

# THERMODYNAMICS

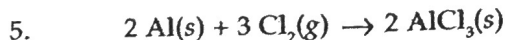
## QUESTIONS

### Multiple-Choice

#### Questions 1-4

- (A) Free energy change ( $\Delta G$ )
- (B) Entropy change ( $\Delta S$ )
- (C) Heat of vaporization
- (D) Heat of fusion
- (E) Heat capacity

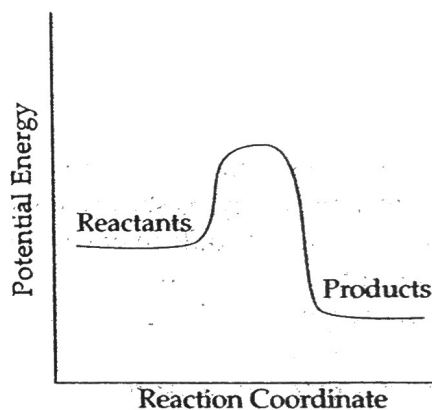
1. If this has a negative value for a process, then the process occurs spontaneously.
2. This is a measure of how the disorder of a system is changing.
3. This is the energy given off when a substance condenses.
4. This is the energy taken in by a substance when it melts.



The reaction above is not spontaneous under standard conditions but becomes spontaneous as the temperature decreases towards absolute zero. Which of the following is true at standard conditions?

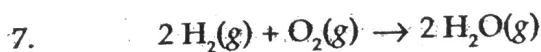
- (A)  $\Delta S$  and  $\Delta H$  are both negative.
- (B)  $\Delta S$  and  $\Delta H$  are both positive.
- (C)  $\Delta S$  is negative and  $\Delta H$  is positive.
- (D)  $\Delta S$  is positive and  $\Delta H$  is negative.
- (E)  $\Delta S$  and  $\Delta H$  are both equal to zero.

6.



Which of the following is true of the reaction shown in the diagram above?

- (A) The reaction is endothermic because the reactants are at a higher energy level than the products.
- (B) The reaction is endothermic because the reactants are at a lower energy level than the products.
- (C) The reaction is exothermic because the reactants are at a higher energy level than the products.
- (D) The reaction is exothermic because the reactants are at a lower energy level than the products.
- (E) The reaction is endothermic because the reactants are at the same energy level as the products.

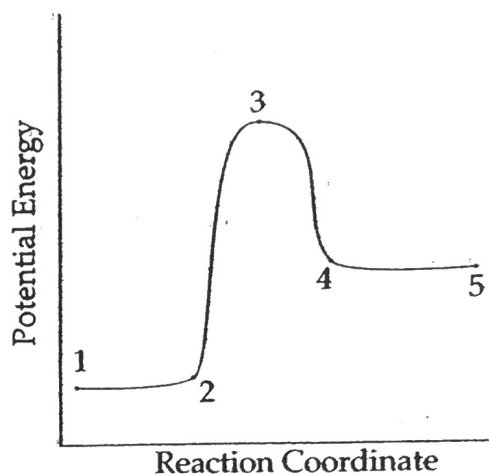


Based on the information given in the table below, what is  $\Delta H^\circ$  for the above reaction?

Bond	Average bond energy (kJ/mol)
H-H	500
O=O	500
O-H	500

- (A) -2,000 kJ  
 (B) -1,500 kJ  
 (C) -500 kJ  
 (D) +1,000 kJ  
 (E) +2,000 kJ
8. Which of the following is true of a reaction that is spontaneous at 298 K but becomes non-spontaneous at a higher temperature?
- (A)  $\Delta S^\circ$  and  $\Delta H^\circ$  are both negative.  
 (B)  $\Delta S^\circ$  and  $\Delta H^\circ$  are both positive.  
 (C)  $\Delta S^\circ$  is negative and  $\Delta H^\circ$  is positive.  
 (D)  $\Delta S^\circ$  is positive and  $\Delta H^\circ$  is negative.  
 (E)  $\Delta S^\circ$  and  $\Delta H^\circ$  are both equal to zero.
9. Which of the following will be true when a pure substance in liquid phase freezes spontaneously?
- (A)  $\Delta G$ ,  $\Delta H$ , and  $\Delta S$  are all positive.  
 (B)  $\Delta G$ ,  $\Delta H$ , and  $\Delta S$  are all negative.  
 (C)  $\Delta G$  and  $\Delta H$  are negative, but  $\Delta S$  is positive.  
 (D)  $\Delta G$  and  $\Delta S$  are negative, but  $\Delta H$  is positive.  
 (E)  $\Delta S$  and  $\Delta H$  are negative, but  $\Delta G$  is positive.

10.



Which point on the graph shown above corresponds to activated complex, or transition state?

- (A) 1  
 (B) 2  
 (C) 3  
 (D) 4  
 (E) 5
11.  $\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) \quad \Delta H^\circ = -390 \text{ kJ/mol}$
- $\text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) \quad \Delta H^\circ = -290 \text{ kJ/mol}$
- $2\text{C}(\text{s}) + \text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_2(\text{g}) \quad \Delta H^\circ = +230 \text{ kJ/mol}$
- Based on the information given above, what is  $\Delta H^\circ$  for the following reaction?
- $\text{C}_2\text{H}_2(\text{g}) + \frac{5}{2} \text{O}_2(\text{g}) \rightarrow 2 \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
- (A) -1300 kJ  
 (B) -1070 kJ  
 (C) -840 kJ  
 (D) -780 kJ  
 (E) -680 kJ

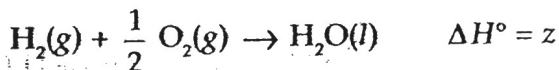
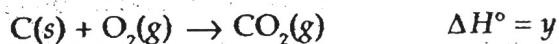
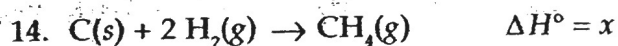
4.

12. If an endothermic reaction is spontaneous at 298 K, which of the following must be true for the reaction?

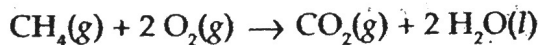
- I.  $\Delta G$  is greater than zero.
  - II.  $\Delta H$  is greater than zero.
  - III.  $\Delta S$  is greater than zero.
- (A) I only
  - (B) II only
  - (C) I and II only
  - (D) II and III only
  - (E) I, II, and III

13. The addition of a catalyst will have which of the following effects on a chemical reaction?

- I. The enthalpy change will decrease.
  - II. The entropy change will decrease.
  - III. The activation energy will decrease.
- (A) I only
  - (B) II only
  - (C) III only
  - (D) I and II only
  - (E) II and III only



Based on the information given above, what is  $\Delta H^\circ$  for the following reaction?



- (A)  $x + y + z$
- (B)  $x + y - z$
- (C)  $z + y - 2x$
- (D)  $2z + y - x$
- (E)  $2z + y - 2x$

15. For which of the following processes will  $\Delta S$  be positive?

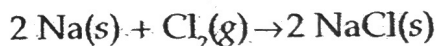
- I.  $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$
- II.  $2 H_2(g) + O_2(g) \rightarrow 2 H_2O(g)$
- III.  $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

- (A) I only
- (B) II only
- (C) I and II only
- (D) I and III only
- (E) I, II, and III

16. In which of the following reactions is entropy increasing?

- (A)  $2 SO_2(g) + O_2(g) \rightarrow 2 SO_3(g)$
- (B)  $CO(g) + H_2O(g) \rightarrow H_2(g) + CO_2(g)$
- (C)  $H_2(g) + Cl_2(g) \rightarrow 2 HCl(g)$
- (D)  $2 NO_2(g) \rightarrow 2 NO(g) + O_2(g)$
- (E)  $2 H_2S(g) + 3 O_2(g) \rightarrow 2 H_2O(g) + 2 SO_2(g)$

17. When pure sodium is placed in an atmosphere of chlorine gas, the following spontaneous reaction occurs.



Which of the following statements is true about the reaction?

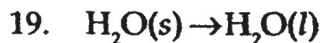
- I.  $\Delta S > 0$
- II.  $\Delta H < 0$
- III.  $\Delta G > 0$

- (A) I only
- (B) II only
- (C) I and II only
- (D) II and III only
- (E) I, II, and III



Gaseous hydrogen and fluorine combine in the reaction above to form hydrogen fluoride with an enthalpy change of  $-540$  kJ. What is the value of the heat of formation of  $\text{HF}(\text{g})$ ?

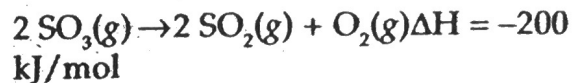
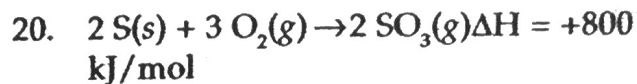
- (A)  $-1080$  kJ/mol
- (B)  $-540$  kJ/mol
- (C)  $-270$  kJ/mol
- (D)  $270$  kJ/mol
- (E)  $540$  kJ/mol



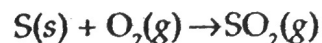
Which of the following is true of the reaction shown above at room temperature?

- I.  $\Delta G$  is greater than zero.
- II.  $\Delta H$  is greater than zero.
- III.  $\Delta S$  is greater than zero.

- (A) II only
- (B) III only
- (C) I and II only
- (D) I and III only
- (E) II and III only



Based on the information given above, what is  $\Delta H$  for the following reaction?



- (A) 300 kJ
- (B) 500 kJ
- (C) 600 kJ
- (D) 1000 kJ
- (E) 1200 kJ

2 SC  
kJ/r

2 SC  
kJ/r

Bas  
wh:

KEY

# THERMODYNAMICS

## QUESTIONS

### Multiple-Choice

NO calculator!

$$\Delta G = \Delta H - T\Delta S$$
$$(+)=(-)-(+)(-)$$

one variable is favorable & one variable is not favorable.

- (A)
- (B)
- (C)
- (E)
- (F)

#### Questions 1-4

- (A) Free energy change ( $\Delta G$ )
- (B) Entropy change ( $\Delta S$ )
- (C) Heat of vaporization
- (D) Heat of fusion
- (E) Heat capacity

A

1. If this has a negative value for a process, then the process occurs spontaneously.

B

2. This is a measure of how the disorder of a system is changing.

C

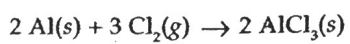
3. This is the energy given off when a substance condenses.

D

4. This is the energy taken in by a substance when it melts.

A

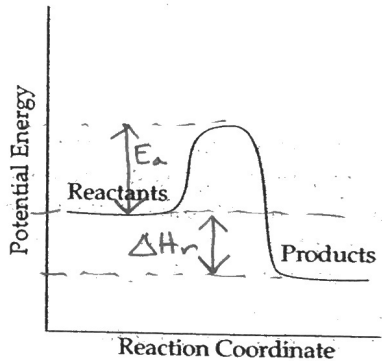
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The reaction above is not spontaneous under standard conditions but becomes spontaneous as the temperature decreases towards absolute zero. Which of the following is true at standard conditions?

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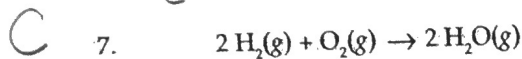
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- (D) The reaction is exothermic because the reactants are at a lower energy level than the products.
- (E) The reaction is endothermic because the reactants are at the same energy level as the products.

$$\Delta H_r^\circ = \left[ \sum E_{\text{of Bonds Broken}} \right] - \left[ \sum E_{\text{of Bonds Formed}} \right]$$

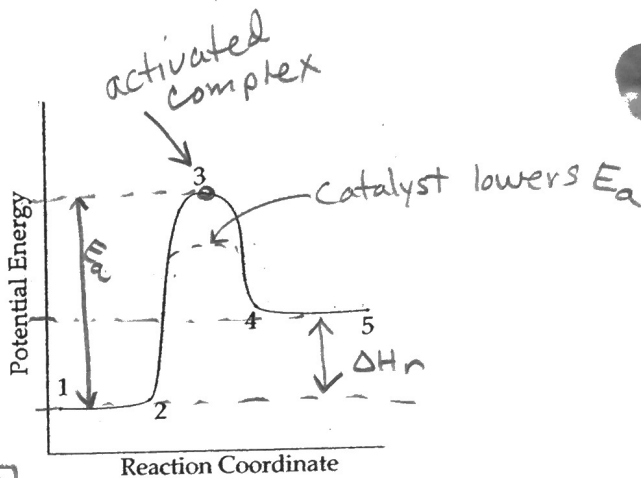


Based on the information given in the table below, what is  $\Delta H^\circ$  for the above reaction?

Bond	Average bond energy (kJ/mol)
H-H	500
O=O	500
O-H	500

Energy needed to break bonds

- (A) -2,000 kJ  
 (B) -1,500 kJ  
 (C) -500 kJ  
 (D) +1,000 kJ  
 (E) +2,000 kJ
- $[2(500) + 500] - [4(500)]$   
 $\Delta H_r = -500 \text{ kJ}$



Which point on the graph shown above corresponds to activated complex, or transition state?

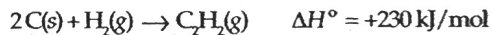
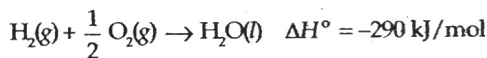
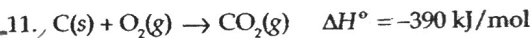
- (A) 1  
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A 8. Which of the following is true of a reaction that is spontaneous at 298 K but becomes non-spontaneous at a higher temperature?

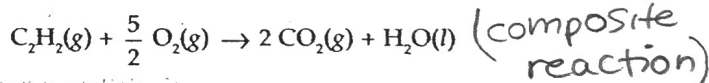
$\Delta G = \Delta H - T\Delta S$   
 $(-) = (+) - (+)(-)$

- (A)  $\Delta S^\circ$  and  $\Delta H^\circ$  are both negative.  
 (B)  $\Delta S^\circ$  and  $\Delta H^\circ$  are both positive.  
 (C)  $\Delta S^\circ$  is negative and  $\Delta H^\circ$  is positive.  
 (D)  $\Delta S^\circ$  is positive and  $\Delta H^\circ$  is negative.  
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A



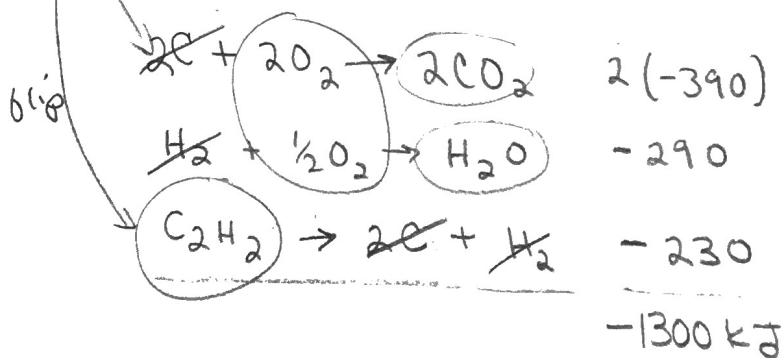
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- (A) -1300 kJ  
 (B) -1070 kJ  
 (C) -840 kJ  
 (D) -780 kJ  
 (E) -680 kJ

B 9. Which of the following will be true when a pure substance in liquid phase freezes spontaneously?

- (A)  $\Delta G$ ,  $\Delta H$ , and  $\Delta S$  are all positive.  
 (B)  $\Delta G$ ,  $\Delta H$ , and  $\Delta S$  are all negative.  
 (C)  $\Delta G$  and  $\Delta H$  are negative, but  $\Delta S$  is positive.  
 (D)  $\Delta G$  and  $\Delta S$  are negative, but  $\Delta H$  is positive.  
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12. If an endothermic reaction is spontaneous at 298 K, which of the following must be true for the reaction?

- I.  $\Delta G$  is greater than zero.
- II.  $\Delta H$  is greater than zero.
- III.  $\Delta S$  is greater than zero.

- (A) I only
- (B) II only
- (C) I and II only
- (D) II and III only
- (E) I, II, and III

$$\Delta G = \Delta H - T\Delta S$$

$$(-) = (+) - (+)(+)$$

$$\Delta G < 0 \quad \Delta H > 0 \quad \Delta S > 0$$

15. For which of the following processes will  $\Delta S$  be positive?

- I.  $\text{NaCl}(s) \rightarrow \text{Na}^+(aq) + \text{Cl}^-(aq)$
- II.  $2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(g)$
- III.  $\text{CaCO}_3(s) \rightarrow \text{CaO}(s) + \text{CO}_2(g)$

- (A) I only
- (B) II only
- (C) I and II only
- (D) I and III only
- (E) I, II, and III

13. The addition of a catalyst will have which of the following effects on a chemical reaction?

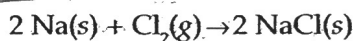
- X I. The enthalpy change will decrease.
- X II. The entropy change will decrease.
- III. The activation energy will decrease.

- (A) I only
- (B) II only
- (C) III only
- (D) I and II only
- (E) II and III only

16. In which of the following reactions is entropy increasing?

- (A)  $2 \text{SO}_2(g) + \text{O}_2(g) \rightarrow 2 \text{SO}_3(g)$
- (B)  $\text{CO}(g) + \text{H}_2\text{O}(g) \rightarrow \text{H}_2(g) + \text{CO}_2(g)$
- (C)  $\text{H}_2(g) + \text{Cl}_2(g) \rightarrow 2 \text{HCl}(g)$
- (D)  $2 \text{NO}_2(g) \rightarrow 2 \text{NO}(g) + \text{O}_2(g)$
- (E)  $2 \text{H}_2\text{S}(g) + 3 \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(g) + 2 \text{SO}_2(g)$

17. When pure sodium is placed in an atmosphere of chlorine gas, the following spontaneous reaction occurs.



Which of the following statements is true about the reaction?

- X I.  $\Delta S > 0$
- II.  $\Delta H < 0$
- X III.  $\Delta G > 0$

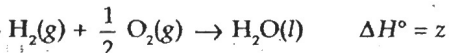
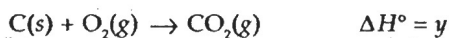
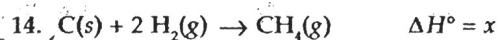
- (A) I only
- (B) II only
- (C) I and II only
- (D) II and III only
- (E) I, II, and III

$$\Delta G = \Delta H - T\Delta S$$

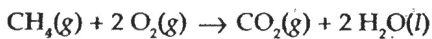
$$(-) = (+) - (+)(-)$$

$$(-) = (-) (+)$$

↓  
must be (-)



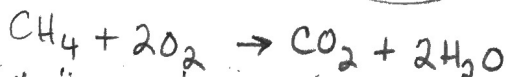
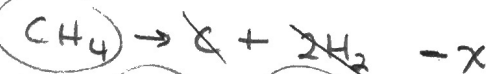
Based on the information given above, what is  $\Delta H^\circ$  for the following reaction?



- (A)  $x + y + z$
- (B)  $x + y - z$
- (C)  $z + y - 2x$
- (D)  $2z + y - x$
- (E)  $2z + y - 2x$

flip

x2



$-x + y + 2z$

$$\Delta H_r = [\Delta H_f \text{ of HF}]_2 - [0 + 0]$$

$$-540 = (x)2 \quad x = 270$$

C 18.  $H_2(g) + F_2(g) \rightarrow 2 HF(g)$   
 Gaseous hydrogen and fluorine combine in the reaction above to form hydrogen fluoride with an enthalpy change of -540 kJ. What is the value of the heat of formation of HF(g)?

- (A) -1080 kJ/mol
- (B) -540 kJ/mol
- (C) -270 kJ/mol
- (D) 270 kJ/mol
- (E) 540 kJ/mol

E 19.  $H_2O(s) \rightarrow H_2O(l)$

$\Delta S = (+)$   
 $\Delta G = (-)$   
 $\Delta H = (+)$

melting of ice

Which of the following is true of the reaction shown above at room temperature?

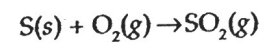
- X I.  $\Delta G$  is greater than zero.
- II.  $\Delta H$  is greater than zero.
- III.  $\Delta S$  is greater than zero.

- (A) II only
- (B) III only
- (C) I and II only
- (D) I and III only
- (E) II and III only

A 20.  $2 S(s) + 3 O_2(g) \rightarrow 2 SO_3(g) \Delta H = +800$   
 kJ/mol

$2 SO_3(g) \rightarrow 2 SO_2(g) + O_2(g) \Delta H = -200$   
 kJ/mol

Based on the information given above, what is  $\Delta H$  for the following reaction?



- (A) 300 kJ
- (B) 500 kJ
- (C) 600 kJ
- (D) 1000 kJ
- (E) 1200 kJ

