

1. C [1]

2. C [1]

3. (a) $(K_c =) \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2}$; 1

Do not award mark if incorrect brackets are used or brackets are missing.

(b) (i) amount (of methanol)/product decreases / less methanol;
(forward reaction) exothermic / reverse reaction endothermic / *OWTTE*; 2

(ii) amount (of methanol)/product increases / more methanol;
3 gas molecules/mol \rightarrow 1 / decrease in volume / fewer gas
molecules on right hand side/products / more gas molecules
on left hand side/reactants; 2

(c) high pressure expensive / greater cost of operating at high pressure;
lower temperature – lower (reaction) rate; 2

(d) increases rate of forward and reverse reactions (equally) / lowers
activation energy/ E_a (of both the forward and reverse reaction
equally) / provides alternative path with lower activation energy/ E_a ; 1
*Accept reactants adsorb onto the catalyst surface and bonds
weaken resulting in a decrease in the activation energy.*

[8]

4. C [1]

5. D [1]

6. (i) reactants and products in same phase/state;
rate of forward reaction = rate of reverse reaction;
concentrations of reactants and products remain constant /
macroscopic properties remain constant; 2 max
Do not accept concentrations are equal.
- (ii) $(K_c) = \frac{[HI_2]}{[H_2][I_2]}$; 1
- (iii) no change to position of equilibrium;
no change to value of K_c ; 2
- (iv) the reaction is exothermic/heat is given out/ ΔH is negative; 1
- (v) no effect (on the value of the equilibrium constant);
as it speeds up forward and reverse reaction / concentrations
of reactants and products do not change / position of equilibrium
does not change / no change in yield; 2
- [8]**
7. D [1]
8. A [1]
9. B [1]
10. $CO_2(g)$ / gas escapes / (gas) pressure / $[CO_2]$ (above liquid) decreases / bubbles (of
 CO_2 gas) form in the liquid;
equilibrium shifts to the right (to replace the lost CO_2 gas); 2
- [2]**

11. D [1]

12. D [1]

13. C [1]

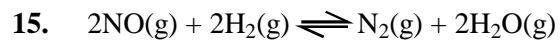
14. (i) $(K_c =) \frac{[\text{SO}_3]^2}{[\text{O}_2][\text{SO}_2]^2}$; 1

(ii) yield (of SO_3) decreases;
forward reaction is exothermic / reverse/backwards reaction is endothermic /
equilibrium shifts to absorb (some of) the heat;
Do not accept exothermic reaction or Le Chatelier's Principle.
Do not allow ECF. 2

(iii) no effect; 1

(iv) no effect;
the rates of both the forward and reverse reactions increase equally; 2

[6]



| | NO(g) | H₂(g) | N₂(g) | H₂O(g) |
|--|--------------|-------------------------|-------------------------|--------------------------|
| Initial/mol dm⁻³ | 0.100 | 0.051 | 0.000 | 0.100 |
| Change/mol dm⁻³ | -0.038 | -0.038 | +0.019 | +0.038 |
| Equilibrium/mol dm⁻³ | 0.062 | 0.013 | 0.019 | 0.138 |

[H₂] at equilibrium = 0.013 (mol dm⁻³);

[N₂] at equilibrium = 0.019 (mol dm⁻³);

[H₂O] at equilibrium = 0.138 (mol dm⁻³);

$K_c = \frac{[\text{N}_2][\text{H}_2\text{O}]^2}{[\text{NO}]^2[\text{H}_2]^2} = \frac{(0.019)(0.138)^2}{(0.062)^2(0.013)^2} = 5.6 \times 10^2$;

Award [4] for final correct answer.

Accept any value also in range 557–560.

Do not penalize significant figures.

4

[4]

16. D

[1]

17. D

[1]