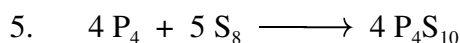


QUESTIONS ON WRITING EQUATIONS AND STOICHIOMETRY

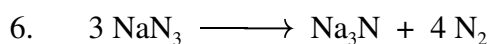
1. a. $2 \text{Na (s)} + \text{Cl}_2 \text{(g)} \longrightarrow 2 \text{NaCl (s)}$
b. $2 \text{C (s)} + \text{O}_2 \text{(g)} \longrightarrow 2 \text{CO (g)}$
c. $\text{C (s)} + \text{O}_2 \text{(g)} \longrightarrow \text{CO}_2 \text{(g)}$
d. $2 \text{K (s)} + 2 \text{H}_2\text{O (l)} \longrightarrow 2 \text{K}^+ \text{(aq)} + 2 \text{OH}^- \text{(aq)} + \text{H}_2 \text{(g)}$
e. $3 \text{H}_2 \text{(g)} + \text{N}_2 \text{(g)} \longrightarrow 2 \text{NH}_3 \text{(g)}$
f. $\text{Cl}_2\text{O}_7 \text{(l)} + 3 \text{H}_2\text{O (l)} \longrightarrow 2 \text{H}_3\text{O}^+ \text{(aq)} + 2 \text{ClO}_4^- \text{(aq)}$
g. $\text{Fe}_3\text{O}_4 \text{(s)} + 4 \text{H}_2 \text{(g)} \longrightarrow 3 \text{Fe (s)} + 4 \text{H}_2\text{O (l)}$
h. $4 \text{FeS}_2 \text{(s)} + 11 \text{O}_2 \text{(g)} \longrightarrow 2 \text{Fe}_2\text{O}_3 \text{(s)} + 8 \text{SO}_2 \text{(g)}$
2. a. $4 \text{Fe (s)} + 3 \text{O}_2 \text{(g)} \longrightarrow 2 \text{Fe}_2\text{O}_3 \text{(s)}$
b. $\text{S}_8 \text{(s)} + 8 \text{O}_2 \text{(g)} \longrightarrow 8 \text{SO}_2 \text{(g)}$
c. $\text{Na}^+ \text{(aq)} + \text{Cl}^- \text{(aq)} \longrightarrow \text{NaCl (s)}$
d. $\text{C}_2\text{H}_5\text{OH (l)} + 3 \text{O}_2 \text{(g)} \longrightarrow 2 \text{CO}_2 \text{(g)} + 3 \text{H}_2\text{O (l)}$
e. $2 \text{H}_2\text{O (l)} \longrightarrow 2 \text{H}_2 \text{(g)} + \text{O}_2 \text{(g)}$
f. $2 \text{H}_2 \text{(g)} + \text{O}_2 \text{(g)} \longrightarrow 2 \text{H}_2\text{O (l)}$
3. a. $3 \text{Mg (s)} + \text{N}_2 \text{(g)} \longrightarrow \text{Mg}_3\text{N}_2 \text{(s)}$
b. $2 \text{Bi}^{+3} \text{(aq)} + 3 \text{H}_2\text{S (g)} + 6 \text{H}_2\text{O (l)} \longrightarrow \text{Bi}_2\text{S}_3 \text{(s)} + 6 \text{H}_3\text{O}^+ \text{(aq)}$
c. $2 \text{Al (s)} + 6 \text{H}_3\text{O}^+ \text{(aq)} \longrightarrow 2 \text{Al}^{+3} \text{(aq)} + 3 \text{H}_2 \text{(g)} + 6 \text{H}_2\text{O (l)}$
d. $2 \text{C}_8\text{H}_{18} \text{(l)} + 25 \text{O}_2 \text{(g)} \longrightarrow 16 \text{CO}_2 \text{(g)} + 18 \text{H}_2\text{O (l)}$
e. $2 \text{CO}_3^{2-} \text{(aq)} + 4 \text{NO (g)} + \text{O}_2 \text{(g)} \longrightarrow 4 \text{NO}_2^- \text{(aq)} + 2 \text{CO}_2 \text{(g)}$
f. $2 \text{HCO}_3^- \text{(aq)} + \text{Cu}^{+2} \text{(aq)} \longrightarrow \text{CuCO}_3 \text{(s)} + \text{CO}_2 \text{(g)} + \text{H}_2\text{O (l)}$
g. $\text{P}_4\text{O}_{10} + 6 \text{H}_2\text{O} \longrightarrow 4 \text{H}_3\text{PO}_4$
4. A) a. If magnesium metal reacts with nitrogen gas to form magnesium nitride then three magnesium atoms will react with one molecule of nitrogen to form one formula unit of magnesium nitride.
b. If bismuth (III) ions react with hydrogen sulfide gas and water to form bismuth (III) sulfide and hydronium ions then two bismuth (III) ions will react with three molecules of hydrogen sulfide and six molecules of water to form one formula unit of bismuth (III) sulfide and six hydronium ions.
c. If aluminum reacts with hydronium ions to form aluminum (III) ions, hydrogen gas and water then two atoms of aluminum will react with six hydronium ion to form two aluminum ions, three molecules of hydrogen, and six molecules of water.

- B) a. If magnesium metal reacts with nitrogen gas to form magnesium nitride then three Moles magnesium will react with one mole of nitrogen to form one mole of magnesium nitride.
- b. If bismuth (III) ions react with hydrogen sulfide gas and water to form bismuth (III) sulfide and hydronium ions then two moles of bismuth (III) ions will react with three moles of hydrogen sulfide and six moles of water to form one mole of bismuth (III) sulfide and six moles of hydronium ions.
- c. If aluminum reacts with hydronium ions to form aluminum (III) ions, hydrogen gas and water then two moles of aluminum will react with six moles hydronium ion to form two moles of aluminum ions, three moles of hydrogen, and six moles of water.



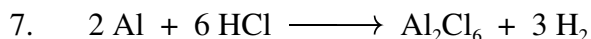
a. $0.50 \text{mol S}_8 \times \frac{4 \text{mol P}_4\text{S}_{10}}{5 \text{mol S}_8} = 0.40 \text{mol P}_4\text{S}_{10}$

b. $16.0 \text{g S}_8 \times \frac{1 \text{mol S}_8}{256.56 \text{g S}_8} \times \frac{4 \text{mol P}_4}{5 \text{mol S}_8} = 4.99 \times 10^{-2} \text{mol P}_4$



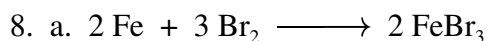
a. $0.219 \text{mol NaN}_3 \times \frac{4 \text{mol N}_2}{3 \text{mol NaN}_3} = 0.292 \text{mol N}_2$

b. $25.0 \text{g N}_2 \times \frac{1 \text{mol N}_2}{28.0134 \text{g N}_2} \times \frac{3 \text{mol NaN}_3}{4 \text{mol N}_2} = 0.669 \text{mol NaN}_3$



a. $25.0 \text{g Al} \times \frac{1 \text{mol Al}}{26.981538 \text{g Al}} \times \frac{3 \text{mol H}_2}{2 \text{mol Al}} \times \frac{2.0158 \text{g H}_2}{1 \text{mol H}_2} = 2.80 \text{g H}_2$

b. $1.00 \times 10^{24} \text{molecules H}_2 \times \frac{1 \text{mol H}_2}{6.022 \times 10^{23} \text{molecules H}_2} \times \frac{2 \text{mol Al}}{3 \text{mol H}_2} \times \frac{26.981538 \text{g Al}}{1 \text{mol Al}} = 29.9 \text{g Al}$



b. $210. \text{g Fe} \times \frac{1 \text{mol Fe}}{55.845 \text{g Fe}} \times \frac{3 \text{mol Br}_2}{2 \text{mol Fe}} \times \frac{159.808 \text{g Br}_2}{1 \text{mol Br}_2} = 901 \text{g Br}_2$

c. $210 \text{g Fe} \times \frac{1 \text{mol Fe}}{55.845 \text{g Fe}} \times \frac{2 \text{mol FeBr}_3}{2 \text{mol Fe}} \times \frac{295.557 \text{g FeBr}_3}{1 \text{mol FeBr}_3} = 1.11 \times 10^3 \text{g FeBr}_3$

d. $\% \text{theo. yield} = \frac{\text{mass FeBr}_3 \text{ recovered}}{\text{theo. yield FeBr}_3} \times 100\% = \frac{974 \text{g}}{1.11 \times 10^3 \text{g}} \times 100\% = 87.7\%$

9. a. Calculate the limiting reagent by using either of the following equations.

$$1.00 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.305 \text{ g Mg}} \times \frac{1 \text{ mol N}_2}{3 \text{ mol Mg}} \times \frac{28.0134 \text{ g N}_2}{1 \text{ mol N}_2} = 0.384 \text{ g N}_2$$

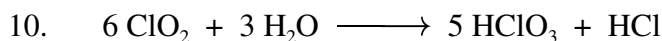
Therefore, 0.384 g of nitrogen gas is required for the complete reaction of 1.00 g of magnesium metal. Since 1.00 g N₂ is present, N₂ is in excess making the Mg the limiting reagent.

OR
$$1.00 \text{ g N}_2 \times \frac{1 \text{ mol N}_2}{28.0134 \text{ g N}_2} \times \frac{3 \text{ mol Mg}}{1 \text{ mol N}_2} \times \frac{24.305 \text{ g Mg}}{1 \text{ mol Mg}} = 2.60 \text{ g Mg}$$

Therefore, 2.60 g of magnesium metal are required for the complete reaction of 1.00 g of nitrogen gas. Since only 1.00 g of Mg is present, Mg is the limiting reagent.

b.
$$1.00 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.305 \text{ g Mg}} \times \frac{1 \text{ mol Mg}_3\text{N}_2}{3 \text{ mol Mg}} \times \frac{100.928 \text{ g Mg}_3\text{N}_2}{1 \text{ mol Mg}_3\text{N}_2} = 1.38 \text{ g Mg}_3\text{N}_2$$

- c. From part (a), 1.00 g Mg consumes 0.384 g N₂, thus, excess N₂ = 1.00 g – 0.384 g = 0.62 g N₂.



a.
$$14.3 \text{ g ClO}_2 \times \frac{1 \text{ mol ClO}_2}{67.452 \text{ g ClO}_2} \times \frac{5 \text{ mol HClO}_3}{6 \text{ mol ClO}_2} = 0.177 \text{ mol HClO}_3$$

b.
$$5.74 \text{ g HCl} \times \frac{1 \text{ mol HCl}}{36.461 \text{ g HCl}} \times \frac{3 \text{ mol H}_2\text{O}}{1 \text{ mol HCl}} \times \frac{18.0152 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 8.51 \text{ g H}_2\text{O}$$

- c. Calculate the limiting reagent by using either of the following equations.

$$4.25 \text{ g ClO}_2 \times \frac{1 \text{ mol ClO}_2}{67.452 \text{ g ClO}_2} \times \frac{3 \text{ mol H}_2\text{O}}{6 \text{ mol ClO}_2} \times \frac{18.0152 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.568 \text{ g H}_2\text{O}$$

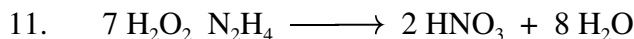
Therefore, 0.568 g of water is required for the complete reaction of 4.25 g of ClO₂. Since 0.853 g H₂O is present, H₂O is in excess making the ClO₂ the limiting reagent.

OR
$$0.853 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.0152 \text{ g H}_2\text{O}} \times \frac{6 \text{ mol ClO}_2}{3 \text{ mol H}_2\text{O}} \times \frac{67.452 \text{ g ClO}_2}{1 \text{ mol ClO}_2} = 6.39 \text{ g ClO}_2$$

Therefore, 6.39 g of ClO₂ are required for the complete reaction of 0.853 g of water. Since only 4.25 g of ClO₂ are present, ClO₂ is the limiting reagent.

Thus, the yield of HClO_3 is based on the amount of ClO_2 present and not on the amount of water.

$$4.25 \text{ g ClO}_2 \times \frac{1 \text{ mol ClO}_2}{67.452 \text{ g ClO}_2} \times \frac{5 \text{ mol HClO}_3}{6 \text{ mol ClO}_2} \times \frac{84.459 \text{ g HClO}_3}{1 \text{ mol HClO}_3} = 4.43 \text{ g HClO}_3$$

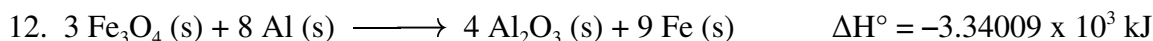


a. $0.0250 \text{ mol N}_2\text{H}_4 \times \frac{2 \text{ mol HNO}_3}{1 \text{ mol N}_2\text{H}_4} = 0.0500 \text{ mol HNO}_3$

b. $22.0 \text{ g N}_2\text{H}_4 \times \frac{1 \text{ mol N}_2\text{H}_4}{32.0450 \text{ g N}_2\text{H}_4} \times \frac{7 \text{ mol H}_2\text{O}_2}{1 \text{ mol N}_2\text{H}_4} = 4.81 \text{ mol H}_2\text{O}_2$

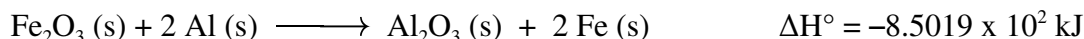
c. $1.87 \text{ mol HNO}_3 \times \frac{8 \text{ mol H}_2\text{O}}{2 \text{ mol HNO}_3} \times \frac{18.0153 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 135 \text{ g H}_2\text{O}$

d. $45.8 \text{ g HNO}_3 \times \frac{1 \text{ mol HNO}_3}{63.0128 \text{ g HNO}_3} \times \frac{7 \text{ mol H}_2\text{O}_2}{2 \text{ mol HNO}_3} \times \frac{34.0146 \text{ g H}_2\text{O}_2}{1 \text{ mol H}_2\text{O}_2} = 86.5 \text{ g H}_2\text{O}_2$



Since ΔH° is negative, the heat per mole of Fe liberated in this reaction is;

$$\frac{-\Delta H^\circ}{\# \text{ mol Fe}} = \frac{3340.09 \text{ kJ}}{9 \text{ mol Fe}} = 371.121 \text{ kJ/mol Fe}$$



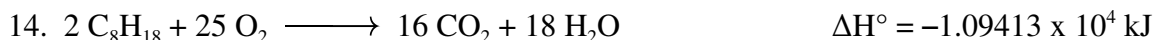
Since ΔH° is negative, the heat per mole of Fe liberated in this reaction is;

$$\frac{-\Delta H^\circ}{\# \text{ mol Fe}} = \frac{850.19 \text{ kJ}}{2 \text{ mol Fe}} = 425.10 \text{ kJ/mol Fe}$$



Since ΔH° is negative, heat will be liberated in this reaction.

$$10.0 \text{ g C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol C}_2\text{H}_5\text{OH}}{46.069 \text{ g C}_2\text{H}_5\text{OH}} \times \frac{1368 \text{ kJ}}{1 \text{ mol C}_2\text{H}_5\text{OH}} = 297 \text{ kJ} \quad \text{or } 297 \text{ kJ RELEASED}$$



Since ΔH° is negative, heat will be liberated in this reaction.

$$6.00 \text{ lb C}_8\text{H}_{18} \times \frac{453.6 \text{ g}}{1 \text{ lb}} \times \frac{1 \text{ mol C}_8\text{H}_{18}}{114.230 \text{ g C}_8\text{H}_{18}} \times \frac{1.09413 \times 10^4 \text{ kJ}}{2 \text{ mol C}_8\text{H}_{18}} = 1.30 \times 10^5 \text{ kJ} \quad \text{or } 1.30 \times 10^5 \text{ kJ RELEASED}$$



Since ΔH° is positive, heat will be absorbed in this reaction.

$$562.0 \text{ gHg} \times \frac{1 \text{ molHg}}{200.59 \text{ gHg}} \times \frac{181.58 \text{ kJ}}{2 \text{ molHg}} = 254.4 \text{ kJ} \quad \text{or } 254.4 \text{ kJ } \mathbf{ABSORBED}$$

QUESTIONS INVOLVING SOLUTIONS

16. The liquid state is usually the easiest state in which to carry out reactions.

<u>Physical State</u>	<u>Advantages</u>	<u>Disadvantages</u>
Gas	Particles in rapid motion. Therefore, particle mix and react rapidly.	Gases occupy large volumes. Special container needed to contain gases.
Solid	Solids occupy small volumes. No special container needed.	Particle movement nearly absent. Therefore, reaction very slow.
Liquid	Particles in motion. Therefore, particles mix and react reasonably fast. Volumes occupied by liquids are almost as small as solids. No special equipment needed.	????????

17. A solution is defined as a **homogeneous mixture**. The definition does not specify the physical state. Thus, a solution may be a solid, liquid or a gas mixture (as long as it is homogeneous).
18. The two components of a solution are the solvent and the solute. The distinction between them is arbitrary. The distinction is often based on the relative amounts of the two components with the solvent being present in a larger amount. Sometimes, the difference is based on the final physical state of the mixture. For example, if one of the components is a solid and the other a liquid then the distinction is made based on the state of the mixture. If the mixture is a liquid then the solvent is considered to be the liquid. If the mix is a solid then the solid is the solvent.
19. Reactions are generally carried out in the liquid state for the advantages listed in problem 1. If one or more of the reactants are gases or solids, they are converted into a **liquid solution** by dissolving them into a liquid solvent.
20. Since chemicals combine by number and not by mass it follows that one would wish to determine the moles of the various reactants present in the reaction. Furthermore, since the most convenient property to measure for a liquid is volume (see reasons for using liquid solutions above), it follows that one would need a conversion factor to convert between the volume of liquid used and the moles of solute dissolved in the solution. Therefore, molarity (M) is the most convenient concentration unit for chemists.

21. $\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{liters of solution}}$

22.
$$\text{M} = \frac{53.5 \text{ gC}_{12}\text{H}_{22}\text{O}_{11}}{746 \text{ mLsoln}} \times \frac{1 \text{ moleC}_{12}\text{H}_{22}\text{O}_{11}}{342.299 \text{ gC}_{12}\text{H}_{22}\text{O}_{11}} \times \frac{1 \text{ mLsoln}}{1 \times 10^{-3} \text{ Lsoln}} = 0.210 \text{ MC}_{12}\text{H}_{22}\text{O}_{11}$$

$$23. \text{ M} = \frac{1.45 \text{ g KCl}}{50.0 \text{ mL soln}} \times \frac{1 \text{ mole KCl}}{74.551 \text{ g KCl}} \times \frac{1 \text{ mL soln}}{1 \times 10^{-3} \text{ L soln}} = 0.389 \text{ M KCl}$$

$$24. \text{ g} = \frac{84.9947 \text{ g NaNO}_3}{1 \text{ mol NaNO}_3} \times \frac{1.00 \text{ mole NaNO}_3}{\text{L soln}} \times \frac{1 \times 10^{-3} \text{ L soln}}{1 \text{ mL soln}} \times 75.0 \text{ mL soln} = 6.37 \text{ g NaNO}_3$$

QUESTIONS INVOLVING ATOMIC MODELS

25. Electrons in energy levels close to the nucleus are of the lower energy and have lower principal quantum number, n . As the value of n increases, the electrons in these levels are further from the nucleus and are of higher energy. Therefore, energy is absorbed by the electron as it is excited from a lower energy level to a higher energy level and energy is released in the reverse process.

a) $n=2$ to $n=1$ **Energy is released** b) $n=2$ to $n=4$ **Energy is absorbed**

c) $n=2$ to $n=\infty$ **Energy is absorbed**

$$26. \text{ a) } \Delta E_{i \rightarrow f} = 2.18 \times 10^{-18} \text{ J} \left[\frac{1}{n_f^2} - \frac{1}{n_i^2} \right] .$$

$$\Delta E_{4 \rightarrow 3} = 2.18 \times 10^{-18} \text{ J} \left[\frac{1}{3^2} - \frac{1}{4^2} \right] = 1.06 \times 10^{-19} \text{ J}$$

$$\Delta E_{3 \rightarrow 2} = 2.18 \times 10^{-18} \text{ J} \left[\frac{1}{2^2} - \frac{1}{3^2} \right] = 3.03 \times 10^{-19} \text{ J}$$

$$\Delta E_{2 \rightarrow 1} = 2.18 \times 10^{-18} \text{ J} \left[\frac{1}{1^2} - \frac{1}{2^2} \right] = 1.64 \times 10^{-18} \text{ J}$$

Energy differences between adjacent levels DECREASE in magnitude as n INCREASES.
(Energy levels are progressively closer together as n increases.)

$$\text{b) } \Delta E = \frac{h \cdot c}{\lambda} \quad \text{or} \quad \lambda = \frac{h \cdot c}{\Delta E} \qquad \text{Spectral Region}$$

$$\lambda_{4 \rightarrow 3} = \frac{6.6262 \times 10^{-34} \text{ J}\cdot\text{s} \times 2.9979 \times 10^8 \text{ m/s}}{1.06 \times 10^{-19} \text{ J}} = 1.88 \times 10^{-6} \text{ m} \qquad \text{Infrared}$$

$$\lambda_{3 \rightarrow 2} = \frac{6.6262 \times 10^{-34} \text{ J}\cdot\text{s} \times 2.9979 \times 10^8 \text{ m/s}}{3.03 \times 10^{-19} \text{ J}} = 6.56 \times 10^{-7} \text{ m} \qquad \text{Visible}$$

$$\lambda_{2 \rightarrow 1} = \frac{6.6262 \times 10^{-34} \text{ J}\cdot\text{s} \times 2.9979 \times 10^8 \text{ m/s}}{1.64 \times 10^{-18} \text{ J}} = 1.21 \times 10^{-7} \text{ m} \quad \text{UV}$$

QUESTIONS ON ELECTRON CONFIGURATIONS

27. Recall that the quantum numbers have allowed values of:

$$\begin{aligned} n &= 1, 2, 3, 4, \dots \\ \ell &= 0, 1, 2, 3, \dots (n-1) \\ m_\ell &= -\ell, (-\ell + 1), \dots 0 \dots (\ell-1), \ell \\ s &= +1/2, -1/2 \end{aligned}$$

- a) $n = 4$
 $\ell = 0$
 $m_\ell = 0$ only possible value
 $s = +1/2, -1/2$ } (\therefore 2 sets of quantum numbers \therefore 2 e $^-$)
- b) $n = 4$
 $\ell = 1$
 $m_\ell = \left\{ \begin{array}{c|c|c} -1 & 0 & +1 \\ \hline s = \pm 1/2 & \pm 1/2 & \pm 1/2 \end{array} \right\}$ (\therefore 6 sets of quantum numbers \therefore 6 e $^-$)
- c) $n = 4$
 $\ell = 2$
 $m_\ell = \left\{ \begin{array}{c|c|c|c|c} -2 & -1 & 0 & +1 & +2 \\ \hline s = \pm 1/2 & \pm 1/2 & \pm 1/2 & \pm 1/2 & \pm 1/2 \end{array} \right\}$ (\therefore 10 sets of quantum numbers \therefore 10 e $^-$)
- d) $n = 4$
 $\ell = 3$
 $m_\ell = \left\{ \begin{array}{c|c|c|c|c|c|c} -3 & -2 & -1 & 0 & +1 & +2 & +3 \\ \hline s = \pm 1/2 & \pm 1/2 & \pm 1/2 & \pm 1/2 & \pm 1/2 & \pm 1/2 & \pm 1/2 \end{array} \right\}$ (\therefore 14 sets of quantum numbers \therefore 14 e $^-$)
- e) $n = 4$
 $\ell = 3$
 $m_\ell = 0$
 $s = \pm 1/2$ } (\therefore 2 sets of quantum numbers \therefore 2 e $^-$)

28. Recall that the quantum numbers have allowed values of:

$$\begin{aligned} n &= 1, 2, 3, 4, \dots \\ \ell &= 0, 1, 2, 3, \dots (n-1) \\ m_\ell &= -\ell, (-\ell + 1), \dots 0, 1, \dots \ell \\ s &= +1/2, -1/2 \end{aligned}$$

Note that ℓ is defined in terms of n , and that m_ℓ is defined in terms of ℓ and therefore m_ℓ is also limited by the value of n .

- a) $n = 2, \ell = 1, m_\ell = 0$ Fits the above requirements: \therefore allowable
- b) $n = 2, \ell = -1$ The minimum value of ℓ is 0: \therefore not allowable

- c) $n = 3, \ell = 0, m_\ell = 0$ Allowable
 d) $n = 3, \ell = 1, m_\ell = -1$ Allowable
 e) $n = 2, \ell = 0, m_\ell = -1$ If $\ell = 0, m_\ell$ must equal 0: \therefore not allowable
 f) $n = 3, \ell = 3, m_\ell = 2$ ℓ cannot equal or exceed n : \therefore not allowable

29. The ℓ quantum number designates the orbital type ($\ell = 0$ for s orbitals; $\ell = 1$ for p orbitals; $\ell = 2$ for d orbitals; $\ell = 3$ for f orbitals; etc.) and the n quantum number designates the principal electronic shell or energy level in which the orbital is found.

- a) $n = 2, \ell = 1, m_\ell = -1$ 2p orbital b) $n = 4, \ell = 0, m_\ell = 0$ 4s orbital
 c) $n = 5, \ell = 2, m_\ell = 0$ 5d orbital

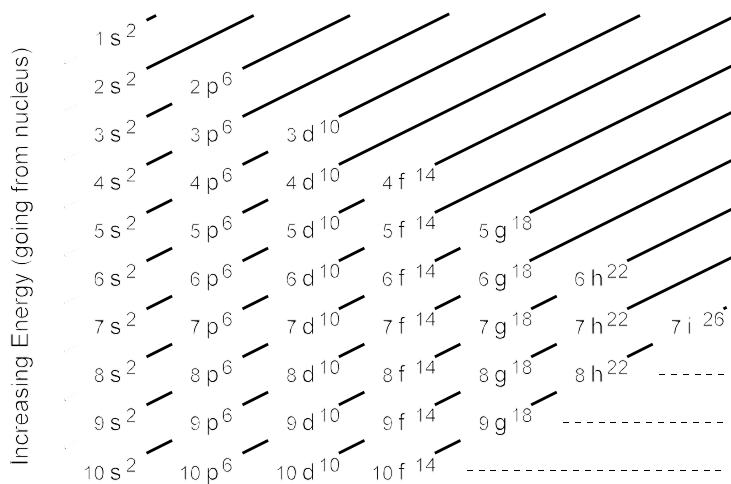
30. The ℓ quantum number designates the orbital type ($\ell = 0$ for s orbitals; $\ell = 1$ for p orbitals; $\ell = 2$ for d orbitals; $\ell = 3$ for f orbitals; etc.) and the n quantum number designates the principal electronic shell or energy level in which the orbital is found.

- a) 3s, $n = 3, \ell = 0$ b) 4p, $n = 4, \ell = 1$ c) 5d, $n = 5, \ell = 2$

31. The Pauli exclusion principle states that no two electrons in a given atom may be assigned the same set of four quantum numbers.

32.

AUFBAU ORDER



33. Hund's rule states that orbitals of a given sublevel are filled singly (with spins parallel) before pairing begins. (Since this results in the production of the maximum number of parallel spins, it is often referred to as maximum spin or maximum multiplicity.)

34. There are 3 orbitals in each p-sublevel, 5 orbitals in each d-sublevel, and 7 orbitals in each f-sublevel.

For 2, 4, and 5 electrons in a p-sublevel, the configurations would look like:



The 2 and 4 electron configurations are of equal paramagnetic character as each contains 2 unpaired electrons. The 5 electron configuration is of lower paramagnetic character as it contains only 1 unpaired electron.

For 2, 5, and 7 electrons in a d-sublevel, the configurations would look like:



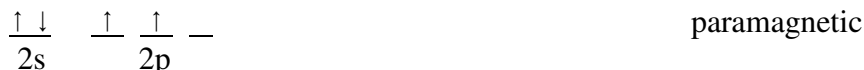
The 2 electron configuration is of lowest paramagnetic character as it has only 2 unpaired electrons. The 7 electron configuration is of next highest paramagnetic character with 3 unpaired electrons and the 5 electron configuration with its 5 unpaired electrons is of highest paramagnetic character.

For 6, 7, and 8 electrons in an f-sublevel, the configurations would be:



Here, the 6 and 8 electron configurations are of equal paramagnetic character with 6 unpaired electrons each. The 7 electron configuration is of higher paramagnetic character as it has one additional unpaired electron.

35. a) C: $1s^2 2s^2 2p^2$



- b) Cl: $1s^2 2s^2 2p^6 3s^2 3p^5$



- c) K: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$



- d) Al: $1s^2 2s^2 2p^6 3s^2 3p^1$



- e) Sr: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2$



f) Sn: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^2$

$\begin{array}{ccccccc} \uparrow\downarrow & \uparrow\downarrow & \uparrow\downarrow & \uparrow\downarrow & \uparrow\downarrow & \uparrow\downarrow & \uparrow & \uparrow & _ \\ 5s & & 4d & & & & 5p & & \end{array}$
 paramagnetic

g) V: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$

$\begin{array}{ccccccc} \uparrow\downarrow & \uparrow & \uparrow & \uparrow & _ & _ & _ \\ 4s & & 3d & & & & \end{array}$
 paramagnetic

h) Zn: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$

$\begin{array}{ccccccc} \uparrow\downarrow & \uparrow\downarrow & \uparrow\downarrow & \uparrow\downarrow & \uparrow\downarrow & \uparrow\downarrow & _ \\ 4s & & 3d & & & & \end{array}$
 diamagnetic

QUESTIONS ABOUT IONIC SUBSTANCES

36. a) Formation of a positive ion requires the removal of one or more electrons from the neutral parent atom. The remaining electrons experience a decrease in the degree of electron-electron repulsion. Consequently, the attractions between the nucleus and the valence electrons now exceed the repulsions between the valence electrons which cause the valence electrons to be drawn inward toward the nucleus and thus decreasing the radius of the ion relative to the parent atom.
- b) Formation of a negative ion requires the addition of one or more electrons to the neutral parent atom. The additional electron(s) cause an increase in the degree of electron-electron repulsions. Consequently, the repulsions between the valence electrons now exceed the attractions between the nucleus and the valence electrons. This causes the valence electrons to be pushed outward away from the nucleus and thus increasing the radius of the ion relative to the parent atom.
37. We should expect the hydrogen ion, H^+ , to be the smallest of all chemical species, since it consists of a lone proton. The hydride ion, H^- , should be larger than the He atom. Although He and H^- both have two electrons ($1s^2$), the H^- has only one proton to interact with the two electrons while He has two protons.
38. Recall that the elements in the s and p blocks tend to form ions with the noble gas configurations.
- a) Mg is in group IIA. These elements have relatively low ionization energies and unfavorable electron affinities and thus form cations. Mg can achieve a noble gas configuration (NGC) by losing two electrons. Therefore, Mg is expected to form a +2 ion (Mg^{+2}).
- b) K is in group IA. Like Mg, K is expected to form a cation but it will achieve an NGC by loss of one electron and therefore K is expected to form a +1 ion (K^+).
- c) Al is in group IIIA. Like Mg and K, Al is expected to form a cation but must lose three electrons to achieve NGC. Therefore Al is expected to form Al^{+3} ions.
- d) P is in group VA. These elements have relatively high ionization energies and favorable electron affinities and therefore form anions. P can achieve an NGC by gaining three electrons. Therefore, P is expected to form an anion with a -3 charge (P^{-3}).

e) I is in group VIIA. Like P, I is expected to form an anion but will achieve an NGC by gaining one electron and thus I is expected to form a -1 ion (I^-).

f) Te is in group VIA. Like P and I, Te is expected to form an anion but with a -2 charge (Te^{2-}).

39. Ionic compounds form only when electrical neutrality is maintained. Therefore the cations and anions must combine in such number that the compound is electrically neutral (i.e., carry no charge).

a) Ca is expected to form Ca^{+2} and S is expected to form S^{2-} . Therefore, the compound expected from Ca and S_8 is CaS .

b) Li is expected to form Li^+ and P is expected to form P^{3-} . Therefore, the compound expected from Li and P_4 is Li_3P .

c) Ga is expected to form both Ga^+ and Ga^{+3} while F is expected to form F^- . Therefore, the compounds expected from Ga and F_2 are GaF and GaF_3 .

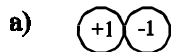
d) Mg is expected to form Mg^{+2} and N is expected to form N^{3-} . Therefore, the compound expected from Mg and N_2 is Mg_3N_2 .

e) Al is expected to form Al^{+3} and O is expected to form O^{2-} . Therefore, the compound expected from Al and O_2 is Al_2O_3 .

f) Na is expected to form Na^+ and H is expected to form H^- . Therefore, the compound expected from Na and H_2 is NaH .

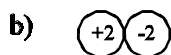
40. Recall that the force of attraction between ions is governed by Coulomb's Law.

$$F \propto \frac{q_1 q_2}{r^2}$$

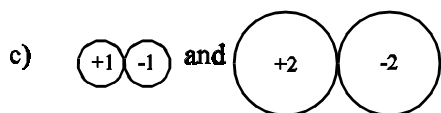


Note that when q_1 and q_2 have opposite charge the force (F) carries a negative sign (attraction) and when q_1 and q_2 have like charges the force (F) carries a positive sign (repulsion).

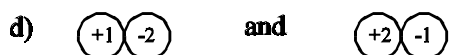
The cations and anions in each set carry the same charges so the force depends only on the sizes of the ions. In the second pair the anion is twice the size of the anion in the first pair. Therefore, the force of attraction in the first pair is twice as high as in the second pair.



The cations and anions in each set are the same size so the force depends only on the charges on the ions. In the second pair of ions the charges are twice as high as in the first pair. Thus, the force of attraction in the second pair is four times as high as in the first pair.



The charges on the ions in the second pair are twice those of the first pair. The sizes of the ions in the second pair are also twice as large as in the first pair. The effects of increased size and charge cancel making the two forces equal.



The sizes of all of the ions are the same. Therefore, the force depends only on the charges on the ions. However, $q_1 \times q_2$ is equal to -2 for each pair. Thus the forces of attraction are the same for the two pairs.

41. The following predictions are based upon interpretation of the changes in the electrostatic forces between two ions (one cation, A, and one anion, B) based on Coulomb's Law. The change in energy between each combination of ions would probably not match **QUANTITATIVELY** the changes in the ionic crystal lattice energy. Never-the-less, the electrostatic (or coulombic) changes predicted below should reflect general changes in the ionic crystal lattice energy and therefore in the general

Coulomb's Law states that,
$$F \propto \frac{q_1 q_2}{r^2}$$

- a) Doubling the charge on A doubles the force
 b) Doubling the charge on B doubles the force
 c) Doubling the charges on both A and b quadruples the force
 d) doubling the radii of both A and B doubles the interatomic distance reduces the force to one-fourth
42. The force of attraction in salts (ionic compounds) is governed by Coulomb's Law. $F \propto \frac{q_1 q_2}{r^2}$
- a) NaF; Both NaF and NaCl contain Na^+ ions and -1 ions. Therefore any difference in the forces of attraction in the two salts must depend only on the difference in sizes of the anions involved. Since the F^- ion is smaller than the Cl^- ion then by Coulomb's Law the force of attraction between Na^+ and F^- ions must be greater than the force of attraction between Na^+ and Cl^- ions.
- b) MgO; The size of $\text{Na}^+ \approx \text{Mg}^{+2}$ and the size of $\text{F}^- \approx \text{O}^{-2}$. Therefore, any difference in the forces of attraction in the two salts must be due to difference in the charges on the respective ions. In MgO the charges on both the cation and anion are twice as large as the charge on in cation and anion in NaF. Therefore, the force of attraction in MgO is approximately four times the force of attraction in NaF.
- c) KCl; Both KCl and RbBr contain $+1$ and -1 ions so again any differences in the strengths of the attractions must be due to difference in size among the ions involved. Both the cation and anion are larger in RbBr than in KCl so the force of attraction in KCl must be larger than in RbBr.
43. $\Delta(\text{EN})$ is a measure of individual bond polarity, i.e., a greater $\Delta(\text{EN})$ produces a greater bond polarity.

a)

BOND	H—F	H—C	H—H
EN of Atoms	2.1 , 4.0	2.1 , 2.5	2.1 , 2.1
$\Delta(\text{EN})$	1.9	0.4	0.0
Polarity of Bonds	H—H < H—C < H—F		

b)

BOND	P—S	Si—Cl	Al—Cl
EN of Atoms	2.1 , 2.5	1.8 , 3.0	1.5 , 3.0
$\Delta(\text{EN})$	0.4	1.2	1.5
Polarity of Bonds	P—S < Si—Cl < Al—Cl		

c)

BOND	Cl—I	P—P	C—N	O—H
EN of Atoms	3.0 , 2.5	2.1 , 2.1	2.5 , 3.0	3.5 , 2.1
$\Delta(\text{EN})$	0.5	0.0	0.5	1.4
Polarity of Bonds	P—P < Cl—I \approx C—N < O—H			

44. Recall the criteria for the prediction of bonding types:

$\Delta(\text{EN}) \geq 1.8$ means the compound is predicted to be ionic.

$\Delta(\text{EN}) \leq 1.8$ means the compound is predicted to be polar covalent.

$\Delta(\text{EN}) \approx 0.0$ means the compound is predicted to be nonpolar covalent.

a)

Compound Formula	I ₂
EN of Atoms	2.5 , 2.5
$\Delta(\text{EN})$	0.0
Bond Type	Nonpolar Covalent

b)

Compound Formula	LiCl
EN of Atoms	1.0 , 3.0
$\Delta(\text{EN})$	2.0
Bond Type	Ionic

c)

Compound Formula	MgTe
EN of Atoms	1.2 , 2.1
$\Delta(\text{EN})$	0.9
Bond Type	Polar Covalent

d)

Compound Formula	Cl ₂ O
EN of Atoms	3.0 , 3.5
$\Delta(\text{EN})$	0.5
Bond Type	Polar Covalent

e)

Compound Formula	H ₂ S
EN of Atoms	2.1 , 2.5
$\Delta(\text{EN})$	0.4
Bond Type	Polar Covalent

f)

Compound Formula	Cs ₂ O
EN of Atoms	0.7 , 3.5
$\Delta(\text{EN})$	2.8
Bond Type	Ionic

g)

Compound Formula	BCl ₃
EN of Atoms	2.0 , 3.0
$\Delta(\text{EN})$	1.0
Bond Type	Polar Covalent

h)

Compound Formula	SO ₂
EN of Atoms	2.5 , 3.5
$\Delta(\text{EN})$	1.0
Bond Type	Polar Covalent

i)

Compound Formula	Al ₂ O ₃
EN of Atoms	1.5 , 3.5
$\Delta(\text{EN})$	2.0
Bond Type	Ionic

