1. **(a)** Forward and reverse reactions at same rate ✓

Achievable from either direction ✓, requires closed system ✓

concentrations of reactants and products are constant ✓

max: [2]

(b) **(i)**

$$K_c = \frac{[\ CH_3OH(g)\ ]}{[\ CO(g)\ ]\ [\ H_2(g)\ ]^2}$$ ✓✓ *1 mark for top; 1 mark for bottom*

[2]

(ii)

$$K_c = \frac{(2.6 \times 10^{-5})}{(3.1 \times 10^{-3})\ (2.4 \times 10^{-2})^2}$$ ✓ = 14.6 ✓ ($dm^6\ mol^{-2}$)

[2]

(c) (i) *Why did the equilibrium move to the right*

fewer molecules on right ✓

reaction relieves increase in pressure ✓

[2]

(ii) *What is the effect, if any, on K_c*

K_c stays same ✓

[1]

(iii) *Rate changes*

Rate increases ✓

Increased collisions/more concentrated ✓

Rates initially forward faster than reverse ✓

At equil, rates same ✓

[4]

(d) **(i)** K_c decreases so products decrease/reactants increase ✓

Therefore equilibrium moves to the left/to endothermic side ✓

2nd mark dependent on first.

[2]

(ii) ΔH is negative because of equilibrium change in **(i)** ✓

*M*ark *consequential on (i)*

[1]

(iii) Partial pressure decreases because less CH_3OH is now present ✓

[1]

[Total: 17]

Abbreviations, annotations and conventions used in the Mark Scheme	/	= alternative and acceptable answers for the same marking point
	;	= separates marking points
	NOT	= answers which are not worthy of credit
	( )	= words which are not essential to gain credit
	____	= (underlining) key words which **must** be used to gain credit
	ecf	= error carried forward
	AW	= alternative wording
	ora	= or reverse argument

1. (a) (i) $K_c = \frac{[NO_2(g)]^2}{[N_2O_4(g)]}$ ✓ [1]

(ii) $K_c = \frac{(0.0150)^2}{(0.0390)} = 5.77 \times 10^{-3}$ ✓ mol dm^{-3} ✓ accept 5.76923 to 5.8×10^{-3}

If (i) is upside down: $\frac{[N_2O_4(g)]}{[NO_2(g)]^2}$, then ans = 173 ✓ dm^3 mol^{-1} ✓ accept 173.33333.....to 170

if no square in (i): $\frac{[NO_2(g)]}{[N_2O_4(g)]}$, then ans = 0.384615..✓ no units ✓ (must be stated)

if no square in (i) and inverse: $\frac{[N_2O_4(g)]}{[NO_2(g)]}$, 2.6 ✓ no units ✓ (must be stated)

[2]

(b) ΔH = (2 x 33) –(9) ✓ = (+)57 kJ mol^{-1} ✓

common errors: –57 ✓× +24 ✓× +75 ✓× –24 ×× [2]

(c) *change* more NO_2 / less N_2O_4 ✓

explanation equilibrium position ⟶ right or forwards / K_c increases ✓

reaction is endothermic ✓

THIS ANSWER IS CONSEQUENTIAL ON SIGN OF THE ANSWER TO (i)

BUT, a candidate interpreting a '+' enthalpy change as 'exothermic' (or vice versa) will lose the 3rd mark but the 2 'logic marks' before are still consequentially available.

[3]

(d) 1 mol N_2O_4 reacts with 2 mol NaOH ✓

amount of NaOH required = 0.00930 mol ✓

volume NaOH = 1000 x 0.0093/0.300 = 31.0 cm^3 / 0.0310 dm^3 ✓

Common errors

3.1 x 10^x (where x is incorrect) ✓✓×

15.5 cm^3 / 0.0155 dm^3 ✓✓×

62 cm^3 / 0.062 dm^3 ✓✓×

1.55 x 10^x (where x is incorrect) ✓××

6.2 x 10^x (where x is incorrect) ✓×× [3]

[Total: 11]