1. 300 mL of 1M HCl at 70°C is mixed with 400 mL of 3M NaOH at 25°C. An acid-base reaction ensues and the final solution reaches an equilibrium temperature of 55°C. Find the \( \Delta H \) of the neutralization reaction in kJ per mole of H\(_2\)O produced. Assume a density of 1g/mL and a specific heat capacity of 4.184 J/g°C for both of the solutions.

(1) 104.6 kJ/mol (2) -104.6 kJ/mol (3) 20.7 kJ/mol (4) -20.7 kJ/mol (5) -26.2 kJ/mol

2. An experimenter accidentally spills 50 g of NaCl into a beaker of 200 mL of water, which was originally at 25°C. After realizing her mistake, she measures the temperature of the water to be 21°C. According to these measurements, what is the heat of dissolution of NaCl, in kJ/mol? The heat capacity of water is 4.184 J/g°C and its density is 1g/mL.

(1) 3.9 kJ/mol (2) -3.9 kJ/mol (3) 4.3 kJ/mol (4) -6.2 kJ/mol (5) 6.2 kJ/mol

3. Which of the following changes (at constant external pressure) would definitely increase the internal energy (E or U) of a gaseous system?

I. Double temperature and halve volume  
II. Halve temperature and double volume  
III. Quadruple temperature and double volume  
IV. Halve temperature and halve volume

(1) I (2) IV (3) I and III (4) II and IV (5) I and IV

4. A chemist is going on a spring diet and is wanting to confirm the caloric content of his favorite snack, Swedish Fish. He puts one box’s worth of Swedish Fish, 88g, in a bomb calorimeter. The bomb calorimeter had an initial temperature of 25°C, and has a final temperature of 85°C. Find the \( \Delta H \) of the combustion of Swedish Fish, in kJ/g. The heat capacity of the calorimeter is 8.15 kJ/°C.

(1) 5.56 kJ/g (2) 5.56 kJ/g (3) 7.83 kJ/g (4) -7.83 kJ/g (5) 3.82 kJ/g

5. A chemist accidentally left an empty 200 g beaker on a hot plate, and he decides to quench it by placing it in 1 L of ice-cold water. The beaker had an initial temperature of 300°C, and the water was at an initial temperature of 0°C. When they reach equilibrium, they are both at 15°C. Find the heat capacity of the beaker in kJ/°C. The heat capacity of water is 4.184 J/g°C and its density is 1 g/mL.

(1) 1.1 k J/°C (2) .22 kJ/°C (3) .80 kJ/°C (4) 1.46 kJ/°C (5) 3.18 kJ/°C

6. Combustion of hexane (C\(_6\)H\(_{14}\)) usually forms H\(_2\)O and CO\(_2\):

\[
2 \text{C}_6\text{H}_{14} + 19 \text{O}_2 \rightarrow 14 \text{H}_2\text{O} + 12 \text{CO}_2 \quad \Delta H^\circ_{\text{rxn}} = -8323.2 \text{ kJ}
\]

However, when O\(_2\) is in limited amounts, an alternative reaction can take place, forming toxic CO rather than CO\(_2\):

\[
2 \text{C}_6\text{H}_{14} +13 \text{O}_2 \rightarrow 14 \text{H}_2\text{O} + 12 \text{CO} \quad \Delta H^\circ_{\text{rxn}} = -4549.6 \text{ kJ}
\]

In addition, CO can be further oxidized to CO\(_2\) in the presence of even more oxygen:

\[
2 \text{CO} + \text{O}_2 \rightarrow 2 \text{CO}_2 \quad \Delta H^\circ_{\text{rxn}} = -565.94 \text{ kJ}
\]

Based on this data, what is the \( \Delta H^\circ \) of CO\(_2\)? The \( \Delta H^\circ \) of hexane is -200 kJ/mol.
7. An environmental chemist wants to convert two toxic gases, CO and NO, to the relatively inert CO₂ and N₂:

\[ 2 \text{CO}(g) + 2 \text{NO}(g) \rightarrow 2 \text{CO}_2(g) + \text{N}_2(g) \quad \Delta H^\circ_{\text{rxn}} = ? \]

Given the following information:

\[ \text{CO}(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CO}_2(g) \quad \Delta H^\circ_{\text{rxn}} = -283.0 \text{ kJ} \]

\[ \text{N}_2(g) + \text{O}_2(g) \rightarrow 2\text{NO}(g) \quad \Delta H^\circ_{\text{rxn}} = 180.6 \text{ kJ} \]

What are the \( \Delta H^\circ_{\text{rxn}} \) for the reaction of CO and NO? What is the \( \Delta H^\circ_f \) for N₂?

(1) 373.3 kJ, 108 kJ (2) 746.6 kJ, 180 kJ (3) 373.3 kJ, 0 kJ (4) 746.6 kJ, 0 kJ (5) none of the above

8. A chemist wants to study the kinetics of a certain reaction. She conducts an experiment and collects the following data:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial Rate (mol/Ls)</th>
<th>Initial [A] (mol/L)</th>
<th>Initial [B] (mol/L)</th>
<th>Initial [C] (mol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46080</td>
<td>8</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>720</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
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<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5760</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

Which of the following are possible rate-determining steps for the reaction?

I. \( 2 \text{A+}B+2 \text{C} \rightarrow \text{E} \)

II. \( 3 \text{A+}2 \text{B+}3 \text{C} \rightarrow \text{E} \)

III. \( \text{A+}\frac{1}{2} \text{B+} \text{C} \rightarrow \text{E} \)

(1) I (2) II (3) III (4) I and III (5) none of the above

9. An experimenter runs a reaction for 20 minutes and collects the following data:
10. How many of the following statements are true?
I. The rate of the reaction decreases as the reaction proceeds.
II. The half-life at the beginning of the reaction is 6.7 minutes.
III. The reaction is of second-order with respect to A.
IV. The rate constant for the reaction is 0.3 mol/Ls.

(1) 0 (2) 1 (3) 2 (4) 3 (5) 4

11. The decomposition of hydrogen peroxide (H₂O₂) is a first-order process which obeys the following equation:

\[ 2 \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O} + \text{O}_2 \quad \Delta E_a = -5 \text{ kJ} \]

At 100°C, the concentration of O₂ increases by 1.25M/min. At what temperature would \([\text{O}_2]\) increase by 2.5M/min? Assume an initial concentration \([\text{H}_2\text{O}_2] = 1 \text{ M}\) for both situations.

(1) 381°C (2) 487°C (3) 593°C (4) 218°C (5) 687°C

12. How many of the following statements are true?
I. As the concentration of reactants increases, the rate constant of the reaction decreases.
II. The rate-determining step is the step with the highest activation energy.
III. Raising the temperature will always increase the rate of a reaction.
IV. The frequency factor for all bimolecular reactions is the same.

(1) 0 (2) 1 (3) 2 (4) 3 (5) 4

13. The formation of a product E can be explained by the following mechanism:

\[ 2 \text{A} + \text{B} \rightarrow \text{C} + \text{D} \text{ (fast, equilibrium)} \]
\[ \text{B} + 2 \text{C} \rightarrow \text{E} \text{ (slow)} \]
The rate law can be expressed as \(k[A]^n[B]^m[D]^p\). What is the order of the overall reaction?

(1) 0  (2) 1  (3) 2  (4) 3  (5) 4

14. An equal amount of CHCl3 and helium gas can be found in a certain balloon. If it is found that all of the helium is effused in 5 seconds, how long would it take for the CHCl3 to effuse?

(1) 19.6 seconds  (2) 27.3 seconds  (3) 20.1 seconds  (4) 18.1 seconds  (5) 9.9 seconds

15. Assume there is 10g of Vanadium (2) oxide in a balloon. Assuming pressure stays constant, what would happen to the balloon’s volume if the temperature of the balloon increased from 100 celsius to 200 celsius? Select the best answer choice.

(1) The volume halves  (2) The volume doubles  (3) The volume increases by less than 2x  (4) The volume increases by more than 2x  (5) The volume stays constant

16. Methane (C3H8) is combusted to form water and carbon dioxide within a rigid container. If 1 atm of methane combuts with 1 atm of oxygen, what is the final pressure?

(1) 1.4 atm  (2) 3.2 atm  (3) .6 atm  (4) .8 atm  (5) 1 atm

17. A scientist took a 1.9488 gram sample of an unknown gas and placed it in a 2 liter flask at 300 kelvin. The scientist notes that the gas exerts .8 atm. What could this gas be?

(1) C2H6  (2) CO2  (3) H2O  (4) C3H8  (5) CH4

18. A microwave is able to heat up 10g of water by 10 celsius using photons with a wavelength of 500 nm. How many photons are required to complete such task?

(1) 4.56 \times 10^{20} photons  (2) 1.09 \times 10^{19} photons  (3) 8.32 \times 10^{4} photons  (4) 8.21 \times 10^{21} photons

19. Examine this redox reaction:

\[
C_6H_8O_6 + 2H^+ + 2NO_2^- \rightarrow C_6H_6O_6 + 2H_2O + 2NO.
\]

Determine the element that is reduced and by how many electrons it is reduced by.

(1) H, 1  (2) O, 1  (3) N, 1  (4) C, 2  (5) This is not a redox reaction

20. Which of the following compounds of Vanadium Oxide is LEAST likely to form?

(1) V2O5  (2) V3O6  (3) VO  (4) VO6  (5) V3O2

21. How much energy (in joules) does 5 million photons with a wavelength of 200 nm exert?

(1) 4.97 \times 10^{-12} J  (2) 2.22 \times 10^{-11} J  (3) 8.35 \times 10^{-12} J  (4) 3.49 \times 10^{-9} J  (5) 4.93 \times 10^{-10} J