CHEM 205 section 03

LECTURE #5 Thurs., Jan.17, 2008

ASSIGNED READINGS:

TODAY'S CLASS: continue Ch.2

NEXT CLASS: **finish Ch.2, start Ch.3**

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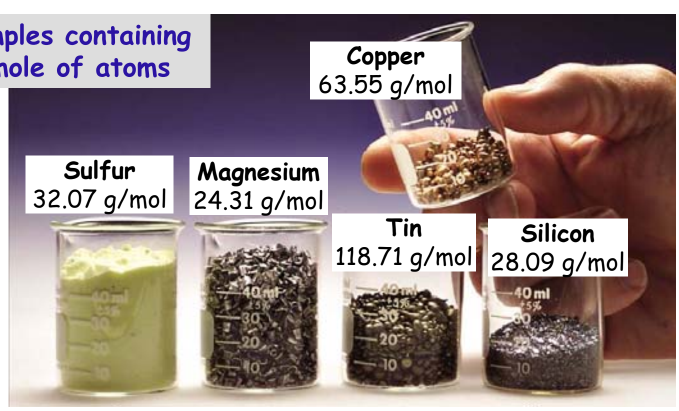
Counting large #s of objects: shorthand units

Unit of convenience	items / unit	Commonly used for…
1 couple	2	people
1 dozen	12	eggs
1 gross *(= 12 dozen)*	144	pencils (at bookstore…)
1 mole *(Latin:* pile, heap)	6.022×10^{23}	**atoms, ions, molecules**

Fig.2.9 Samples containing 1 mole of atoms



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2.5 Atoms & The Mole: the chemists' dozen

Amedeo Avogadro 1776-1856

Unit of convenience	# of items per unit	Usually used for…	Approximate sample size
1 dozen	12	Eggs	Fits in egg carton
1 mole	**6.022×10^{23}** Avogadro's #	**Atoms**	**Fits in your hand**

Where did Avogadro's number, *N*, come from?

- Chose a convenient reference sample size: 12 g of pure ^{12}C
- Experimentally determined the # of atoms
    - Implication: $\dfrac{1 \; \cancel{^{12}C \text{ atom}}}{6.022 \times 10^{23} \; \cancel{^{12}C \text{ atoms}}} = \dfrac{\cancel{12} \text{ amu}}{\cancel{12} \text{ g}}$

THUS: 1 g = 6.022×10^{23} amu ⇨ mass of 1 mole of p^+ *or* n^0

Thus: the mass number shown for each element on the periodic table has dual meaning:

1.) mass of 1 atom, in amu ← CONCEPTUAL

2.) mass of 1 mole of atoms, in grams ← PRACTICAL

Using atomic masses: counting by weighing

- No single atom of an element has "average atomic mass"
- BUT…we call it "atomic mass"
- AND…we use average mass for calculations

Don't COUNT atoms: WEIGH them & calculate # using average mass

How many atoms of carbon are in your pencil's "lead", which is GRAPHITE, C(s) ?

- Estimate: 7.0 g of graphite, C(s)
- Atomic mass: C = 12.01 g/mol

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Ans: 0.58 mol… = 3.5×10^{23} atoms

Which sample has more atoms in it?

103.5 g of lead, Pb(s) *OR* 0.5000 mol of zinc, Zn(s)

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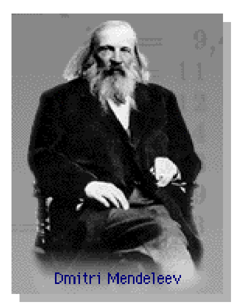
"Mendeleev's dream"…

(there's a cool book by this name…from chemistry's ancient Greek roots through to alchemy & finally developing into modern science…very interesting & reads like a novel…quite fun.)

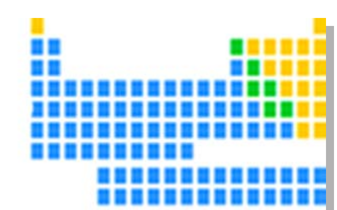
Dmitri Mendeleev:

- Argued that element properties are periodic functions of their atomic weights…
- Developed the modern periodic table.



- We NOW know that element properties are periodic functions of their ATOMIC NUMBERS.

(see p.332 for more on Mendeleev)



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2.6 The Periodic Table:

organized according to both atomic number (Z) & properties

Periods *or* rows (horizontal): Z increases left → right

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac†	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub						

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Elements with similar **properties** are in vertical "groups"

Groups in red boxes: 1A – 8A "main group" elements

Groups in blue box: 3B – 8B, 1B, 2B "transition" elements

Numbering of groups / families:
A/B in U.S.A. (older system)
1-18 rest of world (new IUPAC system)

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac†	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub						

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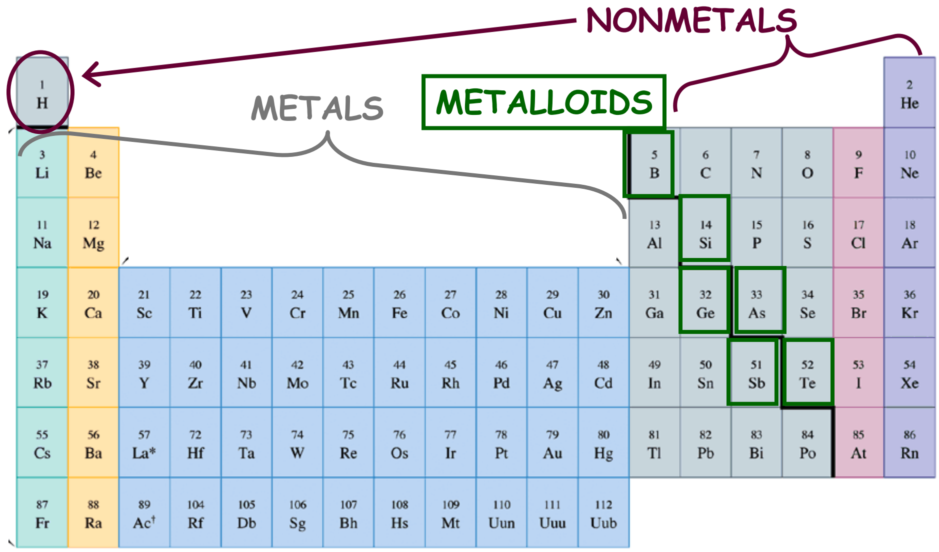
"IUPAC" = International Union of Pure & Applied Chemistry

General trends in PROPERTIES:



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Broad classification by properties

Element class	Where in periodic table?	Characteristic physical properties
METALS *e.g.,* Fe	left side MOST ELEMENTS	▪ conduct heat & electricity ▪ malleable, ductile, lustrous (shiny) ▪ exist as atomic SOLIDS (except for Hg = liquid)
NONMETALS *e.g.,* S	right side (21 of ~112)	▪ insulators, non-malleable ▪ dull solids; liquids; gases… ▪ many exist as diatomic molecules: I_2, H_2, N_2, Br_2, O_2, Cl_2, F_2 "I have no bright or clever friends…"
METALLOIDS B, Si, Ge, As, Sb, Te	Along border b/w metals & nonmetals	▪ some properties of metals & some of non-metals ▪ very ambiguous behaviour

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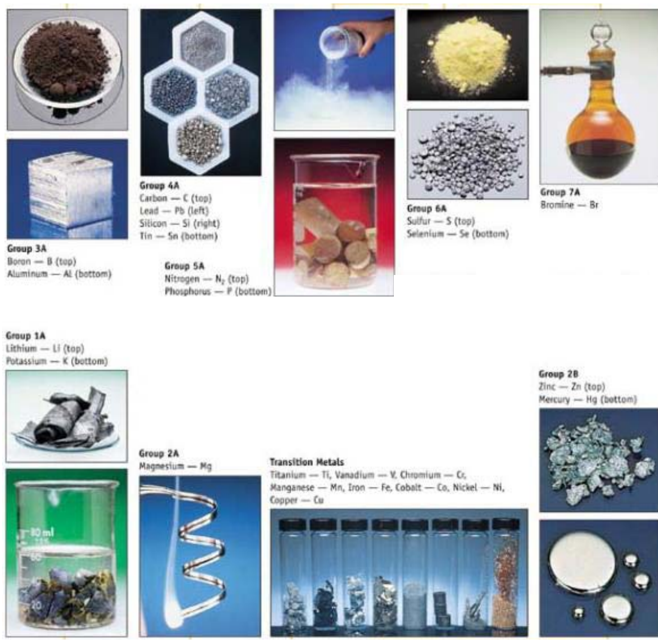
Become familiar with the elements (Fig. 2.10)



Task for each element here:

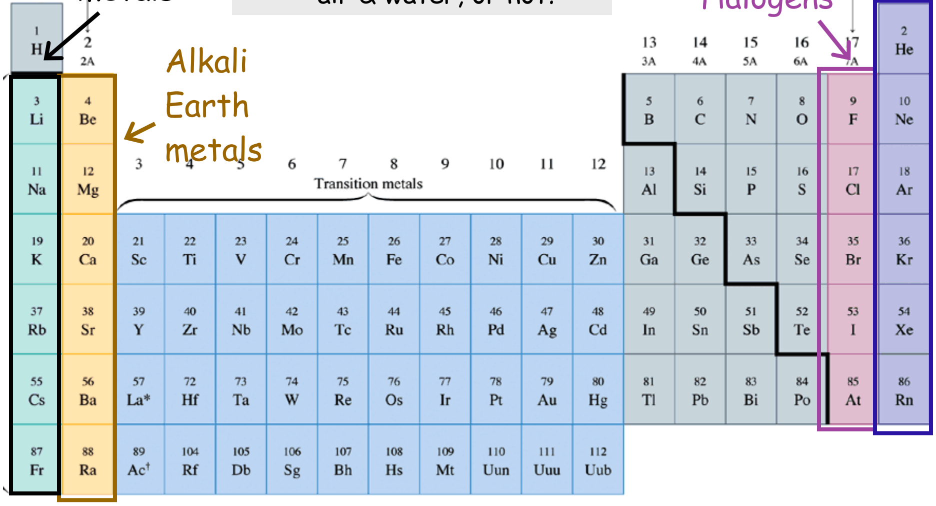
- Locate on P.Table
- Classify as metal *vs.* non-metal
- See section 2.7:
  - Find 2 properties of each (phys./chem.)
  - Write symbol of elemental form *e.g.,* oxygen O_2(g)

& compare your answers with a classmate

2.7 An overview of the elements, by group

Goal: Get a feeling for elements' chemical properties

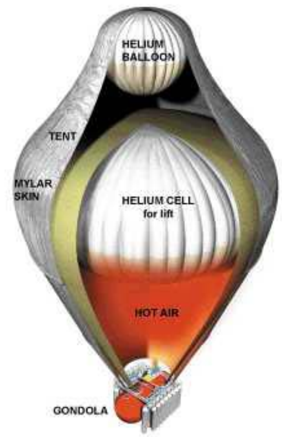
Found in nature in elemental form, or only as compounds?
i.e., Reactive towards air & water, or not?



Group 8A: the noble gases He, Ne, Ar, Kr, Xe, Rn

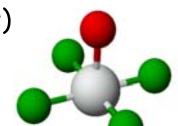
radioactive

- All exist as free atoms: *E.g.,* Kr(g)
- Lighter-than-air balloons: He(g)
- "Neon" signs: *more in Ch.7*



- **The most <u>unreactive</u> elements**

  (although… heavy ones can be forced to react with <u>very</u> reactive substances to form compounds)



$XeOF_4$

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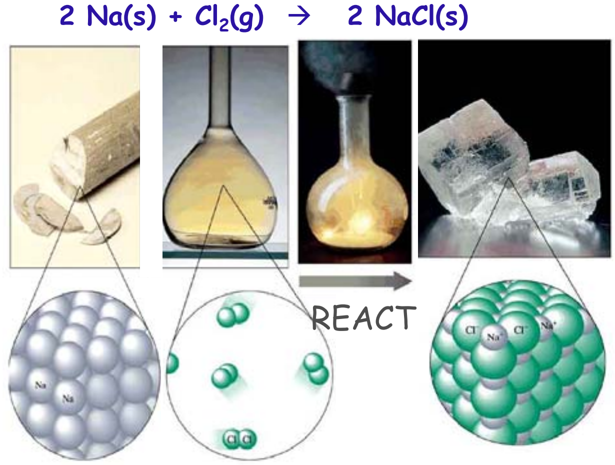
Group 7A: the halogens: F, Cl, Br, I, At

- Exist as diatomic molecules: F_2(g), Cl_2(g), Br_2(l), I_2(s)…
- Quite **reactive**…
- React violently with alkali metals to form ionic compounds (salts)

sodium + chlorine → sodium chloride

2 Na(s) + Cl_2(g) → 2 NaCl(s)



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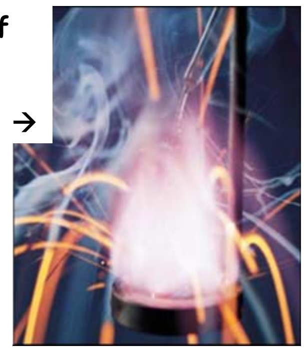
Group 1A: Alkali metals Li, Na, K, Rb, Cs, Fr

- Elemental form: soft silvery "atomic" metals, M(*s*)
- All are violently reactive towards water & air (& halogens)
  - *E.g.,* $K(s) + H_2O(l) \rightarrow H_2(g) + KOH(aq)$ + energy!
    burns!
- THUS: In nature, found only as cations, M^+ *e.g.* in NaCl

Cutting sodium metal Na(s) is like cutting cold butter

Reaction of potassium metal K(s) with water →



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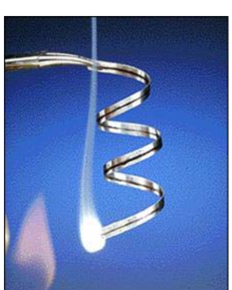
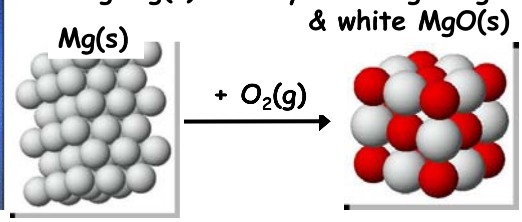
Group 2A: Alkali earth metals Be, Mg, Ca, Sr, Ba, Ra

- Elemental form:
  - Highly reactive metals…
- In nature: found only in compounds, as M^{2+} cations
  e.g. in $CaCO_3$ limestone →



Burning Mg(s) in air yields bright light & white MgO(s)



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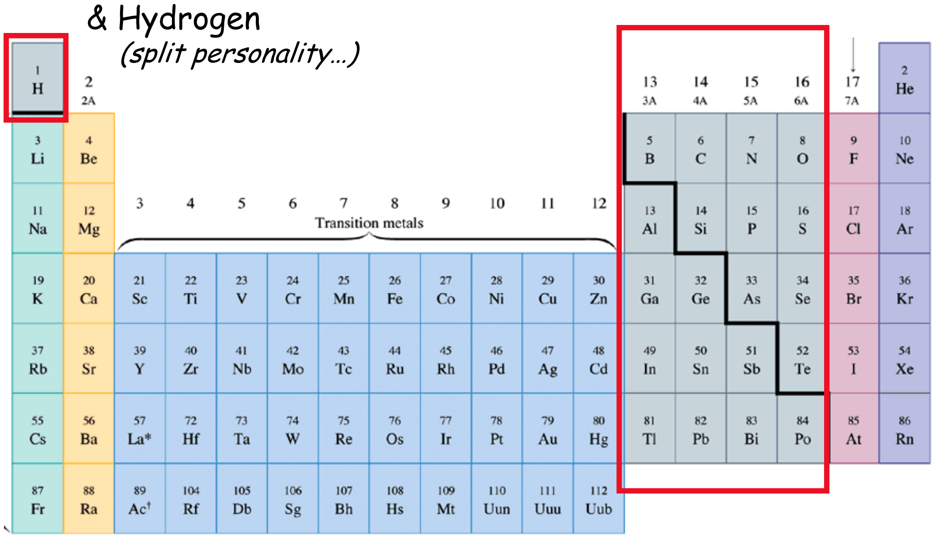
Next: the more diverse "main groups"

less coherent sets of properties

& Hydrogen
(split personality…)



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Hydrogen: the most common element in the universe

- Exists as $H_2(g)$:
  a colourless lighter-than-air gas
- Main component of stars
  …minor component of air
- In most reactions, forms H^+ ion
  (loses its electron, like alkali metals do)
- In some reactions, forms H^- ion
  (gains an electron, like halogens do)
- Highly combustible

The sun is mostly H_2

Shuttle's main engines use H_2 and O_2 as fuel

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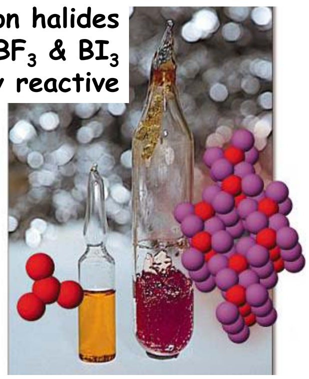
Group 3: B, Al, Ga, In, Tl

Boron: only metalloid in Gp.3

- In nature: as mineral, borax
  - ionic: $Na_2B_4O_5(OH)_4$
  - cleaning agent, antiseptic
- B can be converted in lab to other forms *(see Ch.9)*:

Boron halides
BF_3 & BI_3
Highly reactive



Aluminum:

- Most abundant metal in earth's crust (in ionic compounds…)
- In many minerals, gems

Sapphire: Al_2O_3 with Fe^{3+} or Ti^{3+} impurity gives blue, whereas V^{3+} gives violet.

Ruby: Al_2O_3 with Cr^{3+} impurity

- Refined Al(s) has many uses…

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Group 4A: C, Si, Ge, Sn, Pb

Carbon:

- Elemental form: 3 ***allotropes*** (different forms of pure element)
- Solids with large molecular structures

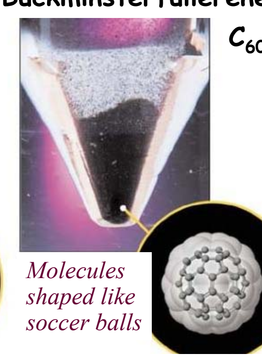
graphite, *C*(gr)

Layers of sheet-like molecules

diamond, *C*(d)

3-D network (1 giant molecule)

Buckminsterfullerene $C_{60}(s)$



Molecules shaped like soccer balls

- Carbon in nature: elemental forms uncommon
  - in covalent compounds: organic substances, coal, biomolecules
  - ionic compounds: carbonates (limestone…)

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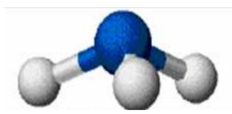
Group 5A: N, P, As, Sb, Bi

Nitrogen:
- ¾ of air = $N_2(g)$
- **very unreactive**

- In compounds:
  - Proteins, DNA, & other biomolecules
  - Ammonia: used as fertilizer



Ammonia, NH_3

Later in course:
see basic correlation between reactivity & structure...

Phosphorus:
- Found as phosphate (ionic) & in biomolecules (*e.g.,* DNA)
- Elemental forms highly reactive

2 allotropes: White phosphorus = $P_4(s)$
Red phosphorus = chain (polymer)

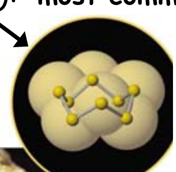
Brandt 1669: *boiled urine for weeks... & isolated elemental phosphorus (!?!)*

Group 6A: O, S, Se, Te, Po ← radioactive

Oxygen: colourless gas
- $O_2(g)$: 20% of air
- Quite reactive...
  - **Reacts so strongly with many substances, lots of energy is released**
  - **Feeds "combustion"**
- Most abundant element (as compounds...) in earth's crust
- Allotrope: O_3 = ozone

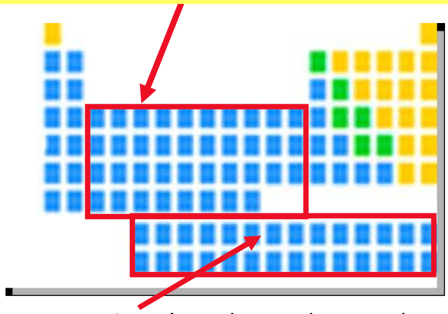
Compounds of S, Se, Te typically very smelly & very toxic... yet S & Se are essential to life
- S = component of amino acids cysteine & methionine

Sulfur: yellow solid
- $S_8(s)$: **most common allotrope**



S(s) forms at volcanoes →

Transition metals



Lanthanides and actinides
"rare earth elements"
subset of transition metals…

Table 2.4 • Abundance of the 10 Most Abundant Transition Elements in the Earth's Crust

Rank	Element	Abundance (ppm)*
4	Iron	41,000
9	Titanium	5,600
12	Manganese	950
18	Zirconium	190
19	Vanadium	160
21	Chromium	100
23	Nickel	80
24	Zinc	75
25	Cerium	68
26	Copper	50

*ppm = g per 1000 kg

- Common metals: Fe, Cu, Ni, Zn…
- In nature: typically found as compounds
  - In elemental form in nature: Ag, Au, Pt (…quite unreactive)
- Most react with air (oxidation), but not violently: *rusting of Fe*
  - Most elemental transition metals can be easily handled

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2.8 Essential Elements

- So important to life, deficiency in any ONE will result in death, severe developmental abnormalities, chronic ailments…

Major elements:

- 99.9% of all atoms in human body are the following 'light' elements:
  - C, H, N, O (99%!)
  - Na, Ca, K, Mg
  - S, P, Cl

Generally as HPO_4^{2-} (P)

Generally as simple ions (Na, Ca, K, Mg, Cl)

Trace elements:

- V, Cr, Mo Mn, Fe, Co, Ni, Cu, Zn
- B, Si, Se, F, Br, I, As, Sn
- Often crucial for function of specific *proteins, enzymes, vitamins…*

Relative quantities ~mimic relative abundances in earth's crust…

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Iron: essential for oxygen transport

- Hemoglobin = the protein that carries oxygen in the blood
- Located inside red blood cells
- Requires Fe to function properly
- Fe deficiency: fatigue, infections, mouth inflammation…
- *A sample exam problem:*

  In the blood of an adult human, there are approx. 2.60×10^{13} red blood cells, containing a total of 2.90 g of iron. On average, how many iron atoms are present in each red blood cell?

ANS = 1.20×10^{9} atoms/rbc (3 SF)

ASSIGNED READINGS

- BEFORE NEXT CLASS:

  Read all of Ch. 2
  master the *mole* concept & calculations
  & work on Ch.2 exercises

  Memorize the first 20 elements…
  (periodic table on midterm exam will not include them!)