STUDENT SOLUTIONS MANUAL

量子化学题解

第6版

IRA N. LEVINE

FOR QUANTUM CHEMISTRY

SIXTH EDITION

PEARSON
Prentice Hall

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Student Solutions Manual for Quantum Chemistry 6th ed.

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第6版

北京世界图书出版公司

SOLUTIONS MANUAL

IRA N. LEVINE

Chemistry Department
Brooklyn College
City University of New York

QUANTUM CHEMISTRY

SIXTH EDITION

PEARSON
Prentice Hall

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Chapter 1

The Schrödinger Equation

1.1 **(a)** F; **(b)** T; **(c)** T; **(d)** Let $w = v_{rms}$ and let H and O symbolize H_2 and O_2. Then $\frac{1}{2}m_H w_H^2 = \frac{1}{2}m_O w_O^2$ and $m_H^2 w_H^2 = m_O^2 w_O^2 (m_H/m_O)$. So $m_H w_H = m_O w_O (m_H/m_O)^{1/2} = m_O w_O (2/32)^{1/2}$ and $m_O w_O = 4m_H w_H$. Then $\lambda_H/\lambda_O = (h/m_H w_H)/(h/m_O w_O) = m_O w_O/m_H w_H = 4$, and the answer is True.

1.2 **(a)** $E_{photon} = h\nu = hc/\lambda = (6.626 \times 10^{-34}\ \text{J s})(2.998 \times 10^{8}\ \text{m/s})/(1064 \times 10^{-9}\ \text{m}) = 1.867 \times 10^{-19}\ \text{J}$.

(b) $E = (5 \times 10^{6}\ \text{J/s})(2 \times 10^{-8}\ \text{s}) = 0.1\ \text{J} = n(1.867 \times 10^{-19}\ \text{J})$ and $n = 5 \times 10^{17}$.

1.3 **(a)** $T_{max} = h\nu - \Phi =$
$(6.626 \times 10^{-34}\ \text{J s})(2.998 \times 10^{8}\ \text{m/s})/(200 \times 10^{-9}\ \text{m}) - (2.75\ \text{eV})(1.602 \times 10^{-19}\ \text{J/eV}) = 5.53 \times 10^{-19}\ \text{J} = 3.45\ \text{eV}$.

(b) The minimum photon energy needed to produce the photoelectric effect is $(2.75\ \text{eV})(1.602 \times 10^{-19}\ \text{J/eV}) = h\nu = hc/\lambda = (6.626 \times 10^{-34}\ \text{J s})(2.998 \times 10^{8}\ \text{m/s})/\lambda$ and $\lambda = 4.51 \times 10^{-7}\ \text{m} = 451\ \text{nm}$.

(c) Since the impure metal has a smaller work function, there will be more energy left over after the electron escapes and the maximum T is larger for impure Na.

1.4 $\lambda = h/mv = 137h/mc = 137(6.626 \times 10^{-34}\ \text{J s})/(9.109 \times 10^{-31}\ \text{kg})(2.998 \times 10^{8}\ \text{m/s}) = 3.32 \times 10^{-10}\ \text{m} = 0.332\ \text{nm}$.

1.5 **(a)** From Sec. 1.3, $\sin\alpha = \lambda/w = h/pw = h/mvw$. We have $T = mv^2/2$ and $v = (2T/m)^{1/2}$, so $\sin\alpha = h/(2Tm)^{1/2}w =$

$$\frac{6.626\times10^{-34}\ \text{J s}}{[2(1000\times1.062\times10^{-19}\ \text{J})(9.109\times10^{-31}\ \text{kg})]^{1/2}(1.00\times10^{-3}\ \text{m})} = 3.88\times10^{-8}$$

Then $\alpha = 3.88 \times 10^{-8}\ \text{rad}\ (360°/2\pi\ \text{rad}) = 2.22 \times 10^{-6}°$.

(b) For fixed T, $w = k/\sin\alpha$, where k is a constant, so $w_2/w_1 = \sin\alpha_1/\sin\alpha_2 = \sin 2.22 \times 10^{-6}°/\sin 1.00° = 2.22 \times 10^{-6}$ and $w_2 = 2.22\times10^{-6}(0.001\ \text{m}) = 2.22 \times 10^{-9}\ \text{m}$.

1.6 From the discussion after Eq. (1.11), $x = x_0 - \frac{1}{2}g(t - t_0)^2 + v_0(t - t_0)$ and $v = dx/dt = v_0 - g(t - t_0)$. Then $T + V = \frac{1}{2}mv^2 + mgx = \frac{1}{2}m[v_0 - g(t - t_0)]^2 + mg[x_0 - \frac{1}{2}g(t - t_0)^2 + v_0(t - t_0)] = \frac{1}{2}mv_0^2 + mgx_0$.

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1.7 $-(\hbar/i)(\partial\Psi/\partial t) = -(\hbar^2/2m)(\partial^2\Psi/\partial x^2) + V\Psi$. For $\Psi = ae^{-ibt}e^{-bmx^2/\hbar}$, we find $\partial\Psi/\partial t = -ib\Psi$, $\partial\Psi/\partial x = -2bm\hbar^{-1}x\Psi$, and $\partial^2\Psi/\partial x^2 = -2bm\hbar^{-1}\Psi - 2bm\hbar^{-1}x(\partial\Psi/\partial x) = -2bm\hbar^{-1}\Psi - 2bm\hbar^{-1}x(-2bm\hbar^{-1}x\Psi) = -2bm\hbar^{-1}\Psi + 4b^2m^2\hbar^{-2}x^2\Psi$. Substituting into the time-dependent Schrödinger equation and then dividing by Ψ, we get $-(\hbar/i)(-ib\Psi) = -(\hbar^2/2m)(-2bm\hbar^{-1} + 4b^2m^2\hbar^{-2}x^2)\Psi + V\Psi$ and $V = 2b^2mx^2$.

1.8 **(a)** F; **(b)** F. (These statements are valid only for stationary states.)

1.9 ψ satisfies the time-independent Schrödinger (1.19). $\partial\psi/\partial x = be^{-cx^2} - 2bcx^2e^{-cx^2}$; $\partial^2\psi/\partial x^2 = -2bcxe^{-cx^2} - 4bcxe^{-cx^2} + 4bc^2x^3e^{-cx^2} = -6bcxe^{-cx^2} + 4bc^2x^3e^{-cx^2}$. Equation (1.19) becomes $(-\hbar^2/2m)(-6bcxe^{-cx^2} + 4bc^2x^3e^{-cx^2}) + (2c^2\hbar^2x^2/m)bxe^{-cx^2} = Ebxe^{-cx^2}$. The x^3 terms cancel and $E = 3\hbar^2c/m =$
$3(6.626 \times 10^{-34}\text{ J s})^2 2.00(10^{-9}\text{ m})^{-2}/4\pi^2(1.00 \times 10^{-30}\text{ kg}) = 6.67 \times 10^{-20}\text{ J}$.

1.10 **(a)** $|\Psi|^2\,dx = (2/b^3)x^2e^{-2|x|/b}\,dx =$
$2(3.0\times10^{-9}\text{ m})^{-3}(0.90\times10^{-9}\text{ m})^2e^{-2(0.90\text{ nm})/(3.0\text{ nm})}(0.0001\times10^{-9}\text{ m}) = 3.29 \times 10^{-6}$.
(b) For $x \geq 0$, we have $|x| = x$ and the probability is given by (1.23) and (A.7) as
$\int_0^{2\text{ nm}} |\Psi|^2\,dx = (2/b^3)\int_0^{2\text{ nm}} x^2e^{-2x/b}\,dx = (2/b^3)e^{-2x/b}(-bx^2/2 - xb^2/2 - b^3/4)\Big|_0^{2\text{ nm}} =$
$-e^{-2x/b}(x^2/b^2 + x/b + 1/2)\Big|_0^{2\text{ nm}} = -e^{-4/3}(4/9 + 2/3 + 1/2) + 1/2 = 0.0753$.
(c) Ψ is zero at $x = 0$, and this is the minimum possible probability density.
(d) $\int_{-\infty}^{\infty} |\Psi|^2\,dx = (2/b^3)\int_{-\infty}^{0} x^2e^{2x/b}\,dx + (2/b^3)\int_0^{\infty} x^2e^{-2x/b}\,dx$. Let $w = -x$ in the first integral on the right. This integral becomes $\int_{\infty}^{0} w^2e^{-2w/b}(-dw) = \int_0^{\infty} w^2e^{-2w/b}\,dw$, which equals the second integral on the right [see Eq. (4.10)]. Hence
$\int_{-\infty}^{\infty} |\Psi|^2\,dx = (4/b^3)\int_0^{\infty} x^2e^{-2x/b}\,dx = (4/b^3)[2!/(b/2)^3] = 1$, where (A.8) in the Appendix was used.

1.11 The interval is small enough to be considered infinitesimal. At $t = 0$,
$|\Psi|^2\,dx = (32/\pi c^6)^{1/2}x^2e^{-2x^2/c^2}\,dx = [32/\pi(2.00\text{ Å})^6]^{1/2}(2.00\text{ Å})^2e^{-2}(0.001\text{ Å}) = 0.000216$.

1.12 $\int_a^b |\Psi|^2\,dx = \int_{1.5000\text{ nm}}^{1.5001\text{ nm}} a^{-1}e^{-2x/a}\,dx = -e^{-2x/a}/2\Big|_{1.5000\text{ nm}}^{1.5001\text{ nm}} = (-e^{-3.0002} + e^{-3.0000})/2 =$
4.978×10^{-6}.

1.13 **(a)** This function is not real and cannot be a probability density.

(b) This function is negative when $x < 0$ and cannot be a probability density.

(c) This function is not normalized and can't be a probability density.

1.14 **(a)** There are four equally probable cases for two children: BB, BG, GB, GG, where the first letter gives the gender of the older child. The BB possibility is eliminated by the given information. Of the remaining three possibilities BG, GB, GG, only one has two girls, so the probability that they have two girls is 1/3.

(b) The fact that the older child is a girl eliminates the BB and BG cases, leaving GB and GG, so the probability is 1/2 that the younger child is a girl.

1.15 The 138 peak arises from the case $^{12}C^{12}CF_6$, whose probability is $(0.9889)^2 = 0.9779$. The 139 peak arises from the cases $^{12}C^{13}CF_6$ and $^{13}C^{12}CF_6$, whose probability is $(0.9889)(0.0111) + (0.0111)(0.9889) = 0.02195$. The 140 peak arises from $^{13}C^{13}CF_6$, whose probability is $(0.0111)^2 = 0.000123$. (As a check, these add to 1.) The 139 peak height is (0.02195/0.9779)100 = 2.24. The 140 peak height is (0.000123/0.9779)100 = 0.0126.

1.16 There are 26 cards, 2 spades and 24 nonspades, to be distributed between B and D. Imagine that 13 cards, picked at random from the 26, are dealt to B. The probability that every card dealt to B is a nonspade is $\frac{24}{26}\frac{23}{25}\frac{22}{24}\frac{21}{23}\cdots\frac{14}{16}\frac{13}{15}\frac{12}{14} = \frac{13(12)}{26(25)} = \frac{6}{25}$. Likewise, the probability that D gets 13 nonspades is $\frac{6}{25}$. If B does not get all nonspades and D does not get all nonspades, then each must get one of the two spades and the probability that each gets one spade is $1 - \frac{6}{25} - \frac{6}{25} = 13/25$. (A commonly given answer is: There are four possible outcomes, namely, both spades to B, both spades to D, spade 1 to B and spade 2 to D, spade 2 to B and spade 1 to D, so the probability that each gets one spade is 2/4 = 1/2. This answer is wrong, because the four outcomes are not all equally likely.)

1.17 **(a)** The Maxwell distribution of molecular speeds; **(b)** the normal (or Gaussian) distribution.

1.18 **(a)** Real; **(b)** imaginary; **(c)** real; **(d)** imaginary; **(e)** imaginary; **(f)** real; **(g)** real; **(h)** real; **(i)** real.

1.19 **(a)** A point on the x axis three units to the right of the origin.

(b) A point on the y axis one unit below the origin.

(c) A point in the second quadrant with x coordinate –2 and y coordinate +3.

1.20 $\dfrac{1}{i}=\dfrac{1}{i}\dfrac{i}{i}=\dfrac{i}{i^2}=\dfrac{i}{-1}=-i$

1.21 **(a)** $i^2=-1$. **(b)** $i^3=ii^2=i(-1)=-i$. **(c)** $i^4=ii^3=i(-i)=-i^2=1$.

(d) $i^*i=(-i)i=1$.

(e) $(1+5i)(2-3i)=2+10i-3i-15i^2=17+7i$.

(f) $\dfrac{1-3i}{4+2i}=\dfrac{1-3i}{4+2i}\dfrac{4-2i}{4-2i}=\dfrac{4-14i-6}{16+8i-8i+4}=\dfrac{-2-14i}{20}=-0.1-0.7i$.

1.22 **(a)** –4 **(b)** $2i$; **(c)** $6-3i$; **(d)** $2e^{i\pi/5}$.

1.23 **(a)** 1, 90°; **(b)** 2, $\pi/3$;

(c) $z=-2e^{i\pi/3}=2(-1)e^{i\pi/3}$. Since –1 has absolute value 1 and phase π, we have $z=2e^{i\pi}e^{i\pi/3}=2e^{i(4\pi/3)}=re^{i\theta}$, so the absolute value is 2 and the phase is $4\pi/3$ radians.

(d) $|z|=(x^2+y^2)^{1/2}=[1^2+(-2)^2]^{1/2}=5^{1/2}$; $\tan\theta=y/x=-2/1=-2$ and $\theta=-63.4°=296.6°=5.176$ radians.

1.24 On a circle or radius 5. On a line starting from the origin and making an angle of 45° with the positive x axis.

1.25 **(a)** $i=1e^{i\pi/2}$; **(b)** $-1=1e^{i\pi}$;

(c) Using the answers to Prob. 1.23(d), we have $5^{1/2}e^{5.176i}$;

(d) $r=[(-1)^2+(-1)^2]^{1/2}=2^{1/2}$; $\theta=180°+45°=225°=3.927$ rad. $2^{1/2}e^{3.927i}$.

1.26 **(a)** Using Eq. (1.36) with $n=3$, we have $e^{i\cdot 0}=1$,
$e^{i(2\pi/3)}=\cos(2\pi/3)+i\sin(2\pi/3)=-0.5+i\sqrt{3}/2$, and $e^{i(4\pi/3)}=-0.5-i\sqrt{3}/2$.

(b) We see that ω in (1.36) satisfies $\omega\omega^*=e^0=1$, so the nth roots of 1 all have absolute value 1. When k in (1.36) increases by 1, the phase increases by $2\pi/n$.

1.27 $\dfrac{e^{i\theta}-e^{-i\theta}}{2i}=\dfrac{\cos\theta+i\sin\theta-[\cos(-\theta)+i\sin(-\theta)]}{2i}=\dfrac{\cos\theta+i\sin\theta-(\cos\theta-i\sin\theta)}{2i}=\sin\theta$,

where (2.14) was used.

$\dfrac{e^{i\theta}+e^{-i\theta}}{2}=\dfrac{\cos\theta+i\sin\theta+[\cos(-\theta)+i\sin(-\theta)]}{2}=\dfrac{\cos\theta+i\sin\theta+\cos\theta-i\sin\theta}{2}=\cos\theta$.

1.28 **(a)** From $f = ma$, $1\ \text{N} = 1\ \text{kg m/s}^2$.

(b) $1\ \text{J} = 1\ \text{kg m}^2/\text{s}^2$.

1.29 $F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} = \dfrac{2(1.602\times10^{-19}\ \text{C})79(1.602\times10^{-19}\ \text{C})}{4\pi(8.854\times10^{-12}\ \text{C}^2/\text{N-m}^2)(3.00\times10^{-13}\ \text{m})^2} = 0.405\ \text{N}$, where 2 and 79 are the atomic numbers of He and Au.

1.30 **(a)** T; **(b)** F; **(c)** F; **(d)** T; **(e)** F; **(f)** T.

Chapter 2

The Particle in a Box

2.1 **(a)** The auxiliary equation is $s^2 + s - 6 = 0$ and $s = [-1 \pm \sqrt{1+24}]/2 = 2$ and -3. So $y = c_1 e^{2x} + c_2 e^{-3x}$.

(b) Setting $x = 0$ and $y = 0$, we get $0 = c_1 + c_2$ (Eq. 1). Differentiation of y gives $y' = 2c_1 e^{2x} - 3c_2 e^{-3x}$. Setting $x = 0$ and $y' = 1$, we have $1 = 2c_1 - 3c_2$ (Eq. 2). Subtracting twice Eq. 1 from Eq. 2, we get $1 = -5c_2$ and $c_2 = -0.2$. Equation 1 then gives $c_1 = 0.2$.

2.2 **(a)** The quadratic formula gives the solutions of the auxiliary equation $s^2 + ps + q = 0$ [Eq. (2.7)] as $s = (-p \pm \sqrt{p^2 - 4q})/2$. To have equal roots of the auxiliary equation requires that $p^2 - 4q = 0$. Setting $q = p^2/4$ in the differential equation (2.6), we have $y'' + py' + (p^2/4)y = 0$ (Eq. 1). The auxiliary-equation solution is $s = -p/2$. Thus we must show that $y_2 = xe^{-px/2}$ is the second solution. Differentiation gives $y_2' = e^{-px/2} - pxe^{-px/2}/2$ and $y_2'' = -pe^{-px/2} + p^2 xe^{-px/2}/4$. Substitution in Eq. (1) gives the left side of Eq. (1) as $-pe^{-px/2} + p^2 xe^{-px/2}/4 + pe^{-px/2} - p^2 xe^{-px/2}/2 + p^2 xe^{-px/2}/4$, which equals zero and completes the proof.

(b) The auxiliary equation $s^2 - 2s + 1 = (s-1)^2 = 0$ has roots $s = 1$ and $s = 1$. From part (a), the solution is $y = c_1 e^x + c_2 xe^x$.

2.3 In comparing Eqs. (1.8) and (2.2), y in (2.2) is replaced by x, and x in (2.2) is replaced by t. Therefore x and its derivatives in (1.8) must occur to the first power to have a linear differential equation. **(a)** Linear; **(b)** linear; **(c)** nonlinear; **(d)** nonlinear; **(e)** linear.

2.4 **(a)** F; **(b)** F; **(c)** T; **(d)** F (only solutions that meet certain conditions such as being continuous are allowed as stationary-state wave functions); **(e)** T.

2.5 **(a)** Maximum at $x = l/2$. Minimum at $x = 0$ and $x = l$, where the ends of the box are at $x = 0$ and l.

(b) Maximum at $l/4$ and $3l/4$. Minimum at 0, $l/2$, and l.

(c) Minimum at 0, $l/3$, $2l/3$, and l. Maximum at $l/6$, $l/2$, $5l/6$.

2.6 **(a)** $\int_0^{l/4} |\psi|^2 \, dx = (2/l)\int_0^{l/4} \sin^2(n\pi x/l)\, dx = (2/l)[x/2 - (l/4n\pi)\sin(2n\pi x/l)]\Big|_0^{l/4} = 1/4 - (1/2n\pi)\sin(n\pi/2)$, where (A.2) in the Appendix was used.

(b) The $(1/2n\pi)$ factor in the probability makes the probability smaller as n increases, and the maximum probability will occur for the smallest value of n for which the sine factor is negative. This value is $n = 3$.

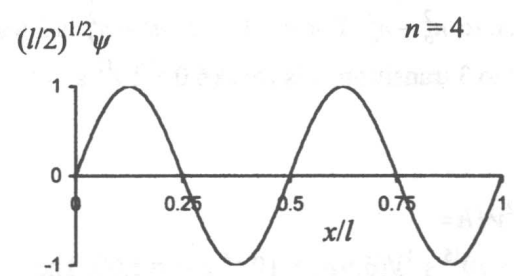
(c) 0.25.

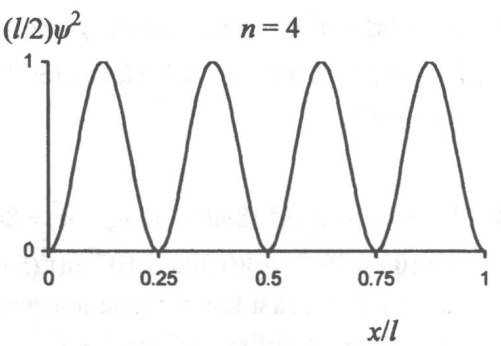
(d) The correspondence principle, since in classical mechanics the probability is uniform throughout the box.

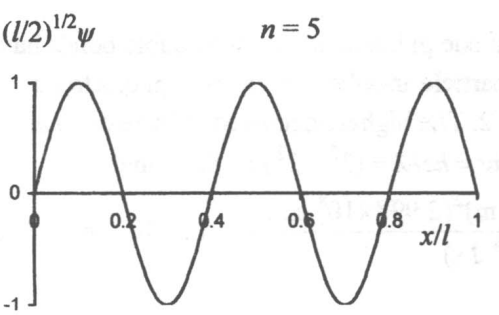
2.7 **(a)** The probability is $|\psi|^2\,dx = (2/l)\sin^2(\pi x/l)\,dx = (1/\text{Å})\sin^2(\pi \cdot 0.600/2)\cdot(0.001\ \text{Å})$ $= 6.55 \times 10^{-4}$. The number of times the electron is found in this interval is about $10^6(6.55 \times 10^{-4}) = 655$.

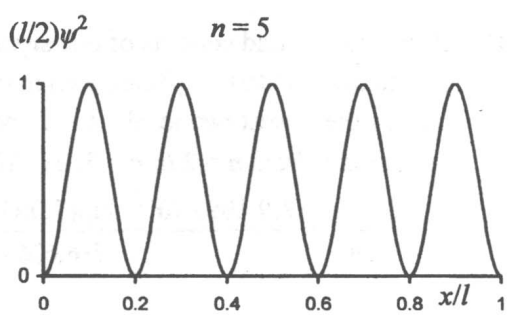
(b) The probability ratio for the two intervals is $\sin^2[\pi(1.00/2.00)]/\sin^2[\pi(0.700/2.00)]$ $= 1.260$ and about $1.260(126) = 159$ measurements will be in the specified interval.

2.8 **(a)** The number of interior nodes is one less than n.









(b) $\psi^2 = (2/l)\sin^2(4\pi x/l)$ and $d(\psi^2)/dx = (4/l)(4\pi/l)\sin(4\pi x/l)\cos(4\pi x/l)$. At $x = l/2$, $d(\psi^2)/dx = (4/l)(4\pi/l)\sin(2\pi)\cos(2\pi) = 0$.

2.9 **(a)** $E_{\text{upper}} - E_{\text{lower}} = (2^2 - 1^2)h^2/8ml^2 =$ $3(6.626 \times 10^{-34}\ \text{J s})^2/8(9.109 \times 10^{-31}\ \text{kg})(1.0 \times 10^{-10}\ \text{m})^2 = 1.81 \times 10^{-17}\ \text{J}$.

(b) $|\Delta E| = h\nu = hc/\lambda$ and $\lambda = hc/|\Delta E| =$
$(6.626 \times 10^{-34}\ \text{J s})(2.998 \times 10^{8}\ \text{m/s})/(1.81 \times 10^{-17}\ \text{J}) = 1.10 \times 10^{-8}\ \text{m} = 110\ \text{Å}$.
(c) Ultraviolet.

2.10 $E = n^2h^2/8ml^2$ and $n = (8mE)^{1/2}l/h$. We have $E = m\upsilon^2/2 = \frac{1}{2}(0.001\ \text{kg})(0.01\ \text{m/s})^2 =$
5×10^{-8} J, so $n = [8(0.001\ \text{kg})(5 \times 10^{-8}\ \text{J})]^{1/2}(0.01\ \text{m})/(6.626 \times 10^{-34}\ \text{J s}) = 3 \times 10^{26}$.

2.11 $E_{\text{upper}} - E_{\text{lower}} = h\nu = (5^2 - 2^2)h^2/8ml^2$ and $l = (21h/8m\nu)^{1/2} =$
$[21(6.626 \times 10^{-34}\ \text{J s})/8(9.1 \times 10^{-31}\ \text{kg})(6.0 \times 10^{14}\ \text{s}^{-1})]^{1/2} = 1.78 \times 10^{-9}\ \text{m} = 1.78\ \text{nm}$.

2.12 $E_{\text{upper}} - E_{\text{lower}} = h\nu = (n^2 - 1^2)h^2/8ml^2$, so $n^2 - 1 = 8ml^2\nu/h = 8ml^2c/\lambda h =$
$8(9.109 \times 10^{-31}\ \text{kg})(2.00 \times 10^{-10}\ \text{m})^2(2.998 \times 10^{8}\ \text{m/s})/[(8.79 \times 10^{-9}\ \text{m})(6.626 \times 10^{-34}\ \text{J s})]$
$= 15$. $n^2 = 16$ and $n = 4$.

2.13 $h\nu = (n_b^2 - n_a^2)h^2/8ml^2$, so ν is proportional to $n_b^2 - n_a^2$. For $n = 1$ to 2, $n_b^2 - n_a^2$ is 3 and for $n = 2$ to 3, $n_b^2 - n_a^2$ is 5. Hence for the 2 to 3 transition, ν is $(5/3)(6.0 \times 10^{12}\ \text{s}^{-1}) =$
$10 \times 10^{12}\ \text{s}^{-1}$.

2.14 $h\nu = (n_b^2 - n_a^2)h^2/8ml^2$, so $n_b^2 - n_a^2 = 8ml^2\nu/h =$
$8(9.109 \times 10^{-31}\ \text{kg})(0.300 \times 10^{-9}\ \text{m})^2(5.05 \times 10^{15}\ \text{s}^{-1})/(6.626 \times 10^{-34}\ \text{J s}) = 5.00$. The squares of the first few positive integers are 1, 4, 9, 16, 25,..., and the only two integers whose squares differ by 5 are 2 and 3.

2.15 Each double bond consists of one sigma and one pi bond, so the two double bonds have 4 pi electrons. With two pi electrons in each particle-in-a-box level, the 4 pi electrons occupy the lowest two levels, $n = 1$ and $n = 2$. The highest-occupied to lowest-vacant transition is from $n = 2$ to $n = 3$, so $|\Delta E| = h\nu = hc/\lambda = (3^2 - 2^2)h^2/8ml^2$ and

$$\lambda = \frac{8ml^2c}{5h} = \frac{8(9.109\times10^{-31}\ \text{kg})(7.0\times10^{-10}\ \text{m})^2(2.998\times10^{8}\ \text{m/s})}{5(6.626\times10^{-34}\ \text{J s})} = 3.2\times10^{-7}\ \text{m} = 320\ \text{nm}$$

2.16 Outside the box, $\psi = 0$. Inside the box, ψ is given by (2.15) as
$\psi = a\cos[\hbar^{-1}(2mE)^{1/2}x] + b\sin[\hbar^{-1}(2mE)^{1/2}x]$. Continuity requires that $\psi = 0$ at $x = -l/2$ and at $x = l/2$, the left and right ends of the box. Using (2.14), we thus have

$0 = a\cos[\hbar^{-1}(2mE)^{1/2}l/2] - b\sin[\hbar^{-1}(2mE)^{1/2}l/2]$ [Eq. (1)]

$0 = a\cos[\hbar^{-1}(2mE)^{1/2}l/2] + b\sin[\hbar^{-1}(2mE)^{1/2}l/2]$ [Eq. (2)].

Adding Eqs. (1) and (2) and dividing by 2, we get $0 = a\cos[\hbar^{-1}(2mE)^{1/2}l/2]$, so

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