CHEMISTRY 103 – Practice Problems #2 (Modules: 4-7)
Stoichiometry (Part II)-Concentration; Gases; Thermochemistry;
Light, Matter, and Electronic Structure (Part I)
Do the topics appropriate for your course
Prepared by Dr. Tony Jacob
https://clc.chem.wisc.edu (Resource page)

Suggestions on preparing for a chemistry exam:
1. Organize your materials (quizzes, notes, etc.).
2. Usually, a good method to prepare for a chem exam is by doing lots of problems. Re-reading sections of the online text or watch video segments is fine, but re-reading large amounts or re-watching a lot of videos takes up time generally better spent doing problems.
3. Practice exams/problems posted by your instructor should be completely worked through as they give you a sense of the exam length, how difficult the problems can be, and the questions’ style. Quizzes written by your instructor should also be re-worked. Good Luck!

STOICHIOMETRY- Concentration
1. How many grams of NaCl are required to produce a 100. ml solution with a NaCl concentration of 1.00 x 10^{-2} M?
   a. 0.0585 g  
   b. 1.00 x 10^{-3} g  
   c. 1.00 g  
   d. 58.5 g  
   e. 100. g

2. If the concentration of ammonium phosphate is 0.30M, what is the concentration of all ions?
   a. 0.10M  
   b. 0.15M  
   c. 0.30M  
   d. 0.90M  
   e. 1.20M

3. Five solutions were prepared as shown below. Use these solutions to answer the question below.
   i. 1.00mol K_2SO_4 dissolved into 1.0L water
   ii. 1.00mol K_2SO_4 dissolved into 500ml water
   iii. 2.00mol K_2SO_4 dissolved into 2.0L water
   iv. 0.25mol K_2SO_4 dissolved into 100ml water
   v. 0.50mol K_2SO_4 dissolved into 100ml water

I. Which solution has the greatest concentration of K_2SO_4?
   a. i  
   b. ii  
   c. iii  
   d. iv  
   e. v

II. Which solution has the smallest concentration of K_2SO_4?
   a. i  
   b. ii  
   c. iii  
   d. iv  
   e. v

III. Which solutions have the same concentrations of K_2SO_4?
   a. iii, iv  
   b. i, ii  
   c. i, ii, iii  
   d. i, iii  
   e. none have the same

4. In lab, you obtain a 3.50 x 10^{-2}M solution of AgNO_3. You take 5.00ml using an Eppendorf pipette, add it to a 50.00ml volumetric flask, and dilute to the mark with deionized water. You then do one more dilution using the same volumes listed above. What is the final concentration of the AgNO_3 solution?
   a. 3.50 x 10^{-2}M  
   b. 3.50M  
   c. 3.50 x 10^{-3}M  
   d. 0.125M  
   e. 3.50 x 10^{-4}M

5. How much water must be added to a 3.30M NaCl solution to generate 150ml of a 1.10M NaCl solution?
   a. 25ml  
   b. 50ml  
   c. 75ml  
   d. 100ml  
   e. 15ml

6. If it takes 25.5ml of 0.250M H_2SO_4 to completely neutralize 35.0ml of a NaOH solution, what was the concentration of the NaOH solution?
   a. 0.0910M  
   b. 0.182M  
   c. 0.686M  
   d. 0.364M  
   e. 0.250M

(coffee time!)
7. If it takes 20. ml of a 0.10M $\text{H}_3\text{PO}_4$ solution to completely neutralize 0.060M $\text{Ba(OH)}_2$ solution, what volume in ml of $\text{Ba(OH)}_2$ was present?
   a. 22ml  
   b. 50.ml  
   c. 33ml  
   d. 20.L  
   e. 20ml

8. What volume (ml) of 0.750M $\text{H}_2\text{SO}_4(aq)$ is required to react completely with 10.5g $\text{Al(OH)}_3(s)$?
   
   $2\text{Al(OH)}_3(s) + 3\text{H}_2\text{SO}_4(aq) \rightarrow 6\text{H}_2\text{O(l)} + \text{Al}_2(\text{SO}_4)_3(aq)$
   
   a. 750. ml  
   b. 180. ml  
   c. 269ml  
   d. 135ml  
   e. 120. ml

9. It is found that 66.85ml of a 0.01150M NaOH solution was needed to completely react with 0.02511g of a triprotic acid, $\text{H}_3\text{A}$. What is the molar mass of this unknown acid?

10. 250.ml 1.50M $\text{AgNO}_3(aq)$ solution was mixed with 150.ml of a 1.75M $\text{Na}_2\text{S}(aq)$ solution and yields a solid.
   a. Write the balanced molecular reaction.
   b. How many moles of the solid product was formed?
   c. Which reactant was the limiting reactant?
   d. How many moles of the excess reactant is left over?
   e. What is the concentration of the excess reactant?

**GASES (PART I)-Gas laws, stoichiometry**

1. A valve between a 10L tank and another 20L tank is opened. In the 10L tank there was 600torr $\text{O}_2(g)$. Assuming the temperature remains constant, what is the final pressure in the tanks after the value is opened?
   a. 600torr  
   b. 400torr  
   c. 300torr  
   d. 200torr  
   e. 100torr

2. Two different gases have equal volumes at the same pressure and temperature. The gases will have the same:
   a. boiling point  
   b. melting point  
   c. mass  
   d. density  
   e. number of molecules

3. What is the relationship between temperature and volume?
   a. $T \propto \frac{1}{V}$  
   b. $T \propto V^2$  
   c. $T \propto \frac{1}{V^2}$  
   d. $T \propto V$  
   e. $T \propto \exp(V)$

4. What is the new pressure if a container’s volume is tripled and temperature (in K) is cut to $\frac{1}{4}$ of its original value?
   a. unchanged.  
   b. $\frac{3}{4}$ times the original pressure.  
   c. $\frac{4}{3}$ times the original pressure.  
   d. $\frac{1}{12}$ times the original pressure.  
   e. 12 times the original pressure.

5. What volume does $1.0 \times 10^2g$ of $\text{SO}_2(g)$ at 750torr and 95˚C occupy?
   a. 3100L  
   b. 12L  
   c. 0.063L  
   d. 48L  
   e. 3400L

6. Which samples of gas below have the same number molecules if the samples are all at the same temperature?
   i. 4.00L $\text{CH}_4(g)$ at 1.0atm  
   ii. 6.00L $\text{SO}_2(g)$ at 0.5atm  
   iii. 3.00L $\text{O}_3(g)$ at 1.0atm  
   iv. 4.00L $\text{O}_3(g)$ at 2.0atm
   a. i, v  
   b. i, iii  
   c. ii, iii  
   d. iii, iv  
   e. ii, iii, iv

*(ice cream time!)*
7. Which relationship(s) shown below are **CORRECT**?
   i. Molar mass is inversely proportional to Density
   ii. Pressure is directly proportional to Temperature
   iii. Moles are directly proportional to Volume
   iv. Density is inversely proportional to Temperature

   a. i, ii, iii  
   b. i, iii, iv  
   c. ii, iii  
   d. i, ii, iv  
   e. i, iii

8. A balloon filled with air is placed in a tray and liquid nitrogen is poured over the balloon, and the balloon starts to collapse. This can best be explained by:
   a. The liquid nitrogen has weakened the polymers that make up the balloon causing it to lose its structural integrity.
   b. The liquid nitrogen causes the O₂(g) and N₂(g) within the balloon to react and form N₂O₂(g) and thereby reduces the number of moles within the balloon causing it to collapse.
   c. The liquid nitrogen lowers the temperature of the O₂(g) and N₂(g) molecules and creates a vacuum within the balloon which causes the sides of the balloon to be pulled in.
   d. The liquid nitrogen causes the O₂(g) and N₂(g) to move slower and lowers the pressure within the balloon such that the outside pressure is greater than the inside pressure causing the balloon to collapse.

9. Which graph best depicts the relationship between pressure and temperature?

![Graph A](image1)

![Graph B](image2)

![Graph C](image3)

![Graph D](image4)

![Graph E](image5)

10. A gas in a non-rigid container (i.e., it can expand/contract) is cooled. What occurs to the **density** of the gas?
   a. increases  
   b. decreases  
   c. stays the same  
   d. depends on the gas  
   e. depends on the moles

11. During an experiment, 3.07g of gas occupied 2.56L at 25.0°C and 700. torr. What is the gas?
   a. N₂  
   b. CO₂  
   c. Kr  
   d. O₂  
   e. C₂H₂

12. Which gas will have the **smallest density** if the gases have the same volumes, temperature, and pressure?
   a. CH₄(g)  
   b. C₃H₈(g)  
   c. C₂H₂(g)  
   d. Ne(g)  
   e. All would have the same density since they are under the same conditions.

13. How many gas molecules are in a 1.74L gas sample at 0.136atm and 25.0°C?
   a. 5.82 x 10²¹  
   b. 0.00967  
   c. 6.94 x 10²²  
   d. 6.23 x 10²⁵  
   e. 103
14. Given the following reaction: \(2\text{Mn}_2\text{O}_3(s) \rightarrow 4\text{Mn(s)} + 3\text{O}_2(g)\), what is the final volume of the \(\text{O}_2(g)\) if 25.0mol of \(\text{Mn}_2\text{O}_3(s)\) is reacted and the gas is collected at 1.50atm and 25.0°C?

15. Using the reaction \(\text{P}_4\text{S}_3(s) + 8\text{O}_2(g) \rightarrow \text{P}_4\text{O}_{10}(s) + 3\text{SO}_2(g)\), how many grams \(\text{P}_4\text{S}_3(s)\) are needed to produce 10.0L of \(\text{SO}_2(g)\) at 25.0°C and 700. torr?
   a. 0.125g   b. 27.6g   c. 82.8g   d. 195g   e. 2.10 \times 10^4g

16. A C, H, and N compound contains 72.71%C and 6.10%H by mass. When 1.250g of this compound in the gas phase at 105.00°C was placed in a 250.0ml glass vessel the resulting pressure was 1.175atm. What is the molecular formula of the compound?

**GASES (PART II)-Partial pressure, velocity, ppm**

1. What is the partial pressure (in torr) of oxygen in a container that contains 2.0mol oxygen gas, 3.0mol nitrogen gas, and 1.0mol carbon dioxide gas with a total pressure of 900torr?
   a. 100torr   b. 200torr   c. 300torr   d. 400torr   e. 600torr

2. Two glass bulbs are separated by a valve; one bulb (\(V = 7.5L\)) contains \(\text{SO}_2(g)\) at 4.5atm and the second bulb (\(V = 12.0L\)) contains \(\text{NH}_3(g)\) at 6.0atm. When the valve is opened the two gases mix. What is the total pressure of the system once the gases have mixed?
   a. 4.5atm   b. 5.25atm   c. 5.4atm   d. 6.0atm   e. none of these

3. If the gases below were in one container, which will have the greatest partial pressure?  
   *(Hint: No calculation needed.)*
   a. 1.0g \(\text{CO}(g)\)   b. 1.0g \(\text{O}_2(g)\)   c. 1.0g \(\text{Ar}(g)\)   d. 1.0g \(\text{N}_2\text{O}(g)\)   e. all have the same

4. A glass container has both \(\text{O}_2(g)\) and \(\text{Ne}(g)\) mixed together. The partial pressure of \(\text{O}_2(g)\) is 2.0atm and the partial pressure of \(\text{Ne}(g)\) is 4.0atm. Additional \(\text{Ne}(g)\) is now added to the container until its partial pressure is doubled while the volume and temperature are held constant. After this has occurred, what is the partial pressure of \(\text{O}_2(g)\)?
   a. 0.67atm   b. 1.34atm   c. 2.0atm   d. 4.0atm   e. 8.0atm

5. A flask contains 4 gases: \(\text{Ne}(g), \text{He}(g), \text{O}_2(g),\) and \(\text{N}_2(g)\). The total pressure is 8.5atm and \(P_{\text{Ne}} = P_{\text{He}} = 2.0\text{atm}\) and \(P_{\text{O}_2} = 1.5\text{atm}\). What is the mol fraction of \(\text{N}_2(g)\)?
   a. 0.59   b. 2.8   c. 0.25   d. 0.35   e. need T and V
   *(have an apple)*
6. A container with CO₂(g) has more CO₂(g) added while the volume and temperature are held constant. Select ALL statements that are CORRECT.

   i. As CO₂(g) is added the total kinetic energy of the molecules will increase.
   ii. As CO₂(g) is added the heat capacity will increase.
   iii. As CO₂(g) is added the density will increase.
   iv. As CO₂(g) is added the velocity of the CO₂(g) will increase.

   a. i, ii
   b. i, iii, iv
   c. ii, iii
   d. ii, iv
   e. i, ii

7. Place the following gases in order of decreasing velocities: CO₂(g) N₂H₄(g) Kr(g) C₂H₆(g)

   greatest velocity  smallest velocity
   a. CO₂ > Kr > C₂H₆ > N₂H₄
   b. Kr > CO₂ > N₂H₄ > C₂H₆
   c. N₂H₄ > CO₂ > C₂H₆ > Kr
   d. C₂H₆ > N₂H₄ > CO₂ > Kr
   e. C₂H₆ > CO₂ > N₂H₄ > Kr

8. What is the temperature of a gas (molar mass = 72.0 g/mol) with a velocity of 525 m/s?

   a. 1.52K  b. 796K  c. 1520K  d. 7.96 x 10⁴ K  e. 8.06 x 10⁴ K

9. Which system will have the greatest average kinetic energy? All systems contain 1.0 mol of gas at STP.

   a. H₂(g)  b. He(g)  c. CO(g)  d. CO₂(g)  e. all are the same

10. What is the total kinetic energy of O₂(g) in a 1.5 L container at 50.0 °C under 0.75 atm pressure?

    a. 4030J  b. 171J  c. 624J  d. 39.8J  e. 1.69J

11. It is found that an unknown gas flows through a small opening in a container at a rate of 124.5 ml/s. An identical container with the same size opening has C₃H₈(g) flowing at a flow rate of 175.0 ml/s. What is the identity of the unknown gas?

    a. C₂H₆(g)  b. Cl₂O(g)  c. O₂(g)  d. Ar(g)  e. C₃H₇F(g)

12. 65.0 g N₂(g) reacted to completion with 40.0 g O₂(g) and produced N₃O₄(g) in a 5.00 L vessel (T = 75.0 °C).

    3N₂(g) + 2O₂(g) → 2N₃O₄(g)

    a. What are the partial pressures of N₂(g) and O₂(g), and the total pressure at the beginning of the reaction before the reaction has started?
    b. What are the partial pressures of N₂(g), O₂(g), N₃O₄(g), and the total pressure at the end of the reaction?

13. a. If dinitrogen monoxide, N₂O, is 0.000050% by volume in the atmosphere, what is the amount of dinitrogen monoxide in ppm?
    b. How many molecules of dinitrogen monoxide would be in 100.0 L of air at STP?

(Snapchat time)
14. Five 1-L containers are at the same T and P and contain: C$_3$H$_8$(g)  SO$_2$(g)  F$_2$(g)  Ar(g)
Answer the next 7 questions using the above information.
I. Which container will have the highest density?
   a. C$_3$H$_8$(g)  b. SO$_2$(g)  c. F$_2$(g)  d. Ar(g)  e. all are the same

II. Which container will have the greatest mass?
   a. C$_3$H$_8$(g)  b. SO$_2$(g)  c. F$_2$(g)  d. Ar(g)  e. all are the same

III. Which container will have the greatest number of molecules?
   a. C$_3$H$_8$(g)  b. SO$_2$(g)  c. F$_2$(g)  d. Ar(g)  e. all are the same

IV. Which container will have molecules with the greatest kinetic energy?
   a. C$_3$H$_8$(g)  b. SO$_2$(g)  c. F$_2$(g)  d. Ar(g)  e. all are the same

V. Which container will have molecules with the greatest velocity?
   a. C$_3$H$_8$(g)  b. SO$_2$(g)  c. F$_2$(g)  d. Ar(g)  e. all are the same

VI. Which container will have molecules with the greatest number of atoms?
   a. C$_3$H$_8$(g)  b. SO$_2$(g)  c. F$_2$(g)  d. Ar(g)  e. all are the same

VII. If all the gases were combined into one flask which gas would have the greatest partial pressure?
   a. C$_3$H$_8$(g)  b. SO$_2$(g)  c. F$_2$(g)  d. Ar(g)  e. all are the same

15. (This is a challenging question.) 5.0mol N$_2$(g) is mixed with 5.0mol O$_2$(g) and allowed to react as shown. If the total pressure before the reaction took place is 800torr, what is the total pressure after the reaction is complete? Assume the volume and temperature are constant during the reaction, and the reaction goes to completion.
   
   2N$_2$(g) + 5O$_2$(g) → 2N$_2$O$_5$(g)
   a. 200torr  b. 228torr  c. 400torr  d. 600torr  e. 800torr

THERMOCHEMISTRY (PART I)-Work, heat, sign conventions, heating curves, specific heat capacity, phase changes
1. Which of the following processes are exothermic? Not a multiple choice question; select all that are exothermic.
   I. Boiling water.  IV. CO$_2$(s) → CO$_2$(g)
   II. Freezing water.  V. 2CH$_3$OH(l) + 3O$_2$(g) → 2CO$_2$(g) + 4H$_2$O(g)
   III. Melting ice  VI. H$_2$ → 2H

2. If ethanol is boiled at a pressure of 1.25atm and the volume increases from 2.25L to 3.50L, which statement is CORRECT? (L atm is an energy unit similar to joules (J))
   CH$_3$CH$_2$OH(l) → CH$_3$CH$_2$OH(g)
   a. 1.56 L atm of work was done on the system
   b. 1.56 L atm of work was done by the system
   c. 1.00 L atm of work was done on the system
   d. 1.00 L atm of work was done by the system
   e. none of the above
   (pizza!)
3. Dry ice, \( \text{CO}_2(s) \), is placed in a sealed expandable bag and allowed to sublimate (change directly from a solid into a gas). Which of the following statements is **CORRECT**.
   a. Heat flows out of the surroundings and work is done on the surroundings.
   b. Heat flows out of the system and work is done by the system.
   c. Heat flows out of the system and work is done by the surroundings.
   d. Heat flows into the system and work is done on the system.
   e. Heat flows out of the system and work is done on the surroundings.

4. I. Na(s) reacting with water is **exothermic**. Which will generate the **largest increase** in **thermal energy**?
   a. Adding 10.0g Na(s) to 200ml water.
   b. Adding 5.0g Na(s) to 100ml water
   c. Adding 5.0g Na(s) to 50ml water.
   d. Adding 1.0g Na(s) to 50ml water.
   e. Since all reactions are Na(s) and water, and the \( \Delta H_{\text{rxn}} \) is the same, the thermal energy will be the same.

II. Na(s) reacting with water is **exothermic**. Which will generate the **largest increase** in **temperature**?
   a. Adding 10.0g Na(s) to 200ml water.
   b. Adding 5.0g Na(s) to 100ml water
   c. Adding 5.0g Na(s) to 50ml water.
   d. Adding 1.0g Na(s) to 50ml water.
   e. Since all reactions are Na(s) and water, and the \( \Delta H_{\text{rxn}} \) is the same, the temperature will be the same.

5. When 5.00g of solid Mg is placed in a solution that contains excess \( \text{HCl(aq)} \) a reaction occurs as shown.
   \[
   \text{Mg(s)} + 2\text{HCl(aq)} \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g})
   \]
The reaction is done at 25.0˚C and 740torr, and the resulting gas is collected in an expandable bag. What is the maximum amount of work in L atm that can be obtained? (Note: L atm is an energy unit similar to joules (J))

6. Below are 2 separate questions.
I. \( \text{C}_2\text{H}_6(\text{g}) \) was combusted in a piston with the reaction shown below. What are the signs of \( q, \Delta V, w, \) and \( \Delta E \)?
   \[
   2\text{C}_2\text{H}_6(\text{g}) + 7\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g})
   \]
   a. \( q > 0; \Delta V = 0; w < 0; \Delta E < 0 \)
   b. \( q > 0; \Delta V < 0; w > 0; \Delta E > 0 \)
   c. \( q < 0; \Delta V < 0; w = 0; \Delta E < 0 \)
   d. \( q < 0; \Delta V > 0; w < 0; \Delta E < 0 \)
   e. \( q < 0; \Delta V > 0; w > 0; \Delta E < 0 \)

II. The following process occurs as shown below. What are the signs of \( q, \Delta V, \) and \( w \)?
   \[
   \text{O}_2(\text{g}) \rightarrow 2\text{O}(\text{g})
   \]
   a. \( q < 0; \Delta V > 0; w < 0 \)
   b. \( q > 0; \Delta V < 0; w > 0 \)
   c. \( q < 0; \Delta V < 0; w > 0 \)
   d. \( q > 0; \Delta V > 0; w < 0 \)
   e. \( q < 0; \Delta V = 0; w = 0 \)

7. A 250.0g sample of lead (specific heat capacity = 0.129J/g˚C) has an initial temperature of 22.0˚C and 2.75kJ are added to the sample of lead. What is the **final temperature** of the lead?
   a. 107˚C  b. 63.3˚C  c. 22.1˚C  d. 22.0˚C  e. -63.3˚C

(text a friend)
8. 289.9g Au(s) at 150.0 °C ($C_s = 0.128 J/g°C$) is dropped into water at 20.0°C ($C_s = 4.184 J/g°C$), and a final temperature 30.6°C is reached. How many grams of water were in the container?

9. Consider the following specific heat capacities of metals.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Specific Heat (J/g °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>0.385</td>
</tr>
<tr>
<td>Co</td>
<td>0.418</td>
</tr>
<tr>
<td>Cr</td>
<td>0.447</td>
</tr>
<tr>
<td>Au</td>
<td>0.129</td>
</tr>
<tr>
<td>Ag</td>
<td>0.237</td>
</tr>
</tbody>
</table>

If the same amount of heat is added to the same mass of each metal all at the same initial temperature, which metal will reach the highest temperature?

a. Cu  
b. Co  
c. Cr  
d. Au  
e. Ag

10. Use the heating curves shown to answer the following questions.

I. If heating curves A and B represent the same chemical, then

a. the mass of A is twice the mass of B  
b. the mass of A is half the mass of B  
c. the mass of A equals the mass of B

II. Now assume the heating curves A, B, and C represent different chemicals. The masses used for these plots are the same for A, B, and C. If heating curve A is lead ($C = 0.129 J/g°C$) and heating curve C is titanium ($C = 0.523 J/g°C$), which chemical could heating curve B be? (Hint: No calculation is needed.)

a. calcium ($C = 0.647 J/g°C$)  
b. gold ($C = 0.129 J/g°C$)  
c. cobalt ($C = 0.421 J/g°C$)  
d. niobium ($0.265 J/g°C$)

11. What is the change in heat as 5.00g H₂O(g) at 130.°C is cooled to H₂O(l) at 100.0°C?

\[ C_s(H_2O(s)) = 2.03 J/g°C, C_s(H_2O(l)) = 4.184 J/g°C, C_s(H_2O(g)) = 2.00 J/g°C, \Delta H_{fus}^o = 333 J/g, \Delta H_{vap}^o = 2256 J/g \]

a. 10,980J  
b. 11,580J  
c. -11,910J  
d. -11,580J  
e. -1,965J

12. 10.0g of benzene was placed into a thermal container and heated. The melting point of benzene is 5.5°C and the boiling point of benzene is 80.1°C. How many steps (q terms) would be needed in a heating curve for benzene to determine the amount of heat required to raise the benzene from 2.5°C to 92.5°C?

a. 1  
b. 2  
c. 3  
d. 4  
e. 5

13. A perfectly insulating Styrofoam™ cup has water at 25.0°C in it, and KNO₃(s) is added and dissolves. The reaction and enthalpy of dissolution is shown:

\[ \text{KNO}_3(s) \rightarrow \text{KNO}_3(aq) \]  
\[ \Delta H_{rxn}^o = 34.89 kJ/mol \]

I. If the system is the KNO₃ what direction is the heat flow?

a. From the system to the surroundings.  
b. From the surroundings to the system.  
c. There is no heat flow. 

II. If the system is the KNO₃, water, and cup what direction is the heat flow?

a. From the system to the surroundings.  
b. From the surroundings to the system.  
c. There is no heat flow. (nap time again!)
14. A 1.0 gram sample of substance was heated and a graph of heat added (J) versus temperature (°C) was generated. Use this graph to answer the questions below.

a. What phase(s) exist at point A and what is/are their temperature?
b. What phase(s) exist at point B and what is/are their temperature?
c. What phase(s) exist at point C and what is/are their temperature?
d. What is the approximate value of $\Delta H_{\text{vap}}$ in units of J/g?
e. What is the melting point of the substance in °C?
f. What is the specific heat capacity (J/g°C) for the chemical as a solid?

15. Which of the following statements is **INCORRECT**?

a. In an insulated container, if a small piece of cold metal is dropped into warm water and the metal is the system, then $q_{\text{sys}} > 0$.
b. In an insulated container, if a piece of warm metal is dropped into cold water, and if the metal and water together are the system, then $q_{\text{sys}} > 0$.
c. If gases in a piston (the system) expand then work will be done on the surroundings.
d. The $\Delta H_{\text{vap}}$ of water (25°C) is greater than $\Delta H_{\text{vap}}$ of water (100°C).

*(take a walk)*
16. The heating curve below represents the heat required to heat 5.00g methanol, CH$_3$OH.

a. How much heat is required to heat 5.00g methanol from -60.0°C to 80.0°C?
b. How much heat is required to boil 10.0g methanol at the boiling point of 65.0°C?
c. If 5.00g methanol at -100.0°C is combined with 5.00g methanol at 40.0°C, what is the final temperature?
d. What is the boiling point of methanol?
e. What is the specific heat capacity of CH$_3$OH(l)?
f. What is the heat of vaporization, $\Delta H_{\text{vap}}^0$, for CH$_3$OH?

![Methanol (5g) Heating Curve](image)

**THERMOCHEMISTRY (PART II)-enthalpy of a reaction, Hess’s law, heat of formation, calorimetry**

1. $\Delta H_{\text{rxn}}^0$ is -1270kJ/mol for the reaction below. What is the value of heat when 3.50g NH$_3$(g) reacts?

$$4\text{NH}_3(g) + 3\text{O}_2(g) \rightarrow 2\text{N}_2(g) + 6\text{H}_2\text{O}(g) \quad \Delta H_{\text{rxn}}^0 = -1270 \text{kJ/mol}$$

a. -0.0153kJ  
 b. -1,111kJ  
 c. -261kJ  
 d. -65.2kJ  
 e. -74.1kJ

2. When 7.29g HCl(g) is produced in the following reaction, 20.4kJ are released. What is the standard enthalpy of reaction ($\Delta H_{\text{rxn}}^0$)?

$$\text{CH}_4(g) + 3\text{Cl}_2(g) \rightarrow 3\text{HCl}(g) + \text{CHCl}_3(g)$$

a. -6.60kJ/mol  
 b. -1.36kJ/mol  
 c. 1.36kJ/mol  
 d. -306kJ/mol  
 e. 306kJ/mol

3. What is the value of heat when 15.0g C$_2$H$_4$(g) reacts with 20.0g O$_2$ in the reaction below?

$$\text{C}_2\text{H}_4(g) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 2\text{H}_2\text{O}(g) \quad \Delta H_{\text{rxn}}^0 = -1040 \text{kJ/mol}$$

a. -556kJ  
 b. -217kJ  
 c. -650kJ  
 d. -1950kJ  
 e. -4990kJ

*(watch some TV)*
4. Given the reactions with their respective $\Delta H_{rxn}^\circ$, what is the $\Delta H_{rxn}^\circ$ for the following reaction:

$$\text{CH}_4(\text{g}) + 4\text{Cl}_2(\text{g}) \rightarrow \text{CCl}_4(\text{l}) + 4\text{HCl(}\text{g})$$

$\Delta H_{rxn}^\circ = ??$

Rxn I: $\text{C(s)} + 2\text{H}_2(\text{g}) \rightarrow \text{CH}_4(\text{g})$ $\Delta H_{rxn}^\circ = -74.9\text{kJ/mol}$
Rxn II: $\text{C(s)} + 2\text{Cl}_2(\text{g}) \rightarrow \text{CCl}_4(\text{l})$ $\Delta H_{rxn}^\circ = -139\text{kJ/mol}$
Rxn III: $\frac{1}{2}\text{H}_2(\text{g}) + \frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{HCl(}\text{g})$ $\Delta H_{rxn}^\circ = -92.3\text{kJ/mol}$

a. -433.3kJ/mol b. -583.1kJ/mol c. -156.4kJ/mol d. 305.1kJ/mol e. -306.2kJ/mol

5. (This is a harder version of Hess’s Law) Given the reactions with their respective $\Delta H_{rxn}^\circ$, what is the $\Delta H_{rxn}^\circ$ for the following reaction:

$$\text{CO}_2(\text{g}) \rightarrow \text{C(s)} + \text{O}_2(\text{g})$$

$\Delta H_{rxn}^\circ = ??$

Rxn I: $\text{H}_2\text{O(l)} \rightarrow \text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g})$ $\Delta H_{rxn}^\circ = 285.8\text{kJ/mol}$
Rxn II: $\text{C}_2\text{H}_6(\text{g}) \rightarrow 2\text{C(s)} + 3\text{H}_2(\text{g})$ $\Delta H_{rxn}^\circ = 84.7\text{kJ/mol}$
Rxn III: $2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O(l)} \rightarrow \text{C}_2\text{H}_6(\text{g}) + \frac{7}{2}\text{O}_2(\text{g})$ $\Delta H_{rxn}^\circ = 1560.5\text{kJ/mol}$

a. 1931kJ/mol b. 1251.3kJ/mol c. 393.9kJ/mol d. 2861.7kJ/mol e. 1394.2kJ/mol

6. The reaction that corresponds to the heat of formation for $\text{Mn}_2\text{O}_3(\text{s})$ is:

a. $4\text{Mn(s)} + 3\text{O}_2(\text{g}) \rightarrow 2\text{Mn}_2\text{O}_3(\text{s})$

b. $2\text{Mn(s)} + 3\text{O(g)} \rightarrow \text{Mn}_2\text{O}_3(\text{s})$

c. $2\text{Mn(s)} + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow \text{Mn}_2\text{O}_3(\text{s})$

d. $\text{Mn}_2\text{O}_3(\text{s}) \rightarrow 2\text{Mn(s)} + \frac{3}{2}\text{O}_2(\text{g})$

e. $2\text{Mn}^{3+}(\text{aq}) + 3\text{O}^-(\text{aq}) \rightarrow \text{Mn}_2\text{O}_3(\text{s})$

7. Calculate the enthalpy for the reaction below, $\Delta H_{rxn}^\circ$, using the standard enthalpies of formation given.

$$2\text{NH}_3(\text{g}) + 3\text{O}_2(\text{g}) + 2\text{CH}_4(\text{g}) \rightarrow 2\text{HCN(}\text{g}) + 6\text{H}_2\text{O(l)}$$

<table>
<thead>
<tr>
<th>Substance</th>
<th>$\Delta H_f^\circ$ (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{NH}_3(\text{g})$</td>
<td>-45.9</td>
</tr>
<tr>
<td>$\text{NH}_3(\text{aq})$</td>
<td>-80.3</td>
</tr>
<tr>
<td>$\text{CH}_4(\text{g})$</td>
<td>-74.9</td>
</tr>
<tr>
<td>$\text{C}_2\text{H}_4(\text{g})$</td>
<td>52.3</td>
</tr>
<tr>
<td>$\text{HCN(}\text{g})$</td>
<td>135.1</td>
</tr>
<tr>
<td>$\text{H}_2\text{O(l)}$</td>
<td>-285.8</td>
</tr>
<tr>
<td>$\text{H}_2\text{O(g)}$</td>
<td>-241.8</td>
</tr>
</tbody>
</table>

a. 1203.0kJ b. -1502.6kJ c. -1203.0kJ d. -30.9kJ e. -1743.4kJ

8. The $\Delta H_{rxn}^\circ$ for methanol burning is -1277kJ/mol as shown in the reaction below.

Given $\Delta H_f^\circ\text{H}_2\text{O(g)} = -241.8\text{kJ/mol}$ and $\Delta H_f^\circ\text{CO}_2(\text{g}) = -393.5\text{kJ/mol}$, what is the standard enthalpy of formation $\Delta H_f^\circ$ for methanol?

$$2\text{CH}_3\text{OH(l)} + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 4\text{H}_2\text{O(g)}$$

$\Delta H_{rxn}^\circ = -1277\text{kJ/mol}$

(has a banana)
9. When 5.50g LiNO$_2$(s) (53.0g/mol) was dissolved in an insulated coffee cup calorimeter containing 75.0g of water at 31.0˚C the temperature increased to 34.4˚C. What is the enthalpy of reaction ($\Delta H_{\text{rxn}}^\circ$) for LiNO$_2$(s)?

\[
C_{\text{soln}} = 4.184 \text{ J/g} \cdot \text{˚C}.
\]

LiNO$_2$(s) $\rightarrow$ LiNO$_2$(aq) $\quad \Delta H_{\text{rxn}}^\circ = ??$

10. What is the final temperature of a solution if 12.5g NH$_4$NO$_3$(s) is dissolved in an insulated coffee cup calorimeter containing 150.0g of water at 50.0˚C? The heat of dissolution is 26.4kJ/mol and $C_{\text{soln}} = 4.184 \text{ J/g} \cdot \text{˚C}$.

\[
\text{NH}_4\text{NO}_3(\text{s}) \rightarrow \text{NH}_4\text{NO}_3(\text{aq}) \quad \Delta H_{\text{rxn}}^\circ = 26.4 \text{kJ/mol}
\]

11. 50.0ml of 2.00M silver(I) nitrate (AgNO$_3$) solution is mixed with 50.0ml of 2.00M sodium iodide (NaI) solution and a precipitate formed in an insulated coffee cup. The solutions were initially at 23.0˚C and the temperature increased to 49.5˚C. What is the enthalpy of reaction ($\Delta H_{\text{rxn}}^\circ$) for AgNO$_3$ reacting with NaI?

\[
C_{\text{soln}} = 4.184 \text{ J/g} \cdot \text{˚C} ; D_{\text{soln}} = 1.0 \text{ g/ml}
\]

AgNO$_3$(aq) + NaI(aq) $\rightarrow$ AgI(s) + NaNO$_3$(aq) $\quad \Delta H_{\text{rxn}}^\circ = ??$

12. A student in lab reacts potassium metal with excess hydrochloric acid and the following data was obtained.

<table>
<thead>
<tr>
<th>Mass K(s)</th>
<th>0.55g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass HCl(aq)</td>
<td>15.00g</td>
</tr>
<tr>
<td>Initial T</td>
<td>21.0˚C</td>
</tr>
<tr>
<td>Final T</td>
<td>75.5˚C</td>
</tr>
</tbody>
</table>

Assume the heat capacity of the solution is 4.184J/g˚C.

a. Write a balanced molecular reaction.

b. Using the above data, what is the enthalpy of reaction ($\Delta H_{\text{rxn}}^\circ$)?

13. 15.5g of tungsten (W) is heated to 185.5˚C and then placed on top of a block of ice at 0.00˚C. After thermal equilibrium had been established, the temperature of the metal and ice were 0.00˚C, and it was found that 1.14g of ice had melted. What is the specific heat capacity of the W?

\[
C_s(\text{H}_2\text{O(s)}) = 2.03 \text{ J/g} \cdot \text{˚C}, \quad C_s(\text{H}_2\text{O(l)}) = 4.184 \text{ J/g} \cdot \text{˚C}, \quad \Delta H_{\text{fus}}^\circ = 333 \text{J/g}
\]

14. 35.0g of zinc (Zn) is heated to 215.0˚C and then placed in water at 100.0˚C. After thermal equilibrium had been established, the temperature of the Zn and water were 100.0˚C, and it was found that 0.692g of water had boiled. What is the specific heat capacity of the Zn?

\[
C_s(\text{H}_2\text{O(l)}) = 4.184 \text{ J/g} \cdot \text{˚C}, \quad C_s(\text{H}_2\text{O(g)}) = 2.00 \text{ J/g} \cdot \text{˚C}, \quad \Delta H_{\text{vap}}^\circ = 2256 \text{J/g}
\]

**LIGHT, MATTER, and ELECTRONIC STRUCTURE (PART I)-light, photoelectric effect**

1. When comparing UV light to IR light in a vacuum which of following statements are CORRECT?

   i. The wavelength of visible light is larger than the wavelength of x-rays light.
   ii. The amplitude of UV light is always greater than the amplitude of visible light.
   iii. The frequency of radio waves is smaller than the frequency of UV light.

   a. i and ii  
   b. ii and iii  
   c. i and iii  
   d. i, ii, and iii  
   e. i 

(almost done!)
2. A photon of light has a frequency of 5.5GHz.
I. What is the energy (J) of this light?
a. 3.61 x 10^{-32} J  

II. What is the wavelength (m) of this light?
a. 1.65 x 10^{15} m  
b. 1.20 x 10^{-40} m  
c. 5.45 x 10^{7} m  
d. 54.5 m  
e. 5.45 x 10^{13} m

III. What is the energy of one mole of this light?
a. 2.19 x 10^{-3} J  
b. 2.17 x 10^{-8} J  
c. 2.19 x 10^{-9} J  
d. 6.05 x 10^{-51} J  
e. 3.64 x 10^{-27} J

3. What is the greatest wavelength (m) of light that would be able to break the C=O bond in CO₂ if the energy of the C=O bond in CO₂ is 799kJ/mol?
a. 2.49 x 10^{-28} m  
b. 2.49 x 10^{-25} m  
c. 6.67 x 10^{6} m  
d. 1.50 x 10^{-7} m  
e. 1.32 x 10^{-18} m

4. For each statement, state whether it is TRUE or FALSE.
a. The wavelength of light is inversely proportional to its frequency. TRUE
b. Light is a combination of an electric vector and an angular momentum vector. TRUE
c. If the amplitude of light is increased its frequency does not change. TRUE
d. Red light has a wavelength of approximately 700nm. TRUE
e. Frequency and energy are directly proportional. TRUE
f. The highest energy light on the electromagnetic spectrum is radiowaves. FALSE
g. If there is complete destructive interference with two waves of light a node is formed. TRUE

5. Which of the following statements is CORRECT? If none of the statements are correct, select choice “e”.
a. If the incident light (light hitting the metal) is below the threshold frequency and the intensity of the incident light is increased electrons will now be ejected. FALSE
b. If the frequency of the incident light is above the threshold frequency and the intensity of the incident light is increased the direction of the ejected electrons will change to accommodate the increased intensity. FALSE
c. If the wavelength of incident light is above the threshold frequency and the wavelength of incident light is decreased the ejected electrons will increase in velocity. FALSE
d. If the frequency of incident light is above the threshold frequency and the frequency of incident light is increased the ejected electrons will increase in temperature. FALSE
e. None of the above statements are correct.

6. I. If incident light of 275nm wavelength is used in a photoelectric effect experiment with titanium metal that has a binding energy of 6.94 x 10^{-19}J, what is the kinetic energy of the emitted electrons?
   a. 0.0J  
b. 2.88 x 10^{-20}J  
c. 7.23 x 10^{-19}J  
d. 6.94 x 10^{-19}J  
e. need more info

II. What is the velocity of the electron from Part I above? (mass of electron = 9.11 x 10^{-31}kg)
   a. 7.95 x 10^{3}m/s  
b. 1.26 x 10^{6}m/s  
c. 1.23 x 10^{6}m/s  
d. 6.32 x 10^{10}m/s  
e. 2.51 x 10^{5}m/s

ANSWERS
Stoichiometry-molarity
1. a  \{1.00 \times 10^{-2} \text{M} \times 0.100L = 1.00 \times 10^{-3} \text{mol NaCl}; 1.00 \times 10^{-3} \text{mol NaCl} \times [58.5g \text{ NaCl}/1mol \text{ NaCl}] = 0.0585g \text{ NaCl}\}

2. e \{\frac{0.30 \text{mol (NH}_4)_3\text{PO}_4}{1L} \left(\frac{4 \text{mol ions}}{1 \text{mol (NH}_4)_3\text{PO}_4}\right) = 1.20 \text{M ions}\}
III. b

4. e  
{use $M_1V_1 = M_2V_2$ 2 times; $(3.50 \times 10^{-2}M)(5.00ml) = M_2(50.00ml)$; $M_2 = 3.50 \times 10^{-3}M$; $(3.50 \times 10^{-3}M)(5.00ml) = M_2(50.00ml)$; $M_2 = 3.50 \times 10^{-4}M$}

5. d  
{dilution problem: $M_1V_1 = M_2V_2$; start with: $M_1 = 3.30M$; $M_2 = 1.10M$; $V_2 = 150ml$ and solve for $V_1$; $V_1 = \frac{M_2V_2}{M_1}$; $V_1 = \frac{(1.10M)(150ml)}{3.30M} = 50.0ml$; $V_1$ is the amount of 3.30M NaCl needed and is not the water added; if $V_2 = V_{total} = 150ml$ and 50ml of this volume is the 3.30M NaCl solution then 100ml of water was needed; that is, $V_2 = V_1 + H_2O; 150 = 50.0 + H_2O; H_2O = 150 - 50 = 100ml$}

6. d  
{M_A \rightarrow M_B: 3$steps; completely neutralize means NaOH was just used up;

**step 1:** find mol $H_2SO_4$: $M = \text{mol/L} \rightarrow \text{mol} H_2SO_4 = M_{H_2SO_4} \times \text{L}H_2SO_4 = (0.250M)(0.0255L) = 0.006375\text{mol} H_2SO_4$;

**step 2:** find mol NaOH: $0.006375\text{mol} H_2SO_4\left(\frac{2\text{mol } NaOH}{1\text{mol } H_2SO_4}\right) = 0.01275\text{mol NaOH}$ ratio of NaOH to $H_2SO_4$ done by inspection, here’s how: acids/bases react (in Chem 103): $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ so there should be 1 $H^+$ for every 1 OH$^-$; in this case, 2 $H^+$ to 2 OH$^-$; can also write a reaction (takes a bit longer): $2\text{NaOH}(aq) + H_2SO_4(aq) \rightarrow 2H_2O(l) + Na_2SO_4(aq)$;

**step 3:** $[\text{NaOH}] = mol\text{NaOH}/L\text{-NaOH}; [\text{NaOH}] = 0.01275\text{mol NaOH}/0.0350L = 0.364M$}

7. b  
{M_A \rightarrow M_B: 3$steps; completely neutralize means all $Ba(OH)_2$ was just used up;

**step 1:** find mol $H_3PO_4$: $M = \text{mol/L} \rightarrow \text{mol} H_3PO_4 = M_{H_3PO_4} \times \text{L}H_3PO_4 = (0.10M)(0.020L) = 0.0020\text{mol} H_3PO_4$;

**step 2:** find mol $Ba(OH)_2$: $0.0020\text{mol} H_3PO_4\left(\frac{3\text{mol } Ba(OH)_2}{2\text{mol } H_3PO_4}\right) = 0.0030\text{mol } Ba(OH)_2$ ratio of $Ba(OH)_2$ to $H_3PO_4$ done by inspection, here’s how: acids/bases react (in Chem 103): $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ so there should be 1 $H^+$ for every 1 OH$^-$; in this case, 6 $H^+$ reacting with 6 OH$^-$; can also write a reaction (takes longer): $3\text{Ba(OH)}_2(aq) + 2H_3PO_4(aq) \rightarrow 6H_2O(l) + Ba_3(PO_4)_2(s)$;

**step 3:** find the volume of $Ba(OH)_2$: volume = $\text{mol } Ba(OH)_2/M\text{ Ba(OH)}_2$; volume $Ba(OH)_2 = 0.0030\text{mol } Ba(OH)_2/0.060M = 0.050L = 50. ml$}

8. c  
{g_A \rightarrow M_B: 3$steps; **step 1:** find mol $Al(OH)_3$: $10.5g \times (1\text{mol } Al(OH)_3/77.9g\text{ Al(OH)}_3) = 0.135\text{mol } Al(OH)_3$;

**step 2:** find mol $H_2SO_4$: $0.135\text{mol } Al(OH)_3\left(\frac{3\text{mol } H_2SO_4}{2\text{mol } Al(OH)_3}\right) = 0.202\text{mol } H_2SO_4$;

**step 3:** find the volume of $H_2SO_4$: volume = $\text{mol } H_2SO_4/M\text{ H}_2\text{SO}_4$; volume $H_2SO_4 = 0.202\text{mol } 0.750M = 0.269L \times (1000ml/1 L) = 269ml$}
9. 97.99g/mol \{M_A \rightarrow \text{mol}_B; \text{2 steps: molar mass} = \frac{\text{grams H}_3A}{\text{mol H}_3A}\; ;

\text{step 1:} \text{find mol NaOH from titration data:} \text{mol NaOH} = M \times L; \text{mol NaOH} = (0.01150M)(0.06685L) = 7.688 \times 10^{-4} \text{ mol NaOH};

\text{step 2:} \text{find mol H}_3A: \; 7.688 \times 10^{-4} \text{ mol NaOH} \left(\frac{1 \text{ mol H}_3A}{3 \text{ mol NaOH}}\right) = 2.5626 \times 10^{-4} \text{ mol H}_3A; \text{ratio of NaOH to H}_3A \text{ done by inspection, here's how: acids/bases react (in Chem 103): } H^+(aq) + OH^-(aq) \rightarrow H_2O(l) \text{ so there should be 1 H}^+ \text{ for every 1 OH}^-; \text{in this case, 3 H}^+ \text{ to 3 OH}^-; \text{can also write a reaction (takes longer): } 3\text{NaOH} + H_3A \rightarrow 3H_2O + Na_3A;

\text{find molar mass: molar mass} = \frac{g \text{H}_3A}{\text{mol H}_3A} = \frac{0.02511g \text{H}_3A}{2.5626 \times 10^{-4} \text{ mol H}_3A} = 97.99g / \text{mol}\}

10. (a) \; 2\text{AgNO}_3(aq) + \text{Na}_2\text{S}(aq) \rightarrow \text{Ag}_2\text{S}(s) + 2\text{NaNO}_3(aq)

\text{b. } 0.188\text{ mol Ag}_2\text{S} \; \text{this is a limiting reagent question since 2 reactant quantities were given; the calculation is: } M_A \rightarrow \text{mol}_B \text{ done twice;}

\text{AgNO}_3: \text{ mol AgNO}_3 = M \times L = (1.5M)(0.250L) = 0.375\text{ mol AgNO}_3; \left(0.375\text{ mol AgNO}_3\right) \left(\frac{1 \text{ mol Ag}_2\text{S}}{2 \text{ mol AgNO}_3}\right) = 0.1875\text{ mol Ag}_2\text{S};

\text{Na}_2\text{S}: \text{ mol Na}_2\text{S} = M \times L = (1.75M)(0.150L) = 0.2625\text{ mol Na}_2\text{S}; \left(0.2625\text{ mol Na}_2\text{S}\right) \left(\frac{1 \text{ mol Ag}_2\text{S}}{1 \text{ mol Na}_2\text{S}}\right) = 0.2625\text{ mol Ag}_2\text{S}

c. \text{AgNO}_3 \; \{\text{AgNO}_3 \text{ produced the smaller amount of product so it is the limiting reagent}\}

d. \text{0.0750\text{ mol Na}_2\text{S} \; \{\text{leftovers = starting amount – amount used; for amount used the calculation is: } LR \rightarrow EX; \left(0.375\text{ mol AgNO}_3\right) \left(\frac{1 \text{ mol Na}_2\text{S}}{2 \text{ mol AgNO}_3}\right) = 0.1875\text{ mol Na}_2\text{S used; leftovers = 0.2625mol – 0.1875mol = 0.0750mol Na}_2\text{S}\}

e. \; 0.188\text{ M} \; \{\text{[Na}_2\text{S]} = \frac{\text{mol Na}_2\text{S (leftover)}}{L_{\text{total}}} = \frac{0.0750\text{ mol Na}_2\text{S}}{(250.\text{ml} + 150.\text{ml}) / 1000} = 0.1875 \text{ M}\}

\text{Gases (Part 1)-gas laws, stoichiometry}

1. d \; \{\text{use } P_1V_1 = P_2V_2; \; V_2 = V_{\text{total}} = 10L + 20L = 30L; \text{ solve for } P_2; \; P_2 = \frac{P_1V_1}{V_2}; \; P_2 = \frac{(600\text{torr})(10L)}{30L} = 200\text{torr}\}

2. e \; \{\text{2 gases with same } P, V, \text{ and } T \text{ have same number of moles and therefore the same number of molecules}\}

3. d \; \{T \text{ is directly proportional to } V\}

4. d \; \{\text{use } \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \text{ and solve for } P_2; \text{ let } V_2 = 3V_1 \text{ and let } T_2 = 1/4T_1; \; \frac{P_1V_1}{T_1} = \frac{P_2(3V_1)}{(1/4)T_1}; \text{ simplify:} \; P_1 = \frac{P_2(3)}{(1/4)}; \text{ solve for } P_2 \rightarrow P_2 = P_1(1/4)(1/3) = 1/12P_1\}

5. d \; \{\text{use } PV = nRT \text{ and solve for } V; \; V = \frac{nRT}{P}; \text{ 100g SO}_2 \times \text{ (1mol SO}_2/64g \text{ SO}_2) = 1.5625\text{mol SO}_2; \; 750\text{torr x (1atm/760torr)} = 0.9868\text{atm}; \; V = \frac{(1.5625\text{molSO}_2)(0.0821\text{Latm} / \text{molK})(95 + 273.15\text{K})}{(0.9868\text{atm})} = 47.86\text{L}\}
6. c \( PV = nRT; \) \( n = \frac{PV}{RT} \); since \( R \) and \( T \) are constant, then \( n \) is proportional to \( PV \) \( (n \propto PV) \); also, the number of molecules is proportional to \( n \) \( (# \text{ molecules} \propto n) \); therefore, the number of molecules is proportional to \( PV \) \( (# \text{ molecules} \propto PV) \); calculate \( PV \) for each option; 

“i”: \( PV = (4.00L)(1.0atm) = 4.0; \) “ii”: \( PV = (6.00L)(0.5atm) = 3.0; \) “iii”: \( PV = (3.00L)(1.0atm) = 3.0; \)

“iv”: \( PV = (4.00L)(2.0atm) = 8.0; \) note that “ii” and “iii” have the same \( PV \) values, and will therefore have the same \( # \text{ moles} \) and the same \( # \text{ molecules} \); to verify this pick a random temperature and see how the numbers work out, for example, \( T = 298K; \)

“ii”: \( n = \frac{PV}{RT} = \frac{(0.5atm)(6.00L)}{(0.0821L\text{atm/molK})(298K)} = 0.1226\text{mol}; \) “iii”: \( n = \frac{PV}{RT} = \frac{(1.0atm)(3.00L)}{(0.0821L\text{atm/molK})(298K)} = 0.1226\text{mol}; \) note how the denominator is the same (same \( T \)) and how the numerator is determined by \( PV \).

7. e Use these two equations: Equation 1: \( (P)(\text{molar mass}) = \text{DRT} \) and Equation 2: \( PV = nRT \); if the variables are on the same side of the equation then those two variables are inversely proportional to one another; if the variables are on opposite sides of the equation then those two variables are directly proportional to one another;

“i”: False; Molar mass and Density in Equation 1 are on opposite sides of the equation so they are directly proportional; 

“ii”: True; \( P \) and \( T \) in Equation 2 or (Equation 2) are on opposite sides of the equation so they are directly proportional; 

“iii”: False; Moles \( (n) \) and \( V \) in Equation 2 are on opposite sides of the equation so they are directly proportional; 

“iv”: True; \( D \) and \( T \) in Equation 1 are on the same side of the equation so they are inversely proportional.

8. d

9. a Direct relationship between \( V \) and \( T \); this means as \( T \) increases \( V \) should linearly increase as well

10. a As \( T \) decreases \( \rightarrow V \) decreases; \( D = \frac{m}{V} \); mass is constant (not losing any gas) and when the \( V \) decreases the \( D \) increases.

11. d Use molar mass = \( \frac{gRT}{PV} \) and solve; molar mass = \( \frac{(3.07g)(0.0821L\text{atm/molK})(25.0 + 273.15K)}{(700torr)(\text{atm}/760torr)(2.56L)} = 31.87g/\text{mol} \); 31.85g/mol \( \approx 32g/mol \rightarrow \text{O}_2 \); all other choices have different molar masses.

12. a \( D = \frac{m}{V} \); all the gases will have the same volume but not the same mass; since they have the same \( P \), \( V \), and \( T \), they will have the same number of moles, \( n \); the gas with the greatest molar mass will have the greatest mass and therefore the greatest \( D \); molar mass \( \text{CH}_4 = 16g/mol, \text{C}_3\text{H}_8 = 44g/mol, \text{C}_2\text{H}_2 = 26g/mol, \) and \( \text{Ne} = 20g/mol \)

13. a Use \( PV = nRT \) and solve for \( n \); \( n = \frac{PV}{RT} \); \( n = \frac{PV}{RT} = \frac{(0.136atm)(1.74L)}{(0.0821L\text{atm/molK})(25.0 + 273.15K)} = 0.009667\text{mol}; \)

\( (0.009667\text{mol})(6.022 \times 10^23\text{molecules}/1\text{mol}) = 5.821 \times 10^21 \text{molecules} \)

14. 612L Find \( \text{mol} \text{O}_2(\text{g}) \) generated: \( 25.0\text{mol Mn}_2\text{O}_3 \times (3\text{mol O}_2/2\text{mol Mn}_2\text{O}_3) = 37.5\text{mol O}_2 \); use \( PV = nRT \) to find volume; \( V = \frac{nRT}{P} \); \( V = \frac{37.5\text{mol}(0.0821L\text{atm/molK})(25.0 + 273.15K)}{1.50\text{atm}} = 611.95L = 612L \)

15. b \( (P,V,T)_A \rightarrow (gB) \); \( PV = nRT \) and solve for \( n_{\text{SO}_2} \); \( n = \frac{PV}{RT} \); \( n = \frac{PV}{RT} = \frac{(700\text{torr})(\text{atm}/760\text{torr})(10.0L)}{(0.0821L\text{atm/molK})(25.0 + 273.15K)} = 0.3763\text{mol SO}_2; \)

\( (0.3763\text{mol SO}_2) \left( \frac{1\text{mol P}_4\text{S}_3}{3\text{mol SO}_2} \right) \left( \frac{220.1g\text{P}_4\text{S}_3}{1\text{mol P}_4\text{S}_3} \right) = 27.61g\text{P}_4\text{S}_3 \)
16. \( C_8H_8N_2 \) \( \{ \%N = 100.0 - 72.71 - 6.10 = 21.19\%; \text{assume 100g of material;} \ 72.71g \ C \left( \frac{1 \text{mol C}}{12.01g \ C} \right) = 6.0541 \text{mol C} \)

\[ 6.10g \ H \left( \frac{1 \text{mol H}}{1.008g \ H} \right) = 6.0516 \text{mol H}; \ 21.19g \ N \left( \frac{1 \text{mol N}}{14.01g \ N} \right) = 1.5125 \text{mol N}; \]

write formula: \( C_{6.0541}H_{6.0516}N_{1.5125} \) and divide by smallest number of moles:

\[ C_{6.0541}H_{6.0516}N_{1.5125} = C_4.0027H_4.0011N_1 = C_4H_4N = \text{EF}; \] molar mass\( \text{EF} = 66.08g/mol \)

molar mass \( = \frac{gRT}{PV} \); molar mass \( = \frac{1.250g}{(0.0821L/\text{mol K})(105.00 + 273.15K)} = 132.11g/\text{mol} \)

ratio \( \frac{\text{molar mass molecular formula}}{\text{molar mass empirical formula}} = \frac{132.11}{66.08} = 1.999 = 2 \); multiply \( \text{EF} \times 2 \);

\( C(4 \times 2)H(4 \times 2)N(1 \times 2) = \text{MF} = C_8H_8N_2 \)

### Gases (Part II)-partial pressure, velocity

1. c \{use \( P_{O_2} = \chi_{O_2}P_T \) and solve for \( P_{O_2} \); find \( \chi_{O_2} = \frac{\text{mol O}_2}{\text{mol Total}} = \frac{2.0}{2.0 + 3.0 + 1.0} = 0.33 \); \( P_{O_2} = (0.33)(900) = 300 \text{ torr} \}

2. c \{use \( P_1V_1 = P_2V_2 \) 2 times; \( \text{SO}_2 \): \( (4.5)(7.5) = (P_{\text{SO}_2})(19.5) \); \( P_{\text{SO}_2} = 1.73 \text{atm} \); \( \text{NH}_3 \): \( (6.0)(12.0) = (P_{\text{NH}_3})(19.5) \);

\( P_{\text{CO}_2} = 3.69 \text{atm} \);

\( P_T = P_{\text{SO}_2} + P_{\text{NH}_3} = 1.73 + 3.69 = 5.42 \text{atm} \}

3. a \{ the gas with smallest molar mass has more molecules and therefore a greater mole fraction and a greater partial pressure \}

4. c \{ even though the pressure of \( \text{Ne(g)} \) has increased, since the gases are treated independently of one another, the partial pressure of \( \text{O}_2(g) \) is unchanged since the \( V, T, \) and \( n \) of \( \text{O}_2 \) are unchanged; hence, it \( P_{O_2} = 2 \text{atm} \}

5. d \{ \( P_{\text{Total}} = P_{\text{Ne}} + P_{\text{He}} + P_{O_2} + P_{N_2} \); \( 8.5 = 2.0 + 2.0 + 1.5 + P_{N_2} \); \( P_{N_2} = 3.0 \text{atm} \); mol fraction \( N_2 = \chi_{N_2} = \frac{\text{mol N}_2}{\text{total mol}} = \frac{P_{N_2}}{P_{\text{Total}}} \}; \chi_{N_2} = \frac{P_{N_2}}{P_{\text{Total}}} \}

\[ \chi_{N_2} = \frac{P_{N_2}}{P_{\text{Total}}} \]

\[ \chi_{N_2} = \frac{3.0 \text{atm}}{8.5 \text{atm}} = 0.353 \}

6. e \{ “ii’’ : True; \( KE = \frac{3}{2}RT \) per mol of gas; if the moles increase, the total KE will increase; on a side note: the average KE (not part of the statement given!) will stay constant same since \( R \) and \( T \) are not changing;

“iii’’ : False; Heat capacity is unchanged by adding more moles;

“iii’’ : True; \( D = \frac{m}{V} \); since the mass is increasing while the volume is held constant, the \( D \) will increase;

\[ v_{\text{rms}} = \sqrt{\frac{3RT}{M}} \] and none of the variables have changed so \( v_{\text{rms}} \) is constant \}

7. d \{ Smaller molecules travel faster than larger ones at the same \( T \); determine molar mass and arrange from smallest to largest \}

8. b \{ \( u_{\text{rms}} = \sqrt{\frac{3RT}{M}} \}; \ 525 = \sqrt{\frac{3(8.314)T}{0.0720}} \}; \ 525 = \sqrt{346.42T}; \ (525)^2 = (\sqrt{346.42T})^2 \}; 275.625 = 346.42T; \ T = 796.1 \text{K} \}

9. e \{ \( KE \propto T \); all are at the same temperature so same KE \}
10. b \[ \text{KE} = \frac{3}{2}RT \text{ per mol of gas}; \text{ start by finding mol: PV} = nRT; n = \frac{PV}{RT}; \]
\[
\begin{align*}
n = \frac{(0.75atm)(1.5L)}{(0.0821L \text{ atm/molK})(50.0 + 273.15K)} &= 0.0424 \text{ mol}; \quad \text{KE} = \left(\frac{3}{2}\right)(8.314J/\text{molK})(50.0 + 273.15K)(0.0424 \text{ mol}) = 170.87J
\end{align*}
\]

11. b \[ \text{rate}_1 = \sqrt{\frac{M_2}{M_1}} \times \frac{175.0ml}{124.5ml} \times \frac{\sqrt{M_2}}{44.1g/mol} \quad \text{rate}^2_2 = \left(\frac{175.0ml}{124.5ml}\right)^2 \times \left(\frac{\sqrt{M_2}}{44.1g/mol}\right)^2 \quad (1.4056)^2 = \frac{M_2}{44.1g/mol}; \]
\[ 1.9758 = \frac{M_2}{44.1g/mol}; \quad M_2 = 87.1g/mol; \]
\[ \text{“a”: molar mass C}_2\text{H}_6 = 30g/mol; \quad \text{“b”: molar mass Cl}_2\text{O} = 87g/mol;} \]
\[ \text{“c”: molar mass O}_2 = 32g/mol; \quad \text{“d”: molar mass Ar} = 40g/mol; \quad \text{“e”: molar mass C}_2\text{H}_7\text{O} = 62g/mol;} \]

12. a. \[ P_{N_2} = 13.27atm; \quad P_{O_2} = 7.15atm; \quad P_T = 20.41atm \]
\[ \left\{ \begin{array}{l} 65.0g \text{N}_2 \left(\frac{1mol \text{N}_2}{28.0g \text{N}_2}\right) = 2.321mol \text{N}_2; \quad P_{N_2} = n_{N_2} \frac{RT}{V} = \frac{(2.321mol)(0.0821L \text{ atm/molK})(75.0 + 273.15K)}{5.00L} = 13.268atm \\
40.0g \text{O}_2 \left(\frac{1mol \text{O}_2}{32.0g \text{O}_2}\right) = 1.250mol \text{O}_2; \quad P_{O_2} = n_{O_2} \frac{RT}{V} = \frac{(1.250mol)(0.0821L \text{ atm/molK})(75.0 + 273.15K)}{5.00L} = 7.146atm \\
P_T = P_{N_2} + P_{O_2} = 13.268 + 7.146 = 20.414atm \end{array} \right. \]
b. \[ P_{N_2} = 2.55atm; \quad P_{O_2} = 0atm; \quad P_{N_3O_4} = 7.15atm; \quad P_T = 9.70atm \]
\[ \{\text{limiting reagent problem since 2 reactant quantities given; determine how many mol N}_3\text{O}_4 \text{ can be made, which reactant is the LR and how many mol of the excess reactant remains;}
\]
\[ \begin{align*}
65.0g \text{N}_2 \left(\frac{1mol \text{N}_2}{28.0g \text{N}_2}\right) &\times \left(\frac{2mol \text{N}_3\text{O}_4}{3mol \text{N}_2}\right) = 1.548mol \text{N}_3\text{O}_4; \\
40.0g \text{O}_2 \left(\frac{1mol \text{O}_2}{32.0g \text{O}_2}\right) &\times \left(\frac{2mol \text{N}_3\text{O}_4}{2mol \text{O}_2}\right) = 1.25mol \text{N}_3\text{O}_4;
\end{align*}
\]
O\text{ is the LR since it yielded the smaller amount; N}_2 \text{ is the EX; 1.25mol N}_3\text{O}_4 \text{ can be produced;}
find left over N\text{; start by finding amount N}_2 \text{ used by doing a LR \rightarrow EX calculation:}
\[ \begin{align*}
40.0g \text{O}_2 \left(\frac{1mol \text{O}_2}{32.0g \text{O}_2}\right) &\times \left(\frac{3mol \text{N}_2}{2mol \text{O}_2}\right) = 1.875mol \text{N}_2 \text{ used; starting amount N}_2 = 65.0g \text{N}_2 \left(\frac{1mol \text{N}_2}{28.0g \text{N}_2}\right) = 2.321mol \text{N}_2;
\end{align*}
\]
left over N\text{ = 2.321} - 1.875 = 0.446mol \text{N}_2 \text{ left over; P}_\text{O}_2 \text{ (after reaction) = 0atm (LR \rightarrow no O}_2 \text{ left);}
\[ \begin{align*}
P_{N_2} = \frac{n_{N_2}RT}{V} = \frac{(0.446mol)(0.0821L \text{ atm/molK})(75.0 + 273.15K)}{5.00L} = 2.550atm; \\
P_{N_3O_4} = \frac{n_{N_3O_4}RT}{V} = \frac{(1.25mol)(0.0821L \text{ atm/molK})(75.0 + 273.15K)}{5.00L} = 7.146atm; \\
P_T = P_{N_2} + P_{O_2} + P_{N_3O_4} = 2.550 + 0 + 7.146 = 9.696atm
\end{align*}
\]
13. a. 0.50ppm \{0.000050%/100 = 0.00000050; 0.00000050 x (1 \times 10^6) = 0.50ppm\}
b. \[ 1.34 \times 10^{18} \text{ CH}_4 \text{ molecules} \{PV = nRT; \text{ solve for n; } n = \frac{PV}{RT} = \frac{(1.00atm)(100.0L)}{(0.0821L \text{ atm/molK})(0.00 + 273.15K)}; \]
\[ n = 4.462 \text{ mol of air; convert to particles: } 4.462 \text{ mol x } (6.022 \times 10^{23} \text{ particles/mol}) = 2.687 \times 10^{24} \text{ particles;}
\]
use ppm: \[ \left(\frac{0.50}{1 \times 10^6}\right) \times 1.344 \times 10^{18} \text{N}_2\text{O molecules} \]
14. I. b {under the same T, P, and V conditions, gas with greatest molar mass has greatest Dx}
II. b {under the same T, P, and V, 2 gases have the same #moles; the one with greater molar mass has the greater mass}
III. e {under the same T, P, and V, 2 gases will have the same number of moles and hence the same number of molecules}
IV. e {all have the same kinetic energy since they are at the same T and kinetic energy is proportional to T}
V. c {since it is the smallest molecule and smaller molecules travel faster than larger ones at the same T}
VI. a {since they contain the same number of moles, the molecule with the most atoms, 11 for C3H8, has the most atoms}
VII. e {since they contain same #moles, they’ll have the same partial pressure since partial pressure is determined by #mol; the mole fraction, χ, for each will be the same}

15. c {Limiting reagent question; find how many moles of N2O5 can be made; 5.0mol N2 x (2mol N2O5/2mol N2) = 5.0mol N2O5; 5.0mol O2 x (2mol N2O5/5mol N2) = 2.0mol N2O5; the smaller amount can be made so 2.0mol N2O5 can be produced; O2 is the LR so 0mol of O2 exist at the end of the reaction;
find how much N2 is left over after the reaction: 5.0mol O2 x (2mol N2/5mol O2) = 2mol N2 used;
mol N2 left over = 5.0mol (starting amount) – 2.0mol (used) = 3.0mol N2;
total gas mol starting = 5.0mol N2 + 5.0mol O2 = 10.0mol gas;
at the end of the reaction: 3.0mol N2 + 2.0mol N2O5 = 5.0mol gas; so the moles have been reduced to half of what they were;
if the V and T are unchanged and the mol decrease by 50% then the P will decrease by 50%: P_T = 800torr(0.50) = 400torr;

**Thermochemistry (Part I)-work, heat, sign conventions, heating curves, specific heat capacity, phase changes**

1. II, V {I.1 → g ⇒ endo; II.1 → s ⇒ exo; III. s → l ⇒ endo; IV. s → g ⇒ endo; V. combustion ⇒ exo; VI. breaking a bond ⇒ endo}
2. b {w = -PΔV = -P(V_f - V_i) = -(1.25atm)(3.50 - 2.25L) = -1.563Latm; negative work means work is done by the system}
3. a {the process: CO_2(s) → CO_2(g) is endothermic and therefore heat will flow into the system which is the same as heat will flow out of the surroundings; the solid turning into a gas means that ΔV > 0 (+) so work is: w = -PΔV; w = -(+)(+) since P is always (+); w < 0 (-); when work is negative then work is done by the system which is the same as work is done on the surroundings}
4. I. a {Thermal energy means the total amount of energy or the sum of the kinetic energy of all the molecules. Since “a” used the most Na it would generate the most thermal energy;}
5. c {Temperature is the average kinetic energy of all the molecules. If “a” is used as the starting point, then choice “b” will increase T in the same amount (half the Na and half the water); choice “d” will increase T less than “a” since it used one-tenth the Na but one-quarter the amount of water; choice “c” will have the greatest T increase since it used one-half the amount of “a” but only one-quarter the amount of water}

5. -5.04Latm {from grams Mg find volume H2; 5.00gMg \( \frac{1molMg}{24.3gMg} \left( \frac{1molH_2}{1molMg} \right) \) = 0.206molH_2; PV = nRT and solve for V;
V = \( \frac{nRT}{P} \); V = \( \frac{(0.206mol)(0.0821Latm/molK)(250 + 273.15K)}{(740torr)(latm/760torr)} \) = 5.18LH_2; now find work using: w = -PΔV;
w = -(740torr) \( \left( \frac{latm}{760torr} \right) \( 5.18L \) = -5.044Latm}

6. I. d {combustion will be exothermic ⇒ q < 0 (-); from the reaction: 2C_2H_6(g) + 7O_2(g) → 4CO_2(g) + 6H_2O(g) ⇒ 9 gas moles reactants produces 10 gas moles products ⇒ ΔV is increasing and ΔV > 0 (+); using w = -PΔV and plugging in the signs yields: w = -(+)(+) (note: P is always positive); w < 0 (-); ΔE = q + w; ΔE = (+) + (-) ⇒ ΔE < 0 (-)}
II. d {endothermic ⇒ q > 0 (+) as it requires energy to break a bond; from the reaction: O_2(g) → 2O(g) ⇒ 1 gas mole of reactants yields 2 gas moles of products ⇒ ΔV > 0 (+); using w = -PΔV and plugging in the signs yields; w = -(+) (note: P is always positive; w < 0 (-)}

7. a {q = C_m(T_f - T_i); 2750J = (0.129)(250)(T_f - 22.0); T_f = 107.3°C}
8. 99.9g  \[ \text{heat lost + heat gained} = 0; 0 = (0.128)(289.8)(30.6 - 150) + (4.184)(x)(30.6 - 20) \rightarrow 0 = -4429.1 + 44.35x; x = 99.87g \]

9. d  \{the smaller the heat capacity the greater the \( \Delta T \) given the same amount of heat being applied\}

10. I. b  \{Note: 1. The same amount of heat has been added to A and B;

2. The temperature has risen twice as much for A as compared to B;

3. Since they are the same chemical they have the same specific heat capacity.

Then considering \( q = Cm\Delta T \), the mass of A must be half the mass of B and therefore A heats up twice as much.\}

II. d  \{Note: 1. The same amount of heat has been added to A, B and C;

2. The T has risen twice as much for A as compared to B, and the T has risen twice as much for B as compared to C.

Since A, B, and C have the same mass and considering \( q = Cm\Delta T \), the specific heat capacity of B must be half as much as C, and the specific heat capacity of B must be double that of A. Niobium has a heat capacity that is double lead’s specific heat capacity and niobium has a heat capacity that is half the specific heat capacity of titanium.\}

11. d  \{heat = \( q \)cool gas + \( q \)condense gas = \( (C H_2O(g) \times \text{mass} \times H_2O(g)) \times \Delta T \times H_2O(g) \) + \( (\Delta H_{\text{vap}} \times \text{mass} \times H_2O) \); note how a negative sign is added to \( \Delta H_{\text{vap}} \); this is because \( \Delta H_{\text{vap}} \) is \( l \rightarrow g \) while this question is the reverse of that: \( g \rightarrow l \) so the sign must be changed; \( 2.00J/g^\circ C)(5.00g)(100 - 130^\circ C) + (-2256J/g)(5.00g) = -11,580J \}

12. e  \{since 2.5\(^\circ C\) is below the melting point the benzene is a solid at this temperature; since 92.5\(^\circ C\) is above the boiling point of benzene it is a gas at this temperature; to find the heat of this process the following calculation would need to be done:

\[ q_{\text{total}} = q_{\text{heat solid:2.5 \rightarrow 5.5}} + q_{\text{melt solid}} + q_{\text{heat liquid:5.5 \rightarrow 80.1}} + q_{\text{boil liquid}} + q_{\text{heat gas:80.1 \rightarrow 92.5}} \]  

13. I. b  \{since the heat is positive (+) \( \rightarrow \) endothermic \( \rightarrow \) energy absorbed by the KNO\(_3\) (system) from the water (surroundings).\}

II. c  \{since the heat is positive (+) \( \rightarrow \) endothermic \( \rightarrow \) energy is absorbed by the KNO\(_3\) (system) from the water (system) both of which together are the system; hence, there is no heat flow between the system and surroundings because of how the system was defined.\}

14. a. solid at 100\(^\circ C\)
b. liquid at 200\(^\circ C\)
c. liquid and gas at 200\(^\circ C\)
d. 750J/g  \{each horizontal component is a phase change; the 1st is melting and the 2nd is boiling; \( \Delta H_{\text{vap}} \) has units of J/g and is the heat required to boil 1.0g of substance as per this problem; \( \Delta H_{\text{vap}} \) is the 2nd horizontal line; \( \Delta H_{\text{vap}} = (1400 - 650J)/1g = 750J/g \}

e. 100\(^\circ C\)  \{each horizontal component is a phase change; the first one is melting and the second one is boiling; read the y-axis which is the temperature for this horizontal component for the mp and bp\}

f. 4J/g\(^\circ C\)  \{\( C_s \) with units = J/g\(^\circ C\), is the heat required to raise 1g of substance 1\(^\circ C\); \( C_s = \frac{q}{m(\Delta T)} \); \( C_s = \frac{(200 - 100J)}{((1.0g)(100 - 75^\circ C))} = \frac{4J}{g^\circ C} \}
15. b  "a": True: If the metal is the system it will absorb heat from the water since it is colder than the water and for the metal that is an endothermic process; since the metal is the system, $q_{sys} > 0$ (+);
  "b": False: If the metal and water are the system, then even though the warm metal will lose heat and the cold water will gain heat, the net change for the heat of the system which includes both the water and metal is zero; $q_{sys} = 0$;
  "c": True: If gases expand $\Delta V > 0$ (+) $\rightarrow w < 0$ (-) from $w = -P\Delta V$ and therefore work is done by the system and work is done on the surroundings;
  "d": True: It takes greater energy to vaporize water at 25°C than water at 100°C since the water at 100°C already has much greater energy and requires less energy to vaporize it.

16. a. $\sim 7,200$ J  [looking at the graph below (lines labeled “a”), start at -60.0°C (heat = $\sim 1,100$J) and go to 80.0°C (heat = $\sim 8,300$J); take the difference: $\Delta$heat = heat$_{final}$ - heat$_{initial}$ = $8,300 - 1,100$J = $7,200$J; this is the heat required to take 5.00g methanol at -60.0°C to 80.0°C; since this was done using a small graph, a reasonable range of answers is acceptable]

   b. $\sim 11,000$ J  [looking at the graph below (lines labeled “b”), start at the beginning of the boiling line at 65.0°C (heat = $\sim 2,675$J) and go to the end of the boiling line still at 65.0°C (heat = $\sim 8,200$J); take the difference: $\Delta$heat = heat$_{final}$ - heat$_{initial}$ = $8,200 - 2,675$J = $5,525$J; this is the heat required to boil 5.00g methanol; to boil 10.0g methanol double the heat: $2 \times 5,525$J = $11,050$J; since this was done using a small graph, a reasonable range of answers is acceptable]

   c. $\sim -45^\circ$ C  [looking at the graph below (lines labeled “c”), look at the cold methanol at -100.0°C: heat = $\sim 150$J, and the hot methanol at 40.0°C: heat = $\sim 2,350$J; the cold methanol will gain heat while the hot methanol will lose heat; find the midpoint of this heat range: from the line drawing it occurs at $\sim 1,250$J; now read across to the y-axis and this is the temperature at which the two samples (one hot and one cold) will reach once thermally equilibrated; $T = \sim -45^\circ$C; since this was done using a small graph, a reasonable range of answers is acceptable]

   d. $\sim 65^\circ$ C  [looking at the graph read across the higher horizontal line until you read the T; this is the boiling point; since this was done using a small graph, a reasonable range of answers is acceptable]

   e. $\sim 2.4$ J/g°C  [use $q = Cm\Delta T$; solve for C: $C = \frac{q}{m\Delta T}$; $C = \frac{(2650 - 675) J}{(5 g)(65 - (-97) \circ C)}$; $C = \frac{1975 J}{(5 g)(162 \circ C)} = 2.438 \frac{J}{g \circ C}$; since this was done using a small graph, a reasonable range of answers would be accepted]

   f. $\sim 1100$ J/g  [$q = (\Delta H_{vap})^0$(mass); $\Delta H_{vap}^0 = \frac{q}{mass}$; $\Delta H_{vap}^0 = \frac{(8200 - 2675) J}{(5 g)} = 1105$ J/g; since this was done using a small graph, a reasonable range of answers is acceptable]
Thermochemistry (Part II)-enthalpy of a reaction, Hess’s law, calorimetry, heat of formation

1. d  Scaling up: $3.50 \text{g NH}_3 \left( \frac{1 \text{mol NH}_3}{17.03 \text{g NH}_3} \right) \left( \frac{-1270 \text{kJ}}{4 \text{mol NH}_3} \right) = -65.25 \text{kJ}$;

this step can also be done as a proportionality: $3.5 \text{g NH}_3 = 4 \text{mol NH}_3$;

convert so units are the same: $0.2055 \text{mol NH}_3 = 4 \text{mol NH}_3$; cross multiply: $4x = -261.01; x = -65.25 \text{kJ}$

2. d  Scaling up: $3 \text{mol HCl} \left( \frac{36.46 \text{g HCl}}{1 \text{mol HCl}} \right) \left( \frac{-20.4 \text{kJ}}{7.29 \text{g HCl}} \right) = -306.08 \text{kJ}$;

this step can also be done as a proportionality: $7.29 \text{g HCl} = 3 \text{mol HCl}$;

convert so units are the same: $0.1999 \text{mol HCl} = 3 \text{mol HCl}$; cross multiply: $0.1999x = -61.2; x = -306.15 \text{kJ}$

3. b  Limiting reagent + scaling up; Scaling up: $15.0 \text{g C}_2\text{H}_4 \left( \frac{1 \text{mol C}_2\text{H}_4}{28.05 \text{g C}_2\text{H}_4} \right) \left( \frac{-1040 \text{kJ}}{1 \text{mol C}_2\text{H}_4} \right) = -556.1 \text{kJ}$ and

$20.0 \text{g O}_2 \left( \frac{1 \text{mol O}_2}{32.0 \text{g O}_2} \right) \left( \frac{-1040 \text{kJ}}{3 \text{mol O}_2} \right) = -216.7 \text{kJ}$; the smaller amount is how much can react and how much heat is evolved;

heat released = -216.7kJ;

this step can also be done as a proportionality: $15.0 \text{g C}_2\text{H}_4 = 1 \text{mol C}_2\text{H}_4$;

convert so units are the same: $0.535 \text{mol C}_2\text{H}_4 = 1 \text{mol C}_2\text{H}_4$; cross multiply: $x = -556.1 \text{kJ}$;

repeat with $20.0 \text{g O}_2 = 3 \text{mol O}_2$; convert so units are the same: $0.625 \text{mol O}_2 = 3 \text{mol O}_2$;

cross multiply: $3x = -650 \text{kJ}; x = -216.7 \text{kJ}$; the smaller amount is how much reacts and how much heat is evolved = -216.7kJ

4. a  \{reaction must produce 1mol of product, Mn$_2$O$_3$, from its elements in their natural state; O$_2$(g) and Mn(s) are the natural states\}

4. c  \{reverse Rxn I and multiply Rxn I by $3/2$; multiply Rxn II by $1/2$; multiply Rxn III by $1/2$; \}

$\Delta H_{\text{rxn}}^0 = [(-1)(-74.9)] + [-139] + [(4)(-92.3)] = -433.3 \text{kJ}$;

Process:

- CH$_4$: only appears in Rxn I; need one on the left and have one on the right $\rightarrow$ reverse Rxn I;
- Cl$_2$: appears in Rxn II and III; skip this chemical;
- CCl$_4$: only appears in Rxn II; need one on the right and have one on the right $\rightarrow$ no change for Rxn II;
- HCl: only appears in Rxn III; need four on the right and have one on the right $\rightarrow$ multiply Rxn III by 4\}

5. c  \{reverse Rxn I and multiply Rxn I by $3/2$; multiply Rxn II by $1/2$; multiply Rxn III by $1/2$; \}

$\Delta H_{\text{rxn}}^0 = [(-1)(3/2)(285.8)] + [(1/2)(84.7)] + [(1/2)(1560.5)] = 393.9 \text{kJ}$

- CO$_2$: only appears in Rxn III; need one on the left and have two on the left $\rightarrow$ multiply Rxn III by $1/2$;
- C: only appears in Rxn II; need one on the right and have two on the right $\rightarrow$ multiply Rxn II by $1/2$;
- O$_2$: appears in Rxns I and III; skip this chemical

Still need to figure out Rxn I: done by inspection; can focus on any chemical in Rxn I but it is easier if you choose a chemical in Rxn I that does not appear in the overall reaction; I will choose H$_2$O; the H$_2$O must cancel out since there is no H$_2$O in the overall reaction; the only other source of H$_2$O is in Rxn III; in Rxn III there are $3/2$ H$_2$O on the left (don’t forget Rxn III was multiplied by $1/2$!); to cancel the $3/2$ H$_2$O on the left from Rxn III, I will need $3/2$ H$_2$O on the right from Rxn I; hence, I will reverse Rxn I and multiply Rxn I by $3/2$.

6. c  \{reaction must produce 1mol of product, Mn$_2$O$_3$, from its elements in their natural state; O$_2$(g) and Mn(s) are the natural states\}
7. c. \( \Delta H_{\text{rxn}}^0 = [\Sigma \Delta H_f^0 \text{(products)} \times \text{mole}_{\text{products}}] - [\Sigma \Delta H_f^0 \text{(reactants)} \times \text{mole}_{\text{reactants}}] \)

\( \left[2\text{mol}(135.1kJ/mol) + 6\text{mol}(-285.8kJ/mol)\right] - \left[2\text{mol}(-45.9kJ/mol) + 3\text{mol}(0kJ/mol) + 2\text{mol}(-74.9kJ/mol)\right] = -1203kJ \)

8. -238kJ/mol

\( \text{[use } \Delta H_{\text{rxn}}^0 = [2(\Delta H_f^0 \text{CO}_2(g)) + 4(\Delta H_f^0 \text{H}_2\text{O}(g))] - [2(\Delta H_f^0 \text{CH}_3\text{OH}(g)) + 4(\Delta H_f^0 \text{O}_2(g))] \text{]} \);

plug in values and solve for \( \Delta H_f^0 \text{CH}_3\text{OH}(g) \);
\(-1277 = [2\text{mol}(-393.5kJ/mol) + 4\text{mol}(-241.8kJ/mol)] - [2x + 3(0)] \);

\(-1277 = [-1754.2] - [2x] \);

solve for \( x \);
\( x = \Delta H_f^0 \text{CH}_3\text{OH}(g) = -238.6kJ/mol \)

9. -11.0kJ/mol

\( \text{[Step 1]: } q_{\text{surr}} = C_{\text{solv}} m_{\text{solv}} (T_f' - T_i) \); \( q_{\text{surr}} = (4.184J/gC)(75.0 + 5.50g)(34.4 - 31.0) \); \( q_{\text{surr}} = 1145J \);

\( \text{[Step 2]: } q_{\text{sys}} = -q_{\text{surr}} \); \( q_{\text{sys}} = -1145J \);

\( \text{[Step 3]: Scaling up: find } \Delta H_{\text{rxn}}^0 \).

\[ 1 \text{molLiNO}_2 \left( \frac{52.95g \text{LiNO}_2}{1 \text{mol LiNO}_2} \right) \left( \frac{-1145J}{5.50g \text{LiNO}_2} \right) = -11,023.2J = -11.0kJ \; \]

this step can also be done as a proportionality:
\[ \frac{5.50g \text{LiNO}_2}{-1145J} = \frac{1 \text{mol LiNO}_2}{xJ} \]

convert so units are the same:
\[ 0.104mol \text{LiNO}_2 \left( \frac{-1145J}{5.50g \text{LiNO}_2} \right) = \frac{1 \text{mol LiNO}_2}{xJ} \]

\( x = 4.116kJ \)

10. 43.9°C

\( \text{[Step 1]: Scaling up: find } q_{\text{sys}} \).

\[ 12.5g \text{NH}_4\text{NO}_3 \left( \frac{1 \text{mol NH}_4\text{NO}_3}{80.17g \text{NH}_4\text{NO}_3} \right) \left( \frac{26.4kJ}{1 \text{mol NH}_4\text{NO}_3} \right) = 4.116kJ \; \]

this step can also be done as a proportionality:
\[ \frac{12.5g \text{NH}_4\text{NO}_3}{xkJ} = \frac{1 \text{mol NH}_4\text{NO}_3}{26.4kJ} \; \]

convert so units are the same:
\[ 0.156mol \text{NH}_4\text{NO}_3 \left( \frac{1 \text{mol NH}_4\text{NO}_3}{26.4kJ} \right) = \frac{1 \text{mol NH}_4\text{NO}_3}{xkJ} \; \]

\( x = 4.116kJ \)

\( \text{[Step 2]: } q_{\text{surr}} = -q_{\text{sys}} \); \( q_{\text{surr}} = -4.125kJ = -4125J \);

\( \text{[Step 3]: } q_{\text{surr}} = C_{\text{solv}} m_{\text{solv}} (T_f' - T_i) \); \( -4125 = (4.184J/gC)(150 + 12.5g)(T_f' - 50) \);

\( -4125 = 679.9T_f - 33995 \)

\( 29870 = 679.9T_f; T_f = 43.9°C \)

11. -111kJ/mol

\( \text{[Step 1]: } q_{\text{surr}} = C_{\text{solv}} m_{\text{solv}} (T_f' - T_i) \).

\( D = m/V; m = D \times V = 1.0g/ml \times 100ml = 100g; \)

mol \text{AgNO}_3 = M \times L = 2.00M \times 0.050L = 0.10mol \text{AgNO}_3; \) mol \text{NaI} = M \times L = 2.00M \times 0.050L = 0.10mol \text{NaI};

both run out at the same time; \( q_{\text{surr}} = (4.184J/gC)(50.0g + 50.0g)(49.5 - 23.0) \); \( q_{\text{surr}} = 11,088J \);

\( \text{[Step 2]: } q_{\text{sys}} = -q_{\text{surr}} \); \( q_{\text{sys}} = -11,088J \);

\( \text{[Step 3]: scaling up: } 1 \text{molAgNO}_3 \left( \frac{-11,088J}{0.10mol \text{AgNO}_3} \right) = -110,880J = -110.9kJ \; \)

this step can also be done as a proportionality:
\[ \frac{0.10mol \text{AgNO}_3}{-11,088J} = \frac{1 \text{mol AgNO}_3}{xJ} \; \]

\( x = -110,880J = -110.9kJ \)

12. a. 2K(s) + 2HCl(aq) → 2KCl(aq) + H₂(g)

\( b. -504.2kJ/mol \)

\( \text{[Step 1]: } q_{\text{surr}} = C_{\text{solv}} m_{\text{solv}} (T_f' - T_i) \); \( q_{\text{surr}} = (4.184J/gC)(15.00 + 0.55g)(75.5 - 21.0°C) \); \( q_{\text{surr}} = 3546J \);

\( \text{[Step 2]: } q_{\text{sys}} = -q_{\text{surr}} \); \( q_{\text{sys}} = -3546J \);

\( \text{[Step 3]: scaling up: } 2 \text{mol K} \left( \frac{39.10g K}{1 \text{mol K}} \right) \left( \frac{-3546J}{0.55g K} \right) = -504.18kJ \)
13. \(0.132\text{J/g}^{\circ}\text{C}\) \{heat transfer + phase change; heat lost + heat gained = 0; for W: \(q = C_{w}(T_f - T_i)\); for ice: \(q = \Delta H_{\text{fus}}(m)\); \(0 = C_s(15.5)(0 - 185.5) + (333)(1.14); 0 = -2875.3C_s + 379.6; 2875.3C_s = 379.6; C_s = 0.1320\text{J/g}^{\circ}\text{C}\}\n
14. \(0.388\text{J/g}^{\circ}\text{C}\) \{heat transfer + phase change; heat lost + heat gained = 0; for Zn: \(q = C_{s}(T_f - T_i)\); for water: \(q = \Delta H_{\text{vap}}(m)\); \(0 = C_s(35.0)(100 - 215) + (2256)(0.692); 0 = -4025C_s + 1561.2; 4025C_s = 1561.2; C_s = 0.3879\text{J/g}^{\circ}\text{C}\}\n
**Light, Matter, and Electronic Structure (Part I)-light, photoelectric effect**

1. i. True; \(\lambda_{\text{vis}} > \lambda_{\text{x-rays}}\) since \(E = \frac{1}{\lambda}\) and \(E_{\text{x-rays}} > E_{\text{vis}}\); “ii”: False; the amplitude refers to the intensity of the light and this is independent of the specific type of light; “iii”: True; since \(v = E\) and \(E_{\text{radio wave}} < E_{\text{UV}}\) the \(v_{\text{radio wave}} < v_{\text{UV}}\}

2. I. b \{\text{E}_{\text{photon}} = h\nu = (6.626 \times 10^{-34}\text{Js})(5.50 \times 10^6\text{s}^{-1}) = 3.644 \times 10^{-27}\text{J} = 3.64 \times 10^{-27}\text{J}\}\n
II. d \{\nu = \frac{c}{\lambda}; \lambda = \frac{c}{v}; \lambda = \frac{3.00 \times 10^8\text{ms}^{-1}}{5.50 \times 10^6\text{s}^{-1}} = 54.5\text{m}\}\n
III. a \{\frac{3.644 \times 10^{-27}}{\text{J}} \times \frac{6.022 \times 10^{23}\text{photons}}{1\text{molphotons}} = 0.002194\text{ J/molphotons}\}\n
3. d \{\text{find energy for one C=O bond in one molecule:} \frac{799\text{kJ}}{\text{mol}} \times \frac{1000\text{J}}{1\text{kJ}} \times \frac{1\text{molbonds}}{6.022 \times 10^{23}\text{bonds}} = 1.327 \times 10^{-18}\text{J/bond}\}\n
Use that energy to find wavelength: \(E = \frac{hc}{\lambda}; \lambda = \frac{hc}{E}; \lambda = \frac{(6.626 \times 10^{-34}\text{Js})(3.00 \times 10^8\text{m/s})}{1.327 \times 10^{-18}\text{J}} = 1.498 \times 10^{-7}\text{m}\}\n
4. a. T \{\nu = \frac{c}{\lambda}\}

b. F \{light is a combination of an electric and magnetic vector, and light is often referred to as electromagnetic radiation\}

c. T \{the amplitude is the “height” of the wave while the frequency is the number of wave cycles per second. Hence, a wave can be higher and yet have the same frequency.\}

d. T \{memorized\}

e. T \{E = \nu h\}

f. F \{gamma rays have the highest energy; radio waves have the lowest energy\}

g. T \{complete destructive interference eliminates the light and a node, e.g., no light, is formed\}

5. c \{“c”: If the wavelength of light is above the threshold and the wavelength is decreased the ejected electrons’ kinetic energy will increase; since \(KE = \frac{1}{2}mv^2\) the velocity of the electrons increases.

“a”: If the incident of light is below the threshold no electrons will be ejected; increasing the intensity will have no effect.

“b”: If the frequency of light is above the threshold and the intensity of the light is increased more electrons will be ejected with the same kinetic energy; direction of ejected electrons is not part of the experiment.

“d”: Temperature is not part of the photoelectric effect results.\}

6. I. b \{\text{E}_{\text{incident}} = \text{E}_{\text{binding}} + \text{E}_{\text{KE} e^\text{-}}; \text{E}_{\text{incident}} = \frac{hc}{\lambda}; E = \frac{(6.626 \times 10^{-34}\text{Js})(3.00 \times 10^8\text{m/s})}{(275\text{nm})(1\text{m} / 1 \times 10^9\text{nm})} = 7.23 \times 10^{-19}\text{J};\}

binding energy = 6.94 \times 10^{-19}\text{J}; \text{E}_{\text{KE} e^\text{-}} = \text{E}_{\text{incident}} - \text{E}_{\text{binding}}; \text{E}_{\text{KE} e^\text{-}} = 7.23 \times 10^{-19}\text{J} - 6.94 \times 10^{-19}\text{J} = 2.88 \times 10^{-20}\text{J}\}

II. e \{\text{KE} = \frac{1}{2}mv^2; m = \text{mass in kg}; 2.88 \times 10^{-20}\text{J} = \frac{1}{2}(9.11 \times 10^{-31}\text{kg})v^2; v^2 = 6.32 \times 10^{10}; v = \sqrt{6.32 \times 10^{10}} = 2.51 \times 10^5\text{m/s}\}