

## SECTION 6 COURSE REVISION

The questions in this Section are designed to help you to revise your understanding of the major principles and results developed in S342 (including those introduced in the three Topic Studies). You are strongly advised to use these questions as an integral part of your revision programme: to that end, it would be a good plan to attempt the questions without referring to the relevant course material.

### PART A (Blocks 1, 4 and 7)

The questions in Part A are concerned with the oxidation of sulfur dioxide ( $\text{SO}_2$ ) to sulfur trioxide ( $\text{SO}_3$ ):



in the presence of a supported  $\text{V}_2\text{O}_5$  catalyst. This reaction is an important step in the manufacture of sulfuric acid by the 'contact process'.

In answering the questions in Part A, you should make the following assumptions:

- that  $\Delta H_m^\ominus$  and  $\Delta S_m^\ominus$  for reaction 6.1 do not vary with temperature;
- that the gases involved in reaction 6.1 behave ideally (both individually and as a mixture).

Any thermodynamic data you need should be taken from the S342 Data Book.

**Q6.1** With reference to reaction 6.1, select *three correct* statements from the key.

KEY for Q6.1

- A The value of  $\Delta G_m^\ominus$  for reaction 6.1 will become more negative with increasing temperature.  
 B The standard equilibrium constant,  $K^\ominus$ , for reaction 6.1 will decrease with increasing temperature.  
 C For reaction 6.1, a plot of  $\ln K^\ominus$  against  $1/T$  will be linear, with a negative slope.  
 D The standard equilibrium constant,  $K^\ominus$ , for reaction 6.1 is given by the following expression

$$K^\ominus = \frac{\{a(\text{SO}_3)\}^2}{\{a(\text{SO}_2)\}^2 a(\text{O}_2)}$$

where  $a$  represents the activity of each gas in the equilibrium mixture.

- E The equilibrium constants  $K^\ominus$  and  $K_p$  for reaction 6.1 are related via the following expression:

$$K^\ominus = K_p/p^\ominus$$

where  $p^\ominus$  is the standard pressure,  $p^\ominus = 1$  bar.

- F At a given temperature, an increase in the overall pressure will increase the value of  $K^\ominus$  for reaction 6.1.  
 G At a given temperature, an increase in the overall pressure will increase the equilibrium yield of  $\text{SO}_3$  from reaction 6.1.  
 H The presence of the  $\text{V}_2\text{O}_5$  catalyst will increase the equilibrium yield of  $\text{SO}_3$  from reaction 6.1 at a given temperature and pressure.

**Q6.2 and Q6.3** Suppose now that the reaction conditions are chosen to ensure that the equilibrium yield,  $y$ , of  $\text{SO}_3$  from reaction 6.1 will be 90%. Assume that the reactants ( $\text{SO}_2$  and  $\text{O}_2$ ) are mixed initially in stoichiometric proportions, and that the equilibrium yield is defined as  $y = p(\text{SO}_3)/p_{\text{tot}}$ , where  $p_{\text{tot}}$  is the total pressure.

**Q6.2** Assuming a total pressure  $p_{\text{tot}} = 1$  bar, determine the value of  $K_p$  for reaction 6.1 corresponding to a 90% equilibrium yield of  $\text{SO}_3$ . Select from the key the value that is closest to your answer.

KEY for Q6.2

- |                                       |                                       |
|---------------------------------------|---------------------------------------|
| A $7.5$ bar                           | E $5.5 \times 10^3$ bar               |
| B $7.5$ bar <sup>-1</sup>             | F $5.5 \times 10^3$ bar <sup>-1</sup> |
| C $4.1 \times 10^2$ bar               | G $2.2 \times 10^4$ bar               |
| D $4.1 \times 10^2$ bar <sup>-1</sup> | H $2.2 \times 10^4$ bar <sup>-1</sup> |

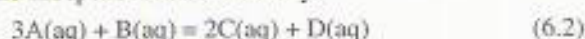
**Q6.3** Assuming a total pressure  $p_{\text{tot}} = 1$  bar, determine the temperature at which the equilibrium yield of  $\text{SO}_3$  from reaction 6.1 would be 90%. Select from the key the value that is closest to your answer.

KEY for Q6.3

- |         |           |
|---------|-----------|
| A 650 K | D 832 K   |
| B 730 K | E 1 700 K |
| C 762 K | F 1 982 K |

### PART B (Block 2)

**Q6.4 and Q6.5** These questions are concerned with a reaction in aqueous solution, which has the following time-independent stoichiometry:



In a kinetic study of this reaction in the temperature range 300–330 K, it was established that the experimental rate equation has the following general form:

$$J = k_R[\text{A}]^\alpha[\text{B}]^\beta \quad (6.3)$$

where  $k_R$  is the rate constant. When the initial concentration of B was held constant, use of the method of initial rates gave a plot of  $\ln J_0$  versus  $\ln [\text{A}]_0$  which was linear with a slope of one. Similarly, with the initial concentration of A held constant, a plot of  $\ln J_0$  versus  $\ln [\text{B}]_0$  was linear with a slope of one. ( $J_0$  is the initial rate of reaction, and  $[\text{A}]_0$  and  $[\text{B}]_0$  are, respectively, the initial concentrations of A and B.) You may assume that the experimental rate equation established under these conditions holds throughout the course of the reaction, with no complications due to the accumulation of products.