Chemical Reactivity
ANSWERS

Rates of Reaction

Collision Theory
STOP AND CHECK (PAGE 6)

- A successful collision requires the particles to collide with:
  - Enough energy
  - The correct orientation.

Activation Energy
STOP AND CHECK (PAGE 7)

- Activation energy is the minimum amount of energy required for a chemical reaction to occur between reactant particles. It is the energy barrier that must be overcome for a reaction to occur.

Concentration
STOP AND CHECK (PAGE 8)

- Concentration is determined by the number of particles in a given volume.
- When the concentration is increased, the reaction rate increases. When the concentration is decreased, the reaction rate decreases.

Defining Surface Area

STOP AND CHECK (PAGE 10)

- The surface area of a solid compound is the total size of all its outside surfaces.
- The surface area is calculated by determining the area of each face individually and then adding them together.

Changing Surface Area

STOP AND CHECK (PAGE 11)

- The surface area of a solid can be changed by grinding it up into grains or a powder.
- When the surface area is increased, the reaction rate increases.

Temperature

STOP AND CHECK (PAGE 13)

- When the temperature is increased, the reaction rate increases.
- The two mechanisms by which temperature affects reaction rate are kinetic energy and activation energy.

Kinetic Energy Mechanism

STOP AND CHECK (PAGE 13)

- A higher temperature means particles have more kinetic energy; a lower temperature means particles have less kinetic energy.
- Increasing temperature increases the kinetic energy of the particles, which increases the rate of collisions (and so successful collisions), and so the reaction rate increases.

Activation Energy

STOP AND CHECK (PAGE 14)

- The more reactants with enough energy to get over the activation energy barrier, the faster the reaction rate will be.
- When the temperature drops, the reactants have less energy, so are less likely to have enough energy to overcome the energy barrier, so the reaction takes a lot longer to get started.

Catalysts

STOP AND CHECK (PAGE 15)

- Catalysts are molecules that increase the rate of reaction but are not used up themselves.
- Common examples of catalysts are platinum, nickel, and vanadium oxide.
- Different reactions require different catalysts; a catalyst is neither a reactant nor a product; only a small amount of a catalyst is needed to increase the reaction rate.
- Adding a catalyst decreases the activation energy of a reaction, so the reaction rate increases.

Rates of Reaction

QUICK QUESTIONS (PAGE 15)

- According to collision theory, a successful collision requires the particles to collide with enough energy and the correct orientation.
- The activation energy is the minimum energy required for a collision to be successful. The higher the activation energy is, the less likely reactants will collide with enough energy to start the reaction. This means the activation energy has a direct impact on how fast a reaction can go.
- The more concentrated the reactants are, the more likely they are to collide, so the more likely they are to collide successfully, so the faster the reaction rate. So, increasing the concentration increases the reaction rate, and decreasing concentration decreases the reaction rate.

- The more surface area exposed, the more particles are available to react. So, the more collisions, the more successful collisions, and a faster reaction rate. So, increasing surface area increases the reaction rate, and decreasing surface area decreases the reaction rate.
- The higher the temperature, the more energy the reactants have. This means they have more kinetic energy, so will collide more often, have more successful collisions, and have a faster reaction rate. It also means they are more likely to have enough energy to overcome the activation energy, so more collisions will be successful, resulting in a faster reaction rate. So, increasing temperature increases the reaction rate, and decreasing temperature decreases the reaction rate.
- Adding a catalyst lowers the activation energy of the reaction, so more particles have enough energy to overcome the energy barrier. More collisions will be successful, and the reaction rate will be faster. So, adding a catalyst increases the reaction rate.

Equilibrium

Two-Way Reactions

STOP AND CHECK (PAGE 17)

- The reverse reaction occurs when the products react to reform the reactants.

Equilibrium

STOP AND CHECK (PAGE 19)

- Equilibrium occurs in a two-way reaction when the reaction rate of the forward reaction is the same as the reaction rate of the reverse reaction.
- The position of equilibrium is the proportion of products formed to reactants leftover when equilibrium was reached.

Equilibrium Constant (K_c)

STOP AND CHECK (PAGE 19)

- The equilibrium constant is calculated using "products over reactants". For a reaction $wA_{(aq)} + xB_{(aq)} + yC_{(aq)} + zD_{(aq)}$ the equation is $K_c = \frac{[C]^y[D]^z}{[A]^w[B]^x}$
- The equilibrium constant equation includes species in the aqueous state and gases. It does not include solids or liquids.
- $K_c = \frac{[SO_3]^2}{[O_2][SO_2]^2}$
- $K_c = \frac{[CH_3COO^-]\ [H_3O^+]}{[CH_3COOH]}$

The Value of Equilibrium Constant (K_c)

STOP AND CHECK (PAGE 22)

- The numbers used when calculating the equilibrium constant are the concentrations of each reactant and product species. (Except, of course, of the liquids and solids.)
- When K_c is less than 0.001, the equilibrium favours the reverse reaction.
- When K_c is greater than 1000, the equilibrium favours the forward reaction.
- When K_c = 1, or between 0.001 - 1000, neither reaction direction is favoured.

The Value of Equilibrium Constant (K_c)

STOP AND CHECK (PAGE 22)

- $K_c = \frac{[HI]^2}{[H_2][I]^2}$
  - $K_c = \frac{[0.43]^2}{[0.0190][0.210]^2}$
  - K_c = 46.341 at 490℃

Disturbing Equilibrium

Le Chatelier's Principle

STOP AND CHECK (PAGE 24)

- Le Chatelier's principle states that if an equilibrium is disturbed (by a change in conditions), the position of equilibrium moves to counteract the change. This means if something is done to a system at equilibrium, the system will do the opposite until equilibrium is reached again.

Change in Concentration

STOP AND CHECK (PAGE 25)

- Adding NH_3 would cause the concentration of N_2 to increase.
- Adding H_2 would cause the concentration of N_2 to decrease.

Change in Pressure

STOP AND CHECK (PAGE 28)

- Pressure can be increased by adding more particles and/or reducing the volume of the system.
- Increasing pressure would cause the concentration of N_2 to decrease.
- Decreasing pressure would cause the concentration of N_2 to increase.

Change in Temperature

STOP AND CHECK (PAGE 30)

- An exothermic reaction transfers energy from the system to the surroundings. An endothermic reaction transfers energy from the surroundings to the system.

- An increase in temperature would shift K_c to be more product favoured and produce more $NH_{3(g)}$.
- A decrease in temperature would shift K_c to be more reactant favoured and produce more $N_{2(g)}$ and $H_{2(g)}$.

Catalysts

STOP AND CHECK (PAGE 31)

- Catalysts increase the forward reaction rate, and also increase the reverse reaction rate.
- Adding a catalyst would cause the system to reach equilibrium more quickly, but the final equilibrium concentration of N2 would be the same as if no catalyst was added.

Disturbing Equilibrium

STOP AND CHECK (PAGE 31)

- Concentration, pressure, and temperature can be changed to disturb the position of equilibrium.
  - **Concentration:** If the concentration of any or all of the reactants is increased, the system will favour the forward reaction to use up some of these extra reactants. The position of equilibrium shifts to the right, the product side. The concentration of all the products increases.
    If the concentration of any or all of the products is increased, the system will favour the reverse reaction to use up some of these extra products. The position of equilibrium shifts to the left, the reactant side. The concentration of all reactants increases.
  - **Pressure:** If the pressure is increased, the system will favour the reaction that forms fewer moles of gas, in order to reduce the pressure again. If the pressure is decreased, the system will favour the reaction that forms more moles of gas, in order to increase the pressure again.
  - **Temperature:** If the temperature is increased, the endothermic reaction will be favoured, as the system absorbs some of the extra energy. If the temperature is decreased, the exothermic reaction will be favoured, as the system releases energy to make up for the energy lost.

Acids and Bases

Acid and Base Definitions

STOP AND CHECK (PAGE 32)

- Acids are proton donors. Bases are proton acceptors.
- An amphiprotic substance can act as both an acid and a base. In other words, an amphiprotic substance can both donate and accept protons.

Acid-Base Reactions

STOP AND CHECK (PAGE 36)

- An acid is a proton donor.
- A base is a proton acceptor.
- The conjugate acid of a base is the molecule formed once that base has accepted a proton. It has one more hydrogen and one more positive charge than the base did originally. The conjugate base of an acid is the molecule formed once that acid has donated a proton. It has one less hydrogen and one less positive charge than the acid did originally.

Acid-Base Strength

STOP AND CHECK (PAGE 38)

- A strong acid fully dissociates, while a weak acid only partially dissociates. In other words, a strong acid will always donate its proton, while only some of a weak acid will donate a proton.
- A strong base fully protonates, while a weak base only partially protonates. In other words, a strong base will always accept a proton, while only some of a weak base will accept a proton.
- Reactions with weak acids or weak bases are two-way reactions because the reaction does not go to completion. There are always both reactants and

products present in the solution. This means both the forward and reverse reactions must be happening at the same time. Weak acid molecules can easily be re-protonated, and weak base molecules can easily lose the hydrogen they just gained.

The pH Scale

STOP AND CHECK (PAGE 40)

- pH = 7 of a neutral solution.
- An acidic solution can have a pH between 0 - 7. A basic solution can have a pH between 7 - 14.
- pH = $-\log[H_3O^+]$

Self-Ionisation of Water

STOP AND CHECK (PAGE 26)

- Water self-ionises to form both hydronium and hydroxide in the reaction:

$$2H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

- Increasing the H_3O^+ concentration decreases the pH. Decreasing the H_3O^+ concentration increases the pH.
- Increasing the OH^- concentration increases the pH. Decreasing the OH^- concentration decreases the pH.

Calculating pH of Strong Acids

STOP AND CHECK (PAGE 42)

- The pH of a strong acid is calculated using the pH equation: pH = $-\log[H_3O^+]$
- pH = $-\log(0.01)$
    - pH = 2
- pH = $-\log(0.005 \times 2)$
    - pH = $-\log(0.01)$
    - pH = 2

- pH = -log(0.2)
    - pH = 0.69897

Calculating pH of Strong Bases

STOP AND CHECK (PAGE 44)

- The auto-dissociation/self-ionisation of water is the equilibrium that is always going on in the water, producing some hydronium and hydroxide ion:

$$2H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

- $K_w = [H_3O^+][OH^-] = 10^{-14}$
- Rearrange the K_w equation:
    - Hydronium: $[H_3O^+] = \frac{10^{-14}}{[OH^-]}$
    - Hydroxide: $[OH^-] = \frac{[H_3O^+]}{10^{-14}}$
- pH is a log scale based on the hydronium H_3O^+ ion concentration. pOH is a log scale based on the hydroxide OH^- ion concentration:

$$pH = -\log[H_3O^+]$$
$$pOH = -\log[OH^-]$$

- **First method:**
    - pOH = -log(0.1)
    - pOH = 1
      pH = 14 – 1
    - pH= 13

  Second method:
    - $[H_3O^+] = \frac{10^{-14}}{0.1}$
    - $[H_3O^+]$ = 10-13
    - pH = -log(10-13)
    - pH= 13
- **First method:**
    - $[OH^-] = 0.0025 \times 2$
    - $[OH^-] = 0.005\ molL^{-1}$
    - pOH = -log(0.005)

- pOH = 2.301
- pH = 14 - 2.301
- pH = 11.7

Second method:

- $[H_3O^+] = \frac{10^{-14}}{0.005}$
- $[H_3O^+] = 2\times10^{-12}$
- pH = $-\log(2\times10^{-12})$
- pH = 11.7

Conductivity of Strong and Weak Acids and Bases

STOP AND CHECK (PAGE 47)

- Solutions of weak acids and weak bases don't have many ions present, as weak acids only partially dissociate, and weak bases only partially protonate, so not many H_3O^+ or OH^- ions are released into the solution. As these solutions have a low number of charged particles available, they are poor conductors. Conversely, solutions of strong acids and strong bases have a lot of ions present, as strong acids fully dissociate, and strong bases fully protonate, so a lot of H_3O^+ or OH^- ions are released into the solution. As these solutions have a lot of charged particles available, they are good electrical conductors.

Acids and Bases

QUICK QUESTIONS (PAGE 47)

- The Brønsted-Lowry definition of an acid is a proton donor. The Brønsted-Lowry definition of a base is a proton acceptor.
- In an acid-base reaction, an acid will donate a proton to form its conjugate base, and a base will accept a proton to form its conjugate acid.
- Acidic solutions have a pH below 7, with a high H_3O^+ concentration and a low OH^- concentration. Basic solutions have a pH above 7 and have a low H_3O^+ concentration, and a high OH^- concentration. A neutral solution has a pH of 7, with an equal concentration of H_3O^+ and OH^- ions.
- The strength of an acid depends on how well it donates protons, i.e. how well it dissociates. A strong acid fully dissociates, so donates all its protons. A weak

acid only partially dissociates, so not all the acid molecules donate their protons.

- The strength of a base depends on how well it accepts protons, i.e. how well it protonates. A strong base fully protonates, so all its molecules accept a proton. A weak base is only partially protonated, so not all the base molecules accept a proton.
- The more charged particles in a solution, the higher conductivity that solution has. A strong acid fully dissociates, and so releases a lot of H_3O^+ ions into the solution. Similarly, a strong base fully protonates, and so releases a lot of OH^- ion solution. In both cases, there is a high concentration of ions, and so both have good electric conductivity. Conversely, a weak acid only partially dissociates, so doesn't release many H_3O^+ ions into the solution, and a weak base only partially protonates, so doesn't release many OH^- ions into the solution. In both cases, there is not a very high concentration of ions, so both have poor conductivity.