

The Oxford Spanish Dictionary and The Graphical Law

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Abstract

We study the Spanish head entries of The Oxford Spanish Dictionary, Spanish-English. English-Spanish, the fourth edition, 2008. We draw the natural logarithm of the number of the Spanish head entries, normalised, starting with a letter vs the natural logarithm of the rank of the letter, normalised. We conclude that the Dictionary can be characterised by $BP(4, \beta H = 0.01)$ i.e. a magnetisation curve in the Bethe-Peierls approximation of the Ising model with four nearest neighbours in the presence of external magnetic field, H , with $\beta H = 0.01$. β is $\frac{1}{k_B T}$ where, T is the ambient temperature and k_B is the tiny Boltzmann constant.

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I. INTRODUCTION

”The more, the merrier.”

In this article, we go over to The Oxford Spanish Dictionary, [1]. We count one by one all the Spanish head entries of The Oxford Spanish Dictionary, Spanish-English. English-Spanish, the fourth edition, 2008,[1], looking for the graphical law. We have started considering magnetic field pattern in [2], in the languages we converse with. We have studied there, a set of natural languages, [2] and have found existence of a magnetisation curve under each language. We have termed this phenomenon as the Graphical Law. Then, we moved on to investigate, [3], into dictionaries of five disciplines of knowledge and found the existence of a curve of magnetisation under each discipline. This was followed by finding of the graphical law in references from [4] to [89].

The planning of the paper is as follows. We give an introduction to the standard curves of magnetisation of Ising model in the section II. In the section III, we describe the analysis of the Spanish head entries of The Oxford Spanish Dictionary, Spanish-English. English-Spanish, the fourth edition, 2008,[1]. Sections IV and V are Acknowledgment and Bibliography respectively.

II. MAGNETISATION

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 para magnet, 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 $L = \frac{1}{N}\sum_i \sigma_i$, 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 $\mu\sum_i \sigma_i$ or, $\mu(N_+ - N_-)$ or, μNL , $M_{max} = \mu N$. $\frac{M}{M_{max}} = L$. $\frac{M}{M_{max}}$ is referred to as reduced magnetisation. Moreover, the Ising Hamiltonian,[90], for the lattice of spins, setting μ to one, is $-\epsilon\sum_{n,n}\sigma_i\sigma_j - H\sum_i \sigma_i$, where n.n refers to nearest neighbour pairs. The difference ΔE of energy if we flip an up spin to down spin is, [91], $2\epsilon\gamma\bar{\sigma} + 2H$, where γ is the number of nearest neighbours of a spin. According to Boltzmann principle, $\frac{N_-}{N_+}$ equals $exp(-\frac{\Delta E}{k_B T})$, [92]. In the Bragg-Williams approximation,[93], $\bar{\sigma} = L$, 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, $c = \frac{H}{\gamma\epsilon}$, $T_c = \gamma\epsilon/k_B$, [94]. $\frac{T}{T_c}$ is referred to as reduced temperature.

Plot of L vs $\frac{T}{T_c}$ or, reduced magnetisation 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 [91]. W. L. Bragg was a professor of Hans Bethe. Rudolf Peierls was a friend of Hans Bethe. At the suggestion of W. L. Bragg, Rudolf Peierls following Hans Bethe improved the approximation scheme, applying quasi-chemical method.

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

In the approximation scheme which is improvement over the Bragg-Williams, [90],[91],[92],[93],[94], due to Bethe-Peierls, [95], reduced magnetisation varies with reduced temperature, for γ neighbours, in absence of external magnetic field, as

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

$\ln \frac{\gamma}{\gamma-2}$ 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.1. Empty spaces in the table, I, mean corresponding point pairs were not used for plotting a line.

BW(c=0)	BW(c=0.005)	BW(c=0.01)	BP(4, $\beta H = 0$)	reduced magnetisation
0	0	0	0	1
0.435	0.437	0.439	0.563	0.978
0.439	0.441	0.443	0.568	0.977
0.491	0.493	0.495	0.624	0.961
0.501	0.504	0.507	0.630	0.957
0.514	0.517	0.519	0.648	0.952
0.559	0.562	0.565	0.654	0.931
0.566	0.569	0.573	0.7	0.927
0.584	0.587	0.590	0.7	0.917
0.601	0.604	0.607	0.722	0.907
0.607	0.610	0.613	0.729	0.903
0.653	0.658	0.661	0.770	0.869
0.659	0.663	0.666	0.773	0.865
0.669	0.674	0.678	0.784	0.856
0.679	0.684	0.688	0.792	0.847
0.701	0.705	0.709	0.807	0.828
0.723	0.728	0.732	0.828	0.805
0.732	0.736	0.743	0.832	0.796
0.753	0.758	0.766	0.845	0.772
0.779	0.784	0.788	0.864	0.740
0.838	0.844	0.853	0.911	0.651
0.850	0.858	0.864	0.911	0.628
0.870	0.877	0.885	0.923	0.592
0.883	0.891	0.899	0.928	0.564
0.899	0.908	0.918		0.527
0.905	0.914	0.926	0.941	0.513
0.944	0.956	0.968	0.965	0.400
		0.985		0.350
		0.998		0.310
0.969	0.985		0.965	0.300
	0.998			0.250
0.987			1	0.200
0.997			1	0.100
1			1	0

TABLE I. Datas for Reduced temperature[for the Bragg-Williams approximation, in the absence (BW(c=0)) and in the presence (BW(c=0.005), BW(c=0.01)) of magnetic field, $c = 0$, $c = \frac{H}{\gamma\epsilon} = 0.005$, $c = \frac{H}{\gamma\epsilon} = 0.01$ respectively and in the Bethe-Peierls approximation, BP(4, $\beta H=0$), in the absence of magnetic field, for four nearest neighbours] vs reduced magnetisation. Reduced temperature is drawn along the x-axis and Reduced magnetisation is drawn along the y-axis. In gnuplot the command is plot ".dat" using 1:2 with line; 1 standing for x-axis and 2 standing for y-axis datas.

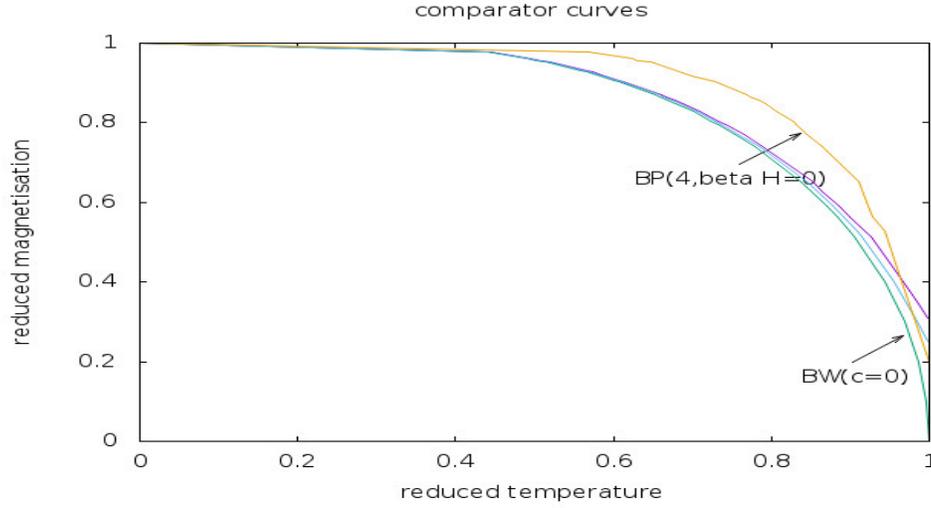


FIG. 1. Reduced magnetisation vs reduced temperature curves, for the Bragg-Williams approximation, in the absence (BW($c=0$)) and in the presence (BW($c=0.005$), BW($c=0.01$)) of magnetic field, $c = 0$, $c = \frac{H}{\gamma\epsilon} = 0.005$, $c = \frac{H}{\gamma\epsilon} = 0.01$, outwards; and in the Bethe-Peierls approximation, BP($4, \beta H=0$), in the absence of magnetic field, for four nearest neighbours (outer in the top).

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

In the Bethe-Peierls approximation scheme , [95], reduced magnetisation varies with reduced temperature, for γ neighbours, in presence of external magnetic field, as

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

Derivation of this formula ala [95] 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,

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

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(m=0.03) 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(m=0.025) 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(m=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 $\beta H = 0.04$. calculated from the equation(4). BP(m=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 $\beta H = 0.02$. calculated from the equation(4). BP(m=0.005) 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.2. Empty spaces in the table, II, mean corresponding point pairs were not used for plotting a line.

BP(m=0.03)	BP(m=0.025)	BP(m=0.02)	BP(m=0.01)	BP(m=0.005)	reduced magnetisation
0	0	0	0	0	1
0.583	0.580	0.577	0.572	0.569	0.978
0.587	0.584	0.581	0.575	0.572	0.977
0.647	0.643	0.639	0.632	0.628	0.961
0.657	0.653	0.649	0.641	0.637	0.957
0.671	0.667		0.654	0.650	0.952
	0.716			0.696	0.931
0.723	0.718	0.713	0.702	0.697	0.927
0.743	0.737	0.731	0.720	0.714	0.917
0.762	0.756	0.749	0.737	0.731	0.907
0.770	0.764	0.757	0.745	0.738	0.903
0.816	0.808	0.800	0.785	0.778	0.869
0.821	0.813	0.805	0.789	0.782	0.865
0.832	0.823	0.815	0.799	0.791	0.856
0.841	0.833	0.824	0.807	0.799	0.847
0.863	0.853	0.844	0.826	0.817	0.828
0.887	0.876	0.866	0.846	0.836	0.805
0.895	0.884	0.873	0.852	0.842	0.796
0.916	0.904	0.892	0.869	0.858	0.772
0.940	0.926	0.914	0.888	0.876	0.740
	0.929			0.877	0.735
	0.936			0.883	0.730
	0.944			0.889	0.720
	0.945				0.710
	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
			1.00	0.964	0.513
				1.00	0.500
					0.400
					0.300
					0.200
					0.100
					0

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

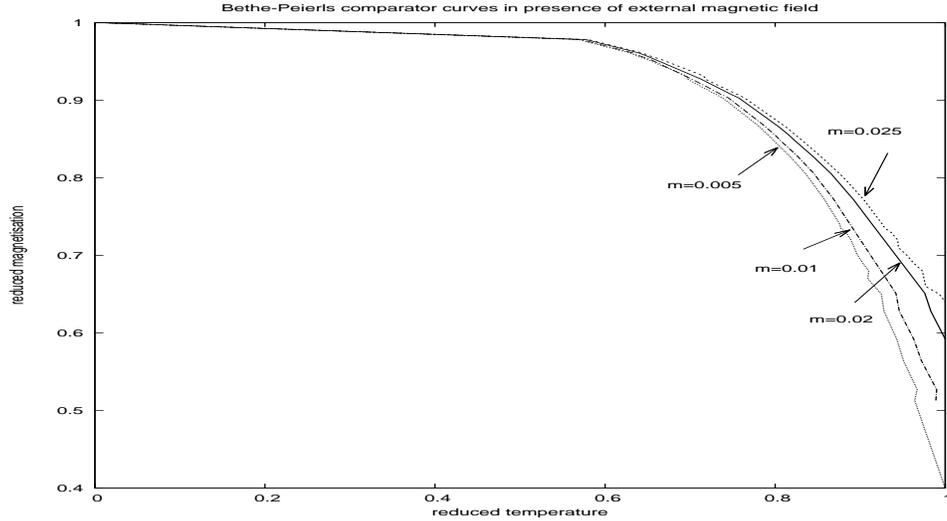


FIG. 2. Reduced magnetisation vs reduced temperature curves for the Bethe-Peierls approximation in the presence of little external magnetic fields, for four nearest neighbours, of the Ising model, with $\beta H = 2m$.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	Ñ	O	P	Q	R	S	T	U	V	W	X	Y	Z
5707	2344	7303	3606	4167	1979	1816	1434	2534	553	203	1588	3474	944	42	1104	5226	309	2788	3087	3038	454	1496	72	32	153	303

TABLE III. Spanish Head Entries

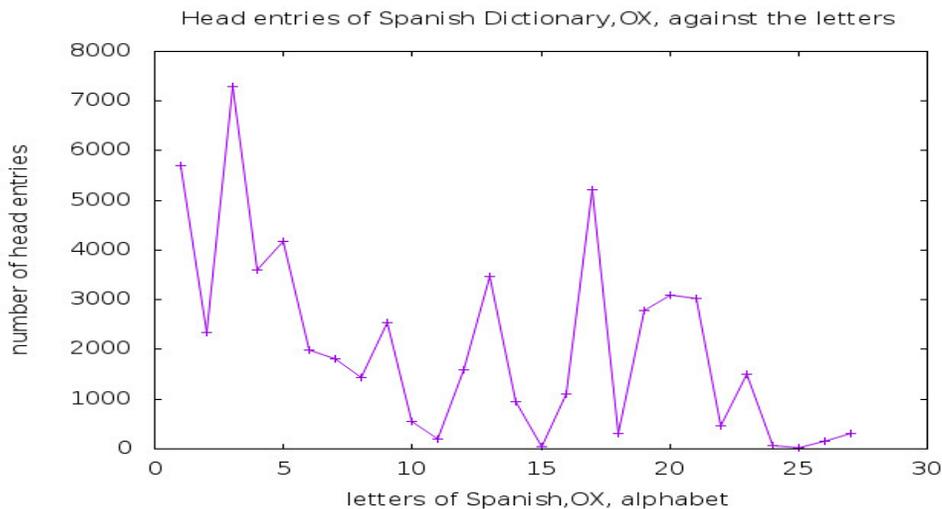


FIG. 3. The vertical axis is number of the Spanish head entries, [1], and the horizontal axis is the respective letters. Letters are represented by the sequence number in the alphabet or, the dictionary sequence,[1].

III. ANALYSIS OF WORDS OF THE SPANISH-ENGLISH DICTIONARY

The Spanish language alphabet is composed of twenty seven letters ala,[1]. As we count all the Spanish head entries, [1], one by one from the beginning to the end, starting with different letters, we obtain the table, III. Highest number of head entries, seven thousand three hundred three, starts with the letter C followed by head entries numbering five thousand seven hundred seven beginning with A, five thousand two hundred twenty six with the letter P etc. To visualise we plot the number of head entries against the respective letters in the dictionary sequence, [1], in the figure fig.3. For the purpose of exploring graphical law, we assort the letters according to the number of head 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} , and a limiting number of head entries. The limiting rank is maximum rank plus one, here it is twenty eight and the limiting number

of head entries is one. As a result both $\frac{lnf}{lnf_{max}}$ and $\frac{lnk}{lnk_{lim}}$ varies from zero to one. Then we tabulate in the adjoining table, IV and plot $\frac{lnf}{lnf_{max}}$ against $\frac{lnk}{lnk_{lim}}$ in the figure fig.4. We then ignore the letter with the highest number of head entries, tabulate in the adjoining table, IV and redo the plot, normalising the $lnfs$ with next-to-maximum lnf_{n-max} , and starting from $k = 2$ in the figure fig.5. Normalising the $lnfs$ with next-to-next-to-maximum lnf_{2n-max} , we tabulate in the adjoining table, IV, and starting from $k = 3$ we draw in the figure fig.6. Normalising the $lnfs$ with next-to-next-to-next-to-maximum lnf_{3n-max} we record in the adjoining table, IV, and plot starting from $k = 4$ in the figure fig.7. Normalising the $lnfs$ with next-to-next-to-next-to-next-to-maximum lnf_{4n-max} we record in the adjoining table, IV, and plot starting from $k = 5$ in the figure fig.8. Normalising the $lnfs$ with nextnextnextnextnext-maximum lnf_{5n-max} we record in the adjoining table, IV, and plot starting from $k = 6$ in the figure fig.9.

k	lnk	lnk/ $\ln k_{im}$	f	lnf	lnf/ $\ln f_{max}$	lnf/ $\ln f_{n-max}$	lnf/ $\ln f_{2n-max}$	lnf/ $\ln f_{3n-max}$	lnf/ $\ln f_{4n-max}$	lnf/ $\ln f_{5n-max}$
1	0	0	7303	8.896	1	Blank	Blank	Blank	Blank	Blank
2	0.69	0.207	5707	8.649	0.972	1	Blank	Blank	Blank	Blank
3	1.10	0.330	5226	8.561	0.962	0.990	1	Blank	Blank	Blank
4	1.39	0.417	4167	8.335	0.937	0.964	0.974	1	Blank	Blank
5	1.61	0.483	3606	8.190	0.921	0.947	0.957	0.983	1	Blank
6	1.79	0.538	3474	8.153	0.916	0.943	0.952	0.978	0.995	1
7	1.95	0.586	3087	8.035	0.903	0.929	0.939	0.964	0.981	0.986
8	2.08	0.625	3038	8.019	0.901	0.927	0.937	0.962	0.979	0.984
9	2.20	0.661	2788	7.933	0.892	0.917	0.927	0.952	0.969	0.973
10	2.30	0.691	2534	7.838	0.881	0.906	0.916	0.940	0.957	0.961
11	2.40	0.721	2344	7.760	0.872	0.897	0.906	0.931	0.947	0.952
12	2.48	0.745	1979	7.590	0.853	0.878	0.887	0.911	0.927	0.931
13	2.56	0.769	1816	7.504	0.844	0.868	0.877	0.900	0.916	0.920
14	2.64	0.793	1588	7.370	0.828	0.852	0.861	0.884	0.900	0.904
15	2.71	0.814	1496	7.311	0.822	0.845	0.854	0.877	0.893	0.897
16	2.77	0.832	1434	7.268	0.817	0.840	0.849	0.872	0.887	0.891
17	2.83	0.850	1104	7.007	0.788	0.810	0.818	0.841	0.856	0.859
18	2.89	0.868	944	6.850	0.770	0.792	0.800	0.822	0.836	0.840
19	2.94	0.883	553	6.315	0.710	0.730	0.738	0.758	0.771	0.775
20	3.00	0.901	454	6.118	0.688	0.707	0.715	0.734	0.747	0.750
21	3.04	0.913	309	5.733	0.644	0.663	0.670	0.688	0.7	0.703
22	3.09	0.928	303	5.714	0.642	0.661	0.667	0.686	0.698	0.701
23	3.14	0.943	203	5.313	0.597	0.614	0.621	0.637	0.649	0.652
24	3.18	0.955	153	5.030	0.565	0.582	0.588	0.603	0.614	0.617
25	3.22	0.967	72	4.277	0.481	0.495	0.500	0.513	0.522	0.525
26	3.26	0.979	42	3.738	0.420	0.432	0.437	0.448	0.456	0.458
27	3.30	0.991	32	3.466	0.390	0.401	0.405	0.416	0.423	0.425
28	3.33	1	1	0	0	0	0	0	0	0

TABLE IV. Spanish head entries of The Oxford Spanish Dictionary,[1] :ranking,natural logarithm, normalisations

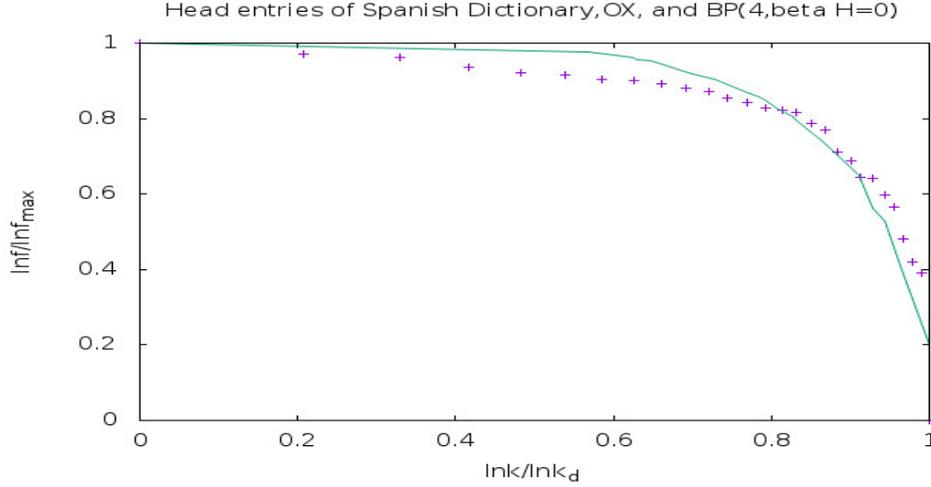


FIG. 4. The vertical axis is $\frac{\ln f}{\ln f_{max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the Spanish head entries of the Oxford Spanish Dictionary with the fit curve being the Bethe-Peierls curve of the Ising model with four nearest neighbours, in the absence of external or, $\beta H = 0$.

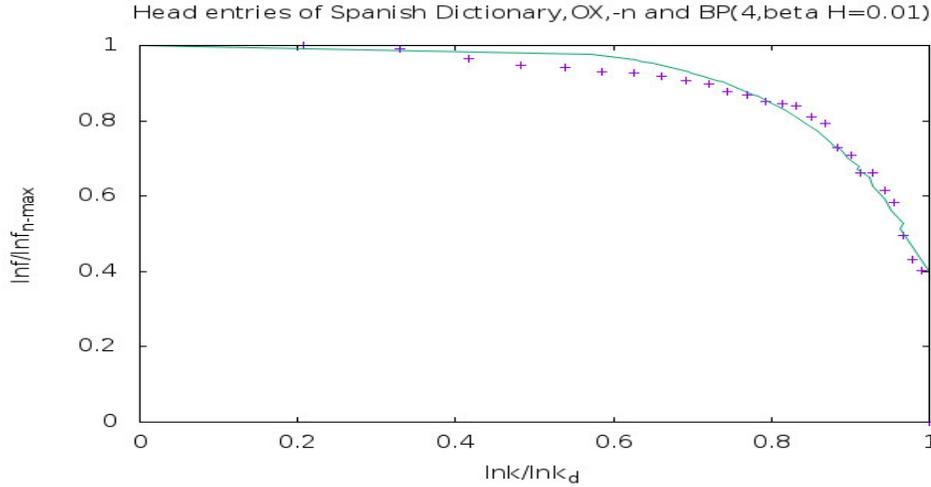


FIG. 5. The vertical axis is $\frac{\ln f}{\ln f_{n-max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the Spanish head entries of the Oxford Spanish Dictionary with the fit curve being the Bethe-Peierls curve of the Ising model with four nearest neighbours, in the presence of little external magnetic field, $m=0.005$ or, $\beta H = 0.01$.

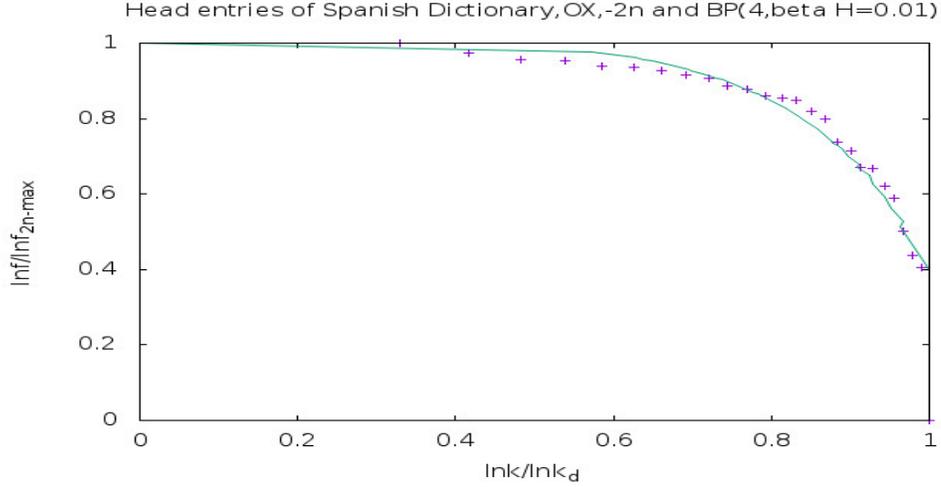


FIG. 6. The vertical axis is $\frac{\ln f}{\ln f_{2n-max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the Spanish head entries of the Oxford Spanish Dictionary with the fit curve being the Bethe-Peierls curve of the Ising model with four nearest neighbours, in the presence of little external magnetic field, $m=0.005$ or, $\beta H = 0.01$.

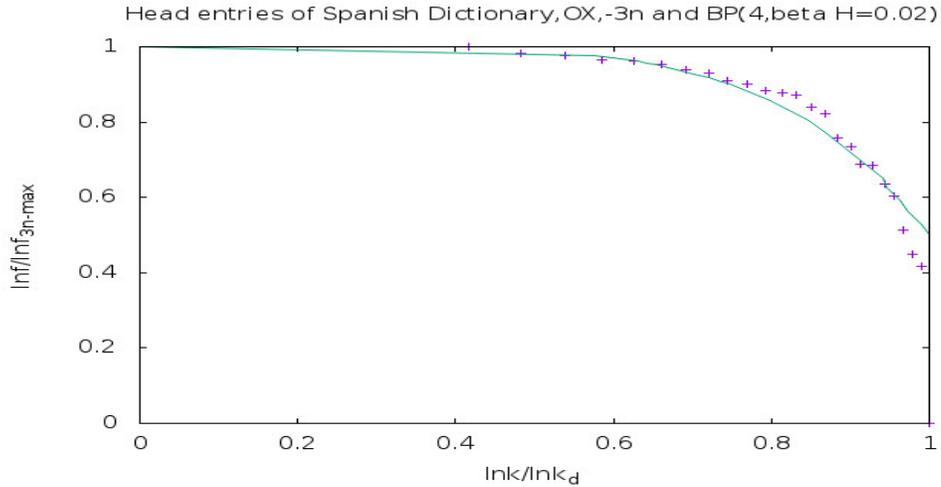


FIG. 7. The vertical axis is $\frac{\ln f}{\ln f_{3n-max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the Spanish head entries of the Oxford Spanish Dictionary with the fit curve being the Bethe-Peierls curve of the Ising model with four nearest neighbours, in the presence of little external magnetic field, $m=0.01$ or, $\beta H = 0.02$.

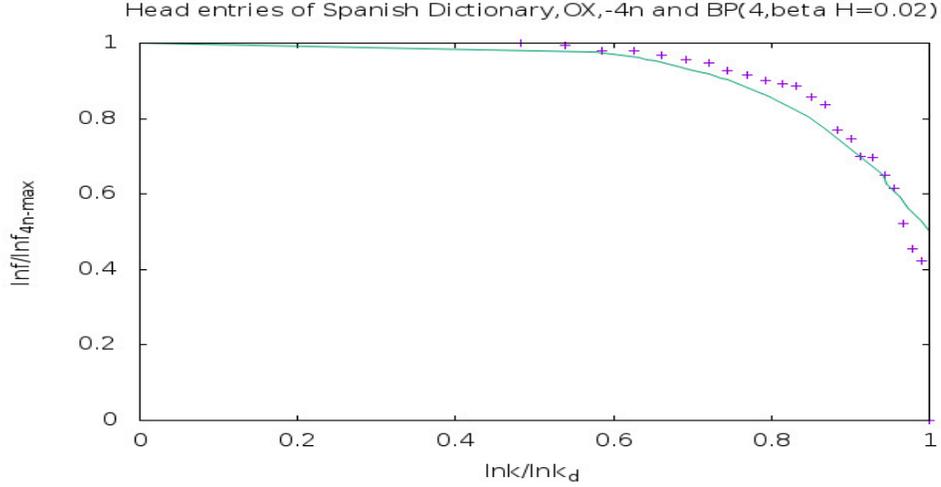


FIG. 8. The vertical axis is $\frac{\ln f}{\ln f_{4n-max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the Spanish head entries of the Oxford Spanish Dictionary with the fit curve being the Bethe-Peierls curve of the Ising model with four nearest neighbours, in the presence of little external magnetic field, $m=0.01$ or, $\beta H = 0.02$.

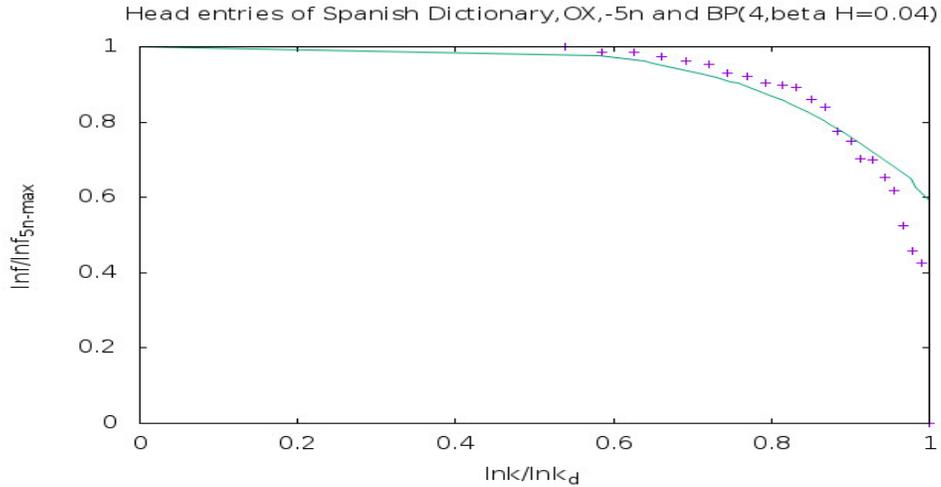


FIG. 9. The vertical axis is $\frac{\ln f}{\ln f_{5n-max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the Spanish head entries of the Oxford Spanish Dictionary with the fit curve being the Bethe-Peierls curve of the Ising model with four nearest neighbours, in the presence of little external magnetic field, $m=0.02$ or, $\beta H = 0.04$.

A. conclusion

From the figures (fig.4-fig.9), we observe that there is a curve of magnetisation, behind the Spanish head entries of The Oxford Spanish Dictionary,[1]. This is the magnetisation curve, $BP(4,\beta H=0.01)$, in the Bethe-Peierls approximation of the Ising model, with four nearest neighbours in the presence of little external magnetic field, H , with $\beta H = 0.01$.

Moreover, the associated correspondence is,

$$\frac{\ln f}{\ln f_{n-max}} \longleftrightarrow \frac{M}{M_{max}},$$
$$\ln k \longleftrightarrow T.$$

k corresponds to temperature in an exponential scale, [97].

IV. ACKNOWLEDGMENT

We have used gnuplot for plotting the figures in this paper.

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