

2.4.2 Equilibrium shifts and industrial choices

Name: _____ Class: _____ Date: _____

Total: 16 marks

KEY WORDS dynamic equilibrium

Objective

Separate equilibrium composition from the speed of reaching it and justify a compromise. All questions and marking guidance are original.

1 Key knowledge and worked examples

In a closed system at dynamic equilibrium, forward and reverse rates are equal. Both reactions continue; concentrations are constant, not necessarily equal. More reactant shifts toward its consumption. Higher pressure favours fewer gas moles. Higher temperature favours the endothermic direction.

■ Worked explanation

$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ is exothermic forward. Higher pressure favours the side with two rather than four gas moles. Lower temperature favours exothermic ammonia formation but slows reaction. A catalyst gives a useful rate at a lower operating temperature without changing equilibrium at that temperature.

2 Practice

2.1 State the two defining observations/conditions of dynamic equilibrium and explain why equal concentrations are not required. [3]

2.2 For $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$, predict the composition effect of compressing the equilibrium mixture at fixed temperature and justify. [2]

2.3 $\text{A} + \text{B} \rightleftharpoons \text{C}$ is exothermic forward. Explain the effect of raising temperature on C yield and the effect of adding a catalyst at fixed temperature. [3]

3 Exam-style questions

3.1 For $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$, $\Delta H < 0$, explain how pressure and temperature favour yield. Then give two reasons an industrial plant might not use the highest pressure and lowest temperature. [5]

3.2 An equilibrium mixture becomes richer in product when one product is continuously removed. Explain this result without claiming the equilibrium constant has changed, and state why an open flowing process needs care when using the phrase dynamic equilibrium. [3]

Solutions

Original marking guidance: M1 method, A1 accuracy, B1 explanation.

2.1 A closed system with equal forward and reverse rates. Constant concentrations result from equal rates; there is no requirement for equal amounts of different substances.

2.2 No shift: two gas moles on each side. Rates may change, but the pressure comparison does not favour one side.

2.3 Higher temperature favours the endothermic reverse reaction and lowers C yield. Catalyst changes approach speed, not equilibrium composition.

3.1 Higher pressure favours two rather than three gas moles; low temperature favours the exothermic direction. Low temperature gives a slow rate. High pressure requires costly equipment/energy and greater safety provision; an explicit rate–yield–cost compromise is needed.

3.2 Removal lowers product concentration, so net forward reaction replaces some product. The closed-system definition does not directly describe the whole flowing process; local equilibrium/steady operation must be distinguished.