

Unit 4 Practice Test

Introduction to Thermochemistry

1. If $\Delta H = +32$ kJ for a certain process, that process
 - A. occurs rapidly.
 - B. is exothermic.
 - C. is endothermic.
 - D. cannot occur.
 - E. requires a catalyst.
2. The quantity of heat needed to raise the temperature of a sample of a substance 1°C is the sample's
 - A. heat capacity.
 - B. specific heat.
 - C. enthalpy.
 - D. work.
 - E. calorimetry.
3. The sign of ΔH for the process $\text{KCl}(s) \rightarrow \text{KCl}(l)$ is
 - A. positive and the process is endothermic.
 - B. negative and the process is endothermic.
 - C. positive and the process is exothermic.
 - D. negative and the process is exothermic.
 - E. impossible to predict with confidence because ΔH°_f for $\text{KCl}(s)$ and ΔH°_f for $\text{KCl}(l)$ are not given.

4. Consider the following specific heats of metals.

Metal	Specific Heat ($\text{J/g}\cdot^\circ\text{C}$)
Copper	0.385
Cobalt	0.418
Chromium	0.447
Gold	0.129
Silver	0.237

If the same amount of heat is added to 100-g samples of each of the metals, which are all at the same temperature, which metal will reach the highest temperature?

- A. copper
 - B. cobalt
 - C. chromium
 - D. gold
 - E. silver
5. Which of the following statements is false?
 - A. The reaction vessel cools when an endothermic reaction occurs.
 - B. An exothermic reaction is characterized by a negative value of ΔH .
 - C. Heat is evolved when an exothermic reaction occurs.
 - D. Heat is added to the system by an endothermic reaction.
 - E. An endothermic reaction causes the surroundings to absorb heat.

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6. Which answer lists all the following responses that are endothermic and none that are exothermic?
1. boiling water
 2. freezing water
 3. condensation of steam
 4. melting ice
- A. 1 and 2 only
B. 2 and 3 only
C. 1 and 4 only
D. 2, 3, and 4 only
E. 2 and 4 only
7. What is the molar heat of combustion of methanol, CH₃OH, if combustion of 1.00 g of methanol causes a temperature rise of 3.68°C in a bomb calorimeter that has a heat capacity of 6.43 kJ/°C? (Formula weight CH₃OH = 32.)
- A. 55.9 kJ/mol
B. 923 kJ/mol
C. 757 kJ/mol
D. 18.3 kJ/mol
E. 368 kJ/mol
8. What is the change in enthalpy for the production of 1.00 mol SnO?
- $$\text{Sn} + \text{SnO}_2 + 92 \text{ kJ} \rightarrow 2 \text{ SnO}$$
- A. -184 kJ
B. -92 kJ
C. -46 kJ
D. 46 kJ
E. 92 kJ
9. Which statement concerning the following is correct?
- $$\text{N}_2(g) + \text{O}_2(g) + 43.2 \text{ kcal} \rightarrow 2 \text{ NO}(g)$$
- A. The reaction is exothermic.
B. The products have an enthalpy loss.
C. The sign of ΔH for the reaction is negative.
D. ΔH of the products exceeds that of the reactants.
E. The products have less enthalpy than the reactants.
10. All of the following are state functions except
- A. w.
B. H.
C. U.
D. P.
E. T.

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11. In one of the following processes, ΔH and ΔU are nearly the same. Select the process.
- A. $2 \text{NH}_3(g) \rightarrow \text{N}_2(g) + 3 \text{H}_2(g)$
 - B. $\text{BaO}(s) + \text{CO}_2(g) \rightarrow \text{BaCO}_3(s)$
 - C. $\text{H}_2\text{O}(g) \rightarrow \text{H}_2(g) + \frac{1}{2} \text{O}_2(g)$
 - D. $\text{I}_2(s) \rightarrow \text{I}_2(g)$
 - E. $\text{Hg}(s) \rightarrow \text{Hg}(l)$
12. What is the change in enthalpy when 1 mol (28 g) of carbon monoxide is oxidized to carbon dioxide?
- $$2 \text{CO}(g) + \text{O}_2(g) \rightarrow 2 \text{CO}_2(g) + 566 \text{ kJ}$$
- A. -566 kJ
 - B. $-566/2 \text{ kJ}$
 - C. $566/2 \text{ kJ}$
 - D. 566 kJ
 - E. $566 \times 2 \text{ kJ}$
13. All of the following have a standard enthalpy of formation value of zero at 25°C and 1.00 atm except
- A. $\text{CO}(g)$.
 - B. $\text{Fe}(s)$.
 - C. $\text{C}(s)$.
 - D. $\text{F}_2(g)$.
 - E. $\text{Ne}(g)$.
14. All of the following statements are true for an exothermic reaction except
- A. The temperature of the reaction system increases.
 - B. The temperature of the surroundings increases.
 - C. Heat passes from the reaction system to the surroundings.
 - D. The products have a higher heat content than the reactants.
 - E. The enthalpy change for the reaction is negative.
15. Which of the following species would need to appear in an Enthalpies of Formation Table at 25°C and 1 atm?
- 1. $\text{O}(g)$
 - 2. $\text{O}_2(g)$
 - 3. $\text{O}_2(l)$
 - 4. $\text{Hg}(l)$
 - 5. $\text{Hg}(s)$
- A. 1 only
 - B. 3 and 4 only
 - C. 1, 3, and 5 only
 - D. 2, 4, and 5 only
 - E. 2 and 4 only

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16. The equation for the standard enthalpy of formation of potassium bromate, KBrO_3 , corresponds to which reaction?

- A. $\text{K}(s) + \frac{1}{2} \text{Br}_2(g) + \frac{3}{2} \text{O}_2(g) \rightarrow \text{KBrO}_3(s)$.
- B. $\text{K}(g) + \frac{1}{2} \text{Br}_2(g) + \frac{3}{2} \text{O}_2(g) \rightarrow \text{KBrO}_3(s)$.
- C. $\text{K}(s) + \frac{1}{2} \text{Br}_2(l) + \frac{3}{2} \text{O}_2(g) \rightarrow \text{KBrO}_3(s)$.
- D. $\text{K}(g) + \text{Br}(g) + 3 \text{O}(g) \rightarrow \text{KBrO}_3(s)$.
- E. $\text{K}(s) + \text{Br}(g) + 3 \text{O}(g) \rightarrow \text{KBrO}_3(s)$.

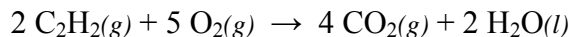
17. Given the following data,

	ΔH° (kJ/mol)
$\text{S}(s) + \text{O}_2(g) \rightarrow \text{SO}_2(g)$	-395
$\text{S}(g) + \text{O}_2(g) \rightarrow \text{SO}_2(g)$	-618

find the heat required for the reaction converting solid sulfur to gaseous sulfur at 298 K and 1 atm pressure.

- A. -1013 kJ/mol
- B. +618 kJ/mol
- C. -618 kJ/mol
- D. -223 kJ/mol
- E. +223 kJ/mol

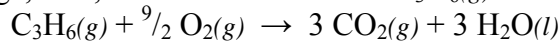
18. For the reaction



[ΔH_f° in kJ/mol are $\text{O}_2(g)$, 0; $\text{C}_2\text{H}_2(g)$, +226.7; $\text{CO}_2(g)$, -393.5; $\text{H}_2\text{O}(l)$, -285.8] the ΔH of reaction is

- A. $2(-285.8) + 4(-393.5) + 2(226.7)$.
- B. $2(-285.8) + 4(-393.5) - 2(226.7)$.
- C. $2(285.8) + 4(393.5) + 2(226.7)$.
- D. $2(285.8) + 4(393.5) - 2(226.7)$.
- E. $-285.8 - 393.5 + 226.7$.

19. Calculate the enthalpy change, ΔH° , for the combustion of $\text{C}_3\text{H}_6(g)$:



[ΔH_f° values in kJ/mol are as follows: $\text{C}_3\text{H}_6(g)$ = 21; $\text{CO}_2(g)$ = -394; $\text{H}_2\text{O}(l)$ = -286.]

- A. -2061 kJ
- B. -2019 kJ
- C. -701 kJ
- D. 2019 kJ
- E. 2061 kJ

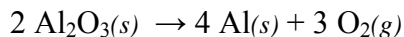
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20. Given the thermochemical equation:



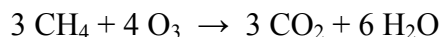
find ΔH for the following reaction



- A. -400 kcal
B. $+400 \text{ kcal}$
C. -200 kcal
D. $+200 \text{ kcal}$
E. $+800 \text{ kcal}$
21. Given the following enthalpies of formation, ΔH_f° , values:

	ΔH_f°
$\text{CH}_4(g)$	-74.8 kJ/mol
$\text{H}_2\text{O}(g)$	-242 kJ/mol
$\text{CO}_2(g)$	-394 kJ/mol
$\text{O}_3(g)$	143 kJ/mol

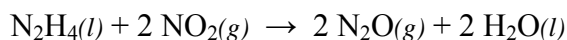
what is ΔH° in kJ for this reaction?



- A. $-3(394) - 6(242) + 4(143) - 3(74.8)$
B. $-3(394) - 6(242) - 4(143) - 3(74.8)$
C. $-3(394) - 6(242) - 4(143) + 3(74.8)$
D. $3(394) + 6(242) + 4(143) + 3(74.8)$
E. $3(394) + 6(242) - 4(143) + 3(74.8)$
22. Given the following enthalpies of formation, ΔH_f° :

$\text{N}_2\text{H}_4(l)$	50.4 kJ/mol
$\text{H}_2\text{O}(l)$	-286 kJ/mol
$\text{N}_2\text{O}(g)$	81.5 kJ/mol
$\text{NO}_2(g)$	33.8 kJ/mol

What is ΔH in kJ for the reaction below?

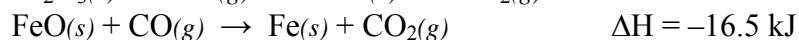
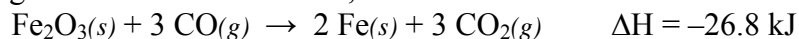


- A. $81.5 - 286 + 50.4 + 33.8$
B. $2(81.5) - 2(286) + 50.4 + 2(33.8)$
C. $-2(81.5) + 2(286) - 50.4 - 2(33.8)$
D. $2(81.5) - 2(286) - 50.4 - 2(33.8)$
E. $-2(81.5) - 2(286) - 50.4 - 2(33.8)$

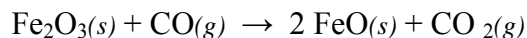
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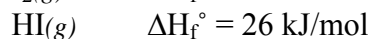
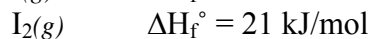
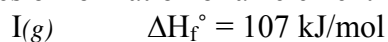
23. The following two reactions are known,



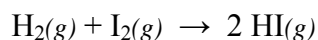
determine the ΔH value for the reaction below.



- A. -43.3 kJ
 - B. -10.3 kJ
 - C. 6.2 kJ
 - D. 10.3 kJ
 - E. 22.7 kJ
24. The enthalpies of formation of an element in various iodine species are as follows:



What other additional information is needed to calculate the enthalpy of the following reaction?



- A. none, because the answer is 2 times 26 kJ/mol
- B. none, because the enthalpy of formation of an element in its stablest form is zero
- C. the enthalpy of formation of gaseous iodine
- D. the enthalpy of formation of gaseous hydrogen
- E. the enthalpy of formation of solid iodine

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Answer Key:

1. C
2. A
3. A
4. D
5. E
6. C
7. C
8. D
9. D
10. A
11. E
12. B
13. A
14. D
15. C
16. C
17. E
18. B
19. A
20. E
21. C
22. D
23. C
24. B

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Answer Justifications:

1. C

The enthalpy of a process provides information about the process's reactant and product bonds and whether energy is needed to be absorbed or released. Since the enthalpy is positive (+), the process is endothermic and absorbs energy.

2. A

The quantity of heat needed to raise the temperature of a sample of a substance 1°C is the definition of heat capacity. This definition is very similar to that of specific heat, which is the quantity of heat needed to raise the temperature of *a unit mass* of a substance 1°C . Enthalpy is the measure of the total energy of a thermodynamic system. Work is the amount of energy transferred by a system to (or from) another system. Calorimetry is the measurement of the temperature changes made by a system.

3. A

Since enthalpy is the measure of the total energy of a thermodynamic system, it expresses the strength of the bonds within compounds and attractions between compounds of the system. Since the process ($\text{KCl}(s) \rightarrow \text{KCl}(l)$) goes between the same substance, there is little change the bonds within KCl. However, since the process turns from a solid to a liquid, the amount of change in the attractions is significantly greater. Attractions within a solid are excessively tight and strong, while those of a liquid are weaker so that the particles are mobile. This means the attractions of the solid needed to be broken in order to become a liquid. Since broken attractions absorb energy, this process is endothermic and carries a positive sign. Another way of thinking of it is that any solid that changes to a liquid is technically melting. Melting takes in energy – endothermic with a positive sign.

4. D

Specific heat is the quantity of heat needed to raise the temperature of *a unit mass* of a substance 1°C . In this question, each sample has been dictated as the same mass (100-g). Therefore, the only difference is the amount of energy required to change the metals' temperature. The specific heat that is the highest will need to absorb the most energy to change the metal's temperature by a single degree. Therefore, the specific heat that is the smallest requires the least amount of energy to change the metal's temperature – this is gold.

5. E

Any endothermic reaction absorbs energy, therefore the reaction takes the energy from the surroundings (as in the reaction vessel). This means that endothermic reactions cause their reaction vessels to become cold. Response A is true. Enthalpy has both a magnitude and direction. Exothermic reactions have negative signs to show the loss of energy by the system, while endothermic reactions have positive signs to show the gain of energy by the system. This makes Responses B, C, and D true. This also makes Response E false since the absorption of heat is by the system, not the surroundings.

6. C

All of the responses listed are phase changes. Phase changes which cause the particles to get further from each other break attractions and are, therefore, endothermic. These would include boiling, melting, and

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sublimation. Phase changes which cause the particles to become closer together also create more attractions and are, therefore, exothermic. These would include condensation, freezing, and deposition. The responses that are endothermic are 1 and 4 – Response C.

7. C

The molar heat of any process is the amount of heat per mole $\left(\frac{kJ}{mol}\right)$.

First, use the heat capacity and temperature increase to calculate the amount of heat for the combustion.

$$q_{comb} = C \times \Delta t = (6.43 \text{ kJ}/^{\circ}\text{C})(3.68^{\circ}\text{C}) = 23.7 \text{ kJ}$$

Note, since the system is undergoing combustion, its enthalpy is negative.

Because this system occurred for 1.00 g of methanol, the amount of moles of methanol can be calculated.

$$\frac{1.00 \text{ g } CH_3OH}{32 \text{ g}} \left(\frac{1 \text{ mol}}{32 \text{ g}}\right) = 0.03125 \text{ mol } CH_3OH$$

Now use the heat and moles to solve for the molar heat of combustion.

$$\frac{23.7 \text{ kJ}}{0.03125 \text{ mol } CH_3OH} = 758 \text{ kJ}/\text{mol}$$

Response C

8. D

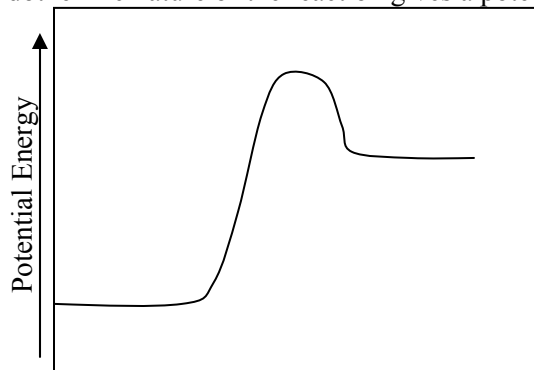
The reaction shows the enthalpy on the reactants side. This means that the enthalpy is endothermic, +92 kJ for 2 moles of SnO. To obtain the enthalpy for 1.00 mol SnO, divide the heat by 2:

$$\frac{+92 \text{ kJ}}{2 \text{ mol } SnO} = +46 \text{ kJ}/\text{mol}$$

Response D

9. D

The reaction shows the enthalpy on the reactants side. This means that the enthalpy is endothermic and positive, making Responses A and C false. In order to consider the remaining Responses, a potential energy diagram can be used. The endothermic nature of the reaction gives a potential energy diagram like this:



This diagram shows that potential energy of the reactants is lower than the potential energy of the products. Notice that the amount of energy of the products is higher than that of the reactants, making Response D true.

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10. A

A state function is any property that depends only on the current state of the system, but does not depend on the path used to obtain that current state. The best examples of state functions are the states themselves – temperature, pressure, mass, and volume. However, state functions also include enthalpy (H), internal energy (U), entropy (S), and Gibb's free energy (G). Work (w) does depend on the path used to obtain the current state. Think of lifting an enormous rock. Picking up the rock directly is terribly difficult and requires a lot of work. However, using a pulley or a lever reduces the amount of work required. So, the equipment being used (the path) alters the amount of work.

11. E

The two major components of internal energy, ΔU , are kinetic and potential energy. The kinetic energy of particles is determined by the vibrations and rotations of the components within the particles. The potential energy of particles is found in the attractions between one particle to another particle and in the bonds holding the particle components together. The enthalpy, ΔH , is the amount of internal energy added to the amount of energy required to displace the environment by changing the system's volume and pressure. Therefore, the internal energy and enthalpy are nearly equal when the volume and pressure do not change; solids are least likely to alter the volume or pressure of the system. The gaseous components of the reactions in Responses A, B, C, and D alter the volume and pressure so that the enthalpy and internal energy are different. The reaction in Response E may also have a slight volume change between the solid and the liquid, but it can not have a pressure change. Therefore, the enthalpy and internal energy will be similar.

12. B

In this reaction, the enthalpy is shown on the products side. Therefore, is it exothermic and negative, -566 kJ for 2 moles of carbon monoxide. In order to determine the enthalpy for one mole of carbon monoxide, the value would need to be divided by 2:

$$\frac{-566 \text{ kJ}}{2 \text{ mol CO}}$$

Response B.

13. A

The standard enthalpy of formation has a zero value when the substance is an element at its natural state. $\text{Fe}(s)$, $\text{C}(s)$, $\text{F}_2(g)$, and $\text{Ne}(g)$ are all elements at their natural states at 25°C and 1.00 atm , so they would all have zero values. $\text{CO}(g)$, on the other hand, is at its natural state but is a compound, not an element. This means that its standard enthalpy of formation can not be equal to zero.

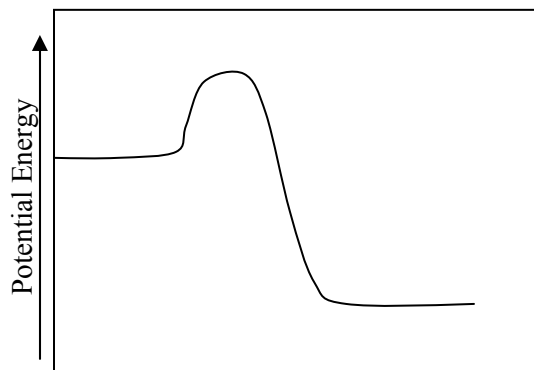
14. D

Exothermic reactions cause the system to release energy and have a negative sign. This means that Responses C and E are true. Since energy is being released from the system, the surroundings will absorb that energy and their temperature will be increased. This means Response B is also true. Since heat is being released from the system, the system's temperature is found to increase as well, making Response A true. [In an exothermic reaction, the total energy absorbed in bond breaking is less than the total energy released in bond making. In other words, the energy needed for the reaction to occur is less than the total energy provided. As a result of this, the extra energy is released, usually in the form of heat.]

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A potential energy diagram can also be used. The exothermic nature of the reaction gives a potential energy diagram like this:



This diagram shows that potential energy of the products is lower than the potential energy of the reactants. Notice that the amount of energy of the reactants is higher than that of the products, making Response D false.

15. C

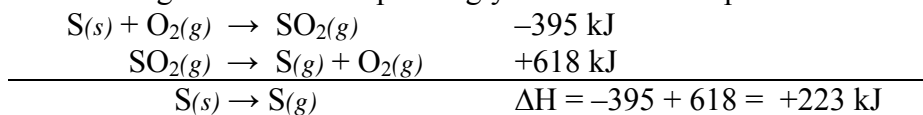
The standard enthalpy of formation values do not have to be added to a table when the values are already known. Since the standard enthalpy of formation is known to be zero when the substance is an element at its natural state, no elements at their natural states need to be added to the table. $O_2(g)$ and $Hg(l)$ are both at their natural states at $25^\circ C$ and 1.00 atm, so they would have values of zero. $O(g)$, $O_2(l)$, and $Hg(s)$ are elemental but are not at their natural states. These would need to be added to the table.

16. C

Equations that represent the standard enthalpy of formation must make one mole of the substance from its elements at their standard states. All of the Responses shown create a single mole of $KBrO_3$. Both Responses D and E have the incorrect elemental formulas for bromine and oxygen, which are both diatomic. Both Responses A and B have bromine listed as gaseous, even though it is a liquid at standard conditions. (Response B also has the metal potassium listed as a gas). Therefore, the only correct Response is C.

17. E

The reaction that is requested is $S(s) \rightarrow S(g)$. This reaction can be obtained by adding the two other reactions together and correspondingly alter their enthalpies:



Notice that the heat of the second reaction is changed from a negative sign to a positive sign; this is because the reaction was reversed, so the heat needed to be reversed as well. Also notice that the chemicals $SO_2(g)$ and $O_2(g)$ are cancelled because they appear on both sides of the reaction as the reactions are added together.

18. B

The quantities that have been provided are standard enthalpies of formation. Therefore, the equation $\Delta H_{rxn} = \sum \Delta H_f^\circ (\text{Products}) - \sum \Delta H_f^\circ (\text{Reactants})$ can be used.

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$$\Delta H_{rxn} = [4 \times \Delta H_f^\circ(\text{CO}_2) + 2 \times \Delta H_f^\circ(\text{H}_2\text{O})] - [2 \times \Delta H_f^\circ(\text{C}_2\text{H}_2) + 5 \times \Delta H_f^\circ(\text{O}_2)]$$

$$\Delta H_{rxn} = [4 \times (-393.5) + 2 \times (-285.8)] - [2 \times (226.7) + 5 \times (0)]$$

This matches Response B.

19. A

The quantities that have been provided are standard enthalpies of formation. Therefore, the equation

$$\Delta H_{rxn} = \sum \Delta H_f^\circ(\text{Products}) - \sum \Delta H_f^\circ(\text{Reactants}) \text{ can be used.}$$

$$\Delta H_{rxn} = [3 \times \Delta H_f^\circ(\text{CO}_2) + 3 \times \Delta H_f^\circ(\text{H}_2\text{O})] - [1 \times \Delta H_f^\circ(\text{C}_3\text{H}_6) + \frac{1}{2} \times \Delta H_f^\circ(\text{O}_2)]$$

$$\Delta H_{rxn} = [3 \times (-394) + 3 \times (-286)] - [1 \times (21) + \frac{1}{2} \times (0)]$$

$$\Delta H_{rxn} = [-2040] - [21] = -2061 \text{ kJ}$$

This matches Response A.

20. E

In comparing the thermochemical equation that has been provided to the one that is desired, the desired equation is the reverse of the given equation and double the given equation. Therefore, the enthalpy of the given equation can have a reversed sign and can be multiplied by two:

$$(-1)(2)(-400) = +800 \text{ kJ.}$$

Response E.

21. C

The quantities that have been provided are standard enthalpies of formation. Therefore, the equation

$$\Delta H_{rxn} = \sum \Delta H_f^\circ(\text{Products}) - \sum \Delta H_f^\circ(\text{Reactants}) \text{ can be used.}$$

$$\Delta H_{rxn} = [3 \times \Delta H_f^\circ(\text{CO}_2) + 6 \times \Delta H_f^\circ(\text{H}_2\text{O})] - [3 \times \Delta H_f^\circ(\text{CH}_4) + 4 \times \Delta H_f^\circ(\text{O}_3)]$$

$$\Delta H_{rxn} = [3 \times (-394) + 6 \times (-242)] - [3 \times (-74.8) + 4 \times (143)]$$

This matches Response C.

22. D

The quantities that have been provided are standard enthalpies of formation. Therefore, the equation

$$\Delta H_{rxn} = \sum \Delta H_f^\circ(\text{Products}) - \sum \Delta H_f^\circ(\text{Reactants}) \text{ can be used.}$$

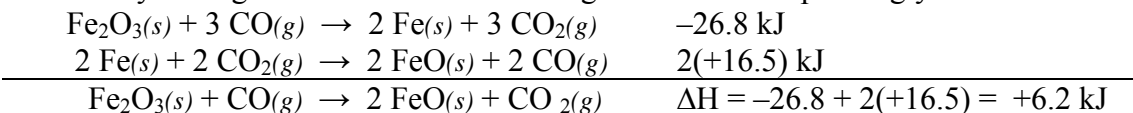
$$\Delta H_{rxn} = [2 \times \Delta H_f^\circ(\text{N}_2\text{O}) + 2 \times \Delta H_f^\circ(\text{H}_2\text{O})] - [1 \times \Delta H_f^\circ(\text{N}_2\text{H}_4) + 2 \times \Delta H_f^\circ(\text{NO}_2)]$$

$$\Delta H_{rxn} = [2 \times (81.5) + 2 \times (-286)] - [1 \times (50.4) + 2 \times (33.8)]$$

This matches Response D.

23. C

The reaction that is requested is $\text{Fe}_2\text{O}_3(s) + \text{CO}(g) \rightarrow 2 \text{FeO}(s) + \text{CO}_2(g)$. This reaction can be obtained by adding the two other reactions together and correspondingly alter their enthalpies:



Unit 4 Practice Test

Introduction to Thermochemistry

Notice that the heat of the second reaction is changed from a negative sign to a positive sign; this is because the reaction was reversed, so the heat needed to be reversed as well. The heat of the second reaction has also been multiplied by three because the reaction's coefficients were multiplied by three. Also notice that two moles of the chemicals $\text{CO}_2(g)$ and $\text{CO}(g)$ are cancelled because they appear on both sides of the reaction as the reactions are added together.

24. B

The reaction that is requested is $\text{H}_2(g) + \text{I}_2(g) \rightarrow 2 \text{HI}(g)$. This reaction has the element hydrogen at its standard state and the element iodine that is not at its standard state. The quantities that have been provided are standard enthalpies of formation. Therefore, the equation

$\Delta H_{rxn} = \sum \Delta H_f^\circ (\text{Products}) - \sum \Delta H_f^\circ (\text{Reactants})$ can be used.

The values of $\text{HI}(g)$ and $\text{I}_2(g)$ have been given. Since the element hydrogen is at its standard state, its enthalpy of formation has a value of zero. Therefore, the equation would look like this:

$$\Delta H_{rxn} = [2 \times \Delta H_f^\circ (\text{HI})] - [1 \times \Delta H_f^\circ (\text{H}_2) + 1 \times \Delta H_f^\circ (\text{I}_2)]$$

$$\Delta H_{rxn} = [2 \times (26)] - [1 \times (0) + 1 \times (21)]$$

All of the required variables are known and the enthalpy of the reaction can be solved according to Response B.