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Gymnastics – Quantum Practice Problem

Quantum Equations

1. Find the energy of the electron in a hydrogen atom that is orbiting in each of the following states:
   a) n = 1

$n = 1$

$E_n = \frac{-2.178 \times 10^{-18}}{(1)^2} = -2.178 \times 10^{-18}$ J

2. Find the energy to excite the electron in a hydrogen atom for each of the following cases
   a) The electron jumps from the ground state (n=1) to the n=2 state

$n_i = 1$

$n_f = 2$

$E = -2.178 \times 10^{-18} \times \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$E = -2.178 \times 10^{-18} \left(\frac{1}{2^2} - \frac{1}{1^2}\right) = 1.634 \times 10^{-10}$ J

3. Hydrogen is excited and a wavelength of 411.0 nm is emitted. If you know that the electron starts at n=6, then what energy level does it end up at?

$\lambda = 411.0$ nm

$n_i = 6$

$n_f = ?$

$E = h\nu$

$c = \lambda\nu$

$411 \text{ nm} \left(\frac{1 \text{ m}}{10^9 \text{ nm}}\right) = 4.11 \times 10^{-7}$ m

(1) $\nu = \frac{3 \times 10^8}{4.11 \times 10^{-7}} = 7.30 \times 10^{12}\ s^{-1}$

$E = -2.178 \times 10^{-18} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

(2) $E = (6.63 \times 10^{-34})(7.3 \times 10^{12})$

$E = 4.8 \times 10^{-21}$ J

(3) $\frac{4.8 \times 10^{-21}}{2.178 \times 10^{-18}} = \frac{-2.178 \times 10^{-18}}{-2.178 \times 10^{-18}} \left(\frac{1}{n_f^2} - \frac{1}{6^2}\right)$

$2.2 \times 10^{-3} = \frac{1}{n_f^2} - \frac{1}{36}$

$(2.99 \times 10^{-2})^{-1} = \left(\frac{1}{n_f^2}\right)^{-1}$

$5 = n_f$

4. Ultraviolet radiation has a frequency of 6.8 x $10^{18}\ s^{-1}$. Calculate the energy, in joules, of the photon.

$h =$

$\nu = 6.8 \times 10^{18}\ s^{-1}$

$E = h\nu$

$E = (6.63 \times 10^{-34})(6.8 \times 10^{18})$

$E = 4.5 \times 10^{-15}$ J

5. What is the wavelength and frequency of photons with an energy of 1.4 x 10^{-21} J?

$E = 1.4 \times 10^{-21}$ J

$\lambda = ?$

$\nu = ?$

$E = h\nu$

$\frac{1.4 \times 10^{-21}}{6.63 \times 10^{-34}} = \frac{(6.63 \times 10^{-34})\nu}{6.63 \times 10^{-34}}$

$2.1 \times 10^{12}\ s^{-1} = \nu$

$c = \lambda\nu$

$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{2.1 \times 10^{12}} = 1.4 \times 10^{-4}$ m

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Use the table below to answer questions 6:

Object	Mass (kg)
Proton	1.672×10^{-27}
Electron	9.109×10^{-31}

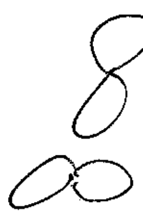
6. What is the de Broglie wavelength of an electron moving at 100 m/s?

$v = 100$ m/s
$m = 9.109 \times 10^{-31}$ kg
$\lambda = \frac{h}{mv}$

$\lambda = \frac{(6.63 \times 10^{-34})}{(9.109 \times 10^{-31})(100)} = 7.28 \times 10^{-6}$ m

Orbitals

7. Draw the p orbital(s), state how many orientations it can take, and explain why it is impossible for it to take on more orientations.



* p orbital (dumb-bell shape)
* 3 possible orientations (1 x, 1 y, 1 z)

8. Which of the following sets of quantum numbers is unacceptable? **Justify your response**

	n	l	m_l	m_s
a.	4	3	-2	+1/2
(b.)	3	3	1	-1/2
c.	3	0	0	-1/2
d.	3	1	1	+1/2
e.	2	0	0	-1/2

l can only be up to $n-1$ (max # for (b) is 2)

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(b.)	3	0	2	-1/2
c.	3	0	0	-1/2
d.	3	1	1	+1/2
e.	2	0	0	-1/2

m_l can only be values of $-l$ to $+l$.

10. Write the orbital that goes with the following quantum numbers:

n	l	Orbital
2	1	2p
4	3	4f
3	0	3s
4	3	4d

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11. Write the electron configuration for P $1s^2 2s^2 2p^6 3s^2 3p^3$ or $[Ne]\,3s^2 3p^3$
12. Write the electron configuration for Fe $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$ or $[Ar]\,4s^2 3d^6$
13. Write the electron configuration for Ca^{2+} → $1s^2 2s^2 2p^6 3s^2 3p^6$ or $[Ar]$
14. Write the electron configuration for F^- → $1s^2 2s^2 2p^6$ or $[Ne]$

Periodic Trends

15. The effective nuclear charge experienced by the outermost electron of Na is different than the effective nuclear charge experienced by the outermost electron of Ne. This difference best accounts for which of the following?

a. Na has a greater density at standard conditions than Ne.
(b) Na has a lower first ionization energy than Ne.
c. Na has a higher melting point than Ne.
d. Na has a higher neutron-to-proton ratio than Ne.
e. Na has fewer naturally occurring isotopes than Ne.

16. Arrange the ions K^+, Cl^-, Ca^{2+}, and S^{2-} in order of decreasing size.

(a) S^{2-}, Cl^-, K^+, Ca^{2+}
b. Ca^{2+}, K^+, Cl^-, S^{2-}
c. K^+, Cl^-, S^{2-}, Ca^{2+}
d. Ca^{2+}, Cl^-, K^+, S^{2-}
e. None of the above

17. The ionization energies for element X are listed in the following table:

First IE	Second IE	Third IE	Fourth IE	Fifth IE
580 kJ/mol	1815 kJ/mol	2740 kJ/mol	11,600 kJ/mol	14,800 kJ/mol

On the basis of the data, element X is most likely to be: ↗ big jump!

a. Na
b. Mg
(c) Al
d. Si
e. P

18. The electron affinities for selected elements in Period 2 are shown below:

Element	$_{13}Al$	$_{14}Si$	$_{15}P$	$_{16}S$	$_{17}Cl$
Electron Affinity	12 kcal/mol	32 kcal/mol	17 kcal/mol	48 kcal/mol	87 kcal/mol

Which of the following answers **best** explains the decrease in electron affinity from silicon to phosphorus:

a. Phosphorus is more stable than silicon
b. Phosphorous has more electrons than silicon
(c) Phosphorus has a half filled 3p orbital, thus, making it more stable
d. Silicon has more electrons to share
e. Phosphorus has a half filled 3d orbital, thus, making it more stable

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19. Account for each of the following in terms of principles of atomic structure, including the number, properties, and arrangements of subatomic particles. You must justify your answers for full credit!

a. The second ionization energy of sodium is about three times greater than the second ionization energy of magnesium.

Sodium has a higher 2nd ionization energy due to the fact that during the first IE, it loses its only valance e⁻ in the 3s orbital. At this point it has a noble gas configuration, so removing an e⁻ will require large amounts of e⁻.

b. The difference between the atomic radii of Na and K is relatively large compared to the difference between the atomic radii of Rb and Cs.

As you go down from Na to K, we add a new s, p, and d orbital. Whereas for Rb to Cs we are introducing f orbitals, which take up more space.

a. Phosphorus forms the fluorides PF_3 and PF_5, whereas nitrogen forms only NF_3.

P has an open d-orbital, so it can move some electrons up into that orbital.

N does not have an open orbital, so it cannot expand its octet by pushing e⁻ to new orbitals.

Lattice Energies

20. Use principles of atomic structure and/or chemical bonding to answer each of the following.

(a) The radius of the Ca atom is 0.197 nanometer; the radius of the Ca^{2+} ion is 0.099 nanometer. Account for this difference.

As you remove e⁻ from Ca^{2+}, it becomes positive. This leads to a removal of orbitals and a shrinking of the overall radius.

(b) The lattice energy of CaO *(s)* is -3,460 kilojoules per mole; the lattice energy for K_2O*(s)* is -2,240 kilojoules per mole. Account for this difference.

CaO is a +2/-2 bond which is a larger charge attraction than the +1/-2 attraction in K_2O. This means more energy is needed to split CaO than K_2O