

6/7 • Atomic Structure & Periodicity

PRACTICE TEST

- How many orbitals make up the **4d** subshell?
a) 0 b) 1 c) 3 **d) 5** e) 7
- In what section of the periodic table is the **4f** subshell being filled?
a) period 4
b) transition elements Y to Cd
c) noble gases
d) group IA
e) lanthanides
- Which one of the following elements has 3 electrons in a **p** subshell?
a) Sb b) Na c) Sc d) V e) Nd
- Which of the following distributions of electrons is correct for three electrons in p-subshell?
a) $\begin{array}{|c|c|c|} \hline \uparrow & \uparrow & \uparrow \\ \hline \end{array}$
b) $\begin{array}{|c|c|c|} \hline \uparrow\downarrow & \uparrow & \text{---} \\ \hline \end{array}$
c) $\begin{array}{|c|c|c|} \hline \uparrow & \uparrow & \downarrow \\ \hline \end{array}$
d) $\begin{array}{|c|c|c|} \hline \uparrow & \uparrow\downarrow & \text{---} \\ \hline \end{array}$
e) $\begin{array}{|c|c|c|} \hline \uparrow\uparrow & \uparrow & \text{---} \\ \hline \end{array}$
- Which one of the following isoelectronic species has the smallest radius?
a) Mg²⁺ b) Na⁺ c) Ne
d) F⁻ e) O²⁻

NOTE: explain your reasoning. All have the same electron configuration, same shell, Mg has the highest Z_{eff}

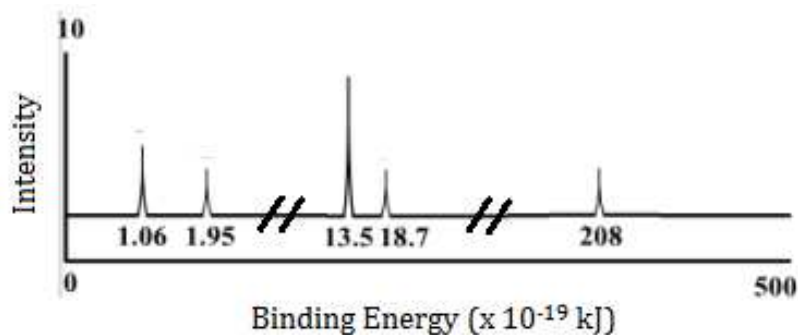
- Electromagnetic radiation at the blue end of the visible spectrum has a wavelength of 400 nm.
 - Calculate the frequency of the radiation. $C = \lambda\nu$ **7.50 x 10¹⁴ 1/s**
 - Calculate the energy of one photon of this radiation. $E = h\nu$ **4.77 x 10⁻¹⁹ J**
 - Calculate the energy of one mole of photons of this radiation.
4.77 x 10⁻¹⁹ J/photon x 6.02 x 10²³ photons/mol = 287000 J/ mol
- When a strontium salt is ignited, it burns with a red flame. The frequency of the light given off by this flame is greater than

- a. Yellow light
- b. Infrared light**
- c. Ultraviolet light
- d. Radio waves**
- e. X-rays

8. An element with the electron configuration $[\text{Xe}]4f^{14}6s^25d^7$ would belong to which class on the periodic table?

- a. Transition elements**
- b. Alkaline earth elements
- c. Halogens
- d. Rare earth elements
- e. None of the above

Use the PES spectrum of Phosphorus below to answer the next 3 questions.



9. Which peak corresponds to the 1s orbital?

- (A) 1.06
- (B) 1.95
- (C) 13.5
- (D) 18.7
- (E) 208**

10. Which peak corresponds to the valence 3p orbital?

- (A) 1.06**
- (B) 1.95
- (C) 13.5
- (D) 18.7
- (E) 208

11. What would you predict for the intensity and binding energy for the 3p orbital for that of sulfur?

- (A) Higher intensity, higher binding energy
- (B) Higher intensity, lower binding energy**
- (C) Lower intensity, higher binding energy
- (D) Lower intensity, lower binding energy

Remember that binding energy and the first ionization energy are similar values

12. Which of the following provides the best explanation for the many chemical similarities between sodium and potassium?

- (A) Both have atomic masses between 20 and 40 amu
- (B) Both have an ns¹ electron configuration for their highest occupied energy level**
- (C) Both are main group elements
- (D) Both are solids at room temperature and pressure
- (E) The atomic numbers of the two elements differ by less than ten

13. Electrons from which valence shell are removed first when transition metals ionize?

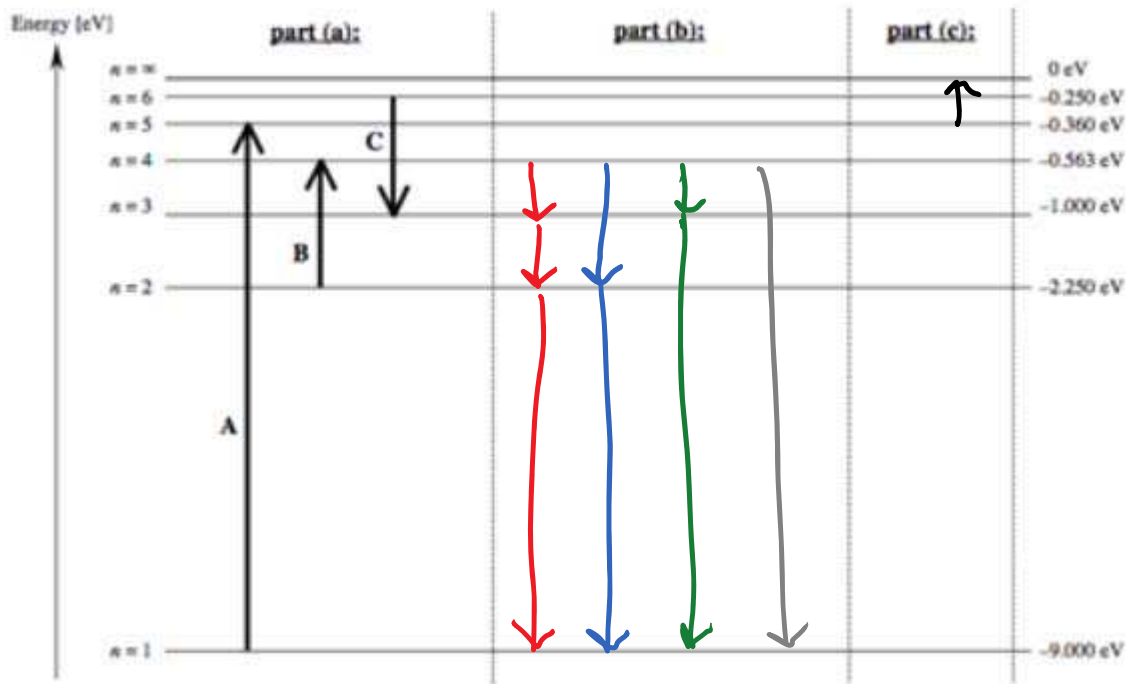
- (A) s**
- (B) p
- (C) d
- (D) f

14. What would be the expected ionic charges for Sn?

- (A) +1 and +2
- (B) +1 and +3
- (C) +2 and +3
- (D) +3 and +4
- (E) +2 and +4**

15. Atoms on the left side of the chart tend to form positive ions because...

- (A) Their principal energy level is almost empty**
- (B) Their principal energy level is almost full
- (C) Their atomic number is less than other elements in that period
- (D) Both B and C
- (E) A, B, and C



16. Fill in the following table for each transition and its associated photon. Give energies in electron-volts and wavelengths in nanometers. $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$

Transition	$ \Delta\text{Energy} $ [eV]	Wavelength [nm]	Is photon emitted or absorbed?	Visible (which color) or UV or IR
A	8.64	152	Abs	UV
B	1.89	657	Abs	visible blue
C	0.750	1654	EM	IR

$$A \quad 8.64 \text{ eV} \times \frac{1.602 \times 10^{-19}}{1 \text{ eV}} = 1.304 \times 10^{-18} \text{ J}$$

$$J = \frac{hc}{\lambda} \quad 1.304 \times 10^{-18} \text{ J} = \frac{(6.626 \times 10^{-34})(3.00 \times 10^8 \text{ m/s})}{\lambda}$$

$$\lambda = 1.524 \times 10^{-7} \text{ m} \times \frac{10^9 \text{ nm}}{1 \text{ m}} = 152 \text{ nm}$$

17. **See diagram on previous page.** There are four different paths that an excited electron in the $n = 4$ level can use to decay to the ground state. (Each “decay path” can consist of one or more de-excitation steps.) Draw all four decay routes in the middle portion of the above energy-level diagram.
18. Suppose that an electron is in the $n = 5$ state of this atom.
- What is the minimum energy needed to ionize the electron? 0.360 eV
 - draw this ionization in the right-hand portion of the previous energy-level diagram.

Atomic and Ionic Radii

19. Atomic radius generally increases as we move

- (A) down a group and from right to left across a period**
(B) up a group and from left to right across a period
(C) down a group and from left to right across a period
(D) up a group and from right to left across a period
(E) down a group; the period position has no effect

20. Electrons in the 1s subshell are much closer to the nucleus in Ar than in He due to the larger _____ in Ar.

- (A) nuclear charge**
(B) paramagnetism
(C) diamagnetism
(D) Hund's rule
(E) azimuthal quantum number

21. Of the following, which gives the correct order for atomic radius for Mg, Na, P, Si and Ar?

- (A) $\text{Mg} > \text{Na} > \text{P} > \text{Si} > \text{Ar}$
(B) $\text{Ar} > \text{Si} > \text{P} > \text{Na} > \text{Mg}$
(C) $\text{Si} > \text{P} > \text{Ar} > \text{Na} > \text{Mg}$
(D) $\text{Ar} > \text{P} > \text{Si} > \text{Mg} > \text{Na}$
(E) $\text{Na} > \text{Mg} > \text{Si} > \text{P} > \text{Ar}$

22. Which of the following is expected to have the largest radius?

- (A) P^{3-}
(B) S^{2-}
(C) Cl^-
(D) Ar
(E) K^+

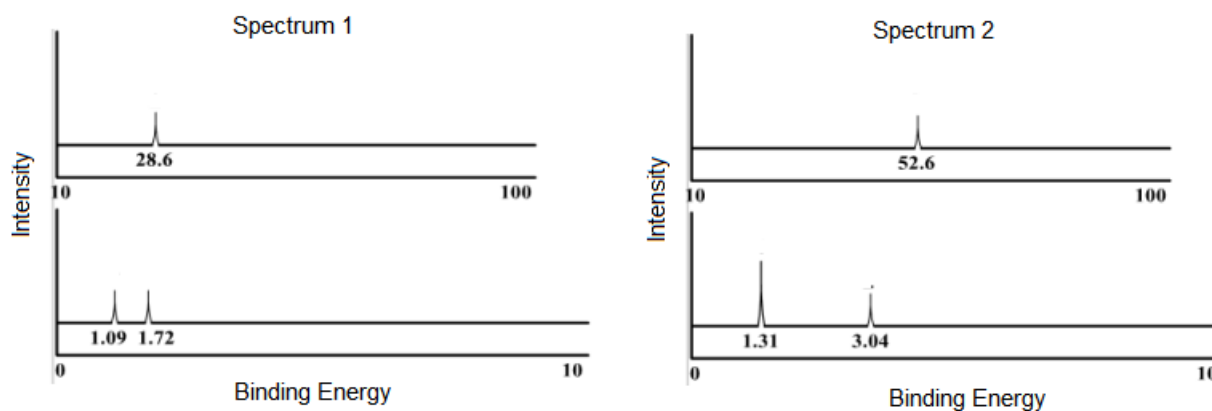
23. Which of the following is expected to have the smallest radius?

- (A) S^{2-}
- (B) **Ca^{2+}**
- (C) Cl^-
- (D) K^+
- (E) P^{3-}

24. Which of the following pairs correctly shows the proper relationship between the two atoms/ions in terms of atomic/ionic radii?

- (A) $Na < Na^+$
- (B) $Cl > Cl^-$
- (C) $Ti < Zn$
- (D) **$N^{3-} > N$**
- (E) $O > S$

Use the PES spectra below to answer the next 3 questions. The spectra represent elements found in the same period on the periodic table.



25. Which of these two elements would have the smaller atomic radii?

- (A) Spectrum 1
- (B) **Spectrum 2 more electrons represented in 2nd energy level, so more protons**
- (C) They are both the same
- (D) There is not enough information

26. What are the identities of the elements represented by each spectrum respectively?

- (A) Fluorine and nitrogen
- (B) Carbon and beryllium
- (C) **Carbon and oxygen use height of peaks to estimate the number of electrons**
- (D) Sodium and carbon
- (E) Fluorine and carbon

27. Which of the following is **not** true regarding the spectra above?

- (A) The 2s peak at 1.72 in spectrum 1 has a lower binding energy than the 2s peak at 3.04 in spectrum 2 due to a decreased effective nuclear charge.
- (B) There are 4 valence electrons represented in spectrum 1
- (C) The valence electrons in spectrum 1 experience more shielding than those represented in spectrum 2.**
- (D) The peak at 52.6 in spectrum 2 is held closer to the nucleus than the peak at 28.6 in spectrum 1.
- (E) The 1s peak in the PES spectrum of Li would have a lower binding energy than both 1s peaks from spectrum 1 and spectrum 2.

Ionization Energy

The first five ionization energies, in kJ/mol, for a particular element are shown below.

I ₁	I ₂	I ₃	I ₄	I ₅
786	1577	3232	4356	16,091

28. The element is likely to form an ionic compound in which the charge is:

- (A) 1+
- (B) 2+
- (C) 3+
- (D) 4+**
- (E) 5+

29. Of the choices below, which gives the order for first ionization energies?

- (A) Kr > Se > Br > Ga > Ge
- (B) Kr > Br > Se > Ge > Ga**
- (C) Ga > Br > Ge > Kr > Se
- (D) Ga > Ge > Se > Br > Kr
- (E) Br > Se > Ga > Kr > Ge

30. An element having which of the following electronic configurations would have the greatest ionization energy?

- (A) [He] 2s² 2p³
- (B) [He] 2s² 2p⁵**
- (C) [Ne] 3s² 3p³
- (D) [Ne] 3s² 3p⁵

31. The electron configuration belonging to the atom with the highest second ionization energy is

- (A) $1s^2 2s^2 2p^6 3s^1$
- (B) $1s^2 2s^2 2p^6 3s^2$
- (C) $1s^2 2s^2 2p^6 3s^2 3p^1$
- (D) $1s^2 2s^2 2p^6 3s^2 3p^4$
- (E) $1s^2 2s^2 2p^6 3s^2 3p^5$

32. Sodium is much more apt to exist as a cation than is chlorine. This is because _____.

- (A) chlorine is a gas and sodium is a solid
- (B) chlorine has a greater ionic radius than sodium does
- (C) chlorine has a greater atomic radius than sodium
- (D) chlorine has a greater ionization energy than sodium does**
- (E) chlorine is more metallic than sodium

Use the following responses to answer the next 3 questions.

- (A) $\text{Cl} \rightarrow \text{Cl}^+ + e^-$
- (B) $\text{Cl}^+ + e^- \rightarrow \text{Cl}$
- (C) $\text{Cl}^+ \rightarrow \text{Cl}^{2+} + e^-$
- (D) $\text{Cl}^{2+} + e^- \rightarrow \text{Cl}^+$

33. **A** The process representing the first ionization energy of chlorine

34. **C** The process representing the second ionization energy of chlorine

35. **C** The process requiring the most energy

Use the following responses to the next 2 questions. Use an answer once, more than once, or not at all.

- (A) Mg & Al
- (B) As & Se
- (C) Cl & F
- (D) Cr & Mo
- (E) Cu & Ag

36. **B** Show a reversal in the trend for first ionization energy because of electron-electron repulsions.

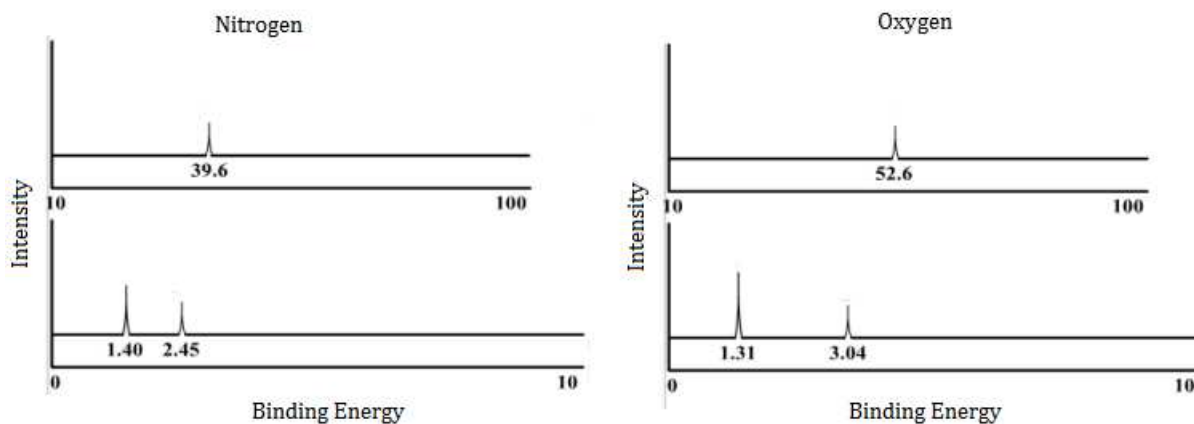
37. **A** Show a reversal in the trend for first ionization energy because of shielding by full orbitals.

Use the following responses to answer the next 5 questions. Use an answer once, more than once, or not at all.

- (A) Increased shielding of valence electrons
- (B) Effective nuclear charge
- (C) $\frac{1}{2}$ filled orbitals
- (D) Fully filled orbitals

38. A Why gold is a better conductor of electricity than copper.
39. B Why the atomic radius decreases as the atomic number increases from 11-17 across the periodic table.
40. A Why atomic radius increases down a group on the periodic table.
41. B Why gallium has an unexpected smaller radius than aluminum?
42. D Why magnesium has an unexpectedly higher ionization energy than aluminum.

Use the PES spectrum of Nitrogen and Oxygen below to answer the next 3 questions.



43. Which of the following best explains why the 1s peak in the nitrogen spectrum has a lower binding energy compared to the 1s peak in the oxygen spectrum?
- (A) Nitrogen atoms have 3 electrons in their p subshell.
 - (B) Oxygen experience more electron-electron repulsions.
 - (C) Nitrogen has a larger atomic radius.
 - (D) Electrons in the p subshell of oxygen atoms provide more shielding than those in nitrogen atoms.
 - (E) Nitrogen atoms have a smaller nuclear charge and coulombic attraction than oxygen atoms.**

44. Given the fact that both elements are in the same period, what information from the PES spectra indicates that oxygen would have a smaller atomic radius?

- (A) The number of peaks
- (B) The intensity of the peaks
- (C) Binding energy of the peaks**
- (D) A and C
- (E) B and C

45. What information from the PES spectra above best accounts for nitrogen having smaller 1st ionization energy than oxygen?

- (A) The number of peaks
- (B) The intensity of the core electron peaks
- (C) The intensity of the valence electron
- (D) Binding energy of the valence electron peaks**
- (E) A and C

46. What trend would you predict for the binding energies of valence electrons moving down a group on the periodic table?

- (A) Increasing binding energy due to increased shielding.
- (B) Increasing binding energy due to decreased shielding.
- (C) Decreasing binding energy due to increased shielding.**
- (D) Decreasing binding energy due to decreased shielding.
- (E) Decreasing binding energy due to decreased nuclear charge.

47. Which of the following elements would require the shortest wavelength of light to ionize?

- (A) Ga
- (B) B
- (C) Al
- (D) C
- (E) N**

48. What would be the necessary wavelength (in nm) from sodium's outermost "s" orbital? The first ionization energy of sodium is 495.8 kJ/mol.

- (A) 350 nm
- (B) **242 nm**
- (C) 124 nm
- (D) 824 nm
- (E) 496 nm

$$E = \frac{hc}{\lambda}$$

Change E from kJ \rightarrow J and from mol \rightarrow atom

$$\frac{495.8 \text{ kJ}}{\text{mol}} \times \frac{1000 \text{ J}}{1 \text{ kJ}} \times \frac{1 \text{ mol}}{6.02 \times 10^{23}} = 8.23588 \times 10^{-19} \text{ J}$$
$$8.23588 \times 10^{-19} \text{ J} = \frac{(6.626 \times 10^{-34}) (2.99 \times 10^8)}{\lambda}$$
$$\lambda = 2.4055 \times 10^{-7} \text{ m}$$
$$(2.405 \times 10^{-7} \text{ m}) \left(\frac{10^9 \text{ nm}}{1 \text{ m}} \right) = 241 \text{ nm}$$

49. Which of the following best describes why tin is considered a metal and carbon a nonmetal despite being in the same group?

- (A) Carbon has smaller atomic radius
- (B) The atomic mass of tin is nearly 10 times that of carbon.
- (C) Tin has less shielding of its valence electrons and a higher ionization energy.
- (D) Tin has more shielding of valence electrons and a lower ionization energy.**
- (E) Tin has more shielding of its valence electrons and a higher ionization energy.

Electronegativity

50. Which of the following best describes the variation of electronegativity with respect to an element's position on the periodic table?

- (A) Increases across a period; increases down a group.
- (B) Increases across a period; decreases down a group.**
- (C) Decreases across a period; increases down a group.
- (D) Decreases across a period; decreases down a group.

51. Which of the following groups of elements is arranged correctly in order of increasing electronegativity?

- (A) $B < O < Al < F$
- (B) $Al < B < O < F$**
- (C) $B < O < F < Al$
- (D) $F < O < B < Al$

52. The ability of an atom in a molecule to attract electrons is best quantified by the _____.

- (A) paramagnetism
- (B) diamagnetism
- (C) electronegativity**
- (D) electron change-to-mass ratio
- (E) first ionization potential

Use the following responses to answer for the next 3 questions.

- (A) O
- (B) Fe
- (C) Rb
- (D) Mg
- (E) N

53. **_A_** What is the most electronegative element of the above?
54. **_B_** Which element readily forms cations with multiple oxidation states?
55. **_D_** Which of the elements above has the smallest ionic radius for its most commonly found ion?
56. An element with a large electronegativity value will likely have
- (A) Valence shell PES peaks with low binding energies
 - (B) A lower first ionization energy
 - (C) A low nuclear charge and a high amount of shielding
 - (D) A and B
 - (E) All of the above**
57. Which of the following BEST explains why silicon has a lower electronegativity than chlorine?
- (A) Si has a lower nuclear charge and similar shielding than Cl**
 - (B) Si has a higher nuclear charge and similar shielding of Cl
 - (C) Si has the equivalent nuclear charge and less shielding than Cl
 - (D) Si has the equivalent nuclear charge and more shielding than Cl
 - (E) None of these

Group Trends

58. Which is not true of nonmetals?
- (A) Most of their oxides are acidic
 - (B) They are poor conductors of heat
 - (C) They are poor conductors of electricity
 - (D) Many are gases at room temperature
 - (E) Most tend to lose electrons readily**
59. All of the following statements concerning the characteristics of the halogens are true EXCEPT:
- (A) The first ionization energies (potentials) decrease as the atomic numbers of the halogens increase.
 - (B) They only require one more electron to have full “s” and “p” orbitals.
 - (C) Fluorine atoms have the smallest radii.
 - (D) They readily form cations.**
 - (E) Fluorine is the most electronegative of the halogens.

60. Element M reacts with chlorine to form a compound with the formula MCl_2 . Element M is more reactive than magnesium and has a smaller radius than barium. This element is ___?

- (A) **Sr**
- (B) K
- (C) Na
- (D) Ra
- (E) Be

61. The only noble gas that does not have the ns^2np^6 valence electron configuration is _____.

- (A) radon
- (B) neon
- (C) **helium**
- (D) krypton
- (E) All noble gases have the ns^2np^6 valence electron configuration.

62. An alkaline earth metal forms a compound with oxygen with the formula _____.
(The symbol M represents any one of the alkaline earth metals.)

- (A) **MO**
- (B) M_2O
- (C) MO_2
- (D) M_2O_2
- (E) MO_3

63. Alkali metals tend to be more reactive than alkaline earth metals because _____.

- (A) alkali metals have lower densities
- (B) alkali metals have lower melting points
- (C) alkali metals have greater atomic radii
- (D) alkali metals are not more reactive than alkaline earth metals
- (E) **alkali metals have lower ionization energies**

64. The element in the periodic table that looks like a metal, is a poor thermal conductor, and acts as an electrical semiconductor is _____.

- (A) Sn
- (B) B
- (C) As
- (D) **Si**
- (E) Ge

Name	Melting point in K	First Ionization energy in kJ mol ⁻¹
Lithium	454	519
Sodium	371	494
Potassium	337	418

65. Atoms of which element have the highest electronegativity?
- Li, since it is most likely to gain electrons**
 - Li, since it are most likely to lose electrons
 - K, since it are most likely to gain electrons
 - Na, since it is the most reactive
66. Atoms of which element have the largest atomic radius?
- Li, since it has the fewest number of protons
 - K, since it has the greatest number of occupied principal shells**
 - K, since it has the greatest number of protons
 - It is not possible to tell without further information
67. From atoms of which element is it easiest to remove an electron?
- Li, since the first ionization is the highest
 - K, since Coulomb's law predicts the force of attraction between the nucleus and the valence electron to be the lowest**
 - Li, since it has the fewest number of protons
 - K, since potassium wants to become 'happy' and a achieve a noble gas electronic configuration
68. Atoms of which element have the highest *second* ionization energy?
- Li, since its second electron is closest to the nuclear charge**
 - Li, since it has the highest nuclear charge
 - K, since it has the highest nuclear charge
 - All second ionization energies are equal
69. The most common ion of which element, will be smaller than the corresponding, parent atom?
- Li
 - Na
 - K
 - All three elements**