**Differential Rate Laws**

One factor that affects rates of reactions is **concentration of reactants**. With higher concentrations of reactants, the **frequency of collisions** between particles will increase and this results in a greater number of **successful (effective) collisions**. The rate of the reaction increases. The **differential rate law** is the mathematical statement of this concept. A chemist was studying the kinetics of the following reaction. She collected the data in the table with experiments at 40°C.

2 NO2 *(g)* + O3 *(g) →* N2O5 *(g)* + O2 *(g)*

|  |  |  |  |
| --- | --- | --- | --- |
| Trial | Initial  [NO2], M | Initial  [O3], M | Initial Rate of Formation  of N2O5, Ms-1 |
| 1 | 0.060 | 0.040 | 2.60 x 10-4 |
| 2 | 0.12 | 0.040 | 5.21 x 10-4 |
| 3 | 0.060 | 0.080 | 1.03 x 10-3 |
| 4 | 0.050 | 0.050 | ? |

The **rate law** for the reaction is:

Rate = k[NO2]m[O3]n

* 1. Determine the **order** for NO2.

* 1. Determine the **order** for O3.

* 1. Calculate the **rate constant** at 40°C.

Include appropriate units.

* 1. Calculate the **initial rate** for trial 4.

* 1. Notice that she was measuring the rate of formation of N2O5. What was the **rate of disappearance of NO2** **in trial 1**? Explain.

1. Given the data below collected at 200°C, answer the questions that follow for the reaction:

2 NO *(g)* + Cl2 *(g)*  2 NOCl *(g)*

|  |  |  |  |
| --- | --- | --- | --- |
| Trial | [NO]0, M | [Cl2]0, M | Initial Rate of disappearance of Cl2, M/min |
| 1 | 0.0400 | 0.0100 | 3.61 x 10-3 |
| 2 | 0.0200 | 0.0100 | 9.04 x 10-4 |
| 3 | 0.0200 | 0.0400 | 3.59 x 10-3 |

* 1. Write a **rate law** for this reaction.

* 1. Determine the **order** of reaction with

respect to NO.

* 1. Determine the **order** of reaction with

respect to Cl2.

* 1. Calculate the value of the **rate constant** at 200°C. Specify its units.

* 1. What is the **overall order** of the reaction?
  2. What would be the effect on the initial rate of reaction if …

i) [NO] is tripled

ii) [Cl2] is halved

iii) Both [NO] and [Cl2] are doubled

3) Given the following data collected at 20°C:

|  |  |  |  |
| --- | --- | --- | --- |
| Trial | Initial  [NH4+], M | Initial  [NO2-], M | Initial Rate of  Disappearance of  NO2-, mol/L·min |
| 1 | 0.010 | 0.020 | 0.0020 |
| 2 | 0.010 | 0.010 | 0.0010 |
| 3 | 0.015 | 0.020 | 0.0030 |
| 4 | 0.020 | ? | 0.0060 |

NH4+ *(aq)* + NO2- *(aq)*  N2 *(g)* + 2 H2O *(l)*

1. Write a **rate law** for the reaction.

1. What is the **order** of reaction for NH4+?

1. What is the **order** of reaction for NO2-?

1. What is the **overall order** of the reaction?

1. Calculate the value of the **rate constant** at 20°C. Include its units.

1. Calculate the **initial [NO2-]** in trial 4.

1. What was the rate of disappearance of NH4+ in trial 1? Explain.

1. What would be the effect on the initial rate of reaction of …

i) Halving the [NH4+]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Trial | Initial  [BrO3-],  M | Initial [Br-], M | Initial  [H+], M | Initial Rate of  disappearance of BrO3-, mol/L·min |
| 1 | 0.10 | 0.10 | 0.10 | 8.0 x 10-4 |
| 2 | 0.20 | 0.10 | 0.10 | 1.6 x 10-3 |
| 3 | 0.20 | 0.20 | 0.10 | 3.2 x 10-3 |
| 4 | 0.10 | 0.10 | 0.20 | 3.2 x 10-3 |

ii) Tripling [NO2-]

iii) Doubling [NH4+] while halving [NO2-]

4) The hypochlorite ion reacts with iodide ions as shown below. Use the initial rates data (collected at 22°C) to answer the questions that follow.

OCl- *(aq)* + I- *(aq)*  OI- *(aq)* + Cl- *(aq)*

|  |  |  |  |
| --- | --- | --- | --- |
| Trial | [OCl-]0, M | [I-]0, M | Initial Rate of Reaction, mol/L·s |
| 1 | 0.00400 | 0.00200 | 0.0186 |
| 2 | 0.00100 | 0.00400 | 0.00234 |
| 3 | 0.00200 | 0.00200 | 0.00461 |
| 4 | ? | 0.00300 | 0.0624 |

1. Write a **rate law** for the reaction.

1. What is the **order** for OCl-?

1. What is the **order** for I-?

1. Calculate the **rate constant** at 22°C.

Include its units.

1. Calculate **[OCl-]** in trial 4.

1. What would be the effect on the initial rate of …
2. Doubling the iodide concentration
3. Quadrupling the hypochlorite concentration
4. Doubling the hypochlorite while

halving the iodide concentration.

5) Bromine can be formed by the following reaction. The data below was collected in a kinetics experiment at 20°C.

BrO3-*(aq)* + 5 Br-*(aq)* + 6 H+*(aq)*  3 Br2*(aq)* + 3 H2O*(l)*

1. Write a **rate law** for the reaction.

1. Determine the **order** for BrO3-.

1. Determine the **order** for Br-.

1. Determine the **order** for H+.

1. What is the **overall order** of the reaction?

1. Rewrite the **rate law**, including the

calculated orders.

1. Calculate the value of the **rate constant** at 20°C. Include its units.

1. What is the effect on the initial rate of reaction of … i) Double [BrO3-]

ii) Triple [Br-]

iii) Halve [H+]

iv) Triple [BrO3-] while double [Br-] & [H+]

6. Acetaldehyde decomposes slowly at room temperature, producing methane and carbon monoxide gases. CH3CHO (g)  CH4 (g) + CO (g)

|  |  |  |
| --- | --- | --- |
| Trial | [CH3CHO]0, M | Initial Rate of Disappearance of CH3CHO, mol L-1 s-1 |
| 1 | 1.75 x 10-3 | 2.06 x 10-11 |
| 2 | 3.50 x 10-3 | 8.24 x 10-11 |
| 3 | 7.00 x 10-3 | ? |

* 1. Write a **rate law** for the decomposition reaction.

b) What is the **order of reaction** for the acetaldehyde? EXPLAIN … do not calculate.

c) Verify your answer to (b) with a calculation.

d) Calculate the value of the **rate constant** at room temperature. Include appropriate units.

e) Calculate the **rate of reaction** in trial 3.

f) Use two unit multipliers to express the rate constant as “M-1h-1”.

7. Given the data in the table below, deduce the rate law “mentally “ ( multiple choice)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Trial | [A]0, M | [B]0, M | [C]0, M | Initial Rate of  Reaction, M/min |
| 1 | 0.40 | 0.20 | 0.10 | 0.060 |
| 2 | 0.20 | 0.20 | 0.10 | 0.030 |
| 3 | 0.20 | 0.60 | 0.10 | 0.030 |
| 4 | 0.40 | 0.20 | 0.20 | 0.24 |

a) Rate = k[A][B][C]

* 1. Rate = k[A]2[C]
  2. Rate = k[A][B][C]2
  3. Rate = k[A][C]2

”.

8. The reaction, 2A + 3B  C + 2D, is first order in

A and second order in B. Its rate law is …

a) Rate = k[A][B]

b) Rate = k[A]2[B]3

c) Rate = k[A]2[B]

d) Rate = k[A][B]2

9. For the reaction 2 A + B  C, which statement below is correct?

1. The rates of disappearance of A and of B are equal
2. The rate of disappearance of B is half the rate of appearance of C
3. The rate of disappearance of A is twice the rate of disappearance of B
4. The rate of appearance of C is twice the

rate of disappearance of A

10. If the rate of formation of ammonia is 0.36

M/s, what is **the rate of disappearance of N2**?

N2 + 3 H2  2 NH3

a) 0.18 M/s

b) 0.24 M/s

c) 0.36 M/s

d) 0.72 M/s

1. If the rate of disappearance of H2 is 0.60 M/s, what is **the rate of appearance of NH3**?

N2 + 3 H2 → 2 NH3

1. 0.20 M/s
2. 0.30 M/s
3. 0.40 M
4. 0.90 M

12. The rate of a reaction is 4x faster when the concentration of a reactant doubles. The

## **order** for this reactant is …

a) 0 b) 1 c) 2 d) 3

1. Which statement(s) below is/are **true** if a reactant is **zero-order** …

* + 1. Changing the concentration of that reactant will have no effect on the rate
    2. That reactant is likely not found in the

rate-determining step of the reaction

* + 1. The concentration of that reactant doesn’t

change during the reaction

* 1. Only (i) is true
  2. Only (ii) is true
  3. Both (i) and (ii) are true
  4. All three statements are true

1. Given the rate law below, which units are possible for the **rate constant**?

Rate = k[A]2[B]1[C]0

* 1. L2/mol2·min
  2. L2/mol2·s2

# c) L3/mol3·s

# d) L3/mol3·min3