Raffles Institution Raffles Programme
Year Four Chemistry

Name: _____ ( ) Class: _____ Date: _____

2022 FE Revision – Chemical Energetics, Reaction Kinetics, Equilibrium ANSWERS

Chemical Energetics

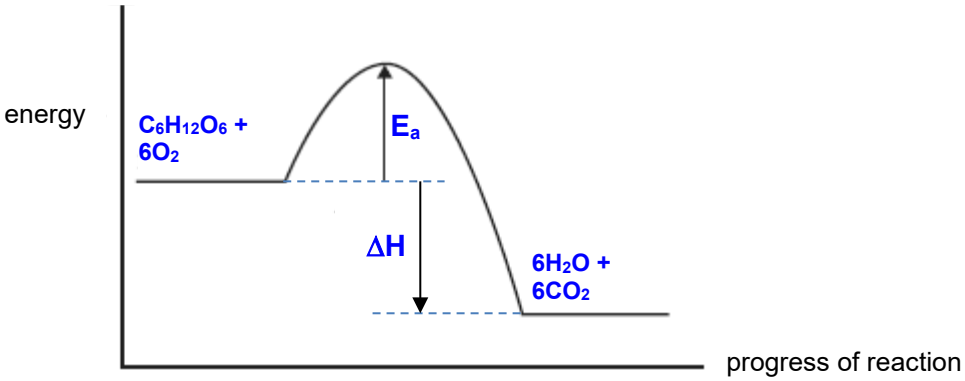
	Exothermic Process	Endothermic Process
1	heat is released	heat is absorbed
2	enthalpy change (ΔH) value is **negative**	enthalpy change (ΔH) value is **positive**
3	the container/surroundings feels **hot**	the container/surroundings feels **cold**
4	bond making	bond breaking
5	energy content of products < energy content of reactants	energy content of products > energy content of reactants
6	e.g. combustion, **neutralization**, respiration, freezing	e.g. photosynthesis, thermal decomposition, melting

Practice Question

1 **(a)** $C_6H_{12}O_6 + \mathbf{6}O_2(g) \rightarrow \mathbf{6}CO_2(g) + \mathbf{6}H_2O(l)$

(b) **(i)** **During respiration, energy is absorbed to break the bonds in $C_6H_{12}O_6$ and the O=O bonds of oxygen.**
Energy is released when the C=O bonds of carbon dioxide and the O-H bonds of water are formed.
The reaction is exothermic because the amount of heat released is greater than the amount of heat absorbed.

(ii)



(iii) ΔH = **energy absorbed for bond breaking** – **energy released by bond making**

= **[+9546 + 6(496)]** – **[6(2x740) + 6(2x460)]**

= **–1878 kJ**

Reaction Kinetics

1 Every reaction has an activation energy (E_a), which is the minimum energy that colliding particles must possess in order to result in a reaction. The smaller the E_a the **faster** the reaction.

2 Factors that increase the speed of a reaction:

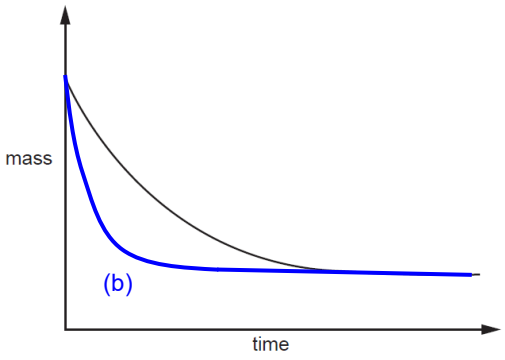
factors	*collision theory explanation*
increase **temperature**	this increases the number of reactant particles having the E_a, causing particles to collide harder and more frequently
increase pressure (only for gases)	this causes particles to be closer thus more frequent effective collisions between them
increase **concentration**	this causes more particles per unit volume thus more frequent effective collisions between reactant particles
increase surface area (by decreasing particle size)	this causes more frequent effective collisions between reactant particles
presence of a catalyst	• this provides an **alternative** pathway with a **lower** E_a, resulting in more reactant particles having the E_a thus more frequent effective collisions between them

4 Increasing the temperature, pressure, surface area or catalyst would increase the slope (gradient) of the graph but the amount of product would finally still be the **same** as that of the control experiment. However, increasing concentration MAY result in increased speed *as well as* increased **amount** of products, since the initial amount of reactant is also increased when its concentration is increased.

Practice Questions

1 (a) **$CuCO_3$ (s) + 2HCl (aq) → $CuCl_2$ (aq) + H_2O (l) + CO_2 (g)**

(b)



(c) **Dilute HCl has less particles (or H^+) per unit volume than concentrated HCl. As such the frequency of effective collisions between acid particles and $CuCO_3$ particles (or CO_3^{2-}) is decreased, resulting in a slower reaction**

2 **(a)** **increase temperature of HCl, increase concentration of HCl, use finer powder of MnO_2, add a catalyst**

(b) **This is due to the decrease in the HCl concentration as the reaction proceeds.**

(c) **When one of the reactants is totally used up the reaction stops.**

Equilibrium

2 When the speed of the forward reaction is **equal** to the speed of the backward reaction, a state of equilibrium is attained. Thus an equilibrium mixture always contains both the **reactants** and the **products**.

3 The reaction does not stop when equilibrium is attained. It's just that the amount of reactants and the amount of products are **constant**.

5 Le Chatelier's Principle states that **if a system at equilibrium is subjected to a disturbance, the equilibrium's response is to counteract the disturbance to minimize its effect.**

6 We can use Le Chatelier's Principle to manipulate the yield of a chemical process.

Haber process: $N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$ $\quad \Delta H$ = negative

(a) Disturbance = Remove some NH_3 from the equilibrium mixture.
System's response = favour the forward reaction to replace the lost NH_3, thus position of equilibrum shifts right, increasing yield of NH_3.

(b) Disturbance = Increase temperature of the equilibrium mixture.
System's response = favour the backward reaction to remove the excess heat, thus position of equilibrium shifts **left**, decreasing yield of NH_3.

(c) Disturbance = Increase pressure of the equilibrium mixture.
System's response = favour the forward reaction to decrease the total number of molecules to relieve the pressure, thus position of equilibrium shifts **right**, increasing yield of NH_3.

7 The Haber process is carried out at a high pressure of **200** atm and a moderate temperature of **450** ^oC, using **iron** (a transition metal) as a catalyst.

Although high pressure would increase yield, operating at pressures above 200 atm is costly and dangerous (due to high risk of accidents). Although low temperature would increase yield, operating at temperatures below 450^oC would result in too **slow** a reaction.

Practice Questions

1 Consider the equilibrium mixture:

$$CrO_4^{2-}\,(aq) + 2H^+\,(aq) \rightleftharpoons Cr_2O_7^{2-}\,(aq) + H_2O\,(l)$$

Would each of the following steps shift position of equilibrium to the right or to the left?

(a) Add a few drops of an acid **position of equilibrium shifts right**

(b) Add water **position of equilibrium shifts left**

(c) Add a few drops of an alkali **position of equilibrium shifts left**

(d) Evaporate away some water **position of equilibrium shifts right**

2 How would a decrease in pressure affect the yield of the product in each of the following equilibria?

(a) $N_2O_4\ (g) \rightleftharpoons 2NO_2\ (g)$ **increase yield of product**

(b) $H_2\ (g) + I_2\ (g) \rightleftharpoons 2HI\ (g)$ **no change in yield of product**

(c) $CO\ (g) + 2H_2\ (g) \rightleftharpoons CH_3OH\ (g)$ **decrease yield of product**

3 Carbonated beverages are made by bubbling carbon dioxide gas into aqueous solution under pressurized condition. The chemical equation depicting this process is shown below:

$$2H_2O\ (l) + CO_2\ (g) \rightleftharpoons H_3O^+\ (aq) + HCO_3^-\ (aq)$$

By using Le Châtelier's Principle, predict:

(a) how the concentration of H_3O^+ (aq) changes when a can of carbonated beverage is opened and then quickly closed to be air-tight again. Explain.

When the can is opened, CO_2 escapes, so the system counteracts this by favouring the backward reaction to replace the lost CO_2, thus position of equilibrium shifts left and H_3O^+ concentration decreases. [2]

(b) how the concentration of CO_2 (g) changes when the pressure in the container is increased at constant temperature. Explain.

When pressure is increased, the system counteracts this by favouring the forward reaction so as to decrease the total number of gas (CO_2) particles, thus position of equilibrium shifts right and concentration of CO_2 decreases. [2]

More Practice Questions

1	2	3	4	5	6
C	B	D	C	C	C

7 Ethanol is made from hydration of ethene.

$$C_2H_4\ (g) + H_2O\ (g) \rightleftharpoons CH_3CH_2OH\ (g)$$

How would you alter the pressure to increase the yield of ethanol? Explain your reasoning.

Pressure should be increased. When pressure is increased, the system counteracts this increase by favouring the forward reaction, to decrease the total number of particles and relieve the pressure. Thus, position of equilibrium shifts right, and yield of ethanol is increased.

8 The following is an important step in the manufacture of sulfuric acid.

$$2SO_2\ (g) + O_2\ (g) \rightleftharpoons 2SO_3\ (g) \qquad \Delta H = -197\ kJ\ mol^{-1}$$

(a) How would the equilibrium react to a decrease in temperature? Give your reasoning.

When the temperature is decreased, the system counteracts this loss of heat by favouring the forward exothermic reaction to replace the heat lost. Thus, the position of equilibrium shifts right.

(b) How would adding a catalyst affect the yield of SO_3?

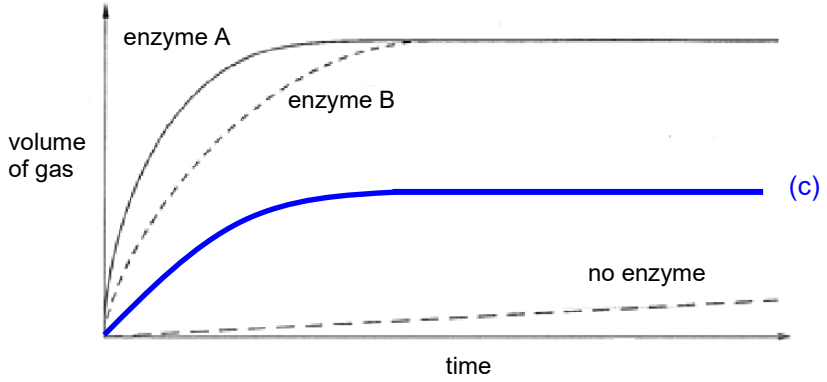
No, a catalyst does not affect the position of equilibrium or the yield

9(a) **Collect the gas produced in a gas syringe. Read the volume of the gas collected at fixed time intervals.**

(b)(i) **Both enzymes increase the rate of the reaction, but Enzyme A increases the rate more than Enzyme B.**

(ii) **The lower the activation energy the faster the reaction.**
An enzyme provides an alternative pathway with a lower activation energy thus the enzyme speeds up the reaction.

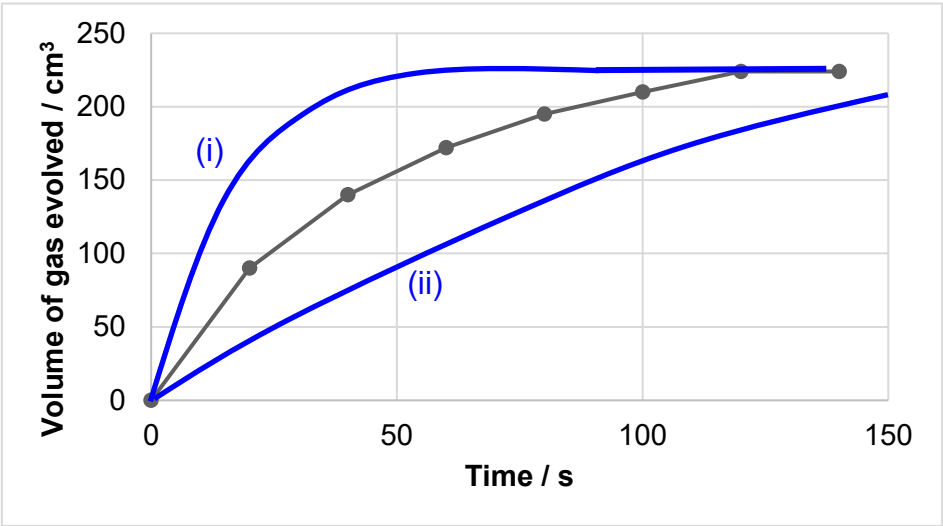
(c)



10 **(a)** **This is because the reaction has stopped and no more gas is produced.**

(b)(i) **At higher temperature more reactant (acid and magnesium) particles have energy greater or equal to E_a (activation energy). Thus particles collide harder and more frequently resulting in more frequent effective collisions and a faster reaction.**

(ii) **Adding water results in a more dilute acid, thus there is less acid particles per unit volume, thus less frequent effective collisions between acid and magnesium particles occur, resulting in slower reaction.**



(c) **The mass of magnesium used is small (0.24 g) thus the change in mass per unit time is very small and the error of measurement is large (especially when ordinary electronic balance is used)**