

Chapter 5 — Energetics

2. Questions for Short Answers

1. What is the difference between enthalpy and enthalpy change?

Ans: Enthalpy (H), also called heat content, is the total amount of thermal energy stored in a compound or system under standard conditions; its unit is kJ mol^{-1} . Enthalpy change (ΔH) is the change in enthalpy which a system undergoes during a reaction. The important practical difference is that the total enthalpy H of a system cannot be measured directly, whereas the change in enthalpy ΔH brought about in a system can be measured comparatively easily. At constant pressure, ΔH is equal to the heat evolved or absorbed.

2. Why is breaking of a bond an endothermic process?

Ans: A chemical bond is a force of attraction which holds two atoms together, so the bonded atoms are at a lower energy than the separate atoms. To pull the atoms apart this force of attraction must be overcome, and that requires energy to be supplied from the surrounding to the system. Since energy is absorbed by the system, bond breaking is always an endothermic process. For example, $\text{H}_2(\text{g}) \rightarrow 2\text{H}(\text{g})$ absorbs 435 kJ/mol and $\text{O}_2(\text{g}) \rightarrow 2\text{O}(\text{g})$ absorbs 498 kJ/mol. Bond making, on the contrary, releases energy and is exothermic.

3. Depict the transition state for the following reaction: $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$

Ans: A reaction takes place when an excited H_2 molecule collides with an excited Cl_2 molecule. At the moment of collision, the H—H and Cl—Cl bonds are only partly broken while the new H—Cl bonds are only partly formed. This short-lived arrangement is the transition state and it is shown by drawing the four atoms in a square with dotted lines for the partly broken and partly formed bonds: $\text{H} \cdots \text{H} \quad : \quad : \quad \text{Cl} \cdots \text{Cl}$ The transition state lies at the peak of the energy profile diagram. After a very short time it either falls back to the reactants ($\text{H}_2 + \text{Cl}_2$) or goes forward to the products (2HCl).

4. Draw the reaction profiles for two exothermic reactions one of which moves faster than the other.

Ans: Both profiles are drawn with energy on the y-axis and the reaction coordinate on the x-axis, and in both the products lie below the reactants, showing a negative ΔH (exothermic). The difference is only in the height of the hump. The faster reaction is drawn with a low hump, that is a small activation energy (E_a), so many colliding molecules have enough energy to reach the transition state. The slower reaction is drawn with a much taller hump, that is a large activation energy, so only a few collisions are successful. The value of ΔH , the drop from reactants to products, may be the same in both diagrams — it is E_a , not ΔH , that decides the speed.

5. What is the role of glycogen in our body?

Ans: Glycogen is the primary storage form of glucose in our body. It is stored in the liver and in the muscles. When the cells need energy for their metabolic activities, this stored glycogen is broken down to release glucose, which then undergoes respiration to provide energy. In this way glycogen acts as the body's ready reserve of carbohydrate energy, while lipids serve as the larger long-term energy reserve.

3. Constructed Response Questions

1. Physical changes which usually occur around us are given in the table. Write down whether they are exothermic or endothermic.

Ans: Conversion of hydrated salt into anhydrous salt — Endothermic (heat must be supplied to drive off the water of crystallisation). Burning of paper — Exothermic. Vapourizing liquid nitrogen — Endothermic. Evaporation of dry ice — Endothermic. Conduction of electricity by metals — Exothermic (the metal gets hot, heat is given out to the surrounding). Dissolving ammonium chloride in water — Endothermic (the solution becomes cold). Formation of rain from clouds — Exothermic (condensation of vapour releases heat to the surrounding). Dissolving sodium carbonate in water — Exothermic (the solution becomes warm).

2. Explain why the reaction between atmospheric gases oxygen and nitrogen does not take place under normal conditions, but in the presence of lightning these gases react to give NO. The reaction stops as soon as the lightning stops.

Ans: The reaction $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g}) - 180.6 \text{ kJ}$ is highly endothermic; 180.6 kJ of energy must be absorbed before the strong bonds of the nitrogen and oxygen molecules can be broken and the transition state can be reached. Under normal conditions the air does not supply anything like this amount of energy, so the activation energy is never reached and no reaction takes place. Lightning releases an enormous amount of energy in a moment, which is enough to break these bonds and push the molecules over the activation energy barrier, so nitric oxide is formed. The moment the lightning stops, the supply of this energy stops as well, the molecules can no longer reach the transition state, and the reaction stops at once.

3. A reaction between natural gas (CH_4) and atmospheric oxygen does not take place when you mix them. As soon as you show a burning match stick, the reaction starts immediately and then it continues until one or both of the reactants is/are used up. Explain.

Ans: Although the combustion of methane is a strongly exothermic reaction, the reactant molecules must first be raised to the transition state before any product can be formed. The energy needed for this is the activation energy. A simple mixture of CH_4 and O_2 at room temperature does not possess this much energy, so no reaction takes place however long they are left together. The burning match stick supplies the activation energy to the molecules near it, and those molecules cross the barrier and react. Because the reaction is exothermic, the heat given out by this first small portion is more than enough to supply the activation energy to the neighbouring molecules. The reaction therefore becomes self-sustaining and spreads on its own, and it continues until one or both of the reactants — the methane or the oxygen — is completely used up.