C, Si, Mn, Ni, Cr etc) to give it the desired special properties.
19. These impurities are burned out; they form oxides that are gases, or that float to the top of the molten iron

    $C + O_2 \rightarrow CO_2(g)$

    $S + CO_2 \rightarrow SO_2(g)$

    $Si + O_2 \rightarrow SiO_2(l)$ [CaO is also added to react with SiO_2]

    $P_4 + 5\ O_2 \rightarrow 2\ P_2O_5(g)$
20. Carbon steel has only about 1% carbon

    Alloy steel has other metals mixed (alloyed) with the iron
21. Corrosion resistant = Cr, Ni

    Hard = added C, Cr, Mn, W

    Magnets = added Si

    Soft = C (less than 0.2%)

GOLD

22. Gold is trapped as tiny particles of metal and/or compounds within the rock. Pulverizing the ore exposes the particles so they can be separated from sand, clay etc during froth flotation (if concentration is required – and it usually is!). Also these particles will then be exposed to the alkaline cyanide solution.

23. Pulp is the muddy mixture (slurry) of crushed ore and alkaline cyanide solution with bubbles of air. It contains the dissolved aurocyanide ion.
24. Gold is not oxidized by oxygen alone. (Note: gold does not tarnish in moist air!) The cyanide helps the gold to oxidize (lose an electron) by forming the complex ion, aurocyanide $Au(CN)^-$.

    $Au \rightarrow Au^+ + e$ Does not go!

    $Au + 2\ CN^- \rightarrow Au(CN)_2^- + e$ Does go!
25. $Au(s) + 2\ CN^-(aq) \rightarrow Au(CN)_2^-(aq) + e$ [x 4]

    $\underline{O_2(g) + 2\ H_2O(l) + 4e \rightarrow 4\ OH^-(aq)}$ ……………[x 1]

    $\underline{4\ Au + 8\ CN^- + O_2(g) + 2\ H_2O(l) \rightarrow 4\ Au(CN)_2^- + 4\ OH^-(aq)}$

26. ON of Au in $Au(CN)_2^-$ = +1

[Au + 2 (-1) = -1, so Au = +1 ……………CN = -1]

27. Activated carbon (powder or fibres) is mixed into the pulp (mud) and the $Au(CN)_2^-$ ions adsorbs onto the carbon particles (stick to surface atoms of the tiny grains of activated carbon).

28. The activated carbon (with the adsorbed $Au(CN)^-$ ions is separated from the pulp (muddy mixture) and the $Au(CN)^-$ ions are washed off the carbon particles using hot alkaline (basic) sodium cyanide solution.

29. The gold (+1) ions [trapped in the $Au(CN)^-$ ions] are reduced by electrolysis. The $Au(CN)_2^-$ ions are made to accept electrons from a negative electrode (see Page 438).

$$Au(CN)_2^- + e^- \rightarrow Au + 2\ CN^-$$

30. The crude gold is purified to about 98% by melting it and adding a flux that combines with impurities to form a slag, which floats on top.

31. The carbon is reactivated by heating strongly (in the absence of air, so it doesn't burn!)

32. When air is bubbled through the muddy, soapy mixture of crushed gold ore, the bubbles rising to the surface carry with them the particles of gold and gold minerals. The sand and clay material (silicate materials) does not stick to the bubbles and simply runs out through a pipe at the bottom of the tank.

33. Roasting involves heating the ore in air. This decomposes gold sulfide to produce gold and sulfur dioxide. Other gold compounds are also decomposed, and so the gold is freer to make contact with the cyanide, water and oxygen, and so become dissolved.

34. $Au_2S(s) + O_2(g) \rightarrow 2\ Au(s) + SO_2(g)$

$Au_2Te_3(s) + 3\ O_2(g) \rightarrow 2\ Au(s) + 3\ TeO_2(g)$

35. The process is called CIP because the activated carbon is mixed into the pulp (muddy mixture of crushed ore, sodium cyanide solution and air).