

1. If the n quantum number of an atomic orbital is equal to 2, what are the possible values of ℓ ? What are the possible values of m_ℓ if the quantum number ℓ is equal to 3? (5 pts)

ℓ ranges from 0 to $n-1$

m_ℓ

0, 1

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

2. Give the notation (using letter designations for ℓ) for the sub-shells denoted by the following quantum numbers. (10 pts)

a) $n = 2, \ell = 0$

b) $n = 3, \ell = 2$

c) $n = 4, \ell = 3$

d) $n = 1, \ell = 0$

2s

3d

4f

1s

3. Write both the electron configurations and the orbital diagrams for the following elements in their ground states. Also, state if the element is paramagnetic or diamagnetic. (20 pts)

a) ${}_{35}\text{Br}$

$[\text{Ar}] 4s^2 3d^{10} 4p^5$

$[\text{Ar}] \begin{array}{c} [\uparrow\downarrow] \\ 4s \end{array} \begin{array}{c} [\uparrow\downarrow] \\ 3d \end{array} \begin{array}{c} [\uparrow\downarrow][\uparrow\downarrow][\uparrow\downarrow] \\ 4p \end{array}$

Paramagnetic

b) ${}_4\text{Be}$

$1s^2 2s^2$

$\begin{array}{c} [\uparrow\downarrow] \\ 1s \end{array} \begin{array}{c} [\uparrow\downarrow] \\ 2s \end{array}$ Diamagnetic

c) ${}_{14}\text{Si}$

$[\text{Ne}] 3s^2 3p^2$

$[\text{Ne}] \begin{array}{c} [\uparrow\downarrow] \\ 3s \end{array} \begin{array}{c} [\uparrow][\uparrow] \\ 3p \end{array}$

Paramagnetic

d) ${}_{10}\text{Ne}$

$1s^2 2s^2 2p^6$

$\begin{array}{c} [\uparrow\downarrow] \\ 1s \end{array} \begin{array}{c} [\uparrow\downarrow] \\ 2s \end{array} \begin{array}{c} [\uparrow\downarrow][\uparrow\downarrow][\uparrow\downarrow] \\ 2p \end{array}$

Diamagnetic

4. Use the Rydberg equation to calculate the wavelength (in nm) of a photon when a hydrogen atom undergoes a transition from $n = 3$ to $n = 5$. Clearly state if light was absorbed or emitted in this transition. Would this transition occur in the infrared or ultraviolet region of the electromagnetic spectrum? $R = 1.0967 \times 10^7 \text{ m}^{-1}$ (15 pts)

$$\frac{1}{\lambda} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

$$n_2 > n_1$$

$$\frac{1}{\lambda} = 1.0967 \times 10^7 \text{ m}^{-1} \left(\frac{1}{3^2} - \frac{1}{5^2} \right) = 1.0967 \times 10^7 \text{ m}^{-1} (0.111 - 0.040)$$

$$\frac{1}{\lambda} = 778657 \text{ m}^{-1}$$

$$\lambda = 1.28 \times 10^{-6} \text{ m} \times \frac{10^9 \text{ nm}}{1 \text{ m}} = \mathbf{1284 \text{ nm}} \quad \text{Infrared region}$$

Light was absorbed

5. If ΔE for an electronic transition in a hydrogen atom is $-3.029 \times 10^{-19} \text{ J}$, find n_f if $n_i = 3$. $R_H = 2.179 \times 10^{-18} \text{ J}$ (10 pts)

$$\Delta E = -R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

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$$-3.029 \times 10^{-19} \text{ J} = -2.179 \times 10^{-18} \text{ J} \left(\frac{1}{n_f^2} - \frac{1}{3^2} \right)$$

$$n_f = \sqrt{\frac{1}{0.2501}} \approx \mathbf{2}$$

6. An experiment shows a 113 mL gas sample has a mass of 0.171 g at a pressure of 721 mmHg and a temperature of 32 °C. Find the molar mass of the gas. (10 pts)

$$R = 0.0821 \text{ L atm/mol K}$$

$$M_w = \frac{m}{n} \quad \text{or} \quad n = \frac{m}{M_w}$$

$$PV = nRT$$

$$T = 32 + 273 = 305 \text{ K}$$

$$P = 721 \text{ mmHg} \times 1 \text{ atm}/760 \text{ mmHg} = 0.9486 \text{ atm}$$

$$PV = \frac{m}{M_w} RT \quad \text{or} \quad M_w = \frac{m RT}{V P}$$

$$M_w = \frac{(0.171 \text{ g}) \left(0.0821 \frac{\text{L atm}}{\text{mol K}}\right) (305 \text{ K})}{(0.113 \text{ L}) (0.9486 \text{ atm})} = \mathbf{39.9 \text{ g/mol}}$$

What volume will one mole of the above gas mixture occupy at STP? (5 pts)

STP (Standard Temperature and Pressure) 1 atm and 0 °C (273 K)

$$v = \frac{nRT}{P} = \frac{(1 \text{ mol}) \left(0.0821 \frac{\text{Latm}}{\text{mol K}}\right) (273 \text{ K})}{1 \text{ atm}} = \mathbf{22.4 \text{ L}}$$

7. Mothballs are composed primarily of the hydrocarbon naphthalene (C_{10}H_8). When 1.025 g of naphthalene is burned in a bomb calorimeter, the temperature of the calorimeter rises from 24.25 °C to 32.33 °C. Find ΔE_{rxn} (kJ/mol) for the combustion of naphthalene. The heat capacity of the calorimeter is 5.86 kJ/°C. (10 pts)

$$Q_{\text{cal}} = C_{\text{cal}} \Delta T$$

$$Q_{\text{cal}} = 5.86 \text{ kJ/}^\circ\text{C}(32.33 \text{ }^\circ\text{C} - 24.25 \text{ }^\circ\text{C}) = 47.3 \text{ kJ}$$

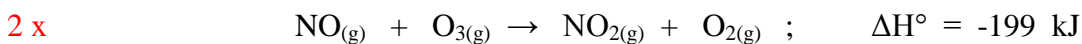
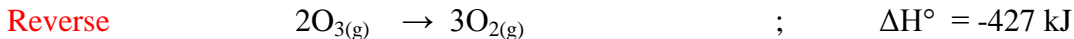
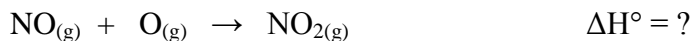
$$Q_{\text{cal}} = - Q_{\text{rxn}}$$

$$Q_{\text{rxn}} = -47.3 \text{ kJ}$$

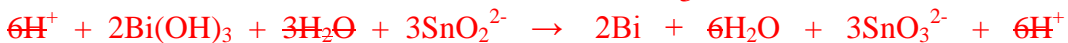
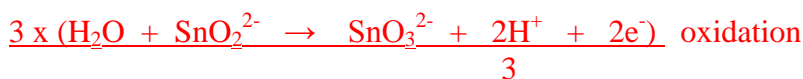
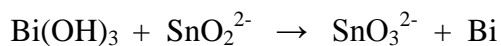
$$1.025 \text{ g} \times 1 \text{ mol}/128 \text{ g} = 8.01 \times 10^{-3} \text{ mol}$$

$$\Delta E_{\text{rxn}} = \frac{-47.3 \text{ kJ}}{8.01 \times 10^{-3}} = \mathbf{-5911 \text{ kJ/mol}}$$

8. Given the following data:

Calculate the ΔH° for the following reaction: (10 pts)

9. Balance the following redox reaction in basic media and clearly label the oxidation and reduction steps. (5 pts)



10. (Extra Credit) A system releases 415 kJ of heat and does 125 kJ of work on the surroundings. What is the change in internal energy of the system? (5 pts)

$$\Delta E = q + w = (-415 \text{ kJ}) + (-125 \text{ kJ}) = -540 \text{ kJ}$$