Class Worksheet 15 Key

1. **Which of the following processes are spontaneous and which are nonspontaneous:**

   (a) The melting of ice cubes at –5°C and 1 atm pressure;

   Non Spontaneous

   (b) Dissolution of sugar in a cup of hot coffee;

   Spontaneous

   (c) The reaction of nitrogen atoms to form N_2 molecules at 25°C and 1 atm;

   Spontaneous

   (d) Alignment of iron filings in a magnetic field;

   Spontaneous

   (e) Formation of CH_4 and O_2 molecules from CO_2 and H_2O at room temperature and 1 atm pressure?

   Non Spontaneous

2. **(a) Give two examples of endothermic processes that are spontaneous.**

   Ammonium nitrate dissolving in water; Naphthalene subliming at room temperature.

   (b) Give an example of a process that is spontaneous at one temperature but nonspontaneous at a different temperature.

   Melting of a solid.

3. **Consider the vaporization of liquid water to steam at a pressure of 1atm.**

   (a) Is the process endothermic or exothermic?

   endothermic

   (b) In what temperature range is it a spontaneous process?

   At or above 100°C

   (c) In what temperature range is it a nonspontaneous process?

   Below 100°C

   (d) At what temperature are the two phases in equilibrium?

   At 100°C

4. **(a) What is special about a reversible reaction?**

   Forward and reverse changes occur by same path; there is only one reversible pathway for a set of conditions.

   (b) Suppose a reversible process is reversed, restoring the system to its original state. What can be said about the surroundings after the process is reversed?

   There is no net change in the surroundings

   (c) Under what circumstances will the vaporization of water to steam be a reversible process?

   The vaporization of water to steam is reversible if it occurs at the boiling point for a specific external pressure.

5. For the isothermal expansion of a gas into a vacuum, $\Delta E = 0$, $q = 0$, and $w = 0$.

(a) Is this a spontaneous process?

Yes

(b) Explain why no work is done by the system during this process.

$W = -P_{ext}\Delta V$; $P = 0$, $w = 0$

(c) In thermodynamics, what is the "driving force" for the expansion of the gas?

Increase in disorder.

6. (a) What is entropy?

The disorder or randomness of a system.

(b) During a chemical process the system becomes more disordered. What is the sign of ΔS for the process?

Positive

(c) Does ΔS for a process depend on the path taken from the initial to the final state of the system? Explain.

No, ΔS is a state function, so it is independent of path.

6. In a chemical reaction two moles of gaseous reactants are converted to three moles of gaseous products. What do you expect for the sign of ΔS?

ΔS is positive

7. How does the entropy of the system change when the following occur:

(a) a solid melts;

Increase

(b) a liquid vaporizes;

Increase

(c) a solid dissolves in water;

Increase

(d) a gas liquefies?

Decrease

8. The normal boiling point of $Br_2(l)$ is 58.8°C and its enthalpy of vaporization is $\Delta H_{vap} = 29.6$kJ/mol.

(a) When $Br_2(l)$ boils at its normal boiling point, does its entropy increase or decrease?

Increase

(b) Calculate the value of ΔS when 1.00 mol of $Br_2(l)$ is vaporized at 58.8°C.

98.0J/K

9. For each of the following pairs, choose the substance with the higher entropy per mole at a given temperature:

(a) Ar(l) or Ar(g);

Ar(g)

(b) He(g) at 3 atm pressure, or He(g) at 1.5atm pressure;

1.5 atm

(c) 1 mole of Ne(g) in 15.0L or 1 mole of Ne(g) in 1.50L;

15.0L

(d) $CO_2(g)$ or $CO_2(aq)$

$CO_2(g)$

10. Predict the sign of the entropy change of the system for each of the following reactions:

(a) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

negative

(b) $Ba(OH)_2(s) \rightarrow BaO(s) + H_2O(g)$

positive

(c) $CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$

negative

(d) $FeCl_2(s) + H_2(g) \rightarrow Fe(s) + 2HCl(g)$

Positive

11. Using S° values, calculate ΔS° values for the following reactions:

(a) $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$

-120.5 J/K

(b) $N_2O_4(g) \rightarrow 2NO_2(g)$

+176.6 J/K

(c) $Be(OH)_2(s) \rightarrow BeO(s) + H_2O(g)$

+152.39 J/K

(d) $2CH_3OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$

+92.3 J/K

12. For a certain reaction, $\Delta H° = -35.4$ kJ and $\Delta S° = -85.5$ j/K.

(a) Is the reaction exothermic or endothermic?

Exothermic

(b) Does the reaction lead to an increase or decrease in the disorder of the system?

Decrease

(c) Calculate $\Delta G°$ for the reaction at 298K.

-9.9kJ

(d) Is the reaction spontaneous at 298K?

Spontaneous

13. Using thermodynamic tables, calculate $\Delta H°$, $\Delta S°$, and $\Delta G°$ at 298K for each of the following reactions. In each case show that $\Delta G° = \Delta H° - T\Delta S°$.

(a) $H_2(g) + F_2(g) \rightarrow 2HF(g)$

$\Delta G° = -541.40$kJ

(b) $C(s, \text{graphite}) + 2Cl_2(g) \rightarrow CCl_4(g)$

$\Delta G° = -64.0$ kJ

(c) $2PCl_3(g) + O_2(g) \rightarrow 2POCl_3(g)$

$\Delta G° = -465.8$ kJ

(d) $2CH_3OH(g) + H_2(g) \rightarrow C_2H_6(g) + 2H_2O(g)$

$\Delta G° = 166.2$ kJ

14. Using thermodynamic tables, calculate $\Delta G°$. For the following reactions. Indicate whether each reaction is spontaneous.

(a) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

-140 kJ

(b) $NO_2(g) + N_2O(g) \rightarrow 3NO(g)$

+104.7 kJ

(c) $6Cl_2(g) + 2Fe_2O_3(s) \rightarrow 4FeCl_3(s) + 3O_2(g)$

+146 kJ

(d) $SO_2(g) + 2H_2(g) \rightarrow S(s) + 2H_2O(g)$

-156.7 kJ

15. A particular reaction is spontaneous at 450K. The reaction is endothermic by 34.5kJ. What can you conclude about the sign and magnitude of ΔS for this reaction?

$\Delta S > +76.7$ J/K

16. For a particular reaction, ΔH = -32kJ and ΔS = -98J/K. Assume that ΔH and ΔS do not vary with temperature.

(a) At what temperature will ΔG = 0?

330K

(b) If T is increased from that in part (a), will the reaction be spontaneous or nonspontaneous?

Spontaneous

17. For the reaction between nitrogen dioxide and nitrous oxide to form nitric oxide, us thermodynamic data to predict how ΔG° varies with increasing temperature.

ΔG° becomes more negative with increasing temperature.

18. Use thermodynamic data to calculate K_p at 298K for each of the following reaction:

(a) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

870

(b) $C_2H_5OH(g) \rightleftharpoons C_2H_4(g) + H_2O(g)$

0.04

(c) $3C_2H_2(g) \rightleftharpoons C_6H_6(g)$

2×10^{87}

19. By using thermodynamic data, calculate the equilibrium pressure of CO_2 in the decarboxylation of barium carbonate to form barium oxide and carbon dioxide at:

(a) 298K;

6.0×10^{-39} atm

(b) 1100K.

1.6×10^{-4} atm

20. The value of Ka for nitrous acid, HNO_2, at 25°C is 4.5×10^{-4}.

(a) Write the equilibrium that corresponds to Ka.

$NHO_2 \rightleftharpoons H^+ + NO_2^-$

(b) Use the value of Ka to calculate ΔG° for the dissociation of nitrous acid.

19.1 kJ

(c) What is the value of ΔG at equilibrium?

zero

(d) What is the value of ΔG when $[H^+] = 0.05M$, $[NO_2^-] = 6.0 \times 10^{-4}M$, and $[HNO_2] = 0.20M$?

-2.72 kJ