UNIT TEST 1 – REACTION KINETICS

CHALLENGER QUESTION **54.3**

1. Which of the following reactions would have the greatest reaction rate at room temperature?

   A. $C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$

   B. $Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$

   C. $AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

   D. $Na_2CO_{3(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

2. Consider the following reaction:

   $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)} \qquad \Delta H = -114\,kJ$

   How could the rate of this reaction be increased?

   A. Reduce the pressure.

   B. Increase the volume.

   C. Remove some $NO_{2(g)}$.

   D. Increase the temperature.

3. An activated complex can be described as

   A. a particle of maximum KE and minimum PE

   B. a stable particle found in a reaction mechanism

   C. an unstable particle that is neither reactant nor product

   D. a particle which is first used then regenerated in a reaction mechanism

4. Which of the following could result in an increase in reaction rate?

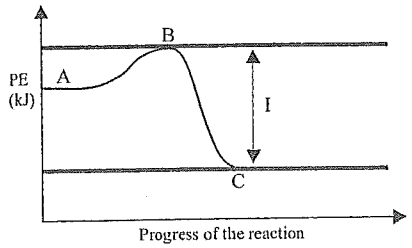
   A. an increase in the activation energy

   B. an increase in the reaction enthalpy

   C. an increase in the frequency of collisions

   D. an increase in the potential energy of the activated complex

5. Consider the following PE diagram:



   Which of the following describes the energy value indicated by **I**?

   A. heat of reaction

   B. activation energy for the reverse reaction

   C. activation energy for the forward reaction

   D. potential energy of the reaction intermediate

6. Consider the following reaction mechanism and overall reaction:

$$\frac{1}{2}O_{2(g)} + NO_{(g)} \rightarrow NO_{2(g)}$$

$$NO_{2(g)} \xrightarrow{\text{sunlight}} NO_{(g)} + O_{(g)}$$

$$O_{(g)} + O_{2(g)} \rightarrow O_{3(g)}$$

$$\frac{3}{2}O_{2(g)} \rightarrow O_{3(g)}$$

   What is the catalyst in this mechanism?

   A. $O_{(g)}$ **B.** $NO_{(g)}$

   C. $NO_{2(g)}$ **D.** sunlight

7. Which of the following could represent the units for reaction rate?

A. g/Ml

B. g/min

C. g/mol

D. mol/L

8. Consider the following reaction:

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

Which of the following would increase the reaction rate?

A. an increase in pressure

B. an increase in temperature

C. an increase in the concentration of H_2

D. an increase in the concentration of $ZnCl_2$

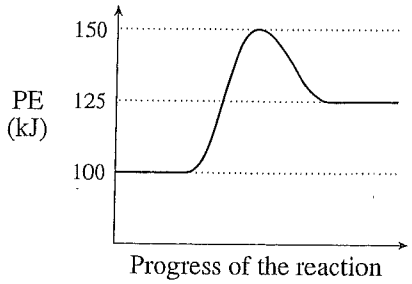
9. Consider the following reaction:

$H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$

Which of the following is true of the activated complex relative to the reactants?

	KE	Stability
A.	high	stable
B.	low	stable
C.	high	unstable
D.	low	unstable

10. Consider the following PE diagram:



Which of the following is true for the forward reaction?

	ΔH (kJ)	PE of Activated Complex (kJ)
A.	–25	50
B.	–25	150
C.	+25	50
D.	+25	150

11. Which of the following could describe a catalyst?

A. A substance that increases the reaction time.

B. A substance that provides an alternate mechanism with a higher activation energy.

C. A substance that is formed in one step and used up in a subsequent step in a reaction mechanism.

D. A substance that is used up in one step and reformed in a subsequent step in a reaction mechanism.

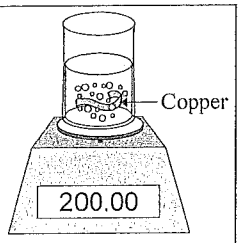
Written Response

1. Consider the following reaction:

$$3Cu_{(s)} + 8HNO_{3(aq)} \rightarrow 3Cu(NO_3)_{2(aq)} + 2NO_{(g)} + 4H_2O_{(l)}$$

A piece of copper is added to a nitric acid solution in an open beaker, allowing the $NO_{(g)}$ to escape. The following data was obtained:

Time (min.)	Mass of beaker and contents (g)
0.0	200.00
1.0	197.50
2.0	195.45
3.0	193.55
4.0	191.70
5.0	189.90
6.0	188.15
7.0	186.45
8.0	184.80



a) Calculate the reaction rate for the time period 2.0 to 6.0 min. **(2 marks)**

b) Calculate the mass of copper consumed in the first 5 minutes. **(3 marks)**

2. Using collision theory, explain why reactions between two solutions occur more rapidly than reactions between two solids. **(2 marks)**

3. Consider the following reaction in an open flask. **(3 marks)**

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

A 155.0 g sample of $CaCO_{3(s)}$ is placed in the flask and $HCl_{(aq)}$ is added. The reaction consumes $HCl_{(aq)}$ at an average rate of 0.200 mol/min for 10.0 min. What mass of $CaCO_{3(s)}$ remains?

4. **a)** Write the equation for Step 3 in the following reaction mechanism. **(1 mark)**

Step 1	$2NO \rightarrow N_2O_2$
Step 2	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$
Step 3	?
Overall Reaction	$2NO + 2H_2 \rightarrow N_2 + 2H_2O$

b) Identify a reaction intermediate in the above mechanism. **(1 mark)**

5. When solid sodium is placed in water at room temperature, an immediate, violent reaction occurs:

$$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)} + \text{energy}$$

a) Describe two methods that could be used to experimentally determine the rate of reaction. **(2 marks)**

Method 1: _____

Method 2: _____

b) Would you expect the activation energy of this reaction to be high or low? Explain, using collision theory. **(2 marks)**

ANSWERS AND SOLUTIONS
UNIT TEST 1 – REACTION KINETICS

1. C	4. C	7. B	10. D	WR1–5. See Solution
2. D	5. B	8. B	11. D	
3. C	6. B	9. D		

1. C

Surface area is the reason. The $AgNO_{3(aq)}$ and $NaCl_{(aq)}$ are completely dissociated into aqueous ions in solution. These are tiny particles, and they are present in a homogeneous medium.

2. D

Increasing the temperature will increase the number of successful collisions and thus increase the rate of all chemical reactions. Reducing pressure or increasing volume (choices A and B) would, in effect, lower the concentration and thus reduce the reaction rate. Removing some $NO_{2(g)}$ for a reaction which goes to completion will have no appreciable effect.

3. C

The activated complex is, by definition, an unstable complex containing partially broken and partially formed bonds. It has the most PE of any species in the reaction mechanism. It is neither reactant nor product.

4. C

An increase in frequency of successful collisions will increase reaction rate.

5. B

Reactants are present at A, activated complex at B, and products at C. The activation energy for the **reverse** reaction is the difference in energy between C and B.

6. B

A catalyst will not be consumed in a chemical reaction. It will be added in the initial step and produced in a later step. $NO_{(g)}$ fits these criteria.

7. B

A reaction rate must have units of change in quantity per unit time or mass per unit time or concentration per unit time.

8. B

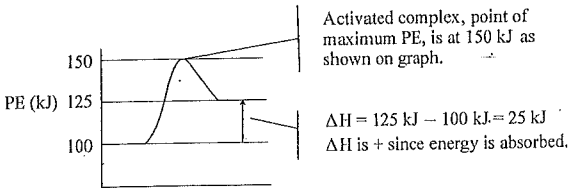
When temperature is increased, particles of matter have a greater kinetic energy leading to more successful collisions and a greater reaction rate.

9. D

The activated complex is an unstable intermediate with a great deal of potential energy. The kinetic energy of the reactants and their former chemical potential energy has been converted to chemical potential energy of the activated complex.

10. D

The reasoning is shown in the diagram:



11. D

A catalyst is not consumed in a chemical reaction. The catalyst provides an alternate reaction pathway, forming an activated complex of lower PE, and it is produced again later in another reaction step.

Written Response

1. *Consider the following reaction:*

$3Cu_{(s)} + 8HNO_{3(aq)} \rightarrow$

$3Cu(NO_3)_{2(aq)} + 2NO_{(g)} + 4H_2O_{(l)}$

A piece of copper is added to a nitric acid solution in an open beaker, allowing the $NO_{(g)}$ *to escape. The following data was obtained:*

a) *Calculate the reaction rate for the time period 2.0 to 6.0 min.* **(2 marks)**

Solution:

$$\text{rate} = \frac{\text{mass change}}{\text{time change}} = \frac{195.45\,\text{g} - 188.15\,\text{g}}{(6.0 - 2.0)\,\text{min}}$$

$$= \frac{7.30\,\text{g}}{4.0\,\text{min}}$$

$$= 1.8\,\text{g/min NO produced}$$

(Deduct $\frac{1}{2}$ mark for incorrect significant figures.)

b) *Calculate the mass of copper consumed in the first 5 minutes.* **(3 marks)**

Solution:

moles NO produced

$$= \frac{200.00\,\text{g} - 189.90\,\text{g}}{30.0\,\text{g/mol}}$$

$$= 0.3367\,\text{mol NO}$$

} ← **1 mark**

moles Cu consumed

$$= 0.3367\,\text{mol NO} \times \frac{3\,\text{mol Cu}}{2\,\text{mol NO}}$$

$$= 0.5050\,\text{mol Cu}$$

} ← **1 mark**

mass Cu consumed

$$= 0.5050\,\text{mol Cu} \times \frac{63.5\,\text{g Cu}}{1\,\text{mol Cu}}$$

$$= 32.1\,\text{g Cu}$$

} ← **1 mark**

2. *Using collision theory, explain why reactions between two solutions occur more rapidly than reactions between two solids.* **(2 marks)**

Solution:

- Particles must be able to collide to react.
- Only the particles on the surface of a solid are available for reaction. In a solution, all particles are available.

← **2 marks**

3. *Consider the following reaction in an open flask:* **(3 marks)**

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

A 155.0 g sample of $CaCO_{3(s)}$ is placed in the flask and $HCl_{(aq)}$ is added. The reaction consumes $HCl_{(aq)}$ at an average rate of 0.200 mol/min for 10.0 min. What mass of $CaCO_{3(s)}$ remains?

Solution:

For Example:

Amount of HCl reacting ← $\frac{1}{2}$ **mark**

$= 0.200\text{mol/min} \times 10.0\text{ min}$

$= 2.00\text{mol}$

Moles of $CaCO_3$ reacting ← $\frac{1}{2}$ **mark**

$$= 2.00\,\text{mol HCl} \times \frac{1\,CaCO_3}{2\,HCl}$$

$$= 1.00\,\text{mol}\,CaCO_3$$

Mass of $CaCO_3$ reacting ←**1 mark**

$$= 1.00\,\text{mol}\,CaCO_3 \times \frac{100.1\,\text{g}}{1\,\text{mol}}$$

$$= 1.00 \times 10^2\,\text{g}$$

Mass remaining $= 155.0\,\text{g} - 100\,\text{g}$ ←**1 mark**

$= 55\,\text{g}$

4. a) *Write the equation for Step 3 in the following reaction mechanism.* **(1 mark)**

Step 1	$2NO \rightarrow N_2O_2$
Step 2	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$
Step 3	**?**
Overall Reaction	$2NO + 2H_2 \rightarrow N_2 + 2H_2O$

Solution:

Step 3:

$N_2O + H_2 \rightarrow N_2 + H_2O$ **(1 mark)**

b) *Identify a reaction intermediate in the above mechanism.* **(1 mark)**

Solution:

Either N_2O_2 **OR** N_2O **(1 mark)**

5. a) *Describe two methods that could be used to experimentally determine the rate of reaction.* **(2 marks)**

For Example:

Any two of the following per unit time:

- Δ mass Na
- Δ volume H_2
- Δ temperature
- Δ pH
- Δ pressure

b) *Would you expect the activation energy of this reaction to be high or low? Explain, using collision theory.* **(2 marks)**

For Example:

The reaction is very fast so many collisions at room temperature would have the needed energy to be successful. The activation energy of this reaction would be low.