Solutions for "Applications of Redox Reactions in Society"

1. Combustion reactions – identify oxidant and reductant

   i. $H_2 + O_2 \rightarrow H_2O$

   Hydrogen is oxidised (oxidation state 0 to +1) and acts as the reductant.
   Oxygen is reduced (0 to −2) and acts as the oxidant.
   1-----mark for correctly identifying the oxidant and reductant.

   ii. *1-----mark for correctly justifying with oxidation numbers*

   ii. $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$

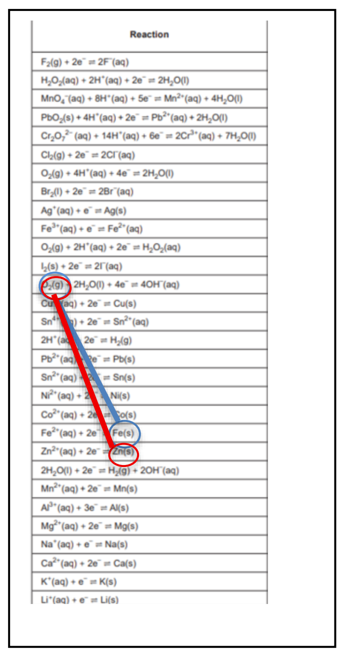
   Carbon is oxidised (−3 to +4) and acts as the reductant.
   Oxygen is reduced (0 to −2) and acts as the oxidant.
   1-----mark for correctly identifying the oxidant and reductant.
   1-----mark for correctly justifying with oxidation numbers

2. Lemon battery (Zn/Cu)

a. Oxidant: H^+ 1-----mark
it is the strongest oxidant present that can gain electrons from Zn.. 1-----mark
b. Reductant: Zn(s) 1-----mark
it is the most reactive metal present as it loses electrons. 1-----mark
c. Anode: Zinc 1-----mark
Cathode: Copper (unreactive electrode) 1-----mark

3. Rusting experiment

a. A: Oxidant – O_2, Reductant – Fe
B: Oxidant – O_2, Reductant – Zn
C: Oxidant – O_2, Reductant – Fe
D: Oxidant – O_2, Reductant – Fe



Reaction
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$
$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$
$PbO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Pb^{2+}(aq) + 2H_2O(l)$
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$
$Na^+(aq) + e^- \rightleftharpoons Na(s)$
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$
$K^+(aq) + e^- \rightleftharpoons K(s)$
$Li^+(aq) + e^- \rightleftharpoons Li(s)$

b. Copper accelerates rusting (A) as Fe is more reactive and becomes the anode, a seen on the E^o series on the right.
1-----mark for suggesting test tube A has more rust
1-----mark for correct explanation with reference to the E^0 series (blue line)

Zinc protects iron (B) as sacrificial anode.
1 -----mark for correct observation that there is no iron rust but the solid white substance may be $Zn(OH)_2$
1----- mark for correct reason as to why there is no rust in test tube B with reference to the E^o series (red line)

c. 1----- mark - Conductivity of a salt solution is greater than normal water.
1-----mark - It is easier for electrons to move from reductant to oxidant

d. 1-----mark - Gold coating would increase corrosion if scratched.

1-----mark for comparing the low reactivity of gold with high reactivity of iron.

1-----mark for suggesting that the iron would preferentially rust or acts as a sacrificial anode.

e. Controlled variables include: nail size, water volume, temperature, exposure time, oxygen availability. 1-----mark for each of any four relevant controlled variables.

f. i. 1-----mark for correctly recalling the difference. Qualitative data is descriptive, quantitative is numerical.
1-----mark for correctly stating why this experiment is qualitative.

ii. 1-----mark For suggesting a bar graph
1-----mark for explaining that it suits data given is specific categories rather than data that follow a trend and continue to change over time (line of best fit).

f. 1-----mark for recognizing that a quantitative method is needed, one that measures a trend over time, ie. mass loss of nails over time.
1-----mark for numbered sequential and logical steps.
1-----mark for repeat statements
1-----mark for clear identification of the DV and IV and how to measure the variables.

4a. i. *1-----mark for lithium is the anode (oxidation), copper is the cathode (reduction).*
1-----mark for the arrow correctly pointing from the reductant to the oxidant. Electrons flow from Li to Cu.

ii. 1-----mark lithium is labelled as the anode and copper is labelled as the cathode.
1-----mark mentions lithium is safer than Na/K as it is less reactive.

iii. 1-----mark $Li(s) \rightarrow Li^{+}(aq) + e^{-}$
1-----mark $Cu^{2+}(aq) + 2e \rightarrow Cu(s)$

b.

1-----mark if reference is made to the position of sodium and lithium in the periodic table and suggests are reason that correctly uses electrostatic attraction between nucleus and valence electrons to explain the increased reactivity of sodium.

1-----mark any other viable reason such as, higher atomic mass of Na per unit charge delivered as compare to Li. Mass consideration for portable devices.

c. *1-----mark for stating that lithium is more reactive according to trends of the periodic table.*
1-----mark for stating an explosive gas is formed with writing a balanced equation
$Na(s) + H_2O(l) \rightarrow H_2(g) + 2OH^-(aq) + 2Na^+(aq)$
or
$Na(s) + H_2O(l) \rightarrow H_2(g) + 2NaOH(aq)$

Blast furnace and green steel

1. *1-----mark oxidant is Fe_2O_3 . Students often make the mistake of identifying Fe as the oxidant but it's the entire compound that is the oxidant not just the Fe.*
   1-----mark - iron is reduced (+3 → 0).
   1-----mark - carbon is reductant
   1-----mark – C is oxidised (0 → +4)

2. *Oxidation half-equation: $C(s) + 2O^{2-}(l) \rightarrow CO_2(g) + 4e^-$*
   1-----mark balanced for species and charge.
   1-----mark for correct states (eg $O^{2-}{}_{(l)}$)

3. *NH_3 is the reductant whilst Fe_2O_3 is the oxidant.*
   N in (NH_3) has an oxidation state of -3 → N_2 with an oxidation state of 0. 1-----mark
   $2NH_3(g) + 3O_2^-(l) \rightarrow N_2(g) + 3H_2O(g) + 6e^-$ (oxidation)(state not necessary) 1-----mark
   Fe in Fe_2O_3 is oxidized from 3+ to 0 1-----mark
   $Fe^{3+}(l) + 3e^- \rightarrow Fe(s)$ States not necessary 1-----mark

4. *a, Either* 1-----mark
   goal 7 (Affordable and clean energy)
   or
   goal 12 (responsible production and consumption)
   or
   goal 13 (climate change)
   1-----mark any valid reason for selection the UNSDG.
   eg goal 7 (production of N_2 as opposed to CO_2) It is wrong for students to state that no Green House G as(GHG) is produced as H_2O is considered a GHG.
   goal 12 (use of ammonia to produce green steel with limited impact on the climate change)
   goal 13 (use of ammonia to limit impact of climate change)
   b. 1-------mark for any plausible Green Chemistry Principle (GCP)
   eg Use of renewable feedstocks .
   1-----mark for an explanation. It is important, however, if the student mentions renewable feedstocks, that they must specify away that renewable energy is supplied to a process.

5. a. *1------mark – identifying intermolecular bonding of NH_3 as dispersion and H-bonding*

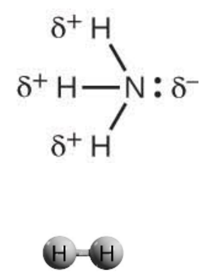
1------mark – identifying intermolecular bonding of H_2 as dispersion force only and greatly weaker than H-bonding due to small size of molecule.

1-----mark – for relating intermolecular bonding to states of each substance at SLC. With reference to greater energy needed to disrupt the intermolecular bonding of NH_3

1-----mark – relating state and the conditions needed to store each substance. Eg. H_2 very cold and high pressure = expensive infrastructure

1-----mark – Diagram must show permanent dipoles of NH_3 and triangular pyramid in shape (or some attempt to make it look polar)

1-----mark – hydrogen shown as symmetrical with no permanent dipoles.



Some attempt made to make H_2 look smaller and symmetrical.

5. b.i

Any two point listed below but not limited to.

- *Steam reforming uses methane (CH_4), which is a fossil fuel and therefore nonrenewable.* *1-----mark*
- *It requires high temperatures, consuming large amounts of energy, often from nonrenewable sources, which does not align with the Green Chemistry Principles of waste minimisation, energy efficiency, or using renewable feedstocks.* *1-----mark*

b. ii.

Green hydrogen can be produced via electrolysis of water using renewable electricity (solar, wind, hydro). *1-----mark*

Cathode (reduction):

$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ *1-----mark*

Anode (oxidation):

$2H_2O(l) \rightarrow 4e^- + 4H^+(aq) + O_2(g)$ *1-----mark*

Or the following equation can also be argued.

$4OH^-(aq) \rightarrow O_2(g) + 4H^+(aq)$ *(since the student may argue an eventual build up OH^-.)*

Metal displacement practical task.

6. *a. Low reactivity, **Cu**, **Ni**, **Fe**, **Zn**, High reactivity* *1-----mark*

*b. Metal **zinc** can be used to protect an iron bridge from rusting.* *1----mark*
*This metal is **more reactive than iron**, as shown by the results and the electrochemical series. It will oxidise preferentially, acting as a **sacrificial anode** and supply electrons to the iron, preventing iron from being oxidised.* *1-----mark*

c. Silver nitrate ($AgNO_3$) *1-----mark*
Ag^+ is the strongest oxidant present (above Cu in the electrochemical series shown in fig 5). Ag^+ ions could react with copper metal

$$Cu(s) + 2Ag^{+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$$ *1-----mark*

This would cause visible changes on the copper surface, explaining the discolouration even though Cu(s) should not react with Cu^{2+}.` *1-----mark*
Pb and Ni metals are more reactive than copper according to the electrochemical series and cannot take electrons from Cu(s), in other words can not oxidise copper. So no displacement would occur. *1-----mark*