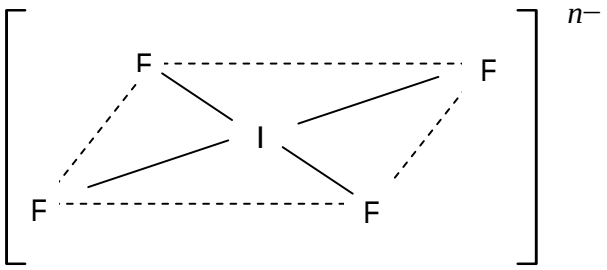
Section A

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

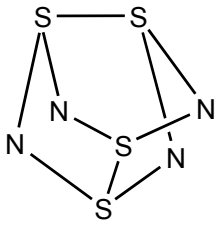
1	Wines often contain a small amount of sulfur dioxide that is added as a preservative. The sulfur dioxide content of a wine is found by the following method: A 50 cm^3 sample of white wine is reacted with 40.0 cm^3 of 0.01 mol dm^{-3} of excess aqueous iodine. The sulfur dioxide in the wine is oxidized to sulfate, SO_4^{2-}, in the process. The unreacted iodine requires exactly 23.60 cm^3 of 0.02 mol dm^{-3} sodium thiosulfate for complete reaction. What is the concentration of sulfur dioxide, in mol dm^{-3}, in the wine?	
	A	1.64 x 10^{-3}
*	**B**	3.28 x 10^{-3}
	C	4.72 x 10^{-3}
	D	9.44 x 10^{-3}

2	A sample of 0.16 g of liquid **A** is vaporised in a graduated syringe at 100 °C and 1 atm. The final volume of the syringe that was recorded is 46 cm^3. By assuming that 1 mol of vapour occupies 22.4 dm^3 at standard temperature and pressure, what is the relative molecular mass of **A**?	
	A	$\frac{0.046 \times 273 \times 22.4}{0.16 \times 373}$
	B	$\frac{0.046 \times 373 \times 22.4}{0.16 \times 273}$
	C	$\frac{0.16 \times 273 \times 22.4}{0.046 \times 373}$
*	**D**	$\frac{0.16 \times 373 \times 22.4}{0.046 \times 273}$

3	Which one of the following sets of compounds consists of a giant ionic structure, a giant covalent structure and a simple covalent structure?	
	A	$C_6H_5CO_2H$, P_4O_{10} and BN
	B	BaO_2, ICl_3 and $SnCl_2$
*	**C**	$AlCl_3$, AlF_3 and SiC
	D	SiO_2, HCl and $BeCl_2$

4	An ion IF_4^{n-} has a square planar structure as shown below.  What is the value of *n*?			
	***A**	1	**B**	2
	C	3	**D**	4

5	Which of the following is a possible configuration of a stable 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	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$

6	S_4N_4 is a thermochomic solid which changes colour with temperature. S_4N_4 has a cage structure as shown in the diagram.  Given the following data, what is the average bond energy of S-N, in kJ mol^{-1}? ΔH_f° (S_4N_4) = +460 kJ mol^{-1} ΔH_{at}° (sulfur) = +279 kJ mol^{-1} ΔH_{at}° (nitrogen) = +497 kJ mol^{-1} (S-S) bond energy in S_4N_4 = = +204 kJ mol^{-1}	
	A	155
*	**B**	280
	C	395
	D	559

7	Self-heating cans can offer benefits to campers without access to a stove or campfire. These soup cans have double walls with an ionic compound such as CaO in a packet and water between the walls. Upon opening the can, the packet breaks, the CaO reacts with water and warms up the soup. $CaO\ (s) + H_2O\ (l) \rightarrow Ca(OH)_2\ (s)$ What are the signs of ΔH, ΔS and ΔG for the overall process?				
	ΔH	**ΔS**	**ΔG**	
***A**	-	-	-	
B	-	+	-	
C	+	+	-	
D	+	+	+	

8 Acetals are derived from aldehydes or ketones, formed by reaction with two equivalents of an alcohol in the presence of an acid catalyst. The reaction below is an example of the formation of an acetal from propanone and methanol.

$$CH_3COCH_3\ (l) + 2CH_3OH(l) \overset{H^+}{\rightleftharpoons} \underset{\text{acetal}}{CH_3C(OCH_3)_2CH_3\ (l)} + H_2O(l)$$

Given that the initial and equilibrium concentrations were as follows, what is the equilibrium constant of the reaction?

	$[CH_3COCH_3]$ / mol dm^{-3}	$[CH_3OH]$ / mol dm^{-3}	$[H^+]$ /mol dm^{-3}	[acetal] /mol dm^{-3}	$[H_2O]$ /mol dm^{-3}
At start	0.20	0.30	0.05	0.00	0.00
At equilibrium				0.04	

	A	0.0207
*	**B**	0.207
	C	4.14
	D	5.17

9 Hardness in tap water can be determined by titrating a water sample against a reagent which forms complex ions with dissolved metal ions. The indicator for this titration requires the pH to be maintained at about 10.

Which of the following, in aqueous solution, could be used to maintain this pH?

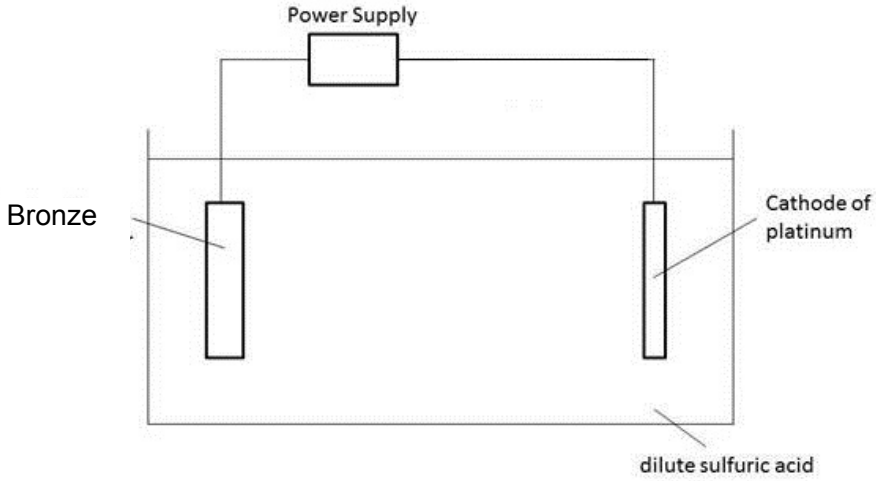
*	**A**	Ammonia and ammonium chloride
	B	Ammonium chloride and hydrochloric acid
	C	Sodium ethanoate and ethanoic acid
	D	Sodium hydroxide and sodium ethanoate

10	Strontium fluoride, SrF_2, has a K_{sp} of 1.0×10^{-9} mol^3 dm^{-9}. When a 50 cm^3 sample of solution **X** was added to a 50 cm^3 sample of 5.0×10^{-4} mol dm^{-3} strontium fluoride solution, a precipitate of strontium fluoride was seen. Which of these solutions is solution **X**?	
	A	0.001 mol dm^{-3} NaF
*	**B**	0.002 mol dm^{-3} BaF_2
	C	0.001 mol dm^{-3} $SrCl_2$
	D	0.002 mol dm^{-3} $SrCrO_4$

11 *Use of the Data Booklet is relevant to this question.*

Bronze is an alloy of copper and tin. The alloy is used for making tools, weapons and building materials.

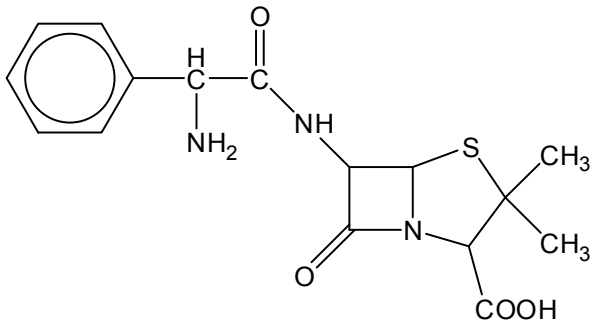
The circuit shown below was set up.

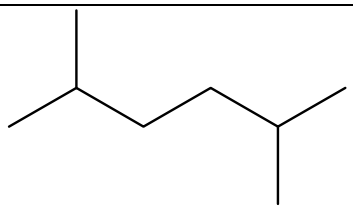
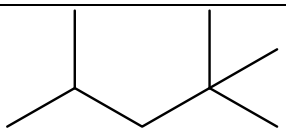
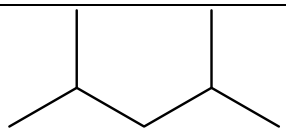
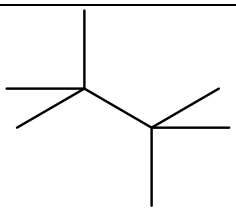


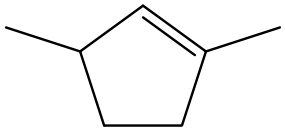
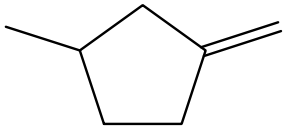
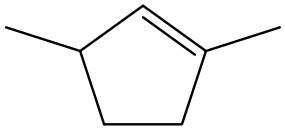
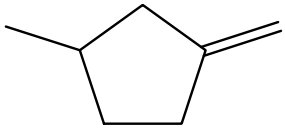
Which of the following observations can be made at the electrodes?

		Anode reaction	**Cathode reaction**
	A	Tin dissolves preferentially	Copper is precipitated
	B	Tin and copper both dissolve	Copper is precipitated
*	**C**	Tin dissolves preferentially	Hydrogen is evolved
	D	Tin and copper both dissolve	Hydrogen is evolved

12	Brine (concentrated sodium chloride solution) was electrolysed using inert electrodes in a cell. The mixture is stirred so that the products of the electrolysis are able to react. The cell is kept cold throughout the entire process. Which one of the following pairs of substances is among the final products?	
	A	Hydrogen and chlorine
*	**B**	Hydrogen and sodium chlorate(I)
	C	Hydrogen and sodium chlorate(V)
	D	Sodium hydroxide and chlorine

13	Ampicillin is a synthetic derivative of penicillin. It is an effective drug against some bacteria inflicted diseases.  ***Ampicillin*** How many enantiomers does ampicillin have?			
	A	8	**B***	16
	C	32	**D**	64

14	Chlorine gas is bubbled into 2-methylpropane in the presence of ultraviolet rays. Which of the following is **not** a possible by-product of the reaction?			
	A		**B**	
	C*		**D**	

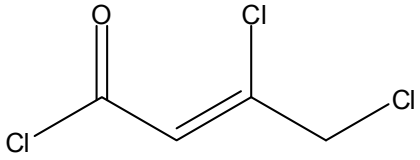
15	Which of the following reactions form a product which can be further oxidised to form a ketone?		
*	**A**		cold dilute $KMnO_4$, KOH (aq)
	B		cold dilute $KMnO_4$, KOH (aq)
	C		cold H_2SO_4 followed by boiling in H_2O
	D		cold H_2SO_4 followed by boiling in H_2O

16 Which pair of reactions will occur via organic intermediates of the same charge?

M $CH_3CH_2CH_3 \rightarrow CH_3CHClCH_3$
N $(CH_3)_3CBr \rightarrow (CH_3)_3COH$
P $C_6H_6 \rightarrow C_6H_5Cl$
Q $CH_3COCH_3 \rightarrow CH_3C(OH)(CN)CH_3$

	A	**M** and **N**	**B**	**N** and **Q**
	C*	**N** and **P**	**D**	**P** and **Q**

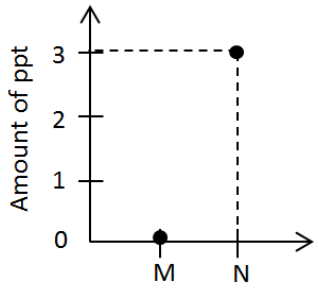
17 Which graph shows the relative amount of precipitate formed when compound **B** treated to the following conditions?



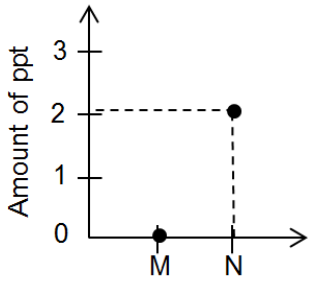
Compound B

M – $AgNO_3$ (aq) at room temperature
N – hot NaOH (aq), followed by HNO_3 and $AgNO_3$ (aq)

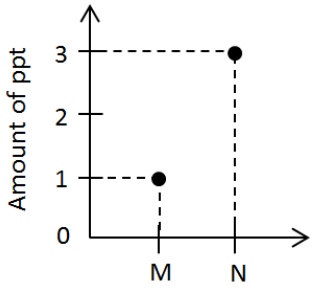
A



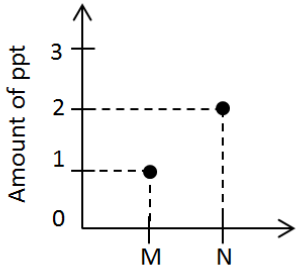
B



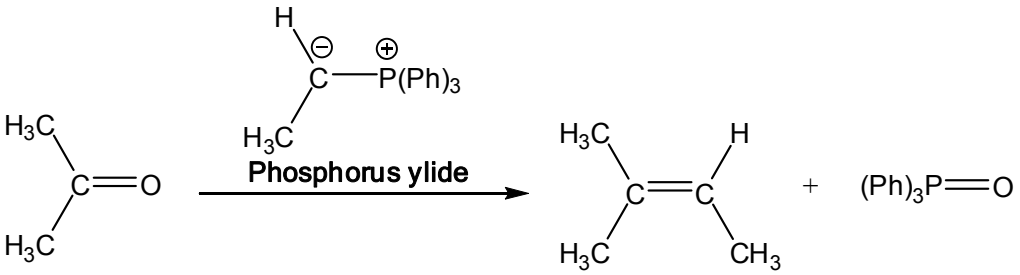
C



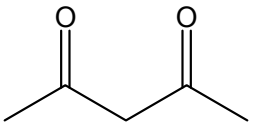
D*



18 The Wittig reaction converts aldehydes or ketones into alkenes. In this reaction, the carbonyl compound reacts with a phosphorous ylide which is a neutral, dipolar compound.

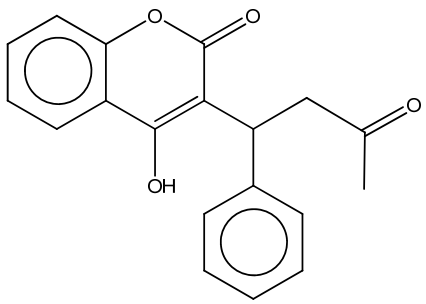


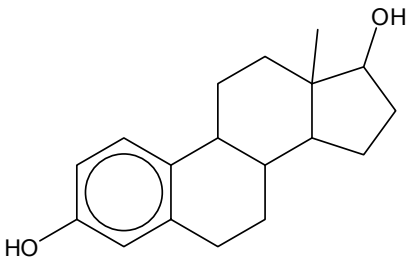
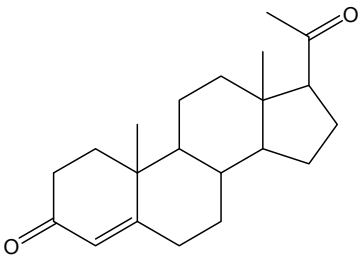
How many stereoisomers will form when pentane-2,4-dione is reacted with excess of the same phosphorous ylide given in the reaction above?



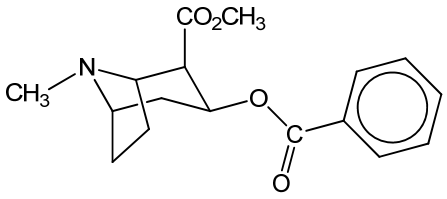
Pentane-2,4-dione

	A	2	**B***	3
	C	4	**D**	5

19	Warfarin is used as a pesticide against rodents. The structural formula of warfarin is given below.  Which of the following statements is true about warfarin?	
	A	It has a total of 4 stereoisomers.
*	**B**	It reacts with ethanoyl chloride to give out white fumes.
	C	It reacts with phosphorus pentachloride to give out white fumes.
	D	It reacts with hot acidified potassium manganate(VII) to form two carbon containing compounds.

20	Steroids are a class of compounds that contains a characteristic arrangement of four cycloalkane rings. The structures of two steroids, estradiol and progesteron, are shown below.  ***Estradiol***  ***Progesteron*** Which of the following **cannot** be used to distinguish estradiol and progesteron?	
*	**A**	Br_2 in CCl_4
	B	neutral $FeCl_3$
	C	acidified $K_2Cr_2O_7$
	D	aqueous alkaline iodine

21 Deuterium, $^{2}_{1}D$, is an isotope of hydrogen. When a weak acid HA is dissolved in heavy water (D_2O), the conjugate base (A^-) abstracts a proton from heavy water to form DA.

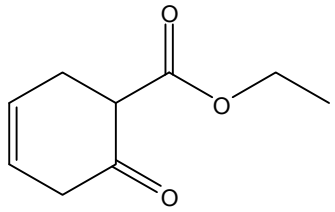


Cocaine

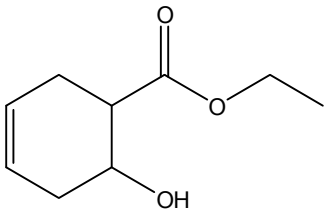
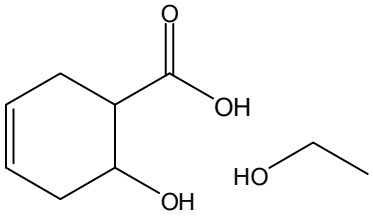
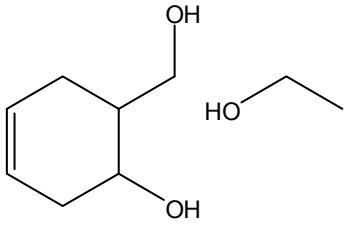
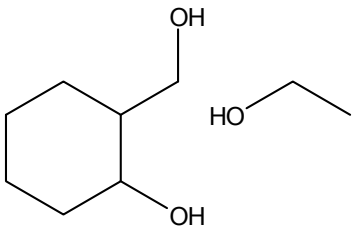
How many deuterium containing functional groups will be formed when cocaine is boiled in a solution of DC*l* in heavy water?

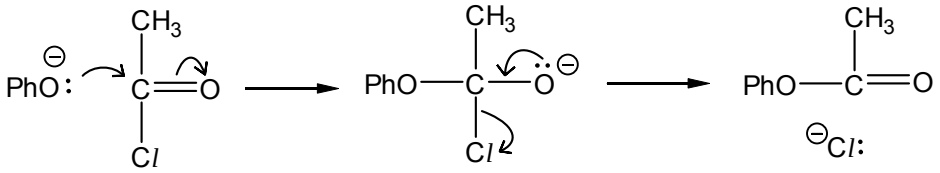
	A	2	**B**	3
	C	4	**D***	5

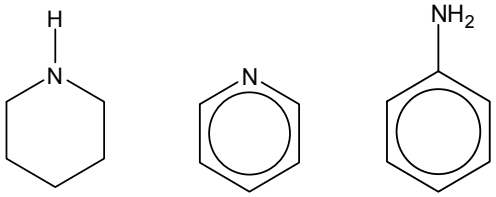
22 What are the products formed when $LiAlH_4$ is slowly added to an ethereal solution of compound **H**, followed by addition of excess water?

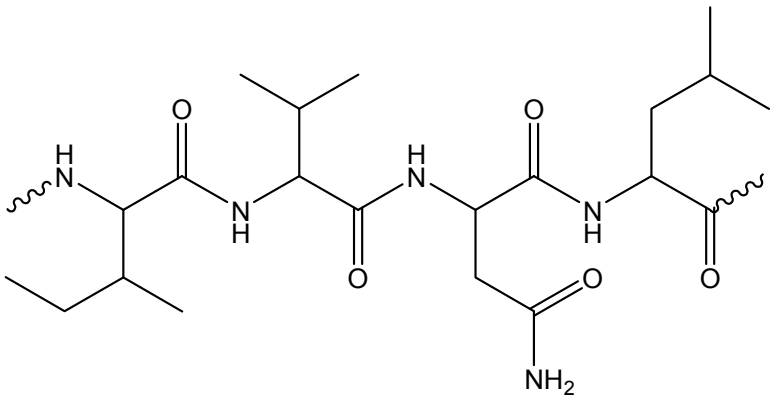


*Compound **H***

	A		**B**	
	C*		**D**	

23	The two-stage reaction sequence given shows a possible mechanism for the reaction between phenoxide ion and ethanoyl chloride.  where Ph = phenyl How should the *overall* reaction be classified?	
	A	Electrophilic addition
	B	Nucleophilic addition
	C	Electrophilic substitution
*	**D**	Nucleophilic substitution

24	The pK_b of three nitrogen containing compounds increases in this order  **I** **II** **III** What are the possible explanations for the relative pK_b of **I and II** as well as **II and III**?			
		I and II		**II and III**
	A	Lone pair of electrons on N in **II** is in a sp^2 hybridised orbital.		**III** is a primary amine.
*	**B**	Lone pair of electrons on N in **II** is in a sp^2 hybridised orbital.		Lone pair of electrons on N in **III** is delocalized into the phenyl group.
	C	Lone pair of electrons on N in **II** is delocalized within the heterocylic ring.		**III** is a primary amine.
	D	Lone pair of electrons on N in **II** is delocalized within the heterocylic ring.		Lone pair of electrons on N in **III** is delocalized into the phenyl group.

25	Which statement regarding the section of a polypeptide chain shown below is **incorrect**? 	
	A	There are five chiral carbons present.
	B	It is made up of 4 different amino acids.
*	**C**	It is more likely to be found on the outside of a globular protein.
	D	It interacts with another protein subunit via hydrogen bonding and Van der Waals forces.

26	Which of the following statement about the elements calcium, strontium and barium is correct?	
	A	The magnitude of the hydration energy of the M^{2+} ion increases from calcium to barium.
	B	The energy required for the process M (g) → M^{2+} (g) + $2e^-$ increases from calcium to barium.
	C	The ease of thermal decomposition increases from calcium carbonate to barium carbonate.
*	**D**	The reactivity of the elements with water increases from calcium to barium.

27	An aqueous solution containing a mixture of copper(II), iron(II), zinc(II) and lead(II) ions was treated with an excess of aqueous ammonia and the solution is filtered. Which of the following gives the correct identity of the precipitates?	
	A	Iron(II) hydroxide, lead(II) hydroxide and zinc(II) hydroxide
	B	Copper(II) hydroxide, lead(II) hydroxide and zinc(II) hydroxide
	C	Lead(II) hydroxide and zinc(II) hydroxide
*	**D**	Iron(II) hydroxide, lead(II) hydroxide

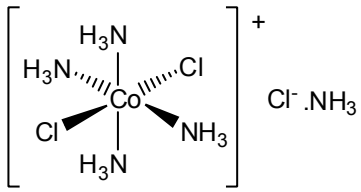
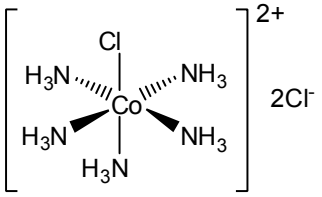
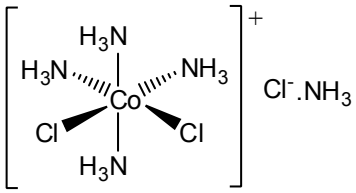
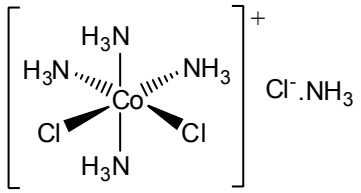
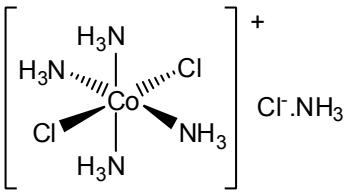
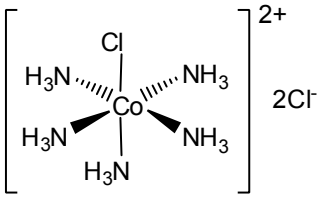
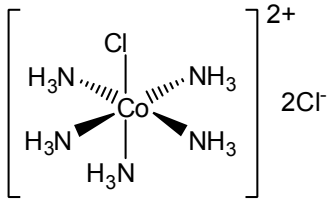
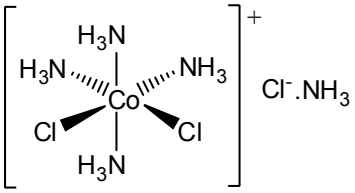
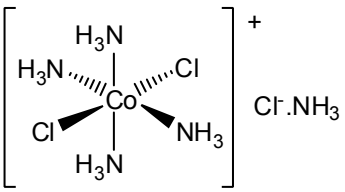
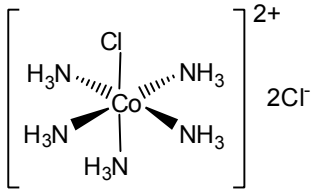
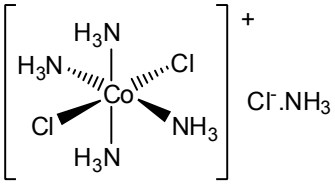
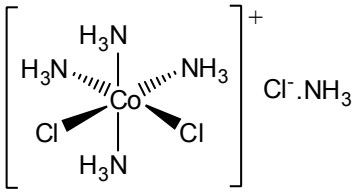
28	The hydrogen compounds of Group VII elements exhibit trends in their properties. Which of the properties increases from HC*l* to HBr to HI?	
	A	The thermal stability of the hydrogen halides.
	B	The hydrogen-halogen bond dissociation energy.
*	**C**	The strength of the intermolecular forces between hydrogen halide molecules.
	D	The pK_a value of the aqueous solution of hydrogen halides.

29	*Use of Data Booklet is relevant to this question.* If cobalt is heated separately with chlorine, bromine and iodine, what are the likely products?				
		chlorine	**bromine**	**iodine**	
*	**A**	$CoCl_2$	$CoBr_2$	CoI_2	
	B	$CoCl_3$	$CoBr_2$	CoI_2	
	C	$CoCl_3$	$CoBr_3$	CoI_2	
	D	$CoCl_3$	$CoBr_3$	CoI_3	

30 Three different complexes can be obtained by reacting aqueous cobalt(III) chloride with ammonia under various conditions. Different proportions of chloride are precipitated when each of the complexes is treated with silver nitrate.

Empirical formula		Colour of solid	No. of moles of AgC*l* precipitated per mole of complex	Does the complex have a dipole moment?
I	$CoCl_3(NH_3)_5$	violet	2	yes
II	$CoCl_3(NH_3)_5$	violet	1	yes
III	$CoCl_3(NH_3)_5$	green	1	no

What are the correct structures for compounds **I**, **II** and **III**?

		I	**II**	**III**
	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 The data below refer to 6 elements, lettered **T** to **Y** (these letters are **not** chemical symbols).

Element	**T**	**U**	**V**	**W**	**X**	**Y**
Atomic Number	*Z*	*Z*+1	*Z*+2	*Z*+3	*Z*+4	*Z*+5
Boiling point/ K	73	93	83	23	1163	1373

Which of the following statement(s) is/are true?

*	**1**	The first ionization energy of **T** is higher than that of **U**.
	2	The ionic radius of **V** is smaller than the ionic radius of **X.**
	3	The hydride of **V** has a higher boiling point than the hydride of **Y**.

32 Which of the following reactions can be considered as acid-base reaction?

*	**1**	$CuO\,(s) + 2NH_3\,(l) \rightarrow Cu(NH_2)_2\,(l) + H_2O\,(l)$
*	**2**	$2CrO_4^{2-}\,(aq) + 2H^+\,(aq) \rightarrow Cr_2O_7^{2-}\,(aq) + H_2O\,(l)$
*	**3**	$SiO_2\,(s) + 4HF\,(l) \rightarrow 2H_2O\,(l) + SiF_4\,(l)$

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

33 The radius and charge of each of the six ions are shown in the table.

ion	J^+	L^+	M^{2+}	X^-	Y^-	Z^{2-}
radius / nm	0.14	0.18	0.15	0.14	0.18	0.15

Which of the following pair(s) show(s) that the first compound has a larger magnitude of lattice energy than the second?

	1	JX MZ
*	**2**	JX LY
*	**3**	MZ LY

34 At 298 K, the dissociation constants for two monobasic carboxylic acids are given below:

	RCOOH	R'COOH
K_a / mol dm^{-3}	2.5×10^{-8}	3.0×10^{-10}

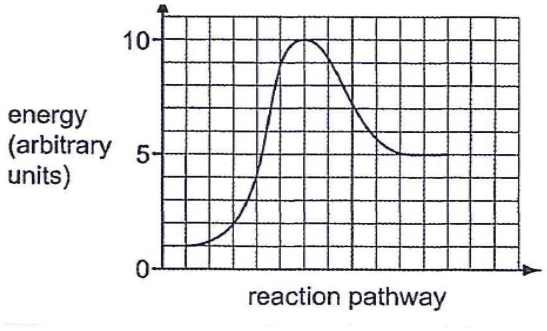
Which of the following statement(s) is/are true for the acids at 298K?

*	**1**	The pH of 1 mol dm^{-3} RCOOH is lower than 1 mol dm^{-3} R'COOH.
*	**2**	The K_b of $RCOO^-$ is smaller than that of $R'COO^-$.
	3	For the same amount of acid, R'COOH requires a larger amount of NaOH than RCOOH to be completely neutralised.

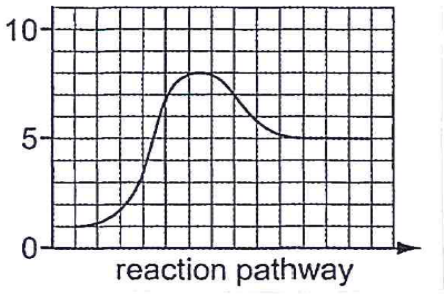
The responses **A** to **D** should be selected on the basis of

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

35 The diagram shows the reaction pathway for a reversible reaction



The reaction is repeated under different conditions and a new energy profile diagram is obtained.



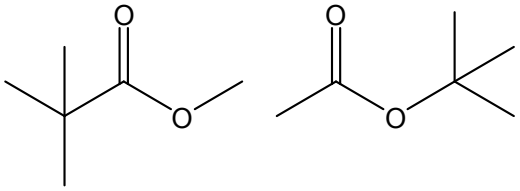
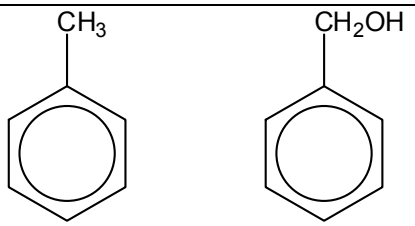
What conclusion(s) can be drawn about the second reaction?

*	**1**	The reaction is catalysed.
*	**2**	The rate constant has increased.
	3	The enthalpy change of the reversed reaction has decreased.

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

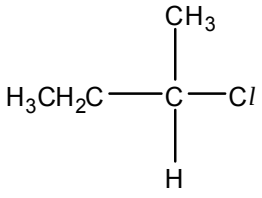
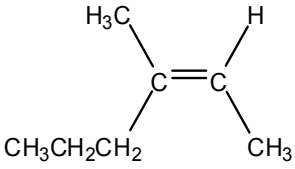
A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

36	*Use of Data Booklet is relevant to this question.* An electrochemical cell is set up using a $Sn^{2+}(aq)/Sn(s)$ half-cell and a $Al^{3+}(aq)/Al(s)$ half-cell. What are the features of the cell obtained?	
*	**1**	Electrons flow in the external circuit from aluminium to tin.
*	**2**	Reduction takes place at the tin terminal and the tin electrode increases in mass over time.
*	**3**	The aluminium electrode is the negative electrode.

37	Which of the following pairs of compounds can be distinguished using acidified potassium dichromate(VI) under suitable conditions?	
*	**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

38	Which of the following reactions is/are likely to form product(s) that is/are optically inactive?	
	1	 with aqueous sodium hydroxide, heating under reflux.
*	**2**	CH_3CHO with HCN in trace amounts of alkali, 10–20 ^oC.
*	**3**	 with HBr (g).

39	The elements **X**, **Y** and **Z** belong to the same period of the Periodic Table. The oxide of **X** reacts with both strong acids and strong alkalis. The oxide of **Y** will give an aqueous of pH < 7 and the oxide of **Z** gives an aqueous solution of pH > 7. Which statement(s) about elements **X**, **Y** and **Z** is/are correct?	
*	**1**	The electronegativity of the elements decreases in the order **Y**, **X**, **Z**.
*	**2**	**X**, **Y** and **Z** could be aluminium, phosphorus and sodium respectively.
	3	The ionic radius decreases in the order **Y**, **X**, **Z**.

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

40	When concentrated HCl is added to blue-green $CuCl_2$ (aq), a yellow-green solution of H_2CuCl_4 is formed. This yellow-green solution then reacts with SO_2 to form a white solid **J**. Which statement(s) about these reactions is/are correct?	
*	**1**	$CuCl_2$ is coloured due to presence of partially filled 3d orbitals in Cu^{2+}(aq).
	2	Concentrated HCl acts as a reducing agent.
	3	White solid **J** is formed due to ligand exchange.

End of paper

Answers

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