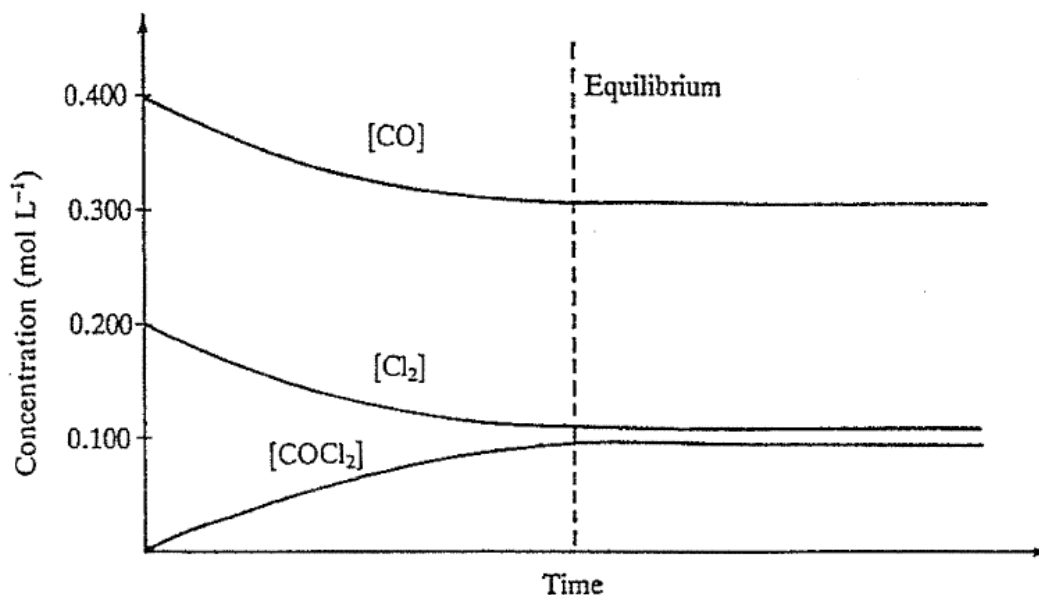


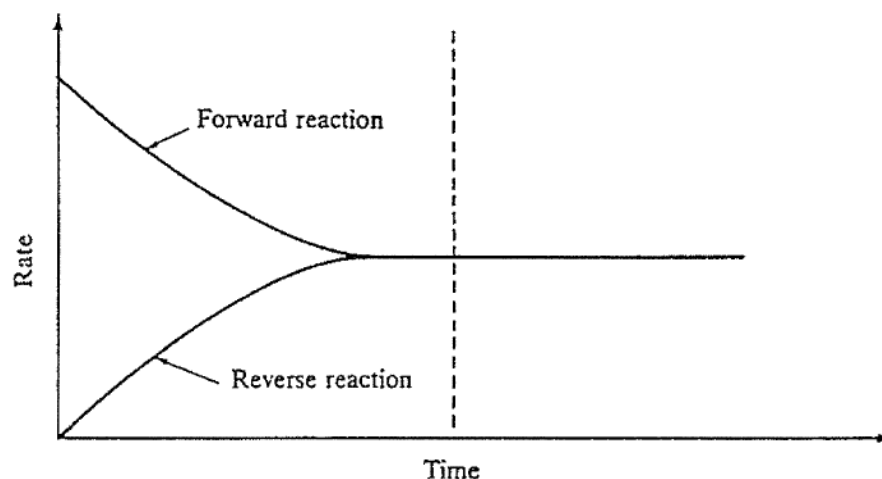
CHEM 3AB EQUILIBRIUM Assignment (Foundations of Chemistry): **SOLUTIONS**

1. a $[\text{Cl}_2] = 0.104 \text{ mol L}^{-1}$
 $[\text{COCl}_2] = 0.096 \text{ mol L}^{-1}$

b.



c.



2. Observe the colour of the mixture over a period of time. If the intensity neither increases nor decreases, the system is at equilibrium.
3. The opposing dynamic processes proceed on a molecular scale at equal rates so that no net change occurs.
4. a. Temperature, Pressure and changes in Concentration through injection of reactants or removal of products.
- b. Temperature ONLY!

5.
 - a. High energy ether molecules escape from the liquid into the gaseous state. As the vapour pressure of the ether increases the rate of condensation of gaseous ether back to the liquid state increases until the rates of evaporation and condensation are equal.
 - b. $\text{ether(l)} \rightleftharpoons \text{ether(g)}$
 - c. Ether would continue to escape from the liquid and leave the jar but the rate of condensation back to the liquid would remain low. Eventually all the ether would evaporate to the surroundings.
6.
 - a. $\text{I}_2(\text{s}) \rightleftharpoons \text{I}_2(\text{alcohol})$
 - b. The rates of crystallisation and dissolution would both decrease but the rate of crystallisation would be greater than the rate of dissolution. The mass of dissolved iodine would decrease as additional solid iodine crystallised from the solution.

7. a.

When a bottle or can of “fizzy” drink is opened the air space above the drink in the sealed container has a saturation vapour pressure of CO_2 gas. When the container is opened the “closed system” that previously existed is no longer present and carbon dioxide leaves the air space in the bottle or can. There is an immediate shift in equilibrium position to the LEFT in the equilibrium between aqueous and gaseous CO_2 . The dissolved carbon dioxide turns rapidly to gas and bubbles or effervescence is formed.

b.

Warm fizzy drinks will go flat as the heat causes the evaporation of CO_2 from the solution which shifts the equilibrium to the left to replace the escaping CO_2 . The quantity of dissolved aqueous CO_2 will diminish and so the drink will become increasingly flat. The other factor to consider is that the system as written is EXOTHERMIC and so added heat will shift the equilibrium position towards the LEFT. The system will “**attempt to minimize the effect of the imposed change**” which in this case is added heat energy by shifting in a direction that will use some of it up. For both reasons the concentration of aqueous CO_2 will decrease.

$$8. \quad K = \frac{[\text{NOBr}]^2}{[\text{NO}]^2[\text{Br}_2]} = \frac{(0.046)^2}{(0.30)^2(0.11)} = 0.21$$

$$9. \quad \begin{aligned} \text{a.} \quad Q_A &= \frac{(0.025)(0.040)}{(0.020)} = 0.050 - \text{at equilibrium} \\ Q_B &= \frac{(0.020)(0.025)}{(0.015)} = 0.033 - \text{not at equilibrium} \end{aligned}$$

b. For system B, the concentration of products must increase.

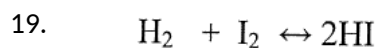
10. a.
$$K = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2}$$
- b.
$$K = \frac{[\text{CH}_3\text{Cl}][\text{HCl}]}{[\text{CH}_4][\text{Cl}_2]}$$
- c.
$$K = \frac{[\text{CO}_2]}{[\text{O}_2]}$$
- d.
$$K = [\text{Mg}^{2+}][\text{OH}^-]^2$$
- e.
$$K = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$$
- f.
$$K = [\text{CO}_2]$$
11. The concentration of Cl is extremely low compared with the concentration of Cl_2 .
12. a. $[\text{O}_2]$, $[\text{NO}_2]$ increase, $[\text{NO}]$ decreases, $[\text{O}_3]$ decreases from adjusted value.
 b. $[\text{O}_3]$, $[\text{NO}]$ increase, $[\text{O}_2]$ decreases, $[\text{NO}_2]$ decreases from adjusted value.
 c. $[\text{O}_2]$, $[\text{NO}_2]$ decrease, $[\text{O}_3]$ increases, $[\text{NO}]$ increases from adjusted value.
 d. $[\text{O}_3]$, $[\text{NO}]$ decreases, $[\text{NO}_2]$ increases, $[\text{O}_2]$ increase from adjusted value.
13. a. All concentrations increase immediately; then $[\text{H}_2\text{O}]$, $[\text{Br}_2]$ increase and $[\text{HBr}]$, $[\text{O}_2]$ decrease.
 b. All concentrations decrease immediately; then $[\text{HBr}]$, $[\text{O}_2]$ increase and $[\text{H}_2\text{O}]$, $[\text{Br}_2]$ decrease.
 c. No effect on concentrations.
14. a. i. $[\text{O}_3]$ increases, $[\text{O}_2]$ decreases.
 ii. $[\text{CO}]$, $[\text{O}_2]$ increase, $[\text{CO}_2]$ decreases.
 b. i. $[\text{N}_2]$, $[\text{O}_2]$ increase, $[\text{NO}_2]$ decreases.
 ii. $[\text{N}_2]$, $[\text{H}_2\text{O}]$ increase, $[\text{NO}]$, $[\text{H}_2]$ decrease.
15. a. $[\text{H}_2\text{O}]$ decreases, $[\text{CO}_2]$ decreases from adjusted value, mass (CaO) decreases, mass $(\text{Ca}(\text{HCO}_3)_2)$ increases.
 b. $[\text{CO}_2]$ increases, $[\text{H}_2\text{O}]$ increases from adjusted value, mass (CaO) increases, mass $(\text{Ca}(\text{HCO}_3)_2)$ decreases.
 c. Immediately $[\text{CO}_2]$, $[\text{H}_2\text{O}]$ decrease; then $[\text{CO}_2]$, $[\text{H}_2\text{O}]$ increase above adjusted values; mass (CaO) increases, mass $(\text{Ca}(\text{HCO}_3)_2)$ decreases.
 d. No effect (except to increase mass of CaO).
 e. $[\text{CO}_2]$, $[\text{H}_2\text{O}]$ decrease, $m(\text{CaO})$ decreases, $m(\text{Ca}(\text{HCO}_3)_2)$ increases.

- 16.
- a.
 - i. $[\text{SO}_3]$, $[\text{NO}]$ increase, $[\text{NO}_2]$ decreases, $[\text{SO}_2]$ decreases from its adjusted value.
 - ii. Rate of forward reaction increases. Rates of forward and reverse reactions become equal when equilibrium is re-established.
 - b.
 - i. Concentrations of all species increase immediately but then there is no change i.e. the system remains at equilibrium.
 - ii. The rates of the forward and reverse reactions increase equally.
 - c.
 - i. Concentrations of all species decrease immediately but there is no further change.
 - ii. The rates of the forward and reverse reactions decrease equally.
 - d.
 - i. $[\text{SO}_2]$, $[\text{NO}_2]$ increase; $[\text{SO}_3]$, $[\text{NO}]$ decrease.
 - ii. Both rates increase but the rate of the reverse reaction is increased more than the rate of the forward reaction. Rates become equal when equilibrium is re-established.
 - e.
 - i. No effect on concentrations.
 - ii. The rates of the forward and reverse reactions increase equally.
- 17.
- a.

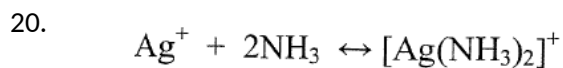
Fast reaction rate will be achieved with **HIGH TEMPERATURE**, **HIGH PRESSURE** and the **PRESENCE OF A CATALYST**.
 - b.

High equilibrium YIELD would be obtained with **HIGH PRESSURE** but **LOW TEMPERATURE**.
 - c.

YES compromise conditions would be required for this reaction. While **HIGH PRESSURE** is of benefit for both rate of attainment of equilibrium and yield Temperature conditions are problematic. A **LOW TEMPERATURE** leads to a **HIGH YIELD** but at a **SLOW RATE OF ATTAINMENT** while **HIGH TEMPERATURE** will attain equilibrium **FASTER** but the **YIELD WILL BE LOWER**. A **COMPROMISE TEMPERATURE** that balances the demands of rate and yield will be required.
- 18.
- a. $\text{NaCl} \leftrightarrow \text{Na}^+ + \text{Cl}^-$
 - b. If HCl is bubbled through a saturated salt (NaCl) solution the concentration of chloride ions in the solution will be raised. As the Cl^- ion is a common ion to the salt saturation equilibrium it will interfere with it. The salt saturation system will respond to the extra chloride ion by **SHIFTING** to the left in an effort to "*minimise the effect of the imposed change*" and in doing so will use up some of the extra chloride ion but will also produce more undissolved NaCl and hence reduce its solubility.



If the equilibrium constant of this reaction is increased by heating then the relative proportion of HI must have increased and so the equilibrium must have shifted to the right. If this is the case then the heat term must have appeared on the left hand side of the equilibrium and hence it must be ENDOTHERMIC.



If iodide ions precipitate out some of the silver ions then this will interfere with the equilibrium above. The system will SHIFT to the left in an effort to “*minimise the effect of the imposed change*” and more of the concentration of the silver complex ion will decrease as more silver ions are produced by the shift. The shift will also cause an increase in the ammonia concentration at the same time.