1. (16 points) Fill in the blanks in the following equations. For coefficients of 1, please write “1” rather than leaving blank.

Example:

\[ \text{___ MgCl}_2(\_ \_) + \text{___ AgNO}_3(\_ \_) \rightarrow \text{___ ___(s)} + 1 \text{ ___(\_)} \]

Answer:

\[ 1 \text{ MgCl}_2(\text{aq}) + 2 \text{ AgNO}_3(\text{aq}) \rightarrow 2 \text{ AgCl(s)} + 1 \text{ Mg(NO}_3)_2(\text{aq}) \]

a) combustion: \[ \text{C}_6\text{H}_{12}\text{O}_6(\text{s}) + 6 \text{ O}_2(\text{g}) \rightarrow 6 \text{ CO}_2(\text{g}) + 6 \text{ H}_2\text{O(}\text{l}) \]

f) \[ \text{BaCl}_2(\text{aq}) + \text{Na}_2\text{CO}_3(\text{aq}) \rightarrow \text{BaCO}_3(\text{s}) + 2 \text{ NaCl(}\text{aq}) \]

c) \[ 1 \text{ Pb(NO}_3)_2(\text{aq}) + 2 \text{ KI(}\text{aq}) \rightarrow 2 \text{ KNO}_3(\text{aq}) + \text{ PbI}_2(\text{s}) \]

2. (5 points) SHOW ALL WORK. How much heat in kJ is needed to increase the temperature of 15.0 g of iron from 20.0 to 40.0 °C? (C_{\text{s,Fe}} = 0.4498 \text{ J/g·°C})

\[ q = m \cdot \Delta T \cdot C_s, \text{ so } q = (15.0 \text{ g})(20.0 \text{ °C})(0.4498 \text{ J/g·°C})(1 \text{ kJ/1000 J}) = 0.135 \text{ kJ} \]

3. (4 points) If a system does 35 J of work and releases 19 J of heat, what is the value of \( \Delta E \) for this change?

\[ \Delta E = -35 \text{ J} + -19 \text{ J} = -54 \text{ J} \]

4. (8 points) How does the potential energy change (increase, decrease, or no change) for each of the following?

a) Two electrons come closer together. increase
b) An electron and a proton become farther apart. increase
c) Two atomic nuclei approach each other. increase
d) a ball rolls downhill decrease
5. (6 points) **SHOW ALL WORK.** Which has more kinetic energy, a 1400 kg car moving at 115 km/h, or a 12,000 kg truck moving at 38 km/h?

\[ KE = \frac{1}{2}mv^2 \]

- Car KE = \( \frac{1}{2}(1400 \text{ kg})(115 \text{ km/h})^2 = 9.25 \times 10^6 \text{ kg}\cdot\text{km}/\text{h}^2 \)
- Truck KE = \( \frac{1}{2}(12,000 \text{ kg})(38 \text{ km/h})^2 = 8.66 \times 10^6 \text{ kg}\cdot\text{km}/\text{h}^2 \)

*Car has more kinetic energy.*

6. (4 points) Give the oxidation state of each atom in the following compounds.

- \( \text{KNO}_3 \text{ K}^{+1}, \text{ N}^{+5}, \text{ O}^{-2} \)
- \( \text{Br}_2 \text{ Br}^{0} \)
- \( \text{MgCO}_3 \text{ Mg}^{+2}, \text{ C}^{+4}, \text{ O}^{-2} \)
- \( \text{O}_3 \text{ O}^{0} \)

7. (12 points) **Briefly define the following terms.**

- **redox reaction** a reaction where electron(s) is(are) transferred from one substance to another
- **nitrogen narcosis** “rapture of the deep”—ill effects experienced by divers that get too much partial pressure of nitrogen
- **nonelectrolyte** compounds that are not ionized when dissolved in water, making a solution that is electrically nonconductive
- **calorimeter** lab instrument used to measure heat or energy of reaction by doing the reaction under insulated conditions and measuring the temperature change

8. (8 points) How would you prepare \( \text{Mg}_3(\text{PO}_4)_2 \) by a precipitation reaction? Write the balanced molecular equation.

\[ 3 \text{ Mg(NO}_3)_2(aq) + 2 \text{ K}_3\text{PO}_4(aq) \rightarrow \text{Mg}_3(\text{PO}_4)_2(s) + 6 \text{ KNO}_3(aq) \]
9. (18 points) Write balanced equations of the appropriate type for the following reactions.
   a) molecular: ammonium nitrate mixed with calcium (changed to beryllium) hydroxide

   \[2 \text{NH}_4\text{NO}_3(aq) + \text{Be(OH)}_2(s) \rightarrow 2 \text{NH}_3(g) + 2 \text{H}_2\text{O}(l) + \text{Be(NO}_3)_2(aq)\]

   b) ionic: the neutralization of nitric acid with potassium hydroxide

   \[\text{H}^+(aq) + \text{NO}_3^-(aq) + \text{K}^+(aq) + \text{OH}^-(aq) \rightarrow \text{H}_2\text{O}(l) + \text{K}^+(aq) + \text{NO}_3^-(aq)\]

   c) net ionic: the dissociation of calcium sulfide in water

   \[\text{CaS}(s) \rightarrow \text{Ca}^{2+}(aq) + \text{S}^{2-}(aq)\]

10. (8 points) **SHOW ALL WORK.** At what temperature (°C) will Xe atoms have the same average speed that Br\(_2\) molecules have at 20 °C?

   \[v_{\text{rms}} = \left(\frac{3RT}{M}\right)^{\frac{1}{2}}\]

   If the samples have the same average speed, then

   \[\left(\frac{3RT_1}{M_1}\right)^{\frac{1}{2}} = \left(\frac{3RT_2}{M_2}\right)^{\frac{1}{2}}\]

   Both sides can be squared and divided by 3R to get

   \[\frac{T_1}{M_1} = \frac{T_2}{M_2}\]

   Finally,

   \[\frac{(293 \text{ K})}{(2)(79.90 \text{ g/mol})(1 \text{ kg/1000 g})} = \frac{T_2}{(131.29 \text{ g/mol})(1 \text{ kg/1000 g})}\]

   \[T_2 = 241, \text{ convert to °C} = (241 - 273) = -32 °C\]

11. (5 points) **SHOW ALL WORK.** What is the pressure (in mm Hg) inside a container of gas connected to a mercury-filled manometer when the level in the arm connected to the container is 17.6 cm lower than the level in the arm open to the atmosphere, and the atmospheric pressure reading outside the apparatus is 754.3 mm Hg?

   17.6 cm Hg = 176 mm Hg

   If the gas being measured pushes the mercury down lower, then it is a higher pressure than the atmosphere. So, 754.3 + 176 = 930 mm Hg
12. (6 points) In an experiment, 40.0 mL of 0.270 M NaOH were mixed with 25.0 mL of 0.330 M Al$_2$(SO$_4$)$_3$. Write the net ionic equation for the reaction that takes place.

\[
\text{Al}^{3+}_{(aq)} + 3 \text{OH}^-_{(aq)} \rightarrow \text{Al(OH)}_3(s)
\]

13. (8 points) Effusion of a 1:1 mixture of two gases through a small pinhole produces the results shown below.

a.) Which gas molecules, white or shaded, have a higher average speed?

b.) If the white molecules have a molecular mass of 25 amu, what is the molecular mass of the shaded molecules?

\[
\text{a) white}
\]

\[
\text{b) } \frac{\text{rate}_{\text{white}}}{\text{rate}_{\text{shaded}}} = \frac{\text{mass}_{\text{shaded}}}{\text{mass}_{\text{white}}}^{\frac{1}{2}}
\]

The rates may be given by the number of particles that have effused through the aperture in the given time, so \( \frac{\text{rate}_{\text{white}}}{\text{rate}_{\text{shaded}}} = 6/5 \). The units of mass cancel out, so the amu units can be used. \((6/5) = \frac{\text{mass}_{\text{shaded}}}{25}^{\frac{1}{2}}\), so \( m = 36 \text{ amu} \).

14. (8 points) a. **SHOW ALL WORK.** How many milliliters of 7.50 M HNO$_3$ must be added to water to make 425 mL of 0.180 M HNO$_3$?

\[
V_iC_i = V_fC_f
\]

\[
V_i \times 7.50\text{M} = 425\text{mL} \times 0.180\text{M}
\]

\[
V_i = \frac{(425\text{mL} \times 0.180)}{7.50} = 10.2 \text{ mL}
\]

b. **Note the different wording:** How many milliliters of 7.50 M HNO$_3$ must be added to 555 mL of water to make 0.180 M HNO$_3$? **Set up the equation, do not solve it!**

\[
V_iC_i = V_fC_f
\]

\[
(7.50)(x) = (0.180)(555 + x)
\]
15. (4 points) What is the total molar concentration of ions in a 0.750 M solution of K\textsubscript{2}CO\textsubscript{3}, assuming complete dissociation?

\[ 3(0.750) = 2.25 \text{ M} \]

16. (12 points) SHOW ALL WORK. For ether (FM = 74.113), a partial pressure of 15 mm Hg results in anesthesia in 50\% of patients. What mass of ether in 10.0 L of air at STP will produce this pressure?

If partial pressure of 15 mmHg is in 1 atm of air, then the partial pressure is \((15/760) = 1.9736\%\) of the air pressure. This means that the mol fraction of ether in air must be 0.019736. To determine the total moles, use

\[ \begin{align*}
PV &= nRT \\
(1 \text{ atm})(10.0 \text{ L}) &= n(0.0821 \text{ L} \cdot \text{atm/molK})(273)
\end{align*} \]

\[ n = 0.446164 \text{ mol gas} \]

\[ \text{mol ether} = (0.019736)(0.446164) = 0.0088058 \text{ mol} \]

\[ 0.0088058 \text{ mol ether} \times (74.113 \text{ g/1 mol}) = 0.65 \text{ g ether} \]

17. (18 points) SHOW YOUR WORK. Assume that you have 1.00 g of nitroglycerin (FM = 227.08 g/mol) in a 500.0 mL steel container at 20.0 °C and 1.00 atm pressure. An explosion occurs, raising the temperature of the container and its contents to 425 °C. The balanced equation is

\[ 4 \text{ C}_3\text{H}_5\text{N}_3\text{O}_9(l) \rightarrow 12 \text{ CO}_2(g) + 10 \text{ H}_2\text{O}_2(g) + 6 \text{ N}_2(g) + \text{ O}_2(g) \]

a) How many moles of nitroglycerin and how many moles of gas (air) were in the container originally?

b) How many moles of gas are in the container after the explosion?

c) What is the pressure (in atm) inside the container after the explosion according to the ideal gas law?

d) If you consider the fact that the gas atoms actually have a nonzero attractive force between them, would you expect the observed pressure to be higher or lower than that predicted in part c? What law quantifies this?

a) \(1.00 \text{ g nitro} \times (1 \text{ mol nitro}/227.08 \text{ g nitro}) = 4.4037 \times 10^{-3} \text{ mol nitro} \)

3 sig fig: \(4.40 \times 10^{-3} \text{ mol nitro} \)

For the air, use \(PV = nRT\)

\((1)(0.5000) = n(0.0821)(293)\)

\[ n = 0.0208 \text{ mol gas (air)} \]

b) \(4.4037 \times 10^{-3} \text{ mol nitro} \times (29 \text{ mol gas}/4 \text{ mol nitro}) = 0.0319 \text{ mol of gaseous reaction products} \)

Add the reaction products to the air already in there to get \((0.0319 + 0.0208) = 0.0527 \text{ mol gas} \)

c) new temp = 425 + 273 = 698 K

\[ PV = nRT \]

\[ P = (0.0527)(0.0821)(698)/(0.5000) = 6.04 \text{ atm} \]

d) Lower, according to the Real Gas Law (also accepted Van der Waals equation, or Kinetic Theory of Gases)
CHEM 10113, Exam 2
October 5, 2011

All equations must be balanced and show phases for full credit. Significant figures count, and box your answers!

1. (16 points) Fill in the blanks in the following equations. For coefficients of 1, please write “1” rather than leaving blank.

Example:

\[
\_ \text{MgCl}_2(\text{___}) + \_ \text{AgNO}_3(\text{___}) \rightarrow \_ \_ \_ \_ \text{(s)} + 1 \_ \_ \_ \_ (\text{___})
\]

**Answer:**

\[
1 \text{MgCl}_2(\text{aq}) + 2 \text{AgNO}_3(\text{aq}) \rightarrow 2 \text{AgCl(s)} + 1 \text{Mg(NO}_3\text{)}_2(\text{aq})
\]

a) \(\text{Mg(OH)}_2(s) + 2 \text{HNO}_3(aq) \rightarrow 2 \text{H}_2\text{O(l)} + \text{Mg(NO}_3\text{)}_2(aq)\)

b) *combustion*: \(\text{C}_3\text{H}_6\text{O}_3(s) + 3 \text{O}_2(g) \rightarrow 3 \text{CO}_2(g) + 3 \text{H}_2\text{O(l)}\)

c) \(3 \text{CaCl}_2(\text{aq}) + 2 \text{K}_3\text{PO}_4(\text{aq}) \rightarrow 1 \text{Ca}_3(\text{PO}_4)_2(s) + 6 \text{KCl(s)}\)

2. (5 points) **SHOW ALL WORK.** How much heat in kJ is needed to increase the temperature of 25.0 g of lead from 30.0 to 43.5 °C? \((C_s,Pb = 0.128 \text{ J/g} \cdot ^\circ\text{C})\)

\[
q = m \cdot \Delta T \cdot C_s, \text{ so } q = (25.0 \text{ g})(13.5 \text{ °C})(0.128 \text{ J/g} \cdot ^\circ\text{C})(1 \text{ kJ/1000 J}) = 0.0432 \text{ kJ}
\]

3. (4 points) If a system does 44 J of work and receives 53 J of heat, what is the value of \(\Delta E\) for this change?

\[
\Delta E = -44 \text{ J} + 53 \text{ J} = 9 \text{ J}
\]

4. (8 points) How does the potential energy change (increase, decrease, or no change) for each of the following?

a) Two electrons become farther apart. **decrease**

b) An electron and a proton become farther apart. **increase**

c) Two atomic nuclei get farther from each other. **decrease**

d) a ball rolls downhill **decrease**
5. (6 points) **SHOW ALL WORK.** Which has more kinetic energy, a 1250 kg car moving at 105 km/h, or a 11,000 kg truck moving at 42 km/h?

KE = \( \frac{1}{2}mv^2 \)

Car KE = \( \frac{1}{2}(1250 \text{ kg})(105 \text{ km/h})^2 = 6.89 \times 10^6 \text{ kg} \cdot \text{km}^2/\text{h}^2 \)

Truck KE = \( \frac{1}{2}(11,000 \text{ kg})(42 \text{ km/h})^2 = 9.70 \times 10^6 \text{ kg} \cdot \text{km}^2/\text{h}^2 \)

The truck has more kinetic energy.

6. (4 points) Give the oxidation state of each atom in the following compounds.

\( \text{HNO}_3 \) H +1, N +5, O -2

\( \text{Ca(OH)}_2 \) Ca +2, O -2, H +1

\( \text{SO}_3 \) S +6, O -2

7. (12 points) **Briefly** define the following terms.

acid (Arrhenius definition) a supplier of H\(^+\) in water

exothermic rxn a reaction that produces heat; warms up, gives off heat to its surroundings, and \( \Delta H \) is negative

mean free path average distance between collisions of particles in a gas

titration an unknown amount of one reactant is combined exactly with a precisely measured volume of a standard solution of the other to determine the unknown concentration (or molar quantity)

8. (8 points) How would you prepare \( \text{Ag}_2\text{SO}_4 \) by a precipitation reaction? Write the balanced molecular equation.

\[ 2 \text{AgNO}_3(aq) + \text{K}_2\text{SO}_4(aq) \rightarrow \text{Ag}_2\text{SO}_4(s) + 2 \text{KNO}_3(aq) \]
9. (18 points) Write balanced equations of the appropriate type for the following reactions.

a) ionic: the neutralization of hydrochloric acid with strontium (changed to cesium) hydroxide

\[ \text{H}^+_{(aq)} + \text{Cl}^-_{(aq)} + \text{CsOH}_{(s)} \rightarrow \text{H}_2\text{O}_{(l)} + \text{Cs}^+_{(aq)} + \text{Cl}^-_{(aq)} \]

b) net ionic: the dissociation of sodium phosphate in water

\[ \text{Na}_3\text{PO}_4_{(s)} \rightarrow 3 \text{Na}^+_{(aq)} + \text{PO}_4^{3-}_{(aq)} \]

c) molecular: mercury(I) sulfide mixed with sulfuric acid

\[ \text{Hg}_2\text{S}_{(s)} + \text{H}_2\text{SO}_4_{(aq)} \rightarrow \text{H}_2\text{S}_{(g)} + \text{Hg}_2\text{SO}_4_{(aq)} \]

10. (8 points) \textbf{SHOW ALL WORK}. At what temperature (°C) will Xe atoms have the same average speed that Cl$_2$ molecules have at 15 °C?

\[ v_{\text{rms}} = \left(\frac{3RT}{M}\right)^{\frac{1}{2}} \]

If the samples have the same average speed, then
\[ \left(\frac{3RT_1}{M_1}\right)^{\frac{1}{2}} = \left(\frac{3RT_2}{M_2}\right)^{\frac{1}{2}} \]

Both sides can be squared and divided by 3R to get
\[ \frac{T_1}{M_1} = \frac{T_2}{M_2} \]

Finally,
\[ \frac{(288 \text{ K})}{(2)(35.453 \text{ g/mol})(1 \text{ kg}/1000 \text{ g})} = \frac{T_2}{(131.29 \text{ g/mol})(1 \text{ kg}/1000 \text{ g})} \]

\[ T_2 = 533, \text{ convert to °C} = (533 - 273) = 260 \text{ °C} \]

11. (5 points) \textbf{SHOW ALL WORK}. What is the pressure (in mm Hg) inside a container of gas connected to a mercury-filled manometer when the level in the arm connected to the container is 18.4 cm lower than the level in the arm open to the atmosphere, and the atmospheric pressure reading outside the apparatus is 755.1 mm Hg?

18.4 cm Hg = 184 mm Hg

If the gas being measured pushes the mercury down lower, then it is a higher pressure than the atmosphere. So, 755.1 + 184 = 939 mm Hg
12. (6 points) In an experiment, 40.0 mL of 0.270 M Na$_2$CO$_3$ were mixed with 25.0 mL of 0.330 M Al(ClO$_4$)$_3$. Write the **net ionic equation** for the reaction that takes place.

$$2 \text{Al}^{3+}_{(aq)} + 3 \text{CO}_3^{2-}_{(aq)} \rightarrow \text{Al}_2(\text{CO}_3)_3(s)$$

13. (8 points) Effusion of a 1:1 mixture of two gases through a small pinhole produces the results shown below.

a.) Which gas molecules, white or shaded, have a higher average speed?

b.) If the white molecules have a molecular mass of 49 amu, what is the molecular mass of the shaded molecules?

\[ a) \text{shaded} \]

\[ b) \left(\frac{\text{rate}_{\text{white}}}{\text{rate}_{\text{shaded}}}\right) = \left(\frac{\text{mass}_{\text{shaded}}}{\text{mass}_{\text{white}}}\right)^{\frac{1}{2}} \]

The rates may be given by the number of particles that have effused through the aperture in the given time, so \(\left(\frac{\text{rate}_{\text{white}}}{\text{rate}_{\text{shaded}}}\right) = \frac{5}{7}\). The units of mass cancel out, so the amu units can be used.

\(\frac{5}{7} = \left(\frac{\text{mass}_{\text{shaded}}}{49}\right)^{\frac{1}{2}}\), so \(m = 25\) amu.

14. (8 points) **SHOW ALL WORK.** How many milliliters of 6.00 M HNO$_3$ must be added to water to make 250 mL (3 sig fig) of 0.150 M HNO$_3$?

\[ V_iC_i = V_fC_f \]

\[ V_i*6.00M = 250mL*0.150M \]

\[ V_i = \frac{(250mL*0.150)}{6.00} = 6.25\ mL \]

b. **Note the different wording:** How many milliliters of 6.00 M HNO$_3$ must be added to 362 mL (3 sig fig) of water to make 0.150 M HNO$_3$? **Set up the equation, do not solve it!**

\[ V_iC_i = V_fC_f \]

\[ (6.00)(x) = (0.150)(362 + x) \]

15. (4 points) What is the total molar concentration of ions in a 0.650 M solution of Li$_3$PO$_4$, assuming complete dissociation?

\[ 4(0.650) = 2.60\ M \]
16. (12 points) **SHOW ALL WORK.** For chloroform (FM = 119.377), a partial pressure of 5.85 mm Hg results in anesthesia in 50% of patients. What mass of chloroform in 10.0 L of air at STP will produce this pressure?

If partial pressure of 5.85 mmHg is in 1 atm of air, then the partial pressure is \( \frac{5.85}{760} = 0.770\% \) of the air pressure. This means that the mol fraction of chloroform in air must be 0.00770. To determine the total moles, use

\[ PV = nRT \]

\[ (1 \text{ atm})(10.0 \text{ L}) = n(0.0821 \text{ L} \cdot \text{atm/molK})(273) \]

\[ n = 0.446164 \text{ mol gas} \]

\[ \text{mol chloroform} = (0.00770)(0.446164) = 0.0034342 \text{ mol} \]

\[ 0.0034342 \text{ mol chloroform} \times (119.377 \text{ g/1 mol}) = 0.410 \text{ g chloroform} \]

17. (18 points) **SHOW YOUR WORK.** Assume that you have 0.995 g of nitroglycerin (FM = 227.08 g/mol) in a 450.0 mL steel container at 25.0 °C and 1.00 atm pressure. An explosion occurs, raising the temperature of the container and its contents to 435 °C. The balanced equation is

\[ 4 \text{ C}_3\text{H}_5\text{N}_3\text{O}_9(\text{l}) \rightarrow 12 \text{ CO}_2(\text{g}) + 10 \text{ H}_2\text{O}(\text{g}) + 6 \text{ N}_2(\text{g}) + \text{ O}_2(\text{g}) \]

a) How many moles of nitroglycerin and how many moles of gas (air) were in the container originally?

b) How many moles of gas are in the container after the explosion?

c) What is the pressure (in atm) inside the container after the explosion according to the ideal gas law?

d) If you consider the fact that the gas atoms actually have a nonzero attractive force between them, would you expect the observed pressure to be higher or lower than that predicted in part c? What law quantifies this?

\[ a) 0.995 \text{ g nitro} \times (1 \text{ mol nitro/227.08 g nitro}) = 4.3817 \times 10^{-3} \text{ mol nitro} \]

3 sig fig; \( 4.38 \times 10^{-3} \text{ mol nitro} \)

For the air, use \( PV = nRT \)

\[ (1)(0.4500) = n(0.0821)(298) \]

\[ n = 0.0184 \text{ mol gas (air)} \]

\[ b) 4.3817 \times 10^{-3} \text{ mol nitro} \times (29 \text{ mol gas/4 mol nitro}) = 0.0318 \text{ mol of gaseous reaction products} \]

Add the reaction products to the air already in there to get (0.0318 + 0.0184) = 0.0502 \text{ mol gas} \]

c) new temp = 435 + 273 = 708 K

\[ PV = nRT \]

\[ P = (0.0502)(0.0821)(708)/(0.4500) = 6.48 \text{ atm} \]

d) Lower, according to the Real Gas Law (also accepted Van der Waals equation, or Kinetic Theory of Gases)
1. (16 points) Fill in the blanks in the following equations. For coefficients of 1, please write “1” rather than leaving blank.

Example:

\[ \underline{\text{MgCl}}_2(\text{aq}) + \underline{\text{AgNO}}_3(\text{aq}) \rightarrow \underline{\text{AgCl}}(\text{s}) + \underline{\text{Mg(NO}}_3\text{)}_2(\text{aq}) \]

**Answer:**

1. \( \text{MgCl}_2(\text{aq}) + 2 \text{AgNO}_3(\text{aq}) \rightarrow 2 \text{AgCl}(\text{s}) + \text{Mg(NO}_3\text{)}_2(\text{aq}) \)

a) \( \text{FeS}(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{H}_2\text{S}(\text{g}) + \text{FeSO}_4(\text{aq}) \)

b) combustion: \( \text{C}_{12}\text{H}_{22}\text{O}_{11}(\text{s}) + 12 \text{O}_2(\text{g}) \rightarrow 12 \text{CO}_2(\text{g}) + 11 \text{H}_2\text{O}(\text{l}) \)

c) \( \text{AgNO}_3(\text{aq}) + \text{KCl}(\text{aq}) \rightarrow \text{KNO}_3(\text{aq}) + \text{AgCl}(\text{s}) \)

2. (5 points) **SHOW ALL WORK.** How much heat in kJ is needed to increase the temperature of 16.4 g of copper from 22.0 to 72.5 °C? \((C_{\text{s,Cu}} = 0.387 \text{ J/g}\cdot\text{°C})\)

\[ q = m \cdot \Delta T \cdot C_s, \text{ so } q = (16.4 \text{ g})(50.5 \text{ °C})(0.387 \text{ J/g}\cdot\text{°C})(1 \text{ kJ/1000 J}) = 0.321 \text{ kJ} \]

3. (4 points) If a system does 45 J of work and receives 28 J of heat, what is the value of \( \Delta E \) for this change?

\[ \Delta E = -45 \text{ J} + 28 \text{ J} = -17 \text{ J} \]

4. (8 points) How does the potential energy change (increase, decrease, or no change) for each of the following?

a) a ball gets carried up a hill **increase**

b) Two electrons become farther apart. **decrease**

c) Two atomic nuclei get closer to each other. **increase**

d) An electron and a proton become farther apart. **increase**
5. (6 points) **SHOW ALL WORK.** Which has more kinetic energy, a 1425 kg car moving at 110 km/h, or a 13,000 kg truck moving at 36 km/h?

KE = \( \frac{1}{2}mv^2 \)

Car KE = \( \frac{1}{2}(1425 \text{ kg})(110 \text{ km/h})^2 = 8.62 \times 10^6 \text{ kg} \cdot \text{km}^2/\text{h}^2 \)

Truck KE = \( \frac{1}{2}(13,000 \text{ kg})(36 \text{ km/h})^2 = 8.42 \times 10^6 \text{ kg} \cdot \text{km}^2/\text{h}^2 \)

**car has more kinetic energy.**

6. (4 points) Give the oxidation state of each atom in the following compounds.

\[
\text{AgNO}_3 \quad \text{Ag} \ +1, \ N \ +5, \ O \ -2
\]

\[
\text{Cl}_2 \quad \text{Cl} \ 0
\]

\[
\text{SO}_4 \quad S \ +8, \ O \ -2
\]

\[
\text{AgCl} \quad \text{Ag} \ +1, \ Cl \ -1
\]

7. (12 points) **Briefly define the following terms.**

base (Arrhenius definition) **a supplier of OH\(^-\) in water**

endothermic rxn **a reaction that absorbs heat; cools down, absorbs heat from its surroundings, and \(\Delta H\) is positive**

electrolyte **compound that is fully dissociated when dissolved in water, making a solution that is electrically conductive**

barometer **is an instrument used to measure atmospheric pressure by measuring how much a column of Hg is pushed up an evacuated glass tube suspended in liquid Hg**

8. (8 points) How would you prepare \(\text{Hg}_2\text{I}_2\) by a precipitation reaction? Write the balanced molecular equation.

\[
\text{Hg}_2(\text{NO}_3)_2(\text{aq}) \ + \ 2 \ \text{KI(aq)} \ \rightarrow \ \text{Hg}_2\text{I}_2(\text{s}) \ + \ 2 \ \text{KNO}_3(\text{aq})
\]
9. (18 points) Write balanced equations of the appropriate type for the following reactions.

a) net ionic: the dissociation of lead(II) acetate in water

\[
Pb(C_2H_3O_2)_2(s) \rightarrow Pb^{2+}(aq) + 2 C_2H_3O_2^-(aq)
\]

b) ionic: the neutralization of perchloric acid with ammonia

\[
H^+(aq) + ClO_4^-(aq) + NH_3(g) \rightarrow NH_4^+(aq) + ClO_4^-(aq)
\]

*also accepted would be:*

\[
H^+(aq) + ClO_4^-(aq) + NH_4^+(aq) + OH^-(aq) \rightarrow NH_4^+(aq) + ClO_4^-(aq) + H_2O(l)
\]

c) molecular: lithium bisulfite mixed with hydroiodic acid

\[
LiHSO_3(aq) + HI(aq) \rightarrow SO_2(g) + H_2O(l) + LiI(aq)
\]

10. (8 points) **SHOW ALL WORK.** At what temperature (°C) will Xe atoms have the same average speed that F\(_2\) molecules have at 10.0 °C?

\[
v_{rms} = \left(\frac{3RT}{M}\right)^{\frac{1}{2}}
\]

If the samples have the same average speed, then

\[
(3RT_1/M_1)\frac{1}{2} = (3RT_2/M_2)\frac{1}{2}
\]

Both sides can be squared and divided by 3R to get

\[
T_1/M_1 = T_2/M_2
\]

Finally,

\[
\frac{(283 \text{ K})}{(2)(19.00 \text{ g/mol})(1 \text{ kg/1000 g})} = T_2/(131.29 \text{ g/mol})(1 \text{ kg/1000 g})
\]

\[
T_2 = 978, \text{ convert to °C } = (978 - 273) = 705 \text{ °C}
\]

11. (5 points) **SHOW ALL WORK.** What is the pressure (in mm Hg) inside a container of gas connected to a mercury-filled manometer when the level in the arm connected to the container is 17.1 cm lower than the level in the arm open to the atmosphere, and the atmospheric pressure reading outside the apparatus is 756.6 mm Hg?

17.1 cm Hg = 171 mm Hg

If the gas being measured pushes the mercury down lower, then it is a higher pressure than the atmosphere. So, 756.6 + 171 = **928 mm Hg**
12. (6 points) In an experiment, 40.0 mL of 0.270 M BeCl$_2$ were mixed with 25.0 mL of 0.330 M Ag$_2$SO$_4$. Write the net ionic equation for the reaction that takes place.

$$\text{Ag}^+\text{(aq)} + \text{Cl}^-\text{(aq)} \rightarrow \text{AgCl(s)}$$

13. (8 points) Effusion of a 1:1 mixture of two gases through a small pinhole produces the results shown below.

a.) Which gas molecules, white or shaded, have a higher average speed?
b.) If the white molecules have a molecular mass of 16 amu, what is the molecular mass of the shaded molecules?

![Diagram of gas molecules]

**a) white**

**b) \((\text{rate}_{\text{white}}/\text{rate}_{\text{shaded}}) = (\text{mass}_{\text{shaded}}/\text{mass}_{\text{white}})^{\frac{1}{2}}\)**

The rates may be given by the number of particles that have effused through the aperture in the given time, so \((\text{rate}_{\text{white}}/\text{rate}_{\text{shaded}}) = 7/4\). The units of mass cancel out, so the amu units can be used.

\((7/4) = (\text{mass}_{\text{shaded}}/16)^{\frac{1}{2}}, \text{ so } m = 49 \text{ amu.}\)

14. (8 points) **SHOW ALL WORK.** How many milliliters of 5.20 M HNO$_3$ must be added to water in order to make 400 mL (3 sig fig) of 0.300 M HNO$_3$?

\[V_iC_i = V_fC_f\]

\[V_i \times 5.20M = 400mL \times 0.300M\]

\[V_i = \frac{(400mL \times 0.300)}{5.20} = 23.1 \text{ mL}\]

**b. Note the different wording:** How many milliliters of 5.20 M HNO$_3$ must be added to 144 mL of water to make 0.300 M HNO$_3$? **Set up the equation, do not solve it!**

\[V_iC_i = V_fC_f\]

\[(5.20)(x) = (0.300)(144 + x)\]

15. (4 points) What is the total molar concentration of ions in a 0.850 M solution of (NH$_4$)$_2$S, assuming complete dissociation?

\[3(0.850) = 2.55 \text{ M}\]
16. (12 points) SHOW ALL WORK. For halothane (FM = 197.381), a partial pressure of 5.70 mm Hg results in anesthesia in 50% of patients. What mass of halothane in 10.0 L of air at STP will produce this pressure?

If partial pressure of 5.70 mmHg is in 1 atm of air, then the partial pressure is (5.70/760) = 0.750% of the air pressure. This means that the mol fraction of halothane in air must be 0.00750. To determine the total moles, use

\[ PV = nRT \]

\[ (1 \text{ atm})(10.0 \text{ L}) = n(0.0821 \text{ L} \cdot \text{atm/molK})(273) \]

\[ N = 0.446164 \text{ mol gas} \]

\[ \text{Mol halothane} = (0.00750)(0.446164) = 0.00334623 \text{ mol} \]

\[ 0.00334623 \text{ mol halothane} \times (197.381 \text{ g}/1 \text{ mol}) = 0.660 \text{ g halothane} \]

17. (18 points) SHOW YOUR WORK. Assume that you have 1.25 g of nitroglycerin (FM = 227.08 g/mol) in a 550.0 mL steel container at 20.0 °C and 1.00 atm pressure. An explosion occurs, raising the temperature of the container and its contents to 455 °C. The balanced equation is

\[ 4 \text{ C}_3\text{H}_5\text{N}_3\text{O}_9(\text{l}) \rightarrow 12 \text{ CO}_2(\text{g}) + 10 \text{ H}_2\text{O}(\text{g}) + 6 \text{ N}_2(\text{g}) + \text{ O}_2(\text{g}) \]

a) How many moles of nitroglycerin and how many moles of gas (air) were in the container originally?

b) How many moles of gas are in the container after the explosion?

c) What is the pressure (in atm) inside the container after the explosion according to the ideal gas law?

d) If you consider the fact that the gas atoms actually have a nonzero attractive force between them, would you expect the observed pressure to be higher or lower than that predicted in part c? What law quantifies this?

a) \[ 1.25 \text{ g nitro} \times (1 \text{ mol nitro}/227.08 \text{ g nitro}) = 5.50466 \times 10^{-3} \text{ mol nitro} \]

3 sig fig: \[ 5.50 \times 10^{-3} \text{ mol nitro} \]

For the air, use \[ PV = nRT \]

\[ (1)(0.5500) = n(0.0821)(293) \]

\[ n = 0.0229 \text{ mol gas (air)} \]

b) \[ 5.50466 \times 10^{-3} \text{ mol nitro} \times (29 \text{ mol gas}/4 \text{ mol nitro}) = 0.0399 \text{ mol of gaseous reaction products} \]

Add the reaction products to the air already in there to get \( (0.0399 + 0.0229) = 0.0628 \text{ mol gas} \)

c) new temp = 455 + 273 = 728 K

\[ PV = nRT \]

\[ P = (0.0628)(0.0821)(728)/(0.5500) = 6.82 \text{ atm} \]

d) Lower, according to the Real Gas Law (also accepted Van der Waals equation, or Kinetic Theory of Gases)