Equilibrium

GCSE P P P A Level P P P

When the system $P + Q \rightleftharpoons R + S$ is at equilibrium,

- All of the reactants have become products, and the reaction no longer proceeds.
- The rates of the forward and reverse reactions are equal.
- $[P][Q] = [R][S]$
- The rates of both the forward and the reverse reaction are equal to zero.

Adapted with permission from UCLES, A Level Chemistry, June 1989, Paper 3, Question 9

Gas Equilibrium

GCSE A Level

An equation for the reaction between hydrogen and iodine gas is given below.

$$H_2\,(g) + I_2\,(g) \longrightarrow 2\,HI\,(g)$$

The factors that affect the rate will be investigated in this question.

Part A Equilibrium

If this reaction is carried out at a higher pressure, what is the effect on the position of equilibrium?

- It would not change
- It depends on the type of reaction
- It would shift to the left
- It would shift to the right

Part B Rate

What would be the effect on the rate?

- It would stay the same
- It would increase
- It depends on the type of reaction
- It would decrease

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Effect of Pressure on Rate

GCSE A Level

Hydrogen and chlorine react together to form hydrogen chloride according to the following reaction.

$$H_2\,(g) + Cl_2\,(g) \rightleftharpoons 2\,HCl\,(g)$$

$$\Delta H = -180\,\mathrm{kJ\,mol^{-1}}$$

Part A Effect of increasing pressure

What is the effect of increasing the pressure on the rate of reaction?

- It depends on the progress of the reaction
- The rate would increase
- The rate would decrease
- The rate would not change

Part B Position of equilibrium

What is the effect on the position of equilibrium?

- It would shift to the left
- It would shift to the right
- It depends on the progress of the reaction
- It would not change

Part C Effect of increasing temperature

What would be the effect of increasing the temperature of the reaction on the rate?

- The rate would increase
- The rate would decrease
- The rate would not change
- Measurements would have to be made to determine this

Part D Position of equilibrium

What would be the effect of increasing the temperature on the position of equilibrium?

- The position of equilibrium would shift to the left
- The position of equilibrium would shift to the right
- The position of equilibrium would not change
- Measurements would have to be made to determine this

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STEM SMART Chemistry Week 20

Basics of Equilibria

A Level

P P P

Hydrogen iodide can decompose into hydrogen and iodine reversibly:

Part A Equation

Suggest an equation for the decomposition (do not include state symbols).

Part B Energy profile

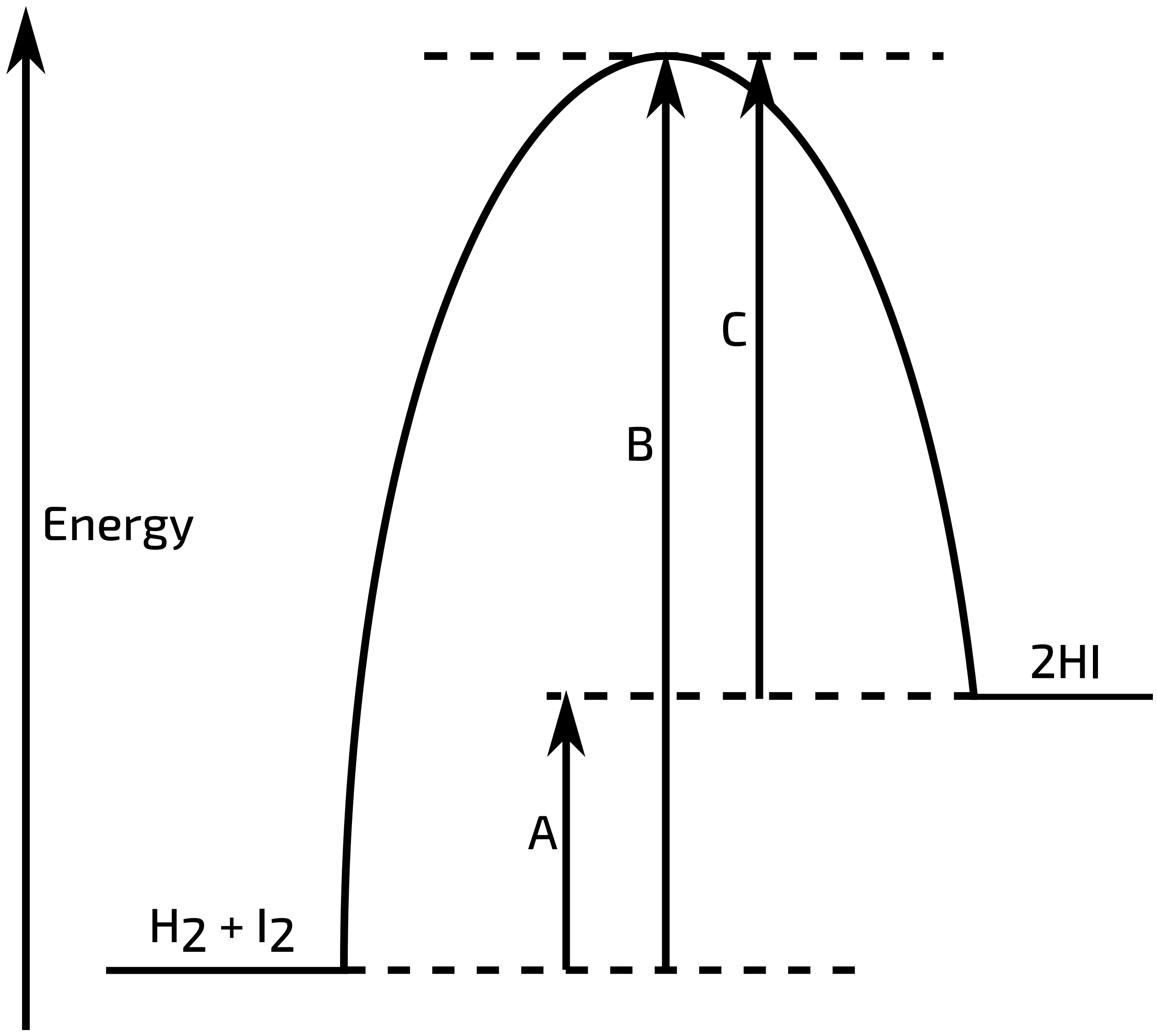

Figure 1: Energy profile for the reaction.

Which arrow represents the activation energy for the hydrogen iodide *formation* reaction?

- None of them
- C
- A
- B

Does the energy profile suggest that the hydrogen iodide *formation* reaction is endothermic, exothermic, or that the enthalpy change is zero?

- Exothermic
- Endothermic
- Zero enthalpy change

Part C Temperature effects

Would increasing the temperature of the reaction mixture favour the elements or the hydrogen iodide side?

- Elements
- Hydrogen iodide

Part D Product effects

If a large amount of hydrogen is added to the reaction vessel, how will the position of equilibrium be affected?

- The equilibrium position will move towards the hydrogen iodide side
- The equilibrium position will move towards the elements side
- The equilibrium position will not change

Part E Pressure effects

If the total pressure of the reaction mixture is increased, how will the position of equilibrium be affected?

- The equilibrium position will move towards the hydrogen iodide side
- The equilibrium position will move towards the elements side
- The equilibrium position will not change

Gameboard:

STEM SMART Chemistry Week 20

Home Gameboard Physical Equilibrium Dynamic Equilibria

Dynamic Equilibria

A Level

This question deals with some of the basic concepts of equilibria. We will be looking at the following equilibria:

$$\mathrm{A} + \mathrm{B} \rightleftharpoons \mathrm{C} + \mathrm{D}$$

The following graph shows how the concentrations of A, B, C and D change during the course of the reaction.

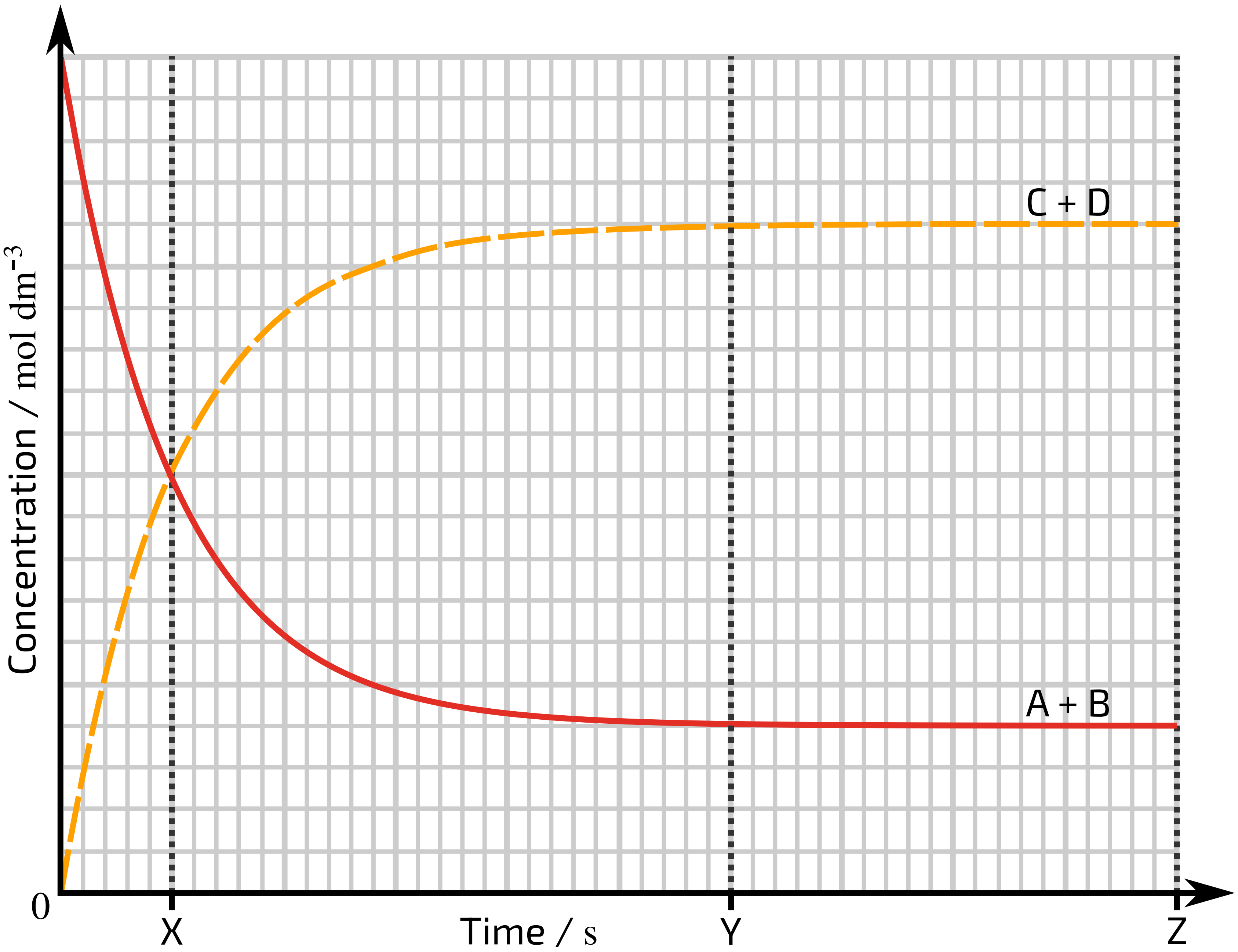

Figure 1: Graph showing the change in concentration of the reactants and products over time.

Part A Point of equilibrium

Suggest the time at which the reaction mixture first reaches equilibrium.

- X
- Y
- Z

Part B Equilibrium condition

What is the relationship between the rates of the forward and reverse reactions at equilibrium?

- The rate of the forward reaction and the rate of the reverse reaction are both zero.
- The rate of the forward reaction is greater than the rate of the reverse reaction.
- The rate of the reverse reaction is greater than the rate of the forward reaction.
- The rate of the forward reaction equals the rate of the reverse reaction.

Part C Equilibrium constant

An equilibrium constant is a measure of the composition of the reaction mixture at equilibrium. For an elementary reaction such as:

$$\mathrm{A + B \rightleftharpoons C + D}$$

The equilibrium constant is given by:

$$\mathrm{K}_c := \frac{[\mathrm{C}][\mathrm{D}]}{[\mathrm{A}][\mathrm{B}]}$$

Where $[\mathrm{X}]$ indicates the concentration of species X. Calculate the equilibrium constant for the above reaction, assuming that at time 0, the concentrations of A and B were equal.

Part D Catalyst effects

What would be the effect of introducing a catalyst on the time taken for the reaction to reach equilibrium?

- It would decrease
- It would increase
- It would stay the same

Water Gas Shift Reaction

A Level

The water gas shift (WGS) is a well-known reaction at the industrial level that has been used for hydrogen generation since the early 1940s. The WGS is commonly associated with steam (water) reacting with carbon monoxide. The main role of this reaction in industrial processes is to increase the level of hydrogen in the feed for the production of bulk chemicals such as methanol, ammonia, and hydrocarbons. The reaction is an equilibrium-limited reaction and several methods have been attempted to increase its yield.

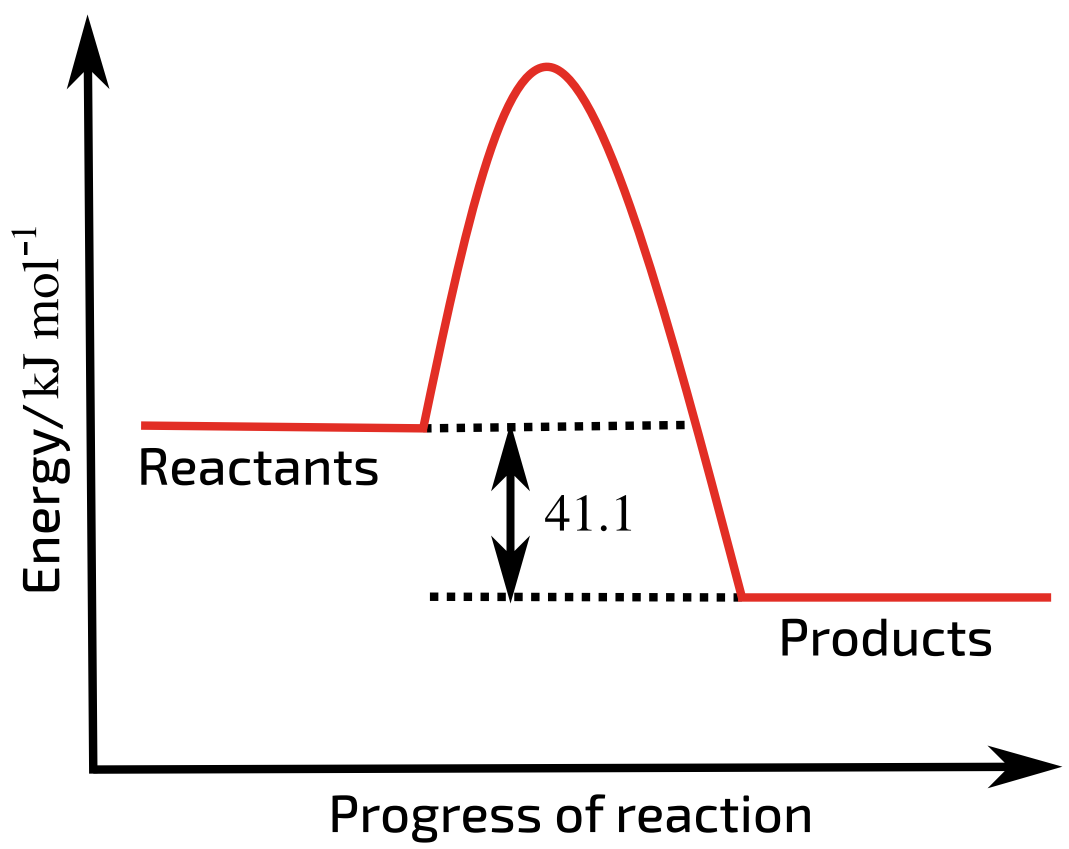

Figure 1: Reaction profile

Part A Equation

Write the equation of the WGS reaction.

Part B Energy change

What is the energy change associated with the reaction?

Part C Temperature effect

What would be the effect of increasing the temperature on the reaction?

- The reaction will proceed faster but less hydrogen will be produced
- Less hydrogen will be produced but the reaction rate would stay the same.
- The reaction rate would increase but the amount of hydrogen will stay the same
- More hydrogen will be produced.

Part D Catalyst effect

$Fe_2O_3 - Cr_2O_3$ is a high-temperature WGS catalyst that is commercially available. How do you think the energy profile would change if you added this catalyst?

- The activation energy will become lower.
- The difference in energy between the reactants and products will become lower.
- The energy of the reactants will become higher. As a result, the energy barrier would be smaller and the reaction will be faster.
- The energy of the products will be lower and more energy will be produced from this reaction

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STEM SMART Chemistry Week 20

Essential Pre-Uni Chemistry I2.1

A Level

Part A (a)

At equilibrium in the reaction $\mathrm{A\,(aq) + B\,(aq) \rightleftharpoons C\,(aq) + D\,(aq)}$, the concentrations in $\mathrm{mol\,dm^{-3}}$ are: $[\mathrm{A}]_{\mathrm{(eq)}} = 0.25$, $[\mathrm{B}]_{\mathrm{(eq)}} = 0.10$, $[\mathrm{C}]_{\mathrm{(eq)}} = 0.030$ and $[\mathrm{D}]_{\mathrm{(eq)}} = 0.010$. Calculate K_{c}.

Part B (b)

The reaction $\mathrm{X\,(aq) + 3\,Y\,(aq) \rightleftharpoons 2\,Z\,(aq)}$ reaches an equilibrium in which the three concentrations in $\mathrm{mol\,dm^{-3}}$ are: $[\mathrm{X}]_{\mathrm{(eq)}} = 2.0 \times 10^{-4}$, $[\mathrm{Y}]_{\mathrm{(eq)}} = 1.6 \times 10^{-5}$, $[\mathrm{Z}]_{\mathrm{(eq)}} = 0.024$. Calculate the magnitude of K_{c}.

Part C (c)

The reaction $\mathrm{A\,(aq) + B\,(aq) \rightleftharpoons C\,(aq) + H_2O\,(l)}$ has an equilibrium constant equal to $0.050\,\mathrm{dm^3\,mol^{-1}}$. If the equilibrium concentration of A is $0.025\,\mathrm{mol\,dm^{-3}}$, and that of B is $0.020\,\mathrm{mol\,dm^{-3}}$, find the equilibrium concentration of C, in $\mathrm{mol\,dm^{-3}}$.

Part D (d)

K_c for the reaction $2\,J\,(aq) \rightleftharpoons K\,(aq) + L\,(aq)$ is found to be 28.2 and at equilibrium, there is $0.815\,mol\,dm^{-3}$ of K and $1.24\,mol\,dm^{-3}$ of L. Calculate the equilibrium concentration of J in $mol\,dm^{-3}$.

Gameboard:

STEM SMART Chemistry Week 20

Essential Pre-Uni Chemistry I2.2

A Level

The reaction $\mathrm{A\,(aq)} \rightleftharpoons \mathrm{B\,(aq)} + \mathrm{C\,(aq)}$ has an equilibrium constant given by:

$K_c = \frac{[\mathrm{B}]_{(eq)}\ [\mathrm{C}]_{(eq)}}{[\mathrm{A}]_{(eq)}}$

Where $[\mathrm{X}]_{(eq)}$ is the equilibrium concentration of X in $\mathrm{mol\,dm^{-3}}$.

Part A (a)

Give the units of K_c

- Pa
- $\mathrm{mol\,dm^{-3}}$
- $\mathrm{dm^3\,mol^{-1}}$
- $\mathrm{mol^2\,dm^{-6}}$

Part B (b)

If a $2.0\,\mathrm{mol\,dm^{-3}}$ solution of A is allowed to reach equilibrium, at which $1.2\,\mathrm{mol\,dm^{-3}}$ of A remains, find the equilibrium concentrations of B and C in $\mathrm{mol\,dm^{-3}}$. Give your answer to 1 significant figure.

Part C (c)

Find the value of K_c. Give your answer to 2 significant figures.

Essential Pre-Uni Chemistry I2.5

A Level

The reaction, $2\,\mathrm{P}\,(\mathrm{aq}) + \mathrm{Q}\,(\mathrm{aq}) \rightleftharpoons \mathrm{R}\,(\mathrm{aq}) + \mathrm{S}\,(\mathrm{aq})$ reaches equilibrium.

If equal volumes of $\mathrm{R}\,(\mathrm{aq})$ and $\mathrm{S}\,(\mathrm{aq})$, both with initial concentration $1.00\,\mathrm{mol\,dm^{-3}}$ are mixed and come to equilibrium at $320\,\mathrm{K}$, the concentration, $[\mathrm{S}]_{\mathrm{eq}} = 0.422\,\mathrm{mol\,dm^{-3}}$.

Part A (a)

Find the equilibrium concentration of P (give your answer to 4 significant figures).

Part B (b)

Find the equilibrium concentration of Q (give your answer to 3 significant figures).

Part C (c)

Find the equilibrium concentration of R (give your answer to 3 significant figures).

Part D (d)

Find K_c.

Part E (e)

If the reaction is exothermic, will the equilibrium constant be higher, lower, or the same at $330\,\mathrm{K}$?

- Higher
- The same
- Lower

Gameboard:

STEM SMART Chemistry Week 20

Physics. You work it out.

Essential Pre-Uni Chemistry I2.9

A Level

The hydration of chloroethanal has an equilibrium constant, K_c, of 37.0 $[\mathbf{2}]$.

$$\mathrm{ClCH_2CHO\,(aq) + H_2O\,(l) \rightleftharpoons ClCH_2CH(OH)_2\,(aq)}$$

Complete the following table by providing any missing initial or equilibrium concentrations.

Initial $[\mathrm{ClCH_2CHO}]$	**Initial** $[\mathrm{ClCH_2CH(OH)_2}]$	**Equilibrium** $[\mathrm{ClCH_2CHO}]$	**Equilibrium** $[\mathrm{ClCH_2CH(OH)_2}]$
1.20 $\mathrm{mol\,dm^{-3}}$	0.00 $\mathrm{mol\,dm^{-3}}$	(a)	(b)
0.00 $\mathrm{mol\,dm^{-3}}$	(c)	(d)	0.292 $\mathrm{mol\,dm^{-3}}$
(e)	0.100 $\mathrm{mol\,dm^{-3}}$	0.0184 $\mathrm{mol\,dm^{-3}}$	(f)
14.0 $\mathrm{mmol\,dm^{-3}}$	0.800 $\mathrm{mmol\,dm^{-3}}$	(g)	(h)
161 $\mathrm{mg\,dm^{-3}}$	0.00 $\mathrm{mg\,dm^{-3}}$	(i)	(j)

Part A (a)

(a) in $\mathrm{mol\,dm^{-3}}$

Part B (b)

(b) in $\mathrm{mol\,dm^{-3}}$

Part C (c)

(c) in $\mathrm{mol\,dm^{-3}}$

Part D (d)

(d) in $\mathrm{mol\,dm^{-3}}$

Part E (e)

(e) in $\mathrm{mol\,dm^{-3}}$

Part F (f)

(f) in $\mathrm{mol\,dm^{-3}}$

Part G (g)

(g) in $\mathrm{mmol\,dm^{-3}}$

Part H (h)

(h) in $\mathrm{mmol\,dm^{-3}}$

Part I (i)

(i) in $\mathrm{mg\,dm^{-3}}$

Part J (j)

(j) in $\mathrm{mg\,dm^{-3}}$

Part K (k)

(k) Trichloroethanal is almost fully hydrated in aqueous solution, with a K_c value of around 10^4 $[\mathbf{3}]$, to give "chloral hydrate". Give the approximate concentration in $\mathrm{mol\,dm^{-3}}$ of chloral hydrate, (to 2 significant figures), required to maintain an equilibrium concentration of $1.0\,\mathrm{nmol\,cm^{-3}}$ of the free, unhydrated form.

$[\mathbf{2}]$ Tadashi Okuyama, Howard Maskill, ‘Organic Chemistry: A Mechanistic Approach′ OUP Oxford, 2013; ISBN $0199693277, 9780199693276$

$[\mathbf{3}]$ *Ibid.*