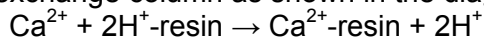


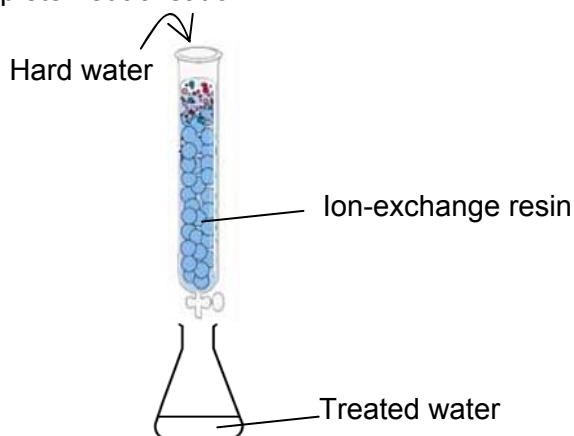
Section A

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

- 1 The hardness present in a water sample due to dissolved calcium ions can be determined by using ion-exchange column as shown in the diagram.



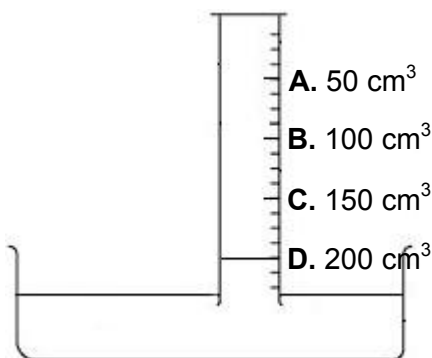
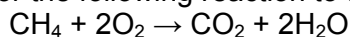
A 50 cm³ sample of a solution containing calcium sulfate was passed through the ion-exchange resin. The calcium ions in the sample were quantitatively exchanged by hydrogen ions. The sample collected in the flask required 25 cm³ of 1.0 × 10⁻² mol dm⁻³ potassium hydroxide for complete neutralisation.



What was the concentration of the calcium sulfate in the original sample?

- | | | | |
|----------|---|----------|---|
| A | 2.5 × 10 ⁻³ mol dm ⁻³ | B | 5.0 × 10 ⁻³ mol dm ⁻³ |
| C | 2.0 × 10 ⁻² mol dm ⁻³ | D | 4.0 × 10 ⁻² mol dm ⁻³ |
- 2 A tube filled with 50 cm³ of methane and 150 cm³ of oxygen at room temperature was inverted over a vessel containing KOH (aq) as shown in the diagram.

The hydrocarbon was ignited for the following reaction to take place.



When the setup is cooled to room temperature, at which level will the liquid be?

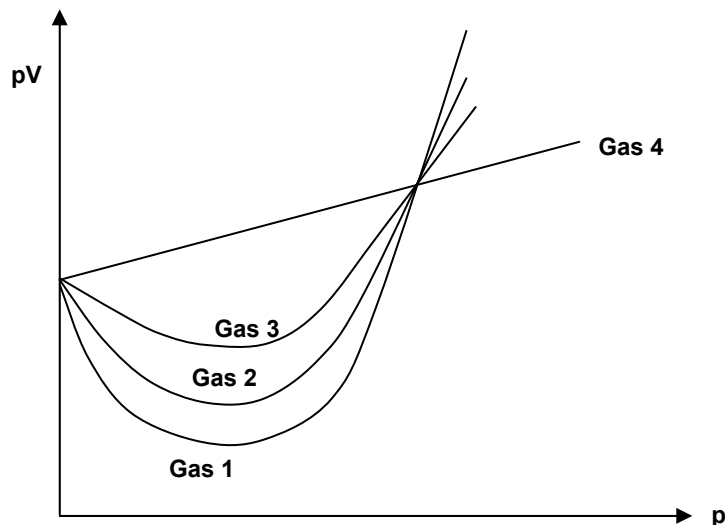
- 3 The successive ionisation energies (IE) of two elements, **A** and **B**, are given below:

IE/ kJ mol ⁻¹	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th
A	550	1065	4138	5500	6910	8760	10230	11800
B	1140	2103	3470	4560	5760	8550	9940	18600

What is the likely formula of the compound that is formed when **A** reacts with **B**?

- A** AB₂ **B** AB **C** A₂B **D** A₂B₃

- 4 The value of pV is plotted against p at the same temperature for four gases, where p is the pressure and V is the volume of the gas.



Which of the following represent the possible identities of Gases 1 to 4?

- | | Gas 1 | Gas 2 | Gas 3 | Gas 4 |
|----------|------------------|-------------------|-------------------|------------------|
| A | Ne | CH ₃ F | HF | H ₂ O |
| B | Ne | HF | CH ₃ F | H ₂ O |
| C | H ₂ O | Ne | CH ₃ F | HF |
| D | H ₂ O | HF | CH ₃ F | Ne |

- 5 In which of the following sequences are the molecules quoted in order of decreasing boiling points?

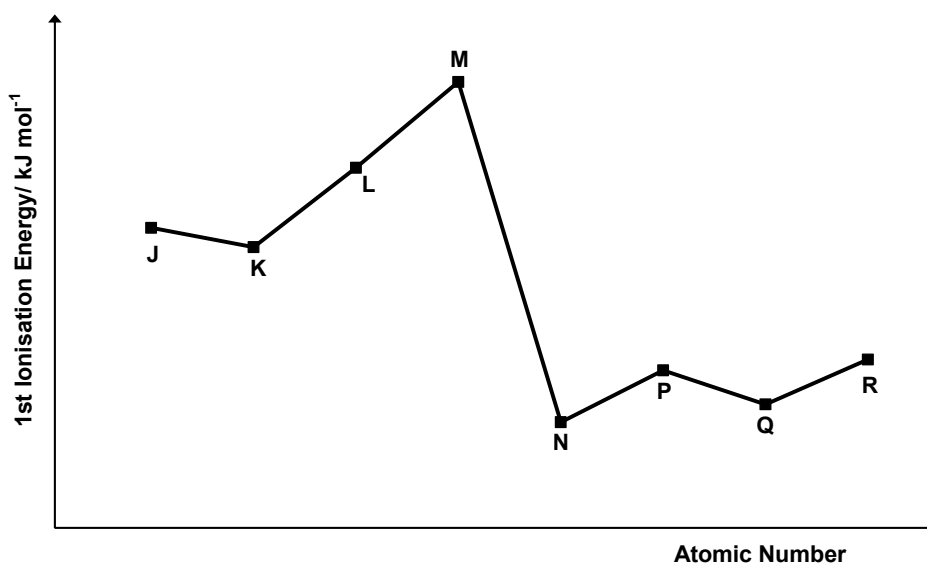
- A** Ti, K, Ca
B I₂, HF, HCl
C SCl₂, AlCl₃, MgCl₂
D CCl₄, CH₄, CH₂Cl₂

- 6 When two liquids are mixed, heat may be evolved if the intermolecular bonds formed are stronger than those broken, even if there is no chemical reaction occurring.

Which of the following pair of liquids, when mixed, will give out heat?

- A CHCl_3 and C_5H_{12}
- B CCl_4 and $(\text{CH}_3)_2\text{CO}$
- C CCl_4 and $\text{CH}_3\text{CH}_2\text{OH}$
- D CH_2Cl_2 and $(\text{CH}_3)_2\text{CO}$

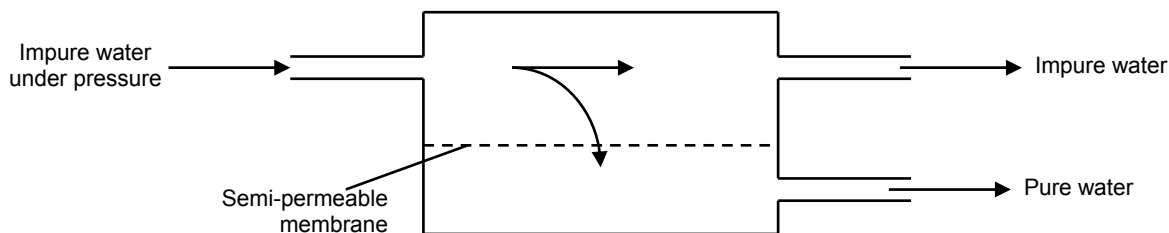
- 7 The following graph shows the first ionisation energies of eight consecutive elements J to R, which have atomic numbers between 3 to 20 in the Periodic Table.



Which one of the following statements about the elements is **false**?

- A Oxides of Q react with dilute $\text{H}_2\text{SO}_4(\text{aq})$.
- B Ions of M are able to act as homogeneous catalysts.
- C The ionic radius of J is larger than the ionic radius of K.
- D N forms a chloride which reacts with water to give a neutral solution.

- 8 Reverse osmosis is a method of obtaining pure water from seawater or polluted water, which is now being used in Singapore and other countries. This process works by applying a constant pressure to a sample of impure water next to a semi-permeable membrane.



The semi-permeable membrane only allows small molecules such as water to pass through, but retains all other molecules and ions.

Hence, what are the correct signs for ΔS and ΔG for the reverse osmosis process?

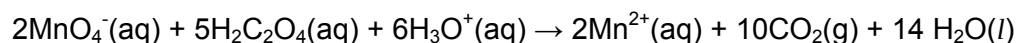
	ΔS	ΔG
A	Positive	Positive
B	Positive	Negative
C	Negative	Positive
D	Negative	Negative

- 9 When 1.200 g of propan-1,2,3-triol was burnt, it was found that 100 g of water was heated from 25 °C to 67 °C. This process was found to have an efficiency of 80%.

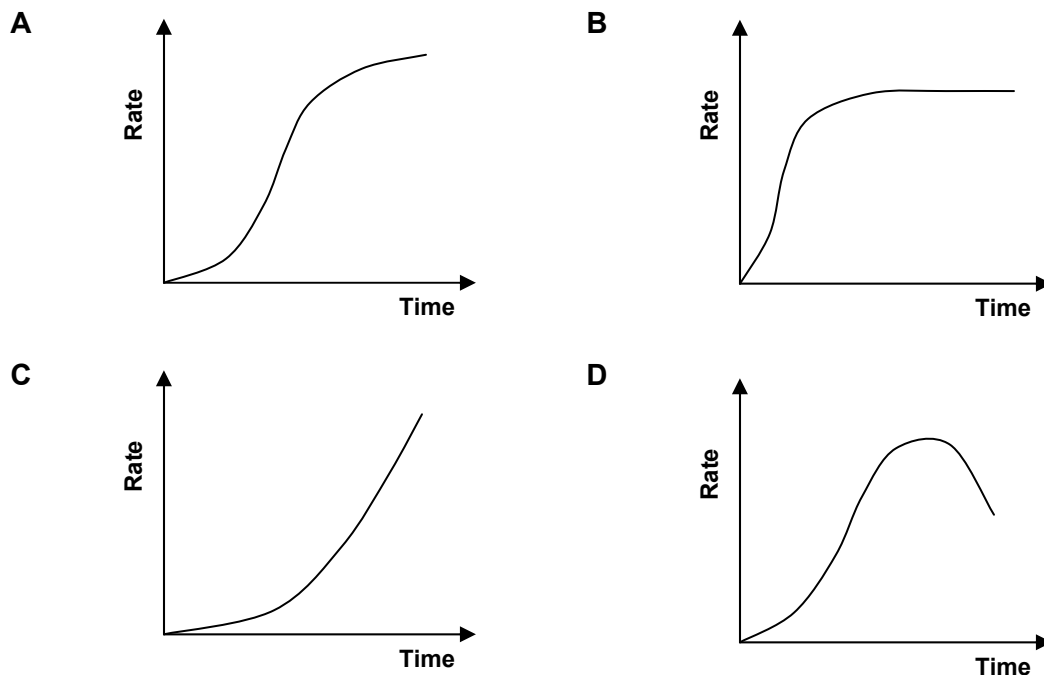
What is the enthalpy change of combustion of propan-1,2,3-triol in kJ mol^{-1} ?

A	-1080	B	-1350
C	-1680	D	-2420

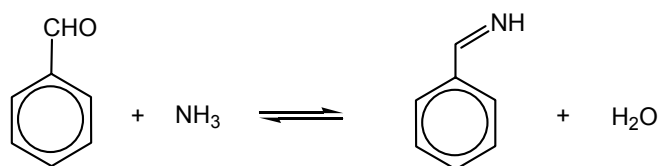
- 10 The reaction between potassium manganate(VII) and ethanedioic acid is an example of auto-catalytic reactions, in which one of the products catalyses the reaction.



Which graph correctly represents the kinetics of this reaction?



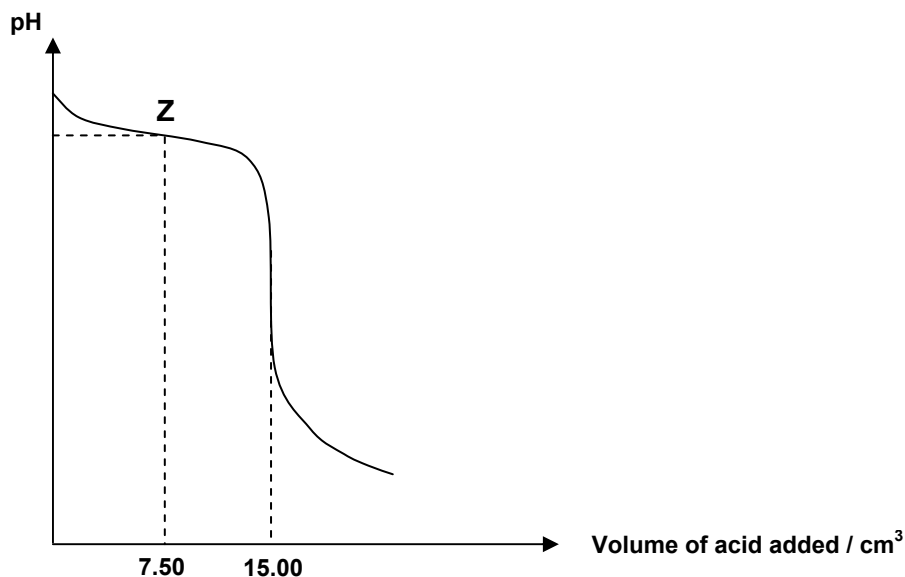
- 11 An imine can be prepared by reacting benzaldehyde with ammonia in methanol:



Which of the following statements about the above reaction sequence is correct?

- A The value of K_c will increase upon the addition of ammonia.
- B The backward reaction is favoured by the addition of benzaldehyde.
- C The forward reaction is favoured by the addition of dilute aqueous sulfuric acid.
- D The preparation of imine proceeds via nucleophilic addition mechanism, followed by elimination mechanism.

- 12 The following graph shows the change in pH when 30.0 cm³ of 1.0 mol dm⁻³ solution of aqueous NH₃ is titrated against 1.0 mol dm⁻³ solution of dilute aqueous H₂SO₄.



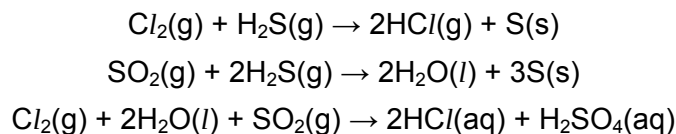
Given that K_b of NH₃ is 1.8×10^{-5} mol dm⁻³, what is the pH of the solution at point Z?

- A** 8.86 **B** 9.26 **C** 9.79 **D** 11.6
- 13 The solubility products of barium carbonate (BaCO₃) and barium molybdate (BaMoO₄) are 2.58×10^{-9} mol² dm⁻⁶ and 3.54×10^{-8} mol² dm⁻⁶ at 25 °C respectively.

Which of the following statements is **false**?

- A** Barium molybdate has a higher solubility than barium carbonate.
- B** Addition of nitric acid will increase the solubility of barium carbonate.
- C** Addition of potassium molybdate to a solution containing barium molybdate will decrease the solubility product of barium molybdate.
- D** When barium nitrate is added to a solution containing equal concentrations of carbonate and molybdate ions, barium carbonate is precipitated first.

- 14 The equations for three reactions are given below:

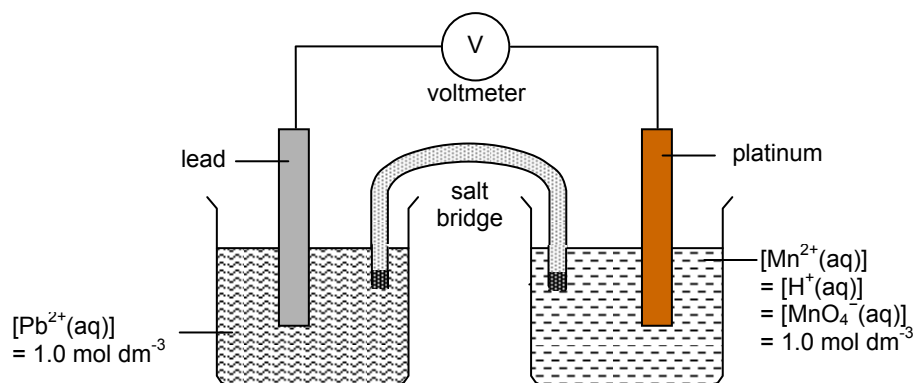


Which is the correct order of strength of the three reacting gases as oxidising agents?

	Strongest	→	Weakest
A	Chlorine	Sulfur dioxide	Hydrogen sulfide
B	Chlorine	Hydrogen sulfide	Sulfur dioxide
C	Hydrogen sulfide	Sulfur dioxide	Chlorine
D	Sulfur dioxide	Hydrogen sulfide	Chlorine

- 15 The use of the Data Booklet is relevant to this question.

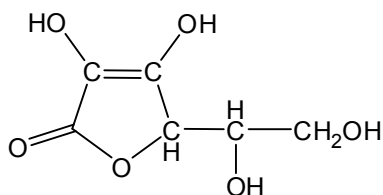
A cell is set up by connecting a Pb^{2+}/Pb half-cell and an acidified $\text{MnO}_4^-/\text{Mn}^{2+}$ half-cell.



Which of the following is a correct description of the effect on the e.m.f (potential difference) of the cell when the corresponding change is made?

	Change	Effect on e.m.f of cell
A	Addition of $\text{NH}_3(\text{aq})$ into oxidation half-cell	Increases
B	Addition of $\text{H}_2\text{SO}_4(\text{aq})$ into reduction half-cell	Decreases
C	Addition of $\text{NaOH}(\text{aq})$ into reduction half-cell	Increases
D	Replace lead with an alloy of lead and zinc	Remains the same

- 16 The diagram shows the structure of vitamin C.

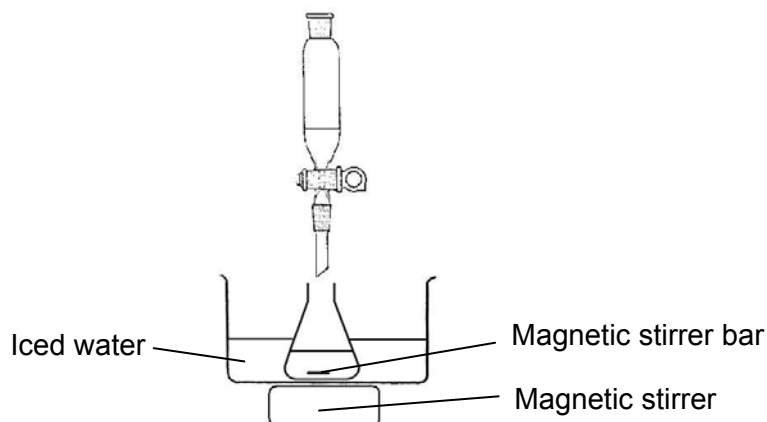


Vitamin C

How many chiral centres will there be in one molecule when vitamin C is reduced with LiAlH_4 and $\text{H}_2(\text{g})$ over Ni catalyst respectively?

	LiAlH_4	$\text{H}_2(\text{g})$ over Ni catalyst
A	4	4
B	2	4
C	4	2
D	2	6

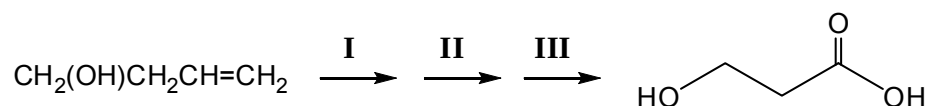
- 17 The diagram shows an experimental setup used in a laboratory.



Which of the following preparations could this setup be used for?

- A** 1,2-dibromoethane from bromine and ethane.
B Ethanol from ethene and concentrated sulfuric acid.
C Ethylamine from ethanamide and lithium aluminium hydride in dry ether.
D Methyl methanoate from methanol, methanoic acid and concentrated sulfuric acid.

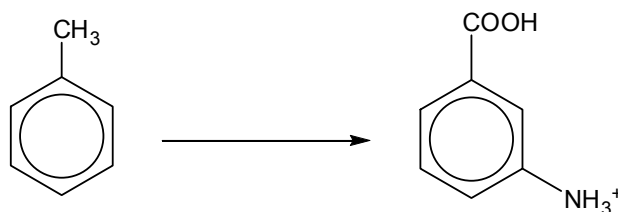
- 18 3-hydroxypropanoic acid can be synthesized as shown below.



What are the reagent(s) and conditions for each step of the synthesis?

	Step I	Step II	Step III
A	Hot, acidified KMnO_4 (aq)	PCl_5 , room temperature	NaOH (aq)
B	Hot, acidified KMnO_4 (aq)	PCl_5 , room temperature	H_2O
C	1. Concentrated H_2SO_4 , cold 2. H_2O , boil	NaOH (aq), I_2 (aq), warm	HCl (aq)
D	1. Concentrated H_2SO_4 , cold 2. H_2O , boil	Hot, alkaline KMnO_4 (aq)	HCl (aq)

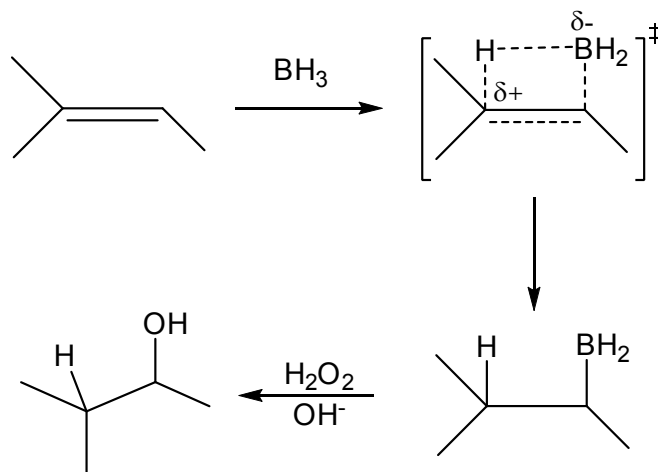
- 19 3-aminobenzoic acid can be produced from methylbenzene in three steps.



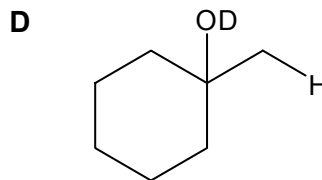
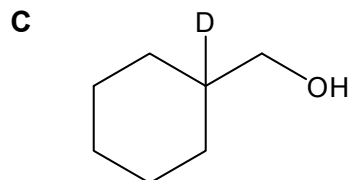
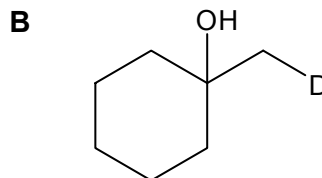
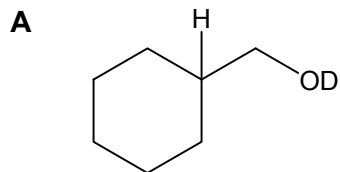
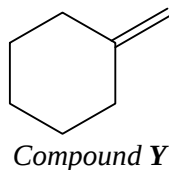
Which is the best method for this synthesis?

	Step 1	Step 2	Step 3
A	Dilute H_2SO_4 , $\text{K}_2\text{Cr}_2\text{O}_7$, heat	Concentrated HNO_3 , Concentrated H_2SO_4 , heat	Concentrated HCl , Sn, heat
B	Dilute H_2SO_4 , KMnO_4 , heat	Concentrated HNO_3 , Concentrated H_2SO_4 , heat	Concentrated HCl , Sn, heat
C	Concentrated HNO_3 , Concentrated H_2SO_4 , heat	Dilute H_2SO_4 , KMnO_4 , heat	Concentrated HCl , Sn, heat
D	Concentrated HNO_3 , Concentrated H_2SO_4 , heat	Concentrated HCl , Sn, heat	Dilute H_2SO_4 , KMnO_4 , heat

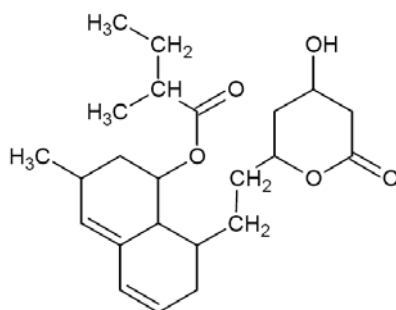
- 20 Hydroboration is a method of preparing alcohols from alkenes in an anti-Markovnikov manner. The reaction involves the formation of a four-membered cyclic transition state, where the partial positive charge is carried on the more highly substituted carbon. The alkylborane undergoes redox reaction with hydrogen peroxide to form an alcohol.



Which of the following will be obtained if the following compound **Y** is subjected to hydroboration using BD_3 followed by H_2O_2 and OH^- ? ($\text{D} = {}^2_1\text{H}$)

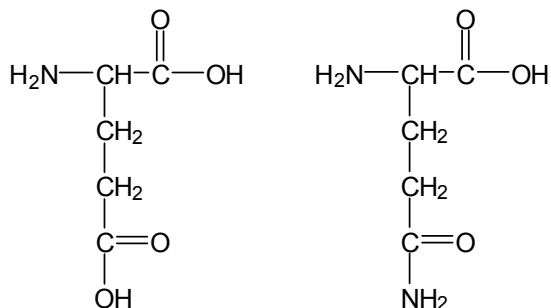


- 21 Lovastatin is often prescribed for cardiovascular disease because it helps to lower the cholesterol level in bloodstream. Which of the following statements about Lovastatin is **false**?



Lovastatin

- A** 1 mole of Lovastatin reacts with 2 moles of bromine in tetrachloromethane.
- B** 1 mole of Lovastatin reacts with 2 moles of dilute sodium hydroxide when heated under reflux.
- C** 1 mole of Lovastatin reacts with 2 moles of 2,4-dinitrophenylhydrazine to form an orange precipitate.
- D** 1 mole of Lovastatin reacts with 1 mole of thionyl chloride to form 1 mole of hot aqueous hydrochloric acid.
- 22 The amino acids, glutamic acid and glutamine, can react with each other to form amide linkages.



Glutamic acid

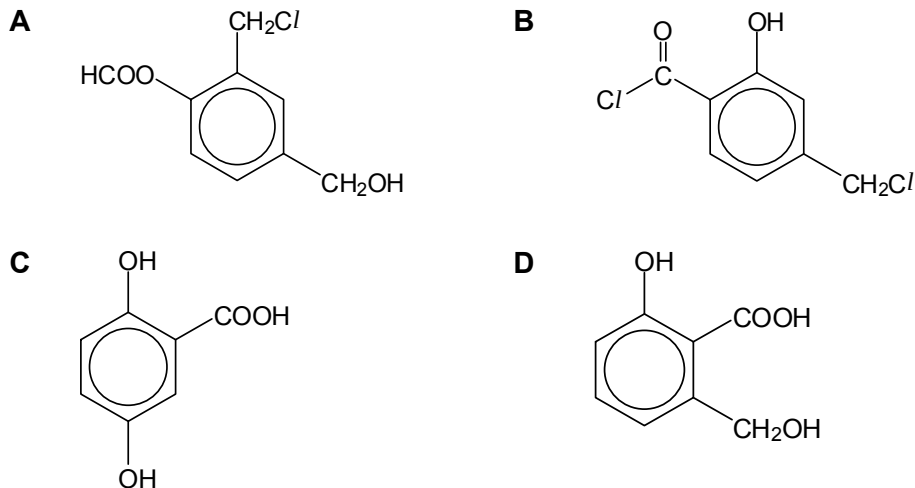
Glutamine

What is the maximum number of different compounds, each containing one **natural** amide linkage that can be formed from one molecule of glutamine and one molecule of glutamic acid?

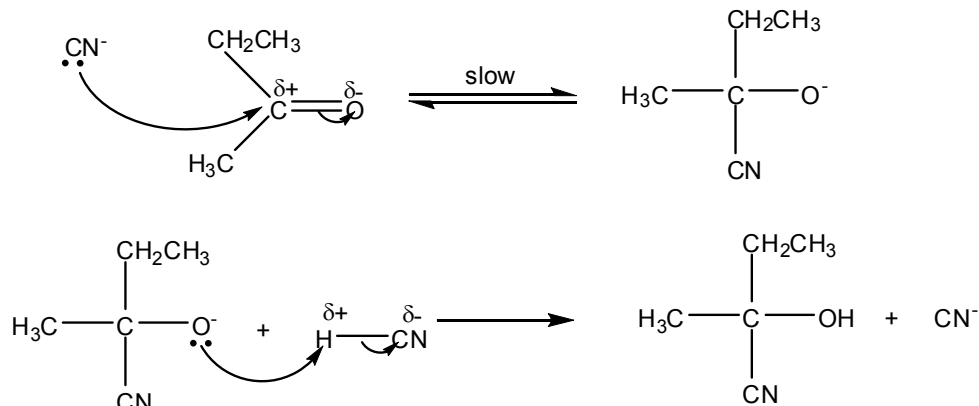
- A** 2
- B** 3
- C** 4
- D** 5

- 23 Compound **Z** reacts with 2 moles of aqueous sodium hydroxide at room temperature and a further 1 mole of aqueous sodium hydroxide during boiling.

Which of the following structure could compound **Z** have?



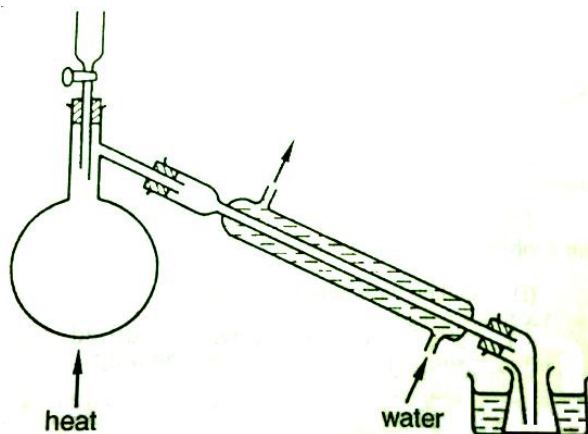
- 24 The mechanism below shows how butanone reacts with hydrogen cyanide.



Which of the following statements is true?

- A** The product mixture is optically active.
- B** The rate of reaction of hydrogen cyanide with butanal is faster than that with butanone.
- C** Cyanohydrin produced can react with ammonia at high pressure to form amine.
- D** Cyanohydrin produced requires potassium manganate(VII) to form carboxylic acid.

- 25 The diagram shows an experimental setup for a chemical synthesis.



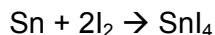
Which of the following equations shows a reaction for which this experiment setup is suitable?

- A** $\text{CH}_3\text{COCl} + \text{C}_2\text{H}_5\text{OH} \rightarrow \text{CH}_3\text{CO}_2\text{C}_2\text{H}_5 + \text{H}_2\text{O}$
- B** $\text{CH}_3\text{CH}_2\text{OH} + \text{PCl}_5 \rightarrow \text{CH}_3\text{CH}_2\text{Cl} + \text{POCl}_3 + \text{HCl}$
- C** $\text{CH}_3\text{CH}_2\text{OH} + \text{H}_2\text{SO}_4 \rightarrow \text{CH}_2=\text{CH}_2 + \text{H}_2\text{O} + \text{H}_2\text{SO}_4$
- D** $3\text{CH}_3\text{CH}_2\text{OH} + \text{K}_2\text{Cr}_2\text{O}_7 + 4\text{H}_2\text{SO}_4 \rightarrow 3\text{CH}_3\text{CHO} + \text{K}_2\text{SO}_4 + \text{Cr}_2(\text{SO}_4)_3 + 7\text{H}_2\text{O}$
- 26 Which of the following properties of hydrogen halides decreases down the group?
- A** Basic strength of halides
- B** Bond length of hydrogen halides
- C** Boiling point of hydrogen halides
- D** Ease of oxidation of hydrogen halides

- 27 Anhydrous barium nitrate and anhydrous magnesium nitrate both decompose on heating, evolving nitrogen dioxide and oxygen and forming an oxide.

Which of the following statements concerning these decompositions is correct?

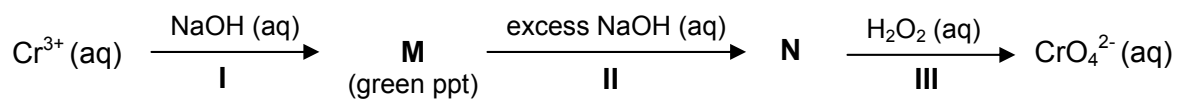
- A The numerical value of the lattice energy of magnesium nitrate is lesser than that of barium nitrate.
 - B Each mole of the nitrate decomposes to form 24 dm³ of nitrogen dioxide at room temperature and pressure.
 - C For both nitrates, the volume of nitrogen dioxide evolved is four times greater than the volume of oxygen.
 - D At the same temperature, the decomposition of one mole of magnesium nitrate has more negative Gibbs free energy (ΔG) than the same amount of barium nitrate.
- 28 Which one of the following statements about Group II elements is correct?
- A The reactivity with cold water decreases down the Group.
 - B The charge density of Group II cations increases from Be to Ba.
 - C The minimum temperature needed for the thermal decomposition of Group II nitrates increases down the Group.
 - D The melting point of Group II carbonates decreases down the Group due to the decreasing polarising power of cations.
- 29 Tin(IV) iodide can be prepared by boiling 0.04 mol of tin (under reflux) with 0.03 mol of iodine dissolved in 5 cm³ of tetrachloromethane which has a boiling point of 77 °C.



Orange crystals of the product are obtained by filtering the hot reaction mixture and then cooling the filtrate. Which of the following would indicate that the reaction is complete?

- A No more purple vapour is seen.
- B The boiling point of the mixture is 77 °C.
- C No more liquid remains in the reaction flask.
- D Crystals begin to deposit in the boiling solvent.

- 30** The reaction scheme starting from a solution containing chromium(III) ions is shown below. Both **M** and **N** are chromium-containing species.



Which of the following statements is correct?

- A** Hydroxide ions act as ligands in Step I.
- B** A redox reaction has occurred in Step II.
- C** **N** is a dark green solution containing $[\text{Cr}(\text{OH})_4]^-$.
- D** An acidic medium is required for the formation of CrO_4^{2-} .

Section B

From questions **31** to **40**, 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 useful 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

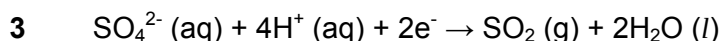
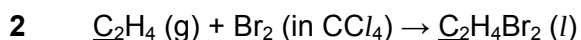
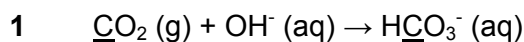
A	B	C	D
1, 2 and 3 are correct	1 and 2 are correct	2 and 3 are correct	Only 1 is correct

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

- 31** Which of the following pair(s) of observation and explanation is/are **false**?

	Observation	Explanation
1	The second ionisation of any element is always higher than its first ionisation energy.	More energy is required to remove an electron from an increasingly more positive species.
2	The second ionisation energy of chromium is lower than that of manganese.	Manganese has one more proton than chromium.
3	The third ionisation energy of strontium is higher than that of yttrium.	Sr^{2+} ion has a larger ionic radius as compared to that of Y^{3+} ion.

- 32** In which of the following reactions is the bond angle in the product smaller than that in the reactant with respect to the underlined atom?

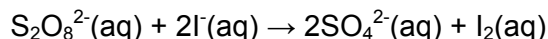


The responses **A** to **D** should be selected on the basis of

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

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

- 33** An experiment was carried out to investigate the initial rate of reaction between ammonia peroxodisulphate, $(\text{NH}_4)_2\text{S}_2\text{O}_8$, an oxidizing agent, and potassium iodide, KI.



The initial concentrations of the $(\text{NH}_4)_2\text{S}_2\text{O}_8$ and KI solutions in the mixture, together with the time taken for the mixture to darken for the various experimental runs are given below:

Experiment	Initial concentration of $(\text{NH}_4)_2\text{S}_2\text{O}_8$/ mol dm⁻³	Initial concentration of KI/ mol dm⁻³	Time taken to darken/ s
1	0.10	0.20	35
2	0.05	0.20	70
3	0.10	0.067	105
4	0.02	0.75	?

Which of the following statements about the reaction is/are true?

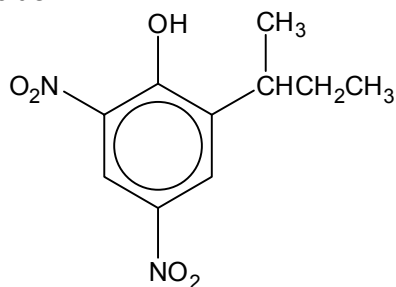
- 1** The reaction involves the formation of an intermediate.
 - 2** The time taken for the mixture to darken in Experiment 4 is 47s.
 - 3** The slow step involves the reaction between 1 mole of $(\text{NH}_4)_2\text{S}_2\text{O}_8$ and 1 mole of KI.
- 34** When a current of 1.02 A was passed through an aqueous sulfate solution of metal **G** for 85 minutes, 1.0 g of metal **G** was deposited at the cathode. Metal **G** has a relative atomic mass of 55.8. Which of the following statements about the above electrolysis is/are correct?
- 1** The charge of an ion of **G** is +3.
 - 2** Increasing the concentration of sulfate ion increased the rate of formation of the element.
 - 3** A colourless gas, which turned acidified $\text{K}_2\text{Cr}_2\text{O}_7$ from orange to green, was evolved at the anode.

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 are correct	2 and 3 are correct	Only 1 is correct

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

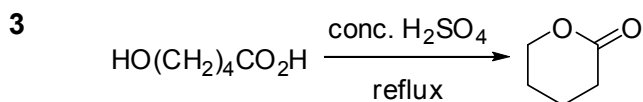
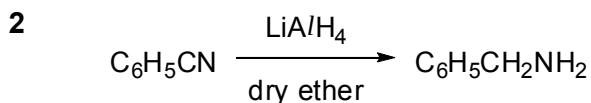
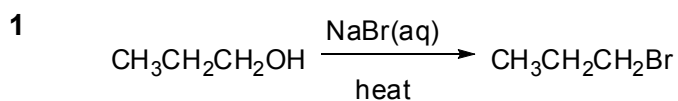
- 35** Binapacryl is used as a fungicide.



Based on the structure above, which of these statement(s) is/are true?

- 1** Its aqueous solution will be acidic
- 2** It exists in optically active forms
- 3** It decolourises aqueous bromine at room temperature

- 36** Which synthesis would **not** yield the product shown?



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

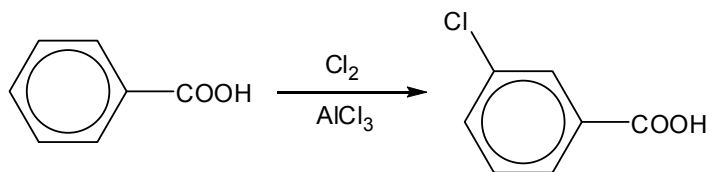
A	B	C	D
1, 2 and 3 are correct	1 and 2 are correct	2 and 3 are correct	Only 1 is correct

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

37 Which of the following pairs of reagents will give a water-soluble organic product when reacted together?

- 1** $\text{CH}_3\text{CH}_2\text{COOH}$ and LiAlH_4
- 2** $\text{CH}_3\text{CH}_2\text{COOH}$ and $\text{CH}_3\text{CH}_2\text{NH}_2$
- 3** $\text{C}_6\text{H}_5\text{NH}_2$ and aqueous HNO_3

38



Which of the following solvent(s) can be used for this reaction?

- 1** Tetrachloromethane
- 2** Benzene
- 3** Water

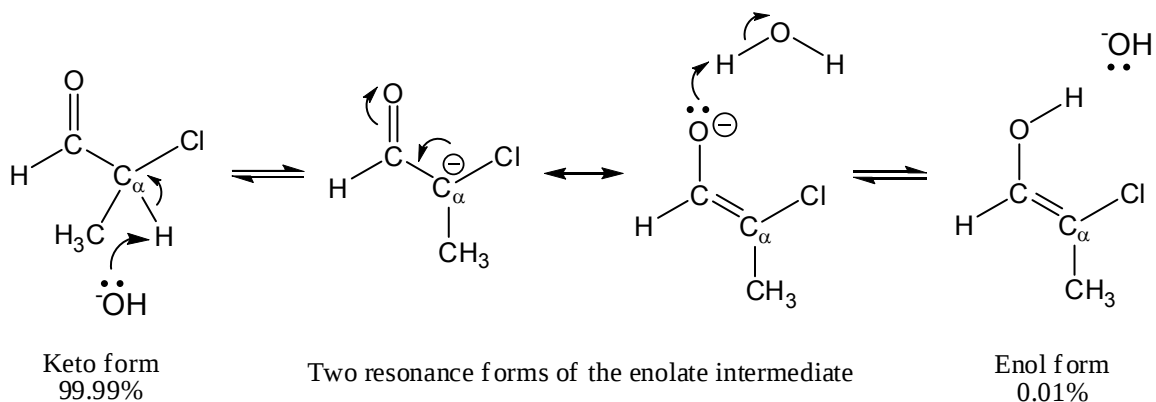
The responses **A** to **D** should be selected on the basis of

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

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

- 39** Carbonyl compounds which have an α -carbon undergo a rapid interconversion with its corresponding enol. This unique isomerism is known as tautomerism.

The mechanism for tautomerism of 2-chloropropanal is:



Which of the following statements can be deduced from the mechanism given above?

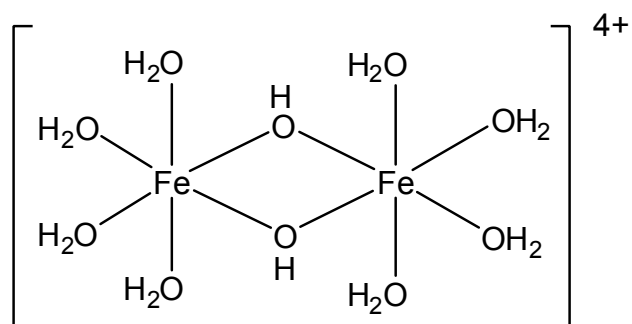
- The mechanism for tautomerism is base catalysed.
- The enolate intermediate is planar about the α -carbon.
- Optically pure 2-chloropropanal becomes a racemic mixture upon standing in aqueous sodium hydroxide solution.

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 are correct	2 and 3 are correct	Only 1 is correct

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

- 40** A bridging ligand is a ligand that connects two or more metal centres. The OH^- acts as a good bridging ligand to produce a bridged complex as shown below:



Which of the following deductions can be made from the structure of this bridged complex?

- 1** The bridged complex contains Fe in the +3 oxidation state.
- 2** OH^- is bonded to the metal centre through dative covalent bonds.
- 3** OH^- is a good bridging ligand since it contains more than one lone pair of electrons.

- End of Paper -