Investigation: Chemical Periodicity

In this activity, you will examine trends in the physical properties of the first 54 elements of the periodic table. Using the data below (use reference materials to fill in the missing data) construct a graph for each pair of quantities:

1. atomic radius versus atomic number
2. ionization energy versus atomic number
3. [melting point](http://www.lenntech.com/periodic-chart-elements/melting-point.htm) versus atomic number
4. [density](http://www.lenntech.com/periodic-chart-elements/density.htm) versus atomic number
5. [electronegativity](http://www.lenntech.com/periodic-chart-elements/electronegativity.htm) versus atomic number

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| --- | --- | --- | --- | --- | --- | --- |
| Atomic Number | Symbol | Atomic Radius (nm) | Ionization Energy (kJ/mol) | Melting Point (C) | Density (kg/m3) | Electronegativity |
| 1 | H | 0.032 | 1312 | -259 | 0.0899 | 2.2 |
| 2 | He | 0.031 | 2372 | -272 | 0.1785 | 0.0000 |
| 3 | Li | 0.123 | 520 | 180 | 0.535 | 0.98 |
| 4 | Be | 0.090 | 899 | 1287 | 1.848 | 1.57 |
| 5 | B | 0.082 | 801 | 2075 | 2.46 | 2.04 |
| 6 | C | 0.077 | 1086 | 3550 | 2.26 | 2.55 |
| 7 | N | 0.075 | 1402 | -210 | 1.251 | 3.04 |
| 8 | O | 0.073 | 1310 | -218 | 1.429 | 3.44 |
| 9 | F | 0.072 | 1681 | -220 | 1.696 | 3.98 |
| 10 | Ne | 0.071 | 2081 | -249 | 0.9 | 0.0000 |
| 11 | Na | 0.154 | 496 | -98 | 0.968 | 0.93 |
| 12 | Mg | 0.136 | 738 | 650 | 1.738 | 1.31 |
| 13 | Al | 0.118 | 578 | 660 | 2.7 | 1.61 |
| 14 | Si | 0.111 | 786 | 1414 | 2.33 | 1.9 |
| 15 | P | 0.106 | 1012 | 44 | 1.823 | 2.19 |
| 16 | S | 0.102 | 1000 | 115 | 1.96 | 2.58 |
| 17 | Cl | 0.099 | 1251 | -102 | 3.214 | 3.16 |
| 18 | Ar | 0.098 | 1521 | -189 | 1.784 | N/A |
| 19 | K | 0.203 | 419 | 64 | 0.856 | 0.82 |
| 20 | Ca | 0.174 | 590 | 842 | 1.55 | 1 |
| 21 | Sc | 0.144 | 630 | 1541 | 2.985 | 1.36 |
| 22 | Ti | 0.132 | 660 | 1668 | 4.507 | 1.54 |
| 23 | V | 0.122 | 650 | 1910 | 6.11 | 1.63 |
| 24 | Cr | 0.118 | 650 | 1907 | 7.14 | 1.66 |
| 25 | Mn | 0.117 | 720 | 1246 | 7.47 | 1.55 |
| 26 | Fe | 0.117 | 759 | 1538 | 7.874 | 1.83 |
| 27 | Co | 0.116 | 758 | 1495 | 8.9 | 1.88 |
| 28 | Ni | 0.115 | 737 | 1455 | 8.908 | 1.91 |
| 29 | Cu | 0.117 | 745 | 1085 | 8.92 | 1.9 |
| 30 | Zn | 0.125 | 906 | 420 | 7.14 | 1.65 |
| 31 | Ga | 0.126 | 579 | 30 | 5.904 | 1.81 |
| 32 | Ge | 0.122 | 762 | 938 | 5.323 | 2.01 |
| 33 | As | 0.120 | 947 | 817 | 5.727 | 2.18 |
| 34 | Se | 0.117 | 941 | 221 | 4.819 | 2.55 |
| 35 | Br | 0.114 | 1140 | -7.3 | 3.12 | 2.96 |
| 36 | Kr | 0.122 | 1351 | -157 | 3.75 | 3 |
| 37 | Rb | 0.216 | 403 | 39 | 1.532 | 0.82 |
| 38 | Sr | 0.191 | 550 | 777 | 2.63 | 0.95 |
| 39 | Y | 0.162 | 616 | 1526 | 4.472 | 1.22 |
| 40 | Zr | 0.145 | 660 | 1855 | 6.511 | 1.33 |
| 41 | Nb | 0.134 | 664 | 2477 | 8.57 | 1.6 |
| 42 | Mo | 0.130 | 685 | 2623 | 10.28 | 2.16 |
| 43 | Tc | 0.127 | 702 | 2157 | 11.5 | 1.9 |
| 44 | Ru | 0.125 | 711 | 2334 | 12.37 | 2.2 |
| 45 | Rh | 0.125 | 720 | 1964 | 12.45 | 2.28 |
| 46 | Pd | 0.128 | 805 | 1555 | 2.023 | 2.2 |
| 47 | Ag | 0.134 | 731 | 962 | 10.49 | 1.93 |
| 48 | Cd | 0.148 | 868 | 321 | 8.65 | 1.69 |
| 49 | In | 0.144 | 558 | 157 | 7.31 | 1.78 |
| 50 | Sn | 0.140 | 709 | 232 | 7.31 | 1.96 |
| 51 | Sb | 0.140 | 832 | 631 | 6.697 | 2.05 |
| 52 | Te | 0.136 | 869 | 450 | 6.23 | 2.1 |
| 53 | I | 0.133 | 1008 | 113 | 4.94 | 2.66 |
| 54 | Xe | 0.131 | 1170 | -112 | 5.9 | 2.6 |

# Questions:

## Atomic radius versus atomic number

A number of physical and chemical properties are related to the sizes of the atoms, but atomic size is somewhat difficult to define. There is no precise outer boundary of an atom. The radius is one half the distance between the centers of two adjacent atoms. The radius of an atom depends on the environment in which it is found. For *bonded* atoms, we customarily speak of a covalent radius, ionic radius, and, in the case of metals, a metallic radius. For atoms that are not bonded together, the radius is known as the van der Waals radius. For comparison, all radii in the above table are covalent.

* 1. **Which is the largest of the first 54 elements?**

Rubidium

* 1. **Describe how the atomic radius varies within a period and within a family.**

The atomic radius decrease from left to right within a period

The atomic radius increase from top to bottom within a family

* 1. **Use your graph to predict the atomic radius of the following elements:**
     1. Cesium 0.3nm (b) tungsten 0.21 nm (c) thallium 0.22nm (d) radon 0.134nm
  2. **Which group of the main group elements contains the largest elements?**

Group one

## Ionization energy versus atomic number

* 1. **How would you explain *ionization energy* to your partner?**

The ionization energy (IE) is qualitatively defined as the amount of energy required to remove the most loosely bound electron, the valence electron, of an isolated gaseous atom to form a cation.

* + 1. **How does the ionization energy vary within a period and within a family?**

The ionization energy increase from left to right within a period.

The ionization energy decrease from top to bottom within a family.

* + 1. **Which element on your graph has the strongest hold of its valence electrons?**

Helium

* 1. **(a) Write the electron configuration for chlorine.**

3s2 3p5

**(b) Which electron is lost when 1251 kJ/mol of energy are applied to a sample of chlorine atoms?**

The valance electron of the chlorine atom

**2. Compare the ionization energies of metals to nonmetals.**

Metals tend to lose electrons and form positive ions. The nonmetals like neon, Ne, fluorine, F, and oxygen, O, have relatively higher ionization energies.

## Melting point versus atomic number

* 1. **Describe the trend of melting points within a period**

Melting points increase from right to left within a period.

* 1. **Which group of elements tends to have the highest melting points**

Group 6 have the highest melting point.

* 1. **Tungsten is used in incandescent light bulbs because it has an extremely high melting point. Which element on your chart could be a reasonable replacement for tungsten? Why?**

Carbon would be a reasonable replacement due to its high melting point.

## Density versus atomic number

* 1. **Describe how density varies within a period.**

Density increase from left to right within a period.

* 1. **Compare the densities of the elements in the second period with the elements in the third period.**

The densities element in the second period is Boron, the densities element in the third period is Chlorine.

Their densities are Br 2.46kg/m3 vs. Cl 3.214kg/m3.

* 1. **Assume that the transition metals given in the table are representative of the other members of this group. How do the densities of the transition metals compare with those of the elements in the main group?**

The density of the transition metals are higher than other elements of the main group.

* 1. **Explain why aluminum and magnesium are more suitable than iron for use in some airplane parts.**

Because they have lower density than iron and aluminum has aluminum oxide layer which is rust resistance.

## Electronegativity versus atomic number

* 1. **Describe how electronegativity varies within a period.**

It increases from left to right within a period.

* 1. **Describe how electronegativity varies within a family.**

It decreases from top to bottom within a family.

## References:

Kimball, D., E. Kuzub and M. Sanader (1993), *Chemistry Laboratory Manual 1*, Student’s Edition, Don Mills: Addison-Wesley Publishers Limited

Petrucci, R.H. (1982), *General Chemistry, Principles and Modern Applications*, 3rd ed. New York: Macmillan Publishing Co., Inc. Whitman, R.L., E.E. Zinck and R.A. Nalepa (1988), *Chemistry Today 1*, 3rd ed. Scarborough: Prentice-Hall Canada Inc.

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