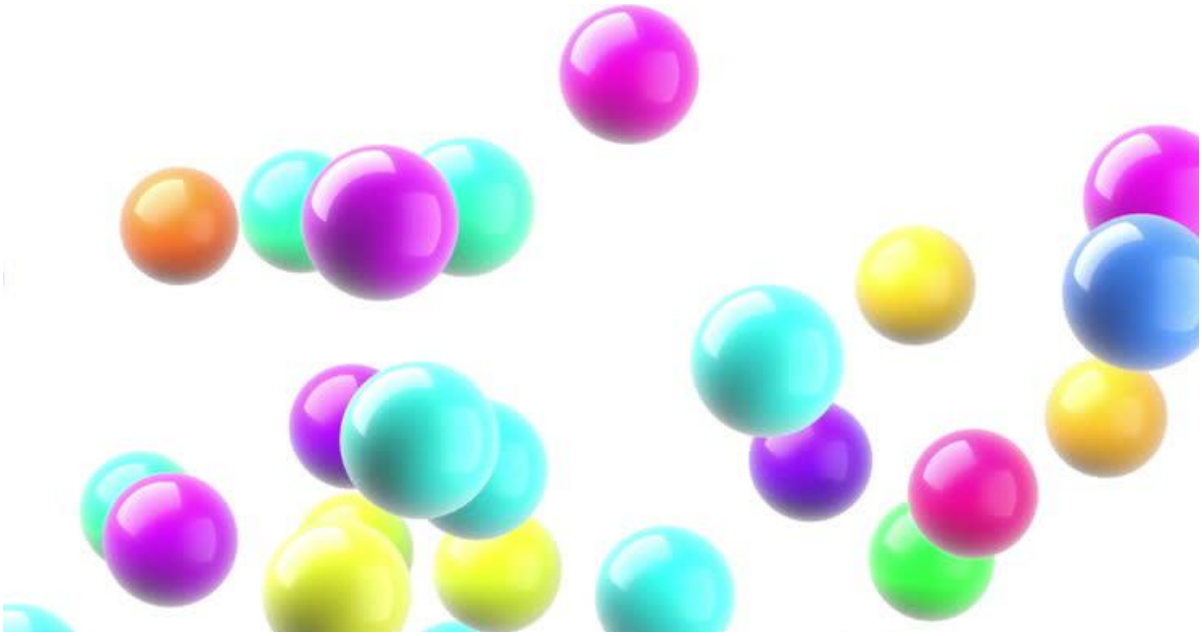
Chemistry 2.6 AS 91166

Demonstrate understanding of chemical reactivity

WORKBOOK

Working to Excellence



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Writing Excellence answers to **Reaction rate Factors – Surface Area** questions

Reaction Rate Factors – Surface Area QUESTION	
Question: Compare and contrast the reactions of 0.5 g of **magnesium ribbon**, Mg(s), with 50.0 mL of 0.100 mol L–1 hydrochloric acid, HCl(aq), and 0.5 g of **magnesium powder**, Mg(s), with 50.0 mL of 0.100 mol L–1 hydrochloric acid, HCl(aq). Refer to collision theory and rates of reaction in your answer.	
ANSWER	
1. state the **collision theory**	
2. Describe the reactants in your reaction and state **which factors are the same**	
3. Describe the reactants in your reaction and state **which factor is different** (the factor affecting reaction rate)	
4. **link** the factor to the collision theory	
5. link the reaction to more <u>successful collisions</u> occurring <u>per unit of time</u>	
6. link to more products (name products) being formed per unit of time AND link to a faster <u>reaction rate</u>	
7. summarize the reaction with the **slower reaction rate**	
8. Explain that both reactions will produce the **same amount of product** eventually as they started with the same amount of reactants	

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Writing Excellence answers to **Reaction Rate Factors – Temperature** questions

Reaction Rate Factors – Temperature QUESTION

Question: A particular reaction is complete when the solution turns cloudy and the paper cross under the flask can no longer be seen. The following experiments were carried out, and the times taken for the cross to disappear recorded. Elaborate on why the reaction in **Experiment 2** occurred faster than the reaction in **Experiment 1**.

experiment		Temperature /ºC	Time for cross to disappear
1	No Cu^{2+} present	25	42
2	No Cu^{2+} present	50	23
3	Cu^{2+} present	25	5

ANSWER

1. state the **collision theory**	
2. Describe the reactants in your reaction and state **which factors are the same**	
3. Describe the reactants in your reaction and state **which factor is different** (the factor affecting reaction rate)	
4. **link** the factor to the collision theory (**activation energy**)	
5. link the reaction to **more of the collisions being successful** occurring per unit of time	
6. next link the factor to the collision theory (**faster moving particles**)	
7. link the reaction to **more successful collisions** occurring per unit of time	
8. link to more products (name products) being formed per unit of time AND link to a faster reaction rate	
9. summarize the reaction with the **slower reaction rate**	
10. Explain that both reactions will produce the **same amount of product** eventually as they started with the same amount of reactants	

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Writing Excellence answers to **Reaction Rate Factors – Catalyst** questions

Reaction Rate Factors – Catalyst QUESTION

Question: A particular reaction is complete when the solution turns cloudy and the paper cross under the flask can no longer be seen. The following experiments were carried out, and the times taken for the cross to disappear recorded. Elaborate on why the reaction in **Experiment 3** occurs faster than the reaction in **Experiment 1**.

experiment		Temperature /ºC	Time for cross to disappear
1	No Cu^{2+} present	25	42
2	No Cu^{2+} present	50	23
3	Cu^{2+} present	25	5

ANSWER

1. state the **collision theory**	
2. Describe the reactants in your reaction and state **which factors are the same**	
3. Describe the reactants in your reaction and state **which factor is different** (the factor affecting reaction rate)	
4. **link** the factor to the collision theory	
5. link the reaction to **more of the collisions being successful** occurring per unit of time	
6. link to more products (name products) being formed per unit of time AND link to a faster reaction rate	
7. summarize the reaction with the **slower reaction rate**	
8. Explain that both reactions will produce the **same amount of product** eventually as they started with the same amount of reactants	

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Chemistry 2.6 AS 91166 Demonstrate understanding of chemical reactivity

Writing Excellence answers to **Equilibrium Expression** questions

Equilibrium Expression QUESTION
Question: The following chemical equation represents a reaction that is part of the Contact Process, which produces sulfuric acid. $2SO_{2(g)} + O_{2(g)} \leftrightarrow 2SO_{3(g)}$ $\Delta H = -200$ kJ mol^{-1}, $Kc = 4.32$ at 600°C **(i)** Write an equilibrium constant expression for this reaction. **(ii):** A reaction mixture has the following concentration of gases at 600°C: $[SO2_{(g)}] = 0.300$ mol L^{-1} $[O2_{(g)}] = 0.100$ mol L^{-1} $[SO3_{(g)}] = 0.250$ mol L^{-1} Justify why this reaction mixture is not at equilibrium, using the equilibrium expression and the data provided

ANSWER	
1. Write out the **equilibrium constant expression** in full $K_c = \frac{[C]^c \times [D]^d}{[A]^a \times [B]^b}$ Given $aA + bB \rightleftharpoons cC + dD$	
2. **Calculate the Q value** by inserting all of the [ ] data given. Show working and remember order of operation and 3sgf Final value will have no units	
3. Write down the Kc value and **compare** with the Q value stating whether it is equal or not (and therefore is or is not at equilibrium)	
4. Link the Q value as either being **bigger** (and lying to the products side as the numerator is greater) OR as being **smaller** (and lying to the reactants side as the numerator is smaller)	

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Chemistry 2.6 AS 91166 Demonstrate understanding of chemical reactivity

Writing Excellence answers to **Equilibrium – Pressure** questions

Equilibrium – Pressure QUESTION

Question: The two reactions shown in the following table are both at equilibrium.
Compare and contrast the effect of increasing the pressure on both reactions, with reference to the equilibrium positions.

Reaction	Equation	Affected by increased pressure
One	$H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$	no
Two	$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$	yes

ANSWER

1. State the **equilibrium principle**	
2. Describe the **factor** in your question AND Link increasing the principle to how the **system responds** [some questions will be decreasing]	
3. **Generally,** explain which side of the equation is favoured (relate to moles) AND the general observations – at visible and particle level.	
4. **Specifically,** in <u>reaction one</u> describe number of moles in both sides of the equation AND link to which direction of reaction would be favoured (and observation)	
5. **Specifically**, in <u>reaction two</u> link number of moles in both sides of the equation to observation AND link to which direction of reaction would be favoured	
6. Describe how the **system shift** in <u>reaction two</u> would effect at particle level AND final observation.	

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Writing Excellence answers to **Equilibrium – Temperature** questions

Equilibrium – Temperature QUESTION

Question: In a reaction, the brown gas nitrogen dioxide, $NO_{2(g)}$, exists in equilibrium with the colourless gas dinitrogen tetroxide, $N_2O_{4(g)}$. The equation for this reaction is represented by:

$2NO_{2(g)} \leftrightarrow N_2O_{4(g)}$

brown gas colourless gas

The table below shows the observations when changes were made to the system. Analyse these experimental observations.

In your answer you should:

- link all of the observations to equilibrium principles
- justify whether the formation of dinitrogen tetroxide from nitrogen dioxide is endothermic or exothermic.

Change		Observations
Pressure	increased (by decreasing the volume of the container)	Colour faded
	decreased (by increasing the volume of the container)	Colour darkened
Temperature	container with reaction mixture put into hot water	Colour darkened
	container with reaction mixture put into ice water	Colour faded

ANSWER

1. State the **equilibrium principle**	
2. Describe the **factor** in your question AND Link the principle to how the **system responds to cooling or heating**	
3. **Generally,** explain which side of the equation is favoured (relate to endothermic or exothermic)	
4. **Specifically,** for your reaction with heating, link the observation to which direction of reaction would be favoured (endothermic or exothermic)	
5. Describe how the **system shift** in heating would affect which products are made AND final observation.	
6. **Specifically,** for your reaction with cooling, link the observation to which direction of reaction would be favoured (endothermic or exothermic)	
7. Describe how the **system shift** in cooling would affect which products are made AND final observation.	

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Writing Excellence answers to **Equilibrium – Concentration** questions

Equilibrium – Concentration QUESTION	
Question: When acid is added to a yellow solution of chromate ions, $CrO_4^{2-}(aq)$, the following equilibrium is established. $2CrO_4^{2-}(aq) + 2H^+(aq) \leftrightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$ **yellow** **orange** Analyse this equilibrium using equilibrium principles to explain the effect on the colour of the solution when: (i) more dilute acid is added **AND** when (ii) dilute base is added:	
ANSWER	
1. State the **equilibrium principle**	
2. Describe the **factor** in your question AND Link the principle to how the **system responds to increasing or decreasing concentration** of reactants	
3. **Generally,** explain which side of the equation is favoured (relate to reactants or products) by increasing or decreasing concentration	
4. **Specifically,** for your reaction explain how you are increasing the concentration of reactants, AND link the direction of reaction that would be favoured	
5. Describe how the **system shift** by increasing the concentration of reactants would affect which substances are made AND final observation.	
6. **Specifically,** for your reaction explain how you are decreasing the concentration of reactants, AND link the direction of reaction that would be favoured	
7. Describe how the **system shift** by decreasing the concentration of reactants would affect which substances are made AND final observation.	

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Writing Excellence answers to **Ions and Conductivity** questions

Ions and Conductivity QUESTION

Question: Some properties of three aqueous solutions A, B and C, of equal concentration are shown in the table below. It is known that the solutions are $NH_{3(aq)}$, $HCl_{(aq)}$ and $NH_4Cl_{(aq)}$

Justify the identification of all three solutions.

- refer to both pH and electrical conductivity of the solutions
- link your answers to appropriate chemical equations.

Solution	A	B	C
pH	5.15	11.6	1.05
Electrical conductivity	good	poor	good

ANSWER

1. Identify each solution as either A, B or C by linking to being a **weak or strong acid or base** and also to the **pH**	
2. State requirements for **conductivity**	
3. **Solution A** (pH 5.15) weak acid salt. Equation 1. [A salt will first dissociate fully into ions] Write equation **AND** link ions formed to conductivity and level of dissociation	
4. **Solution A** (pH 5.15) weak acid salt. Equation 2.[One of the products of dissociation will further react as an acid] Write equation **AND** link ions formed to conductivity and level of dissociation (must form H_3O^+ ions)	
5. **Solution B** (pH 11.6) weak base. Write equation **AND** link ions formed to conductivity and level of dissociation (must form OH^- ions)	
6. **Solution C** (pH 1.05) strong acid. Write equation **AND** link ions formed to conductivity and level of dissociation (must form H_3O^+ ions)	

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Writing Excellence answers to **Reaction Rates of Acids** questions

Reaction Rates of Acids QUESTION

Question: The pH values of 0.100 mol L^{-1} solutions of two acids, HA and HB, are given in the table below.
(i) Compare the relative strengths of the two acids, $HA_{(aq)}$ and $HB_{(aq)}$, using the information given above.
Your answer should include equations and calculations.
(ii) Predict and compare, with reasons, what would be observed when two 5 g samples of calcium carbonate chips, $CaCO_{3(s)}$, are reacted, separately, with excess HA and HB.

Solution	pH
0.100 mol L^{-1} HA(*aq*)	1.0
0.100 mol L^{-1} HB(*aq*)	2.2

ANSWER

1. Write an **equation** for HA [Remembering H_3O^+ must be produced]	
2. **Calculate H_3O^+** for HA $[H_3O^+] = 10^{-pH}$	
3. **For HA** link concentration of ions formed to level of dissociation AND compare to concentration of acid (are they the same?)	
4. Write an **equation** for HB [Remembering H_3O^+ must be produced]	
5. **Calculate H_3O^+** for HB $[H_3O^+] = 10^{-pH}$	
6. **For HB** link concentration of ions formed to level of dissociation AND compare to concentration of acid (are they the same?)	
7. **For HA** link observation of reaction to concentration of ions	
8. then **For HA** link collision frequency to **rate of reaction**	
9. **For HB** link observation of reaction to concentration of ions	
10. then **For HB** link collision frequency to **rate of reaction**	

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Writing Excellence answers to **pH calculations** questions

pH calculations QUESTION 1	
Question: In a solution of potassium hydroxide, KOH, the pH is found to be 12.8. **(i)** Calculate the hydronium ion concentration, $[H_3O^+]$, and the hydroxide ion concentration, $[OH^-]$, in the solution. $K_w = 1 \times 10^{-14}$ **(ii)** Calculate the pH of a 2.25×10^{-4} mol L^{-1} sodium hydroxide, NaOH, solution.	
ANSWER	
STEP 1. **Calculate H_3O^+** for <u>KOH</u> $[H_3O^+] = 10^{-pH}$ (units and 3sgf)	
STEP 2. **Calculate OH^-** for <u>KOH</u> $[OH^-] = K_w / [H_3O^+]$ ($K_w = 1 \times 10^{-14}$) (units and 3sgf)	
STEP 1. **Calculate pOH** for <u>NaOH</u> $pOH = -\log[OH^-]$ (3sgf)	
STEP 2. **Calculate pH** for <u>NaOH</u> pH = 14 - pOH (3sgf)	

pH calculations QUESTION 2	
Question: (i) A solution of nitric acid, $HNO_{3(aq)}$, has a hydronium ion, H_3O^+, concentration of 0.0243 mol L^{-1}. Determine, by calculation, the pH and the concentration of hydroxide ions, OH^-, in this solution. $K_w = 1 \times 10^{-14}$ (ii) Determine the hydroxide ion concentration, $[OH^-]$, of a solution of potassium hydroxide, $KOH_{(aq)}$, with a pH of 11.8.	
ANSWER	
STEP 1. **Calculate pH** for <u>HNO_3</u> $pH = -\log[H_3O^+]$ (3sgf)	
STEP 2. **Calculate OH^-** for <u>HNO_3</u> $[OH^-] = K_w / [H_3O^+]$ ($K_w = 1 \times 10^{-14}$) (units and 3sgf)	
STEP 1. **Calculate H_3O^+** for <u>KOH</u> $[H_3O^+] = 10^{-pH}$ (units and 3sgf)	
STEP 2. **Calculate OH^-** for <u>KOH</u> $[OH^-] = K_w / [H_3O^+]$ ($K_w = 1 \times 10^{-14}$) (units and 3sgf)	

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Writing Excellence answers to **Reaction rate Factors – Surface Area** questions

Reaction Rate Factors – Surface Area QUESTION
Question: Compare and contrast the reactions of 0.5 g of **magnesium ribbon**, Mg(s), with 50.0 mL of 0.100 mol L–1 hydrochloric acid, HCl(aq), and 0.5 g of **magnesium powder**, Mg(s), with 50.0 mL of 0.100 mol L–1 hydrochloric acid, HCl(aq). Refer to collision theory and rates of reaction in your answer.

ANSWER	
1. state the **collision theory**	Chemical reactions between particles of substances only occur when the following conditions have been met: Particles must collide with enough energy (called activation energy EA) and with the correct orientation. If these conditions are met the collision will be considered **successful**.
2. Describe the reactants in your reaction and state **which factors are the same**	In the reaction of hydrochloric acid with Mg ribbon and Mg powder, both form the same products, magnesium chloride and hydrogen gas. $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ The concentration and amount of the hydrochloric acid is the same in both reactions as is the mass of magnesium. (we assume the temperature is also the same)
3. Describe the reactants in your reaction and state **which factor is different** (the factor affecting reaction rate)	However, since Mg powder has a larger surface area than Mg ribbon
4. **link** the factor to the collision theory	the powder will have more Mg particles immediately available to collide than the magnesium ribbon
5. link the reaction to more <u>successful collisions</u> occurring <u>per unit of time</u>	And therefore there will be more effective collisions per second (unit of time)
6. link to more products (name products) being formed per unit of time AND link to a faster <u>reaction rate</u>	and more H_2 gas will be produced initially in the magnesium powder, resulting in a faster rate of reaction.
7. summarize the reaction with the **slower reaction rate**	Mg ribbon will take longer to react because fewer particles are immediately available to collide, so will have a slower rate of reaction.
8. Explain that both reactions will produce the **same amount of product** eventually as they started with the same amount of reactants	Both reactions will eventually produce the same volume of hydrogen gas as the same amounts of each reactant are used.

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Writing Excellence answers to **Reaction Rate Factors – Temperature** questions

Reaction Rate Factors – Temperature QUESTION

Question: A particular reaction is complete when the solution turns cloudy and the paper cross under the flask can no longer be seen. The following experiments were carried out, and the times taken for the cross to disappear recorded. Elaborate on why the reaction in **Experiment 2** occurred faster than the reaction in **Experiment 1**.

experiment		Temperature /ºC	Time for cross to disappear
1	No Cu^{2+} present	25	42
2	No Cu^{2+} present	50	23
3	Cu^{2+} present	25	5

ANSWER

1. state the **collision theory**	Chemical reactions between particles of substances only occur when the following conditions have been met: Particles must collide with enough energy (called activation energy EA) and with the correct orientation. If these conditions are met, the collision will be considered **successful**.
2. Describe the reactants in your reaction and state **which factors are the same**	In the reaction of **experiment 1 and experiment 2**, both have no catalyst added.(we assume the concentration is also the same)
3. Describe the reactants in your reaction and state **which factor is different** (the factor affecting reaction rate)	The only change is an **increase in temperature in Experiment** 2 compared to experiment 2. An increase in temperature means a faster rate of reaction.
4. **link** the factor to the collision theory (**activation energy**)	The activation energy is the energy that is required to start a reaction. When the temperature is higher, the particles have **more kinetic energy**.
5. link the reaction to **more of the collisions being successful** occurring per unit of time	because the particles are moving with more kinetic energy, it will be more likely that when collisions occur they are **more likely to be effective** as a greater proportion of collisions **overcome the activation energy of the reaction.**
6. next link the factor to the collision theory (**faster moving particles**)	When the temperature is higher, the particles have **more kinetic energy**; the particles are **moving faster**
7. link the reaction to **more successful collisions** occurring per unit of time	Because the particles are moving faster, there will be **also more frequent collisions**. Experiment 2 has **more effective collisions per unit of time.** (than experiment 1.
8. link to more products (name products) being formed per unit of time AND link to a faster reaction rate	Experiment 2 will produce more products initially resulting in the solution turning cloudy and the cross disappearing quicker (23s compared to 42s), resulting in a **faster reaction rate**
9. summarize the reaction with the **slower reaction rate**	Experiment 1 is at a lower temperature so will take longer to react (cross to disappear) as the particles are moving slower than in experiment 1, so will have a slower rate of reaction.
10. Explain that both reactions will produce the **same amount of product** eventually as they started with the same amount of reactants	Both reactions will eventually produce the same amount of products if the same amounts of each reactant are used.

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Writing Excellence answers to **Reaction Rate Factors – Catalyst** questions

Reaction Rate Factors – Catalyst QUESTION

Question: A particular reaction is complete when the solution turns cloudy and the paper cross under the flask can no longer be seen. The following experiments were carried out, and the times taken for the cross to disappear recorded. Elaborate on why the reaction in **Experiment 3** occurs faster than the reaction in **Experiment 1**.

experiment		Temperature /ºC	Time for cross to disappear
1	No Cu^{2+} present	25	42
2	No Cu^{2+} present	50	23
3	Cu^{2+} present	25	5

ANSWER

1. state the **collision theory**	Chemical reactions between particles of substances only occur when the following conditions have been met: Particles must collide with enough energy (called activation energy EA) and with the correct orientation. If these conditions are met, the collision will be considered **successful**.
2. Describe the reactants in your reaction and state **which factors are the same**	In the reaction of **experiment 1 and experiment 3**, both are carried out under the same temperature. (we assume the concentration is also the same)
3. Describe the reactants in your reaction and state **which factor is different** (the factor affecting reaction rate)	The only change is the addition of a catalyst **in Experiment** 3 compared to experiment 1. An added catalyst means a faster rate of reaction.
4. **link** the factor to the collision theory	Particles must collide with enough energy to overcome the activation energy of the reaction. The activation energy is the energy that is required to start a reaction. When a catalyst is used, the **activation energy is lowered**. This is because the catalyst provides an **alternative pathway** for the reaction to occur in which the activation energy is lowered.
5. link the reaction to **more of the collisions being successful** occurring per unit of time	Now that the activation energy has been lowered, **more reactant particles will collide** with **sufficient energy** to overcome this lowered activation energy therefore **more effective collisions are occurring more frequently**.
6. link to more products (name products) being formed per unit of time AND link to a faster reaction rate	Experiment 3 will produce more products initially resulting in the solution turning cloudy and the cross disappearing quicker (5s compared to 42s), resulting in a **faster reaction rate**
7. summarize the reaction with the **slower reaction rate**	Experiment 1 has no catalyst so will take longer to react (cross to disappear) as less of the collisions are effective, so will have a slower rate of reaction than experiment 3.
8. Explain that both reactions will produce the **same amount of product** eventually as they started with the same amount of reactants	Both reactions will eventually produce the same amount of products if the same amounts of each reactant are used.

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Writing Excellence answers to **Equilibrium Expression** questions

Equilibrium Expression QUESTION
Question: The following chemical equation represents a reaction that is part of the Contact Process, which produces sulfuric acid. $2SO_{2(g)} + O_{2(g)} \leftrightarrow 2SO_{3(g)}$ $\Delta H = -200$ kJ mol^{-1}, $Kc = 4.32$ at 600°C **(i)** Write an equilibrium constant expression for this reaction. **(ii):** A reaction mixture has the following concentration of gases at 600°C: $[SO2_{(g)}] = 0.300$ mol L^{-1} $[O2_{(g)}] = 0.100$ mol L^{-1} $[SO3_{(g)}] = 0.250$ mol L^{-1} Justify why this reaction mixture is not at equilibrium, using the equilibrium expression and the data provided

ANSWER	
1. Write out the **equilibrium constant expression** in full $K_c = \frac{[C]^c \times [D]^d}{[A]^a \times [B]^b}$ Given $aA + bB \rightleftharpoons cC + dD$	$2SO_{2(g)} + O_{2(g)} \leftrightarrow 2SO_{3(g)}$ $K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$
2. **Calculate the Q value** by inserting all of the [ ] data given. Show working and remember order of operation and 3sgf Final value will have no units	$Q = \frac{0.250^2}{0.300^2 \times 0.100} = 6.94$
3. Write down the Kc value and **compare** with the Q value stating whether it is equal or not (and therefore is or is not at equilibrium)	Since $K_c = 4.32$, $Q \neq K_c$, so this reaction mixture is not at equilibrium.
4. Link the Q value as either being **bigger** (and lying to the products side as the numerator is greater) OR as being **smaller** (and lying to the reactants side as the numerator is smaller)	This number is greater than the K_c value, 4.32, which indicates that the reaction lies to the **products side** as the larger the K_c or Q value, the greater the numerator (products).

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Writing Excellence answers to **Equilibrium – Pressure** questions

Equilibrium – Pressure QUESTION

Question: The two reactions shown in the following table are both at equilibrium.
Compare and contrast the effect of increasing the pressure on both reactions, with reference to the equilibrium positions.

Reaction	Equation	Affected by increased pressure
One	$H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$	no
Two	$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$	yes

ANSWER

1. State the **equilibrium principle**	When a change is made to a system that is at equilibrium, the system responds to **reduce the effect** of that change.
2. Describe the **factor** in your question AND Link increasing the principle to how the **system responds** [some questions will be decreasing]	The factor in the question above is **pressure.** If there is an increase in pressure, the system responds by decreasing the pressure.
3. **Generally,** explain which side of the equation is favoured (relate to moles) AND the general observations – at visible and particle level.	This occurs by **favouring the reaction,** either forward or reverse direction, **that produces fewer gas particles**. Because there are now fewer particles hitting the sides of the container, there is less pressure.
4. **Specifically,** in <u>reaction one</u> describe number of moles in both sides of the equation AND link to which direction of reaction would be favoured (and observation)	In <u>Reaction One</u> there are two moles of gas particles on each side of the equation. Because there are the **same numbers of gas particles on both sides** of the reaction, then a change in pressure will have **no effect** as neither reaction will be favoured.
5. **Specifically**, in <u>reaction two</u> link number of moles in both sides of the equation to observation **AND** link to which direction of reaction would be favoured	In <u>Reaction Two</u> however, there are four moles of gas particles on the reactant side of the equation and two moles of gas particles on the product side of the equation. Therefore, when there is an increase in pressure, the system would shift and **favour the forward reaction**
6. Describe how the **system shift** in <u>reaction two</u> would effect at particle level AND final observation.	meaning there are **now fewer gas particles overall** and hence fewer gas particles hitting the sides of the container and **therefore less pressure overall**.

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Writing Excellence answers to **Equilibrium – Temperature** questions

Equilibrium – Temperature QUESTION

Question: In a reaction, the brown gas nitrogen dioxide, $NO_{2(g)}$, exists in equilibrium with the colourless gas dinitrogen tetroxide, $N_2O_{4(g)}$. The equation for this reaction is represented by:

$2NO_{2(g)} \leftrightarrow N_2O_{4(g)}$

brown gas colourless gas

The table below shows the observations when changes were made to the system. Analyse these experimental observations.

In your answer you should:

- link all of the observations to equilibrium principles
- justify whether the formation of dinitrogen tetroxide from nitrogen dioxide is endothermic or exothermic.

Change		Observations
Pressure	increased (by decreasing the volume of the container)	Colour faded
	decreased (by increasing the volume of the container)	Colour darkened
Temperature	container with reaction mixture put into hot water	Colour darkened
	container with reaction mixture put into ice water	Colour faded

ANSWER

1. State the **equilibrium principle**	When a change is made to a system that is at equilibrium, the system responds to **reduce the effect** of that change.
2. Describe the **factor** in your question AND Link the principle to how the **system responds to cooling or heating**	The factor in the question above is **temperature.** If there is an increase in temperature, the system responds by absorbing more (heat) energy. If there is a decrease in temperature, the system responds by releasing more (heat) energy.
3. **Generally,** explain which side of the equation is favoured (relate to endothermic or exothermic)	With Heating (increasing temperature) this occurs by **favouring the reaction,** either forward or reverse direction, **that is endothermic**. With cooling (decreasing temperature) this occurs by **favouring the reaction,** either forward or reverse direction, **that is exothermic**.
4. **Specifically,** for your reaction with heating, link the observation to which direction of reaction would be favoured (endothermic or exothermic)	With heating In this case, the colour darkened, indicating that this favoured the **reverse reaction,** which must be the **endothermic** direction.
5. Describe how the **system shift** in heating would affect which products are made AND final observation.	So **more** $2NO_{2(g)}$, nitrogen dioxide, which is a brown gas, would be formed and there would be **less** $N_2O_{4(g)}$ dinitrogen tetroxide, which is a colourless gas
6. **Specifically,** for your reaction with cooling, link the observation to which direction of reaction would be favoured (endothermic or exothermic)	With cooling In this case, the colour lightened, indicating that this favoured the **forward reaction**, which must be the **exothermic** direction.
7. Describe how the **system shift** in cooling would affect which products are made AND final observation.	So **more** $N_2O_{4(g)}$ dinitrogen tetroxide, which is a colourless gas would be formed and there would be **less** $2NO_{2(g)}$, nitrogen dioxide, which is a brown gas,

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Chemistry 2.6 AS 91166 Demonstrate understanding of chemical reactivity

Writing Excellence answers to **Equilibrium – Concentration** questions

Equilibrium – Concentration QUESTION	
Question: When acid is added to a yellow solution of chromate ions, $CrO_4^{2-}(aq)$, the following equilibrium is established. $2CrO_4^{2-}(aq) + 2H^+(aq) \leftrightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$ **yellow** **orange** Analyse this equilibrium using equilibrium principles to explain the effect on the colour of the solution when: (i) more dilute acid is added **AND** when (ii) dilute base is added:	
ANSWER	
1. State the **equilibrium principle**	When a change is made to a system that is at equilibrium, the system responds to **reduce the effect** of that change.
2. Describe the **factor** in your question AND Link the principle to how the **system responds to increasing or decreasing concentration** of reactants	The factor in the question above is **concentration of reactants.** If there is an increase in concentration of reactants, the system responds by increasing the rate products are made. If there is a decrease in concentration of reactants, the system responds by decreasing the rate products are made.
3. **Generally,** explain which side of the equation is favoured (relate to reactants or products) by increasing or decreasing concentration	An increase in concentration of reactants **favours the forward reaction,** and a decrease in concentration of reactants **favours the reverse reaction.**
4. **Specifically,** for your reaction explain how you are increasing the concentration of reactants, AND link the direction of reaction that would be favoured	Adding dilute acid increases the concentration of the acid, one of the reactants, so the reaction moves in the forward direction and favours the products, therefore it will increase the rate that the added acid is 'used up'
5. Describe how the **system shift** by increasing the concentration of reactants would affect which substances are made AND final observation.	More $Cr_2O_7^{2-}(aq)$ would be produced and the solution would turn more **orange**.
6. **Specifically,** for your reaction explain how you are decreasing the concentration of reactants, AND link the direction of reaction that would be favoured	Adding base means that acid that reacts with the base is removed from the equilibrium (by neutralisation) and the concentration of the acid decreases. This will drive the equilibrium in the backwards direction and this favours the reactants to increase the rate of replacing the H^+ "used up"
7. Describe how the **system shift** by decreasing the concentration of reactants would affect which substances are made AND final observation.	More $CrO_4^{2-}(aq)$, would be produced and the solution would turn more **yellow**.

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Chemistry 2.6 AS 91166 Demonstrate understanding of chemical reactivity

Writing Excellence answers to **Ions and Conductivity** questions

Ions and Conductivity QUESTION

Question: Some properties of three aqueous solutions A, B and C, of equal concentration are shown in the table below. It is known that the solutions are $NH_{3(aq)}$, $HCl_{(aq)}$ and $NH_4Cl_{(aq)}$

Justify the identification of all three solutions.

- refer to both pH and electrical conductivity of the solutions
- link your answers to appropriate chemical equations.

Solution	A	B	C
pH	5.15	11.6	1.05
Electrical conductivity	good	poor	good

ANSWER

1. Identify each solution as either A, B or C by linking to being a **weak or strong acid or base** and also to the **pH**	Solution A with a pH of 5.15 is a weak acid (salt) and is $NH_4Cl_{(aq)}$ Solution B with a pH of 11.6 is a weak base and is $NH_{3(aq)}$ Solution C with a pH of 1.05 is a strong acid and is $HCl_{(aq)}$
2. State requirements for **conductivity**	In order to conduct electricity there needs to be the presence of **free moving charged particles**. The more charged particles there are available the better conductivity there will be. Ions in solution provide the charged particle.
3. **Solution A** (pH 5.15) weak acid salt. Equation 1. [A salt will first dissociate fully into ions] Write equation **AND** link ions formed to conductivity and level of dissociation	$NH_4Cl \rightarrow NH_4^+ + Cl^-$ $NH_4Cl_{(aq)}$ is solution **A**: good conductor of electricity – it fully dissociates in solution into ammonium and chloride ions, which conduct electricity.
4. **Solution A** (pH 5.15) weak acid salt. Equation 2.[One of the products of dissociation will further react as an acid] Write equation **AND** link ions formed to conductivity and level of dissociation (must form H_3O^+ ions)	$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$ Its pH (5.15) is that of a weak acid, as the ammonium ion is a weak acid and partially dissociates in water, producing hydronium ions.
5. **Solution B** (pH 11.6) weak base. Write equation **AND** link ions formed to conductivity and level of dissociation (must form OH^- ions)	$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ $NH_{3(aq)}$ is solution B: its pH (11.6) is that of a weak base as NH_3 so it **partially dissociates** in water, producing hydroxide ions. It is a poor conductor of electricity as it is only partially dissociated into ions in water. The remaining NH_3 molecules are neutral and do not conduct electricity.
6. **Solution C** (pH 1.05) strong acid. Write equation **AND** link ions formed to conductivity and level of dissociation (must form H_3O^+ ions)	$HCl + H_2O \rightarrow H_3O^+ + Cl^-$ $HCl_{(aq)}$ is solution **C**: low pH (1.05) is that of a strong acid, HCl fully dissociates in water, producing hydronium ions. It is a good conductor of electricity as it fully dissociates into ions in solution which conduct electricity.

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Chemistry 2.6 AS 91166 Demonstrate understanding of chemical reactivity

Writing Excellence answers to **Reaction Rates of Acids** questions

Reaction Rates of Acids QUESTION

Question: The pH values of 0.100 mol L^{-1} solutions of two acids, HA and HB, are given in the table below.
(i) Compare the relative strengths of the two acids, $HA_{(aq)}$ and $HB_{(aq)}$, using the information given above.
Your answer should include equations and calculations.
(ii) Predict and compare, with reasons, what would be observed when two 5 g samples of calcium carbonate chips, $CaCO_{3(s)}$, are reacted, separately, with excess HA and HB.

Solution	pH
0.100 mol L^{-1} HA(*aq*)	1.0
0.100 mol L^{-1} HB(*aq*)	2.2

ANSWER

1. Write an **equation** for HA [Remembering H_3O^+ must be produced]	$HA + H_2O \rightarrow A^- + H_3O^+$
2. **Calculate H_3O^+** for HA $[H_3O^+] = 10^{-pH}$	pH = 1.0 $[H_3O^+]$ = 0.100 mol L^{-1}
3. **For HA** link concentration of ions formed to level of dissociation AND compare to concentration of acid (are they the same?)	HA is a **strong acid** since it fully dissociates, as shown by concentration of hydronium ions in HA solution – same as original concentration of HA (both 0.100 mol L^{-1}).
4. Write an **equation** for HB [Remembering H_3O^+ must be produced]	$HB + H_2O \rightleftharpoons B^- + H_3O^+$
5. **Calculate H_3O^+** for HB $[H_3O^+] = 10^{-pH}$	pH = 2.2 $[H_3O^+]$ = 0.00631 mol L^{-1}
6. **For HB** link concentration of ions formed to level of dissociation AND compare to concentration of acid (are they the same?)	HB is a **weak acid** since it only partially dissociates; as shown by the concentration of hydronium ions in HB solution – concentration is only 0.00631 mol L^{-1}.
7. **For HA** link observation of reaction to concentration of ions	Expect reaction to be more vigorous; rapidly produces gas / bubbles (CO_2) – since the concentration of hydrogen ions is high,
8. then **For HA** link collision frequency to **rate of reaction**	there will be more frequent collisions resulting in a faster rate of reaction.
9. **For HB** link observation of reaction to concentration of ions	Expect a slower reaction, taking longer to produce the same volume of gas – since the concentration of hydrogen ions is low,
10. then **For HB** link collision frequency to **rate of reaction**	there will be less frequent collisions resulting in a slower rate of reaction.

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Chemistry 2.6 AS 91166 Demonstrate understanding of chemical reactivity

Writing Excellence answers to **pH calculations** questions

pH calculations QUESTION 1	
Question: In a solution of potassium hydroxide, KOH, the pH is found to be 12.8. **(i)** Calculate the hydronium ion concentration, $[H_3O^+]$, and the hydroxide ion concentration, $[OH^-]$, in the solution. $K_w = 1 \times 10^{-14}$ **(ii)** Calculate the pH of a 2.25×10^{-4} mol L^{-1} sodium hydroxide, NaOH, solution.	
ANSWER	
STEP 1. **Calculate H_3O^+** for <u>KOH</u> $[H_3O^+] = 10^{-pH}$ (units and 3sgf)	$[H_3O^+] = 10^{-pH}$ $[H_3O^+] = 1.58 \times 10^{-13}$ $molL^{-1}$
STEP 2. **Calculate OH^-** for <u>KOH</u> $[OH^-] = K_w / [H_3O^+]$ ($K_w = 1 \times 10^{-14}$) (units and 3sgf)	$[OH^-] = K_w / [H_3O^+]$ $[OH^-] = 0.0633$ $molL^{-1}$
STEP 1. **Calculate pOH** for <u>NaOH</u> $pOH = -\log[OH^-]$ (3sgf)	$pOH = -\log[OH^-]$ pOH = 3.60
STEP 2. **Calculate pH** for <u>NaOH</u> pH = 14 - pOH (3sgf)	pH = 14 - pOH pH = 14 - 3.60 pH = 10.4

pH calculations QUESTION 2	
Question: (i) A solution of nitric acid, $HNO_{3(aq)}$, has a hydronium ion, H_3O^+, concentration of 0.0243 mol L^{-1}. Determine, by calculation, the pH and the concentration of hydroxide ions, OH^-, in this solution. $K_w = 1 \times 10^{-14}$ (ii) Determine the hydroxide ion concentration, $[OH^-]$, of a solution of potassium hydroxide, $KOH_{(aq)}$, with a pH of 11.8.	
ANSWER	
STEP 1. **Calculate pH** for <u>HNO_3</u> $pH = -\log[H_3O^+]$ (3sgf)	$pH = -\log[H_3O^+]$ pH = 1.61
STEP 2. **Calculate OH^-** for <u>HNO_3</u> $[OH^-] = K_w / [H_3O^+]$ ($K_w = 1 \times 10^{-14}$) (units and 3sgf)	$[OH^-] = K_w / [H_3O^+]$ $[OH^-] = 4.12 \times 10^{-13}$ $molL^{-1}$
STEP 1. **Calculate H_3O^+** for <u>KOH</u> $[H_3O^+] = 10^{-pH}$ (units and 3sgf)	$[H_3O^+] = 10^{-pH}$ $[H_3O^+] = 1.58 \times 10^{-12}$ $molL^{-1}$
STEP 2. **Calculate OH^-** for <u>KOH</u> $[OH^-] = K_w / [H_3O^+]$ ($K_w = 1 \times 10^{-14}$) (units and 3sgf)	$[OH^-] = K_w / [H_3O^+]$ $[OH^-] = 6.31 \times 10^{-3}$ $molL^{-1}$

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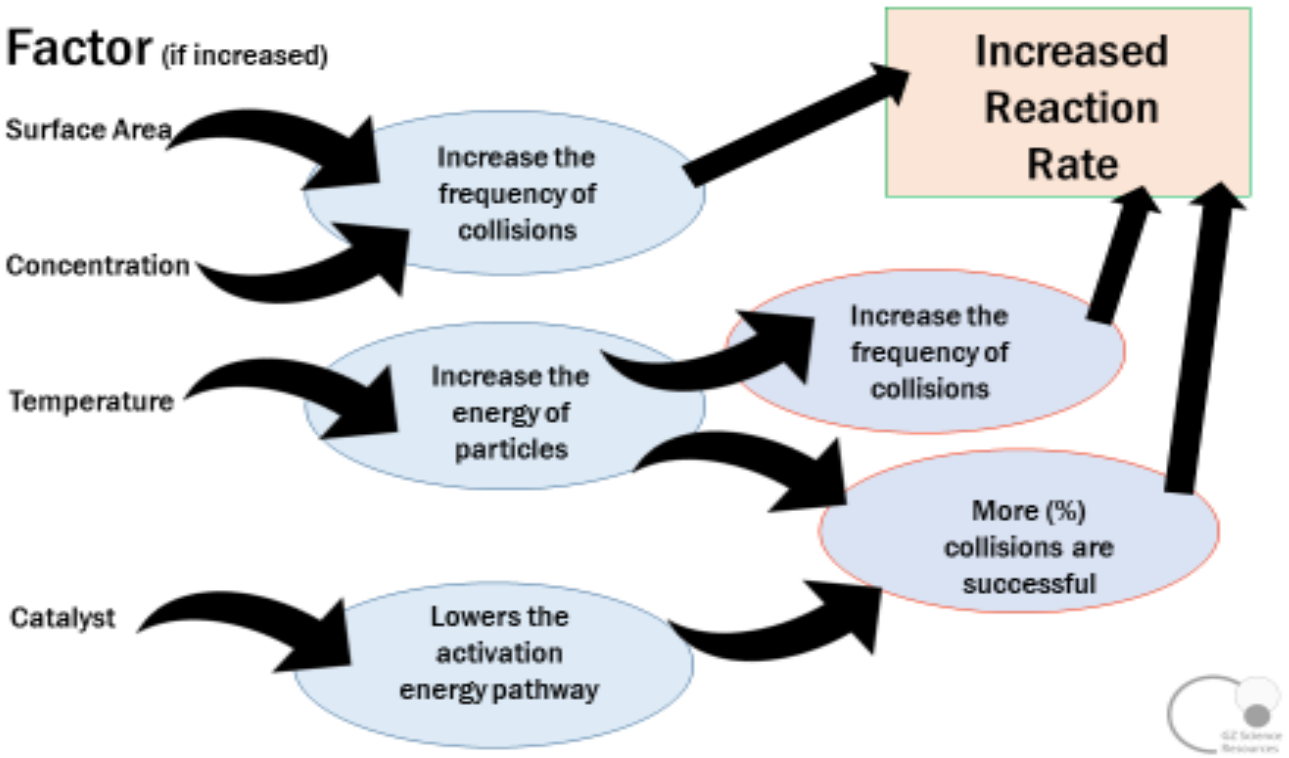
Reaction rates



Le Chatelier's Principle

When a change is applied to a system at equilibrium, the system responds so that the effects of the change are minimised

Change in conditions		Direction of change in equilibrium position
Concentration	- increase products	In the reverse direction
	- decrease products	In the forward direction
	- increase reactants	In the forward direction
	- decrease reactants	In the reverse direction
Pressure	Increase	In the direction with the least no. of moles of gas
	Decrease	In the direction with the greater no. of moles of gas
Temperature	Increase	In the direction of the endothermic reaction
	Decrease	In the direction of the exothermic reaction
Catalyst added		No change in equilibrium position or in K_c Equilibrium is reached more quickly (ie reaction rate changes)

K_C **decreases** when temperature **increases**

↓

Exothermic reaction

↑

K_C **increases** when temperature **decreases**

K_C **increases** when temperature **increases**

↓

Endothermic reaction

↑

K_C **decreases** when temperature **decreases**

Acid		Conjugate Base
HCl	hydrochloric acid	Cl^-
H_2SO_4	sulfuric acid	HSO_4^-
HNO_3	nitric acid	NO_3^-
CH_3COOH	acetic acid	CH_3COO^-
NH_4^+	ammonium ion	NH_3
H_3PO_4	phosphoric acid	$H_2PO_4^-$

Base		Conjugate Acid
H_2O	water	H_3O^+
SO_4^{2-}	sulfate ion	HSO_4^-
NH_3	ammonia	NH_4^+
OH^-	hydroxide ion	H_2O
HCO_3^-	hydrogen carbonate ion	H_2CO_3
CO_3^{2-}	carbonate ion	HCO_3^-