



4. At 25 °C, 200 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> nitric acid is added to 5.0 g of magnesium powder. If the experiment is repeated using the same mass of magnesium powder, which conditions will result in the same initial reaction rate?

	Volume of HNO <sub>3</sub> / cm <sup>3</sup>	Concentration of HNO <sub>3</sub> / mol dm <sup>-3</sup>	Temperature / °C
A.	200	2.0	25
B.	200	1.0	50
C.	100	2.0	25
D.	100	1.0	25

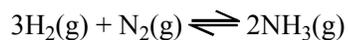
5. Sodium carbonate and hydrochloric acid react according to the equation below.



Which conditions will produce the fastest initial rate with 2.0 g of powdered sodium carbonate?

- A. 100 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> hydrochloric acid at 323 K
- B. 50 cm<sup>3</sup> of 2.0 mol dm<sup>-3</sup> hydrochloric acid at 323 K
- C. 100 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> hydrochloric acid at 348 K
- D. 50 cm<sup>3</sup> of 2.0 mol dm<sup>-3</sup> hydrochloric acid at 348 K
6. Under which conditions will the reaction between 1.0 g calcium carbonate and excess hydrochloric acid be the fastest? Assume that all reactions are carried out at the same temperature.
- A. One large piece of calcium carbonate and 2 mol dm<sup>-3</sup> hydrochloric acid
- B. One large piece of calcium carbonate and 1 mol dm<sup>-3</sup> hydrochloric acid
- C. Powdered calcium carbonate and 2 mol dm<sup>-3</sup> hydrochloric acid
- D. Powdered calcium carbonate and 1 mol dm<sup>-3</sup> hydrochloric acid
7. Powdered manganese(IV) oxide, MnO<sub>2</sub>(s), increases the rate of the decomposition reaction of hydrogen peroxide, H<sub>2</sub>O<sub>2</sub>(aq). Which statements about MnO<sub>2</sub> are correct?
- I. The rate is independent of the particle size of MnO<sub>2</sub>.
- II. MnO<sub>2</sub> provides an alternative reaction pathway for the decomposition with a lower activation energy.
- III. All the MnO<sub>2</sub> is present after the decomposition of the hydrogen peroxide is complete.
- A. I and II only                      C. II and III only
- B. I and III only                      D. I, II and III

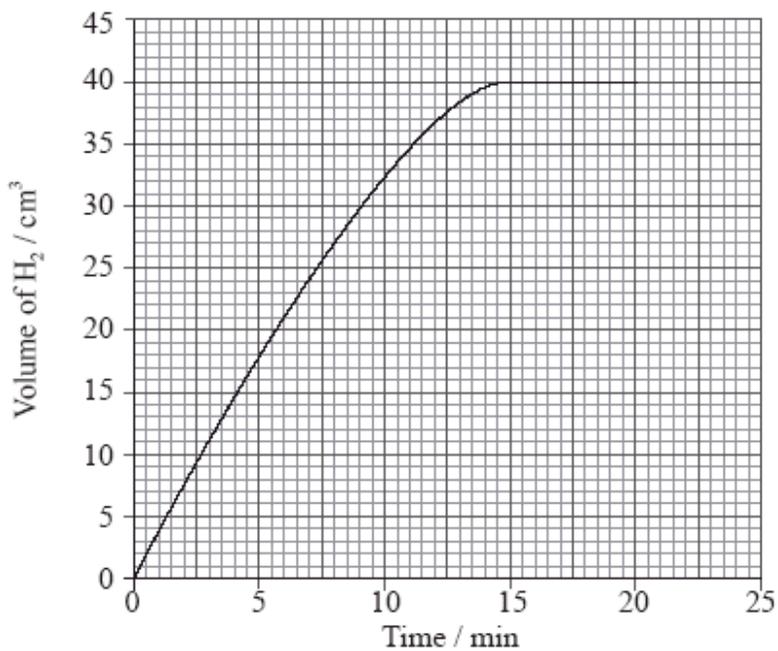
8. The Haber process uses an iron catalyst to convert hydrogen gas,  $\text{H}_2(\text{g})$ , and nitrogen gas,  $\text{N}_2(\text{g})$ , to ammonia gas,  $\text{NH}_3(\text{g})$ .



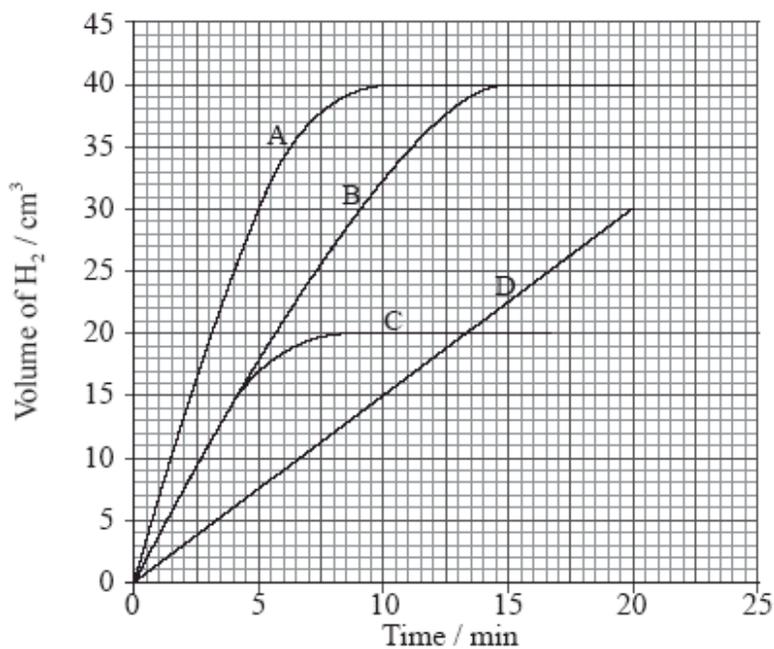
Which statements are correct for this equilibrium system?

- I. The iron catalyst increases the rates of the forward and reverse reactions equally.
  - II. The iron catalyst does not affect the value of the equilibrium constant,  $K_c$ .
  - III. The iron catalyst increases the yield of ammonia gas,  $\text{NH}_3(\text{g})$ .
- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III
9. Which unit could be used for the rate of a chemical reaction?
- A. mol
- B.  $\text{mol dm}^{-3}$
- C.  $\text{mol dm}^{-3} \text{ s}^{-1}$
- D.  $\text{dm}^3$
10. Which of the following can **increase** the rate of a chemical reaction?
- I. Increasing the temperature
  - II. Adding a catalyst
  - III. Increasing the concentration of reactants
- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

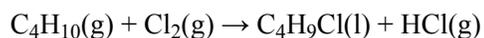
11. A piece of zinc was added to aqueous nitric acid and the volume of hydrogen gas produced was measured every minute. The results are plotted on the graph below.



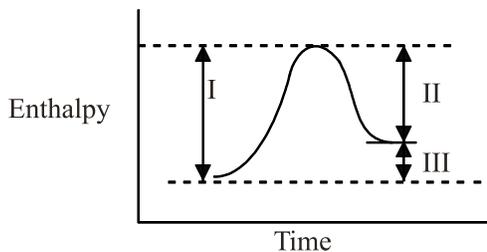
Which graph would you expect if the same mass of powdered zinc was added to nitric acid with the same concentration?



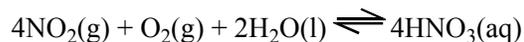
12. Which changes increase the rate of the reaction below?



- I. Increase of pressure
  - II. Increase of temperature
  - III. Removal of  $\text{HCl}(\text{g})$
- A. I and II only  
B. I and III only  
C. II and III only  
D. I, II and III
13. Which quantities in the enthalpy level diagram are altered by the use of a catalyst?



- A. I and II only  
B. I and III only  
C. II and III only  
D. I, II and III
14. The formation of nitric acid,  $\text{HNO}_3(\text{aq})$ , from nitrogen dioxide,  $\text{NO}_2(\text{g})$ , is exothermic and is a reversible reaction.



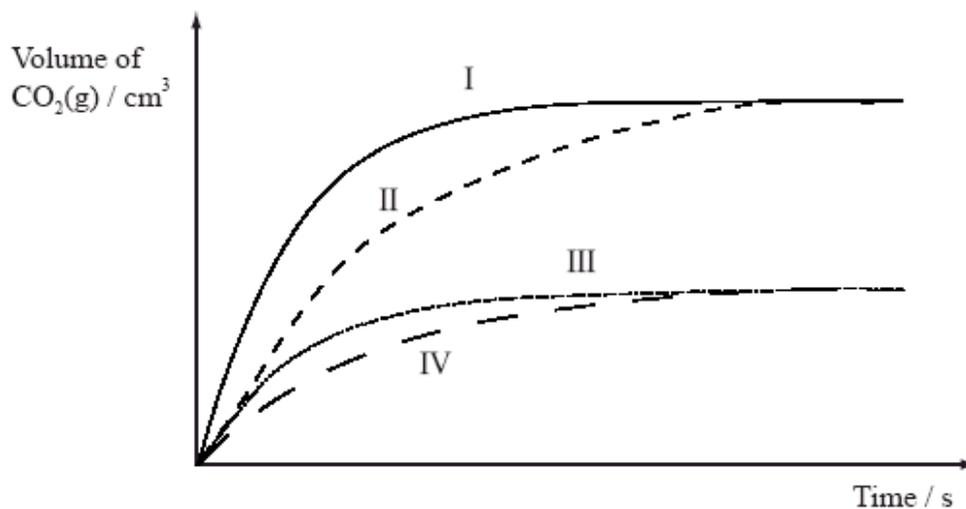
What is the effect of a catalyst on this reaction?

- A. It increases the yield of nitric acid.  
B. It increases the rate of the forward reaction only.  
C. It increases the equilibrium constant.  
D. It has no effect on the equilibrium position.

15. What is the best definition of *rate of reaction*?
- The time it takes to use up all the reactants
  - The rate at which all the reactants are used up
  - The time it takes for one of the reactants to be used up
  - The increase in concentration of a product per unit time

16. Which factors can affect reaction rate?
- The state of the reactants
  - The frequency of the collisions between particles
  - The average kinetic energy of the particles
- I and II only
  - I and III only
  - II and III only
  - I, II and III

17. Equal masses of powdered calcium carbonate were added to separate solutions of hydrochloric acid. The calcium carbonate was in excess. The volume of carbon dioxide produced was measured at regular intervals. Which curves best represent the evolution of carbon dioxide against time for the acid solutions shown in the table below.

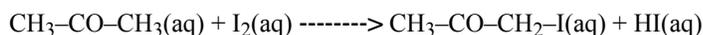


	25 cm <sup>3</sup> of 2 mol dm <sup>-3</sup> HCl	50 cm <sup>3</sup> of 1 mol dm <sup>-3</sup> HCl	25 cm <sup>3</sup> of 1 mol dm <sup>-3</sup> HCl
A.	I	III	IV
B.	I	IV	III
C.	I	II	III
D.	II	I	III

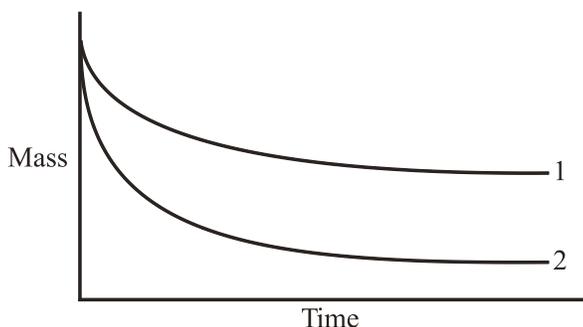
18. What is the function of iron in the Haber process?
- It shifts the position of equilibrium towards the products.
  - It decreases the rate of the reaction.
  - It provides an alternative reaction pathway with a lower activation energy.
  - It reduces the enthalpy change of the reaction.
19. Hydrochloric acid is reacted with large pieces of calcium carbonate, the reaction is then repeated using calcium carbonate powder. How does this change affect the activation energy and the collision frequency?

	Activation energy	Collision frequency
A.	increases	increases
B.	stays constant	increases
C.	increases	stays constant
D.	stays constant	stays constant

20. Which statement is true about using sulfuric acid as a catalyst in the following reaction?



- The catalyst increases the rate of reaction.
  - The catalyst lowers the activation energy for the reaction.
  - The catalyst has been consumed at the end of the chemical reaction.
- I and II only
  - I and III only
  - II and III only
  - I, II and III
21. Excess magnesium, was added to a beaker of aqueous hydrochloric acid. A graph of the mass of the beaker and contents was plotted against time (line 1).

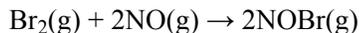


What change in the experiment could give line 2?

- The same mass of magnesium in smaller pieces
- The same volume of a more concentrated hydrochloric acid
- A lower temperature
- A more accurate instrument to measure time

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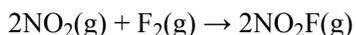
1. Bromine and nitrogen(II) oxide react according to the following equation.



Which rate equation is consistent with the experimental data?

$[\text{Br}_2] / \text{mol dm}^{-3}$	$[\text{NO}] / \text{mol dm}^{-3}$	Rate / $\text{mol dm}^{-3} \text{ s}^{-1}$
0.10	0.10	$1.0 \times 10^{-6}$
0.20	0.10	$4.0 \times 10^{-6}$
0.20	0.40	$4.0 \times 10^{-6}$

- A. rate =  $k[\text{Br}_2]^2 [\text{NO}]$
- B. rate =  $k[\text{Br}_2] [\text{NO}]^2$
- C. rate =  $k[\text{Br}_2]^2$
- D. rate =  $k[\text{NO}]^2$
2. Which step is the rate-determining step of a reaction?
- A. The step with the lowest activation energy
- B. The final step
- C. The step with the highest activation energy
- D. The first step
3. The rate information below was obtained for the following reaction at a constant temperature.

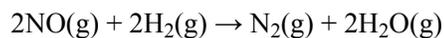


$[\text{NO}_2] / \text{mol dm}^{-3}$	$[\text{F}_2] / \text{mol dm}^{-3}$	Rate / $\text{mol dm}^{-3} \text{ s}^{-1}$
$2.0 \times 10^{-3}$	$1.0 \times 10^{-2}$	$4.0 \times 10^{-4}$
$4.0 \times 10^{-3}$	$1.0 \times 10^{-2}$	$8.0 \times 10^{-4}$
$4.0 \times 10^{-3}$	$2.0 \times 10^{-2}$	$1.6 \times 10^{-3}$

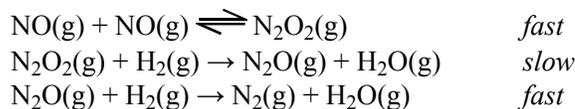
What are the orders of the reaction with respect to  $\text{NO}_2$  and  $\text{F}_2$ ?

- A.  $\text{NO}_2$  is first order and  $\text{F}_2$  is second order
- B.  $\text{NO}_2$  is second order and  $\text{F}_2$  is first order
- C.  $\text{NO}_2$  is first order and  $\text{F}_2$  is first order
- D.  $\text{NO}_2$  is second order and  $\text{F}_2$  is second order

4. Consider the following reaction.

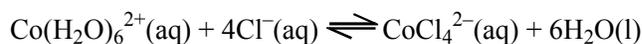


A proposed reaction mechanism is:



What is the rate expression?

- A. rate =  $k[\text{H}_2][\text{NO}]^2$       C. rate =  $k[\text{NO}]^2[\text{H}_2]^2$   
 B. rate =  $k[\text{N}_2\text{O}_2][\text{H}_2]$       D. rate =  $k[\text{NO}]^2[\text{N}_2\text{O}_2]^2[\text{H}_2]$
5. Which experimental procedure could be used to determine the rate of reaction for the reaction between a solution of cobalt chloride,  $\text{CoCl}_2(\text{aq})$ , and concentrated hydrochloric acid,  $\text{HCl}(\text{aq})$ ?



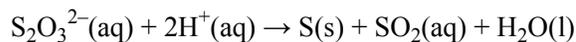
- A. Measure the change in pH in a given time  
 B. Measure the change in mass in a given time  
 C. Use a colorimeter to measure the change in colour in a given time  
 D. Measure the change in volume of the solution in a given time
6. The following data were obtained for the reaction between gases A and B.

Experiment	Initial [A] / mol dm <sup>-3</sup>	Initial [B] / mol dm <sup>-3</sup>	Initial rate / mol dm <sup>-3</sup> min <sup>-1</sup>
1	$1.0 \times 10^{-3}$	$1.0 \times 10^{-3}$	$2.0 \times 10^{-4}$
2	$2.0 \times 10^{-3}$	$1.0 \times 10^{-3}$	$2.0 \times 10^{-4}$
3	$2.0 \times 10^{-3}$	$2.0 \times 10^{-3}$	$4.0 \times 10^{-4}$

Which relationship represents the rate expression for the reaction?

- A. rate =  $k[\text{B}]^2$   
 B. rate =  $k[\text{A}]^2$   
 C. rate =  $k[\text{A}]$   
 D. rate =  $k[\text{B}]$

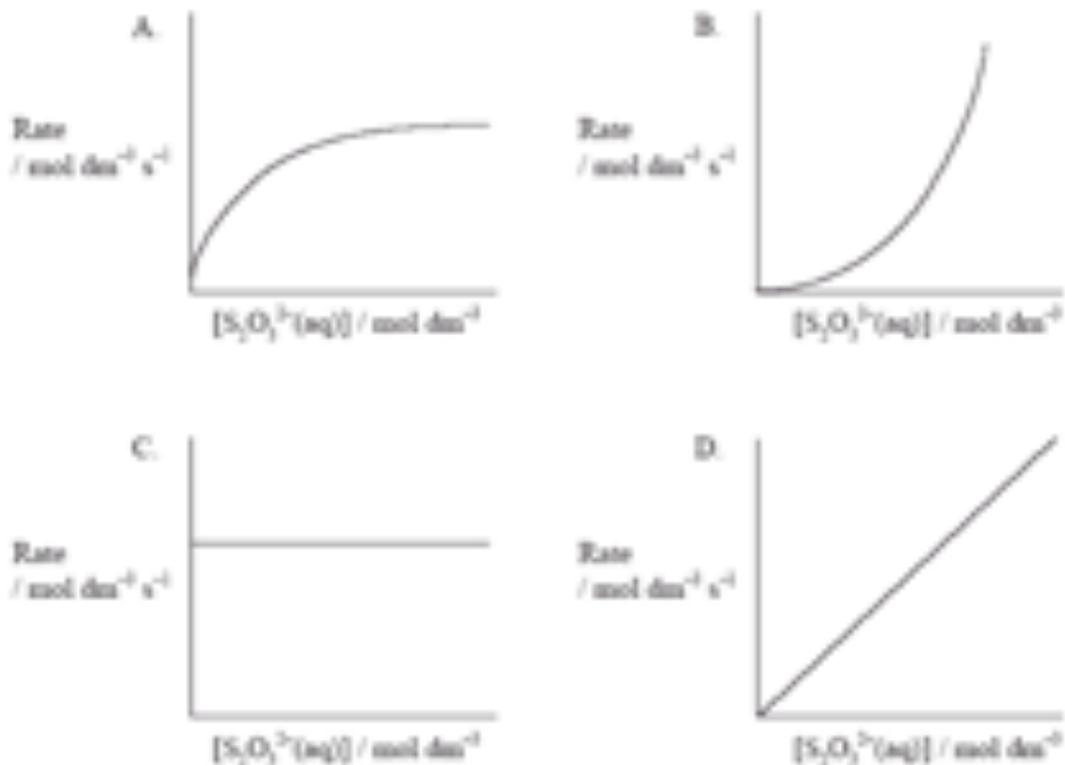
7. Sodium thiosulfate solution,  $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ , and hydrochloric acid,  $\text{HCl}(\text{aq})$ , react spontaneously to produce solid sulfur,  $\text{S}(\text{s})$ , according to the equation below.



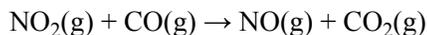
A student experimentally determined the rate expression to be:

$$\text{rate} = k[\text{S}_2\text{O}_3^{2-}(\text{aq})]^2$$

Which graph is consistent with this information?



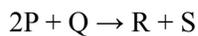
8. Consider the following reaction.



At  $T < 227^\circ\text{C}$  the rate expression is  $\text{rate} = k[\text{NO}_2]^2$ . Which of the following mechanisms is consistent with this rate expression?

- A.  $\text{NO}_2 + \text{NO}_2 \rightleftharpoons \text{N}_2\text{O}_4$       *fast*  
 $\text{N}_2\text{O}_4 + 2\text{CO} \rightarrow 2\text{NO} + 2\text{CO}_2$       *slow*
- B.  $\text{NO}_2 + \text{CO} \rightarrow \text{NO} + \text{CO}_2$       *slow*
- C.  $\text{NO}_2 \rightarrow \text{NO} + \text{O}$       *slow*  
 $\text{CO} + \text{O} \rightarrow \text{CO}_2$       *fast*
- D.  $\text{NO}_2 + \text{NO}_2 \rightarrow \text{NO}_3 + \text{NO}$       *slow*  
 $\text{NO}_3 + \text{CO} \rightarrow \text{NO}_2 + \text{CO}_2$       *fast*

9. Consider the following reaction.

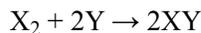


This reaction occurs according to the following mechanism.



What is the rate expression?

- A.  $\text{rate} = k[P]$                       C.  $\text{rate} = k[P][Q]$   
B.  $\text{rate} = k[P][X]$                   D.  $\text{rate} = k[P]^2[Q]$
10. What happens when the temperature of a reaction increases?
- A. The activation energy increases.                      C. The enthalpy change increases.  
B. The rate constant increases.                              D. The order of the reaction increases.
11. This question refers to the following reaction.

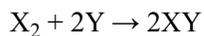


The reaction occurs in a series of steps.



What is the rate-determining step for this reaction mechanism?

- A.  $X_2 + 2Y \rightarrow 2XY$                       C.  $X_2 \rightarrow 2X$   
B.  $X_2 + Y \rightarrow XY + X$                       D.  $X + Y \rightarrow XY$
12. This question refers to the following reaction.



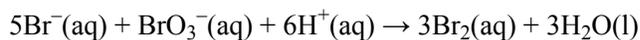
The reaction occurs in a series of steps.



What is the rate expression for this reaction?

- A.  $\text{rate} = k[XY]$                               C.  $\text{rate} = k[X_2]$   
B.  $\text{rate} = k[X_2][Y]^2$                       D.  $\text{rate} = k[2X]$

13. Consider the following reaction.



The rate expression for the reaction is found to be:

$$\text{rate} = k[\text{Br}^-][\text{BrO}_3^-][\text{H}^+]^2$$

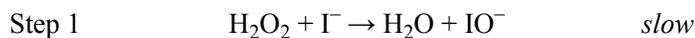
Which statement is correct?

- A. The overall order is 12.
  - B. Doubling the concentration of all of the reactants at the same time would increase the rate of the reaction by a factor of 16.
  - C. The units of the rate constant,  $k$ , are  $\text{mol dm}^{-3} \text{s}^{-1}$ .
  - D. A change in concentration of  $\text{Br}^-$  or  $\text{BrO}_3^-$  does not affect the rate of the reaction.
14. The rate expression for a reaction is:

$$\text{rate} = k [\text{X}][\text{Y}]$$

Which statement is correct?

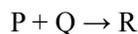
- A. As the temperature increases the rate constant decreases.
  - B. The rate constant increases with increased temperature but eventually reaches a constant value.
  - C. As the temperature increases the rate constant increases.
  - D. The rate constant is not affected by a change in temperature.
15. Consider the following reaction mechanism.



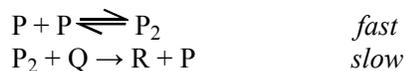
Which statement correctly identifies the rate-determining step and the explanation?

- A. Step 2 because it is the faster step
- B. Step 1 because it is the slower step
- C. Step 1 because it is the first step
- D. Step 2 because it is the last step

16. Two species, P and Q, react together according to the following equation.



The accepted mechanism for this reaction is



What is the order with respect to P and Q?

	<b>P</b>	<b>Q</b>
A.	1	1
B.	1	2
C.	2	1
D.	2	2

17. The activation energy of a reaction may be determined by studying the effect of a particular variable on the reaction rate. Which variable must be changed?

- A. pH
- B. Concentration
- C. Surface area
- D. Temperature

18. What is the order of reaction with respect to  $\text{NO}_2(\text{g})$  and  $\text{F}_2(\text{g})$  given the following rate data at a certain temperature?

$[\text{NO}_2(\text{g})] / \text{mol dm}^{-3}$	$[\text{F}_2(\text{g})] / \text{mol dm}^{-3}$	Rate / $\text{mol dm}^{-3} \text{min}^{-1}$
0.1	0.2	0.1
0.2	0.2	0.4
0.1	0.4	0.2

	<b>Order with respect to <math>\text{NO}_2(\text{g})</math></b>	<b>Order with respect to <math>\text{F}_2(\text{g})</math></b>
A.	first	first
B.	first	second
C.	second	first
D.	second	second