

Food Chemistry Periodic Table



Celebrating the International Year of the Periodic Table 2019

Created by Jane K Parker

Acknowledgements and thanks to the RSC Food Group Committee: Robert Cordina, Bryan Hanley, Taichi Inuit, John Points, Kathy Ridgway, Martin Rose, Wendy Russell, Mike Saltmarsh, Maud Silvent, Clive Thomson, Kath Whittaker, Pete Wilde, and to Martin Chadwick, Cian Moloney and Ese Omoaruhke, for contributions to the elements, to Flaticons for use of their free icons, and to Alinea and TDMA for photographs of He and Ti.

In slideshow mode, [click on an element](#) in periodic table to find out more, [return via the RSC Food Group Logo](#).

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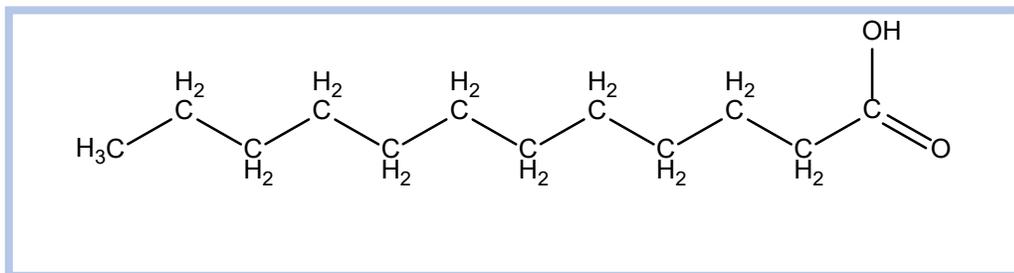
Food Chemistry Periodic Table



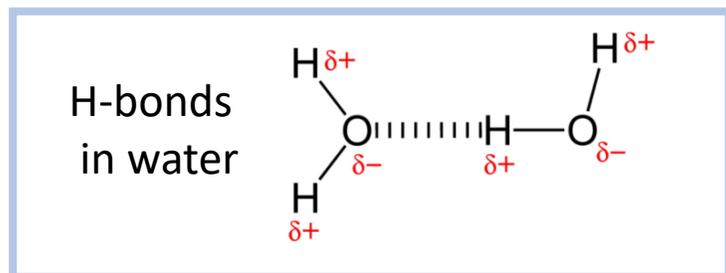
<u>H</u>																	<u>He</u>
<u>Li</u>	<u>Be</u>											<u>B</u>	<u>C</u>	<u>N</u>	<u>O</u>	<u>F</u>	<u>Ne</u>
<u>Na</u>	<u>Mg</u>											<u>Al</u>	<u>Si</u>	<u>P</u>	<u>S</u>	<u>Cl</u>	<u>Ar</u>
<u>K</u>	<u>Ca</u>	<u>Sc</u>	<u>Ti</u>	<u>V</u>	<u>Cr</u>	<u>Mn</u>	<u>Fe</u>	<u>Co</u>	<u>Ni</u>	<u>Cu</u>	<u>Zn</u>	<u>Ga</u>	<u>Ge</u>	<u>As</u>	<u>Se</u>	<u>Br</u>	<u>Kr</u>
<u>Rb</u>	<u>Sr</u>	<u>Y</u>	<u>Zr</u>	<u>Nb</u>	<u>Mo</u>	<u>Tc</u>	<u>Ru</u>	<u>Rh</u>	<u>Pd</u>	<u>Ag</u>	<u>Cd</u>	<u>In</u>	<u>Sn</u>	<u>Sb</u>	<u>Te</u>	<u>I</u>	<u>Xe</u>
<u>Cs</u>	<u>Ba</u>	<u>La</u>	<u>Hf</u>	<u>Ta</u>	<u>W</u>	<u>Re</u>	<u>Os</u>	<u>Ir</u>	<u>Pt</u>	<u>Au</u>	<u>Hg</u>	<u>Tl</u>	<u>Pb</u>	<u>Bi</u>	<u>Po</u>	<u>At</u>	<u>Rn</u>
<u>Fr</u>	<u>Ra</u>	<u>Ac</u>	<u>Rf</u>	<u>Db</u>	<u>Sg</u>	<u>Bh</u>	<u>Hs</u>	<u>Mt</u>	<u>Ds</u>	<u>Rg</u>	<u>Cn</u>	<u>Nh</u>	<u>Fl</u>	<u>Mc</u>	<u>Lv</u>	<u>Ts</u>	<u>Og</u>

Occurrences in food

- Core element in organic compounds (fats, proteins, carbohydrates, vitamins).



- Key element in water, H₂O, which is 70% of the human body and 70% of many foods.
- Hydrogen bonds give water its unique properties.



Roles in food

- H⁺ gives one of the five basic tastes – sour.
- the higher the concentration of H⁺, the lower the pH
 - pH 2 Lemon juice (very sour)
 - pH 3 Apple (sour)
 - pH 5 Meat (not sour)
 - pH 7 Tea or water (not sour)
- Hydrogen-bonds, one of the strongest forms of bonding, are crucial for the 3D-structure of many natural molecules, e.g. proteins.
- Hydrogen is used to hydrogenate vegetable fat to make it solidify, but this also gives trans fatty acids (TFA) as a by-product.
- TFAs are associated with cardiovascular disease and possibly cancer so the WHO limits intake of TFAs to 1% of the diet.

Role in Food Chemistry

- Important element in analytical chemistry.
- It is employed in techniques used extensively for food testing (compositional analysis, flavour analysis, new product development and safety assessments).
- Used as a carrier gas for chromatographic analysis as it is inert and unreactive.
- Liquid helium used as a cryogenic refrigerant for use in superconducting magnets such as those used nuclear magnetic resonance (NMR) instruments.
- Helium is used as an alternative to nitrogen in inert food packaging gases.

Helium
Beer

Role in Food

- Edible helium balloons are being served at Alinea, a 3* Michelin restaurant in Chicago.
- They are prepared from flavoured invert sugar which is inflated with Helium from a cylinder.



Helium Beer

- Helium was a huge phenomenon in 2014 with demands well exceeding supply.
- Adverts showed that after a sip of beer you could sound like Donald Duck.
- The press release by Stone Brewing “Stone Stochasticity Project Cr(He)am Ale with Helium” was published 1st April 2014.
- Helium is not soluble in water, so technically Helium beer is impossible.



Li

Lithium

3

Occurrences in food

- Lithium is present in small quantities in food and water.
- Levels in water commonly range from 2 to 70 ppb but some water in the Andes contains over 200 ppm.
- The liver of grass eating animals contains around 5mg/kg.
- Crustaceans and molluscs take up lithium from water and plants take it up from the soil.
- A typical daily intake of lithium is around 1 mg/day.



Occurrences in Drinks!

- When 7up was invented it contained lithium citrate.
- The giant size bottle top proclaimed “lithiated”.

Lithium as a drug

- Lithium citrate and lithium carbonate are used to treat bipolar disorder.

Occurrences in food

- Beryllium tastes sweet but is toxic.
- Beryllium dust is the most dangerous.
- Those mining beryllium were susceptible to acute beryllium poisoning through inhalation.

Role in the body

- It has no identified role in the body.
- Swallowing powdered emeralds was tried as a cure for the black death.

You are unlikely to have eaten very much –
unless you have swallowed an emerald!

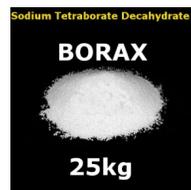


beryllium aluminium cyclosilicate



Role in Food

- Boric acid and sodium tetraborate (Borax) are permitted in food in the EU but not the USA.
- They are both only permitted as preservatives in caviar to a maximum of 4g/kg.
- It can be used to give a rubbery texture to rice noodles.
- Boron is essential for plant growth.
- Borate ions form complexes with apioses in pectin.



Role in the body

- Boron has an impact on parathormone.
- It affects the metabolism of Mg, Ca and P.
- But Boron deficiency in humans has never been reported.

Occurrence in food

- Peas, beans, soybeans, spinach and carrots.



Other uses

- Borax is also a household disinfectant!
- Boric acid is used as an insecticide.

Carbon is ubiquitous

- Carbon is present in all foods and drinks.
- The only exception is still drinking water.
- And even that will contain traces of carbonates.
- Sparkling water contains carbon dioxide.
- Carbon is an essential component of fats, proteins, sugar and carbohydrates, providing the backbone for all nutrients.
- Even flavourings are based on carbon skeletons.

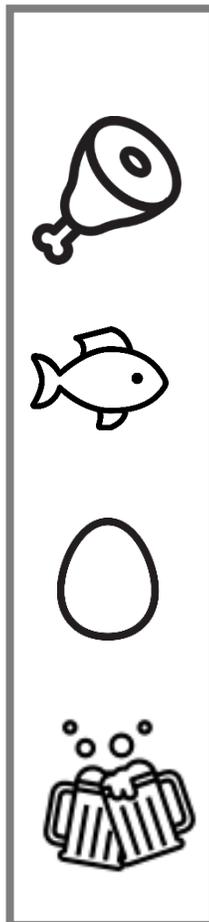
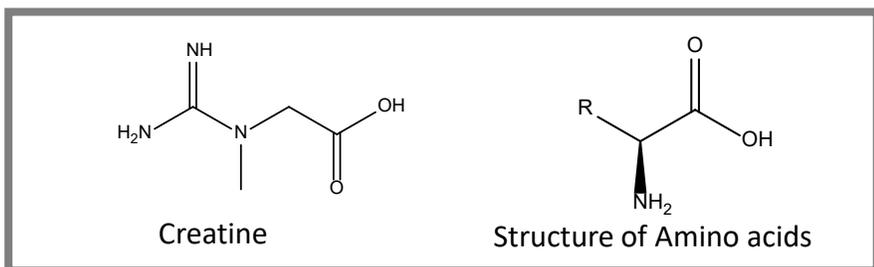
Occurrences in Food

- Calcium carbonate (CaCO_3) is the main component of egg shells.
- It is used as an anticaking agent and also as an antacid.
- Sodium bicarbonate (NaHCO_3) is baking soda.
- It releases CO_2 to create bubbles which make the cake rise.
- Carbon black is an insoluble black food colouring.
- It is formed from charred vegetable fibres – nuts, cellulose etc.
- Carbon dioxide bubbles in champagne give the tingle on the tongue – this is known as chemesthesis.



Occurrences in food

- Found in meat, poultry, fish, seafood, dairy and eggs, soy beans and legumes e.g. peas.
- An essential element in all plants and animals.
- It is part of all amino acids, the building blocks of protein, the building blocks of life.
- It needs converting to other forms such as nitrates, before plants are able to use it.
- Creatine is used as a supplement to increase muscle mass.



Nitrogen Gas

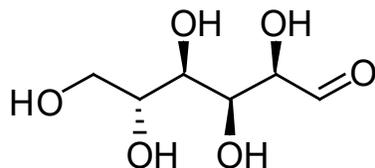
- Nitrogen gas is used to purge food packaging of oxygen and extend shelf life.
- Cold brew coffee is pumped with nitrogen to displace air for fresh creamy coffee.
- Liquid nitrogen is used to make ice cream and “smoke effects”.
- Guinness bubbles contain nitrogen.

Nitrogen Compounds

- Nitrites and nitrates inhibit bacterial growth and oxidation so are used for curing and pickling.
- Nitrites can react with amines to form nitrosamines, so should be eaten in moderation.
- Nitrogen compounds, such as pyrroles, pyrazines and pyridines contribute to the aroma of many roasty, toasty, baked foods.

Oxygen the Baddie

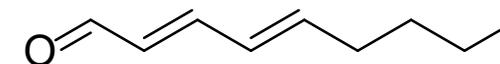
- Many foods spoil in the presence of oxygen.
- This reduces shelf life and changes the colour and alters the flavour and texture of foods.
- It also promotes microbial degradation as some yeasts, bacteria and moulds require O_2 to grow.
- Antioxidants such as ascorbic acid (vitamin C) are added to food to prevent oxidation.
- Oxygen scavengers can be found in sachets of dried food and low moisture foods to remove O_2 from the packet.



A glucose molecule
contains 6 oxygens

Oxygen the Goodie

- Food doesn't taste the same without oxidation.
- French fries require the oxidation of lipids to produce that yummy fried taste.
- Oxygen containing cyclic compounds – especially those derived from glucose, often have a sweet caramel taste.
- Ozone (O_3) can be used to degrade pesticide residues.
- Oxygen can be used in packaging to prevent the growth of anaerobic bacteria.

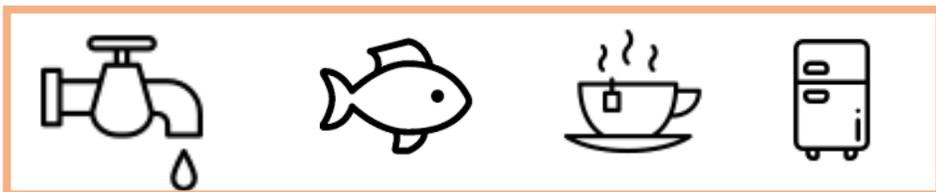


2,4-nonadienal

Fried note in fries, from
oxidation of oil

Occurrences in food

- Found naturally in fish and tea.
- So fluoride is added to water in parts of the UK to bring the levels up to 1 ppm, mainly to prevent dental caries

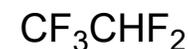
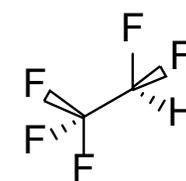


Role in the Food

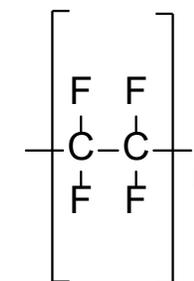
- Found in Teflon (tetrafluoroethylene) non stick cookware.
- Fluorinated gases are used as refrigerants, but are being phased out because they also deplete ozone.

Roles in the Body

- Protective trace mineral for emerging teeth and dental maintenance, preventing tooth decay.
- Fluoride (generally as NaF) important to protect bones from mineral loss and inhibits calcification of soft tissues.
- Fluoride compounds e.g. tin fluoride added to toothpaste.



Refrigerant
(hydrofluorocarbon)



PTFE – polytetra-
fluoroethylene

Ne

Neon

10

OK, we admit it, we can't really do Neon.....



Occurrences in food

- Most dietary sodium (~75%) comes from sodium chloride (NaCl) added to processed foods (soups, bread).

Roles in the body

- Sodium is an essential electrolyte, important for nerve and muscle function.
- Sodium deficiency (hyponatremia) can cause muscle spasms and cramps.
- An excess of sodium increases blood pressure and increases risk of cardiovascular diseases. An excess of sodium can also cause lethargy and restlessness.



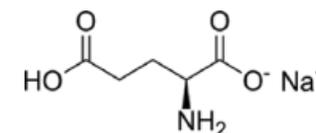
It's salty!

Sodium salts in food

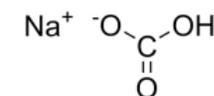
- Sodium chloride: preservative, tastant, flavour enhancer, promotes Maillard browning.
- Monosodium glutamate: gives a savoury (umami) taste.
- Sodium bicarbonate (baking soda) is used as a raising agent in baking.



Sodium chloride



Monosodium glutamate



Sodium bicarbonate

Mg

Magnesium

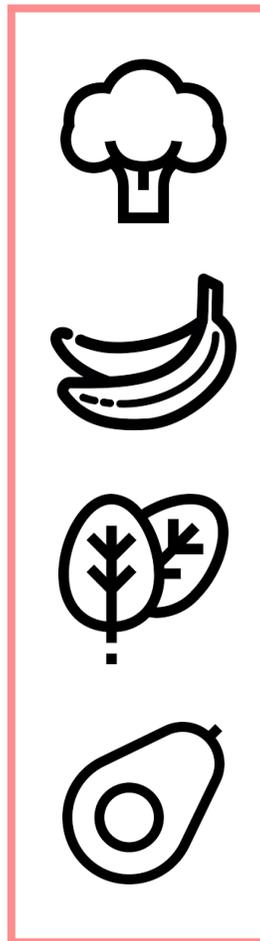
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Occurrences in food

- All green leafy vegetables.
- Nuts and seeds, bananas, avocado and tuna.
- Used to fortify some breakfast cereals.
- Available as a dietary supplement.

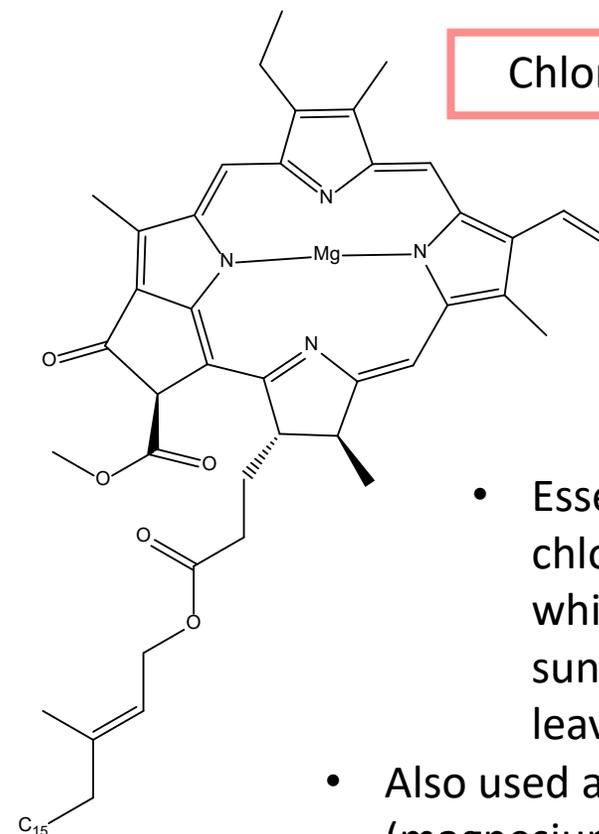
Roles in the body

- Essential for human body - adult body contains ~25 g, mostly in bones.
- Cofactor in many enzyme systems so regulates many metabolic processes.
- Required for production of energy.
- Required for development of bones.
- Regulates heart beat and nerve impulses.



Roles in food

Chlorophyll



- Essential part of chlorophyll (A or B) which capture sunlight to make leaves green.
- Also used as an antacid (magnesium hydroxide).
- Can be used as salt (sodium) replacement but very bitter.

Occurrences in food

- Aluminium silicate is used as an anticaking agent (milk powder).
- Aluminium is used in the “silver” balls used to decorate cakes and biscuits.
- BUT biggest source is from cereals, as it taken up from the soil by the crops.
- Typical adult ingests 1-10 mg of Al daily from water, additives and food containers.



Roles in food

- Aluminium frying pans are often used to cook food.
- Aluminium is used for food-storage and food packaging (e.g. aluminium foil).
- Sodium aluminium sulfate in double-acting baking powder (i.e. activation by heat rather than a simple acid-base reaction) is banned in EU but permitted in the US.
- Aluminium “lakes” are carriers for dyes of any colour.
- They are made from aluminium oxide (clay).
- The water-soluble dye is co-precipitated with aluminium oxide to make an insoluble pigment.



Aluminium lakes

Roles in food

- Silicon dioxide and silicates are used as anti-caking agents.

Roles in food chemistry

- Silica is fundamental for chromatography as it is used to support stationary phases.
- Chromatography is important for analysing food, checking purity, spotting adulteration, quantifying active components.



Aluminosilicate

Occurrences in food

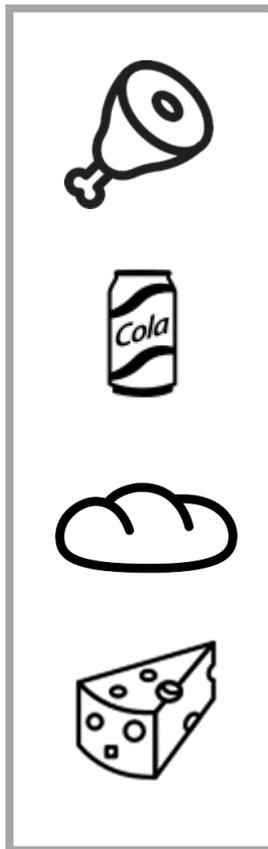
- Silicon plays an important role in bone mineralisation and soft tissue development.
- Is essential for healthy hair, nail and nails.
- Is found in unrefined cereals, but availability to the body can be low from cereal-based products.
- Is found in lower levels in meat and beer, but availability is higher.
- Deficiency is considered a factor in the development of atherosclerosis.

Roles in food Industry

- Aluminosilicates (zeolites) are used to catalyse the formation of sugar-based biosurfactants for use in the food industry.
- They can also be used to filter carcinogens from smoke for use in smoked foods.

Role in the body

- Is found in all cells in the body.
- Plays a structural role in nucleic acids and cell membranes.
- Is an essential mineral for growth and repair.
- Essential for bone health.
- Phosphorus from animal sources is more easily absorbed than from plant sources.
- Deficiency is called hypophosphatemia and causes rickets, osteomalacia and osteoporosis.



Roles in food

- Phosphorus is widely used in the food industry as monophosphates, diphosphates or polyphosphates.
- Phosphates are used as stabilisers and emulsifiers.
- They hold onto water in meat products.
- Interact with proteins in processed cheese.
- Inhibit growth of spoilage organisms in bread.
- Riboflavin phosphate is a label-friendly alternative to synthetic colours.
- Phosphoric acid is present in many soft drinks.
- However it weakens tooth enamel.

Occurrences in food

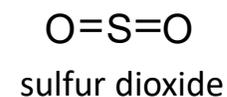
- Proteins (S-containing amino acids are cysteine and methionine).
- Particularly eggs, meat, coffee, vegetables.
- Sulfur compounds responsible for aroma of onions, leeks, garlic and the compound that makes you cry.
- Glucosinolates in brassica (broccoli, sprouts, etc.) have potential anticancer properties.
- They break down to isothiocyanates which give an acrid mustardy flavour.



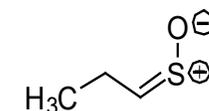
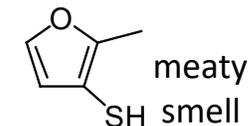
Sulfur compounds stink!

Roles in food

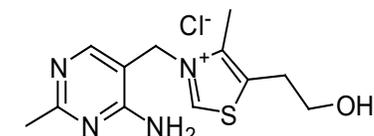
- Sulfates used as fertiliser to improve crop quality.
- Disulfide bonds between cysteine residues hold proteins together.
- Disulfide bonds in gluten essential for stabilisation of bubbles in bread.
- SO₂ is used as a preservative e.g. in wine, dried fruit.
- Variety of sulfur compounds contribute to the aroma of foods, particularly savoury aromas.



H₂S
eggy
smell



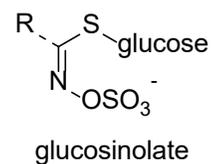
lachrymator in onions



thiamine - Vitamin B1

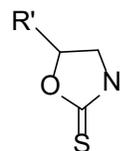
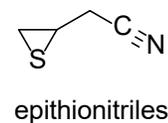
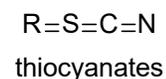
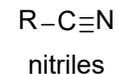
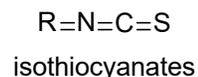
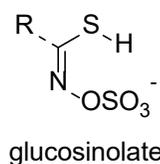
Role of glucosinolates in Brassica

- In vacuole of the plant cell



myrosinase

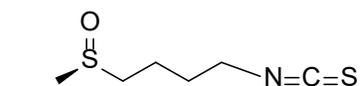
glucose



oxazolidene-2-thiones

- In cytoplasm of the plant cell
- Non-volatile
- Can have bitter taste

- Anticarcinogenic
- Volatile
- Pungent, mustard aroma



Sulforaphane
Active component
in brassica

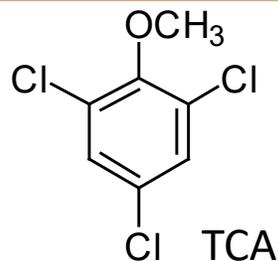


Occurrence in Food

- Only found combined in nature, with other elements such as sodium as NaCl in table and sea salt.
- Found in seaweed, rye, tomatoes, lettuce, celery, olives and prepared foods.

Role in the Body

- Chloride ions regulate fluid in and out of cells and are essential to life.
- HCl is required in the stomach to digest food.
- Plays a role in perception of salty taste in combination with Na⁺.



Role in the Food Industry

- Chlorine kills bacteria and other microbes and is a disinfectant used by the water industry.
- Major use as antibacterial agent to clean kitchen surfaces and utensils.
- This powerful disinfectant is used to wash chickens in the US. It poses no harm, but may cover up unhygienic living conditions and poor poultry management.
- Chlorinated compounds are often responsible for off notes and taints on food.
- Trichloroanisole (TCA) is responsible for the “corked” note in wine.
- 2,6-Dichlorophenol has a disinfectant note which can be detected at 4 ppb.



Roles in food

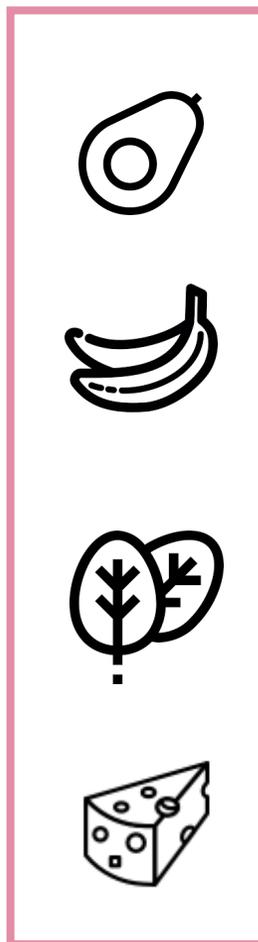
- Argon is used as an alternative to nitrogen in inert food packaging gases.
- It is heavier than nitrogen so it more readily displaces oxygen.
- High pressure Argon (4MPa) has been used to pretreat potato slices prior to refrigerated storage under nitrogen.
- Moisture, colour and vitamin C were all maintained for longer, and fewer microbes were detected.

Occurrences in food

- Avocados, starchy roots and tubers.
- Bananas, citrus fruits.
- Leafy vegetables, legumes.
- Whole grains, dairy products.

Roles in the body

- Vital mineral and electrolyte for the body.
- Helps regulate fluid balance.
- Promotes muscle and nervous system function and brain health.
- Helps removal of excess Na to reduce blood pressure (K & Na ions flow in cells).
- Adequate intake (AI) 3,500 mg/day.



Roles in food

- Potassium occurs naturally in most fruit and vegetables in the form of phosphate, sulfate and citrate salts.
- Potassium chloride, KCl tastes salty so it is used to partially replace sodium chloride in salt replacers, but tastes bitter and metallic.
- Potassium hydrogen sulphite(E228) used to inhibit yeast in wine.
- Can be used in functional roles: baking powder $\text{KNaC}_4\text{H}_4\text{O}_6$ (E337), pH control and protein modification.
- Largest use of potassium is as a plant fertiliser.

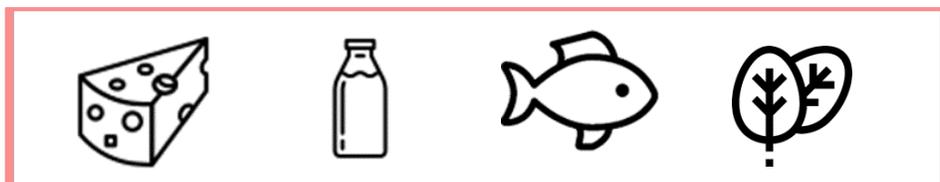
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Calcium

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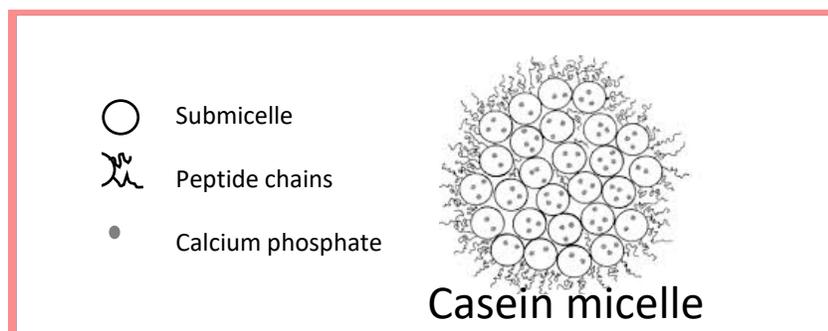
Occurrences in food

- Dairy products, green leafy vegetables and fish.



Role in the Body

- Promotes strong bones and teeth.



Role in Food

- Calcium is necessary for formation of casein micelles in milk.
- During cheese making, the pH is lowered to make the micelles aggregate and form curds.
- Goats milk is less rich in calcium, so calcium chloride is sometimes added to strengthen the curds.
- Calcium carbonate is a permitted colour in food (white).
- It is also added to breakfast cereals and non-dairy milks to boost calcium intake.
- Calcium chloride is used in canned vegetables to keep them firm and also to condition dough in bread-making.
- It forms cross links with alginates to form beads.
- One use of these beads is to create bubbles which burst to give flavour in fancy cocktails.



Occurrences in food

- Rare earth found at very low levels in food and in nature.
- No known effects on the body.

Occurrences in food

- Titanium oxide (TiO_2) is mined from the earth.
- It is used as a whitening agent in chewing gum, icings and decorations.
- It makes foods look more vibrant.
- It is not readily absorbed by the body.
- It has no nutritional value.
- Also used as an anti-caking agent.



Occurrences in food

- The best food sources of vanadium are mushrooms, shellfish, black pepper, parsley, dill weed, beer, wine, grain and grain products.
- Evidence that it is essential for humans is only circumstantial.
- Vanadium has shown some therapeutic effect against diabetes.
- Organic complexes of vanadium better absorbed than the inorganic forms.
- The vanadium complex amavadin accumulates in fly agaric mushrooms making them toxic.



Cr

Chromium

24

Occurrences in food

- Sugars and preserves contain the highest levels of chromium and are the largest source of dietary exposure.
- Vegetables, egg yolk, whole grains, meat, dairy and fruit.



Role in body

- Tri-valent chromium Cr(III) or Cr³⁺ is essential to human life and plays an important role in carbohydrate, lipid and protein metabolism.
- Helps with blood sugar control.
- However, hexavalent, Cr(VI) or Cr⁶⁺ is toxic.

Historically

- In the early 19th century, dichromate was used to colour bakery products.

Occurrences in food

- An essential element that is present in most foods, particularly green vegetables.
- Highest concentrations are found in nuts.
- Beverages, cereals and bread make the highest contribution to the dietary exposure due to the larger amounts consumed.
- Manganese aspartate, manganese ascorbate, manganese pidolate and manganese bisglycinate can be used in dietary supplements.

Role in body

- Both nutritionally essential and potentially toxic!
- Is key for the formation and function of one of the most important antioxidants in the body.
- Required for healthy cartilage and bones.
- Co-factor for many different enzymes.
- Provides proline for collagen formation in skin cells.
- Absorption decreases if iron supplements are used.



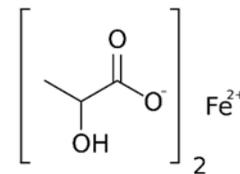
Occurrences in food

- In meat, fish, liver and egg yolk, iron is present as haem iron (haemoglobin) and is readily absorbed.
- In plant sources i.e. dark green vegetables, legumes, whole grains, it is present as non-haem iron.
- Recently, a company producing plant-derived burgers have isolated a plant based haem iron (leghaemoglobin) found in the root nodules of soya, to mimic the colour and flavour changes in meat.
- It changes to brown when cooked.
- Flours, breakfast cereal and breads are sometimes fortified with Iron (II) lactate, fumarate or succinate.

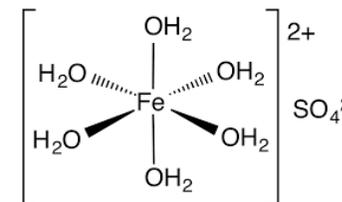
Are you getting enough?

Role in the Body

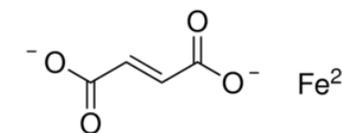
- Iron helps form red blood cells, provides oxygen and aids in the transport of oxygen to all parts of the body.
- It is required to convert nutrients to adenosine triphosphate (ATP) during cellular respiration, thus providing energy for the body.
- It supports good immunity and cognitive function
- Bioavailability is increased when iron is chelated to an amino acid such as glycine to form ferrous glycine.



Iron (II) lactate



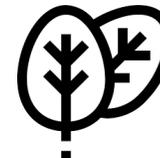
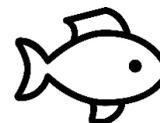
Iron(II) sulphate



Iron (II) fumarate

Are you eating enough Iron?

- Iron is essential for good health in humans. However, the following groups are more prone to inadequate levels of iron and defects such as deficiency anaemia, thus may require particular attention and perhaps higher levels of iron compared to the generic requirements (which is ~10mg a day):
 - Children require more iron as it is necessary for their growth.
 - Females 11-49 years lose iron especially due to menstrual blood loss, pregnancy and lactation. Pregnant women may need to consume higher amounts of iron-rich food.
 - Older adults may be at risk of higher iron losses due to gastrointestinal diseases and medication usage
 - Athletes may lose iron through increased sweat, urine, gastrointestinal blood loss and destruction of blood cells as a result of physical impact.
- Consuming diets that are low in both haem and non-haem iron increase the risk of complications for iron deficiency.
- However, ingesting excess iron from nutraceuticals can be dangerous.

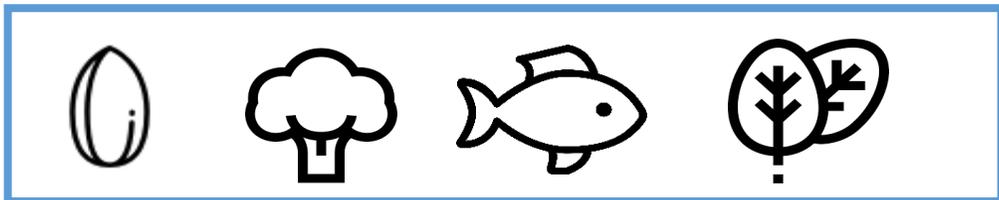


Occurrences in food

- Found in fish, nuts, leafy green vegetables, such as broccoli and spinach, and cereals, including oats.

History

- Cobalt deficiency has been a concern historically in farm animals, e.g., “bush sickness” in New Zealand which was cured by adding cobalt to the fertilisers.
- Cobalt chloride was used in Canada in the 1960s as a foam stabiliser in beer.
- This predisposed regular drinkers to heart attacks.



Role in body

- It is a key component of vitamin B12 and is required for the synthesis of haemoglobin.
- Vitamin B12 binds with a salivary intrinsic factor (haptocorrin) under acidic condition in stomach as a part of its absorption process. Thus those with low stomach acid secretion and who are taking anti-acid medication have higher risk of B12 deficiency.
- Cobalamin deficiency in humans is a realistic concern for vegans and vegetarians.
- It is becoming a major concern in patients who have undergone weight-loss surgery. Their follow-up nutritional counselling focuses on providing absorbable forms of cobalamin, e.g. as nasal sprays.

Occurrences in food

- Nickel is present in most foods.
- Concentrations of nickel are high in nuts.
- But beverages and cereals contribute the most to dietary exposure due to larger consumption.



Occurrences in food

- Copper is an essential element with food being the major source.
- Copper is found at highest concentrations in offal, shellfish, and nuts, but cereals and bread are the highest sources of exposure due to the larger amounts of these foods that are consumed.
- 20-25% of copper intake from drinking tap water.
- 50g of high cocoa solids chocolate can contain RDA of copper (900 μg).
- Copper is antibacterial, used to be used in hospitals in door handles and plates to reduce transmission of infection.



Role in Body

- Required for activity of range of enzymes needed for a huge range of essential metabolic functions:-
 - Iron transport
 - Electron transport in respiratory reactions
 - Melanin and pigment production
 - Growth and production of nervous tissue
 - Protection against free radical damage
 - Growth and development of bones and connective tissue
 - Healthy thyroid function
- Copper deficiency can lead to neural dysfunction, osteoporosis, blood, bone and connective tissue disorders.

Occurrences in food

- Zinc is an essential element for human health, and is present in plants and animals.
- It is essential for the functioning of insulin.
- It is a key component of > 200 enzymes many of which are important in human metabolism.
- Zinc is found at highest concentrations in meat.
- Bread, cereals, meat, meat products and milk are the major contributors to the dietary exposure.
- Normal dietary exposures is unlikely to be of toxicological concern.



Ga

Gallium

31

Occurrences in food

- Found in low levels in the body
- Not harmful.
- No known role in the body.

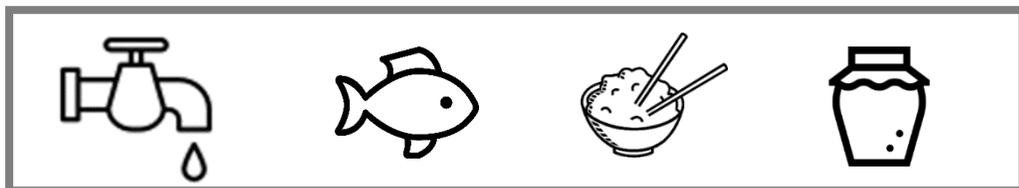
Roles in food

- Trace element.
- Found in many healing herbs such as ginger, ginseng and aloe vera. Also in broccoli, celery, garlic, shitake mushrooms, milk, onions, rhubarb.
- Germanium has been reported to improve the immune system, boost the body's oxygen supply, but little scientific evidence.
- In fact the US FDA concludes that use of germanium as a nutritional supplement presents potential health hazard.



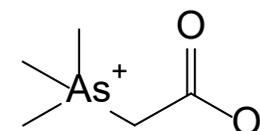
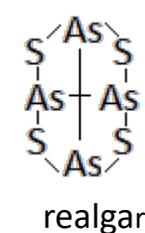
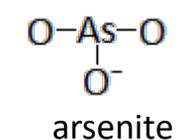
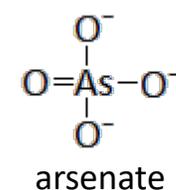
Occurrences in food

- Inorganic arsenic is present in drinking water in contaminated regions.
- Inorganic arsenic contamination of rice can be a big problem.
- Vegetables can also be a source of inorganic arsenic.
- Organic arsenic, which is less toxic than the inorganic form, is found in fish and seafood.
- Tetraarsenic tetrasulfide (realgar) exists as a bright red crystal and was traditionally mixed with rice liquor and drunk during the Chinese Dragon Boat Festival.



Toxicity

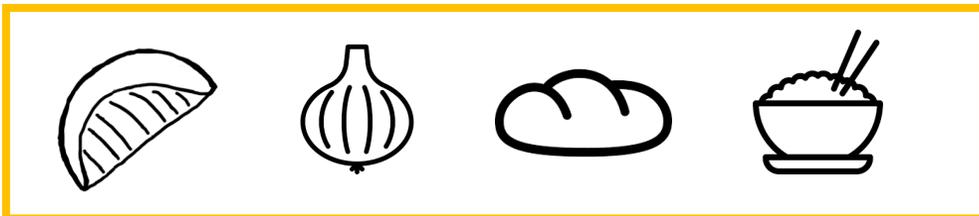
- One of the first chemicals classified as a Group I carcinogen.
- Inorganic acid is more toxic than organic arsenic.
- Toxicity can lead to skin, lung and bladder cancers.
- Toxicity can also lead to metabolic, developmental and cardiovascular disorders



arsenobetaine
(most common
form of arsenic in
seafood)

Occurrences in food

- Occurs in Brazil nuts, wholegrain products, and in brown rice.
- Also found in poultry and seafood.
- Onions, garlic, mushrooms.



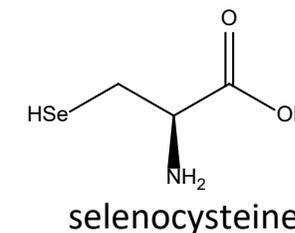
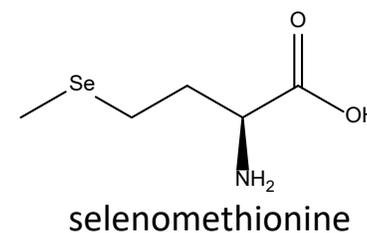
- Selenium enters food chain via soil during growth.
- It occurs as selenium analogues of Sulphur-containing amino acids.
- Selenomethionine is available as a dietary supplement (selenium yeast).



Like Sulfur, Se-compounds stink!

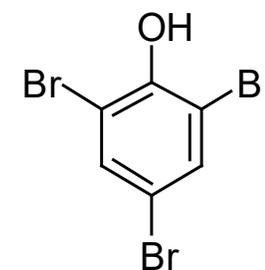
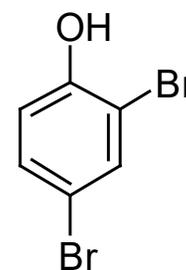
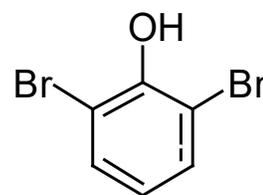
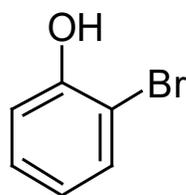
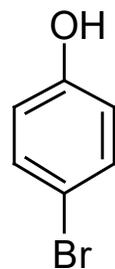
Roles in the body

- Plant foods especially wheat provide much of the Se in the diet.
- Plays a key role in the thyroid which produces hormones affecting mood.
- Antioxidant that works with Vitamin E to protect cell membranes.
- Required for the production of glutathione, most important antioxidant.
- Trace mineral essential for strong immune systems.
- Recommended RDA 55µg.



Occurrences in food

- Found naturally in earth's crust and seawater.
- In the US, Potassium bromate is added to flour for bread making.
- It makes the dough more elastic.
- Bromophenols are important for the flavour of crustaceans.
- They have a medicinal taste which is perceived as an off-note.
- but at low levels impart a "marine-like" or "iodoform" quality.
- Bromate is regulated in drinking water.



Bromophenols in crustaceans.

Kr

Krypton

36

Occurrences in food

- Rare odourless tasteless gas.

Rb

Rubidium

37

Occurrences in food

- No known toxicity or deficiency for Rubidium.
- No known role in body.
- Present in earth's crust so present in water and absorbed by crops.

Sr

Strontium

38

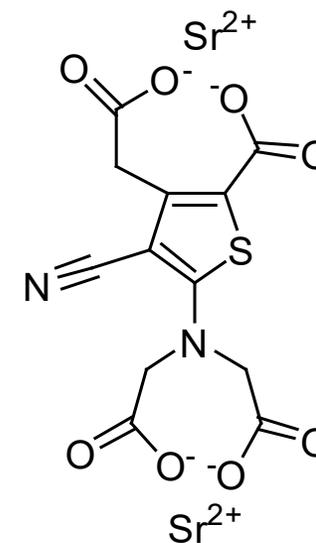
Occurrences in food

- Strontium is a mineral found in seawater and soil.
- The main source in the body is seafood.
- It is also found in whole milk, wheat bran, meat, poultry, and root vegetables.
- Strontium citrate is available as a supplement.



Role in the Body

- Strontium ranelate can increase bone formation and prevent bone loss due to osteoporosis.



Strontium ranelate

39	Y	Yttrium	44	Ru	Ruthenium
40	Zr	Zirconium	45	Rh	Rhodium
41	Nb	Niobium	46	Pd	Palladium
42	Mo	Molybdenum	47	Ag	Silver
43	Tc	Technetium	48	Cd	Cadmium

Role in food

- Generally the most stable of the transition metals.
- Rarely occur in food and are relatively inert.
- Very few have a role in the body.
- However, some are toxic and regulated.

Three examples

MoAgCd

Occurrences in food

- Highest concentrations are found in nuts and offal, and dark green vegetables.
- Cereals and Bread are the main sources of exposure due to the higher consumption of these foods.
- Plant material grown above ground contains higher concentrations of molybdenum compared with foods from tubers or animals.
- A relatively rare element and an essential constituent of several enzymes in the human body.

Role in the body

- A component of enzymes needed for metabolism.
- Instrumental for iron storage in the body and production of uric acid.
- Deficiencies of this mineral are rare



Occurrences in food

- Silver is a permitted additive in the EU under Annex II of Regulation 1333/2008.
- It is permitted for use as a coating on confectionery and as small particles in alcoholic drinks.
- Unfortunately a considerable proportion silver wrapped chocolates have been shown to be wrapped in aluminium, which is not a permitted additive, rather than silver.
- Silver is available as foil and wire at purity up to 99.998%.

Role in food

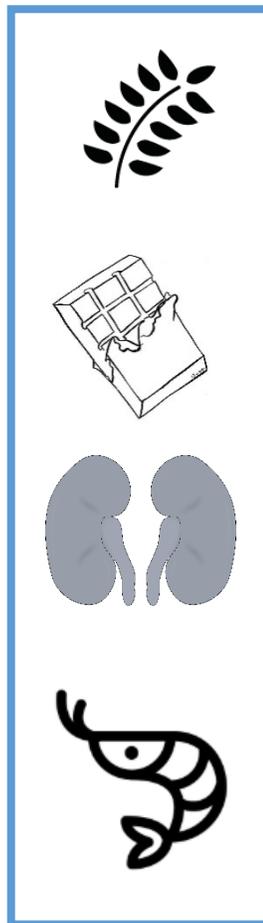
- While silver itself is not toxic, most silver salts are poisonous.
- Intake of silver is estimated at about 2 micrograms/kg bodyweight/day from food and water
- Excess intake of silver, either as colloidal silver or from working in an atmosphere where there is silver dust, produces argyria, a condition where the skin turns grey or blue-grey.

History

- Herodotus records that water was stored in vessels made of silver in order to keep it fresh.

Occurrences in food

- Crop plants readily absorb cadmium from the soil.
- For non-smokers, the major sources of cadmium are vegetables, grains and tubers, due to the large quantities consumed.
- Other foods that include high concentrations of cadmium are shellfish and offal such as kidney and liver.
- There has recently been concern over levels of cadmium in chocolate and cocoa products, as we eat a lot.



Role in food

- Problems caused by cadmium exposure through food are extremely rare.
- As cadmium is a naturally occurring heavy metal, which is toxic at high doses, it is highly restricted by food legislation.
- Studies have shown that around 5% of the population may exceed the European Food Safety Authority recommended limits of $2.5\mu\text{g}/\text{kg}$ body weight, however this limit is 10% of that set by the WHO (World Health Organisation) at $25\mu\text{g}/\text{kg}$.

Occurrences in food

- The biological role of indium is unclear.
- Some people believe it is essential for human health.
- So indium sulfate is sold as a dietary supplement.
- It may enhance the absorption of other minerals.

Occurrences in food

- Bronze and pewter are two well-known alloys of tin that have been used to make dishes and other culinary equipment.
- Tin cans have been used for canning food for nearly 200 years and these cans are made from steel sheets with a coating of tin to prevent rusting.
- Canned foods contained higher concentrations of tin presumably as a result of the slow dissolution of the tin coating.
- Normal dietary exposures to tin are unlikely to be of toxicological concern.
- Tin oxide is used to make edible gold decorations for confectionary.



Use in Food Industry

- Metalloid similar Arsenic
- Antimony trioxide (Sb_2O_3) is used as a catalyst during the manufacture of PET.
- Sb_2O_3 can migrate into food from PET packaging.
- Controlled by Food Adulteration Regulations.

Te

Tellurium

52

Occurrences in food

- Rare element present in the earth's crust.
- Low levels present in the food chain as a result.

Occurrences in food

- Widely found in foods such as fish and seafood, seaweed, dairy products and products made from grains.
- Main sources seaweed (kelp), white fish, milk and yoghurt.
- Sometimes added to salt to prevent iodine deficiency disorders. Although this is not common in the UK.
- The main component of the red food colouring erythrosine is iodine.



Role in the Body

- Iodine deficiency can lead to an enlargement of the thyroid, seen as a swelling of throat area.
- Important mineral for production of thyroid hormones which help regulate metabolism and development of babies' brains during pregnancy.
- EFSA RDA for iodine is 150mcg / day for adults .
- Iodine supplements mainly for pregnancy use potassium iodide, potassium iodate.

History

- Iodine is used to disinfect cows' udders before milking.

Xe

Xenon

54

Use in Food Industry

- Pulsed Xenon flash light treatment has been shown to inactivate 13 food-related microorganisms.
- It could inactivate food poisoning bacteria.

Cs

Caesium

55

Occurrences in food

- Natural occurring cosmic and terrestrial radiation means that some Caesium enters the food chain.
- It is only present at low levels.
- It has relatively low toxicity

Occurrences in food

- Some food accumulate significant amounts of Barium from the soil.
- Barium may be found in Brazil nuts, seaweed, fish, and certain plants.
- The amount of barium found in food and water usually is not high enough to be a health concern.
- Vegetables and grains take up Barium from the soil and this is the major source in the human body (22mg per person).



57	La	Lanthanum	65	Tb	Terbium
58	Ce	Cerium	66	Dy	Dysprosium
59	Pr	Praseodymium	67	Ho	Holium
60	Nd	Neodymium	68	Er	Erbium
61	Pm	Promethium	69	Tm	Thulium
62	Sm	Samarium	70	Yb	Ytterbium
63	Eu	Europium	71	Lu	Lutetium
64	Gd	Gadolinium			

Role in food

- Rarely occur in food.

72	Hf	Hafnium	77	Ir	Iridium
73	Ta	Tantalum	78	Pt	Platinum
74	W	Tungsten	79	Au	Gold
75	Re	Rhenium	80	Hg	Mercury
76	Os	Osmium			

Role in food

- Rarely occur in food and are relatively inert.
- Very few have a role in the body.
- However, some are toxic and regulated.

Two Examples:

AuHg

Edible Gold Glitter – is it real gold?

- The gold glitter used to decorate most eggs, cakes, and confectionary is a mixture of brown colouring, titanium oxide and iron oxide.
- However, 23 ct edible gold leaf is available (£200/g) for food use.
- Gold is inert and passes through the body unchanged.



Mercury

Occurrences in food

- The sources of mercury contamination are environmental, industrial and agricultural.
- Exposure to mercury is mainly from the diet and dental amalgam.
- Mercury can exist in inorganic and organic forms in food.
- The organic forms, such as methylmercury, are more toxic following ingestion.
- Highest concentrations of total mercury are found in Offal, Fish, and some vegetables
- Fish is the major contributor to dietary exposure.



Tl

Thallium

81

Occurrences in food

- Thallium compounds are naturally present in the environment, in air, water and soil.
- Mainly formed as a result of smelting.
- Can sometimes accumulate in food in contaminated areas.
- Thallium is toxic.
- In the USA, the reference daily intake is set at 0.00001kg/kg bodyweight/day.



Pb

Lead

82

Occurrences in food

- Lead is naturally present in the environment, in air, water and soil.
- It enters the food chain via crops which absorb lead from the environment.
- Offal has the highest lead concentration.
- However the greatest contributions to dietary exposure is from beverages, bread and some vegetables.
- Adverse effects resulting from normal dietary exposure are likely to be very small.

Occurrences in food

- Occurs naturally in low concentrations in tubers, roots and sea vegetables.
- Present in Pepto-Bismol which relieves symptoms of nausea, indigestion and diarrhoea.



Role in the body

- Not essential for the body.
- No nutritional benefits.
- Pepto-Bismol reduces acidity and may absorb toxins.
- But in higher doses it is toxic.



Occurrences in food

- Doesn't occur naturally in foods.
- Radioactive metal present in the earth's crust and therefore also in seawater.
- There is some concern that these radioactive metals may be concentrated in kelp.
- They may be chelated by the surface bacterial slimes on kelp.
- However research shows that the quantities that may enter the human food chain as a result, are so low as to not pose a danger to human health.



As

Astatine

85

Occurrences in food

- Rarest of the naturally occurring elements.
- Only 1g exists at any time.
- Highly radioactive.
- Not present in food.
- Potential use in radiotherapy.



Occurrences in food

- Doesn't occur naturally in foods.
- Radioactive noble gas.
- High exposure (e.g. in mines) leads to an increase in the incidence of lung cancer.
- Naturally occurring low levels are emitted from the ground.
- Can sometimes occur hot springs, and spring water.



89	Ac	Actinium	97	Bk	Berkelium
90	Th	Thorium	98	Cf	Californium
91	Pa	Protactinium	99	Es	Einsteinium
92	U	Uranium	100	Fm	Fermium
93	Np	Neptunium	101	Md	Mendelevium
94	Pu	Plutonium	102	No	Nobelium
95	Am	Americium	103	Lr	Lawrencium
96	Cm	Curium			

Role in food

- Rarely occur in food, and only do so as a result of contamination.

87	Fr	Francium	110	Ds	Darmstadtium
88	Ra	Radium	111	Rg	Roentgenium
89	Ac	Actinides 89-103	112	Cn	Copernicium
104	Rf	Rutherfordium	113	Nh	Nihonium
105	Db	Dubnium	114	Fl	Flerovium
106	Sg	Seaborgium	115	Mc	Moscovium
107	Bh	Bohrium	116	Lv	Livermorium
108	Hs	Hassium	117	Ts	Tennessee
109	Mt	Meitnerium	118	Og	Oganesson

Role in food

- Never occur in food.