

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 is manufactured in a multi-step process.

In the first step of the manufacture of sulfuric acid, sulfur dioxide, SO_2 , can be made from the combustion of hydrogen sulfide, H_2S , shown in **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	$\text{H}_2\text{S}(\text{g})$	$\text{O}_2(\text{g})$	$\text{SO}_2(\text{g})$	$\text{H}_2\text{O}(\text{l})$
$S^\circ / \text{JK}^{-1} \text{mol}^{-1}$	206	205	248	70

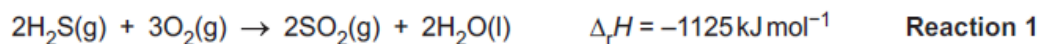
Using calculations, explain whether **Reaction 1** is feasible at 20°C .

Calculations

Explanation for feasible or non feasible . [4]

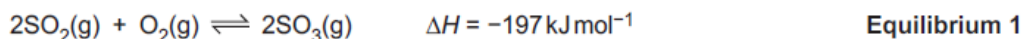
- (iii) Calculate the standard enthalpy change of formation, $\Delta_f H^\circ$, of hydrogen sulfide using the enthalpy change for **Reaction 1**, and the standard enthalpy changes of combustion below.

Substance	$\Delta_c H^\circ / \text{kJ mol}^{-1}$
$\text{S}(\text{s})$	-296.8
$\text{H}_2(\text{g})$	-285.8



$\Delta_f H^\circ$ 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 sulfur trioxide, SO_3 , using **Equilibrium 1**.



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

- The chemist fills a 10.2 dm^3 container with $\text{SO}_2(\text{g})$ at RTP, and then adds 12.0 g of $\text{O}_2(\text{g})$.
- The chemist adds the vanadium(V) oxide catalyst, and heats the mixture. The mixture is allowed 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).

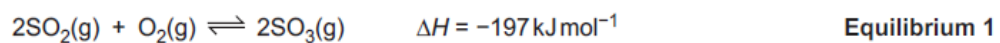
Explain whether the temperature in the second experiment is higher or lower than 1000 K .

[2]

- (iv) Explain the significance of the expression: $K_p \gg 1$.

[1]

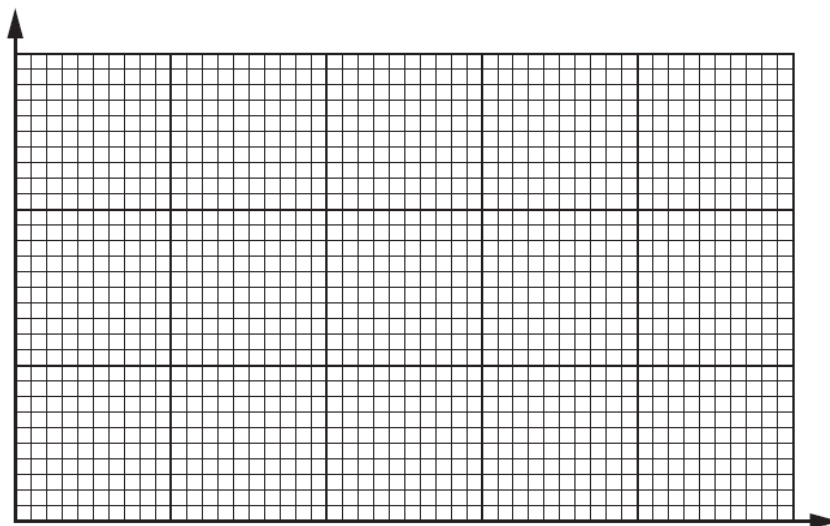
(c) (i) Vanadium(V) oxide, $V_2O_5(s)$, is used as a catalyst in **equilibrium 1**.



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 heterogeneous catalyst.

[1]

Total Marks for Question Set 18: 23

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