Atomic Structure & Periodic Table (Periodicity) Free Response Example questions – answers

1994 D

(a) Ca^{2+} has fewer electrons, thus it is smaller than Ca (*1 pt.*)

The outermost electron in Ca is in a 4*s* orbital, whereas the outermost electron in Ca^{2+} in in a 3*p* orbital (*1 pt.*)

Note: The first point is earned for indicating the loss of electrons, the second point for indicating the outermost electrons are in different shells -- must account for the magnitude of the size difference between Ca and Ca^{2+}.

(b) *U* for CaO is more negative than *U* for K_2O, so it is more difficult to break up the CaO lattice (stronger bonds in CaO). (*1 pt.*)

Ca^{2+} is smaller than K^+, so internuclear separations (between cations and O^{2-}) are less,

OR, (*1 pt.*)

Ca^{2+} is more highly charged than K^+, thus cation—O^{2-} bonds are stronger

Note: understanding what "lattice energy" is earns 1 point; size or charge explanation needed for the second point. Responses that use Lewis structures or otherwise indicate *molecules* rather than ionic lattice earn no points.

(c) (i) Ca has more protons and is smaller. The outermost electrons are more strongly held by the nuclear charge of Ca. (*1 pt.*)

(ii) The outermost electrons in Ca are in the 4*s*, which is a higher energy orbital (more shielded) than the 3*p* electron in K. (*1 pt.*)

Note: for (i), the idea of attraction between nucleus and electrons must be present; for (ii), a "noble-gas configuration" argument must be tied to an energy argument in order to earn credit.

(d) The highest energy (outermost) electron in Al is in a 3*p* orbital, whereas that electron in Mg is in a 3*s* orbital. (*1 pt.*)

The 3*p* electron in Al is of higher energy (is more shielded) than is the 3*s* electron in Mg. (*1 pt.*)

Note: noting that different orbitals are involved earns the first point; a correct energy argument earns the second point.

Responses that attribute the greater stability of Ca over K (or K^+ over Ca^+, or Mg over Al) to the stability of a completely filled (*vs.* half or partially filled) orbital earn NO credit.

1997

Question 6
(8 points)

(a) Response must contain a cogent discussion of the forces between the nucleus and the outermost (or "ionized") electron. For example, a discussion of "the outermost electron on K ..." should include one of the following:

i. it is farther from nucleus than the outermost electron on Li
ii. it is more shielded from the nucleus (or "experiences a lower effective nuclear charge") than the outermost electron on Li
iii. it is in a higher energy orbital (4*s*) than the outermost electron on Li (2*s*)." — *2 points for any one*

Notes: "K is larger than Li" earns 1 point.
No points earned for "K electron is easier to remove" (or some other restatement).

(b) Nitrogen has one less proton than oxygen — *1 point*
Nitride and oxide ions are isoelectronic — *1 point*
or ,
In nitride ion the electron/proton ratio is greater, causing more repulsion; thus, nitride is the larger ion. — *2 points*

(c) A Zn atom has more protons (10 more) than an atom of Ca — *1 point*

Electrons in *d* orbitals of Zn have a lower principal quantum number; thus, they are not in orbitals that are farther from the nucleus. — *1 point*

(d) Correct identification of the orbitals involved (2*s* versus 2*p*) — *1 point*

Clear statement that the two orbitals have different energies — *1 point*

Note: Arguments that "the 2*p* orbital is farther out than the 2*s* orbital", or that "the Be atom has a filled subshell, which is a more stable configuration" earn no explanation point.

General note: For all parts (a) through (d), discussions of position in the periodic table earn no points.

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1999 SCORING GUIDELINES

Question 2

9 points

(a) (i) $\nu = \dfrac{c}{\lambda} = \dfrac{3.00 \times 10^{17}\ \text{nm/sec}}{495\ \text{nm}}$ (*or*, $= \dfrac{3.00 \times 10^{8}\ \text{m/sec}}{495 \times 10^{-9}\ \text{m}}$) $= 6.06 \times 10^{14}\ \text{sec}^{-1}$ ***1 pt***

(ii) $E = h\nu = (6.626 \times 10^{-34}\ \text{J sec})(6.06 \times 10^{14}\ \text{sec}^{-1}) = 4.02 \times 10^{-19}\ \text{J}$ ***1 pt***

(iii) $(4.02 \times 10^{-19}\ \text{J})(6.022 \times 10^{-23}\ \text{mol}^{-1})(0.00100\ \text{kJ/J}) = 242\ \text{kJ/mol}$ ***1 pt***

Note: No units required if answers are numerically same as above. No penalty if answers are correct with different units and units are explicitly indicated (*e.g.*, for part (ii), 4.02×10^{-22} kJ is acceptable)

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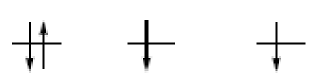
(a) The isotopes have the same number (34) of protons, ***1 pt.***
but a different number of neutrons. ***1 pt.***

- No comment about the number of electrons is necessary

(b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^4$
or ***1 pt.***
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^4$

- No point is earned for [Ar] $4s^2\ 3d^{10}\ 4p^4$, because the question specifically asks for a complete electron configuration.

Since there are three different $4p$ orbitals, there must be two unpaired electrons. ***1 pt.***



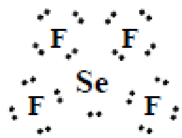
<u>Notes:</u> The second part should have some explanation of Hund's rule, and may include a diagram. The second point can still be earned even if the first point is not IF the electron configuration is incorrect, but the answer for the second part is consistent with the electron configuration given in the first part.

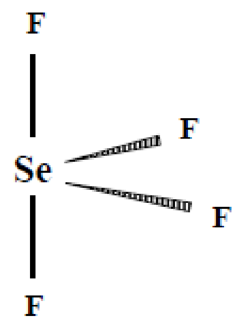
(c) (i) The ionized electrons in both Se and Br are in the same energy level, but Br has more protons than Se, so the attraction to the nucleus is greater. *1 pt.*

Note: There should be two arguments in an acceptable answer -- the electrons removed are from the same (4*p*) orbital ***and*** Br has more protons (a greater nuclear charge) than Se.

(ii) The electron removed from a Te atom is in a 5*p* orbital, while the electron removed from an Se atom is in a 4*p* orbital. The 5*p* orbital is at a higher energy than the 4*p* orbital, thus the removal of an electron in a 5*p* orbital requires less energy. *1 pt.*

(d) *1 pt.*





Notes: One point earned for a correct Lewis diagram and a sketch. The Lewis diagram and the molecular structure may be combined into one sketch if both aspects (electron pairs and structure) are correct. Dots, lines, or a mixture of both can be used in the Lewis diagram. The lone pair of electrons need not be shown in the sketch -- just the atomic positions. No credit earned for just a verbal description of molecular geometry ("see-saw", "saw-horse", or something "distorted"), because the question clearly asks the student to "sketch the molecular structure".