A New Way to Study Biochemistry Words by Using Games

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Abstract: Games are highly appreciated by the population, so due to the Covid19 pandemic confinement we decided to carry out an Internet research of several games, in order to use them for the assimilation of new words of Biochemical students. Games found in puzzle books allow the stimulation of memory, reasoning and other brain capacities, such as keeping us out of stress and improving our knowledge. For this reason, we thought that they could be interesting for relieving students of the stress of confinement, and at the same time allowing to learn Biochemical words with those games. Games found in puzzle books are based on two types of problems, based in numbers or in letters. Among the games based in numbers, the most frequent include sudokus, suzenjou, kakuros, arithmograms; while those based in letters include crosswords, self-defined, and games of words or letters. We decided to perform various puzzles based on letters, and the easiest to implement were those based on words and syllables games. The simplest word games are based on searching within a set of words, those that have some part in common. In this sense, we invented rhyming games, in which words ended in –ine (frequent ending of amino acids, nitrogenous bases, nucleosides and some proteins), in –ose (frequent ending in carbohydrates), or in - ic / –ate (frequent termination of fatty acids and other intermediate acids of metabolism, or of their corresponding salts). Thus, the students were able to observe these characteristics in the nomenclature. On the other hand, incomplete word games allow you to fill in the names of the metabolites using groups of letters to choose from. Our proposal includes various word games that we can apply to the Biochemistry course so that students remember them.

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Introduction

Puzzles or brain teasers are highly appreciated by the majority of the population because they allow learning

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without an active study and enjoying when incorporating knowledge. This effect produces an effective learning without a high effort. In addition, games provide several benefits to those who play them, as they allow a temporary escape from the daily problems and can improve psychological and stress problems. These benefits come from the satisfaction of solving a problem that initially seemed too difficult to solve. During the quarantine it was of great importance, therefore, to keep out the head from worrying due to personal problems and to entertain in other aspects of live. For this reason, there were numerous web pages that provided us with various activities to carry out (visits to museums, songs, books, recorded plays and films), and in particular, pages that provided us with new puzzles for individual or dual entertainment (Broncano, 2020), that could be carried out after printing the games and without using a computer, which was one of the most valued electro domestic used at home by all the inhabitants. By age and sex, games are usually more appreciated by men than by women, and younger people play much more than older people. For this reason, the application of puzzles to Biochemistry may be much appropriated due to the age of our students, despite that in the Chemistry degree there are a majority of women.

Puzzles games found on the Internet can be classified into two large groups. On one hand, those that are based on numbers and allow learning mathematics (sudokus, number tables, games for addition or subtraction, ...), and on the other hand, those that are based on letters and are widely used in studies of grammar, and also in language learning. In a subject like Biochemistry, which requires the student to know a number of words, we thought that number games were not very useful. Although some numerical problems can also be solved in Biochemistry, it is not easy to think on games with results obtained from a problem. So, we focused on letter-based games. In order to use this kind of games for Biochemistry words, the members of our teaching innovation group (Quimet, Metabolisme en Química, GINDO-UB180) prepared several games for these students. These games were proposed as a continuous study tasks for the students of the Biochemistry subject in the Chemistry Degree during the confinement (spring semesters of the course 2019 to 2020, and autumn semester of the course 2020 to 2021). In fact, Chemistry Degree at the University of Barcelona is taught in a double semester mode, so that the students can take all the subjects of the Degree in any of the semesters.

First at all, we look for the most important words found in the appendices of some Biochemistry books in order to have a list of the most commonly used words (Nelson and Cox, 2006; Stryer, 1995). We selected those words and compared the relation between the letters that they contain. Afterwards, we carried out a search through grammar games for children and games for learning languages on Internet, and finally we tried to adapt them by preparing several Biochemistry games based on the ones we had found. The aim of this paper is to present examples of the words' games we proposed to our students during the Covid19 confinement, although those games can be also used also actually for the self-study of Biochemistry.

Method

Summary of the Biochemistry Words found

Biochemistry words were separated in groups, which presented several relations between their letters. Although not all, most of the carbohydrates or derivatives ended in the three letters –ose (arabinose, erythrose, fructose, galactose, glucose, mannose, ribose, ribulose, sedoheptulose, sorbose, triose, xylose, xylulose, aldose, amylose, hexose, ketose, lactose, maltose, maltotriose, pentose, sucrose, tetrose). Most of the amino acids finish in –ine (alanine, arginine, asparagine, cysteine, phenylalanine, glycine, glutamine, histidine, isoleucine, leucine, lysine, methionine, proline, tyrosine, threonine, serine, valine), as well as other nitrogen compounds, such as bases and nucleosides (adenine, adenosine, cytidine, cytosine, deoxyadenosine, deoxycytidine, deoxyguanosine, deoxyinosine, deoxythymidine, guanosine, inosine, thymidine, uridine). Enzymes finish in –ase (acyltransferase, aconitase, adenylate cyclase, aminotransferase, arginase, carboxylase, ceramidase, colipase, desaturase, dehydrogenase, diastase, elastase, elongase, endonuclease, endopeptidase, phosphodiesterase, phosphofructokinase, phosphoglucomutase, phosphorylase, phosphoribosylmutase, hexokinase, protease, thiolase, transferase, translocase). Finally, lipids, acids and other intermediate end in –ic or in –ate, depending on the acid or salt form (arachidonic, behenic, caproic, stearic, lauric, linoleic, margaric, myristic, nervonic, oleic, palmitic, palmitoleic, prostanoic, ascorbic, citric, folic, fumaric, isocitric, lactic, malic, malonic, phenylacetic, pyruvic, succinic). Those words and other ones were selected for the word games proposed to students.

Word Games related with Letters

Some of the games to learn words are based in letters, syllables or words. Those games were used with students during the Covid19 confinement, as it has previously described (Moreno and Centelles, 2022), and include the following games.

Syllables' or Letters Groups' Games

These games are based on the use of several words that are missing a syllable or a group of letters. This syllable or group of letters can be the same for all the words (words lacking a common syllable or a letter group, words that rhyme with individual rhyme), or different for each word (unique incomplete words, words with different rhymes), or for two word (double incomplete words, words with two-by-two-rhymes). In these last cases, it is easier to show a list of the syllables or letter groups to be filled at the words.

Anagrams

An anagram is a word that has the same letters of another one. These letter's games can be directly obtained from a single word (individual anagram of a word), from a group of words (collective anagram of several

words). Several pages can be found in Internet to get anagrams of a simple word, although many of the Biochemical words cannot be found there (Words, 2021).

Codes to Translate Words

These games develop a word by using a secret code, which can be shown in the game or it is unknown and must be guessed from other words that contain words and their translations like a Rosetta stone. The easiest method is to use a numeric code, although the code may also be alphabetic. The letters found can directly form the word or be anagrams to form them later (words translated from a numerical code, anagrams after a translation of a numerical code). The codes can also be used to find syllables in a hidden word.
In a similar way, the hidden words can contain a space for the letters and each letter can be found following a line that forms a maze (letter's mazes). This last game is easier than an anagram, as the lines show the order of these letters in the word.

Chained Words

It is really difficult to prepare a game with chained words, as many words in Biochemistry end in –ose, –ine, –ase, –ic or –ate, while few words begin with those syllables or groups of letters. Instead, a possible chained game consists in using dominoes pieces. Each domino is a rectangular tile with a line dividing its face into two ends, and these ends can contain a biomolecule's name, a formula, or the biomolecule family's name. In these cases, the student would have to look for the fitting between a biomolecule's name and either its formula or the biomolecule's family.

Results

Word games related with letters were divided in 4 groups: syllables' or letters groups' games, anagrams, codes to translate words and chained words. Hereby we show some new games of each group, that could be proposed to Biochemistry students of the Chemistry degree, in order that they could learn the nomenclature of the main molecules while playing.

Words with Rhyme (Syllables' or Letters Groups' Games)

Separate the following words in groups depending on the rhyme:
A) Ending in –ATE
B) Ending in –ASE
C) Ending in –INE
D) Ending in –OSE

Words:

ALAN_ _ _	CITR_ _ _	GLUC_ _ _	MAL_ _ _
ALDOL_ _ _	ELAST_ _ _	GLYC_ _ _	PROL_ _ _
ARABIN_ _ _	FRUCT_ _ _	HEXOKIN_ _ _	PYRUV_ _ _
ARGIN_ _ _	FUMAR_ _ _	ISOCITR_ _ _	RIB_ _ _
CARBOXYL_ _ _	GALACT_ _ _	ISOLEUC_ _ _	THIOL_ _ _

Is it possible to separate in groups depending on their rhyme in the following groups: 1) amino acids, 2) sugars, 3) Krebs cycle intermediates, 4) enzymes?

Solution:

1) Amino acids (–INE): ALANINE, ARGININE, GLYCINE, ISOLEUCINE, PROLINE

2) Sugars (–OSE): ARABINOSE, FRUCTOSE, GALACTOSE, GLUCOSE, RIBOSE

3) Krebs cycle intermediates (–ATE): CITRATE, FUMARATE, ISOCITRATE, MALATE, PYRUVATE

4) Enzymes (–ASE): ALDOLASE, CARBOXYLASE, ELASTASE, HEXOKINASE, THIOLASE

Incomplete Words (Syllables' or Letters Groups' Games)

Choose one of the letters groups in order to complete the following words:

Words:

AR_ _ _NOSE	HIS_ _ _INE
CY_ _ _NE	LAC_ _ _E
FR_ _ _OSE	P_ _ _INE
GA_ _ _TOSE	RI_ _ _E
GL_ _ _MATE	VAL_ _ _

Letter groups:

ABI	STI
BOS	TID
INE	TOS
LAC	UCT
ROL	UTA

Classify the previous words in the groups of biomolecules: 1) amino acids, 2) sugars. Search dimers in both groups.

Solutions:

(2) ARABINOSE	(1) HISTIDINE
(1) CYSTINE (2 cysteine)	(2) LACTOSE (glucose+galactose)

(2) FRUCTOSE (1) PROLINE
(2) GALACTOSE (2) RIBOSE
(1) GLUTAMATE (1) VALINE

Simple Anagrams (Anagrams)

From the following anagrams, find the hidden nitrogenized compounds. Which of them is not an amino acid? Which is the amino acid that does not end in –ine? (only the two acidic and this one show this characteristic).

Anagrams:
NIELANA
NARTROPHYT
INDITHESI
DIESONANA
SILICONEUE
PAGANISERA

Solutions:
ALANINE
TRYPTOPHAN (the amino acid that does not end in –ine, and also the other two acidic amino acids: aspartic and glutamic)
HISTIDINE
ADENOSINE (it is a nucleoside)
ISOLEUCINE
ASPARAGINE

Syllables' anagrams (Anagrams)

From the following syllable's anagrams, find the hidden lipids. Which lipid can be hydrolyzed?
Anagrams:
TER-LES-CHO-OL
ATE-LE-O
TATE-MY-RIS
TATE-MI-PAL
ER-A-OL-GLYC-TRI-CYL

Solution:
CHO-LES-TER-OL

O-LE-ATE

MY-RIS-TATE

PAL-MI-TATE

TRI-A-CYL-GLYC-ER-OL (can be hydrolyzed to glycerol and fatty acids)

Words with a Numeric Code (Codes to Translate Words)

From the following numeric code, translate the following words into amino acids:

Numeric code:

A – B – C – D – E – F – G – H – I – J – K – L – M

01 – 02 – 03 – 04 – 05 – 06 – 07 – 08 – 09 – 10 – 11 – 12 – 13

N – O – P – Q – R – S – T – U – V – W – X – Y – Z

14 – 15 – 16 – 17 – 18 – 19 – 20 – 21 – 22 – 23 – 24 – 25 – 26

Word codes:

07-12-21-20-01-13-09-14-05

03-25-19-20-05-09-14-05

16-05-14-25-12-01-12-01-14-09-14-05

16-18-15-12-09-14-05

01-19-16-01-18-20-01-20-05

22-01-12-09-14-05

Solution:

GLUTAMINE

CYSTEINE

PHENYLALANINE

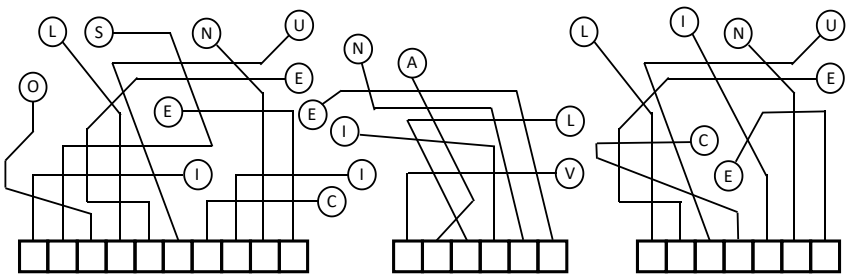
PROLINE

ASPARTATE

VALINE

Words with Letter Mazes (Codes to Translate Words)

Find the biomolecules hidden in these letter maze:



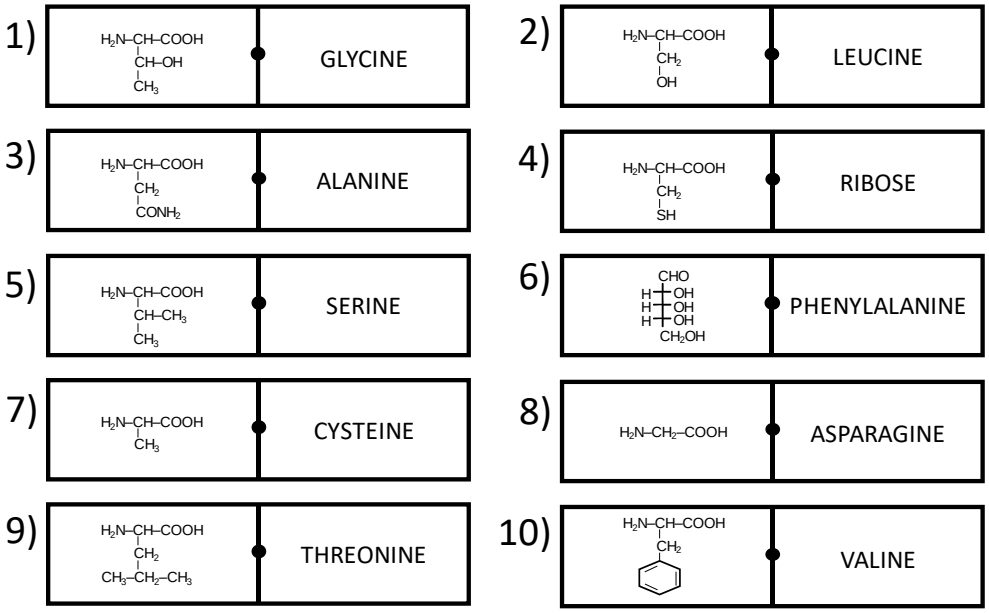
What kind of biomolecules are they? Which of them are isomers?

Solution:
ISOLEUCINE, VALINE, LEUCINE. All are branched-chain amino acids.
LEUCINE and ISOLEUCINE are isomers.

Dominoes with Nomenclature and Structures (Chained Words)

In this game, each name of biomolecule fits only with one structure.

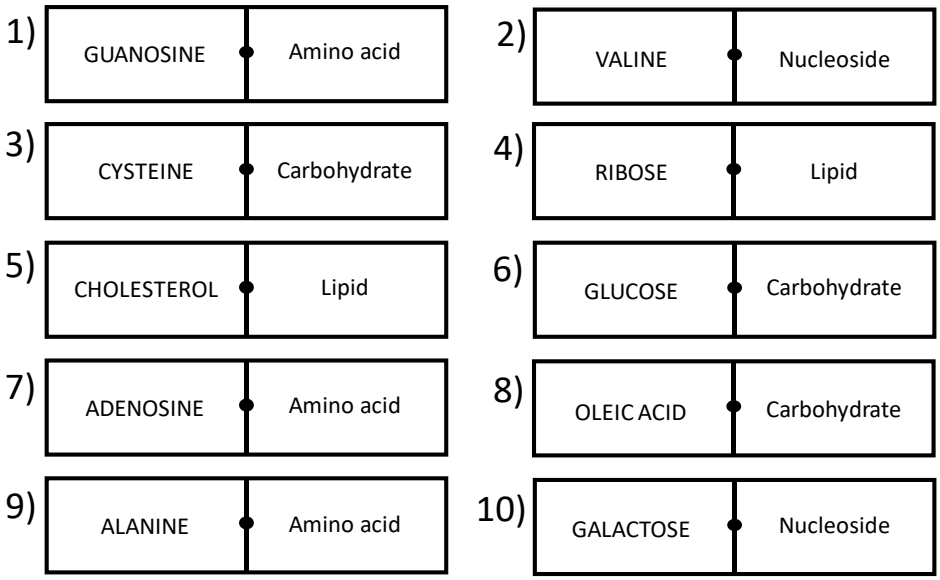
Chain the following domino tiles fitting names and chemical structures. Which molecule is not an amino acid?



Solution:
1 – 8 – 3 – 7 – 4 – 6 – 10 – 5 – 2 – 9 – 1
Ribose is a sugar, and all other molecules are amino acids.

Dominoes with Nomenclature and Biomolecule's Family (Chained Words)

In this game, each biomolecule's family can fit with several names, and thus there are several solutions, although only those that use all the tiles are valids.
Chain all the domino tiles in order that all the biomolecule's families fit with the names of the molecules.



Possible solutions:

1 – 2 – 7 – 9 – 3 – 6 – 4 – 5 – 8 – 10 – 1
1 – 2 – 7 – 9 – 3 – 4 – 5 – 8 – 6 – 10 – 1
1 – 9 – 2 – 7 – 3 – 6 – 4 – 5 – 8 – 10 – 1
1 – 9 – 2 – 7 – 3 – 4 – 5 – 8 – 6 – 10 – 1

7 – 2 – 1 – 9 – 3 – 6 – 4 – 5 – 8 – 10 – 7
7 – 2 – 1 – 9 – 3 – 4 – 5 – 8 – 6 – 10 – 7
7 – 9 – 2 – 1 – 3 – 6 – 4 – 5 – 8 – 10 – 7
7 – 9 – 2 – 1 – 3 – 4 – 5 – 8 – 6 – 10 – 7

1 – 3 – 6 – 4 – 5 – 8 – 10 – 7 – 9 – 2 – 1
1 – 3 – 4 – 5 – 8 – 6 – 10 – 7 – 9 – 2 – 1
1 – 9 – 3 – 6 – 4 – 5 – 8 – 10 – 7 – 2 – 1
1 – 9 – 3 – 4 – 5 – 8 – 6 – 10 – 7 – 2 – 1

7 – 3 – 6 – 4 – 5 – 8 – 10 – 1 – 9 – 2 – 7
7 – 3 – 4 – 5 – 8 – 6 – 10 – 1 – 9 – 2 – 7
7 – 9 – 3 – 6 – 4 – 5 – 8 – 10 – 1 – 2 – 7
7 – 9 – 3 – 4 – 5 – 8 – 6 – 10 – 1 – 2 – 7

Discussion

In the present work, several games based on letters, syllables and words are shown. These games could be applied to Biochemistry students of the Chemistry Degree, in order that these students could learn some of the words shown in the glossaries of the Biochemistry books. We have classified these games into four main groups: 1- words lacking a syllable or a group of letters, 2- anagram words, 3- translation of codes or mazes, and 4- dominoes and other chained words games. In the four groups, games could be played individually and do not require a competition between several players. Games that involve a competition between several players, such as hangman game, tend to be more amusing due to interactions between players and allow competition between those players. However, the games we are looking for do not require a competition from one player against the other. In the games that we present, the player competes exclusively with himself to obtain the words that are

requested. Group 1 games (words lacking a syllable or a group of letters) are the simplest games to prepare, although they are also the easiest to solve. The easiest games to solve are those that include the possible syllables or groups of letters that can be used in the game. In this case, resolution consists on gradually substituting the various groups of letters included and identifying for each lacking word if it makes sense or not. When lacking letters are not included in the game, solving the game can be more difficult, as there are more possibilities. However, when there are several words that contain the same group of missing letters, the game is easier. In group 2 games (anagram words), games are simple to prepare, but also present a higher difficulty to solve depending on the letters of the word. In fact, if a word contains n letters different from each other, there can be found (n! – 1) anagram words. This makes preparing these words easier. Thus, the word "soup" presents (4! – 1) = (4 · 3 · 2 · 1 - 1) = (24 – 1) = 23 anagrams: "sopu, spou, spuo, supo, suop, opus, opsu, oups, ousp, ospu, osup, puos, puso, posu, pous, psuo, psou, usop, uspo, uops, uosp, upos, upso". Therefore, it is easy to propose one of the anagrams as a game to find a word, but it will be somehow more difficult to find the solution of this word by combining the letters. However, students can more easily find the word by using the anagram generators found in Internet (Words, 2021). Even more difficult to solve are those anagrams that include several words, since the number of letters increases and as they are part of different words it is more difficult to cheat with the automatic anagram generators. In group 3 games (codes and mazes to translate words), mazes are easier than anagrams of group 2, since by following the corresponding path, it is possible to reach the position of the letter within the word, without having to analyze the possible anagrams of the word. Regarding the translation by using codes, if the code is included in the game, resolution of the game is easier than in the case that the player has to guess the code from other words included. Acrostics (poems that have a hidden word) (Acrostic, 2022) can be a good way to guess a secret code. For example, from the first letter (or another letter) of each verse of a poem, it is possible to obtain a secret word. Numerical codes are easier, and it is possible to define a letter with the first number and define the code by alphabetic order beginning from this letter. In Biochemistry, the translations of codes can be seen in the translation of messenger RNA to proteins. Thus, another possibility is to use the one-letter code for amino acids to generate words, and apply the code for the three bases (which can be found in a general Biochemistry book) to identify those words. Finally, group 4 games (dominoes and other chained words games) are the most difficult games to prepare. Few words in Biochemistry start with ine– or with ne–, and thus it is very difficult to chain them with so many biomolecules ending in –ine. Therefore, other types of games that do not rely on chaining the letters of the words should be used. One possibility is to chain two sets included in a tile, just as dominoes are chained. A simple game that a single player can play is a chain using two sets with the same number of elements (for example, name of a biomolecule and its chemical structure) and these sets are related by searching for the formula that corresponds to the name of the biomolecule. In this case, an exclusive sequence of tiles is obtained as solution of this game. However, it is possible to complicate the game, and even propose it for two or more players, by relating the names of biomolecules with the type of biomolecule (carbohydrate, lipid, amino acid, nucleotides). In this case, it is possible to obtain several results, although not always with as many options as those obtained by using dominoes. In the example shown hereby, due to the use of several double tiles that target the same type of biomolecules, the problem allows several solutions, just as it happens with dominoes. However, it is possible to

request the longest possible path or the path that contains a specified number of tokens.

Conclusion

Several games were developed to study Biochemistry words, and these games could be applied to the Biochemistry students of the Chemistry Degree. These games were classified into 4 groups.

Group 1 games (syllables' or letters groups' games) are easy to prepare and also easy to solve.

Group 2 games (anagrams) are easy to prepare and more difficult to solve.

Group 3 games (codes to translate words) were divided in numeric (or other) codes and letter mazes codes. While letter mazes codes are easier to solve than anagrams, numeric (or other) codes could be more difficult to solve (especially when the code is not directly given).

Group 4 games (chained words) are difficult to prepare by using directly words. Thus, other chained games as dominoes can be more difficult to solve than previous groups. The most complex game is the one containing names and structures, as requires a knowledge of the structures of biomolecules.

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References

Acrostics, 2022. https://en.wikipedia.org/wiki/Acrostic

Broncano, J.C. (2020). 100 pasatiempos para toda la familia para descargar e imprimir. https://www.tuexperto.com/2020/03/30/100-pasatiempos-para-toda-la-familia-para-descargar-e-imprimir/

Moreno E.; Centelles, J.J. (2022). Juegos sencillos destinados a aprender la nomenclatura de las biomoléculas. Nodos del Conocimiento (In Print).

Nelson D.L., Cox M.M. (2006). Lehninger. Principios de Bioquímica. Cuarta Edición. Ediciones Omega.

Stryer L. (1995). Bioquímica. Cuarta Edición. Editorial Reverté, S.A.

Words, 2021. (https://palabr.as/generador-anagramas) / (https://www.palabrascon.com/anagramas. php) (https://www.wordplays.com/anagram-solver/) / (https://es.yourdictionary.com/buscador-de-palabras/anagramador/) / (https://es.wikipedia.org/wiki/Acr%C3%B3stico) (https://www.thewordfinder.com/anagram-solver/)