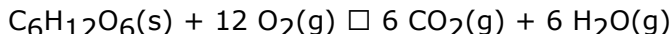


1. Consider the reaction below:



Which of the following is an incorrect expression of the rate?

1. rate = $(\Delta[\text{H}_2\text{O}] / 6 \cdot \Delta t)$
2. rate = $-(\Delta[\text{O}_2] / 12 \cdot \Delta t)$
3. rate = $(\Delta[\text{CO}_2] / 6 \cdot \Delta t)$
4. rate = $-(\Delta[\text{C}_6\text{H}_{12}\text{O}_6] / \Delta t)$ **Correct**

Explanation: rate = $-(\Delta[\text{O}_2] / 12 \cdot \Delta t) = (\Delta[\text{CO}_2] / 6 \cdot \Delta t) = (\Delta[\text{H}_2\text{O}] / 6 \cdot \Delta t)$

2. The overall reaction



Has an empirically determined rate law, rate = $k \cdot [\text{NO}_2]^2 \cdot [\text{Br}_2] \cdot [\text{O}_2]^{-1}$.

If $k = 3.0 \times 10^4 \text{ M}^{-1} \cdot \text{s}^{-1}$, $[\text{NO}_2] = 0.01 \text{ M}$, $[\text{Br}_2] = 0.02 \text{ M}$ and $[\text{O}_2] = 0.01 \text{ M}$, what is the observed rate?

1. $0.3 \text{ M} \cdot \text{s}^{-1}$
2. $0.0006 \text{ M} \cdot \text{s}^{-1}$
3. $300 \text{ M} \cdot \text{s}^{-1}$
4. $6.0 \text{ M} \cdot \text{s}^{-1}$ **Correct**

Explanation: rate = $k \cdot [\text{NO}_2]^2 \cdot [\text{Br}_2] \cdot [\text{O}_2]^{-1}$

$$= (3.0 \times 10^4 \text{ M}^{-1} \cdot \text{s}^{-1}) \cdot (0.01 \text{ M})^2 \cdot (0.02 \text{ M}) \cdot (0.01 \text{ M})^{-1}$$
$$= 6.0 \text{ M} \cdot \text{s}^{-1}$$

3. Consider the rate constants below:

- I. $k = 7.45 \times 10^{-2} \text{ M}^{-2} \cdot \text{s}^{-1}$
- II. $k = 1.79 \times 10^{-2} \text{ M}^3 \cdot \text{s}^{-1}$
- III. $k = 4.77 \times 10^{-2} \text{ M}^1 \cdot \text{s}^{-1}$

Which response arranges them from lowest to highest order.

1. III, II, I
2. I, II, III
3. I, III, II
4. II, I, III
5. II, III, I **Correct**
6. III, I, II

Explanation: $k = 1.79 \times 10^{-2} \text{ M}^3 \cdot \text{s}^{-1}$ would correspond to a negative 2nd order reaction. $k = 4.77 \times 10^{-2} \text{ M}^1 \cdot \text{s}^{-1}$ would correspond to a 0 order reaction. $k = 7.45 \times 10^{-2} \text{ M}^{-2} \cdot \text{s}^{-1}$ would correspond to a 3rd order reaction.

4. Consider the data below:

Experiment number	[A] M	[B] M	[C] M	[D] M	initial rate $\text{M} \cdot \text{s}^{-1}$
1	0.42	0.5	1.12	2.01	1.06×10^{-6}
2	0.84	0.5	1.12	2.01	2.12×10^{-6}
3	0.75	0.25	1.12	2.01	1.89×10^{-6}
4	1.23	0.93	0.97	2.01	3.58×10^{-6}
5	0.21	1.35	0.56	5.53	8.02×10^{-6}

What is the overall order of this reaction?

1. 1
2. 2 **Correct**
3. 3

4. 4

Explanation:

The most obvious order to solve for first is the order A. This is because A is the only species for which two experiments were performed in which it was the only species whose concentration was changed. The order of A is 1, as shown below.

$$(\text{rate}_1 / \text{rate}_2) = ([A]_1 / [A]_2)^a$$

$$(1.06 \times 10^{-6} / 2.12 \times 10^{-6}) = (0.42 / 0.84)^a$$

$$(1/2) = (1/2)^a$$

$$a = 1$$

Next we can solve for the order of B, by making use of knowing the order of A.

$$(\text{rate}_1 / \text{rate}_3) = ([A]_1 / [A]_3) ([B]_1 / [B]_3)^b$$

$$(1.06 \times 10^{-6} / 1.89 \times 10^{-6}) = (0.42 / 0.75) (0.5 / 0.25)^b$$

$$0.56 = (0.56) (0.5 / 0.25)^b$$

$$b = 0$$

Now we know we can ignore B for the rest of the work.

$$(\text{rate}_1 / \text{rate}_5) = ([A]_1 / [A]_5) ([C]_1 / [C]_5)^{-1} ([D]_1 / [D]_5)^{-1}$$

$$(1.06 \times 10^{-6} / 3.58 \times 10^{-6}) = (0.42 / 0.21) (1.12 / 0.56)^{-1}$$

$$0.296 = (0.341) (1.12 / 0.97)^c$$

$$0.867 = (1.15)^c$$

$$\log 0.867 = c \log 1.15$$

$$-0.06 = c 0.06$$

$$c = -1$$

Lastly we can solve for the order of D.

$$(\text{rate}_1 / \text{rate}_5) = ([A]_1 / [A]_5) ([C]_1 / [C]_5)^{-1} ([D]_1 / [D]_5)^d$$

$$(1.06 \times 10^{-6} / 8.02 \times 10^{-6}) = (0.42 / 0.21) (1.12 / 0.56)^{-1} (2.01 / 5.53)^d$$

$$0.132 = (2) (2)^{-1} (0.363)^d$$

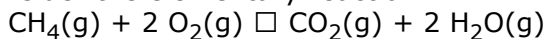
$$\log 0.132 = d \log 0.363$$

$$-0.88 = d -0.44$$

$$d = 2$$

The overall order is 2.

5. Consider the elementary reaction:



If $k = 9.7 \times 10^6 \text{ M}^{-1} \cdot \text{hr}^{-1}$, and there is initially $0.014 \text{ M H}_2\text{O}$, how long will it take for the H_2O concentration to reach 7.95 M ?

1. 36 ms

2. 22 ms

3. 13 ms **Correct**

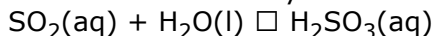
4. 5 ms

Explanation: $(1/[\text{H}_2\text{O}]) = (1/[\text{H}_2\text{O}]_0) - 2kt$

$$(1/7.95) = (1/0.014) - 2(9.7 \times 10^6 \text{ M}^{-1} \cdot \text{hr}^{-1})(t)$$

$$t = 0.0000036 \text{ hours} = 13 \text{ ms}$$

6. Consider the elementary reaction:



If $k = 1.21 \times 10^{-4} \text{ M}^{-1} \cdot \text{s}^{-1}$, and there is initially 2.3 M of SO_2 , what is the half life of the reaction?

1. 1.0 hr **Correct**

2. 1.6 hr

3. 2.6 hr

4. not enough information

Explanation: $t_{1/2} = 1 / [\text{SO}_2]k$

$$= 1 / 1.19 \times 10^{-4} \text{ M}^{-1} \cdot \text{s}^{-1} \cdot 2.3 \text{ M}$$

$$= 3,593 \text{ sec}$$

7. A student studying the kinetics of a reaction finds that the natural log of some concentration data produces a straight line when plotted as a function of time. What is the order of the reaction?

1. 0th order
2. 1st order **Correct**
3. 2nd order
4. not enough information

Explanation: First order reactions exhibit a log-linear relationship between elapsed time and the concentration of reactants or products.

8. Collision theory predicts that
 1. raising a system's temperature will accelerate any reactions. **Correct**
 2. reaction intermediates are short-lived.
 3. activation energy has no effect on reaction rate.
 4. all collisions are productive.

Explanation: Collision theory states that molecules must collide with sufficient energy and correct orientation in order to react and that both the frequency and energy of the collisions is directly proportional to system's temperature.

9. Transition state theory assumes that formation of the transition state is (reversible/irreversible) and (does/doesn't) require a minimum amount of energy.
 1. irreversible, does
 2. reversible, doesn't
 3. reversible, does **Correct**
 4. reversible, doesn't

Explanation: TST states that a reactant (or set of reactants) must achieve their transition state (also called activated complex) before forming products. The transition state is inherently short-lived as it is in quasi-equilibrium with the reactant(s) ground state and either rapidly decays back to the ground state or goes on to form products (this is treated as irreversible for the purposes of TST).

10. What is the activation energy for a reaction that has a rate constant (k) of magnitude 4.03×10^5 and a pre-exponential factor (A) of 10^6 ?
 1. $2.25 \text{ kJ}\cdot\text{mol}^{-1}$ **Correct**
 2. $2.25 \text{ J}\cdot\text{mol}^{-1}$
 3. $2,251 \text{ kJ}\cdot\text{mol}^{-1}$
 4. not enough information

Explanation: $k = A \cdot e^{(-E_a/R \cdot T)}$

$$E_a = -\ln(k/A) \cdot R \cdot T$$

$$= -\ln(4.03 \times 10^5 / 10^6) \cdot R \cdot T$$

$$= 2,251.66 \text{ J}\cdot\text{mol}^{-1}$$

11. What is a reaction's activation energy of raising the temperature from $100 \text{ }^\circ\text{C}$ to $1000 \text{ }^\circ\text{C}$ causes the rate to increase by a factor of 5?
 1. $E_a = 1.2 \text{ kJ}\cdot\text{mol}^{-1}$
 2. $E_a = 1.5 \text{ kJ}\cdot\text{mol}^{-1}$
 3. $E_a = 3.9 \text{ kJ}\cdot\text{mol}^{-1}$
 4. $E_a = 7.1 \text{ kJ}\cdot\text{mol}^{-1}$ **Correct**

Explanation: $\ln(k_2/k_1) = (E_a/R) \cdot (1/T_1 - 1/T_2)$

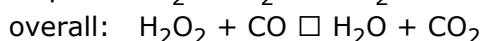
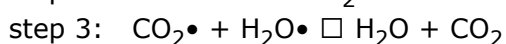
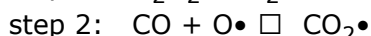
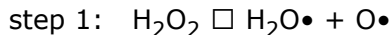
$$E_a = R \cdot \ln(k_2/k_1) / (1/T_1 - 1/T_2)$$

We are told the rate increased by a factor of 5, therefore $k_2/k_1 = 5$

$$E_a = 8.314 \cdot \ln(5) / (1/373 - 1/1273)$$

$$E_a = 7,059 \text{ J}\cdot\text{mol}^{-1} = 7.1 \text{ kJ}\cdot\text{mol}^{-1}$$

12. Consider the reaction mechanism below:



Which step must be the slow step if the reaction is experimentally determined to be 2nd order overall?

1. step 1
2. step 2
3. step 3 **Correct**
4. Any step.

Explanation: If steps 1 or 2 were the rate-determining step, the overall order of the reaction would be 1st order, $\text{rate} = k \cdot [\text{H}_2\text{O}_2]$ and $\text{rate} = k \cdot [\text{H}_2\text{O}_2] \cdot [\text{CO}] \cdot [\text{H}_2\text{O} \bullet]^{-1}$, respectively.

13. Consider the reaction mechanism below:

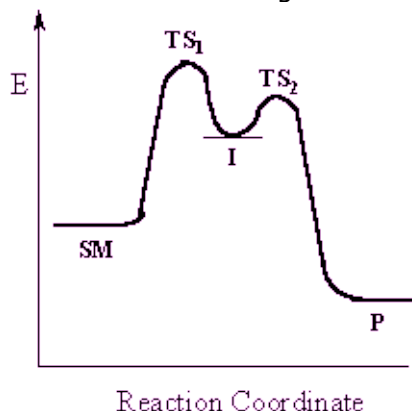
- step 1: $\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2$
step 2: $\text{ClO} + \text{O}_3 \rightarrow \text{Cl} + 2 \text{O}_2$
overall: $2 \text{O}_3 \rightarrow 3 \text{O}_2$

Which species is a catalyst and which is an intermediate, respectively?

1. Cl, ClO **Correct**
2. ClO, Cl
3. O_3 , O_2
4. O_2 , O_3

Explanation: The chlorine radical is consumed in step 1 and then regenerated stoichiometrically in step 2. The hypochlorite radical is generated in step 1 and then consumed stoichiometrically in step 2.

14. Consider the diagram below:



How many steps does this reaction have? Which **reverse** step is the slowest?

1. 1, $\text{P} \rightarrow \text{TS}_2$
2. 1, $\text{P} \rightarrow \text{I}$
3. 2, $\text{P} \rightarrow \text{I}$ **Correct**
4. 3, $\text{I} \rightarrow \text{SM}$
5. 2, $\text{I} \rightarrow \text{TS}_1$

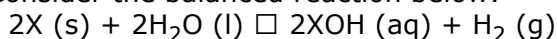
Explanation: There are two steps, as evidenced by the two peaks and two transition states. The energetic barrier separating P and TS₂ is much larger than the barrier between I and TS₁, therefore the $\text{P} \rightarrow \text{I}$ is slower than the $\text{I} \rightarrow \text{SM}$ step.

15. The (chlorine radical/catalytic converter) is a heterogeneous catalyst and (chlorine radical/catalytic converter) acts on only one substrate.

1. catalytic converter, chlorine radical **Correct**
2. catalytic converter, catalytic converter
3. chlorine radical, catalytic converter
4. chlorine radical, chlorine radical

Explanation: The catalytic converter is a solid catalyst that accelerates reactions of gaseous species and it acts on numerous substrates (being composed of numerous catalysts in fact).

16. Consider the balanced reaction below:



The species 'X' would be which of the following?

1. an alkali metal **Correct**
2. an alkaline earth metal

3. a halogen
4. a chalcogen

Explanation: The stoichiometry and (implied) charges on the species in the generic reaction above would all suggest an alkali metal such as potassium for X.

Example: $2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

17. Which of the following **is not** true of alkaline earth metals?

1. React with halogens to form salts
2. Tend to form a +2 charge
3. Somewhat reactive toward water
4. Gain electrons to achieve noble gas configuration **Correct**
5. Have 2 electrons in their highest energy shell

Explanation: Having 2 electrons in their highest energy level makes the alkaline earth metals' shortest path to noble gas configuration the loss of two electrons.

18. Which member of the boron family is a deadly poison

1. Boron (B)
2. Aluminum (Al)
3. Gallium (Ga)
4. Indium (In)
5. Thallium (Tl) **Correct**

Explanation: Thallium is highly toxic and has been used historically in rat poisons and insecticides. Its use for murder has earned it the nicknames "The Poisoner's Poison" and "Inheritance Powder."

19. The nitrogen group contains (1/2) non-metal(s), (1/2) metalloid(s) and (1/2) metal(s). Do not consider the synthetic superheavy element Ununpentium (Uup) in arriving at your answer.

1. 2, 1, 2
2. 1, 2, 2
3. 2, 2, 1 **Correct**
4. 1, 1, 1
5. 2, 2, 2

Explanation: N and P are non-metals, As and Sb are metalloids and Bi is a metal.

20. Which member of the carbon family is most abundant in Earth's crust?

1. Carbon (C)
2. Silicon (Si) **Correct**
3. Germanium (Ge)
4. Tin (Sn)
5. Lead (Pb)

Explanation: Measured by mass, silicon is roughly 25% of the Earth's crust.

21. Which of the following statements **is not** true of the oxygen family?

1. They often have an oxidation number of -2
2. Are good reducing agents **Correct**
3. Contains elements crucial to life
4. Are also called chalcogens

Explanation: Oxygen (and other members) tend to be good oxidizing agents.

22. Which of the following **is not** true of the halogen family?

1. Its members are often found in their pure forms. **Correct**
2. It contains the heaviest element required for life.
3. It contains most of the diatomic elements.
4. Its members are good oxidizing agents.
5. Its name mean salt-forming.

Explanation: The high reactivity of the halogens results in their being found predominantly as their respective anions or oxoanions.

23. Alumina (Al_2O_3) is produced in which of the following processes?

1. Bayer process **Correct**
2. Contact process

- Hall process
- Claus process

Explanation: The Bayer process amounts to the following overall reaction:



24. Which of the following gemstones is/are derived from aluminum oxides?

- Diamond
 - Sapphire
 - Ruby
- I
 - II
 - III
 - I and II
 - I and III
 - II and III **Correct**
 - none

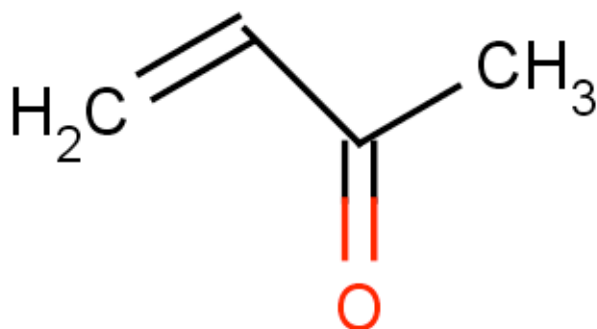
Explanation: Diamond is a covalent network of carbon (one of its allotropes). Sapphire and Ruby are aluminum oxides with trace impurities.

25. How many structural isomers would a hydrocarbon of formula C_5H_{10} have? (Hint: this is an unsaturated hydrocarbon, so its isomers either have one double bond or are cyclical)

- 8 isomers
- 9 isomers
- 10 isomers **Correct**
- 11 isomers
- 12 isomers

Explanation: The formula C_5H_{10} , would describe pent-1-ene, pent-2-ene, 2-methylbut-2-ene, 2-methylbut-1-ene, 3-methylbut-1-ene, cyclopentane, 1-methylcyclobutane, 1-ethylcyclopropane, 1,2-dimethylcyclopropane, bicyclo[1.1.0]butane.

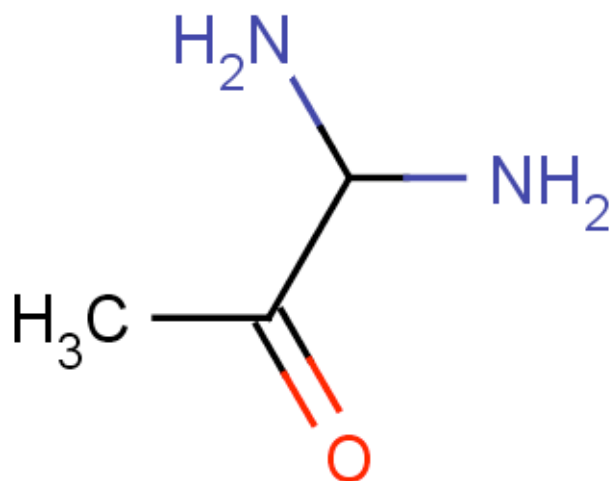
26. What would be the name of the following molecule?



- but-1-en-2-oic acid
- but-1-en-2-one
- but-3-en-2-one **Correct**
- prop-3-en-2-al
- prop-1-en-2-oic acid

Explanation: The ketone group (internal double bonded oxygen) has higher priority than the ene group (double bonded carbons) and so we number the 4 carbon chain (but) to give the ketone group the lower number.

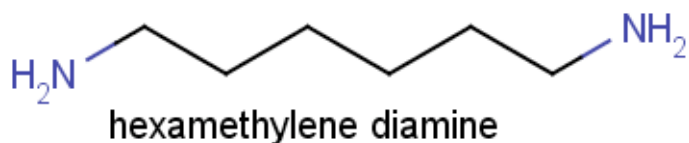
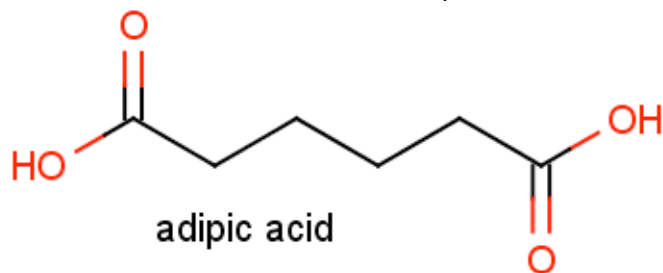
27. What would be the name of the following molecule?



- 1,1-diaminopropan-2-one **Correct**
- 3,3-diaminopropan-2-one
- 1-amino-2-oxopropylamine
- 2-oxopropanimidamide
- 2-oxopropanamineamine

Explanation: The ketone group takes priority and dictates that the suffix be -one. Since it is in the middle of the 3 carbon chain, we begin numbering such that the next highest priority functional group has the lowest number possible (1,1 in this case) and we use its infix -amino rather than its suffix -amine.

28. Condensation polymerization reactions between the following two species produces nylon. What type of bond is formed and what is produced aside from the polymer itself?



- Ester bond, H⁺
- Ester bond, nothing
- Ether bond, H⁺
- Amide bond, NH₂OH
- Ether bond, water
- Amide bond, water **Correct**

Explanation: Elimination of water at the site of the reaction results in an amide bond formed between the carboxyl and amine groups of the two molecules.

29. Which of the following biopolymers is/are formed by condensation reactions?

- I. DNA
- II. Protein
- III. Starch

- 1. I
- 2. II
- 3. III
- 4. I and II
- 5. I and III
- 6. II and III
- 7. I, II and III **Correct**

Explanation: DNA, deoxyribonucleic acid, has phosphodiester linkages between the sugars along the backbone. Protein contains amide bonds between the amino acid residues. Starch (like all polysaccharides) contains ether linkages between the sugars.

30.3 Which two monosaccharides are found in table sugar?

- 1. glucose and fructose **Correct**
- 2. galactose and glucose
- 3. galactose and fructose
- 4. rhamnose and glucose

Explanation: Table sugar is formed by an $\alpha(1\rightarrow2)$ between glucose and fructose.