Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 Which one of the following statements about 20.3 g of $Co_2(SO_4)_3$ is **incorrect**?

[Molar mass = 406 g mol^{-1}, Avogadro's constant = 6.0 x 10^{23} mol^{-1}]

A It contains 0.10 mol of Co^{3+} ions.

B It contains 0.15 mol of SO_4^{2-} ions.

C It contains 47.3% of oxygen by mass.

D It contains 1.5 x 10^{23} atoms.

2 In theory, 3 mol of $NH_3OH^+(aq)$ is required to convert 1 mol of $BrO_3^-(aq)$ to $Br^-(aq)$.

Which one of the following statements about this reaction is correct?

A NH_3OH^+ is acting as an oxidising agent.

B The change in oxidation number of nitrogen is +4.

C N_2O is the nitrogen–containing product.

D The reaction is likely to have a high activation energy.

3 Which one of the following is a possible configuration of a stable $\mathbf{M}^{3+}$ ion in the ground state?

A $1s^2\ 2s^2\ 2p^3$

B $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$

4 The pressure rating of a car tire is typically given to be 210 kPa. This is based on an internal air temperature of 25°C.

A driver decides to inflate the tires of his car to the rated pressure after driving at a high speed for some time, during which the internal air temperature has risen to 40°C.

What will be the drop in pressure in each tire when the temperature has returned to 25°C?

A 9.3 kPa **B** 10.1 kPa **C** 78.8 kPa **D** 200 kPa

5 $LiAlH_4$ and $NaBH_4$ are used as a source of hydride ions, H^-, in many organic reactions. Both chemical formulae consist of a metal cation and an anion made up of a group of atoms.

Solid $LiAlH_4$ decomposes upon heating to 150 °C while solid $NaBH_4$ melts at a temperature of 400 °C.

Which one of the following statements about $LiAlH_4$ and $NaBH_4$ is correct?

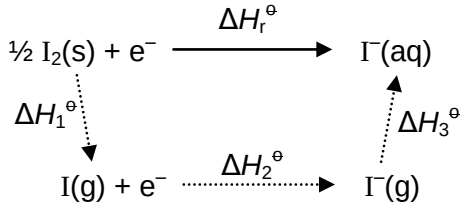
A The H^- from $LiAlH_4$ is more available for donation due to the higher polarity of the Al–H bond compared to B–H bond in $NaBH_4$.

B The release of H^- from $LiAlH_4$ and $NaBH_4$ involves homolytic fission of a covalent bond.

C The lower stability of $LiAlH_4$ to heat can be explained by the higher charge density of the cation and anion present compared to $NaBH_4$.

D The presence of a distinct melting point for $NaBH_4$ means that the covalent bonds in the anions are weaker than the ionic bonds between the cations and anions.

6 The enthalpy change of the following half equation ($\Delta H_r^{\ominus}$) is determined using Hess's Law:



Which one of the following shows the correct signs for the different enthalpy changes?

	$\Delta H_1^{\ominus}$	$\Delta H_2^{\ominus}$	$\Delta H_3^{\ominus}$
A	+	+	–
B	+	–	–
C	+	–	+
D	–	+	+

7 Hydrogen peroxide is thermodynamically unstable and decomposes over time to form water and oxygen gas.

$$H_2O_2(l) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

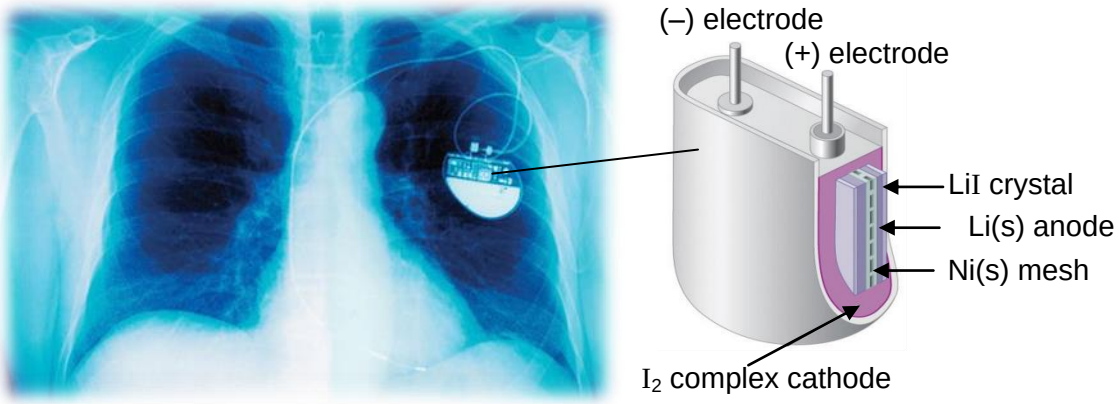
The following data are provided:

- $O_2(g) + 2H_2(g) \rightarrow 2H_2O(l)$ $\quad \Delta H_1^{\ominus} = -572$ kJ mol^{-1}; $\Delta S_1^{\ominus} = -325$ J mol^{-1} K^{-1}
- $O_2(g) + H_2(g) \rightarrow H_2O_2(l)$ $\quad \Delta H_2^{\ominus} = -188$ kJ mol^{-1}; $\Delta S_2^{\ominus} = -225$ J mol^{-1} K^{-1}

What is the value of $\Delta G^{\ominus}$, in kJ mol^{-1}, for the decomposition of hydrogen peroxide?

A –117 **B** –354 **C** –359 **D** –596

8 Artificial pacemakers are used to regulate the heartbeat of cardiac patients. The device is powered by a water–free lithium iodide battery as shown below.



Adapted from UC Davis ChemWiki

Which one of the following statements about the lithium iodide battery is correct?

A The I_2 complex cathode carries a negative charge.

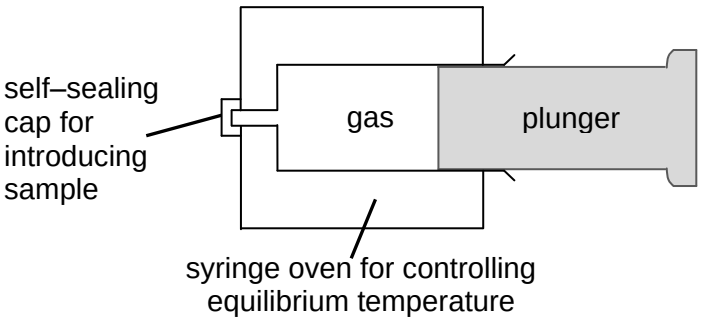
B The cell potential of the lithium iodide battery has a value of +3.58 V at the conditions prevailing in the battery.

C The Ni mesh provides a medium for electrons to flow from Li(s) to I_2 complex.

D The pacemaker will be able to last for more than 5 years if it contains 6 g of reactive Li(s) and operates at an average of 0.8 mA.

9 A gaseous dimer, **X**, is introduced into an empty gas syringe which has a movable, tightly–fitting plunger. The gas is allowed to expand until equilibrium is reached at a controlled temperature at which 20 % of **X** dissociates into its monomer **W**.

$$\mathbf{X}(g) \rightleftharpoons 2\mathbf{W}(g)$$



Which one of the following statements is correct?

A The pressure inside the syringe at equilibrium will be higher than the atmospheric pressure.

B The forward reaction is exothermic.

C The value of the equilibrium constant, K_p is 0.167 atm

D The dissociation of dimer **X** will be favoured when the plunger is pushed back into the equilibrium mixture.

10 The table below gives the concentration and pH values of the aqueous solutions of two compounds **S** and **T**. Either compound could be a monoprotic acid or base.

	S	**T**
concentration	2 mol dm^{-3}	2 mol dm^{-3}
pH	2	11

Student **P** concluded that **S**(aq) is a strong acid.

Student **Q** concluded that the extent of dissociation is lower in **S**(aq) than in **T**(aq).

Student **R** concluded that no suitable indicator exists for the titration of **S**(aq) and **T**(aq).

Which of the students are correct?

A **P** and **Q** only

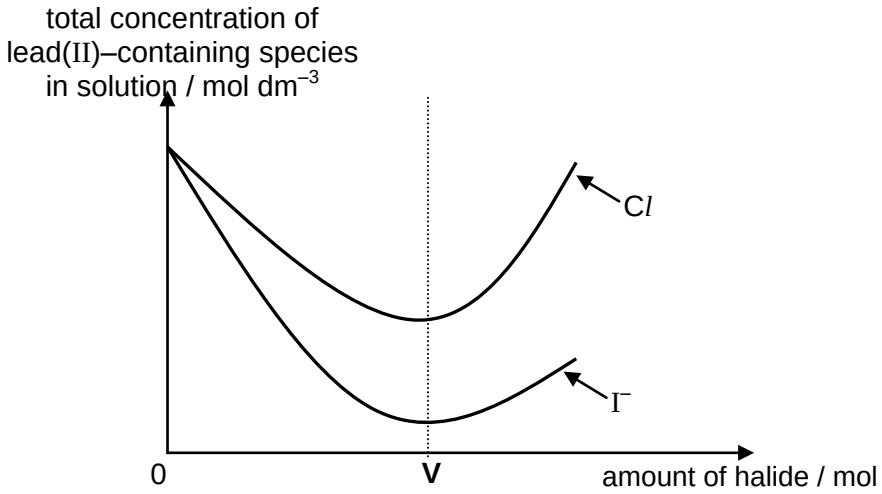
B **Q** and **R** only

C **R** only

D none of the students

11 The reaction between Pb^{2+}(aq) and different halides is investigated.

When solid NaC*l* or NaI is added in increasing amounts to a solution of Pb^{2+}(aq) in separate experiments, the following graphs are obtained.



Which one of the following deductions is correct?

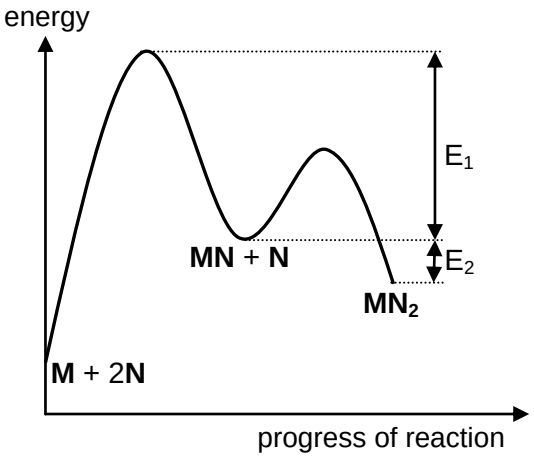
A The increase in both graphs after **V** cm^3 is due to common ion effect.

B The concentration of Pb^{2+}(aq) for both graphs is at its minimum at **V** cm^3.

C The ionic product is higher than the solubility product for both salts between 0 and **V** cm^3.

D The precipitate that will be formed first if Pb^{2+}(aq) is added to a solution containing equal amounts of Cl^-(aq) and I^-(aq) is lead(II) chloride.

12 The energy profile of the reaction between **M** and **N** is shown below.



Which one of the following is a correct statement?

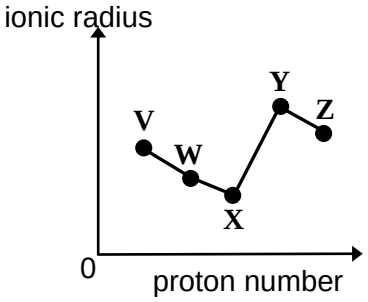
A The rate equation for the forward reaction is rate = k[**M**][**N**]

B The activation energy for the reverse reaction is calculated by E_1.

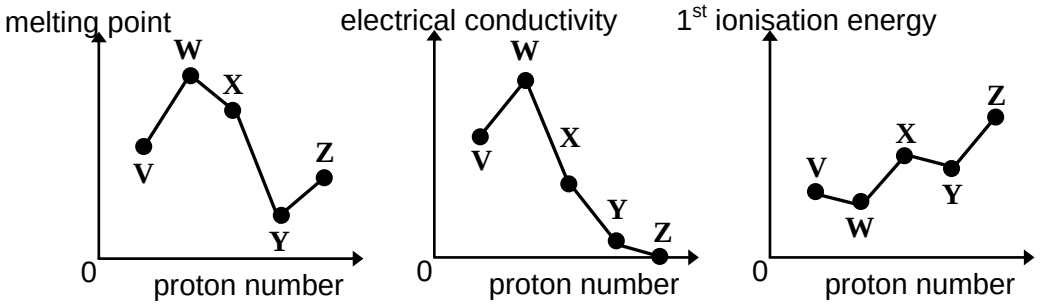
C The equilibrium concentrations of **M** and **N** decrease when temperature decreases.

D Only the rate of the forward reaction increases when temperature increases.

13 The graph below shows the ionic radius of five consecutive elements in the third period of the Periodic Table.



Three corresponding graphs of the same elements are provided below, each with a point that is wrongly represented.



Which of the following correctly identifies the error point in each of the graphs?

	melting point	electrical conductivity	1st ionisation energy
A	**X**	**X**	**W**
B	**X**	**Y**	**Y**
C	**Z**	**X**	**Y**
D	**Z**	**Y**	**W**

14 Which one of the following statements of Group II elements (magnesium to barium) is correct?

A The tendency to form complex ions decreases down the Group.

B The reactivity with cold water decreases down the Group.

C The acidity of an aqueous solution of the Group II chlorides increases.

D The minimum temperature required for the decomposition of the Group II nitrates decreases.

15 Which one of the following best explains why barium hydroxide has a higher solubility than magnesium hydroxide?

A The hydroxide ion is a very small anion.

B The charge density of barium ions is smaller than that of magnesium ions.

C The hydration of barium ions is more exothermic than that of magnesium ions.

D The lattice energy of barium hydroxide is less exothermic than that of magnesium hydroxide.

16 The Group VII element astatine, At_2, is radioactive with a short half-life.

Which one of the following statements is most likely to be correct for astatine or its compounds?

A At_2 reacts with $S_2O_3^{2-}$ to produce SO_4^{2-}.

B AgAt is soluble in concentrated aqueous NH_3.

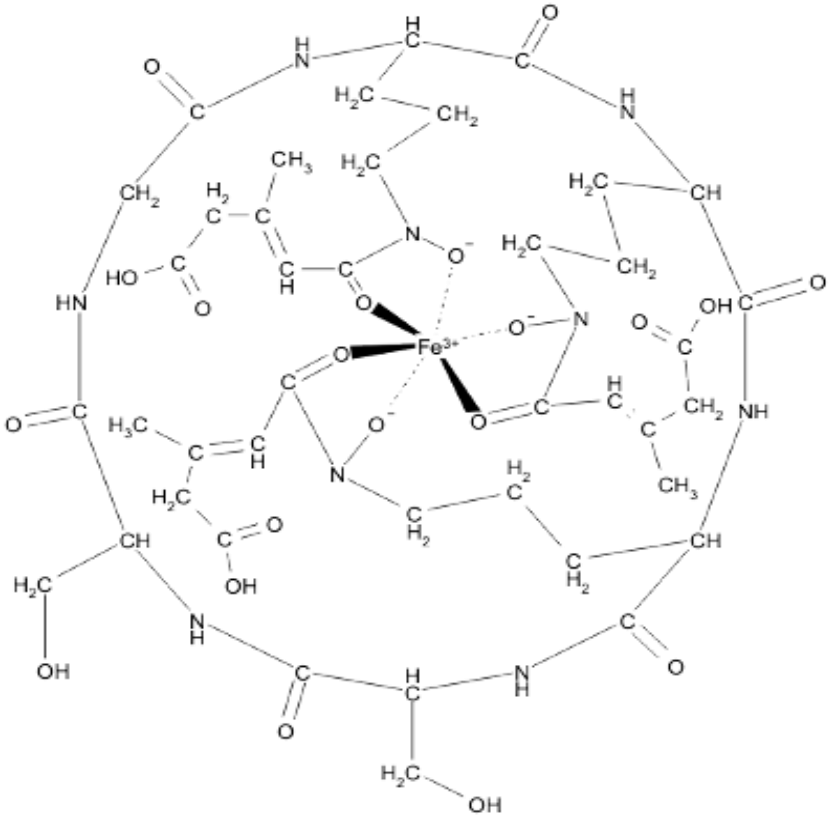
C KAtO can be obtained by bubbling At_2 into hot, aqueous KOH.

D HAt cannot be prepared by heating KAt with concentrated H_2SO_4.

17 Which set of data correctly illustrates copper as a typical transition element and calcium as an *s*-block element?

	property	**copper**	**calcium**
A	density /g cm^{-3}	8.92	1.54
B	electrical conductivity /relative units	9.6	85
C	melting point /°C	810	1083
D	metallic radius /nm	0.197	0.117

18 Living systems have difficulty assimilating iron because most iron compounds found in nature are not very soluble in water. Microorganisms have adapted to this problem by secreting an iron-binding compound called a siderophore that forms a water soluble complex with iron(III). One such complex is ferrichrome.



Ferrichrome

Which one of the following statements about ferrichrome is **not** correct?

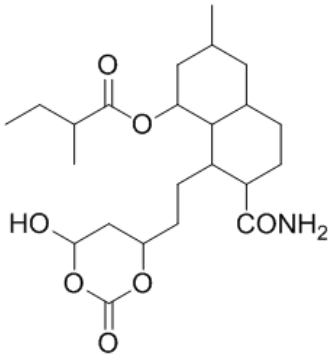
A The siderphore is a hexadentate ligand.

B Iron(III) ions only form ionic bonds in the ferrichrome.

C The electronic configuration of the central metal ion is [Ar] $3d^5$.

D The overall charge of ferrichrome is zero.

19 Compound **P**, a derivative of a cholesterol lowering drug, is shown below.

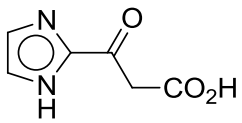


P

What is the correct number of chiral centres in **P** and the number of carbon-containing compounds produced in its reaction with hot H_2SO_4(aq)?

	number of chiral centres in **P**	number of carbon-containing compounds after reaction
A	8	3
B	8	6
C	9	3
D	9	6

20 The following compound is reacted with $NaBH_4$ in dry ethanol.



How many sp^2 and sp^3 hybridised carbon atoms does a molecule of the product contain?

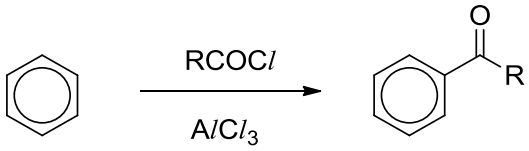
	sp^2	sp^3
A	0	6
B	2	4
C	3	3
D	4	2

21 A compound of molecular formula C_8H_{10} is allowed to irradiate with bromine under *uv* light to produce a mixture of monosubstituted products.

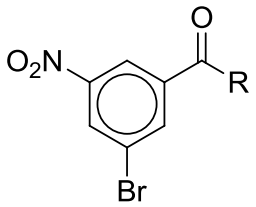
What is the total possible number of isomeric products, including stereoisomers, that can be obtained?

A 3 **B** 5 **C** 6 **D** 9

22 Aromatic compounds such as benzene can undergo Friedel Crafts *acylation* using an acyl chloride, RCOC*l* in the presence of a halogen carrier such as A*l*C*l*$_3$ as shown below.



To obtain compound **A**, the following three steps are required:



compound **A**

Step **1**: acylation
Step **2**: bromination
Step **3**: nitration

Which order of the above steps would give the best yield of compound **A**?

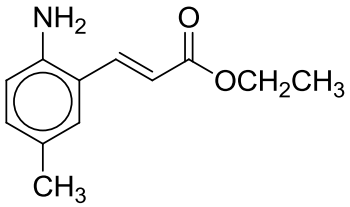
A **1** **2** **3**

B **1** **3** **2**

C **2** **1** **3**

D **2** **3** **1**

23 A student synthesised the following compound in the laboratory and wrote four statements about this compound.



Which one of the statements below is **incorrect**?

A On heating with acidified $K_2Cr_2O_7$(aq), the colour of the solution turns green.

B On warming with 2,4-dinitrophenylhydrazine, no orange crystals will be formed.

C On heating with alkaline aqueous iodine, a pale yellow precipitate will be formed.

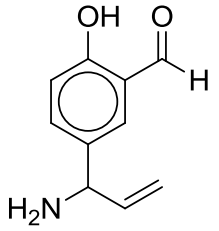
D On adding Br_2(aq), one molecule of the compound will incorporate one bromine atom in the major product.

24 An organic compound, $C_{10}H_{11}NO_2$ has the following physical and chemical properties:

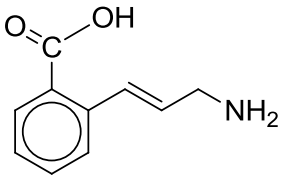
- It gives a brick red precipitate when warmed with Fehling's solution.
- It gives a purple colouration when warmed with neutral $FeCl_3$(aq).
- It is moderately soluble in water.

Which one of the following is a possible structure of this compound?

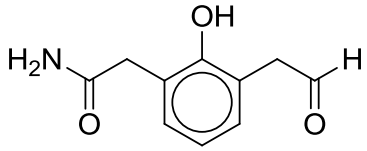
A



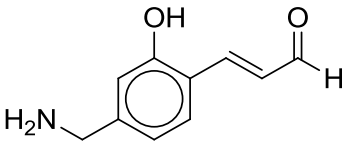
C



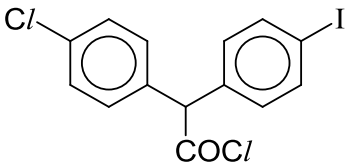
B



D



25 The following compound is derived from DDT, an insecticide.



The compound is boiled with NaOH(aq), cooled and the resultant solution is acidified with dilute HNO_3(aq). $AgNO_3$(aq) is then added to the mixture before concentrated NH_3(aq) is added dropwise, until present in excess.

Which observation is made when NH_3(aq) was added?

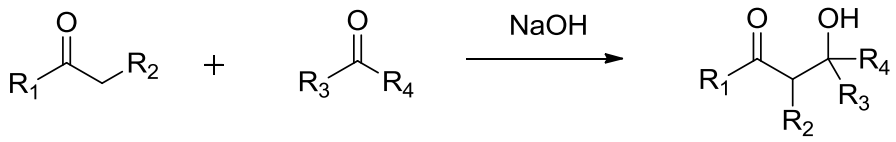
A All the precipitate remains.

B All the precipitate dissolves.

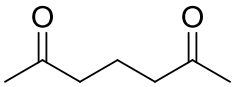
C The precipitate appears less yellow.

D The precipitate appears more yellow.

26 The aldol reaction between two carbonyl compounds involves the removal of a H^+ from a carbon atom adjacent to the carbonyl group by NaOH, and subsequent formation of the product. An example is shown below.

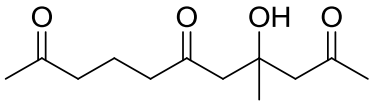


The following compound is a diketone.

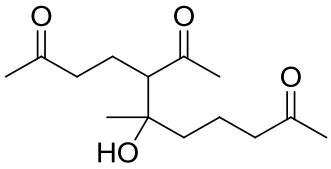


Which one of the following products **cannot** possibly be formed from the above diketone via the aldol reaction?

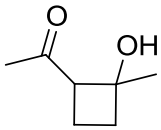
A



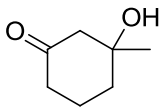
B



C



D



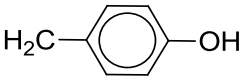
27 Below are four nitrogen-containing compounds, labelled **1** - **4**.

$CH_3CHCl NH_2$	$CH_3CH_2NH_2$	CH_3CONH_2	$C_6H_5NH_2$
1	**2**	**3**	**4**

Which one of the following gives the correct order of decreasing pK_b values of the above compounds?

A	**2**	**3**	**4**	**1**
B	**3**	**4**	**1**	**2**
C	**4**	**1**	**2**	**3**
D	**4**	**3**	**1**	**2**

28 1 mol of the tetrapeptide tyr-ser-gln-gly is boiled with NaOH(aq) until no further reaction occurs.

amino acid	R group
gln	$CH_2CH_2CONH_2$
gly	H
ser	CH_2OH
tyr	

How many moles of NaOH will react?

A 4 **B** 5 **C** 6 **D** 7

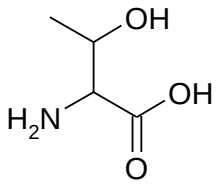
29 Peptide **P** contains seven amino acid residues. When **P** is partially hydrolysed, the following dipeptide and tripeptide fragments are produced.

gly-ala
ser-lys
ala-gly-ser
ala-met
lys-gly

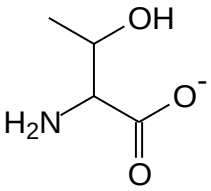
What could be the structure of peptide **P**?

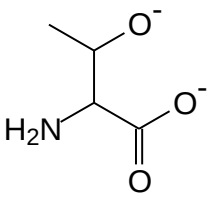
A gly-ser-lys-ala-met-gly-ala
B ala-met-gly-ala-gly-ser-lys
C ala-gly-ser-lys-gly-ala-met
D lys-gly-ala-met-ala-gly-ser

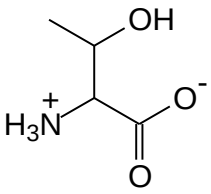
30 The amino acid threonine has the following structure:

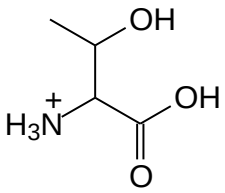


In alkaline solution, it exists as

A


B


C


D


Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** **only** are correct	**1** only is correct

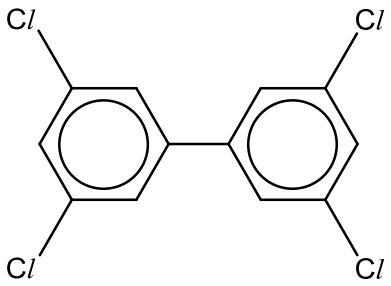
No other combination of statements is used as a correct response.

31 **Z** is an organic compound containing only carbon, hydrogen and chlorine.

When a given sample of **Z** is burnt completely in air, 2.75 g of CO_2 and 0.281 g of H_2O are produced.

Which of the following are possible structures of **Z**?

1



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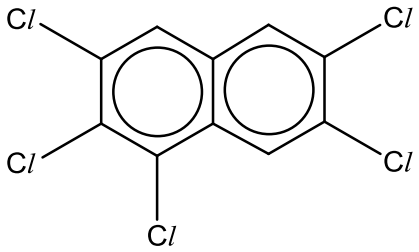

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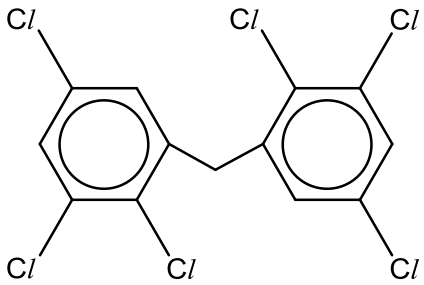


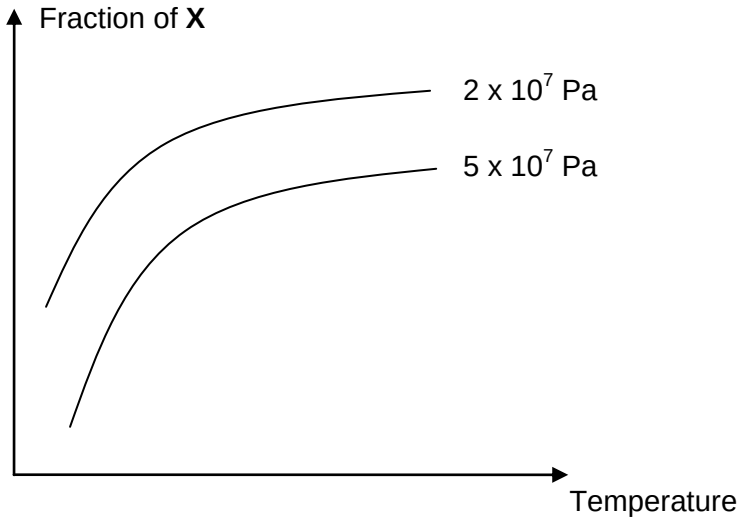
32 In which of the following pairs of compounds would the first compound have a higher melting point than the second compound?

1 Na_2O, K_2O

2 AlF_3, $AlCl_3$

3 $NH_2CH_2CO_2H$, $HOCH_2CO_2H$

33 The graph below shows how the fraction of a substance, **X**, produced in an equilibrium mixture varies with temperature at pressures of 2×10^7 Pa and 5×10^7 Pa respectively.



In which of the following equilibria would **X** represent the underlined species?

1 $C(s) + H_2O(g) \rightleftharpoons H_2(g) + \underline{CO}(g)$ $\Delta H = +131$ kJ mol^{-1}

2 $\underline{C_2F_4}(g) + 2HCl(g) \rightleftharpoons 2CHClF_2(g)$ $\Delta H = -128$ kJ mol^{-1}

3 $2N_2(g) + 6\underline{H_2O}(g) \rightleftharpoons 4NH_3(g) + 3O_2(g)$ $\Delta H = +1267$ kJ mol^{-1}

34 The Kolbe reaction involves decarboxylative dimerisation of carboxyate ions by electrolysis. When an aqueous solution of sodium carboxylate is electrolysed, the overall equation is as follows:

$$2\mathbf{R}CO_2Na + 2H_2O \rightarrow \mathbf{R}\text{–}\mathbf{R} + 2CO_2 + 2NaOH + H_2$$

where **R** = CH_3, C_2H_5 etc.

Which of the following statements about the anode and cathode are correct?

	anode	**cathode**
1	The solution around the anode turns moist blue litmus red.	The solution around the cathode turns moist red litmus blue.
2	**R**CO_2Na is oxidised to **R**–**R** at the (+) terminal.	H_2O is reduced to H_2 at the (–) terminal.
3	The redox potential involving H_2O is the least positive.	The redox potential involving H_2O is the most positive.

35 Which of the following **incorrectly** describes the reactivity of Period 3 elements?

1 P burns with a bright flame in air to form solid P_4O_6 only.

2 A*l* reacts rapidly in the presence of steam to give solid $Al(OH)_3$ and H_2 gas.

3 Si reacts in excess Cl_2 to give a chloride which gives a weakly acidic solution in water.

36 A manganese complex formed from a solution containing potassium bromide and oxalate ion, $C_2O_4^{2-}$, is purified and analysed. It is found to have an empirical formula of $MnK_4C_4Br_2O_8$. An aqueous solution of the complex has similar electrical conductivity as an equimolar solution of $K_4[Fe(CN)_6]$.

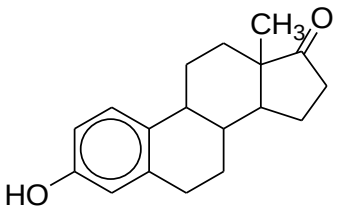
What can be deduced from the above information?

1 The complex is $Mn(C_2O_4)_2Br_2$.

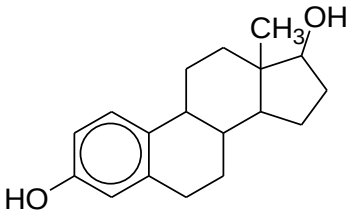
2 The manganese ion in the complex has a +2 charge.

3 The anionic portion of the complex has a coordination number of 6.

37 Two female sex hormones are oestrone and oestradiol.



oestrone



oestradiol

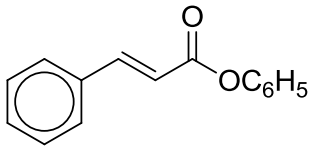
Which of the following reagents could be used to distinguish between the two hormones?

1 $SOCl_2$

2 $KMnO_4/H^+$

3 $LiAlH_4$ in dry ether

38 Compound **B** is related to methyl cinnamate, used as a flavouring agent.

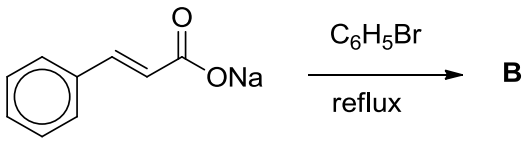


Compound **B**

A student suggested the following three methods to synthesise compound **B.**

Which of the following synthetic routes is **not** correct?

1



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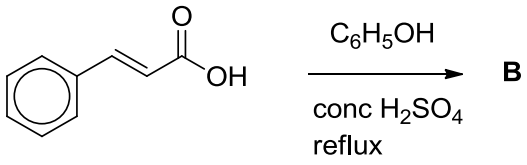

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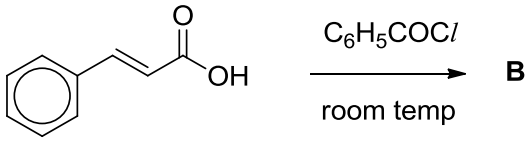
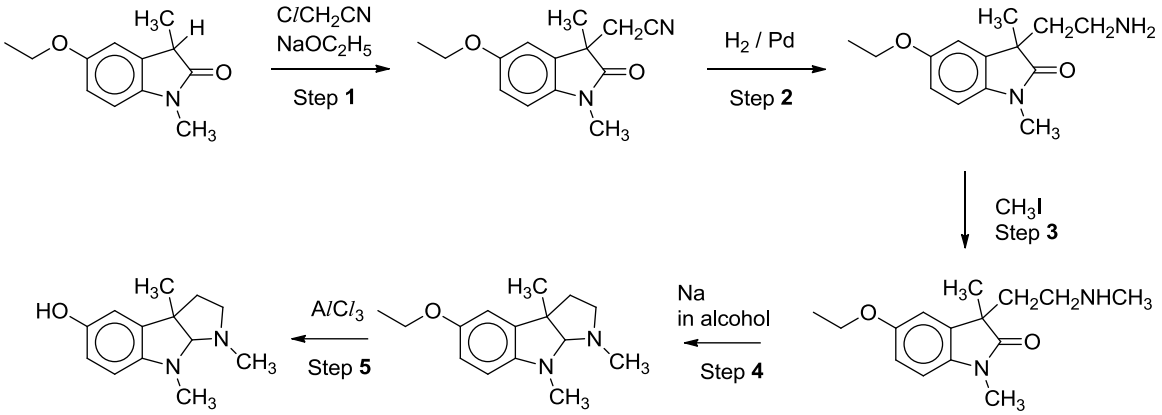


39 The synthesis of physostigmine, a reversible cholinesterase inhibitor that was found in Calabar beans, was first achieved in 1935. Part of the synthetic route is shown below.



Which type of reaction is shown by at least one step in the above route?

1 reduction

2 nucleophilic substitution

3 electrophilic substitution

40 What is a possible type of reaction that occurs when a protein undergoes denaturation?

1 neutralisation

2 precipitation

3 reduction