2.3.1: Foods- Elemental Diets

The Atomic Theory in Foods

Introduction: Minerals, Elements, and Compounds

Nutrition books are often confusing when they discuss human nutrient requirements. For example, one, in discussing essential minerals in sports nutrition[1] says "Minerals are elements". But only one common essential mineral, iron (symbolized Fe for the Latin "Ferrum") is commonly ingested as an element. Iron is an ***element*** because it is made up of a *single kind of atom*, designated by the symbol Fe. Other symbols are given in the Table below. Iron metal particles are actually found in breakfast cereals[2], and the easiest way to prove it is to float a cereal flake on water and pull it around with a magnet. You can also see it extracted in several YouTube videos like this one. Sometimes iron is added as a ***compound***, like "ferrous sulfate", $FeSO_4$. A compound has atoms of several elements bonded together is specific ratios. The ratios are given by the subscripts in the formula; in this case, ferrous sulfate is made from 1 atom of iron, 1 of the element sulfur, and 4 atoms of the element oxygen.

Another essential mineral that is common misidentified is "iodine". The nutrient we actually ingest is not the element iodine, but a compound of iodine like potassium iodide, KI (K is the symbol for potassium, after the German Kallium).

While the mineral KI looks and tastes like table salt, the element iodine is a dark purple (almost black) solid, sometimes dissolved in alcohol to give a brown solution used to disinfect minor wounds. It's a toxic element with the formula $I_{2<}$, showing that an element may be made up of ***molecules*** which contain two or more atoms bonded together, as long as the atoms are the same.

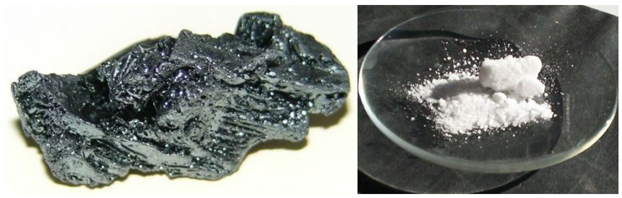
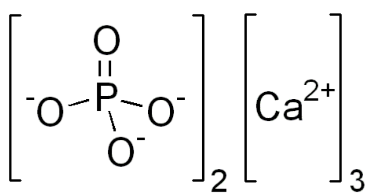


Figure 2.3.1.1: (left) The element iodine (I_2) and (right) Potassium Iodide (KI)

When iodine crystals are heated, they "sublime" (turn directly to a gas) to give purple vapors composed of diatomic molecules. The liquid phase, which also contains diatomic molecules, only forms under higher than atmospheric pressure. All the phases are the element iodine, because they contain only I atoms. (See Bromine as an example)

Other essential minerals are referred to as "elements", but are actually either toxic or useless to our body as elements. Foods must contain nutrients in chemical compounds that are easily digested and absorbed in our bodies in order for them to be nutritious. For example, the *element* phosphorus may have several forms. One, P_4, is very toxic and actually burns when exposed to air, making a glow that's responsible for its name.

Four images side by side. First shows a block of white solid. Second shows a glassware container with red powder in it. Next is a chunk of brick colored solid. Final form is a chunk of metallic solid.



P is double bonded to 1 O and single bonded to three O negative ions. This structure is enclosed in a square bracket with a subscript 2. Calcium superscript 2 positive is also enclosed in a square bracket with subscript 3.

Figure 2.3.1.2: (left) Forms of elemental phosphorus: white phosphorus (P4) is on left and (right) The atomic structure of mineral tricalcium phosphate; it is a white powder like KI (above)

The nutrient form of phosporus is illustrated by mineral phosphates, like $Ca_3(PO_4)_2$, which contains 3 calcium atoms (we will see later, they're in the form of *"ions"* each with a 2+ charge, Ca^{2+}) and 2 "phosphate ions", each made of 1 phosphorus atom bonded to 4 oxygen atoms, and having an overall 3- charge. Phosphorus is also supplied in *biomolecules* found in meats and vegetables.

"Elemental Diets"

An "Elemental diet" is a solution of nutrients that can be administered intravenously (or with a gastric feeding tube) for people with digestive disorders, like Crohn's disease or colitis. There are no *elements* in an elemental diet, but the simplest chemical compounds that can provide complete (or near complete) nutrition. A typical elemental diet shows us what is required to maintain our bodies.[3] We require ounces to pounds of macronutrients daily, but typically less than 5 g (.2 oz) of micronutrients.

- Macronutrients (needed for energy and construction of body parts)
  - Carbohydrates: Corn Syrup Solids, Mono and Diglycerides, Esters of Mono and Diglycerides
  - Essential lipids:Fractionated Coconut Oil, Canola Oil, High Oleic Safflower Oil,

- Amino Acids: (L-Glutamine), L-Isoleucine, L-Leucine, L-Lysine-L-Aspartate, N-Acetyl-L-Methionine, L-Phenylalanine, L-Threonine, (L-Proline), L-Tryptophan, (Glycine), L-Histidine, L-Arginine, L-Valine, (L-Alanine), (L-Serine), (L-Tyrosine), (L-Cystine), (Taurine, a sulfonic acid).
- Micronutrients (used mostly in regulators of body processes)
  - Minerals: Tripotassium Citrate, Tricalcium Phosphate, Dicalcium Phosphate, Sodium Chloride, Magnesium Acetate, Ferrous Sulfate, Zinc Sulfate, Manganese Sulfate, Cupric Sulfate, Potassium Iodide, Chromium Chloride, Sodium Molybdate, Sodium Selenite, (missing: F, V, B, Sn, Ni).
  - Vitamins: Choline Bitartrate (B), (M-Inositol), Niacinamide (B3), Calcium-D-Pantothenate (B6), Thiamine Chloride Hydrochloride (B1), Pyridoxine Hydrochloride (B6), Riboflavin (B2), Folic Acid (B9), Cyanocobalamin (B12), D-Biotin (D7), Vitamin D3, L-Ascorbic Acid (C), DL-Alpha Tocopherol Acetate (E), Vitamin A Acetate, Phylloquinone (K1).
- Other
  - Nutritional Supplement: L-Carnitine (normally synthesized from amino acids).
  - Emulsifier, thickeners: Diacetyl Tartaric Acid, Propylene Glycol Alginate.

The ratio of chemical elements in our bodies is sometimes presented as a "formula for a human being", which does not represent any actual chemical compound, but just tells us the relative numbers of atoms:

$$H_{375,000,000}O_{132,000,000}C_{85,700,000}N_{6,430,000}Ca_{1,500,000}P_{1,020,000}S_{206,000}Na_{183,000}K_{177,000}Cl_{127,000}Mg_{40,000}Si_{38,600}Fe_{2,680}Zn_{2,110}Cu_{76}I_{14}Mn_{13}F_{13}Cr_{7}Se_{4}Mo_{3}Co_{1}$$

So for just 1 cobalt (Co) atom, we need 2,680 iron atoms, 1,500,000 calcium (Ca) atoms, etc. Clearly, there's a lot that chemistry can tell us about nutrition. But how do we know what is an "element" and what is a "compound", and what compounds provide the elements we need to maintain our bodies?

How Do We Know What Substances Contain Essential Elements?

The early greek philosophers (Empedocles, Lucretius and Democritus) proposed that everything was made of atoms, but had no way of providing evidence for the claim. Evidence that each chemical element is composed of one kind of atom (that is unchanged during chemical reactions) finally developed between 1750 and 1850. Looking at the pictures of potassium iodide (KI) and iodine (I_2) above, will help to imagine how implausible it must have seemed that they share a common iodine atom.

Evidence for unchanging atoms as the components of elements came from weight measurements. Joseph Priestley and Antoine Lavoisier finally correctly interpreted the loss of weight when some substances burn (wood or sugar) and the gain in weight of others, by recognizing the fact that the mass of atoms in gases had been neglected. Lavoisier showed that mercury (Hg) gains weight because it combines with oxygen molecules from air to make solid mercuric oxide:

$$2\,\mathrm{Hg} + \mathrm{O_2} \rightarrow 2\,\mathrm{HgO}\cdot$$

But wood loses weight because it is converted to gaseous molecules of carbon dioxide and water of equal mass. The combustion reaction is similar to the combusion of the sugar, glucose, which the basis for the metabolism of carbohydrates in our bodies to provide energy:

$$\mathrm{C_6H_{12}O_6} + 6\,\mathrm{O_2} \rightarrow 6\,\mathrm{CO_2} + 6\,\mathrm{H_2O}$$

Earlier, van Helmont[5] had failed to recognize that incorporation of carbon dioxide gas contributed the most to the weight gain of trees; he thought it was the water, because the soil showed virtually no change in mass. Nonetheless, he showed committment to the idea of *concervation of mass*, that no mass should be lost or gained during a chemical change. The equation for photosynthesis is just the reverse of the combustion equation above,

$$6\,\mathrm{CO_2} + 6\,\mathrm{H_2O} \;\rightarrow \mathrm{C_6H_{12}O_6} + 6\,\mathrm{O_2}$$
$$\text{carbon dioxide} + \text{water} + \text{light energy } \;\rightarrow \text{carbohydrate} + \text{oxygen}$$

so we could say that trees are mostly carbohydrate, and that when they burn, they release the energy that they had absorbed from the sun while growing:

As Lavoisier continued his experiments with oxygen, he noticed something else. Although oxygen combined with many other substances, it never behaved as though it were itself a combination of other substances. Lavoisier was able to decompose the red calx into mercury and oxygen, but he could find no way to break down oxygen into two or more new substances. Because of this he suggested that oxygen must be an **element**—an ultimately simple substance which could not be decomposed by chemical changes.

This was the fundamental discovery that allows us to identify tricalcium phosphate as a good source of "phosphorus" or potassium iodide as a good source of "iodine".

John Dalton[1] (1766 to 1844) was a generation younger than Lavoisier and different from him in almost every respect. Dalton came from a working class family and only attended elementary school. Apart from this, he was entirely self-taught. Even after he became famous, he never aspired beyond a modest bachelor's existence in which he supported himself by teaching mathematics to private pupils. Dalton made many contributions to science, and he seems not to have realized that his atomic theory was the most important of them. In his "New System of Chemical Philosophy" published in 1808, only the last seven pages out of a total of 168 are devoted to it!

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