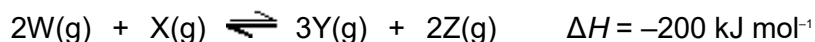


- Q1.** (a) The gaseous reactants **W** and **X** were sealed in a flask and the mixture left until the following equilibrium had been established.



Write an expression for the equilibrium constant,  $K_p$ , for this reaction.

State one change in the conditions which would both increase the rate of reaction and decrease the value of  $K_p$ . Explain your answers.

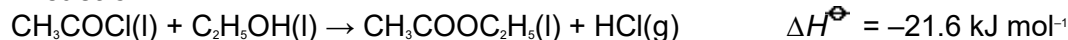
(7)

- (b) Ethyl ethanoate can be prepared by the reactions shown below.

**Reaction 1**



**Reaction 2**



- (i) Give one advantage and one disadvantage of preparing ethyl ethanoate by **Reaction 1** rather than by **Reaction 2**.
- (ii) Use the information given above and the data below to calculate values for the standard entropy change,  $\Delta S^\ominus$ , and the standard free-energy change,  $\Delta G^\ominus$ , for **Reaction 2** at 298 K.

	$\text{CH}_3\text{COCl}(\text{l})$	$\text{C}_2\text{H}_5\text{OH}(\text{l})$	$\text{CH}_3\text{COOC}_2\text{H}_5(\text{l})$	$\text{HCl}(\text{g})$
$S^\ominus / \text{JK}^{-1}\text{mol}^{-1}$	201	161	259	187

(8)  
(Total 15 marks)

- Q2.** The compound lithium tetrahydridoaluminate(III),  $\text{LiAlH}_4$ , is a useful reducing agent. It behaves in a similar fashion to  $\text{NaBH}_4$ . Carbonyl compounds and carboxylic acids are reduced to alcohols. However,  $\text{LiAlH}_4$  also reduces water in a violent reaction so that it must be used in an organic solvent.

Which one of the following concerning the violent reaction between  $\text{LiAlH}_4$  and water is **false**?

- A A gas is produced.
- B The activation energy for the reaction is relatively high.
- C The reaction has a negative free-energy change.
- D Aqueous lithium ions are formed.

(Total 1 mark)

**Q3.** (a) (i) Draw a fully-labelled Born–Haber cycle for the formation of solid barium chloride,  $\text{BaCl}_2$ , from its elements. Include state symbols for all species involved.

(ii) Use your Born–Haber cycle and the standard enthalpy data given below to calculate a value for the electron affinity of chlorine.

Enthalpy of atomisation of barium	+180 $\text{kJ mol}^{-1}$
Enthalpy of atomisation of chlorine	+122 $\text{kJ mol}^{-1}$
Enthalpy of formation of barium chloride	–859 $\text{kJ mol}^{-1}$
First ionisation enthalpy of barium	+503 $\text{kJ mol}^{-1}$
Second ionisation enthalpy of barium	+965 $\text{kJ mol}^{-1}$
Lattice formation enthalpy of barium chloride	–2056 $\text{kJ mol}^{-1}$

.....  
.....

.....  
 .....

(9)

- (b) Use data from part (a)(ii) and the entropy data given below to calculate the lowest temperature at which the following reaction becomes feasible.



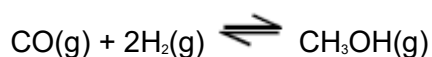
	BaCl <sub>2</sub> (s)	Ba(s)	Cl <sub>2</sub> (g)
S <sup>⊖</sup> / J K <sup>-1</sup> mol <sup>-1</sup>	124	63	223

.....  
 .....  
 .....  
 .....  
 .....

(4)

(Total 13 marks)

**Q4.** The following information concerns the equilibrium gas-phase synthesis of methanol.



At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa. The number of moles of CO, H<sub>2</sub> and CH<sub>3</sub>OH present are 0.160, 0.320 and 0.180, respectively.

Thermodynamic data are given below.

Substance	ΔH <sub>f</sub> <sup>⊖</sup> / kJ mol <sup>-1</sup>	S <sup>⊖</sup> / J K <sup>-1</sup> mol <sup>-1</sup>
CO(g)	-110	198

H <sub>2</sub> (g)	0	131
CH <sub>3</sub> OH(g)	-201	240

The standard entropy change for this reaction is

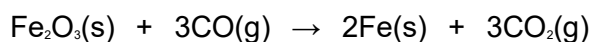
- A -220 J K<sup>-1</sup> mol<sup>-1</sup>
- B +220 J K<sup>-1</sup> mol<sup>-1</sup>
- C -89 J K<sup>-1</sup> mol<sup>-1</sup>
- D +89 J K<sup>-1</sup> mol<sup>-1</sup>

(Total 1 mark)

**Q5.** Use the data in the table below to answer the questions which follow.

Substance	Fe <sub>2</sub> O <sub>3</sub> (s)	Fe(s)	C(s)	CO(g)	CO <sub>2</sub> (g)
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-824.2	0	0	-110.5	-393.5
$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$	87.4	27.3	5.7	197.6	213.6

- (a) The following equation shows one of the reactions which can occur in the extraction of iron.



- (i) Calculate the standard enthalpy change and the standard entropy change for this reaction.

Standard enthalpy change .....

.....

.....

.....

.....

.....

Standard entropy change .....

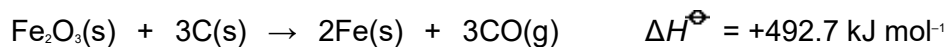
.....  
.....  
.....  
.....

(ii) Explain why this reaction is feasible at all temperatures.

.....  
.....  
.....

(9)

(b) The reaction shown by the following equation can also occur in the extraction of iron.



The standard entropy change,  $\Delta S^\ominus$ , for this reaction is  $+542.6 \text{ J K}^{-1} \text{ mol}^{-1}$

Use this information to calculate the temperature at which this reaction becomes feasible.

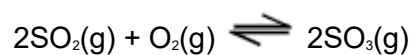
.....  
.....  
.....

(3)

(c) Calculate the temperature at which the standard free-energy change,  $\Delta G^\ominus$  has the same value for the reactions in parts (a) and (b).

.....  
.....  
.....

**Q6.** This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:



Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$
$\text{SO}_3(\text{g})$	-396	+257
$\text{SO}_2(\text{g})$	-297	+248
$\text{O}_2(\text{g})$	0	+204

This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm<sup>3</sup>. At equilibrium, the vessel contains 0.0500 mol of  $\text{SO}_2(\text{g})$ , 0.0800 mol of  $\text{O}_2(\text{g})$  and 0.0700 mol of  $\text{SO}_3(\text{g})$ .

The standard entropy change for this reaction is

- A** -222 J K<sup>-1</sup> mol<sup>-1</sup>
- B** -195 J K<sup>-1</sup> mol<sup>-1</sup>
- C** -186 J K<sup>-1</sup> mol<sup>-1</sup>
- D** +198 J K<sup>-1</sup> mol<sup>-1</sup>

(Total 1 mark)