L13 - Chemistry of Life

1. Chemistry Basics

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References

A little chemistry because
our bodies are made of – and use – chemicals

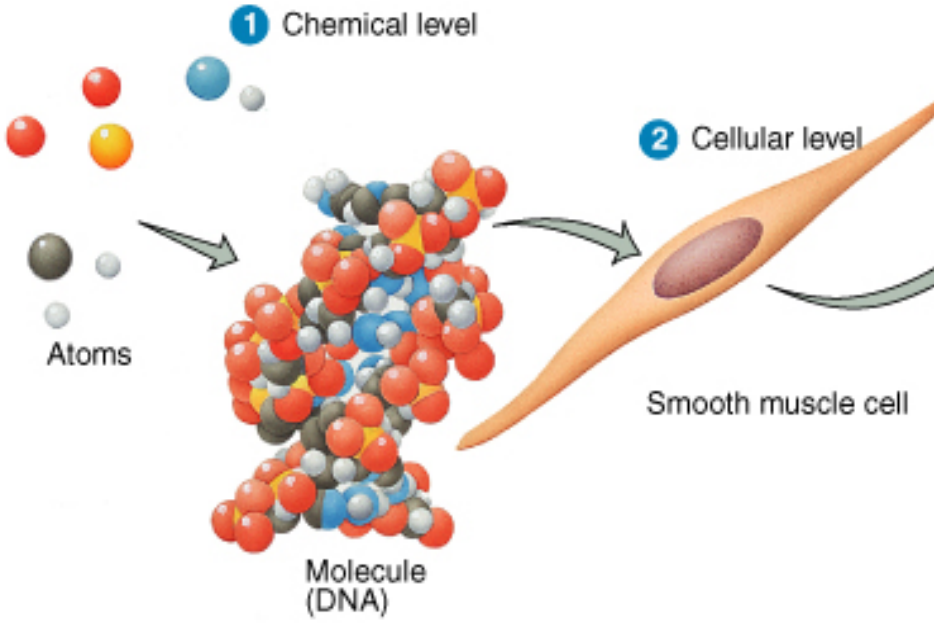
- ***Textbook:***
  - ***Human Biology, 11/ed, Starr and McMillan***
  - *Chapter 2*
- ***These notes***
- ***This Links***
  - *http://bcs.whfreeman.com/thelifewire9e/default.asp#542578__591163__*
  - *http://bcs.whfreeman.com/thelifewire9e/default.asp#542578__591165__*

Lecture Outline

- *Basic Chemistry*
  - *Atoms*
  - *Isotopes*
  - *Molecules and Compounds*
  - *Chemical Bonds*

The Human Body is highly organized because it's constructed from ATOMS

- *Atoms interact to form MOLECULES*
- *Molecules interact to form all the BODY'S STRUCTURES*
- *Atoms interact in very precise ways*
  - *Because of their atomic structure*
  - *i.e., their "atomic anatomy"*
- *Let's investigate the world of atoms...*



From Fig. 1.1 - from Tortora and Grabowski, *Introduction to the Human Body*, 6ed, Wiley

Everything in our world is made of elements

- ***Over 90% of human body is composed of <u>four</u> elements***
  - *Carbon ~ 18%*
  - *Nitrogen ~ 3%*
  - *Oxygen ~ 65%*
  - *Hydrogen ~ 10%*

- ***Every element has its own <u>symbol</u> derived from name***
  - *H for hydrogen*
  - *Na for sodium (natrium, Latin)*

- ***Atoms** are the smallest units that have the properties of a given element*

Human	
Oxygen	65
Carbon	18
Hydrogen	10
Nitrogen	3
Calcium	2
Phosphorus	1.1
Potassium	0.35
Sulfur	0.25
Sodium	0.15
Chlorine	0.15
Magnesium	0.05
Iron	0.004
Iodine	0.0004

Earth's crust	
Oxygen	46.6
Silicon	27.7
Aluminum	8.1
Iron	5.0
Calcium	3.6
Sodium	2.8
Potassium	2.6
Magnesium	2.1
Other elements	1.5

Fig. 2.1 – from Starr and MacMillan *Human Biology*, 10ed, Brooks Cole

ATOMS consist of 2 areas & 3 kinds of subatomic particles

1. ***Central nucleus*, containing**
   - *positively-charged* ***protons*** *(1)*
   - *neutral* ***neutrons*** *(2)*

2. ***Electron cloud* (electron shell), containing**
   - *Negatively-charged* ***electrons*** *(3)*
   - *Move rapidly around the nucleus*

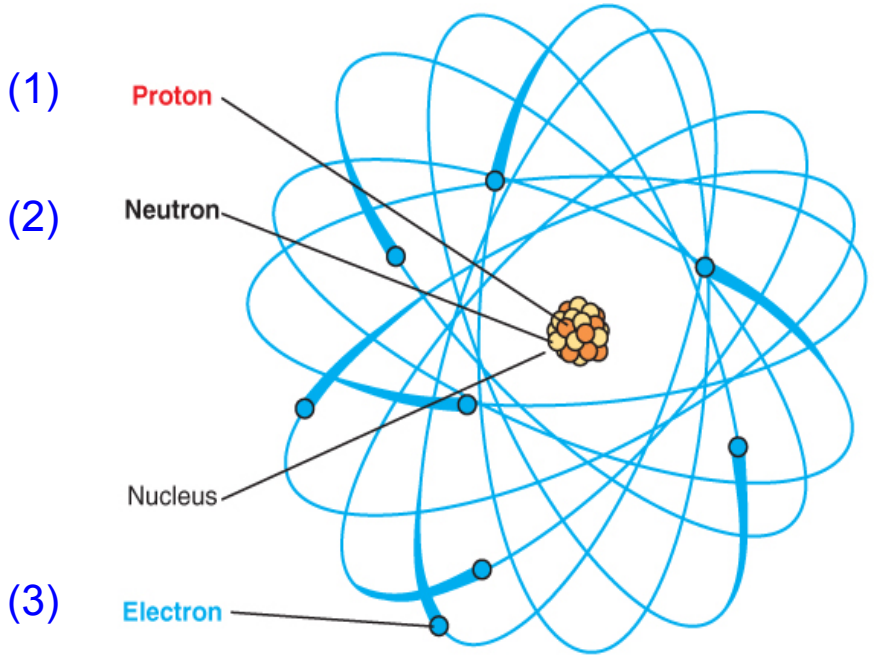


FIGURE B-1

The atom. The atom consists of two regions. The central nucleus contains protons and neutrons and makes up 99.9 percent of the mass. Surrounding the nucleus is the electron cloud, where the electrons move rapidly around the nucleus. (Figure not drawn to scale.)

Fig. B1 - from Appendix B, Sherwood et al, *Human Physiology: From Cells to Systems.* 2nd Canadian Edition, Appendix B, Nelson

***Atomic Number* of an atom**

- ***Number of protons in nucleus***
- *All atoms of an element have the same atomic number*
- *Usually written as a subscript to lower left of atomic symbol*

***Atomic Weight* of an atom**

- ***Weight of protons plus neutrons***
  - *Protons & neutrons each = 1 atomic mass unit (amu)*
  - *Electrons are light & have almost no mass*
- ***Number of protons plus neutrons***
- *Usually written as a superscript to upper left of atomic symbol*

***Electrically Neutral* Atoms**

- *Have the SAME number of protons and electrons*

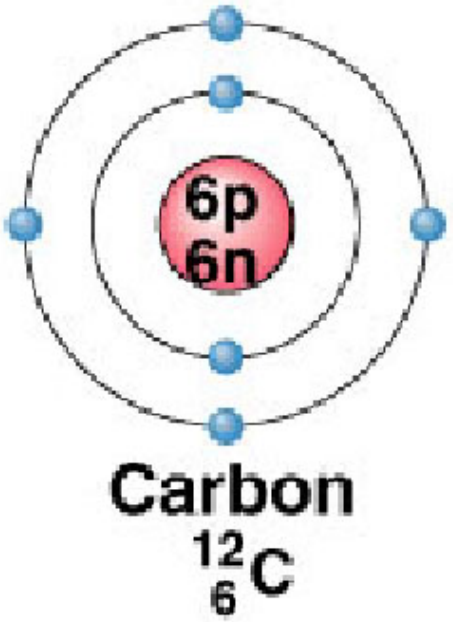


Image from – Starr and Taggart, *Biology: The Unity and Diversity of Life*, 8ed, Wadsworth Publishing

Electrons & Their Shells

- ***Electrons orbit around the atom nucleus inside various "shells" around the nucleus***
- ***Outermost shell is the VALENCE shell***
  - *Containing valence electrons*
- ***Atoms tend to lose, gain or share electrons until they are surrounded by 8 valence electrons***
  - *first shell, closest to nucleus, lowest energy*
    - *holds up to 2 electrons*
  - *second shell – holds up to 8 electrons*
  - *third shell – tends to hold up to 8 electrons*
  - ***Some atoms will hold more than 8 electrons***
    - *depending on size of atom and location within periodic chart*
- ***Atom is MOST STABLE when its OUTER shell is FILLED***

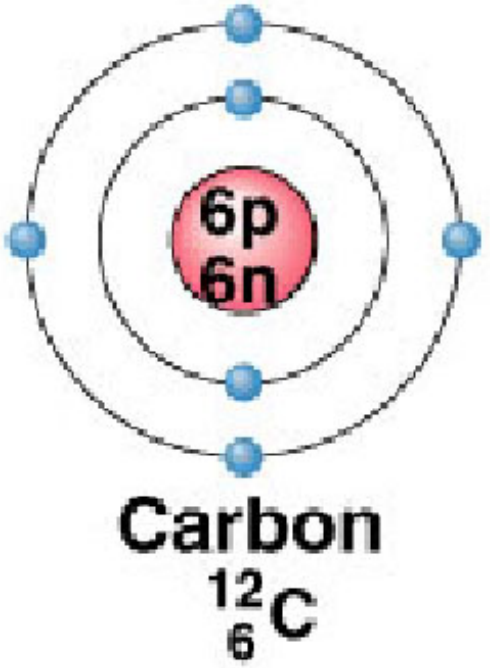


Image from – Starr and Taggart, *Biology: The Unity and Diversity of Life*, 8ed, Wadsworth Publishing

Example – Carbon

Atomic number 6

- *has 6 protons and 6 electrons*

Atomic weight 12

- *subtract 6 protons from 12 to determine number of neutrons*
  - *i.e., 12 – 6 = 6 neutrons*
- *6 protons + 6 neutrons = 12*

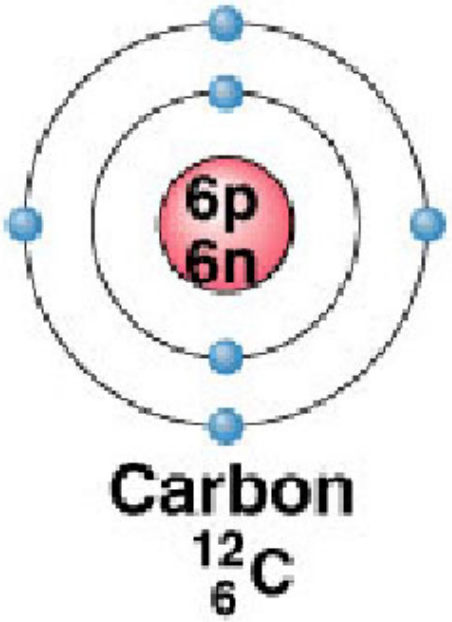


Image from – Starr and Taggart, *Biology: The Unity and Diversity of Life*, 8ed, Wadsworth Publishing

The 6 electrons – which shells do they orbit in?

- *2 in first shell*
- *4 in second shell*

Second shell can house up to 8 electrons

- *Having only 4 makes carbon atom unstable*
- *Becomes stable when 4 more electrons enter second shell*
  - *May come from up to 4 other atoms*

Many elements have ISOTOPES, with the same number of protons but with a different number of neutrons

Therefore isotopes have a different atomic weight

$^{12}_{6}C$ $^{13}_{6}C$ $^{14}_{6}C^{*}$

*radioactive

Some isotopes are unstable - radioactive isotopes

- *Unstable nucleus spontaneously decays, giving off rays of different energy & subatomic particles*
- *Can be used as a tracer - carbon 14 dating, medical imaging…*
- *Radiation kills healthy cells & cancerous cells*

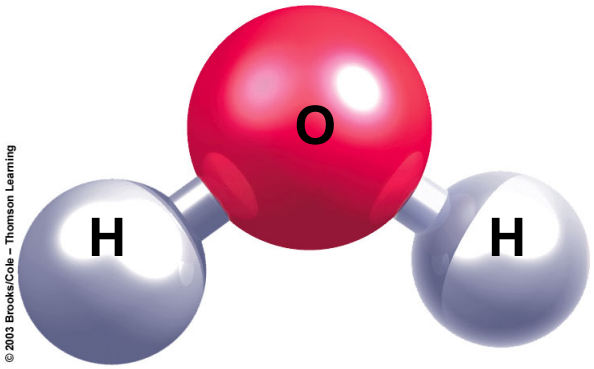
Atoms interact with other atoms to form compounds and molecules

Molecules

- ***Groups of 2 or more atoms held together in a stable association***
- *Some molecules are made up of only ONE element - i.e., oxygen has 2 oxygen atoms*

Compounds

- ***Molecules containing more than one type of element***
- *Bound in proportions that NEVER vary*
- *i.e., water always has one oxygen and two hydrogen atoms*



Chemical Bonds

- ***Hold atoms together in molecules or compounds***

Image from: Starr & Taggart, *Biology: The Unity and Diversity of Life*, 10ed, Brooks Cole

Chemical Bookkeeping – Chemical Reactions

Use symbols for elements when writing formulas

- *Formula for glucose is* ***$C_6H_{12}O_6$***
  - *6 carbons*
  - *12 hydrogens*
  - *6 oxygens*

- ***Chemical equation shows reaction**: Reactants --> Products*
  - *All atoms are accounted for on both sides of the equation*

  - ***Atoms are RE-ARRANGED, but NEVER LOST***

    i.e., general equation for photosynthesis:

    - ***$6CO_2$ + $6H_2O$ --> $C_6H_{12}O_6$ + $6O_2$***
    - *6 carbon dioxide + 6 water --> 1 glucose + 6 oxygen*

      (Reactants) ***(Products)***

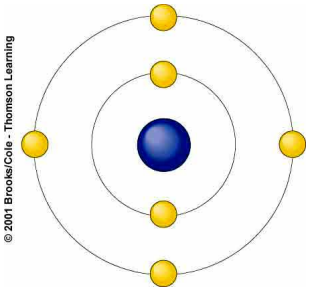
What Determines Whether Atoms Will Interact?

- ***The number & arrangement of their electrons (i.e., atomic structure) defines chemical interactions***

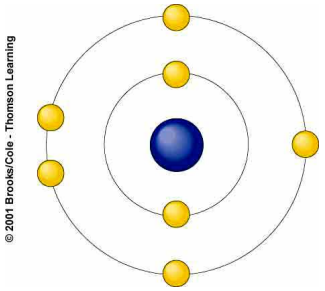
Electron vacancies

- ***UNFILLED valence shells make atoms likely to react***
- *i.e., hydrogen, carbon, oxygen, and nitrogen all have vacancies in their outer shells*

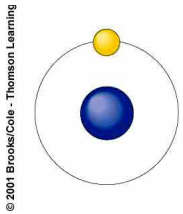
- ***Valence shell – where atoms bond together***
- *An atom with eight electrons in the valence shell will usually not bond – 'noble gases'*



CARBON
6p+ , 6e$^-$



NITROGEN
7p+ , 7e$^-$



HYDROGEN
1p+ , 1e$^-$

Images from: Starr & Taggart, *Biology: The Unity and Diversity of Life*, 10ed, Brooks Cole

The union between the electrons of neighbouring atoms is called a CHEMICAL BOND

Form in attempts to stabilize the outer shells of the interacting atoms

- *to "fill" their outer shells*

- ***Bonds between atoms determine how chemical compounds form, fall apart, and re-form***

- ***Three important bonds in biological molecules***
  1. *Ionic bond*
  2. *Covalent bond*
  3. *Hydrogen bond – (discussed in a later lecture)*

IONIC BONDS are formed by the attraction of oppositely charged ions

In Ionic Bonding *(e.g., formation of Sodium Chloride - table salt)*

1. ***One atom loses electrons & becomes a positively charged ion***
2. ***And another atom gains these electrons & becomes a negatively charged ion***
3. ***Charge differences attract the 2 ions to each other***

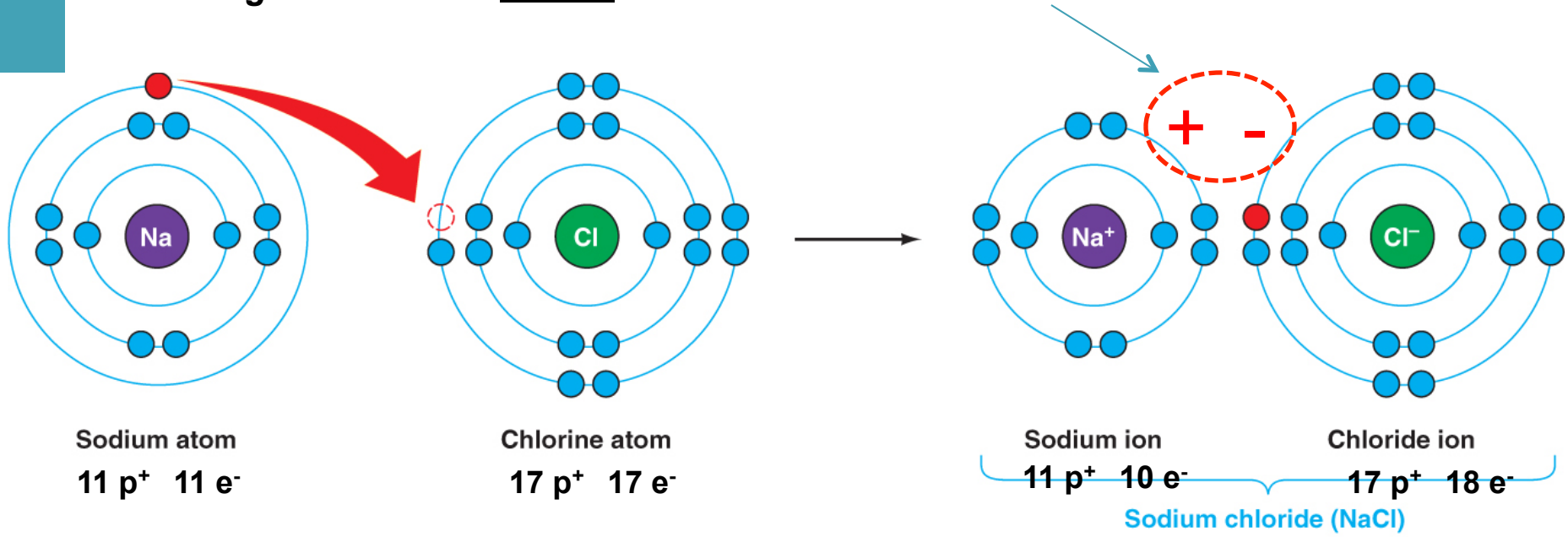


Figure from Sherwood et al, *Human Physiology: From Cells to Systems.* 2nd Canadian Edition, Appendix B, Nelson

Ions and ionic bonds. Sodium (Na) and chlorine (Cl) atoms both have partially filled outermost shells. Therefore, sodium tends to give up its lone electron in the outer shell to chlorine. As a result, sodium becomes a positively charged ion, and chlorine becomes a negatively charged ion known as chloride. The oppositely charged ions attract each other, forming an ionic bond.

COVALENT BONDS *form when atoms share a pair of valence electrons*

- Each atom's attractive forces "pulls" on the other atom's unpaired electron
- i.e., positively charged nuclei are ATTRACTED to negatively charged electron pair
- The attraction between atoms "holds" them together – the covalent bond

-Causing the 2 electrons to occupy a SHARED orbital

-Covalent bonds are very STABLE

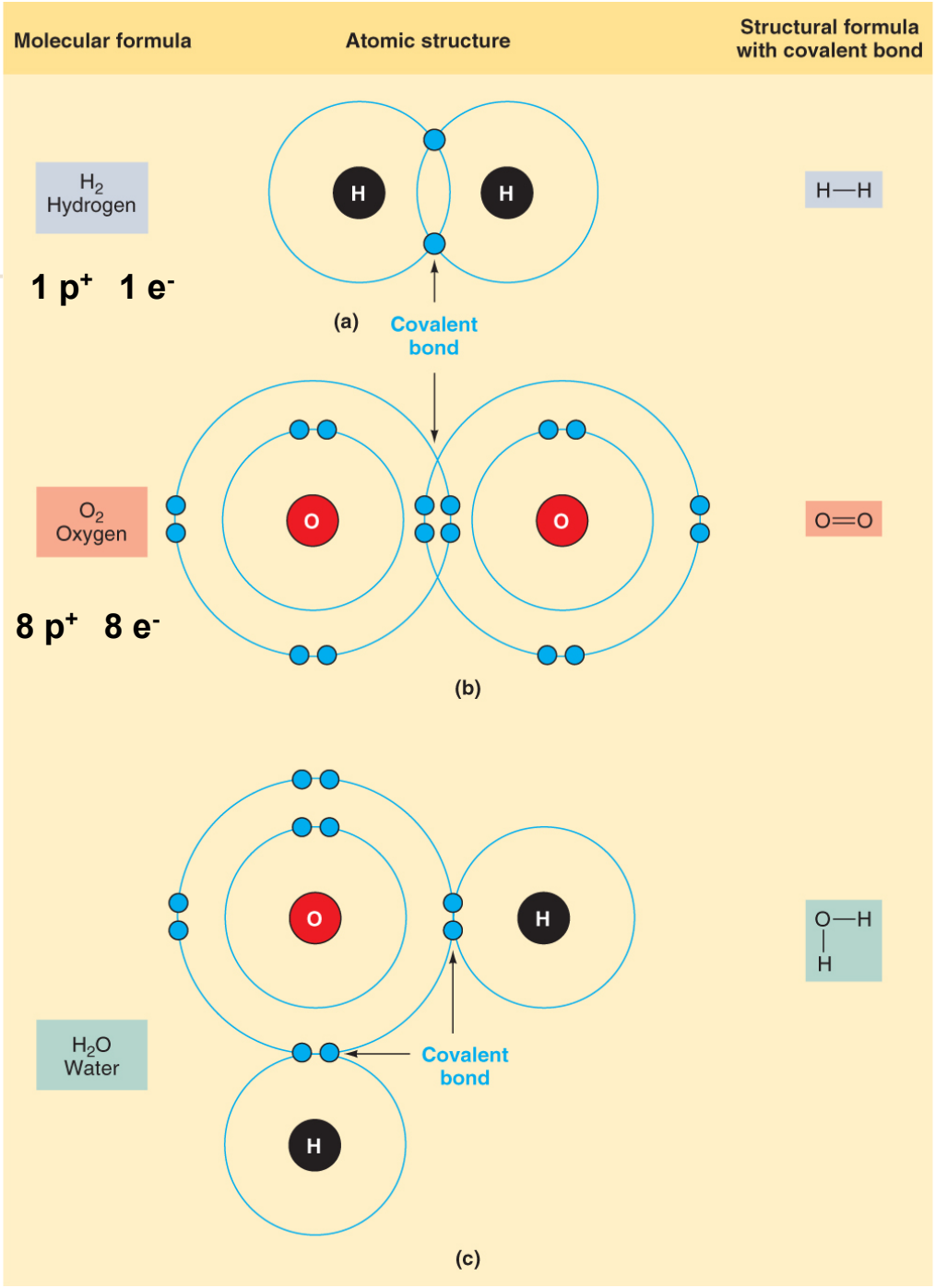


Fig. B4 - from Appendix B, from Sherwood et al, *Human Physiology: From Cells to Systems.* 2nd Canadian Edition, Appendix B, Nelson

Summaries – Chemical Bonds

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