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2020 HSC Chemistry Exam Solutions
Section I: Multiple Choice Questions

1. B.

The magnetic field in a mass spectrometer is used to deflect the ions into a circular path.

2. C.

Phenol red would be yellow in face cleanser (pH = 5.0) and red in soap (pH = 9.0). All the other indicators would give the same colour for both substances.

3. C.

Amines are organic bases. Alkanes, alcohols and esters are neutral.

4. A.

IR spectroscopy identifies the functional groups present in an organic molecule. Butane and propane are both alkanes and would have similar IR spectra. All the other pairs contain different functional groups so they can be distinguished with IR spectroscopy.

5. A.

There are 2 signals on the ^{13}C NMR spectrum which indicates 2 C environments. Chloroethane contains 2 C environments, 1-chloropropane has 3 C environments, 1,2-dichloroethane has 1 C environment (due to symmetry) and 1,2-dichloropropane has 3 C environments.

6. D.

The $-$OH functional group needs to be given the lowest number possible and all substituents are numbered relative to it and written alphabetically.

7. C.

Compound 2 contains the alkene (C=C) functional group and the hydroxyl ($-$OH) functional group, whereas Compound 3 contains the ester ($-$COO$-$) functional group.

8. D.

When HCl is added, the weak base is neutralised to its conjugate acid. At a pH of 9, 40 mL of acid has been added and there will be similar amounts of a weak base and its conjugate acid in the reaction mixture, so the solution can act as a buffer. This is supported by the gradient of the titration curve being relatively flat at pH = 9.

9. A.

$NaHCO_3$ is a base that readily reacts with carboxylic acids. All the other compounds are not acidic.

10. D.

$NaCH_3COO$ is a basic salt, NaCl is a neutral salt and NH_4Cl is an acidic salt.

11. B.

This reaction produces 2 precipitates whereas A and D only produce 1 precipitate and C produces no precipitate.

$$\mathrm{Ba(OH)_{2(aq)} + MgSO_{4(aq)} \rightarrow BaSO_{4(s)} + Mg(OH)_{2(s)}}$$

12. C.

Polyesters are thermoplastics with intermolecular forces (dipole-dipole forces and dispersion forces) between their polymer chains; these are broken at higher temperatures which soften the plastic. Polyesters can't form H-bonds since there they don't contain a $-OH$ group.

13. B.

Methanoic acid has a trigonal planar shape around the C atom (3 electrons groups around the C atom), whereas methanol has a tetrahedral shape around the C atom (4 electron groups around the C atom).

14. B.

$$K_\mathrm{w} = [\mathrm{H_3O^+}][\mathrm{OH^-}]$$

In a neutral solution such as water, $[\mathrm{H_3O^+}] = [\mathrm{OH^-}]$

$$\begin{aligned} \implies 5.5 \times 10^{-14} &= [\mathrm{H_3O^+}]^2 \\ [\mathrm{H_3O^+}] &= 2.3 \times 10^{-7}\ \mathrm{mol\,L^{-1}} \\ \mathrm{pH} &= -\log_{10}(2.3 \times 10^{-7}) \\ &= 6.63 \end{aligned}$$

15. D.

The source must be a charged ion so A cannot be the answer. Of the remaining options, D can have $m/z = 12 + 2 \times 1 + 35 = 49$ if it contains ^{35}Cl OR $m/z = 12 + 2 \times 1 + 37 = 51$ if it contains ^{37}Cl.

16. C.

As temperature increases, the yield of product Z increases so the reaction must be endothermic. As pressure decreases, the yield of product Z increases, so there must be more moles of gas on the products side relative to the reactants. This is consistent with C which has $\Delta H > 0$, 2 moles of gas on the reactants side and 3 moles of gas on the products side.

17. D.

The following equilibrium is present:

$$\mathrm{CuSO_{4(s)}} \rightleftharpoons \mathrm{Cu^{2+}{}_{(aq)}} + \mathrm{SO_4^{2-}{}_{(aq)}}$$

When NaOH is added, the $\mathrm{OH^-}$ ions will form a precipitate with $\mathrm{Cu^{2+}}$ ions:

$$\mathrm{Cu^{2+}{}_{(aq)}} + 2\,\mathrm{OH^-{}_{(aq)}} \rightarrow \mathrm{Cu(OH)_{2(s)}}$$

This effectively removes some $\mathrm{Cu^{2+}}$ from the system, so Le Chatelier's principle predicts the system will shift right in an attempt to increase $[\mathrm{Cu^{2+}}]$. This will cause more $\mathrm{CuSO_4}$ solid to dissolve, so its mass will decrease. The blue colour of the $\mathrm{CuSO_4}$ solution will fade since the $[\mathrm{Cu^{2+}}]$ in the final mixture will ultimately be lower than in the original saturated solution (which had the maximum amount of dissolved $\mathrm{CuSO_4}$ in it).

18. A.

$\mathrm{H_2O}$ is a stronger acid than $\mathrm{HCO_3^-}$, so $\mathrm{H_2O}$ can readily act as a Brönsted-Lowry acid by donating a proton to $\mathrm{HCO_3^-}$, which acts as a Brönsted-Lowry base by accepting the proton:

$$\mathrm{HCO_3^-{}_{(aq)}} + \mathrm{H_2O_{(l)}} \rightleftharpoons \mathrm{H_2CO_{3(aq)}} + \mathrm{OH^-{}_{(aq)}}$$

This produces $\mathrm{OH^-}$ ions which cause the pH of the solution to be greater than 7.

19. D.

When the system is cooled, the rates of both the forward and reverse reactions will decrease since the $\mathrm{NO_2}$ and $\mathrm{N_2O_4}$ particles will have a lower average KE and less collisions can overcome the activation energy barrier. However, the rate of the reverse endothermic reaction (which has a higher activation energy) will decrease to a greater extent than the forward exothermic reaction. After t, the rates of the forward and reverse reactions will approach each other and become equal when equilibrium is re-established.

20. C.

$$\mathrm{Ag_2CrO_{4(s)}} \rightleftharpoons 2\,\mathrm{Ag^+{}_{(aq)}} + \mathrm{CrO_4^{2-}{}_{(aq)}}$$

K_{sp} can be calculated using any of the data points on the graph which represents the concentration of the ions in a saturated solution. Using $[\mathrm{Ag^+}] = 1 \times 10^{-4}\ \mathrm{mol\,L^{-1}}$ and $[\mathrm{CrO_4^{2-}}] = 11 \times 10^{-5}\ \mathrm{mol\,L^{-1}}$:

$$\begin{aligned} K_{\mathrm{sp}} &= [\mathrm{Ag^+}]^2[\mathrm{CrO_4^{2-}}] \\ &= (1 \times 10^{-4})^2 \times 11 \times 10^{-5} \\ &= 1.1 \times 10^{-12} \end{aligned}$$

Section II: Short Answer Questions

Question 21

The molecular ion peak is at $m/z = 44$, so the molar mass of the compound is 44 $\mathrm{g\,mol^{-1}}$. This is consistent with propane (C_3H_8) which has a molar mass of:

$$\begin{aligned} M &= (3 \times 12.01 + 8 \times 1.008)\ \mathrm{g\,mol^{-1}} \\ &= 44.09\ \mathrm{g\,mol^{-1}} \end{aligned}$$

Question 22

The cation can be identified with a flame test. This involves dipping a Pt wire that was previously cleaned with concentrated HCl into the salt solution, placing the wire into a Bunsen flame and observing the flame colour. A brick red flame colour would indicate the cation is Ca^{2+}, an apple green flame colour will indicate the cation is Ba^{2+} while no observed flame colour will indicate that the cation is Mg^{2+}.

To identify the anion, red litmus paper can be dipped into the solution and if it turns blue, then this indicates the presence of OH^- ions. Excess HNO_3 can be added to the salt and if a vinegar smell is detected, then this indicates the presence of CH_3COO^- which has been protonated to CH_3COOH. To confirm the presence of CH_3COO^-, $FeCl_3$ can be added which forms a red-brown solution with CH_3COO^-. The further addition of HCl will cause the red-brown colour to disappear. If the litmus does not turn blue and no vinegar smell is detected after the addition of excess HNO_3, then the anion present must be Cl^-. This can be confirmed by adding $AgNO_3$ which should result in the formation of a white precipitate:

$$Ag^+{}_{(aq)} + Cl^-{}_{(aq)} \rightarrow AgCl_{(s)}$$

Question 23

The reaction conditions used must be considered to optimise the yield and reaction rate of the process. A catalyst is used in Reactors 1 and 2 to increase the rate of reactions by lowering the activation energy of the reactions. Moderate temperatures of $200 - 300$°C and $50 - 70$°C are used to increase the average KE of the reactant particles so that a greater proportion of collisions can overcome the activation energy barrier. The temperatures used should also produce an optimal yield and this will depend on whether the reactions are endothermic or exothermic.

The purity of the ethane-1,2-diol product was also considered. In this process, there are 2 separators that are used to purify and separate the products of the reaction to ensure that there are minimal impurities in the product that may cause issues with their use.

The availability of reagents would also be considered. Ethene and oxygen are used as raw materials for this process. Oxygen can be obtained easily from the atmosphere, but the industrial process needs to ensure ethene is readily available, possibly by locating the plant for this process close to a thermal or catalytic cracking industrial plant that produces ethene from crude oil.

Question 24

(a) The ester functional group (−COO−).

(b) Soot is produced when a fuel undergoes incomplete combustion in the presence of insufficient O_2. Biodiesel already contains oxygen within its structure, so it will require less moles of O_2 to undergo complete combustion compared to diesel under the same conditions:

$$\mathrm{C_{14}H_{30}O_{2(l)}} + \frac{41}{2}\,\mathrm{O_{2(g)}} \rightarrow 14\,\mathrm{CO_{2(g)}} + 15\,\mathrm{H_2O_{(l)}}$$
$$\mathrm{C_{18}H_{38(l)}} + \frac{55}{2}\,\mathrm{O_{2(g)}} \rightarrow 18\,\mathrm{CO_{2(g)}} + 19\,\mathrm{H_2O_{(l)}}$$

Biodiesel is therefore more likely to undergo complete combustion (and less likely to undergo incomplete combustion) than diesel, so its combustion will produce less soot overall.

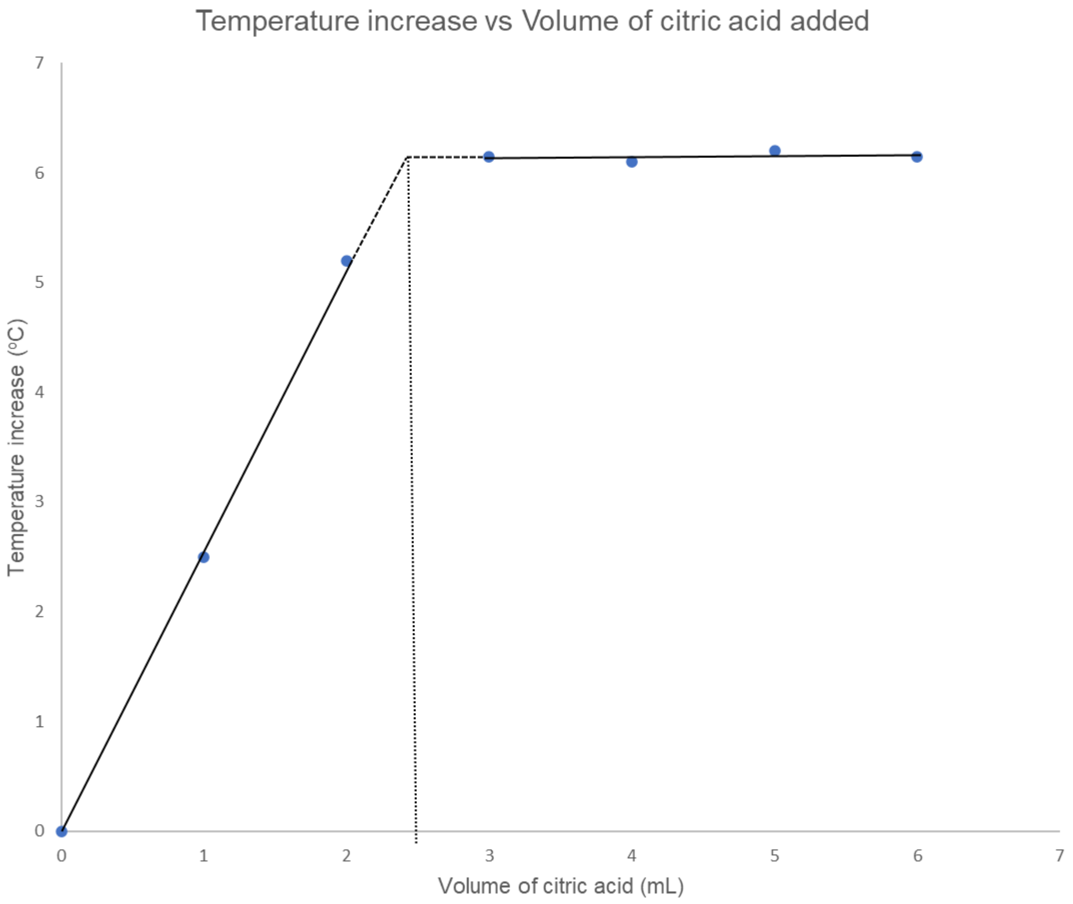
(c)

$$\begin{aligned} m(\mathrm{C_{14}H_{30}O_2}) &= \frac{2141\ \mathrm{MJ}}{38\ \mathrm{MJ\,kg^{-1}}} \\ &= 56\ \mathrm{kg} \\ V(\mathrm{C_{14}H_{30}O_2}) &= \frac{56\ \mathrm{kg}}{0.90\ \mathrm{kg\,L^{-1}}} \\ &= 63\ \mathrm{L} \end{aligned}$$

(d) One advantage of ethanol is that it is a renewable fuel since it can be produced by fermentation of sugars from crops like sugar cane. Using ethanol as a fuel will help reduce our reliance on non-renewable fossil fuels like petrol. Furthermore, ethanol is more likely to undergo complete combustion than petrol, since it already contains oxygen in its structure. This leads to less toxic pollutants like CO and soot being produced.

A disadvantage of using ethanol as a fuel is that large areas of arable land are required to grow crops for ethanol production, which can lead to land degradation issues such as soil erosion, deforestation and fertiliser run-off. The land used for ethanol production may also compete with food production. Another disadvantage is that expensive engine modifications are required to use fuels with a high concentration of ethanol since ethanol is corrosive and requires a different air-to-fuel ratio to operate than petrol.

Question 25



The turning point of the graph indicates when the citric acid has stoichiometrically reacted with the NaOH. Extrapolating from the graph, this occurs when approximately 2.4 mL of citric acid has been added.

$$\begin{aligned} n(C_6H_8O_7) &= 1.0\ \text{mol}\,\text{L}^{-1} \times 2.4 \times 10^{-3}\ \text{L} \\ &= 2.4 \times 10^{-3}\ \text{mol} \\ n(\text{NaOH}) &= 3 \times 2.4 \times 10^{-3}\ \text{mol} \\ &= 7.2 \times 10^{-3}\ \text{mol} \\ \implies [\text{NaOH}] &= \frac{7.2 \times 10^{-3}\ \text{mol}}{8.0 \times 10^{-3}\ \text{L}} \\ &= 0.90\ \text{mol}\,\text{L}^{-1} \end{aligned}$$

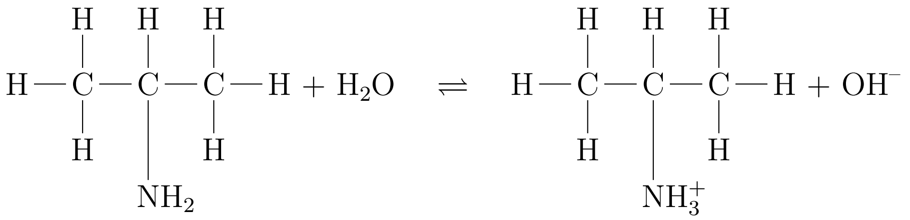
Question 26

(a) $N_{2(g)} + O_{2(g)} \rightleftharpoons 2\,NO_{(g)}$

(b) From the graph, the forward reaction is endothermic while the reverse reaction is exothermic. When the temperature is increased, the rates of both the forward and reverse reactions will increase since the particles will have a higher average KE so a greater proportion of particles can successfully collide to overcome the activation energy barrier. However, the rate of the forward endothermic reaction, which has a higher activation energy than the reverse exothermic reaction (evident from the graph), will be increased to a greater extent. As such, the forward reaction rate will be higher than the reverse reaction rate, causing the equilibrium to shift right due to the net forward reaction that occurs. This causes [NO] to increase while $[N_2]$ and $[O_2]$ decreases, so $K = \dfrac{[NO]^2}{[N_2][O_2]}$ will increase.

Question 27

(a)



$$CH_3CH(NH_2)CH_3 + H_2O \rightleftharpoons CH_3CH(NH_3^+)CH_3 + OH^-$$

(b)

	$C_3H_7NH_2$	$C_3H_7NH_3^+$	OH^-
Initial	1.00	0	0
Change	$-x$	$+x$	$+x$
Equilibrium	$1.00 - x$	x	x

$$K_b = \frac{[C_3H_7NH_3^+][OH^-]}{[C_3H_7NH_2]}$$

$$4.37 \times 10^{-4} = \frac{x^2}{1.00 - x}$$

Assume that $1.00 - x \doteqdot 1.00$ since K_b has a small value.

$$4.37 \times 10^{-4} = \frac{x^2}{1.00}$$

$$\implies x = 0.0209 \text{ mol L}^{-1}$$

$$[OH^-] = 0.0209 \text{ mol L}^{-1}$$

Checking the assumption,

$$K_b = \frac{0.0209^2}{1.00 - 0.0209}$$

$$= 4.46 \times 10^{-4}$$

$\implies$ The assumption does introduce some inaccuracy but it is likely acceptable. Not making an assumption and solving a quadratic equation would give a more accurate result ($0.0207 \text{ mol L}^{-1}$), but I imagine that both answers would be acceptable.

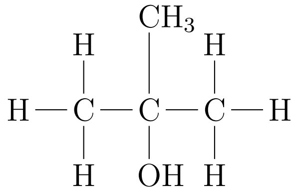
Question 28

NaOH is hygroscopic and cannot be prepared as a primary standard. The solid NaOH weighed would contain water absorbed from the atmosphere, so the NaOH solution produced would be more dilute than expected. Furthermore, this is a weak acid-strong base titration which produces a basic salt, so the pH at the equivalence point will occur at pH > 7. Bromocresol green would NOT be a suitable indicator since it changes colour over the pH range of $3.2 - 5.2$, so the end point will NOT closely correspond with the equivalence point. Both of these mistakes would lead to inaccurate results.

The results are also unreliable as seen in the table, where none of the titres recorded are concordant or consistent with each other (± 0.10 mL). This is likely due to the use of an unsuitable indicator with an end point that will not be sharp, leading to significantly different titres in each titration.

Question 29

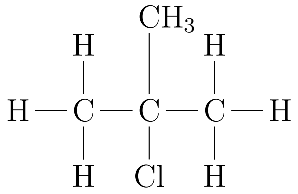
A is a tertiary alcohol since it is not oxidised by $Cr_2O_7^{2-}/H^+$. The only tertiary alcohol with a chemical formula of C_4H_9OH is:



$H-\underset{H}{\overset{H}{C}}-\underset{OH}{\overset{CH_3}{C}}-\underset{H}{\overset{H}{C}}-H$

A

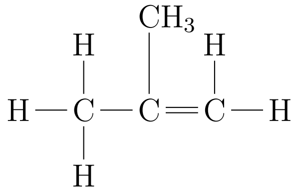
A can undergo a substitution reaction with the Lucas reagent (concentrated $HCl/ZnCl_2$) to form haloalkane **D**:



$H-\underset{H}{\overset{H}{C}}-\underset{Cl}{\overset{CH_3}{C}}-\underset{H}{\overset{H}{C}}-H$

D

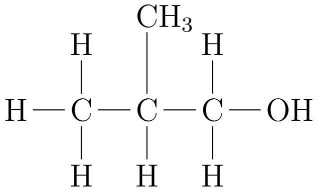
A can be dehydrated with concentrated H_2SO_4 to form alkene **C**:



$H-\underset{H}{\overset{H}{C}}-\overset{CH_3}{C}=\overset{H}{C}-H$

C

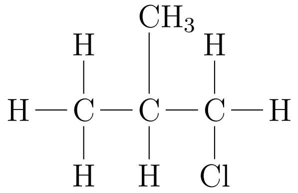
B is an isomer of **A** that can also be dehydrated to alkene **C**:



$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{CH_3}{C}}-\underset{H}{\overset{H}{C}}-OH$

B

E is an isomer of **D** which is formed from an addition reaction between **C** and HCl:



$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{CH_3}{C}}-\underset{Cl}{\overset{H}{C}}-H$

E

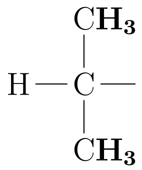
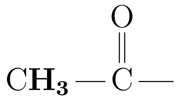
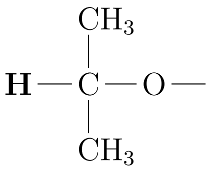
Question 30

IR spectrum

- No absorption at 3230 – 3550 cm^{-1} indicates that there is no O–H bond present.
- Strong absorption at 1680 – 1750 cm^{-1} indicates a C=O group.

^1H NMR spectrum

There are 3 signals on the ^1H NMR spectrum, so there are 3 ^1H environments, which are summarised in the table below:

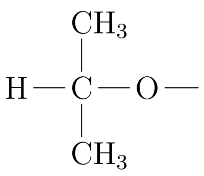
δ (ppm)	Integration	Multiplicity	^{1}H Neighbours ($n + 1$ rule)	Conclusion
1.2	6H	Doublet (2)	1	2 equivalent CH_3- groups with a low δ  $H-\overset{\mathbf{CH_3}}{\underset{\mathbf{CH_3}}{C}}-$
2.0	3H	Singlet (1)	0	A deshielded CH_3- group adjacent to a C=O group  $\mathbf{CH_3}-\overset{O}{\overset{\parallel}{C}}-$
5.0	1H	Septet (7)	6	A deshielded CH group adjacent to an O atom  $\mathbf{H}-\overset{CH_3}{\underset{CH_3}{C}}-O-$

^{13}C NMR spectrum

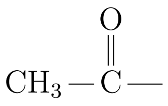
There are 4 signals on the ^{13}C NMR spectrum, so there are 4 C environments:

- The signals at 22 and 22.5 pm represents the CH_3- groups in the molecule.
- The signal at 70 ppm represents a C–O (ester) environment.
- The signal at 170 ppm represents a C=O (ester) environment.

From the information above, the two fragments that make up the molecule are:

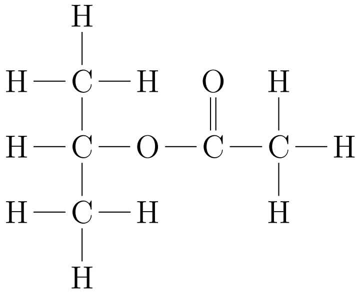


$H-\overset{CH_3}{\underset{CH_3}{C}}-O-$



$CH_3-\overset{O}{\overset{\parallel}{C}}-$

The structure is therefore:



Question 31

$$\begin{aligned}
n(\mathrm{SCN^-}) &= 0.0500\ \mathrm{mol\,L^{-1}} \times 0.02865\ \mathrm{L} \\
&= 1.43 \times 10^{-3}\ \mathrm{mol} \\
n(\mathrm{Ag^+})_{\mathrm{leftover}} &= 1.43 \times 10^{-3}\ \mathrm{mol} \\
n(\mathrm{Ag^+})_{\mathrm{added}} &= 0.100\ \mathrm{mol\,L^{-1}} \times 0.02500\ \mathrm{L} \\
&= 2.50 \times 10^{-3}\ \mathrm{mol} \\
n(\mathrm{Ag^+})_{\mathrm{reacted}} &= n(\mathrm{Ag^+})_{\mathrm{added}} - n(\mathrm{Ag^+})_{\mathrm{leftover}} \\
&= 2.50 \times 10^{-3}\ \mathrm{mol} - 1.43 \times 10^{-3}\ \mathrm{mol} \\
&= 1.07 \times 10^{-3}\ \mathrm{mol}
\end{aligned}$$

$$\mathrm{Ag^+}_{(aq)} + \mathrm{Cl^-}_{(aq)} \rightarrow \mathrm{AgCl}_{(s)}$$

$$\begin{aligned}
n(\mathrm{Cl^-}) &= 1.07 \times 10^{-3}\ \mathrm{mol} \\
m(\mathrm{Cl^-}) &= 1.07 \times 10^{-3}\ \mathrm{mol} \times 35.45\ \mathrm{g\,mol^{-1}} \\
&= 0.0378\ \mathrm{g} \\
&= 37.8\ \mathrm{mg} \\
[\mathrm{Cl^-}] &= \frac{37.8\ \mathrm{mg}}{0.100\ \mathrm{L}} \\
&= 378\ \mathrm{mg\,L^{-1}}
\end{aligned}$$

Question 32

Methyl propanoate is an ester produced from methanol and propanoic acid, and it has a higher BP than methanol (the alcohol).

Methanol is a polar molecule that can form strong hydrogen bonds due to its polar hydroxyl group (−OH). Methyl propanoate is also polar but it forms weaker dipole-dipole forces due to its polar ester group (−COO−). However, methyl propanoate has a much larger molar mass than methanol and thus stronger dispersion forces which can compensate for its lack of hydrogen bonding. This results in more energy being required to overcome the intermolecular forces of methyl propanoate, giving it a higher BP than methanol.

However, propanoic acid still has a higher BP than methyl propanoate since it contains a polar −OH group and an additional polar C=O group, allowing them to form very strong and extensive hydrogen bonds that require significant energy to overcome.

Question 33

(a)

$$\begin{aligned} 2\,\mathrm{HCl}_{(aq)} + \mathrm{Ca(OH)}_{2(s)} &\rightarrow \mathrm{CaCl}_{2(aq)} + 2\,\mathrm{H_2O}_{(l)} \\ n(\mathrm{HCl}) &= 2.00\ \mathrm{mol\,L^{-1}} \times 0.100\ \mathrm{L} \\ &= 0.200\ \mathrm{mol} \\ n(\mathrm{Ca(OH)_2}) &= \frac{1}{2} \times 0.200\ \mathrm{mol} \\ &= 0.100\ \mathrm{mol} \end{aligned}$$

(b)

$$\begin{aligned} \mathrm{Ca(OH)}_{2(s)} &\rightleftharpoons \mathrm{Ca^{2+}}_{(aq)} + 2\,\mathrm{OH^-}_{(aq)} \\ n(\mathrm{Ca^{2+}})_{\mathrm{eq}} &= 0.100\ \mathrm{mol} \\ [\mathrm{Ca^{2+}}]_{\mathrm{eq}} &= \frac{0.100\ \mathrm{mol}}{0.100\ \mathrm{L}} \\ &= 1.00\ \mathrm{mol\,L^{-1}} \\ K_{\mathrm{sp}} &= [\mathrm{Ca^{2+}}][\mathrm{OH^-}]^2 \\ 5.02 \times 10^{-6} &= 1.00 \times [\mathrm{OH^-}]^2 \\ \implies [\mathrm{OH^-}] &= 2.24 \times 10^{-3}\ \mathrm{mol\,L^{-1}} \\ \mathrm{pOH} &= -\log_{10}(2.24 \times 10^{-3}) \\ &= 2.650 \\ \mathrm{pH} &= 14 - 2.650 \\ &= 11.350 \end{aligned}$$

Question 34

HCl is a strong acid that completely ionises in water to form H^+ ions, whereas acrylic acid is a weak acid that only partially ionises in water to form H^+ ions.

$$
\begin{gathered}
HCl_{(aq)} \rightarrow H^+{}_{(aq)} + Cl^-{}_{(aq)} \\
C_2H_3COOH_{(aq)} \rightleftharpoons H^+{}_{(aq)} + C_2H_3COO^-{}_{(aq)}
\end{gathered}
$$

Therefore, at the same concentration, HCl will have a higher $[H^+]$ and thus a lower pH than acrylic acid since $\text{pH} = -\log_{10}[H^+]$.

When the concentration of HCl decreases by 10-fold, $[H^+]$ will also decrease by a factor of 10, so its pH will incrementally increase by 1. However, when the concentration of acrylic acid decreases by 10-fold, the pH increases by less than 1 because of the equilibrium system. As the acid concentration decreases, $[C_2H_3COOH]$, $[H^+]$ and $[C_2H_3COO^-]$ will all decrease due to dilution. Le Chatelier's principle predicts that the equilibrium will shift right, where there are more aqueous particles to counteract the change. This effectively increases the degree of ionisation of acrylic acid, causing more H^+ ions to be produced, so $[H^+]$ will not decrease by exactly 10-fold at each increment on the graph. The pH will thus increase by less than 1. In a very dilute acrylic acid solution (e.g. $1 \times 10^{-6}\ \text{mol L}^{-1}$), its degree of ionisation approaches 100% and the pH converges very closely to that of HCl.

Question 35

$$
\begin{aligned}
A &= [I_3^-]_{eq} \times 2.76 \times 10^4 \\
0.745 &= [I_3^-]_{eq} \times 2.76 \times 10^4 \\
\implies [I_3^-]_{eq} &= 2.70 \times 10^{-5}\ \text{mol L}^{-1}
\end{aligned}
$$

$$
\begin{aligned}
[I^-]_{\text{initial}} &= 4[I_2]_{eq} + 3[I_3^-]_{eq} \\
7.00 \times 10^{-4}\ \text{mol L}^{-1} &= 4[I_2]_{eq} + 3 \times 2.70 \times 10^{-5}\ \text{mol L}^{-1} \\
\implies [I_2]_{eq} &= 1.55 \times 10^{-4}\ \text{mol L}^{-1}
\end{aligned}
$$

$$
\begin{aligned}
[I^-]_{eq} &= 2[I_2]_{eq} \\
&= 2 \times 1.55 \times 10^{-4}\ \text{mol L}^{-1} \\
&= 3.10 \times 10^{-4}\ \text{mol L}^{-1}
\end{aligned}
$$

$$
\begin{aligned}
K &= \frac{[I_3^-]_{eq}}{[I^-]_{eq}[I_2]_{eq}} \\
&= \frac{2.70 \times 10^{-5}}{1.55 \times 10^{-4} \times 3.10 \times 10^{-4}} \\
&= 564
\end{aligned}
$$

Question 36

$$\mathrm{NaOH_{(s)}} \rightarrow \mathrm{Na^{+}{}_{(aq)}} + \mathrm{OH^{-}{}_{(aq)}} \qquad \Delta H = -44.5\ \mathrm{kJ\,mol^{-1}}$$

$$\begin{aligned} n(\mathrm{NaOH}) &= \frac{10.0\ \mathrm{g}}{(22.99 + 16.00 + 1.008)\ \mathrm{g\,mol^{-1}}} \\ &= 0.250\ \mathrm{mol} \\ q_{\mathrm{NaOH_{(s)}}} &= -44.5\ \mathrm{kJ\,mol^{-1}} \times 0.250\ \mathrm{mol} \\ &= -11.125\ \mathrm{kJ} \end{aligned}$$

$$\mathrm{HCl_{(aq)}} + \mathrm{NaOH_{(aq)}} \rightarrow \mathrm{NaCl_{(aq)}} + \mathrm{H_2O_{(l)}} \qquad \Delta H = -56.1\ \mathrm{kJ\,mol^{-1}}$$

$$\begin{aligned} n(\mathrm{HCl}) &= 2.00\ \mathrm{mol\,L^{-1}} \times 0.10000\ \mathrm{L} \\ &= 0.200\ \mathrm{mol} \end{aligned}$$

HCl is the limiting reagent while NaOH is in excess.

$$\begin{aligned} n(\mathrm{H_2O})_{\mathrm{formed}} &= 0.200\ \mathrm{mol} \\ q_{\mathrm{neut}} &= -56.1\ \mathrm{kJ\,mol^{-1}} \times 0.200\ \mathrm{mol} \\ &= -11.22\ \mathrm{kJ} \end{aligned}$$

$$\begin{aligned} q_{\mathrm{total}} &= -11.125\ \mathrm{kJ} + -11.22\ \mathrm{kJ} \\ &= -22.345\ \mathrm{kJ} \end{aligned}$$

Assuming no heat loss,

$$\begin{aligned} q_{\mathrm{mixture}} &= -q_{\mathrm{total}} \\ &= 22.345\ \mathrm{kJ} \\ &= 22345\ \mathrm{J} \\ q_{\mathrm{mixture}} &= mc\Delta T \\ 22345\ \mathrm{J} &= (103 + 10.0)\ \mathrm{g} \times 3.99\ \mathrm{J\,g^{-1}\,K^{-1}} \times (T_{\mathrm{f}} - 22.5\ \mathrm{K}) \\ \implies T_{\mathrm{f}} &= 72.1^{\circ}\mathrm{C} \end{aligned}$$