School Name:____________________________________________________________
Team Members:____________________________________________________________

Multiple Choice Score: ______/50
Laboratory Score: ______/20
Composite Score: ______/70

Rank: ______

You may separate these pages during the test, but they must be reassembled IN ORDER and re-stapled at the end of the exam time.
1. The local weather forecaster reports that the current barometric pressure is 30.4 inches of mercury. What is the current pressure in atmospheres?
   A) 1.02 atm
   B) 10.29 atm
   C) 1.00 atm
   D) 4.05 atm
   E) 910 atm

2. Charles's law states that:
   A) Equal amounts of gases occupy the same volume at constant temperature and pressure.
   B) The volume of a fixed amount of gas is inversely proportional to its pressure at constant temperature.
   C) The volume of a fixed amount of gas is directly proportional to its temperature in Kelvin at constant pressure.
   D) The total pressure of a mixture of gases is the simple sum of the partial pressure of all of the gaseous compounds.
   E) The rates of effusion of gases are inversely proportional to the square roots of their molar masses.

3. Consider a sample of gas in a container on a comfortable spring day. The Celsius temperature suddenly doubles, and you transfer the gas to a container with twice the volume of the first container. If the original pressure was 12 atm, what is a good estimate for the new pressure?
   A) 3 atm
   B) 5.5 atm
   C) 6.4 atm
   D) 12 atm
   E) 15 atm

4. You are holding two balloons, an orange balloon and a blue balloon. The orange balloon is filled with neon (Ne) gas and the blue balloon is filled with argon (Ar) gas. The orange balloon has twice the volume of the blue balloon. Which of the following best represents the mass ratio of Ne:Ar in the balloons?
   A) 1:1
   B) 1:2
   C) 2:1
   D) 1:3
   E) 3:1

For questions 5 and 6: You have two samples of the same gas in the same size container, with the same pressure. The gas in the first container has a Kelvin temperature four times that of the gas in the other container

5. The ratio of the number of moles of gas in the first container compared to that in the second is
   A) 1:1
   B) 4:1
   C) 1:4
   D) 2:1
   E) 1:2
6. The ratio of the average velocity of particles in the first container compared to that in the second is
A) 1:1
B) 4:1
C) 1:4
D) 2:1
E) 1:2

For questions 7 and 8: Three 1.00-L flasks at 25°C and 725 torr contain the gases CH₄ (flask A), CO₂ (flask B), and C₂H₆ (flask C).

7. In which flask is there 0.039 mol of gas?
A) Flask A
B) Flask B
C) Flask C
D) all
E) none

8. In which single flask do the molecules have the greatest mass, the greatest average velocity, and the highest kinetic energy?
A) Flask A
B) Flask B
C) Flask C
D) All are the same.
E) No one flask has all these.

9. A 41.1-g sample of Ne gas exerts a certain pressure in a container of fixed volume. What mass of Ar is required to exert half the pressure at the same conditions of volume and temperature?
A) 81.4 g Ar
B) 1.02 g Ar
C) 163 g Ar
D) 821 g Ar
E) 40.7 g Ar

10. Given a cylinder of fixed volume filled with 1 mol of argon gas, which of the following is correct? (Assume all gases obey the ideal gas law.)
A) If the temperature of the cylinder is changed from 25°C to 50°C, the pressure inside the cylinder will double.
B) If a second mole of argon is added to the cylinder, the ratio T/P would remain constant.
C) A cylinder of identical volume filled with the same pressure of helium must contain more atoms of gas because He has a smaller atomic radius than argon.
D) Two of the above.
E) None of the above.
11. For an ideal gas, which pairs of variables are inversely proportional to each other (if all other factors remain constant)?

1. $V$ and $T$
2. $T$ and $n$
3. $n$ and $V$
4. $P$ and $T$

A) 1 and 2 only
B) 3 and 4 only
C) 2 only
D) 1 and 3 only
E) 1, 3, and 4 only

12. The mass of 1.12 liters of gas $Y$ at STP is found to be 6.23 g. The density of gas $Y$ is

A) 10.6 g/L
B) 5.56 g/L
C) 15.6 g/L
D) 0.200 g/L
E) 0.180 g/L

13. Which of the following is the best qualitative graph of $P$ versus molar mass of a 1-g sample of different gases at constant volume and temperature?

A) 

B) 

C) 

D) 

E) none of these

14. Given reaction $2\text{NH}_3(g) + 3\text{Cl}_2(g) \rightarrow \text{N}_2(g) + 6\text{HCl}(g)$, you react 5.0 L of $\text{NH}_3$ with 5.0 L of $\text{Cl}_2$ measured at the same conditions in a closed container. Calculate the ratio of pressures in the container ($P_{\text{final}}/P_{\text{initial}}$).

A) 0.75
B) 1.00
C) 1.33
D) 1.50
E) none of these
15. Calculate the density of nitrogen at STP.
   A) 0.312 g/L
   B) 0.625 g/L
   C) 0.800 g/L
   D) 1.25 g/L
   E) 1.60 atm

16. Calcium hydride combines with water according to the equation:
    \[ \text{CaH}_2(s) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{H}_2(g) + \text{Ca(OH)}_2(s) \]

   Beginning with 84.0 g of CaH2 and 42.0 g of H2O, what volume of H2 will be produced at 273 K
   and a pressure of 1327 torr?
   A) 29.9 L
   B) 15.0 L
   C) 5.39 \times 10^2 L
   D) 25.7 L
   E) none of these

17. A mixture is prepared from 15.0 L of ammonia and 15.0 L chlorine measured at the same conditions;
   these compounds react according to the following equation:
   \[ 2\text{NH}_3(g) + 3\text{Cl}_2(g) \rightarrow \text{N}_2(g) + 6\text{HCl(g)} \]

   When the reaction is completed, what is the volume of each gas (NH3, Cl2, N2, and HCl, respectively)?
   Assume the final volumes are measured under identical conditions.
   A) 0.00 L, 5.00 L, 7.50 L, 45.0 L
   B) 5.00 L, 0.00 L, 5.00 L, 30.0 L
   C) 0.00 L, 0.00 L, 7.50 L, 45.0 L
   D) 0.00 L, 0.00 L, 5.00 L, 30.0 L
   E) 0.00 L, 10.0 L, 15.0 L, 90.0 L

18. A 1.00-g sample of a gaseous compound of boron and hydrogen occupies 0.820 L at 1.00 atm and
   3°C. What could be the molecular formula for the compound?
   A) BH3
   B) B2H6
   C) B4H10
   D) B3H12
   E) B3H14

19. A mixture of KCl and KClO3 weighing 1.34 grams was heated; the dry O2 generated occupied 143
    mL at STP. What percent of the original mixture was KClO3, which decomposes as follows:
    \[ 2\text{KClO}_3(s) \rightarrow 2\text{KCl(s)} + 3\text{O}_2(g) \]
    A) 38.9%
    B) 58.4%
    C) 87.6%
    D) 10.7%
    E) 23.7%
For questions 20 and 21: Zinc metal is added to hydrochloric acid to generate hydrogen gas, which is collected over a liquid whose vapor pressure is the same as pure water at 20.0°C (18 torr). The volume of the gas mixture is 1.7 L and its total pressure is 0.810 atm.

20. Determine the partial pressure of the hydrogen gas in this mixture.
   A) 562 torr
   B) 580 torr
   C) 598 torr
   D) 616 torr
   E) 634 torr

21. Determine the number of moles of hydrogen gas present in the sample.
   A) 42 mol
   B) 0.82 mol
   C) 1.3 mol
   D) 0.056 mol
   E) 22 mol

22. Hydrogen and chlorine gases react to form HCl. You and a friend are on opposite sides of a long hallway, you with H₂ and your friend with Cl₂. You both want to form HCl in the middle of the room. Which of the following is true?
   A) You should release the H₂ first.
   B) Your friend should release the Cl₂ first.
   C) You both should release the gases at the same time.
   D) You need to know the length of the room to answer this question.
   E) You need to know the temperature to answer this question.

23. Which of the following pollutant gases is not produced directly in a combustion engine?
   A) CO
   B) CO₂
   C) O₃
   D) NO
   E) NO₂

24. Real gases are those that
   A) only behave ideally at high pressures or low temperatures
   B) deviate from ideal behavior
   C) are only available naturally in the earth's atmosphere
   D) are called real gases because their behavior can easily be modeled
   E) have an even number of protons
25. The rate of effusion of an unknown gas was measured and found to be 11.9 mL/min. Under identical conditions, the rate of effusion of pure oxygen (O₂) gas is 14.0 mL/min. Based on this information, the identity of the unknown gas could be:
   A) F₂
   B) NO
   C) CO₂
   D) C₂H₂
   E) none of these

26. For a particular process \( q = 20 \text{ kJ} \) and \( w = 15 \text{ kJ} \). Which of the following statements is true?
   A) Heat flows from the system to the surroundings.
   B) The system does work on the surroundings.
   C) \( \Delta E = 35 \text{ kJ} \)
   D) All of the above are true.
   E) None of the above are true.

27. According to the first law of thermodynamics, the energy of the universe is constant. Does this mean that \( \Delta E \) is always equal to zero?
   A) Yes, \( \Delta E = 0 \) at all times, which is why \( q = -w \).
   B) No, \( \Delta E \) does not always equal zero, but this is only due to factors like friction and heat.
   C) No, \( \Delta E \) does not always equal zero because it refers to the system's internal energy, which is affected by heat and work.
   D) No, \( \Delta E \) never equals zero because work is always being done on the system or by the system.
   E) No, \( \Delta E \) never equals zero because energy is always flowing between the system and surroundings.

28. Of energy, work, enthalpy, and heat, how many are state functions?
   A) 0
   B) 1
   C) 2
   D) 3
   E) 4
29. \(\text{C}_2\text{H}_5\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l), \Delta H = -1.37 \times 10^3 \text{ kJ}\)

For the combustion of ethyl alcohol as described in the above equation, which of the following is true?

I. The reaction is exothermic.
II. The enthalpy change would be different if gaseous water was produced.
III. The reaction is not an oxidation–reduction one.
IV. The products of the reaction occupy a larger volume than the reactants.

A) I, II
B) I, II, III
C) I, III, IV
D) III, IV
E) only I

30. How much heat is required to raise the temperature of a 5.75-g sample of iron (specific heat = 0.450 J/g°C) from 25.0°C to 79.8°C?

A) 2.54 J
B) 315 J
C) 700 J
D) 848 J
E) 142 J

31. Two metals of equal mass with different heat capacities are subjected to the same amount of heat. Which undergoes the smallest change in temperature?

A) The metal with the higher heat capacity.
B) The metal with the lower heat capacity.
C) Both undergo the same change in temperature.
D) You need to know the initial temperatures of the metals.
E) You need to know which metals you have.

32. The enthalpy of fusion of ice is 6.020 kJ/mol. The heat capacity of liquid water is 75.4 J/mol·°C. What is the smallest number of ice cubes at 0°C, each containing one mole of water, necessary to cool 500 g of liquid water initially at 20°C to 0°C?

A) 1
B) 7
C) 14
D) 15
E) 126

33. 30.0 mL of pure water at 282 K is mixed with 50.0 mL of pure water at 306 K. What is the final temperature of the mixture?

A) 294 K
B) 297 K
C) 342 K
D) 588 K
E) 24 K
34. If 5.0 kJ of energy is added to a 15.5-g sample of water at 10.0°C, the water is
   A) boiling
   B) completely vaporized
   C) frozen solid
   D) decomposed
   E) still a liquid

35. The total volume of hydrogen gas needed to fill the Hindenburg was \(2.11 \times 10^8\) L at 1.00 atm and 24.7°C. How much energy was evolved when it burned?
   \[\text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{H}_2\text{O}(l), \Delta H = -286\ kJ\]
   A) \(8.64 \times 10^6\) kJ
   B) \(2.98 \times 10^{10}\) kJ
   C) \(3.02 \times 10^4\) kJ
   D) \(2.47 \times 10^9\) kJ
   E) \(4.94 \times 10^9\) kJ

36. Given the equation \(S(s) + \text{O}_2(g) \rightarrow \text{SO}_2(g), \Delta H = -296\ kJ\), which of the following statement(s) is (are) true?
   I. The reaction is exothermic.
   II. When 0.500 mole sulfur is reacted, 148 kJ of energy is released.
   III. When 32.0 g of sulfur are burned, \(2.96 \times 10^5\) J of energy is released.
   A) All are true.
   B) None is true.
   C) I and II are true.
   D) I and III are true.
   E) Only II is true.

37. Which of the following statements is/are true?
   I. \(q\) (heat) is a state function because \(\Delta H\) is a state function and \(q = \Delta H\).
   II. When 50.0 g of aluminum at 20.0°C is placed in 50.0 mL of water at 30.0°C, the \(\text{H}_2\text{O}\) will undergo a smaller temperature change than the aluminum. (The density of \(\text{H}_2\text{O} = 1.0\ \text{g/mL},\) specific heat capacity of \(\text{H}_2\text{O} = 4.18\ \text{J/g°C},\) specific heat capacity of aluminum = 0.89 J/g°C)
   III. When a gas is compressed, the work is negative since the surroundings are doing work on the system and energy flows out of the system.
   IV. For the reaction (at constant pressure) \(2\text{N}_2(g) + 5\text{O}_2(g) \rightarrow 2\text{N}_2\text{O}_5(g),\) the change in enthalpy is the same whether the reaction takes place in one step or in a series of steps.
   A) I, II, IV
   B) II, III
   C) II, III, IV
   D) II, IV
   E) All of the above statements are true.
38. Consider the following processes:

\[ 3B \rightarrow 2C + D \]  \[ \Delta H (kJ/mol) \]  \[ -125 \]
\[ (1/2)A \rightarrow B \]  \[ 150 \]
\[ E + A \rightarrow D \]  \[ 350 \]

Calculate \( \Delta H \) for: \( B \rightarrow E + 2C \)
A) 325 kJ/mol
B) 525 kJ/mol
C) -175 kJ/mol
D) -325 kJ/mol
E) none of these

39. Calculate \( \Delta H^\circ \) for the reaction \( C_4H_4(g) + 2H_2(g) \rightarrow C_4H_8(g) \), using the following data:
\( \Delta H^\circ_{\text{combustion}} \) for \( C_4H_4(g) = -2341 \) kJ/mol
\( \Delta H^\circ_{\text{combustion}} \) for \( H_2(g) = -286 \) kJ/mol
\( \Delta H^\circ_{\text{combustion}} \) for \( C_4H_8(g) = -2755 \) kJ/mol
A) -128 kJ
B) -158 kJ
C) 128 kJ
D) 158 kJ
E) none of these

40. Using the following thermochemical data, calculate \( \Delta H^\circ \) of \( \text{Tm}_2\text{O}_3(s) \).

\[ 2\text{TmCl}_3(s) + 3\text{H}_2\text{O}(l) \rightarrow \text{Tm}_2\text{O}_3(s) + 6\text{HCl}(g) \]  \[ \Delta H^\circ = 388.1 \) kJ/mol \]
\[ 2\text{Tm}(s) + 3\text{Cl}_2(g) \rightarrow 2\text{TmCl}_3(s) \]  \[ \Delta H^\circ = -1973.2 \) kJ/mol \]
\[ 4\text{HCl}(g) + \text{O}_2(g) \rightarrow 2\text{Cl}_2(g) + 2\text{H}_2\text{O}(l) \]  \[ \Delta H^\circ = -202.4 \) kJ/mol \]
A) -1888.7 kJ/mol
B) -1787.5 kJ/mol
C) 2563.7 kJ/mol
D) -2158.9 kJ/mol
E) 1382.7 kJ/mol

41. The heat combustion of acetylene, \( \text{C}_2\text{H}_2(g) \), at 25°C is -1299 kJ/mol. At this temperature, \( \Delta H^\circ \) values for \( \text{CO}_2(g) \) and \( \text{H}_2\text{O}(l) \) are -393 and -286 kJ/mol, respectively. Calculate \( \Delta H^\circ \) for acetylene.
A) 2376 kJ/mol
B) 625 kJ/mol
C) 227 kJ/mol
D) -625 kJ/mol
E) -227 kJ/mol
42. The following statements concerning petroleum are all true except:
   A) It is a thick, dark liquid composed mostly of hydrocarbons.
   B) It must be separated into fractions (by boiling) in order to be used efficiently.
   C) Some of the commercial uses of petroleum fractions include gasoline and kerosene.
   D) It was probably formed from the remains of ancient marine organisms.
   E) All of its hydrocarbon chains contain the same number of carbon atoms.

43. The coal with the highest energy available per unit burned is
   A) Lignite.
   B) Subbituminous.
   C) Bituminous.
   D) Anthracite.
   E) They are equal in energy value.

44. All of the following statements about the greenhouse effect are true except:
   A) It occurs only on earth.
   B) The molecules H2O and CO2 play an important role in retaining the atmosphere's heat.
   C) Low humidity allows efficient radiation of heat back into space.
   D) The carbon dioxide content of the atmosphere is quite stable.
   E) A and D

45. One of the main advantages of hydrogen as a fuel is that:
   A) The only product of hydrogen combustion is water.
   B) It exists as a free gas.
   C) It can be economically supplied by the world's oceans.
   D) Plants can economically produce the hydrogen needed.
   E) It contains a large amount of energy per unit volume of hydrogen gas.

46. Which of the following is both a greenhouse gas and a fuel?
   A) carbon dioxide
   B) coal
   C) freon
   D) methane
   E) nitrogen

47. Using the information below, calculate \( \Delta H^\circ \) for PbO(s)
   \[ \text{PbO(s) + CO(g) \rightarrow Pb(s) + CO}_2(g) \quad \Delta H^\circ = -131.4 \text{ kJ} \]
   \[ \Delta H^\circ \text{ for CO}_2(g) = -393.5 \text{ kJ/mol} \]
   \[ \Delta H^\circ \text{ for CO(g)} = -110.5 \text{ kJ/mol} \]
   A) -151.6 kJ/mol
   B) -283.0 kJ/mol
   C) +283.0 kJ/mol
   D) -372.6 kJ/mol
   E) +252.1 kJ/mol
48. You take 295.5 g of a solid at 30.0°C and let it melt in 425 g of water. The water temperature decreases from 85.1°C to 30.0°C. Calculate the heat of fusion of this solid.
   A) 160 J/g
   B) 166 J/g
   C) 331 J/g
   D) 721 J/g
   E) cannot solve without the heat capacity of the solid

49. Consider the reaction:
\[ 2\text{ClF}_3(g) + 2\text{NH}_3(g) \rightarrow \text{N}_2(g) + 6\text{HF}(g) + \text{Cl}_2(g) \]
When calculating the \( \Delta H^\circ_{\text{rxn}} \), why is the \( \Delta H^\circ \) for \( \text{N}_2 \) not important?
   A) Because nitrogen is in its standard elemental state and no energy is needed for this product to exist.
   B) Because any element or compound in the gaseous state requires a negligible amount of energy to exist.
   C) Because the products are not included when calculating \( \Delta H^\circ_{\text{rxn}} \).
   D) Because nitrogen is in its elemental state and does not contribute to the reaction itself.
   E) Two of the above statements explain why \( \text{N}_2 \) is not important when calculating \( \Delta H^\circ_{\text{rxn}} \).

50. Consider the following specific heats of metals.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Specific Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>0.387 J/(g°C)</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.02 J/(g°C)</td>
</tr>
<tr>
<td>Iron</td>
<td>0.450 J/(g°C)</td>
</tr>
<tr>
<td>Silver</td>
<td>0.237 J/(g°C)</td>
</tr>
<tr>
<td>Lead</td>
<td>0.127 J/(g°C)</td>
</tr>
</tbody>
</table>

If the same amount of heat is added to 25.0 g of each of the metals, which are all at the same initial temperature, which metal will have the highest temperature?
   A) Zinc
   B) Magnesium
   C) Iron
   D) Silver
   E) Lead
LABORATORY SECTION: You are to find the specific heat of the metal.
Available supplies: Styrofoam cups, water, thermometer, balance, periodic table
SAMPLE NUMBER: __________ Answers must be in this space.

CREATE A DATA TABLE FOR ALL RELEVANT INFORMATION COLLECTED:

FORMULAS USED:

SUPPORTING CALCULATIONS:

IDENTITY OF METAL: __________