The rest of the Semester

All of Chemistry

Today

Groups 1-IV

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Things everyone should know

Get to know the chemistry of the elements

How is each element found in nature

Reactions involving compounds with those elements

Practical uses of those compounds

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First what is the most abundant element in the Universe?

A. Hydrogen

B. Helium

C. Oxygen

D. Silicon

E. Iron

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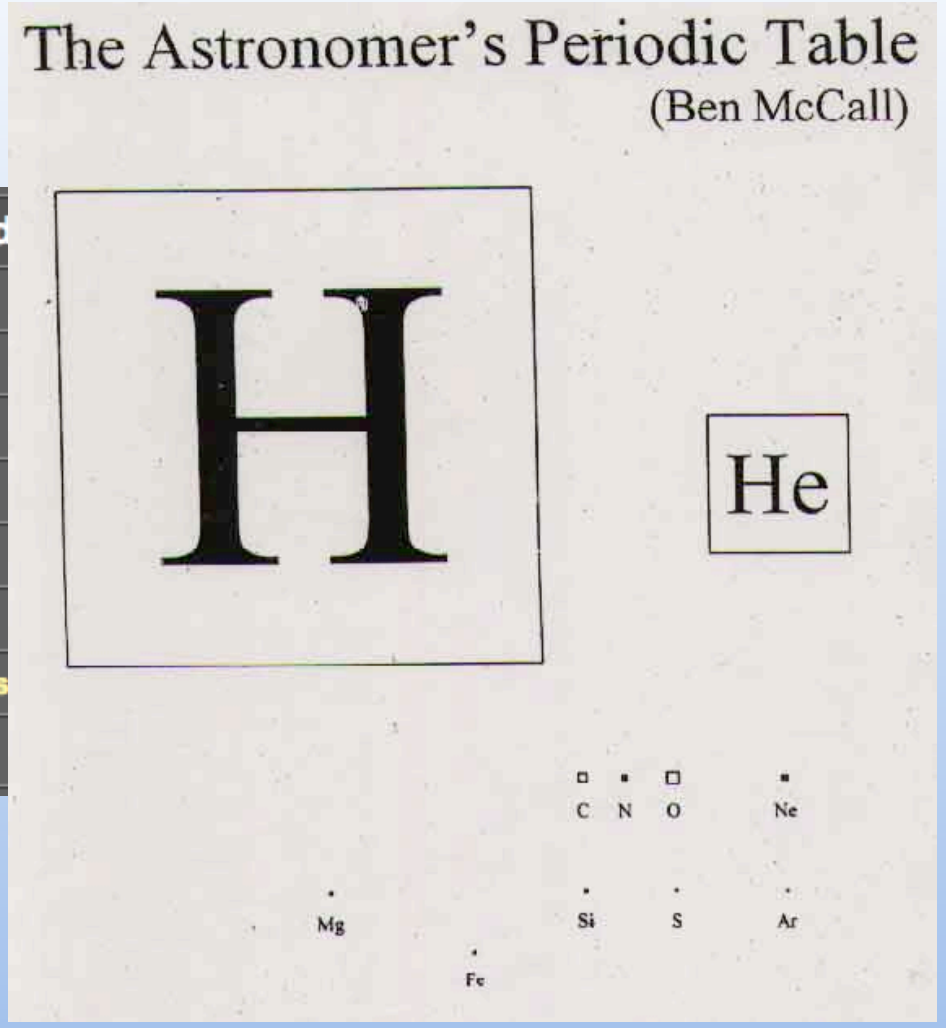
Number of atoms per 10,000,000 of hyd		
hydrogen	10,000,000	sulfur
helium	1,400,000	iron
oxygen	6,800	argon
carbon	3,000	aluminum
neon	2,800	sodium
nitrogen	910	calcium
magnesium	290	all other elements
silicon	250	



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Fact Sheet: Hydrogen

Hydrogen

- is the simplest, most abundant element in the universe;
- is the lightest known element;
- is a colourless, odourless gas;
- is non-toxic;
- burns readily with oxygen, releasing considerable energy as heat and producing only water as exhaust;
- produces no carbon dioxide or carbon monoxide emission when burnt in air, and therefore does not contribute to global warming as does the burning of fossil fuels;

What about in our part of the universe?

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First what is the most abundant element on the Earth's crust?

A. Hydrogen

B. Helium

C. Oxygen

D. Silicon

E. Iron

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TABLE 18.1 Distribution (Mass Percent) of the 18 Most Abundant Elements in the Earth's Crust, Oceans, and Atmosphere

Element	Mass Percent	Element	Mass Percent
Oxygen	49.2	Titanium	0.58
Silicon	25.7	Chlorine	0.19
Aluminum	7.50	Phosphorus	0.11
Iron	4.71	Manganese	0.09
Calcium	3.39	Carbon	0.08
Sodium	2.63	Sulfur	0.06
Potassium	2.40	Barium	0.04
Magnesium	1.93	Nitrogen	0.03
Hydrogen	0.87	Fluorine	0.03
		All others	0.49

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Monahans Sand Dune's State Park

Sand is SiO_2

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Elemental Makeup of you?

A. Hydrogen

B. Helium

C. Oxygen

D. Silicon

E. Iron

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TABLE 18.2 Abundance of Elements in the Human Body

Major Elements	Mass Percent	Trace Elements (in alphabetical order)
Oxygen	65.0	Arsenic
Carbon	18.0	Chromium
Hydrogen	10.0	Cobalt
Nitrogen	3.0	Copper
Calcium	1.4	Fluorine
Phosphorus	1.0	Iodine
Magnesium	0.50	Manganese
Potassium	0.34	Molybdenum
Sulfur	0.26	Nickel
Sodium	0.14	Selenium
Chlorine	0.14	Silicon
Iron	0.004	Vanadium
Zinc	0.003	

Note by atoms, Hydrogen is the most abundant

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Periodic Table

Grouped by "common chemistry"

1. Chemistry dominated by the number of valence electrons (this is the "group")

2. Compounds that are formed nearly always achieve nobel gas like structures (octet rule)

3. Periodic Trends (radius, ionization energy,...)

4. The 2nd row is very special. Overlapping 2p orbitals leads to pi bonding. Highly electronegative atoms lead to H-bonding

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Periodic Table
Grouped by "common chemistry"

5. Most elements for a stable compound with themselves making a nobel gas structure as with metallic bonding or network solids or small molecules (N_2, P_4,...)

6. Most everything makes a hydride from ionic hydrides like NaH to covalent H_2O to HCl

7. Most everything makes an oxide. Basic oxides on the left (MgO), acidic on the right (CO_2).

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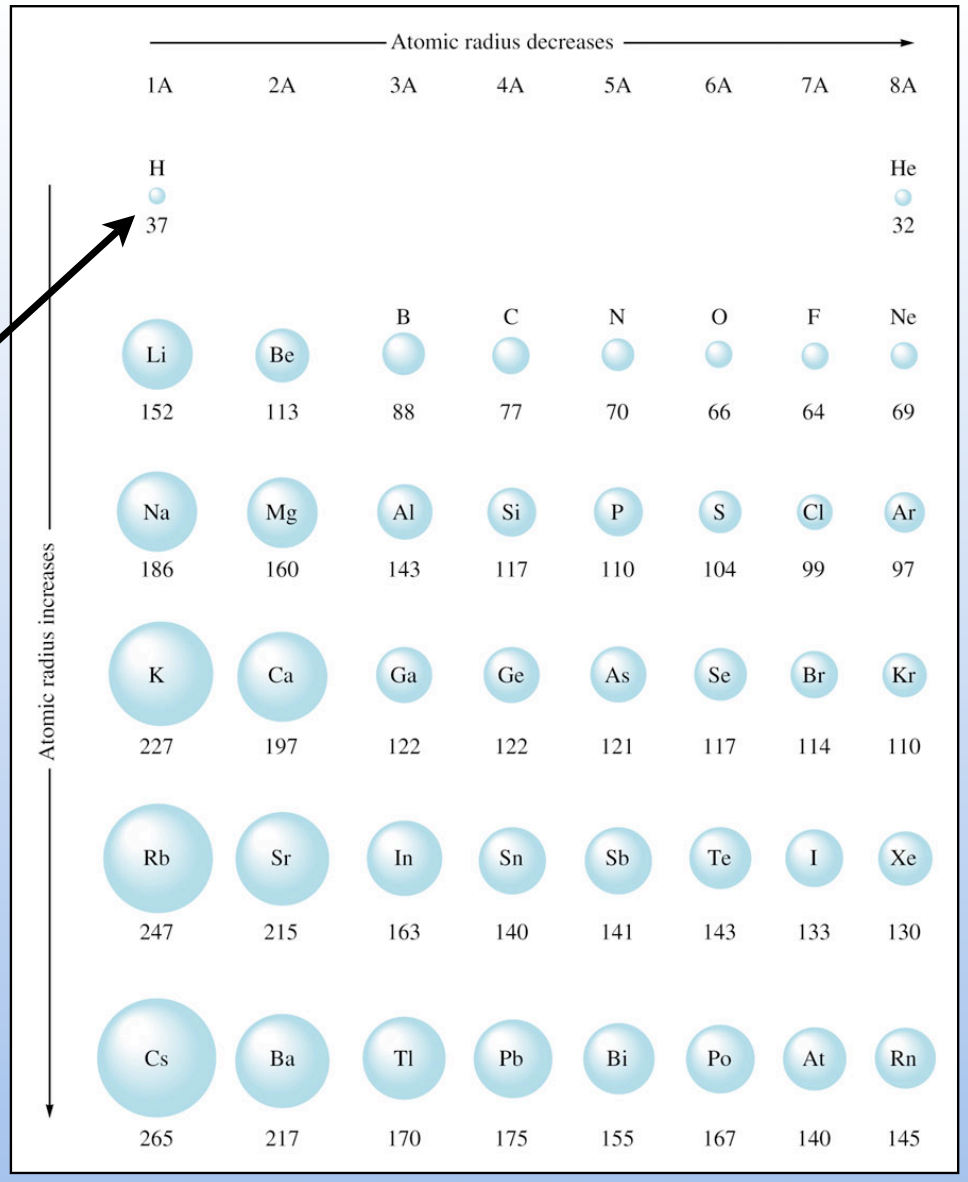
Hydrogen
In a group of its own

very small
only a single
1s electron

greater
electronegativity
than other group 1



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Hydrogen

electronegativity of 2.1
(nearly exactly the same as carbon)

might lose an electron (+1 oxidation state)
might gain an electron (-1 oxidation state)

$$2K(s) + H_2(g) \longrightarrow 2KH(s)$$

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$

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Reactant	Reaction with hydrogen
Group 1 metals (M)	$2\ M(s) + H_2(g) \longrightarrow 2\ MH(s)$
Group 2 metals (M, not Be or Mg)	$M(s) + H_2(g) \longrightarrow MH_2(s)$
some *d*-block metals (M)	$2\ M(s) + x\ H_2(g) \longrightarrow 2\ MH_x(s)$
oxygen	$O_2(g) + 2\ H_2(g) \longrightarrow 2\ H_2O(l)$
nitrogen	$N_2(g) + 3\ H_2(g) \longrightarrow 2\ NH_3(g)$
halogen (X_2)	$X_2(g,l,s) + H_2(g) \longrightarrow 2\ HX(g)$

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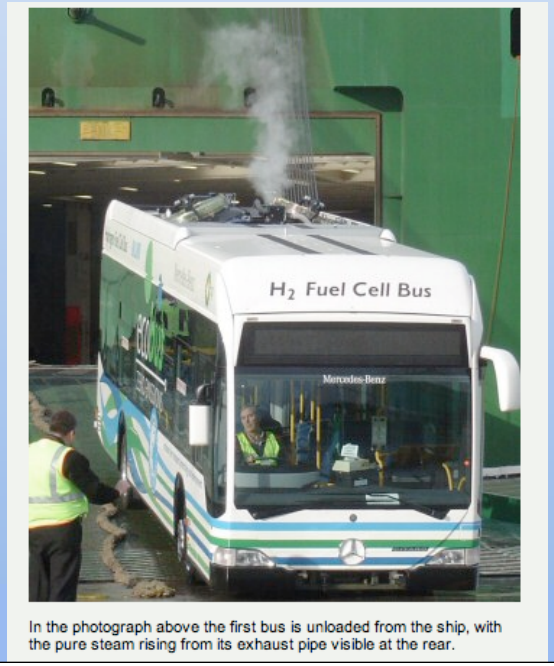
Who cares about hydgrogen

$$2H_2 + O_2 \longrightarrow 2H_2O$$

reaction = 2x(enthalpy of formation of water)
$-475\ kJ\ mol^{-1}$

Most energy per mass of any reaction



In the photograph above the first bus is unloaded from the ship, with the pure steam rising from its exhaust pipe visible at the rear.

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The problem is there is no H_2

Where to get it?

Steam reforming of methane (1000°C, Ni Catalyst)

$$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g)$$

Water gas shift (130°C)

$$CO(g) + H_2O(g) \longrightarrow CO_2(g) + H_2(g)$$

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Other fun with H_2

H^+ can oxidize metals

$$Zn + 2H^+ \longrightarrow Zn^{2+} + H_2$$

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Other fun with H_2

H_2 can reduce oxides

$$CuO + H_2 \longrightarrow Cu + H_2O$$

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TABLE 20.1 Standard Reduction Potentials in Water at 25°C

Standard Potential (V)	Reduction Half-Reaction
+2.87	$F_2(g) + 2e^- \longrightarrow 2F^-(aq)$
+1.51	$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$
+1.36	$Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$
+1.33	$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$
+1.23	$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O(l)$
+1.06	$Br_2(l) + 2e^- \longrightarrow 2Br^-(aq)$
+0.96	$NO_3^-(aq) + 4H^+(aq) + 3e^- \longrightarrow NO(g) + H_2O(l)$
+0.80	$Ag^+(aq) + e^- \longrightarrow Ag(s)$
+0.77	$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$
+0.68	$O_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2O_2(aq)$
+0.59	$MnO_4^-(aq) + 2H_2O(l) + 3e^- \longrightarrow MnO_2(s) + 4OH^-(aq)$
+0.54	$I_2(s) + 2e^- \longrightarrow 2I^-(aq)$
+0.40	$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$
+0.34	$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$
0	$2H^+(aq) + 2e^- \longrightarrow H_2(g)$
−0.28	$Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$
−0.44	$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$
−0.76	$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$
−0.83	$2H_2O(l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$
−1.66	$Al^{3+}(aq) + 3e^- \longrightarrow Al(s)$
−2.71	$Na^+(aq) + e^- \longrightarrow Na(s)$
−3.05	$Li^+(aq) + e^- \longrightarrow Li(s)$

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Group 1 metals
Alkali Metals

All have a nS^1 electronic configuration
Very low ionization energy
Behave like a metal (easily oxidized)
From +1 ion always
low boiling and melting points
react violently with water (and most anything else)
from basic hydride and oxides

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$$2Na + 2H_2O \longrightarrow 2Na^+ + 2OH^- + H_2(g)$$

Is this reaction exothermic?

1. Yes
2. No

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← Best Reducing Agents

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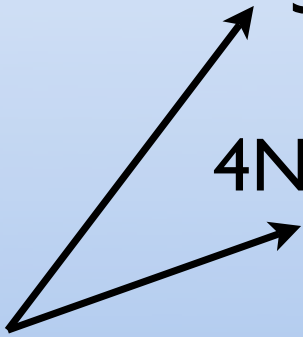
Group 1 elements will react with nearly anything

$$2Na(s) + Cl_2(g) \longrightarrow NaCl(s)$$

$$3Li(s) + N_2(g) \longrightarrow 2Li_3N(s)$$

$$4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$$



reactions with air

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Hydrides and oxides are basic

$$Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$$

Nucleophilic (wants nuclei) Electron rich

$$NaH(s) + H_2O(l) \qquad 2NaOH(aq) + H_2(g)$$

H in -1 oxidation state (can deprotonate nearly anything)

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Where are they?

Everywhere as ions

Na^+, K^+ are everywhere
(Li^+ because it has such a large charge density often makes insoluble compounds)
Rb, Cs, Fr very little in the universe

Na^+ and K^+ critical in biochemistry

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Group II metals
Alkali Earth Metals

All have a nS^2 electronic configuration
Very low ionization energy
Behave like a metal (easily oxidized)
From +2 ion always
react with water (and most anything else)

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Difference compared to group 1

+2 ions have a very high charge density
Often they make insoluble compounds

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Which is easier to oxidize?

A. Magnesium

B. Carbon

C. They are the same

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