Average reaction rate and instantaneous reaction rate

NAME: Solutions

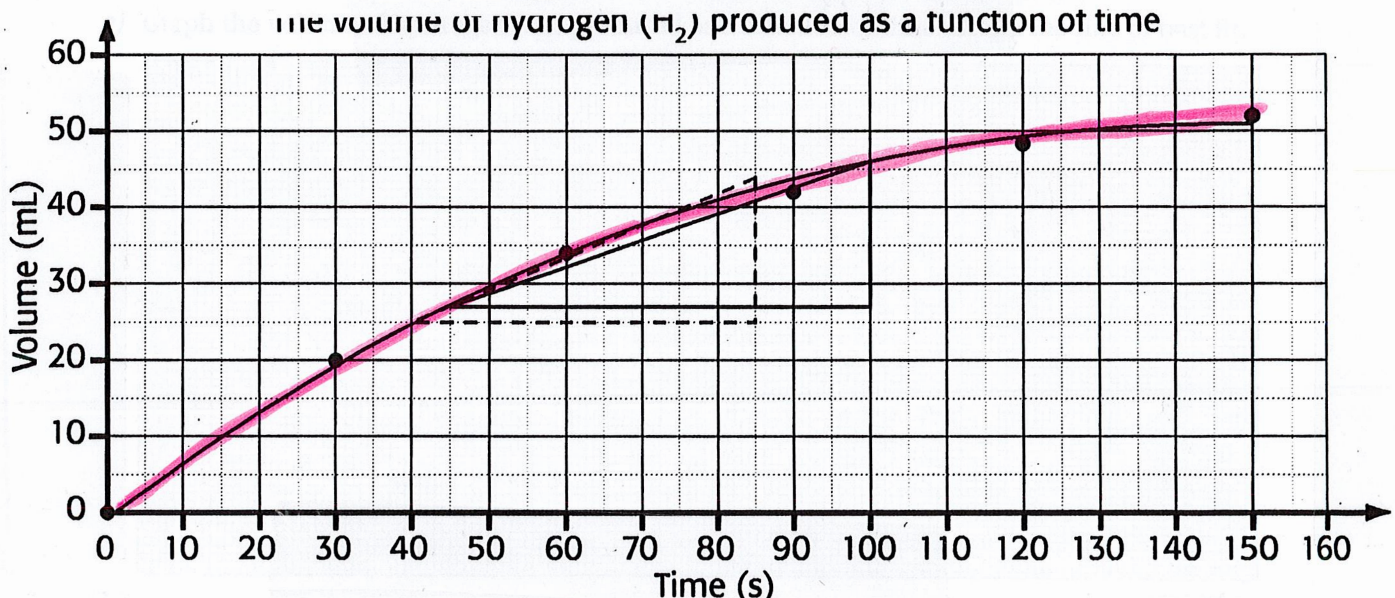
1) Zinc (Zn) and hydrochloric acid (HCl) react according to this equation:

$$Zn_{(s)} + 2\ HCl_{(aq)} \rightarrow ZnCl_{2\ (aq)} + H_{2\ (g)}$$

Table 1 shows the results during the reaction.

TABLE 1
Volume of hydrogen (H_2) produced as a function of time

t (s)	*V* (mL)	*t* (s)	*V* (mL)	*t* (s)	*V* (mL)
0	0	60	34	120	48
30	20	90	42	150	52



b) Calculate the average rate of formation of hydrogen between the 45th and the 100th second.

$$v_{\bar{x}} = \frac{\Delta V}{\Delta t} = \frac{46\ \text{mL} - 27\ \text{mL}}{100\ \text{s} - 45\ \text{s}} = 0.345\ \text{mL/s}$$

Answer: __________

c) Calculate the instantaneous rate at precisely 60 seconds after the beginning of the reaction.

$$= \frac{\Delta V}{\Delta t} = \frac{43\ \text{mL} - 25\ \text{mL}}{85\ \text{s} - 40\ \text{s}} = 0.400\ \text{mL/s}$$

Answer: __________

2) The following graph shows the progress of the concentration over time for a certain reaction:

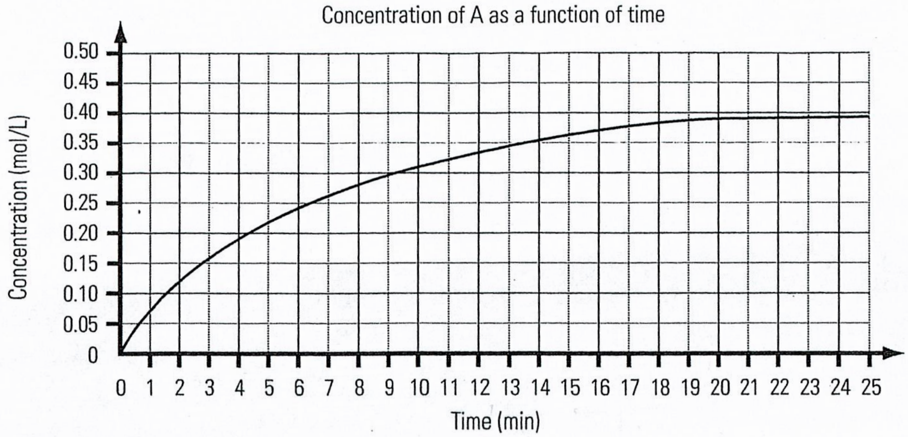


Figure 1 Graph of a hypothetical reaction

a) Does the graph show the concentration of the reactant or the product? Justify your answer.

It shows the concentration of the product, since its concentration is zero at the beginning and increases over time.

b) Calculate the average rate of the reaction between 10 and 20 minutes, in moles per litre-second (mol/(L·s)).

Data:

$t_i = 10 \text{ min} = 600 \text{ s}$

$t_f = 20 \text{ min} = 1200 \text{ s}$

$[A]_i = 0.31 \text{ mol/L}$

$[A]_f = 0.39 \text{ mol/L}$

$r_{\bar{x}} = ?$

Calculation:
Slope of the secant (see graph in Figure 1):

$$r_{\bar{x}} = \frac{\Delta[A]}{\Delta t}$$

$$= \frac{0.39 \text{ mol/L} - 0.31 \text{ mol/L}}{1200 \text{ s} - 600 \text{ s}}$$

$$= 1.33 \times 10^{-4} \text{ mol/(L·s)}$$

Answer: The average rate of the reaction between 10 and 20 minutes is 1.3×10^{-4} mol/(L·s).

c) Calculate the instantaneous rate at 15 minutes, in moles per litre-second (mol/(L·s)).

Data:

$t_i = 7 \text{ min} = 420 \text{ s}$

$t_f = 23 \text{ min} = 1380 \text{ s}$

$[A]_i = 0.30 \text{ mol/L}$

$[A]_f = 0.43 \text{ mol/L}$

$r_{t = 15 \text{ min}} = ?$

Slope of the tangent (see graph in Figure 1):

$$r_{t = 15 \text{ min}} = \frac{\Delta[A]}{\Delta t}$$

$$= \frac{0.43 \text{ mol/L} - 0.30 \text{ mol/L}}{1380 \text{ s} - 420 \text{ s}}$$

$$= 1.35 \times 10^{-4} \text{ mol/(L·s)}$$

Answer: The instantaneous rate of the reaction at 15 minutes is 1.4×10^{-4} mol/(L·s).

d) Compare the average reaction rate between 10 and 20 minutes (calculated in *b*) to the instantaneous reaction rate at 15 minutes (calculated in *c*) and explain your answer.

The average reaction rate between 10 and 20 minutes is almost identical to the average reaction rate at 15 minutes, since 15 minutes represents the average between 10 and 20 minutes.

e) Calculate the instantaneous rate at 5 minutes, in moles per litre-second (mol/(L·s)).

Data:

$t_i = 3\text{ min} = 180\text{ s}$

$t_f = 7\text{ min} = 420\text{ s}$

$[A]_i = 0.18\text{ mol/L}$

$[A]_f = 0.27\text{ mol/L}$

$r_{t=5\text{ min}} = ?$

Slope of the tangent (see graph in Figure 1):

$$r_{t=5\text{ min}} = \frac{\Delta[A]}{\Delta t}$$

$$= \frac{0.27\text{ mol/L} - 0.18\text{ mol/L}}{420\text{ s} - 180\text{ s}}$$

$$= 3.75 \times 10^{-4}\text{ mol/(L·s)}$$

Answer: **The instantaneous rate of the reaction at 5 minutes is 3.75×10^{-4} mol/(L·s).**

f) Compare the instantaneous rate at 5 minutes (calculated in *e)*) to the instantaneous rate at 15 minutes (calculated in *c)*) and explain your answer.

The instantaneous rate at 5 minutes is higher than the instantaneous rate at 15 minutes, since the quantity of reactants diminishes over time.