

1. If the n quantum number of an atomic orbital is equal to 4, what are the possible values of ℓ ? What are the possible values of m_ℓ if the quantum number ℓ is equal to 1? (5 pts)

ℓ ranges from 0 to $n-1$ m_ℓ
 0, 1, 2, 3 -1, 0, +1

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

a) $n = 3, \ell = 2$ b) $n = 2, \ell = 0$ c) $n = 2, \ell = 1$ d) $n = 4, \ell = 3$
3d 2s 2p 4f

3. Balance the following redox reactions by using the half-reaction method. Clearly label the oxidation and reduction step to receive full credit. (20 pts)

a) $\text{ClO}_3^- + \text{I}^- \rightarrow \text{I}_2 + \text{Cl}^-$ (acidic)

(Reduction) $6e^- + 6\text{H}^+ + \text{ClO}_3^- \rightarrow \text{Cl}^- + 3\text{H}_2\text{O}$

(Oxidation) $3 \times (2\text{I}^- \rightarrow \text{I}_2 + 2e^-)$

(Overall) $6\text{H}^+ + \text{ClO}_3^- + 6\text{I}^- \rightarrow 3\text{I}_2 + \text{Cl}^- + 3\text{H}_2\text{O}$

b) $\text{CrO}_4^{2-} + \text{Cu} \rightarrow \text{Cr(OH)}_3 + \text{Cu(OH)}_2$ (basic)

(Reduction) $2 \times (3e^- + 5\text{H}^+ + \text{CrO}_4^{2-} \rightarrow \text{Cr(OH)}_3 + \text{H}_2\text{O})$

(Oxidation) $3 \times (2\text{H}_2\text{O} + \text{Cu} \rightarrow \text{Cu(OH)}_2 + 2\text{H}^+ + 2e^-)$

$4\text{OH}^- + 4\text{H}^+ + 4\text{H}_2\text{O} + 2\text{CrO}_4^{2-} + 3\text{Cu} \rightarrow 2\text{Cr(OH)}_3 + 3\text{Cu(OH)}_2 + 4\text{OH}^-$

(Overall) $8\text{H}_2\text{O} + 2\text{CrO}_4^{2-} + 3\text{Cu} \rightarrow 2\text{Cr(OH)}_3 + 3\text{Cu(OH)}_2 + 4\text{OH}^-$

4. An electron has a de Broglie wavelength of 225 nm. What is the speed (velocity) of the electron in m/s? The mass of an electron is 9.11×10^{-31} kg. (10 pts)

$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$1 \text{ nm} = 10^{-9} \text{ m}$$

$$\lambda = \frac{h}{mv}$$

$$225 \text{ nm} \times 1 \text{ m}/10^9 \text{ nm} = 2.25 \times 10^{-7} \text{ m}$$

$$1 \text{ J} = \text{kg m}^2/\text{s}^2$$

$$v = \frac{h}{m\lambda} = \frac{6.626 \times 10^{-34} \text{ J s}}{(9.11 \times 10^{-31} \text{ kg})(2.25 \times 10^{-7} \text{ m})} = 3.23 \times 10^3 \text{ m/s}$$

5. An electron in the $n = 7$ level of a hydrogen atom relaxes down to a lower energy level, emitting light of 397 nm. What is the final value of n ? (15 pts)

$$R_H = 2.179 \times 10^{-18} \text{ J}$$

$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$c = 3.0 \times 10^8 \text{ m/s}$$

$$\Delta E = h\nu = h \frac{c}{\lambda}$$

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

$$397 \text{ nm} \times 1 \times 10^{-9} \text{ m}/1 \text{ nm} = 3.97 \times 10^{-7} \text{ m}$$

$$\Delta E_{\text{photon}} = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J s})(3.0 \times 10^8 \text{ m/s})}{3.97 \times 10^{-7} \text{ m}} = 5.01 \times 10^{-19} \text{ J}$$

$$\Delta E_{\text{photon}} = -\Delta E_{\text{atom}} = -5.01 \times 10^{-19} \text{ J}$$

$$\Delta E = -R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) = -5.01 \times 10^{-19} \text{ J} = -2.179 \times 10^{-18} \text{ J} \left(\frac{1}{n_f^2} - \frac{1}{7^2} \right)$$

$$n_f = \sqrt{\frac{1}{0.2503}} \approx 2$$

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)

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

$$PV = nRT$$

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

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

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

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

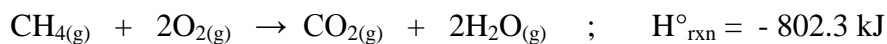
7. A syringe containing 1.55 mL of oxygen gas is cooled from 95.3 °C to 0.0 °C. What is the final volume of the oxygen gas in the syringe? Assume the pressure remains constant. (5 pts)

$$T_1 = 95.3 + 273 = 368.3 \text{ K}$$

$$T_2 = 0.0 + 273 = 273 \text{ K}$$

$$V_2 = \frac{(1.55 \text{ mL})(273 \text{ K})}{(368.3 \text{ K})} = 1.15 \text{ mL}$$

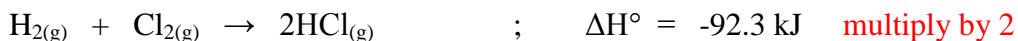
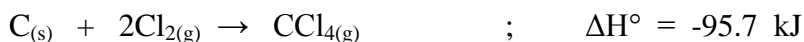
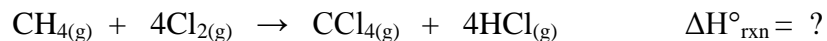
8. What mass of natural gas (CH₄) must you burn to emit 267 kJ of heat? (5 pts)



Emits energy (exothermic) = negative sign for energy

$$\frac{16 \text{ g}}{\text{mol}} \times \frac{\text{mol}}{-802.3 \text{ kJ}} \times (-267 \text{ kJ}) = 5.32 \text{ g}$$

9. Given the following data:

Calculate the $\Delta H^\circ_{\text{rxn}}$ for the following reaction: (10 pts)10. Suppose that a 25 g sample of iron is initially at 35.0 °C. What is the final temperature of the sample after releasing 14.8 J of heat? (10 pts)

Cs or S = 0.449 J/g °C

$$Q = m \times S \times \Delta T$$

Releasing energy = exothermic (negative sign)

$$-14.8 \text{ J} = 25 \text{ g} \times 0.449 \text{ J/g } ^\circ\text{C} \times (T_f - 35.0 \text{ } ^\circ\text{C})$$

$$T_f = 33.7 \text{ } ^\circ\text{C}$$

11. (Extra Credit) Draw the shapes of the p-orbitals and include axis labels. (5 pts)

