

Chemistry Revision

Measures of length

- ▶ k (kilo) 10^3
- ▶ M (mega) 10^6
- ▶ G (Giga) 10^9
- ▶ T (Tera) 10^{12}

- ▶ m (milli) 10^{-3}
- ▶ μ (micro) 10^{-6}
- ▶ n (nano) 10^{-9}
- ▶ p (pico) 10^{-12}

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| ▶ T (Tera) | 10^{12} | ▶ p (pico) | 10^{-12} |
- ▶ 1 Ångström is equal to $0.1\text{nm} = 10^{-10}$

Basic Chemistry Revision

- ▶ What is a mole?



Basic Chemistry Revision

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- ▶ In chemistry terms a mole is the unit for amount of substance



Basic Chemistry Revision

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- ▶ In chemistry terms a mole is the unit for amount of substance
- ▶ What is molar mass?



Basic Chemistry Revision

- ▶ What is a mole?
- ▶ In chemistry terms a mole is the unit for amount of substance
- ▶ What is molar mass?
- ▶ Molar mass is the relative formula mass in g, M_r (units g/mol)



Elements are Materials too!

The Periodic Table puts elements in order of the structure of their atoms (how many protons they have and how many electrons they have in their outer shell) They are listed in the order of their atomic number, which is the number of protons in each atom.

Periodic Table of Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																	
1 H Hydrogen 1.00794	Atomic # Symbol Name Atomic Mass																2 He Helium 4.002602																	
C Solid Hg Liquid H Gas Rf Unknown Metals Alkaline earth metals Akalk metals Lanthanoids Actinoids Transition metals Poor metals Other nonmetals Noble gases																		2 Li Lithium 6.941	4 Be Beryllium 9.012182															10 Ne Neon 20.1797
11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050																	18 Ar Argon 39.948																
4 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.887	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.9216	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798																	
5 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29																	
6 Cs Cesium 132.9054519	56 Ba Barium 137.327	57-71		72 Hf Hafnium 178.49	73 Ta Tantalum 180.94738	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.222	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.976627	83 Bi Bismuth 208.980399	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222.0175)																
7 Fr Francium (223)	88 Ra Radium (226)	89-103		104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (292)	117 Uus Ununseptium (294)	118 Uuo Ununoctium (294)																
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.																																		
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57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.967																				
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03688	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)																				

Periodic Table of Elements

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3	11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050																	13 Al Aluminum 26.9815386	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.887	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.796						
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For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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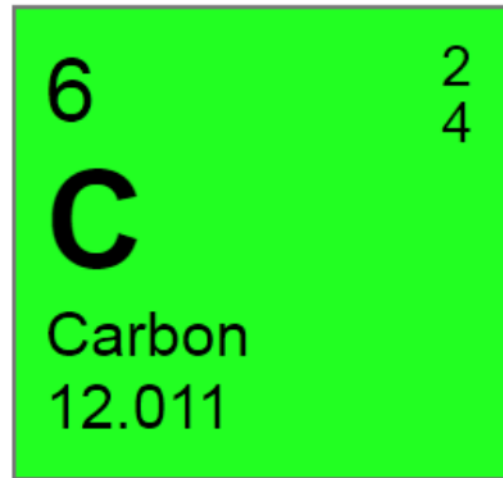
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57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90768	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
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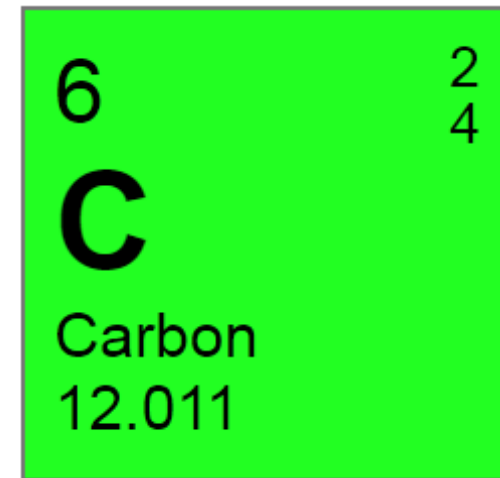
1 electron in its outer shell

Full shell

What do the numbers mean?

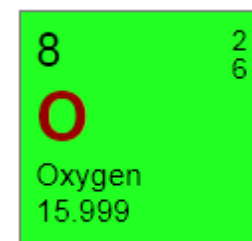
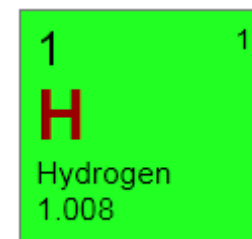


- ▶ Atomic number (No. protons=No. electrons) C=6
- ▶ No neutrons can vary giving different isotopes
- ▶ Electron shells 2,4
- ▶ Relative atomic mass (atomic weight) is an average of the atomic masses of all the different isotopes weighted by abundance C=12.011
- ▶ Mass number =No. protons + No. neutrons
- ▶ For C the No. neutrons =12 - 6 = 6



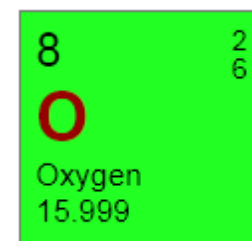
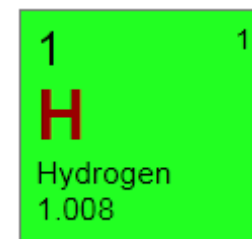
Example

- ▶ Atomic number (No. protons=No. electrons) $C=6$
- ▶ Relative atomic mass (atomic weight) is an average of the atomic masses of all the different isotopes weighted by abundance $C=12.011$
- ▶ To find Relative formula mass (M_r) add the relative atomic masses for all the atoms in its chemical formula
- ▶ What is the relative formula mass of water?



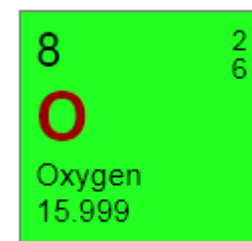
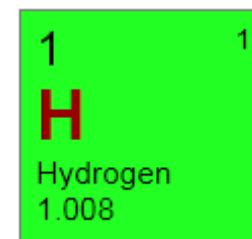
Example

- ▶ Atomic number (No. protons=No. electrons) $Z=6$
- ▶ Relative atomic mass (atomic weight) is an average of the atomic masses of all the different isotopes weighted by abundance $A_r=12.011$
- ▶ To find Relative formula mass (M_r) add the relative atomic masses for all the atoms in its chemical formula
- ▶ What is the relative formula mass of water?
- ▶ H_2O so $H + H + O$



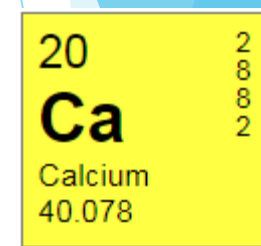
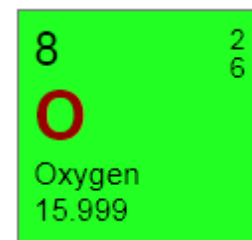
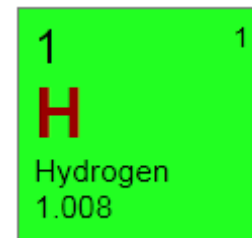
Example

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- ▶ What is the relative formula mass of water?
- ▶ H_2O so $H + H + O$
- ▶ $M_r = 1+1+16 = 18$



Example 2

- ▶ What is the relative formula mass of Ca(OH)_2 ?
- ▶ $\text{Ca} + \text{O} + \text{H} + \text{O} + \text{H}$
- ▶ $M_r = 40 + 16 + 1 + 16 + 1 = 74$



Mole

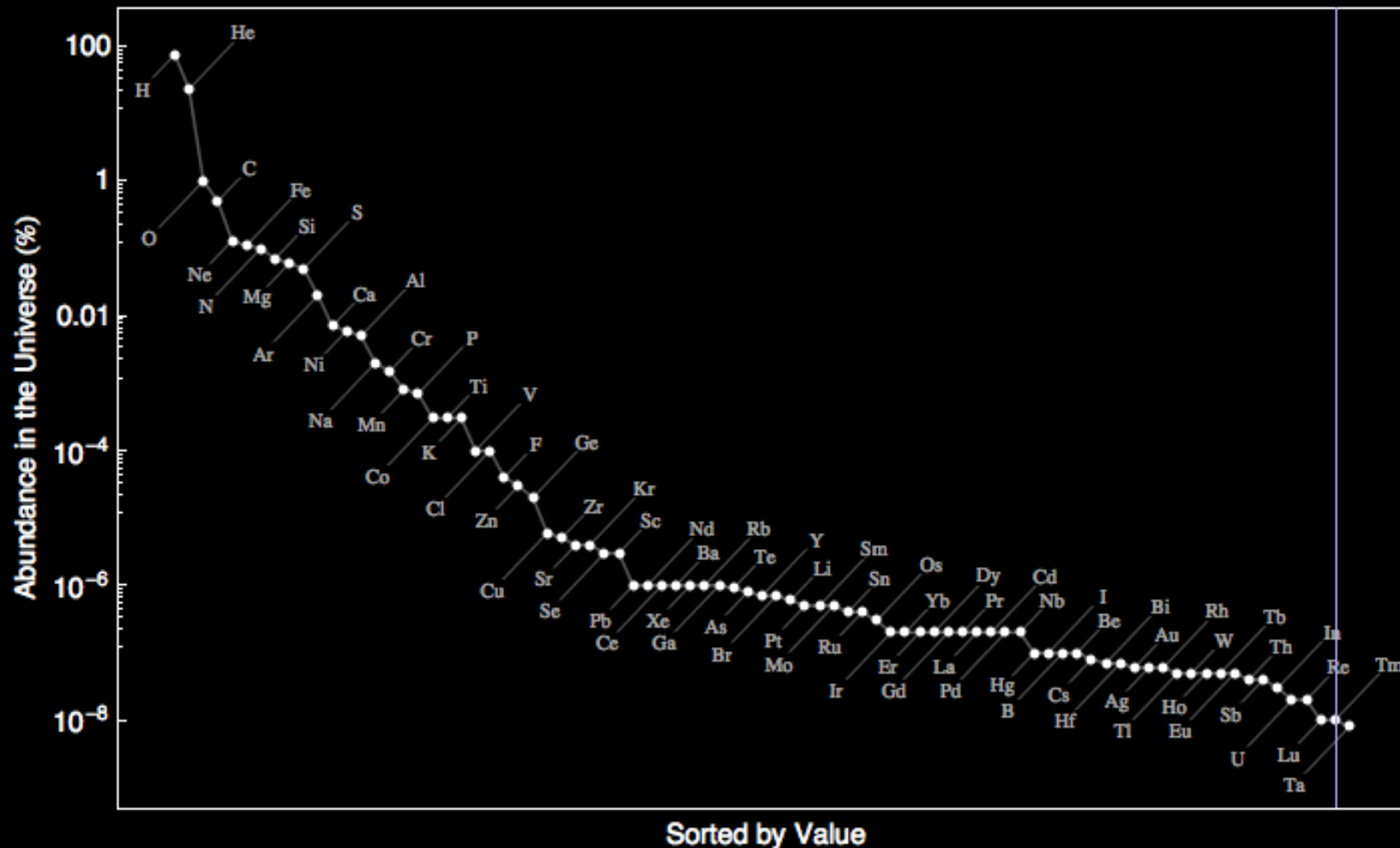
- ▶ One mole (mol) = $6 \times 10_{23}$ (Avagadro's number)
- ▶ This is equal to the number of carbon atoms in 12g of carbon
- ▶ Mr of water is 18
- ▶ Molar mass of water is 18g/mol
- ▶ Mr of calcium hydroxide is 74 so its molar mass is 74g/mol

Periodic Table Facts

- ▶ The rows of the periodic table are called periods
- ▶ An element's period number is the highest unexcited energy level for an electron of that element.
- ▶ Columns of elements form groups, elements in a group share common properties and have the same outer electron arrangement
- ▶ Most of the elements are metals
- ▶ Size of an atom is determined by the diameter of the outer shell so atoms don't always get larger as their atomic number increases, in fact element atoms decrease in size as you go from left to right
- ▶ As you go down, the melting point tends to decrease.
- ▶ As you go down or right the ionization energy increases. (energy to remove the most weakly bound electron).
- ▶ Francium is the rarest element on earth.
- ▶ The only letter not in the periodic table is the letter J.
- ▶ The country Argentina is named after the element silver (symbol Ag) which is argentum in Latin.
- ▶ Although there is helium on Earth, it was first discovered by observing the sun.

Table 1.1 Relative Abundance of Elements in the Universe

Element	Relative Abundance (Si = 1)
Hydrogen (H)	12,000
Helium (He)	2,800
Oxygen (O)	16
Nitrogen (N)	8
Carbon (C)	3
Iron (Fe)	2.6
Silicon (Si)	1
Magnesium (Mg)	0.89
Sulfur (S)	0.33
Nickel (Ni)	0.21
Aluminum (Al)	0.09
Calcium (Ca)	0.07
Sodium (Na)	0.045
Chlorine (Cl)	0.025



Up to date, curated data provided by *Mathematica*'s ElementData function from Wolfram Research, Inc.

Elements used in making mechanical parts

- ▶ Aluminium
- ▶ Iron -Used to make steel
- ▶ Copper

Elements with high temperature properties

- ▶ Tungsten
- ▶ Platinum
- ▶ Molybdenum
- ▶ Tantalum

Silicon

25% of the earth's crust is silicon

“Silicon is the seventh most abundant element in the universe and the second most abundant element on the planet after oxygen” - Royal Society of Chemistry

Silica - an oxide of silicon is the most common component of sand.

Silicon is a metalloid, neither metal nor non-metal. It looks metallic but unlike metal it gets better at conducting electricity with higher temperatures.

Silicon is a semiconductor

Uses - transistors, solar cells, computer chips (with trace elements of boron or phosphorous)

Silicone is a polymer of **silicon**, oxygen, carbon and hydrogen. Don't confuse the two.

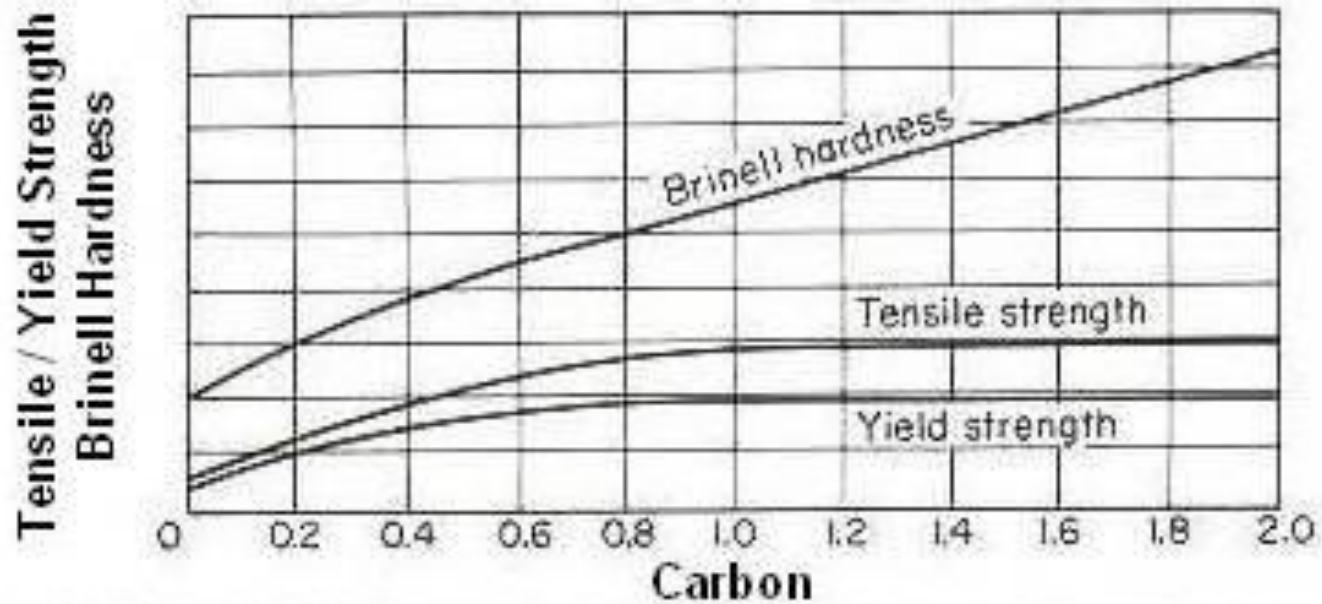
Silicon = cement, bricks, glass, computers, chips

Silicone = moulds, foam, coatings, cookware

Carbon

- ▶ Element with the highest melting point.
- ▶ Carbon is the main element in polymers together with Hydrogen
- ▶ Carbon is unique in that it is known to form up to 10 million different compounds. Carbon is important to the existence of life

Carbon



Effect of Carbon on Mechanical Properties of Steel

Metals

- ▶ What is a metal?
- ▶ Example of a metal?
- ▶ What do we know about metals?

Metals

1 H Hydrogen												2 He Helium																							
		Metals Metalloids Non-Metals																																	
		Transition Metals																																	
3 Li Lithium		4 Be Beryllium										5 B Boron		6 C Carbon		7 N Nitrogen		8 O Oxygen		9 F Fluorine		10 Ne Neon													
11 Na Sodium		12 Mg Magnesium										13 Al Aluminium		14 Si Silicon		15 P Phosphorus		16 S Sulfur		17 Cl Chlorine		18 Ar Argon													
19 K Potassium		20 Ca Calcium		21 Sc Scandium		22 Ti Titanium		23 V Vanadium		24 Cr Chromium		25 Mn Manganese		26 Fe Iron		27 Co Cobalt		28 Ni Nickel		29 Cu Copper		30 Zn Zinc		31 Ga Gallium		32 Ge Germanium		33 As Arsenic		34 Se Selenium		35 Br Bromine		36 Kr Krypton	
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Metal Properties Worksheet

Property	Metals	Non-metals
Appearance		
State at room temperature		
Density		
Strength		
Malleable or brittle		
Conduction of heat		
Conduction of electricity		
Magnetic material		
Sound when hit		

Metal Properties Worksheet Answer

Property	Metals	Non-metals
Appearance	Shiny	Dull
State at room temperature	Solid (except mercury, which is a liquid)	About half are solids, about half are gases, and one (bromine) is a liquid
Density	High (they feel heavy for their size)	Low (they feel light for their size)
Strength	Strong	Weak
Malleable or brittle	Malleable (they bend without breaking)	Brittle (they break or shatter when hammered)
Conduction of heat	Good	Poor (they are insulators)
Conduction of electricity	Good	Poor (they are insulators, apart from graphite)
Magnetic material	Only iron, cobalt and nickel	None
Sound when hit	They make a ringing sound (they are sonorous)	They make a dull sound

Metals-Properties

All metals are:

- ▶ Solid
- ▶ Shiny
- ▶ Ductile
- ▶ Malleable
- ▶ Good conductors
- ▶ Lose electrons easily

Most metals:

- ▶ Are solid at room temperature
- ▶ Are hard and strong
- ▶ Have a high density
- ▶ Are sonorous

- ▶ Three metals are magnetic

Metals-Properties

All metals are:

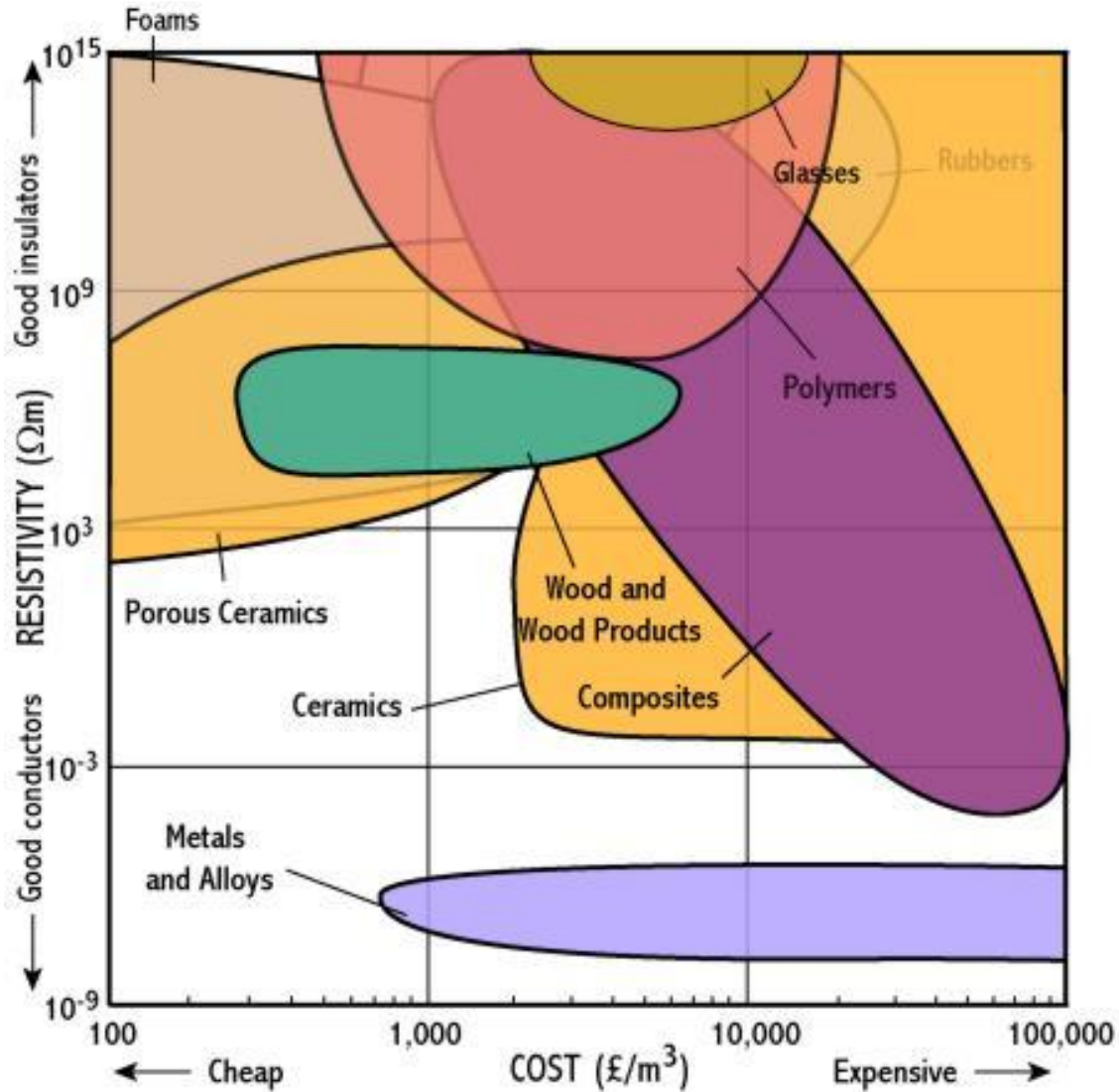
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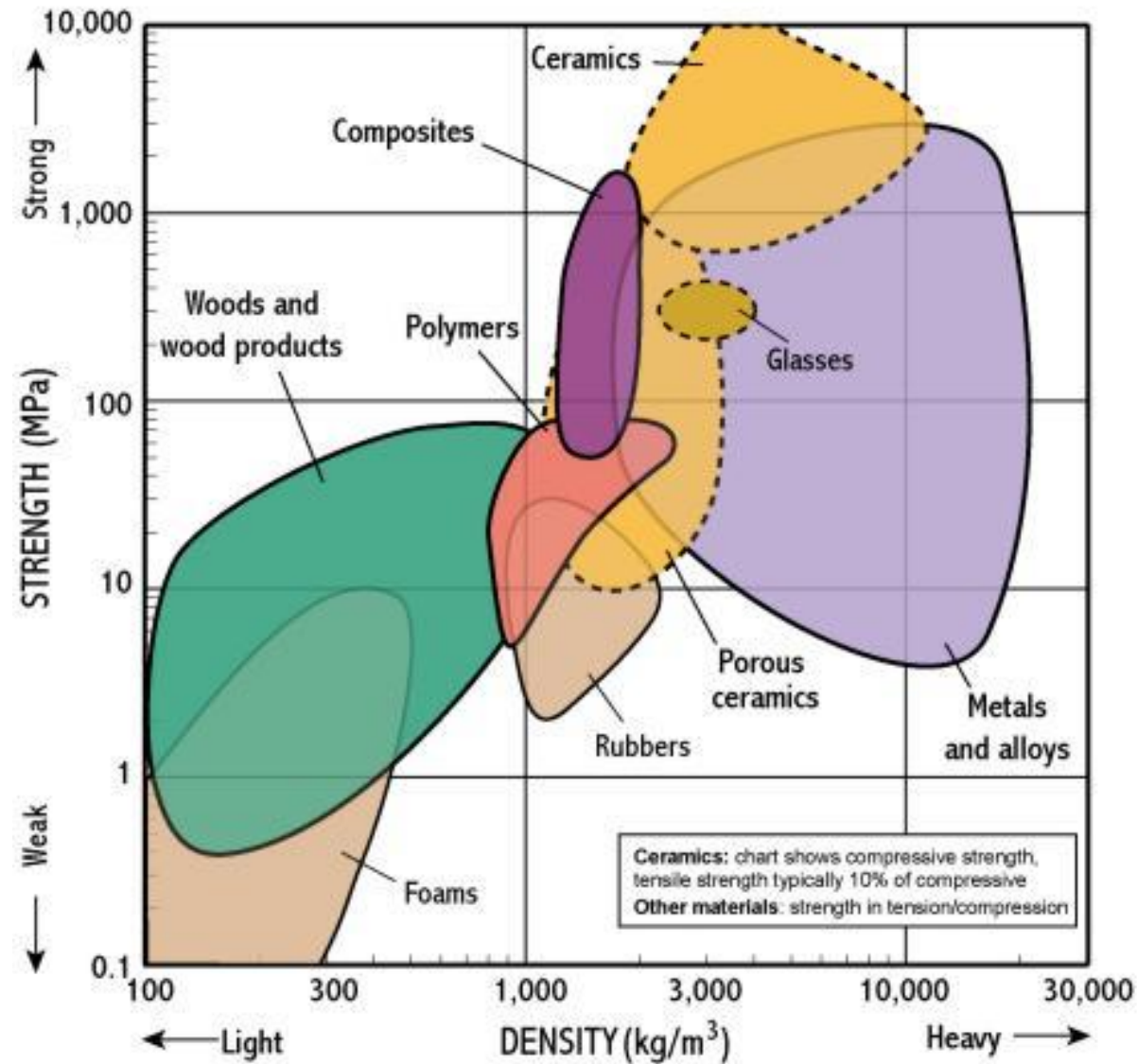
- ▶ Are solid at room temperature
- ▶ Are hard and strong
- ▶ Have a high density
- ▶ Are sonorous

- ▶ Three metals are magnetic
–Iron, Cobalt, Nickel

Electrical resistivity against cost



Strength against Density



Metals-properties

- ▶ Crystal Structure
- ▶ Large number free electrons
- ▶ Metallic bond
- ▶ Good electrical conductivity
- ▶ Opaque
- ▶ Uniform atoms
- ▶ High tensile strength
- ▶ Low shear strength
- ▶ Good ductility
- ▶ Plastic flow
- ▶ Impact strength
- ▶ Relatively high weight
- ▶ Moderate hardness
- ▶ Non porous
- ▶ High density

Metals-properties of ferrous metals

- ▶ Ferrous metals mild steel, carbon steel, stainless steel, cast iron, and wrought iron.
- ▶ used for their tensile strength and durability, especially mild steel which helps hold up the tallest skyscrapers and the longest bridges in the world.
- ▶ also find ferrous metals in housing construction, industrial containers, large-scale piping, automobiles, rails for railroad and transportation, most of tools and hardware you use around the house, and the knives you cook with at home.
- ▶ Due to the high amounts of carbon used when creating them, most ferrous metals and alloys are vulnerable to rust when exposed to the elements. While this isn't true of wrought iron, which is so iron pure that it resists oxidization, or stainless steel, which is protected thanks to its high chromium content, it's a good rule of thumb that if you see rust, it's a ferrous metal.
- ▶ Most ferrous metals also have magnetic properties, which makes them very useful in the creation of large motors and electrical appliances.
- ▶ Steady price - usually cheaper than non-ferrous metals.

Metals-properties of non-ferrous metals

- ▶ Non-ferrous metals aluminum, brass, copper, nickel, tin, lead, and zinc, as well as precious metals like gold and silver. While non-ferrous metals can provide strength, they are primarily used where their differences from ferrous metals can provide an advantage.
- ▶ much more malleable than ferrous metals.
- ▶ much lighter, making them well-suited for use where strength is needed, but weight is a factor, such as in the aircraft or canning industries.
- ▶ Higher resistance to rust and corrosion, which is why you'll find these materials in use for gutters, water pipes, roofing, and road signs.
- ▶ non-magnetic, which makes them perfect for use in small electronics and as electrical wiring.
- ▶ Varying price - usually more expensive than ferrous metals

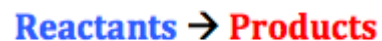
Balancing Chemical Equations

- ▶ Let's take a look at this scale. We can see that it is unbalanced, with the left side weighing more than the right side. In order for the two sides to be balanced, we need to put a little more mass on the right side until they are the same mass.

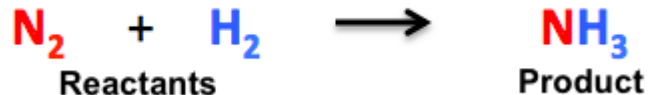
<https://study.com/academy/lesson/balanced-chemical-equation-definition-examples.html>



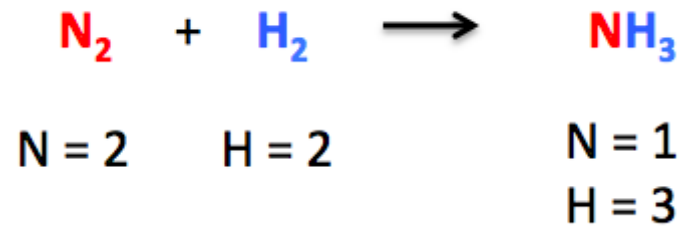
- ▶ Just like we want the scale to be balanced on both sides, a chemical equation should also be balanced on both sides. A chemical equation shows us the substances involved in a chemical reaction - the substances that react (reactants) and the substances that are produced (products). In general, a chemical equation looks like this:
- ▶ Chemical Equation: General Form



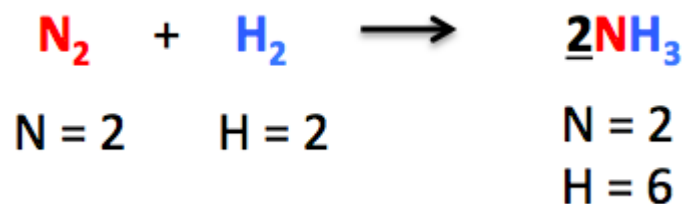
- ▶ According to the **law of conservation of mass**, when a chemical reaction occurs, the mass of the products should be equal to the mass of the reactants. Therefore, the amount of the atoms in each element does not change in the chemical reaction. As a result, the chemical equation that shows the chemical reaction needs to be balanced. A **balanced chemical equation** occurs when the number of the atoms involved in the reactants side is equal to the number of atoms in the products side.
- ▶ Let's take a look at an equation representing a chemical reaction:
- ▶



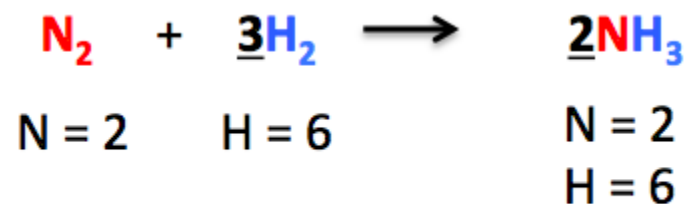
- ▶ In this chemical reaction, nitrogen (N₂) reacts with hydrogen (H₂) to produce ammonia (NH₃). The reactants are nitrogen and hydrogen, and the product is ammonia. If we look at this equation, we can see that the equation is not balanced.



- ▶ The equation is not balanced because in the reactants side, there are 2 nitrogen (N) atoms and 2 hydrogen (H) atoms. In the products side, there are 1 nitrogen (N) atoms and 3 hydrogen (H) atoms. The number of the atoms is not balanced on both sides.
- ▶ To balance the chemical equation above, we need to make use of coefficients. A coefficient is a number that we place in front of a chemical formula. In the chemical equation, to make the number of nitrogen (N) atoms equal on both sides, first, we place a coefficient of 2 in front of NH₃.



- Once we do that, the number of nitrogen (N) atoms on both sides is balanced. However, the number of hydrogen (H) atoms is not balanced on both sides. We need to make use of another coefficient in front of H₂. This time, we put a coefficient of 3 in front of H₂ to balance the chemical equation.



The equation above is now balanced. There are 2 nitrogen (N) atoms and 6 hydrogen (H) atoms on both the reactants and products side. Since there is no coefficient in front of N₂, that means the coefficient is equal to 1.

Steps to Balance an Equation

- ▶ Practice always makes perfect. In general, to balance an equation, here are the things we need to do:
- ▶ Count the atoms of each element in the reactants and the products.
- ▶ Use coefficients; place them in front of the compounds as needed.
- ▶ The steps are simple, but it is a process of trial and error. Let's take a look at a few more example equations and techniques that can be used to balance each one.

Example 1

- ▶ This is a reaction between methane (CH₄) and oxygen (O₂), producing carbon dioxide (CO₂) and water (H₂O).



$$\text{C} = 1$$

$$\text{H} = 4$$

$$\text{O} = 2$$

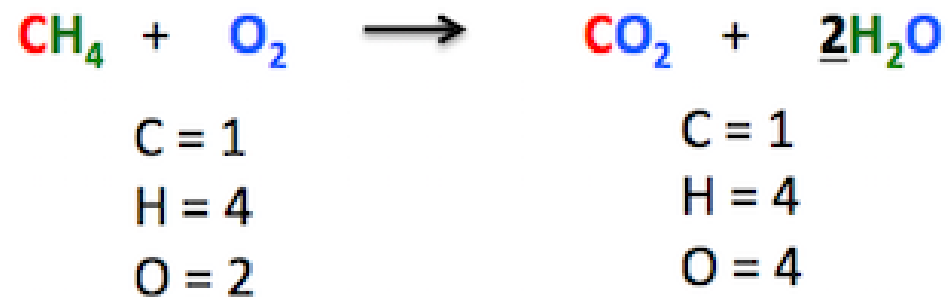
$$\text{C} = 1$$

$$\text{H} = 2$$

$$\text{O} = 3$$

The reaction shown is a combustion reaction: a compound reacts with oxygen and produces carbon dioxide and water. The technique is to balance the carbon (C) atoms first, then the hydrogen (H) atoms, and then the oxygen (O) atoms.

- In this case, the carbon (C) atoms are already balanced. So now we look at the hydrogen (H) atoms. There are 4 hydrogen (H) atoms on the reactants side and 2 hydrogen (H) atoms on the products side. To balance them, we put a coefficient of 2 in front of H₂O.



- ▶ The hydrogen (H) atoms are now balanced. Due to the coefficient 2 in front of H₂O, there are a total of 4 oxygen (O) atoms on the products side. To balance the oxygen atoms on both sides, we put a coefficient of 2 in front of O₂. The chemical equation is now balanced.



$$\text{C} = 1$$

$$\text{H} = 4$$

$$\text{O} = 4$$

$$\text{C} = 1$$

$$\text{H} = 4$$

$$\text{O} = 4$$

Example 2

This is a reaction between ferric oxide (Fe₂O₃) and carbon (C), producing Iron (Fe) and carbon dioxide (CO₂).



Fe = 2

O = 3

C = 1

Fe = 1

O = 2

C = 1

- ▶ This reaction is not balanced. First, we need to balance the oxygen atoms. We do this by making it so that there are 6 oxygen atoms on each side. To do this, we need to put a coefficient of 2 in front Fe₂O₃ and a coefficient of 3 in front of CO₂.



$$\text{Fe} = 4$$

$$\text{O} = 6$$

$$\text{C} = 1$$

$$\text{Fe} = 1$$

$$\text{O} = 6$$

$$\text{C} = 3$$

- ▶ Now that the oxygen atoms are balanced, we need to balance the iron (Fe) atoms first. To do this, we need to put a coefficient of 4 in front of Fe in the products side. Now that the Fe atoms are balanced, we can balance the carbon atoms. We do this by putting a coefficient of 3 in front of C on the reactants side. The chemical equation is now balanced.



$$\text{Fe} = 4$$

$$\text{O} = 6$$

$$\text{C} = 3$$

$$\text{Fe} = 4$$

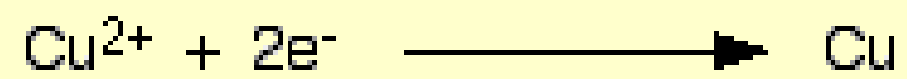
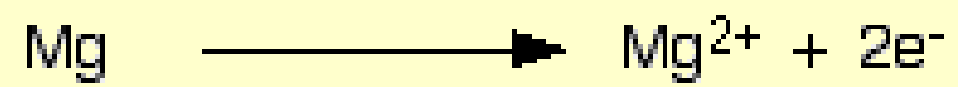
$$\text{O} = 6$$

$$\text{C} = 3$$

- ▶ https://www.google.com/search?q=balancing+equations&rlz=1C1GCEB_enGB835GB835&oq=balancing+equations&aqs=chrome.0.69i59j0l5.5944j0j4&sourceid=chrome&ie=UTF-8

Electron-half-equations

- ▶ What is an electron-half-equation?
- ▶ When magnesium reduces hot copper(II) oxide to copper, the ionic equation for the reaction is:
$$\text{Cu}^{2+} + \text{Mg} \longrightarrow \text{Cu} + \text{Mg}^{2+}$$
- ▶ You can split the ionic equation into two parts, and look at it from the point of view of the magnesium and of the copper(II) ions separately. This shows clearly that the magnesium has lost two electrons, and the copper(II) ions have gained them.

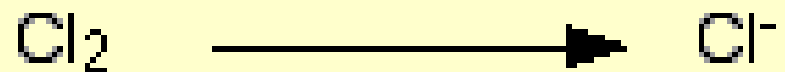


- ▶ These two equations are described as "electron-half-equations" or "half-equations" or "ionic-half-equations" or "half-reactions" - lots of variations all meaning exactly the same thing!
- ▶ Any redox reaction is made up of two half-reactions: in one of them electrons are being lost (an oxidation process) and in the other one those electrons are being gained (a reduction process).

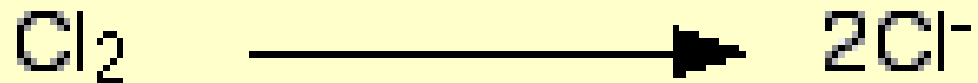
REDOX

- ▶ Working out electron-half-equations and using them to build ionic equations
- ▶ In the example above, we've got at the electron-half-equations by starting from the ionic equation and extracting the individual half-reactions from it. That's doing everything entirely the wrong way round!
- ▶ In reality, you almost always start from the electron-half-equations and use them to build the ionic equation.
- ▶ ***Example 1: The reaction between chlorine and iron(II) ions***
- ▶ Chlorine gas oxidises iron(II) ions to iron(III) ions. In the process, the chlorine is reduced to chloride ions.

- ▶ You start by writing down what you know for each of the half-reactions. In the chlorine case, you know that chlorine (as molecules) turns into chloride ions:



- ▶ The first thing to do is to balance the atoms that you have got as far as you possibly can:



- ▶ ALWAYS check that you have the existing atoms balanced before you do anything else. If you forget to do this, everything else that you do afterwards is a complete waste of time!
- ▶ Now you have to add things to the half-equation in order to make it balance completely.
- ▶ All you are allowed to add are:
 - ▶ electrons
 - ▶ water
 - ▶ hydrogen ions (unless the reaction is being done under alkaline conditions - in which case, you can add hydroxide ions instead)