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Chemistry review

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Answers

Practice exam questions

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Check your answers to the questions in this issue.

When plants attack (pp. 2–6)

1 **a** Ester(s) and amine (tertiary).

b Any three from: phenol, alcohol (secondary), ether, amine (tertiary).

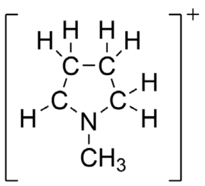
c There are five chiral centres.

2 **a** The molecular formula is $C_{10}H_{14}N_2$.

b The molecular ion, M^+, appears at *m*/*z* = 162.

c The peak with *m*/*z* = 163 is caused by the molecules containing a ^{13}C atom. 1.1% of all carbon atoms are ^{13}C, so in a molecule with 10 carbon atoms, there is just over a 10% chance of a particular molecule containing a ^{13}C atom and having a *m*/*z* value of 163.

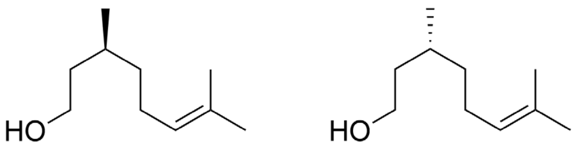
d



m/*z* = 84

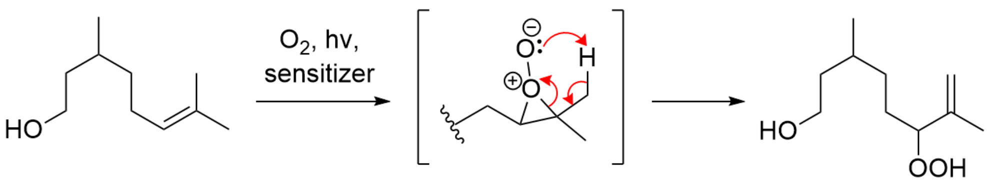
Rose oxide (pp. 10–13)

1



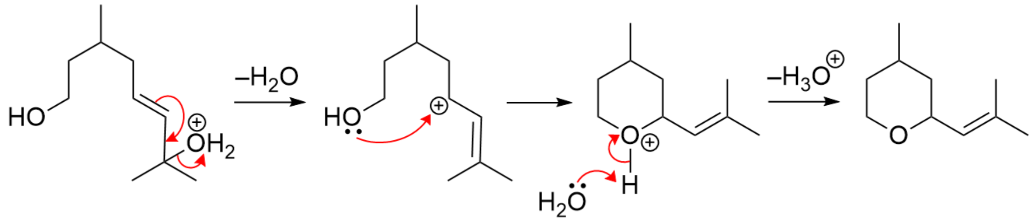
2 **a** The product is the *E*-isomer. The *E*-isomer has greater stability and lower energy than the *Z*-isomer, because the larger groups on the C=C bond are positioned as far apart as possible.

b



3 **a** The acid catalyst (notice, after cyclisation, H^+ is regenerated) assists the cyclisation by protonating the –OH group of the tertiary alcohol. On protonation, a stronger (positively charged) electrophile is formed. Also, nucleophilic attack through the C=C bond, leads to the loss of H_2O (water), which serves as a good leaving group, as it is an uncharged, stable molecule.

b



The race towards sustainable fuels (pp. 18–22)

1 Biodiesel is primarily made up of fatty acid methyl esters (FAME), which are produced through transesterification. Diesel is made from hydrocarbons obtained from crude oil through refining processes.

2 Vegetable oils are renewable and widely available, but they can compete with food crops for land and resources.

3 First-generation biofuels are made from food crops like corn (for bioethanol) and oilseeds (for biodiesel). They can compete with food production and raise concerns about land use and food security. Second-generation biofuels are made from non-food biomass, like wood or algae. They do not compete with food crops and can make use of waste materials, which makes them more sustainable in the long term.

4 Catalysts are involved in pretreatment processes to break down complex sugars from biomass (like wood) into fermentable sugars. Acid or alkaline catalysts are used to hydrolyse lignin and hemicellulose into simpler sugars that yeast can ferment into bioethanol. Specific enzymes like cellulases can break down the cellulose into glucose, which can then be fermented. For biodiesel formation, transesterification of triglycerides (fats or oils) with methanol requires a base catalyst (such as sodium hydroxide).

Autoxidation of aldehydes (pp. 26–28)

1 Benzaldehyde will show a strong, sharp absorption band around 1700 cm^{-1} due to the carbonyl (C=O) bond. On oxidation to benzoic acid, the carbonyl absorption band shifts to give a strong, sharp band around 1690 cm^{-1}. Also, a broad, strong absorption band in the region 2500–3300 cm^{-1} appears due to the O–H bond in the carboxylic acid.

2 Aldehydes like 2-methylundecanal have a hydrogen atom attached to a carbonyl carbon, which makes them more easily oxidised. In the first propagation step of the radical chain mechanism for aldehyde autoxidation, a hydrogen atom is selectively abstracted from the carbonyl group, as this is a particularly weak C–H bond. For a ketone, like 2-undecanone, abstraction of this type of hydrogen is not possible (and the C–H bonds in the ketone are stronger bonds).

3 Antioxidants (like vitamin E) prevent rancidity caused by autoxidation, extending the shelf life of oils and fats. During autoxidation reactive radicals are formed, such as RC(=O)•, and vitamin E donates a hydrogen atom to the radicals, which stops the radical chain mechanism.

4 Copper(II) ions in aqueous solution absorb light in the red region of the spectrum. Copper(II) ions have partially filled d-orbitals and when they form complexes the d-orbitals are split into different energy levels. The energy difference between the split d-orbitals corresponds to absorption of light from the red region of the spectrum – absorption of this light causes the d electrons of copper(II) to move from their ground state (lower energy) to an excited state (higher energy). The light that passes through the solution and out the other side will have all the colours in it except for red. We see this mixture of wavelengths as blue.

Fascinating phosphorus (pp. 29–33)

1 $P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$

2 Phosphorus trichloride (PCl_3) has a trigonal pyramidal (or pyramidal shape) due to the phosphorus atom having three bonding pairs with chlorine, and one lone pair of electrons.

3 $C_2H_5OH + PCl_5 \rightarrow C_2H_5Cl + POCl_3 + HCl$

4 $H_3PO_4\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + H_2PO_4^-\ (aq)$

$H_2PO_4^-\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + HPO_4^{2-}\ (aq)$

$HPO_4^{2-}\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + PO_4^{3-}\ (aq)$

5 $pK_a = -\log_{10}(K_a) = -\log_{10}(7.1 \times 10^{-3}) = 2.15$

Using the Henderson-Hasselbalch equation:

$pH = pK_a + \log_{10}([NaH_2PO_4] / [H_3PO_4])$

So, $pH = 2.15 + \log_{10}(0.15 / 0.10) = 2.15 + 0.18 = 2.33$ (at 298 K)

6 Phosphorus is vital for plant growth, particularly for root development and energy transfer (ATP). However, excessive use of phosphate fertilisers leads to eutrophication – where runoff causes algal blooms in water bodies, reducing oxygen levels and harming aquatic life.