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Research Article

QUANTITATIVE STRUCTURE- PROPERTY RELATIONSHIP STUDY FOR PREDICTION OF BOILING POINT OF ALIPHATIC ALKANES

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ABSTRACT

Objective: QSPR (quantitative structure property relationship) models represent well-established tools for the molecular design of new compounds with desired properties. These are statistically based and aimed at extracting the maximum information from experimental data on compounds of known structure. The main objective of the study is to calculate the topological descriptors and to generate the multiple linear regression models for the prediction of boiling point of aliphatic alkanes.

Methods: Quantitative structure-property relationship (QSPR) studies had been performed on 30 compounds of a series of aliphatic alkanes. Multivariable models were developed for calculating a number of topological descriptors to predict the boiling points of 30 alkanes having 1-10 carbon atoms. The QSPR models were generated to determine multiple correlation coefficient and standard error by using SPSS software. The experimental boiling point values have been correlated with calculated boiling point by using multiple linear regression (MLR) analysis.

Results: This study produced good predictive models which gave statistically significant correlations with good multiple correlation coefficient (R = 0.997) and minimum standard error (SE = 4.753) using topological descriptors as QSPR parameters.

Conclusion: The models were used to predict the boiling points of alkanes for a set of test data from 1-10 carbon atoms for which no experimental boiling point data existed.

Keywords: Multiple correlation coefficient; MLR models; QSPR; Topological descriptors.

INTRODUCTION

Quantitative Structure-property relationship (QSPR) is an alternative approach for estimating boiling point of any compound. The premise of QSPR is that phsico-chemical properties can be correlated with molecular structure characteristics (geometric and electronic) expressed in terms of appropriate molecular descriptors[1]. QSPR studies are undoubtly of great importance in modern chemistry and pharmacy. QSPR have been traditionally developed by selecting, a priori, an analytical model (typically) linear, polynomial or lag-linear to quantity the correlation between selected molecular indices and desired physico-chemical properties, followed by regression analysis to determine model parameters[2]. The various alkanes can be characterized by their physical properties including boiling points. Experimental boiling point datas are not available for all of the alkanes with n ≤ 10. This lack of data is a motivation for constructing boiling point models which can be used to estimate the b.p. of alkanes for which no data is available[3].

MATERIALS AND METHODS

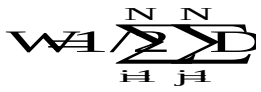
Alkanes

A series of 30 alkanes were selected (up to 10 carbon atom) for the present study. Then the structures of these alkanes were generated for the calculation of various topological descriptors by methematical expressions.

Calculation of Topological Descriptors[4-9]

a. Wiener Index [W]

It can be calculated as given below.



Where- Dij is graph distance matrix.

b. Schultz Index [MTI]

It can be calculated as given below.

$$MTI = \sum \text{elements of } \underline{V}\left(\underline{A} + \underline{D}\right)$$

Where- V = Valency row matrix , A = Adjacency matrix, D = Distance matrix

c. Randic Index [^1X_p]

It can be calculated as given below.

$$^1X_p = \sum (\delta_1 \, \delta_2)^{-1/2}$$

Where- ^1X_p = a path of order 1(i.e., a path of 1 connected edges or bonds), δ = Sum over all paths of order 1.

d. Balaban Index [J]

It can be calculated as given below.

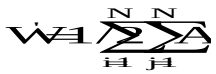
Where- M = Number of Bonds, U = Minimum no. of cuts to reduce a cyclic compound to acyclic.

e. Harary Index [H]

It can be calculated as given below.

f. Wiener Index [W']

It can be calculated as given below.



Where- Aij is graph adjacencey matrix

g. Balaban Index [J']

It can be calculated as given below.

Where- M = Number of Bonds, U = Minimum no. of cuts to reduce a cyclic compound to acyclic.

h. Randic Index [^2X_p]

It can be calculated as given below.

$$^2X_p = \sum (\delta_1 \delta_2 \delta_3)^{-1/2}$$

Where- ^2X_p = a path of order 2(i.e., a path of 2 connected edges or bonds), δ = Sum over all paths of order 2.

Generation of Multiple Linear Regression [MLR] models for the b.p. of alkanes with n ≤10

In this method regression analysis was done in a stepwise fashion by taking topological descriptors such as W (wiener index), SMTI (schultz index), ^1X_p(randic index), J(balaban index), H(harary index), W'(wiener index), J'(balaban index), ^2X_p (randic index) (table 1) for correlation with boiling point of alkanes.

a) MLR models using 1 parameter:-B.P v/s W etc

b) MLR models using 2 parameter:- B.P v/s W, MTI etc

c) MLR models using 3 parameter:- B.P v/s W, MTI, ^1X_p etc

d) MLR models using 4 parameter:- B.P v/s W, MTI, ^1X_p, J etc

e) MLR models using 5 parameter:- B.P v/s W, MTI, ^1X_p, J, H etc

f) MLR models using 6 parameter:- B.P v/s W, MTI, ^1X_p, J, H, W' etc

g) MLR models using 7parameter:-B.P v/s W, MTI, ^1X_p, J, H, W', J' etc

h) MLR models using 8 parameter:-B.P v/s W, MTI, ^1X_p, J, H,W', J', ^2X_p etc

Table 1: The name of alkanes, their experimental boiling point and topological properties which are used in present study

S. No.	Name of the Compound	Experimental B.P.	W	MTI	J	^1X_P	H	W'	J'	^2X_P
1	Methane	-162.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Ethane	-88.60	2.00	4.00	1.00	1.00	1.00	1.00	1.00	0.00
3	Propane	-42.20	4.00	16.00	1.63	1.41	2.25	2.00	2.83	0.71
4	Butane	-0.10	10.00	38.00	1.98	1.91	3.61	3.00	5.74	1.00
5	2-methyl propane	-11.20	9.00	36.00	3.32	1.73	3.75	3.00	5.18	1.73
6	Pentane	36.10	20.00	74.00	2.19	2.41	5.03	4.00	9.67	1.35
7	2-methyl butane	27.00	18.00	68.00	2.54	2.27	5.25	4.00	9.08	1.80
8	2,2-di methyl propane	9.50	16.00	64.00	3.02	2.00	5.50	4.00	8.00	2.00
9	Hexane	68.80	35.00	128.00	2.34	2.91	6.49	5.00	14.57	1.71
10	2-methyl pentane	60.90	32.00	118.00	2.63	2.77	6.69	5.00	13.85	2.18
11	3-methyl pentane	63.30	31.00	114.00	2.75	2.81	6.75	5.00	14.04	1.92
12	2,2-di methyl butane	49.80	28.00	106.00	3.17	2.56	7.08	5.00	12.80	2.06
13	2,3-di methyl butane	58.10	29.00	108.00	3.00	2.64	6.94	5.00	13.22	2.49
14	Heptane	98.50	56.00	204.00	2.45	3.41	7.99	6.00	20.48	2.06
15	3-ethyl pentane	93.50	48.00	174.00	2.99	3.35	8.34	6.00	20.08	1.80
16	2,2-di methyl pentane	79.20	46.00	170.00	3.16	3.06	8.50	6.00	18.36	2.46
17	2,3-di methyl pentane	89.80	46.00	168.00	3.14	3.18	8.48	6.00	19.08	2.63
18	2,4-di methyl pentane	80.60	48.00	176.00	2.95	3.13	8.40	6.00	18.76	3.02
19	2- methyl hexane	90.10	52.00	190.00	2.68	3.27	8.20	6.00	19.62	2.54
20	3-methyl hexane	91.80	50.00	182.00	2.83	3.31	8.27	6.00	19.85	2.30
21	Octane	125.60	84.00	306.00	2.53	3.91	9.50	7.00	27.40	2.41
22	3-methyl heptane	118.90	76.00	276.00	2.86	3.81	9.81	7.00	26.65	3.01
23	2,2,3,3-tetramethyl butane	106.50	58.00	214.00	4.02	3.25	10.99	7.00	22.75	3.00
24	2,3,3-tri methyl pentane	114.70	62.00	226.00	3.71	3.50	10.56	7.00	24.53	2.79
25	2,3,4-tri methyl pentane	113.70	65.00	236.00	3.46	3.55	10.37	7.00	24.88	3.34
26	2,2,4-tri methyl pentane	99.30	66.00	242.00	3.39	3.42	10.91	7.00	23.92	3.51
27	Nonane	150.70	120.00	438.00	2.59	4.41	11.03	8.00	35.31	2.77
28	2-methyl octane	143.00	114.00	416.00	2.89	4.27	11.26	8.00	34.15	3.53
29	Decane	174.20	165.00	564.00	2.66	4.91	12.56	9.00	44.23	3.12
30	2-methyl nonane	166.90	158.00	578.00	2.78	4.77	12.80	9.00	42.92	3.61

RESULTS AND DISCUSSION

In the present study the boiling point models for alkanes have been generated by the help of 8 topological descriptors ((W, MTI, J, ^1X_P, H, W', J' & ^2X_P) using multiple linear regression methods. Total 255 MLR models were prepared out of which 8 models selected on the basis of good R values (which are more near to 1) and SE (minimum standard) are listed below:

Model no. 5 : BP = - 65.553 + 16.709 * H

R = 0.952, SE = 17.510, F = 879.460

Model no. 29: BP = - 148.628 + 83.753 * ^1X_P – 1.689 * J'

R = 0.987, SE = 9.319, F = 1668.212

Model no. 50: BP = - 147.621 – 0.570 * W + 78.032 * ^1X_P + 0.651 * J'

R = 0.990, SE = 8.330, F = 1399.624

Model no. 112: BP = - 141.369 – 0.443 * W + 1.247 * J – 14.703 * H + 61.675 * W'

R = 0.991, SE = 7.968, F = 1149.549

Model no.167: BP = -141.536 + 0.045 * W – 0.152 * MTI + 0.354 * J – 14.116* H +61.907 * W

R = 0.991, SE = 7.839, F = 950.920

Model no. 221: BP = - 149.882 – 0.426 * W – 0.034 * MTI + 1.550 * J + 66.963 * ^1X_P + 4.038

* H + 4.055 * ^2X_P

R = 0.995, SE = 6.085, F = 1325.203

Model no. 254: BP = - 149.371 – 0.367 * W – 0.053 * MTI + 1.118 * J + 45.032 * ^1X_P – 2.594

* H + 23.298 * W' – 0.822 * ^2X_P

R = 0.995, SE = 5.745, F = 1275.891

Model no.255: BP = - 162.978 + 0.156 * W – 0.025 * MTI + 2.211 * J + 73.720 * ^1X_P + 8.917

* H + 1.785 * W' – 3.885 * J' – 2.461 * ^2X_P

Out of these models, the model 255 (with 8 topological parameters) gives good value of R and less standard error and can be considered as best model for prediction of approximate boiling point of any alkane for which BP is not present. The values obtained for BP from it are more close to that of experimental BP. The plot of experimental v/s calculated B.P. values for model 255 is given in figure1.

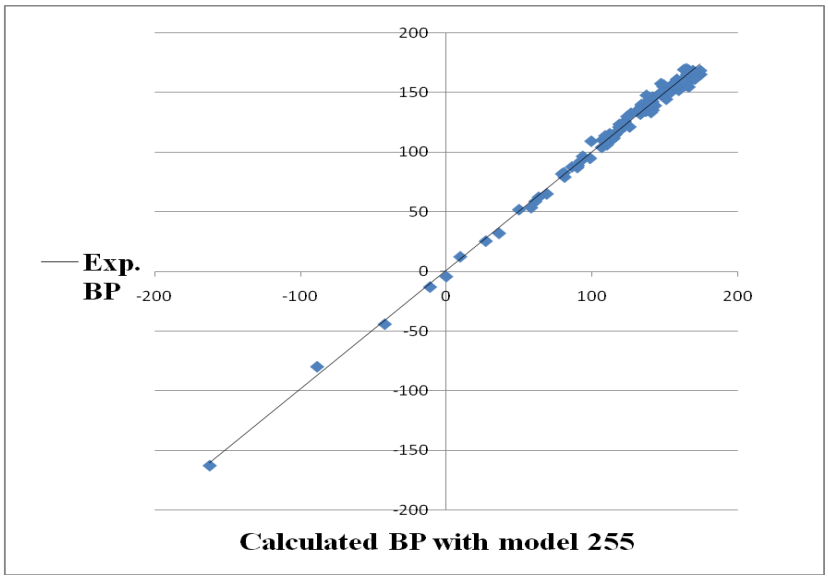


Fig. 1: Experimental boiling points v/s calculated boiling points using model no.255

CONCLUSION

The results and discussion made above leads to the conclusion that QSPR study can be successfully done for predicting boiling point of aliphatic alkanes by using topological properties. Thus, the model 255 (with 8 topological properties) can be used for the determination of approximate boiling point of any alkane having n≤10.

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