1. C

[1]

2. C

[1]

3. (a) $(K_c =) \frac{[CH_3OH]}{[CO][H_2]^2}$; 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 → 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 =) $[SO_3]^2 / [O_2] [SO_2]^2$; 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 <u>equally</u>; 2

[6]

15. $2NO(g) + 2H_2(g) \rightleftharpoons N_2(g) + 2H_2O(g)$

	NO(g)	**H_2(g)**	**N_2(g)**	**H_2O(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

$[H_2]$ at equilibrium = 0.013 (mol dm^{-3});
$[N_2]$ at equilibrium = 0.019 (mol dm^{-3});
$[H_2O]$ at equilibrium = 0.138 (mol dm^{-3});
$K_c = [N_2][H_2O]^2 / [NO]^2[H_2]^2 = (0.019)(0.138)^2 / (0.062)^2(0.013)^2 = 5.6 \times 10^2$;
*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]