1 This question is about the equilibrium reaction between hydrogen and carbon dioxide.

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g) \qquad \Delta H^{\ominus} = +40 \text{ kJ mol}^{-1}$$

What effect would the following changes have on the rate of reaction and the yield of carbon monoxide?

(a) **Increase** in temperature.

(1)

	Rate	Yield of CO
☒ **A**	increase	increase
☒ **B**	increase	decrease
☒ **C**	increase	no change
☒ **D**	no change	decrease

(b) **Increase** in pressure.

(1)

	Rate	Yield of CO
☒ **A**	increase	increase
☒ **B**	increase	decrease
☒ **C**	increase	no change
☒ **D**	no change	no change

(Total for Question = 2 marks)

2 Carbon monoxide and chlorine react together and reach equilibrium:

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$$

If the pressure of the system is then **increased** at constant temperature, which of the following statements is correct?

☒ **A** The equilibrium moves to the left and K_p decreases.

☒ **B** The equilibrium moves to the right and K_p increases.

☒ **C** The equilibrium moves to the right, then back to the left and K_p remains the same.

☒ **D** The equilibrium moves to the right and K_p remains the same.

(Total for Question = 1 mark)

3 The indicator methyl orange is a weak acid and may be represented by the formula HA(aq). The equation for its dissociation is shown below.

$$HA(aq) \rightleftharpoons A^-(aq) + H^+(aq)$$

Colour: Red Yellow

Under certain conditions, at equilibrium, a solution of HA has a yellow colour. On addition of a small volume of dilute sodium hydroxide, the colour of this solution would

☒ **A** change from yellow to red.

☒ **B** change from yellow to orange.

☒ **C** change from yellow to orange and then to red.

☒ **D** not change.

(Total for Question = 1 mark)

4 The following system was allowed to reach equilibrium at 300 °C.

$$\underset{\text{Colourless}}{2HI(g)} \rightleftharpoons \underset{\text{Colourless}}{H_2(g)} + \underset{\text{Purple}}{I_2(g)} \qquad \Delta H = -53.0 \text{ kJ mol}^{-1}$$

(a) What would you see if the equilibrium mixture was cooled to 250 °C?

(1)

☒ **A** No visible change.

☒ **B** The colour gets lighter.

☒ **C** The mixture turns colourless.

☒ **D** The mixture goes a darker purple.

(b) The equilibrium mixture at 300 °C was compressed in a gas syringe to occupy a smaller volume. What would be seen immediately?

(1)

☒ **A** No visible change.

☒ **B** The colour gets lighter.

☒ **C** The mixture turns colourless.

☒ **D** The mixture goes a darker purple.

(Total for Question = 2 marks)

5 A solution of iodine in aqueous potassium iodide is brown. The following equilibrium exists in this solution.

$$\underset{\text{Brown}}{I_2(aq)} + H_2O(l) \rightleftharpoons \underbrace{IO^-(aq) + I^-(aq) + 2H^+(aq)}_{\text{Colourless}}$$

What would be the effect, if any, on the colour of the solution if five drops of dilute sodium hydroxide solution were added to 5 cm^3 of the iodine solution?

☒ **A** No visible change.

☒ **B** The colour gets lighter.

☒ **C** The mixture turns colourless.

☒ **D** The mixture goes a darker colour.

(Total for Question = 1 mark)

6 Methane hydrate is found on continental shelves deep in oceans. It forms methane in an endothermic equilibrium reaction, which may be represented as

$$CH_4.6H_2O(s) \rightleftharpoons CH_4(g) + 6H_2O(l)$$

(a) Which of the following changes would **increase** the equilibrium yield of methane?

(1)

☒ **A** Increasing the temperature and decreasing the pressure.

☒ **B** Decreasing both the temperature and the pressure.

☒ **C** Increasing both the temperature and the pressure.

☒ **D** Decreasing the temperature and increasing the pressure.

(b) Which of the following would **decrease** the value of the equilibrium constant, K_p, for the above equilibrium?

(1)

☒ **A** Decreasing the pressure

☒ **B** Increasing the pressure

☒ **C** Decreasing the temperature

☒ **D** Increasing the temperature

(Total for Question = 2 marks)

7 Methane hydrate is found on continental shelves deep in oceans. It forms methane in an endothermic equilibrium reaction, which may be represented as

$$CH_4.6H_2O(s) \rightleftharpoons CH_4(g) + 6H_2O(l)$$

(a) Which of the following changes would **decrease** the equilibrium yield of methane?

(1)

☒ **A** Decreasing the temperature and decreasing the pressure.

☒ **B** Increasing the temperature and decreasing the pressure.

☒ **C** Decreasing the temperature and increasing the pressure.

☒ **D** Increasing the temperature and increasing the pressure.

(b) Which of the following would **increase** the value of the equilibrium constant, K_p, for the above equilibrium?

(1)

☒ **A** Decreasing the pressure

☒ **B** Increasing the pressure

☒ **C** Decreasing the temperature

☒ **D** Increasing the temperature

(Total for Question = 2 marks)

8 Which of the following **cannot** alter the position of a chemical equilibrium?

- ☒ **A** Increasing the amount of catalyst
- ☒ **B** Increasing the reactant concentration
- ☒ **C** Increasing the temperature
- ☒ **D** Increasing the total pressure

(Total for Question = 1 mark)

9 $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91 \text{ kJ mol}^{-1}$

The conditions which would produce the greatest yield of methanol are

- ☒ **A** high pressure and high temperature.
- ☒ **B** high pressure and low temperature.
- ☒ **C** low pressure and low temperature.
- ☒ **D** low pressure and high temperature.

(Total for Question = 1 mark)

10 (a) For the equilibrium reaction between hydrogen and iodine

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

increasing the pressure of the system

(1)

☒ **A** has no effect on the rate or the position of equilibrium.

☒ **B** increases the rate but does not affect the position of equilibrium.

☒ **C** increases the rate and shifts the equilibrium to the right.

☒ **D** increases the rate and shifts the equilibrium to the left.

(b) The equation for the equilibrium reaction between hydrogen and iodine may also be written as

$$\tfrac{1}{2}H_2(g) + \tfrac{1}{2}I_2(g) \rightleftharpoons HI(g)$$

This change to the equation, compared to that in part (a),

(1)

☒ **A** has no effect on the value of the equilibrium constant.

☒ **B** halves the value of the equilibrium constant.

☒ **C** doubles the value of the equilibrium constant.

☒ **D** square roots the value of the equilibrium constant.

(Total for Question = 2 marks)

11 The first stage in the manufacture of nitric acid is the oxidation of ammonia:

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \quad \Delta H = -906 \text{ kJ mol}^{-1}$$

(a) In modern industrial plants this reaction is carried out at a pressure of around 3 atm. Which of the following statements is **incorrect**? The raised pressure

(1)

☒ **A** helps push the reactants through the reactor.

☒ **B** shifts the position of equilibrium to the right.

☒ **C** increases the cost of the reactor.

☒ **D** increases the energy cost of this part of the process.

(b) A platinum-rhodium alloy catalyst is used in this reaction. Which of the following statements is **incorrect**? The catalyst

(1)

☒ **A** lowers the activation energy of the reaction.

☒ **B** has no effect on the equilibrium constant for the reaction.

☒ **C** alters the enthalpy change of the reaction.

☒ **D** reduces the energy cost of this part of the process.

(c) The operating temperature of this reaction is about 900 °C. The use of a high temperature

(1)

☒ **A** increases the rate of the reaction and the equilibrium yield.

☒ **B** increases the rate of the reaction and decreases the equilibrium yield.

☒ **C** decreases the rate of the reaction and the equilibrium yield.

☒ **D** decreases the rate of the reaction and increases the equilibrium yield.

(Total for Question = 3 marks)

12 An important step in the production of sulfuric acid is the oxidation of sulfur dioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -196 \text{ kJ mol}^{-1}$$

Which of the conditions below is best suited to produce a high yield of sulfur trioxide, SO_3?

☒ **A** 1 atm pressure and 800 °C.

☒ **B** 2 atm pressure and 800 °C.

☒ **C** 1 atm pressure and 400 °C.

☒ **D** 2 atm pressure and 400 °C.

(Total for Question = 1 mark)

13 Which of these will **not** improve the **overall** yield of the Haber process?

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H \qquad 92 \text{ kJ mol}^{-1}$$

☒ **A** Increasing the pressure.

☒ **B** Liquefying then removing the ammonia from the reaction.

☒ **C** Increasing the temperature.

☒ **D** Recycling unreacted nitrogen and hydrogen.

(Total for Question 1 mark)

14 1,2-dichloroethane decomposes in the presence of a catalyst.

$$CH_2ClCH_2Cl(g) \rightleftharpoons CH_2{=}CHCl(g) + HCl(g) \qquad \Delta H = +51 \text{ kJ mol}^{-1}$$

Which of the following would result in an increase in the equilibrium yield of chloroethene?

☒ **A** Increasing the temperature.

☒ **B** Increasing the pressure.

☒ **C** Increasing the surface area of the catalyst.

☒ **D** Changing the catalyst to a more efficient one.

(Total for Question = 1 mark)

15 In the equilibrium below, what effect would the changes described have on the system?

$$2H_2S(g) + SO_2(g) \rightleftharpoons 3S(s) + 2H_2O(g) \qquad \Delta H \text{ is negative}$$

(a) Increase in temperature

(1)

☒ **A** increase rate, decrease yield

☒ **B** increase rate, increase yield

☒ **C** decrease rate, decrease yield

☒ **D** decrease rate, increase yield

(b) Decrease in pressure

(1)

☒ **A** increase rate, decrease yield

☒ **B** increase rate, increase yield

☒ **C** decrease rate, decrease yield

☒ **D** decrease rate, increase yield

(Total for Question = 2 marks)

16 Brown nitrogen dioxide, NO_2, exists in equilibrium with colourless dinitrogen tetroxide, N_2O_4.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \quad \Delta H \quad 57.2 \text{ kJ mol}^{-1}$$
brown colourless

(a) The **pressure** is increased. When equilibrium is restored, the appearance of the mixture of gases will be

(1)

☒ **A** colourless.

☒ **B** unchanged.

☒ **C** paler brown.

☒ **D** darker brown.

(b) The **temperature** is increased. When equilibrium is restored, the appearance of the mixture of gases will be

(1)

☒ **A** colourless.

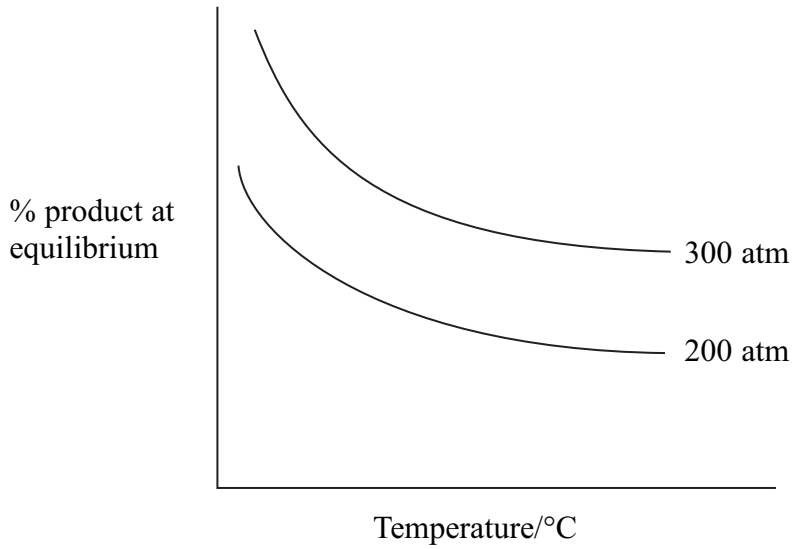
☒ **B** unchanged.

☒ **C** paler brown.

☒ **D** darker brown.

(Total for Question 2 marks)

17 The graph below shows the yield of product in a gaseous equilibrium at different temperatures and pressures.



The forward reaction in the equilibrium is

☒ **A** exothermic, and the number of moles of gas is increasing.

☒ **B** endothermic, and the number of moles of gas is increasing.

☒ **C** exothermic, and the number of moles of gas is decreasing.

☒ **D** endothermic, and the number of moles of gas is decreasing.

(Total for Question 1 mark)