Module 4: systems and matter

IMPORTANT: for updates, please go to the Blog link at the top right corner

Main topics:

- elements: protons, neutrons, electrons
- atomic mass, isotopes
- isotopes vs. ions
- bonds: ionic and covalent
- periodic table: columns
- half lives
- pH and pOH
- melting and boiling points
- surface tension: adhesion and cohesion
- organic vs. inorganic substances
- proteins, fats, carbohydrates

Atoms and molecules:

- atom: one nucleus with protons and neutrons, electrons around the nucleus
- element: one type of atom, defined by the number of protons
- protons: positive charge, give the atom identity
- neutrons: neutral charge, gives the atom more mass
- electrons: much smaller (1/1800), negative charge, gives the atom charge

Examples: see https://ptable.com/?lang=en#Properties
Helium: He, discovered in the sun (helios), 2 protons, 2 neutrons, 2 electrons
Carbon: C, 6 protons, 6 neutrons, 6 electrons

Atomic mass is the mass of all of the protons and neutrons (electrons are too light to count)
Isotopes:
Wait: why does carbon have atomic mass of 12.011 instead of 12?
There are other types of carbon, called **isotopes** (same type)
C12/6, C13/6, C14/6
Each of these has the same number of protons (identity) but more neutrons

check: how many protons, neutrons and electrons in C14/6?

Ions and bonds:

so far we've been playing with the nucleus.

If you change the number of electrons from a match with protons (C6/12 has 6 electrons), we can add or take away electrons:

Na+ is Sodium missing an electron

Cl- is Chlorine with an extra electron

Why?

Look again at the periodic table: https://ptable.com/?lang=en#Properties

Everyone wants to be on the right hand column, called the noble gases

To get there, Na loses an electron to look like Neon, while Chlorine adds an electron to look like Argon (see for yourself)

These sorts of bonds, where one gives up and one takes is a very strong bond, called **ionic** (because it involves ions)

NaCl (salt) is one example:

- Ionic bonds have high melting points
- They conduct electricity, especially in water

The weaker type of bond you will see is called **covalent**.

Think of a pilot and co-pilot: both share the duties

In a covalent bond, neither one is more positive or negative, they share an electron.

Molecular Hydrogen (H2) and Molecular oxygen (O2) are good examples

so are plastics, water and other substances

Covalent bonds:

- Weak bonds
- Don't conduct electricity as well as ionic solutions
- low melting points (water, plastic, butter)

Periodic table classes:

The periodic table (here it is again: https://ptable.com/?lang=en#Properties) is key to solving riddles in APES around pollution, toxins, and many other things:

Example:

Strontium 90/38 is a radioactive isotope, a product of nuclear reactions (reactor meltdowns, nuclear weapons)

Look at the periodic table, find Strontium.

What is above it?

Calcium is part of your bones, so when you ingest Sr90/38, it is absorbed into your bones just like Calcium, since elements in the same column are chemically similar.

What sort of cancer would this cause?

Question: Cesium is a radioactive element, where would it go in your body?

Radioactivity:

The good news is these do not hang around forever, they decay into other things, some radioactive, some not.

A half life is the amount of time it takes something radioactive to decay into half of the amount it

was before.
So, If you have 128 grams of Strontium 90/38, which has a half life of about 30 years, after 30 years you will have:
64 grams
Then 30 years later it will be all gone, right?
Nope: 32 grams
Then continue: 16, 8,4,2...
It never really goes completely away
We'll show you some cool ways to calculate how much is left soon...

Acids and Bases: pH
In aqueous (water) solutions, we often need to know if a solution is acidic or basic
Acids have more Hydrogen ions (H+) floating around
Bases have more hydroxide (OH-) ions floating around
Water is amphoteric (both) since it is really H-OH
Water has pH (potency of Hydrogen) of 7, in between 0 (acid) and 14 (totally base, dude)
First look at most solutions is a good guess:
NaOH base
HCL acid
See?
You try: KOH, HNO_3, H_2SO_4, H_3PO_4
Which were acids and bases?
The scale is confusing, and we'll get into it with some calculators soon...

Melting and boiling points:
Water is everywhere, and we study it a lot
The melting and freezing point for water is 0°C at one atmosphere (very interesting stuff happens at other pressures, like ice hockey)
The boiling and condensation point for water at one atmosphere is 100°C (again, interesting things happen at other pressures like pressure cookers and freeze dried ice cream)
It turns out that anything added to water raises the melting and boiling points.
You may have heard to add salt when cooking pasta: this raises the boiling point a bit so the pasta cooks a bit faster.
It also explains why they add salt to ice to make ice cream, or pour salt on road to melt ice...
You can demonstrate changing pressure on melting by slowly chewing on an ice cube: pressure makes ice melt (ice hockey skates)

Surface tension: adhesion and cohesion
Water is very cool stuff: it likes to stick to other stuff (adhesion) as well as to other water (cohesion)
This makes for interesting phenomena when the sides of a container are very close, like in roots or thin hair:
As the water molecules climb up the sides of the roots (adhesion) they stretch out the molecules in the middle (cohesion).
This is called surface tension
This make the curve stretch and then shorten, so water moves up the column (roots, long hair).
This is called capillary action, and is very important for all plants.

Surface tension is also how water striders "sit" on the water: their feet stretch the water molecules. Soaps destroy the cohesion, making water "wetter", also making little bugs fall into the water...

Organic and inorganic compounds:
Anything with a carbon backbone (like you) is an organic chemical compound
Anything without carbon is called inorganic, like salts, metals and minerals
These could be anything from the foods you eat (more on this later) to the gasoline you might put into your car.
Organic compounds can be water soluble, or not.
Hydrocarbons like gasoline and oil have only C-H bonds, so are insoluble in water (like greasy hands, or olive oil in salad dressing)
Alcohols are organic compounds with an OH molecule attached, so they can dissolve oils while also dissolving in water.
Some important alcohols:

- methanol CH_3OH (toxic)
- ethanol C_2H_5OH (makes you drunk)
- propanol (C_3H_7OH) known as rubbing alcohol

Proteins, fats and carbohydrates:
All three of these can act as fuel in your body, as your body is really clever that way.
Oddly, though, even your awesome body cannot repair tissues or grow new ones without proteins
Why?
Proteins are the only food source with Nitrogen, which is key to amino acids (amines means Nitrogen)
Proteins can be used as fuel for your body by "de-amination" meaning taking off the nitrogen
Fats and carbohydrates have similar chemical formula, but vastly different structures.
Fats all have an alcohol backbone, with little strands coming off made of C-H bonds (like a hydrocarbon)
This is why most fats do not mix with water...
Carbohydrates are C-H-O bonds (anything that ends in -ate means with oxygen)
Carbs can be long strings, like starches, or compact little hexagons or pentagons like sugars
Fun fact: sugar alcohols look like sugar to your body, but don't behave like sugars-used in drinks and candies...

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