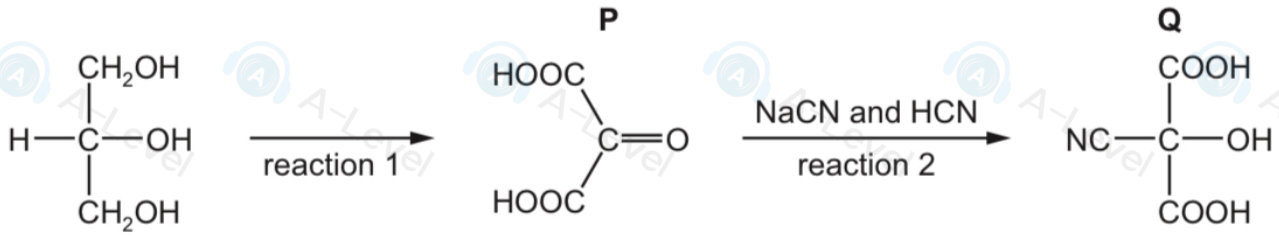
3 Glycerol, $CH_2(OH)CH(OH)CH_2OH$, is widely used in the food industry and in pharmaceuticals.

(a) A series of reactions starting from glycerol is shown.



(i) Suggest the reagent(s) and conditions for reaction 1.

.....

..... [2]

(ii) Name the reaction mechanism for reaction 2.

..... [1]

(iii) Give the observation you would make when 2,4-dinitrophenylhydrazine is added to **P**.

..... [1]

(iv) **Q** does **not** show optical isomerism.

Explain why.

.....

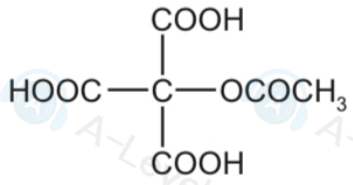
.....

.....

..... [1]

(v) When **Q** is heated with excess aqueous ethanoic acid in the presence of a catalytic amount of sulfuric acid, two reactions take place to form compound **R**.

R



Identify the two types of reaction that occur.

1 .....

2 .....

[2]

(b) Glycerol can be used as a starting material in the manufacture of nitroglycerine, $C_3H_5N_3O_9$.

Nitroglycerine decomposes rapidly on heating to form a mixture of gases.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

A sample of nitroglycerine decomposes, releasing 1.06 dm^3 of $O_2(g)$ at 850 K and 1.00×10^5 Pa.

(i) Calculate the mass of nitroglycerine that decomposes.

mass of nitroglycerine = ... g [3]

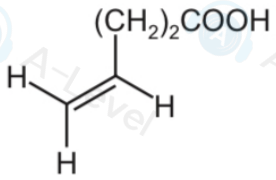
(ii) Calculate the total volume of gas released by this decomposition at 850 K and 1.00×10^5 Pa.

total volume of gas = ... dm^3 [1]

(c) Fats are compounds made from glycerol and unsaturated carboxylic acids.

4-pentenoic acid is an example of an unsaturated carboxylic acid.

4-pentenoic acid



(i) Give the molecular formula of 4-pentenoic acid.

..... [1]

(ii) Draw the repeat unit of the addition polymer that can be formed from 4-pentenoic acid.

[1]

(iii) Unsaturated acids are often brominated before being added to soft drinks.

Complete the mechanism for the addition of Br_2 to 4-pentenoic acid.

- Include the structures of the intermediate and the product of the reaction.
- Include all charges, partial charges, lone pairs and curly arrows.

In the mechanism, R has been used to represent $(CH_2)_2COOH$.

[4]

(d) A reaction of another unsaturated carboxylic acid, **T**, is shown.

(i) **T** is one of a pair of geometrical (*cis-trans*) isomers.

Draw the other geometrical isomer of **T** and explain why the molecules exhibit this form of isomerism.

.....

.....

.....

[3]

(ii) Identify the reagent used to convert **T** to **U**.

..... [1]

(iii) The C–Br bond has an absorption between 500 cm^{-1} and 600 cm^{-1} in an infrared spectrum.

The infrared spectra for both **T** and **U** have absorptions between 2850 cm^{-1} and 2950 cm^{-1}. These correspond to C–H bonds.

Identify:

- two other absorptions that would be seen in the infrared spectra of both **T** and **U**
- one other absorption that would **only** be seen in the infrared spectrum of **T**.

For each absorption, give the range of the absorption and the bonds that correspond to these absorptions.

absorption 1 present in both spectra .....

.....

.....

absorption 2 present in both spectra .....

.....

.....

absorption **only** present in spectrum of **T** .....

.....

.....

[3]

[Total: 24]

3 **(a)** Describe what is meant by dynamic equilibrium.

.....

.....

..... [2]

(b) Reaction 4 describes the reversible reaction between yellow $Fe^{3+}(aq)$ and colourless $SCN^{-}(aq)$ to produce red $FeSCN^{2+}(aq)$.

reaction 4 $Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$

yellow colourless red

An equilibrium mixture contains $Fe^{3+}(aq)$, $SCN^{-}(aq)$ and $FeSCN^{2+}(aq)$. A few colourless crystals of soluble KSCN(s) are added. The mixture is then left until it reaches equilibrium again. The temperature of both equilibrium mixtures is the same.

(i) Deduce the changes that occur, if any, in the equilibrium mixture after KSCN(s) is added compared to the original equilibrium mixture.

- change in appearance

  .....

- change in relative concentration of $Fe^{3+}(aq)$

  .....

- change in value of the equilibrium constant, K_c

  .....

[3]

(ii) The expression for the equilibrium constant, K_c, for reaction 4 is shown.

$$K_c = \frac{[FeSCN^{2+}(aq)]}{[Fe^{3+}(aq)] \times [SCN^{-}(aq)]}$$

5.00×10^{-5} mol of $Fe^{3+}(aq)$ and 5.00×10^{-5} mol of $SCN^{-}(aq)$ are added together and allowed to reach equilibrium. The total volume of the mixture is 25.0 cm^3.

At equilibrium the concentration of $FeSCN^{2+}(aq)$ is 4.23×10^{-4} mol dm^{-3}.

Calculate the equilibrium constant, K_c, for reaction 4.

Include the units in your answer.

K_c = ...

units .....

[4]

2 **(a)** Table 1 gives physical data for some of the Period 3 elements.

Table 1

atomic number, *Z*	11	12	13	14	15	16	17
bonding present in element	M						C
first ionisation energy / kJ mol^{-1}	494	736	577	786	1060	1000	1260
maximum oxidation number							+7
anionic radius / nm	–	–	–	0.271	0.212	0.184	0.181

(i) Complete the row in the table labelled 'bonding present in element'.

Use C = covalent, I = ionic, M = metallic, as appropriate. [1]

(ii) Explain the difference between the first ionisation energies of the elements with atomic numbers 11 and 17.

.....

.....

.....

.....

..... [2]

(iii) Explain the difference between the first ionisation energies of the elements with atomic numbers 15 and 16.

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..... [2]

(iv) Complete the row in the table labelled 'maximum oxidation number'. [1]

(v) Explain the variation in anionic radius for the elements with atomic numbers 14 to 17.

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..... [2]