

# TOPIC TEST 1 - REACTION RATES AND EQUILIBRIUM

NAME: \_\_\_\_\_

## PART 1: Multiple Choice

Answer ALL questions in Part 1 on the Separate Multiple Choice Answer Sheet provided. Each question in this part is worth 1 mark. This part carries 20 marks out of 50.

1. Consider the following equilibrium equation and expression for a 1.0 mol L<sup>-1</sup> solution of oxalic acid:



$$K = \frac{[\text{H}^+][\text{HC}_2\text{O}_4^{1-}]}{[\text{H}_2\text{C}_2\text{O}_4]} = 6.4 \times 10^{-5} \text{ at } 25^\circ\text{C}$$

*reactants ↑*

At equilibrium at 25°C, which of the following species will be present in the greatest concentration?

- a) H<sup>+</sup>(aq) \*
- b) HC<sub>2</sub>O<sub>4</sub><sup>1-</sup>(aq) \*
- c) H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>(aq) \*
- d) H<sup>+</sup>(aq), HC<sub>2</sub>O<sub>4</sub><sup>1-</sup>(aq) and H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>(aq) are present in equal concentrations.

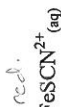
2. In which of the following reactions will there be an increase in the proportion of products if the volume of the reacting system is reduced?

- a) H<sub>2</sub>(g) + I<sub>2</sub>(g) <=> 2 HI(g) \*
- b) 2 NO<sub>2</sub>(g) <=> N<sub>2</sub>O<sub>4</sub>(g) ✓
- c) 2 SO<sub>3</sub>(g) <=> 2 SO<sub>2</sub>(g) + O<sub>2</sub>(g) \*
- d) H<sub>2</sub>O(g) + C(s) <=> H<sub>2</sub>(g) + CO(g) \*

3. Which of the following changes would increase the molar concentration of the products in any chemical reaction at equilibrium?

- a) Decrease the pressure. \*
- b) Increase the temperature. ✓
- c) Increase the molar concentration of the reactants. ✓
- d) Add a catalyst.

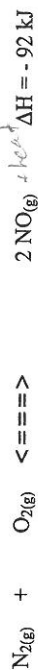
4. When KSCN and FeCl<sub>3</sub> are mixed, a red solution of FeSCN<sup>2+</sup>(aq) is produced as shown in the following equation.



The intensity of the red colour could be increased by the addition of:

- a) Ag<sup>+</sup> ions to form insoluble AgSCN. \*
- b) Sn<sup>2+</sup> ion to reduce Fe<sup>3+</sup>(aq) to Fe<sup>2+</sup>(aq). \*
- c) a small volume of water. \*
- d) a small volume of concentrated Fe<sup>3+</sup>(aq) solution. ✓

5. Consider the following system at equilibrium:



Which of the following changes will be certain to increase the concentration of the product NO(g)?

- I Increase the temperature. \*
- II Decrease the temperature. ✓
- III Decrease the pressure. \*
- IV Increase the oxygen concentration. ✓
- V Introduce a catalyst. \*

- a) I and II.
- b) II and IV.
- c) II and V.
- d) III and II.

6. Which of the following statements is an equilibrium state?

- a) Liquid bromine and bromine vapour in a sealed tube held at a constant temperature. ✓
- b) Burning a strip of magnesium above a Bunsen burner flame. \*
- c) A bottle containing a dilute solution of sodium chloride. \*
- d) A bubbling mixture of zinc and hydrochloric acid in an open beaker. \*

7. Assuming equilibrium is reached in the reaction:



A greater yield of carbon dioxide will be best obtained by:

- a) raising the temperature and pressure. ✓
- b) lowering the temperature and raising the pressure. ✓
- c) lowering the temperature and pressure. \*
- d) raising the temperature and lowering the pressure. \*

8. Water is added to a vessel containing a saturated solution of copper sulfate in contact with solid copper sulfate. The final solution volume is now twice the original volume and temperature of the solution has been kept constant. Excess solid copper sulfate is added and equilibrium is again established with excess solid continuing to be in contact with the solution.

Which of the following statements is TRUE?

- The  $[Cu^{+2}]_{(aq)}$  will have decreased to half of its original concentration.
- The  $[Cu^{+2}]_{(aq)}$  will have doubled.
- The  $[Cu^{+2}]_{(aq)}$  will have increased while the  $SO_4^{2-}{}_{(aq)}$  will have decreased.
- The  $[Cu^{+2}]_{(aq)}$  will remain the same.

9. Addition of a catalyst may cause any except one of the following changes to occur. Identify the exception.

- Change the value of the equilibrium constant for the reaction.
- Allow formation of intermediate molecules not found in the uncatalyzed reaction.
- Increase the percentage of collisions that result in reaction.
- Increase the rates of both forward and reverse reactions.

10. The salt, silver chloride, is only slightly soluble. Hence its solubility would be:

- less in water than in silver nitrate solution.
- greater in water than in silver nitrate solution.
- less in water than in sodium chloride solution.
- greater in water than in sodium nitrate solution.

11. The following statements refer to the chemical reaction between  $CaCO_3(s)$  and a dilute acid solution. Which one of the statements is FALSE?

- The rate of the reaction decreases with increasing time.
- The initial rate of reaction increases with increasing initial temperature.
- The initial rate of reaction increases with increasing initial concentration of  $H^+(aq)$ .
- The initial rate of reaction is independent of the state of sub-division of  $CaCO_3(s)$ .

12. An increase in temperature of 10 degrees normally does not double the kinetic energy of particles or double the number of collisions. Yet, this temperature increase may be enough to double the rate of a slow reaction. Which of the following statements explains this?

- The collisions are both more frequent and more effective. The number of molecular collisions that involve sufficient energy to provide the activation energy for reaction may be in fact doubled.
- If the reaction is endothermic the reaction goes faster at a higher temperature because heat is taken up in the reaction.
- If the reaction is exothermic the reaction goes faster at a higher temperature because heat is given out in the reaction.
- There is no sensible explanation for this: it is one of the mysteries of chemistry.

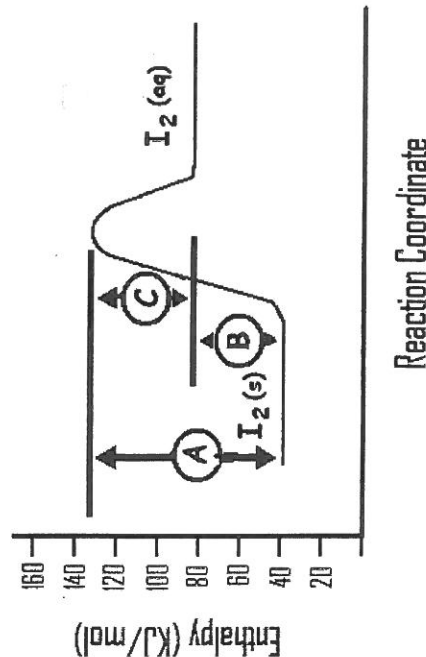
13. When solid silver carbonate is added to water, the following equilibrium is established:



A small quantity of soluble sodium carbonate solid is added to a saturated solution of silver carbonate and stirred. Assuming there is no significant change to the volume of the system, which of the following statements is correct?

- The  $[CO_3^{2-}]$  will increase and the  $[Ag^+]$  will not change.
- The  $[CO_3^{2-}]$  will decrease and the  $[Ag^+]$  will increase.
- The  $[CO_3^{2-}]$  will increase and the  $[Ag^+]$  will decrease.
- The  $[CO_3^{2-}]$  and the  $[Ag^+]$  will not change.

14. The potential energy diagram below refers to the reaction



Which of the following statements is FALSE?

- 'A' is the activation energy for the reaction  $I_2(s) \rightarrow I_2(aq)$
- $\Delta H$  for the reaction is positive and has the value 'B'
- At equilibrium the rate of reaction  $I_2(aq) \rightarrow I_2(s)$  is faster than that of  $I_2(s) \rightarrow I_2(aq)$
- An increase in temperature will alter the equilibrium position and increase the solubility of  $I_2$

15. Solid calcium carbonate heated in a sealed system at 500°C and 500 kPa gets to equilibrium as seen below:



Which of the following statements regarding this system is TRUE?

- a) The addition of more  $\text{CaCO}_3(\text{s})$  will increase final production of  $\text{CO}_2$  in a new equilibrium state. ☒
- b) The addition of more  $\text{CO}_2(\text{g})$  to the system will result in less  $\text{CaO}(\text{s})$  present in the system. ☒
- c) Increasing the pressure of the system to 800 kPa by the addition of inert Argon gas will increase the amount of  $\text{CaCO}_3(\text{s})$  in the system. ☒
- d) Increasing the temperature to 800°C will increase the amount of  $\text{CaCO}_3(\text{s})$  in the system. ☒

16. Consider the reaction:



To speed up this reaction we could:

- a) increase the pressure. ☒
- b) increase the temperature. ☒
- c) add a catalyst. ☒
- d) all of the above. ☒

17. Refer to the last equation. In order to increase the yield of chlorine, we could:

- a) add more oxygen to the system. ☒
- b) increase the volume. ☒
- c) increase the temperature. ☒
- d) add more water vapour to the system. ☒

18. Which of the following reactions is most likely to go farthest toward completion at room temperature?

- a)  $4\text{Fe}(\text{s}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{Fe}_2\text{O}_3(\text{s}) + 1674 \text{ kJ}$
- b)  $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g}) \quad \Delta H = -879 \text{ kJ}$  ☒
- c)  $\text{Cu}(\text{s}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CuO}(\text{s}) \quad \Delta H = -155 \text{ kJ}$  ☒
- d)  $\text{NH}_4\text{Cl}(\text{s}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{Cl}^-(\text{aq}) \quad \Delta H = 47 \text{ kJ}$  ☒

19. Two separate closed systems are set up and allowed to come to equilibrium.



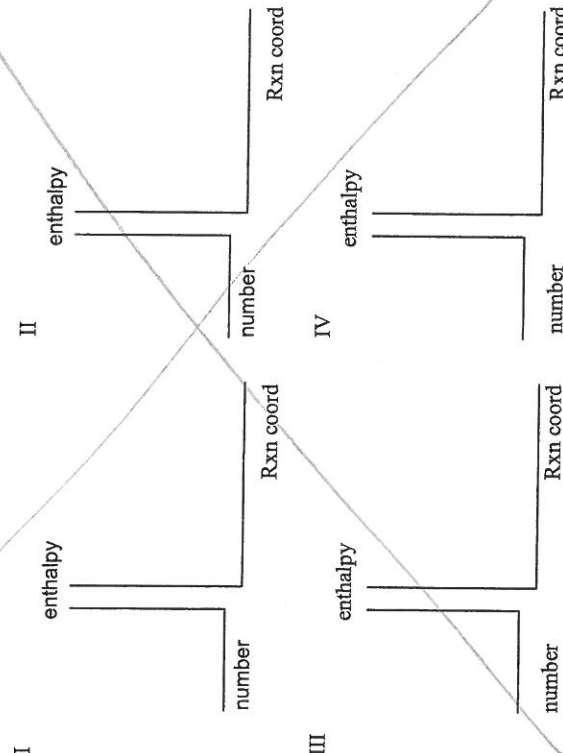
The pressure on both systems is then doubled by halving the volume. You would expect that:

- a) a higher proportion of products would form in both systems since both reactions would proceed faster. ☒
- b) a smaller proportion of HI would appear in System 1. ☒
- c) a larger proportion of  $\text{H}_2\text{S}$  would appear in System 2. ☒
- d) the ratio of reactants to products would not change in either of the systems. ☒

20. The diagrams below show reaction profile diagrams for the reaction



along with a graph showing the distribution of the kinetic energies of the particles at various temperatures. Which pair of diagrams could be used to help explain why an increase in temperature results in an increased rate of reaction?



## Part B Short answer questions

(30 marks out of 50)

1. What is the effect of adding a catalyst to a chemical system which is in equilibrium? Explain why this is the case. [2]

Answer:

No effect  
Both  $\rightarrow$  and  $\leftarrow$  Rxn Rate  $\uparrow$

2. The reduction of iron oxide with hydrogen is a reversible reaction.

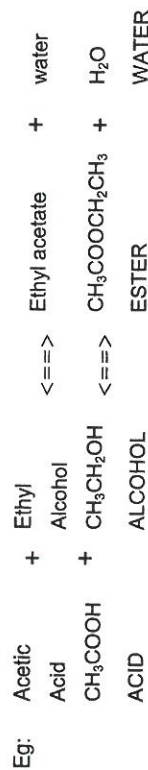


State two ways of ensuring that the forward reaction goes mainly to products and say why this occurs. [2]

Answer: Remove  $\text{H}_2\text{O}$  so  $\rightarrow$  favoured  
" " " " " "

or Continuously replenish reactants

3. Esterification is a reaction between an acid and an alcohol to form an ester.

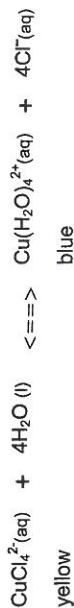


You are given a small quantity of a pure ester (eg ethyl acetate, which smells like nail polish). Briefly describe a method of efficiently converting it into acid and alcohol so the alcohol could be recovered explaining how the process works. [2]

Answer: Add  $\text{OH}^-$  to neutralize  $\text{CH}_3\text{COOH}$

$\therefore \leftarrow$  favoured  
 $\therefore$  more alcohol produced

4. A solution of copper ions in hydrochloric acid usually has a green colour owing to the existence of the complex  $\text{CuCl}_4^{2-}$ , which is yellow, in equilibrium with  $\text{Cu}(\text{H}_2\text{O})_4^{2+}$ , which is blue.



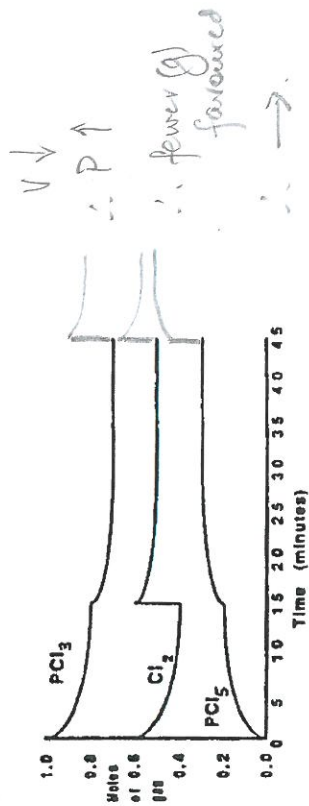
- (a) What colour change, if any, would you expect to be observed when such a solution was diluted liberally with water? Explain your answer. [2]

Answer: green  $\rightarrow$  blue  
As more  $\text{Cu}(\text{H}_2\text{O})_4^{2+}$  will form  
( $\rightarrow$  favoured)

- (b) What colour change, if any, would you expect to be observed if a significant amount of sodium chloride solid was added and stirred? Explain your answer. [2]

Answer:  $[\text{Cl}^-]$  increases  
 $\therefore \leftarrow$  favoured  
 $\therefore$  green soln  $\rightarrow$  yellow

5. The following graph refers to the  $\text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{PCl}_5(\text{g})$  equilibrium: (c)



Initially only  $\text{PCl}_3(\text{g})$  and  $\text{Cl}_2(\text{g})$  are present

- (a) When was equilibrium first established? 10-12' [1]

- (b) What change occurred at the 15 minute mark? [1]

$[\text{Cl}_2] \uparrow$

- (c) Explain what then happened to the three gases (after the 15 minute mark) using Le Chatelier's Principle, i.e. the **change** and the system's **response** to the change.

system partially counteracts change  
by reducing  $[Cl_2]$  by  $\rightarrow$  favoured  
until new equlbm form

[2]

- (d) Suggest a change that may have occurred at the 30 minute mark?

Add catalyst

[1]

- (e) The temperature was constant for the whole 45 minutes. If you were able to calculate  $K$  at the 14 minute mark, would  $K$  be larger, smaller or the same at the 40 minute mark? Explain your answer.

same  
only  $\Delta T$  can change  $K$

[2]

- (e) At 45 minutes the total volume of the reaction vessel **decreased**. Show the effect of the concentration of each species on the graph above. Explain.

[2]

$\downarrow V \therefore \uparrow P \therefore$  fewer (g) favoured  
ie  $\rightarrow$  rxn

6. The graph below shows equilibrium yield curves for the Haber Process. Describe what the plots show in terms of the equilibrium reaction



and explain why this is the case.

[4]

7. Three systems, all at 100°C, containing  $N_2O_4$  and  $NO_2$  were analysed and found to contain the concentrations shown in the table below.

SYSTEM	$[N_2O_4]$ (mol/L)	$[NO_2]$ (mol/L)
1	0.0049	0.0385
2	0.0042	0.0299
3	0.0031	0.0103

The equilibrium constant for the reaction



is 0.213 at 100°C.

- (a) Write the equilibrium constant expression for the reaction as it is written above.

[1]

$$K = \frac{[NO_2]^2}{[N_2O_4]}$$

- (b) Calculate the values for  $K$  for each of the three systems described in the table above and state whether or not the system is at equilibrium. Show your working below and enter your answers into the table below.

[3]

$$\textcircled{1} K = \frac{0.0385^2}{0.0049}$$

$$\textcircled{2} K = 0.213$$

$$= 0.3025$$

$$\textcircled{3} K = 0.0342$$

SYSTEM	'K' value calculated	At equilibrium?	More reactants or products?
1	0.3025	X	products
2	0.213	✓	—
3	0.0342	X	reactants

- (c) If any of the systems are NOT at equilibrium, state whether more reactants or products need to be formed before equilibrium is established. Write your answers in the fourth column of the table above.

[2]

