Cambridge AS & A Level

CHEMISTRY

Paper 2

Topical Past Paper Questions

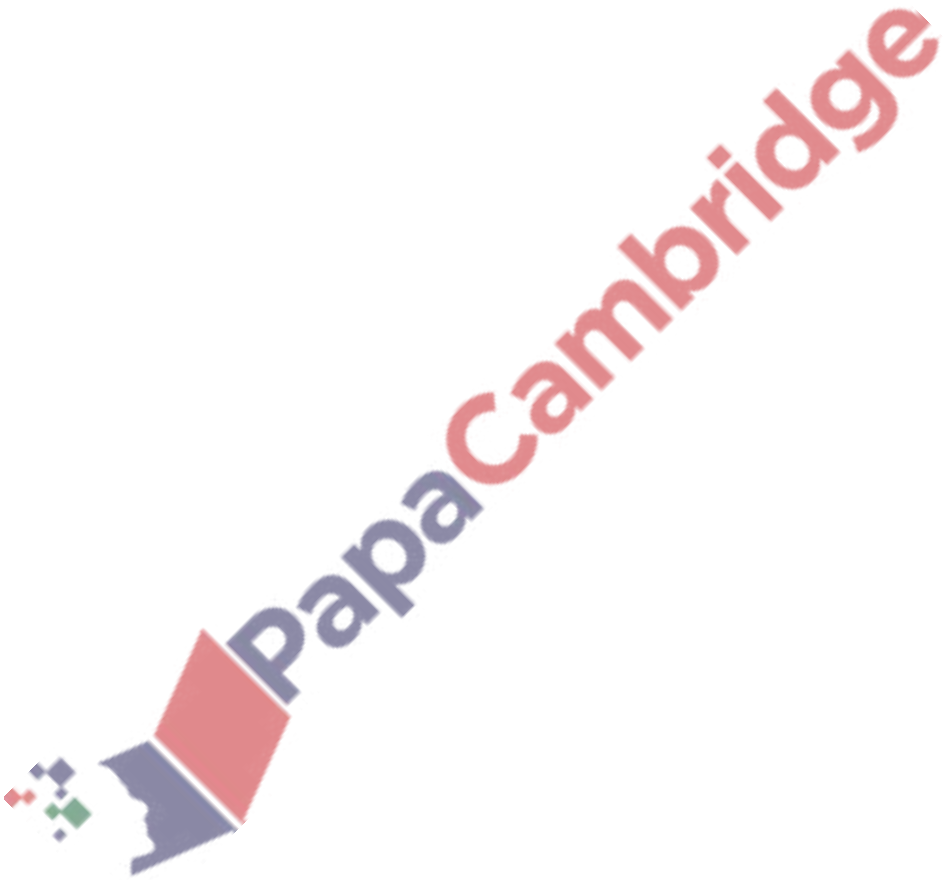
+ Answer Scheme

2015 - 2021

PapaCambridge

Chapter 8

Reaction kinetics



8.1 Effect of temperature: on reaction rates, rate constants; activation energy

32. 9701_m21_qp_22 Q: 1

The rate of chemical reactions is affected by changes in temperature and pressure.

(a) (i) Draw a curve on the axes to show the Boltzmann distribution of energy of particles in a sample of gaseous krypton atoms at a given temperature.

Label the curve **T1** and label the axes.

[2]

(ii) On the diagram in **(a)(i)**, draw a second curve to show the distribution of energies of the krypton atoms at a higher temperature.

Label the second curve **T2**. [1]

(b) The Boltzmann distribution assumes that the particles behave as an ideal gas.

(i) State **two** assumptions of the kinetic theory as applied to an ideal gas.

1 .....

.....

2 .....

.....

[2]

(ii) 2.00 g of krypton gas, Kr(g), is placed in a sealed 5.00 dm^3 container at 120 °C.

Calculate the pressure, in Pa, of Kr(g) in the container.
Assume Kr(g) behaves as an ideal gas.

Show your working.

pressure = ... Pa [3]

(iii) State and explain the conditions at which krypton behaves most like an ideal gas.

.....

.....

.....

..... [2]

(c) Krypton reacts with fluorine in the presence of ultraviolet light to make krypton difluoride, $KrF_2(g)$.

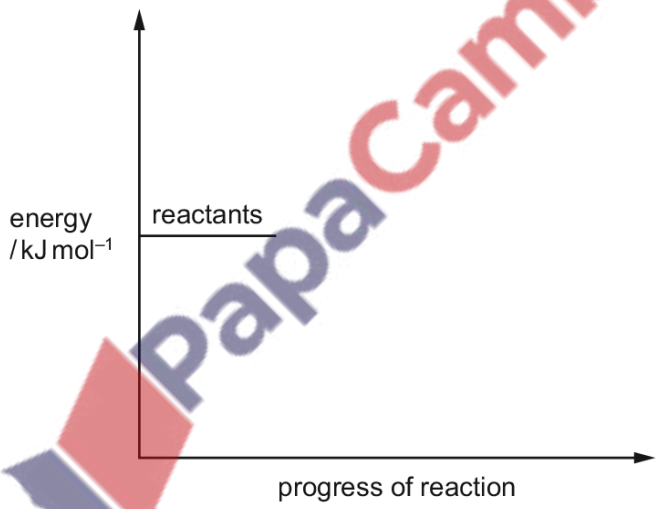
$$Kr(g) + F_2(g) \rightarrow KrF_2(g)$$

activation energy for the reaction, $E_a = +385\,kJ\,mol^{-1}$

enthalpy change of formation of KrF_2, $\Delta H_f = +60.2\,kJ\,mol^{-1}$

(i) Use this information to complete the reaction profile diagram for the formation of KrF_2. Label E_a and ΔH_f on the diagram.

Assume the reaction proceeds in one step.



[2]

(ii) Explain, in terms of activation energy, E_a, and the collision of particles, how an increase in temperature affects the rate of a chemical reaction.

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.....

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..... [2]

[Total: 14]

33. 9701_s17_qp_22 Q: 3

The hydrogen halides, HC*l*, HBr and HI, can undergo thermal decomposition.
In a sealed container an equilibrium is established according to the equation shown.

$$2HX(g) \rightleftharpoons H_2(g) + X_2(g) \qquad \text{(where X = C}l\text{, Br or I)}$$

(a) Some bond energies are shown in the table.

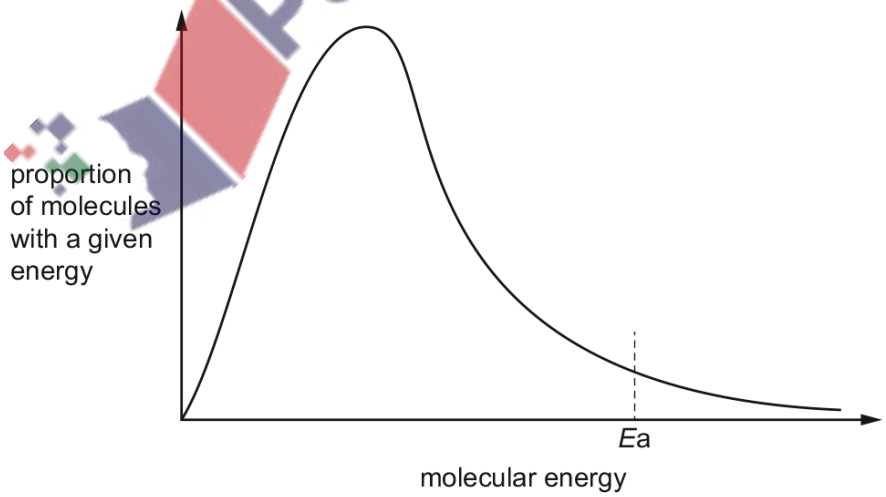
	bond energy / kJ mol^{-1}
H–Br	366
H–H	436
Br–Br	193

Use these data to calculate a value for the enthalpy change, ΔH, for the thermal decomposition of hydrogen bromide, HBr, according to the equation shown.

ΔH = ... kJ mol^{-1} [1]

(b) At a temperature of 700 K a sample of HBr is approximately 10% decomposed. Changing the temperature affects both the rate of decomposition of HBr and the percentage that decomposes.

The Boltzmann distribution for a sample of HBr at 700 K is shown. *E*a represents the activation energy for the reaction.



(i) Using the same axes, sketch a second curve to indicate the Boltzmann distribution at a higher temperature. [2]

(ii) With reference to the curves, state and explain the effect of increasing temperature on the **rate** of decomposition of HBr.

.....

.....

.....

..... [3]

(iii) The decomposition of HBr is endothermic.

State the effect of increasing temperature on the **percentage** of HBr that decomposes. Use Le Chatelier's principle to explain your answer.

.....

.....

.....

..... [3]

(iv) At 700 K HBr is approximately 10% decomposed but hydrogen iodide, HI, is approximately 20% decomposed.

Explain this difference with reference to bond strengths and the factors that affect them.

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.....

..... [3]

(c) At temperatures above 1500 K, HCl will decompose.

A sample of 0.300 mol of HCl decomposed in a sealed container.

The resulting equilibrium mixture was found to contain 1.50×10^{-2} mol of Cl_2.

(i) Calculate the amounts, in mol, of H_2 and HCl present in the equilibrium mixture.

H_2 = ... mol

HCl = ... mol
[2]

(ii) Calculate the mole fraction of each gas in the equilibrium mixture.

mole fraction of HCl = ...

mole fraction of H_2 = ...

mole fraction of Cl_2 = ...
[1]

(d) In another experiment under different conditions, an equilibrium mixture was produced with mole fractions for each species as shown.

species	mole fraction
HCl	0.88
H_2	0.06
Cl_2	0.06

(i) Write the expression for the equilibrium constant, K_p, for the decomposition of HCl.

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

K_p =

[1]

(ii) Explain why the total pressure of the system does **not** need to be known for K_p to be calculated for this experiment.

.....

..... [1]

(iii) Calculate the value of K_p for this experiment.

K_p = ... [1]

[Total: 18]

34. 9701_w17_qp_21 Q: 1

Ammonia, NH_3, is manufactured from nitrogen and hydrogen by the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

(a) Some bond energies are given.

N≡N = 944 kJ mol^{-1}
H–H = 436 kJ mol^{-1}

(i) Explain the meaning of the term *bond energy*.

.....

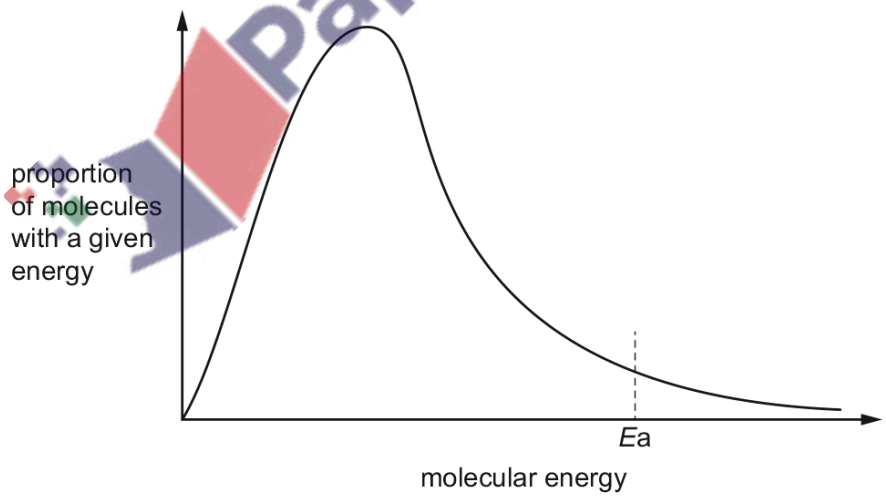
..... [2]

(ii) Use the data to calculate a value for the N–H bond energy.
You must show your working.

N–H bond energy = ... kJ mol^{-1} [2]

(b) The Haber process is usually carried out at a temperature of approximately 400 °C in the presence of a catalyst. Changing the temperature affects both the rate of production of ammonia and the yield of ammonia.

The Boltzmann distribution for a mixture of nitrogen and hydrogen at 400 °C is shown.
*E*a represents the activation energy for the reaction.



(i) Using the same axes, sketch a second curve to indicate the Boltzmann distribution at a higher temperature. [2]

(ii) **With reference to the Boltzmann distribution**, state and explain the effect of increasing temperature on the rate of production of ammonia.

.....

.....

.....

..... [3]

(iii) State and explain the effect of increasing temperature on the yield of ammonia.
Use Le Chatelier's principle to explain your answer.

.....

.....

.....

..... [3]

(c) At a pressure of 2.00×10^7 Pa, 1.00 mol of nitrogen, $N_2(g)$, was mixed with 3.00 mol of hydrogen, $H_2(g)$. The final equilibrium mixture formed contained 0.300 mol of ammonia, $NH_3(g)$.

(i) Calculate the amounts, in mol, of $N_2(g)$ and $H_2(g)$ in the equilibrium mixture.

$N_2(g)$ = ... mol

$H_2(g)$ = ... mol
[2]

(ii) Calculate the partial pressure of ammonia, pNH_3, in the equilibrium mixture.

Give your answer to **three** significant figures.

pNH_3 = ... Pa [3]

(d) In another equilibrium mixture the partial pressures are as shown.

substance	partial pressure / Pa
$N_2(g)$	2.20×10^6
$H_2(g)$	9.62×10^5
$NH_3(g)$	1.40×10^4

(i) Write the expression for the equilibrium constant, K_p, for the production of ammonia from nitrogen and hydrogen.

K_p =

[1]

(ii) Calculate the value of K_p for this reaction.

State the units.

K_p = ...

units = ...

[2]

(iii) This reaction is repeated with the same starting amounts of nitrogen and hydrogen. The same temperature is used but the container has a smaller volume.

State the effects, if any, of this change on the yield of ammonia and on the value of K_p.

effect on yield of ammonia .....

effect on value of K_p .....

[2]

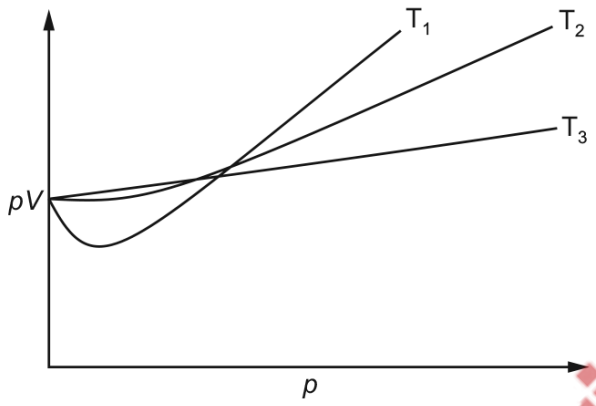
[Total: 22]

8.2 Homogeneous and heterogeneous catalysts including enzymes

35. 9701_S15_qp_21 Q: 2

The relationship $pV = nRT$ can be derived from the laws of mechanics by assuming ideal behaviour for gases.

(a) The graph represents the relationship between pV and p for a real gas at three different temperatures, T_1, T_2 and T_3.



(i) Draw **one** line on the graph to show what the relationship should be for the same amount of an **ideal** gas. [1]

(ii) State and explain, with reference to the graph, which of T_1, T_2 or T_3 is the lowest temperature.

.....

..... [1]

(iii) Explain your answer to **(ii)** with reference to intermolecular forces.

.....

..... [1]

(iv) State and explain the effect of pressure on the extent to which a gas deviates from ideal behaviour.

.....

.....

.....

..... [2]

(b) A flask with a volume of 100 cm^3 was first weighed with air filling the flask, and then with another gas, **Y**, filling the flask. The results, measured at 26 °C and 1.00 × 10^5 Pa, are shown.

Mass of flask containing air = 47.930 g

Mass of flask containing **Y** = 47.989 g

Density of air = 0.00118 g cm^{-3}

Calculate the relative molecular mass, M_r, of **Y**.

M_r of **Y** = ... [4]

(c) Although nitrogen gas makes up about 79% of the atmosphere it does not easily form compounds.

(i) Explain why nitrogen is so unreactive.

.....

..... [1]

(ii) Explain why the conditions in a car engine lead to the production of oxides of nitrogen.

.....

..... [1]

(iii) Give an equation for a reaction involved in the removal of nitrogen monoxide, NO, from a car's exhaust gases, in the catalytic converter.

..... [1]

One of the main reasons for reducing the amounts of oxides of nitrogen in the atmosphere is their contribution to the formation of acid rain.

(iv) Write an equation for the formation of nitric acid from nitrogen dioxide, NO_2, in the atmosphere.

..... [1]

(v) Write equations showing the catalytic role of nitrogen monoxide, NO, in the oxidation of atmospheric sulfur dioxide, SO_2.

.....

..... [2]

[Total: 15]