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Summary

Description	In the previous chapter 4, formulae-based mnemonics have been discussed in a time economic ground to predict the bond order of homo and heteronuclear diatomic species without drawing their electronic configurations based on molecular orbital theory (MOT). In this chapter 5, prediction of bond order of oxide-based acid radicals has been discussed without drawing their Lewis structures in a time economic way. This chapter explores the results and gives implications for context-based teaching, learning, and assessment. Bond-order of oxide-based acid radicals previously predicted by the conventional method after drawing Lewis structures of radicals. Now, with the help of this time economic innovative mnemonics, bond-order of oxide-based acid radicals can be predicted from the simple molecular formulae of the oxide-based acid radicals without drawing their Lewis structures.
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Chapter – 5

INNOVATIVE METHOD FOR THE PREDICTION OF THE BOND ORDER OF OXIDE BASED ACID RADICALS

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In the previous chapter 4, formulae-based mnemonics have been discussed in a time economic ground to predict the bond order of homo and heteronuclear diatomic species without drawing their electronic configurations on the basis of molecular orbital theory (MOT).

In this chapter 5, prediction of bond order of oxide-based acid radicals has been discussed without drawing their Lewis structures in a time economic way. This chapter explores the results and gives implications for context-based teaching, learning, and assessment. Bond-order of oxide-based acid radicals previously predicted by the conventional method after drawing Lewis structures of radicals.

Now, with the help of this time economic innovative mnemonics, bond-order of oxide-based acid radicals can be predicted from the simple molecular formulae of the oxide-based acid radicals without drawing their Lewis structures.

METHODOLOGY

A. The conventional method for prediction of bond order of oxide-based acid radicals

Remember the following steps to determine the bond order of the oxide-based acid radical:

- Draw the Lewis structure of the oxide-based acid radicals.
- Count the total number of bonds.
- Count the number of bond groups between individual atoms.
- Divide the number of bonds between atoms by the total number of bond groups in the molecule to get Bond Order of the oxide-based acid radicals.

B. Innovative method for prediction of bond order of oxide-based acid radicals

Bond order of oxide-based acid radicals can be calculated from the simple molecular formulae of the acid radicals in the following way[1, 2].

1.A. Das, "Innovative Mnemonics In Chemical Education: Review Article", *African Journal of Chemical Education* 8 (July 2018):144-189, https://www.ajol.info/index.php/ajce/article/view/176086.

2.A. Das, "Innovative Mnemonics Make Chemical Education Time Economic – A Pedagogical Review Article", *World Journal of Chemical Education* 6 (Sept 2018):154-174, doi:10.12691/wjce-6-4-2, http://pubs.sciepub.com/wjce/6/4/2/index.html.

In case of oxide-based acid radicals

Bond Order (B.O.) = Valency of the peripheral atom + (Charge on Acid Radical / Total number of peripheral atoms)

= Vo + (e/Np) = 2 + (Charge on Acid Radical /Total number of peripheral atoms)

Vo = Valency of the oxygen atom = 2, e = Charge on Acid Radical and Np = Total number of peripheral atoms

RESULTS AND DISCUSSION

Prediction of bond order of oxide-based acid radicals by innovative method:

It can be illustrated by the following examples

Ex:

ClO_4^- : (Valency of one Peripheral atom Oxygen = 2, Charge on acid radical = -1, Total Number of Peripheral atoms = 04), Therefore B.O. = 2 + (-1/4) = 1.75

ClO_3^- : (Valency of one Peripheral atom Oxygen = 2, Charge on acid radical = -1, Total Number of Peripheral atoms = 03), Therefore B.O. = 2 + (-1/3) = 1.66

ClO_2^- : (Valency of one Peripheral atom Oxygen = 2, Charge on acid radical = -1, Total Number of Peripheral atoms = 02), Therefore B.O. = 2 + (-1/2) = 1.5

AsO_4^{3-} : (Valency of one Peripheral atom Oxygen = 2, Charge on acid radical = -3, Total Number of Peripheral atoms = 04), Therefore B.O. = 2 + (-3/4) = 1.25

AsO_3^{3-}: (Valency of one Peripheral atom Oxygen = 2, Charge on acid radical = -3, Total Number of Peripheral atoms = 03), Therefore B.O. = 2 + (-3/3) = 1.0

SO_4^{2-} : (Valency of Peripheral atom Oxygen = 2, Charge on acid radical = -2, Number of Peripheral atoms = 04), Therefore B.O. = 2 + (-2/4) = 1.5

SO_3^{2-} : (Valency of Peripheral atom Oxygen = 2, Charge on acid radical = -2, Number of Peripheral atoms = 03), Therefore B.O. = 2 + (-2/3) = 1.33

PO_4^{3-} ; (Valency of Peripheral atom Oxygen = 2, Charge on acid radical = -3, Number of Peripheral atoms = 04), Therefore B.O. = 2 + (-3/4) = 1.25

BO_3^{3-} ; (Valency of Peripheral atom Oxygen = 2, Charge on acid radical = -3, Number of Peripheral atoms = 03), Therefore B.O. = 2 + (-3/3) = 1

CO_3^{2-} ;(Valency of Peripheral atom Oxygen = 2, Charge on acid radical = -2, Number of Peripheral atoms = 03), Therefore B.O. = 2 + (-2/3) = 1.33

SiO_4^{4-}:(Valency of Peripheral atom Oxygen = 2, Charge on acid radical = - 4, Number of Peripheral atoms = 04), Therefore B.O. = 2 + (- 4/4) = 1

Oxoacids and their anions (oxide based acid radicals)

Formula of Oxoacid	Name	Radicals
$HClO_4$	Perchloric acid	tetraoxochlorate (ClO_4^-)
$HClO_3$	Chloric acid	trioxochlorate (ClO_3^-)
$HClO_2$	Chlorous acid	dioxochlorate (ClO_2^-)
$HClO$	Hypochlorous acid	monooxochlorate (ClO^-)
H_3AsO_4	Arsenic acid	tetraoxoarsenate (AsO_4^{3-})
H_3AsO_3	Arsenous acid	trioxoarsenate (AsO_3^{3-})
H_2SO_4	Sulfuric acid	tetraoxosulfate (SO_4^{2-})
H_2SO_3	Sulfurous acid	trioxosulfate (SO_3^{2-})
H_3PO_4	Phosphoric acid	tetraoxophosphate (PO_4^{3-})
H_3PO_3	Phosphorous acid	trioxophosphate (PO_3^{3-})
H_3BO_3	Boric acid	trioxoborate (BO_3^{3-})
H_2CO_3	Carbonic acid	trioxocarbonate (CO_3^{2-})

APPLICATIONS OF BOND ORDER IN CHEMICAL EDUCATION:

Relation of different bond parameters (Bond length, Bond Strength, Bond energy, Thermal stability and Reactivity) with Bond order:

B.O. α 1 / Bond length or Bond distance;

B.O. α Bond strength;

B.O. α Bond Energy;

B.O. α Bond dissociation Energy;

B.O. α Thermal Stability; B.O. α 1 / Reactivity

Correlation among Literature values of bond-distances (Å) of some oxide-based acid radicals with their predicted bond order values:

Literature values of the Cl-O average bond lengths in ClO_4^-, ClO_3^- and ClO_2^- are 1.50, 1.57 and 1.64 (Å) for their predicted bond orders values 1.75, 1.6 and 1.5 respectively; As-O average bond lengths in AsO_4^{3-} and

AsO_3^{3-} are 1.75 and 1.77 (Å) for their predicted bond order values 1.25 and 1.0 respectively which suggests that with increasing Bond-Order bond length decreases.

Conclusion

It may be expected that this time economic innovative mnemonic, described in this chapter 5, will help students and educators in chemical education at Undergraduate, Senior Undergraduate and Post-Graduate level to predict the bond order of oxide-based acid radicals without drawing their Lewis structures in a time economic way. Experiments, *in vitro*, on 100 students, showed that, by using this innovative formula, students can save up to 2-3 minutes' time in the examination hall to solve different problems regarding bond order and its related properties like bond length, bond Strength, bond dissociation energy etc. of oxide-based acid radicals in inorganic chemistry. On the basis of this, I can strongly recommend using this time economic innovative mnemonic in inorganic chemistry.

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