Oxford Cambridge and RSA

A level Chemistry A

H432/01 Periodic table, elements and physical chemistry

Question Set 18

1. (a) (i) Sulfuric acid is an important chemical used to make detergents, fertilisers and dyes. It ismanufactured in a multi-step process.

In the first step of the manufacture of sulfuric acid, sulfur dioxide, SO_2, can be made from thecombustion of hydrogen sulfide, H_2S, shown in **Reaction 1**.

$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(l)$ $\quad \Delta_r H = -1125\,kJ\,mol^{-1}$ **Reaction 1**

Explain why the enthalpy change for **Reaction 1** has a negative value.

Use ideas about enthalpy changes associated with bond breaking and bond making. **[1]**

(ii) Some standard entropy values are given below.

Substance	$H_2S(g)$	$O_2(g)$	$SO_2(g)$	$H_2O(l)$
$S^{\ominus}$ / J K^{-1} mol^{-1}	206	205	248	70

Using calculations, explain whether **Reaction 1** is feasible at 20 °C.

Calculations

Explanation for feasible or non feasible . **[4]**

(iii) Calculate the standard enthalpy change of formation, $\Delta_f H^{\ominus}$, of hydrogen sulfide using the enthalpy change for **Reaction 1**, and the standard enthalpy changes of combustion below.

Substance	$\Delta_c H^{\ominus}$ / kJ mol^{-1}
S(s)	−296.8
$H_2(g)$	−285.8

$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(l)$ $\quad \Delta_r H = -1125\,kJ\,mol^{-1}$ **Reaction 1**

$\Delta_f H^{\ominus}$ of hydrogen sulfide = …… kJ mol^{-1} **[3]**

(b) **(i)** The second step in the manufacture of sulfuric acid is the conversion of SO_2 into sulfurtrioxide, SO_3, using **Equilibrium 1**.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -197\,kJ\,mol^{-1}$ **Equilibrium 1**

An industrial chemist carries out some research into **Equilibrium 1**.

- The chemist fills a $10.2\,dm^3$ container with $SO_2(g)$ at RTP, and then adds $12.0\,g$ of $O_2(g)$.
- The chemist adds the vanadium(V) oxide catalyst, and heats the mixture. The mixture isallowed to reach equilibrium at a pressure of $2.50\,atm$ and a temperature of $1000\,K$.
- A sample of the equilibrium mixture is analysed, and found to contain $0.350\,mol$ of SO_3.

Write an expression for K_p for **Equilibrium 1**. Include the units.

units =

[2]

(ii) Determine the value of K_p for **Equilibrium 1** at 1000

K.Show all your working.

Give your answer to **3** significant figures.

K_p =

[5]

(iii) The chemist repeats the experiment in **(b)** at a different temperature.

The chemist finds that the value of K_p is greater than the answer to **(b)(ii)**.

Explain whether the temperature in the second experiment is higher or lower than $1000\,K$. **[2]**

(iv) Explain the significance of the expression: K_p 1.

[1]

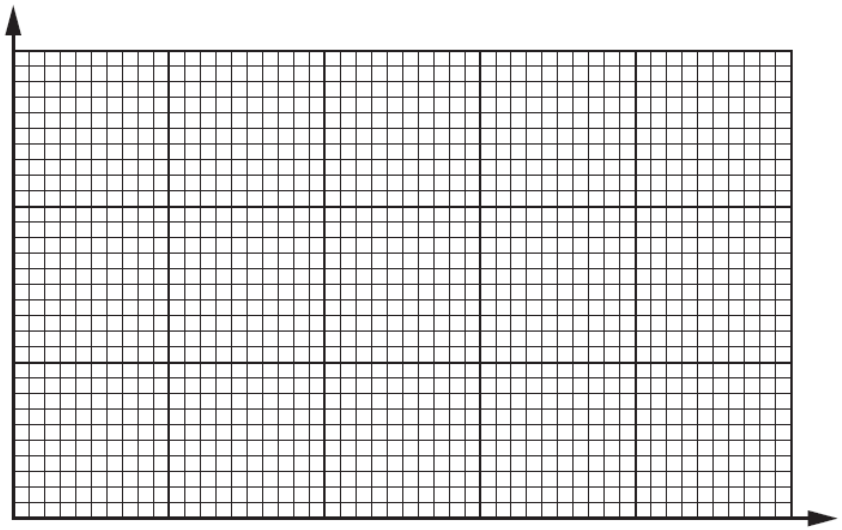
(c) **(i)** Vanadium(V) oxide, $V_2O_5(s)$, is used as a catalyst in **equilibrium 1**.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197\,kJ\,mol^{-1} \qquad \textbf{Equilibrium 1}$$

Explain how the presence of $V_2O_5(s)$ increases the rate of reaction.

Include a labelled sketch of the Boltzmann distribution, on the grid below.

Label the axes.



..... **[4]**

(ii) Explain whether vanadium(V) oxide is acting as a homogeneous or heterogeneouscatalyst.

[1]

Total Marks for Question Set 18: 23