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Solving the Mysteries of Chemistry in Packets

Jerry Jean Preston

Chemistry is a subject that is often relegated to cumbersome equations and formulae in schools. But, if we take a good look around us, we will see that Chemistry comes alive before our eyes. Almost everything that surrounds us requires chemistry and its minion chemicals to support it. Look at the paper that we write on or read from. If it weren't for bleaching chemicals, our writing paper would still retain the dark colour of the source pulp and would be almost illegible. The wooden chairs that we sit on and tables we write on would have used gum, paint and varnish expertly. Pesticides and insecticides would have been sprayed on the vegetables that are grown and eaten, for our safety and health benefits.

A specific set of chemical elements – semiconductors such as ***silicon*** and ***germanium*** – are the pillars of the electronics industry, including desktop computers, mobile phones, smart phones, tablets, etc. The art of cooking ultimately is all about mixing and matching flavourful, edible *chemicals* or ingredients. Human beings have managed to eradicate a major share of the nightmarish pains that have plagued them for centuries, thanks to medicinal chemicals. Surgeries can be performed without having to bear the attendant pain due to the discovery of anaesthetic chemicals.

Plastics have ushered in a new era of consumerism. Plastic containers come as paper covers, bottles, boxes and tubes. It is nearly paper-light, yet waterproof, and this facilitates the convenient and economical transportation of a large number of consumables, such as food products, medicines, cosmetics, toiletries, etc. The polyester and synthetic clothes that we wear, the cement that helps us stand storeys higher than the ground level, defying gravity – chemistry is everywhere!

But even after leaving its touch so prominently, chemistry remains an unsung and invisible hero. In the humdrum process of completing the syllabus, teachers often forget its wonderful omnipresence, and chemistry ends up as another boring *learn-by-heart* subject.

In such a situation, product packets can be a quirky means to animate a chemistry lesson. The labels on packaged foods, cosmetics and toiletries can make interesting *reference materials*. Chemistry often appears in all its quiet brilliance as the ingredients listed on these *Fast Moving Consumer Goods (FMCG)* and as a

result, packets are one of the few places where chemistry is clearly visible for all to see and learn from. Students will be delighted to see their boring chemical formulae emerge as the stars in their daily shopping choices. Learning from packets will reduce the monotony of memorization that is unavoidable to an extent, in chemistry lessons.

In the movie *Evolution* (2001), *Professor Ira Kane* (played by *David Duchovny* of *X-Files* fame) requires ***selenium*** to combat alien DNA that is spreading on earth. Two of his academically weakest students come to his rescue when they suggest that their favourite hair product *Head and Shoulders* contains lots of ***selenium sulphide*** in it. This shows how a product label can be an influential chemistry teacher, as even the weakest students cannot forget their favourite product.

This article looks at two chemistry topics that can be taught by observing product ingredients. One is the common food additives in packaged foods. They include colours, flavours, anti-oxidants, emulsifiers and stabilisers that are numbered either using E numbers or INS numbers. The prefix *E* stands for *Europe*, while *INS* stands for *International Numbering System*. The other topic is a nomenclature system for certain organic compounds, other than those propounded by the *International Union of Pure and Applied Chemistry (IUPAC)*. Both topics will mostly be unfamiliar to chemistry teachers in schools and are also outside the conventional chemistry syllabus. While the former is part of flavour chemistry, the latter is part of the *International Nomenclature of Cosmetic Ingredients (INCI)*. However, the ubiquity of packets and the brand culture will endear the lessons to students. Like the students in *Evolution*, they will remember the lessons taught by their packet-chemistry teachers, long after they have forgotten the formulae and equations.

Packaged foods often contain some cryptic ingredients like *E440, E110*, etc. These are the E-numbered food additives and in some products, the E is replaced by INS. There is an entire series of chemicals from 100 to 1599 that have been catalogued for use in the European Union, and most of them have also been adopted by the INS. (Trivia: E440 is pectin, an emulsifier, and E110 is the colour sunset yellow.)

For higher classes where topics in organic chemistry have to be covered, the chemicals on labels of shampoo, lotion or perfume bottles can be studied. Students should have a clear idea of the following before experimenting with cosmetic labels:

- **Aliphatic hydrocarbons like alkanes, alkenes, alkynes**
- **Cycloalkanes**
- **Aromatic hydrocarbons (Arenes like benzene)**
- **Functional groups containing halogens (Haloalkanes or alkyl halides)**
- **Functional groups containing oxygen: alcohols (R-OH), ethers (R-O–R'), aldehydes (R-CHO), carboxylic acids (R- COOH), esters (R- COO-R')**
- **Functional groups containing nitrogen like amines**
- **IUPAC nomenclature for the above compounds**

Teachers should familiarise themselves with the *International Nomenclature of Cosmetic Ingredients (INCI)* as it still retains some trivial or common names which have been discredited by the IUPAC. Some of the important stem names for alcohols and fatty acids in the INCI system are given below.

CARBONS (MAIN CHAIN)	IUPAC STEM TERM	INCI FATTY ACIDS	INCI FATTY ALCOHOLS
6	Hexane	Capric	Hexyl
7	Heptane	Heptanoic	Heptyl
8	Octane	Caprylic	Carylyl
9	Nonane	Pelagronic	Nonyl
10	Decane	Capric	Decyl
11	Undecane	Undecanoic	Undecyl
12	Dodecane	Lauric	Lauryl
13	Tridecane	Tridecanoic	Tridecyl
14	Tetradecane	Myristic	Myristyl
15	Pentadecane	Pentadecanoic	Pentadecyl
16	Hexadecane	Palmitic	Cetyl
17	Heptadecane	Margaaric	Heptadecyl
18	Octadecane	Stearic	Stearyl
19	Nonadecane		
20	Eicosane	Arachidic	Arachidyl
21	Heneicosane		
22	Docosane	Behenic	Behenyl

Some other ingredients that can be encountered on cosmetic product labels:

Ethylene glycol: ethane 1,2 – diol (IUPAC name)

Propylene glycol: propane 1,2 – diol (IUPAC name)

Paraben: parahydroxy benzoates or esters of parahydroxybenzoic acid

Carbomer: an expanded molecule derived by the insertion of C_2 molecules in the original molecule

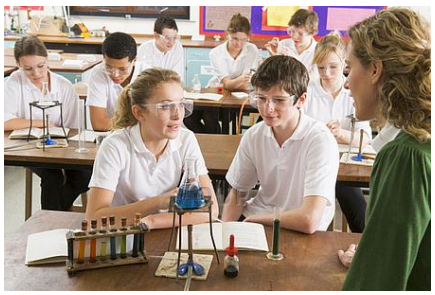
Aqua: water

Triclosan: 5-chloro-2-(2, 4-dichlorophenoxy) phenol (IUPAC name)

Students can be asked to skim through the ingredients of cosmetic packets where they might find a few alcohols like *stearyl alcohol, cetearyl alcohol, cetyl alcohol*; ethers like *stearyl ether*; esters like *isopropyl myristate, glycol stearate*, etc. Starting from here, the concept of INCI nomenclature and how cosmetics do not follow the IUPAC nomenclature can be introduced to them. They can also try and draw the structures of some of these compounds after the basic INCI rules have been introduced in the class. This can be done after translating INCI names into their respective IUPAC names. Other INCI terms like *aqua, paraben* and *carbomer* can also be taught in a similar way.

For studying chemistry through such hands-on techniques, teachers and students will require many packets of packaged foods, shampoos, creams, etc. It may be financially unviable to buy all the brands or keep track of simultaneous expiry. Too many bottles or packets of a product can remain unused and get spoiled. Instead, one can *crowd source* the product labels. If a student is researching a shampoo, they can borrow their friends' preferred brand for some time. They can note down the ingredients and return it once the experiments are over.

Due to the novelty of the topics, teachers will have to do quite a bit of preparation and be open to the excitement of teaching beyond the textbook. The effort will broaden their *chemical* horizons, and present them with holistically enriched students of the subject.



Jerry Jean Preston *is a teacher based in Coimbatore, who has taught in various educational institutes like Centre for Management Studies, Jain University, Bangalore; Sree Sankaracharya University of Sanskrit, Kerala; St Xavier's College for Women, Aluva, Kerala, etc. She is in the process of completing her PhD. She is interested in creative writing and developing methods to make the teaching-learning process a more interesting one.*

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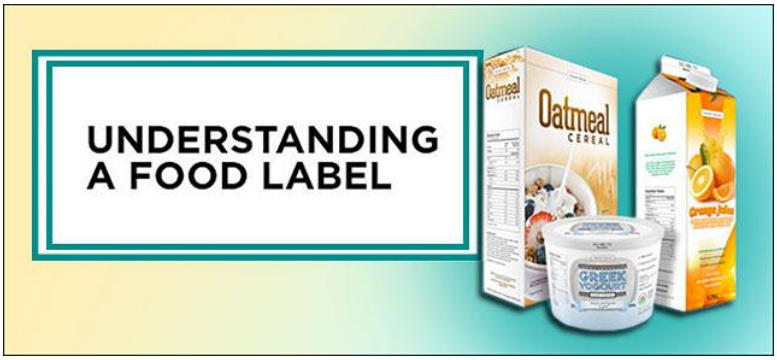
Lesson Plan on Chemistry in Packaged Labels (Classes 8-10)

Jerry Jean Preston



Time: 1 week for student preparation, 1 period for quiz, 2 periods for student presentations

Objective: To sensitize students to E-numbers (or INS numbers) and the chemistry on packaged food labels

Method: Quiz and student presentations

Materials required: Labels of packaged foods, preferably with ingredients having E-numbers (or INS numbers)

Teacher Preparation:

Most chemistry teachers are unaware about the concept of E-numbering, so they will have to do a bit of prior preparation themselves. Before conducting the quiz, teachers should make a catalogue of about 100 packaged foods and their E-numbered ingredients. Though this will require an exhaustive study of food labels, it will be helpful if the teacher has access to a departmental store through which she can walk and browse products. This catalogue will help in verifying student responses for the question “Name a product with E-number ….” during the quiz. The teacher can print a table for 100 products as shown below. When visiting the departmental store, they can make the entries for the products.

	Food Colours E100 – E199	Preservatives E200 – E299	Antioxidants, Acidity Regulators E300 – E399	Thickeners, Stabilisers, Emulsifiers E400 – E499	Acidity Regulators, Anti Caking Agents	Flavour Enhancers E600 – E699	Antibiotics E700 – E799	Glazing Agents, Sweeteners E900 – E999	Additional Chemicals E 1000 – E 1599
Product 1									
Product 2									
Product 3									
Product 4									
Product 5									
Product 6									
					| | |				
Product 100									

Teachers can check the Wikipedia entry for E-numbers to familiarise themselves with the topic. Other resources are:

- '*Current EU approved additives and their E Numbers*' <https://www.food.gov.uk/science/additives/enumberlist> on the website of *Food Standards Agency, UK*.
- *Understanding Food Additives*

  <http://www.understandingfoodadditives.org/index.htm> is a colourful website produced with the help of *Food Additives and Ingredients Association* and the *Chemical Industry Education Centre*. It has a visual aid for each class of food additive to make it interesting for students. It also picks the important details from the otherwise overwhelming list of food additives.

Terms to Remember:

- **E numbers**: These are codes for chemical ingredients added to foods that have been approved for use within the European Union (E stands for Europe). There are 9 main classes of food additives which include colours, preservatives, acidity regulators, sweeteners, glazing agents, and so on. The chemicals in each class are numbered serially.
- **INS**: International Numbering System. This system is similar to the E-numbering system, except that it uses INS in place of E in the code. This list is prepared by the *Codex Alimentarius*, a division of the UN. It works with the *World Health Organisation (WHO)* and *Food and Agriculture Organization (FAO)*. However, most packaged foods in India use the E prefix, instead of the INS prefix.
- **Food colour**: a food additive that adds or restores the colour of food.
- **Preservative**: a food additive that prevents deterioration of food by microbial action.
- **Antioxidant**: a food additive that prevents deterioration of food due to the process of oxidation. It also reduces browning of certain foods.
- **Acidity regulator**: a food additive that controls the acidity or alkalinity of a food. It can be an acid or a base.
- **Thickener**: a food additive that increases the viscosity of the food.
- **Stabiliser**: a food additive that maintains a uniform dispersion of two or more components in the food. A dispersion is a system of particles of one state (solid, liquid or gas) in a continuous phase of another state. So it can be solid particles in solid/ liquid/ gas phase; liquid particles in solid/ liquid/ gas phase; or gas particles in solid/liquid/ gas phase. Whipped cream is a dispersion of gas particles in a liquid phase. Gelatine is a dispersion of liquid in solid. An emulsion is a dispersion of liquid in liquid.
- **Emulsifier**: a food additive that maintains a uniform emulsion of two or more phases in the food. An emulsion is a mixture of two or more immiscible liquids. Milk is an emulsion of water and fat. Mayonnaise is an emulsion of oil, egg yolk and vinegar.
- **Anti-caking agent**: a food additive that reduces sticking of food components.
- **Flavour enhancer**: a food additive that enhances existing flavour and/or odour of food.
- **Glazing agent**: a food additive that adds a shiny surface or protective coating to the food.
- **Sweetener**: a food additive that imparts sweet taste. It excludes the conventional mono- and disaccharide sugars.

Before the quiz and presentations (introducing the topic):

The teacher can set the stage for the topic of E-numbers on food packets. Begin with interesting and creative questions like the following:

- *If you do not eat the food in your tiffin box and leave it there for the next day, it starts to rot. Why does food not rot in packets in departmental stores, even after a long journey from the factory to the shop? Can you name some preservatives?*
- *Do you know that the fruit preparations in dairy desserts and jellies would remain liquid, if it did not contain gelling agents?*

The website *Understanding Food Additives* has interesting visual cues which can be used to begin the topic. For e.g., mayonnaise with and without an emulsifier, cocoa milk with and without a stabiliser, etc.

Distribute a few empty food packets in class and ask students to look at the ingredients on it. *Do they see certain common ingredients like preservatives, antioxidants, colour, etc.? Do they see numbers like E211, E322, E110, etc.? What does E stand for? On certain packets the numbers may be prefixed with INS instead of E? What is INS?*

Then introduce the concept of E-numbers or INS numbers and the main classes of food additives. Give a copy of the following worksheet to each student. Ask them to write down the E-numbers or INS numbers on 5 packaged foods. They should also find out the corresponding names of the ingredients. As far as possible, each student's food should be different from those of the other students. This will help them later, during the **E-number lottery**.

Ingredients: Dehydrated Potatoes, Modified Food Starch, Corn Oil, Sugar, Salt, Soy Lecithin, Leavening (Monocalcium Phosphate and Sodium Bicarbonate), and Dextrose.
No Preservatives.

Student's Worksheet

	Food Colours E100 – E199	Preservatives E200 – E299	Antioxidants, Acidity Regulators E300 – E399	Thickeners, Stabilisers, Emulsifiers E400 – E499	Acidity Regulators, Anti Caking Agents E500 – E 599	Flavour Enhancers E600 – E699	Antibiotics E700 – E799	Glazing Agents, Sweeteners E900 – E999	Additional Chemicals E 1000 – E 1599
Product 1									
Product 2									
Product 3									
Product 4									
Product 5									

Divide the class into 9 groups – one for each class of food additive:

1. Colours 2. Preservatives 3. Antioxidants 4. Acidulants 5. Emulsifiers 6. Anti-Caking Agents 7. Flavours 8. Gelling Agents, Stabilisers and Thickeners 9. Sweeteners

Each group has to make a presentation on their assigned food additive. [Note: The topics for presentations do not follow the serial order in the E-number series. The classes, antibiotics (E700 – 799), glazing agents (E900 – 999) and other chemicals (E1000 – 1599) in the series have been avoided. Students can be made aware of this.] The students should also be prepared for a quiz on the main food additives and their E-numbers.

E number Lottery and Quiz (after 1 week)

The class can be divided into 2 groups, and the teacher can conduct an **E-number lottery** first by calling out an E-number. The group should give the name of the food additive and a packaged food which has this ingredient. They can look into their filled-in worksheets for this.

The lottery is a motivation for the students to complete their worksheets. The teacher can call out about 20 E-numbers, however, too many can become boring. When selecting an E-number, they should ensure that they know a packaged food which contains this ingredient. This is where the teacher's E number bank of 100 food products will come useful. They can verify if the student's food response actually contains the mentioned E number. Also, this is where the group with the most varied assortment of foods will have an edge. After the lottery, the teacher can begin the quiz. When preparing questions for the quiz, they should take care to balance the topic areas. Three questions for each class of food additives may be used and they should also have back-up questions, in case of passed questions, a draw, or other unforeseen situations.

The following is a sample set of questions:

1. ***Name a common emulsifier which means 'egg yolk' in ancient Greek.***
2. ***On food packets, we find that flavours and colours are '****natural', 'nature identical'* ***or 'synthetic'. What do these mean?***
3. ***This is a natural stabiliser and is used in jams and marmalades. What is it?***
4. ***We know of 4 basic tastes –*** *sweet, sour, bitter* ***and*** *salt****. There is a fifth taste which is found in monosodium glutamate, savouries, crisps and soya sauce. Name this flavour.***
5. *Sorbic acid* ***and*** *benzoic acid* ***(and their salts) are commonly used as……***
6. ***The orange yellow colour obtained from the roots of turmeric is ……***
7. *Ascorbic acid* ***is an important anti-oxidant. What is it more commonly known as?***
8. ***These additives are much sweeter than sugar, but have less calories. So they are used in diabetic foods and low calorie foods. What are they?***
9. ***What is added to common table salt to make it flow easily?***
10. *Carrageenan* ***is a stabiliser that is made from ……***
11. ***Maggi noodles claims to have avoided this flavour. It is commonly known as*** *ajinomoto****. What is its chemical name?***
12. ***The acid found in*** *vinegar* ***is known as ……***

Answers:

1. Lecithin (E 322)
2. *Natural* flavours and colours – found in natural sources; *Nature identical* – exactly the same molecules as in natural sources, however they are made synthetically; *Synthetic* – do not occur in nature, have to be made in factories
3. Pectin (E 440)
4. Umami
5. Preservatives
6. Curcumin (E100)
7. Vitamin C (E 300)
8. Intense or artificial sweeteners
9. Anti-caking agent: magnesium carbonate (E504)
10. Algae
11. MSG (monosodium glutamate) (E621)
12. Acetic acid (E260)

Student Presentations

After the quiz, the groups can make presentations for about 10 minutes. The teacher can remind students of the standard presentation tips, some of which are given below. They can also be used as evaluation points:

- ✓ Verify all points, especially the scientific facts, statistics, etc.
- ✓ Begin interestingly with a question, anecdote, joke or trivia.
- ✓ Do not read out verbatim from presentation slides as each slide is only a cue for what you say. What you finally present should be three times the content on the slide.
- ✓ Do not clutter presentation slides with information. Do not copy-paste paragraphs onto a slide. Ensure that the font is big or easily visible. Choose a professional font, not something decorative or floral. Each slide can have maybe a visual and a caption, or maybe 4 lines.
- ✓ Recap the main points when you end for reinforcement.

The teacher should also check if the group has balanced out its duties - collecting data, making slides, oral presentation - amongst its members.

Appendix: Sample of a Completed Worksheet (Some Packaged Foods and the E numbered Ingredients)

	Food Colours E100 – E199	Preservatives E200 – E299	Antioxidants, Acidity Regulators E300 – E399	Thickeners, Stabilisers, Emulsifiers E400 – E499	Acidity Regulators, Anti Caking Agents E500 – E 599	Flavour Enhancers E600 – E699	Antibiotics E700 – E799	Glazing Agents, Sweeteners E900 – E999	Additional Chemicals E 1000 –E 1599
Mapro Mango Jam	E110 – Sunset yellow	E211 Class II- Sodium benzoate	E330 - Citric acid	E440 i - Pectin		Natural, Nature identical and Artificial			
Tata Salt					E536 – Potassium ferrocyanide				
Pappai Ice Cream				E435 – Polysorbate (Emulsifier), E471 e - Glycerides of fatty acids (Emulsifiers), E461 – Methyl cellulose					
Maggi Noodles	E150 d – Sulphite ammonia caramel		E330 - Citric acid		E500 ii – Sodium carbonate (Raising agent)	E635 – Disodium ribonucleotide			
Lotte Choco Pie			E322 – Lecithin (Emulsifier), E341 i – Calcium phosphate	E476 – Polyglycerol polyricinoleate (Emulsifier), E407 – Carrageenan (Emulsifier), E415 – Xanthan	E500 ii - Sodium carbonate, E503 ii – Ammonium carbonate				

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Words Section

Colloid (noun)

Meaning

- A homogeneous non-crystalline substance consisting of large molecules or ultramicroscopic particles of one substance dispersed through a second substance. Colloids include gels, sols, and emulsions; the particles do not settle, and cannot be separated out by ordinary filtering or centrifuging like those in a suspension. *(Oxforddictionaries.com)*

Origin (and additional information) ~ The term's first known use was in mid-19th century, around *1840-50*. It is derived from Greek *kolla* meaning *glue* + *-oid*.

The term *colloidal suspension* refers unambiguously to the overall mixture. Unlike a solution, whose solute and solvent constitute only one phase, a colloid has a dispersed phase (the suspended particles) and a continuous phase (the medium of suspension). To qualify as a colloid, the mixture must be one that does not settle or would take a very long time to settle appreciably.

The dispersed-phase particles have a diameter of between approximately 1 and 1000 nanometers. Such particles are normally easily visible in an optical microscope, although at the smaller size range, an ultramicroscope or an electron microscope may be required. Homogeneous mixtures with a dispersed phase in this size range may be called *colloidal aerosols, colloidal emulsions, colloidal foams, colloidal dispersions,* or *hydrosols*. Some colloids are translucent because of the *Tyndall effect*, which is the scattering of light by particles in the colloid, while others may be opaque or have a slight colour. Colloidal suspensions are the subject of interface, and colloid science and this field of study was introduced in 1861 by Scottish scientist **Thomas Graham**.

Based on the nature of interaction between the dispersed phase and the dispersion medium, colloids can be classified as

- *Hydrophilic colloids*: These are water-loving colloids. The colloid particles are attracted towards water.
- *Hydrophobic colloids*: These are opposite in nature to hydrophilic colloids. The colloid particles are repelled by water. They are also called *irreversible sols*.

Words Section

A *hydrocolloid* is defined as a colloid system wherein the colloid particles are hydrophilic polymers dispersed in water. Hydrocolloids can be either irreversible (single-state) or reversible. For example, *agar*, a reversible hydrocolloid of seaweed extract, can exist in a gel and solid state, and alternate between states with the addition or elimination of heat.

Many hydrocolloids are derived from natural sources. For example, *agar-agar* and *carrageenan* are extracted from *seaweed*, *gelatin* is produced by hydrolysis of proteins of bovine and fish origins, and *pectin* is extracted from *citrus peel* and *apple pomace*. Gelatin desserts like *jelly* or *Jell-O* are made from gelatin powder, another effective hydrocolloid. Hydrocolloids are employed in food mainly to influence texture or viscosity (e.g., a sauce). Hydrocolloid-based medical dressings are used for skin and wound treatment. Other main hydrocolloids are *xanthan gum, gum arabic, guar gum, locust bean gum*, cellulose derivatives as *carboxymethyl cellulose, alginate* and *starch*.

Usage ~

i. *He showed that these materials were long, chain-like molecules, and not colloids, as previously thought.*
ii. *This assumption is generally verified in colloid science and has been precisely verified for this material only at low concentration of monovalent salt.*
iii. *According to some, taking the colloidal herbal medicine was a traditional way to raise energy levels in winter.*

Derivatives~ *colloid*- adjective; *colloidal*- adjective