1 Explain what you understand by the term *dynamic equilibrium*.

All concentrations remain constant/macroscopic properties constant
Rate of forward reaction = rate of reverse reaction

2 Explain what is meant by a *closed system*.

No exchange of matter with surroundings

3 Describe, on a molecular level, how equilibrium is established when a liquid is placed in a closed container.

Rate of evaporation = rate of condensation

4 Write expressions for the equilibrium constant, K_c, for

$CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

$K_c = \frac{[CO_2(g)][H_2(g)]^4}{[CH_4(g)][H_2O(g)]^2}$
$K_c = \frac{[NH_3(g)]^2}{[N_2(g)][H_2(g)]^3}$
$K_c = \frac{[SO_3(g)]^2}{[SO_2(g)]^2[O_2(g)]}$

5 Write expressions for the equilibrium constant, K_{c1}, for the reactions shown and state the relationship between the values of K_{c1} and K_c in 4

$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(g)$
$\frac{1}{2}N_2(g) + \frac{3}{2}H_2(g) \rightleftharpoons NH_3(g)$
$SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2}O_2(g)$

$K_c = \frac{[CO_2(g)][H_2(g)]^4}{[CH_4(g)][H_2O(g)]^2}$	$K_{c1} = \frac{[CH_4(g)][H_2O(g)]^2}{[CO_2(g)][H_2(g)]^4}$	$K_{c1} = 1/K_c$
$K_c = \frac{[NH_3(g)]^2}{[N_2(g)][H_2(g)]^3}$	$K_{c1} = \frac{[NH_3(g)]}{[N_2(g)]^{1/2}[H_2(g)]^{3/2}}$	$K_{c1} = \sqrt{K_c}$
$K_c = \frac{[SO_3(g)]^2}{[SO_2(g)]^2[O_2(g)]}$	$K_{c1} = \frac{[SO_2(g)][O_2(g)]^{1/2}}{[SO_3(g)]}$	$K_{c1} = 1/\sqrt{K_c}$

6 Explain the connection between the value of the equilibrium constant and the position of equilibrium.

Bigger value of K_c – more the position of equilibrium lies towards the right
$K_c >> 1$ position of equilibrium long way to right
$K_c << 1$ position of equilibrium long way to left

7 Predict, for each of the reactions shown, the effect of the changes below on the position of equilibrium and the value of the equilibrium constant

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$	$\Delta H = +206\ kJ\ mol^{-1}$
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$	$\Delta H = -92\ kJ\ mol^{-1}$
$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$	$\Delta H = +52\ kJ\ mol^{-1}$

increasing the pressure decreasing the temperature adding hydrogen adding a catalyst

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$	**Increase P**	**Decrease T**	**Add H_2**	**Catalyst**
Effect on position of equilibrium	To left	To left	To left	No change
Effect on K_c	No change	decreases	No change	No change

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$	**Increase P**	**Decrease T**	**Add H_2**	**Catalyst**
Effect on position of equilibrium	To right	To right	To right	No change
Effect on K_c	No change	increases	No change	No change

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$	**Increase P**	**Decrease T**	**Add H_2**	**Catalyst**
Effect on position of equilibrium	No change	To left	To right	No change
Effect on K_c	No change	decreases	No change	No change

8 Explain whether the reaction A ⇌ B is endothermic or exothermic from the values of the equilibrium constant.

$K_c = 1.2 \times 10^4$ at 500 K and $K_c = 5.6 \times 10^5$ at 1000 K

Endothermic

9 Write expressions for the reaction quotient, Q, for the following reactions

2A(g) + Q(g) ⇌ 2X(g) + 3D(g)	$Q = \frac{[X]^2[D]^3}{[A]^2[Q]}$
A(g) + 3Q(g) ⇌ 4X(g) + D(g)	$Q = \frac{[X]^4[D]}{[A][Q]^3}$

10 Given the value of K_c and the value of Q deduce whether

A the system is at equilibrium
B proceeds to the right towards equilibrium
C proceeds to the left towards equilibrium

(a) A(g) + X(g) ⇌ 2Q(g) + Z(g)

Value of K_c = 0.0300	Value of Q = 0.100

Q > K_c therefore to the left

(b) 2A(g) + X(g) ⇌ 2Q(g) + 2Z(g)

Value of K_c = 0.0200	Value of Q = 0.0100

Q < K_c therefore to the right

(c) A(g) + 2X(g) ⇌ Q(g) + 3Z(g)

Value of K_c = 0.160	Value of Q = 0.160

Q = K_c therefore at equilibrium