Topic 7 practice questions Wed 4/12 *[38 marks]*

Consider the following reaction taking place at 375 °C in a $1.00\ dm^3$ closed container.

$$Cl_2(g) + SO_2(g) \rightleftharpoons SO_2Cl_2(g) \quad \Delta H^\ominus = -84.5\ kJ$$

1a. Deduce the equilibrium constant expression, K_c, for the reaction. *[1 mark]*

Markscheme

$(K_c) = \frac{[SO_2Cl_2]}{[Cl_2][SO_2]}$;

Ignore state symbols.

Square brackets [ ] required for the equilibrium expression.

Examiners report

This was the most popular question in Section B and there was a generally pleasing level of performance. In (a)(i) most candidates were able to correctly deduce the equilibrium constant.

1b. If the temperature of the reaction is changed to 300 °C, predict, stating a reason in each case, whether the equilibrium concentration of SO_2Cl_2 and the value of K_c will increase or decrease. *[3 marks]*

Markscheme

value of K_c increases;

$[SO_2Cl_2]$ increases;

decrease in temperature favours (forward) reaction which is exothermic;

Do not allow ECF.

Examiners report

In (ii) most candidates realized the exothermic reaction would be favoured, and gained full marks for their explanation. However, some candidates seemed not to appreciate that the specified temperature of 300 °C was lower than the original, and so based their answers on a temperature increase.

1c. If the volume of the container is changed to $1.50\ dm^3$, predict, stating a reason in each case, how this will affect the equilibrium concentration of SO_2Cl_2 and the value of K_c. *[3 marks]*

Markscheme

no effect on the value of K_c / depends only on temperature;

$[SO_2Cl_2]$ decreases;

increase in volume favours the reverse reaction which has more gaseous moles;

Do not allow ECF.

Examiners report

In (iii) most forgot to mention the word gaseous when talking about the particles and many forgot that K_c is only affected by temperature.

1d. Suggest, stating a reason, how the addition of a catalyst at constant pressure and temperature will affect the equilibrium concentration of SO_2Cl_2. *[2 marks]*

Markscheme

no effect;

catalyst increases the rate of forward and reverse reactions (equally) / catalyst decreases activation energies (equally);

Examiners report

In (iv) candidates correctly stated that concentration would not change and stated that reaction rates of both forward and reverse reactions would be affected equally. However, some answered 'the addition of a catalyst does not affect K_c or the position of equilibrium' which did not answer the question and scored no marks as they had not commented on the concentration of $SOCl_2$.

A solution of hydrogen peroxide, H_2O_2, is added to a solution of sodium iodide, NaI, acidified with hydrochloric acid, HCl. The yellow colour of the iodine, I_2, can be used to determine the rate of reaction.

$$H_2O_2(aq) + 2NaI(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + I_2(aq) + 2H_2O(l)$$

The experiment is repeated with some changes to the reaction conditions. For each of the changes that follow, predict, stating a reason, its effect on the rate of reaction.

1e. The concentration of H_2O_2 is increased at constant temperature. *[2 marks]*

Markscheme

increases rate of reaction;

molecules (of H_2O_2) collide more frequently / more collisions per unit time;

No ECF here.

Examiners report

In (c), most scored the marks in (i) and were able to correctly describe the effect of concentration on rate in terms of collision theory, although some forgot to mention the frequency of the collisions just stating there would be more.

1f. The solution of NaI is prepared from a fine powder instead of large crystals. *[2 marks]*

Markscheme

no effect / (solution) remains unchanged;

solid NaI is not reacting / aqueous solution of NaI is reacting / surface area of NaI is not relevant in preparing the solution / *OWTTE*;

Examiners report

In part (ii), most candidates assumed that the rate would increase with surface area of the solute, and few realized that once the sodium iodide was in solution then the particle size of the solid used to make it was not relevant as it is the solution which reacts.

1g. Explain why the rate of a reaction increases when the temperature of the system increases. *[3 marks]*

Markscheme

kinetic energy/speed of reacting molecules increases;

frequency of collisions increases per unit time;

greater proportion of molecules have energy greater than activation energy/E_a;

Accept more energetic collisions.

Examiners report

Part (d) was well answered but some candidates lost marks due to imprecise responses. For example it is the kinetic energy that increases with temperature, not energy. Also there were some errors such as the omission of the idea of frequency when referring to collisions and the belief that an increase in temperature caused a decrease in activation energy.

Consider the following reaction studied at 263 K.

$$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$$

It was found that the forward reaction is first order with respect to Cl_2 and second order with respect to NO. The reverse reaction is second order with respect to NOCl.

2a. State the rate expression for the forward reaction. *[1 mark]*

Markscheme

$\text{rate} = k[NO]^2[Cl_2]$;

Examiners report

In part (a) the rate expression was correctly stated although some confused this with an equilibrium constant expression.

2b. Predict the effect on the rate of the forward reaction and on the rate constant if the concentration of NO is halved. *[2 marks]*

Markscheme

rate of reaction will decrease by a factor of 4;

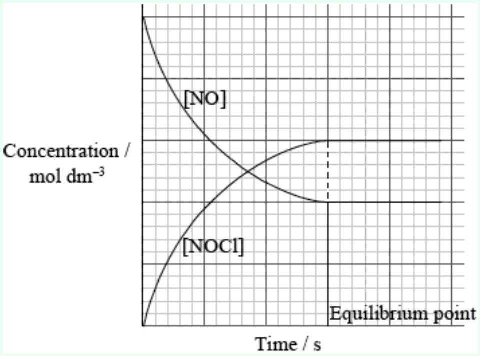
no effect on the rate constant;

Examiners report

Only the better candidates realized that the rate of reaction will decrease by a factor of four and there will be no effect on the rate constant.

2c. 1.0 mol of Cl_2 and 1.0 mol of NO are mixed in a closed container at constant temperature. Sketch a graph to show how the concentration of NO and NOCl change with time until after equilibrium has been reached. Identify the point on the graph where equilibrium is established. *[4 marks]*

Markscheme



y axis labelled concentration/mol dm^{-3} and *x* axis is labelled time/s;

gradient for [NO];

gradient for [NOCl] will be equal and opposite;

equilibrium point identified / two curves level off at same time;

Examiners report

Although most candidates were able to correctly sketch the concentration versus time graph many forgot to label the axes or include units.

2d. State **two** situations when the rate of a chemical reaction is equal to the rate constant. *[2 marks]*

Markscheme

zero order reaction;

all concentrations are $1.0\ \text{mol dm}^{-3}$;

Examiners report

The better candidates were able to figure out that the rate of a chemical reaction is equal to the rate constant when all concentrations are $1.0\ \text{mol dm}^{-3}$ or for a zero order reaction.

Consider the following equilibrium reaction.

$$\text{Cl}_2\text{(g)} + \text{SO}_2\text{(g)} \rightleftharpoons \text{SO}_2\text{Cl}_2\text{(g)} \quad \Delta H^{\ominus} = -84.5\ \text{kJ}$$

In a $1.00\ \text{dm}^3$ closed container, at 375 °C, $8.60 \times 10^{-3}\ \text{mol}$ of SO_2 and $8.60 \times 10^{-3}\ \text{mol}$ of Cl_2 were introduced. At equilibrium, $7.65 \times 10^{-4}\ \text{mol}$ of SO_2Cl_2 was formed.

2e. Deduce the equilibrium constant expression, K_c, for the reaction. *[1 mark]*

Markscheme

$(K_c) = \frac{[\text{SO}_2\text{Cl}_2]}{[\text{Cl}_2][\text{SO}_2]}$;

Ignore state symbols.

Square brackets [ ] required for the equilibrium expression.

Examiners report

In part (e), the equilibrium constant expression was correctly stated by the majority but calculating the value of K_c proved to be difficult.

2f. Determine the value of the equilibrium constant, K_c. *[3 marks]*

Markscheme

7.84×10^{-3} mol of SO_2 and 7.84×10^{-3} mol of Cl_2;

$7.84 \times 10^{-3}\ mol\ dm^{-3}$ of SO_2, $7.84 \times 10^{-3}\ mol\ dm^{-3}$ of Cl_2 **and**

$7.65 \times 10^{-4}\ mol\ dm^{-3}$ of SO_2Cl_2;

12.5;

*Award **[1]** for 10.34*

*Award **[3]** for the correct final answer*

Examiners report

A large number of candidates obtained the incorrect answer of 10.34 as a result of using the initial concentrations of the reactants instead of equilibrium concentrations.

2g. If the temperature of the reaction is changed to 300 °C, predict, stating a reason in each case, whether the equilibrium concentration of SO_2Cl_2 and the value of K_c will increase or decrease. *[3 marks]*

Markscheme

value of K_c increases;

$[SO_2Cl_2]$ increases;

decrease in temperature favours (forward) reaction which is exothermic;

Do not allow ECF.

Examiners report

[N/A]

2h. If the volume of the container is changed to $1.50\ dm^3$, predict, stating a reason in each case, how this will affect the equilibrium concentration of SO_2Cl_2 and the value of K_c. *[3 marks]*

Markscheme

no effect on the value of K_c / depends only on temperature;

$[SO_2Cl_2]$ decreases;

increase in volume favours the reverse reaction which has more gaseous moles;

Do not allow ECF.

Examiners report

The application of Le Chatelier's principle was handled well by the majority with minor omissions such as not using the term gaseous particles in part (iv).

2i. Suggest, stating a reason, how the addition of a catalyst at constant pressure and temperature will affect the equilibrium concentration of SO_2Cl_2. *[2 marks]*

Markscheme

no effect;

catalyst increases the rate of forward and reverse reactions (equally) / catalyst decreases activation energies (equally);

Examiners report

Some candidates stated that the addition of a catalyst does not affect the value of K_c or the position of equilibrium, which did not answer the question and scored no marks because they had not commented on the concentration of $SOCl_2$. Some candidates correctly stated that a catalyst increases the rate of forward and reverse reactions equally.

Consider the following equilibrium.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H^\ominus = -198\ kJ\ mol^{-1}$$

3. Deduce the equilibrium constant expression, K_c, for the reaction. *[1 mark]*

Markscheme

$(K_c =)[SO_3]^2/[O_2][SO_2]^2$;

Examiners report

Nearly all candidates deduced the equilibrium constant expression for the reaction given in (a) (i).