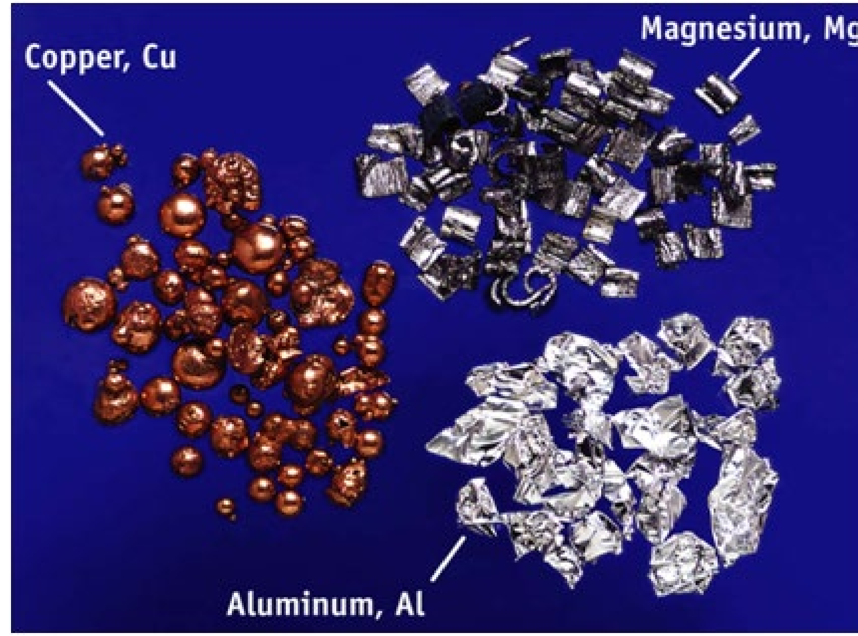
METALS



CHEMISTRY 1000

NONMETALS

Topic #2: The Chemical Alphabet

Fall 2020

Dr. Susan Findlay

Forms of Carbon

METALLOIDS

The Periodic Table: A Chemical Index

- In 1869, **Dmitri Mendeleev** (1834-1907) noticed that certain elements exhibited similar behaviour – most notably, the ratios with which they formed molecules with hydrogen and with oxygen. By arranging the elements in order of increasing mass and such that similar elements formed columns, he developed the first periodic table:

TABELLE II

REIHEN	GRUPPE I. — R^2O	GRUPPE II. — RO	GRUPPE III. — R^2O^3	GRUPPE IV. RH^4 RO^2	GRUPPE V. RH^3 R^2O^5	GRUPPE VI. RH^2 RO^3	GRUPPE VII. RH R^2O^7	GRUPPE VIII. — RO^4
1	H = 1							
2	Li = 7	Be = 9,4	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27,3	Si = 28	P = 31	S = 32	Cl = 35,5	
4	K = 39	Ca = 40	— = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56, Co = 59, Ni = 59, Cu = 63.
5	(Cu = 63)	Zn = 65	— = 68	— = 72	As = 75	Se = 78	Br = 80	
6	Rb = 85	Sr = 87	?Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru = 104, Rh = 104, Pd = 106, Ag = 108.
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 122	Te = 125	J = 127	
8	Cs = 133	Ba = 137	?Di = 138	?Ce = 140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er = 178	?La = 180	Ta = 182	W = 184	—	Os = 195, Ir = 197, Pt = 198, Au = 199.
11	(Au = 199)	Hg = 200	Tl = 204	Pb = 207	Bi = 208	—	—	
12	—	—	—	Th = 231	—	U = 240	—	— — — —

The Periodic Table: A Chemical Index

- Mendeleev's periodic table was incomplete – all of the ________ _______ were missing, but it was remarkably accurate in other respects. If there appeared to be a 'missing' element, he left a blank space, assuming that it would be discovered at a later date. He was proven correct with the discoveries of _________ (69.7 u) in 1875 and ____________________ (72.6 u) in 1886.

- In 1913, H.G.J. Moseley (1887-1915) noted that the periodic table would be more descriptive if the elements were listed in order of increasing ______________ rather than increasing mass. This led to the modern periodic table and **law of periodicity**:

The Periodic Table: A Chemical Index

Periodic Table with Element Names
(using the 1-18 group nomenclature)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hydrogen 1.0079 **H** 1																	Helium 4.0026 **He** 2
Lithium 6.941 **Li** 3	Beryllium 9.0122 **Be** 4											Boron 10.811 **B** 5	Carbon 12.011 **C** 6	Nitrogen 14.0067 **N** 7	Oxygen 15.9994 **O** 8	Fluorine 18.9984 **F** 9	Neon 20.1797 **Ne** 10
Sodium 22.9898 **Na** 11	Magnesium 24.3050 **Mg** 12											Aluminum 26.9815 **Al** 13	Silicon 28.0855 **Si** 14	Phosphorus 30.9738 **P** 15	Sulfur 32.066 **S** 16	Chlorine 35.4527 **Cl** 17	Argon 39.948 **Ar** 18
Potassium 39.0983 **K** 19	Calcium 40.078 **Ca** 20	Scandium 44.9559 **Sc** 21	Titanium 47.88 **Ti** 22	Vanadium 50.9415 **V** 23	Chromium 51.9961 **Cr** 24	Manganese 54.9380 **Mn** 25	Iron 55.847 **Fe** 26	Cobalt 58.9332 **Co** 27	Nickel 58.693 **Ni** 28	Copper 63.546 **Cu** 29	Zinc 65.39 **Zn** 30	Gallium 69.723 **Ga** 31	Germanium 72.61 **Ge** 32	Arsenic 74.9216 **As** 33	Selenium 78.96 **Se** 34	Bromine 79.904 **Br** 35	Krypton 83.80 **Kr** 36
Rubidium 85.4678 **Rb** 37	Strontium 87.62 **Sr** 38	Yttrium 88.9059 **Y** 39	Zirconium 91.224 **Zr** 40	Niobium 92.9064 **Nb** 41	Molybdenum 95.94 **Mo** 42	Technetium (98) **Tc** 43	Ruthenium 101.07 **Ru** 44	Rhodium 102.906 **Rh** 45	Palladium 106.42 **Pd** 46	Silver 107.868 **Ag** 47	Cadmium 112.411 **Cd** 48	Indium 114.82 **In** 49	Tin 118.710 **Sn** 50	Antimony 121.757 **Sb** 51	Tellurium 127.60 **Te** 52	Iodine 126.905 **I** 53	Xenon 131.29 **Xe** 54
Cesium 132.905 **Cs** 55	Barium 137.327 **Ba** 56	**La-Lu**	Hafnium 178.49 **Hf** 72	Tantalum 180.948 **Ta** 73	Tungsten 183.85 **W** 74	Rhenium 186.207 **Re** 75	Osmium 190.2 **Os** 76	Iridium 192.22 **Ir** 77	Platinum 195.08 **Pt** 78	Gold 196.967 **Au** 79	Mercury 200.59 **Hg** 80	Thallium 204.383 **Tl** 81	Lead 207.19 **Pb** 82	Bismuth 208.980 **Bi** 83	Polonium (210) **Po** 84	Astatine (210) **At** 85	Radon (222) **Rn** 86
Francium (223) **Fr** 87	Radium 226.025 **Ra** 88	**Ac-Lr**	Rutherfordium (265) **Rf** 104	Dubnium (268) **Db** 105	Seaborgium (271) **Sg** 106	Bohrium (270) **Bh** 107	Hassium (277) **Hs** 108	Meitnerium (276) **Mt** 109	Darmstadtium (281) **Ds** 110	Roentgenium (280) **Rg** 111	Copernicium (285) **Cn** 112	Nihonium (284) **Nh** 113	Flerovium (289) **Fl** 114	Moscovium (288) **Mc** 115	Livermorium (293) **Lv** 116	Tennessine (294) **Ts** 117	Oganesson (294) **Og** 118

Lanthanum 138.906 **La** 57	Cerium 140.115 **Ce** 58	Praseodymium 140.908 **Pr** 59	Neodymium 144.24 **Nd** 60	Promethium (145) **Pm** 61	Samarium 150.36 **Sm** 62	Europium 151.965 **Eu** 63	Gadolinium 157.25 **Gd** 64	Terbium 158.925 **Tb** 65	Dysprosium 162.50 **Dy** 66	Holmium 164.930 **Ho** 67	Erbium 167.26 **Er** 68	Thulium 168.934 **Tm** 69	Ytterbium 173.04 **Yb** 70	Lutetium 174.967 **Lu** 71
Actinium 227.028 **Ac** 89	Thorium 232.038 **Th** 90	Protactinium 231.036 **Pa** 91	Uranium 238.029 **U** 92	Neptunium 237.048 **Np** 93	Plutonium (240) **Pu** 94	Americium (243) **Am** 95	Curium (247) **Cm** 96	Berkelium (247) **Bk** 97	Californium (251) **Cf** 98	Einsteinium (252) **Es** 99	Fermium (257) **Fm** 100	Mendelevium (258) **Md** 101	Nobelium (259) **No** 102	Lawrencium (262 **Lr** 103

Metals are in yellow boxes. Nonmetals are in blue boxes. Metalloids are in green boxes.

Elements in white boxes have been made in such small quantities that their bulk properties have not been measured.

The Periodic Table: A Chemical Index

- Terminology used to describe regions of the periodic table:
  - Periods
  - Groups
  - s-block (“alkali metals” and “alkaline earth metals”)
  - p-block (group 13, group 14, “pnictogens”, “chalcogens”, “halogens” and “noble gases”)
  - d-block (“transition metals”)
  - f-block (“lanthanides” and “actinides”)
  - Metals (conductors)
  - Nonmetals (insulators)
  - Metalloids (intrinsic semiconductors)

You are required to memorize the names, symbols and atomic numbers for the first 36 elements.
i.e. hydrogen (H) to krypton (Kr)
Some symbols may be omitted from the periodic table on future tests.
You are NOT required to memorize atomic masses.

What is a Metal?

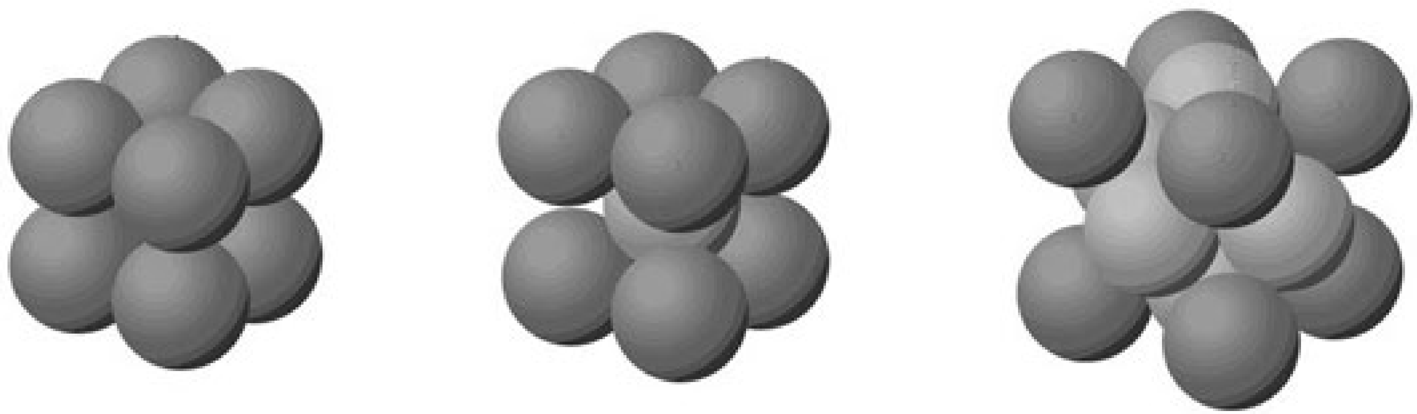
- Most of the elements in the periodic table are metals. How can we recognize if an element is a metal?
  - It's opaque and its smooth surfaces reflect light ("metallic luster").
  - It's **malleable** (can be hammered into sheets without breaking).
  - It's **ductile** (can be stretched into wires without breaking).
  - It has a high **boiling point**. (The melting points of metals vary widely – though most have high melting points too.)
  - It conducts heat and electricity.

- These properties arise because of the structure of metals. The simplest metals can be considered to behave as an organized arrangement of 'cations' surrounded by a 'sea of electrons':

What is a Metal?

- Metals usually form **crystal lattices** in which the atoms are closely packed. These lattices are held together by electrostatic attractions between the cations and the electrons.

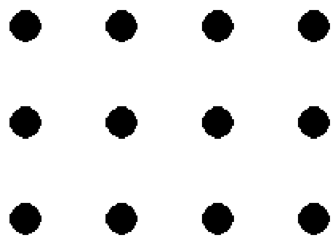
- So, at the atomic level, metals look similar to some of the pictures shown below:

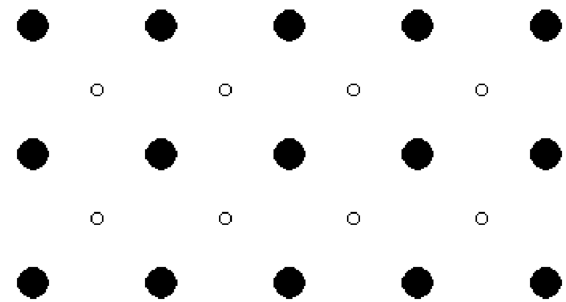


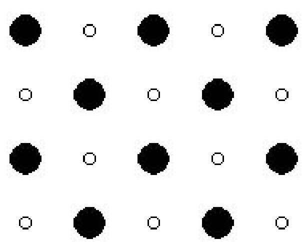
- These lattices are made up of repeating units called **unit cells**. All of the unit cells in a lattice are *identical* and have the *same symmetry as the overall lattice*. There can be no "gaps" between unit cells and all cells must have the same orientation.

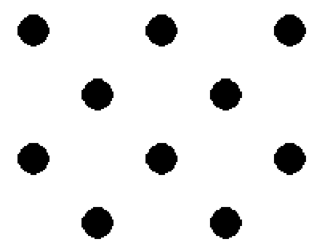
Metal Lattices

- Find the smallest "unit cell" in each of the following pictures:









- The smallest unit cell in a lattice is called the primitive unit cell.
- Note that these are two-dimensional pictures while metals are three-dimensional!

Metal Lattices

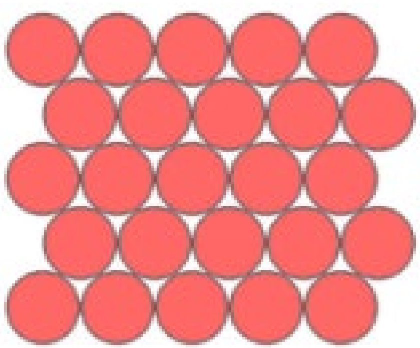
- How do these lattices arise? Consider what would happen if you poured marbles into the bottom of a box. How would they naturally arrange themselves? Why?

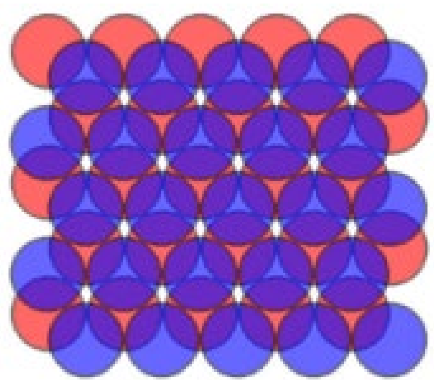
OR

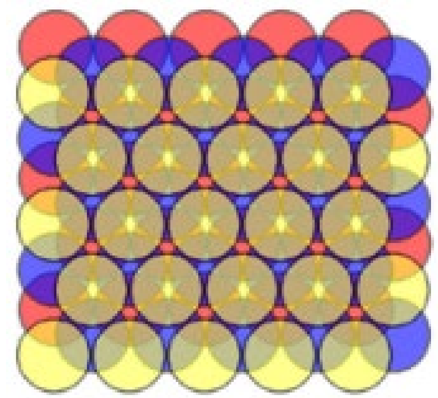
If you were to add a second layer of marbles, where would they go?

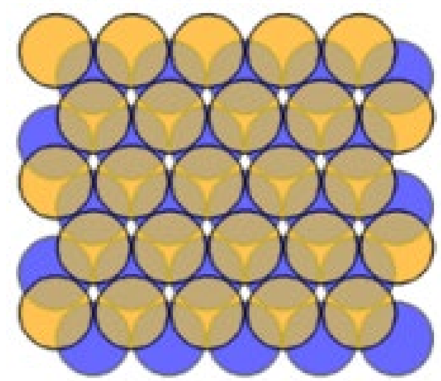
Metal Lattices

- The marbles on the previous page adopted a "closest packing" arrangement that is observed in the structures of many metals. There are two kinds of "closest packing" lattices: **cubic closest packed (ccp)** and **hexagonal closest packed (hcp)**.
- The difference between these two lattices arises when the third row of atoms is added:



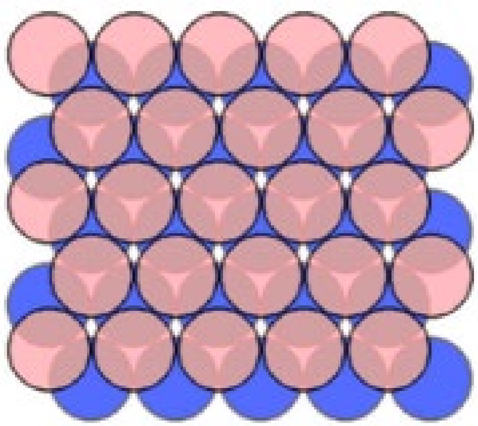






Metal Lattices

- Where's the hexagon in hexagonal closest packing (hcp)?
  - Rotate the image from the previous page upward so that we can see the lattice in three-dimensions:



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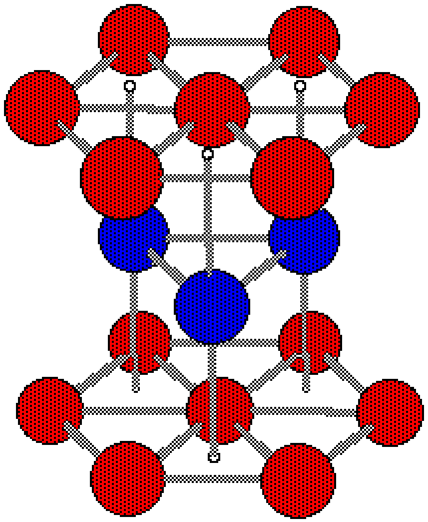
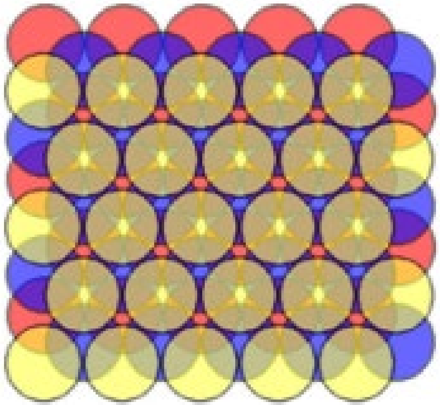


  - Note that the layer sequence is red-blue-red-blue (more generally referred to as ABAB)

- Can you find a unit cell smaller than the hexagon shown on the right? Outline a primitive (i.e. smallest) unit cell on each picture.

Metal Lattices

- Where's the cube in cubic closest packing (ccp)?
  - Rotate the image from the previous page upward so that we can see the lattice in three-dimensions:



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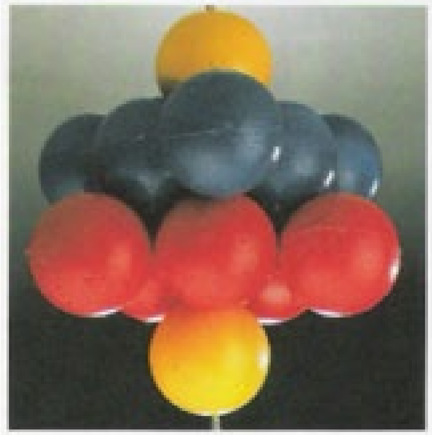

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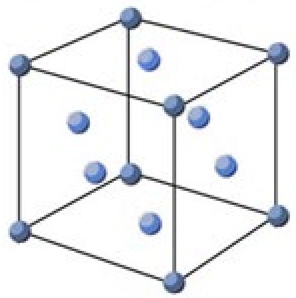
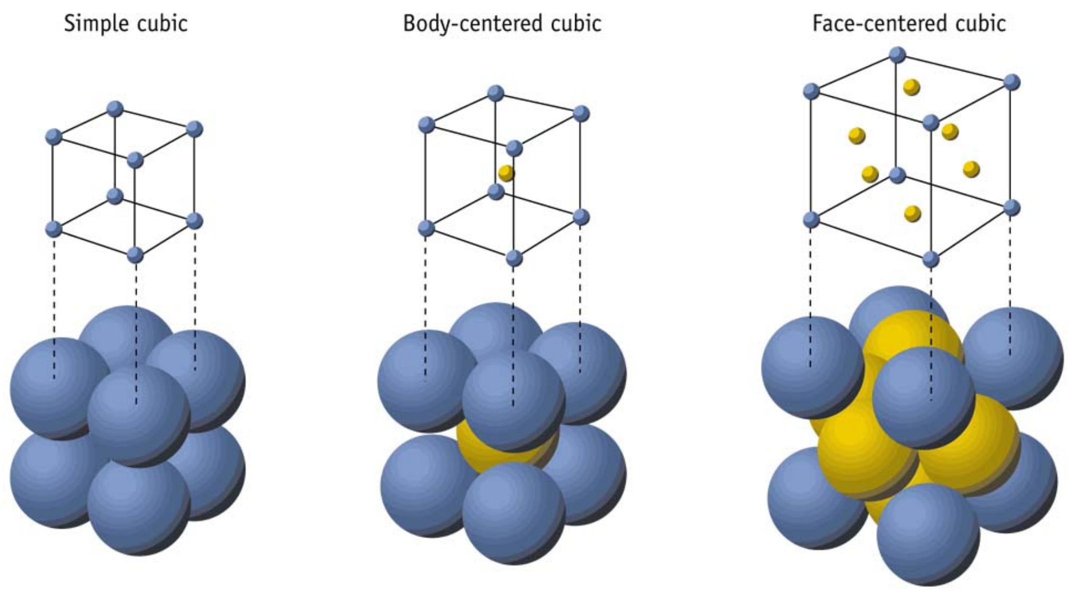
  - Note that the layer sequence is red-blue-yellow-red-blue-yellow (more generally referred to as ABCABC)
  - A unit cell contains atoms from four of the layers from the picture on the left. *On the unit cell at the left, label which layer each atom comes from (A, B or C).*
  - In addition to the atom at each corner of the cube, there is also an atom in the center of each face of the cube. For this reason, cubic closest packing (ccp) can also be called **face centered cubic (fcc)**.



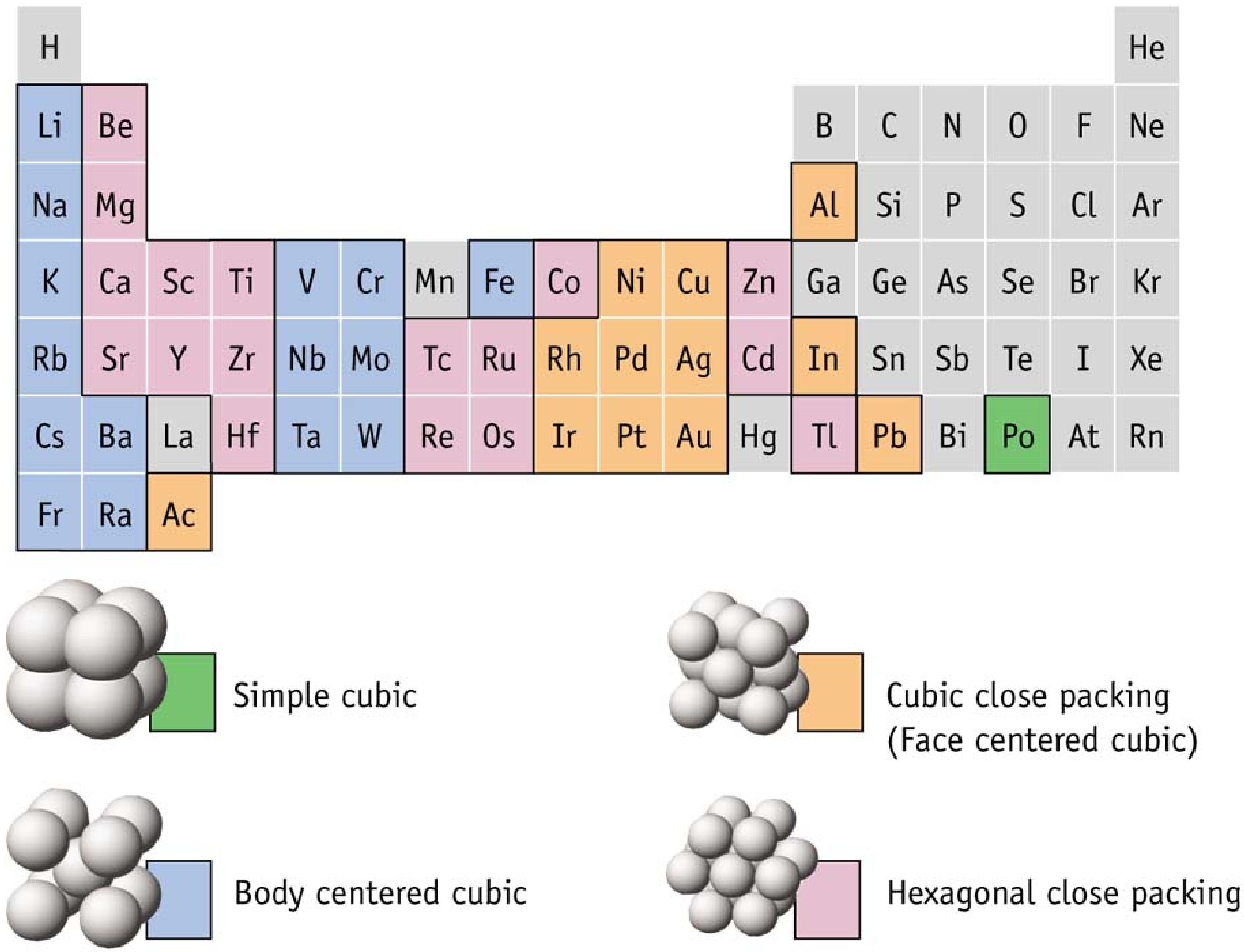
Metal Lattices

- Face-centered cubic (fcc) is one of three types of cubic unit cells. The other two are **body-centered cubic (bcc)** and **simple cubic**:



Note that these pictures include parts of the atoms that are not contained by the unit cell. ***The unit cell only contains the fraction of each atom that is *inside* the cube!***

Metal Lattices



How can we Determine a Lattice's Structure

- Crystalline solids (including metals) can be analyzed by **x-ray crystallography**, in which an x-ray is passed through a crystal. The crystal acts as a diffraction grating (the x-rays can pass through gaps in the crystal structure but not through the atoms themselves), and analysis of the resulting **diffraction pattern** allows a chemist to determine the structure of the crystal (elements as well as arrangement of atoms).