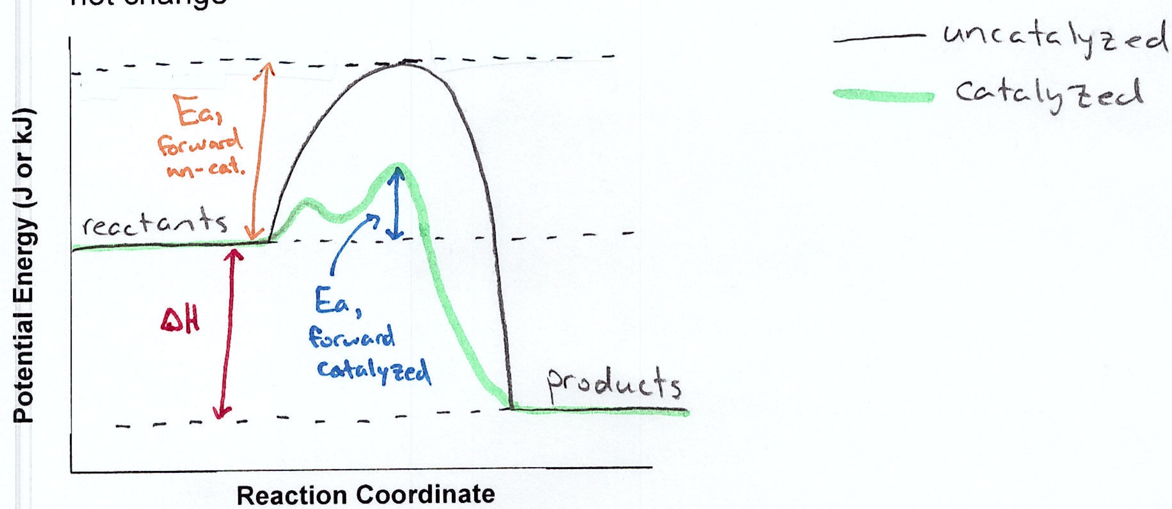
Catalysis and Reaction Rates

* • **Catalyst**: a substance that increases the rate of a chemical reaction by providing an alternative energy pathway with a lower activation energy

- Catalysts bind to the reactants and align the reactants so they will react. This will speed up the reaction rate, which will produce a greater yield of products in the same time period as an un-catalyzed reaction
- Catalysts are not consumed during reactions, so the composition and amount of the catalyst is the same before and after a chemical reaction.

• Potential energy diagrams can explaining how catalysts work

- * It is important to note that even though the catalysts increase the reaction rate by providing an alternate energy pathway with a lower activation energy, the net energy change/enthalpy change (ΔH) for the reaction does not change



* • **Enzymes:** compounds that act as catalysts in living systems

- Usually proteins
- EXAMPLE: chlorophyll is a catalyst that speeds up the reaction rate of splitting water molecules into oxygen and hydrogen ions

• Catalysts are important for environmental and economic reasons

- Catalysts are used in exhausts systems of vehicles to speed up the combustion of exhaust gases (less harmful fumes released to the atmosphere)
- Using catalysts means less activation energy to start reactions, which on an industrial sized production saves money

*****Elephant Toothpaste Demo*****

*****Now try pg. 418 #1, 2, 6 and pg. 420 #7, 8, 10, 14, 15, 19*****

Section 11.2 Review Answers

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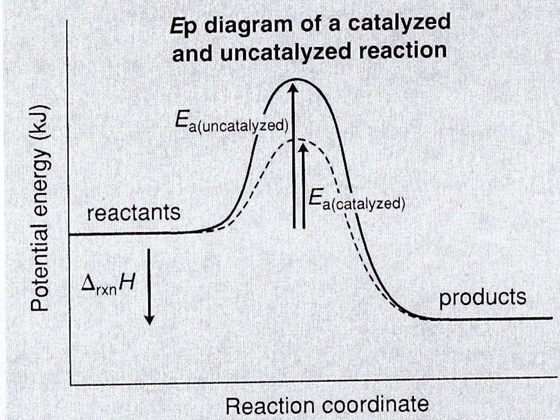
1. A catalyst has no effect on the total energy change from reactants to products because ΔH is only dependent on the potential energy difference between the reactants and products, not the pathway taken. As shown in the diagram below, the initial and final potential energy positions have not changed, so the enthalpy change for the reaction does not change.



2. Only a small amount of catalyst is necessary because a catalyst is regenerated when the reaction is complete and can be reused.

3. Enzymes and catalysts both speed up reactions and are regenerated at the completion of the reaction. Enzymes are extremely large molecules that only operate well at temperatures found in living systems, while catalysts are small molecules, often ions, that are not adversely affected by temperature.

4. **(a)** Pt(s), Pd(s), and Rh(s)

(b) hydrocarbons, CO(g), and NOx(g) are removed; CO_2(g), H_2O(g), and N_2(g) are the eventual products

5. The difference between a reactant in a reaction and a catalyst is that a reactant is consumed, whereas a catalyst is regenerated when the reaction is complete. If chlorine atoms were reactants, once they were consumed, they would no longer affect the ozone layer. Since they are catalysts, however, the chlorine atoms present can promote the destruction of the ozone layer forever (unless they can be removed in another way).

6. Students' answers will depend on the values they interpolate from the graph.

(a) 575 kJ

(b) 350 kJ

(c) The catalyzed reaction is faster because the activation energy is lower.

(d) 750 kJ

(e) 525 kJ

(f) –175 kJ

(g) 175 kJ

(h) According to Hess's Law, if you reverse a reaction, you change the sign of the ΔH. In this case, the reaction is reversed, so the ΔH changes from –175 kJ to 175 kJ.

Chapter 11 Review Answers

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Answers to Understanding Concepts Questions

7. Catalysts are substances that increase the rate of a reaction by providing an alternate, lower activation energy pathway. If the energy barrier is lowered, a larger proportion of molecules will have sufficient energy when they collide to result in a reaction.

8. There is no effect on ΔH when a catalyst is added, therefore the enthalpy change of reaction remains the same. The catalyst changes the pathway of the reaction but as per Hess's law this has no effect on the enthalpy change of the reaction.

9. As molecules collide, their kinetic energy is converted to potential energy as bonds are broken. The species formed during this process is the activated complex, a highly unstable arrangement containing partial bonds. As the bonds reform to make more stable products, the potential energy is converted back into kinetic energy.

10. A catalyst, although part of a reaction, is not consumed or produced during the reaction and cannot be considered a reactant or product. Therefore, above the arrow, indicating that it is part of the reaction but not reactant or product is most appropriate.

11. (a) One example of an industrial catalyst is vanadium (V) oxide, $V_2O_5(s)$, used to speed up the second reaction of the contact process to produce sulfuric acid, $H_2SO_4(aq)$, commercially. Other industrial catalysts include Mo(VI) complexes which are used to make polyesters, nickel or platinum to hydrogenate vegetable oil and platinum, palladium and rhodium catalysts used in catalytic converters.

(b) One example of an enzyme is pepsin. It is produced by cells of the stomach and is used to digest protein in the stomach. Enzymes are used throughout the body to catalyze important reactions. Other enzymes include amylase, which digests starch, and carbonic anhydrase which catalyzes the conversion of carbon dioxide gas into carbonic acid.

(c) Both enzymes and catalysts increase the rate of reactions by providing an alternate lower-energy pathway. Catalysts are often small molecules or atoms that catalyze reactions between other relatively small molecules. These reactions may occur at very high temperatures. Enzymes must be able to facilitate effective collisions between very large molecules at relatively low temperatures. To do this, enzymes are complex, very large molecules that are folded in a specific way to create an active site on which the substrate molecules bind. Because the enzyme's activity is dependent on its shape, which in turn is dependent on conditions, its activity can be regulated through changes in pH, such as what happens with pepsin's activation in the stomach (low pH) and deactivation in the intestine (high pH).

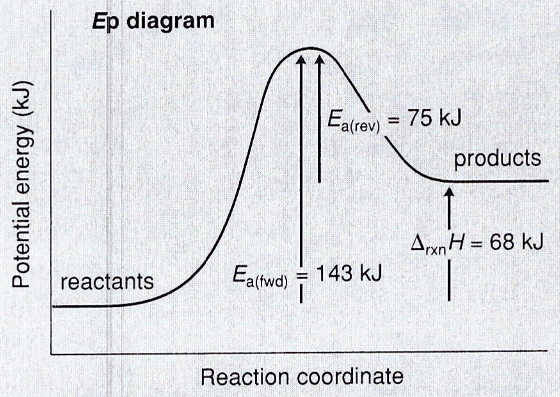
12. At high temperatures, the shape of an enzyme is altered which changes the shape of the active site. This change in shape will decrease or eliminate the enzyme activity, reducing the rate of the reaction.

Answers to Applying Concepts Questions

13. (a) The reaction is endothermic since the $E_{a(fwd)}$ is larger than the $E_{a(rev)}$.

$\Delta H = E_{a(fwd)} - E_{a(rev)} = 143\text{ kJ} - 75\text{ kJ} = 68\text{ kJ}$; since this is positive we know the reaction is endothermic.

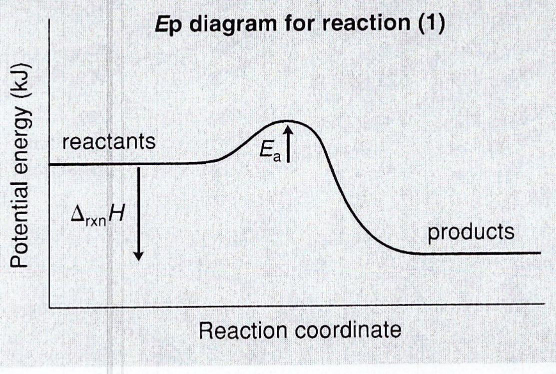
(b)



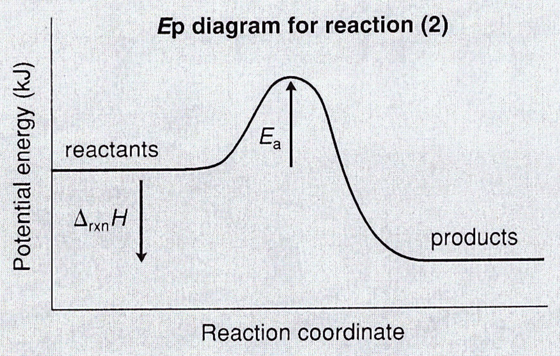
14. (a) $\Delta H = 50\text{ kJ}$, $E_{a(fwd)} = 70\text{ kJ}$, $E_{a(rev)} = 20\text{ kJ}$

(b) $\Delta H = 50\text{ kJ}$, $E_{a(fwd\text{-}cat)} = 58\text{ kJ}$, $E_{a(rev\text{-}cat)} = 8\text{ kJ}$

15. (a)



Reaction coordinate



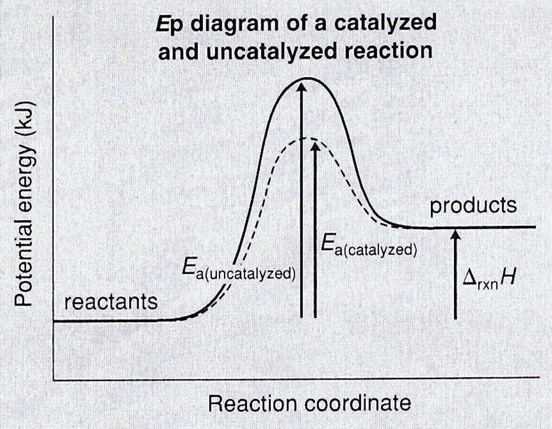
(b) Reaction (1) would have a faster rate given the same conditions, as its activation energy is lower, so more collisions will be effective.

16. The activated complex cannot be isolated because it is highly unstable, due to its partial bonds, and it is short-lived.

17. The activation energy required for the combustion of gasoline must be quite high, so the reaction will not occur spontaneously. The spark required for ignition provides the necessary activation energy.

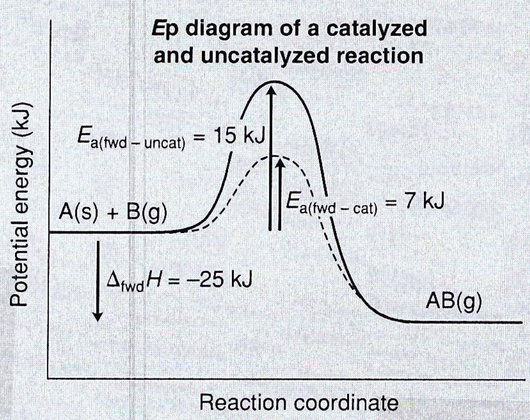
18. (a) A catalyst has no effect on the total energy change because it only affects the path taken from reactants to products. As the potential energy diagram in (b) illustrates, the initial and final potential energy positions of the reactants and products do not change with the addition of a catalyst.

(b)



19. (a) 7 kJ

(b)


Ep diagram of a catalyzed and uncatalyzed reaction
Potential energy (kJ)
E a(fwd – uncat) = 15 kJ
E a(fwd – cat) = 7 kJ
A(s) + B(g)
Δfwd H = –25 kJ
AB(g)
Reaction coordinate