Name_____ Date_____ Period_____

Topic: Kinetics & Equilibrium

Outline

1. **Collision theory states that a reaction is most likely to occur if reactant particles collide with the proper energy and orientation.**
   - ✓ This is sometimes called an "effective collision."

2. **The rate of a chemical reaction depends on temperature, concentration, nature of the reactants, surface area and the presence of a catalyst.**

3. **Energy absorbed or released by a chemical reaction can be represented by a potential energy diagram.**

4. **The amount of energy released or absorbed during a chemical reaction is the heat of reaction.**
   - ✓ Heat of reaction equals the PE of the products – PE of reactants.
   - ✓ Positive heat of reaction implies an endothermic reaction.
   - ✓ Negative heat of reaction implies an exothermic reaction.

5. **A catalyst provides an alternative pathway for a chemical reaction. The catalyst lowers reaction the activation energy required to start up the reaction.**
   - ✓ Adding a catalyst increases the rate of the forward and reverse reactions equally, so there is no shift in equilibrium.
   - ✓ Know how the use of a catalyst affects the PE diagram.

6. **Entropy is a measure of the randomness or disorder in a system. A system with greater disorder has greater entropy.**

7. **Systems in nature tend to undergo changes towards lower energy (tend to be exothermic) and higher entropy.**

8. **At equilibrium the rate of the forward reaction equals the rate of the reverse reaction.**
   - ✓ This state can only be achieved IF the system (container) is closed and the conditions of Temp and Pressure are held steady.

9. **The measurable quantities of reactants and products remain constant at equilibrium.**
   - ✓ This does NOT mean the amounts of products and reactants is the same as each other, but rather that the amounts are no longer changing.

10. **Types of equilibrium include chemical, phase and solution.**
    - ✓ Solutions that are saturated represent an equilibrium between the processes of dissolving and precipitating.
    - ✓ An example of a phase equilibrium would be the simultaneous melting and freezing of water if the system is held at $0^{o}C$.

11. **LeChatelier's principle can be used to predict the effect of stress on a system in equilibrium.**
    - ✓ Stresses include a change in pressure, volume, concentration, and temperature.
    - ✓ You should be able to predict if a "shift left" or a "shift right" occurs due to a particular stress.

Rate of Reaction & Equilibrium – questions from previous Regents exams

1. Given the equation representing a phase change at equilibrium:

$$C_2H_5OH(\ell) \rightleftharpoons C_2H_5OH(g)$$

Which statement is true?
(1) The forward process proceeds faster than the reverse process.
(2) The reverse process proceeds faster than the forward process.
(3) The forward and reverse processes proceed at the same rate.
(4) The forward and reverse processes both stop.

2. A 5.0-gram sample of zinc and a 50.-milliliter sample of hydrochloric acid are used in a chemical reaction. Which combination of these samples has the fastest reaction rate?
(1) a zinc strip and 1.0 M HCl(aq)
(2) a zinc strip and 3.0 M HCl(aq)
(3) zinc powder and 1.0 M HCl(aq)
(4) zinc powder and 3.0 M HCl(aq)

3. For a given reaction, adding a catalyst increases the rate of the reaction by
(1) providing an alternate reaction pathway that has a higher activation energy
(2) providing an alternate reaction pathway that has a lower activation energy
(3) using the same reaction pathway and increasing the activation energy
(4) using the same reaction pathway and decreasing the activation energy

4. Given the equation representing a reaction at equilibrium:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \text{energy}$$

Which change causes the equilibrium to shift to the right?
(1) decreasing the concentration of $H_2(g)$
(2) decreasing the pressure
(3) increasing the concentration of $N_2(g)$
(4) increasing the temperature

5. Given the equation representing a system at equilibrium:

$$H_2O(s) \rightleftharpoons H_2O(\ell)$$

At which temperature does this equilibrium exist at 101.3 kilopascals?
(1) 0 K (3) 32 K
(2) 0°C (4) 273°C

6. Which statement must be true when solution equilibrium occurs?
(1) The solution is at STP.
(2) The solution is supersaturated.
(3) The concentration of the solution remains constant.
(4) The masses of the dissolved solute and the undissolved solute are equal.

7. Which statement must be true for any chemical reaction at equilibrium?
(1) The concentration of the products is greater than the concentration of the reactants.
(2) The concentration of the products is less than the concentration of the reactants.
(3) The concentration of the products and the concentration of the reactants are equal.
(4) The concentration of the products and the concentration of the reactants are constant.

8. Given the balanced equation representing a reaction at 101.3 kPa and 298 K:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + 91.8\ \text{kJ}$$

Which statement is true about this reaction?
(1) It is exothermic and $\otimes H$ equals –91.8 kJ.
(2) It is exothermic and $\otimes H$ equals +91.8 kJ.
(3) It is endothermic and $\otimes H$ equals –91.8 kJ.
(4) It is endothermic and $\otimes H$ equals +91.8 kJ.

9. Which balanced equation represents a phase equilibrium?

(1) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
(2) $2NO_2(g) \rightleftharpoons N_2O_4(g)$
(3) $Cl_2(g) \rightleftharpoons Cl_2(\ell)$
(4) $3O_2(g) \rightleftharpoons 2O_3(g)$

10. Given the system at equilibrium:

$$2POCl_3(g) + \text{energy} \rightleftharpoons 2PCl_3(g) + O_2(g)$$

Which changes occur when $O_2(g)$ is added to this system?

(1) The equilibrium shifts to the right and the concentration of $PCl_3(g)$ increases.
(2) The equilibrium shifts to the right and the concentration of $PCl_3(g)$ decreases.
(3) The equilibrium shifts to the left and the concentration of $PCl_3(g)$ increases.
(4) The equilibrium shifts to the left and the concentration of $PCl_3(g)$ decreases.

11. In terms of energy and entropy, systems in nature tend to undergo changes toward
(1) higher energy and higher entropy
(2) higher energy and lower entropy
(3) lower energy and higher entropy
(4) lower energy and lower entropy

12. Explain, in terms of collision theory, why the rate of a chemical reaction increases with an increase in temperature. [1]

Base your answers to questions 13 through 15 on the information below.

A beaker contains 100.0 milliliters of a dilute aqueous solution of ethanoic acid at equilibrium. The equation below represents this system.

$$HC_2H_3O_2(aq) \rightleftharpoons H^+(aq) + C_2H_3O_2^-(aq)$$

13. Compare the rate of the forward reaction to the rate of the reverse reaction for this system. [1]

14. Describe what happens to the concentration of $H^+(aq)$ when 10 drops of concentrated $HC_2H_3O_2(aq)$ are added to this system. [1]

15. Draw a structural formula for ethanoic acid. [1]

Base your answer to question 16 on the information below.

"Hand Blasters" is a toy that consists of a set of two ceramic balls, each coated with a mixture of sulfur and potassium chlorate, $KClO_3$. When the two balls are struck together, a loud popping noise is produced as sulfur and potassium chlorate react with each other.

16. Identify *one* source of the activation energy for this reaction. [1]

Base your answers to questions 17 through 18 on the reaction represented by the balanced equation below.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell) + 571.6\ kJ$$

17. Identify the information in this equation that indicates the reaction is exothermic. [1]

18. Explain why the entropy of the system *decreases* as the reaction proceeds. [1]

Base your answers to question 19 on the information below.

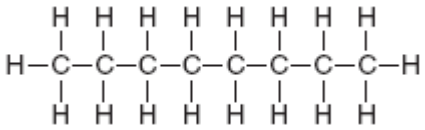
The equilibrium equation below is related to the manufacture of a bleaching solution. In this equation, $Cl^-(aq)$ means that chloride ions are surrounded by water molecules.

$$Cl_2(g) + 2OH^-(aq) \rightleftharpoons OCl^-(aq) + Cl^-(aq) + H_2O(\ell)$$

19. Explain, in terms of collision theory, why increasing the concentration of $Cl_2(g)$ increases the concentration of $OCl^-(aq)$ in this equilibrium system. [1]

Base your answers to questions 20 and 21 on the information below.

A gasoline engine burns gasoline in the presence of excess oxygen to form carbon dioxide and water. The main components of gasoline are isomers of octane. A structural formula of octane is shown below.



One isomer of octane is 2,2,4-trimethylpentane.

20. In the space *in your answer booklet*, draw a structural formula for 2,2,4-trimethylpentane. [1]

21. Explain, in terms of the arrangement of particles, why the entropy of gasoline vapor is greater than the entropy of liquid gasoline. [1]