

Metals Are Reductive but Some Are More than Others

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Abstract. *One of the first insights given to the students when they learn the reactions of oxidation-reduction is that metals are reductive. Apart from this important aspect of the chemical characteristics of metals, it is important to highlight that some are more reductive than others. The idea of an electrochemical potential of a chemical, and, in this case a metal, is used as a sign of how difficult it will be for this metal to undergo an oxidation when it is in contact with its peers. This experiment intends to prove that when two different metals are in contact through an electrolytic conductor, they produce an electro driven force which is attributed to the difference of the electrochemical potential existing among the present species. Due to this fact, and to prove the existing theories on this issue, and still in order to be able to compare results, an experimental work was carried on. By using some manual dexterity, very simple equipment was used and it allowed a successful experiment.*

Keywords. Corrosion, Electrochemical, Experiments, Teaching.

1. Introduction

When consulting the standard reduction potential table, the students observe the existence of values of negative and positive potential which leads them to conclude on the spontaneity of the reactions that occur when different metals get in contact via an electrolyte [1].

In this experiment the students can verify the change of signal when they move the voltmeter forceps that were used to do the readings. This fact allows us to infer in which direction the redox reaction occurs [2].

Also, from this experiment, the need to establish conditions and choose an element to be used as a standard electrode emerged [3].

2. Methodology

We can describe the methodology used based on the tasks that were followed in every step:

- Bibliographic research on the table of the standard potentials of reduction;
- Preparation of materials – mop stripes;
- Preparation of the auxiliary equipment – acrylic boards;
- Preparation of the metals studied;
- Preparation of ionic solutions of the metal elements involved with the concentration 1 mol.dm^{-3} ;
- Preparation of a saturated solution of potassium nitrate.

These experiments were carried on so as to allow, with the results obtained, the building of the tables presented on item 4 of this work.

Also, a table with the values of pattern potential of reduction for the same chemical species studied was similarly built.

By comparing the experimental results with the pattern values that are internationally acknowledged, the students analyzed the reproducibility of the potential of the metals under study so that they could conclude on the pedagogical/didactical value of the experimental work.

3. The Equipment

Two $330 \times 170 \times 5$ -mm acrylic boards (Plexiglas – PMMA) were used. They were holed with a $\varnothing = 5$ mm screw so that, later, fixing screws can be introduced, according to figure 1.

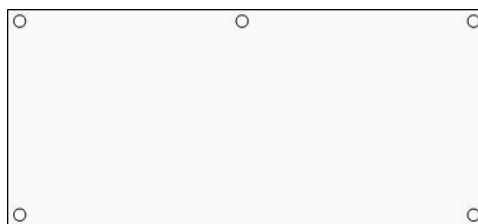


Figure 1. Acrylic board

Seven 120 x 20 x 1-mm stripes of absorbing tissue, usually used in mops at home, were cut. Later they were soaked in an electrolyte concentration and seven different pieces of metal are placed on them (each metal with the corresponding ion concentration, 1 mol.dm⁻³ in the stripes), as it is shown in fig 2:

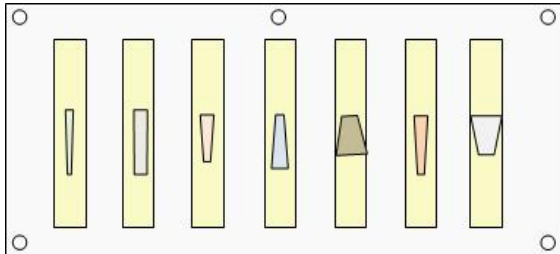


Figure 2. Stripes tissues with metals

Note - Without any pedagogical intent, the metals were placed by order of the atomic number. Thus we have the metal and salt used for the electrolyte of its ion:

- $_{12}\text{Mg}$ – Magnesium / MgSO_4
- $_{13}\text{Al}$ – Aluminium / $\text{Al}_2(\text{SO}_4)_3$
- $_{26}\text{Fe}$ – Iron / FeSO_4
- $_{29}\text{Cu}$ – Copper / CuSO_4
- $_{30}\text{Zn}$ – Zinc / ZnSO_4
- $_{47}\text{Ag}$ – Silver / AgNO_3
- $_{82}\text{Pb}$ – Lead / $\text{Pb}(\text{NO}_3)_2$

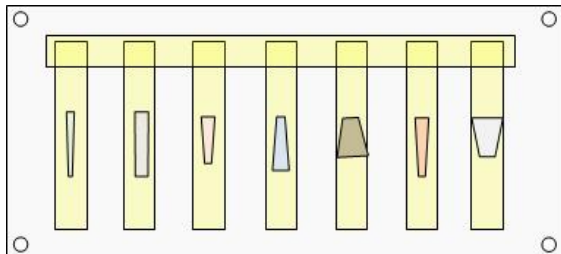


Figure 3. Salt bridge connecting all stripes

After that, a longer mop stripe, 260 x 20 x 1 mm, was cut and sunk in an electrolyte of saturated potassium nitrate [4] and then placed in a way as to connect all the others “as a comb”, as depicted in figure 3.

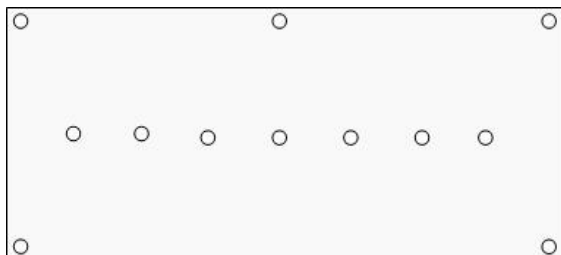


Figure 4. Top acrylic board

Finally, we place a second acrylic board on top of the first one, with 3 mm Ø holes located strategically in the same direction of the metals on the mop stripes to be able to introduce the voltmeter forceps so that the readings of the potential differences can be done, as represented in figures 4 and 5.

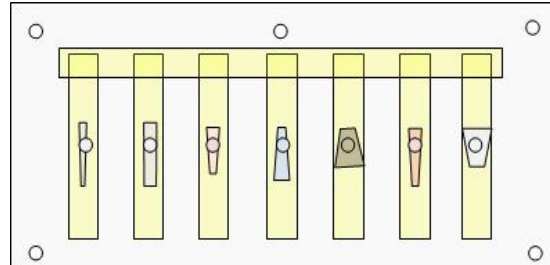


Figure 5. Equipment ready to experiment

Final assembly already fixed and ready for the electrochemical potential readings. Once the screws/nuts are quite tight adjusting the acrylic boards, the system is ready for the measuring, as shown in figure 6. In figure 7 is shown the final equipment being used.



Figure 6. Partial equipment



Figure 7. Final equipment and the reading instrument.

4. Experimental Results

The values of standard potential [5] for the metals studied are presented in table 1.

Table 1. – Standard Potential Electrodes / E^o, of the metals studied

M ⁿ⁺ + ne → M ^o	E ^o / V
Mg ²⁺ (aq) + 2e → Mg ^o	- 2,36 V
Al ³⁺ (aq) + 3e → Al ^o	- 1,68 V
Zn ²⁺ (aq) + 2e → Zn ^o	- 0,76 V
Fe ²⁺ (aq) + 2e → Fe ^o	- 0,44 V
Pb ²⁺ (aq) + 2e → Pb ^o	- 0,13 V
2H ⁺ (aq) + 2e → H ₂ (g)	0,00 V
Cu ²⁺ (aq) + 2e → Cu ^o	+ 0,34 V
Ag ⁺ (aq) + e → Ag ^o	+ 0,80 V

In table 2 the theoretical standard values are shown and in figure 8 we represent, on a line, the theoretical position of the metals studied.

Table 2. – Theoretical standard values / V

Theoretical	Mg	Al	Fe	Cu	Zn	Ag	Pb
Mg	Mg ²⁺ Mg ^o	+0,68	+1,92	+2,70	+1,60	+3,16	+2,23
Al	-0,68	Al ³⁺ Al ^o	+1,24	+2,02	+0,92	+2,48	+1,55
Fe	-1,92	-1,24	Fe ²⁺ Fe ^o	+0,78	-0,32	+1,24	+0,31
Cu	-2,70	-2,02	-0,78	Cu ²⁺ Cu ^o	-1,10	+0,46	-0,47
Zn	-1,60	-0,92	+0,32	+1,10	Zn ²⁺ Zn ^o	+1,56	+0,63
Ag	-3,16	-2,48	-1,24	-0,46	-1,56	Ag ⁺ Ag ^o	-0,93
Pb	-2,23	-1,55	-0,31	+0,47	-0,63	+0,93	Pb ²⁺ Pb ^o

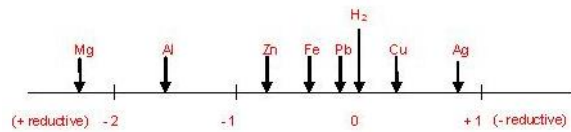
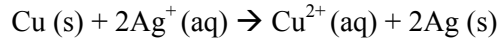
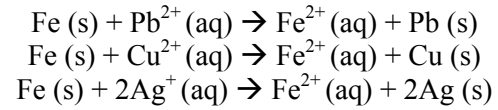
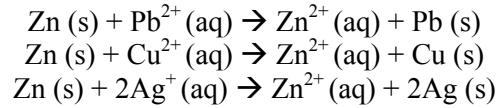
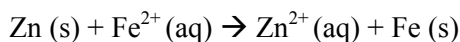
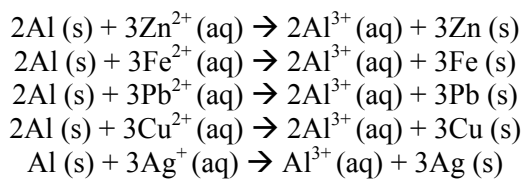
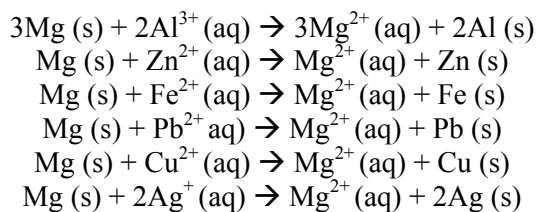


Figure 8. Theoretical position of the studied metals

Considering that the spontaneous reactions, the thermodynamically possible ones, are those that present a difference of positive potential among the pairs of metals studied. They can be represented according to the following chemical equations:



In order to record the average values obtained we carried out several experiments.

In table 3, we present the experimental results of the driven force between the pairs of metals used in the study.

With the experimental results we represent, on a line, as a reference, the more reductive metal. We can see its position compared with the one of its peers (figure 9).

Table 3. – Experimental results / V

Experimental	Mg	Al	Fe	Cu	Zn	Ag	Pb
Mg	Mg ²⁺ Mg ^o	+1,24	+1,35	+1,80	+1,49	+2,19	+1,38
Al	-1,20	Al ³⁺ Al ^o	+0,27	+0,59	+0,32	+0,98	+0,13
Fe	-1,25	-0,25	Fe ²⁺ Fe ^o	+0,59	-0,21	+0,98	+0,11
Cu	-1,78	-0,51	-0,58	Cu ²⁺ Cu ^o	-0,47	+0,39	-0,47
Zn	-1,42	-0,36	+0,13	+0,36	Zn ²⁺ Zn ^o	+1,41	+0,21
Ag	-2,16	-0,98	-1,01	-0,39	-1,39	Ag ⁺ Ag ^o	-0,86
Pb	-1,32	-0,15	-0,11	+0,47	-0,17	+0,86	Pb ²⁺ Pb ^o

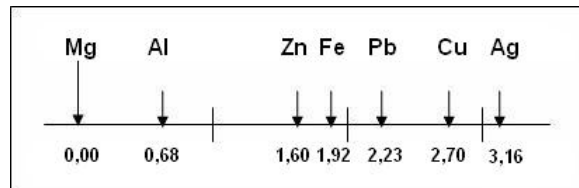


Figure 9. Theoretical position of the studied metals (more reductive).

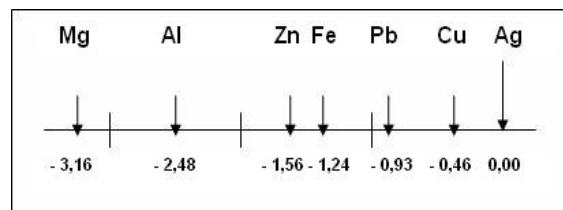


Figure 10. Theoretical position of the studied metals (less reductive).

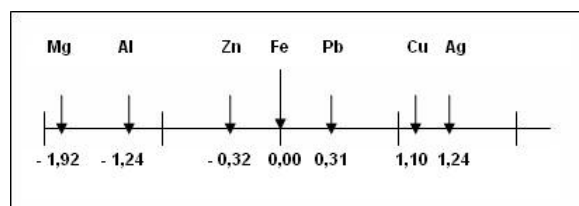


Figure 11. Theoretical position of the studied metals highlighting iron' position.

Similarly, and by using, as a reference, the values obtained for the less reductive metal, we can see the relative position of its peers (figure 10).

Since iron is quite important in the construction of any structure, which leads to the studies of protection to corrosion, we suggest a representation that highlights its relative position among the several metals studied.

5. Conclusions

This experiment allows the transmission and/or consolidation of electrochemical knowledge [6], namely the notion of potential and the importance of the existence of the standard electrode. Being aware that there is a wide range of factors contributing to a sometimes substantial difference between the values obtained in the experiment and the standard values, we must consider this the kind of work that can be carried out in a classroom and stands out as a motivating factor.

Naming the reasons that justify the not so good results can lead to a valuable and healthy scientific discussion among the students.

To infer which spontaneous reactions, electrical resistances, ionic interferences and concentrations, work temperature and, naturally, the experimental mistakes is always the appropriate scientific attitude.

6. Acknowledgements

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