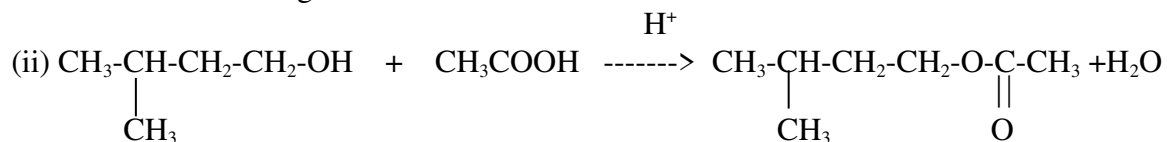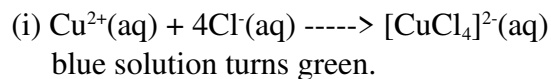# Year 12 Chemistry Exam 2nd Semester 2001

Solutions

Multiple Choice

1B, 2C, 3C, 4D, 5C, 6D, 7A, 8C, 9D, 10D, 11A, 12B, 13A, 14D, 15B
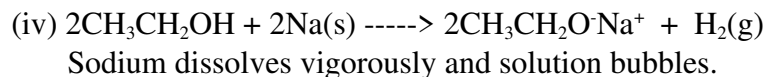16C, 17A, 18B, 19D, 20C, 21A, 22C, 23A, 24C, 25D, 26C, 27A, 28A, 29C, 30C
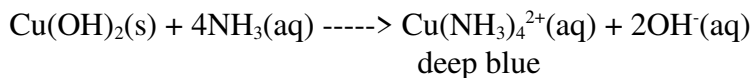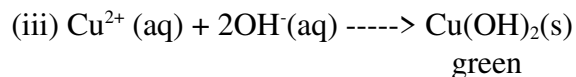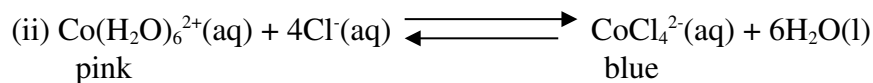
Short Answers

Question 1

(i) $Cu^{2+}(aq) + 4Cl^-(aq) \longrightarrow [CuCl_4]^{2-}(aq)$
    blue solution turns green.

(ii) CH_3-CH-CH_2-CH_2-OH $+$ CH_3COOH $\xrightarrow{\quad H^+ \quad}$ CH_3-CH-CH_2-CH_2-O-C-CH_3 $+H_2O$
         | | ||
         CH_3 CH_3 O

   Sweet smelling ester formed

(iii) no reaction

(iv) $2CH_3CH_2OH + 2Na(s) \longrightarrow 2CH_3CH_2O^-Na^+ + H_2(g)$
    Sodium dissolves vigorously and solution bubbles.

Question 2

(i) $2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$
    yellow   orange

(ii) $Co(H_2O)_6^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CoCl_4^{2-}(aq) + 6H_2O(l)$
     pink   blue

(iii) $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$
                              green

    $Cu(OH)_2(s) + 4NH_3(aq) \longrightarrow Cu(NH_3)_4^{2+}(aq) + 2OH^-(aq)$
                                   deep blue
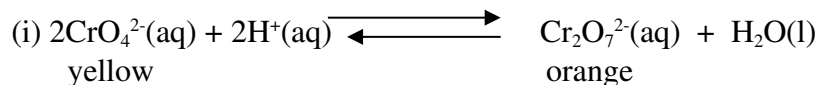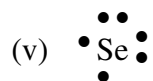
Question 3

(i) S (ii) Mn (iii) As (iv) Mo

Question 4

(i) selenium, (ii) Group 6A, period 4, (iii) nonmetal

(iv) gases or brittle solids at room temperature, dull, non-conductors, low melting point

(v) $\cdot \overset{\cdot \cdot}{\underset{\cdot}{Se}} \cdot \cdot$
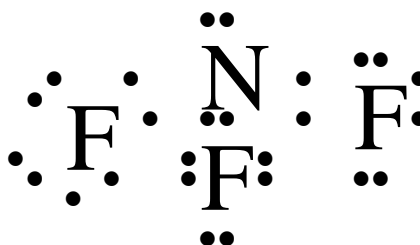
(vi) two of O, S, Te, Po

(vii) 2, krypton

Question 5

(i) Huge jump in energy from 4th to 5th because the electron of the 5th ionsation process is removed from a full orbital.

(ii)   (a) transition elements (b) noble gases (c) alkali metals (d) Group 5A (e) halogens (f) period 4 (g) metals (h) nonmetals (i) metals (j) halogens

Question 6
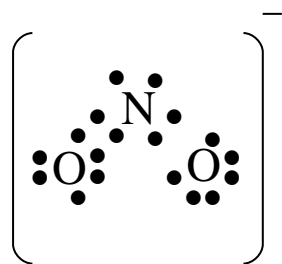
bent

trigonal pyramidal

Question 7

(i) If polar bonds are arranged symmetrically in the 3 planes then the molecule will be non-polar, as in CCl_4.

(ii) polar
  polar
  nonpolar
  nonpolar

Question 8

(i) $K_{eq} = \dfrac{[CO_2(g)]\,[NH_3(g)]^2}{[NH_2COONH_4(aq)]}$
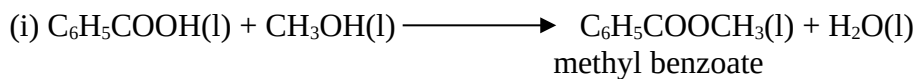
(ii) $K_{eq} = \dfrac{[Cl_2(g)]^2}{[HCl(aq)]^4[O_2(g)]}$
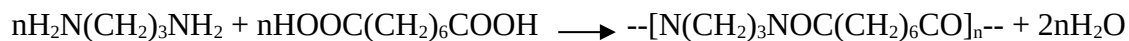
(iii) $K_{eq} = [H_2S(g)]\,[NH_3(g)]$

(iv) $K_{eq} = [CuSO_4(aq)]$

Question 9
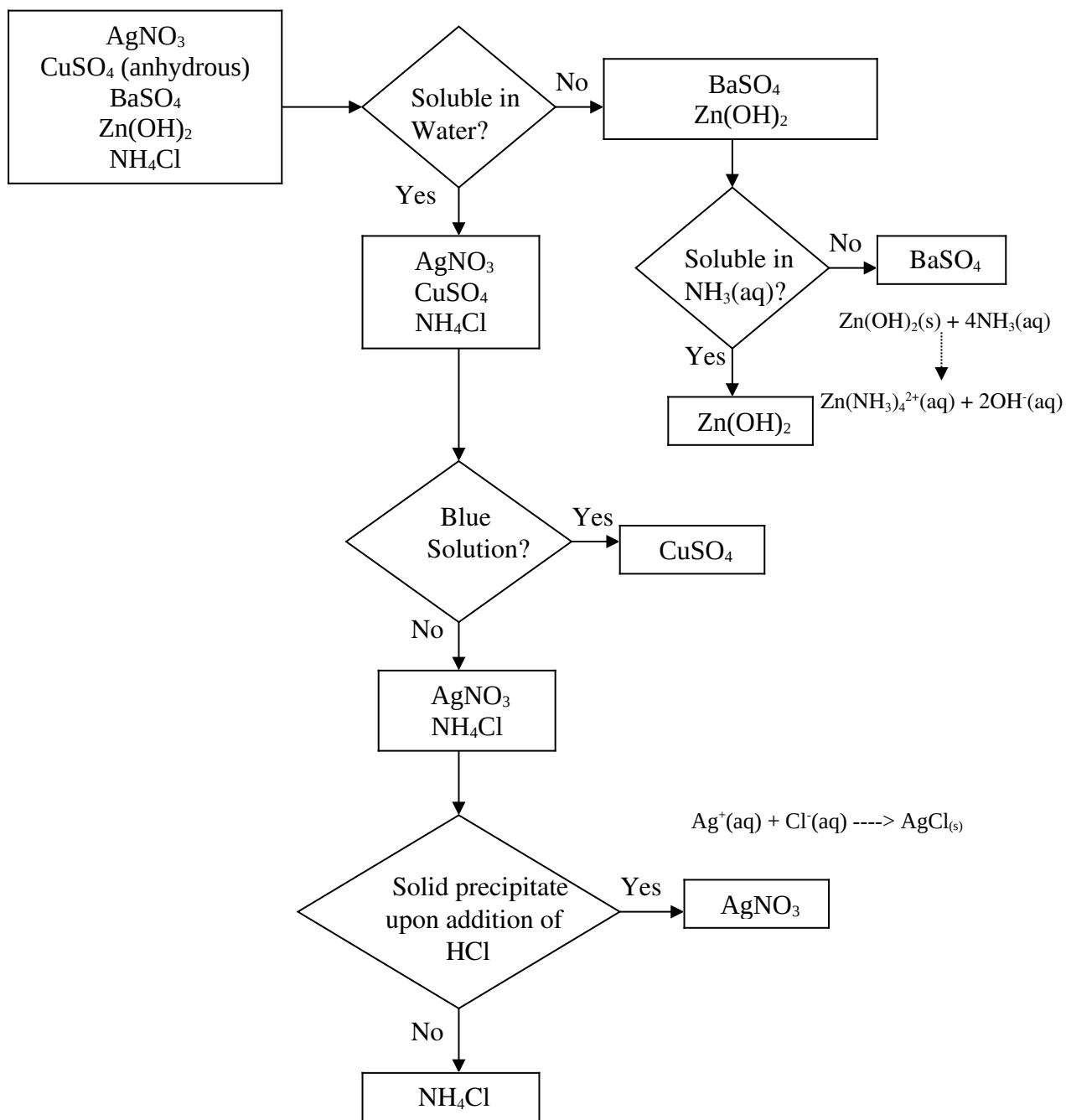
(i) 2-methyl-4-propyl cyclopentanone

(ii) 2-amino-4-methyl cyclohexanol

(iii) methyl butanoate

Question 10

(i) $C_6H_5COOH(l) + CH_3OH(l) \longrightarrow C_6H_5COOCH_3(l) + H_2O(l)$
  methyl benzoate

(ii)

$nH_2N(CH_2)_3NH_2 + nHOOC(CH_2)_6COOH \longrightarrow$ --$[N(CH_2)_3NOC(CH_2)_6CO]_n$-- $+ 2nH_2O$

Question 11

AgNO$_3$ CuSO$_4$ (anhydrous)   BaSO$_4$ Zn(OH)$_2$ NH$_4$Cl

Soluble in Water? — No → BaSO$_4$ Zn(OH)$_2$

Yes ↓

AgNO$_3$ CuSO$_4$ NH$_4$Cl

BaSO$_4$ Zn(OH)$_2$ → Soluble in NH$_3$(aq)? — No → BaSO$_4$

$Zn(OH)_2(s) + 4NH_3(aq)$

Yes ↓

Zn(OH)$_2$

$Zn(NH_3)_4{}^{2+}(aq) + 2OH^-(aq)$

Blue Solution? — Yes → CuSO$_4$

No ↓

AgNO$_3$ NH$_4$Cl

$Ag^+(aq) + Cl^-(aq) ----> AgCl_{(s)}$

Solid precipitate upon addition of HCl — Yes → AgNO$_3$

No ↓

NH$_4$Cl

Question 12

higher
same
lower
same
lower

Calculations

Question 1

(i)

	E°(volts)
2NiOOH(s) + 2H₂O(l) + ~~2e⁻~~ ---> 2Ni(OH)₂(s) + ~~2OH⁻(aq)~~	+ 0.490
Cd(s) + ~~2OH⁻(aq)~~ ------------> Cd(OH)₂(s) + ~~2e⁻~~	+ 0.809
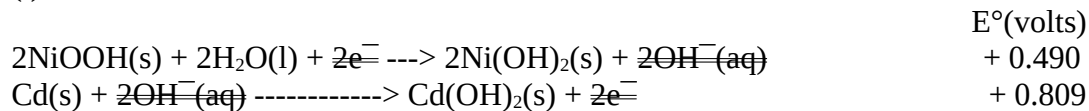
Answer: $2NiOOH(s) + 2H_2O(l) + Cd(s) ---> 2Ni(OH)_2(s) + Cd(OH)_2(s)$

(ii)

$E_{battery}$ = + 0.490 + 0.809

      = 1.30V

      Answer: 1.30V

(iii)

$Q = It$

$Q = 0.05 \times (6 \times 60 \times 60) = 1080$ C

$n(e) = Q/(9.65 \times 10^4) = 1080/(9.65 \times 10^4) = 0.01119$ moles

1 mole of electrons = 6.02×10^{23} electrons

0.01119 moles of electrons = $(0.01119 \times 6.02 \times 10^{23})$ electrons = 6.74×10^{21} electrons
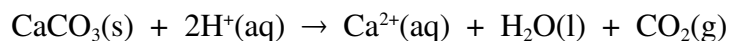
      Answer: 6.74×10^{21} electrons

(iv)

$n(Cd) = n(e)/2 = 0.01119/2 = 5.596 \times 10^{-3}$ moles

$m(Cd) = n(Cd) \times M(Cd) = 5.596 \times 10^{-3} \times 112.4 = 0.629$g

      Answer: 0.629g

Question 2

$CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$

$n(CaCO_3) = (1/2)n(H^+) = (1/2)n(HCl)_{reacting}$

$n(H^+)_{total} = n(HCl) = c.V = (0.0905$ mol L$^{-1})(0.100$ L$) = 9.05 \times 10^{-3}$ mol.

$n(H^+)$excess $= n(OH^-) = c.V = (0.250$ mol L$^{-1})(0.0170$ L$) = 4.25$ x 10^{-3} mol.

Hence, $n(H^+)_{reacting} = n(H^+)_{total} - n(H^+)_{excess}$

$$= 9.05 \text{ x } 10^{-3} \text{ mol } - 4.25 \text{ x } 10^{-3} \text{ mol } = 4.80 \text{ x } 10^{-3} \text{ mol.}$$

$n(CaCO_3) = (1/2) n(H^+)_{reacting} = 2.40$ x 10^{-3} mol

$m(CaCO_3) = n.M = (2.40$ x 10^{-3} mol$)(100.09$ g mol$^{-1}) = 0.2402$ g

Hence, percentage purity= $(m(CaCO_3))/(m(sample))$ x $100 = (0.2402$ g$)/(0.2450$ g$)$ x $100 = $ 98.0%

   Answer: The sample is 98.0% calcium carbonate by mass.

Question 3

(i) $m(NaOCl) = 30.0$ g

         $n(NaOCl) = m/M = (30.0$ g$)/(74.44$ g mol$^{-1}) = 0.403$ mol L^{-1}

Answer: The concentration of sodium hypochlorite in original solution $= 0.403$ mol L^{-1}

(ii)   From the balanced equation, $n(OCl^-) = (1/2) n(S_2O_3^{2-})$

         $n(S_2O_3^{2-}) = c.V = (0.250$ mol L$^{-1})(0.0475$ L$) = 0.011875$ mol

         $n(OCl^-)$ (in 20.0 mL) $= 5.9375$ x 10^{-3} mol.

         $c(OCl^-) = n/V = (5.9375$ x 10^{-3} mol$)/(0.020$ L$) = 0.297$ mol L^{-1}

Answer: The concentration of hypochlorite ions in final solution $= 0.297$ mol L^{-1}

Question 4

(i)

$C_xH_yN_z + AO_2(g) \rightarrow$ x $CO_2(g) + (y/2) H_2O + z N$

$m(CO_2) = 4.753$ g   Hence, $n(CO_2) = m/M = (4.753$ g$)/(44.01$ g mol$^{-1}) = 0.108$ mol.
$n(C) = 0.108$ mol   Hence, $m(C) = n.M = (0.108$ mol$)(12.01$ g mol$^{-1}) = \underline{1.297 \text{ g C}}$

$m(H_2O) = 3.405$ g   Hence, $n(H_2O) = m/M = (3.405$ g$)/(18.016$ g mol$^{-1}) = 0.1890$ mol

n(H) = 2n(H_2O) = 0.3780 mol. Hence, m(H) = (0.3780 mol)(1.008 g mol^{-1}) = <u>0.381 g H</u>

Hence, m(N) = m(sample) - [m(C) + m(H)] = 2.435 g − 1.678 g = 0.757 g

Hence, n(C) = 0.108 mol; n(H) = 0.378 mol; n(N) = m/M = (0.757 g)/(14.01 g mol-1) = 0.054 mol

Simplest ratios: 2   7   1

       <u>Answer: The empirical formula of the compound is C_2H_7N</u>

(ii)

2.435 g of compound occupies 1.321 L at 25 °C and 101.3 kPa
Convert to STP by applying the combined gas law equation:

       V_1/T_1 = V_2/T_2 Hence, V_2 = $(V_1)(T_2)/(T_1)$ = 1.210 L at STP

       n(vapour) = (1.210 L)/(22.41 L mol-1) = 0.05402 mol.

       Since n = m/M,   M = m/n = (2.435 g)/(0.05402 mol) = 45.08 g mol^{-1}

       E.F.M. = 2(C) + 7(H) + 1(N) = 45.08
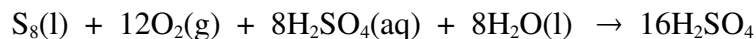
       Clearly, the true formula mass (molar mass) = E.F.M.

       <u>Answer: The true formula of the compound = E.F. = C_2H_7N</u>

<u>Question 5</u>

(i) To combine the equations,   multiply the second equation by 4
                                    multiply the third equation by 8
                                    multiply the fourth equation by 8

  Then cancel out the intermediate products.   This leads to the combined equation:

      $S_8(l)$ + $12O_2(g)$ + $8H_2SO_4(aq)$ + $8H_2O(l)$ → $16H_2SO_4$

Cancel the $8H_2SO_4$ from both sides since this is provided – not produced - in the reaction:

      $S_8(l)$ + $12O_2(g)$ + $8H_2O(l)$ → $8H_2SO_4$
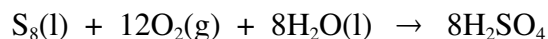
      Clearly, n(S_8) = 1/8 n(H_2SO_4) = 1/8 (10^6 g)/(98.076 g mol^{-1}) = 1274.5 mol.

      m(S_8) = n.M = (1274.5 mol)(256.48 g mol^{-1}) = 3.269 x 10^5 g.

m(S_8) impure $=$ (100)/(98) . (3.269 x 105 g) $=$ 3.34 x 10^5 g

Answer: 3.34 x 10^5 g of the 98% pure liquid sulfur is needed.

(ii) From the balanced equation, n(O_2) $=$ 12/8 n(H_2SO_4) $=$ 12/8(10196 mol) $=$ 15294 mol.

   V(O_2) $=$ (15294 mol)(22.41 L mol^{-1}) $=$ 342739 L at S.T.P.

 Now change from STP to non-STP using $P_1V_1/T_1 = P_2V_2/T_2$ Hence, $V_2 = (P_1)(V_1)(T_2)/(P_2)(T_1)$

      $V_2 = 8.08$ x 10^5 L

   Answer: The volume of oxygen gas required is 8.08 x 10^5 L

(iii) From the balanced equation, n($H_2O(l)$) $=$ n(H_2SO_4) $=$ 10196 mol.

m(H_2O) $=$ n.M $=$ (10196 mol)(18.016 g mol^{-1}) $=$ 1.84 x 10^5 g or 1.84 x 10^2 kg.

   Answer: The mass of water required is 1.84 x 10^2 kg

Essay

<u>Essay 1</u>

Van der Waal's forces: their nature and significance.

VDW forces include all intermolecular forces of attraction. These may be discussed under the headings of hydrogen bonding, dipole-dipole interactions and dispersion forces. The first type - hydrogen bonds - occur between polar molecules in which a hydrogen atom in one molecule attached to a fluorine, oxygen or nitrogen atom is attracted electrostatically to the lone pair of a fluorine, oxygen or nitrogen atom in an adjacent molecule. The strength of the attraction depends on the strength of the particular bond dipoles involved in each molecule and how closely the atoms are able to approach each other. The most significant hydrogen bonds are the ones within liquid or solid water. The effect is to significantly increase the intermolecular forces, thus raising the melting and boiling point of water above the values shown by similarly sized non-polar molecules. In addition, hydrogen bonding in water allows this common liquid to interact strongly with, and dissolve, many other polar and ionic substances, resulting in water being described as the "universal solvent". Without hydrogen bonding between water molecules, life on earth would be vastly different – there would be no ice and little or no liquid water on the planet at its present temperatures - our planet would be a steamy world similar to Venus where clouds of gas obscure the surface of the planet.

Dipole-dipole forces occur between polar molecules, but are not strong enough to qualify as hydrogen bonding. Such interactions occur between polar gas molecules such as sulfur dioxide, carbon monoxide and nitrogen monoxide resulting in a higher boiling and melting point than occurs in the case of similarly sized non-polar molecules. These changes are less marked than the ones involving hydrogen bonding. Water is still able to interact quite significantly with such polar molecules. Hydrogen chloride gas, for example, is highly soluble (and highly ionized) in water due to dipole-dipole interactions.

Dispersion forces occur between all adjacent molecules in the solid and liquid state, but are only of significance where hydrogen bonds and dipole–dipole interactions are absent. Dispersion forces are the only interactions between non-polar molecules. While much weaker than hydrogen bonds, they become stronger as the number of electrons in the adjacent molecules increases. All hydrocarbons, for example, are non-polar, but exhibit an increase in boiling points as their formula masses increase. Short chain hydrocarbons are all gases at room temperature, but heptane, with a seven carbon chain has almost the same boiling point as the much smaller water molecule. Longer chain hydrocarbons such as wax, become solids at room temperature when they exceed about 20 carbon atoms in length. The properties of many polymers are determined by the total dispersion forces between the very long chains of atoms. PVC, for example, is much stronger than polythene due to the presence of larger chlorine atoms greatly increasing the dispersion forces within the material.

Essay 2

Extraction, purification and uses of gold and iron.

The differences between the chemical extraction and purification processes required for gold and iron are due to the great difference in their chemical reactivities. Gold - one of the least active metals - is found largely in the uncombined state in quartz rocks, and its extraction requires the separation of the very small amounts of the precious metal from the large amount of rock material containing it. After crushing, the very tiny specks of gold are leached out of the mass by selective dissolving of the gold when it forms a soluble complex ion in a cyanide solution through which air is bubbled:

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

The dicyanoaurate(I) ions are then concentrated by adsorbing them onto the surface of activated charcoal in a process which is known as the carbon-in-pulp treatment. After washing the ions off the charcoal, the concentrated solution is then electrolysed using inert anodes and steel wool cathodes. The gold is then reduced to the pure metal on the surface of the steel wool:

$$Au(CN)_2^-(aq) + e^- \rightarrow Au(s) + 2CN^-(aq).$$
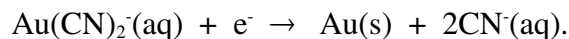
Thus, the changes in the oxidation numbers of the gold through the entire process are from 0 to +1 (dissolving) then from +1 back to 0 (reduction).
After treating with acid to dissolve the steel wool, the gold is about 98% pure. It undergoes further purification in mints to produce gold which is 99.9% pure.
Due to its lack of reaction in air and with other chemicals, gold is used in coinage, jewelry, dentistry and in plating more active metals such as in electronic contacts in computers which must resist the corrosive effects of sparks.
Iron is a comparatively active metal seldom found free in nature (except in meteorites) and exists in the [+3] oxidation state principally as hematite (Fe_2O_3).
It must be reduced to the [0] oxidation state by reacting it with a suitable reducing agent (carbon monoxide is chosen) at high temperature in a blast furnace. It must also be separated from silica type impurity by adding limestone to the mixture, which converts it to calcium silicate:

$$3CO(g) + Fe_2O_3(s) \rightarrow 3CO_2(g) + 2Fe(l)$$
$$CaCO_3(s) + SiO_2(s) \rightarrow CaSiO_3(l) + CO_2(g)$$
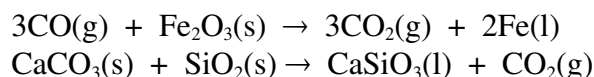
The iron product (cast iron) is only about 96% pure. The main impurity is carbon which is then removed by oxidizing the carbon in a Bessemer Converter, resulting in wrought iron (99.5% pure iron).
It is not necessary to purify the iron any further because it is usually then alloyed with other metals to create desired properties (eg, with chromium to form stainless steel, or with tungsten and molybdenum to produce tool steel.)
Due to the high tensile strength of steel, it is used extensively in constructing buildings, bridges, motor vehicles, machinery and tools.

Unlike gold, iron does not resist corrosion because the layer of oxide which forms on its surface is porous to both oxygen and water. The iron surface must be painted or coated with zinc (galvanizing) or other impervious material. Iron structures may also be protected electrochemically or electrolytically. Without this protection, iron rapidly corrodes in moist air, resulting in the total breakdown of the metal to useless rust. Such corrosion requires the regular replacement of many iron objects such as exhaust pipes on motor vehicles.