1. A chemist set up a synthesis of phosphorus trichloride by mixing 18.8 g of white phosphorus (P₄) with 59.4 g of chlorine gas and obtained 72.4 g of liquid phosphorus trichloride. P₄(s) + 6Cl₂(g) → 4PCl₃(l)
   a. Calculate the mass (in g) of phosphorus trichloride that can be made from the reactants.

   \[
   \text{mass}_{\text{PCl}_3} = \frac{18.8 \text{ g P}_4 \times 1 \text{ mol P}_4 \times 6 \text{ mol Cl}_2 \times 71.9 \text{ g Cl}_2}{124.9 \text{ g P}_4 \times 1 \text{ mol P}_4} = 64.6 \text{ g Cl}_2
   \]

   b. Calculate the percentage yield of the product.

   \[
   \text{actual yield} \times 100 = \frac{72.4 \text{ g PCl}_3}{74.7 \text{ g PCl}_3} \times 100 = 94.4\%
   \]

2. Which of the following sets of quantum numbers is invalid?
   a. \( n = 6, l = 2, m_l = -1, m_s = +\frac{1}{2} \)
   b. \( n = 1, l = 0, m_l = 0, m_s = -\frac{1}{2} \)
   c. \( n = 5, l = 4, m_l = 3, m_s = +\frac{1}{2} \)
   d. \( n = 4, l = 1, m_l = 0, m_s = +\frac{1}{2} \)

3. Which of the following instruments directly measures the partial pressure of a substance?
   a. Capacitance manometer
   b. Ionization gauge
   c. Mass spectrometer
   d. Barometer

4. Which one of the following sets of quantum numbers corresponds to a 6p electron?
   a. \( n = 6, l = 1, m_l = -2, m_s = +\frac{1}{2} \)
   b. \( n = 6, l = 2, m_l = 0, m_s = -\frac{1}{2} \)
   c. \( n = 5, l = 4, m_l = -1, m_s = +\frac{1}{2} \)
   d. \( n = 6, l = 1, m_l = -1, m_s = +\frac{1}{2} \)

5. A mixture of gas contains 4 moles of O₂, 5 moles of N₂, and 2 moles of CO₂. The total pressure is 12.1 atmospheres. What is the partial pressure of each gas?

   \[
   \text{Partial pressure} = \text{mole ratio (mol)} \times \text{total pressure}
   \]

   \[
   \begin{align*}
   \text{O}_2 &= \frac{4}{11} \times 12.1 = 4.40 \text{ atm} \\
   \text{CO}_2 &= \frac{2}{11} \times 12.1 = 2.2 \text{ atm} \\
   \text{N}_2 &= \frac{5}{11} \times 12.1 = 5.56 \text{ atm}
   \end{align*}
   \]
6. A 0.5 mol sample of oxygen is confined at 0°C and 1 atm in a cylinder with a movable piston. The piston compresses the gas so that the final volume is half the initial volume and the final pressure is 2.2 atm. What is the final temperature of the gas in degree Celsius?

\[ \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \]

\[ \frac{273.15}{1} \cdot \frac{1}{2} = \frac{2.2}{T_2} \]

\[ T_2 = \frac{273.15}{2} \cdot \frac{1}{2.2} \approx 59.4 \text{ K} \]

7. Consider the sine waves representing light of electromagnetic radiation. Which one corresponds to photons with the largest energy?

(a) \[ \text{E} = h \frac{\pi}{\lambda} = h (\frac{c}{\lambda}) \]

(b) \[ \text{E} = 4 \]

(c) \[ \text{E} = 3 \]

8. TRUE or FALSE: At a given temperature, all gas molecules in a sample have the same velocity.

9. Write the noble gas core electron configuration for the following species:
   a. Mg: \[ \underline{1s^2} 2s^2 2p^6 3s^2 3p^2 = \text{Ne} [3s^2] \]
   b. Zn$^{2+}$: \[ \underline{1s^2} 2s^2 2p^6 3s^2 3p^6 4s^2 3d^9 = \text{Ar} [4s^2 3d^9] \]

10. Which of the following gives the correct order for atomic radius for Mg, Na, P, Si, and Ar?
   a. Mg > Na > P > Si > Ar
   b. Ar > Si > Na > Mg
   c. Si > P > Ar > Na > Mg
   d. Na > Mg > Si > P > Ar
   e. Ar > P > Si > Mg > Na

11. Which of the following characteristics of trace analysis is incorrect?
   a. Trace analysis means measuring substances in a sample at very low levels of concentration.
   b. Trace analysis can be either destructive or non-destructive.
   c. Atomic Absorption Spectroscopy (AAS) is a form of non-destructive trace analysis.
   d. In AAS, the frequencies of light absorbed depend on the chemical identity of the elements represent.
   e. In X-ray fluorescence (XRF), atoms gain energy from X-rays, causing them to fluoresce.

12. A neon atom emits light at many wavelengths, two of which are at 616.4 and 638.3 nm. Both of these transitions are to the same final state.
   a. What is the energy difference between the two states for each transition?

   \[ E_1 = \frac{6.626 \times 10^{-34} \times 2 \times 10^6}{616.4 \times 10^{-9}} \]

   \[ E_2 = \frac{6.626 \times 10^{-34} \times 2 \times 10^6}{638.3 \times 10^{-9}} \]

   \[ \Delta E = E_2 - E_1 \]

   b. If a transition between the two higher energy states could be observed, what would be the frequency of the light?
13. When chlorine is added to acetylene, 1,1,2,2-tetrachloroethane is formed: \( 2 \text{Cl}_2(g) + C_2H_2(g) \rightarrow C_2H_2\text{Cl}_4(l) \). How many liters of chlorine will be needed to make 75.0 g of \( C_2H_2\text{Cl}_4 \)? (The pressure is 1.0 atm, and the temperature is 298 K.)

\[
75.9 \text{ g } C_2H_2\text{Cl}_4 \times \frac{1 \text{ mol } C_2H_2\text{Cl}_4}{167.6 \text{ g } C_2H_2\text{Cl}_4} \times \frac{2 \text{ mol } \text{Cl}_2}{1 \text{ mol } C_2H_2\text{Cl}_4} = 0.895 \text{ mol } \text{Cl}_2
\]

\[
\frac{PV}{nRT} = \frac{0.895 \text{ atm } \text{L}}{0.08206 \text{ atmL/molK} \times 298 \text{ K}} = 2.19 \text{ L}
\]

14. Which has the largest 2nd ionization energy between K and Ca?
   a. K
   b. Ca
   c. Both K and Ca have the same second ionization energy
   d. It's impossible to tell

15. Which atomic orbital has 3 nodal surfaces?
   a. 3s and 3p
   b. 3s and 4s
   c. 4s and 4p
   d. All p atomic orbitals

16. What is the frequency of yellow light with wavelength of 595 nm?

\[
3 \times 10^8 \text{ s}^{-1} = \left( \frac{595 \times 10^{-9} \text{ m}}{1 \text{ m}} \right) \times \lambda, \quad \lambda = \frac{595 \times 10^{-9} \text{ m}}{3 \times 10^8 \text{ s}^{-1}} = 5.04 \times 10^{-7} \text{ m}
\]

17. Which of the following is not a postulate of the kinetic molecular theory of gases?
   a. Gas molecules are in constant random motion
   b. Gas molecules are attracted to each other.
   c. Gas molecules are infinitely small.
   d. All gas molecules behave the same.
   e. Gas molecules have elastic collisions.

18. What volume of 1.57 M HCl would react completely with 22.5 g Mg?

\[
\text{Mg(s) + 2HCl(aq) \rightarrow H}_2(g) + MgCl_2(aq)
\]

\[
\frac{22.5 \text{ g Mg}}{1 \text{ mol Mg}} \times \frac{1 \text{ mol H}_2}{2 \text{ mol HCl}} = 1.85 \text{ mol H}_2
\]

\[
\frac{1.85 \text{ mol H}_2}{1.57 \text{ mol HCl}} = V
\]

\[
V = 1.17 \text{ L}
\]

19. Which ionic crystal should have the largest lattice energy?
   a. LiCl
   b. LiBr
   c. CaO
   d. SrO
   e. BaSO_4

20. The pressure in a natural gas tank is maintained at 2.20 atm. On a day when the temperature is 15°C, the volume of the gas in the tank is 3.25 cm³. What is the volume of the same quantity of gas on a day when the temperature is 31°C?

\[
\frac{V_1}{T_1} = \frac{V_2}{T_2} \Rightarrow \frac{3.25}{15+273} = \frac{V_2}{31+273}
\]

\[
V_2 \approx 3.43 \text{ cm}^3
\]

21. Which of the following conditions might we expect a gas to not behave like an ideal gas?
   a. High temperature
   b. Low temperature
   c. High pressure
   d. Both (b) and (c)
   e. All of them
22. Which electron configuration represents a violation of Hund's rule for an atom in its ground state?

a) \[ \begin{array}{c|c|c|c|c}
1s & 2s & 2p \\
\hline
\uparrow \downarrow & \uparrow \downarrow & \uparrow \uparrow \\
\end{array} \]

b) \[ \begin{array}{c|c|c|c|c}
1s & 2s & 2p \\
\hline
\uparrow \downarrow & \uparrow \downarrow & \uparrow & \uparrow \\
\end{array} \]

c) \[ \begin{array}{c|c|c|c|c}
1s & 2s & 2p \\
\hline
\uparrow \downarrow & \uparrow \downarrow & \uparrow \downarrow & \downarrow \\
\end{array} \]

d) \[ \begin{array}{c|c|c|c|c}
1s & 2s & 2p \\
\hline
\uparrow \downarrow & \uparrow \downarrow & \uparrow \downarrow & \downarrow \\
\end{array} \]

e) \[ \begin{array}{c|c|c|c|c|c}
1s & 2s & 2p \\
\hline
\uparrow & \uparrow & \uparrow & \uparrow & \uparrow & \uparrow \\
\end{array} \]

23. Which of the following is an excited-state electron configuration?
   a. \( 1s^2 2s^2 2p^2 \)
   b. \( 1s^2 2s^2 2p^5 \)
   c. \( 1s^2 2s^2 2p^3 3s^1 \)
   d. \([Ar] 4s^2 3d^{10} 4p^1 \)

24. Which of the following has the smallest ionization energy.
   a. Mg
   b. Se
   c. Br
   d. Po

25. The retina of a “predator” eye can function in nearly dark conditions, at \( 2.00 \times 10^{-17} \) J. For light of 685 nm wavelength, how many photons does this energy correspond to?

26. Which of the following species has the largest radius?
   a) Rb\(^+\) 1\underline{2} 1\underline{3} 2\underline{6} 3\underline{7} 
   b) Sr\(^{2+}\) 3\underline{6} 3\underline{7} 
   c) Br\(^-\) 3\underline{6} 3\underline{7} 
   d) Kr 3\underline{6} 3\underline{6} 
   e) Ar 1\underline{8} 1\underline{8}