

Reactions that go both ways

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

Name: _____ Date: _____ Class: _____

These twenty problems train you to recognise reversible reactions, describe dynamic equilibrium and use Le Chatelier's principle to predict how concentration, pressure, temperature and catalysts change an equilibrium. They also apply the ideas to the Haber and contact processes with calculations.

They match GCSE and IGCSE chemistry, O Level, CBSE Class 9-10 science and NGSS high school chemistry. For each shift, give the direction and the reason.

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

Problem 1 Reversible or not? (easy)

Heating blue hydrated copper(II) sulfate gives white anhydrous copper(II) sulfate and water. Adding water reverses the change.

1. Write the equation using the reversible arrow.
2. State what colour change shows the forward reaction.
3. Explain why this is called a reversible reaction.

Problem 2 True or false? (easy)

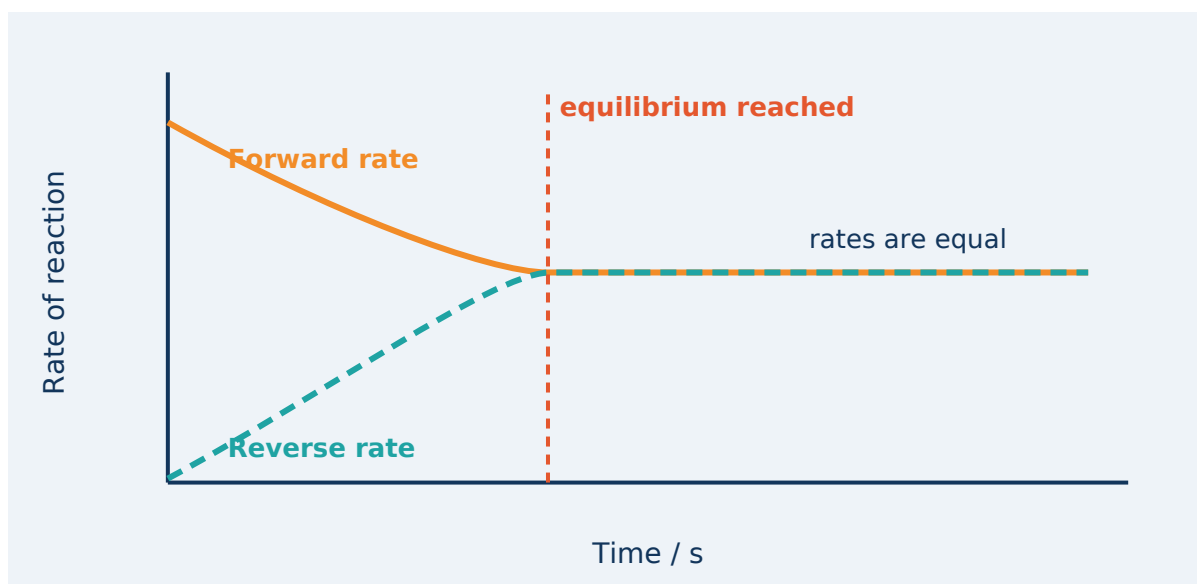
Decide whether each statement about dynamic equilibrium is true or false.

1. The forward and reverse reactions both continue.
2. The amounts of reactants and products are always equal.
3. The system must be closed.
4. The concentrations keep changing.

Problem 3 Reading a rate graph (easy)

The graph shows the rates of the forward and reverse reactions for a reversible reaction in a closed flask.

1. State which rate is higher at time zero.
2. State where on the graph equilibrium is reached.
3. Compare the two rates after that time.



Rates against time for a reversible reaction.

Problem 4 Open or closed? (easy)

Calcium carbonate decomposes on heating: $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$.

1. Explain why the solid is completely converted when heated in an open crucible.
2. State what happens in a sealed tube.
3. State why a closed system is needed for equilibrium.

Problem 5 Making ammonia: basics (easy)

Ammonia is made in the Haber process.

1. Name the source of each raw material.
2. Name the catalyst and the temperature.
3. State one use of ammonia.

Problem 6 State the principle (easy)

Aarav in Pune adds extra nitrogen to the Haber mixture at equilibrium: $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$.

1. State Le Chatelier's principle.
2. Predict the direction of shift.
3. Predict what happens to the amount of ammonia.

Problem 7 Concentration changes (medium)

$\text{CO}(\text{g}) + 2\text{H}_2(\text{g}) \rightleftharpoons \text{CH}_3\text{OH}(\text{g})$ is used to make methanol. Predict the direction of shift for each change.

1. Add more hydrogen.
2. Remove methanol as it forms.
3. Add more methanol.
4. Explain why removing the product helps an industrial plant.

Problem 8 Count the gas molecules (medium)

Predict the effect of increasing the pressure on each equilibrium.

1. $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
2. $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$
3. $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$
4. $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$

Problem 9 Temperature and ΔH (medium)

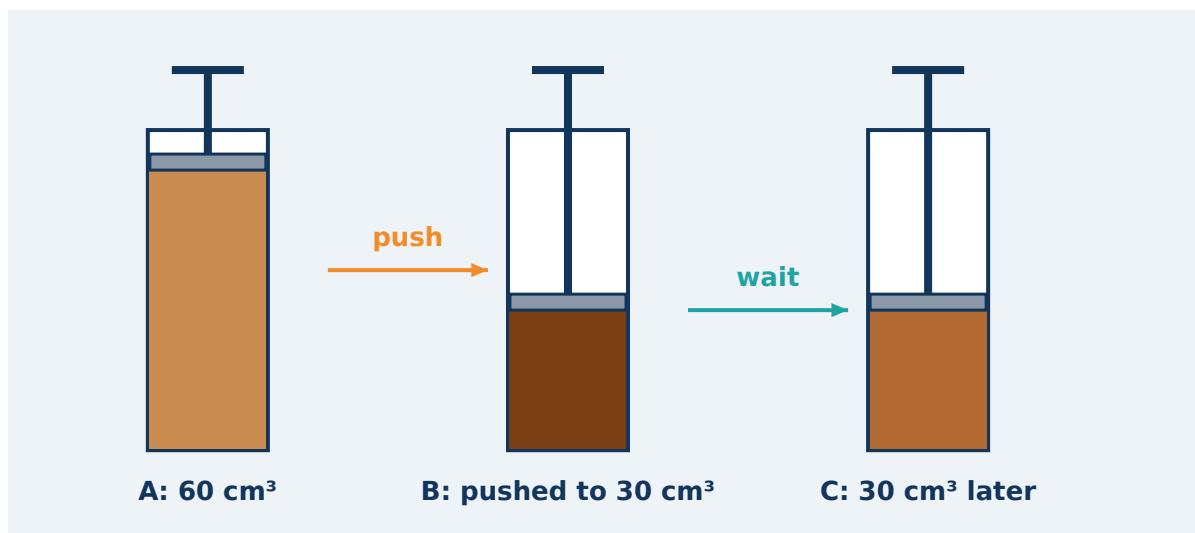
Diego in Texas studies two reactions.

1. $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g})$, $\Delta H = +180 \text{ kJ/mol}$. Predict the effect of raising the temperature on the yield of NO.
2. $2\text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$, $\Delta H = -57 \text{ kJ/mol}$. Predict the colour change on cooling (NO_2 is brown, N_2O_4 is colourless).
3. Explain both predictions.

Problem 10 Squeezing the syringe (medium)

A syringe contains brown NO_2 and colourless N_2O_4 in equilibrium: $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$. The plunger is pushed in.

1. Explain why the gas first becomes darker.
2. Explain why it then becomes paler.
3. Name the direction in which the equilibrium shifts.



The gas mixture before and after compression.

Problem 11 Adding a catalyst (medium)

A catalyst is added to a mixture at equilibrium.

1. State the effect on the position of equilibrium.
2. State the effect on the time needed to reach equilibrium.

3. Explain why.

Problem 12 Choosing the pressure (medium)

Typical equilibrium yields of ammonia at 450 °C: 100 atm 16%, 200 atm 28%, 400 atm 46%, 800 atm 63%.

1. Describe the trend.
2. Explain it using Le Chatelier's principle.
3. Suggest why plants do not use 800 atm.

Problem 13 Why not a cold reactor? (medium)

The Haber reaction is exothermic, but plants run at about 450 °C.

1. State the temperature that favours the highest yield.
2. Explain why a low temperature is not used.
3. Describe the compromise.

Problem 14 Amounts at equilibrium (medium)

A reactor holds 40 mol of N₂ and 120 mol of H₂. At equilibrium 30% of the nitrogen has reacted.

1. Calculate the moles of N₂ that reacted.
2. Calculate the moles of N₂, H₂ and NH₃ at equilibrium.
3. Calculate the percentage of the mixture that is ammonia.

Problem 15 Cobalt colours (medium)

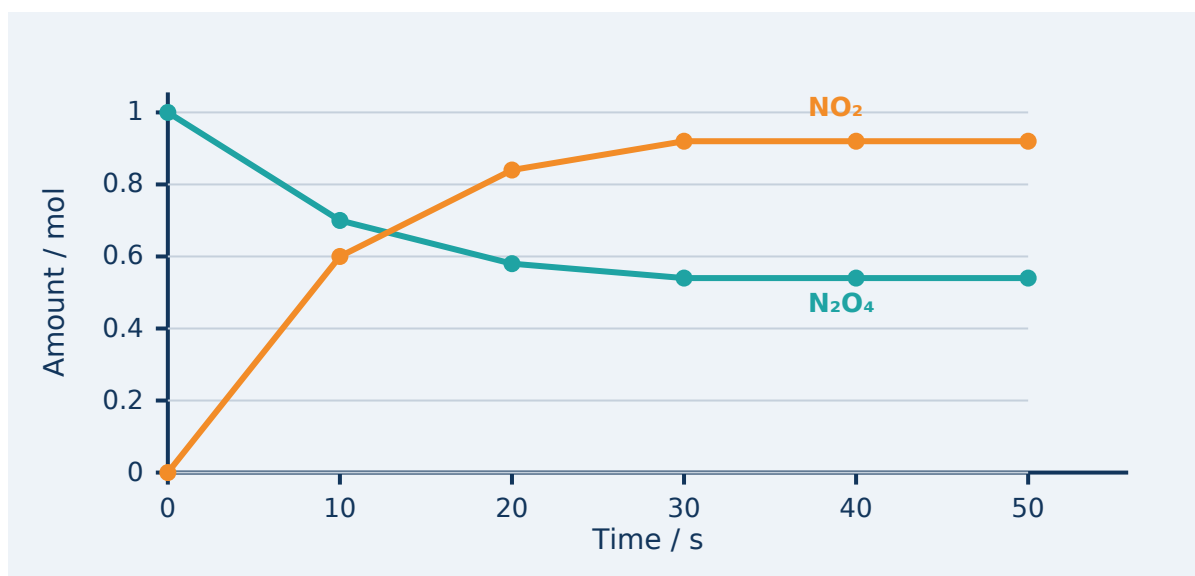
Wanjiru investigates $[\text{Co}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ (pink) + $4\text{Cl}^{-}(\text{aq}) \rightleftharpoons [\text{CoCl}_4]^{2-}(\text{aq})$ (blue) + $6\text{H}_2\text{O}(\text{l})$. The forward reaction is endothermic.

1. Predict the colour on adding concentrated hydrochloric acid.
2. Predict the colour on adding water.
3. Predict the colour on heating, and on cooling in ice.

Problem 16 Graph of amounts (hard)

Emma in Leeds follows $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ in a sealed flask that starts with 1.00 mol of N₂O₄.

1. State the time at which equilibrium is reached.
2. Calculate the percentage of N₂O₄ that has reacted at equilibrium.
3. Show that the final amount of NO₂ agrees with the equation.
4. Explain why the lines are flat although the reactions continue.



Amounts of N₂O₄ and NO₂ against time.

Problem 17 Making sulfur trioxide (hard)

In the contact process, $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$, $\Delta H = -197 \text{ kJ/mol}$. Industry uses about 450 °C, about 2 atm and a vanadium(V) oxide catalyst.

1. Predict the effect of high pressure on the yield.
2. Predict the effect of a low temperature on the yield.
3. Explain why 450 °C is used.
4. Suggest why a very high pressure is not needed.

Problem 18 Ammonia mass per pass (hard)

A plant feeds 14.0 kg of nitrogen (Ar: N = 14, H = 1) into a reactor and 25% of it reacts on each pass.

1. Calculate the moles of N₂ fed in.
2. Calculate the mass of ammonia made on the first pass.
3. Calculate the mass of unreacted nitrogen that is recycled.
4. Calculate the mass of ammonia if all the nitrogen reacted.

Problem 19 Evaluate a plan (hard)

A manager suggests running the Haber process at 100 °C, 1000 atm and without an iron catalyst to maximise the yield.

1. State one advantage of the plan.
2. Give three disadvantages.
3. Suggest a better set of conditions.

Problem 20 Spot the errors (hard)

A student wrote: 'At equilibrium the reaction has stopped. The amounts of reactants and

products are equal. Adding a catalyst moves the equilibrium to the right. Raising the pressure shifts the equilibrium towards the side with more gas molecules.' Correct all four errors.