Islip Invitation 2016
Chemistry Lab Experiment

Instructions

- Do not open this booklet until instructed to do so.
- Goggles must be worn at all times during this examination.
- You are allowed to separate the packet and work in any order as long as the packet is stapled in the correct order when submitted to the event supervisor.

Test Format:

Part A of this event consists of multiple choice questions pertaining to gas laws and thermodynamics. All multiple choice responses must be recorded on the ScanTron provided.  
[40 points]

Part B of this event consists of constructed response questions. All constructed responses must be recorded in the space provided.
[20 points]

Part C requires the team to perform a thermochemical experiment. The total points from this section will serve as the first tiebreaker, if needed.
[Tiebreaker]
1. A balloon filled with 0.01 mol of hydrogen gas is kept constant at 25 degrees Celsius. If the pressure is changed from 1 atm to 1.5 atm, what is the resulting volume of the balloon?
   A) 0.27 L    B) 0.12 L    C) 0.15 L    D) 0.25 L    E) 0.30 L

2. Base your answer to the following question on the following molecules.
   
   \( (A) \text{H}_2 \quad (B) \text{O}_2 \quad (C) \text{Br}_2 \quad (D) \text{N}_2 \quad (E) \text{F}_2 \)
   
   Which molecule as a gas effuses the fastest?
   A) E    B) B    C) D    D) A    E) C

3. "The pressure of a given mass of gas varies directly with the absolute, Kelvin, temperature with the volume being kept constant." This statement best illustrates
   A) Avogadro’s Principle    B) Combined Gas Law
   C) Charles’ Law    D) Boyle’s Law
   E) Gay–Lussac’s Law

4. The gaseous pressure in a 500 mL flask is 250 mmHg at 284 K. What is the number of moles of gas present in the flask?
   A) 0.00705 mole    B) 181 moles    C) 7.05 moles    D) 0.00143 mole    E) 143 moles

5. A gas has a density of 0.25 g/L at a pressure of 0.0821 atm and a temperature of 27.0°C. What is the molar mass of the gas?
   A) 38. g/mol    B) 0.25 g/mol    C) 75. g/mol    D) 30. g/mol    E) 25. g/mol

6. The temperature of a sample of \text{H}_2\text{O} is decreased. Which of the following can be true?
   A) Volume constant, pressure constant, density constant
   B) Volume decreased, pressure constant, density increased
   C) Volume constant, pressure decreased, density constant
   D) Volume constant, pressure increased, density constant
   E) Volume decreased, pressure increased, density decreased

7. A student collected a sample of gas using water displacement. Which of the following measurements is necessary to determine the vapor pressure of the water in the sample?
   A) The temperature of the water    B) The water solubility of the gas
   C) The volume of the water    D) The kinetic energy of the gas
   E) The volume of the gas

8. Equal numbers of moles of \text{CO}_2\text{(g)}, \text{NH}_3\text{(g)}, \text{SO}_2\text{(g)} are placed into 3 separate identical containers. If each container has an identical pinhole leak, which of the following is true about the moles of gas remaining in each container after some time has elapsed?
   A) \text{mol CO}_2 < \text{mol NH}_3 < \text{mol SO}_2    B) \text{mol NH}_3 < \text{mol SO}_2 < \text{mol CO}_2
   C) \text{mol SO}_2 < \text{mol CO}_2 < \text{mol NH}_3    D) \text{mol NH}_3 < \text{mol CO}_2 < \text{mol SO}_2
   E) \text{mol CO}_2 < \text{mol SO}_2 < \text{mol NH}_3
9. Hydrogen gas is collected over water at 29°C. The total pressure of the system is 773 torr. If the vapor pressure of water at 29°C is 30 torr, what is the partial pressure of the hydrogen gas?

A) 30 torr  B) 753 torr  C) 773 torr  D) 803 torr  E) 743 torr

10. A gaseous mixture contains 4.50 moles hydrogen, 2.50 moles oxygen, and 3.00 moles argon. This system exerts a total pressure of 0.500 atmosphere. What is the partial pressure of the hydrogen?

A) 0.025 atm  B) 0.356 atm  C) 0.325 atm  D) 0.135 atm  E) 0.225 atm

11. Which of the following is NOT an assumption of the ideal gas law?

A) There is no effect of the kinetic energy of particles on the equation of state
B) Particles are sizeless
C) There are no intermolecular forces
D) All gases behave in the same manner
E) All collisions are elastic

12. Base your answer to the following question on the elements below.

(A) Cl  (B) At  (C) Li  (D) Ne  (E) Ca

Which does not readily combine with other elements?

A) A  B) B  C) C  D) D  E) E

13. The pressure of a real gas is sometimes less than that predicted by the ideal gas law because the ideal gas law does not include the factor of

A) intermolecular forces  B) size of molecules
C) energy of molecules  D) shape of molecules
E) mass of molecules

14. A 320. mL sample of a dry gas is collected at 47°C and 740 mm Hg. What is its volume at 7°C and 560 mm Hg?

A) 483 mL  B) 277 mL  C) 320 mL  D) 370 mL  E) 212 mL

15. A sample a gas would have the same volume if

<table>
<thead>
<tr>
<th>Kelvin Temperature</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) doubled</td>
<td>doubled</td>
</tr>
<tr>
<td>(B) halved</td>
<td>doubled</td>
</tr>
<tr>
<td>(C) doubled</td>
<td>halved</td>
</tr>
<tr>
<td>(D) unchanged</td>
<td>doubled</td>
</tr>
</tbody>
</table>

A) A  B) B  C) C  D) D  E) None of the above
16. A sample of an ideal gas has a volume of 3800 mL at 100. mmHg and 127°C. What would be its volume at STP?
A) 17,200 mL    B) 1,970 mL    C) 733 mL    D) 4,230 mL    E) 341 mL

17. How much heat is absorbed when 50.0 grams of water is heated from 22.0°C to 36.0°C?

\[
\text{Specific heat of water} = 4.184 \text{ J} \cdot \text{g}^{-1} \cdot \text{°C}^{-1}
\]

A) 1,510 J    B) 2,930 J    C) 4,520 J    D) 7,530 J    E) 15,060 J

18. C(s) + O_2(g) → CO_2(g) \Delta H = -394 kJ mol^{-1}
CO(g) + \frac{1}{2} O_2(g) → CO_2(g) \Delta H = -283 kJ mol^{-1}

From this information, calculate \Delta H of the equation
C(s) + \frac{1}{2} O_2(g) → CO(g)
A) −394 kJ mol^{-1}    B) −111 kJ mol^{-1}    C) −283 kJ mol^{-1}    D) −222 kJ mol^{-1}    E) −577 kJ mol^{-1}

19. Gas 1 and gas 2 are in containers of equal volume (V_1 = V_2). If T_1 = T_2, m_1 < m_2, and n_1 = n_2, then what is true about the pressure, P, in the two containers?
*Note: T is the temperature in Kelvins, m is the molecular mass of the gas, n is the quantity of matter in moles.*
A) P_1 > P_2    B) P_1 = P_2, always
C) Not enough data to tell.    D) P_1 < P_2
E) P_1 = P_2, at low temperatures only

20. Which of the following is not considered standard pressure?
A) 101.3 kPa    B) 760 mmHg
C) 760 torr    D) 1 atm
E) all of the above are standard pressure

21. Which curve represents the relationship between the volume of an ideal gas and its pressure for a certain number of molecules at a constant temperature?
A) 
![](image1)
B) 
![](image2)
C) 
![](image3)
D) 
![](image4)
22. If the temperature remains constant while the volume of a given amount of gas is tripled, the pressure will be
   A) 3 times the original pressure     B) \(\frac{2}{3}\) of the original pressure
   C) the same as the original pressure  D) \(\frac{1}{3}\) of the original pressure
   E) 9 times the original pressure

23. Base your answer to the following question on the information below:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mass</th>
<th>Pressure</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas A</td>
<td>2 moles</td>
<td>760 mm.</td>
<td>273° K.</td>
</tr>
<tr>
<td>Gas B</td>
<td>1 mole</td>
<td>380 mm.</td>
<td>273° K.</td>
</tr>
<tr>
<td>Gas C</td>
<td>1 mole</td>
<td>760 mm.</td>
<td>273° K.</td>
</tr>
<tr>
<td>Gas D</td>
<td>2 moles</td>
<td>760 mm.</td>
<td>546° K.</td>
</tr>
</tbody>
</table>

Which gas occupies the smallest volume?
   A) A  B) B  C) C  D) D

24. "The pressure of a given mass of gas varies directly with the absolute, Kelvin, temperature with the volume being kept constant." This statement illustrates
   A) Gay–Lussac’s Law  B) Charles’ Law
   C) Boyle’s Law       D) Dalton’s Law
   E) Avogadro’s Principle

25. \(\text{LiBr(s)} \rightarrow \text{Li}^+(aq) + \text{Br}^-(aq); \Delta H = -11.4\ \text{kcal}\)

\(\text{LiBr}\) dissolves in water according to the equation above. If 2.00 mol of \(\text{LiBr}\) is dissolved in 1000. mL of water at 0.00°C, what is the final temperature of the water?
   A) 22.8°C  B) 0.00°C  C) -11.4°C  D) 11.4°C  E) -22.8°C

26. The density of a gas
   A) decreases as the mass of the gas increases
   B) varies directly with absolute temperature at a constant volume
   C) varies inversely with pressure at constant temperature
   D) varies directly with the absolute temperature at constant pressure
   E) varies inversely with the absolute temperature at constant pressure

27. I. Water boils at a higher temperature at low altitudes than at high altitudes

BECAUSE

II. the atmospheric pressure decreases as the altitude increases.

   A) I and II are BOTH FALSE
   B) I and II are BOTH TRUE but II IS NOT a correct explanation of I
   C) I and II are BOTH TRUE and II IS a correct explanation of I
   D) I is TRUE, II is FALSE
   E) I is FALSE, II is TRUE
28. Base your answer to the following question on the image below.

If the atmospheric pressure is 730 torr, what is the pressure of the gas labeled A?
A) 35 torr  B) 795 torr  C) 765 torr  D) 695 torr  E) 630 torr

29. If 25 g of hydrogen gas in a closed container is heated from 0°C to 273°C the mass of the gas at 273°C will be
A) 25 g  B) $25 \times 273$ g  C) $25 \times \frac{546 \text{ g}}{273}$  D) $25 \times \frac{273 \text{ g}}{546}$  E) $25 \times \frac{1 \text{ g}}{273}$

30. The random motion of gas molecules helps to explain the
A) compressibility of gases  B) fact that gases fill their container  
C) low density of gases  D) fixed volume of gases  
E) transparency of gases

31. For a confined gas, when the temperature is increased and the volume is decreased at the same time, the
A) density decreases  B) average kinetic energy is decrease  
C) pressure increases  D) molecules move slower  
E) number of collisions decreases

32. Carbon tetrachloride, (CCl₄), melts at −23°C and boils at 76.8°C. At standard pressure, which has the highest average kinetic energy?
A) CCl₄(l) at 0°C  B) CCl₄(s) at −50°C  
C) CCl₄(g) at 100°C  D) CCl₄(l) → CCl₄(g) at 76.8°C  
E) CCl₄(s) → CCl₄(l) at −23°C
33. Air pressure is graphed as a function of temperature. The extrapolated line intersects the horizontal axis at about $-280^\circ C$. Which term is applied to this temperature value?

A) Critical temperature  
B) Freezing point  
C) Absolute zero  
D) Boiling point  
E) Triple point

34. When sulfuric acid, $\text{H}_2\text{SO}_4$, is added to water in a beaker, the container and its contents get hot. This shows that the solution reaction is

A) exothermic and evolves energy  
B) exothermic and absorbs energy  
C) endothermic and evolves energy  
D) endothermic and absorbs energy  
E) none of the above

35. The temperature of a sample of carbon dioxide gas is a measure of its

A) kinetic and potential energy  
B) average potential energy  
C) total kinetic energy  
D) average kinetic energy  
E) total potential energy

36. The table below shows mass and volume data for four samples of substances at 298 K and 1 atmosphere.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mass (g)</th>
<th>Volume (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>30.</td>
<td>60.</td>
</tr>
<tr>
<td>B</td>
<td>40.</td>
<td>50.</td>
</tr>
<tr>
<td>C</td>
<td>45.</td>
<td>90.</td>
</tr>
<tr>
<td>D</td>
<td>90.</td>
<td>120.</td>
</tr>
</tbody>
</table>

Which two samples could consist of the same substance?

A) $A$ and $B$,  
B) $B$ and $C$,  
C) $A$ and $C$,  
D) $C$ and $D$
37. A gas occupies a volume of 444 mL at 273 K and 79.0 kPa. What is the final kelvin temperature when the volume of the gas is changed to 1880 mL and the pressure is changed to 38.7 kPa?
A) 31.5 K  B) 566 K  C) 2360 K  D) 292 K

38. As the temperature of a gas is increased from 0°C to 10°C at constant pressure, the volume of the gas will
A) increase by $\frac{1}{273}$  B) increase by $\frac{10}{273}$
C) decrease by $\frac{10}{273}$  D) decrease by $\frac{1}{273}$

39. A reaction inside a bomb calorimeter caused the temperature of the bomb calorimeter (heat capacity 2500. J K⁻¹) to raise 3.000°C. What is the energy change for this reaction?
A) $\Delta E = +7500$. J  B) $\Delta E = -7500$. J
C) $\Delta E = +7500$. J  D) $\Delta H = -7500$. J
E) $\Delta H = +7500$. J

40. Based on the table below, what is the free energy change for the reaction $C_2H_4(g) + 3 O_2(g) \rightarrow 2 H_2O(g) + 2 CO_2(g)$?

<table>
<thead>
<tr>
<th>Reaction</th>
<th>$\Delta G^\circ$, kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CH_4(g) + 2 O_2 (g) \rightarrow CO_2(g) + 2 H_2O(g)$</td>
<td>$-192$</td>
</tr>
<tr>
<td>$2 ; CH_4(g) \rightarrow C_2H_6(g) + H_2(g)$</td>
<td>$-16$</td>
</tr>
<tr>
<td>$C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g)$</td>
<td>$+24$</td>
</tr>
<tr>
<td>$H_2(g) + \frac{1}{2} O_2 (g) \rightarrow H_2O(g)$</td>
<td>$-55$</td>
</tr>
</tbody>
</table>

A) +104 kcal  B) +282 kcal  C) -408 kcal  D) -282 kcal  E) -104 kcal
1. The following questions (a-d) refer to the diagram of the Earth's Atmosphere Profile.

a. The troposphere contains 75%-90% of atmospheric gases. Explain why. (2)
b. The stratosphere contains about 10% of the atmospheric gases. Explain why jet planes tend to travel in this layer of the atmosphere. (1)

c. The stratosphere contains the ozone layer. Explain the importance of the ozone layer to life on Earth AND give one example of a pollutant partly responsible for the breakdown of the ozone layer. (2)

d. The thermosphere has increased temperature with increased altitude. Explain why. (1)
2. Label the following diagram of the Carbon Cycle by placing the correct terms to represent the processes shown with the arrows. (1 each)

1. 

2. 

3. 

4. 

5. 

6. 

7. 

8. 

Decomposers

Fossil Fuel
3. Diborane (B₂H₆) is a highly reactive boron hydride, which was once considered as a possible rocket fuel for the U.S. space program. Calculate ΔH for the synthesis of diborane from its elements, according to the equation. Show your work and put your final answer with proper units on the line at the bottom of this page. (6)

\[ 2B(s) + 3H_2(g) \rightarrow B_2H_6(g) \]

using the following data:

<table>
<thead>
<tr>
<th>REACTION</th>
<th>ΔH (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) 2B(s) + 3/2 O₂(g) → B₂O₃(s)</td>
<td>-1273 kJ</td>
</tr>
<tr>
<td>(b) B₂H₆(g) + 3 O₂(g) → B₂O₃(s) + 3H₂O(g)</td>
<td>-2035 kJ</td>
</tr>
<tr>
<td>(c) H₂ (g) + 1/2 O₂(g) → H₂O(l)</td>
<td>-286 kJ</td>
</tr>
<tr>
<td>(d) H₂O (l) → H₂O(g)</td>
<td>44 KJ</td>
</tr>
</tbody>
</table>

Final Answer: ____________________
Part C: Thermochemical Lab - Applying Hess's Law

The enthalpy change for any reaction depends on the products and reactants and is independent of the pathway or the number of steps between the reactant and product.

In this experiment, you will measure and compare the quantity of heat involved in the reaction of sodium hydroxide solution with dilute hydrochloric acid solution, shown below:

\[
\text{Na}^+_{(aq)} + \text{OH}^-(aq) + \text{H}^+(aq) + \text{Cl}^-(aq) \rightarrow \text{Na}^+(aq) + \text{Cl}^-(aq) + \text{H}_2\text{O}
\]

Safety:

- Hydrochloric acid and sodium hydroxide are corrosive. Avoid direct contact. If any touches your skin, wash it off immediately.
- Solid sodium hydroxide is especially dangerous because it absorbs moisture rapidly from the air, forming an extremely corrosive liquid. Avoid spilling this solid, and if a spill occurs, clean it up immediately.
- Be sure to close the lids of bottles of sodium hydroxide securely, immediately after using.

Objectives: To provide experimental verification of Hess's Law

Materials:

- 2 large styrofoam cups
- 100 mL graduated cylinder
- sodium hydroxide, NaOH
- 1.0 M sodium hydroxide solution
- 1.0 M Hydrochloric acid solution
- thermometers
- balance
- 250 mL beaker
- glass stirring rod

Dispose of solutions according to your teacher's instructions. A lab coat or apron is strongly recommended.
Procedure:
1. Accurately measure 50.0 mL of 1.0 M hydrochloric acid solution into your calorimeter and 50.0 mL of 1.0 M sodium hydroxide into a 250 mL beaker.
2. Record the temperatures and volumes of each solution.
3. Add the sodium hydroxide solution to the acid solution in the styrofoam cup. Stir the mixture with the thermometer and record the highest temperature reached.
4. Discard the solution as directed by the event supervisors.

Data Table:

<table>
<thead>
<tr>
<th>Volume of 1.0 M HCl solution used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of 1.0 M NaOH solution used</td>
</tr>
<tr>
<td>Initial temperature of the NaOH solution (before mixing)</td>
</tr>
<tr>
<td>Highest final temperature of mixture</td>
</tr>
</tbody>
</table>

Calculations: Show all work.

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Calculations (Show all work!)</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Change in temperature</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Moles of HCl used</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Moles of NaOH used</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Energy released</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Heat of reaction</td>
<td></td>
</tr>
</tbody>
</table>