



# CORROSION INHIBITION OF CARBON STEEL IN SODIUM CHLORIDE SOLUTION USING ARTEMISIA PLANT EXTRACT

Ishraq K. Ibrahim and Juman A. Naser\*

Department of Chemistry, College of Education for Pure Science- Ibn Al-Haitham,  
University of Baghdad, Baghdad, Iraq.

## Abstract

The mechanism of corrosion inhibition of Artemisia extract as eco-friendly inhibitor at concentrations (2, 4, 6, 8, 10) mL/L on carbon steel in 0.6 M NaCl solution at different temperatures (303, 313, 323, 333) K investigated by the weight loss measurements. Infrared spectroscopy (FTIR), scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) techniques have been done to the surface of carbon steel in an absence and present the extract to investigate the formation of an adsorbed layer. The results confirmed that the inhibition efficiency increases as the concentration of extract increase, while it decreases with an increase in the temperature. So, the maximum value of inhibition efficiency was (87.5%) for the maximum concentration of inhibitor.

**Key words:** Inhibition, Corrosion, Carbon Steel, Artemisia extract, Physisorption.

## Introduction

Carbon steel is widely used in industrial and municipal applications such as tanks, pipes, water facilities and heat exchangers. It is exposed corrosion in potable and salty water, especially in presence of the aggressive chloride ion (Revie *et al.*, 2008; Valcarce *et al.*, and Vazquez, 2010; Branzoi *et al.*, 2014; Meresht *et al.*, 2011). The use of corrosion inhibitors in the system of closed metal cooling is the most economically effective method (McCafferty, 2010; Hong *et al.*, 2017). The most common inhibitors are organic compounds containing heterogeneous atoms such as oxygen, nitrogen, sulfur, and phosphorous, which adsorb on the surface of metal (Markhali *et al.*, 2013; Obot *et al.*, 2013). The adsorption process occurs through the interaction of the free double electrons of the inhibitor molecules with the empty orbitals in the surface of metal, which creates a protective layer (Noor *et al.*, 2008; Obi-Egbedi *et al.*, 2011). In recent years, the use of organic compounds as an inhibitors has been limited due to their high cost, toxicity and environmental hazard (Ramde *et al.*, 2014; Fiori-Bimbi *et al.*, 2015). Thus, the plant extracts were used as green inhibitors of corrosion due to their contain several compounds such as polyphenols, alkaloids, sugars, amino acids and vitamins (Rani and Basu 2012; Haddadi *et al.*,

2019). An inhibition efficiency of 94 % has been achieved with *Juglans regia* green fruit shell extract for low carbon steel in 3.5% NaCl medium (Haddadi *et al.*, 2019). An inhibition efficiency about 98.8 % was acquired with 600 ppm of persian liquorice extract for carbon steel in 3.5% NaCl solution (Alibakhshi *et al.*, 2019). Inhibition efficiency of 92% was recorded with rice straw extract for carbon steel in 3.5% NaCl medium (Othman *et al.*, 2019). It is clear from these works that inhibitions effectiveness of the plant extracts is due to a presence of many organic molecules in their compositions (Li *et al.*, 2014).

This study aims to investigate the mechanism of corrosion of carbon steel in sodium chloride solution 0.6 M in various concentration of Artemisia extract as an environmentally friendly and economical inhibitor under the air influence at different temperatures. Previous studies, have shown that Artemisia plant extract contains many active compounds as it contains volatile oils, polyphenols, alkaloids, flavonoids, glycosides, and tannins which have beneficial effects on many diseases such as malaria, hepatitis, antioxidant, anti inflammatory, antibacterial and antifungal agents (Sharifi-Rad *et al.*, 2017; Nigam *et al.*, 2019; Abad *et al.*, 2012; Msaada *et al.*, 2015). Weight loss method, infrared spectroscopy (FTIR) and energy dispersion spectroscopy (EDS) were

\*Author for correspondence : E-mail : juman\_chem@yahoo.com

used to evaluate the effect of artemisia extract inhibition. Hence, the surface of metal was examined in an absence and presence of the inhibitor using the electronic scanning microscope (SEM).

## Materials and Methods

### Preparation of samples

Carbon steel samples were used in the current study are composed of the following composition given in Table 1. The used samples in weight loss measurements have been cut into 3cm x 1.5cm x 2mm pieces. The metal surface of carbon steel samples were smoothed by different grades of SiC paper and washed by distilled water, then dried with a cloth.

### Preparation of corrosive solution

To conduct the study of corrosion, saline solution of 0.6 M NaCl was prepared by dissolve sodium chloride crystals in distilled water.

### Preparation of inhibitor

Artemisia plant powder was washed with distilled water to remove the soil and dust residue and then 10 g was extracted by boiling water for 3 h. The water was evaporated from the extracted plant to obtain a concentrated solution 200 mL after the filtration. The plant extract has been used to investigate the inhibition of carbon steel in various concentrations (2, 4, 6, 8 and 10) mL L<sup>-1</sup> at different temperatures (303, 313, 323 and 333) K.

### Experiments of corrosion

The study of presence of an inhibitor concentrations from Artemisia plant extract on the corrosion of carbon steel in 0.6 M NaCl medium was investigated by weight loss method at range of the temperatures after 3 h of the immersion period for all concentrations. The values of inhibition efficiency IE% and corrosion rate CR were calculated. The samples of carbon steel have been weighed after the immersion in 50 mL of the corrosive medium in an absence and presence of different concentrations of the inhibitor. The samples were cleaned using distilled water and dried with a cloth, then weighed by balance Sartorius Lab-210S (Germany).

The corrosion rates CR were estimated from the relationship as given (Obot *et al.*, 2013):

$$CR = \frac{\Delta w}{A \times t} \quad (1)$$

**Table 1:** The chemical composition of carbon steel sample.

C %	Mo %	Si %	Mn %	P %	S %	Cr %	Al %	Cu %	Ni %
0.128	0.002	0.0289	0.437	0.0052	0.0024	0.0028	0.0383	0.0113	0.0148

where  $\Delta W$  is the weight loss (g), A is the total area of carbon steel sample (m<sup>2</sup>) and t is the time of immersion (day).

The inhibition efficiency was estimated by utilizing the following relationship:

$$IE\% = \frac{CR_{uninh.} - CR_{inh.}}{CR_{uninh.}} \times 100 \quad (2)$$

where CR<sub>uninh.</sub> and CR<sub>inh.</sub> are the rates of corrosion for samples of carbon steel in an absence and presence of the inhibitor, respectively.

### FTIR analysis

The components of inhibitor which adsorbed on the carbon steel surface can be characterized by FTIR technique. The infrared spectrum of the extract and scratched sample was performed by mixing them with potassium bromide to prepare a pallets. FTIR spectrums were performed by FTIR spectrometer SIDCO-600 (England).

### SEM analysis

The carbon steel morphology were tested by scanning electron microscopy (SEM). The micrographs of SEM were taken to observe the protective layer of inhibitor and to determine the differences in the morphology of sample surface in an absence and presence of the inhibitor with the saline corrosive solution.

### EDS analysis

EDS spectrums confirmed the presence of percentages of chlorine, sodium and oxygen on the carbon steel surface. The samples were immersed in 50 mL of 0.6 M NaCl for 3 h in an absence and presence of the maximum concentration of inhibitor with the corrosive solution. SEM and EDS analysis was done using a scanning electron microscope Tescan- Mira3 (France).

## Results and discussion

### FT-IR analysis

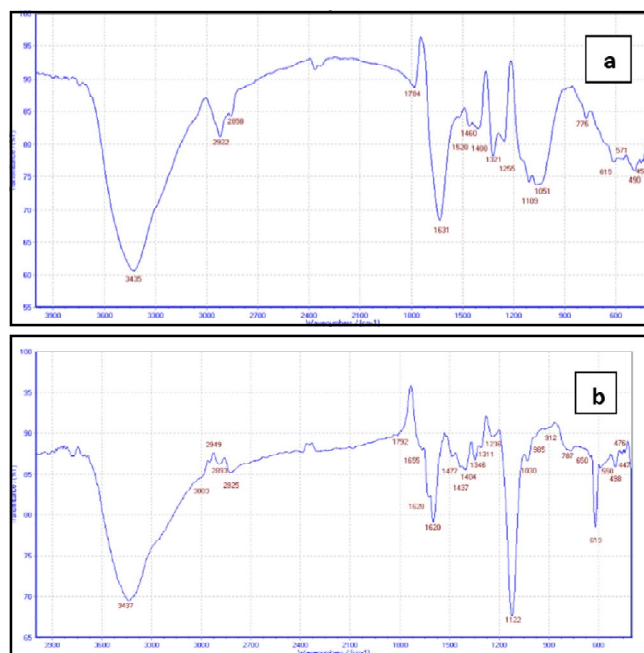
A spectroscopic study with FTIR technique was done to find the functional groups of molecules which present in the extract and their stability in 0.6 M sodium chloride solution. The spectrum of Artemisia extract is shown in Fig. 1a. A broad band is observed at 3435 cm<sup>-1</sup> attributed to the stretching vibration of hydroxyl O–H or amine N–H groups. Whereas, a clear absorption peak at 1631 cm<sup>-1</sup> due to the stretching vibration of carbonyl group (C=O) (Kemp, 2009). Thus, it is clear that the extracted organic

compounds are remain stable in 0.6 M NaCl.

Fig. 1b shows FT-IR spectrum of the adsorbed layer which protecting the surface of carbon

steel after immersed in NaCl in presence of Artemisia extract.

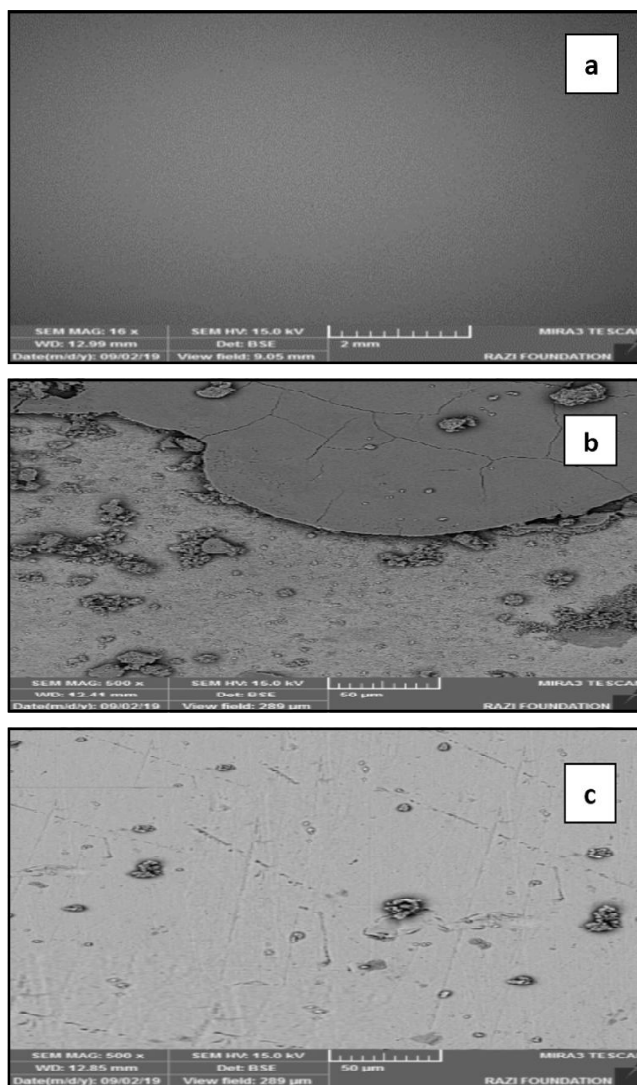
When comparing Fig. 1a and 2b, it is noted that the significant peaks of the molecules of inhibitor which are present in the adsorbed layer on the surface of carbon steel. While a shifting of these values was observed in the immersed Fig 1b. The broad band of hydroxyl O–H and amine N–H groups are shifted to  $3437\text{ cm}^{-1}$ , while peak of carbonyl group is shifted to  $1620\text{ cm}^{-1}$ . So, the peaks at  $1109\text{ cm}^{-1}$  shifted to  $1122\text{ cm}^{-1}$ . All these changes in the characteristic peaks indicate that the inhibitor molecules are adsorbed on the metal surface in 0.6 M NaCl medium.



**Fig. 1:** FTIR spectrum of a; the Artemisia extract and b; the scratched layer of the carbon steel sample immersed in 0.6 M NaCl.

### SEM analysis

The SEM micrographs of the surface of carbon steel were taken before and after the immersion in 0.6 M NaCl in an absence and presence of Artemisia extract are shown in Fig. 2. Thus, Fig. 2a shows the polished surface of carbon steel before immersion in saline solution and Fig. 2b shows the immersed surface of carbon steel in 0.6 M NaCl solution in an absence of the inhibitor. It is clear that the surface of metal heavily corroded. However, Fig. 2c shows the immersed surface of carbon steel in 0.6 M NaCl medium in presence of the inhibitor. As the presence of the inhibitor in the corrosive solution led to a decrease in the corrosion rate and gave a smooth form to the surface of carbon steel through the formation of a protective layer (Morad and El-Dean, 2006).



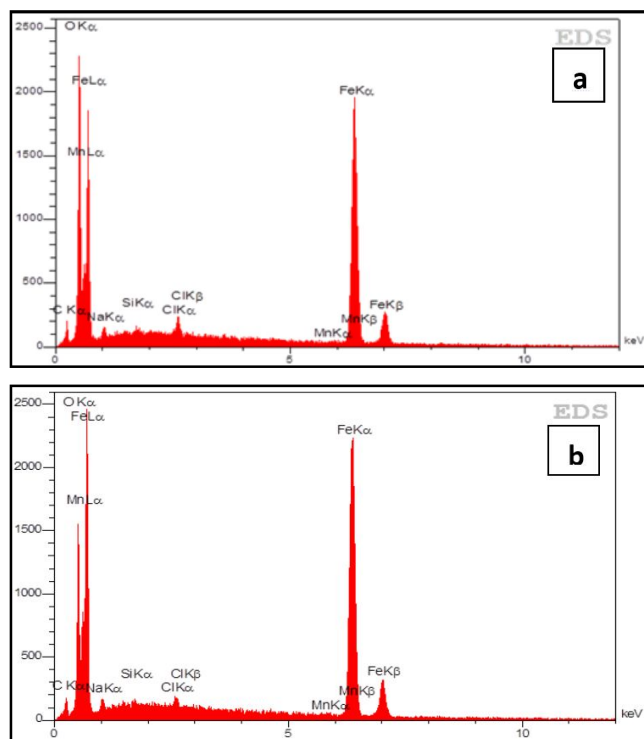
**Fig. 2:** SEM micrograph of carbon steel surface a; before the immersion, b; after the immersion in 0.6 M NaCl solution and c; in presence of the inhibitor.

### EDS analysis

EDS analysis was performed to determine the weight percentage of elements that present in low carbon steel in 0.6 M NaCl solution in an absence and presence of the inhibitor, Fig. 3a. It was observed from the EDS analysis of carbon steel immersed in the aggressive solution of 0.6 M NaCl that the oxygen concentration was high 18.2% , Fig. 3b and Table 2, due to the oxidation of the alloy surface. In the presence of inhibitor, a decrease in the concentration of chlorine was observed in presence of the inhibitor, which confirms the formation

**Table 2:** EDS element ratios of carbon steel surface immersed in 0.6 M NaCl solution in an absence and presence of the inhibitor.

NaCl medium	C	O	Na	Si	Cl	Mn	Fe
Un inhibitor	6.35	26.71	0.69	0.14	0.95	0.11	65.05
Inhibitor	6.43	18.20	0.91	0.18	0.62	0.23	73.42



**Fig. 3:** EDS spectrum of carbon steel surface immersed in 0.6 M NaCl solution in a; an absence and b; presence of the inhibitor.

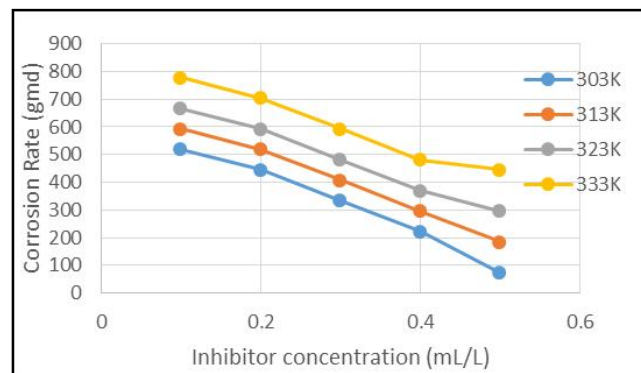
of a protective layer from the inhibitor molecules on the alloy surface (Ostovari *et al.*, 2009). While an increase in the oxygen concentration is attributed to the donor oxygen atoms which present in the inhibitor molecules.

### Measurements of weight loss

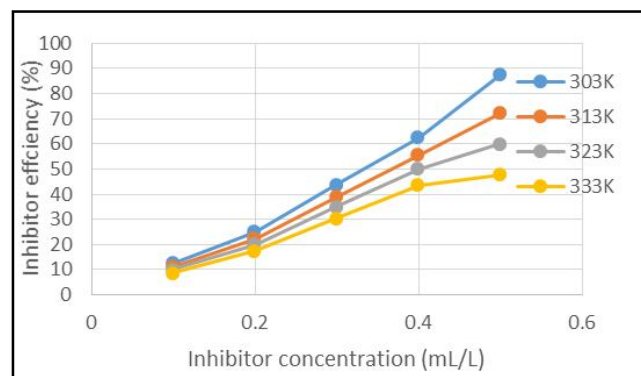
#### Effect of concentration and temperature

The measurements of weight loss applied to investigate the inhibitive properties of Artemisia extract on the corrosion of carbon steel in 0.6 M NaCl solution in an absence and presence of various concentrations of the extract at different temperatures (303–333) K. It is clear from the results that the inhibition efficiency IE% increased as the concentration of the extract increased, while it decreased with an increase in the temperature that confirms a physisorption mechanism (Kamal and Sethuraman, 2013). This refers to increasing in the adsorbed molecules of extract on the carbon steel surface as a result to increasing extract concentration. The maximum efficiency of inhibition was 87.5% by Artemisia extract at concentration 10 mL/L and 303 K. Fig. 4 shows the corrosion rate values against concentrations for the corrosion of carbon steel in 0.6 M NaCl in presence of various concentrations of the extract and at different temperatures. Thus, the weight loss of carbon steel increased with increasing temperature reflecting the desorption process of the adsorbed extract molecules

from the carbon steel surface at high temperatures. Fig. 5 shows the inhibition efficiency values versus concentrations for the corrosion of carbon steel in 0.6 M NaCl at different temperatures in presence of the various inhibitor concentrations. The inhibition efficiency increases as the concentration of the extract increase and it decreases with an increase in the temperatures.



**Fig. 4:** Corrosion rate values of carbon steel in 0.6 M NaCl at different temperatures in an absence and presence of the various inhibitor concentrations.



**Fig. 5:** Inhibition efficiency values of carbon steel in 0.6 M NaCl at different temperatures in an absence and presence of the various inhibitor concentrations.

### Conclusions

FTIR, SEM and EDS techniques was performed to the immersed carbon steel in 0.6 M NaCl in an absence and present the extract of Artemisia plant to investigate the formation of an adsorbed layer on the surface of metal. The inhibition efficiency increases as the concentration of the extract increase and it decreases with an increase in the temperatures range (303-333) K. In addition the maximum value of inhibition efficiency was (87.5%) for a concentration 10 mL/L of the extract of Artemisia plant.

### References

- Abad, M.J., L.M. Bedoya, L. Apaza and P. Bermejo (2012). The *Artemisia* L. genus: a review of bioactive essential oils. *Molecules*, **17**(3): 2542-2566.␣

- Alibakhshi, E., M. Ramezanzadeh, S.A. Haddadi, G. Bahlakeh, B. Ramezanzadeh and M. Mahdavian (2019). Persian Liquorice extract as a highly efficient sustainable corrosion inhibitor for mild steel in sodium chloride solution. *Journal of cleaner production*, **210**: 660-672.‡
- Branzoi, F., V. Branzoi and C. Licu (2014). Corrosion inhibition of carbon steel in cooling water systems by new organic polymers as green inhibitors. *Materials and Corrosion*, **65(6)**: 637-647.‡
- Fiori-Bimbi, M.V., P.E. Alvarez, H. Vaca and C.A. Gervasi (2015). Corrosion inhibition of mild steel in HCL solution by pectin. *Corrosion Science*, **92**: 192-199.‡
- Haddadi, S.A., E. Alibakhshi, G. Bahlakeh, B. Ramezanzadeh and M. Mahdavian (2019). A detailed atomic level computational and electrochemical exploration of the *Juglans regia* green fruit shell extract as a sustainable and highly efficient green corrosion inhibitor for mild steel in 3.5 wt% NaCl solution. *Journal of Molecular Liquids*, **284**: 682-699.‡
- Hong, S., H. Wiggenhauser, R. Helmerich, B. Dong, P. Dong and F. Xing (2017). Long-term monitoring of reinforcement corrosion in concrete using ground penetrating radar. *Corrosion Science*, **114**: 123-132.‡
- Kamal, C. and M.G. Sethuraman (2013). *Hydroclathrus clathratus* marine alga as a green inhibitor of acid corrosion of mild steel. *Research on Chemical Intermediates*, **39(8)**: 3813-3828.‡
- Kemp, W. (2009). *Organic Spectroscopy*, 3rd edn., Palgrave, New York, 58-88.‡
- Li, X., S. Deng, H. Fu and X. Xie (2014). Synergistic inhibition effects of bamboo leaf extract/major components and iodide ion on the corrosion of steel in H<sub>3</sub>PO<sub>4</sub> solution. *Corrosion Science*, **78**: 29-42.‡
- Markhali, B.P., R. Naderi, M. Mahdavian, M. Sayebani and S.Y. Arman (2013). Electrochemical impedance spectroscopy and electrochemical noise measurements as tools to evaluate corrosion inhibition ofazole compounds on stainless steel in acidic media. *Corrosion Science*, **75**: 269-279.‡
- Mc Cafferty, E. (2010). Introduction to corrosion science. *Springer Science and Business Media*.‡
- Meresht, E.S., T.S. Farahani and J. Neshati (2011). Failure analysis of stress corrosion cracking occurred in a gas transmission steel pipeline. *Engineering Failure Analysis*, **18(3)**: 963-970.‡
- Morad, M.S. and A.K. El-Dean (2006). 2, 22 -Dithiobis (3-cyano-4, 6-dimethylpyridine): A new class of acid corrosion inhibitors for mild steel. *Corrosion science*, **48(11)**: 3398-3412.‡
- Msaada, K., N. Salem, O. Bachrouch, S. Bousselmi, S. Tammar, A. Alfaify and M. Hammami (2015). Chemical composition and antioxidant and antimicrobial activities of wormwood (*Artemisia absinthium* L.) essential oils and phenolics. *Journal of Chemistry*, 2015.‡
- Nigam, M., M. Atanassova, A.P. Mishra, R. Pezzani, H.P. Devkota, S. Plygun and J. Sharifi-Rad (2019). Bioactive Compounds and Health Benefits of Artemisia Species. *Natural Product Communications*, **14(7)**: 1934578X19850354.‡
- Noor, E.A. and A.H. Al-Moubaraki (2008). Thermodynamic study of metal corrosion and inhibitor adsorption processes in mild steel/1-methyl-4 [42 (-X)-styryl pyridinium iodides/hydrochloric acid systems. *Materials Chemistry and Physics*, **110(1)**: 145-154.‡
- Obi-Egbedi, N.O. and I.B. Obot (2011). Inhibitive properties, thermodynamic and quantum chemical studies of alloxazine on mild steel corrosion in H<sub>2</sub>SO<sub>4</sub>. *Corrosion science*, **53(1)**: 263-275.‡
- Obot, I.B., E.E. Ebenso and M.M. Kabanda (2013). Metronidazole as environmentally safe corrosion inhibitor for mild steel in 0.5 M HCl: experimental and theoretical investigation. *Journal of Environmental Chemical Engineering*, **1(3)**: 431-439.‡
- Ostovari, A., S.M. Hoseinie, M. Peikari, S.R. Shadizadeh and S.J. Hashemi (2009). Corrosion inhibition of mild steel in 1 M HCl solution by henna extract: A comparative study of the inhibition by henna and its constituents (Lawson, Gallic acid, á-d-Glucose and Tannic acid). *Corrosion Science*, **51(9)**: 1935-1949.‡
- Othman, N.K., S. Yahya and M.C. Ismail (2019). Corrosion inhibition of steel in 3.5% NaCl by rice straw extract. *Journal of Industrial and Engineering Chemistry*, **70**: 299-310.‡
- Ramde, T., S. Rossi and C. Zanella (2014). Inhibition of the Cu65/Zn35 brass corrosion by natural extract of *Camellia sinensis*. *Applied Surface Science*, **307**: 209-216.‡
- Rani, B.E. and B.B.J. Basu (2012). Green inhibitors for corrosion protection of metals and alloys: an overview. *International Journal of corrosion*, 2012.‡
- Revie, R.W. (2008). Corrosion and corrosion control: an introduction to corrosion science and engineering. *John Wiley and Sons*.‡
- Sharifi-Rad, J., A. Sureda, G.C. Tenore, M. Daglia, M. Sharifi-Rad, M. Valussi and R. Sharifi-Rad (2017). Biological activities of essential oils: From plant chemoecology to traditional healing systems. *Molecules*, **22(1)**: 70.‡
- Valcarce, M.B. and M. Vazquez (2010). Phosphate ions used as green inhibitor against copper corrosion in tap water. *Corrosion science*, **52(4)**: 1413-1420.‡