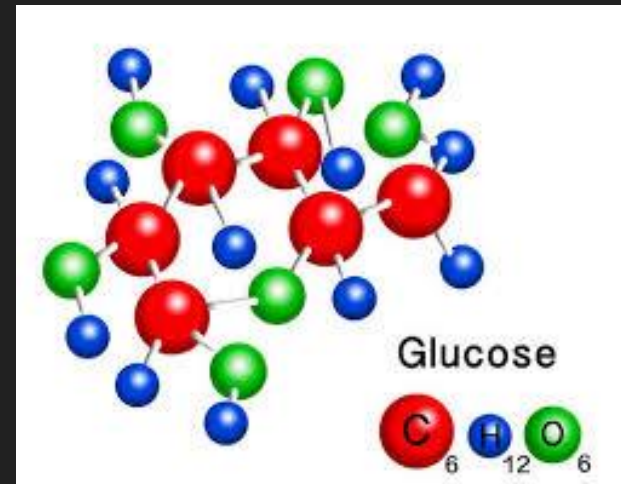


# Elements are the Building Blocks of Matter

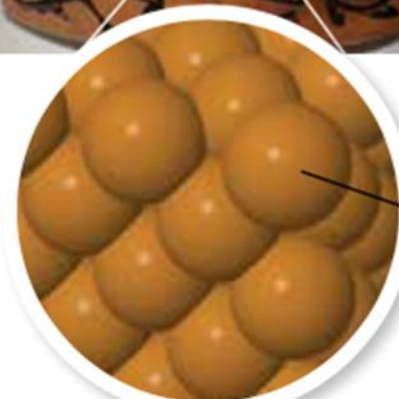


# Elements

## Elements:

- The basic building blocks of matter
- Made up of one type of atom (cannot be broken down further)
- About 90 elements occur naturally (carbon, silver, oxygen)
- Some elements are synthesized in labs
- Have varying properties

Figure 2.6: Copper is made up of one type of atom, and cannot be broken down further.



copper  
atom

Copper (Cu) is shiny and malleable. This means it can be hammered into thin sheets such as the copper leaf used on this car hood by B.C. artist Michael Nicoll Yahgulanaas. This piece is part of a series called *Coppers from the Hood*.



# Element Names and Symbols

Each element has a






- Chemical name

- Based on Latin words, countries, names of famous scientists

- Chemical symbol

- One or two letters (first letter is capitalized)

**Table 2.2** Symbols and Names of Selected Elements

Name of Element	Element Symbol	Origin of Symbol or Name
carbon	C	<i>Carbo</i> = Latin for coal and charcoal. Carbon in the form of soot and charcoal has been known to humans for many thousands of years. 
copper	Cu	<i>Cuprum</i> = Latin for cyprium, meaning metal of Cyprus, an island country near Greece. The ancient Romans obtained much of their copper from mines on Cyprus. 
francium	Fr	<i>France</i> = Marguerite Perey discovered this element in France in 1939. 
lead	Pb	<i>Plumbum</i> = Latin for lead. This element's name has the same root as "plumbing" because the ancient Romans used lead in their plumbing systems. Unfortunately, lead is toxic and their pipes poisoned their water. 
sulfur	S	<i>Sulphurium</i> = Latin for sulfur. In Canada, the United States, and Great Britain, there has been some switching back and forth of the name of this element from sulfur to sulphur. The spelling "sulfur" is now considered standard. 

# Examples:

- Carbon: C
- Oxygen: O
- Aluminum: Al
- Gold: Au
- Polonium: Po





# Elements can be organized by their properties

1860s: Dmitri Mendeleev

- Russian teacher and chemist
- Looked at different ways to organize the elements
- Wrote properties of elements on cards so that he could rearrange them and compare properties (“chemical solitaire”)
- Properties included atomic mass (average mass of an atom of an element), density, and melting point

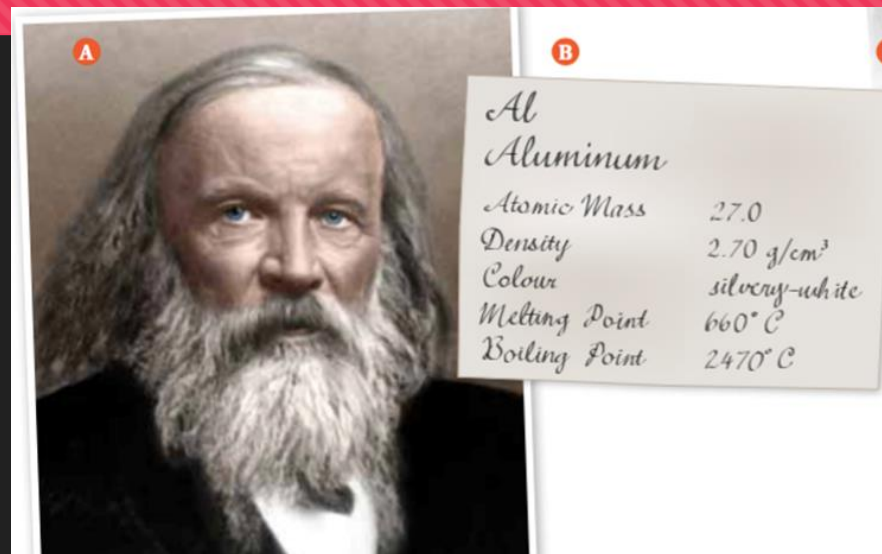
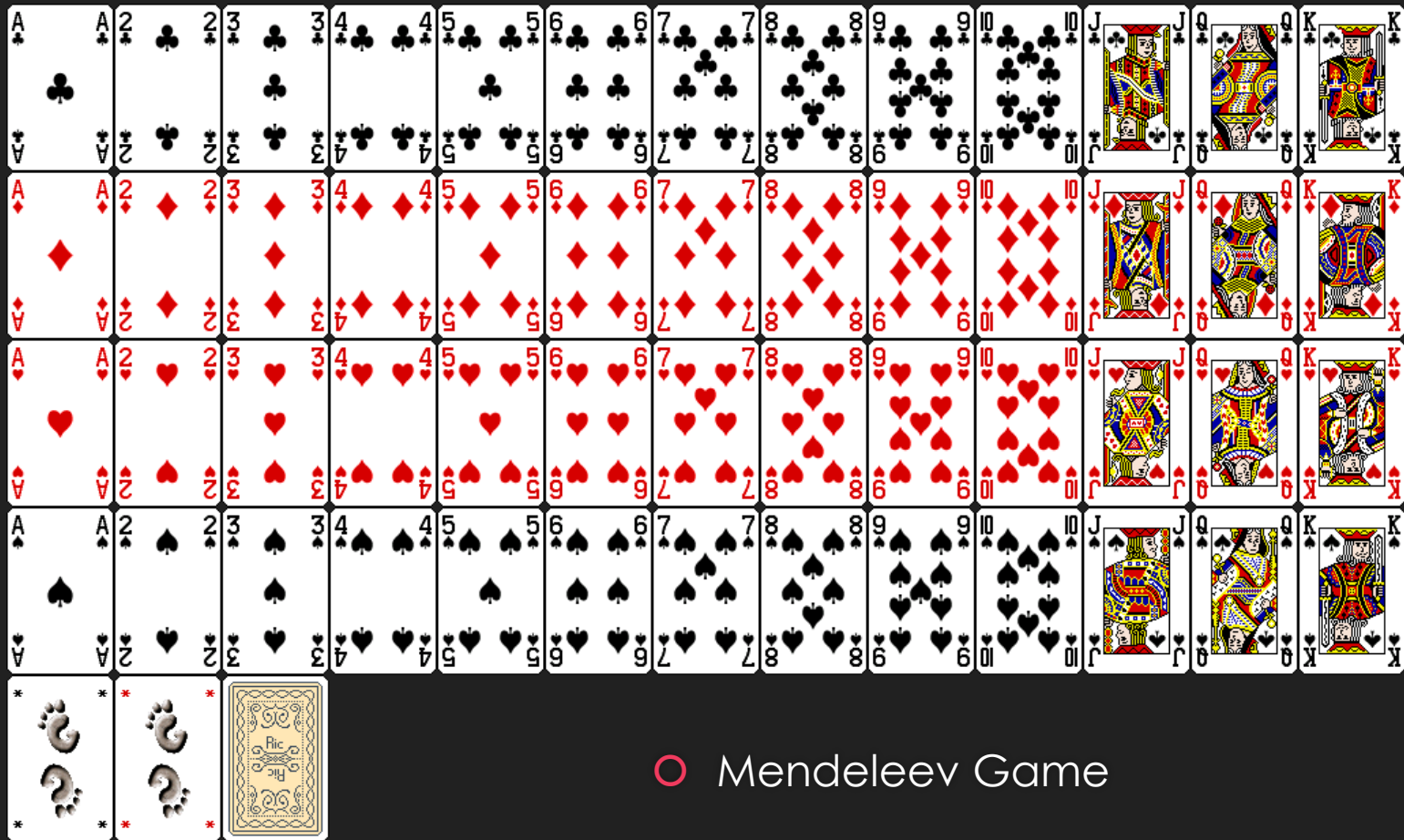


Figure 2.7: A) Dmitri Mendeleev B) Mendeleev wrote the properties of elements on cards like this one so he could rearrange them and compare properties.

# Dmitri Mendeleev



# The Predictive Power of Mendeleev's Table

- Mendeleev's periodic table:
  - Ordered the elements by increasing atomic mass
  - Grouped elements into “families” based on similar properties (density, melting point)
  - Left gaps in his periodic table to predict the existence of elements not yet found yet
  - These missing elements would have properties similar to other elements in the same families

I	II	III	IV	V	VI	VII	VIII		
H 1.01									
Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0			
Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5			
K 39.1	Ca 40.1		Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	Fe 55.9	Co 58.9	Ni 58.7
Cu 63.5	Zn 65.4			As 74.9	Se 79.0	Br 79.9			
Rb 85.5	Sr 87.6	Y 88.9	Zr 91.2	Nb 92.9	Mo 95.9		Ru 101	Rh 103	Pd 106
Ag 108	Cd 112	In 115	Sn 119	Sb 122	Te 128	I 127			
Ce 133	Ba 137	La 139		Ta 181	W 184		Os 194	Ir 192	Pt 195
Au 197	Hg 201	Tl 204	Pb 207	Bi 209					
			Th 232		U 238				

# The Predictive Power of Mendeleev's Table

Mendeleev's Table

<i>Al</i>	<i>Si</i>
<i>?</i>	<i>?</i>
<i>In</i>	<i>Sn</i>

Properties of Gallium



Properties of Germanium



Property	Mendeleev's Prediction	Actual Data
Atomic mass	68	69.72
Density (g/cm <sup>3</sup> )	6.0	5.904
Melting point (°C)	low	29.78

Property	Mendeleev's Prediction	Actual Data
Atomic mass	72	72.61
Density (g/cm <sup>3</sup> )	5.5	5.32
Melting point (°C)	high	947

Figure 2.8: The gaps in Mendeleev's table predicted the existence of yet-to-be-discovered elements. Mendeleev used the properties of other elements in the same families to predict the properties of these elements.



## Discussion Questions

1. Why did Mendeleev leave gaps in his periodic table?
2. How was Mendeleev able to predict the properties of gallium and germanium?

# Modern Periodic Table

Mendeleev's periodic table was ordered by increasing atomic mass:

- Did not work perfectly – some elements were out of order so they would fit in a family that had similar properties

Modern periodic table is ordered by increasing **atomic number**:

- Henry Moseley: scientist that determined an element's atomic number (the number of protons in an atom)
- When elements are arranged according to increasing atomic number, the elements fit perfectly and do not require re-ordering

The modern periodic table consists of

- **Groups** (1-18): A vertical column of elements; also called a *family*
  - Elements of common properties
- **Periods** (1-7): A horizontal row of elements
  - Mass increasing from left to right

Figure 2.9

Periodic Table of the Elements

Group

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.0																	2 He Helium 4.0
2 Li Lithium 6.9	3 Be Beryllium 9.0																10 Ne Neon 20.2
3 Na Sodium 22.99	4 Mg Magnesium 24.31											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	
4 K Potassium 39.1	5 Ca Calcium 40.1	6 Sc Scandium 45.0	7 Ti Titanium 47.9	8 V Vanadium 50.9	9 Cr Chromium 52.0	10 Mn Manganese 54.9	11 Fe Iron 55.8	12 Co Cobalt 58.9	13 Ni Nickel 58.7	14 Cu Copper 63.5	15 Zn Zinc 65.4	16 Ga Gallium 69.7	17 Ge Germanium 72.6	18 As Arsenic 74.9	19 Se Selenium 79.0	20 Br Bromine 79.9	36 Kr Krypton 83.8
5 Rb Rubidium 85.5	6 Sr Strontium 87.6	7 Y Yttrium 88.9	8 Zr Zirconium 91.2	9 Nb Niobium 92.9	10 Mo Molybdenum 95.9	11 Tc Technetium (98)	12 Ru Ruthenium 101.1	13 Rh Rhodium 102.9	14 Pd Palladium 106.4	15 Ag Silver 107.9	16 Cd Cadmium 112.4	17 In Indium 114.8	18 Sn Tin 118.7	19 Sb Antimony 121.8	20 Te Tellurium 127.6	21 I Iodine 126.9	54 Xe Xenon 131.3
6 Cs Cesium 132.9	7 Ba Barium 137.3	8 La Lanthanum 138.9	9 Hf Hafnium 178.5	10 Ta Tantalum 180.9	11 W Tungsten 183.8	12 Re Rhenium 186.2	13 Os Osmium 190.2	14 Ir Iridium 192.2	15 Pt Platinum 195.1	16 Au Gold 197.0	17 Hg Mercury 200.6	18 Tl Thallium 204.4	19 Pb Lead 207.2	20 Bi Bismuth 209.0	21 Po Polonium (209)	22 At Astatine (210)	86 Rn Radon (222)
7 Fr Francium (223)	8 Ra Radium (226)	9 Ac Actinium (227)	10 Rf Rutherfordium (261)	11 Db Dubnium (268)	12 Sg Seaborgium (269)	13 Bh Bohrium (270)	14 Hs Hassium (269)	15 Mt Meitnerium (278)	16 Ds Darmstadtium (281)	17 Rg Roentgenium (280)	18 Cn Copernicium (285)	19 Nh Nihonium (286)	20 Fl Flerovium (289)	21 Mc Moscovium (289)	22 Lv Livermorium (293)	23 Ts Tennessine (294)	118 Og Oganesson (294)
8 Ce Cerium 140.1	9 Pr Praseodymium 140.9	10 Nd Neodymium 144.2	11 Pm Promethium (145)	12 Sm Samarium 150.4	13 Eu Europium 152.0	14 Gd Gadolinium 157.3	15 Tb Terbium 158.9	16 Dy Dysprosium 162.5	17 Ho Holmium 164.9	18 Er Erbium 167.3	19 Tm Thulium 168.9	20 Yb Ytterbium 173.0	21 Lu Lutetium 175.0				
90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	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)				

Legend:

- metal (blue)
- semi-metal (green)
- non-metal (yellow)
- natural (O)
- synthetic (Db)

Example element box (Titanium):

Atomic Number → 22  
Symbol → Ti  
Name → Titanium  
Atomic Mass → 47.9  
Ion charge(s) → 4+, 3+

Based on mass of C-12 at 12.00.

Any value in parentheses is the mass of the most stable or best known isotope for elements that do not occur naturally.



Atomic Number	→	8	2-	← Ion charge
Chemical Symbol	→	<b>O</b>		
Chemical Name	→	Oxygen		
Atomic Mass	→	16.0		

Figure 2.10: A typical box from the periodic table tells you the element's name, symbol, atomic number, and atomic mass. The symbol's font tells you the element's state.



# Discussion Questions

1. What was Moseley's contribution to the periodic table and what problem did it resolve?
2. Give the symbol and atomic number for each of the following elements:
  - a) manganese
  - b) magnesium
  - c) arsenic
  - d) astatine

# Elements are classified as metals, non-metals, or semi-metals.

Three broad categories of elements shown on the periodic table

- Metals (blue)
  - Non-metals (yellow)
  - Semi-metals (metalloids) (green)
- 
- Elements of Groups 1, 2, and 13 to 18 are called *main-group elements* or *representative elements*
  - Elements in Groups 3 to 12 are called *transition elements*

# Periodic Table of the Elements

Periodic Table of the Elements

1																	18	
1	1+ <b>H</b> Hydrogen 1.0																	2 0 <b>He</b> Helium 4.0
2	3 1+ <b>Li</b> Lithium 6.9	4 2+ <b>Be</b> Beryllium 9.0																
3	11 1+ <b>Na</b> Sodium 23.0	12 2+ <b>Mg</b> Magnesium 24.3																
4	19 1+ <b>K</b> Potassium 39.1	20 2+ <b>Ca</b> Calcium 40.1	21 3+ <b>Sc</b> Scandium 45.0	22 4+ <b>Ti</b> Titanium 47.9	23 5+ <b>V</b> Vanadium 50.9	24 3+ <b>Cr</b> Chromium 52.0	25 2+ <b>Mn</b> Manganese 54.9	26 3+ <b>Fe</b> Iron 55.8	27 2+ <b>Co</b> Cobalt 58.9	28 2+ <b>Ni</b> Nickel 58.7	29 2+ <b>Cu</b> Copper 63.5	30 2+ <b>Zn</b> Zinc 65.4	31 3+ <b>Ga</b> Gallium 69.7	32 4+ <b>Ge</b> Germanium 72.6	33 3- <b>As</b> Arsenic 74.9	34 2- <b>Se</b> Selenium 79.0	35 1- <b>Br</b> Bromine 79.9	36 0 <b>Kr</b> Krypton 83.8
5	37 1+ <b>Rb</b> Rubidium 85.5	38 2+ <b>Sr</b> Strontium 87.6	39 3+ <b>Y</b> Yttrium 88.9	40 4+ <b>Zr</b> Zirconium 91.2	41 3+ <b>Nb</b> Niobium 92.9	42 2+ <b>Mo</b> Molybdenum 95.9	43 7+ <b>Tc</b> Technetium (98)	44 3+ <b>Ru</b> Ruthenium 101.1	45 3+ <b>Rh</b> Rhodium 102.9	46 2+ <b>Pd</b> Palladium 106.4	47 1+ <b>Ag</b> Silver 107.9	48 2+ <b>Cd</b> Cadmium 112.4	49 3+ <b>In</b> Indium 114.8	50 4+ <b>Sn</b> Tin 118.7	51 3+ <b>Sb</b> Antimony 121.8	52 2- <b>Te</b> Tellurium 127.6	53 1- <b>I</b> Iodine 126.9	54 0 <b>Xe</b> Xenon 131.3
6	55 1+ <b>Cs</b> Cesium 132.9	56 2+ <b>Ba</b> Barium 137.3	57 3+ <b>La</b> Lanthanum 138.9	72 4+ <b>Hf</b> Hafnium 178.5	73 5+ <b>Ta</b> Tantalum 180.9	74 6+ <b>W</b> Tungsten 183.8	75 4+ <b>Re</b> Rhenium 186.2	76 3+ <b>Os</b> Osmium 190.2	77 3+ <b>Ir</b> Iridium 192.2	78 4+ <b>Pt</b> Platinum 195.1	79 3+ <b>Au</b> Gold 197.0	80 2+ <b>Hg</b> Mercury 200.6	81 1+ <b>Tl</b> Thallium 204.4	82 2+ <b>Pb</b> Lead 207.2	83 3+ <b>Bi</b> Bismuth 209.0	84 2+ <b>Po</b> Polonium (209)	85 1- <b>At</b> Astatine (210)	86 0 <b>Rn</b> Radon (222)
7	87 1+ <b>Fr</b> Francium (223)	88 2+ <b>Ra</b> Radium (226)	89 3+ <b>Ac</b> Actinium (227)	104 <b>Rf</b> Rutherfordium (265)	105 <b>Db</b> Dubnium (268)	106 <b>Sg</b> Seaborgium (269)	107 <b>Bh</b> Bohrium (270)	108 <b>Hs</b> Hassium (269)	109 <b>Mt</b> Meitnerium (278)	110 <b>Ds</b> Darmstadtium (281)	111 <b>Rg</b> Roentgenium (280)	112 <b>Cn</b> Copernicium (285)	113 <b>Nh</b> Nihonium (286)	114 <b>Fl</b> Flerovium (289)	115 <b>Mc</b> Moscovium (289)	116 <b>Lv</b> Livermorium (293)	117 <b>Ts</b> Tennessine (294)	118 <b>Og</b> Oganesson (294)

metal

semi-metal

non-metal

O natural

Db synthetic

Atomic Number  
Symbol  
Name  
Atomic Mass

22  
Ti  
Titanium  
47.9

4+  
3+  
Ion charge(s)



metal



semi-metal



non-metal



natural



synthetic

Atomic Number	22	4+
Symbol	Ti	3+
Name	Titanium	
Atomic Mass	47.9	

Based on mass of C-12 at 12.00.

Any value in parentheses is the mass of the most stable or best known isotope for elements that do not occur naturally.

58 3+ <b>Ce</b> Cerium 140.1	59 3+ <b>Pr</b> Praseodymium 140.9	60 3+ <b>Nd</b> Neodymium 144.2	61 3+ <b>Pm</b> Promethium (145)	62 3+ <b>Sm</b> Samarium 150.4	63 3+ <b>Eu</b> Europium 152.0	64 3+ <b>Gd</b> Gadolinium 157.3	65 3+ <b>Tb</b> Terbium 158.9	66 3+ <b>Dy</b> Dysprosium 162.5	67 3+ <b>Ho</b> Holmium 164.9	68 3+ <b>Er</b> Erbium 167.3	69 3+ <b>Tm</b> Thulium 168.9	70 3+ <b>Yb</b> Ytterbium 173.0	71 3+ <b>Lu</b> Lutetium 175.0
90 4+ <b>Th</b> Thorium 232.0	91 5+ <b>Pa</b> Protactinium 231.0	92 6+ <b>U</b> Uranium 238.0	93 5+ <b>Np</b> Neptunium (237)	94 4+ <b>Pu</b> Plutonium (244)	95 3+ <b>Am</b> Americium (243)	96 3+ <b>Cm</b> Curium (247)	97 3+ <b>Bk</b> Berkelium (247)	98 3+ <b>Cf</b> Californium (251)	99 3+ <b>Es</b> Einsteinium (252)	100 3+ <b>Fm</b> Fermium (257)	101 2+ <b>Md</b> Mendelevium (258)	102 2+ <b>No</b> Nobelium (259)	103 3+ <b>Lr</b> Lawrencium (262)

# Metals

- Shiny and hard (typically)
- Malleable and ductile (can be made into sheets and drawn out into wires)
- Conducts electricity and heat
- Typically solid at room temperature
- Found to the left of the zigzag line on the periodic table





# Alkali Metals

Alkali metals:

- Found in Group 1 (all elements, except hydrogen)
- Shiny and soft
- Highly reactive with water and oxygen (often stored in a non-reactive liquid such as oil)

1																		2	
1 H																		2 He	
2																			
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	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr												
37 Rb	38 Sr	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe												
55 Cs	56 Ba	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn												
87 Fr	88 Ra																		
alkali metals		alkaline-earth metals																	





# Metals: Alkaline-earth Metals

Alkaline-earth metals:

- Found in Group 2
- Shiny and soft (but not as soft as alkali metals)
- Highly reactive (but not as reactive as alkali metals)



1																		2	
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	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr												
37 Rb	38 Sr	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe												
55 Cs	56 Ba	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn												
87 Fr	88 Ra																		
alkali metals		alkaline-earth metals																	

Figure 2.12: Magnesium (left) burns easily in air when ignited.

# Non Metals

- Not shiny, malleable, or ductile
- Poor conductor of electricity and heat
- Found to the right of the zigzag line on the periodic table
- Generally gases or brittle, dull solids



Metal

VS



Non-metal

# Non-metals: Hydrogen

Hydrogen:

- Usually on the left side of the periodic table
- Lightest element
- Colourless, odourless, tasteless
- Highly flammable
- Makes up over 90% of atoms in the universe
- On Earth: Most hydrogen is found combined with oxygen as water

1 H								18 2 He
							17 9 F	10 Ne
3 Li	4 Be	5 B	6 C	7 N	8 O		16 S	18 Ar
11 Na	12 Mg	13 Al	14 Si	15 P			34 Se	36 Kr
19 K	20 Ca	31 Ga	32 Ge	33 As			52 Te	54 Xe
37 Rb	38 Sr	49 In	50 Sn	51 Sb			84 Po	86 Rn
55 Cs	56 Ba	81 Tl	82 Pb	83 Bi			85 At	
87 Fr	88 Ra							

hydrogen

halogens

noble gases

Figure 2.13

# Non-metals: Halogens

Halogens:

- Found in Group 17
- Highly reactive (therefore usually found in nature as part of compounds)

1 H								18 2 He	
								17	
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	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr		
37 Rb	38 Sr	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe		
55 Cs	56 Ba	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn		
87 Fr	88 Ra								

hydrogen

halogens

noble gases

Figure 2.13

# Non-metals: Noble Gases

Noble gases:

- Found in Group 18
- Odourless, colourless gases
- Least reactive of all of the elements
  - Helium and neon never form compounds
  - Other noble gases form compounds with great difficulty

18									
1 H								2 He	
17									
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	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr		
37 Rb	38 Sr	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe		
55 Cs	56 Ba	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn		
87 Fr	88 Ra								

hydrogen

halogens

noble gases

Figure 2.13



# Semi-metals

- Also known as *metalloids*
- Found in the green boxes in a staircase shape
- Have physical and chemical properties of both metals and non-metals
  - Shiny (like metals)
  - Brittle and not ductile (like non-metals)
  - Poor conductors of heat and electricity (like non-metals)

1		2																17						18	
1																								2	
H																								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	31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr										
37	Rb	38	Sr	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe										
55	Cs	56	Ba	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn										
87	Fr	88	Ra																						

Figure 2.14

# Semi-metals: Silicon

Silicon:

- Second-most abundant element in Earth's crust (after oxygen)
- Used in many electronic devices (computers, smartphones)
- Used to make silicone (material used in cookware, contact lenses, prosthetics)



## Discussion Questions

1. Make a table to summarize the characteristic properties of metals, non-metals, and semi-metals.
2. What makes hydrogen an unusual element?
3. What characteristics define semi-metals?

	State at Room Temperature	Appearance	Conductivity	Malleability and Ductility
Metals	<ul style="list-style-type: none"> <li>• solid except for mercury (a liquid)</li> </ul>	<ul style="list-style-type: none"> <li>• shiny lustre</li> </ul>	<ul style="list-style-type: none"> <li>• good conductors of heat and electricity</li> </ul>	<ul style="list-style-type: none"> <li>• malleable</li> <li>• ductile</li> </ul>
Non-metals	<ul style="list-style-type: none"> <li>• some gases</li> <li>• some solids</li> <li>• only bromine is a liquid</li> </ul>	<ul style="list-style-type: none"> <li>• not very shiny</li> </ul>	<ul style="list-style-type: none"> <li>• poor conductors of heat and electricity</li> </ul>	<ul style="list-style-type: none"> <li>• brittle</li> <li>• not ductile</li> </ul>
Metalloids	<ul style="list-style-type: none"> <li>• solids</li> </ul>	<ul style="list-style-type: none"> <li>• can be shiny or dull</li> </ul>	<ul style="list-style-type: none"> <li>• may conduct electricity</li> <li>• poor conductors of heat</li> </ul>	<ul style="list-style-type: none"> <li>• brittle</li> <li>• not ductile</li> </ul>