Question 7

7. Account for each of the following observations in terms of atomic theory and/or quantum theory.

(a) Atomic size decreases from Na to Cl in the periodic table.

Across the periodic table from Na to Cl, the number of electrons in the *s*- and *p*- orbitals of the valence shell increases, as does the number of protons in the nucleus. The added electrons only partially shield the added protons, resulting in an increased effective nuclear charge. This results in a greater attraction for the electrons, drawing them closer to the nucleus, making the atom smaller.	One point is earned for indicating the increase in nuclear charge. One point is earned for attributing the size decrease to the greater attraction of the nucleus for the electrons caused by the increase in nuclear charge.

(b) Boron commonly forms molecules of the type BX_3. These molecules have a trigonal planar structure.

Boron has three valence electrons, each of which can form a single covalent bond with X. The three single covalent bonds of the boron atom orient to minimize electron-pair interaction, resulting in bond angles of 120° and a trigonal planar structure.	One point is earned for describing the valence electrons and the bonds. One point is earned for a correct VSEPR argument.

(c) The first ionization energy of K is less than that of Na.

Both Na and K have an s^1 valence-shell electron configuration (Na: [Ne] $3s^1$; K: [Ar] $4s^1$). The K atom valence electron has a higher *n* quantum number, placing it farther from the nucleus than the Na atom valence electron. The greater distance results in less attraction to the nucleus. Because its valence electron is less attracted to its nucleus, the K atom has the lower ionization energy.	One point is earned for the size explanation. One point is earned for describing the attraction to the nucleus.

(d) Each element displays a unique gas-phase emission spectrum.

Each element has a unique set of quantized energy states for its electrons (because of its unique nuclear charge and unique electron configuration). As the electrons of an element absorb quanta of energy, they change to higher energy states (are excited) – during de-excitation, energy is released as EM radiation as the electrons cascade to lower energy states. Each photon of the EM radiation is associated with a specific wavelength ($\lambda = hc/E$), a flux of which produces the lines of the emission spectrum.	One point is earned for describing the quantized energy states and emission phenomenon. One point is earned for describing the effect of the uniqueness of the nucleus and/or electron configuration.

Answer EITHER Question 7 below OR Question 8 printed on page 24. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 15 percent.

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   (d) Each element displays a unique gas-phase emission spectrum.

(a) If we move from Na to Cl in the periodic table, we are moving
from left to right on a period.
As we go across a period, both numbers of electrons and number
of protons in the nucleus,
However, increase in effective nuclear charge is much bigger than
increase in repulsion between electrons.
Therefore, nucleus pulls electrons to inside more strongly and
atomic size decreases.

(c) Ionization energy is energy needed to remove an electron from the outermost
shell.
K is in the 4th period and Na is in the 3rd period.
It means that K has one more outer shell and thus, less influence of
positive charge of nucleus
Therefore, it requires less energy.

(d) Max Planck found that lights emit energy by a certain unit called quantum.
Quantum is a stack of energy and has specific value.
Therefore, element has specific energy level that can display unique
gas-phase emission spectrum.

(b) Boron is a typical element of Boron group and has 3 valence electrons.
If each of these are shared by 3 atoms of element X,
There exists no lone pair which can exert some influence by repulsion

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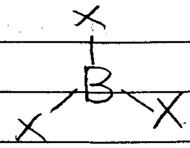
ADDITIONAL PAGE FOR ANSWERING QUESTION 7.

with each other.

Therefore, the structure is not distorted



Incomplete octet

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a) The number of valence shells remains the same, but a proton and an electron are added for each consecutive element. However, the increasing size of the nucleus (because of proton) will create larger effective nuclear charge, thus pulling the outer shell closer in. Therefore, if this charge is increasing across a period, the atomic size will decrease across a period

b) Boron deviates from the octet rule and thus can form a max of 3 bonds with other atoms. Therefore it will favor forming molecules of the type BX_3. The trigonal planar structure is associated with the fact that there are 3 effective pairs around the Boron and 0 lone pairs.

c) The K atom has one more valence shell than Na. This means that the attraction between the valence electrons and the nucleus is smaller in K atoms. As a result, the ionization energy, (i.e energy required to remove an electron from valence shell) will be less in K because its outermost electrons are not being pulled in as much as those in Na

d) Each element has a unique mass and proton number. Consequently, the emission

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 7B2

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In the gas-phase spectrum must account for the elements' unique atomic numbers and masses.

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   (d) Each element displays a unique gas-phase emission spectrum.

(a) As one moves along a row in the periodic table (from Na to Cl) the atomic radius decreases. This is because new protons are being added, and ~~an~~ therefore the electrons are being pulled closer to the nucleus. Because the electrons are all being added to the same shell, there will be no extra opposing shielding.

(b)
```
  X
  |
X-B-X
```
Boron is an exception to the octet rule, and will not have any lone pairs even if it does not have 8 surrounding electrons. In the diagram to the left, it is simple to see that this is trigonal planar.

(c) the first ionization energy is the energy required to remove an electron from the outer shell of an atom. as one goes down a column, this value decreases, as it becomes easier to remove the outer electron.

(d) $\lambda = \frac{h}{mv}$

when in gas-phase, each element will have a different Vrms, depending on its molecular mass. $V_{rms} = \sqrt{\frac{3RT}{M}}$.

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 7C2

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therefore, the λ emitted will be different for every element.

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Question 7

Sample: 7A
Score: 7

This response earned 7 out of 8 possible points: 2 points for part (a), 2 points for part (b), 2 points for part (c), and 1 out of 2 possible points for part (d). The second point was not earned in part (d) because the response does not explain the relationship between energy levels and emission.

Sample: 7B
Score: 6

The points were not earned in part (d) because differences in emission spectra are attributed to differences in mass and number of protons. There is no mention of electron energy states or transitions among them.

Sample: 7C
Score: 3

In part (b) 1 point was earned for noting that compounds of the type BX_3 do not have lone pairs of electrons, resulting in a trigonal planar structure. However, the second point was not earned because there is no explanation as to why boron forms compounds of the type BX_3 . In part (c) no points were earned because even though the definition of ionization energy is correct, the response only states what the trend is and does not explain *why* the trend exists. In part (d) no points were earned because differences in emission spectra are incorrectly attributed to differences in root-mean-square speed.