HOMEWORK 5A

Definitions
Barometer; Boyle’s Law

Questions

1. The pressure of the first two gases below is determined with a manometer that is filled with mercury (density = 13.6 g/mL). The pressure of the last two gases below is determined with a monometer that is filled with silicone oil (density = 1.30 g/mL). Assume an atmospheric pressure of 756 mm Hg, and determine the pressure of each gas in (1) mm Hg, (2) torr, (3) atmospheres and (4) pascals.

   (a)  
   (b)  
   (c)  
   (d)  

   ![Manometers](image)

2. Given the following data:

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>87</td>
<td>16</td>
</tr>
<tr>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>58</td>
<td>24</td>
</tr>
<tr>
<td>44</td>
<td>32</td>
</tr>
<tr>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>29</td>
<td>48</td>
</tr>
</tbody>
</table>

   (a) graph \( Y \) versus \( X \)  
   (b) graph \( Y \) versus \( 1/X \)  
   (c) graph \( \log Y \) versus \( \log X \)  
   (d) graph \( XY \) versus \( X \)
**HOMEWORK 5B**

*Definitions*

Charles’s Law; Absolute Zero; Avogadro’s Law; Standard Temperature and Pressure (STP)

*Questions*

1. Calculate the moles of gas contained in a 986 mL flask at 29.2ºC with a pressure of 688 torr.

2. Calculate the density of ammonia gas at 27°C and 635 torr.

3. A compound is found to be 24.8% carbon, 2.1% hydrogen, and 73.1% chlorine by mass. When the compound was vaporized, a 256 mL flask at 373 K and 751 torr contained 0.800 g of the gaseous compound. For the compound, determine its
   (a) empirical formula
   (b) molar mass
   (c) molecular formula

4. Draw a qualitative graph to show how the first property varies with the second in each of the following. In each case, assume the moles of gas are constant.
   (a) p versus T with constant V
   (b) p versus V with constant T
   (c) p versus 1/V with constant T
   (d) log p versus log V with constant T
   (e) pV versus V with constant T

**HOMEWORK 5C**

*Definitions*

Dalton’s Law of Partial Pressures; Partial Pressure; Mole Fraction

*Questions*

1. Calculate the volume of oxygen gas that can be produced at 30.0°C and 725 torr from the complete decomposition of 4.10 g mercury (II) oxide.

2. Urea, H₂NCONH₂, is used as a nitrogen source in fertilizers, and can be produced commercially from the reaction of ammonia with carbon dioxide:

   \[ 2 \text{NH}_3 (g) + \text{CO}_2 (g) \rightarrow \text{H}_2\text{NCONH}_2 (s) + \text{H}_2\text{O} (g) \]

   Calculate the mass of urea that can be produced if 500. L of ammonia at 223°C and 90. atm are reacted with 600. L of carbon dioxide at 223°C and 45 atm.

3. When a flask is charged with 0.265 g of ammonia gas and 0.720 g of nitrogen gas, the pressure was measured to be 4.43 atm.
   (a) Draw Lewis structures and bond-orbital models for molecules for each gas.
   (b) Find the partial pressures of each gas.
Definitions

Kinetic Molecular Theory; Joule; Diffusion; Effusion

Questions

1. Determine the pressure of dry hydrogen gas collected in each of the following eudiometers. Assume an atmospheric pressure of 756.0 torr and a temperature of 22.0°C. Water vapor pressure at 22.0°C is 19.8 torr.

2. Acetylene gas, C_2H_2, and calcium hydroxide are produced when solid calcium carbide, CaC_2, reacts with water. From a sample containing calcium carbide, 2.18 L of acetylene are collected over water in a eudiometer. The water level inside the eudiometer is 87.5 mm higher than the outside, the water temperature is 21.5°C, the atmospheric pressure is 758.7 torr, and the water vapor pressure at 21.5°C is 19.2 torr.

   (a) Calculate the mass of the calcium carbide that reacted.

   (b) If the sample was known to be 90.0% calcium carbide by mass, calculate the mass of the sample that reacted.

3. Calculate the root-mean-square-velocity of nitrogen molecules

   (a) at 273 K

   (b) at 546 K

4. Graph the relative number of nitrogen molecules versus their velocities

   (a) at 273 K

   (b) at 546 K
Questions

1. A 3.50 g sample of a compound containing only carbon, hydrogen, and nitrogen was burned, producing 3.35 g of carbon dioxide and 4.11 g of water. The effusion rate of the compound was measured and found to be 24.6 mL/min. Under the same conditions, the effusion rate of argon gas was found to be 26.4 mL/min.
   (a) Determine the empirical formula of the compound
   (b) Determine the molar mass of the compound
   (c) Determine the molecular formula of the compound

2. Table 5.3 in the text book does not give the van der Waals constants $a$ and $b$ for gaseous Br$_2$. Predict their numerical values and explain your reasoning.

3. Calculate the pressure of 0.5000 moles of nitrogen gas in a 10.000 L container at 25.0°C using:
   (a) the ideal gas law equation
   (b) the van der Waals equation

4. Have access to Handout 7 from the Class Web Site

Definitions

Exothermic; Endothermic; Bond Energy; Enthalpy; Calorimeter; Heat Capacity; Specific Heat Capacity; Molar Heat Capacity

Questions

1. Using the bond energies from Table 8.4 in the text book, estimate the energy change for the reaction:
   \[ \text{CH}_4 (g) + 2\text{O}_2 (g) \rightarrow \text{CO}_2 (g) + 2\text{H}_2\text{O} (g) \]

2. In a coffee-cup calorimeter, 50.0 mL of 1.00 M sulfuric acid is mixed with 150.0 mL of 1.00 M sodium hydroxide, both at 24.6°C. After the reaction, the solution reaches a maximum temperature of 31.2°C, and the solution’s mass is measured to be 202.2 g. If the specific heat capacity of the solution is 4.184 J/g°C, calculate the heat of the reaction, in kJ per mole of sodium sulfate.
Questions

1. A 0.125 g sample of magnesium metal is added to 20 mL of a 1.0 M hydrochloric acid solution in a calorimeter, and the temperature of the solution increases from 21.4°C to 48.9°C. If the mass of the solution is 20.655 g and the specific heat capacity of the solution is 4.184 J/g°C, calculate the heat of the reaction, in kJ per mole of magnesium.

2. Using your answer from question 1, calculate the amount of heat released or absorbed when the given amounts of magnesium metal react with excess hydrochloric acid.
   (a) 0.250 moles of Mg
   (b) 4.75 grams of Mg

3. The reaction between hydrochloric acid and barium hydroxide has a heat of neutralization of −118 kJ per mole of barium chloride. In a coffee-cup calorimeter, 100.0 mL of 0.500 M hydrochloric acid is mixed with 300.0 mL of 0.100 M barium hydroxide, both at 25.0°C. After the reaction, the final mixture has a mass of 400.0 g and has a specific heat capacity of 4.184 J/g°C. Calculate the final temperature of the mixture.

4. A 0.1964 g sample of quinone (C₆H₄O₂) is burned in a bomb calorimeter that has a heat capacity of 1.56 kJ/C°, and the temperature of the calorimeter rises from 21.0°C to 24.2°C. Calculate the heat of combustion of quinone in kJ per gram of quinone.

5. Using your answer from question 4, calculate the amount of heat released or absorbed when the given amounts of quinone are burned.
   (a) 3.65 grams of quinone
   (b) 75.0 mL of quinone (density = 1.256 g/mL)

6. A bomb calorimeter with a heat capacity of 10.8 kJ/C° has an initial temperature of 23.32°C. A 1.056 g sample of benzoic acid is combusted in the calorimeter. If the benzoic acid has a heat of combustion of −26.42 kJ/g benzoic acid, calculate the final temperature of the bomb calorimeter.
HOMEWORK 5H

Definitions

Hess’s Law; Lattice Energy; Standard Enthalpy of Formation

Questions

1. Given the heat of combustions for the following reactions:
   \[
   \begin{align*}
   C_2H_2(g) + \frac{3}{2}O_2(g) & \rightarrow 2CO_2(g) + H_2O(g) & \Delta H = -1257 \text{ kJ} \\
   C(s) + O_2(g) & \rightarrow CO_2(g) & \Delta H = -394 \text{ kJ} \\
   H_2(g) + \frac{1}{2}O_2(g) & \rightarrow H_2O(g) & \Delta H = -242 \text{ kJ}
   \end{align*}
   \]
   calculate the \( \Delta H \) for the reaction:
   \[
   2C(s) + H_2(g) \rightarrow C_2H_2(g)
   \]

2. Using the heat of combustions for \( C_4H_8 \) \((-2341 \text{ kJ/mol})\), \( C_4H_8 \) \((-2755 \text{ kJ/mol})\), and \( H_2 \) \((-242 \text{ kJ/mol})\), calculate the \( \Delta H \) for the reaction:
   \[
   C_4H_4 + 2H_2 \rightarrow C_4H_8
   \]

3. Have access to Handout 8 from the Class Web Site.

HOMEWORK 5I

Definitions

State Function; Petroleum; Natural Gas; Coal

Questions

1. Using the standard heat of formations in Appendix 4 (pages A21-A23) of your text book, calculate \( \Delta H^\circ \) for the combustion of octane, in kJ/gram of octane, and \( \Delta H^\circ \) for the combustion of ethanol, in kJ/gram of ethanol. Determine which fuel provides the most energy per gram. (The standard heat of formation for octane is found only in Table 6.2)
   \[
   \begin{align*}
   (a)\ 2C_8H_{16}(l) + 25O_2(g) & \rightarrow 16CO_2(g) + 18H_2O(g) \\
   (b)\ C_2H_5OH(l) + 3O_2(g) & \rightarrow 2CO_2(g) + 3H_2O(g)
   \end{align*}
   \]

2. The standard heat of combustion of butane gas, \( C_4H_{10} \), is \(-49.52 \text{ kJ/gram of butane} \). Using the standard heat of formations in Appendix 4 (pages A21-A23) of your text book, calculate the standard heat of formation of butane gas.
Definitions

Internal Energy; Heat; Work; First Law of Thermodynamics

Questions

1. Calculate the change in internal energy for each of the following:
   (a) a gas absorbs 45 kJ of heat and expands, doing 29 kJ of work on the surroundings.
   (b) a gas releases 125 kJ of heat and is compressed, having 104 kJ of work done on it.

2. A gas expands from 62 mL to 287 mL against a constant pressure of 0.985 atm. Calculate the work done by the gas in each of the following units:
   (a) Latm
   (b) J

3. A balloon containing 313 g helium has a volume of 1910. L at 28°C. The temperature of the helium decreases to 13°C and the volume of the balloon shrinks to 1814 L against a constant pressure of 1.00 atm. The molar heat capacity of helium is 20.8 J/mol°C. For the helium, calculate
   (a) q
   (b) w
   (c) ΔE
   (d) ΔH

HOMEWORK 4R

1. Give the missing information for each gas:

<table>
<thead>
<tr>
<th></th>
<th>V</th>
<th>n</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>5.00 atm</td>
<td>2.00 mol</td>
<td>155°C</td>
</tr>
<tr>
<td>(b)</td>
<td>228 torr</td>
<td>2.00 L</td>
<td>155 K</td>
</tr>
<tr>
<td>(c)</td>
<td>0.447 atm</td>
<td>775 mL</td>
<td>0.0300 mol</td>
</tr>
<tr>
<td>(d)</td>
<td>2.25 L</td>
<td>10.5 mol</td>
<td>75°C</td>
</tr>
</tbody>
</table>

2. Calculate the density of gaseous trichlorsilane (SiHCl₃) at 85°C and 758 torr.

3. Calculate the molar mass of a gaseous substance if a 0.532 L sample of the gas at 99.5°C and 753.4 torr has a mass of 1.1394 g.

4. If the gas in question 3 was found to be 36.4% carbon, 6.1% hydrogen, and 57.5% fluorine by mass, determine its empirical and molecular formulas.

5. When 0.623 g of methane gas, 1.02 g of nitrogen gas, and 1.35 g of argon gas are placed in a flask, they produce a pressure of 587 torr. Find the partial pressures of each gas.

(continued on next page)
6. Give the pressure of dry oxygen gas is each of the following gas collecting devices. Assume atmospheric pressure is 758 torr and the temperature is 21°C. Water vapor pressure at 21°C is 19 torr.

7. A 370. mL sample of oxygen gas is produced in the laboratory from the decomposition of potassium chlorate. The oxygen is collected by water displacement in an Erlenmeyer flask, the level of water inside the flask the same as the level of water outside the flask. The water temperature is 27.0°C and atmospheric pressure is 754.0 torr. Water vapor pressure at 27.0°C is 26.7 torr. Calculate the mass of potassium chlorate that was decomposed.

8. Calculate the root-mean-square velocity of methane molecules at 273 K.

9. Consider three identical flasks filled with different gases:
   Flask A: CO at 760 torr and 0°C
   Flask B: N₂ at 250 torr and 0°C
   Flask C: H₂ at 100 torr and 0°C
   (a) In which flask will the molecules have the greatest average kinetic energy?
   (b) In which flask will the molecules have the greatest average velocity?

10. The diffusion rate of an unknown gas is measured and found to be 31.50 mL/min. Under identical conditions, the diffusion rate of oxygen gas is found to be 30.50 mL/min. Identify the unknown gas if it is known to be either ammonia, carbon monoxide, nitrogen monoxide, carbon dioxide, or nitrogen dioxide.

11. For the following gases:
    \[ \text{CO}_2 \quad \text{HF} \quad \text{He} \]
    (a) arrange them from smallest to largest according to the van der Waal’s constant \(a\).
    (b) arrange them from smallest to largest according to the van der Waal’s constant \(b\).

    (continued on next page)
12. The heat change of a substance can be given by the following relationship:

\[ q = C_m \Delta T \]

Graph each of the following relationships:

(a) \( q \) vs. \( \Delta T \) (at constant \( m \))
(b) \( m \) vs. \( \Delta T \) (at constant \( q \))
(c) \( m \) vs. \( \frac{1}{\Delta T} \) (at constant \( q \))
(d) \( m \Delta T \) vs. \( m \) (at constant \( q \))
(e) \( \log m \) vs. \( \log \Delta T \) (at constant \( q \))

13. A balloon filled with 156 grams of helium gas has a volume of 876 L at STP. While the pressure remains constant, the temperature of the balloon is increased to 38.0°C, and it expands to a volume of 998 L. Calculate \( q \), \( w \), \( \Delta E \) and \( \Delta H \) for the helium in the balloon. The heat capacity for helium gas is 5.20 J/g°C.

14. For the incomplete combustion of silicon:

\[ 2\text{Si}(s) + \frac{1}{2}\text{O}_2(g) \rightarrow 2\text{SiO}(g) \quad \Delta H = -88.2 \text{ kJ} \]

calculate the amount of heat released for each of the following:

(a) 5.00 mol of Si is reacted
(b) 5.00 g of Si is reacted

15. In coffee-cup calorimeter 20.0 mL of 0.500 M silver nitrate, initially at 22.60°C, are mixed with 30.0 mL of 0.300 M hydrochloric acid, also at 22.60°C. After the solutions mix, and a precipitate is formed, the temperature of the mixture reaches a maximum of 23.85°C. The mass of the solution was 51.22 g. Assuming the heat capacity of the solution is 4.184 J/g°C, find the heat of the reaction, in kilojoules per mole of silver chloride.

16. The reaction between sulfuric acid and sodium hydroxide has a heat of neutralization of \(-112 \text{ kJ} \) per mole of sodium sulfate. In a coffee-cup calorimeter, 100.0 mL of 0.200 M sulfuric acid is mixed with 100.0 mL of 0.300 M sodium hydroxide, both at 23.50°C. After the reaction, the final mixture has a mass of 202.0 g and has a specific heat capacity of 4.184 J/g°C. Calculate the final temperature of the mixture.

17. A 1.625 g sample of wax is burned in a bomb calorimeter that has a heat capacity of 1.75 kJ/C°, and the temperature of the calorimeter rises from 22.30°C to 25.24°C. Calculate the heat of combustion of wax in kJ per gram of wax.

18. Camphor (C_{10}H_{16}O) has a heat of combustion of \(-5904 \text{ kJ/mol} \). When a sample of camphor with a mass of 0.1204 g is burned in a bomb calorimeter, the temperature increases from 21.75°C to 24.03°C. Calculate the heat capacity of the calorimeter.

19. Given the following data:

\[ \text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{H}_2\text{O}(l) \quad \Delta H = -258.8 \text{ kJ} \]
\[ \text{N}_2\text{O}_5(g) + \text{H}_2\text{O}(l) \rightarrow 2\text{HNO}_3(l) \quad \Delta H = -76.6 \text{ kJ} \]
\[ \frac{1}{2}\text{N}_2(g) + \frac{1}{2}\text{O}_2(g) + \frac{1}{2}\text{H}_2(g) \rightarrow \text{HNO}_3(l) \quad \Delta H = -174.1 \text{ kJ} \]

calculate the \( \Delta H \) for the reaction:

\[ 2\text{N}_2(g) + 5\text{O}_2(g) \rightarrow 2\text{N}_2\text{O}_5(g) \]

(continued on next page)
20. The heat of combustion of solid carbon to carbon dioxide is \(-393.5\) kJ/mol, and the heat of combustion of carbon monoxide to form carbon dioxide is \(-283.3\) kJ/mol. Use these data to calculate the \(\Delta H\) for the reaction

\[
2C(s) + O_2(g) \rightarrow 2CO(g)
\]

21. Given the following data:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lattice Energy of NaCl</td>
<td>(-786) kJ/mol</td>
</tr>
<tr>
<td>First Ionization Energy of Na</td>
<td>495 kJ/mol</td>
</tr>
<tr>
<td>Second Ionization Energy of Na</td>
<td>4560 kJ/mol</td>
</tr>
<tr>
<td>Electron Affinity of Cl</td>
<td>(-349) kJ/mol</td>
</tr>
<tr>
<td>Bond Energy of Cl₂</td>
<td>239 kJ/mol</td>
</tr>
<tr>
<td>Sublimation Energy of Na</td>
<td>109 kJ/mol</td>
</tr>
</tbody>
</table>

estimate the standard heat of formation for solid sodium chloride.

22. Calculate \(\Delta H^\circ\) for each of the following reactions using the standard heat of formations in Appendix 4 (pages A21-A23) of your text book:

(a) \(2 \text{NO}(g) + \text{O}_2(g) \rightarrow 2 \text{NO}_2(g)\)

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

23. The reusable booster rockets of the space shuttle use a mixture of aluminum and ammonium perchlorate as fuel. A possible reaction is:

\[
3\text{Al}(s) + 3\text{NH}_4\text{ClO}_4(s) \rightarrow \text{Al}_2\text{O}_3(s) + \text{AlCl}_3(s) + 3\text{NO}(g) + 6\text{H}_2\text{O}(g)
\]

Calculate \(\Delta H^\circ\), in kJ/gram Al, for this reaction using the standard heat of formations in Appendix 4 (pages A21-A25) of your text book:

24. Consider the reaction:

\[
2 \text{ClF}_3(g) + 2 \text{NH}_3(g) \rightarrow \text{N}_2(g) + 6 \text{HF}(g) + \text{Cl}_2(g) \quad \Delta H^\circ = -1196 \text{ kJ}
\]

Using the standard heat of formations in Appendix 4 (pages A21-A23) of your text book, calculate the standard heat of formation of gaseous chlorine trifluoride.

25. Using the bond energies from Table 8.4 in the text book, estimate the heat of reaction for each of the following:

(a) \(\text{H}_2 + \text{Cl}_2 \rightarrow 2 \text{HCl}\)

(b) \(\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3\)

**HOMEWORK 4R ANSWERS**

1. (a) 14.1 L  (b) 0.0472 mol  (c) 141 K  (d) 133 atm
2. 4.60 g/L
3. 66.1 g/mol
4. \(\text{CH}_2\text{F}, \ \text{C}_2\text{H}_4\text{F}_2\)
5. 209 torr \(\text{CH}_4\), 196 torr \(\text{N}_2\), 182 torr \(\text{Ar}\)

(continued on next page)
6. (a) 354 mm Hg  (b) 1112 mm Hg  (c) 739 mm Hg  (d) 728 mm Hg
7. 1.17 g KClO₃
8. 651 m/s
9. (a) all are equal  (b) flask C
10. nitrogen monoxide
11. (a) He, CO₂, HF  (b) He, HF, CO₂
12. (a)  (b)  (c)  (d)  (e)

13. q = 30,800 J, w = -12,400 J, ΔE = 18,400 J, ΔH = 30,800 J
14. (a) -221 kJ  (b) -7.85 kJ
15. -29.8 kJ/mol AgCl
16. 25.49°C
17. -3.17 kJ/g wax
18. 2.05 kJ/C°
19. -25.6 kJ
20. -220.4 kJ
21. -412 kJ
22. (a) -112 kJ  (b) -940. kJ
23. -33.07 kJ/g
24. -169 kJ/mol
25. (a) -183 kJ  (b) -109 kJ