

Atomic structure

- Until the early 20th century, chemists considered atoms to be indivisible particles.
- The discovery of SUBATOMIC PARTICLES changed the way we view atoms!

The subatomic particles

PROTON

- a small, but relatively massive particle that carries an overall unit POSITIVE CHARGE

NEUTRON

- a small, but relatively massive, particle that carries NO CHARGE
- slightly more massive than the proton

ELECTRON

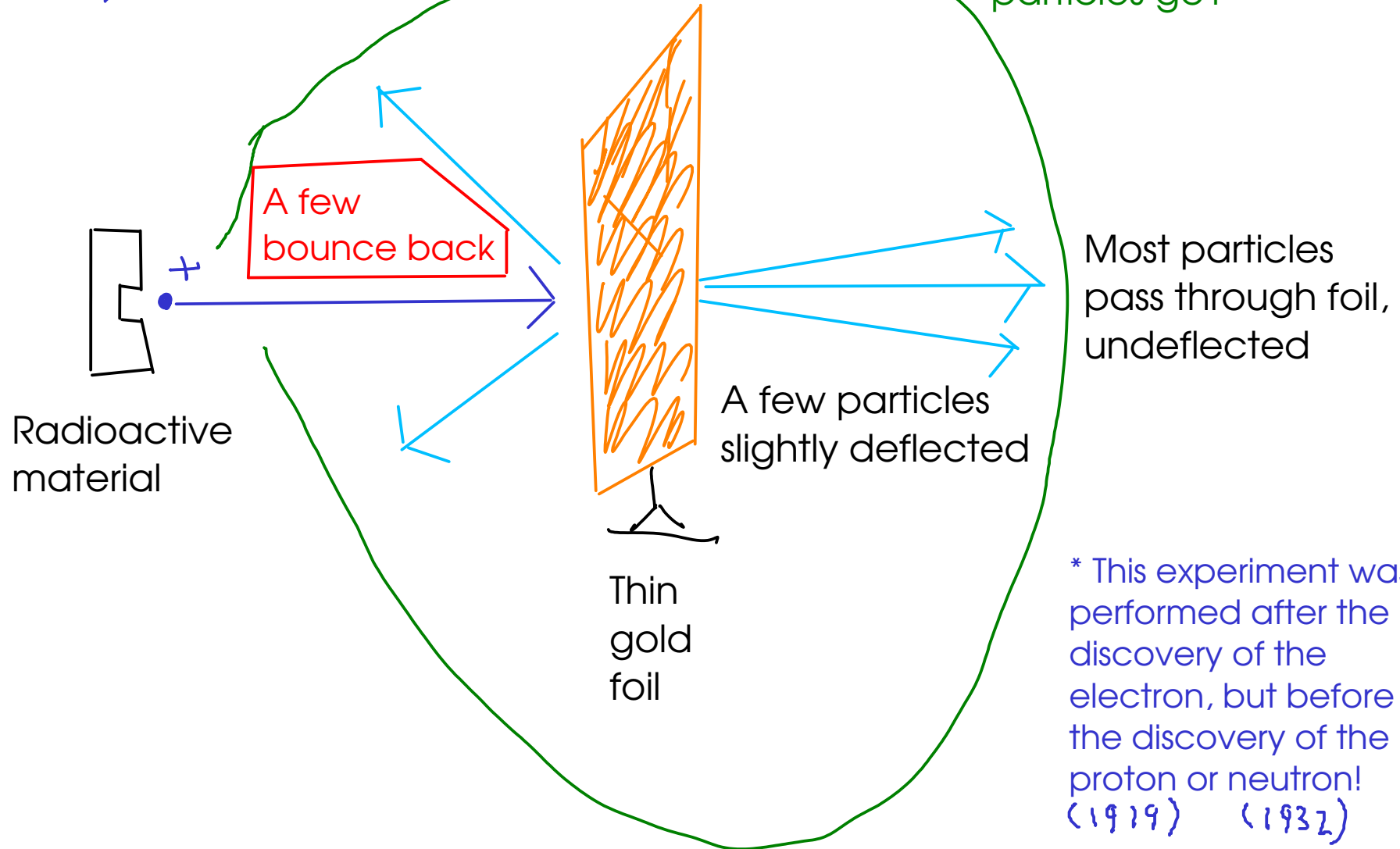
- a small particle that carries an overall unit NEGATIVE CHARGE
- about 2000 times LESS massive than either protons or neutrons

Putting it together...

- In the early 20th century, there was a debate on the structure of the atom.

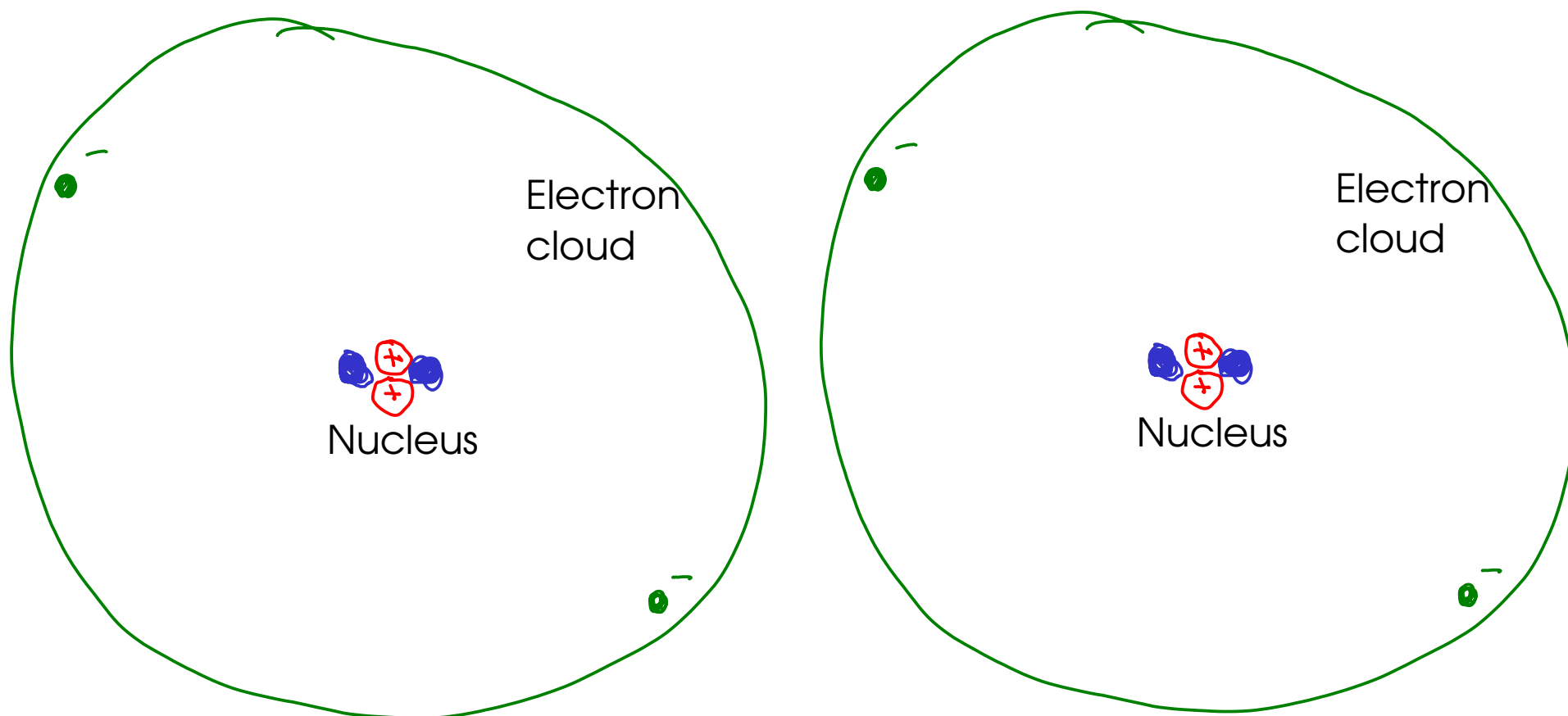
RUTHERFORD EXPERIMENT (1911)

Where do the particles go?



NUCLEAR MODEL

- Atoms are mostly empty space
- NUCLEUS, at the center of the atom, contains protons and neutrons. This accounts for almost all the mass of an atom
- Electrons are located in a diffuse ELECTRON CLOUD surrounding the nucleus



Why are atoms stable (why don't they change identity) during a reaction? The nucleus of an atom is not involved in chemical reactions, and the nucleus controls what kind of atom you have!

Atomic terms

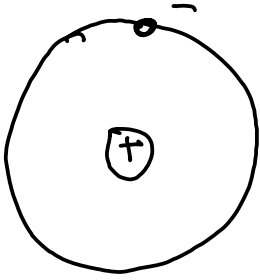
- ATOMIC NUMBER: The number of protons in the atomic nucleus. Each ELEMENT has the SAME NUMBER OF PROTONS in every nucleus. In neutral atoms, the number of ELECTRONS is also equal to the atomic number.

Example: Helium has an atomic number of 2. Every helium atom has two protons in its nucleus.

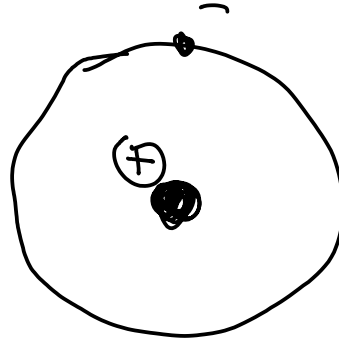
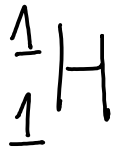
- MASS NUMBER: The number of protons PLUS the number of neutrons in the atomic nucleus, Atoms of the same element may have DIFFERENT mass numbers.

- ISOTOPES: are atoms of the same element with different mass numbers. In other words, they have the same number of protons but different numbers of neutrons.

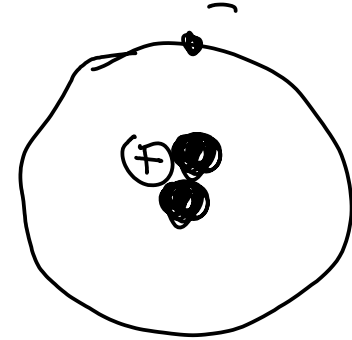
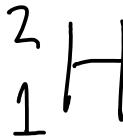
A few isotopes



Hydrogen-1



Hydrogen-2
"Deuterium"



Hydrogen-3
"Tritium"



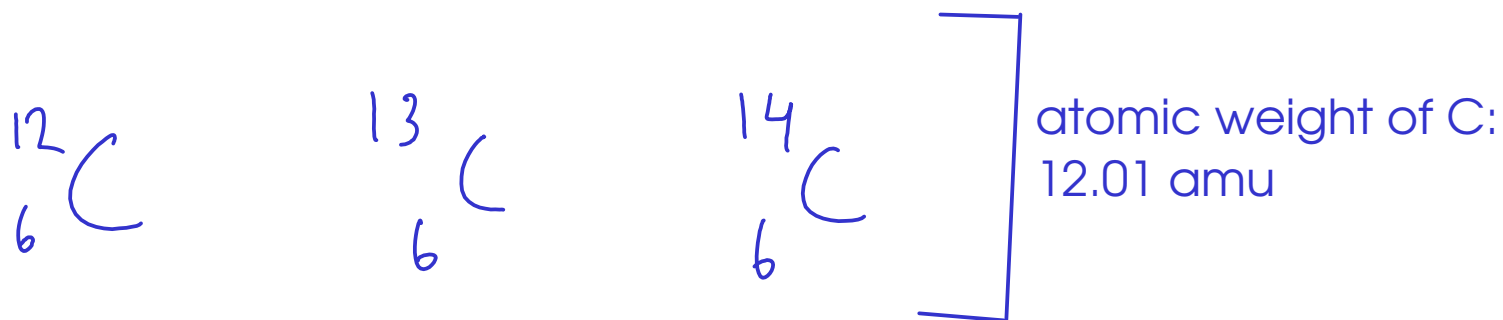
Isotopes

- Have identical CHEMICAL properties
- Differ in MASS
- May differ in stability. Elements may have some isotopes that are RADIOACTIVE

Atomic weight

- The AVERAGE MASS of all naturally occurring isotopes of an element.

Example: Hydrogen has an atomic weight of 1.008 "atomic mass units"
(Naturally-occurring hydrogen is almost all Hydrogen-1!)



(Natural carbon is mostly carbon-12)



(Natural chlorine is mostly chlorine-35)

Periodic Table

- Mendeleev (1869):
 - When atoms are arranged in order of their atomic weight, some of their chemical and physical properties repeat at regular intervals (periods)
 - Some of the physical and chemical properties of atoms could be calculated based on atomic weight
- Mendeleev was able to predict the properties of previously unknown elements using his "periodic law"

Modern periodic table

- organized based on ATOMIC NUMBER rather than ATOMIC WEIGHT. This eliminated some problems (elements out of order) with Mendeleev's original arrangement

Organization of the table

GROUPS

- columns
- atoms in a group often have similar chemical (and sometimes physical) properties

Group numbering:

- 1) Roman numerals: Similar to Mendeleev's groupings
 - "A" groups: Main group or "representative" elements
 - "B" groups: Transition elements (also called transition metals)
- 2) Arabic numerals: IUPAC (international) accepted numbering system

PERIODS

- rows
- Atoms in later periods are generally larger than in earlier periods
- More on the significance of periods at the end of the course!

Groups and periods

	IA																	VIIIA	
1	H	IIA																	He
2	Li	Be											IIIA	IVA	VA	VIA	VIIA		Ne
3	Na	Mg	IIIB	IVB	VB	VIB	VIIB	VIII B	IB	IIB		Al	Si	P	S	Cl		Ar	
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br		Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I		Xe
6	Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At		Rn
7	Fr	Ra	*	Rf	Db	Sg	Bh	Hs	Mt										

- The "A" groups are called the main (or representative) groups
- The "B" groups are called the transition elements

GROUP numbers shown in GREEN

PERIOD numbers shown in RED

The elements in the purple box have similar chemistry to the transition elements, even though they are listed in the "A" groups. A/B group notation isn't perfect!

Categories of elements

METALS

- good conductors of heat and electricity
- almost all solids at room temperature (exception: Mercury - Hg - is liquid)
- appearance: shiny, mirrored surface - mostly grey
- ductile (can be drawn into wires), malleable (can be hammered)
- located on the left hand side of the periodic table

NONMETALS

- poor conductors of heat and electricity. Most nonmetals do not conduct well at all (insulators)
- many of the nonmetals are gases at room temperature. A few solids, and one liquid (bromine)
- color: Nonmetals may be white, black, purple, green, blue, orange, or colorless etc.
 - usually have low melting points in the solid form
 - solids tend to be brittle (not malleable) - break when hit
 - located on the right hand side of the periodic table

METALLOIDS / SEMICONDUCTORS

- in between metals and nonmetals on the table
- most periodic tables have a zig-zagging line where the metalloids are
- properties tend to be "between" metals and nonmetals, too!
- some have chemical reactivity like a nonmetal, but conduct electricity better than nonmetals
- some have unusual electrical properties (silicon / germanium diodes) , and are useful in electronics

Types of elements on the periodic table

IA												VIII A					
H	IIA											III A	IVA	VA	VIA	VIIA	He
Li	Be											B	C	N	O	F	Ne
Na	Mg	IIIB	IVB	VB	VIB	VII B	VIII B	IB	IIB	Al	Si	P	S	Cl	Ar		
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac*	Rf	Db	Sg	Bh	Hs	Mt	*"inner" transition metals go here								

This red line appears in some way on most periodic tables. It's the dividing line between metals and nonmetals. You can find the metalloids here!

METALS shown in BLACK

NONMETALS shown in BLUE

METALLOIDS shown in PURPLE

Blocks on the periodic table

11
Na
Sodium
22.99

Atomic number: This is always a whole number. The periodic table is arranged by atomic number!

Element symbol: A one or two letter abbreviation for the name of the element. Sometimes, the abbreviation is based on a language OTHER THAN ENGLISH! (Example: Na is short for "natrium", the Latin name of sodium.)

Element name: Sometimes, this is left off of periodic tables, especially small ones!

Atomic weight: This is a decimal number, but for radioactive elements it is replaced with a number in parenthesis.

88
Ra
Radium
(226)

For RADIOACTIVE ELEMENTS - elements where the atomic nucleus breaks down, causing the atom to break apart - the MASS NUMBER of the most stable ISOTOPE is given in (parenthesis) instead of the atomic weight!

CHEMICAL COMPOUNDS

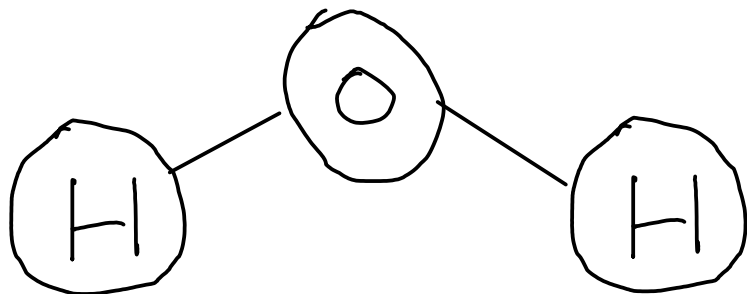
- Dalton's theory does not mention this, but there is more than one way for atoms to come together to make chemical compounds!
- There are TWO common kinds of chemical compound, classified based on how the atoms in the compound are held together:

① MOLECULAR COMPOUNDS

② IONIC COMPOUNDS

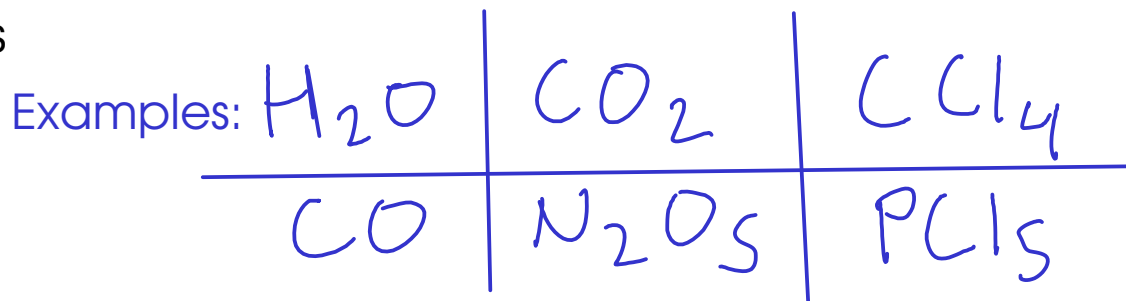
MOLECULAR COMPOUNDS

- form when atoms SHARE outer electrons with each other. This results in a set of connected atoms called a MOLECULE



Stick figure of a water (H_2O) molecule

- usually form between nonmetals and other nonmetals or between nonmetals and metalloids



CANDLE WAX is made up of molecular compounds

- some solid at room temperature. These solids tend to have low melting points.

PCl_5 is a solid, $mp = 180^\circ C$

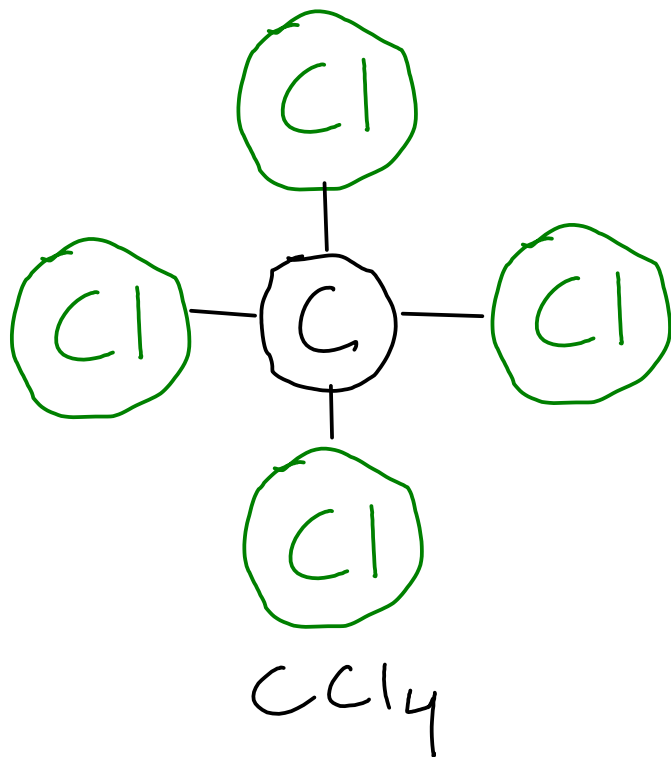
- many are liquids or gases at room temperature

H_2O, CCl_4 : liquids CO, CO_2, N_2O_5 : gases

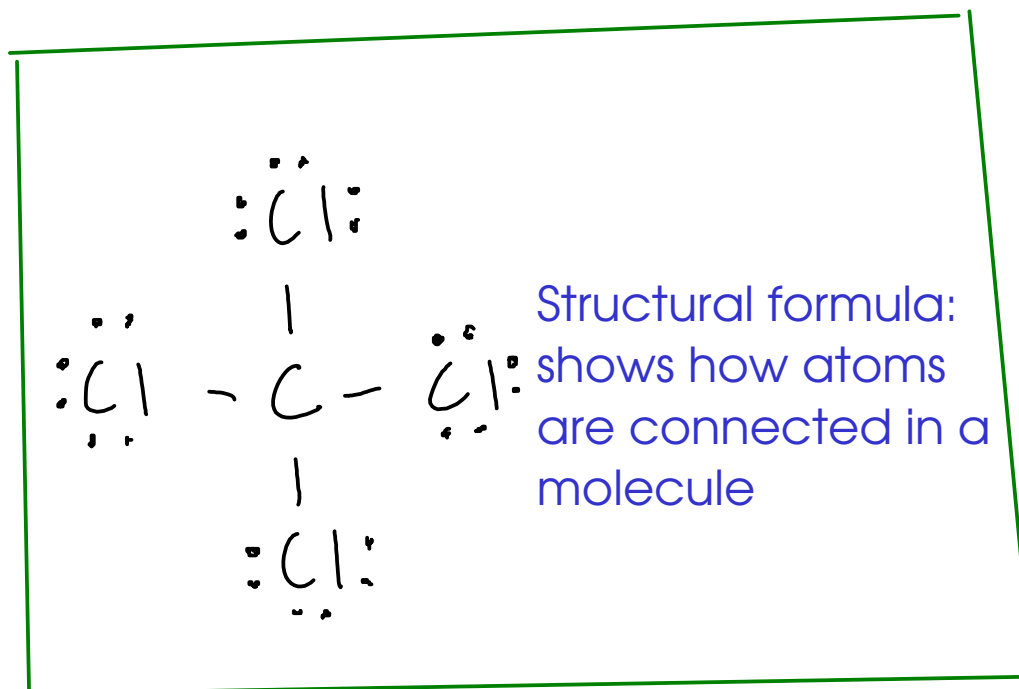
MOLECULAR FORMULAS

- formula of a molecular compound represents the EXACT NUMBER OF ATOMS OF EACH ELEMENT in a single molecule of the compound

Example: Each molecule of CCl_4 contains exactly one carbon atom and four chlorine atoms



"ball and stick" model



IONIC COMPOUNDS

- formed when atoms TRANSFER ELECTRONS between each other forming charged atoms, called IONS.

Two kinds of ions:

cation

① CATIONS: formed when an atom LOSES one or more electrons.

- overall, a cation has a POSITIVE charge, because it has more protons in the nucleus than electrons in the electron cloud

- usually formed by METALS, but occasionally hydrogen will also form a cation

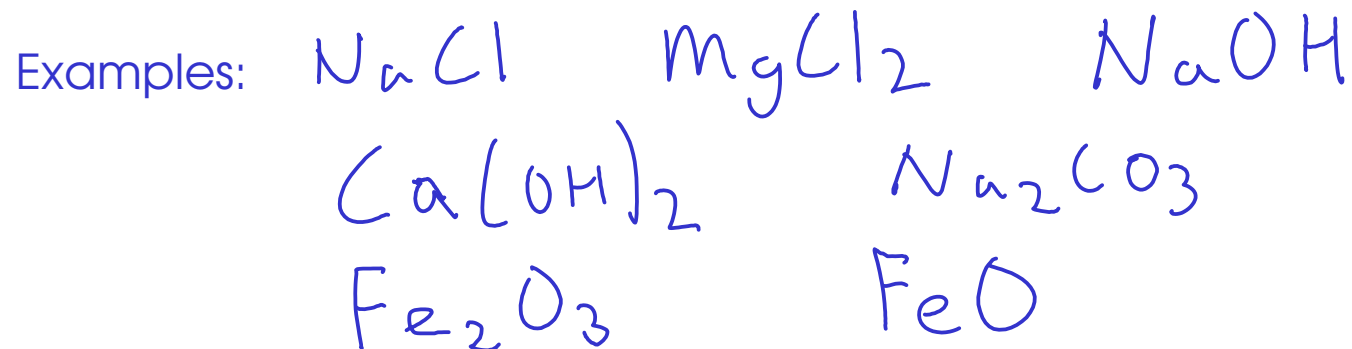
② ANIONS: formed when an atom GAINS one or more electrons

- overall, an anion has a NEGATIVE charge, because it has more electrons in the electron cloud than protons in the nucleus

- usually formed by NONMETALS

IONIC COMPOUNDS

- USUALLY form from metals combining with nonmetals, or from metals combining with metalloids



- almost always solid at room temperature, and usually have relatively high melting points

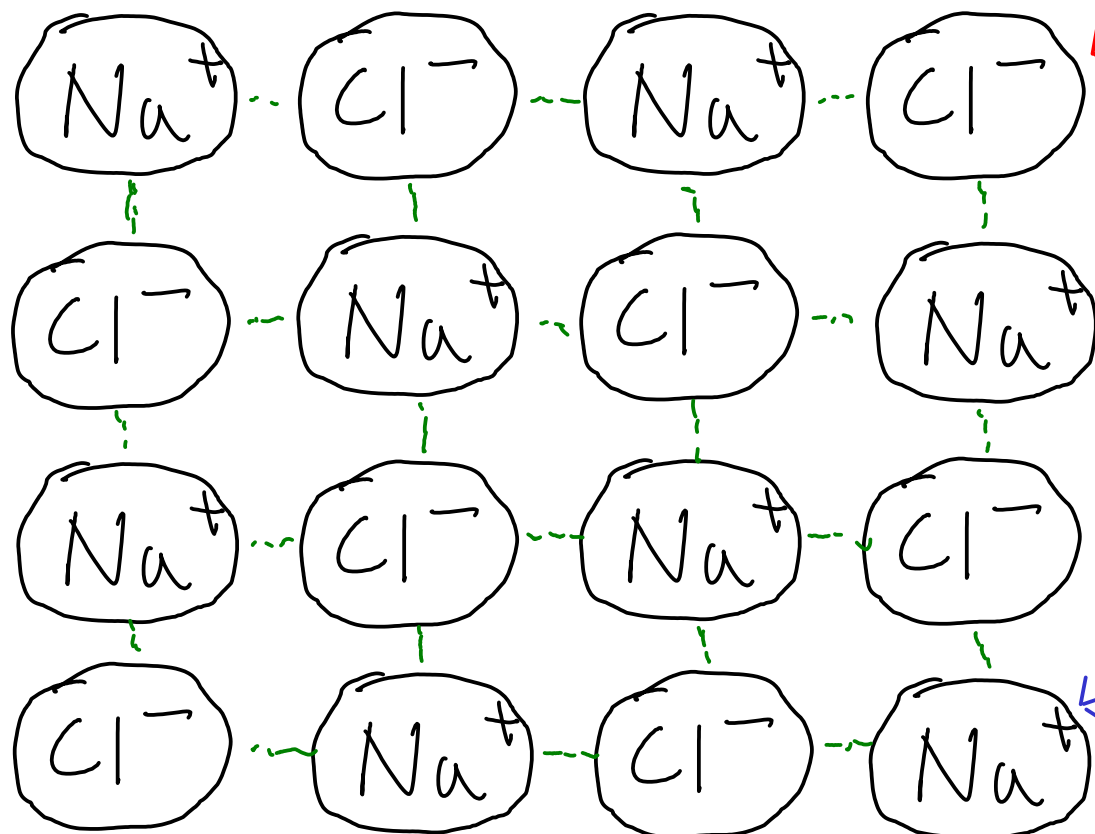
All of the above are solids at room temperature. NaCl has a melting point of 801°C .

- as solids, do not conduct electricity. If dissolved in water (some do not dissolve significantly in water), will form a solution that conducts electricity.

IONIC COMPOUNDS

- ionic compounds are held together by ELECTROSTATIC INTERACTIONS

(in other words, the attraction between oppositely charged ions!)



Each chloride ion is strongly attracted to ALL of the sodium ions surrounding it!

Each sodium ion is strongly attracted to ALL of the chlorine atoms surrounding it!

There are no "molecules" in ionic compounds - in the sense that you can't point to a discrete unit of atoms that are connected to only each other

IONIC FORMULAS

- since there are no "molecules", an ionic formula cannot describe how many and what kinds of atoms are in a molecule!
- all ionic compounds are observed to be (overall) electrically neutral, so the IONS they contain must be present in such a way that the charges BALANCE EACH OTHER
- an ionic formula gives the SMALLEST WHOLE NUMBER RATIO OF CATION TO ANION in the ionic compound

