1. A chemist set up a synthesis of phosphorus trichloride by mixing 18.8 g of white phosphorus \((P_4)\) with 59.4 g of chlorine gas and obtained 72.4 g of liquid phosphorus trichloride. \(P_4(s) + 6Cl_2(g) \rightarrow 4PCl_3(l)\)
   a. Calculate the mass (in g) of phosphorus trichloride that can be made from the reactants.
   b. Calculate the percentage yield of the product.

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. \(n = 5, l = 4, m_l = 3, m_s = +1\)
   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. \(n = 5, l = 1, m_l = -1, m_s = -\frac{1}{2}\)
   d. \(n = 6, l = 1, m_l = -1, m_s = +\frac{1}{2}\)

5. A mixture of gas contains 4 moles of \(O_2\), 5 moles of \(N_2\), and 2 moles of \(CO_2\). The total pressure is 12.1 atmospheres. What is the partial pressure of each gas?
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?

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

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
   b. Zn$^{2+}$

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>P>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 or 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?
    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: $2Cl_2(g) + C_2H_2(g) \rightarrow C_2H_2Cl_4(l)$. How many liters of chlorine will be needed to make 75.0 g of $C_2H_2Cl_4$? (The pressure is 1.0 atm, and the temperature is 298 K.)

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?

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?
   \[ Mg(s) + 2HCl(aq) \rightarrow H_2(g) + MgCl_2(aq) \]

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 3.25cm$^3$. What is the volume of the same quantity of gas on a day when the temperature is 31°C?

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) \(1s^2 2s^2 2p^1\)
   b) \(1s^2 2s^2 2p^6\)
   c) \(1s^2 2s^2 2p^4 3s^1\)
   d) \([Ar]\) \(4s^2 3d^{10} 4p^1\)

23. Which of the following is an excited-state electron configuration?
   a. \(1s^2 2s^2 2p^1\)
   b. \(1s^2 2s^2 2p^6\)
   c. \(1s^2 2s^2 2p^4 3s^1\)
   d. \([Ar]\) \(4s^2 3d^{10} 4p^1\)

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

25. The retina of a “predator” eye can function in nearly dark condition, 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) \(\text{Rb}^+\)
   b) \(\text{Sr}^{2+}\)
   c) \(\text{Br}^-\)
   d) \(\text{Kr}\)
   e) \(\text{Ar}\)
Extra Problems

Spring 2019 Exam

1. The complete combustion of pentane, C$_5$H$_{12}$, with oxygen produces carbon dioxide and water. The sum of the stoichiometric coefficients of the balanced equation is:
   a. 15  
   b. 20  
   c. 21  
   d. 32

2. Hydrogen peroxide, H$_2$O$_2$, decomposes completely into hydrogen and oxygen, H$_2$ and O$_2$. If 10.0 g of H$_2$O$_2$ are decomposed, how many grams of molecular oxygen (theoretical yield) can be produced?
   a. 0.941 g  
   b. 9.41 g  
   c. 10.00 g  
   d. Not enough information

3. Consider the reaction: 2 H$_2$(g) + O$_2$(g) → 2 H$_2$O(l). Which reactant is the limiting reactant if 5.0 mole of H$_2$ is combined with 2.0 mole of O$_2$ to make H$_2$O?
   a. H$_2$  
   b. O$_2$  
   c. H$_2$O  
   d. All are limiting

4. Ammonia gas can be prepared by the reaction: CaO(s) + 2 NH$_4$Cl(s) → 2 NH$_3$(g) + H$_2$O(g) + CaCl$_2$(s) If 212 g of CaO reacts with 224 g of NH$_4$Cl, which reactant is left over?
   a. CaO  
   b. NH$_4$Cl  
   c. Neither  
   d. Both

5. If 21 g of H$_2$S is burned in air (e.g. in the presence of an excess O$_2$) and 18 g of SO$_2$ forms, what is the percentage yield?
   2 H$_2$S (g) + 3 O$_2$(g) → 2 SO$_2$(g) + 2 H$_2$O(g)
   a. 46 %  
   b. 60 %  
   c. 86 %  
   d. 100 %
6. 96.0 mL of a NaOH solution of unknown concentration is titrated with 4.00 M hydrochloric acid, HCl. The end point is reached when 150.0 mL of acid are added to the base. What was the concentration of the original NaOH solution?
a. 1.56 mol/L  
b. 3.13 mol/L  
c. 6.25 mol/L  
d. 12.5 mol/L

7. A gas will behave most like an ideal gas under conditions of __________.
a. high temperature and high pressure  
b. high temperature and low pressure  
c. low temperature and high pressure  
d. low temperature and low pressure

8. A balloon originally had a volume of 4.39 L at 44.0°C and a pressure of 729 torr. The balloon must be cooled to __________°C to reduce its volume to 3.78 L (at constant pressure). Assume ideal behavior.
a. 0.00  
b. 38.0  
c. 72.9  
d. 100

9. A sample of a gas at 1.0 atm is expanded at constant temperature from 10 L to 15 L. The final pressure is __________ atm.
a. 1.5  
b. 7.5  
c. 3.3  
d. 0.67

10. How many liters will 0.25 moles of CO₂ occupy at 0.0 °C and 1.0 atmosphere of pressure? Assume ideal behavior.
a. 1.4 L  
b. 5.6 L  
c. 24 L  
d. 280 L

11. Krypton gas in a 0.500 L container has a pressure of 0.75 atm at 30°C. How many moles of gas are there in the flask? Assume ideal behavior.
a. 0.015 mol  
b. 0.020 mol  
c. 0.30 mol  
d. 0.050 mol

12. A sample of natural gas contains 3.6 mol methane, 0.43 mol ethane, and 0.27 mol propane. If the total pressure of the gases is 8.00 atm, what is the partial pressure of ethane?
a. 0.10 atm  
b. 0.40 atm  
c. 0.80 atm  
d. 1.00 atm
13. According to the kinetic molecular theory of gases, which of the following gases will have the highest average molecular speed at the same temperature, e.g. 30°C? Assume ideal behavior.
   a. SF\textsubscript{6}
   b. F\textsubscript{2}
   c. Br\textsubscript{2}
   d. All gases have the same average speed at the same temperature.

14. Rank the following types of electromagnetic radiation from lowest energy to highest photon energy: UV X-rays microwaves radio waves
   a. X-rays < UV < microwaves < radio waves
   b. microwaves < radio waves < X-rays < UV
   c. radio waves < microwaves < UV < X-rays
   d. microwaves < radio waves < UV < X-rays

15. Fill in the blanks: In a gas discharge tube (the demo we saw in class), when an electric current passes through the gas, the electrons in the gas atoms/molecules . When the electrons _______ to a lower energy state, they will simultaneously a photon.
   a. are relaxed, emit, absorb
   b. are excited, relax, emit
   c. are emitted, are excited, emit
   d. are excited, relax, absorb

16. What is the frequency $\nu$ (Hz) of red light with a wavelength of $\lambda = 715$ nm?
   a. $2.38 \text{ Å} \sim 10^{14}$ Hz
   b. $21.5 \text{ Å} \sim 10^{10}$ Hz
   c. $1.77 \text{ Å} \sim 10^{14}$ Hz
   d. $4.20 \text{ Å} \sim 10^{14}$ Hz

17. Blue light with a wavelength of $\lambda = 400$ nm causes the emission of an electron from the surface of potassium by the photoelectric effect. What is the energy in J of a blue photon with $\lambda = 400$ nm.
   a. $4.98 \text{Å} \sim 10^{-19}$ J
   b. $1.03 \text{Å} \sim 10^{-19}$ J
   c. $3.07 \text{Å} \sim 10^{-23}$ J
   d. $6.05 \text{Å} \sim 10^{-18}$ J

18. In the emission spectrum of hydrogen, there is a red line which belongs to the Balmer series. What is the wavelength ($\lambda$, nm) of this red light when the emission originates from a $n = 3$ to $n = 2$ transition.
   a. 410 nm
   b. 434 nm
   c. 486 nm
   d. 656 nm

19. Which electronic transition in the H atom emits a photon with the greatest energy?
   a. $n = 5 \rightarrow n = 1$
   b. $n = 5 \rightarrow n = 2$
   c. $n = 5 \rightarrow n = 3$
   d. $n = 5 \rightarrow n = 4$
20. An electron in which orbital is described by the following quantum numbers:
\( n = 3, l = 1, m_l = 1, m_s = -\frac{1}{2} \)?
   a. 3s
   b. 3p
   c. 3d
   d. 3f

21. Which one of the following is the correct ground-state electron configuration for a silicon (Si) atom?
   a. \([\text{Ne}] 2s^2 2p^2\)
   b. \([\text{Ne}] 3s^2 3p^4 3d^{10}\)
   c. \([\text{Ne}] 3s^2 3p^2\)
   d. \([\text{Ar}] 5s^2 5p^4 4d^{10}\)

22. Rank the following atoms from smallest atomic radius to largest atomic radius: B F Ne Na
   a. Na < Ne < F < B
   b. B < F < Ne < Na
   c. Ne < F < B < Na
   d. Na < B < F < Ne

23. How many core and valence electrons are there in a ground-state P atom?
   a. 2 and 13
   b. 8 and 5
   c. 12 and 3
   d. 10 and 5

24. Consider the periodic table. Which one of the following statements is false?
   a. Atomic size increases moving down a group.
   b. Ionization energies decrease moving right on a period.
   c. Effective nuclear charge is caused by shielding.
   d. Electron affinity increases moving right on a period.

25. Consider the alkali metals. Which of the four listed below has the smallest atomic radius?
   a. Li
   b. Na
   c. K
   d. Rb