

Name: \_\_\_\_\_ Date: \_\_\_\_\_

- For which process is  $\Delta S$  negative?
  - evaporation of 1 mol of  $\text{CCl}_4(\text{l})$
  - mixing 5 mL ethanol with 25 mL water
  - compressing 1 mol Ne at constant temperature from 1.5 atm to 0.5 atm
  - raising the temperature of 100 g Cu from 275 K to 295 K
  - grinding a large crystal of KCl to powder
  
- In which reaction is  $\Delta S^\circ$  expected to be positive?
  - $\text{I}_2(\text{g}) \rightarrow \text{I}_2(\text{s})$
  - $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{s})$
  - $\text{CH}_3\text{OH}(\text{g}) + (3/2)\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
  - $2\text{O}_2(\text{g}) + 2\text{SO}(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$
  - none of these
  
- Which statement is true?
  - All real processes are irreversible.
  - A thermodynamically reversible process takes place infinitely fast.
  - In a reversible process, the state functions of the system are always much greater than those of the surroundings.
  - There is always more heat given off to the surroundings in a reversible process than in an unharnessed one.
  - All statements (a–d) are true.
  
- A mixture of hydrogen and chlorine remains unreacted until it is exposed to ultraviolet light from a burning magnesium strip. Then the following reaction occurs very rapidly:
$$\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{HCl}(\text{g}) \quad \Delta G = -45.54 \text{ kJ}$$
$$\Delta H = -44.12 \text{ kJ}$$
$$\Delta S = -4.76 \text{ J/K}$$
  - The reactants are thermodynamically more stable than the products.
  - The reaction has a small equilibrium constant.
  - The ultraviolet light raises the temperature of the system and makes the reaction more favorable.
  - The negative value for  $\Delta S$  slows down the reaction.
  - The reaction is spontaneous, but the reactants are kinetically stable.

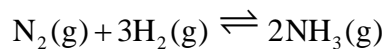
5. Which statement below is not upheld by the second law of thermodynamics?
- A) The change of entropy of the universe is always positive.
  - B) The entropy of a perfect crystal at 0 K is zero.
  - C) Machines always waste some energy.
  - D) A machine is never 100% efficient.
  - E) All of these
6. Which of the following shows a decrease in entropy?
- A) precipitation
  - B) gaseous reactants forming a liquid
  - C) a burning piece of wood
  - D) melting ice
  - E) two of these
7. A chemical reaction is most likely to be spontaneous if it is accompanied by
- A) increasing energy and increasing entropy.
  - B) lowering energy and increasing entropy.
  - C) increasing energy and decreasing entropy.
  - D) lowering energy and decreasing entropy.
  - E) None of these (a-d)
8. The second law of thermodynamics states that
- A) the entropy of a perfect crystal is zero at 0 K.
  - B) the entropy of the universe is constant.
  - C) the energy of the universe is increasing.
  - D) the entropy of the universe is increasing.
  - E) the energy of the universe is constant.
9. If the change in entropy of the surroundings for a process at 446 K and constant pressure is  $-326 \text{ J/K}$ , what is the heat flow absorbed by for the system?
- A) 326 kJ
  - B) 1.37 kJ
  - C)  $-145 \text{ kJ}$
  - D) 120 kJ
  - E) 145 kJ

10. The heat of vaporization for 1.0 mole of water at 100.°C and 1.0 atm is 40.62 kJ/mol. Calculate  $\Delta S$  for the process  $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g})$  at 100.°C.
- A) 109 J/K mol
  - B) -109 J/K mol
  - C) 406 J/K mol
  - D) -406 J/K mol
  - E) none of these
11. For a spontaneous exothermic process, which of the following must be true?
- A)  $\Delta G$  must be positive.
  - B)  $\Delta S$  must be positive.
  - C)  $\Delta S$  must be negative.
  - D) Two of the above must be true.
  - E) None of the above (a-c) must be true.
12. For a particular chemical reaction  $\Delta H = 5.5 \text{ kJ}$  and  $\Delta S = -25 \text{ J/K}$  Under what temperature condition is the reaction spontaneous?
- A) When  $T < -220 \text{ K}$ .
  - B) When  $T < 220 \text{ K}$ .
  - C) The reaction is spontaneous at all temperatures.
  - D) The reaction is not spontaneous at any temperature.
  - E) When  $T > 220 \text{ K}$ .
13. In which case must a reaction be spontaneous at all temperatures?
- A)  $\Delta H$  is positive,  $\Delta S$  is positive.
  - B)  $\Delta H = 0$ ,  $\Delta S$  is negative.
  - C)  $\Delta S = 0$ ,  $\Delta H$  is positive.
  - D)  $\Delta H$  is negative,  $\Delta S$  is positive.
  - E) none of these
14. Consider the dissociation of hydrogen:
- $$\text{H}_2(\text{g}) \rightleftharpoons 2\text{H}(\text{g})$$
- One would expect that this reaction:
- A) will be spontaneous at any temperature.
  - B) will be spontaneous at high temperatures.
  - C) will be spontaneous at low temperatures.
  - D) will not be spontaneous at any temperature.
  - E) will never happen.

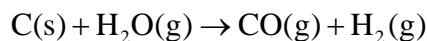
15. For the process  $\text{CHCl}_3(\text{s}) \rightarrow \text{CHCl}_3(\text{l})$ ,  $\Delta H^\circ = 9.21 \text{ kJ/mol}$  and  $\Delta S^\circ = 43.9 \text{ J/mol}\cdot\text{K}$ . What is the melting point of chloroform?
- A)  $-63^\circ\text{C}$
  - B)  $210.^\circ\text{C}$
  - C)  $131^\circ\text{C}$
  - D)  $63^\circ\text{C}$
  - E)  $-131$
16. For the process  $\text{S}_8(\text{rhombic}) \rightarrow \text{S}_8(\text{monoclinic})$  at  $110^\circ\text{C}$ ,  $\Delta H = 3.21 \text{ kJ/mol}$  and  $\Delta S = 8.70 \text{ J/K}\cdot\text{mol}$  (at  $110^\circ\text{C}$ ). Which of the following is correct?
- A) This reaction is spontaneous at  $110^\circ\text{C}$  ( $\text{S}_8(\text{monoclinic})$  is stable).
  - B) This reaction is spontaneous at  $110^\circ\text{C}$  ( $\text{S}_8(\text{rhombic})$  is stable).
  - C) This reaction is nonspontaneous at  $110^\circ\text{C}$  ( $\text{S}_8(\text{rhombic})$  is stable).
  - D) This reaction is nonspontaneous at  $110^\circ\text{C}$  ( $\text{S}_8(\text{monoclinic})$  is stable).
  - E) Need more data.
17. At constant pressure, the following reaction  $2\text{NO}_2(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g})$  is exothermic. The reaction (as written) is
- A) always spontaneous.
  - B) spontaneous at low temperatures, but not high temperatures.
  - C) spontaneous at high temperatures, but not low temperatures.
  - D) never spontaneous.
  - E) Cannot tell.
18. Given that  $\Delta H_{\text{vap}}$  is  $67.4 \text{ kJ/mol}$ , and the boiling point is  $83.4^\circ\text{C}$ , 1 atm, if one mole of this substance is vaporized at 1 atm, calculate  $\Delta G$ .
- A)  $-189 \text{ J/K mol}$
  - B)  $189 \text{ J/K mol}$
  - C)  $808 \text{ J/K mol}$
  - D)  $-808 \text{ J/K mol}$
  - E) 0
19. Given that  $\Delta H_{\text{vap}}$  is  $67.5 \text{ kJ/mol}$ , and the boiling point is  $83.4^\circ\text{C}$ , 1 atm, if one mole of this substance is vaporized at 1 atm, calculate  $\Delta S$ .
- A)  $-189 \text{ J/K mol}$
  - B)  $189 \text{ J/K mol}$
  - C)  $809 \text{ J/K mol}$
  - D)  $-809 \text{ J/K mol}$
  - E) 0

20.  $\Delta H^\circ$  is zero for a chemical reaction at constant temperature.
21. For a certain process at 355 K,  $\Delta G = -12.0$  kJ and  $\Delta H = -9.2$  kJ. Therefore,  $\Delta S$  for the process is
- A) 0
  - B) 7.9 J/K mol
  - C) -7.9 J/K mol
  - D) -25.9 J/K mol
  - E) 25.9 J/K mol
22. Consider the following processes:
- I. Condensation of a liquid..
  - II. Increasing the volume of 1.0 mol of an ideal gas at constant temperature..
  - III. Dissolving an ionic solid in water..
  - IV. Heating 1.0 mol of an ideal gas at constant volume..
- For how many of these is  $\Delta S$  positive?
- A) 0
  - B) 1
  - C) 2
  - D) 3
  - E) 4
23. For the reaction  $\text{Cl}_2\text{O}(\text{g}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow 2\text{ClO}_2(\text{g})$ ,
- $\Delta H^\circ = 126.4$  kJ/mol and  $\Delta S^\circ = -74.9$  J/K mol. At 365°C,  $\Delta G^\circ$  equals
- A) 153.7 kJ/mol
  - B) 47.9 kJ/mol
  - C) 174.2 kJ/mol
  - D) 78.6 kJ/mol
  - E) 155.5 kJ/mol

24. Given that  $\Delta G_f^\circ$  for  $\text{NH}_3 = -16.669 \text{ kJ/mol}$ , calculate the equilibrium constant for the following reaction at 298 K:



- A)  $6.98\text{e}5$   
B)  $8.35\text{e}2$   
C) 1.01  
D)  $4.55\text{e}69$   
E)  $5.83\text{e}8$
25. At 699 K,  $\Delta G^\circ = -23.25 \text{ kJ}$  for the reaction  $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$ . Calculate  $\Delta G$  for this reaction if the reagents are both supplied at 10.0 atm pressure and the product is at 1.41 atm pressure.
- A)  $-22.8 \text{ kJ}$   
B)  $22.8 \text{ kJ}$   
C)  $0.5 \text{ kJ}$   
D)  $-46.0 \text{ kJ}$   
E)  $46.0 \text{ kJ}$
26. Water gas, a commercial fuel, is made by the reaction of hot coke carbon with steam.



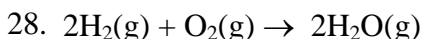
When equilibrium is established at  $848^\circ\text{C}$  the concentrations of  $\text{CO}$ ,  $\text{H}_2$ , and  $\text{H}_2\text{O}$  are  $4.00 \times 10^{-2}$ ,  $4.00 \times 10^{-2}$ , and  $1.00 \times 10^{-2}$  mole/liter, respectively. Calculate the value of  $\Delta G^\circ$  for this reaction at  $848^\circ\text{C}$ .

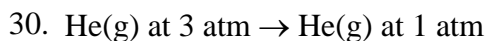
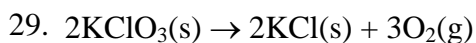
- A)  $12.9 \text{ kJ}$   
B)  $-12.92 \text{ kJ}$   
C)  $55.84 \text{ kJ}$   
D)  $17.08 \text{ kJ}$   
E) none of these

Use the following to answer questions 27-30:

Would you predict an increase or decrease in entropy for each of the following?

27. The freezing of water





31. For the reaction  $2\text{HF}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{F}_2(\text{g})$ ,  $\Delta G^\circ = 38.3$  kJ, at 1000 K. If, at this temperature, 5.00 moles of  $\text{HF}(\text{g})$ , 0.500 moles of  $\text{H}_2(\text{g})$ , and 0.75 moles of  $\text{F}_2(\text{g})$  are mixed in a 1.00-L container:

- A) Some HF will decompose (to yield  $\text{H}_2$  and  $\text{F}_2$ ).
- B) The system is at equilibrium.
- C) Some HF will be formed (from  $\text{H}_2$  and  $\text{F}_2$ ).
- D) Not enough data are given to answer this question.
- E) None of these (a-d).

32. Which of the following is true?

- A) By *spontaneous* we mean that the reaction or process will always proceed to the right (as written) even if very slowly. Increasing the temperature may speed up the reaction, but it does not affect the spontaneity of the reaction.
- B) By *spontaneous* we mean that the reaction or process will always proceed to the left (as written) even if very slowly. Increasing the temperature may speed up the reaction, but it does not affect the spontaneity of the reaction.
- C) By *spontaneous* we mean that the reaction or process will always proceed to the left (as written) even if very slowly. Increasing the temperature may speed up the reaction and it generally affects the spontaneity of the reaction.
- D) By *spontaneous* we mean that the reaction or process will always proceed to the right (as written) even if very slowly. Increasing the temperature may speed up the reaction, and it generally affects the spontaneity of the reaction.
- E) None of the above is true.

## Answer Key

1. C
2. E
3. A
4. E
5. B
6. A
7. B
8. D
9. E
10. A
11. E
12. D
13. D
14. B
15. A
16. A
17. B
18. E
19. B
20. False
21. B
22. D
23. C
24. A
25. D
26. D
27. decrease in entropy
28. decrease in entropy
29. increase in entropy
30. increase in entropy
31. C
32. D