Pretest 1

**Multiple Choice**
*Identify the choice that best completes the statement or answers the question.*

1. Which one of the following thermodynamic quantities is not a state function?
   a. work
   b. enthalpy
   c. entropy
   d. internal energy
   e. free energy

2. The enthalpy change, $\Delta H$, of a process is defined as:
   a. The maximum amount of useful work that can be done in a system.
   b. The increase or decrease in temperature in a system.
   c. The quantity of heat transferred in or out of a system as it undergoes a change at constant pressure.
   d. The change in molecular disorder in a system.
   e. None of these are correct.

3. A system is compressed from 50.0 L to 5.0 L at a constant pressure of 10.0 atm. What is the amount of work done?
   a. $2.5 \times 10^4$ J
   b. 450 J
   c. $4.6 \times 10^4$ J
   d. $-450$ J
   e. $-4.6 \times 10^4$ J

4. If 4.168 kJ of heat is added to a calorimeter containing 75.40 g of water, the temperature of the water and the calorimeter increases from 24.58°C to 35.82°C. Calculate the heat capacity of the calorimeter (in J/°C). The specific heat of water is 4.184 J/g•°C.
   a. 622 J/°C
   b. 55.34 J/°C
   c. 315.5 J/°C
   d. 25.31 J/°C
   e. 17.36 J/°C

5. A 50.0 mL solution of 1.2 $M$ HCl at 24.1°C is mixed with 50.0 mL of 1.3 $M$ NaOH, also at 24.1°C, in a coffee-cup calorimeter. After the reaction occurs, the temperature of the resulting mixture is 29.8°C. The density of the final solution is 1.05 g/mL. Calculate the molar heat of neutralization. Assume the specific heat of the solution is 4.184 J/g•°C. The heat capacity of the calorimeter is 32.5 J/°C.
   a. 41.7 kJ/mol
   b. 58.5 kJ/mol
   c. 44.8 kJ/mol
   d. 13.0 kJ/mol
   e. 33.9 kJ/mol
6. The burning of 80.3 g of SiH₄ at constant pressure gives off 3790 kJ of heat. Calculate \( \Delta H \) for this reaction:

\[
\text{SiH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{SiO}_2(\text{s}) + 2\text{H}_2\text{O}(\ell)
\]

a. \(-1520\) kJ/mol rxn
b. \(-47.2\) kJ/mol rxn
c. \(-4340\) kJ/mol rxn
d. \(-2430\) kJ/mol rxn
e. \(+4340\) kJ/mol rxn

7. Given the following at 25°C and 1.00 atm:

\[
1/2\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{NO}_2(\text{g}) \quad \Delta H^0 = 33.2\text{ kJ}
\]

\[
\text{N}_2(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g}) \quad \Delta H^0 = 11.1\text{ kJ}
\]

Calculate the \( \Delta H^0 \) for the reaction below at 25°C.

\[
2\text{NO}_2(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g})
\]

a. \(+11.0\) kJ
b. \(+44.3\) kJ
c. \(+55.3\) kJ
d. \(-22.1\) kJ
e. \(-55.3\) kJ

8. Given the standard heats of formation for the following compounds, calculate \( \Delta H^0_{298} \) for the following reaction:

\[
\begin{array}{cccc}
\Delta H^0(\text{kJ/mol}) & \text{CH}_4(\text{g}) & + & \text{H}_2\text{O}(\text{g}) & \rightarrow & \text{CH}_3\text{OH}(\ell) & + & \text{H}_2(\text{g}) \\
& -75 & & -242 & & -238 & & 0 \\
\end{array}
\]

a. \(+79\) kJ
b. \(-79\) kJ
c. \(+594\) kcal
d. \(-594\) kcal
e. \(-405\) kJ

9. Estimate the heat of reaction at 298 K for the reaction shown, given the average bond energies below.

\[
\text{Br}_2(\text{g}) + 3\text{F}_2(\text{g}) \rightarrow 2\text{BrF}_3(\text{g})
\]

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<thead>
<tr>
<th>Bond</th>
<th>Bond Energy</th>
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<tbody>
<tr>
<td>Br–Br</td>
<td>193 kJ/mol</td>
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<tr>
<td>F–F</td>
<td>155 kJ/mol</td>
</tr>
<tr>
<td>Br–F</td>
<td>249 kJ/mol</td>
</tr>
</tbody>
</table>

a. \(-836\) kJ
b. \(-150\) kJ
c. \(-89\) kJ
d. \(-665\) kJ
e. \(-1222\) kJ
10. Which of the following is not a formation reaction?
   a. \( \frac{1}{2} \text{H}_2(\ell) + \frac{1}{2} \text{Br}_2(\ell) \rightarrow \text{HBr}(g) \)
   b. \( \text{H}_2(\ell) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{H}_2\text{O}(\ell) \)
   c. \( \text{Ca}(s) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CaO}(s) \)
   d. \( 4\text{Al}(s) + 3\text{O}_2(g) \rightarrow \text{Al}_2\text{O}_3(s) \)
   e. \( \text{H}_2\text{O}(\ell) + \text{SO}_3(\ell) \rightarrow \text{H}_2\text{SO}_4(\ell) \)

11. Which one of the following statements is false? For a reaction carried out at constant temperature and constant pressure in an open container, _____.
   a. the work done by the system can be set equal to \(-PV\Delta V\)
   b. the work done by the system can be set equal to \(V\Delta P\)
   c. the work done by the system can be set equal to \(-\Delta nRT\) where \(\Delta n\) is the number of moles of gaseous products minus the number of moles of gaseous reactants
   d. the heat absorbed by the system can be called \(q_p\)
   e. the heat absorbed by the system can be called \(\Delta H\)

12. The heat of vaporization of methanol, \(\text{CH}_3\text{OH}\), is 35.20 kJ/mol. Its boiling point is 64.6°C. What is the change in entropy for the vaporization of methanol?
   a. \(-17.0 \text{ J/mol} \cdot \text{K}\)
   b. 3.25 \text{ J/mol} \cdot \text{K}
   c. 17.0 \text{ J/mol} \cdot \text{K}
   d. 104 \text{ J/mol} \cdot \text{K}
   e. 543 \text{ J/mol} \cdot \text{K}

13. Use the data below to calculate \(\Delta H^0_f\) for benzene, \(\text{C}_6\text{H}_6(\ell)\), at 25°C and 1 atm.
    \[
    2\text{C}_6\text{H}_6(\ell) + 15\text{O}_2(g) \rightarrow 12\text{CO}_2(g) + 6\text{H}_2\text{O}(\ell)
    \]
    \[
    \Delta H^p = -6535 \text{ kJ}
    \]
    \[
    \Delta H^0_f(\text{CO}_2(g)) = -393.5 \text{ kJ/mol}, \Delta H^0_f(\text{H}_2\text{O}(\ell)) = -285.8 \text{ kJ/mol}
    \]
   a. \(49.1 \text{ kJ/mol}\)
   b. \(3.51 \times 10^4 \text{ kJ/mol}\)
   c. \(103 \text{ kJ/mol}\)
   d. \(1.76 \times 10^3 \text{ kJ/mol}\)
   e. \(561 \text{ kJ/mol}\)

14. Calculate the standard energy change, \(\Delta E^0\), for the reaction below.
    \[
    \begin{align*}
    12\text{NH}_3(\ell) + 21\text{O}_2(g) & \rightarrow 8\text{HNO}_3(\ell) + 4\text{NO}(g) + 14\text{H}_2\text{O}(g) \\
    \Delta H^p_f(\text{kJ/mol}) & \quad -45.9 \quad 0 \quad -133.9 \quad 91.3 \quad -241.8
    \end{align*}
    \]
   a. \(-3,540 \text{ kJ/mol}\)
   b. \(-201.3 \text{ kJ/mol}\)
   c. \(-2,259 \text{ kJ/mol}\)
   d. \(-4270 \text{ kJ/mol}\)
   e. \(-3,503 \text{ kJ/mol}\)
15. What is the entropy change of the reaction below at 298 K and 1 atm pressure?

\[
\begin{array}{ccc}
N_2(g) + 3H_2(g) & \rightarrow & 2NH_3(g) \\
S_{298}^0 (J/mol\cdot K) & 191.5 & 130.6 & 192.3
\end{array}
\]

a. -198.7 J/K  
b. 76.32 J/K  
c. -129.7 J/K  
d. 303.2 J/K  
e. 384.7 J/K

16. Which chemical change listed below represents a decrease in entropy?

a. \(N_2(g) + 3H_2(g) \rightarrow NH_3(g)\)

b. \(CaCO_3(s) \rightarrow CaO(s) + CO_2(g)\)

c. \(2NO_2(g) \rightarrow N_2(g) + 2O_2(g)\)

d. \(2C_2H_2(\ell) + 5O_2(g) \rightarrow 12CO_2(g) + 6H_2O(g)\)

e. \(2NaCl(\ell) \rightarrow 2Na(\ell) + Cl_2(g)\)

17. Which of the following statements regarding the third law of thermodynamics is incorrect?

a. The absolute \(S\) is zero at 0 Kelvin.

b. The absolute \(S\) at 298 K can be positive or negative.

c. Pure substances have positive absolute \(S\) at \(T > 0\) Kelvin.

d. Absolute zero gives a reference point for determining absolute \(S\).

e. The absolute \(S\) is greater at 300 K than 100 K for a given substance.

18. A process occurs spontaneously and \(\Delta S_{\text{system}} < 0\). Which statement below must be true?

a. \(\Delta S_{\text{surroundings}} > 0\)

b. \(\Delta S_{\text{universe}} > 0\)

c. The pressure is constant.

d. Both (a) and (b) are correct.

e. All of these answers are correct.

19. For a particular reaction at 25°C, \(\Delta H^0 = -297\) kJ/mol, and \(\Delta S^0 = -113.3\) J/mol\(\cdot\)K. At which of the following temperatures would the reaction become spontaneous?

a. 2750 K  
b. 3250 K  
c. 2450 K  
d. 10500 K  
e. 3750 K

20. Calculate \(\Delta G^0\) for the reaction below. The standard molar entropy change for the reaction at 298 K is \(-287.5\) J/mol\(\cdot\)K.

\[
3NO_2(g) + H_2O(\ell) \rightarrow 2HNO_3(aq) + NO(g) + 136.8\text{kJ}
\]

a. \(-51.2\) kJ/mol  
b. \(85,500\) kJ/mol  
c. \(-68.4\) kJ/mol  
d. \(-236\) kJ/mol  
e. \(-222\) kJ/mol
21. Evaluate $\Delta G^\circ$ for the reaction below at 25°C.

$$2\text{C}_2\text{H}_2(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\ell)$$

$\Delta G^\circ_f(\text{kJ/mol})$

<table>
<thead>
<tr>
<th>Reaction</th>
<th>$\Delta G^\circ$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2\text{C}_2\text{H}_2(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\ell)$</td>
<td>$209.2$</td>
</tr>
</tbody>
</table>

a. $-1409$ kJ  
b. $-2599$ kJ  
c. $-1643$ kJ  
d. $-2470$ kJ  
e. $-766$ kJ

22. For which set of values of $\Delta H$ and $\Delta S$ will a reaction be spontaneous (product-favored) at all temperatures?

a. $\Delta H = +10$ kJ, $\Delta S = -5$ J/K  
b. $\Delta H = -10$ kJ, $\Delta S = -5$ J/K  
c. $\Delta H = -10$ kJ, $\Delta S = +5$ J/K  
d. $\Delta H = +10$ kJ, $\Delta S = +5$ J/K  
e. no such values exist

23. In the following reaction, the rate of formation of $\text{NH}_3$ is 0.15 mol/L·min. What is the rate of reaction?

$$\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$$

a. 0.15 mol/L·min  
b. 0.075 mol/L·min  
c. $-0.075$ mol/L·min  
d. 0.20 mol/L·min  
e. 0.30 mol/L·min

24. Suppose a reaction $\text{A} + \text{B} \rightarrow \text{C}$ occurs at some initial rate at 25°C. Which response includes all of the changes below that could increase the rate of this reaction?

I. lowering the temperature  
II. adding a catalyst  
III. increasing the initial concentration of B

a. I  
b. II  
c. III  
d. I and II  
e. II and III

25. The gas phase reaction $\text{A} + \text{B} + \text{C} \rightarrow \text{D}$ has a reaction rate which is experimentally observed to follow the relationship $rate = k[A]^2[C]$. The reaction is ____ order in $\text{A}$, ____ order in $\text{B}$, and ____ order in $\text{C}$.

a. first; second; third  
b. first; second; zero  
c. second; zero; first  
d. second; first; zero  
e. second; zero; zero
26. A hypothetical reaction $X + 2Y \rightarrow \text{Products}$ is found to be first order in $X$ and second order in $Y$. What are the units of $k$, the specific rate constant, if reaction rate is expressed in units of moles per liter per second?
   a. $M \cdot s^{-1}$
   b. $M^{-2} \cdot s^{-1}$
   c. $M^{-3} \cdot s$
   d. $M \cdot s^{-1}$
   e. $M^{-1} \cdot s$

27. A troublesome reaction that is responsible in part for acid rain is
   \[ \text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 \]
   Rate data have been determined at a particular temperature for the reaction in which all reactants and products are gases.

<table>
<thead>
<tr>
<th>Trial Run</th>
<th>Initial [SO$_3$]</th>
<th>Initial [H$_2$O]</th>
<th>Initial Rate (M$\cdot$s$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.35 $M$</td>
<td>0.35 $M$</td>
<td>0.150</td>
</tr>
<tr>
<td>2</td>
<td>0.70 $M$</td>
<td>0.35 $M$</td>
<td>0.600</td>
</tr>
<tr>
<td>3</td>
<td>0.35 $M$</td>
<td>0.70 $M$</td>
<td>0.300</td>
</tr>
<tr>
<td>4</td>
<td>0.70 $M$</td>
<td>0.70 $M$</td>
<td>1.20</td>
</tr>
</tbody>
</table>

   The rate-law expression is ____.
   a. $\text{rate} = k[\text{SO}_3]^2[\text{H}_2\text{O}]^2$
   b. $\text{rate} = k[\text{SO}_3][\text{H}_2\text{O}]$
   c. $\text{rate} = k[\text{SO}_3][\text{H}_2\text{O}]^2$
   d. $\text{rate} = k[\text{SO}_3]^2$
   e. $\text{rate} = k[\text{SO}_3][\text{H}_2\text{O}]$

28. A plot of $\frac{1}{[D]}$ versus time is linear for the reaction $D \rightarrow E$. What is the kinetic order of the reaction?
   a. second
   b. first
   c. zero
   d. one-half
   e. negative one

29. The rate constant for the first order reaction below is $k = 3.3 \times 10^{-2}$ min$^{-1}$ at 57 K. What is the half-life for this reaction at 57 K?
   \[ A \rightarrow B + C \]
   a. 21 min
   b. 30 min
   c. 61 min
   d. 9.1 min
   e. 1200 min
30. A molecule of ethyl alcohol is converted to acetaldehyde in one's body by zero order kinetics. If the concentration of alcohol is 0.015 mol/L and the rate constant = $6.4 \times 10^{-5}$ mol/L•min, what is the concentration of alcohol after 3.5 hours?
   a. 0.0016 mol/L
   b. $9.6 \times 10^{-7}$ mol/L
   c. $4.3 \times 10^{-3}$ mol/L
   d. 0.15 mol/L
   e. 0.0032 mol/L

31. The specific rate constant, $k$, for a reaction is $2.64 \times 10^{-2}$ s$^{-1}$ at 25°C, and the activation energy is 74.0 kJ/mol. Calculate $k$ at 50°C. (The universal gas constant = 8.314 J/mol•K.)
   $$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$
   a. 0.832 s$^{-1}$
   b. 71.9 s$^{-1}$
   c. 0.266 s$^{-1}$
   d. 1.08 s$^{-1}$
   e. 0.0265 s$^{-1}$

32. Which of the following statements about catalysts are false?
   a. A catalyst lowers the activation energy.
   b. A catalyst can make a nonspontaneous reaction spontaneous.
   c. A catalyst speeds up both the forward and reverse reaction.
   d. A catalyst speeds up the rate of reaction.
   e. Catalyst are often transition metals and transition metal oxides.

33. Consider the hypothetical reaction shown below.
   $$A + 2B \rightarrow AB_2$$
   Assume that the following proposed mechanism is consistent with the rate data.

   | Step | Reaction | Rate
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>$B + B \rightarrow B_2$</td>
<td>slow</td>
</tr>
<tr>
<td>2</td>
<td>$B_2 + A \rightarrow AB + B$</td>
<td>fast</td>
</tr>
<tr>
<td>3</td>
<td>$B + AB \rightarrow AB_2$</td>
<td>fast</td>
</tr>
<tr>
<td>4</td>
<td>$A + 2B \rightarrow AB_2$</td>
<td>overall</td>
</tr>
</tbody>
</table>

   Which one of the following statements must be true? The reaction is ____.
   a. first order in $A$, second order in $B$, and third order overall
   b. second order in $B$ and second order overall
   c. first order in $A$ and first order overall
   d. second order in $B$, zero order in $A$, and third order overall
   e. second order in $A$ and second order overall
34. Which idea listed below is not a part of the collision theory of reaction rates?
   a. Molecules must be properly oriented when they collide to react.
   b. Molecules must collide to react.
   c. Molecules must collide with enough kinetic energy to overcome the potential energy stabilization of the bonds.
   d. Effective collisions result in a chemical reaction.
   e. All molecular collisions result in a reaction.

35. Which statement concerning biological catalysts is false?
   a. Enzymes are proteins that act as catalysts for specific biochemical reactions.
   b. The reactants in enzyme-catalyzed reactions are called substrates.
   c. Each enzyme catalyzes many different reactions in a living system.
   d. Enzyme-catalyzed reactions are important examples of zero-order reactions.
   e. Discovery or synthesis of catalysts that mimic the efficiency of naturally occurring enzymes would saved on the costs of using high temperature and high pressure in commercial processes.
### MULTIPLE CHOICE

<table>
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<th>PTS:</th>
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