Little Oxford English Dictionary and the Graphical law

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Abstract

We study the Little Oxford English Dictionary. We draw the natural logarithm of the number of entries and headwords normalised, respectively, starting with a letter vs the natural logarithm of the rank of the letter, normalised as well as unnormalised. We observe that the plots of the entries and the headwords are almost the same. We find that the entries and the headwords underlie a magnetisation curve of a Spin-Glass in presence of little external magnetic field.

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I. INTRODUCTION

English is the most spoken language, used as lingua-franca by many all over the world, enriching the language as well as getting enriched by the language. Interactions of the English langauge with other languages of Europe is an interesting subject of its own. Apparently, above half of the vocabulary has come from latin. We have studied two languages from Europe recently. One is Romanian. Another is Basque. Both exibits almost the same features in our analysis. Romanian is known to be a Romance language, off-shoot of spoken latin. Basque, from our analysis, appears to be a Romance language, in all practicality. What about the English language from our perspective? To go into that topic, we have started with the Little Oxford English Dictionary, [1]. There are all types of entries or, entries or, generalised words and headwords. We count all the entries letter by letter, followed by enumeration of headwords letter by letter.

In the preliminary study, [2], the present author has gone into probing the word (and verb,adverb,adjective) contents along the letters in a language. The letters were arranged in ascending order of their ranks from the rank one. The letter with the highest number of words starting with, was taken as of rank one. For a natural language, a dictionary from it to English, was a natural choice for that type of study. The author has found that behind each language which was subjected to investigation, there is a curve of magnetisation. From that the author has conjectured that behind any written natural language there are curves of magnetisation, for words, verbs, adverbs and adjectives respectively. A prelimimnary study of Webster's English dictionary was also undertaken. The graphical law was found to exist in the contemporary chinese usages, [2], also.

Moreover, we looked into, [3], dictionaries of five disciplines of knowledge and found existence of a curve magnetisation under each discipline. This was followed by finding of graphical law behind the bengali language,[4], the basque language[5]. This was pursued by finding of graphical law behind Romanian, [6], five more disciplines of knowledge, [7], Onsager core of Abor-Miri, Mising languages,[8] and Onsager Core of Romanised Bengali language,[9] respectively.

We describe how a graphical law is hidden within in the Little Oxford English Dictionary, in this article. We organise the paper as follows. We explain our method of study in the section IV after giving an introduction to magnetisation and the the standard curves of magnetisation of Ising model in the sections II and III respectively. In the ensuing section, section V, we narrate our graphical results. We describe how natural logarithm of number of generalised words or, all entries arranged in descending order, normalised by different normalisers when plotted against the respective rank are fit with lines of magnetisations. Then we conclude about the existence of the graphical law. The same thing is carried on for the headwords. The section VI is Discussion. In that section we try to find out relationship of the English language, on the basis of the Little Oxford English Dictionary, with other languages on the basis of underlying magnetisation curves. We end up through acknowledgement section VII and bibliography.

II. MAGNETISATION

The two dimensional Ising model,[10], in absence of external magnetic field, is prototype of an Ising model. In case of square lattice of planar spins, one spin interacts with four other nearest neighbour spins i.e. on an average to another one spin. Below a certain ambient temperature, denoted as T_c, the two dimensional array of spins reduces to a planar magnet with magnetic moment per site varying as a function of $\frac{T}{T_c}$. This function was inferred, [11], by Lars Onsager way back in 1948, [12] and thoroughly deduced thereafter by C.N.Yang[13]. This function we are referring to as Onsager solution. Moreover, systems, [14], showing behaviour like Onsager solution is rare to come across. Graphically, the Onsager solution appears as in fig.1. In the Bragg-Williams and Bethe-Peierls approximations for an Ising model in any dimension, in (absence)presence of external magnetic fields, reduced magnetisation as a function of reduced temperature, below the phase transition temperature, T_c, vary as in the figures 2-4. The Bragg-Williams and Bethe-Peierls approximations are motivated below.

A. Bragg-Williams approximation

Let us consider a coin. Let us toss it many times. Probability of getting head or, tale is half i.e. we will get head and tale equal number of times. If we attach value one to head, minus one to tale, the average value we obtain, after many tossing is zero. Instead let us consider a one-sided loaded coin, say on the head side. The probability of getting head is more than one half, getting tale is less than one-half. Average value, in this case, after many tossing we obtain is non-zero, the precise number depends on the loading. The loaded coin is like ferromagnet, the unloaded coin is like paramagnet, at zero external magnetic field. Average value we obtain is like magnetisation, loading is like coupling among the spins of the ferromagnetic units. Outcome of single coin toss is random, but average value we get after long sequence of tossing is fixed. This is long-range order. But if we take a small sequence of tossing, say, three consecutive tossing, the average value we obtain is not fixed, can be anything. There is no short-range order.

Let us consider a row of spins, one can imagine them as spears which can be vertically up or, down. Assume there is a long-range order with probability to get a spin up is two third. That would mean when we consider a long sequence of spins, two third of those are with spin up. Moreover, assign with each up spin a value one and a down spin a value minus one. Then total spin we obtain is one third. This value is referred to as the value of long-range order parameter. Now consider a short-range order existing which is identical with the long-range order. That would mean if we pick up any three consecutive spins, two will be up, one down. Bragg-Williams approximation means short-range order is identical with long-range order, applied to a lattice of spins, in general. Row of spins is a lattice of one dimension.

Now let us imagine an arbitrary lattice, with each up spin assigned a value one and a down spin a value minus one, with an unspecified long-range order parameter defined as above by $L = \frac{1}{N}\Sigma_i \sigma_i$, where σ_i is i-th spin, N being total number of spins. L can vary from minus one to one. $N = N_+ + N_-$, where N_+ is the number of up spins, N_- is the number of down spins. $L = \frac{1}{N}(N_+ - N_-)$. As a result, $N_+ = \frac{N}{2}(1+L)$ and $N_- = \frac{N}{2}(1-L)$. Magnetisation or, net magnetic moment , M is $\mu\Sigma_i\sigma_i$ or, $\mu(N_+ - N_-)$ or, $\mu N L$, $M_{max} = \mu N$. $\frac{M}{M_{max}} = L$. $\frac{M}{M_{max}}$ is referred to as reduced magnetisation. Moreover, the Ising Hamiltonian,[10], for the lattice of spins, setting μ to one, is $-\epsilon\Sigma_{n.n}\sigma_i\sigma_j - H\Sigma_i\sigma_i$, where n.n refers to nearest neighbour pairs. The difference $\triangle E$ of energy if we flip an up spin to down spin is, [15], $2\epsilon\gamma\bar{\sigma} + 2H$, where γ is the number of nearest neighbours of a spin. According to Boltzmann principle, $\frac{N_-}{N_+}$ equals $exp(-\frac{\triangle E}{k_B T})$, [16]. In the Bragg-Williams approximation,[17], $\bar{\sigma} = L$, considered in the thermal average sense. Consequently,

$$ln\frac{1+L}{1-L} = 2\frac{\gamma\epsilon L + H}{k_B T} = 2\frac{L + \frac{H}{\gamma\epsilon}}{\frac{T}{\gamma\epsilon/k_B}} = 2\frac{L+c}{\frac{T}{T_c}} \quad (1)$$

where, $c = \frac{H}{\gamma\epsilon}$, $T_c = \gamma\epsilon/k_B$, [18]. $\frac{T}{T_c}$ is referred to as reduced temperature.

Plot of L vs $\frac{T}{T_c}$ or, reduced magentisation vs. reduced temperature is used as reference curve. In the presence of magnetic field, $c \neq 0$, the curve bulges outward. Bragg-Williams is a Mean Field approximation. This approximation holds when number of neighbours interacting with a site is very large, reducing the importance of local fluctuation or, local order, making the long-range order or, average degree of freedom as the only degree of freedom of the lattice. To have a feeling how this approximation leads to matching between experimental and Ising model prediction one can refer to FIG.12.12 of [15]. W. L. Bragg was a professor of Hans Bethe. Rudlof Peierls was a friend of Hans Bethe. At the suggestion of W. L. Bragg, Rudlof Peierls following Hans Bethe improved the approximation scheme, applying quasi-chemical method.

B. Bethe-peierls approximation in presence of four nearest neighbours, in absence of external magnetic field

In the approximation scheme which is improvement over the Bragg-Williams, [10],[15],[16],[17],[18], due to Bethe-Peierls, [19], reduced magnetisation varies with reduced temperature, for γ neighbours, in absence of external magnetic field, as

$$\frac{ln\frac{\gamma}{\gamma-2}}{ln\frac{factor-1}{factor^{\frac{\gamma-1}{\gamma}}-factor^{\frac{1}{\gamma}}}} = \frac{T}{T_c}; factor = \frac{\frac{M}{M_{max}}+1}{1-\frac{M}{M_{max}}}. \tag{2}$$

$ln\frac{\gamma}{\gamma-2}$ for four nearest neighbours i.e. for $\gamma = 4$ is 0.693. For a snapshot of different kind of magnetisation curves for magnetic materials the reader is urged to give a google search "reduced magnetisation vs reduced temperature curve". In the following, we describe datas generated from the equation(1) and the equation(2) in the table, I, and curves of magnetisation plotted on the basis of those datas. BW stands for reduced temperature in Bragg-Williams approximation, calculated from the equation(1). BP(4) represents reduced temperature in the Bethe-Peierls approximation, for four nearest neighbours, computed from the equation(2). The data set is used to plot fig.2. Empty spaces in the table, I, mean corresponding point pairs were not used for plotting a line.

BW	BW(c=0.01)	BP(4,βH = 0)	reduced magnetisation
0	0	0	1
0.435	0.439	0.563	0.978
0.439	0.443	0.568	0.977
0.491	0.495	0.624	0.961
0.501	0.507	0.630	0.957
0.514	0.519	0.648	0.952
0.559	0.566	0.654	0.931
0.566	0.573	0.7	0.927
0.584	0.590	0.7	0.917
0.601	0.607	0.722	0.907
0.607	0.613	0.729	0.903
0.653	0.661	0.770	0.869
0.659	0.668	0.773	0.865
0.669	0.676	0.784	0.856
0.679	0.688	0.792	0.847
0.701	0.710	0.807	0.828
0.723	0.731	0.828	0.805
0.732	0.743	0.832	0.796
0.756	0.766	0.845	0.772
0.779	0.788	0.864	0.740
0.838	0.853	0.911	0.651
0.850	0.861	0.911	0.628
0.870	0.885	0.923	0.592
0.883	0.895	0.928	0.564
0.899	0.918		0.527
0.904	0.926	0.941	0.513
0.946	0.968	0.965	0.400
0.967	0.998	0.965	0.300
0.987		1	0.200
0.997		1	0.100
1	1	1	0

TABLE I. Reduced magnetisation vs reduced temperature datas for Bragg-Williams approximation, in absence of and in presence of magnetic field, $c = \frac{H}{\gamma\epsilon} = 0.01$, and Bethe-Peierls approximation in absence of magnetic field, for four nearest neighbours .

C. Bethe-peierls approximation in presence of four nearest neighbours, in presence of external magnetic field

In the Bethe-Peierls approximation scheme , [19], reduced magnetisation varies with reduced temperature, for γ neighbours, in presence of external magnetic field, as

$$\frac{ln\frac{\gamma}{\gamma-2}}{ln\frac{factor-1}{e^{\frac{2\beta H}{\gamma}}factor^{\frac{\gamma-1}{\gamma}}-e^{-\frac{2\beta H}{\gamma}}factor^{\frac{1}{\gamma}}}} = \frac{T}{T_c}; factor = \frac{\frac{M}{M_{max}}+1}{1-\frac{M}{M_{max}}}. \tag{3}$$

Derivation of this formula ala [19] is given in the appendix of [7].

$ln\frac{\gamma}{\gamma-2}$ for four nearest neighbours i.e. for $\gamma = 4$ is 0.693. For four neighbours,

$$\frac{0.693}{ln\frac{factor-1}{e^{\frac{2\beta H}{\gamma}}factor^{\frac{\gamma-1}{\gamma}}-e^{-\frac{2\beta H}{\gamma}}factor^{\frac{1}{\gamma}}}} = \frac{T}{T_c}; factor = \frac{\frac{M}{M_{max}}+1}{1-\frac{M}{M_{max}}}. \tag{4}$$

In the following, we describe datas in the table, II, generated from the equation(4) and curves of magnetisation plotted on the basis of those datas. BP(4, $\beta H = 0.06$) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that $\beta H = 0.06$. calculated from the equation(4)' BP(4, $\beta H = 0.05$) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that $\beta H = 0.05$. calculated from the equation(4), BP(4, $\beta H = 0.04$) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that $\beta H = 0.04$. calculated from the equation(4), BP(4, $\beta H = 0.02$) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that $\beta H = 0.02$. calculated from the equation(4), BP(4, $\beta H = 0.01$) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that $\beta H = 0.01$. calculated from the equation(4), The data set is used to plot fig.3 and fig.4. Empty spaces in the table, II, mean corresponding point pairs were not used for plotting a line.

D. Spin-Glass

In the case coupling between(among) the spins, not necessarily n.n, for the Ising model is(are) random, we get Spin-Glass. When a lattice of spins randomly coupled and in an external magnetic field, goes over to the Spin-Glass phase, magnetisation increases steeply like $\frac{1}{T-T_c}$ i.e. like the branch of rectangular hyperbola, upto the the phase transition temperature, followed by very little increase,[20–22], in magnetisation, as the ambient temperature continues to drop.

Theoretical study of Spin Glass started with the paper by Edwards, Anderson,[23]. They were trying to explain two experimental results concerning continuous disordered freezing(phase transition) and sharp cusp in static magnetic susceptibility. This was followed by a paper by Sherrington, Kickpatrick, [24], who dealt with Ising model with interactions being present among all neighbours. The interaction is random, follows Gaussian distribution and does not distinguish one pair of neighbours from another pair of neighbours, irrespective of the distance between two neighbours. In presence of external magnetic field, they predicted

BP(4,$\beta H = 0.1$)	BP(4,$\beta H = 0.08$)	BP(4,$\beta H = 0.06$)	BP(4,$\beta H = 0.05$)	BP(4,$\beta H = 0.04$)	BP(4,$\beta H = 0.02$)	BP(4,$\beta H = 0.01$)	reduced magnetisation
0	0	0	0	0	0	0	1
0.597	0.589	0.583	0.580	0.577	0.572	0.569	0.978
0.603	0.593	0.587	0.584	0.581	0.575	0.572	0.977
0.660	0.655	0.647	0.643	0.639	0.632	0.628	0.961
0.673	0.665	0.657	0.653	0.649	0.641	0.637	0.957
0.688	0.679	0.671	0.667		0.654	0.650	0.952
			0.716			0.696	0.931
0.745	0.734	0.723	0.718	0.713	0.702	0.697	0.927
0.766	0.754	0.743	0.737	0.731	0.720	0.714	0.917
0.787	0.775	0.762	0.756	0.749	0.737	0.731	0.907
0.796	0.783	0.770	0.764	0.757	0.745	0.738	0.903
0.848	0.832	0.816	0.808	0.800	0.785	0.778	0.869
0.854	0.837	0.821	0.813	0.805	0.789	0.782	0.865
0.866	0.849	0.832	0.823	0.815	0.799	0.791	0.856
0.878	0.859	0.841	0.833	0.824	0.807	0.799	0.847
0.902	0.882	0.863	0.853	0.844	0.826	0.817	0.828
0.931	0.908	0.887	0.876	0.866	0.846	0.836	0.805
0.940	0.917	0.895	0.884	0.873	0.852	0.842	0.796
0.966	0.941	0.916	0.904	0.892	0.869	0.858	0.772
0.996	0.968	0.940	0.926	0.914	0.888	0.876	0.740
1			0.929			0.877	0.735
	0.977		0.936			0.883	0.730
	0.989		0.944			0.889	0.720
	0.990		0.945				0.710
	1.00		0.955			0.897	0.700
			0.963			0.903	0.690
			0.973			0.910	0.680
						0.909	0.670
			0.993			0.925	0.650
				0.976	0.942		0.651
			1.00				0.640
				0.983	0.946	0.928	0.628
				1.00	0.963	0.943	0.592
					0.972	0.951	0.564
					0.990	0.967	0.527
						0.964	0.513
					1.00		0.500
						1.00	0.400
							0.300
							0.200
							0.100
							0

TABLE II. Bethe-Peierls approx. in presence of little external magnetic fields

in their next paper, [25], below spin-glass transition temperature a spin-glass phase with non-zero magnetisation. Almeida etal, [26], Gray and Moore, [27],finally Parisi, [28], [29] improved and gave final touch, [30], to their line of work. Parisi and collaborators, [31]-[35], wrote a series of papers in postscript, all revolving around a consistent assumption of constant magnetisation in the spin-glass phase in presence of little constant external magnetic field.

In another sequence of theoretical work, by Fisher etal,[36–38], concluded that for Ising model with nearest neighbour or, short range interaction of random type spin-glass phase does not exist in presence of external magnetic field.

For recent series of experiments on spin-glass, the references, [39, 40], are the places to look into.

For an indepth account, accessible to a commonner, the series of articles by late P. W. Anderson in Physics Today, [41]-[47], is probably the best place to look into. For a book to enter into the subject of spin-glass, one may start at [48].

Here, in our work to follow, spin-glass refers to spin-glass phase of a system with infinite range random interactions.

III. CURVES OF MAGNETISATION

The Ising Hamiltonian,[10],[19],for a lattice of spins is $-\epsilon\Sigma_{n.n}\sigma_i\sigma_j - H\Sigma_i\sigma_i$, where n.n refers to nearest neighbour pairs, σ_i is i-th spin, H is external magnetic field and ϵ is coupling between two nearest neighbour spins. σ_i is binary i.e. can take values ± 1. At a temperature T, below a certain temperature called phase transition temperature, T_c, for the two dimensional Ising model in absence of external magnetic field i.e. for H equal to zero, the exact, unapproximated, Onsager solution gives reduced magnetisation as a function of reduced temperature as, [13], [19],

$$\frac{M}{M_{max}} = [1 - (sinh\frac{0.8813736}{\frac{T}{T_c}})^{-4}]^{1/8}.$$

Graphically, the Onsager solution appears as in fig.1. In the Bragg-Williams and Bethe-

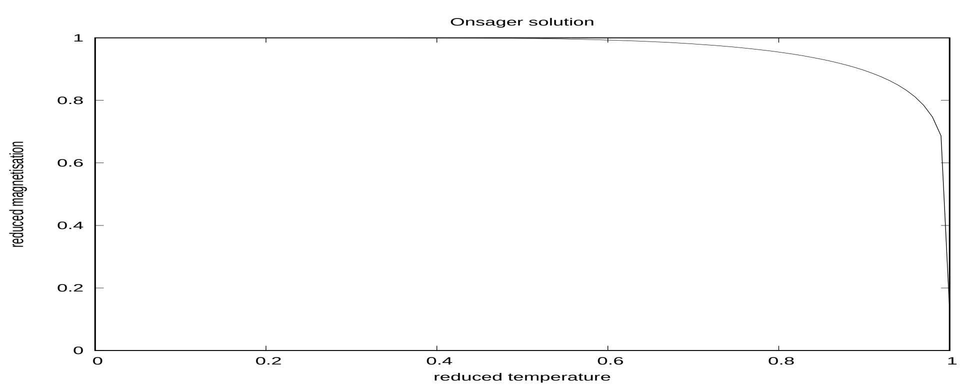

FIG. 1. Reduced magnetisation vs reduced temperature curves for exact solution of two dimensional Ising model, due to Onsager, in absence of external magnetic field

Peierls approximations for an Ising model in any dimension, in presence of external magnetic fields, reduced magnetisation as a function of reduced temperature, below the phase

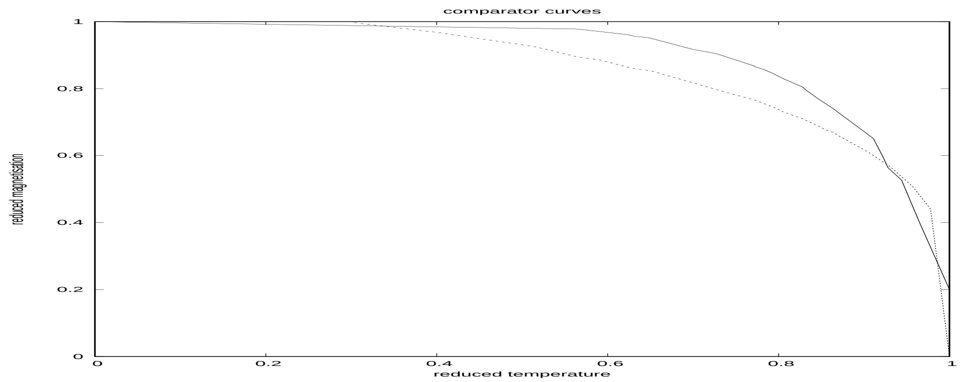

FIG. 2. Reduced magnetisation vs reduced reduced temperature curves for Bragg-Williams approximation, in presence of little magnetic field, BW(c=0.01) and Bethe-Peierls approximation in absence of magnetic field, BP(4,βH=0), for four nearest neighbours (outer one).

transition temperature, T_c, vary as in the figures 3-5. The graphs in the figures,1-4, are

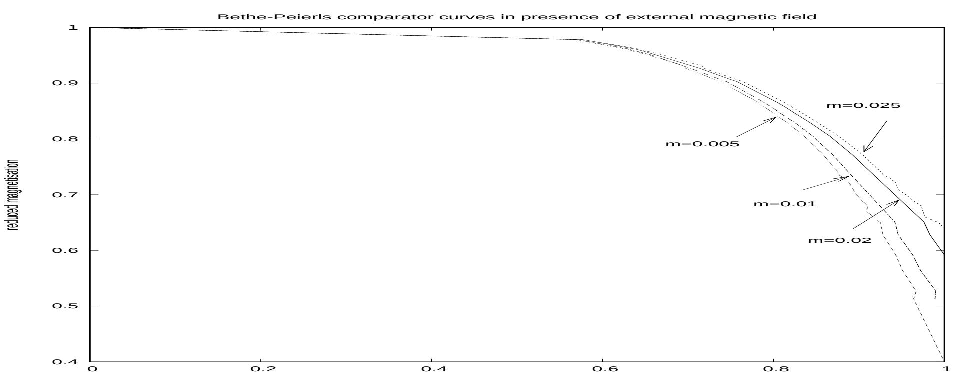

FIG. 3. Reduced magnetisation vs reduced temperature curves, BP(4,βH), for Bethe-Peierls approximation in presence of little external magnetic fields, for four nearest neighbours, with $\beta H = 2m$.

used in the sections to follow as reference curves.

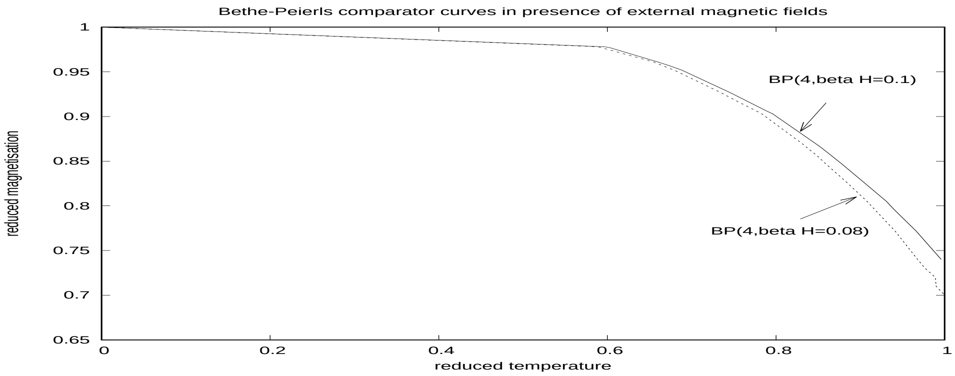

FIG. 4. Reduced magnetisation vs reduced temperature curves, BP(4,βH=0.1) and BP(4,βH=0.08).

letter	A	B	C	D	E	F	G	H	I	J	K	L	M
number	2446	2480	4122	2691	1832	2027	1453	1610	1982	412	337	1398	2238
splitting	2363+83	2290+190	4102+20	2688+3	1826+6	2008+19	1415+38	1578+32	1889+93	411+1	325+12	1385+13	2217+21
letter	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
number	786	1150	3652	225	2331	5428	2679	949	702	1184	17	159	74
splitting	770+16	1051+99	3634+18	225+0	2323+8	5411+17	2387+292	936+13	702+0	1169+15	15+2	138+21	74+0

TABLE III. english entries: the first row represents letters of the english alphabet in the serial order, the second row is the respective number of entries, the third row describes the splitting of entries.

IV. METHOD OF STUDY

The English language alphabet is composed of twenty six letters. We take the the Little Oxford English Dictionary, [1]. Then we count all the entries in the dictionary, [1], one by one from the beginning to the end, starting with different letters. This has been done in two steps for the dictionary. First, we have counted all entries initiating with A form the section for the letter A. The number is two thousand three hundred sixty three. Second, we have enlisted all entries initiating with A form the sections for the letters B, D,..,Z. Then we have removed from the list entries already appearing in the section belonging to A. Then we have counted the number of the entries in that list. The number is eighty three. As a result total number of words beginning with A is two thousand three hundred and sixty three. This exercise was then followed for B,C,..Z. The result is the table, III. Next we count all the head-words, written in boldface, in the dictionary, [1], one by one from the beginning to the end, starting with different letters. This has been done in two steps for the dictionary. First, we have counted all the head-words, initiating with A form the section for the letter A. The number is one thousand three hundred eleven. Second, we have enlisted all head-words initiating with A form the sections for the letters B, D,..,Z. Then we have removed from the list entries already appearing in the section belonging to A. Then we have counted the number of the head-words in that list. The number is zero. As a result total number of words beginning with A is one thousand three hundred and eleven. This exercise was then followed for B,C,..Z. The result is the table, IV.

To visualise the pattern of change of number of entries and head-words along the the letters initiating with, we draw the number of entries and head-words vs. sequence number of the respective letters in the fig.5.

letter	A	B	C	D	E	F	G	H	I	J	K	L	M
number	1311	1186	2083	1285	869	977	752	840	948	201	180	704	1217
splitting	1311+0	1186+0	2083+0	1285+0	867+2	977+0	751+1	840+0	948+0	201+0	180+0	704+0	1217+0
letter	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
number	431	552	1812	119	1066	2484	1185	562	376	597	7	82	39
splitting	431+0	552+0	1812+0	119+0	1066+0	2484+0	1185+0	562+0	376+0	597+0	7+0	82+0	39+0

TABLE IV. english headwords: the first row represents letters of the english alphabet in the serial order, the second row is the respective number of headwords, the third row describes the splitting of headwords.

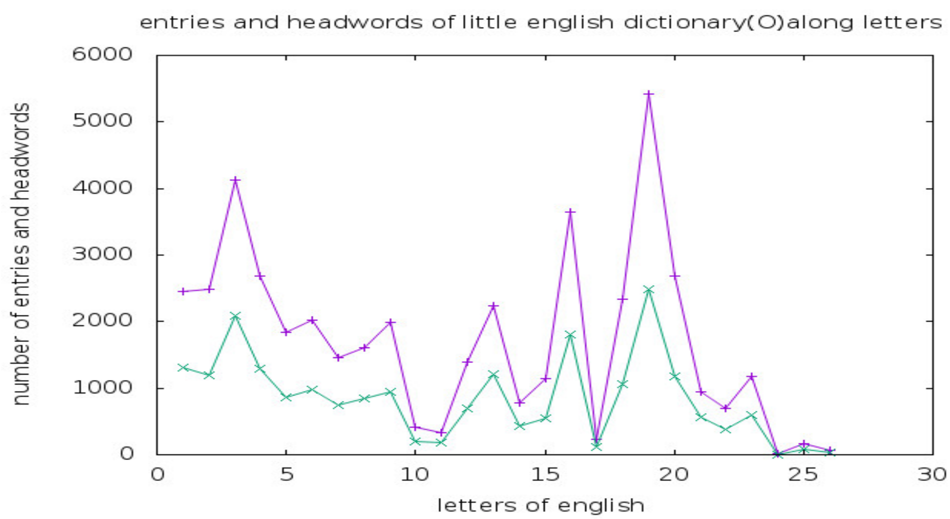

FIG. 5. Vertical axis is number of entries and head-words of english and horizontal axis is the respective letters of the English alphabet. Letters are represented by the sequence number in the alphabet.

To explore for the occurance of graphical law in the entries, we assort the letters according to the number of entries, in the descending order, denoted by f and the respective rank, denoted by k. k is a positive integer starting from one. Moreover, we attach a limiting rank, k_{lim}, or, k_d and a limiting number of words. The limiting rank is maximum rank plus one, here it is twenty seven and the limiting number of words is one. As a result both $\frac{lnf}{lnf_{max}}$ and $\frac{lnk}{lnk_{lim}}$ varies from zero to one. Then we plot $\frac{lnf}{lnf_{max}}$ against $\frac{lnk}{lnk_{lim}}$. We then ignore the letters with the highest, then next highest, then next next highest and so on number of words and redo the plot, normalising the lnfs with next-to-maximum $lnf_{nextmax}$, and starting from $k=2$; next-to-next-to-maximum $lnf_{nextnextmax}$, and starting from $k=3$; next-to-next-to-next-to-maximum $lnf_{nextnextnextmax}$, and starting from $k=4$, nnnnmax $lnf_{nnnnmax}$, and starting from $k = 5$, nnnnnmax $lnf_{nnnnnmax}$, and starting from $k = 6$, nnnnnnmax $lnf_{nnnnnnmax}$, and starting from $k = 7$, 10n-max $lnf_{nnnnnnnnnnmax}$, and starting from $k = 11$. The results are the table V and the figures (fig.6-fig.14).

To explore for the occurance of graphical law in the head-words, we assort the letters according to the number of head-words, in the descending order, denoted by f and the respective rank, denoted by k. k is a positive integer starting from one. Moreover, we attach a limiting rank, k_{lim}, or, k_d and a limiting number of words. The limiting rank is maximum rank plus one, here it is twenty seven and the limiting number of words is one. As a result both $\frac{lnf}{lnf_{max}}$ and $\frac{lnk}{lnk_{lim}}$ varies from zero to one. Then we plot $\frac{lnf}{lnf_{max}}$ against $\frac{lnk}{lnk_{lim}}$. We then ignore the letters with the highest, then next highest, then next next highest and so on number of words and redo the plot, normalising the lnfs with next-to-maximum $lnf_{nextmax}$, and starting from $k = 2$; next-to-next-to-maximum $lnf_{nextnextmax}$, and starting from $k = 3$; next-to-next-to-next-to-maximum $lnf_{nextnextnextmax}$, and starting from $k = 4$, nnnnmax $lnf_{nnnnmax}$, and starting from $k = 5$, nnnnnmax $lnf_{nnnnnmax}$, and starting from $k = 6$, 10n-max $lnf_{10n-max}$, and starting from $k = 11$. The results are the table VI and the figures (fig.18-fig.24).

V. RESULTS

A. all words

k	lnk	lnk/lnk_{lim}	f	lnf	lnf/lnf_{max}	lnf/lnf_{nmax}	lnf/lnf_{nnmax}	lnf/lnf_{nnnmax}	lnf/$lnf_{nnnnmax}$	lnf/$lnf_{nnnnnmax}$	lnf/$lnf_{nnnnnnmax}$	lnf/lnf_{9nmax}	lnf/lnf_{10nmax}
1	0	0	5428	8.599	1	Blank	Blank	Blank	Blank	Blank	Blank	Blank	Blank
2	0.69	0.209	4122	8.324	0.968	1	Blank	Blank	Blank	Blank	Blank	Blank	Blank
3	1.10	0.333	3652	8.203	0.954	0.985	1	Blank	Blank	Blank	Blank	Blank	Blank
4	1.39	0.421	2691	7.898	0.918	0.949	0.963	1	Blank	Blank	Blank	Blank	Blank
5	1.61	0.488	2679	7.893	0.918	0.948	0.962	0.999	1	Blank	Blank	Blank	Blank
6	1.79	0.542	2480	7.816	0.909	0.939	0.953	0.990	0.990	1	Blank	Blank	Blank
7	1.95	0.591	2446	7.802	0.907	0.937	0.951	0.988	0.988	0.998	1	Blank	Blank
8	2.08	0.630	2331	7.754	0.902	0.932	0.945	0.982	0.982	0.992	0.994	Blank	Blank
9	2.20	0.667	2238	7.713	0.897	0.927	0.940	0.977	0.977	0.987	0.989	Blank	Blank
10	2.30	0.697	2027	7.614	0.885	0.915	0.928	0.964	0.965	0.974	0.976	1	Blank
11	2.40	0.727	1982	7.592	0.883	0.912	0.926	0.961	0.962	0.971	0.973	0.997	1
12	2.48	0.752	1832	7.513	0.874	0.903	0.916	0.951	0.952	0.961	0.963	0.987	0.990
13	2.56	0.776	1610	7.384	0.859	0.887	0.900	0.935	0.936	0.945	0.946	0.970	0.973
14	2.64	0.800	1453	7.281	0.847	0.875	0.888	0.922	0.922	0.932	0.933	0.956	0.959
15	2.71	0.821	1398	7.243	0.842	0.870	0.883	0.917	0.918	0.927	0.928	0.951	0.954
16	2.77	0.839	1184	7.077	0.823	0.850	0.863	0.896	0.897	0.905	0.907	0.929	0.932
17	2.83	0.858	1150	7.048	0.820	0.847	0.859	0.892	0.893	0.902	0.903	0.926	0.928
18	2.89	0.876	949	6.855	0.797	0.824	0.836	0.868	0.868	0.877	0.879	0.900	0.903
19	2.94	0.891	786	6.667	0.775	0.801	0.813	0.844	0.845	0.853	0.855	0.876	0.878
20	3.00	0.909	702	6.554	0.762	0.787	0.799	0.830	0.830	0.839	0.840	0.861	0.863
21	3.04	0.921	412	6.021	0.700	0.723	0.734	0.762	0.763	0.770	0.772	0.791	0.793
22	3.09	0.936	337	5.820	0.677	0.699	0.709	0.737	0.737	0.745	0.746	0.764	0.767
23	3.14	0.952	225	5.416	0.630	0.651	0.660	0.686	0.686	0.693	0.694	0.711	0.713
24	3.18	0.964	159	5.069	0.589	0.609	0.618	0.642	0.642	0.649	0.650	0.666	0.668
25	3.22	0.976	74	4.304	0.501	0.517	0.525	0.545	0.545	0.551	0.552	0.565	0.567
26	3.26	0.988	17	2.833	0.329	0.340	0.345	0.359	0.359	0.362	0.363	0.372	0.373
27	3.30	1	1	0	0	0	0	0	0	0	0	0	0

TABLE V. entries of the Little Oxford English Dictionary: ranking, natural logarithm, normalisations

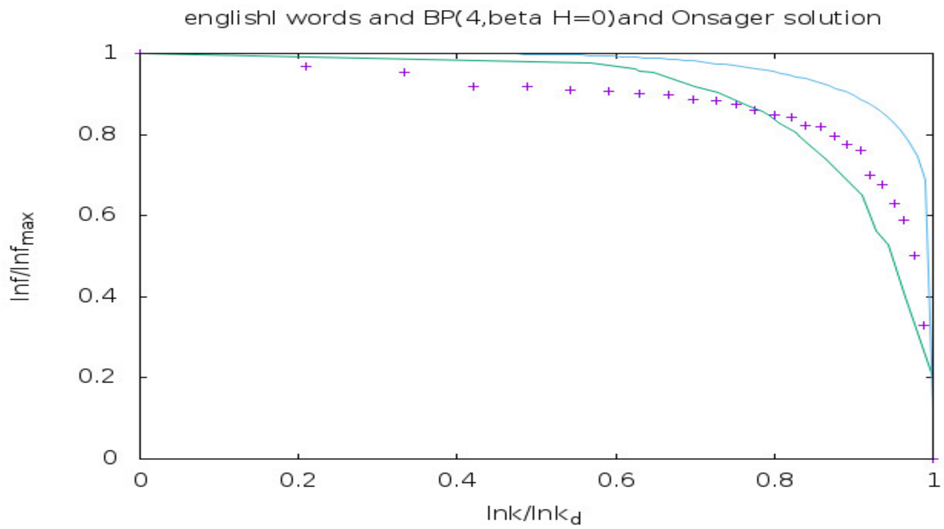

FIG. 6. Vertical axis is $\frac{lnf}{lnf_{max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the entries of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and in absence of external magnetic field. The uppermost curve is the Onsager solution.

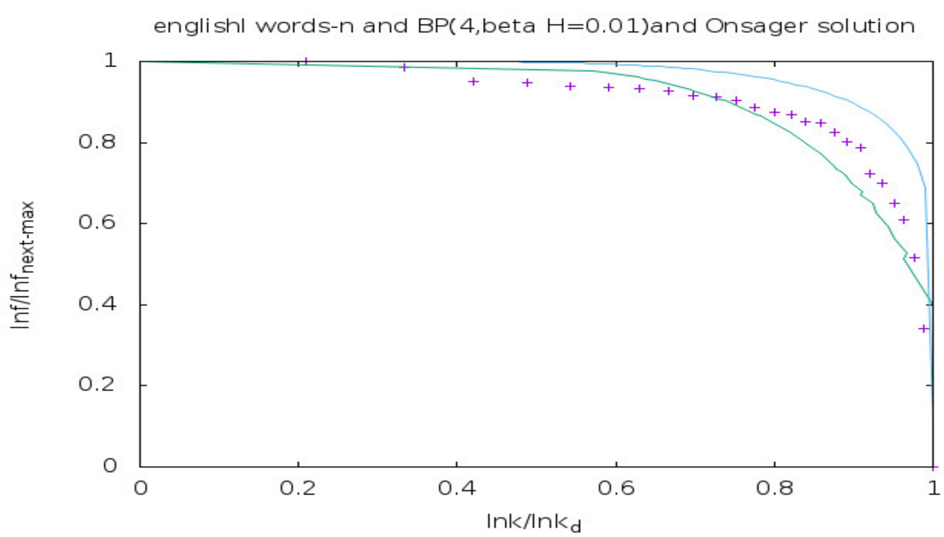

FIG. 7. Vertical axis is $\frac{lnf}{lnf_{next-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the entries of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.005$ or, $\beta H = 0.01$. The uppermost curve is the Onsager solution.

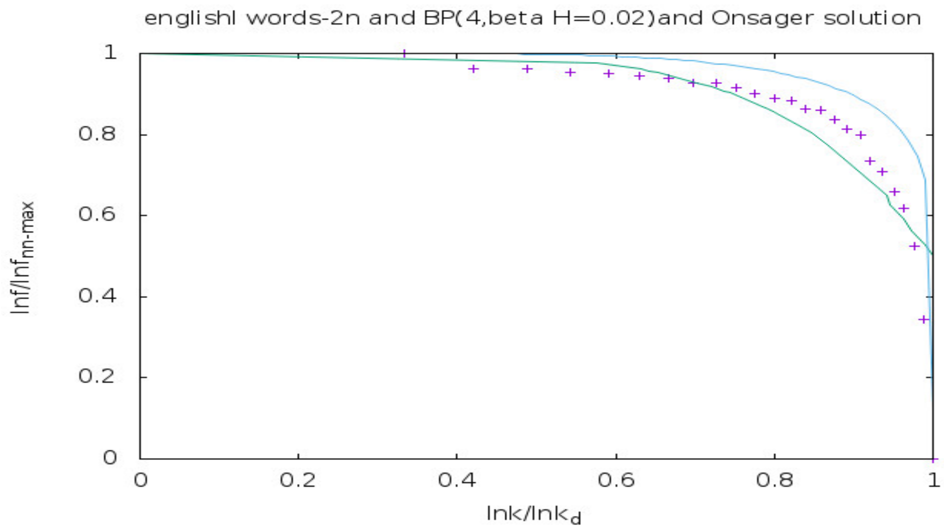

FIG. 8. Vertical axis is $\frac{lnf}{lnf_{nn-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the entries of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.01$ or, $\beta H = 0.02$. The uppermost curve is the Onsager solution.

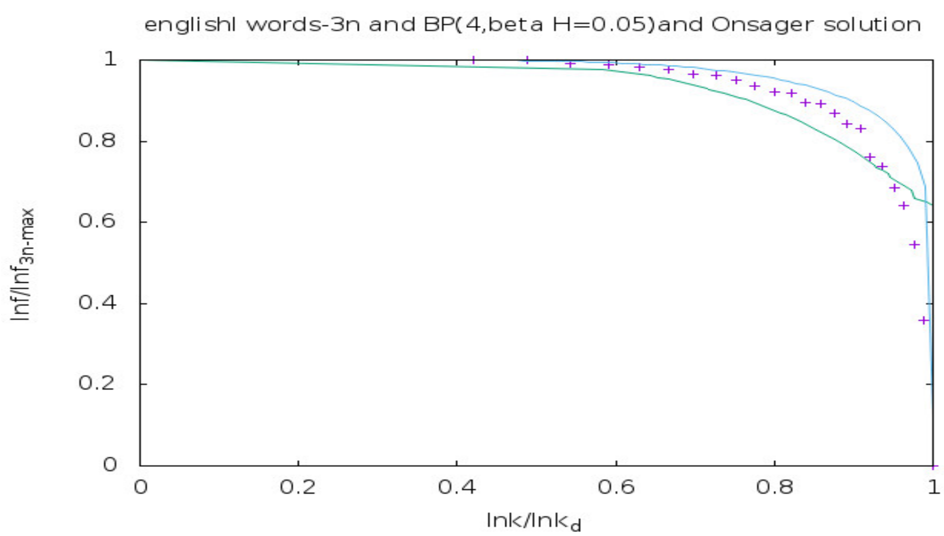

FIG. 9. Vertical axis is $\frac{lnf}{lnf_{nnn-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the entries of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.025$ or, $\beta H = 0.05$. The uppermost curve is the Onsager solution.

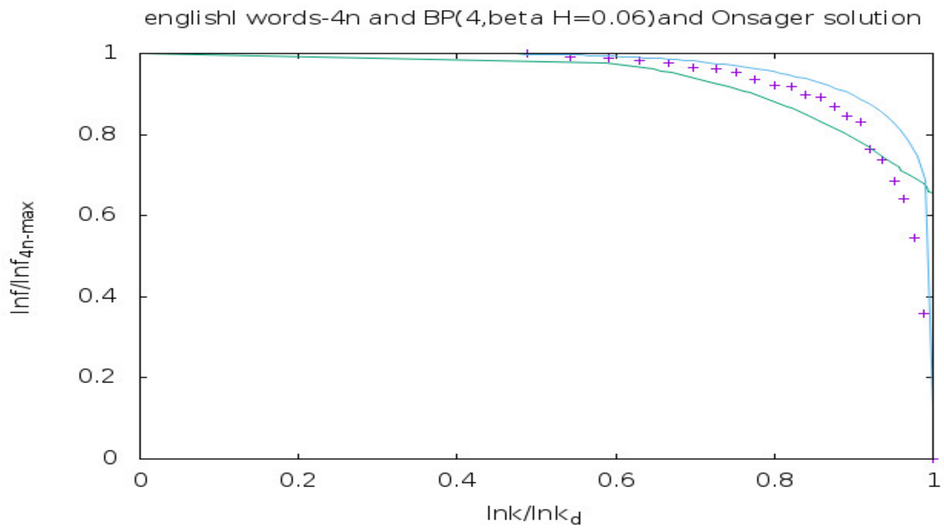

FIG. 10. Vertical axis is $\frac{lnf}{lnf_{nnnn-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the entries of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.03$ or, $\beta H = 0.06$. The uppermost curve is the Onsager solution.

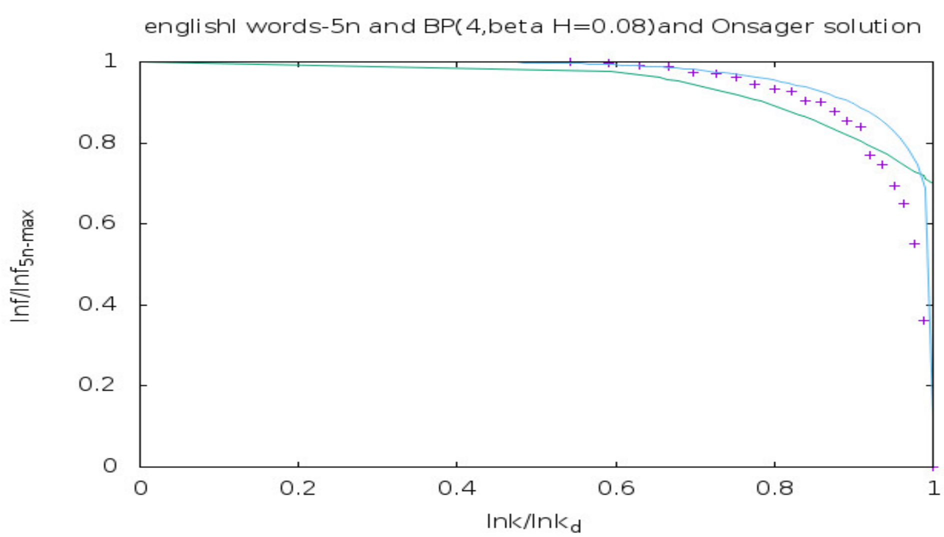

FIG. 11. Vertical axis is $\frac{lnf}{lnf_{nnnnn-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the entries of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.04$ or, $\beta H = 0.08$. The uppermost curve is the Onsager solution.

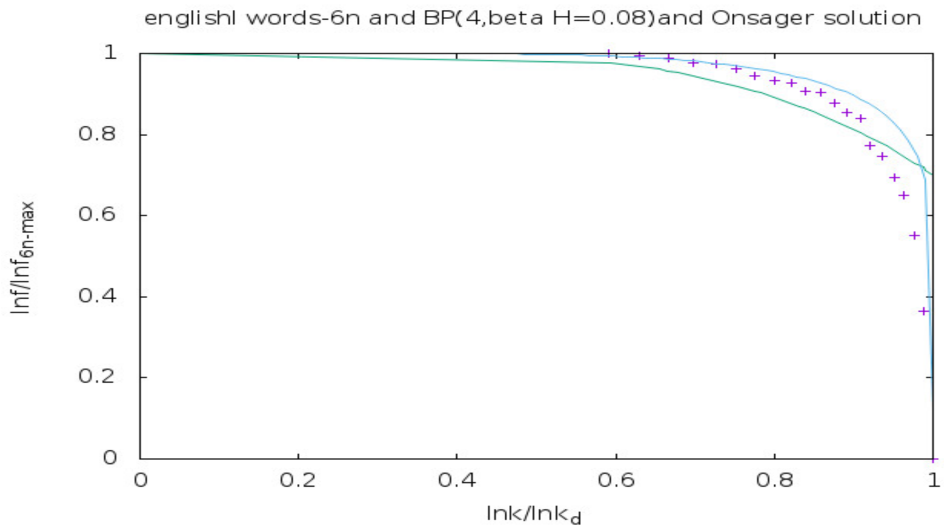

FIG. 12. Vertical axis is $\frac{lnf}{lnf_{nnnnnn-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the entries of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.04$ or, $\beta H = 0.08$. The uppermost curve is the Onsager solution.

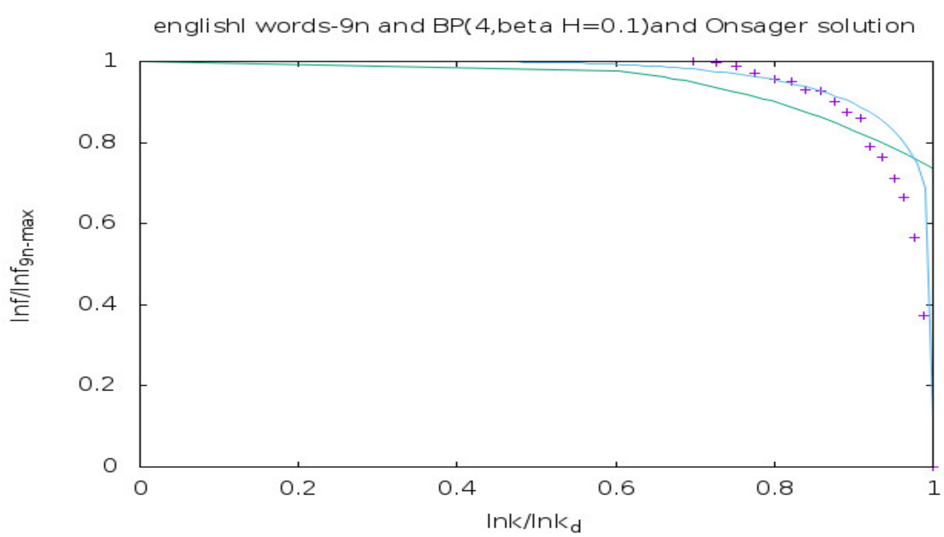

FIG. 13. Vertical axis is $\frac{lnf}{lnf_{nnnnnnnnn-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the entries of the english language, with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.05$ or, $\beta H = 0.1$. The reference curve is the Onsager solution. The entries of the Little Oxford English Dictionary are not going over to the Onsager solution.

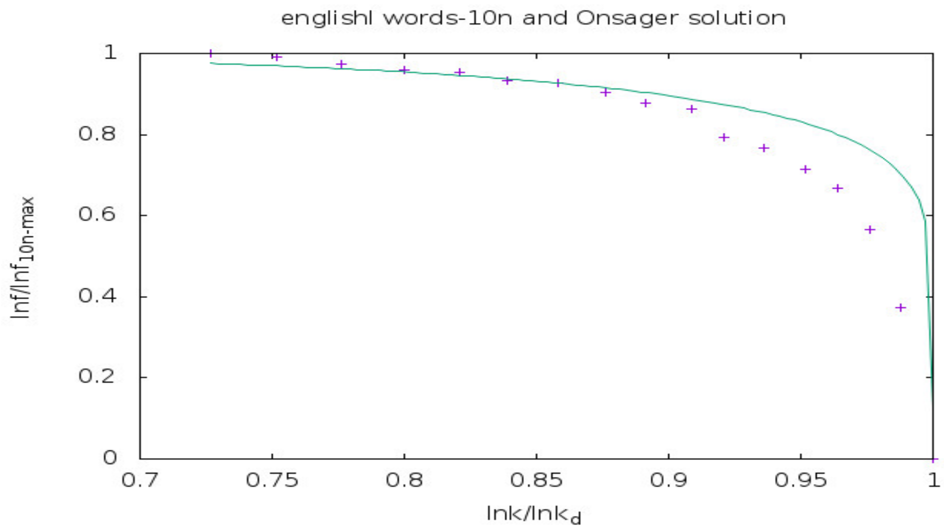

FIG. 14. Vertical axis is $\frac{lnf}{lnf_{10n-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the entries of the english language. The reference curve is the Onsager solution. The entries of the Little Oxford English Dictionary are not going over to the Onsager solution.

1. conclusion

From the figures (fig.6-fig.14), we observe that behind the entries of the dictionary, [1], there is a magnetisation curve, BP(4,$\beta H = 0.01$), in the Bethe-Peierls approximation with four nearest neighbours, in presence of liitle magnetic field, $\beta H = 0.01$.
Moreover, the associated correspondance with the Ising model is,

$$\frac{lnf}{lnf_{next-to-maximum}} \longleftrightarrow \frac{M}{M_{max}},$$

and

$$lnk \longleftrightarrow T.$$

k corresponds to temperature in an exponential scale, [49]. As temperature decreases, i.e. lnk decreases, f increases. The letters which are recording higher entries compared to those which have lesser entries are at lower temperature. As the English language expands, the letters which get enriched more and more, fall at lower and lower temperatures. This is a manifestation of cooling effect as was first observed in [50] in another way.
On the top of it, on successive higher normalisations, entries of the English language,[1], do not go over to Onsager solution in the normalised lnf vs $\frac{lnk}{lnk_{lim}}$ graphs.
As matching of the plots in the figures fig.(6-14), with comparator curves i.e. the magnetisation curves of Bethe-Peierls approximations, is with large dispersions and dispersion does not reduce significantly over higher orders of normalisations, to explore for possible existence of spin-glass transition, in presence of little external magnetic field, $\frac{lnf}{lnf_{max}}$, $\frac{lnf}{lnf_{next-max}}$ and $\frac{lnf}{lnf_{nn-max}}$ are drawn against lnk in the figures fig.15-fig.17.

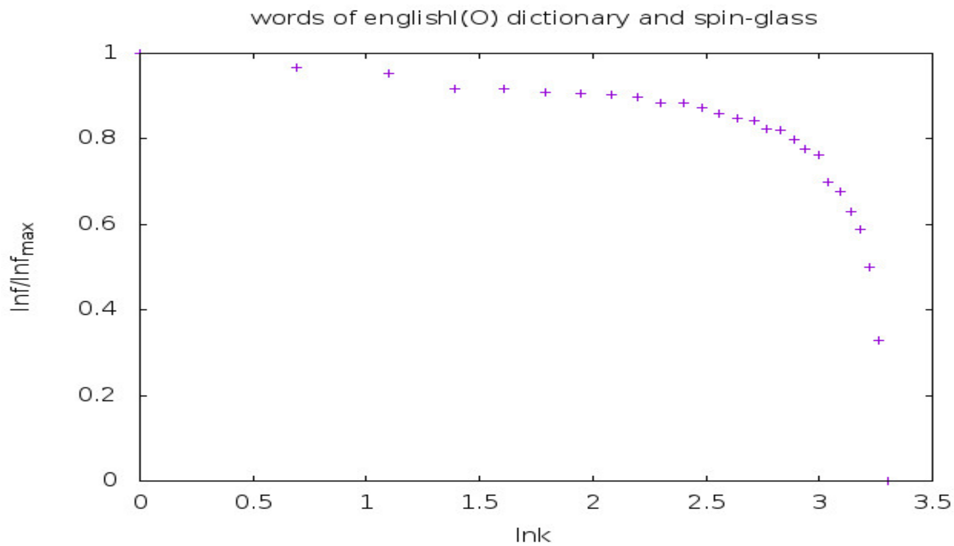

FIG. 15. Vertical axis is $\frac{lnf}{lnf_{max}}$ and horizontal axis is lnk. The + points represent the entries of the english language.

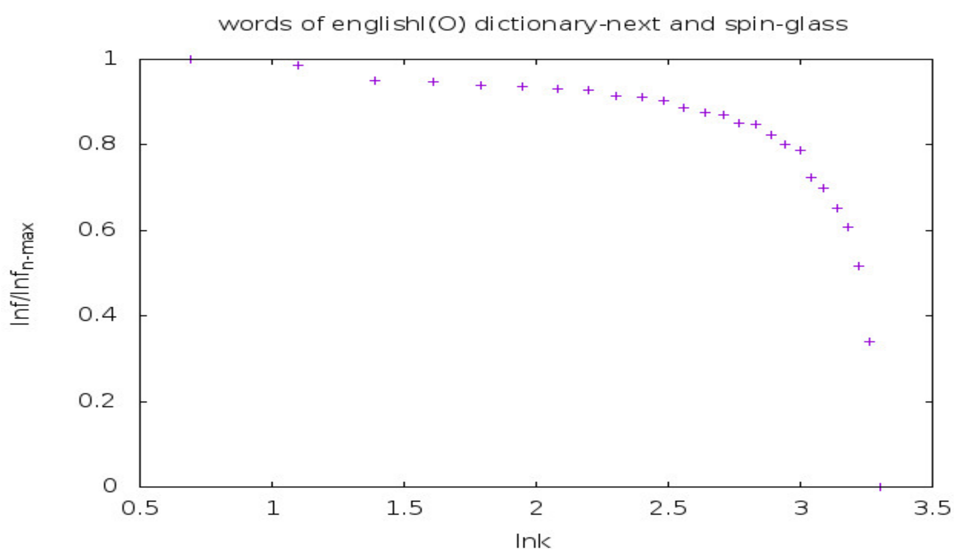

FIG. 16. Vertical axis is $\frac{lnf}{lnf_{next-max}}$ and horizontal axis is lnk. The + points represent the entries of the english language.

In the figures Fig.15-Fig.17, the points has a smoothened transition, rather than a clearcut transition. Above the transition point(s), the line is almost horizontal, increasing little and below the transition point(s), pointsline rises sharply, but without the tail part, like the branch of a rectangular hyperbola. Hence, the entries of the English language,[1], better

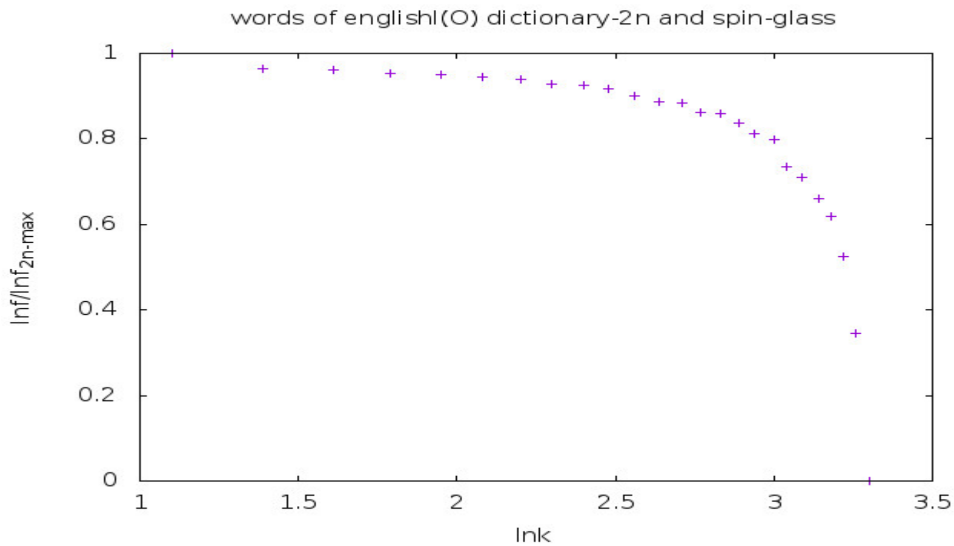

FIG. 17. Vertical axis is $\frac{lnf}{lnf_{nn-max}}$ and horizontal axis is lnk. The + points represent the entries of the english language.

be described, to underlie a Spin-Glass magnetisation curve, [20], in the presence of little magnetic field.

k	lnk	lnk/lnk_{lim}	f	lnf	lnf/lnf_{max}	lnf/lnf_{nmax}	lnf/lnf_{nnmax}	lnf/lnf_{nnnmax}	lnf/$lnf_{nnnnmax}$	lnf/$lnf_{nnnnnmax}$	lnf/lnf_{10nmax}
1	0	0	2484	7.818	1	Blank	Blank	Blank	Blank	Blank	Blank
2	0.69	0.209	2083	7.642	0.977	1	Blank	Blank	Blank	Blank	Blank
3	1.10	0.333	1812	7.502	0.960	0.982	1	Blank	Blank	Blank	Blank
4	1.39	0.421	1311	7.179	0.918	0.939	0.957	1	Blank	Blank	Blank
5	1.61	0.488	1285	7.159	0.916	0.937	0.954	0.997	1	Blank	Blank
6	1.79	0.542	1217	7.104	0.909	0.930	0.947	0.990	0.992	1	Blank
7	1.95	0.591	1186	7.078	0.905	0.926	0.943	0.986	0.989	0.996	Blank
8	2.08	0.630	1185	7.077	0.905	0.926	0.943	0.986	0.989	0.996	Blank
9	2.20	0.667	1066	6.972	0.892	0.912	0.929	0.971	0.974	0.981	Blank
10	2.30	0.697	977	6.884	0.881	0.901	0.918	0.959	0.962	0.969	Blank
11	2.40	0.727	948	6.854	0.877	0.897	0.914	0.955	0.957	0.965	1
12	2.48	0.752	869	6.767	0.866	0.886	0.902	0.943	0.945	0.953	0.987
13	2.56	0.776	840	6.733	0.861	0.881	0.897	0.938	0.940	0.948	0.982
14	2.64	0.800	752	6.623	0.847	0.867	0.883	0.923	0.925	0.932	0.966
15	2.71	0.821	704	6.557	0.839	0.858	0.874	0.913	0.916	0.923	0.957
16	2.77	0.839	597	6.392	0.818	0.836	0.852	0.890	0.893	0.900	0.933
17	2.83	0.858	562	6.332	0.810	0.829	0.844	0.882	0.884	0.891	0.924
18	2.89	0.876	552	6.314	0.808	0.826	0.842	0.880	0.882	0.889	0.921
19	2.94	0.891	431	6.066	0.776	0.794	0.809	0.845	0.847	0.854	0.885
20	3.00	0.909	376	5.930	0.759	0.776	0.790	0.826	0.828	0.835	0.865
21	3.04	0.921	201	5.303	0.678	0.694	0.707	0.739	0.741	0.746	0.774
22	3.09	0.936	180	5.193	0.664	0.680	0.692	0.723	0.725	0.731	0.758
23	3.14	0.952	119	4.779	0.611	0.625	0.637	0.666	0.668	0.673	0.697
24	3.18	0.964	82	4.407	0.564	0.577	0.587	0.614	0.616	0.620	0.643
25	3.22	0.976	39	3.664	0.469	0.479	0.488	0.510	0.512	0.516	0.535
26	3.26	0.988	7	1.946	0.249	0.255	0.259	0.271	0.272	0.274	0.284
27	3.30	1	1	0	0	0	0	0	0	0	0

TABLE VI. headwords of the Little Oxford English Dictionary:ranking, natural logarithm, normalisations

B. headwords

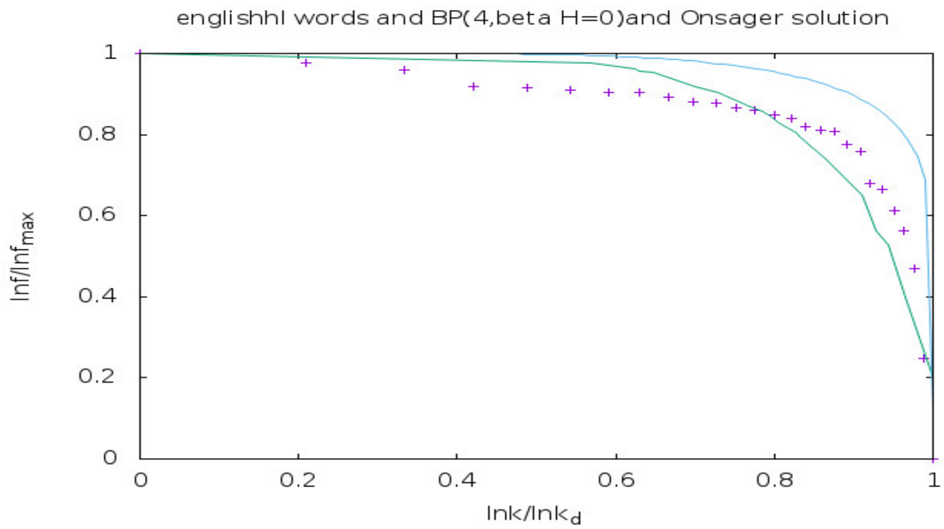

FIG. 18. Vertical axis is $\frac{lnf}{lnf_{max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the headwords of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and in absence of external magnetic field. The uppermost curve is the Onsager solution.

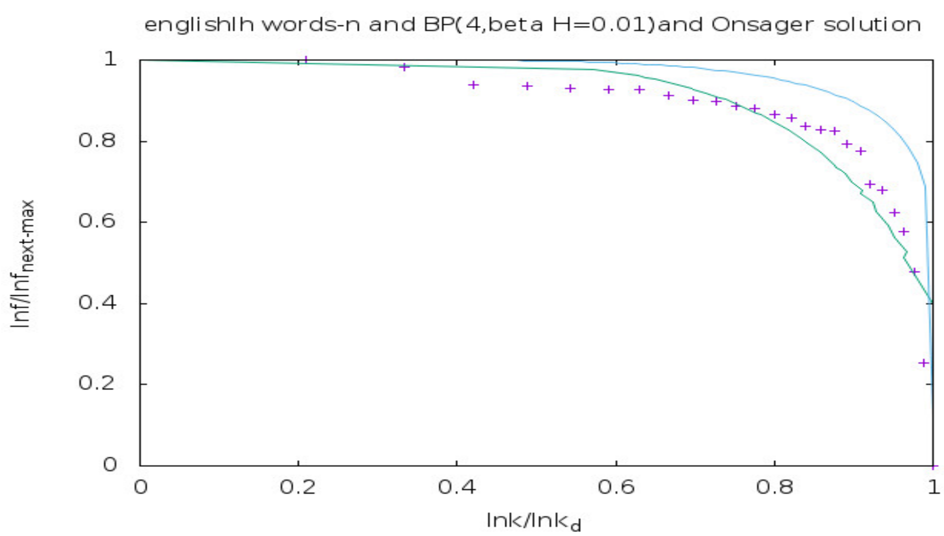

FIG. 19. Vertical axis is $\frac{lnf}{lnf_{next-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the headwords of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.005$ or, $\beta H = 0.01$. The uppermost curve is the Onsager solution.

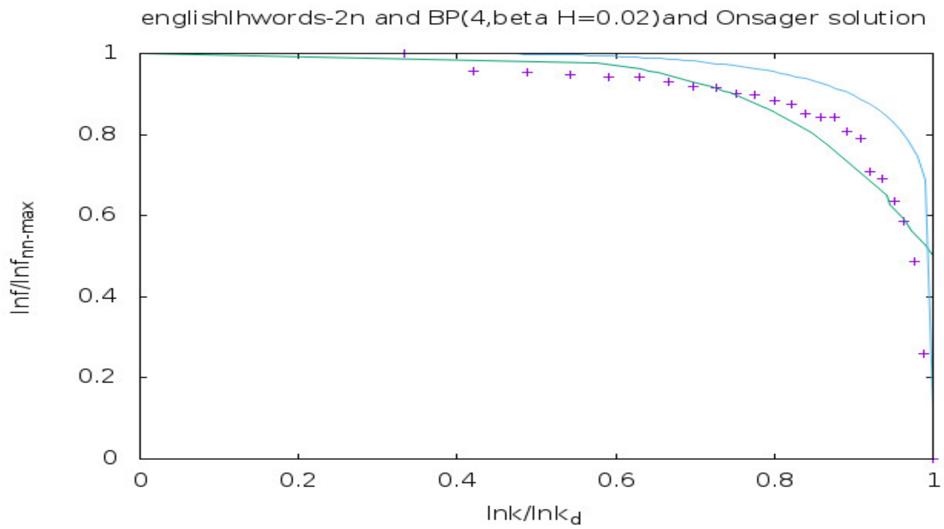

FIG. 20. Vertical axis is $\frac{lnf}{lnf_{nn-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the headwords of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.01$ or, $\beta H = 0.02$. The uppermost curve is the Onsager solution.

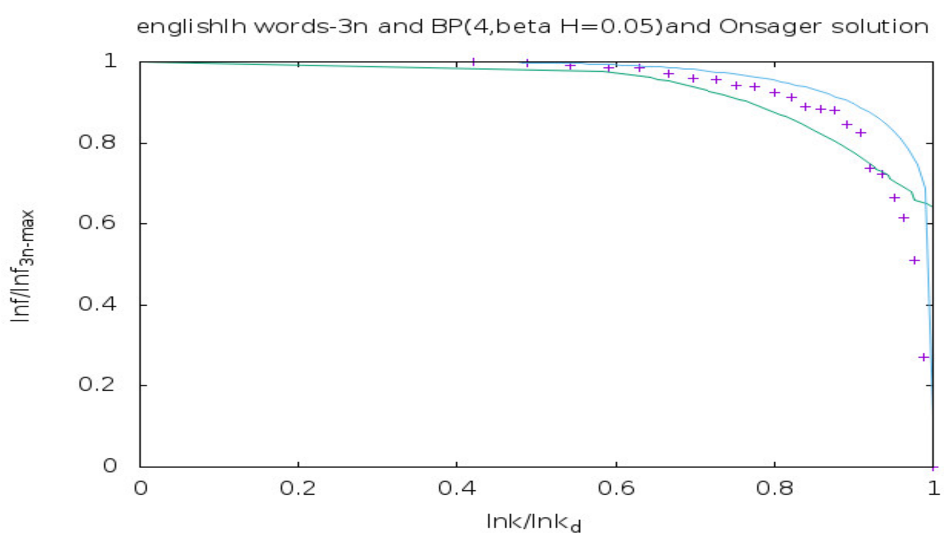

FIG. 21. Vertical axis is $\frac{lnf}{lnf_{nnn-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the headwords of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.025$ or, $\beta H = 0.05$. The uppermost curve is the Onsager solution.

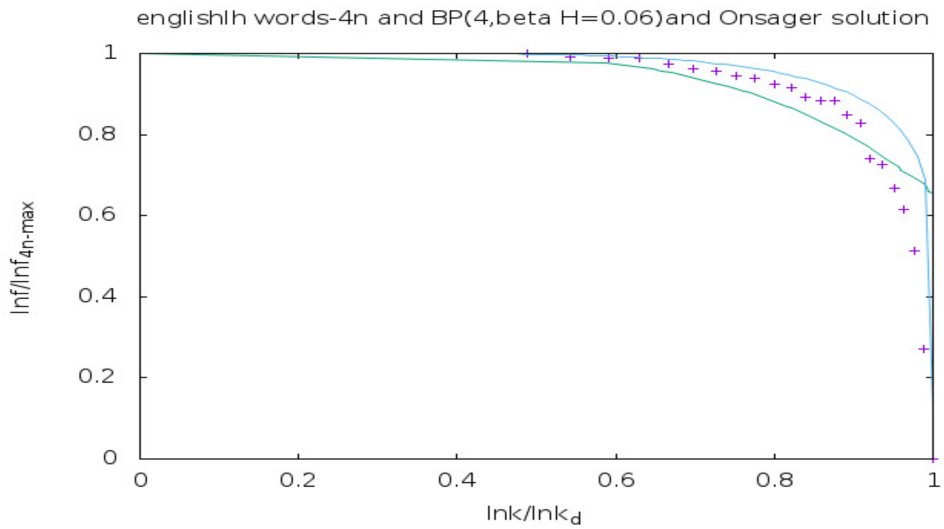

FIG. 22. Vertical axis is $\frac{lnf}{lnf_{nnnn-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the headwords of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.03$ or, $\beta H = 0.06$. The uppermost curve is the Onsager solution.

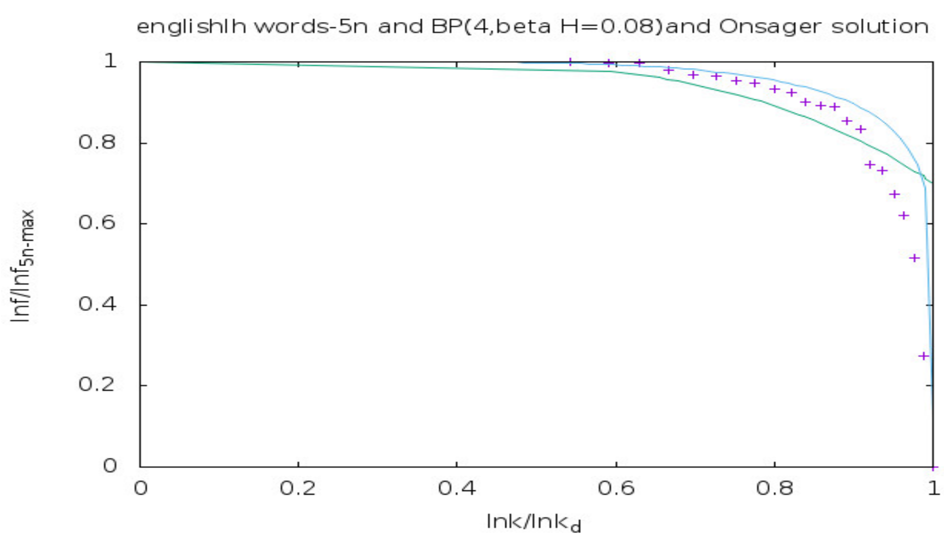

FIG. 23. Vertical axis is $\frac{lnf}{lnf_{nnnnn-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the headwords of the english language with the fit curve being Bethe-Peierls curve in presence of four nearest neighbours and little magnetic field, $m = 0.04$ or, $\beta H = 0.08$. The uppermost curve is the Onsager solution.

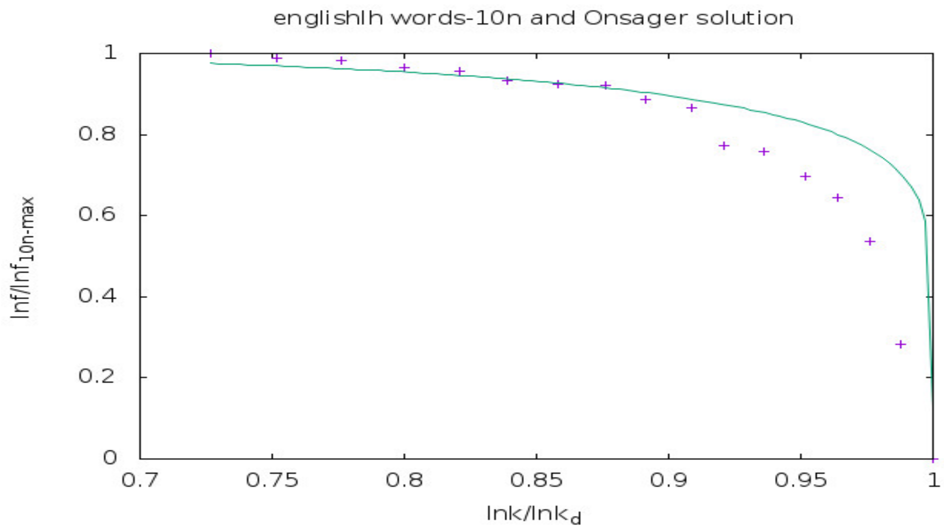

FIG. 24. Vertical axis is $\frac{lnf}{lnf_{10n-max}}$ and horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the headwords of the english language. The uppermost curve is the Onsager solution. The headwords of the Little Oxford English Dictionary are not going over to the Onsager solution.

1. conclusion

From the figures (fig.18-fig.24), we observe that behind the head-words of the Little Oxford English Dictionary, [1], there is a magnetisation curve, BP(4,βH = 0.01), in the Bethe-Peierls approximation with four nearest neighbours, in presence of liitle magnetic field, $\beta H = 0.01$.

Moreover, the associated correspondance with the Ising model is,

$$\frac{lnf}{lnf_{next-to-maximum}} \longleftrightarrow \frac{M}{M_{max}},$$

and

$$lnk \longleftrightarrow T.$$

k corresponds to temperature in an exponential scale, [49]. As temperature decreases, i.e. lnk decreases, f increases. The letters which are recording higher entries compared to those which have lesser entries are at lower temperature. As the English language expands, the letters which get enriched more and more, fall at lower and lower temperatures. This is a manifestation of cooling effect as was first observed in [50] in another way.

On the top of it, on successive higher normalisations, headwords of the Little Oxford English Dictionary, do not go over to Onsager solution in the normalised lnf vs $\frac{lnk}{lnk_{lim}}$ graphs.

As matching of the plots in the figures fig.(18-24), with comparator curves i.e. the magnetisation curves of Bethe-Peierls approximations, is with large dispersions and dispersion does not reduce significantly over higher orders of normalisations, to explore for possible existence of spin-glass transition, in presence of little external magnetic field, $\frac{lnf}{lnf_{max}}$, $\frac{lnf}{lnf_{next-max}}$ and $\frac{lnf}{lnf_{nn-max}}$ are drawn against lnk in the figures fig.(25-27).

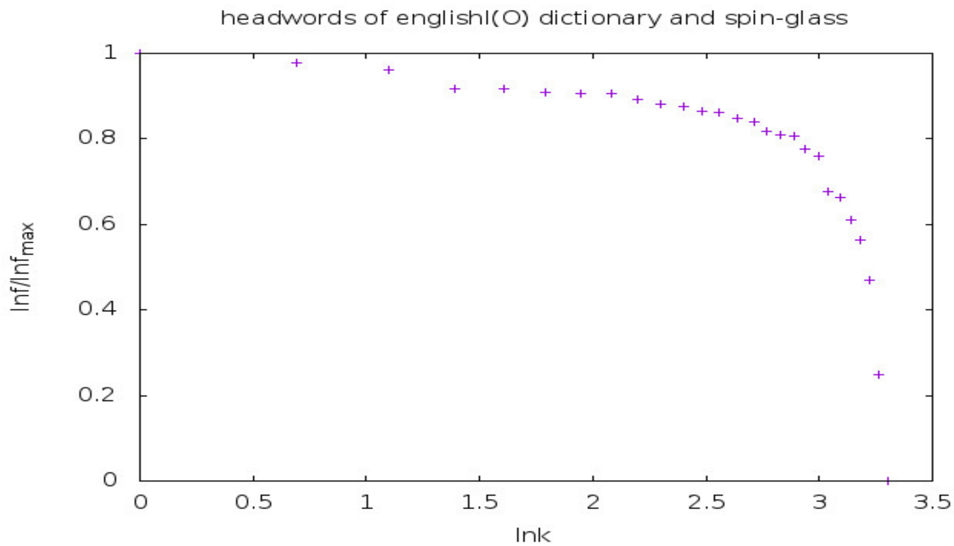

FIG. 25. Vertical axis is $\frac{lnf}{lnf_{max}}$ and horizontal axis is lnk. The + points represent the headwords of the english language.

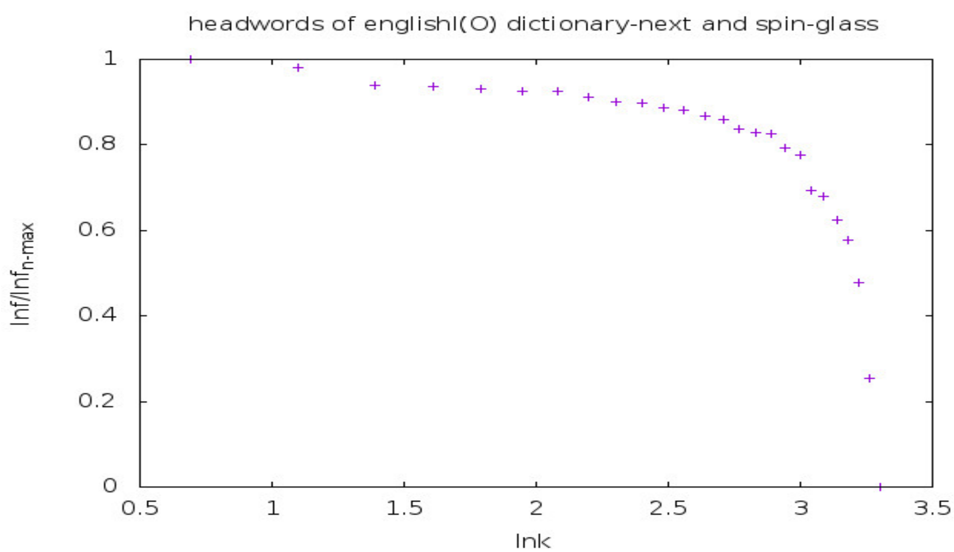

FIG. 26. Vertical axis is $\frac{lnf}{lnf_{next-max}}$ and horizontal axis is lnk. The + points represent the headwords of the english language.

In the figures Fig.25-Fig.27, the points has a smoothened transition, rather than a clearcut transition. Above the transition point(s), the line is almost horizontal, increasing little and below the transition point(s), pointsline rises sharply, but without the tail part, like the branch of a rectangular hyperbola. Hence, the headwords of the English language,[1], better

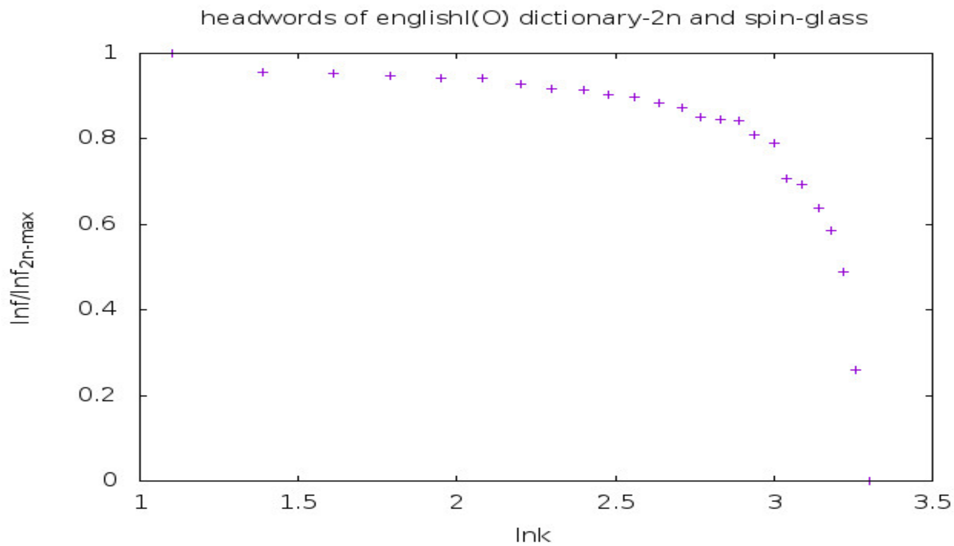

FIG. 27. Vertical axis is $\frac{lnf}{lnf_{nn-max}}$ and horizontal axis is lnk. The + points represent the headwords of the english language.

be described, to underlie a Spin-Glass magnetisation curve, [20], in the presence of little magnetic field.

VI. DISCUSSION

We compare the English language with the Basque and the Romanian in the table, VII. To make the comparison more explicit, we draw $\frac{lnf}{lnf_{max}}$ vs lnk simultaneously in the figure Fig.28for both the entries and headwords of the English langauge,[1], as well as $\frac{lnf}{lnf_{max}}$ vs lnk for headwords of the English,[1], headwords of the Basque, [51] and words of the Romanian language,[52], in the figure Fig.29, to put forward their relative spin-glass natures.

Moreover, it is of immediate interest to carry on the analysis of this paper to the non-compound words and to the non-derived words of the Little Oxford English Dictionary, [1]. It is of further interest to continue the analysis with the Pocket Oxford English Dictionary, [53], then with the Concise Oxford English Dictionary, [54], then to the complete Oxford English Dictionary.

	Englishle	Englishlh	basque	romanian
$\frac{lnf}{lnf_{max}}$ vs $\frac{lnk}{lnk_{lim}}$	BP(4, β H=0)	BP(4, β H=0)	BW(c=0.01)	BW(c=0.01)
$\frac{lnf}{lnf_{next-max}}$ vs $\frac{lnk}{lnk_{lim}}$	BP(4, β H=0.01)	BP(4, β H=0.01)	BP(4, β H=0.01)	BP(4, β H=0)
$\frac{lnf}{lnf_{nnmax}}$ vs $\frac{lnk}{lnk_{lim}}$	BP(4, β H=0.02)	BP(4, β H=0.02)	BP(4, β H=0.01)	BP(4, β H=0)
$\frac{lnf}{lnf_{nnnmax}}$ vs $\frac{lnk}{lnk_{lim}}$	BP(4, β H=0.05)	BP(4, β H=0.05)	BP(4, β H=0.02)	BP(4, β H=0)
$\frac{lnf}{lnf_{nnnnmax}}$ vs $\frac{lnk}{lnk_{lim}}$	BP(4, β H=0.06)	BP(4, β H=0.06)	BP(4, β H=0.05)	
$\frac{lnf}{lnf_{nnnnnmax}}$ vs $\frac{lnk}{lnk_{lim}}$	BP(4, β H=0.08)	BP(4, β H=0.08)	BP(4, β H=0.08)	
$\frac{lnf}{lnf_{nnnnnnmax}}$ vs $\frac{lnk}{lnk_{lim}}$	BP(4, β H=0.08)		BP(4, β H=0.1)	
$\frac{lnf}{lnf_{10nmax}}$ vs $\frac{lnk}{lnk_{lim}}$	Onsager:no	Onsager:no	Onsager:no	Onsager:no
Onsager core	NO	NO	NO	NO
spin-glass	transition	consideration		
$\frac{lnf}{lnf_{max}}$ vs lnk	rectangular hyperbolic rise	rectangular hyperbolic rise	rectangular hyperbolic rise	rectangular hyperbolic rise
$\frac{lnf}{lnf_{next-max}}$ vs lnk	rectangular hyperbolic rise	rectangular hyperbolic rise	rectangular hyperbolic rise	rectangular hyperbolic rise
$\frac{lnf}{lnf_{nn-max}}$ vs lnk	rectangular hyperbolic rise	rectangular hyperbolic rise	rectangular hyperbolic rise	

TABLE VII. comparison of generalised words, headwords of the English and the words of the basque and the romanian languages

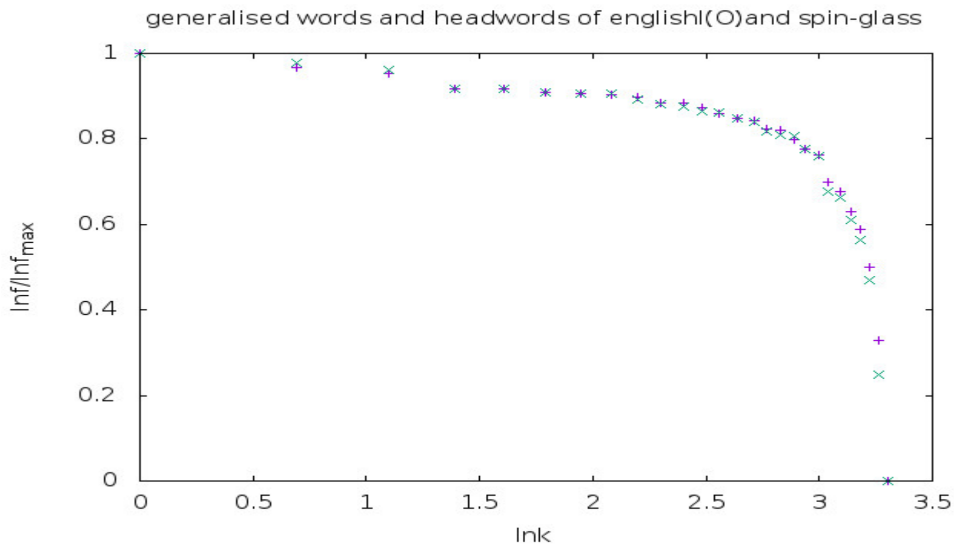

FIG. 28. Vertical axis is $\frac{lnf}{lnf_{max}}$ and horizontal axis is lnk. The + points represent the entries of the english language and the × points represent the headwords of the english language.

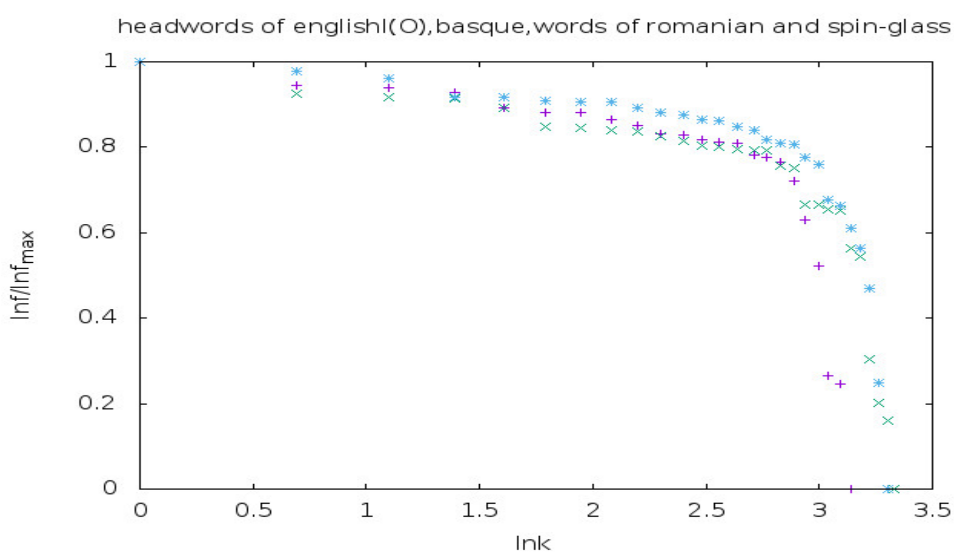

FIG. 29. Vertical axis is $\frac{lnf}{lnf_{max}}$ and horizontal axis is lnk. The ∗ points represent the headwords of the Little Oxford English Dictionary, the +points represent the headwords of the basque language and the × points represent the words of the romanian language.

VII. ACKNOWLEDGEMENT

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