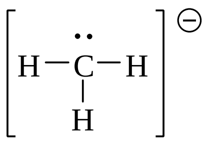
Marks

- Complete the following table. Give, as required, the formula, the systematic name, the oxidation number of the underlined atom and, where indicated, the number of *d* electrons for the element in this oxidation state. **5**

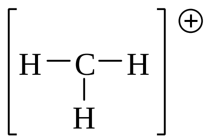
Formula	Systematic name	Oxidation number	Number of *d* electrons
$\underline{C}O_2$	**carbon dioxide**	**+IV or +4**	**0**
$Na_2\underline{Cr}O_4$	**sodium dichromate**	**+VI or +6**	**0**
$\underline{Fe}Cl_3{\cdot}3H_2O$	**iron(III) chloride-3-water**	**+III or +3**	**5**
	potassium sulfate		

- Draw the Lewis structures, showing all valence electrons for the following species. **3**

CH_3^-



CH_3^+



Indicate which of these species you expect will be more stable and explain why.

CH_3^- is more stable as it has a full octet of electrons

- Desferal is a siderophore-based drug that is used in humans to treat iron-overload. One molecule of Desferal (molecular formula: $C_{25}H_{48}O_8N_6$) can bind one Fe^{3+} ion. A patient with an iron-overload disease had an excess of 5.34×10^{-4} M Fe^{3+} in her bloodstream. Assuming the patient had a total blood volume of 4.84 L, what mass of Desferal would be required to complex all of the excess Fe^{3+}? **2**

As one mole of Deferal will complex one mole of Fe^{3+}, the number of moles of Desferal required is:

number of moles = concentration × volume = $(5.34\times10^{-4}) \times 4.84 = 2.58\times10^{-3}$ M

The molar mass of $C_{25}H_{48}O_8N_6$ is:

(25 × 12.01 (C)) + (48 × 1.008 (H)) + (8 × 16.00 (O)) + (6 × 14.01 (N)) = 560.694

Hence, the mass required is:

mass = number of moles × molar mass = $(2.58 \times 10^{-3}) \times (560.694)$ = 1.45 g

Answer: **1.45 g**

Marks
5

- Glycine, NH_2CH_2COOH, the simplest of all naturally occurring amino acids, has a melting point of 292 °C. The pK_a of the acid group is 2.35 and the pK_a associated with the amino group is 9.78. Draw a structure that indicates the charges on the molecule at the physiological pH of 7.4.

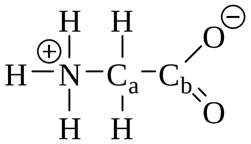
As pH = 7.4 is higher than the pK$_a$ of the acid group, -COOH, it will exist primarily in its deprotonated, conjugate base form, -COO$^-$.

As pH = 7.4 is lower than the pK$_a$ of the amino group, -NH$_2$, it will exist primarility in its protonated form, -NH$_3^+$.

Glycine will exist in the uncharged, zwitterionic form: $H_3\overset{\oplus}{N}-CH_2-COO^{\ominus}$

Describe the hybridisation of the two carbon atoms and the nitrogen atom in glycine and the geometry of the atoms surrounding these three atoms.

The structure is:



N has 4 bonds and no lone pairs: sp^3 with a tetrahedral arrangement.

C$_a$ has 4 bonds and no lone pairs: sp^3 with a tetrahedral arrangement.

C$_b$ has 3 bonds and no lone pairs: sp^2 with a trigonal planar arrangement.

Glycine has an unusually high melting point for a small molecule. Suggest a reason for this.

Glycine with a positively and a negatively charged end. There is therefore ionic bonding between the molecules leading to strong intermolecular forces.

2

- Many gases are available for use in compressed gas cylinders, in which they are stored at high pressures. Calculate the mass of oxygen gas that can be stored at 20 °C and 170 atm pressure in a cylinder with a volume of 60.0 L.

Using the ideal gas law, PV = nRT, the number of moles that can be stored is:

$$\mathbf{n = \frac{PV}{RT} = \frac{(170)\times(60.0)}{(0.08206)\times(20+273)} = 424\,mol}$$

As the molar mass of O$_2$ is (2 × 16.00) = 32.00, this corresponds to a mass of:

mass = number of moles × molar mass = 424 × 32.00 = 13600 g = 13.6 kg

Answer: **13.6 kg**

Marks 6

- If 20.0 mL of a 0.100 M solution of sodium phosphate is mixed with 25.0 mL of a 0.200 M solution of zinc chloride, what mass of zinc phosphate will precipitate from the reaction?

25.0 mL of a 0.200 M solution of $ZnCl_2$ contains:

$$n(Zn^{2+}(aq)) = \text{concentration} \times \text{volume} = 0.200 \times \frac{25}{1000} = 0.00500 \text{ mol}$$

20.0 mL of a 0.100 solution of Na_3PO_4 contains:

$$n(PO_4^{3-}) = 0.100 \times \frac{20}{1000} = 0.00200 \text{ mol}$$

The ionic equation for the precipitation reaction is:

$$3Zn^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Zn_3(PO_4)_2(s)$$

As $n(Zn^{2+}(aq) > \frac{3}{2} \times n(PO_4^{3-}(aq))$, PO_4^{3-} which is the limiting reagent. The maximum amount of product depends on $n(PO_4^{3-})$. The amount of zinc phosphate formed is:

$$n(Zn_3(PO_4)_2(s) = \tfrac{1}{2} \times n(PO_4^{3-}(aq)) = \tfrac{1}{2} \times 0.00200 = 0.00100 \text{ mol}$$

The formula mass of zinc phosphate is:

$$(3 \times 65.39 \text{ (Zn)}) + 2 \times (30.97 \text{ (P)} + 4 \times 16.00 \text{ (O)}) = 386.11$$

The mass of this amount of zinc phosphate is therefore:

$$\text{mass} = \text{number of moles} \times \text{formula mass} = 0.00100 \times 386.11 = 0.386 \text{ g}$$

Answer: **0.386 g**

ANSWER CONTINUES ON THE NEXT PAGE

What is the final concentration of zinc ions in solution after the above reaction?

The number of moles of $Zn^{2+}(aq)$ removed by precipitation = 3 × 0.00100 = 0.00300 mol. The amount remaining is therefore:

$$n(Zn^{2+}(aq)) = 0.00500 - 0.00300 = 0.00200 \text{ mol}$$

The total volume of the solution after mixing is (20.0 + 25.0) = 45.0 mL so the concentration is:

$$[Zn^{2+}(aq)] = \frac{\text{number of moles}}{\text{volume}} = \frac{0.00200}{(45/1000)} = 0.0444\,\text{M}$$

Answer: **0.0444 M**

What is the final concentration of sodium ions in solution after the above reaction?

20.0 mL of a 0.100 solution of Na_3PO_4 contains:

$$n(Na^{+}) = 3 \times 0.100 \times \frac{20}{1000} = 0.00600 \text{ mol}$$

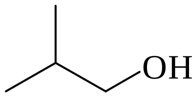
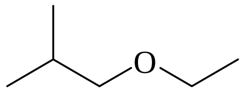
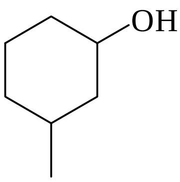
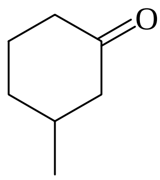
After mixing, this amount is contained in a volume of 45.0 mL so the concentration is:

$$[Na^{+}(aq)] = \frac{\text{number of moles}}{\text{volume}} = \frac{0.00600}{(45/1000)} = 0.133\,\text{M}$$

Answer: **0.133 M**

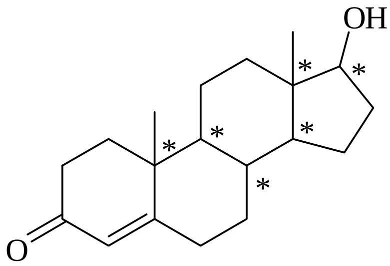
- Complete the following table. Make sure you complete the name of the starting material or major product where indicated.

Marks 11

STARTING MATERIAL	REAGENTS/ CONDITIONS	CONSTITUTIONAL FORMULA(S) OF MAJOR ORGANIC PRODUCT(S)
CH_3CH_2CHO	**1. $NaBH_4$** **2. H^+ / H_2O**	$CH_3CH_2CH_2OH$
$CH_3CH{=}CHCH_3$	**dilute H_2SO_4 / heat**	$CH_3CH_2CH(OH)CH_3$ **Name: 2-butanol**
	1. Na metal 2. CH_3CH_2Br	
	**$Cr_2O_7^{2-}$ / H^+**	 **Name: 3-methylcyclohexanone**
$CH_3-C(=O)-OCH_2CH_2CH_3$ **Name: propyl acetate**	3 M NaOH / heat	$CH_3CO_2^-$ + $CH_3CH_2CH_2OH$
$CH_3-C(=O)-O-C(=O)-CH_3$	excess $CH_3CH_2NH_2$	$CH_3CO_2^-$ + $H_3C-C(=O)-NH-CH_2CH_3$

Marks
8

The structure of testosterone, an important male hormone, is shown below.



testosterone

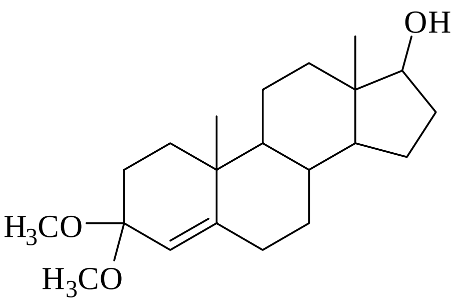
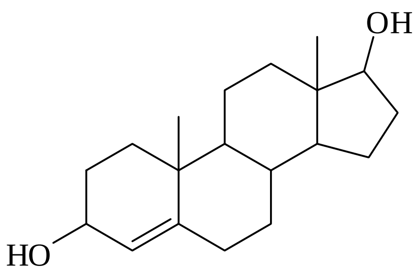
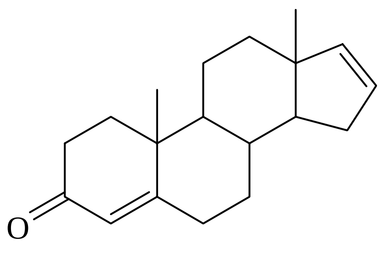
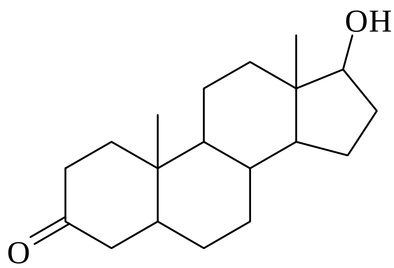
Give the molecular formula of testosterone. **$C_{19}H_{28}O_2$**

Identify the functional groups present in testosterone.

conjugated ketone, alkene, alcohol (secondary)

How many stereogenic (chiral) centres are there in testosterone? **6 (marked above)**

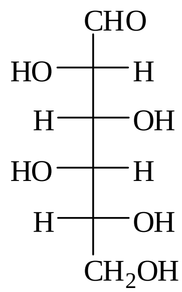
Draw the constitutional formula of the product formed when testosterone is treated with the following reagents.

excess methanol / HCl	$LiAlH_4$ in dry ether; then $H^{\oplus}$ / H_2O
	
concentrated H_2SO_4 / heat	H_2 / Pd catalyst
	

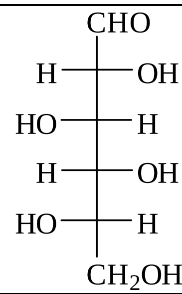
Marks 9

- The stucture of D-idose is shown below. Draw the Fischer projection of L-idose in the space provided.

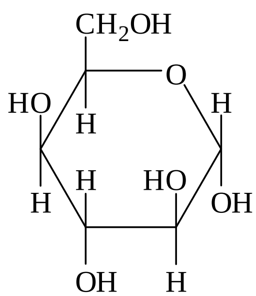
D-idose

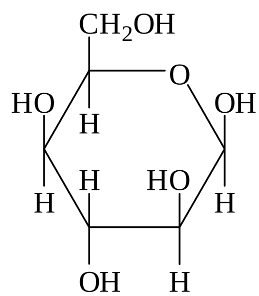


L-idose

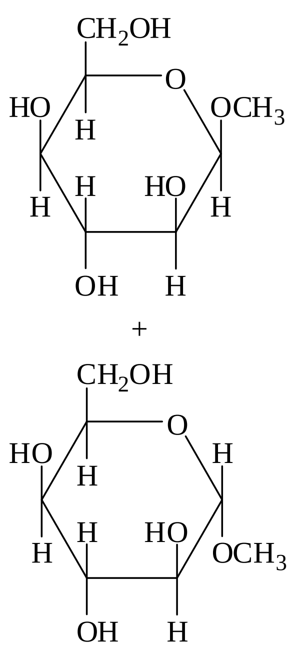
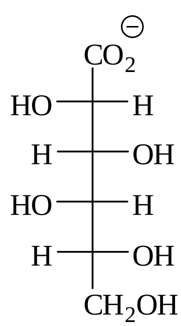
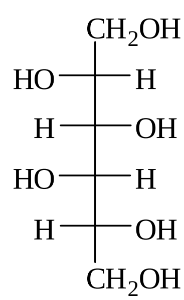


D-Idose is in equilibrium with two cyclic pyranose forms. Give the Haworth projection of these two cyclic forms.



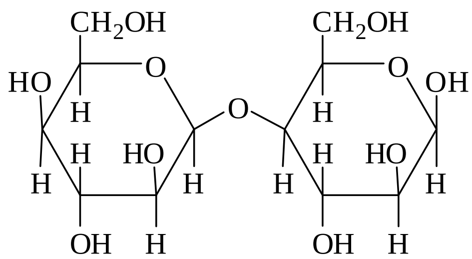


Give the products obtained when D-idose is treated with the following reagents.

methanol / $H^{\oplus}$	$[Ag(NH_3)_2]^{\oplus}/OH^{\ominus}$ solution	1. $NaBH_4$ 2. dilute acid
		

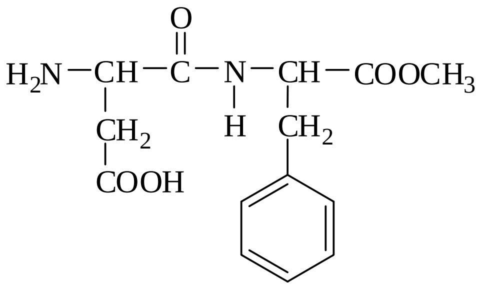
ANSWER CONTINUES ON THE NEXT PAGE

Draw the Haworth structure of a reducing disaccharide, which, on acid hydrolysis, yields D-idose as the only product.

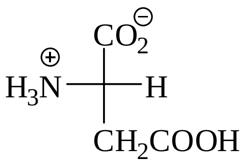
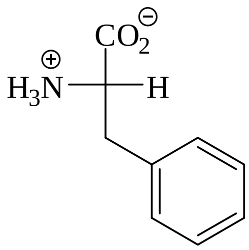


Marks
9

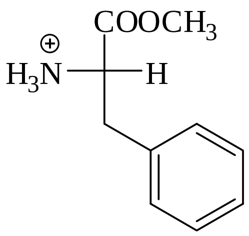
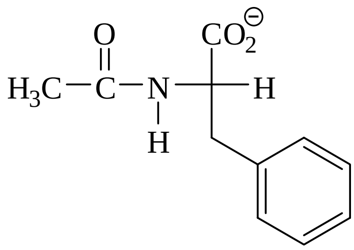
- The constitutional formula of aspartame, a non-nutritive artificial sweetener, is shown below.



Hydrolysis of aspartame yields the *N*-terminal amino acid, aspartic acid (Asp) and the *C*-terminal amino acid, phenylalanine (Phe), together with methanol. Give the structures of the amino acids, Asp and Phe, as the zwitterions.

Asp	Phe
	

Give the products when phenylalanine is treated with the following reagents.

excess methanol / HCl	$(CH_3CO)_2O$ / dilute NaOH
	

Give the constitutional formula of the dipeptide Phe-Asp at the following pH values.

pH 1.0	pH 12.0