IB DP CHEMISTRY

Reactivity 2 · How Much, How Fast, and How Far?

TOPICAL WORKSHEET

R2.1 How Much? The Amount of Chemical Change

R2.2 How Fast? The Rate of Chemical Change · R2.3 How Far? The Extent of Chemical Change

Standard and Higher Level · Syllabus 2025

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Original exam-style questions written for the IB Diploma Programme Chemistry course (first assessment 2025)

Section A — Multiple Choice (15 marks)

Circle the letter of the best answer to each question. Each question is worth 1 mark.

1. In a chemical reaction, the limiting reagent is the reactant that **[1]**

A is present in the greatest amount

B is completely used up first, determining the maximum amount of product formed

C has the highest molar mass

D is not involved in the reaction

2. For the reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, if 1.0 mol of N_2 reacts completely, the amount of H_2 required is **[1]**

A 1.0 mol

B 2.0 mol

C 3.0 mol

D 6.0 mol

3. Percentage yield is best defined as **[1]**

A (actual yield ÷ theoretical yield) × 100%

B (theoretical yield ÷ actual yield) × 100%

C actual yield − theoretical yield

D the mass of desired product divided by total reactant mass

4. A reaction has a theoretical yield of 12.0 g of product. If 9.00 g is actually obtained, the percentage yield is **[1]**

A 25.0%

B 57.6%

C 75.0%

D 133%

5. Atom economy is best described as **[1]**

A the percentage of reactant atoms that end up in the desired product

B the same quantity as percentage yield

C the total number of atoms in the reactants

D the cost of the raw materials used in a reaction

6. The rate of a chemical reaction is best defined as **[1]**

A the total energy released by the reaction

B the change in concentration of a reactant or product per unit time

C the equilibrium constant of the reaction

D the enthalpy change divided by time

7. Which of the following does NOT generally increase the rate of a reaction between a solid and a gas? **[1]**

A increasing the temperature

B increasing the surface area of the solid (e.g. using powder instead of a lump)

C adding a suitable catalyst

D reducing the pressure of the gas

8. On a Maxwell-Boltzmann energy distribution curve, the area under the curve to the right of the activation energy, E_a, represents **[1]**

A the total number of molecules in the sample

B the fraction of molecules with insufficient energy to react

C the fraction of molecules with enough energy to react upon collision

D the average kinetic energy of all molecules

9. A catalyst increases the rate of a reaction by **[1]**

A increasing the average kinetic energy of the reacting particles

B providing an alternative pathway with a lower activation energy

C increasing the enthalpy change of the reaction

D shifting the position of equilibrium towards the products

10. On a concentration-time graph for a reactant being consumed, the rate of reaction at any point is given by **[1]**

A the y-intercept of the graph

B the gradient (slope) of the tangent to the curve at that point

C the x-intercept of the graph

D the total area under the curve

11. For the equilibrium $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, the expression for K_c is **[1]**

A $K_c = [SO_3] \div [SO_2][O_2]$

B $K_c = [SO_3]^2 \div ([SO_2]^2[O_2])$

C $K_c = [SO_2]^2[O_2] \div [SO_3]^2$

D $K_c = [SO_2][O_2] \div [SO_3]$

12. For the equilibrium $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, increasing the total pressure will shift the equilibrium position **[1]**

A towards the reactants, since they occupy more volume

B towards the products, since there are fewer moles of gas on that side

C not at all, since pressure only affects rate, not equilibrium position

D towards the products, since NH_3 is denser

13. For an endothermic forward reaction at equilibrium, increasing the temperature will **[1]**

A shift the equilibrium position towards the reactants

B shift the equilibrium position towards the products, increasing the yield

C have no effect on the equilibrium position

D decrease the value of K_c

14. A dynamic equilibrium is best described as a state in which **[1]**

A the forward and reverse reactions have both stopped

B the forward and reverse reactions continue to occur at equal rates, so concentrations remain constant

C only the forward reaction occurs

D the concentrations of reactants and products are always equal to each other

15. Adding a catalyst to a reaction at equilibrium will **[1]**

A shift the equilibrium position towards the products

B shift the equilibrium position towards the reactants

C have no effect on the position of equilibrium, but allow equilibrium to be reached faster

D increase the value of K_c

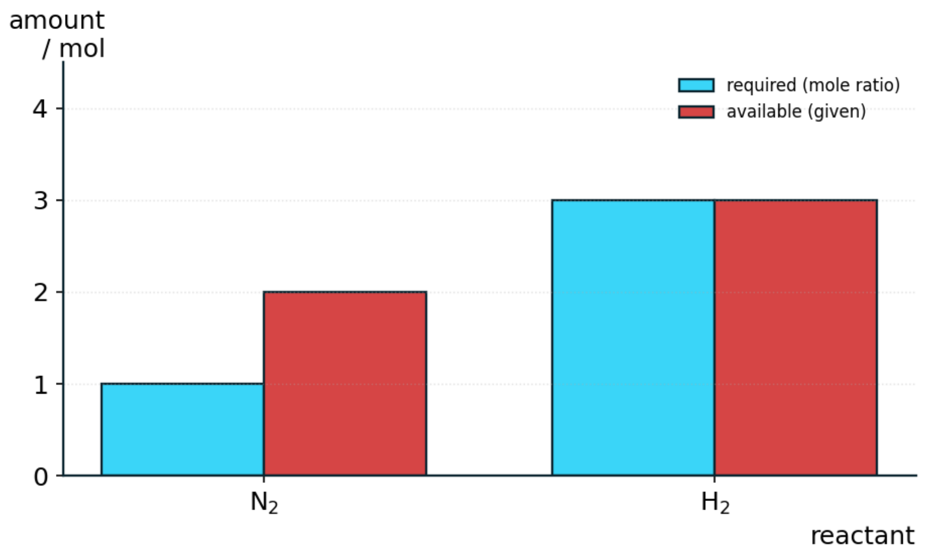
Section B — Structured Questions (65 marks)

Answer all questions in the space provided. Working must be shown for full marks.

R2.1 The Amount of Chemical Change

Question 1 [7 marks]

Ammonia is manufactured industrially by the reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$. The graph compares the amount of each reactant required by the mole ratio with the amount actually available in a particular mixture.



Reacting amounts: required (mole ratio) vs available (given data).

(a) Using the graph, identify the limiting reagent in this mixture. **[2]**

(b) Explain your answer to part (a), using the mole ratio of the equation. **[3]**

(c) Calculate the maximum amount, in moles, of NH_3 that can be produced from this mixture. **[2]**

Question 2 [6 marks]

Continuing from the reaction in Question 1 ($N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, $M(NH_3) = 17.03\ g\ mol^{-1}$), the maximum amount of NH_3 produced was 2.00 mol.

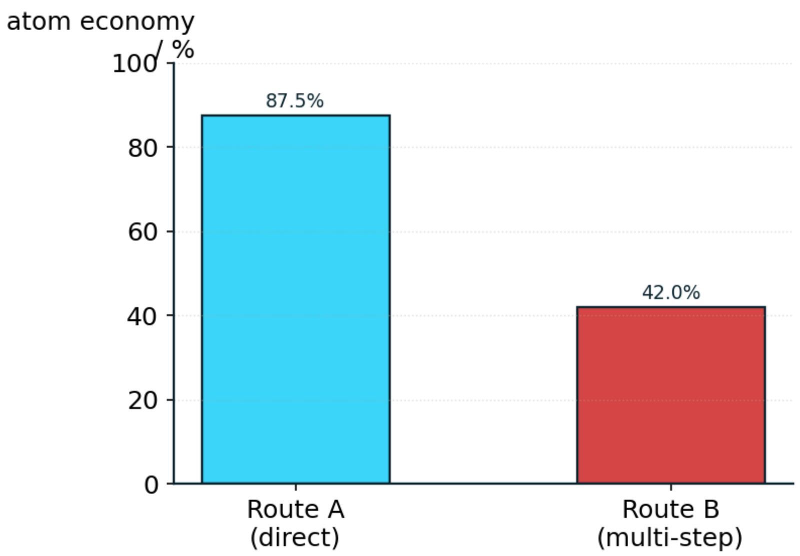
(a) Calculate the maximum mass of NH_3 that could be produced. **[2]**

(b) Define the term 'limiting reagent'. **[2]**

(c) Suggest why, in industrial processes such as the Haber process, one reactant is often deliberately used in excess. **[2]**

Question 3 [7 marks]

The graph compares the atom economy of two alternative synthesis routes for making the same desired product.



Atom economy of two synthesis routes (given data).

(a) Using the graph, identify which route has the higher atom economy. **[2]**

(b) Define 'atom economy', and explain why a chemist would generally prefer Route A over Route B. **[3]**

(c) The reaction $CH_3Br + NaOH \rightarrow CH_3OH + NaBr$ produces methanol as the desired product ($M(CH_3Br) = 94.94$, $M(NaOH) = 40.00$, $M(CH_3OH) = 32.04\ g\ mol^{-1}$). Calculate the atom economy of this reaction. **[2]**

Question 4 [6 marks]

A student carries out a synthesis reaction with a theoretical yield of 8.50 g of product, but only obtains 6.80 g in practice.

(a) Define the term 'percentage yield'. **[2]**

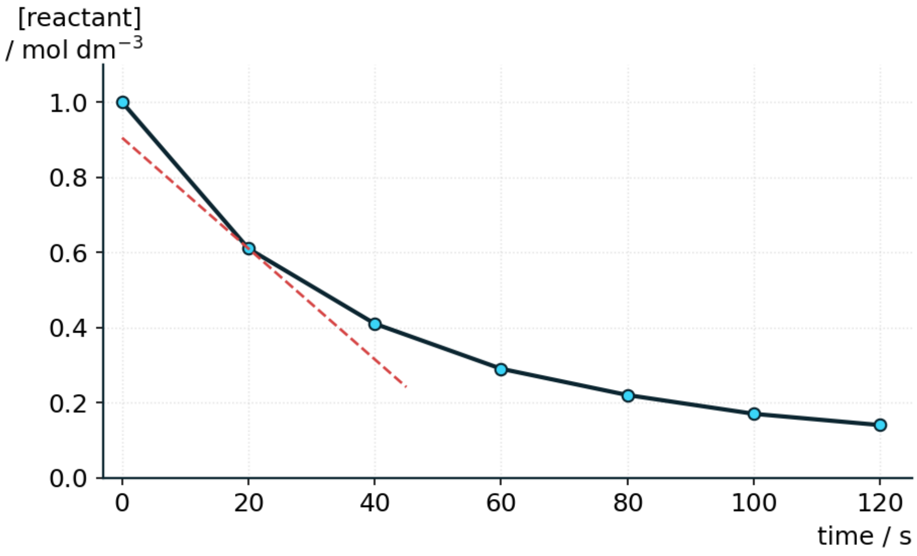
(b) Calculate the percentage yield for this reaction. **[2]**

(c) Suggest one reason why the percentage yield of a reaction is often less than 100%. **[2]**

R2.2 The Rate of Chemical Change

Question 5 [7 marks]

The graph shows how the concentration of a reactant changes with time during a reaction.



Concentration-time graph for a reaction (given data).

(a) Describe how the rate of reaction changes as the reaction proceeds, using the shape of the graph. **[2]**

(b) Using the tangent drawn on the graph at t = 20 s, estimate the initial rate of reaction. **[3]**

(c) Explain, using collision theory, why the rate of reaction decreases as the reaction proceeds. **[2]**

Question 6 [6 marks]

Several factors influence the rate of a chemical reaction.

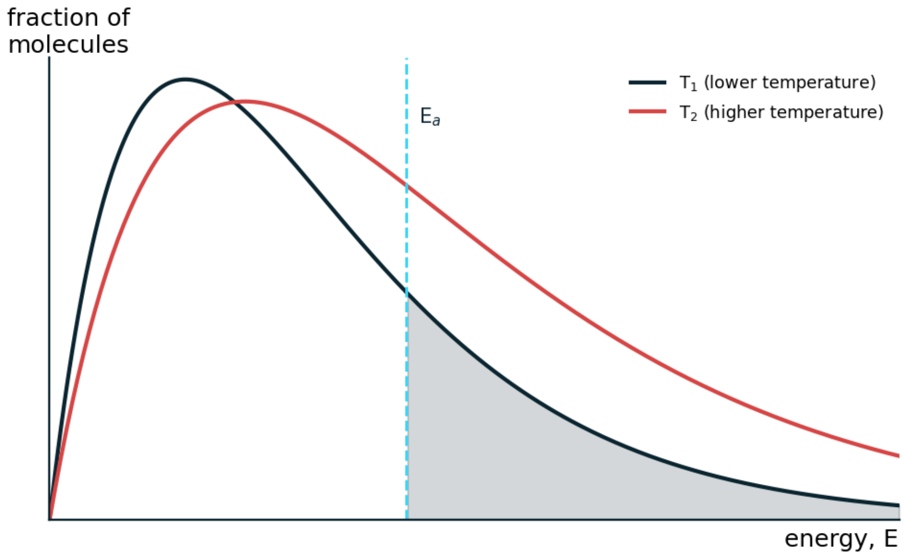
(a) State two factors (other than temperature) that can increase the rate of a reaction. **[2]**

(b) Explain, using collision theory, why increasing the temperature increases the rate of a reaction. **[2]**

(c) Explain why increasing the surface area of a solid reactant increases the rate of reaction. **[2]**

Question 7 [7 marks]

The graph shows Maxwell-Boltzmann energy distribution curves for the same sample of gas at two different temperatures, T_1 and T_2, with the activation energy, E_a, marked.



Maxwell-Boltzmann energy distribution at two temperatures (schematic).

(a) Identify which curve, T_1 or T_2, represents the higher temperature, and justify your answer. **[2]**

(b) Using the graph, explain why increasing the temperature increases the rate of reaction. **[3]**

(c) Explain, with reference to the graph, how a catalyst could increase the rate of reaction without any change in temperature. **[2]**

R2.3 The Extent of Chemical Change

Question 8 [6 marks]

Hydrogen and iodine react according to the equilibrium $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$. At a certain temperature, the equilibrium concentrations were found to be $[H_2]$ = 0.220 mol dm^{-3}, $[I_2]$ = 0.220 mol dm^{-3}, and [HI] = 1.560 mol dm^{-3}.

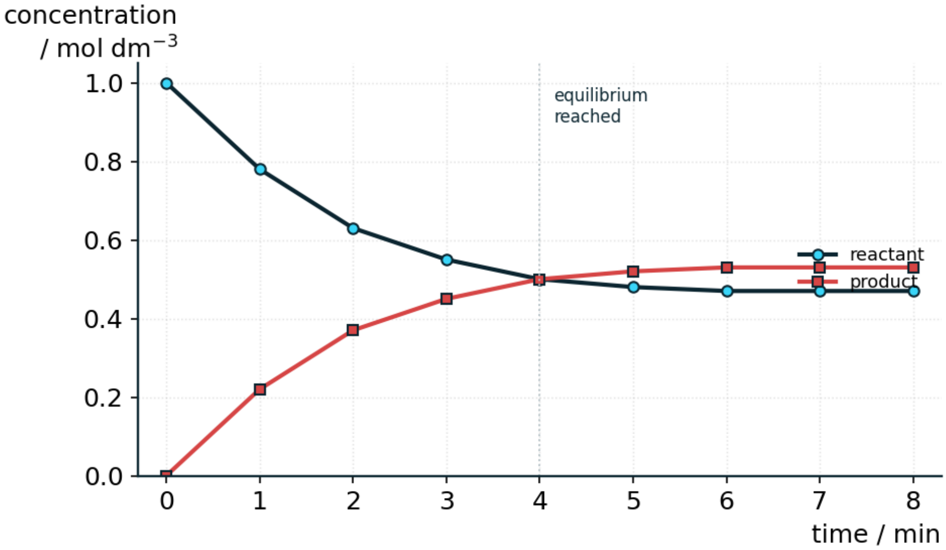
(a) Write the expression for K_c for this equilibrium. **[2]**

(b) Calculate the value of K_c at this temperature. **[2]**

(c) State the units (if any) of K_c for this equilibrium, explaining your reasoning. **[2]**

Question 9 [7 marks]

The graph shows how the concentrations of a reactant and a product change with time as a reversible reaction approaches equilibrium in a closed system.



Concentration vs time as equilibrium is approached (given data).

(a) Using the graph, identify the approximate time at which equilibrium is first reached, and state how you can tell. **[2]**

(b) Explain, in terms of the dynamic nature of chemical equilibrium, why the concentrations remain constant after this point even though the reaction has not stopped. **[3]**

(c) Describe how the graph would differ if the initial concentration of the reactant were doubled (with all other conditions unchanged). **[2]**

Question 10 [6 marks]

Le Chatelier's principle can be used to predict how an equilibrium system responds to a change in conditions.

(a) State Le Chatelier's principle. **[2]**

(b) Predict and explain the effect of increasing the total pressure on the equilibrium position of $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. **[2]**

(c) Predict and explain the effect of increasing the temperature on an equilibrium in which the forward reaction is exothermic. **[2]**