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Answers to Practice Test Questions 4
Electrons, Orbitals and Quantum Numbers

1. Heisenberg's uncertainty principle states that the precision of our knowledge about a particle's position and its momentum are inversely related. If we have more information about its position, we must have less information about its momentum (and vice versa).
   As a result, the model of the atom in which an electron orbits a nucleus in circular fashion cannot be correct as we could know the electron's precise momentum and position at the same time (which would violate Heisenberg's uncertainty principle).

2. A substance that is diamagnetic has no unpaired electrons.
   A substance that is paramagnetic contains one or more unpaired electrons.
   A substance can be identified as either paramagnetic or diamagnetic by exposing it to a magnetic field. Paramagnetic substances will be attracted to the magnetic field while diamagnetic substances will be slightly repelled by the magnetic field.

3. The Pauli exclusion principle states that no two electrons in a chemical species can have the same quantum state. In other words, no two electrons in an atom or molecule can have the exact same set of quantum numbers.
   Because of the Pauli exclusion principle, there can only be two electrons per atomic orbital. This limits the number of electrons allowed per subshell. e.g. $1s^1$ and $1s^2$ are allowed, but $1s^3$ is not.

4.

(a) particles only (b) light only

(c) both (d) particles only

5.

(a) **Step 1: Convert speed of bullet into SI units**

$$v = 1200\,\tfrac{km}{h} \times \frac{1000m}{1km} \times \frac{1h}{60\min} \times \frac{1\min}{60s} = 333.3\,\tfrac{m}{s}$$

Step 2: Convert mass of bullet into SI units

$$m = 2.5g \times \frac{1kg}{1000g} = 2.5 \times 10^{-3}kg$$

Step 3: Calculate momentum of bullet

$$p = mv = \left(2.5 \times 10^{-3}kg\right)\left(333.3\,\tfrac{m}{s}\right) = 0.83\,\tfrac{kg\cdot m}{s}$$

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Step 4: Calculate wavelength of bullet

$$\lambda = \frac{h}{p} = \frac{6.626 \times 10^{-34}\ \frac{J}{Hz}}{0.83\ \frac{kg \cdot m}{s}} \times \frac{1Hz}{1\ \frac{1}{s}} = 8.0 \times 10^{-34}\, m$$

Step 5: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

(b) The wavelength is much, much smaller than the accuracy of any conceivable measurement of the motion of the bullet, so quantum mechanical effects are <u>not</u> important for bullets.

6.

(a) **Step 1: Calculate the energy of one photon**

$E = h\nu$ and $c = \lambda\nu$ therefore

$$E = \frac{hc}{\lambda} = \frac{\left(6.626 \times 10^{-34}\ \frac{J}{Hz}\right)\left(2.9979 \times 10^{8}\ \frac{m}{s}\right)}{\left(525nm\right)} \times \frac{10^{9}\,nm}{1m} \times \frac{1Hz}{1\ \frac{1}{s}} = 3.78 \times 10^{-19}\, J$$

Step 2: Calculate the energy of one mole of photons

$$E_{molar} = E_{photon}N_A = \left(3.78 \times 10^{-19}\ \frac{J}{photon}\right)\left(6.02214 \times 10^{23}\ \frac{photons}{mol}\right) = 2.28 \times 10^{5}\ \frac{J}{mol} = 228\ \frac{kJ}{mol}$$

Step 3: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

(b) $p = \frac{h}{\lambda}$ and $p = mv$ therefore $mv = \frac{h}{\lambda}$ therefore

$$v = \frac{h}{\lambda m} = \frac{\left(6.626 \times 10^{-34}\ \frac{J}{Hz}\right)}{\left(525nm\right)\left(1.0086649u\right)} \times \frac{10^{9}\,nm}{1m} \times \frac{1Hz}{1\ \frac{1}{s}} \times \frac{1u}{1.6605 \times 10^{-27}\,kg} \times \frac{1\ \frac{kg \cdot m^2}{s^2}}{1J} = 0.754\ \frac{m}{s}$$

7. A 6f orbital corresponds to the quantum numbers *n* = __6__, *l* = __3__.

The possible values of m_l for an electron in a 6f orbital range from __-3__ to __+3__.

The possible values of m_s for an electron in a 6f orbital range from __-½ __ to __+½ __.

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8.

Quantum Numbers of Two Electrons	Could this be a pair of electrons in the same orbital? Circle yes or no.	Briefly, justify your answer.
$n = 3$, $l = 1$, $m_l = 0$, $m_s = +½$ and $n = 3$, $l = 1$, $m_l = 0$, $m_s = -½$	YES / NO	n, l and m_l are the same, so the electrons are in the same orbital. The m_s values are opposite, indicating opposite spins.
$n = 3$, $l = 2$, $m_l = 1$, $m_s = +½$ and $n = 3$, $l = 1$, $m_l = 1$, $m_s = -½$	YES / NO	The values for l are different, so the two electrons described are in different orbitals.
$n = 3$, $l = 1$, $m_l = 1$, $m_s = +½$ and $n = 3$, $l = 1$, $m_l = 1$, $m_s = +½$	YES / NO	Both electrons have all four quantum numbers the same. They cannot therefore belong to the same atom.
$n = 3$, $l = 2$, $m_l = 2$, $m_s = +½$ and $n = 3$, $l = 2$, $m_l = 1$, $m_s = -½$	YES / NO	The values for m_l are different, so the two electrons described are in different 3d orbitals.

9. *See your notes/text for pictures of the different types of orbitals.*

(a) $4d_{xy}$, $4d_{xz}$, $4d_{yz}$, $4d_{x2-y2}$, <u>or</u> $4d_{z2}$

(b) 6s

(c) $3p_x$, $3p_y$, <u>or</u> $3p_z$

(d) $2p_x$, $2p_y$, <u>or</u> $2p_z$

10.

(a) 1
A complete (and valid) set of four quantum numbers can only describe one electron in an atom.

(b) none
l must be smaller than *n*

(c) 6
This set of quantum numbers describes all the electrons in a set of 5p orbitals.

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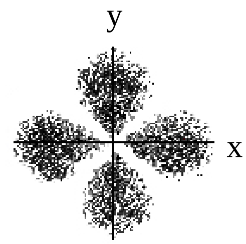
11.

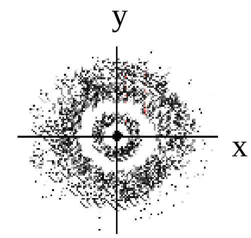
(a)

(i)



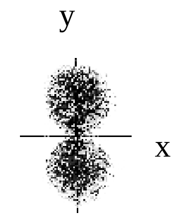
2 nodal planes
+ <u>0 radial nodes</u>
2 nodes total
Therefore $n = 2 + 1 = 3$

(ii)



0 nodal planes
+ <u>2 radial nodes</u>
2 nodes total
$n = 2 + 1 = 3$

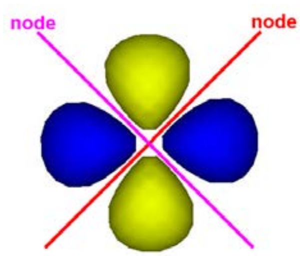
(iii)

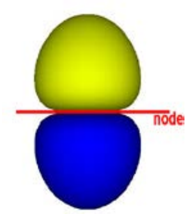


1 nodal plane
+ <u>0 radial nodes</u>
1 node total
$n = 1 + 1 = 2$

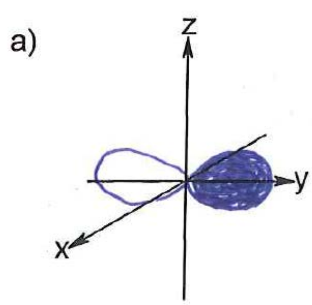
	(i)	(ii)	(iii)
label	$3d_{x^2-y^2}$	$3s$	$2p_y$
n	3	3	2
ℓ	2	0	1

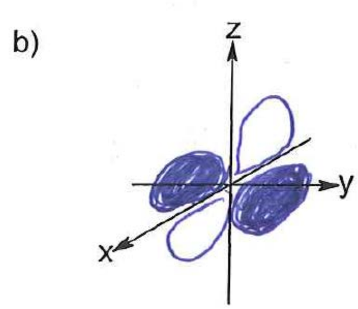
(b)





12.





It would also have been acceptable to relabel the axes to avoid drawing in three dimensions (which this unartistic person probably should have done for the d_{xz} orbital; see computer-generated images on next page).

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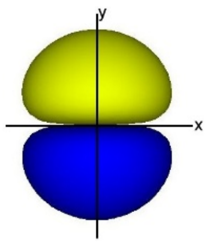
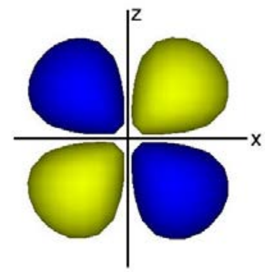
(a)

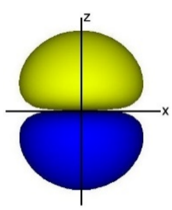


(b)

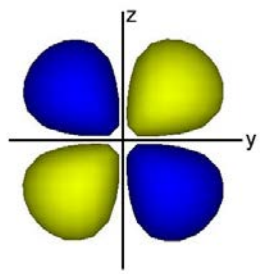


13.

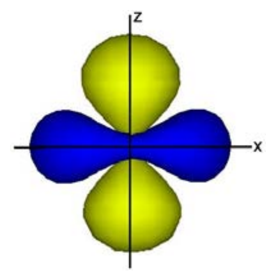
(a)



(b)

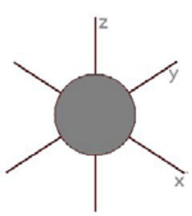


(c)

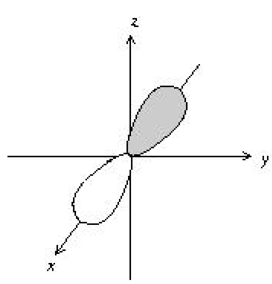


Or draw at an angle to show "doughnut"

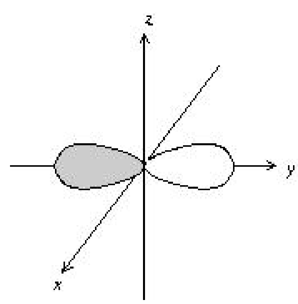
14.



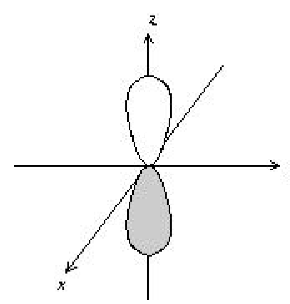
2*s*



2p_x



2p_y



2p_z

15.

(a) *draw a p orbital*

(b) *draw a p orbital along a different axis than your answer to part (a)*

(c) *draw a d orbital*

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16.

(a) 5

(b) $n = 5$ $l = 2$ $m_l = -2, -1, 0, +1$ or $+2$ $m_s = +½$ or $-½$

(c) The energy of the photon released when H relaxes from the $n = 5$ to the $n = 1$ state (ground state) is equal to the energy difference between an electron with $n = 5$ and an electron with $n = 1$.

H has one proton so $Z = 1$.

Step 1: Calculate the energy for H with *n* = 1

$$E_{n=1} = -R_H \frac{Z^2}{n^2} = -R_H \frac{(1)^2}{(1)^2} = -R_H = -2.179872 \times 10^{-18} J$$

Step 2: Calculate the energy for H with *n* = 5

$$E_{n=3} = -R_H \frac{Z^2}{n^2} = -R_H \frac{(1)^2}{(5)^2} = -\frac{1}{25} R_H = -8.719488 \times 10^{-20} J$$

Step 3: Calculate the difference in energy between the *n* = 1 and *n* = 5 states ($\Delta E = E_{final} - E_{initial}$)

$$\Delta E = E_{n=1} - E_{n=5} = (-2.179872 \times 10^{-18} J) - (-8.719488 \times 10^{-20} J) = -2.092677 \times 10^{-18} J$$

Step 4: Calculate the energy of the photon released

Since the sign of ΔE is negative, energy is released.

The energy of the photon released is 2.092677×10^{-18}J.

Step 5: Calculate the frequency of the photon released

$$E = h\nu$$

$$\nu = \frac{E}{h} = \frac{2.092677 \times 10^{-18} J}{6.626070 \times 10^{-34} \frac{J}{Hz}} = 3.158248 \times 10^{15} Hz$$

Step 6: Calculate the wavelength of the photon released

$$c = \nu\lambda$$

$$\lambda = \frac{c}{\nu} = \frac{2.997925 \times 10^{8} \frac{m}{s}}{3.158248 \times 10^{15} Hz} \times \frac{1 Hz}{1 \frac{1}{s}} = 9.492368 \times 10^{-8} m$$

$$\lambda = 9.492368 \times 10^{-8} m \times \frac{10^9 nm}{1 m} = 94.92368 nm$$

Step 7: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

The energy of the photon has a similar order of magnitude to R_H and the wavelength is in the UV range (expect UV, visible or IR).