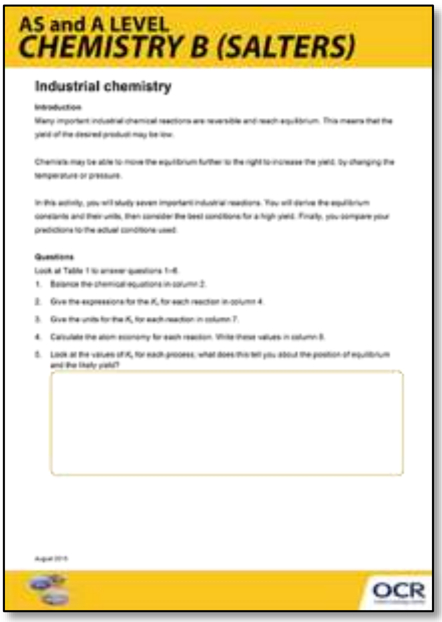
Industrial chemistry

Instructions and answers for teachers

These instructions should accompany the OCR resource 'Industrial chemistry' which supports OCR A Level Chemistry B.


AS and A LEVEL
CHEMISTRY B (SALTERS)

Industrial chemistry

Introduction

Many important industrial chemical reactions are reversible and reach equilibrium. This means that the yield of the desired product may be low.

Chemists may be able to move the equilibrium further to the right to increase the yield, by changing the temperature or pressure.

In this activity, you will study seven important industrial reactions. You will derive the equilibrium constants and their units, then consider the best conditions for a high yield. Finally, you compare your predictions to the actual conditions used.

Questions

Look at Table 1 to answer questions 1–6.

1. Balance the chemical equations in column 2.
2. Give the expressions for the K_c for each reaction in column 4.
3. Give the units for the K_c for each reaction in column 7.
4. Calculate the atom economy for each reaction. Write these values in column 8.
5. Look at the values of K_c for each process; what does this tell you about the position of equilibrium and the likely yield?

The Activity:

Learners consider seven industrial reactions, derive their equilibrium constants and consider the factors which will affect the yield and K_c. Finally, they reconcile their predictions to the actual conditions used.

This activity offers an opportunity for maths skills development.

Learning outcomes:

This lesson element relates to the specification learning outcomes ES(p), ES(q), CI(f), CI(g), CI(h).

Associated materials:

'Industrial chemistry' Lesson Element learner activity sheet.

Introduction

Learners could undertake this activity after they have studied factors affecting equilibrium constants in *The chemical industry*.

Instructions

Learners follow the instructions on the activity sheet, filling in the empty columns of the table and answering the questions.

Answers to questions

Answers to questions 1–4:

Process	Equation (unbalanced)	Expression for K_c	Units for K_c	Atom economy
Haber	$N_2 + 3H_2 \rightleftharpoons 2NH_3$	$= \frac{[NH_3]^2}{[N_2][H_2]^3}$	$dm^6\ mol^{-2}$	100%
Contact	$2SO_2 + O_2 \rightleftharpoons 2SO_3$	$= \frac{[SO_3]^2}{[SO_2]^2[O_2]}$	$dm^3\ mol^{-1}$	100%
Birkeland–Eyde	$N_2 + O_2 \rightleftharpoons 2NO$	$= \frac{[NO]^2}{[N_2][O_2]}$	none	100%
Ostwald	$4NH_3 + 5O_2 \rightleftharpoons 4NO + 6H_2O$	$= \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$	$mol\ dm^3$	52.6%
Industrial ethanol	$C_2H_4 + H_2O \rightleftharpoons C_2H_5OH$	$= \frac{[C_2H_5OH]}{[C_2H_4][H_2O]}$	$dm^3\ mol^{-1}$	100%
Deacon	$4HCl + O_2 \rightleftharpoons 2Cl_2 + 2H_2O$	$= \frac{[Cl_2]^2[H_2O]^2}{[HCl]^4[O_2]}$	$dm^3\ mol^{-1}$	79.8%
Cativa	$CO + CH_3OH \rightleftharpoons CH_3COOH$	$= \frac{[CH_3COOH]}{[CO][CH_3OH]}$	$dm^3\ mol^{-1}$	100%

5. A high value of K_c suggests that the equilibrium position lies to the right and the yield of product should be high.

6. If the reaction is exothermic, the value of K_c will decrease when the temperature is raised. This is because the equilibrium shifts to the right to try to oppose the rise in temperature.

Answers to questions 7 and 8:

Process	Temperature for high yield	Pressure for high yield
Haber	low	high
Contact	low	high
Birkeland–Eyde	high	doesn't matter
Ostwald	low	low
Industrial ethanol	low	high
Deacon	low	high
Cativa	low	high

9. Some exothermic processes do not use a very low temperature because the reaction would be too slow. Instead, a higher temperature and a catalyst are used to increase the rate.

   High pressures can be expensive to maintain as they require thick-walled containers and energy-hungry compressors. At high pressures, reactants or products can be corrosive or explosive.

10. The endothermic reaction (Birkeland–Eyde process) gives a high yield at high temperature, so the reaction is fast enough without needing a catalyst.