6.2 Reversible reactions and equilibrium

Name: _____ Class: _____ Date: _____ **Total: 41 marks**

KEY WORDS dynamic equilibrium • Le Chatelier principle

Objective

Represent reversible reactions, define equilibrium and (HT) apply Le Chatelier's principle. Original questions for spec statements 4.6.2.1–4.6.2.7.

1 Key knowledge and worked examples

Reversible reactions use the $\rightleftharpoons$ arrow: $A + B \rightleftharpoons C + D$. Exothermic in one direction transfers the **same energy** endothermically in the other.

Dynamic equilibrium: in a **closed system**, reached when the **forward and reverse rates are equal** – concentrations constant, both reactions still happening.

(HT) Le Chatelier – the system **counteracts** a change:

Change	Position shifts
reactant concentration ↑	toward products
product concentration ↓	toward products
pressure ↑ (gases)	toward the side with **fewer gas molecules**
temperature ↑	toward the **endothermic** direction
catalyst added	**no shift** – equilibrium reached sooner

Worked example (3 marks, HT). $N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$ (exothermic forward). Predict the effect of raising the pressure and of raising the temperature.

Four gas molecules on the left, two on the right – higher pressure shifts toward ammonia; higher temperature shifts the position in the endothermic direction – the reverse – so the ammonia yield falls; a catalyst would not change the yield, only the speed.

2 Practice

2.1 What arrow shows a reversible reaction? [1]

2.2 What is equal at equilibrium? [1]

2.3 *(HT)* $2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$ – which side has fewer gas molecules? [1]

3 Exam-style questions

3.1 Explain what is meant by dynamic equilibrium in a closed system. [4]

3.2 *(HT)* For a hypothetical $A(g) + B(g) \rightleftharpoons C(g)$ reaction with an endothermic forward direction, predict and explain the effect of (a) adding more A at fixed volume; (b) cooling the mixture. [4]

3.3 *(HT)* Why do industries sometimes use a moderate temperature rather than a low one for an exothermic equilibrium process? [3]

3.4 Heating blue hydrated copper sulfate forms white anhydrous copper sulfate and water, taking in 72 kJ for a stated amount. Describe the reverse change and its energy transfer for the corresponding amount. Also write the reversible word equation for ammonium chloride forming ammonia and hydrogen chloride; state which direction heating favours. [4]

3.5 In a sealed vessel, forward/reverse rates at 0, 10, 20 and 30 minutes are respectively 0.8/0.0, 0.5/0.2, 0.3/0.3 and 0.3/0.3 in the same units. The reactant and product amounts at 20 minutes are 0.60 and 0.20 mol. Identify the first recorded equilibrium time, explain why the unequal amounts are allowed, and evaluate: "Both reactions have stopped." [4]

3.6 *(HT)* $A(g) + B(g) \rightleftharpoons C(g)$ is at equilibrium in a fixed-volume vessel. More C is added. Distinguish the immediate concentration change from the subsequent reaction and explain what happens until a new equilibrium is reached. Must C return exactly to its original concentration? [4]

3.7 *(HT)* Predict and explain the effect of compression at fixed temperature on (a) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$; (b) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$; (c) $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$. For (a), also predict expansion. [6]

3.8 *(HT)* A forward reaction is exothermic. At 300 °C it gives 80% equilibrium yield and production rate 2 units; at 400 °C it gives 55% and rate 8 units. A plant needs at least 50% yield and rate 5 units. Choose a temperature and justify it. Explain the yield trend, and predict how heating would affect yield for a different endothermic forward reaction. [5]

3.9 *(HT)* Without a catalyst, a closed system reaches equilibrium in 20 minutes with reactant concentration 0.60 mol/dm^3 and product concentration 0.20 mol/dm^3. A suitable catalyst gives the same final concentrations in 4 minutes at the same temperature, with the same starting amounts. Explain its effects on forward/reverse rates and position, and evaluate: "A faster reaction always has a larger equilibrium yield." [4]