



[illegible]

(b). Under certain conditions,  $K_c$  for **equilibrium 25.1** is  $0.160 \text{ dm}^3 \text{ mol}^{-1}$ .

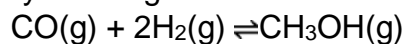
Species	Equilibrium concentration / mol dm <sup>-3</sup>
SO <sub>2</sub>	2.00
O <sub>2</sub>	1.20

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..... [4]

3. This question looks at equilibrium reactions used by industry for preparing important chemicals.

Methanol can be manufactured by reacting carbon monoxide with hydrogen.



An equilibrium mixture contains  $3.10 \times 10^{-3} \text{ mol dm}^{-3}$  CO,  $2.40 \times 10^{-3} \text{ mol dm}^{-3}$  H<sub>2</sub> and an unknown concentration of CH<sub>3</sub>OH.

- i. Write an expression for the equilibrium constant,  $K_c$ .

[1]

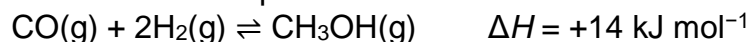
- ii. The value of  $K_c$  for this equilibrium is  $14.6 \text{ dm}^6 \text{ mol}^{-2}$ .

Determine the equilibrium concentration methanol, CH<sub>3</sub>OH(g).

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

equilibrium concentration of CH<sub>3</sub>OH(g) = .....  $\text{dm}^6 \text{ mol}^{-2}$  [2]

4. The equilibrium system below is set up.



The equilibrium system is compressed at constant temperature.

What is the effect on the value of  $K_c$  and the amount, in moles, of  $\text{CH}_3\text{OH}$ ?

	$K_c$	Amount in moles of $\text{CH}_3\text{OH}$
<b>A</b>	increases	increases
<b>B</b>	decreases	decreases
<b>C</b>	no change	no change
<b>D</b>	no change	increases

Your answer

[1]

5. A catalyst is added to a system in equilibrium.

What is the effect on the rates of the forward and reverse reactions?

- A** There is no effect on the rate in either direction.
- B** Both rates increase by the same factor.
- C** The rate in the forward direction increases by a greater factor than the reverse direction.
- D** The rate in the reverse direction increases by a greater factor than the forward direction.

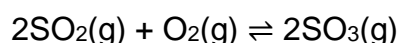
Your answer

[1]

6. What is the partial pressure of  $\text{O}_2$  (in Pa) in a gas mixture containing 21%  $\text{O}_2$  by volume and with a total pressure of  $1.0 \times 10^5 \text{ Pa}$ ?

partial pressure of  $\text{O}_2$  = ..... Pa [1]

7. The reversible reaction of sulfur dioxide and oxygen to form sulfur trioxide is shown below.



An equilibrium mixture contains 2.4 mol SO<sub>2</sub>, 1.2 mol O<sub>2</sub> and 0.4 mol SO<sub>3</sub>.  
The total pressure is 250 atm.

What is the partial pressure of SO<sub>3</sub>?

- A 15 atm
- B 25 atm
- C 100 atm
- D 200 atm

Your answer

[1]

8. Methane is an important raw material for manufacturing chemicals. Hydrogen can be manufactured from methane and steam as shown below in **equation 17.1**.



The rate of reaction is increased by using a catalyst.

A chemist investigates the equilibrium shown in **equation 17.1** as outlined below.



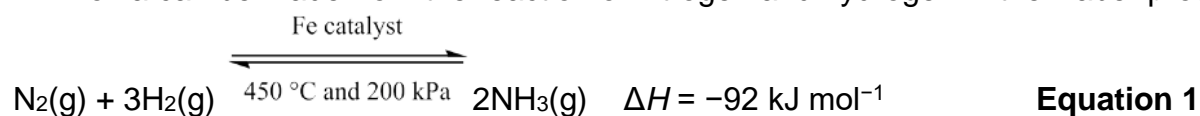
- A chemist mixes together 1.000 mol CH<sub>4</sub> and 1.400 mol of H<sub>2</sub>O in a sealed container.
- The mixture is heated to constant temperature and allowed to reach equilibrium. The equilibrium mixture contains 0.200 mol of CH<sub>4</sub> and the total pressure is 30.0 atm.

Use this information to calculate  $K_p$  for the equilibrium in **equation 17.1**.

Show all your working.

[7]

9. Ammonia can be made from the reaction of nitrogen and hydrogen in the Haber process.



A chemist mixes together 0.450 mol  $\text{N}_2$  with 0.450 mol  $\text{H}_2$  in a sealed container.

The mixture is heated and allowed to reach equilibrium.

At equilibrium, the mixture contains 0.400 mol  $\text{N}_2$  and the total pressure is 500 kPa.

Calculate  $K_p$ .

Show **all** your working.

Include units in your answer.

$K_p = \dots\dots\dots$  units  $\dots\dots\dots$  [5]

10. The values of  $K_p$  for **equilibrium 18.1** at 298 K and 1000 K are shown below.
- $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$                       **Equilibrium 18.1**

Temperature / K	$K_p / \text{atm}^{-1}$
298	$K_p = 2.19 \times 10^{12}$
1000	$K_p = 2.03 \times 10^{-1}$

- i. Predict, with a reason, whether the forward reaction is exothermic or endothermic.

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..... **[1]**

- ii. The chemist increases the pressure of the equilibrium mixture at the same temperature.

State, and explain in terms of  $K_p$ , how you would expect the equilibrium position to change.

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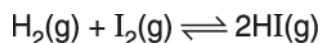
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..... **[3]**

11. A student mixes hydrogen and iodine at room temperature and pressure and allows the mixture to reach dynamic equilibrium.



$$\Delta H = -9 \text{ kJ mol}^{-1} \quad \text{equilibrium 3.1}$$

- i. A closed system is required for dynamic equilibrium to be established.

State **one** other feature of this dynamic equilibrium.

[1]

- ii. The student heats the equilibrium mixture keeping the volume constant.

Predict how the composition of the equilibrium mixture changes on heating.

Explain your answer.

[2]

- iii. Predict and explain what effect, if any, an increase in the pressure would have on the position of the equilibrium.

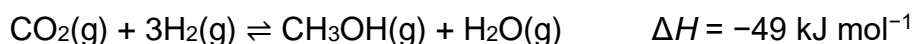
effect

explanation

[1]

12. Methanol,  $\text{CH}_3\text{OH}$ , is an important feedstock for the chemical industry.

In the manufacture of methanol, carbon dioxide and hydrogen are reacted together in the reversible reaction shown below.



High pressures and low temperatures would give a maximum equilibrium yield of methanol.



- i. Explain this statement in terms of le Chatelier's principle.

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[3]

- ii. Explain why the actual conditions used by the chemical industry might be different.

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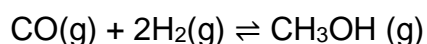
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[2]

13. A chemist investigates the equilibrium that produces methanol:



The chemist mixes CO(g) with H<sub>2</sub>(g) and leaves the mixture to react until equilibrium is reached.

The equilibrium mixture is analysed and found to contain the following concentrations.

Substance	Concentration/mol dm <sup>-3</sup>
CO (g)	0.310
H <sub>2</sub> (g)	0.240
CH <sub>3</sub> OH(g)	0.260

Calculate the numerical value of  $K_c$  for this equilibrium.

Give your answer to an **appropriate** number of significant figures.

$$K_c = \dots\dots\dots \text{dm}^6 \text{mol}^{-2} \text{ [2]}$$

**END OF QUESTION paper**