Answers to Exercise 5.3
Periodic Trends

1. nitrogen (smallest) boron aluminum scandium (largest)

2. krypton (lowest) argon neon helium (highest)

3. carbon

4.

(a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

(b) [Ne] $3s^2\ 3p^6$

(c) Ca^{2+} _114_ pm Cl^- _167_ pm K^+ _152_ pm S^{2-} _170_ pm

(d) The main structural difference between the four ions is the number of protons in the nucleus: S^{2-} has 16 protons, Cl^- has 17 protons, K^+ has 19 protons and Ca^{2+} has 20 protons.

In the atoms with more protons in the nucleus, the valence electrons are more strongly attracted to the nucleus (feeling a stronger effective nuclear charge) so the radius is smaller.

Therefore, when ranked from smallest to largest, the ions are $Ca^{2+} < K^+ < Cl^- < S^{2-}$.

5.

(a)

Relevant electron configurations: $H = 1s^1$ $H^{-1} = 1s^2$ $He = 1s^2$ $He^{-1} = 1s^2\,2s^1$

Electron affinity is the energy released when a neutral gaseous atom gains an electron. A larger electron affinity indicates that gaining an electron is more favourable.

The electron gained by hydrogen is added to the same subshell (1*s*) as the existing electron. It is attracted to the nucleus (+1 charge) and only partially shielded by the other electron. As such, both electrons experience a positive effective nuclear charge and formation of H^{-1} is favourable.

If helium were to gain an electron, that electron would be added to a new shell ($n = 2$). The two electrons in the 1*s* orbital would almost entirely shield the +2 charge of the nucleus, so it would not be favourable to add an electron to He.

Since H^{-1} can form and He^{-1} cannot, hydrogen has a larger electron affinity than helium *(which is one of the few elements to have a negative electron affinity).*

(b)

Second ionization energy is the energy required to remove an electron from X^{+1} in the gas phase where X is the element of interest.

The electron configuration of Ca^+ is [Ar] $4s^1$.

The electron configuration of K^+ is [Ne] $3s^2\ 3p^6$.

Removal of an electron from a 3p orbital requires substantially more energy than removal of an electron from a 4s orbital. The electron in the 4s orbital is (a) farther away from the nucleus and (b) experiences a lower effective nuclear charge due to being shielded by all of the 3s and 3p electrons. The electron in the 3p orbital is (a) closer to the nucleus and (b) more strongly attracted to the nucleus because it only experiences partial shielding by the electrons in the same shell as it.

This argument assumes a similar number of protons giving a similar nuclear charge, as is the case for this question.

(c)

Br and Br^{-1} have the same number of protons, but Br^{-1} has one more electron. This extra electron partially shields the other electrons in the valence shell from the positive charge of the nucleus. As such, the effective nuclear charge felt by the valence electrons of Br^{-1} is smaller than that felt by the valence electrons of Br, and they are not pulled as strongly toward the nucleus (increasing the atomic radius).

(d)

Nitrogen has two more protons in its nucleus than boron does. It also has two more electrons, but these do not completely shield the valence electrons from the increased positive charge of the nucleus. As such, the effective nuclear charge felt by the valence electrons of nitrogen is higher than that felt by the valence electrons of boron. The valence electrons of nitrogen are therefore pulled more strongly toward the nucleus (decreasing the atomic radius).

6.

(a) First ionization energy: the energy required to excite an electron out of a neutral gaseous atom in the ground state

$$\mathrm{A}_{(g)} \rightarrow \mathrm{A}^{+}_{(g)} + e^{-}$$

Second ionization energy: the energy required to excite the second electron out of a neutral gaseous atom in the ground state

$$\mathrm{A}^{+}_{(g)} \rightarrow \mathrm{A}^{2+}_{(g)} + e^{-}$$

(b) The electron configurations for these three atoms are very similar: [Noble Gas] $\#s^1$

The first electron removed from Li, Na or K is a valence electron. The second electron removed from Li, Na or K is a core electron.

Core electrons require much more energy to remove than valence electrons because they are much less shielded by the other core electrons in the same shell.

For every other element under consideration, both the first and second electrons removed are valence electrons.