Chapter 7 – Answers to questions (for in-chapter questions)

1  a  Because NH₃ has smaller, less heavier molecules than HCl which diffuse away from any source faster.
   b  NH₃ because it has diffused away from the heated ammonium chloride faster than HCl. This has then turned red litmus paper blue.
   c  Because eventually the NH₃ and HCl meet again above the tube and re-form ammonium chloride.
      \[
      \text{NH}_3(g) + \text{HCl}(g) \rightarrow \text{NH}_4\text{Cl}(s)
      \]

2  When the clothes are hung on a line, water molecules can evaporate into the air and in time this loss of water causes the clothes to dry. If the wet clothes are kept in a plastic laundry bag, evaporation of water molecules cannot occur.

3  a  CoCl₂.6H₂O(s) → CoCl₂(s) + 6H₂O(g)
   b  By adding water to the blue anhydrous CoCl₂(s)
   c  If a liquid containing water is added to blue anhydrous CoCl₂(s), the solid will turn purple as hydrated CoCl₂.6H₂O forms.

4  a  If some of the vapour is removed, the rate of condensation will suddenly become less than the rate of evaporation which will remain unchanged.
   b  As time goes on, more molecules enter the vapour phase by evaporation than those leaving it by condensation. So, the concentration of molecules in the gas phase increases.
   c  Eventually, as the concentration of molecules in the gas phase rises, the rate of condensation will equal the rate of evaporation and equilibrium is attained once more.

5  As more radioactive $^{212}$PbCl₂(s) gets into solution, the rate at which $^{212}$PbCl₂ returns to the solid rises and the rate at which $^{212}$PbCl₂ goes into solution falls. Eventually, these two rates become equal, equilibrium has been attained and the concentration of $^{212}$PbCl₂ in the solution, and hence its radioactivity, reaches a constant value.

6  a  Because the system is not closed and the CaO produced is constantly being removed.
   b  Liming the soil (after conversion to Ca(OH)₂) or trapping unwanted acidic gases in industry.
7  a  \( \text{CaCO}_3(s) \rightarrow \text{CaO}(s) + \text{CO}_2(g) \)

Rel. mol. mass \( \text{CaCO}_3 \) = 100.1

Rel. mol. mass \( \text{CaO} \) = 56.1

Theoretically, 100.1 g \( \text{CaCO}_3 \) produces 56.1 g \( \text{CaO} \)

So, 100.1 tonnes \( \text{CaCO}_3 \) produces 56.1 tonnes \( \text{CaO} \)

and 1 tonne \( \text{CaCO}_3 \) produces \( \frac{56.1}{100.1} \) tonnes \( \text{CaO} \)

Theoretical yield = 0.56 tonnes \( \text{CaO} \)

b  Percentage yield = \( \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100 \)

= \( \frac{0.50}{0.56} \times 100\% = 89\% \)

8  a  The number of molecules of \( \text{H}_2 \) in the container does not change. Neither does the number of molecules of \( \text{I}_2 \), or the number of molecules of \( \text{HI} \).

b  Rate of conversion of \( \text{H}_2 \) and \( \text{I}_2 \) to \( \text{HI} \) equals rate of decomposition of \( \text{HI} \) to \( \text{H}_2 \) and \( \text{I}_2 \).

c  Because the experiments start with the same amount of both \( \text{H}_2 \) and \( \text{I}_2 \) and equal amounts of \( \text{H}_2 \) and \( \text{I}_2 \) are produced from \( \text{HI} \) or used up in forming \( \text{HI} \).

d  Because equilibrium is attained at the same time for all the gases involved in the equilibrium.

9  a  Yes, because if there is no butanedioic acid in one solvent you would not expect to have any in the other solvent when the two are in contact and in equilibrium.

b  Because the graph is a straight line with a constant gradient equal to

\[
\frac{[\text{butanedioic acid (ether)}]}{[\text{butanedioic acid (aq)}]}
\]

c  It is independent of the amount taken.

10 a  In expt. 1, \( \text{mol H}_2 \) reacted = \( 1.26 \times 10^{-2} \)

\( \text{mol I}_2 \) reacted = \( 1.26 \times 10^{-2} \)

\( \text{mol HI} \) formed = \( 2.52 \times 10^{-2} \)

\( \therefore \) No. of mol \( \text{H}_2 \) reacted = no. of mol \( \text{I}_2 \) reacted = \( \frac{1}{2} \) no. of mol \( \text{HI} \) formed.

(The same is true of expt. 2.)

b  Because the initial amounts of both \( \text{H}_2 \) and \( \text{I}_2 \) are zero and equal amounts of \( \text{H}_2 \) and \( \text{I}_2 \) form when \( \text{HI} \) decomposes.

c  Study the reaction using radioactive iodine along the lines similar to that using radioactive \( \text{PbCl}_2 \) in section 7.2.
11  a \[ K_c = \frac{[\text{NH}_3(\text{g})]^2}{[\text{N}_2(\text{g})][\text{H}_2(\text{g})]^3} \] 
\[ \text{b } K_c = \frac{[\text{N}_2(\text{g})][\text{H}_2(\text{g})]^3}{[\text{NH}_3(\text{g})]^2} \] 
\[ \text{c } K_c = \frac{[\text{NO}_2(\text{g})]^2}{[\text{NO}(\text{g})]^2[\text{O}_2(\text{g})]} \] 
\[ \text{d } K_c = \frac{[\text{NO}_2(\text{g})]}{[\text{NO}(\text{g})][\text{O}_2(\text{g})]^{1/2}} \] 

12  a \[ \frac{1}{x} \] 
\[ \text{b } \sqrt{y} \] 

13  a \[(\text{mol dm}^{-3})^2, \] 
\[ \text{b } (\text{mol dm}^{-3})^2, \] 
\[ \text{c } (\text{mol dm}^{-3})^{-1}, \] 
\[ \text{d } (\text{mol dm}^{-3})^{-1/2} \] 

14  a \[ K_c = \frac{[\text{N}_2\text{O}_4(\text{g})]}{[\text{NO}_2(\text{g})]^2} = 200 \text{ mol}^{-1} \text{ dm}^3 \text{ at } 298K \]
\[ \text{b } 200 = \frac{0.02}{[\text{NO}_2(\text{g})]^2}, \therefore [\text{NO}_2(\text{g})]^2 = \frac{0.02}{200} = \frac{1}{10000} \]
\[ \Rightarrow [\text{NO}_2(\text{g})] = \frac{1}{100} = 0.01 \text{ mol dm}^3 \]
\[ K_c = \frac{[\text{NO}_2(\text{g})]}{[\text{N}_2\text{O}_4(\text{g})]^{1/2}} = \sqrt{\frac{1}{200}} = 7.1 \times 10^{-2} \text{ mol}^{1/2} \text{ dm}^{-3/2} \]

15  a The extent of reaction is greatest for Cl\(_2\), then Br\(_2\) and least for I\(_2\).
\[ \text{b } \text{Cl}_2 \text{ and Br}_2 \text{ with } \text{H}_2 \]

16  a i \[ K_p = \frac{\text{P}_{\text{N}_2\text{O}_4}}{\text{P}_{\text{NH}_3}^3} \]
\[ \text{ii } K_p = \frac{(\text{P}_{\text{NO}_2})^2}{\text{P}_{\text{N}_2\text{O}_4}} \]
\[ \text{b } \text{i atm}^2, \text{ ii atm} \]
\[ \text{c } \]
\[ \text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g}) \]

<table>
<thead>
<tr>
<th></th>
<th>N(_2)O(_4)</th>
<th>\rightleftharpoons</th>
<th>2NO(_2)</th>
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<tbody>
<tr>
<td>Initial</td>
<td>1.0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>0.5</td>
<td></td>
<td>1.0</td>
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\[ \text{Equilibrium pressure } \frac{1}{3} \text{ atm } \quad \frac{2}{3} \text{ atm } \]
\[ K_p = \frac{(\text{P}_{\text{NO}_2})^2}{\text{P}_{\text{N}_2\text{O}_4}} = \frac{(\frac{2}{3})^2 \text{ atm}^2}{(\frac{1}{3}) \text{ atm}} = 0.17 \text{ atm} \]
17  a  When pure O\(_2\) is added, the rate of the forward reaction increases and that of the back reaction stays at the same rate. So, the concentrations of SO\(_2\) and O\(_2\) begin to fall and that of SO\(_3\) rises. This causes the forward reaction rate to fall and the back reaction rate to rise. Eventually, the forward rate equals the back rate and equilibrium is formed.

b  Adding O\(_2\) is a change on the system and the system has responded by tending to remove this change (i.e. the added O\(_2\)).

c  Compressing the mixture increases the pressure. The system will respond to this change by moving to the right producing SO\(_3\) (i.e. fewer molecules) and therefore reducing the pressure.

18  a  It maintains a closed system.

b  When the bottle is opened, CO\(_2\)(g) escapes. This causes the equilibria in both reactions to move to the left. Therefore, [H\(^+\)(aq)] and the acidity both fall.

19  a  \(K_p = \frac{z^2}{x \cdot y}\),  

b  \(\frac{x}{2}, \frac{y}{2}, \frac{z}{2}\),  

c  \(\frac{z^2}{x \cdot y}\)

d  When the overall pressure changes, each of the partial pressures change in the same proportion. But, because 2 mol of reactants forms 2 mol of products, the system cannot respond by increasing or reducing the pressure in response to an imposed change of pressure. So, changes in pressure have no effect on this reaction.

20  a  The proportion of ammonia decreases.

b  +92 kJ mol\(^{-1}\),  

c  \(1 \times 10^{-2}\) atm\(^2\)  

d  Increasing the temp will cause \(K_p\) to increase.

21  a  dilute and weak,  

b  concentrated and strong

22  a  i  \(\text{Na}_2\text{O}(s) + 2\text{HCl(aq)} \rightarrow 2\text{NaCl(aq)} + \text{H}_2\text{O(l)}\)

   ii  \(\text{Na}_2\text{S}(s) + 2\text{HCl(aq)} \rightarrow 2\text{NaCl(aq)} + \text{H}_2\text{S(g)}\)

   b  Your answer will depend on your definition of a base. If you define a base as a substance which produces (donates) OH\(^-\) ions or O\(^{2-}\) ions or a substance which reacts with acids to form a salt and water, the answer is ‘No’.

   If, however, you define a base as a substance which accepts H\(^+\) ions, the answer is ‘Yes’, because in the reaction HCl(aq) is donating H\(^+\) ions (acting as an acid) and S\(^{2-}\) ions in Na\(_2\)S is accepting H\(^+\) ions (acting as a base).

23  a  i  CH\(_3\)COOH,  

   ii  NH\(_4^+\),  

   iii  H\(_2\)CO\(_3\)

   b  i  H\(_2\)O,  

   ii  SO\(_4^{2-}\),  

   iii  NH\(_2^-\)

24  a  i  and ii are more acidic than iii.

   b  i > ii > iii.

   c  Between water and ammonium