1) The law of ________ states that energy that can be neither created or destroyed.
   A) kinetic energy
   B) the consecration of energy
   C) potential energy
   D) the conservation of energy
   E) thermochemistry
   Answer:  D

2) The first law of thermodynamics
   A) defines chemical energy.
   B) defines entropy.
   C) is a statement of conservation of energy.
   D) provides a criterion for the spontaneity of a reaction.
   Answer:  C

3) The nutritional calorie (abbreviated Cal) is equal to
   A) 1 mcal.
   B) 4.184 J.
   C) 4.184 cal.
   D) 1 kcal.
   Answer:  D

4) Define heat capacity.
   A) the quantity of heat required to lower the temperature of 1 mole of a substance by 1°C
   B) the quantity of heat required to change a system's temperature by 1°C
   C) the quantity of heat required to lower the temperature of 1 gram of a substance by 1°C
   D) the quantity of heat required to raise the temperature of 1 g of a substance by 1°F
   E) the quantity of heat required to lower the temperature of 1 liter of a substance by 1°C
   Answer:  B

5) Define specific heat capacity.
   A) the quantity of heat required to lower the temperature of 1 mole of a substance by 1°C
   B) the quantity of heat required to change a system's temperature by 1°C
   C) the quantity of heat required to raise the temperature of 1 gram of a substance by 1°C
   D) the quantity of heat required to lower the temperature of 1 gram of a substance by 1°F
   E) the quantity of heat required to lower the temperature of 1 liter of a substance by 1°C
   Answer:  C

6) Which of the following processes is endothermic?
   A) the freezing of water
   B) the combustion of butane
   C) a hot cup of coffee (system) cools on a countertop
   D) the chemical reaction in a "hot pack" often used to treat sore muscles
   E) the vaporization of rubbing alcohol
   Answer:  E

7) Which of the following processes is exothermic?
   A) a candle flame
B) baking bread  
C) the chemical reaction in a "cold pack" often used to treat injuries  
D) the vaporization of water  
E) None of the above are exothermic.  
Answer: A

8) Determine the specific heat capacity of an alloy that requires 59.3 kJ to raise the temperature of 150.0 g alloy from 298 K to 398 K.  
A) 4.38 J/g°C  
B) 2.29 J/g°C  
C) 3.95 J/g°C  
D) 2.53 J/g°C  
E) 1.87 J/g°C  
Answer: C

9) A 5.00-g sample of liquid water at 25.0°C is heated by the addition of 84.0 J of energy. The final temperature of the water is ________°C. The specific heat capacity of liquid water is 4.18 J/gK.  
A) 95.2  
B) 25.2  
C) -21.0  
D) 29.0  
E) 4.02  
Answer: D

10) A sample of copper at 100°C was dropped into 100.0 g of water at 40°C. The final temperature of the system was 60°C. What was the mass of the copper (in kg) of the copper sample if the specific heat capacity of copper is 0.385 J/g°C; water is 4.184 J/g°C  
A) 0.543 kg  
B) 6.62 kg  
C) 1.26 kg  
D) 7.94 kg  
E) 3.64 kg  
Answer: A

11) Determine the final temperature of a gold nugget (mass = 376 g) that starts at 398 K and loses 4.85 kJ of heat to a snowbank when it is lost. The specific heat capacity of gold is 0.128 J/g°C.  
A) 133 K  
B) 398 K  
C) 187 K  
D) 297 K  
E) 377 K  
Answer: D

12) Use the standard reaction enthalpies given below to determine ΔH°_rxn for the following reaction:  
   2 NO(g) + O₂(g) → 2 NO₂(g)  
   ΔH°_rxn = ?
   
Given:
   N₂(g) + O₂(g) → 2 NO(g)  
   ΔH°_rxn = +183 kJ  
   1/2 N₂(g) + O₂(g) → NO₂(g)  
   ΔH°_rxn = +33 kJ
A) -150. kJ
B) -117 kJ
C) -333 kJ
D) +115 kJ
E) +238 kJ
Answer: B

13) Use the standard reaction enthalpies given below to determine $\Delta H^\circ_{\text{rxn}}$ for the following reaction:

$$2 \text{S}(s) + 3 \text{O}_2(g) \rightarrow 2 \text{SO}_3(g) \quad \Delta H^\circ_{\text{rxn}} = ?$$

Given:

$$\text{SO}_2(g) \rightarrow \text{S}(s) + \text{O}_2(g) \quad \Delta H^\circ_{\text{rxn}} = +296.8 \text{ kJ}$$

$$2 \text{SO}_2(g) + \text{O}_2(g) \rightarrow 2 \text{SO}_3(g) \quad \Delta H^\circ_{\text{rxn}} = -197.8 \text{ kJ}$$

A) -494.6 kJ
B) -692.4 kJ
C) -791.4 kJ
D) 1583 kJ
E) -293.0 kJ
Answer: C

14) How much heat is transferred per mole of NH$_3$(g) formed in the reaction shown below?

$$\text{N}_2(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g) \quad \Delta H^\circ = -92.2 \text{ kJ}$$

A) 92.2 kJ
B) 46.1 kJ
C) 30.7 kJ
D) 15.4 kJ
Answer: B

15) How much heat is required to generate 3 mole of NH$_3$(g) in the reaction shown below?

$$\text{N}_2(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g) \quad \Delta H^\circ = -92.2 \text{ kJ}$$

A) 92.2 kJ
B) 46.1 kJ
C) 30.7 kJ
D) 138.3 kJ
Answer: D

16) Use the information provided to determine $\Delta H^\circ_{\text{rxn}}$ for the following reaction:

$$\Delta H^\circ_{\text{f}} \text{ (kJ/mol)} \quad \text{CH}_4(g) + 4 \text{Cl}_2(g) \rightarrow \text{CCl}_4(g) + 4 \text{HCl}(g) \quad \Delta H^\circ_{\text{rxn}} = ?$$

<table>
<thead>
<tr>
<th>Substance</th>
<th>$\Delta H^\circ_{\text{f}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_4$(g)</td>
<td>-75</td>
</tr>
<tr>
<td>CCl$_4$(g)</td>
<td>-96</td>
</tr>
<tr>
<td>HCl(g)</td>
<td>-92</td>
</tr>
</tbody>
</table>

A) -389 kJ
B) -113 kJ
C) +113 kJ
D) -71 kJ
E) +79 kJ
Answer: E
17) Given: \( 4 \text{NO}_2(g) + \text{O}_2(g) \rightarrow 2 \text{N}_2\text{O}_5(g) \) \( \Delta H^\circ = -110.2 \text{kJ} \)
find \( \Delta H^\circ \) for \( \text{N}_2\text{O}_5(g) \rightarrow 2 \text{NO}_2(g) + 1/2 \text{O}_2(g) \).
A) -220.4 kJ
B) -55.1 kJ
C) 55.1 kJ
D) 220.4 kJ
Answer: C

18) Find \( \Delta H \) for \( \text{BaCO}_3(s) \rightarrow \text{BaO}(s) + \text{CO}_2(g) \)
given
\[
\text{Ba}(s) + \text{O}_2(g) \rightarrow \text{BaO}(s) \quad \Delta H = -1107.0 \text{kJ}
\]
\[
\text{Ba}(s) + \text{CO}_2(g) + 1/2 \text{O}_2(g) \rightarrow \text{BaCO}_3(g) \quad \Delta H = -822.5 \text{kJ}
\]
A) -1929.5 kJ
B) -1376.0 kJ
C) -284.5 kJ
D) 269.0 kJ
Answer: D

19) Choose the thermochemical equation that illustrates \( \Delta H^\circ_f \) for \( \text{Li}_2\text{SO}_4 \).
A) \( 2 \text{Li}^+(aq) + \text{SO}_4^{2-}(aq) \rightarrow \text{Li}_2\text{SO}_4(aq) \)
B) \( 2 \text{Li}(s) + 1/8 \text{S}_8(s, \text{rhombic}) + 2 \text{O}_2(g) \rightarrow \text{Li}_2\text{SO}_4(s) \)
C) \( \text{Li}_2\text{SO}_4(aq) \rightarrow 2 \text{Li}^+(aq) + \text{SO}_4^{2-}(aq) \)
D) \( 8 \text{Li}_2\text{SO}_4(s) \rightarrow 16 \text{Li}(s) + \text{S}_8(s, \text{rhombic}) + 16 \text{O}_2(g) \)
E) \( 16 \text{Li}(s) + \text{S}_8(s, \text{rhombic}) + 16 \text{O}_2(g) \rightarrow 8 \text{Li}_2\text{SO}_4(s) \)
Answer: B

20) For the reaction \( 2\text{CH}_4(g) + 3 \text{Cl}_2(g) \rightarrow 2 \text{CHCl}_3(l) + 3 \text{H}_2(g) \), \( \Delta H^\circ = -118.6 \text{kJ} \).
\( \Delta H^\circ_f = -134.1 \text{kJ/mol for CHCl}_3(l) \). Find \( \Delta H^\circ_f \) for \( \text{CH}_4(g) \).
A) -193.4 kJ/mol
B) -74.8 kJ/mol
C) 74.8 kJ/mol
D) 193.4 kJ/mol
Answer: B

21) When a 100 g ring adsorbs 128.0 J of heat, its temperature increases by 10.0 C. What is the ring made of?

<table>
<thead>
<tr>
<th>Name of Metal</th>
<th>Atomic Mass, amu</th>
<th>Specific Heat, J/g°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>26.98</td>
<td>.900</td>
</tr>
<tr>
<td>Copper</td>
<td>63.55</td>
<td>.385</td>
</tr>
<tr>
<td>Gold</td>
<td>197.0</td>
<td>.131</td>
</tr>
<tr>
<td>Iron</td>
<td>55.85</td>
<td>.451</td>
</tr>
<tr>
<td>Lead</td>
<td>207.2</td>
<td>.128</td>
</tr>
<tr>
<td>Silver</td>
<td>107.9</td>
<td>.237</td>
</tr>
<tr>
<td>Tin</td>
<td>118.7</td>
<td>.222</td>
</tr>
</tbody>
</table>

Answer: LEAD
22) Determine the enthalpy of reaction for the following:
\[ \text{H}_2(g) + (1/2)\text{O}_2(g) \rightarrow \text{H}_2\text{O}(g) \]

Using the following bond enthalpies (in kJ/mol): H–H (432); O=O (496); H–O (463)

**Solution:**

\[ \Delta H = \Sigma E_{\text{reactant bonds broken}} \text{ minus } \Sigma E_{\text{product bonds broken}} \]

\[ \Delta H = [432 + (0.5)(496)] - [(2)(463)] \]

\[ \Delta H = 680 - 926 \]

\[ \Delta H = -246 \text{ kJ} \]

23) Use the standard reaction enthalpies given below to determine \( \Delta H^\circ_{\text{rxn}} \) for the following reaction:

\[ \text{P}_4(g) + 10 \text{Cl}_2(g) \rightarrow 4\text{PCl}_5(s) \quad \Delta H^\circ_{\text{rxn}} = ? \]

Given:

\[ \text{PCl}_5(s) \rightarrow \text{PCl}_3(g) + \text{Cl}_2(g) \quad \Delta H^\circ_{\text{rxn}} = +157 \text{ kJ} \]

\[ \text{P}_4(g) + 6 \text{Cl}_2(g) \rightarrow 4 \text{PCl}_3(g) \quad \Delta H^\circ_{\text{rxn}} = -1207 \text{ kJ} \]

A) -1835 kJ  
B) -1364 kJ  
C) -1050 kJ  
D) -1786 kJ  
E) -2100 kJ  
Answer: A

24) Give the units of heat capacity.

A) J/°C  
B) J/g °C  
C) Jmole/°C  
D) g/°C  
E) gmole °C  
Answer: A

25) Give the units of specific heat capacity.

A) J/°C  
B) J/g °C  
C) Jmole °C  
D) g/°C  
E) gmole °C  
Answer: B

26) Which of the following substances (with specific heat capacity provided) would show the greatest temperature change upon absorbing 100.0 J of heat?

A) 10.0 g Cu, \( C_{\text{Cu}} = 0.385 \text{ J/g}°\text{C} \)
B) 10.0 g H₂O, CH₂O = 4.18 J/g°C  
C) 10.0 g ethanol, Cethanol = 2.42 J/g°C  
D) 10.0 g Al, CAl = 0.903 J/g°C  
E) 10.0 g Pb, CPb= 0.128 J/g°C  
Answer: E

27) The specific heat capacity of methane gas is 2.20 J/g-K. How many joules of heat are needed to raise the temperature of 5.00 g of methane from 36.0°C to 75.0°C?  
A) 88.6 J  
B) 429 J  
C) 1221 J  
D) 0.0113 J  
E) 22.9 J  
Answer: B

28) It takes 11.2 kJ of energy to raise the temperature of 145 g of benzene from 23.0°C to 68.0°C. What is the specific heat of benzene?  
A) 1.14 J/(g ∙ °C)  
B) 1.72 J/(g ∙ °C)  
C) 3.48 J/(g ∙ °C)  
D) 5.25 J/(g ∙ °C)  
Answer: B

29) A 50.0-g sample of liquid water at 25.0°C is mixed with 29.0 g of water at 45.0°C. The final temperature of the water is ________°C.  
A) 102  
B) 27.6  
C) 35.0  
D) 142  
E) 32.3  
Answer: E

30) Identify what a bomb calorimeter measures.  
A) measures ΔH for aqueous solutions  
B) measures ΔE for combustion reactions  
C) measures ΔH for reduction solutions  
D) measures ΔT for aqueous solutions  
E) measures ΔE for oxidation reactions  
Answer: B

31) Which of the following processes is endothermic?  
A) the freezing of water  
B) the combustion of butane  
C) a hot cup of coffee (system) cools on a countertop  
D) the chemical reaction in a "hot pack" often used to treat sore muscles  
E) the vaporization of rubbing alcohol  
Answer: E
32) According to the following reaction, how much energy is required to decompose 59.0 kg of Fe₃O₄? The molar mass of Fe₃O₄ is 231.55 g/mol.

\[ \text{Fe}_3\text{O}_4(s) \rightarrow 3 \text{Fe(s)} + 2 \text{O}_2(g) \quad \Delta H^\circ_{\text{rxn}} = +1118 \text{ kJ} \]

A) $1.42 \times 10^5$ kJ
B) $1.13 \times 10^4$ kJ
C) $2.85 \times 10^5$ kJ
D) $5.70 \times 10^5$ kJ
E) $8.55 \times 10^5$ kJ

Answer: C