

RAFFLES INSTITUTION
2014 YEAR 6 PRELIMINARY EXAMINATION

HIGHER 2



CHEMISTRY

9647/01

Paper 1 Multiple Choice

26 September 2014

1 hour

Additional Materials: Multiple Choice Answer Sheet
 Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write in soft pencil.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Write your name, class and index number in the spaces provided on the Answer Sheet.

There are **forty** questions on this paper. Answer **all** questions.

For each question there are four possible answers **A**, **B**, **C** and **D**.

Choose the one you consider to be correct and record your choice with a soft pencil on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

This document consists of **20** printed pages.

Section A

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

- 1 Chromate(VI) ions can undergo condensation in the presence of acid to form dichromate(VI) ions via the following equation:



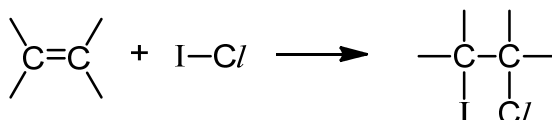
Further condensation can proceed in strong acidic solutions to form trichromates and tetrachromates.

Which pair shows the formulae of a trichromate and a tetrachromate ion?

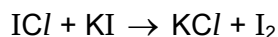
	trichromate	tetrachromate
A	$\text{Cr}_3\text{O}_{10}^{2-}$	$\text{Cr}_4\text{O}_{14}^{2-}$
B	$\text{Cr}_3\text{O}_{10}^{2-}$	$\text{Cr}_4\text{O}_{13}^{2-}$
C	$\text{Cr}_3\text{O}_{11}^{2-}$	$\text{Cr}_4\text{O}_{14}^{2-}$
D	$\text{Cr}_3\text{O}_{11}^{2-}$	$\text{Cr}_4\text{O}_{13}^{2-}$

- 2 The degree of unsaturation of an unknown fatty acid is usually determined by its iodine number, which is the mass of iodine atoms that add across all C=C bonds in 100 g of fatty acid in the following addition reaction.

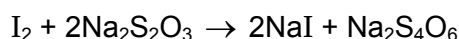
Iodine is introduced to the fatty acids in the form of ICl as ICl is more reactive than I_2 .



In one reaction, 1.72×10^{-3} mol of ICl (in excess) were added to 0.100 g of fatty acid, and the excess ICl is converted to I_2 as follows:



The I_2 produced was titrated against sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

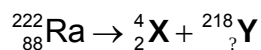


It was found that 1.39×10^{-3} mol of $\text{Na}_2\text{S}_2\text{O}_3$ were required for complete titration.

What is the iodine number of the unknown fatty acid?

- | | | | |
|----------|-----|----------|-----|
| A | 88 | B | 130 |
| C | 177 | D | 260 |

- 3 Which statement about the reactants and products of the radioactive decay reaction below is correct?



- A Y has fully filled 4f orbitals.
 B Y has more neutrons than Ra.
 C Y exists as a diatomic molecule.
 D The first ionisation energy of Y is greater than that of X.
- 4 The first six ionisation energies (in kJ mol^{-1}) of a Period 2 element, Z, are shown.

1090 2350 4610 6220 37831 47277

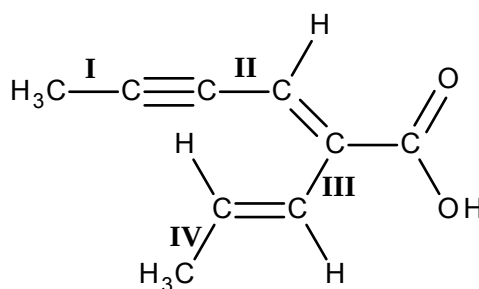
Which diagram represents the arrangement of electrons in the ion, Z^{2-} ?

	1s	2s	2p		
A	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow$	$\uparrow$	
B	$\uparrow\downarrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$
C	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow$	$\uparrow$
D	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$

- 5 Dinitrogen pentoxide, N_2O_5 , exists as covalent molecules, $\text{O}_2\text{N}-\text{O}-\text{NO}_2$ in the gas phase, but as the ionic $[\text{NO}_2^+\text{NO}_3^-]$ in the solid phase or in solution.

Which of the following statements is correct?

- A There are a total of 4 double bonds in N_2O_5 .
 B N_2O_5 is a non-polar molecule.
 C NO_3^- is isoelectronic with CO_3^{2-} .
 D NO_2^+ has a smaller bond angle than NO_3^- .
- 6 Which carbon-carbon bond (I, II, III or IV) in molecule X is the shortest?



molecule X

- A I B II C III D IV

- 7 A typical ping pong ball is made of an air-filled plastic and has a volume of 40.0 cm^3 .
At 27°C and 105.6 kPa , a slightly dented ping pong ball of volume 38.5 cm^3 is filled with air. To restore its spherical shape, the air inside the dented ball is heated to a constant temperature of 60°C . The pressure of air inside the ball increases and creates a uniform outward force.

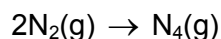
Assuming that the air inside the ping pong ball behaves ideally, what is the pressure of air inside the ball at 60°C when the shape is restored?

- | | | | |
|----------|---------|----------|---------|
| A | 113 kPa | B | 122 kPa |
| C | 226 kPa | D | 244 kPa |

- 8 *Use of the Data Booklet is relevant to this question.*
Nitrogen exists as a diatomic molecule, N_2 , and phosphorus as the molecule as shown.

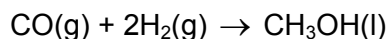


Imagine that nitrogen were to form a similar molecule, N_4 .



What would be the value of ΔH for the above reaction?

- | | | | |
|----------|-----------------------------|----------|-----------------------------|
| A | $+1028 \text{ kJ mol}^{-1}$ | B | $+1348 \text{ kJ mol}^{-1}$ |
| C | $+1954 \text{ kJ mol}^{-1}$ | D | $+2628 \text{ kJ mol}^{-1}$ |
- 9 The following reaction is thermodynamically feasible at low temperature.



What are the signs of ΔH_r and ΔS_r for the reaction?

- | | ΔH_r | ΔS_r |
|----------|--------------|--------------|
| A | – | – |
| B | + | – |
| C | – | + |
| D | + | + |

- 10 Quarter-life, $t_{1/4}$, of a radioactive isotope is defined as the time taken for the sample to decay to $\frac{1}{4}$ its original amount.

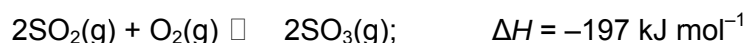
Potassium-argon dating is used to determine the age of a rock. ^{40}K is a radioactive isotope of potassium and it decays to ^{40}Ar with a constant $t_{1/4}$ of 2.50×10^9 years.

A sample of moon rock was found to contain 6.25% of the original amount of ^{40}K .

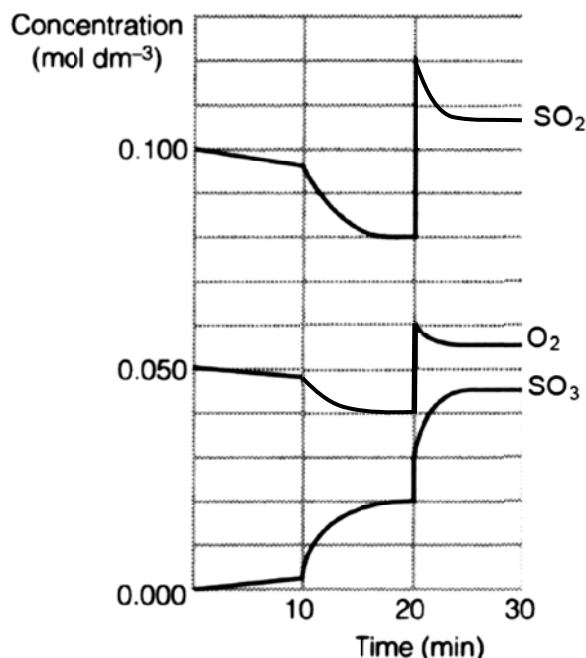
How old is the rock?

- | | | | |
|----------|--------------------------|----------|-----------------------------|
| A | 2.50×10^9 years | B | 5.00×10^9 years |
| C | 7.50×10^9 years | D | 1.00×10^{10} years |

- 11 During the Contact process, sulfur dioxide is converted to sulfur trioxide as shown by the equation below.



The graph below shows how the concentration of the three gases changed when a series of changes was made.



Which conclusion can be drawn from this information?

- A At 10 min, some sulfur dioxide gas was removed from the system.
 B At 20 min, the numerical value of the equilibrium constant, K_c , was 1.56.
 C At 20 min, the pressure of the system was decreased by increasing the volume.
 D The temperature of the mixture at 30 min was higher than that at 20 min.
- 12 A typical aspirin tablet contains 324 mg of acetylsalicylic acid ($M_r = 180$), a monobasic acid. When one aspirin tablet was dissolved in a glass containing 150 cm^3 of water at room temperature, the pH of the resulting solution is 2.72.

What is the approximate $\text{p}K_a$ of acetylsalicylic acid at this temperature?

- A 2.70 B 3.52 C 3.70 D 4.52
- 13 Manganese(II) hydroxide is sparingly soluble and the numerical value of its solubility product at 25°C is 1.90×10^{-13} .
- What is the minimum pH required to precipitate manganese(II) hydroxide from a manganese(II) sulfate solution such that the concentration of the manganese(II) ion in the solution is less than $1.80 \times 10^{-8} \text{ mol dm}^{-3}$?

- A 11.5 B 9.0 C 5.0 D 2.5

- 14 Use of the Data Booklet is relevant to this question.

The $E^\ominus_{\text{cell}}$ of a voltaic cell is found to be +0.19 V. One of the half-cells contains 1 mol dm⁻³ each of K₂S₂O₈(aq) and K₂SO₄(aq).

If both half-cells are under standard conditions, what is the identity of the species that will be used up in the other half-cell?

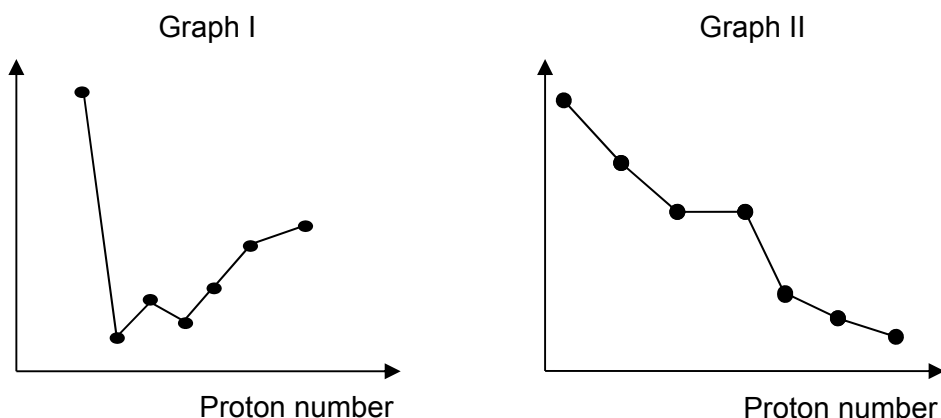
- A Co²⁺ B Fe²⁺ C Co³⁺ D Fe³⁺

- 15 During electrolysis under suitable conditions, 0.015 mol of manganese is deposited on the cathode when 0.090 mol of electrons is passed through a manganese-containing electrolyte.

Which of the following substances could have been the electrolyte?

- A MnCl₂ B MnF₃ C MnO₂ D K₂MnO₄

- 16 The graphs below show the variation of two properties of the Period 3 elements (Na to Cl) and their compounds.



Which properties are illustrated in Graphs I and II?

	Graph I	Graph II
A	first ionisation energy of the elements	pH of the oxides when added to water
B	first ionisation energy of the elements	pH of the chlorides when added to water
C	second ionisation energy of the elements	pH of the oxides when added to water
D	second ionisation energy of the elements	pH of the chlorides when added to water

- 17 Strontium lies between calcium and barium in Group II in the Periodic Table.

Which property could be predicted for strontium or its compounds?

- A Strontium sulfate is soluble in water.
- B Strontium is reduced by cold water, liberating hydrogen.
- C Strontium hydroxide decomposes to the oxide on heating.
- D Strontium nitrate(V) decomposes on heating to form strontium nitrate(III) and oxygen.

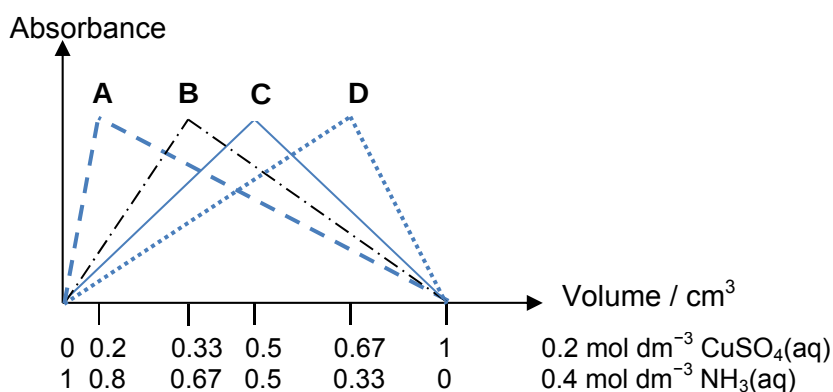
- 18 Cyanogen, $(\text{CN})_2$, is a toxic, colourless and pungent gas. It is called a pseudohalogen and its reactions resemble that of Cl_2 . The corresponding pseudohalide is the cyanide ion.

Which statement is most likely to be true for cyanogen and cyanide?

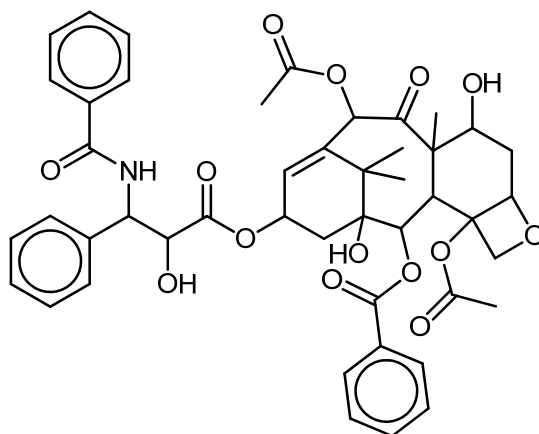
- A Sodium cyanide reacts with hot concentrated sulfuric acid to form cyanogen.
- B Silver cyanide is insoluble in excess concentrated aqueous ammonia.
- C Hydrogen cyanide is less stable to heat than hydrogen iodide.
- D Cyanogen disproportionates in aqueous sodium hydroxide.

- 19 Aqueous copper(II) sulfate forms a deep blue solution when aqueous ammonia is added. The colour intensity of the mixture can be analysed by measuring its absorbance using a colorimeter.

Which graph, **A**, **B**, **C** or **D**, correctly represents the absorbance against volume of solutions used when $0.2 \text{ mol dm}^{-3} \text{ CuSO}_4(\text{aq})$ is mixed with $0.4 \text{ mol dm}^{-3} \text{ NH}_3(\text{aq})$ in the given proportions?



- 20 Taxol can be used in cancer chemotherapy.

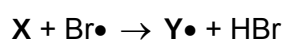


Taxol

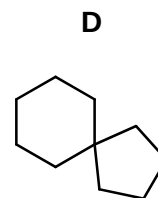
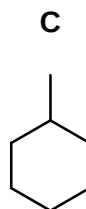
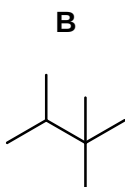
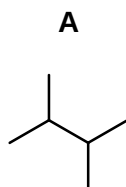
Which combination of the number of chiral centres and of amide and ester linkages does Taxol possess?

	number of chiral centres	number of amide linkages	number of ester linkages
A	10	0	3
B	10	1	4
C	11	0	3
D	11	1	4

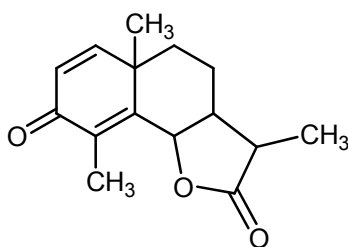
- 21 When heated with bromine, hydrocarbon **X** undergoes free radical substitution. In a propagation step, the free radical **Y•** is formed by the loss of one hydrogen atom.



What is the structure of hydrocarbon **X** if there are 3 possible theoretical forms of **Y•**?



- 22 Santonin is a drug that was once widely used to expel parasitic worms from the body.



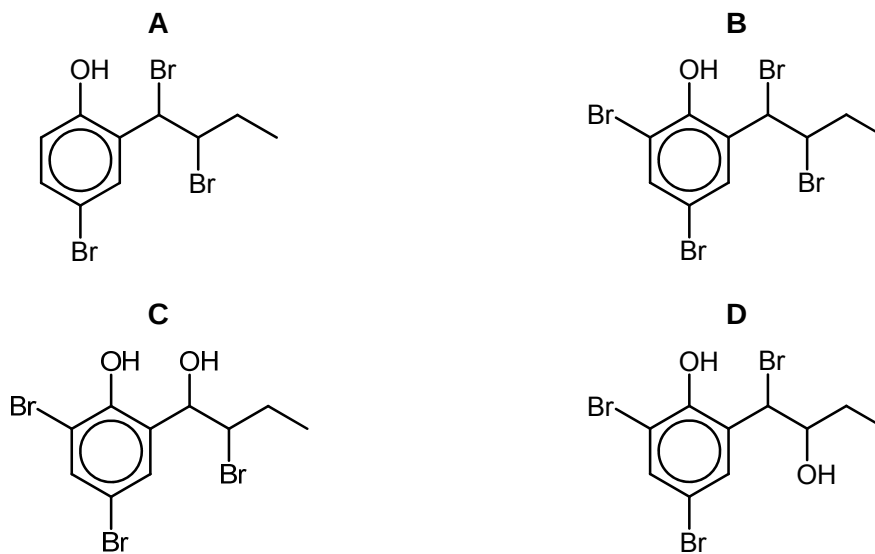
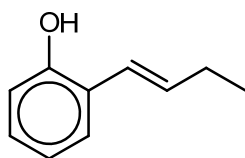
santonin

When santonin is first heated with dilute H_2SO_4 , and then the product of this reaction is treated with cold acidified KMnO_4 , a final product is obtained.

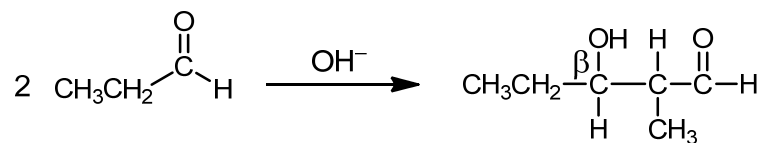
How many hydrogen atoms in each molecule of the final product can be displaced with sodium metal?

- A 6 B 5 C 4 D 2

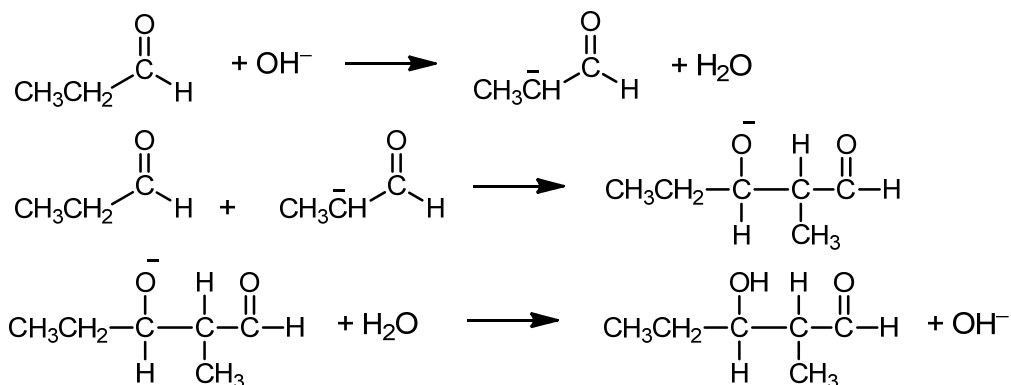
- 23 What is the major organic product formed when excess aqueous bromine is added to the following compound?



- 24 In the Aldol reaction, two molecules of an aldehyde or a ketone react with each other in the presence of a base to form a β -hydroxy carbonyl compound. For example, treatment of propanal, $\text{CH}_3\text{CH}_2\text{CHO}$, with NaOH(aq) forms 3-hydroxy-2-methylpentanal.



The mechanism of the Aldol reaction is shown below.



Which product could be formed when pentan-3-one is treated with NaOH(aq) ?

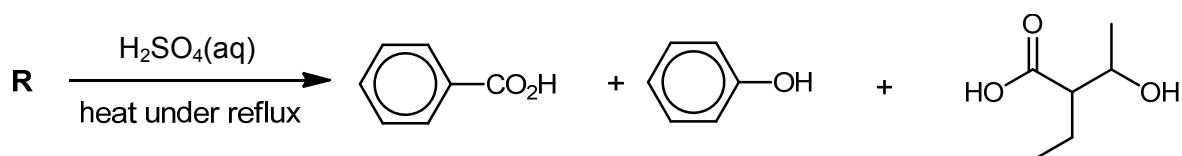
- A** $\text{CH}_3\text{C}(=\text{O})\text{CH}(\text{CH}_2\text{CH}_3)\text{CH}(\text{OH})(\text{CH}_3)\text{CH}_2\text{CH}_2\text{CH}_3$
- B** $\text{CH}_3\text{C}(=\text{O})\text{CH}(\text{CH}_2\text{CH}_3)\text{CH}(\text{OH})(\text{CH}_2\text{CH}_3)\text{CH}_2\text{CH}_3$
- C** $\text{CH}_3\text{CH}_2\text{C}(=\text{O})\text{CH}(\text{CH}_3)\text{CH}(\text{OH})(\text{CH}_2\text{CH}_3)\text{CH}_2\text{CH}_3$
- D** $\text{CH}_3\text{CH}_2\text{C}(=\text{O})\text{CH}(\text{CH}_3)\text{CH}(\text{OH})(\text{CH}_3)\text{CH}_2\text{CH}_2\text{CH}_3$

- 25 X is $\text{HOCH}_2\text{CH}(\text{OH})\text{CHO}$.
Y is $\text{HOCH}_2\text{COCH}_2\text{OH}$.

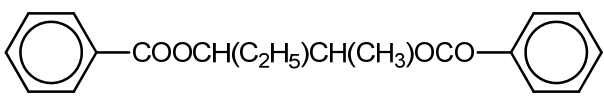
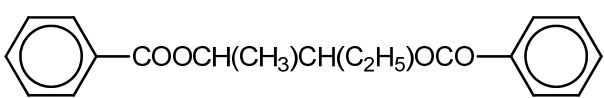
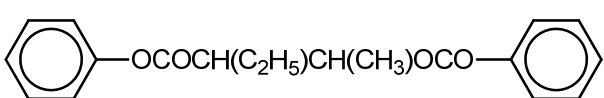
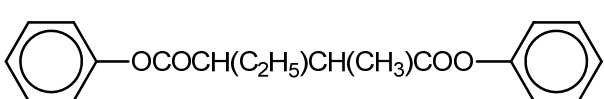
Which statement about X and Y is correct?

- A X can be directly oxidised to Y.
B X and Y have different empirical formulae.
C Both X and Y react with Fehling's solution.
D Both X and Y can be reduced to $\text{HOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{OH}$.

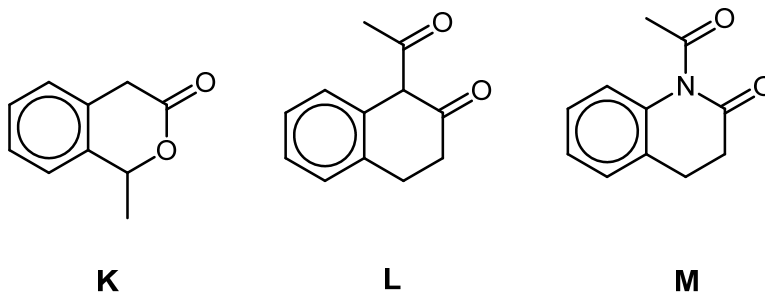
- 26 Diester R undergoes the following reaction.



What is the structure of diester R?

- A 
- B 
- C 
- D 

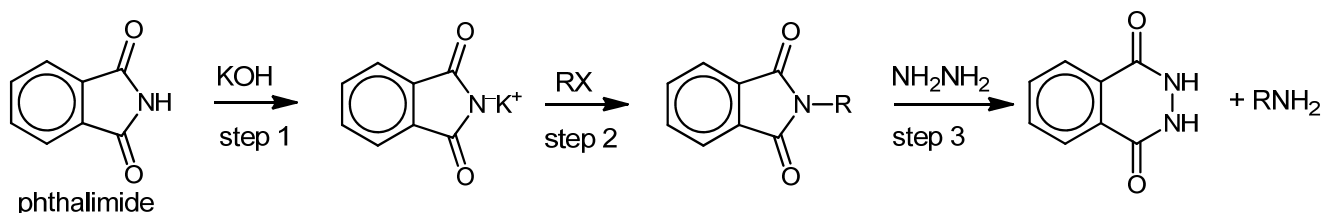
27 Compounds **K**, **L** and **M** have the following structures.



Which pair of statements about the properties of **K**, **L** and **M** is correct?

	gives an orange precipitate with 2,4-dinitrophenylhydrazine	gives a yellow precipitate with hot alkaline aqueous iodine
A	K, L and M	L only
B	L and M only	L and M only
C	L only	L only
D	L only	K and L only

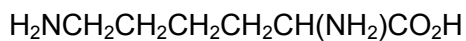
28 Phthalimides can be used to synthesise amines via the following pathway.



What types of reaction took place in steps 1, 2 and 3?

	step 1	step 2	step 3
A	nucleophilic substitution	reduction	nucleophilic substitution
B	nucleophilic substitution	nucleophilic substitution	reduction
C	acid-base reaction	nucleophilic substitution	reduction
D	acid-base reaction	nucleophilic substitution	nucleophilic substitution

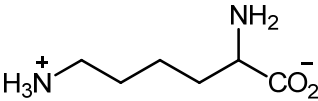
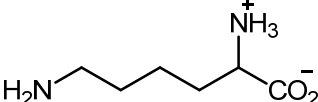
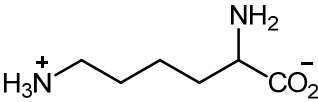
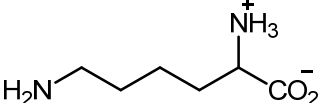
- 29 Lysine is an essential amino acid and it has the following structure.



Lysine has pK_a values of 2.18, 8.95 and 10.53.

The isoelectric point, pI , of an amino acid is the pH at which the amino acid exists predominantly as zwitterions with no net charge.

What is the pI of lysine and its predominant species present at pI ?

	pI	predominant species at pI
A	5.57	
B	5.57	
C	9.74	
D	9.74	

- 30** Cyclic peptides are polypeptides in which the amino termini and carboxyl termini are joined by a covalent bond to form a ring structure.

A cyclic peptide consisting of 8 amino acid residues undergoes partial hydrolysis to yield the following peptides:

pro-leu

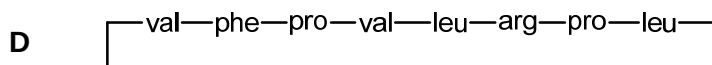
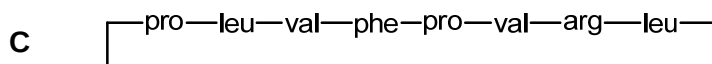
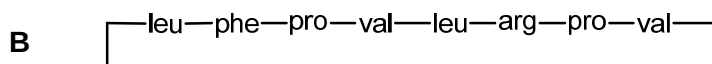
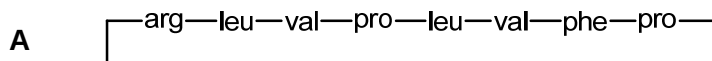
leu-val

leu-arg-pro

val-phe-pro

pro-val-leu

What could be a possible structure of the cyclic peptide?



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 The following tests were carried out on separate fresh samples of $\text{CrCl}_3(\text{aq})$.

Which statements give the correct observation with the corresponding test?

- 1** When $\text{NaOH}(\text{aq})$ is added, a grey-green precipitate is obtained and the precipitate dissolves in excess $\text{NaOH}(\text{aq})$ to form a dark green solution.
- 2** When $\text{NaOH}(\text{aq})$ is added in excess, followed by the addition of $\text{H}_2\text{O}_2(\text{aq})$ with heating, the end product is a yellow solution.
- 3** When $\text{Na}_2\text{CO}_3(\text{s})$ is added, a colourless gas is evolved and the gas forms a white precipitate in $\text{Ca}(\text{OH})_2(\text{aq})$.

32 Which statements do **not** explain why iodine, I_2 , exists as a solid, while water, H_2O , exists as a liquid at r.t.p.?

- 1** In the lattice structure of ice, each water molecule is hydrogen bonded to four other water molecules.
- 2** Iodine is non-polar while water is polar.
- 3** Iodine molecules have a large electron cloud.

33 Which statements about the Group IV elements, carbon, silicon and lead, and their compounds are correct?

- 1** Silicon exhibits more oxidation states than carbon.
- 2** Lead(IV) oxide has a higher melting point than carbon dioxide.
- 3** Silicon tetrachloride reacts with water, but carbon tetrachloride does not.

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.

- 34** The table describes some of the chemistry and the thermodynamic properties of Group II elements.

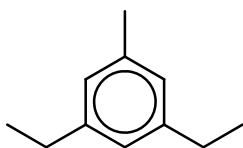
process	name and symbol of quantity
$M(OH)_2(s) + aq \rightarrow M(OH)_2(aq)$ $MCO_3(s) \rightarrow MO(s) + CO_2(g)$ $M^{2+}(aq) + 2e^- \rightleftharpoons M(s)$	enthalpy change of solution, $\Delta H^\ominus_{soln}$ Gibbs free energy change of decomposition, $\Delta G^\ominus$ electrode reduction potential, $E^\ominus$

Which statements about the relative values of these quantities are correct?

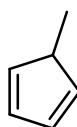
- 1** $\Delta H^\ominus_{soln}$ for $Ba(OH)_2$ is more exothermic than $\Delta H^\ominus_{soln}$ for $Ca(OH)_2$.
 - 2** $\Delta G^\ominus$ for $SrCO_3$ is more negative than $\Delta G^\ominus$ for $MgCO_3$.
 - 3** $E^\ominus(Mg^{2+}/Mg)$ is more negative than $E^\ominus(Ca^{2+}/Ca)$.
- 35** One mole of hydrocarbon, on heating with excess hot acidified $KMnO_4(aq)$, produces two moles of carbon dioxide.

What could the hydrocarbon be?

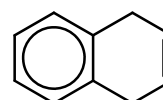
1



2



3

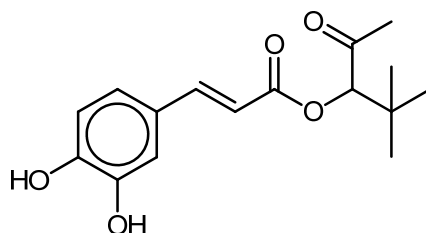


The responses **A** to **D** should be selected on the basis of

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.

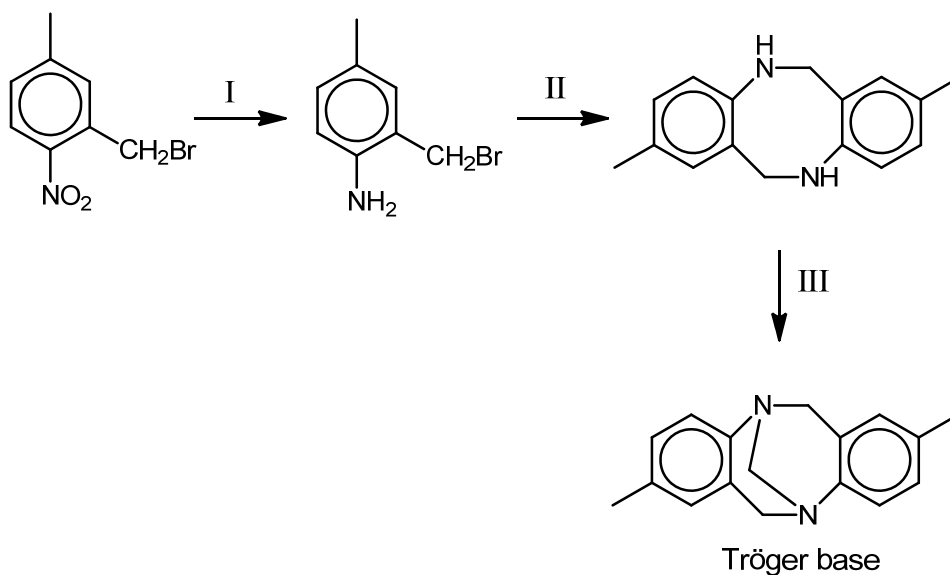
36 Which statements about compound **F** are correct?



compound **F**

- When **F** is heated under reflux with excess acidified $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$, one of the products has a molecular formula of $\text{C}_7\text{H}_6\text{O}_4$.
- F** reacts with hydrogen in the presence of a nickel catalyst to give a product with 2 chiral centres.
- 1 mol of the organic product of the reaction between **F** and NaBH_4 reacts with 1 mol of PCl_5 .

37 The following reaction scheme shows the synthesis of Tröger base.



Which of the following statements are **incorrect**?

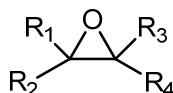
- LiAlH_4 in dry ether can be used for step I.
- Step II is dimerisation.
- The reagent used for step III is CH_2Br_2 .

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

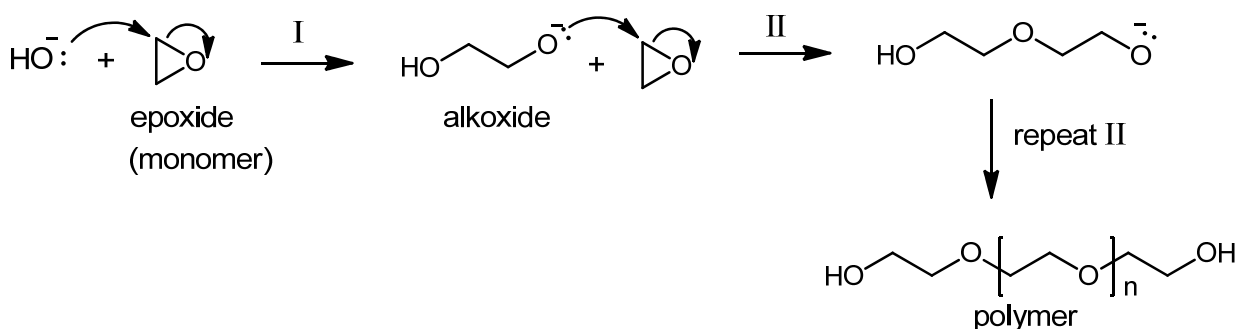
No other combination of statements is used as a correct response.

38 Epoxides have the general structure of



where R_1 , R_2 , R_3 and R_4 are hydrogen atoms and/or alkyl groups.

The highly strained three-membered ring of an epoxide is readily opened with a nucleophile such as OH^- to form an alkoxide, which can ring open another epoxide monomer to build a polymer chain. This process forms new C–O bonds in the polymer backbone.



Under anionic conditions, the ring opening follows $\text{S}_{\text{N}}2$ mechanism, in which the ring opening of an unsymmetrical epoxide occurs at the more accessible, less substituted carbon.

In which pairs would the epoxide monomers give the polymers shown?

	epoxide	polymer
1		
2		
3		

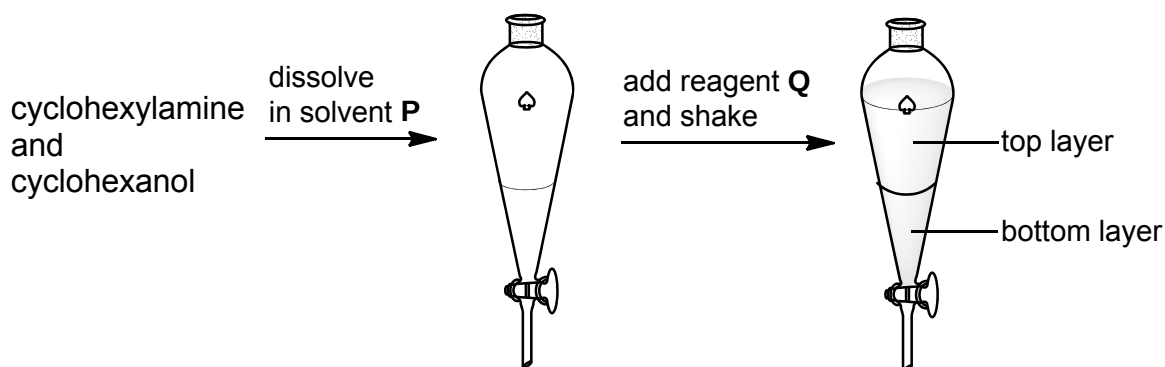
The responses **A** to **D** should be selected on the basis of

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.

- 39** Cyclohexylamine and cyclohexanol are readily soluble in organic solvents such as ethoxyethane, $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$ and dichloromethane, CH_2Cl_2 .

Cyclohexylamine and cyclohexanol can be separated by the following extraction procedure.



The densities of ethoxyethane and dichloromethane are 0.713 g cm^{-3} and 1.33 g cm^{-3} respectively.

Which combinations of solvent **P**, reagent **Q**, and species present in the top and bottom layers are correct?

	solvent P	reagent Q	top layer	bottom layer
1	dichloromethane	dil HCl	ammonium salt of cyclohexylamine	cyclohexanol
2	ethoxyethane	aq NaOH	cyclohexylamine	sodium salt of cyclohexanol
3	ethoxyethane	H_2O	cyclohexylamine	cyclohexanol

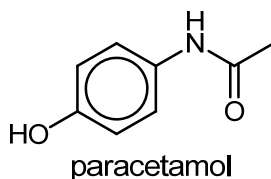
The responses **A** to **D** should be selected on the basis of

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.

40 Use the table of characteristic values for infra-red absorption in the *Data Booklet* to answer this question.

Infra-red absorption can be used to identify functional groups in organic compounds. For example, ethyl ethanoate shows absorption at $1000\text{--}1300\text{ cm}^{-1}$ and $1680\text{--}1750\text{ cm}^{-1}$.



In which ranges would an absorption peak be detected in the infra-red spectrum of paracetamol?

- 1** $2070\text{--}2250\text{ cm}^{-1}$
- 2** $2840\text{--}3095\text{ cm}^{-1}$
- 3** $3230\text{--}3550\text{ cm}^{-1}$

Suggested Answers to 2014 H2 Chemistry Paper 1

1	B	11	B	21	B	31	A
2	B	12	B	22	A	32	B
3	A	13	A	23	C	33	C
4	C	14	A	24	C	34	D
5	C	15	D	25	D	35	A
6	B	16	C	26	C	36	C
7	A	17	C	27	D	37	B
8	A	18	D	28	D	38	B
9	A	19	B	29	C	39	D
10	B	20	D	30	D	40	C