



AVERAGE AND INSTANTANEOUS RATES

Course: SCH4U Grade 12 Chemistry

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20 Practice Problems with Answers and Detailed Solutions

FULL worksheet contains 20 representative problems on:

✓ Average rate from concentration changes, ✓ reactant disappearance, ✓ product appearance,
✓ stoichiometric rate relationships, ✓ instantaneous rate from tangent lines, ✓ central secant rate
estimates from data tables

All problems are designed to reflect style and difficulty commonly seen on quizzes, tests, and final exams. Detailed solutions are included to help students understand the reasoning behind every step.

PART A - FUNDAMENTAL PROBLEMS

Problems 1-15. Simple calculations and basic applications

PART B - INTERMEDIATE PROBLEMS

Problems 16-30. Typical unit test questions involving multiple steps

PART C - ADVANCED PROBLEMS

Problems 31-40. More challenging calculations requiring deeper understanding

PART D - CHALLENGE PROBLEMS

Problems 41-50. Difficult exam-style questions combining multiple concepts

SUITABLE FOR:

quizzes, unit tests and final exam preparation

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Section 1. Essential Summary

This page includes only the formulas and habits needed to solve calorimetry problems efficiently

Formula	Use
$q = m \cdot \Delta T$	Heat gained or lost by a substance
$\Delta T = T_f - T_i$	Temperature change with sign
$q_{cal} = C_{cal} \Delta T$	Heat absorbed by a calorimeter
$q_{sys} = -q_{surrounds}$	Sign convention for coffee-cup and bomb calorimetry
$q_{cal} = q_{sys} = 0$	Heat exchange between substances
$\Delta H = q_{surrounds}$	Enthalpy at constant pressure

Important definitions: coffee-cup calorimetry is usually constant pressure, so q_p can be used for ΔH . Bomb calorimetry is constant volume, so the result is commonly treated as ΔU for ICML-style calculations.

Fast method: identify what gains heat, identify what loses heat, convert volumes to masses when density is given, calculate ΔT carefully, include C_{cal} when provided, then apply the sign convention at the end.

Important notes: for dilute aqueous solutions, use density = 1.00 g/mL and $c = 4.184 \text{ J/g } ^\circ\text{C}$ only when stated or clearly assumed. For reactions, the solution and calorimeter are surroundings, while the chemical reaction is the system.

Common mistakes: using only one solution volume after mixing, forgetting that $q_{surrounds}$ has the opposite sign of q_{system} , ignoring the limiting reagent, mixing J and kJ , and using the sample mass instead of moles when a molar amount is requested.

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Section 2. Practice Problems

Part A. Average rate from concentration changes

Problem 3 The concentration of H_2O_2 changes as shown. Calculate the average rate of disappearance from 0 to 100 s and from 100 to 300 s, then state what happens to the rate

Time (s)	0	100	200	300
$[\text{H}_2\text{O}_2]$ (M)	0.800	0.640	0.520	0.430

Part C. Instantaneous rate from tangent lines and data

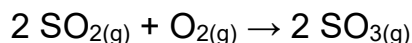
Problem 14 A tangent line to the concentration-time curve for product Y at 80 s passes through the points (60 s, 0.145 M) and (100 s, 0.205 M). Estimate the instantaneous rate of appearance of Y at 80 s

Problem 17 Use a central secant from 10 s to 30 s to estimate the instantaneous rate of appearance of product P at 20 s

Time (s)	0	10	20	30	40
$[\text{P}]$ (M)	0.000	0.035	0.062	0.083	0.099

Part D. Mixed exam-style problems

Problem 19 For the reaction below, $[\text{SO}_3]$ increases from 0.120 M to 0.270 M in 75.0 s. Calculate the average rate of appearance of SO_3 , the average reaction rate, the rate of disappearance of SO_2 , and the rate of disappearance of O_2



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Solutions

Problem 3 Solution

Given: $[\text{H}_2\text{O}_2]$ decreases from 0.800 M to 0.640 M from 0 to 100 s, and from 0.640 M to 0.430 M from 100 to 300 s

Average rate of disappearance = $([\text{reactant}]_{\text{initial}} - [\text{reactant}]_{\text{final}}) / \Delta t$

From 0 to 100 s: $(0.800 \text{ M} - 0.640 \text{ M}) / 100 \text{ s} = 1.60 \times 10^{-3} \text{ M/s}$

From 100 to 300 s: $(0.640 \text{ M} - 0.430 \text{ M}) / 200 \text{ s} = 1.05 \times 10^{-3} \text{ M/s}$

Final answer: The rate decreases from $1.60 \times 10^{-3} \text{ M/s}$ to $1.05 \times 10^{-3} \text{ M/s}$

Problem 14 Solution

Given: Tangent points are (60 s, 0.145 M) and (100 s, 0.205 M) for product Y

For a product, instantaneous rate of appearance = slope of the tangent

Slope = $(0.205 \text{ M} - 0.145 \text{ M}) / (100 \text{ s} - 60 \text{ s}) = 0.060 \text{ M} / 40 \text{ s} = 1.50 \times 10^{-3} \text{ M/s}$

Final answer: Instantaneous rate of appearance of Y = $1.50 \times 10^{-3} \text{ M/s}$

Problem 17 Solution

Given: To estimate the instantaneous rate at 20 s, use the points around it: 10 s and 30 s

For a product, rate of appearance = central secant slope

Slope = $(0.083 \text{ M} - 0.035 \text{ M}) / (30 \text{ s} - 10 \text{ s}) = 0.048 \text{ M} / 20 \text{ s} = 2.40 \times 10^{-3} \text{ M/s}$

Final answer: Estimated instantaneous rate of appearance of P at 20 s = $2.40 \times 10^{-3} \text{ M/s}$

Problem 19 Solution

Given: $[\text{SO}_3]_{\text{initial}} = 0.120 \text{ M}$, $[\text{SO}_3]_{\text{final}} = 0.270 \text{ M}$, $\Delta t = 75.0 \text{ s}$

SO_3 appearance rate = $\Delta[\text{SO}_3] / \Delta t$, and reaction rate = $1/2 \times \text{SO}_3$ appearance rate

SO_3 appearance rate = $(0.270 \text{ M} - 0.120 \text{ M}) / 75.0 \text{ s} = 2.00 \times 10^{-3} \text{ M/s}$

Reaction rate = $(1/2)(2.00 \times 10^{-3}) = 1.00 \times 10^{-3} \text{ M/s}$

SO_2 disappears at $2 \times$ reaction rate = $2.00 \times 10^{-3} \text{ M/s}$

O_2 disappears at $1 \times$ reaction rate = $1.00 \times 10^{-3} \text{ M/s}$

Final answer: SO_3 appearance = $2.00 \times 10^{-3} \text{ M/s}$; reaction rate = $1.00 \times 10^{-3} \text{ M/s}$; SO_2 disappearance = $2.00 \times 10^{-3} \text{ M/s}$; O_2 disappearance = $1.00 \times 10^{-3} \text{ M/s}$

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Section 4. Answer Key

Problem	Answer
3	0-100 s: 1.60×10^{-3} M/s; 100-300 s: 1.05×10^{-3} M/s; rate decreases
14	1.50×10^{-3} M/s
17	2.40×10^{-3} M/s
19	SO ₃ 2.00×10^{-3} M/s; reaction rate 1.00×10^{-3} M/s; SO ₂ 2.00×10^{-3} M/s; O ₂ 1.00×10^{-3} M/s

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