

- Dalton's theory sets LIMITS on what can be done with chemistry. For example:

- ① Chemistry can't convert lead (an element) into gold (another element). Sorry, alchemists!
- ② You can't have a compound form in a chemical reaction that contains an element that was not in your starting materials.
- ③ You can only make a certain amount of desired product from a fixed amount of starting material.

## 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

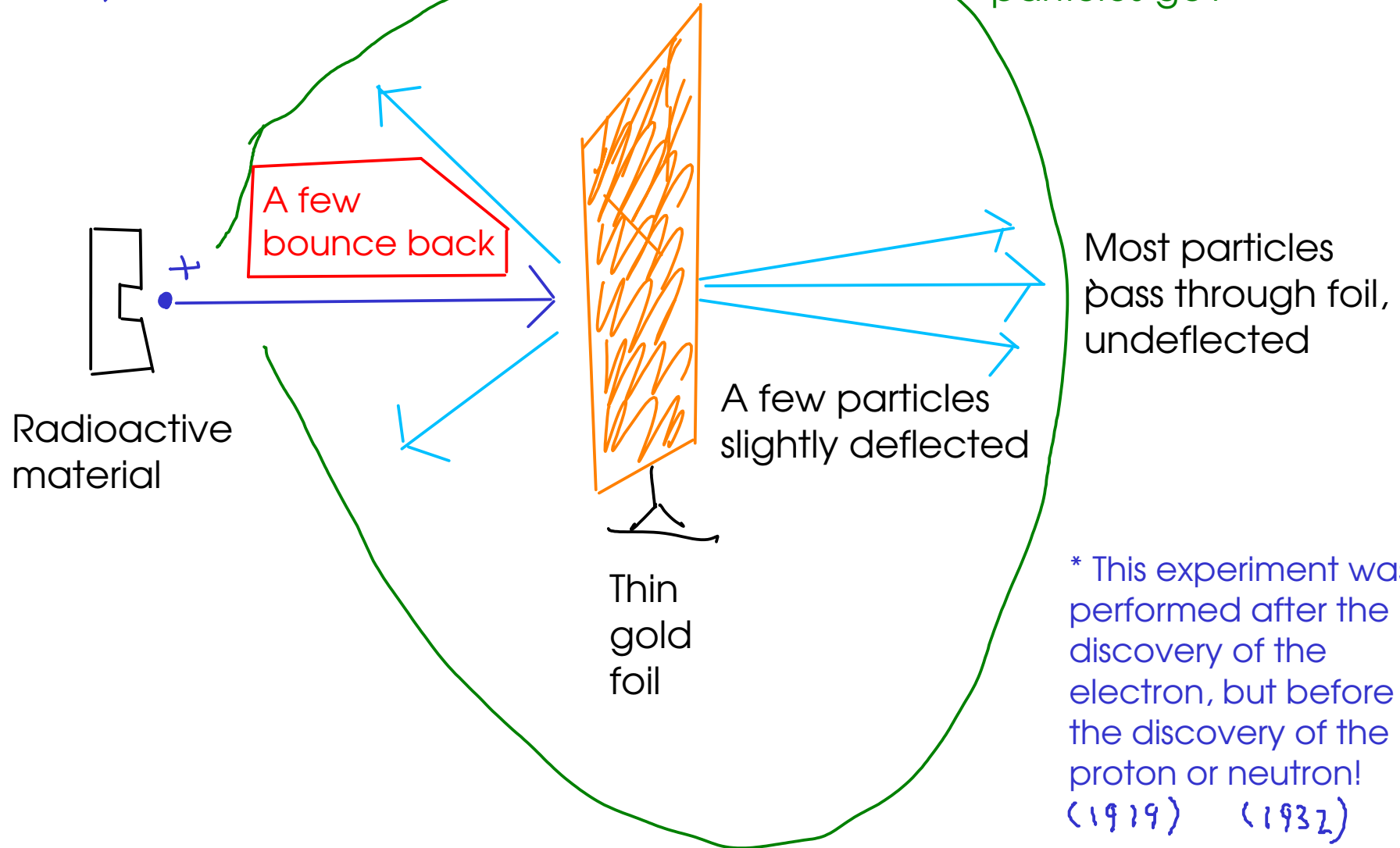
- a small particle that carries an overall unit NEGATIVE CHARGE
- about 2000 times LESS massive than either protons or neutrons

## Putting it together...

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

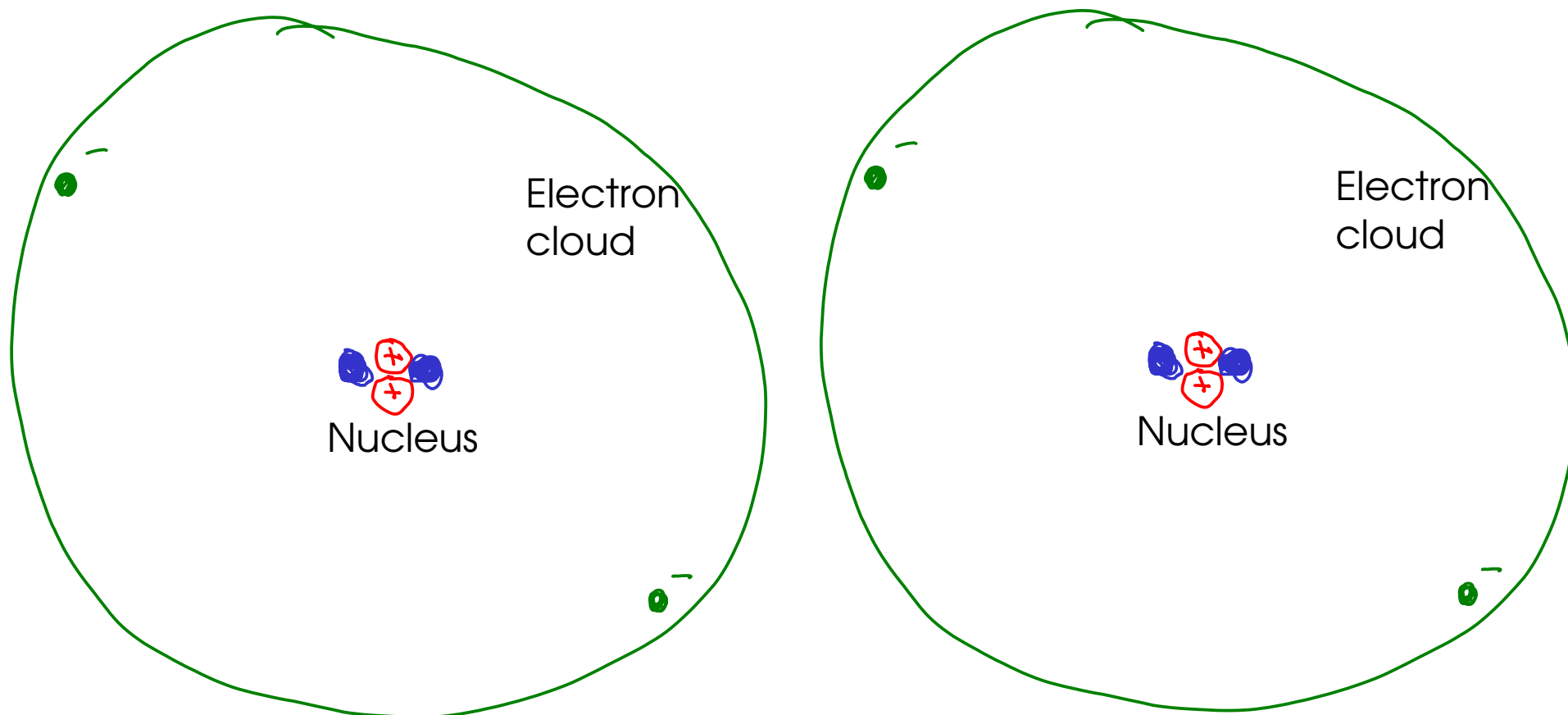
### RUTHERFORD EXPERIMENT (1911)

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

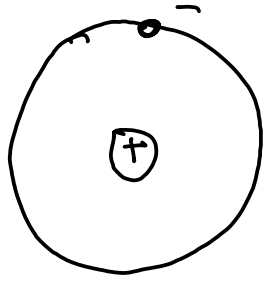
- ATOMIC NUMBER: The number of protons in the atomic nucleus. Each ELEMENT has the SAME NUMBER OF PROTONS in every nucleus. In neutral atoms, the number of ELECTRONS is also equal to the atomic number.

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

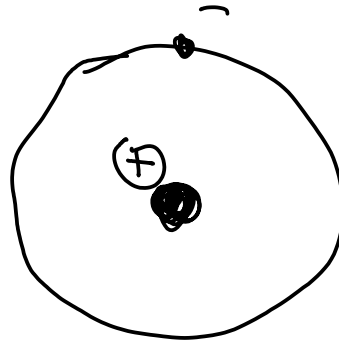
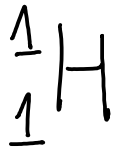
- MASS NUMBER: The number of protons PLUS the number of neutrons in the atomic nucleus, Atoms of the same element may have DIFFERENT mass numbers.

- 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.

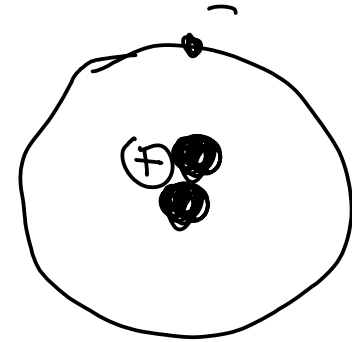
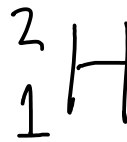
## A few isotopes



Hydrogen-1



Hydrogen-2  
"Deuterium"



Hydrogen-3  
"Tritium"



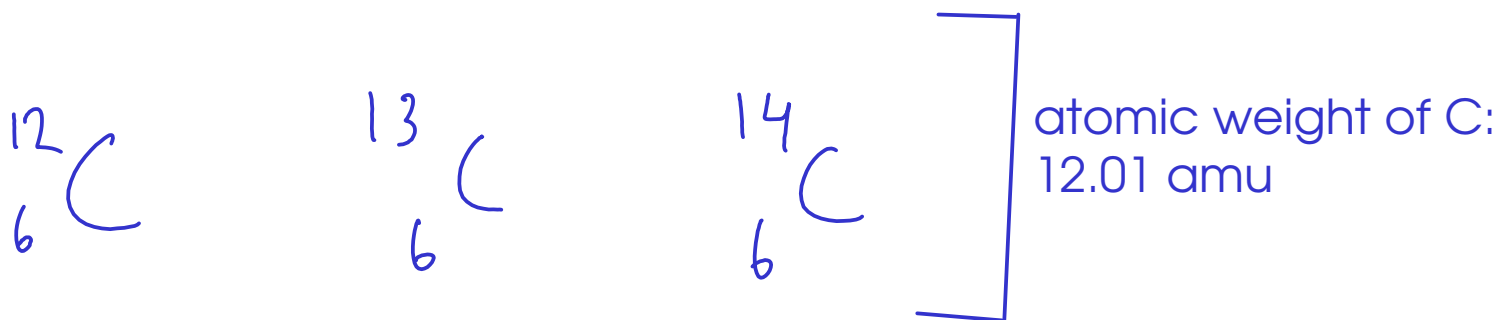
## Isotopes

- 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											III A	IV A	V A	VIA	VII A	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg	IIIB	IVB	VB	VIB	VII B	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	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac*	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												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!