Chemistry Unit 3 Model Answers

year 11 chem (University of Western Australia)

Chemistry Unit 3 Model Answers

Equilibrium

Kinetic theory questions

1. Consider the below equilibrium system for nitrogen dioxide and dinitrogen tetroxide. Answer all questions with reference to relevant kinetic theory.

$$N_2O_4(g) \quad \rightleftharpoons \quad 2NO_2(g) \qquad \Delta H = +ve$$

$$Colourless \qquad Brown$$

a) Explain the observations that would be taken if the volume of the container was decreased.

- [N2O4] and [NO2] would increase,
- Initially causing the brown colour of the container to darken
- Increasing the frequency of collisions between reactants[1] and thus initially increasing the rate of both the forward and reverse reactions.
- The reverse reaction has more gaseous reactants, thus its rate would increase by more,
- Causing NO2 to be consumed faster than it is produced.
- This will cause the colour of the container to get lighter over time until equilibrium is re-established,
- at which point the container will still be overall darker than initially.

b) Explain what would happen to the concentration of N_2O_4 if the temperature was increased.

- An increase in temperature will increase the frequency and proportion of collisions with E >= E_a, thus initially increasing the rates of both the forward and reverse reaction.
- The forward reaction is endothermic, and thus its rate will increase by more,
- causing N_2O_4 to be consumed faster than it is produced,
- and thus $[N_2O_4]$ will decrease over time until equilibrium is re-established.

1 N.B. if the equilibrium expression is describing a physical process as opposed to a chemical reaction this must be changed to reflect this (e.g. if it's $CO_{2\,(aq)} \rightleftarrows CO_{2\,(g)}$, it might be "the rate of collisions between $CO_{2\,(g)}$ and the surface of the liquid)

2. A common industrial process used to produce ammonia is the Haber system:

$3H_{2\,(g)} + N_{2\,(g)} \rightleftarrows 2NH_{3\,(g)}$ ΔH=-ve

Discuss the ideal conditions for this reaction making appropriate reference to kinetic theory in regards to temperature, pressure, and a catalyst.

- ***Temperature***
- An increase in temperature increases the frequency and proportion of collisions with $E>=E_a$, thus increasing the rate of reaction for both the forward and reverse reactions.
- The reverse reaction is endothermic, so its rate will increase by more,
- causing ammonia to be consumed faster than it is produced,
- thus decreasing yield.
- To compromise rate and yield a moderate temperature is used.

- ***Pressure***
- An increase in pressure will increase $[H_2]$, $[N_2]$, and $[NH_3]$, causing the frequency of collisions between reactants for both the forward and reverse reactions to increase, thus increasing the rate of reaction for both.
- The forward reaction has more gaseous particles and so its rate will increase by more,
- causing NH_3 to be produced faster than it is consumed,
- thus increasing yield.
- Thus a high temperature is used to maximise rate and yield.[2]

- ***Catalyst***
- A catalyst provides an alternate reaction pathway with a lower E_a, thus increasing the proportion of collisions with $E>=E_a$, thus increasing the rate of reaction, without affecting the yield.
- Thus a catalyst is used.
- (Catalysts are also reusable and thus cost effective)

2 N.B. for some processes a temperature or pressure is lower than predicted, this is because maintaining high pressures and temperatures is expensive and dangerous, and some reactions have high enough rate or yield without needing them (this is sometimes asked about in questions specifically)

Acids and Bases

General

3. A solution is made by combining equal amounts of hydrochloric acid and ammonia. Will the solution be acidic, basic, or neutral? Explain.

- The HCl will dissolve to form H^+ and Cl^-. The Cl^- is neutral and thus does not affect pH,
- but the H^+ will react with the ammonia to produce ammonium:
- $NH_{3\,(aq)} + H^+ \rightleftarrows NH_4^+$
- NH_4^+ is the conjugate acid of a weak base, and thus will be a weak acid:
- $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftarrows NH_{3\,(aq)} + H_3O^+{}_{(aq)}$
- Thus in the final solution $[H_3O^+] > [OH^-]$ and so the solution will be acidic.[3]

Buffers

4. A buffer solution consists of a mixture of CH_3COOH and CH_3COO^-. Explain what will happen to the pH of the solution if a small amount of HNO_3 is added.

- The HNO_3 will produce H_3O^+ and NO_3^+. NO_3^+ is neutral and so will not affect the pH.
- The H_3O^+ will react with the CH_3COO^- to form CH_3COOH:
- $CH_3COO^-{}_{(aq)} + H_3O^+{}_{(aq)} \rightleftarrows CH_3COOH_{(aq)} + H_2O_{(l)}$
- This will minimise the increase in $[H_3O^+]$, and thus the pH will only decrease minimally, as $pH=-\log[H_3O^+]$.

Indicator Choice

5. A solution containing ammonium is titrated against sodium hydroxide. What indicator should be used and why?

- Ammonium and hydroxide react to produce ammonia, which is a weak base, as it is the conjugate base of a weak acid:
- $NH_4^+ + OH^- \rightarrow H_2O + NH_3$
- $NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-$
- Therefore, at equivalence, $[OH^-]>[H^+]$, so the solution will be basic.
- The end point must be equal to the equivalence point, and thus we must pick an indicator that changes colour in the basic pH range, such as phenolphthalein.

3 N.B. best not to talk about pH unless directly asked, because at any temperature other that 25°C neutral pH won't be 7.