



Physics. You work it out.

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Competing Reactions

A Level
P P P

A compound X can produce two possible products, Y and Z, under the same reaction conditions. An energy profile for this reaction can be represented as shown below.

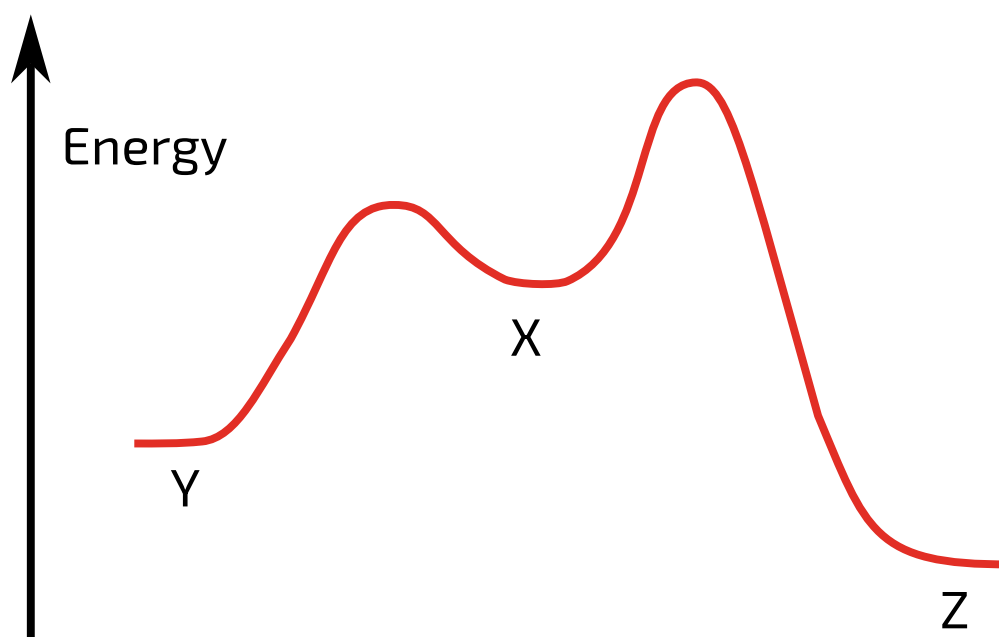


Figure 1: A reaction profile for the reaction described.

Part A Activation energy

The *activation energy* is the energy required for a reaction to take place. It is given by the difference in energy between the and the state. In the set-up above, the reaction producing product Y has a activation energy than the process producing product Z due to the state being in energy for the former.

Items:

minimum

maximum

optimal

starting materials

products

transition

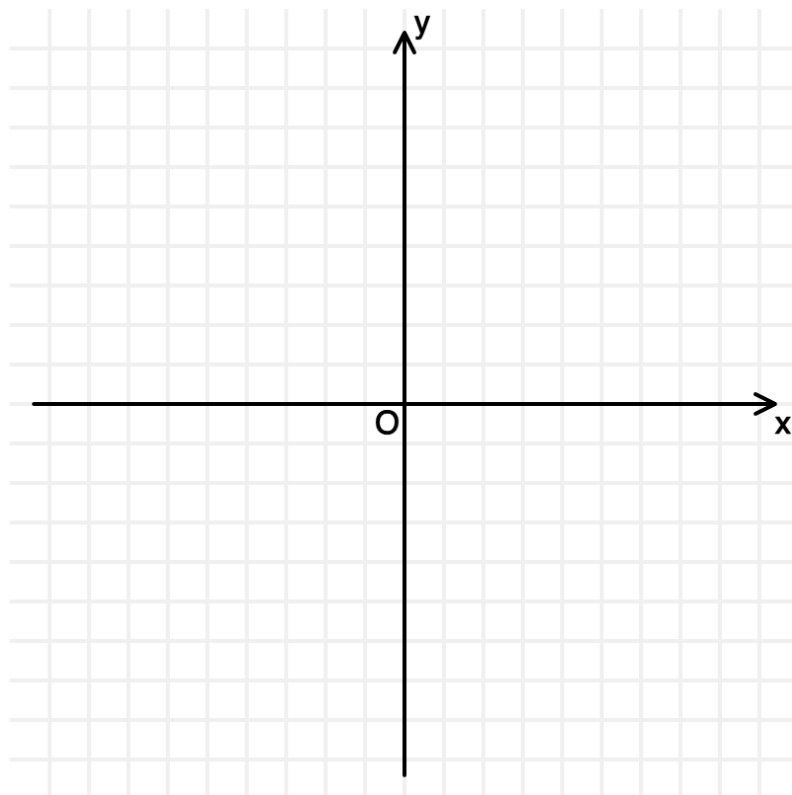
higher

lower

Part B Molecular speed distribution

What do we call the distribution of molecular speeds?

What does this distribution look like (assume particle speed is on the x-axis, and number of particles on the y-axis)?



Part C Temperature dependence

Which product (Y or Z) will be favoured at lower temperatures and which will be favoured at higher temperatures? Explain your reasoning.

At lower temperatures, the reaction is under control, and so the reaction with the lower is favoured. This means product is favoured at low temperatures. At higher temperatures, the reaction is under control, and so the reaction with the lower is favoured. This means product is favoured at high temperatures.

Items:

kinetic

thermodynamic

energy of products

energy of reactants

activation energy

Y

Z

Part D Gold catalyst

The addition of a gold catalyst to the above reaction results in the formation only of Z, regardless of the temperature at which the reaction is carried out. Which of the following statements help(s) to explain this observation?

- ☐ Gold increases the activation energy for the formation of Y
 - ☐ Gold decreases the activation energy for the formation of Y
 - ☐ Gold increases the activation energy for the formation of Z
 - ☐ Gold decreases the activation energy for the formation of Z
 - ☐ Gold lowers the energy of X
 - ☐ Gold lowers the energy of Y
 - ☐ Gold lowers the energy of Z
-

Adapted with permission from OCSEB, STEP Chemistry, Jun 1996, Question 1

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Ammonia Decomposition

A Level



In an experiment, the decomposition of gaseous ammonia to N_2 and H_2 on a hot tungsten wire was studied by monitoring the change in pressure with time. The rate equation for this reaction may be written in terms of either the concentration or the partial pressure of ammonia. In terms of the partial pressure of ammonia, p_{NH_3} , it is:

$$\text{rate} = -k(p_{\text{NH}_3})^\alpha,$$

where α is the order of the reaction and k is the rate constant.

At the start of the reaction, the only gas present was ammonia at an initial pressure of 200 mmHg. The table below shows how the total pressure varied with time.

Time / s	Total pressure / mmHg
100	214
200	227
300	238
400	249
500	259
600	270
800	292

Part A Equation

Write a balanced equation, including state symbols, for the decomposition of one mole of ammonia.

Part B Pressure vs concentration

Using the ideal gas law, we can show that pressure is directly proportional to concentration at constant temperature. What is the proportionality constant we need to multiply concentration by to get the pressure?

The following symbols may be useful: R , T , V , n , p

Part C Total pressure

The initial partial pressure of ammonia is p_0 mmHg. After a time t it is $(p_0 - x)$ mmHg. Find an expression for the *total* pressure of reactants and products, p_T , at time t , expressed in mmHg (don't include the unit in your expression).

The following symbols may be useful: p_0 , t , x

Part D Partial pressure

Find an expression for the *partial pressure of ammonia* at time t as a function of p_0 and p_T , expressed in mmHg (don't include the unit in your expression).

The following symbols may be useful: p_0 , p_T

Part E Graph

Which of the following statements are true about the graph of the partial pressure of ammonia against time?

- ☐ It appears to be approximately a straight line.
 - ☐ It appears to be approximately a parabola
 - ☐ It appears to be approximately S-shaped
 - ☐ It has a positive gradient throughout
 - ☐ It has zero gradient throughout
 - ☐ It has a negative gradient throughout
 - ☐ It has both a positive and a negative gradient over different intervals.
 - ☐ The graph is steepest at around $t = 400$ s
 - ☐ The graph gets steeper at higher times
-

Part F Order

What is the order of the reaction, α ?

Part G Rate constant

What is the rate constant of the reaction? Give your answer to 2 s.f.

Adapted with permission from OCR, STEP Chemistry, Jun 1999, Question 2

Gameboard:

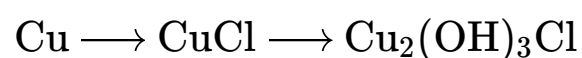
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A Rusty Carillon

A Level



An excavated Chinese ancient bronze musical instrument, carillon, was covered entirely by rust. Chemical analysis showed that the rust contains CuCl , Cu_2O and $\text{Cu}_2(\text{OH})_3\text{Cl}$. Simulation experiments showed that CuCl was formed first under the action of both air and Cl containing aqueous solution and then $\text{Cu}_2(\text{OH})_3\text{Cl}$ produced in the following way:



Rate constants k_c for this reaction were measured at various temperatures in a simulation experiment in order to obtain its kinetic parameters. The results of the experiment are given below.

Temperature / °C	$k_c / \text{mol dm}^{-3} \text{s}^{-1}$
25	1.29×10^{-4}
40	2.50×10^{-4}

Part A Activation energy

Find the value of the activation energy of this reaction.

Adapted from the International Chemistry Olympiad, Beijing 1995, Problem 1.2

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Essential Pre-Uni Chemistry G2.2

A Level



Use the following standard molar entropy values in $\text{J K}^{-1} \text{mol}^{-1}$ to help answer the questions in this section.

$\text{H}_2\text{O (l)}$	69.9	HCl (g)	186.8	NaCl (s)	72.1
$\text{H}_2\text{O (g)}$	188.7	$\text{Cl}_2 \text{ (g)}$	223.1	$\text{ZnCl}_2 \text{ (s)}$	111.5
$\text{H}_2 \text{ (g)}$	130.7	$\text{H}_2\text{SO}_4 \text{ (l)}$	156.9	Zn (s)	41.6
Na (s)	51.2	Zn (g)	150.0	$\text{NaHSO}_4 \text{ (s)}$	113.0
$\text{O}_2 \text{ (g)}$	205.2	$\text{CO}_2 \text{ (g)}$	213.6	C (s) graphite	5.7

Calculate the standard entropy change when...

Part A (a)

2.50 mol of solid zinc chloride decomposes into its gaseous elements.

Part B (b)

2.0 g of sodium reacts fully with chlorine gas.

Part C (c)

10.0 mg of zinc vapour deposits onto a surface.

Part D (d)

40.0 m³ (at RTP) of steam condenses. Give your answer to 3 significant figures.

Part E (e)

200 cm³ of water (1.00 g cm⁻³) is electrolysed.

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Essential Pre-Uni Chemistry H1.3



Part A (a)

A phase change at constant pressure has an enthalpy change of 58 kJ mol^{-1} and an entropy change of $85 \text{ J K}^{-1} \text{ mol}^{-1}$. Find the temperature at which the entropy change of the surroundings is equal in magnitude and opposite in sign to that of the system (i.e. the temperature at which the phase change occurs at this pressure.)

Part B (b)

The neutralisation of one mole of acid at 305 K increases the entropy of the surroundings by 180 J K^{-1} at constant pressure. Find the enthalpy of neutralisation.

Part C (c)

The reaction of 3.5 g of lithium raises the entropy of the surroundings by 220 J K^{-1} at constant pressure and 294 K . Find the molar enthalpy change for the reaction.

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Essential Pre-Uni Chemistry H2.1



Part A (a)

At 298 K the decomposition of hydrogen peroxide has an enthalpy change of -98 kJ mol^{-1} and an entropy change of $62.9 \text{ J K}^{-1} \text{ mol}^{-1}$. Calculate the free energy change at constant pressure.

Part B (b)

The free energy change for a reaction at constant pressure is -4.5 kJ mol^{-1} . If the temperature is 320 K and the entropy change is $-12 \text{ J K}^{-1} \text{ mol}^{-1}$, find the enthalpy change.

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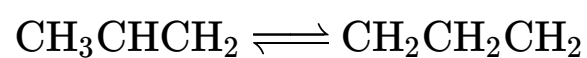
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Essential Pre-Uni Chemistry I1.1



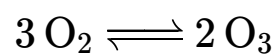
Write expressions for K_p for the following gas phase equilibria, using the notation $p(\text{A})$ for the partial pressure of A :

Part A (a)



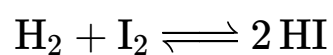
The following symbols may be useful: C, H, p

Part B (b)



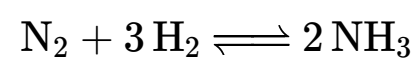
The following symbols may be useful: O, p

Part C (c)



The following symbols may be useful: H, I, p

Part D (d)



The following symbols may be useful: H, N, p

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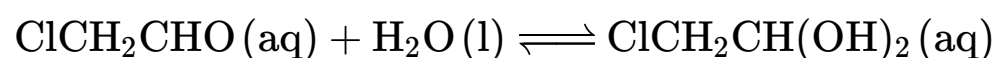
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Essential Pre-Uni Chemistry I2.9

A Level



The hydration of chloroethanal has an equilibrium constant, K_c , of 37.0 [2].



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

Initial [ClCH ₂ CHO]	Initial [ClCH ₂ CH(OH) ₂]	Equilibrium [ClCH ₂ CHO]	Equilibrium [ClCH ₂ CH(OH) ₂]
1.20 mol dm ⁻³	0.00 mol dm ⁻³	(a)	(b)
0.00 mol dm ⁻³	(c)	(d)	0.292 mol dm ⁻³
(e)	0.100 mol dm ⁻³	0.0184 mol dm ⁻³	(f)
14.0 mmol dm ⁻³	0.800 mmol dm ⁻³	(g)	(h)
161 mg dm ⁻³	0.00 mg dm ⁻³	(i)	(j)

Part A (a)

(a) in mol dm⁻³

Part B (b)

(b) in mol dm⁻³

Part C (c)

(c) in mol dm⁻³

Part D (d)

(d) in mol dm⁻³

Part E (e)

(e) in mol dm⁻³

Part F (f)

(f) in mol dm⁻³

Part G (g)

(g) in mmol dm⁻³

Part H (h)

(h) in mmol dm^{-3}

Part I (i)

(i) in mg dm^{-3}

Part J (j)

(j) in mg dm^{-3}

Part K (k)

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

[2] Tadashi Okuyama, Howard Maskill, 'Organic Chemistry: A Mechanistic Approach' OUP Oxford, 2013; ISBN 0199693277, 9780199693276

[3] *Ibid.*

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Essential Pre-Uni Chemistry J5.10

A Level



A buffer of pH 7.8 is prepared by taking 200 cm^3 of 0.020 mol dm^{-3} "tris" solution and adding dilute hydrochloric acid from a burette until the pH is correct. If this requires 1.35 cm^3 of 2.0 mol dm^{-3} HCl(aq) , calculate the $\text{p}K_{\text{a}}$ of the conjugate acid of "tris".

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pH in Ester Hydrolysis

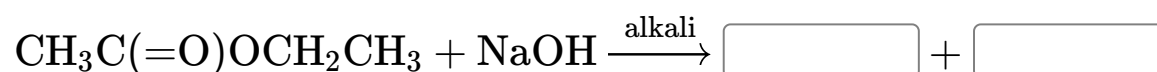
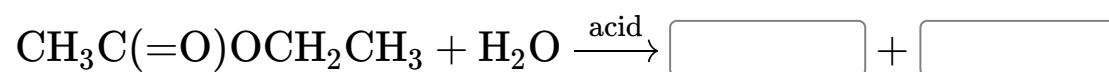
A Level



The hydrolysis of an ester can be carried out in both alkaline and acidic conditions.

Part A Equations

Fill in the gaps to complete the reaction equations for hydrolysis of ethyl ethanoate under acidic and alkaline conditions respectively.



Items:

H_2O

CH_3OH

$\text{CH}_3\text{CH}_2\text{OH}$

HCOOH

CH_3COOH

HCOONa

CH_3COONa

Part B pH rate profile

A study of the rate of hydrolysis of ethyl ethanoate in buffered solutions gave the following pH rate profile:

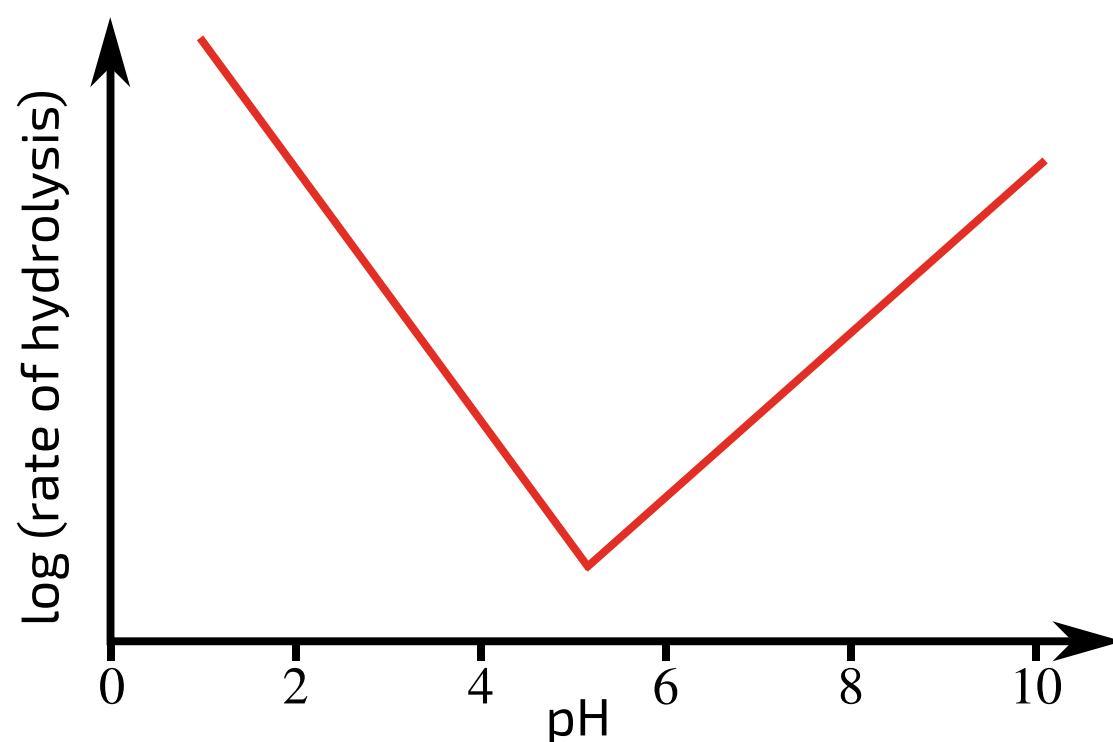


Figure 1: pH rate profile for ester hydrolysis

Which of the following statements help explain the trends seen in this profile?

- ☐ at higher pH, the H^+ concentration is higher, speeding up acid-catalysed hydrolysis
- ☐ at higher pH, the OH^- concentration is higher, speeding up base-catalysed hydrolysis
- ☐ at lower pH, the H^+ concentration is higher, speeding up acid-catalysed hydrolysis
- ☐ at lower pH the OH^- concentration is higher, speeding up base-catalysed hydrolysis

Part C pH 5.5

At pH 5.5, the rate for the acid hydrolysis reaction is the same as the rate for the alkaline hydrolysis reaction. What are the concentrations of H^+ and OH^- at this pH?

Give your answers to 2 sf.

Concentration of H^+ :

Concentration of OH^- :

Part D Rate constant comparison

Which of the following statements about the rate constants for the two hydrolysis processes is/are correct?

- ☐ The rate constants for the acid and alkaline hydrolysis are equal, as the rate for both processes can be made equal under certain conditions.
- ☐ The rate constant for the acid hydrolysis is higher than the rate constant for the alkaline hydrolysis, as the rate for both processes is equal when the H^+ concentration is higher than the OH^- concentration.
- ☐ The rate constant for the alkaline hydrolysis is higher than the rate constant for the acid hydrolysis, as the rate for both processes is equal when the H^+ concentration is higher than the OH^- concentration.
- ☐ The rate constant for the acid hydrolysis is higher than the rate constant for the alkaline hydrolysis, as the acid hydrolysis dominates at neutral pH when the H^+ and OH^- concentrations are equal.
- ☐ The rate constant for the alkaline hydrolysis is higher than the rate constant for the acid hydrolysis, as the alkaline hydrolysis dominates at neutral pH when the H^+ and OH^- concentrations are equal.

Adapted with permission from OCSEB, STEP Chemistry, June 1991, Question 1.