

Synthesis, Spectrophotometric, Voltammetric and DFT Studies of THICZs for sensing small molecules.

Zehbah Ali Al-Ahmed¹*, Ibrahim H.I.Habib², Reham R. Khattab³, Reda M. Abdelhameed², Mohamed El-Naggar⁴, Moursi H. Abu Bieh³, Sergey A. Pisarevd⁵, Andrey Voronkov⁶, Mardia T. El Sayed²*

¹College of Art and Sciences - Dhahran Aljounb, King Khalid University, Saudi Arabia

²Applied Organic Chemistry Department, Chemical Industries Research Division, National Research Centre, Dokki, 12311, Egypt.

³Photochemistry Department, Chemical Industries Research Division, National Research Centre, Dokki, 12311, Egypt.

⁴Chemistry Department, Faculty of Sciences, University of Sharjah, Sharjah, 27272, UAE.

⁵Institute of Physiologically Active Compounds, Russian Academy of Sciences,142432 Chernogolovka, Russian Federation.

⁶Digital Bio Pharm Ltd., 145-157 St. John Street, London, EC1V 4PW, U.K.

Corresponding authors:

Dr. Mardia El Sayed, mardia.elsayed2016@gmail.com Dr. Zehbah Ali Ahmed, zehbah.ahmed_999@yahoo.com

Abstract

Absorption spectra of tetrahydro[3,2-b]indolo-carbazoles (THICZs) with respective molecular property and alkyl substituents have been prerecorded in diverse solvents in the scope between 200 to 600 nm for very fewer times in the literary study. The photo physical behaviour of liquified THICZs belonging to the existence surroundings. The solvatochromic behaviours of THICZs and solvent substance physical phenomenon can be analysed by implementation of linear solvating energy state conception. Compound 4 show excellent properties for sensing small molecules. The electrochemical behaviour of some THICZs was investigated at carbon paste electrode where two electrode reactions were involved, irreversible oxidation-one electron transfer and quasi-reversible redox reactions forming phenolic followed by quinolone moiety electro active species. The DFT which means (calculated molecular orbital energies (B3LYP/6-31G) and HOMO-LUMO gap / space for some presented indolocarbazoles have been performed.

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/jhet.4153



Key words:

Indolocarbazoles, Spectrophotometric, Voltammetric Studies, DFT- calculated molecular orbitals, Chemical Sensors.

Conclusion

Accepted Articl

The significance of this article including measuring the dissolving agent actions on Ultraviolet–visible (UV–vis) absorption spectra of our target THICZs come from its significant applications in many fields like designing new dyes, engineering light-emitting....etc. furthermore it can be useful in the fields of photodynamic therapy and molecular imaging. Solvatochromism, changing the colour of chemical compounds due to a change in solvent polarity, is important tool for understanding the solvent effects on chemical and biological processes. In this work, some of THICZs were synthesized and its structures were characterized by assorted instrumentation of spectral and analytical data. Those have been utilized for investigating in antithetic solvent for perceptive effects of dissolving agent on the absorption spectra of these THICZs. In addition, Quantitative classification of solvatochromic behaviours of targeted THICZs compounds was analyzed via linear salvation energy relationship. The principal outcome points that there is positive solvatochromism which implement bath chromic shift with increase in solvent polarizability and solvent bond basicity. This declares stabilization of the electronic excited state proportional to the ground state. The positive mark of a coefficient for all THICZs show a hypsochromic shifts with accelerative solvent hydrogen-bond donor acidity. This intimate stabilization of the ground state relational to the electronic excited state. Count on the structure of indolic compounds, cyclic voltammetry established that few indolic compounds were susceptible to oxidation under certain conditions while others were apparently resisted to the oxidation. Form the DFT studies we can say that the *tris*-indole compound **3b** its HOMO generally corresponds to that of the dimeric structure 3a, while LUMO is mostly the corresponding orbital of the 2-indolyl substituent. The aromatic character of the central ring in compound 4 does not alter significantly the orbital picture of the non-substituted scaffold. The energy difference between *trans* and *cis* isomers of compound **3d** (ca. 0.80 kcal / mol in favor of the former) could be considered almost negligible in the present investigations context.

List of Abbreviations (if any)

THICZs : Tetrahydro[3,2-b]indolo-carbazoles OLEDs : Organic light-emitting diodes OFETS : Organic field-effect transistors

DSSCs: Dye sensitized solar cells

PSCs: Photovoltaic solar cells

LSER : Linear solvation energy relationship

1. Introduction

5,11-tetrahydroindolo[3,2-*b*]carbazoles (we will named it THICZs for short) have attracted overmuch care all over the past decennary because of their prospective electrical and optical material possession (high charge carrier mobility). It has been demonstrated that it could be utilized as progressive substantial for organic light-emitting diodes (OLEDs) [1], organic field-effect transistors (OFETS) [2], organic thin-film transistors [3] and dye sensitized solar cells (DSSCs) [4] and even photovoltaic solar cells PSCs [5]. Lately, diverse 6,12-diaryl-5,11-dihydroindolo[3,2-*b*]carbazoles have been rumored as electrode active materials which modify the energy density of an electrochemical cell. [6]. Later, a related derivative named 6,12-di(4-(N,N-diphenylamino)phenyl)-5,11-dihydroindolo[3,2-*b*]carbazole was planned and synthesized as a hole-transporting substantial for organic light emitting diodes [7].

Examination of solvent effects on absorption spectra of organic compounds continuing for ample time period and the individual researchers terminated that the photo-physical action of organic compounds calculate on the nature of its surroundings, i.e. the intensity, shape, and maximum absorption wavelength of the absorption band of organic compounds in solution be strongly on the solvent-solute fundamental interaction and solvent nature [8]. The importance of measuring the solvent personal property on Ultraviolet–visible (UV–vis) absorption spectra come from its significant applications in many fields like designing new dyes, engineering light-emitting diodes and building phototropic materials, also can be useful in the fields of photodynamic therapy and molecular imaging. Solvatochromism, changing the colour of chemical compounds due to a change in solvent polarity, is important for understanding the solvent effects on chemical and biological processes [9-13].

The implementation of electrochemical techniques in bio-activity prediction of pharmaceuticals has increased significantly over the past few years. Cyclic voltammetry studies were used to explore the electrochemical behaviour of drugs and their mode of action in the human body, such

as metabolism, which is one of the essential track in drug breakthrough. Indole derivatives were well-known electro active compounds that were ready to oxidize or reduce at various types of carbon-based electrodes. [14] Theoretical investigations using the density functional theory (DFT) performings [15] are proven to be the extremely valuable to predict properties of the various organic compounds including reactive intermediates.

In this work, some of Tetrahydro[3,2-*b*]indolo-carbazoles (THICZs) were synthesized and its structures was characterized by assorted implementation of spectral information. All synthesised organic molecules (THICZs) were investigated in antithetical organic solvent for knowing personal effects of solvents on the absorption spectrum. In addition, Quantitative classification of solvatochromic behaviours of target THICZs compounds was investigated using linear salvation energy relationship. On the other hand, some of synthesised THICZs were selected to study their electrochemical activities at carbon paste electrode. The DFT measured molecular orbital energies (B3LYP/6-31G) and HOMO-LUMO gaps for some synthesized indolocarbazoles have been performed.

2. Results and Discussion

2.1. Synthesis and structure orientation of THICZs

THICZs (**3a-f**) were prepared by two different reported synthetic approaches.[16-18] The first is one-pot synthesis using direct contact of indole with different aromatic aldehydes and the second is step by step synthesis using dimerization of indole forming bis-indolylmethane (BIMs) (**2**) then reacted with the other aldehydes molecule to give the comparable THICZs (**3a-f**). In the present study the first method was used for the synthesis of the mixed THICZs **3b**. Where the well-known BIM (**2**) R=3-indolyl, (that derived from aldol condensation of indole and indole-3carboxyaldehyde) and formalin 37 % solution were used in equal molar ratios (1:1). The reaction mixture has liquified in methanol and with a few drops of conc. H₂SO₄ were added drop wisly. Then the mixture was stirring under refluxing for about 1hr. The product was precipitated and separated from the hot solution giving few quantity of the clean THICZs **3b**. Then good amounts of the compounds could be neutralized, extracted, washed, dried, and purified *via* column chromatography eluted by CH₂Cl₂ of the reaction mixture dropping the second output in improved yields 80 to 86 % (*Scheme 1*). Whereas other THICZs (**3a**, **3c**, **3d**, **3e**, **3f**) have been synthesized by the straightforward approaching of employ the indole itself with the proper aldehydes either formaldehyde or aromatic aldehyde. The mixture of indole and aldehyde in equal molar amount liquified in methanol with a couple of drops of sulphuric acid was reflux for 1hr to afford the THICZs precipitated from the reaction mixture in its pure form. The work up procedure is the same as mention above. All THICZs (**3a-f**) were prepared and proved by implementation of analytical and spectral information. The 6,12-Dihydroindolo(3,2-b)carbazole (**3a**), and the THICZs (**3e**, **3f**) are known in the literature and their identities are equivalent to our synthesized samples [16-18]. Whereas the THICZs (**3b**, **3c** and **3d**) novel derivatives were synthesized and confirmed by the means of ¹H- and ¹³C-NMR, ESI-MS and IR spectra (see supporting information). The aromatisation of compound **3d** to form directly compound **4** has been performed according to the recently reported method by *Sven Van Snick and Wim Dehaen* [19].Where the desired oxidation reaction have been done by I2 in CH₃CN under reflux for 14 hours to get pure indolo[3,2-*b*]carbazole derived compounds (**4**). Compound **4** was characterized by its spectral and analytical data see experimental section.



Scheme 1: Synthesis of different types of THICZs

The trans isomer (*Figure 1*) has reported by *Rong Guand et al.* [20].



Figure 1: Confirmed trans-form of diphenyl-tetrahydroindolo[3,2-b]carbazole

Our derived function compounds were proved instrumentality by ¹H- and ¹³C-NMR, ESI-MS and IR spectra. The ¹H-NMR spectra of our synthesized THICZs **3a-f** was compared with the reported one that prepared by iodine catalyst and proved by single crystal x-ray. As we in this current work have used the method of equimolecular amounts of indoles and aldehydes or ketones and we have got the identical ¹H-NMR and identical ¹³C-NMR as the reported one by *Rong Gu*and *et al.* thus, accordingly we can report that the means of using methanol as solvent with drops of conc. H₂SO₄ should afford also the trans isomer similar to the reaction catalyzed by iodine. Thus we should report that our previous reported structure of THICZs as cis-form resulted from condensation of BIMs and aldehydes or ketones, should be corrected into its trans form (*Figure 1*) [20]. The x-ray crystallography indicated that the spirocyclicindole is in the trans form. The mechanism of the two possibility formation of both THICZs cis and trans form has been clearly illustrated in our previously reported articles [16, 18]. That perhaps attributed to the performing the reaction under vigorous conditions of conc. H₂SO₄ under reflux leads to a rearrangement of 3,3-alkylated bisindolylmethane into a 3,2-alkylated bisindolylmethane. This

2.2. Spectrophotometric studies

2.2.1. The solvent actions on the absorption spectra

In this section the solvent effects on the UV/visible absorption spectra of synthesized THICZs have been described in details. The solvatochromic behaviours of THICZs and solvent solute interactions can be investigated by methods for instrumentation of linear solvating energy relationships conception projected by *Kamlet* and *Taft* [21].The spectral profiles of the compounds (3 mg in 10 mL solvent) under investigation were pre-recorded with six organic

solvents with broad assortment of solvent parameters for instance dielectric constant ε , refractive index n and solvatochromic parametric quantity α , β and π^* . The spectra of **THICZs** (3a-3f and 4) in diverse organic solvents are bestowed in *Figure* S1-6, individually. Table (1) shows the maximum absorptions wavelength of THICZs under different solvents (appearing at 237-310 nm). It is clear that there is appreciable occurrence in absorption visibility of the molecules with alteration in polarity of the medium. Compound 3a show two main peaks in non-polar solvent (chloroform), one is maximum wavelength at 244 nm and it is related to π - π * electronic transitions and the second at 282 nm and it is related to $n-\pi^*$ electronic transitions. The non-polar solvents have ability to act though polarizability by London fundamental interaction besides effort a blurring of the vibronic manifold. That can be attributed to the solvent's tendency to adjust its dipole moment with the dipole moment of the matter. However, in polar aprotic solvent such dimethylsulfoxide, dimethylformamide and tetrahydrofuran, the maximum wavelength are shifted to higher wavelength 286, 295 and 302 nm, respectively. This shifts because compound **3a** has free hydrogen in its structure, this make it able to forming hydrogen bonding. In contrast, the wavelength in polar protic solvent such as methanol shifted to lower wavelength (237 nm). The maximum wavelengths of compound **3b** are higher than compound **3a** because compound **3b** has three unit of indole. Compound **3b** in chloroform as solvent show maximum wavelength at 304 nm (n- π^* transitions) rather than 246 nm (π - π^* transitions), this is due to the free N-H unit of compound **3b**. The maximum wavelengths of compound **3c** and **3d** are the same as compound **3a**, but in visible region the peak at 412 nm start to be appear due to increasing the number of benzene ring. The promising results are located on the discussion of compound **3e** and **3f**, the two compounds have the same chemical formula but different on substitution position. Stable molecular conformation of compounds **3e** and **3f** obtained by running MM2 energy minimizations in ChemBio 3D 15.1 are presented in Figure S7 and S8. The maximum wavelength of compound **3e** and **3f** are the same in non-polar solvent but in the case of polar solvent such as methanol or DMF the maximum wavelength are completely dissimilar (Figure 2), this may be due to the relatively strong guest-host interaction between the compound 3e and the methanol environment.



Article

vten

Figure 2: UV/Visible absorption spectra of compound **3e** and **3f** in solvent chloroform and methanol.

Table 1. UV/vis spectral data (λ_{max} nm) of some [3,2-b]indolo-carbazolesinvarious solvents

Sol ent/	$_{\lambda \max} nm/v_{\max} 10^3 (cm^{-1})$													
compounds	4	4		3a		3b		3c	•	3d		3e		3f
C.1 ₃ OH	207	48.31	237	42.19	311	32.15	237	42.19	281	35.58	295	33.89	233	42.91
TH	289	41.49	302	33.11	306	32.67	237	42.19	235	42.55	236	42.37	238	42.01
DMF	342	41.49	295	33.89	305	32.78	282	35.46	284	35.21	284	35.21	270	37.03
CHCl ₃	241	29.29	244	40.98	304	32.89	245	40.81	241	41.49	246	40.65	244	40.98
CH_2Cl_2	241	35.59	280	35.71	236	42.37	235	42.55	238	42.01	234	42.73	230	43.47
DMSO	281	34.61	286	34.96	310	32.25	286	34.96	286	34.96	282	35.46	286	34.96

2.2.2. Multiple linear regression analysis

The effect of solvent polarity and hydrogen bonding on the absorption spectra are interpreted by means of linear solvation energy relationship (LSER) using a Kamlet–Taft Eq [21].

 $v_{max} = v_0 + a\alpha + b\beta + s\pi^*$

Where v_{max} is maximum absorption wave number of the given compound processed experimentally, v_0 was calculated by the regression method, the other parameters *i.e.* the Kamlet-Taft coefficients a, b and s was also calculated using regression analysis method (Table 2). Negative values of both s and b (Table 2) indicate that there is positive solvatochromism which means bathochromic shift with increase in solvent polarizability and solvent bond basicity. This suggests stabilization of the electronic excited state relative to the ground state. The positive sign of a coefficient for all compounds indicate a hypochromic shifts with increasing solvent hydrogen-bond donor acidity. This suggests stabilization of the ground state relative to the electronic excited state.

Table (2) Regression fits to solvatochromic parameters (*Kamlet–Taft* Eq.)

Compounds	v	S	b	a	R^2
3a	34.658±0.596	-9.105±0.952	-3.181±0.154	9.291±0.283	0.946
3 b	29.377±0.462	11.694±0.754	-9.520±0.333	4.980±0.551	0.984
3c	49.119±0.816	-11.195±0.467	-3.545 ± 0.842	1.593 ± 0.999	0.982
3d	52.823±0.668	-12.583±0.799	-7.358±0.631	5.829 ± 0.739	0.940
3e	51.396±0.716	-9.838 ± 0.101	-8.427 ± 0.222	7.252 ± 0.353	0.957
3f	48.061±0.972	-9.230±0.661	-3.679 ± 0.930	2.277 ± 0.091	0.932
4	46.151±0.981	-10.051 ± 0.681	-5.459 ± 0.930	3.517±0.581	0.959

2.2.3. Sensing of organic solvent molecules

Accepted Articl

To examine the possibility of **4** for sensing of small molecules, the samples (3 mg) of **4** were soluble in different organic solvents (THF, CHCl₃, CH₂Cl₂, DMF, DMSO and MeOH, respectively) to form a clear solution for UV/visible absorption studies. As is shown in *Figure* **3a** the absorption intensity of **4** is hugely dependent on the solvent molecules. The order of quenching effects is THF< CHCl₃<CH₂Cl₂<DMF<DMSO<MeOH as shown in *Figure* **3b**.





Figure 3: (a) UV-Visible spectrum of aromatic derivatives **4 and** (b) Absorbance intensity (284 nm) of **4** soluble into different organic solvents.

2.3.Voltammetric Studies

The Met Rohm model 693 VA processor and 694 VA stand equipped with three electrodes were employed. The electrodes were Ag/AgCl- 3M KCl a reference electrode and a platinum counter electrode. The carbon paste electrode CPE was used as a working electrode for electrochemical measurements and was prepared by mixing 200 μ L paraffin oil and 250 mg synthetic carbon powder 1-2 micron in agate mortar for at least 20 min. The paste was then packed into the tip of a 1 mL insulin plastic syringe and a copper wire was inserted to obtain the external electric contact. Electrochemical detection was performed by cyclic voltammetry, scanning between -0.1 and 1.3 V in a 10 mL working solution. Two stock solutions of **3d** and **4** were prepared by dissolving 25 mg in 50 ml acetonitrile "ACN". Working solution was prepared by transferring aliquot of the stock solution to 10 ml aqueous acetonitrile solution (90 % ACN). No peaks were observed by the cited compounds (**3d** or **4**) in Britton-Robinson buffer solution and at different

pH values. This was as a result of salting out effect, but on increasing the proportion of organic phase in the working solution up to 90 %, the peaks were developed. As depicted in *Figure* 4, two peaks were generated by the compound 3d at sweep rate 250 mV/s, the first peak was at oxidation potential around 0.9 V corresponding to irreversible one electron transfer [22]. This electrochemical oxidation reaction may be attributed to chemical deprotonating of nitrogen leading finally to hydroxylation of benzene ring in the indole derivatives (scheme 2) [23]. The second peak was at about 0.55 V and is due to reduction of phenolic indole forming quinone [24, 25]. The peaks heights were proportional to the concentrations of the **3d** species. The electrochemical reaction may be ascribed as a quasi-reversible reaction which was confirmed by appearing a reduction peak on scanning first from high to low potentials (reduction direction) then by oxidation scan. This was indicated also by potential shift on increasing the scan rate from 10 to 500 mV/s and on repeating cyclic voltammetry measurements as shown in *Figures* 5 and 6, respectively. It is worth mentioning that white particles apparently were shown on repeating the electrolysis most likely due to the formation of dimers or trimmers [26]. The electrochemical behaviour of compound 4, on the other hand, was released an irreversible cyclic voltammogram with a tiny and broad peak at oxidation potential of about 0.75 V in the same medium of 90 % CAN and at scan rate 500 mV/s (Figure 7). This phenomenon may be explained by the delocalization of the free electron along the neighbouring aromatic rings after deprotonating indolic nitrogen. The expected electrochemical oxidation reaction of compound 3d is presented in Scheme 2.



rticl

Accepte

Figure 4: Cyclic voltammogram of **3d** at carbon paste electrode in acetonitrile with scan rate 250 mV/s.



Figure 5: Cyclic voltammetric measurements of 3d in acetonitrile at different scan rates.



Scheme 2: Expected electrochemical oxidation reaction of compound 3d.

tic

ccepte



Figure 6: Repeated cyclic voltammograms of 0.9 mM **3d** compound repeated 5 times at scan rate 500 mV/s in 90% CAN.



Figure 7: Cyclic voltammogram of **4** at carbon paste electrode in acetonitrile at scan rate 500 mV/s in 90 % CAN.

2.4.Theoretical DFT studies

The DFT studies for several molecules were performed using the B3LYP [27, 28] functional in the 6-31G (d) Pople polarized basis set. Calculations were performed using the version 4 of the ORCA quantum chemistry program package [29]. The sketch map of the subjected structures for DFT studies are illustrated in *Figure 8*. The values of total energy and frontier orbital levels are presented in the Table 3.



Figure 8: The sketch map of requested structures for DFT studies

Table 3: The values of total energy and frontier orbital levels of requested compounds.

Structure	- E_{tot} , hartree	E(HOMO),	E(LUMO), eV		
		eV			
1 (2,3-dimethylindole)	442.1589377	(#38) -4.992	(#39) 0.126		
3 a	803.3587383	-5.201	(#68) -0.016		
		(#67) -5.139	0.082		
		-5.367	(#98) -0.243		
3b	1165.7488387	-5.194	0.024		
		(#97) -5.023	0.160		
4	802.1784877	-5.184	(#67) -0.906		
		(#66) -4.820	0.365		
		-5.390	(#140) -0.118		
Trans-3d	1722.9889549	-5.269	0.032		
		(#139) -5.088	0.151		
		-5.391	(#140) -0.116		
Cis-3d	1722.9876875	-5.237	0.028		
		(#139) -5.064	0.124		
		-5.461	(#139) -0.922		
4	1721.8175255	-5.079	0.059		
		(#138) -4.602	0.209		

Diagrams of the frontier orbitals plotted at the ± 0.025 is contours (*Figure* 9 and 10) reveal that for the dimeric compound **3a** they are formed by the corresponding frontier orbitals of the monomeric indole fragments as calculated in 1 (2,3-dimethylindole derivative). For the *tris*-indole compound **3b** the HOMO generally corresponds to that of the dimeric structure **3a**, while LUMO is mostly the corresponding orbital of the 2-indolyl substituent. The aromatic character of the central ring in **4** does not alter significantly the orbital picture of the non-substituted scaffold.

The similar picture observed for the *bis*-[3,4-*bis*-(methoxy)-phenyl] derivatives **3d**, **4** (*Figure* **10**). The energy difference between *trans* and *cis* isomers of **3d** (ca. 0.80 kcal / mol in favor of the former) could be considered almost negligible in the present investigations context.

10 cceb









LUMO



3a

1





3b





3a

Figure 9: represented diagrams of the frontier orbitals HOMO and LOMO plotted at the±0.025 of compounds **1** (2,3-dimethylindole derivative), **3a** and **3b**.



T1C

ccepte

Figure 10: Represented diagrams of the frontier orbitals HOMO and LOMO plotted at the±0.025 of compounds **3d** (cis/trans) and **4**.

Conflict of Interest

Authors declare no conflicts of interest

Acknowledgements

This work was financially supported by the National Research Centre, Egypt. The NMR and Mass Spec service were carried out in The Central Unit for Analysis and Scientific Services (CUASS) at the National Research Centre, Egypt. The Digital Bio Pharm LTD Company (London, UK) (R25GM067122) is greatly acknowledged.

Experimental section

General information

The melting points were measured on a Boetius-Mikroheiztisch the company VEB weighing, Rapido Radebeul/VEB NAGEMA measured and are uncorrected. The carbon, hydrogen and nitrogen content of the substances were performed on a CHNS-932 automatic analyzer of the company LECO Corporation in the automatic Micro chemical determined. The reactions were followed up using thin layer chromatography on aluminium foil fluorescent indicator from Merck KGaA (silica gel 60 F254, layer thickness 0.2 mm). The separations were with column chromatography at atmospheric pressure on silica gel 60 (Grain size from 0.063 to 0.200 mm) from Merck KGaA. The NMR spectra were recorded on a Gemini 2000 (400/100 MHz). The ATR spectra were recorded on an FT-IR spectrometer IFS 28 by Bruker, the KBr spectra on an FT-IR Spectrometer Spectrum BX the Company Perkine Elmer measured. The ESI mass spectra were recorded on a Finnigan LCQ Classic by thermal Electron measured the sample was injected directly. Optical spectra of the samples were determined on a JASCO UV 3100 spectrometer. *The chemical and physical data of new compounds along with their spectra have been presented in the supporting information file.*

References

a) H.-P. Zhao, X.-T. Tao, P. Wang, Y. Ren, J.-X. Yang, Y.-X. Yan, C.-X. Yuan, H.-J. Liu, D.-C. Zou and M.-H. Jiang, Org. Electron., 2007, 8, 673–682; b) H.-P. Zhao, X.-T. Tao, F.-Z. Wang, Y. Ren, X.-Q. Sun, J.-X. Yang, Y.-X. Yan, D.-C. Zou, X. Zhao and M.-H. Jiang, Chem. Phys. Lett., 2007, 439, 132–137; c) H.-P. Zhao, F.-Z. Wang, C.-X. Yuan, X.-T. Tao, J.-L. Sun, D.-C. Zou and M.-H. Jiang, Org. Electron., 2009, 10, 925–931; d) S. Lengvinaite,

J. V. Grazulevicius, S. Grigalevicius, R. Gu, W. Dehaen, V. Jankauskas, B. Zhang and Z. Xie, *Dyes Pigm.*, 2010, **85**, 183–188.

- [2] a) Y. Wu, Y. Li, S. Gardner and B. S. Ong, J. Am. Chem. Soc., 2005, 127, 614–618; b)Y Li,
 Y. Wu and B. S. Ong, *Macromolecules*, 2006, 39, 6521–6527; c) P.-L. T. Boudreault, S. Wakim, N. Blouin, M. Simard, C. Tessier, Y. Tao and M. Leclerc, J. Am. Chem. Soc., 2007, 129, 9125–9136; d) Y. Guo, H. Zhao, G. Yu, C.-a. Di, W. Liu, S. Jiang, S. Yan, C. Wang, H. Zhang, X. Sun, X. Tao and Y. Liu, Adv. Mater., 2008, 20, 4835–4839; e) P.-L. T. Boudreault, A. A. Virkar, Z. Bao and M. Leclerc, Org. Electron., 2010, 11, 1649–1659.
- [3] David C., Miriam M., Laura U., Espinosa R., Pedro M., Indolocarbazole-Based Ligands for Ladder-Type Four-Coordinate Boron Complexes, Org. Lett., 2010, 12 (14), pp 3164–3167.
- [4] X.-H. Zhang, Z.-S. Wang, Y. Cui, N. Koumura, A. Furube and K. Hara, J. Phys. Chem. C, 2009, 113, 13409–13415.
- [5] E. Zhou, S. Yamakawa, Y. Zhang, K. Tajima, C. Yang and K. Hashimoto, *J. Mater. Chem.*, 2009, **19**, 7730–7737; Y. Xia, X. Su, Z. He, X. Ren, H.Wu, Y. Cao and D. Fan, *Macromol. Rapid Commun.*, 2010, **31**, 1287–1292; E. Zhou, J. Cong, K. Tajima and K. Hashimoto, *Chem. Mater.*, 2010, **22**, 4890–4895.
- [6] Ajit Kumar Mahapatra, GiridhariHazra and PrithidipaSahoo, Synthesis of indolo[3,2b]carbazole-based new colorimetric receptor for anions: A unique color change for fluoride ions, *Beilstein Journal of Organic Chemistry* 2010, 6, No. 12.
- [7] DaliusGudeika^a, KarolisNorvaisa^a, Egle´Stanislovaityte, OleksandrBezvikonnyi^a, DmytroVolyniuk^a, PavloTuryk^a, IrynaHladka^a, Valeriy M. Yashchuk^b, Juozas V. Grazulevicius^a, High-triplet-energy derivatives of indole and carbazole as hosts for blue phosphorescent organic light-emitting diodes, Dyes and Pigments, Volume 139, April 2017, Pages 487–497.
- [8] HayelomDargoBeyene, EphriemTadesse, Study Of Solvent Effect On Uv-Visible Spectra Of A Newly Synthesized Azo-Dye, 2-(3-Carboxyl-4-Hydroxylphenyl)-1-(4-Nitrophenyl) Diazene (PNASA), International journal of technology enhancements emerging engineering research, 2014, VOL 2, ISSUE 12.
- [9] M. S. Zakerhamidi, A. Ghanadzadeh and M. Moghadam," Solvent Effects on the UV/ Visible Absorption Spectra of Some Aminoazobenzene Dyes", Chemical Science Transactions, Vol.1, no.1, 2012.

- [10] Adeogun A. L, Egwuonwu N.W," Perturbation of spectral properties of 3,4-diphe Diphenylthiophene by polar and nonpolar solvents", African Journal of Biotechnology, 6, 2007.
- [11] Matias I. Sancho and Maria C. Almandoz, "Spectroscopic Study of Solvent Effects on the Electronic Absorption Spectra of Flavone and 7-Hydroxyflavone in Neat and Binary Solvent Mixtures", International Journal of Molecular Sciences, 12, (4), 201.
- [12] Louise E. Agrapidis-Paloympis and Robert A. Nash," The effect of solvents on the ultraviolet absorbance of sunscreens", Journal of the Society of Cosmetic Chemists, Vol.3 8, 1987.
- [13] C.N.R.RAO,UV/Visible spectroscopy of organic compounds, 3rd Ed.

Artic

Accepte

- [14] Siddiqui, M. R., AlOthman, Z. A., &Rahman, N. (2013). Analytical techniques in pharmaceutical analysis: A review. Arabian Journal of chemistry., 10, S1409–S1421.
- [15] Koch, W., Holthausen, M. C. (2001). A Chemist's Guide to Density Functional Theory.Weinheim, FRG: Wiley-VCH Verlag GmbH.
- [16] Mardia T. El Sayed, Andrey Voronkov, Ifedayo Victor Ogungbe, Salwa M. El-Hallouty, Khadiga M. Ahmed, Berishvili Vladimir, Konstantin Balakin, Anti-Cancer, Molecular Docking and Structure Activity Relationship Studies of Some Novel Synthetic Spiroindolo[3,2-b]Carbazoles as Predicted HER2 and BrK Kinase Inhibitors, Current Bioactive Compounds, 13, 2017, DOI: 10.2174/1573407213666170213154357.
- [17] Mardia T. El-Sayed, Kazem Mahmoud, Andreas Hilgeroth, and Issa M. I. Fakhr, Synthesis of Novel Indolo-Spirocyclic Compounds, J. Heterocyclic Chem., 53, 188 (2016).
- [18] Mardia T. El Sayed, Khadiga M. Ahmed, Kazem Mahmoud, Andreas Hilgeroth, Synthesis, cytostatic evaluation and structure activity relationships ofnovelbisindolylmethanes and their corresponding tetrahydroindolocarbazoles, European Journal of Medicinal Chemistry 90 (2015) 845-859.
 - [19] Marwa A.M.Sh.El-Sharief, Mohamed H.El-Naggar, Entesar M.Ahmed, Shahenda M.El-Messery, Abeer E. Mahmoud, Mamdouh M.Ali, Lamiaa M.Salem, Karima F.Mahrous, Mardia T.El Sayed, Tetrahydroindolocarbazoles (THICZs) as new class of urokinase (uPA) inhibitors: Synthesis, anticancer evaluation, DNA-damage determination, and molecular modelling study, Bioorganic Chemistry, Volume 80, October 2018, Pages 545-554.

- [20] GuRong, Sven Van Snick, KoenRobeyns, Luc Van Meervelt, WimDehaen, Org. Biomol. Chem. 7 (2009) 380-385.
 - [21] a) Anthony F. Lagalante, Robert L. Hall, and Thomas J. Bruno, Kamlet–Taft Solvatochromic Parameters of the Sub- and Supercritical Fluorinated Ethane Solvents, J. Phys. Chem. B, 1998, 102 (34), 6601–6604. b) Robert W. Taft, Mortimer J. Kamlet, Michael H. Abraham, Linear Solvation Energy Relations, Journal of Solution Chemistry 14(3):153-186.
- [22] C. M. A Brett, A. M. Oliveira-Brett, Electrochemistry. Principles, Methods and Applications, Oxford University Press, Oxford, UK1993.
- [23] R. N. Goyal, N. Kumar, N. K. Singhal, *Bioelectrochem. Bioenerg*. 1998, 45, 47.
- [24] A. Radi, G. E. Bekhiet, *Bioelectrochem. Bioenerg*. 1998, 45, 275.
- [25] P. Bozkaya, B. Dogan, S. Suzen, D. Nebioglu, S. A. Ozkan, Can. J. Anal. Sci. Spect. 2006, 51, 125.
- [26] T. A. Enache, A. M. Oliveira-Brett, Pathways of Electrochemical Oxidation of Indolic Compounds, *Electroanalysis* 2011, 23 (6), 1337–1344.
- [27] Becke, A. D. (1993). A new mixing of Hartree–Fock and local density-functional theories. *The Journal of Chemical Physics*, **98** (2), 1372–1377.
- [28] Lee, C., Yang, W., Parr, R. G. (1988). Development of the Colle-Salvetti correlationenergy formula into a functional of the electron density. *Physical Review B*, **37** (2), 785-789.
- [29] Neese, F. (2012). The ORCA program system. *Wiley Interdisciplinary Reviews: Computational Molecular Science*, **2**(1), 73–78.