

Reactions that go both ways

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Worksheet answers

Each answer states the direction of the shift or the calculation steps, then the result in bold. For every prediction, check that your reason mentions gas molecules for pressure, the sign of ΔH for temperature, or the concentration that was changed.

Level: Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS1-6

Problem 1 Reversible or not?

1. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O} \rightleftharpoons \text{CuSO}_4 + 5\text{H}_2\text{O}$. 2. Blue to white. 3. The products can react together to reform the reactants. **$\text{CuSO}_4 \cdot 5\text{H}_2\text{O} \rightleftharpoons \text{CuSO}_4 + 5\text{H}_2\text{O}$.**

Problem 2 True or false?

1. True. 2. False: they are constant, not necessarily equal. 3. True. 4. False: they stay constant. **True, false, true, false.**

Problem 3 Reading a rate graph

1. The forward rate, because there are no products yet. 2. At the point where the lines meet and become flat (the vertical dashed line). 3. They are equal. **Rates are equal at equilibrium.**

Problem 4 Open or closed?

1. The carbon dioxide escapes into the air, so the reverse reaction cannot happen. 2. The gas stays in the tube, so the reverse reaction occurs and an equilibrium is reached. 3. Otherwise the substances escape and the forward and reverse rates can never balance. **Closed system needed.**

Problem 5 Making ammonia: basics

1. Nitrogen from the air; hydrogen from natural gas. 2. Iron catalyst and about 450 °C. 3. Making fertilisers. **Iron, 450 °C.**

Problem 6 State the principle

1. If a change is made to a system at equilibrium, the position shifts to oppose the change. 2. To the right, using up the extra N_2 . 3. It increases. **Shift right; more NH_3 .**

Problem 7 Concentration changes

1. Right. 2. Right. 3. Left. 4. The equilibrium keeps shifting right to replace the product, so more methanol is made. **Right, right, left.**

Problem 8 Count the gas molecules

1. 4 molecules to 2: shifts right. 2. 3 molecules to 2: shifts right. 3. 1 molecule to 2: shifts left. 4. 2 molecules to 2: no shift. **Right, right, left, no change.**

Problem 9 Temperature and ΔH

1. The yield of NO increases. 2. The mixture becomes paler. 3. Heating favours the endothermic direction, which is the forward reaction in (1). Cooling favours the exothermic direction, which is the forward reaction in (2) and makes colourless N_2O_4 . **More NO when hot; paler when cooled.**

Problem 10 Squeezing the syringe

1. Pushing the plunger squeezes the same molecules into a smaller volume, so the brown colour is more concentrated. 2. The higher pressure shifts the equilibrium to the side with fewer gas molecules, producing colourless N_2O_4 . 3. Left, towards N_2O_4 . **Shift left.**

Problem 11 Adding a catalyst

1. No effect. 2. Equilibrium is reached sooner. 3. The catalyst lowers the activation energy for both directions equally, so the forward and reverse rates both rise but stay balanced. **Faster, same position.**

Problem 12 Choosing the pressure

1. The yield rises as pressure rises. 2. Higher pressure favours the side with fewer gas molecules, which is the ammonia side (2 against 4). 3. Very high pressure needs expensive thick-walled equipment and a lot of energy for compression, and it is more dangerous. **Higher pressure, higher yield.**

Problem 13 Why not a cold reactor?

1. A low temperature, because the forward reaction is exothermic. 2. The rate would be far too slow for particles to have enough energy for successful collisions. 3. About $450\text{ }^{\circ}\text{C}$ gives a reasonable rate while keeping a useful yield, and the iron catalyst speeds up the reaction. **$450\text{ }^{\circ}\text{C}$ is a compromise.**

Problem 14 Amounts at equilibrium

1. $0.30 \times 40 = 12\text{ mol}$. 2. $N_2 = 40 - 12 = 28\text{ mol}$; $H_2 = 120 - 36 = 84\text{ mol}$; $NH_3 = 2 \times 12 =$

24 mol. 3. Total = $28 + 84 + 24 = 136$ mol, and $24 \div 136 \times 100 = 17.6\%$. **17.6% ammonia.**

Problem 15 Cobalt colours

1. Blue: extra chloride shifts the equilibrium right. 2. Pink: water shifts the equilibrium left. 3. Heating gives blue (endothermic direction favoured) and cooling gives pink. **Blue, pink, blue then pink.**

Problem 16 Graph of amounts

1. About 30 s, when both lines become flat. 2. N_2O_4 reacted = $1.00 - 0.54 = 0.46$ mol, which is 46%. 3. Each N_2O_4 gives 2NO_2 , so $2 \times 0.46 = 0.92$ mol, matching the graph. 4. The forward and reverse reactions continue at equal rates, so the amounts stay constant. **46% reacted; $\text{NO}_2 = 0.92$ mol.**

Problem 17 Making sulfur trioxide

1. Higher yield, because 3 gas molecules become 2. 2. Higher yield, because the forward reaction is exothermic. 3. A low temperature is too slow; 450°C and the catalyst give a good rate with a high yield. 4. The yield is already very high at low pressure, so the cost of compression is not worth it. **Compromise conditions.**

Problem 18 Ammonia mass per pass

1. $M(\text{N}_2) = 28$, so $14\,000 \div 28 = 500$ mol. 2. 25% reacts: 125 mol N_2 gives 250 mol NH_3 ; $M = 17$, so $250 \times 17 = 4250$ g = 4.25 kg. 3. $375 \text{ mol} \times 28 = 10\,500$ g = 10.5 kg. 4. $1000 \text{ mol} \times 17 = 17\,000$ g = 17.0 kg. **4.25 kg per pass; 10.5 kg recycled.**

Problem 19 Evaluate a plan

1. The low temperature and high pressure both favour a high equilibrium yield. 2. Without a catalyst and at 100°C the reaction is extremely slow; 1000 atm needs very expensive, dangerous equipment; high energy cost of compression. 3. About 450°C , 200 atm and an iron catalyst, with recycling of unreacted gases. **Use 450°C , 200 atm, iron.**

Problem 20 Spot the errors

1. Both reactions continue at equal rates. 2. The amounts are constant, not necessarily equal. 3. A catalyst does not move the position; it only speeds up reaching equilibrium. 4. Higher pressure shifts towards fewer gas molecules. **Four corrections.**