1.5: Unit 1 Practice Problems

Unit 1A

Exercise 1

What is true about the Rutherford atom model?

a. It explains why atoms do not send out electromagnetic radiation permanently
b. It explains why alpha particles get scattered by atoms
c. It explains the atomic spectrum of the hydrogen atom
d. It explains the wave-particle dualism

Answer

b) It explains why alpha particles get scattered by atoms

Exercise 2

The Bohr radius (the radius of the electron orbit for the H atom in its ground state) is 5.29 x 10^{-11} m. Calculate the radius of an electron in the third shell of the H atom according to the Bohr atom model.

Answer

$r_3 = 3^2 \times 5.29 \times 10^{-11}$ m = 47.61×10^{-11} m.

Exercise 3

The electron in an H atom undergoes an electronic transition from the 3rd to the 2nd shell. What frequency does the light that is emitted have? The energy of the electron in the first shell is -2.18 x 10^{-18} J.

Answer

Energy of electron in the 3rd shell: $E_3 = -2.18 \times 10^{-18}$ J / 3^2 = -0.24×10^{-18} J

Energy of electron in the 2nd shell: $E_2 = -2.18 \times 10^{-18}$ J / 2^2 = -0.545×10^{-18} J

Energy difference between the two electrons: E_3-E_2 = 0.305×10^{-18} J

Frequency of emitted light: n=(E_3-E_2)/h = 0.305×10^{-18} J/ 6.63×10^{-34} Js = 4.60×10^{14} s^-

Exercise 4

What is the mass of a photon with a wavelength of 400 nm that travels though space?

Answer

λ = h/mc --> m = h/λc = 6.63×10^{-34}Js / (400 x 10^{-9} m x 3.00 x 10^{8} m/s) = 5.525×10^{-36} kg.

Exercise 5

Two objects are moving at the same speed. Which (if any) of the following statements are true?

a. The DeBroglie wavelength of the heavier object is longer than that of the lighter one.
b. If one object has twice as much mass as the other, its wavelength is one-half of the other
c. Doubling the speed of one of the objects will have the same effect on its wavelength as doubling its mass.

Answer

a) If one object has twice as much mass as the other, its wavelength is one-half of the other

b) Doubling the speed of one of the objects will have the same effect on its wavelength as doubling its mass

Exercise 6

The power of a red laser with a wavelength of 630 nm) is 1.00 Watt (1.00 Js). How many photons per second does the laser emit?

Answer

$\nu = c/\lambda = 3.00 \times 10^{8}$ m/s / 630×10^{-9} m $= 4.76 \times 10^{14}\ s^{-1}$

$E = h\nu = 6.63 \times 10^{-34}$ Js $\times 4.76 \times 10^{14}\ s^{-1} = 3.157 \times 10^{-19}$ J

photons = 1 J / 3.157×10^{-19} J $= 3.2 \times 10^{18}$

Unit 1B

Exercise 7

Which of the following waves would you consider to be standing matter wave?

a. The vibration of a drum.
b. Sound traveling through open air.
c. A tsunami.
d. None of the above.

Answer

a) The vibration of a drum.

Exercise 8

What are orbitals (more than one answer can be correct)?

a. Wave functions that describe the electrons as three-dimensional standing matter waves in an atom.
b. Spaces inside an atom in which the electron travels as a classical particle.
c. Solutions of the Schrödinger equation for the hydrogen atom.

Answer

a) Wave functions that describe the electrons as three-dimensional standing matter waves in an atom.

c) Solutions of the Schrödinger equation for the hydrogen atom.

Exercise 9

Which quantum numbers l are allowed when the quantum number n is 4?

Answer

l can be 3,2,1,0

Exercise 10

Which quantum numbers m are allowed when the quantum number l is 3?

Answer

-3,-2,-1,0,+1,+2,+3

Exercise 11

What is true about the following wave function?

$$\Psi = \frac{1}{\sqrt{2\pi}} \quad \frac{\sqrt{6}}{2}\cos\theta \quad \frac{4}{81\sqrt{6}a_0 3/2}\left[6-\frac{r}{a_0}\right]\frac{r}{a_0}e^{-r/3a_0}$$

a. Its does not have angular nodes
b. Its does not have spherical nodes
c. Its amplitude is 0 at the nucleus
d. The wave function represents an s orbital

Answer

c) Its amplitude is 0 at the nucleus

Exercise 12

The angular part of the wavefunction of an orbital has the following form:

$$\Theta\Phi(x,y,z) = \frac{1}{4}\sqrt{\frac{15}{\pi}}\frac{\left(x^2-y^2\right)}{r^2}$$

Which planes are the planar nodes in this orbital?

Answer

The wavefunction is 0 for x=y and x=-y. So it is two planes that bisect the x and the y axis.

Unit 1C

Exercise 13

Order the following orbitals with respect to their penetration abilities:

4s, 4p, 4d, 4f

Answer

4s > 4p > 4d > 4f

Exercise 14

What is the effective nuclear charge on an electron in an He^+ ion?

Answer

$$\sigma = 0 \rightarrow Z_{eff} = Z = 2$$

Exercise 15

Calculate the orbital energy of a 3p electron in a sulfur atom using the Slater rules.

Answer

$(1s^2)\ (2s^2\ 2p^6)\ (3s^2\ 3p^4)$

$$\sigma = 5\times0.35 + 8\times0.85 + 2\times1 = 10.55$$
$$Z_{eff} = Z - \sigma = 16 - 10.55 = 5.45$$
$$E = -\frac{Z_{eff}^2\times13.6eV}{n^2} = -\frac{5.45^2\times13.6eV}{3^2} = -44.9eV$$

Exercise 16

Calculate the orbital energy of a 3d electron in a palladium atom using the Slater rules.

Answer

$(1s^2)$ $(2s^2\ 2p^6)$ $(3s^2\ 3p^6)(3d^{10})(4s^2 4p^6)(4d^8)(5s^2)$

$$\sigma = 9\times0.35 + 18 = 21.15$$
$$Z_{eff} = Z - \sigma = 46 - 21.15 = 24.85$$
$$E = -\frac{Z_{eff}^2\times13.6eV}{n^2} = -\frac{24.85^2\times13.6eV}{3^2} = -933eV$$

Exercise 17

Calculate how much higher the first ionization energy of an oxygen atom is compared to a fluorine atom. Use the Slater rules to answer the question.

Answer

O: $(1s^2)$ $(2s^2\ 2p^4)$

$$\sigma(2p_{oxygen}) = 5\times0.35 + 2\times0.85 = 3.45$$
$$Z_{eff}(2p_{oxygen}) = Z(2p_{oxygen}) - \sigma(2p_{oxygen}) = 8 - 3.45 = 4.55$$
$$E(2p_{oxygen}) = -\frac{Z_{eff}^2\times13.6eV}{n^2} = -\frac{4.55^2\times13.6eV}{2^2} = -70.4eV$$

$$\sigma(2p_{fluorine}) = 6\times0.35 + 2\times0.85 = 3.8$$
$$Z_{eff}(2p_{fluorine}) = Z(2p_{fluorine}) - \sigma(2p_{fluorine}) = 9 - 3.8 = 5.2$$
$$E(2p_{fluorine}) = -\frac{Z_{eff}^2\times13.6eV}{n^2} = -\frac{5.2^2\times13.6eV}{2^2} = -91.9eV$$

$$E(2p_{fluorine}) - E(2p_{oxygen}) = -91.9eV - (-70.4eV) = -21.5eV$$
$$\rightarrow \Delta IE = IE_{fluorine} - IE_{oxygen} = 21.5eV$$

Dr. Kai Landskron (Lehigh University). If you like this textbook, please consider to make a donation to support the author's research at Lehigh University: Click Here to Donate.