

6. Use the principles of atomic structure and/or chemical bonding to explain each of the following. In each part, your answer must include references to both substances.

(a) The atomic radius of Li is larger than that of Be.

Both Li and Be have their outer electrons in the same shell (and/or they have the same number of inner core electrons shielding the valence electrons from the nucleus). However, Be has four protons and Li has only three protons. Therefore, the effective nuclear charge experienced (attraction experienced) by the valence (outer) electrons is greater in Be than in Li, so Be has a smaller atomic radius.

1 point earned for indicating that Be has more protons than Li

1 point earned for indicating that since the electrons are at about the same distance from the nucleus, there is more attraction in Be as a result of the larger number of protons

(b) The second ionization energy of K is greater than the second ionization energy of Ca.

The second electron removed from a potassium atom comes from the third level (inner core). The second electron removed from a calcium atom comes from the fourth level (valence level). The electrons in the third level are closer to the nucleus so the attraction is much greater than for electrons in the fourth level.

1 point earned for saying that electrons are removed from an inner (third) level in potassium but one level higher, (fourth level) in calcium

1 point earned for saying that the distance to the nucleus is less for the third level, so attraction is greater and more energy is needed to remove an electron

7. Account for the following observations using principles of atomic structure and/or chemical bonding. In each part, your answer must include specific information about both substances.

(a) The Ca^{2+} and Cl^- ions are **isoelectronic**, but their radii are not the same. Which ion has the larger radius? Explain.

Both Ca^{2+} and Cl^- ions have 18 electrons. Their electron configuration is $1s^2 2s^2 2p^6 3s^2 3p^6$. However, they differ by the number of protons in the nucleus. Calcium has 20 protons and chlorine has 17 protons.

The valence electrons are shielded by the same number of electrons in each ion (10), so the effective nuclear charge (ENC) experienced by the valence electrons in Ca^{2+} is +10 and for Cl^- the ENC is +7. The valence electrons in Cl^- experience a smaller attraction to the nucleus due to the smaller nuclear charge, so Cl^- has the larger ionic radius.

(The same argument is acceptable when comparing the total number of protons versus total number of electrons for each ion.)

1 point for indicating that chloride ion has the larger ionic radius

1 point for correct explanation

(d) The first ionization energy of Be is 900 kJ mol^{-1} , but the first ionization energy of B is 800 kJ mol^{-1} .

The electron configuration for Be is $1s^2 2s^2$, whereas the electron configuration for B is $1s^2 2s^2 2p^1$. The first electron removed in boron is in a $2p$ subshell, which is higher in energy than the $2s$ subshell, from which the first electron is removed in beryllium. The higher in energy the subshell containing the electron to be removed (ionized), the lower the ionization energy.

1 point for indicating the difference in the subshell where the first electron is removed for each element

1 point for associating higher energy sublevel with lower ionization energy

(c) As shown in the table below, the first ionization energies of Si, P, and Cl show a trend.

Element	First Ionization Energy (kJ mol ⁻¹)
Si	786
P	1,012
Cl	1,251

(i) For each of the three elements, identify the quantum level (e.g., $n = 1$, $n = 2$, etc.) of the valence electrons in the atom.

The valence electron is located in the $n = 3$ level for all three atoms.

One point is earned for the principal quantum level for all three elements.

(ii) Explain the reasons for the trend in first ionization energies.

Because the valence electrons in all three elements are shielded by the same number of inner core electrons and the nuclear charge increases going from Si to P to Cl, the valence electrons feel an increasing attraction to the nucleus going from Si to P to Cl. Valence electrons having a greater attraction to the nucleus, as in Cl, will be more difficult to remove, so Cl has the highest ionization energy. P has the second highest ionization energy, and Si has the lowest ionization energy.

One point is earned for explaining that greater ionization energy is due to increased nuclear charge.

Note: Explanations of the trend on the basis of effective nuclear charge are acceptable.