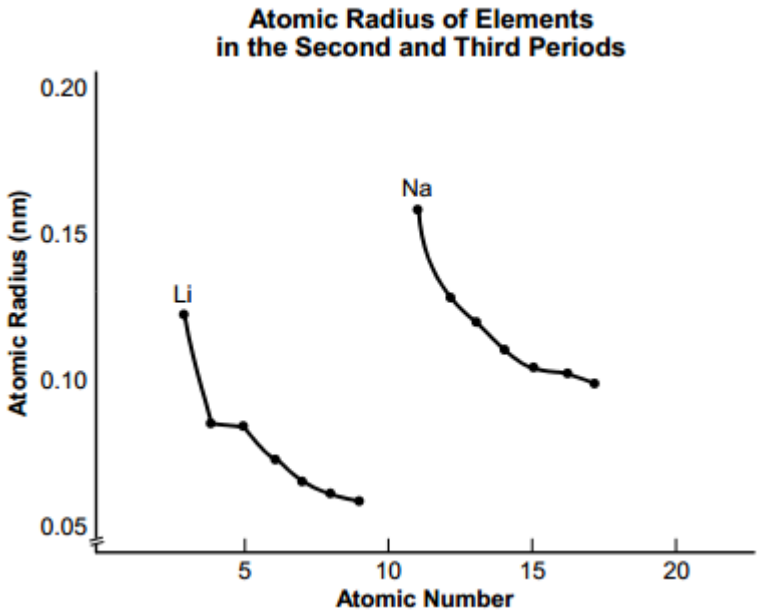
Question Source:

CEOE (Oklahoma) Physical Science Sample Test

Use the graph below to answer the question that follows.



The graph shows the relationship between atomic radius and atomic number for elements in the second and third periods of the periodic table. According to the graph, which of the following statements are true?

1. Within a group, atomic radius tends to decrease as atomic number increases.
2. Within a period, atomic radius tends to decrease as atomic number increases.
3. The largest element in the fourth period is expected to be potassium.
4. Within a period, main group metals tend to be smaller than nonmetals.

a. I and III only

b. I and IV only

c. II and III only

d. III and IV only

Correct Response: C.

In each curve on the graph, the atomic number is increasing in increments of one as the atomic radius decreases. This indicates that each curve represents a period of the periodic table. The second period starts with lithium (Li), which has the largest atomic radius of the elements in the second period. The third period starts with sodium (Na), which has the largest atomic radius of the elements in the third period. Given this trend in the periodic table, the fourth period should start with potassium (K), which will have the largest atomic radius of the elements in the fourth period.

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Which of the following properties is most likely to be associated with nonpolar covalent substances?

a. high freezing point
b. good electrical conduction
c. high boiling point
d. poor thermal conduction

Correct Response: D.

Molecules held together by covalent molecular bonds are formed by the sharing of electrons. In a nonpolar molecule, the electrons are shared equally between the bonding atoms. This equal sharing causes the forces between the molecules of a nonpolar covalent substance to be relatively weak. Weak intermolecular forces result in the poor conduction of thermal energy—the energy of molecular motion—through the substance.

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Use the reaction below to answer the question that follows.

$$2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$$

The chemical equation shown represents the combustion of octane, a component of gasoline. If 114 g of octane are burned in the presence of excess oxygen, how many grams of carbon dioxide will be produced?

a. 44 g

b. 176 g

c. 352 g

d. 912 g

Correct Response: C.

The coefficients of the chemical equation state that for every 2 moles of octane consumed, 16 moles of carbon dioxide will be produced. Since 1 mole of octane has a mass of 8(12 g) + 18(1 g) = 114 g, 1 mole of octane is combining with oxygen and will therefore produce 8 moles of carbon dioxide. The mass of 8 moles of carbon dioxide is 8[1(12 g) + 2(16 g)] = 352 g.

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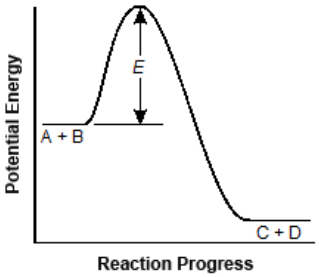
Use the graph below to answer the question that follows.

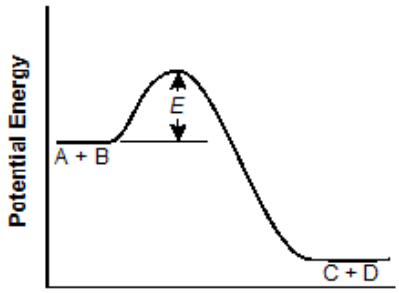


The graph shows the activation energy (*E*) for the following reaction:

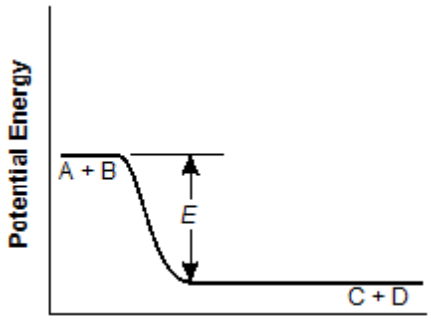
$A + B \longrightarrow C + D$

Which of the following graphs will result if a catalyst is added to the reactants?

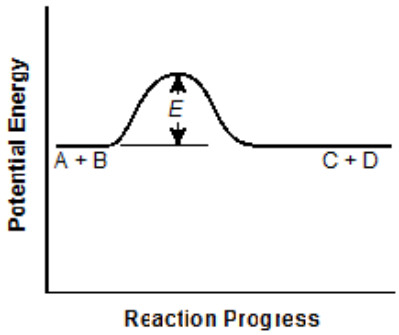
a.



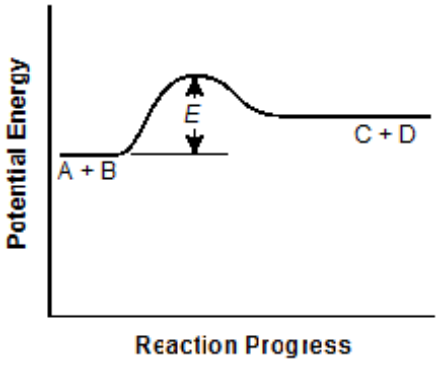
c.



b.



d.



Correct Response: A.

A catalyst increases the reaction rate of a chemical reaction's progress without altering the chemical properties of the reactants or the products. It does this by lowering the activation energy of the reaction. This is reflected in graph A.

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The reaction of a strong acid with a carbonate will result in the formation of a salt plus which of the following?

a. $CO_2 + H_2O$

b. $CO + H_2O$

c. $CO_2 + H_2O_2$

d. $CO + H_2$

Correct Response: A.

When a strong acid reacts with a carbonate, a salt plus carbon dioxide and water are produced. In such a reaction, the acid donates two hydrogen ions (H^+) to the carbonate ion (CO_3^{2-}) to produce carbonic acid (H_2CO_3), which is a weak acid. Carbonic acid, which is unstable, rapidly decomposes into water (H_2O) and carbon dioxide (CO_2). An example of this type of reaction is that between sulfuric acid and sodium carbonate as shown below.

$$H_2SO_4 + Na_2CO_3 \longrightarrow Na_2SO_4 + H_4CO_3 \longrightarrow Na_2SO_4 + H_2O + CO_2$$

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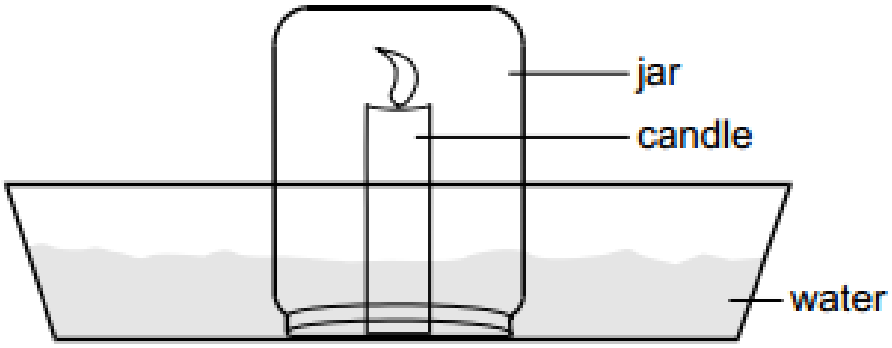
A lit candle, with a molecular formula of $C_{25}H_{52}$, is placed upright in a pan of water, and a glass jar is inverted and placed over the candle. The mouth of the jar is submerged in the water, as shown in the diagram below.



The water level in the jar rises, the candle's flame goes out, and the water rises further. An observer suggests that the water rises because oxygen is being consumed, which creates a partial vacuum. A second observer points out that this explanation violates the law of conservation of matter since the system is closed.

Using your knowledge of science, write an essay in which you explain the behavior of this system in terms of scientific laws and concepts. In your essay:

- evaluate each observer's conclusion about the system;
- write a balanced chemical equation for the burning of the candle;
- describe how the gas laws explain the behavior of this system; and
- describe the system's initial state and its final state in terms of pressure.

The second observer's conclusion is more accurate, because matter can neither be created nor destroyed. Also, the water acts as a seal, creating a closed system inside the jar. Because it is a closed system, matter cannot enter or leave the system. The first observer's conclusion is partially correct if one considers that the oxygen being "consumed" during combustion is molecular oxygen (O_2) rather than atomic oxygen. However, the first observer has failed to take into account the fact that a chemical change has occurred, and the oxygen atoms have been incorporated into water and carbon dioxide molecules. Since the system is closed, there is no net loss of oxygen atoms from the system.

The balanced chemical equation for the burning candle is:

$$C_{25}H_{52} + 38O_2 \rightarrow 26H_2O + 25CO_2$$

If one assumes that the O_2 and CO_2 are in a gaseous state, the $C_{25}H_{52}$ is in a solid state, and the H_2O is in a liquid state, then the gas laws would pertain to the O_2 and CO_2 only. According to Avogadro's law, the volume of a gas is directly proportional to the number of moles of the gas present (at constant pressure and temperature). Also, one mole of any ideal gas, regardless of its identity or chemical structure, occupies the same volume at a given temperature and pressure. The balanced chemical equation for the combustion of the candle indicates that there are more moles of O_2 than there are of CO_2, so according to Avogadro's law, there would be a smaller volume of gas at the conclusion of the reaction than there was in the system initially.

The rise in the water level can be explained by looking at the conditions in the system when the jar is first inverted over the candle and after the flame burns out. Initially when the jar is inverted over the burning candle, the air pressure inside the jar equals the atmospheric pressure, so the water level is even inside and outside the jar. As O_2 reacts and CO_2 is produced, the volume of gas in the jar decreases. However, because the jar is rigid, the actual volume of space occupied by the gas does not change. This results in fewer gas molecules occupying the same volume of space, and so the pressure inside the jar drops. The pressure exerted by the air on the water outside the jar does not change though. Essentially, the atmospheric pressure pushes down on the water outside the jar and pushes the water up into the jar where the pressure is less. The gas laws state that the pressure exerted by a gas is inversely proportional to its volume, so as the water rises in the jar, there is less space available for the gas molecules and the pressure increases. When the water stops rising in the jar, equilibrium has been reached. That is, the pressure inside the jar pushing down on the water plus the weight of the water equals the force pushing down on the water outside the jar.