How many significant figures are there in each of these measurements?

76.070 g
5

85000. mm
5
decimal point

0.001030 kg
4

156.0002 g
7

0.10 s
2

17000000 mg
2

120000 km
4

1350 ms
3

Calculations with measurements

When you calculate something using measured numbers., you should try to make sure the ANSWER reflects the quality of the data used to make the calculation.

An ANSWER is only as good as the POOREST measurement that went into finding that answer!

$$
\begin{array}{r}
14.206 \\
154.72 \\
1.6 \\
+\ 0.222 \\
\hline
170.748
\end{array}
$$

Round so that there's only one uncertain digit in the answer!

How should we report this answer? How much uncertainty is in this answer?

170.7 ± 0.1

* If you add an uncertain number to either a certain or an uncertain number, then the result is uncertain!

* If you add certain numbers together, the result is certain!

For addition and subtraction, round FINAL ANSWERS to the same number of decimal places as the measurement with the fewest decimal places. This will give an answer that indicates the proper amount of uncertainty.

For multiplication and division, round FINAL ANSWERS to the same number of SIGNIFICANT FIGURES as the measurement with the fewest SIGNIFICANT FIGURES!

4 3 3

15.62 × 0.0667 × 35.0 = 36.4|6489

How should we report this answer?

36.5

3 2 5

25.4 × 0.00023 × 15.201 = 0.088|804242

How should we report this answer?

0.089

A few more math with significant figures examples:

$$\underset{5}{15047} \times \underset{2}{11} \times \underset{4}{0.9876} = 163464.5892$$

160000 ~~16~~

Placeholder zeros, even though they aren't SIGNIFICANT, still need to be included, so we know how big the number is!

$$
\begin{array}{r}
147.3 \\
2432 \\
0.97 \\
+\ 111.6 \\
\hline
2691.87
\end{array}
$$

2692

DENSITY CALCULATION

$$\frac{14.7068\ g}{2.7\ mL} \quad (6 \text{ and } 2 \text{ significant figures})$$

$$= 5.446962963\ g/mL$$

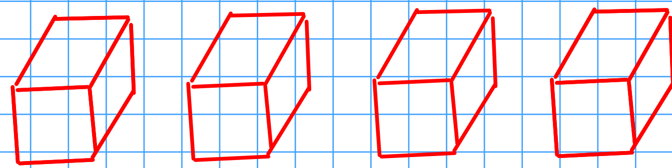
5.4 g/mL

To improve (make more precise) this calculated density, we must improve the poorest measurement. We must use a more precise device to measure the VOLUME (which only has two significant figures in this example)!

Exact Numbers

- Some numbers do not have any uncertainty. In other words, they weren't measured!

1) Numbers that were determined by COUNTING!



How many blocks are to the left?

exactly 4

2) Numbers that arise from DEFINITIONS, often involving relationships between units

12 in = 1 ft

km = 10^3 m

* All metric prefixes are exact!

- Treat exact numbers as if they have INFINITE significant figures!

Example

You'll need to round the answer to the right number of significant figures!

Convert 4.45 m to in, assuming that 2.54 cm = 1 in

EXACT!

$1\ in = 2.54\ cm$

$cm = 10^{-2}\ m$

$$4.45\ m \times \frac{cm}{10^{-2}\ m} \times \frac{1\ in}{2.54\ cm} = 175.19685039 4\ in$$

3 ∞ ∞

175 in

DALTON'S ATOMIC THEORY

- 1808: Publication of Dalton's "A New System of Chemical Philosophy", which contained the atomic theory

- Dalton's theory attempted to explain two things:

(1) CONSERVATION OF MASS

- The totat amount of mass remains constant in any process, chemical or physical!

(2) LAW OF DEFINITE PROPORTIONS (also called the LAW OF CONSTANT COMPOSITION): All pure samples of a given compound contain the same proportion of elements by mass

The parts of Dalton's theory

(1) Matter is composed of small, chemically indivisible ATOMS

(2) ELEMENTS are kinds of matter that contan only a single kind of atom. All the stoms of an element have identical chemical properties.

(3) COMPOUNDS are kinds of matter that are composed of atoms of two or more ELEMENTS which are combined in simple, whole number ratios.

Most importantly,

(4) CHEMICAL REACTIONS are REARRANGEMENTS of atoms to form new compounds.

- Atoms are not gained or lost during a chemical reaction.
- Atoms do not change their identity during a chemical reaction.
- All the atoms that go into a chemical reaction must go out again!

Another look at chemical reactions

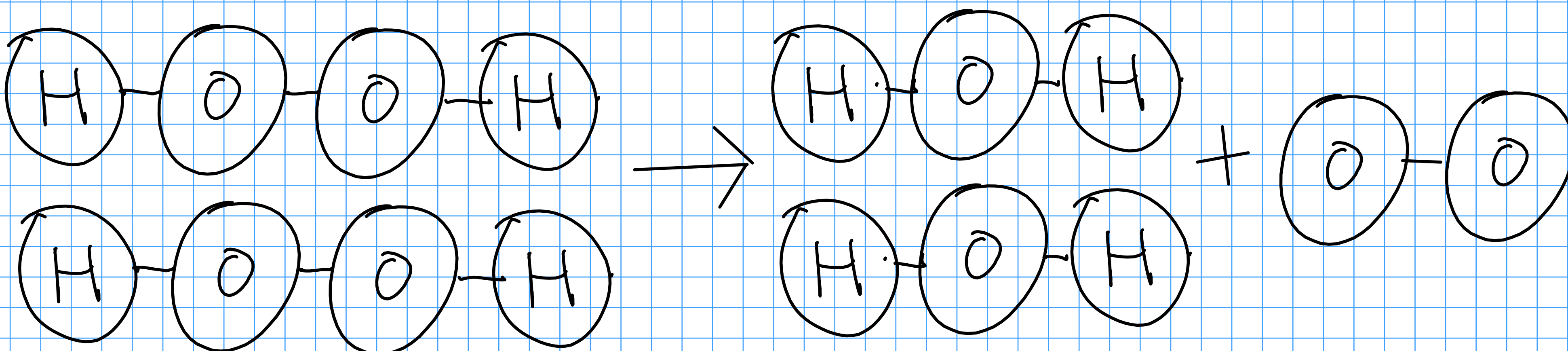
You observed this reaction in the oxygen lab:

HYDROGEN PEROXIDE → WATER + OXYGEN GAS

$$H_2O_2 \longrightarrow H_2O + O_2$$

... but wouldn't this mean that somehow an extra oxygen atom would form?

Not according to Dalton's theory. Dalton's theory would predict a different RATIO of water and oxygen would form:



$$2\ H_2O_2 \longrightarrow 2\ H_2O + O_2$$

- 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 carres an overall unit POSITIVE CHARGE

NEUTRON

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

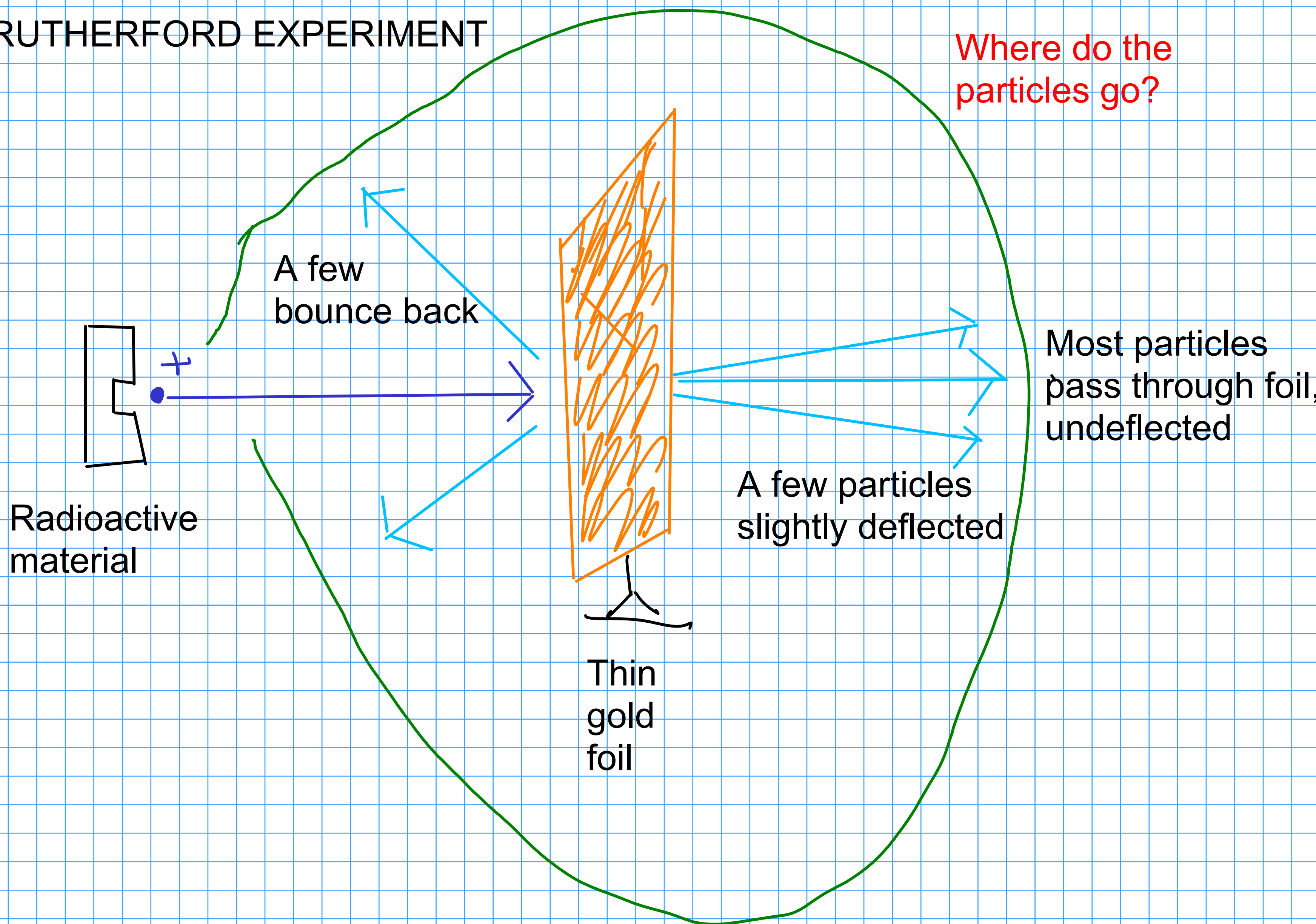
ELECTRON

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

Putting it together...

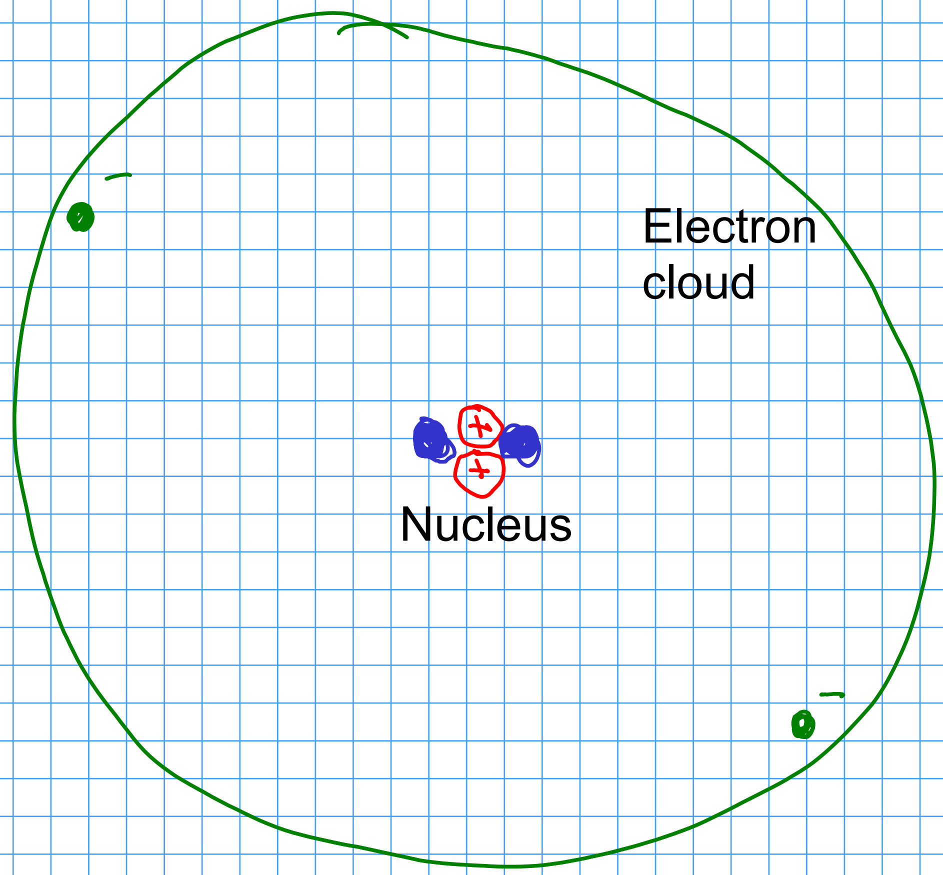
- In the early 20th century, there was a debate on how the newly discovered subatomic particles actually made an atom.

RUTHERFORD EXPERIMENT



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



Atomic terms

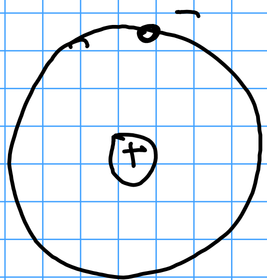
- ATOMIC NUMBER: The number of protons in the atomic nucleus. Each ELEMENT has the SAME NUMBER OF PROTONS in every nucleus. In neutral atoms, the number of ELECTRONS is also equal to the atomic number.

  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.

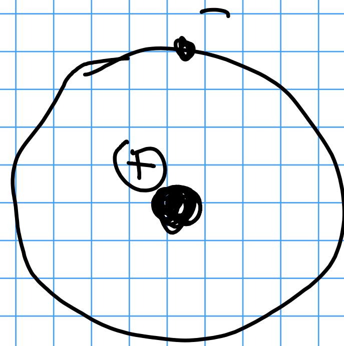
- ISOTOPES: are atoms of the same element with different mass numbers. In other words, they have the same number of protons but different numbers of neutrons.

A few isotopes



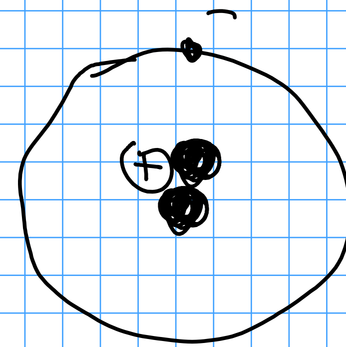
Hydrogen-1

$^{1}_{1}H$



Hydrogen-2
"Deuterium"

$^{2}_{1}H$



Hydrogen-3
"Tritium"

mass # → 3

atomic # → 1

$^{3}_{1}H$

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!)

$$^{12}_{6}C, \quad ^{13}_{6}C, \quad ^{14}_{6}C$$

atomic weight of C:
12.01 amu

(Natural carbon is mostly carbon-12)

$$^{35}_{17}Cl \quad ^{37}_{17}Cl$$

atomic weight of Cl:
35.45 amu

(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 or 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: Transistion 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

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

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											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 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!

GROUP numbers shown in GREEN

PERIOD numbers shown in RED

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

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!

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											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

METALS shown in BLACK

NONMETALS shown in BLUE

METALLOIDS shown in PURPLE