Kitchen Elements

Model 1. All of the *elements* on the periodic table can be found in nature as *pure substances*. An element is made of *atoms*, therefore a sample of the element calcium would be made of many calcium *atoms*. A *compound* is also a *pure substance*. A compound is made of *molecules*, therefore a sample of the pure compound water would be made of many water (i.e. H_2O) *molecules*.

Table 1.1. Examples of various types of matter at room temperature (70°F/21°C)

Item	Classification	Is it a Molecule?	Chemical Formula
Calcium	Element	No	Ca
Sodium	Element	No	Na
Iron	Element	No	Fe
Oxygen	Element	Yes	O_2
Carbon dioxide	Compound	Yes	CO_2
Water	Compound	Yes	H_2O
Vitamin C	Compound	Yes	$C_6H_8O_6$
Sodium chloride (i.e. table salt)	Compound	Yes	NaCl
Sucrose (i.e. table sugar)	Compound	Yes	$C_{12}H_{22}O_{11}$
Monosodium glutamate (i.e. MSG)	Compound	Yes	$NaC_5H_8O_4N$

Molecules are formed from the *bonding* of two or more *atoms*. Most matter on earth, including food, is a mixture of different types of *molecules*. A molecule is the smallest, neutral (that is, without charge) unit of a substance formed by bonding *two or more atoms* together. Molecules and compounds are often used interchangeably to describe a substance. The simplest way of thinking about it is that a *compound* must contain at least two different elements and a *molecule* is anything that has more than one atom.

> *Key Concept*
> *Molecules* are formed from the *bonding* of two or more *atoms*.
> Most matter on earth, including food, is a mixture of different types of *molecules*.

hydrogen 1 **H** 1.0079																		helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305												aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	**57-70** *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	**89-102** **	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

*Lanthanide series	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
**Actinide series	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

Figure 1.1. The Periodic Table of the Elements lists all the known elements by increasing size (left to right and top to bottom)

All living things (animals, plants microbes, and smaller life forms) are made of atoms and molecules. How those molecules are organized, interact and react are the building blocks for life. Molecules are often divided into two categories, organic (those molecules containing carbon atoms) and inorganic molecules (everything else).

Nutrition Facts

Serving Size 1 medium orange (140g)
Servings Per Container 1

Amount Per Serving	
Calories 65	Calories from Fat 3
	% Daily Values*
Total Fat 0g	**0%**
Saturated Fat 0g	**0%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Potassium 238mg	**7%**
Sodium 0mg	**0%**
Total Carbohydrate 16g	**5%**
Dietary Fiber 3g	**12%**
Sugars 13g	
Protein 1g	**2%**
Vitamin A 6% •	Vitamin C 105%
Calcium 12%	

*Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs.

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2400mg	2400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Figure 1.2. Nutrition Data for 1 medium orange[1]

Most food is a mixture of molecules. Consider the nutrition data for a medium orange in Figure 2.

Food molecules are typically classified in three main categories: *Fat*, *Carbohydrate*, and *Protein*.

Fat, Carbohydrate and Protein are large classes of molecules that contain many different specific examples. See Table 2.

Cholesterol is a molecule; it has the molecular formula $C_{27}H_{46}O$.

Vitamin A ($C_{20}H_{30}O$) and Vitamin C ($C_6H_8O_6$) are both molecules.

For Sodium, Calcium and Iron – see model 2.

[1] The nutrition data for 1 medium Florida orange was supplied by the United States Department of Agriculture Agricultural Research Service, National Nutrient Database for Standard Reference Release 27. The data is in the public domain.

Table 1.2. Examples of food molecules from the major classes: fat, carbohydrate and protein.

Type	***Specific example***	***Molecular formula***
Fat	Linolenic acid [2]	$C_{18}H_{30}O_2$
Fat	Oleic Acid[3]	$C_{18}H_{34}O_2$
Carbohydrate	Glucose (i.e. dextrose)	$C_6H_{12}O_6$
Carbohydrate	maltose	$C_{12}H_{22}O_{11}$
Protein	Alanine[4]	$C_3H_7NO_2$
Protein	Glutamate[3]	$C_5H_9NO_4$

1. Using the *Periodic Table of the Elements* in Figure 1.1, circle the elements found the items of Table 1.1. How can you tell what *elements* are present?

2. Consider Table 1.1. How does the formula of an element differ from that of a compound? How can you distinguish elements from compounds based on their chemical formulas?

3. Does your answer to question 2 make you want to go back and revise your answer to question 1? How so?

[2] An omega-3 fatty acid found in green leaves and some seed oils.
[3] The primary fatty acid found in olive oil
[4] Alanine and glutamate are components of protein

4. According to Table 1.1, oxygen exists as a molecule, but not a compound – why is this?

5. Using the information in Figure 1.2 and Table 1.2, how many different elements from the Periodic Table are represented by the molecular formulas of food molecules? What elements are present most often?

Model 2. Sodium, Calcium and Iron appear on nutrition data labels for all foods[5], and yet the pure elements sodium, calcium are indigestible by humans. In fact, the pure elements sodium and calcium are downright harmful! They will burn your skin and certainly your mouth if you try to consume them. The element iron is not harmful, but it is not very digestible. Sodium, calcium and iron are examples of *metals*. How then can most benefit from these metals in our food?

Table 1.3. Sodium, calcium and iron in food.

Pure Element	As found in food	Food sources
Sodium (Na)	**sodium** chloride (i.e. table salt, $NaCl$), mono**sodium** glutamate (i.e. MSG, $NaC_5H_8O_4N$), **sodium** bicarbonate (baking soda, $NaHCO_3$), **sodium** benzoate ($NaC_7H_5O_2$)	Milk, celery, bacon and condiments like Worcestershire sauce.[6]
Calcium (Ca)	**calcium** citrate ($Ca_3C_{12}H_{10}O_{14}$) **calcium** lactate ($CaC_6H_{10}O_6$)	Calcium supplements, cheese
Iron (Fe)	Heme ($FeC_{34}H_{32}O_4N_4$) **ferrous**[7] sulfate ($FeSO_4$) **ferrous** fumarate ($FeC_4H_4O_2$)	Meat, fortified infant cereal

6. Compare the column *Pure Element* versus the column *As found in food* from Table 1.3. What can you conclude about the sodium, calcium and iron represented in the *As found in food* column.

7. Based on the information given above and in Table 1.3, how are we able to consume and benefit from the sodium, calcium and iron in our diets?

[5] www.nutrition.gov
[6] MedlinePlus. Sodium in your diet.
[7] The word *ferrous* is derived from the latin word *ferrum,* which means *iron*

Model 3. Sodium, calcium, iron and other metals found in food are most often consumed as part of *ionic compounds*. Ionic compounds are comprised of two halves: a cation (pronounced CAT-EYE-UN) and an anion (pronounced AN-EYE-UN). The cation carries positive charge, while the anion carries negative charge – together the charges balance each other and the overall compound is net neutral. Finally, an *ion* is different from an *element*. For example, the *element* sodium has a neutral charge, but the sodium *ion* does not.

Table 1.4. Examples of ionic compounds found in food.

Ionic Compound	Molecular formula	Cation	Anion
sodium chloride	NaCl	Na^{+}	Cl^{-}
monosodium glutamate	$NaC_5H_8O_4N$	Na^{+}	$[C_5H_8O_4N]^{-1}$
sodium bicarbonate	$NaHCO_3$	Na^{+}	$[HCO_3]^{-1}$
sodium benzoate	$NaC_7H_5O_2$	Na^{+}	$[C_7H_5O_2]^{-1}$
calcium citrate	$Ca_3C_{12}H_{10}O_{14}$	3x Ca^{+2}	2x $[C_6H_5O_7]^{-3}$
calcium lactate	$CaC_6H_{10}O_6$	Ca^{+2}	$[C_6H_{10}O_6]^{-2}$
ferrous sulfate	$FeSO_4$	Fe^{+2}	$[SO_4]^{-2}$
ferrous fumarate	$FeC_4H_4O_2$	Fe^{+2}	$[C_4H_4O_2]^{-2}$

In an ionic compound - for example, sodium chloride - the cation is always carrying a positive charge (Na^{+}) and the anion is always carrying a negative charge (Cl^{-}), but sometimes the ionic compound will be represented with cation and anion listed one after the other (e.g. NaCl) – without the charges explicitly shown. In the NaCl example, the combination of one positive charge and one negative charge creates the overall neutral compound (NaCl). While the charges on the sodium cation and chloride anion might not always be shown – they are always present. You should learn to recognize the pattern of naming that identifies an ionic compound like sodium chloride.

In addition, all but one of the *anions* in Table 1.4 is made of many atoms – and these ions are said to be *polyatomic*[8]. In these cases, the charge is associated with one or more discreet atoms. For example, the anion fumarate is drawn in Figure 1.3.

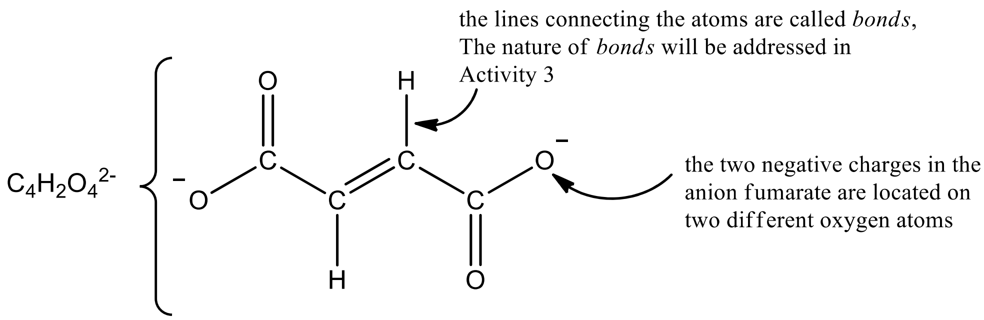


Figure 1.3. The anion fumarate.

8. From Table 1.4, what can you tell about the pattern of naming ionic compounds? What comes first, what comes second?

9. Explain how calcium citrate is a net neutral ionic compound. Remember, the negative and positive charges must balance out in the final compound.

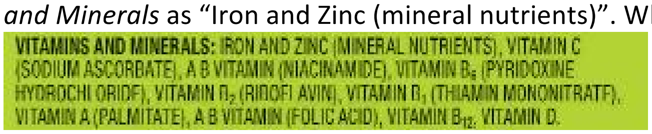
10. Propose a molecular formula for calcium fumarate. Give a rationale for your answer.

[8] Poly = many, atomic = atoms, as in elements.

11. While sodium chloride is what we know a “table salt”, all the other compounds in Table 1.4 are also examples of “salts”. What must be the basic requirements for a *salt*?

Putting it all together:

12. On the cereal box shown below, the zinc and iron in this cereal are listed under *Vitamins and Minerals* as “Iron and Zinc (mineral nutrients)”. What does that mean?



13. Find the molecular formula for the following compounds. Determine the types of atoms present in each substance using the Periodic Table. For each substance determine whether it is an element or a compound.
    a. Fructose
    b. Sodium citrate
    c. Aspartame

14. Are any of the compounds in the preceding problem an *ionic compound*? How can you tell? List the cation and anion.