NAME		Class	

ST ANDREW'S JUNIOR COLLEGE

JC2 Preliminary Examination

H2 Chemistry (9729) **19 Sep 2019**

Paper 1 Multiple Choice **1 hour**

Additional Materials: Multiple Choice Answer Sheet, Data Booklet

READ THESE INSTRUCTIONS:

Write in soft pencil.

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

There are **thirty** 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 correct and record your choice in **soft pencil** on the separate Answer sheet.

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.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of **14** printed pages (including this page).

1 Which statement about one mole of sodium metal is always true?

A It has the same mass as one mole of ^{12}C.

B It has the same number of atoms as 18 g of water.

C It has the same number of atoms as $\frac{1}{12}$ mole of ^{12}C.

D It has the same number of atoms as 12 dm^3 of fluorine gas at r.t.p.

Ans: D
12/24 = 0.5 mol of F_2 = 1.0 mol of F atoms = 6.02 x 10^{23} H atoms

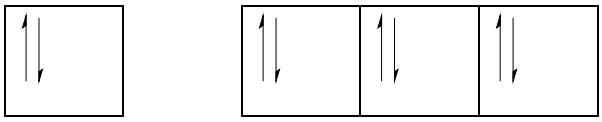
2 0.84 g of an oxide **M**O of a metal **M** was dissolved in excess sulfuric acid. 25.0 cm^3 of 0.12 mol dm^{-3} potassium manganate(VII) solution was required to oxidise $\mathbf{M^{2+}}$ to $\mathbf{M^{3+}}$.

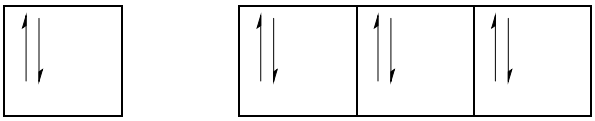
What is the relative atomic mass of **M**?

A 36.0 **B** 40.0 **C** 52.0 **D** 56.0

Ans: B
Amt of MnO_4^- = 25/1000 x 0.12 = 0.003 mol
Amt of e gained by MnO_4^- = Amt of e lost by M^{2+} = 5 x 0.003 = 0.015 mol
M_r of MO = 0.84/0.015 = 56
A_r of M = 56-16 = 40

3 **X** and **Y** are elements found in the first three periods of the Periodic Table. The outermost shell electronic configurations of two species are given as follows:

$\mathbf{X^{2-}}$: 

$\mathbf{Y^{2+}}$: 

What can best be deduced from the above information?

A **X** has a larger proton number than **Y**.

B **X** has more unpaired electrons than **Y** at the ground state.

C **X** exists as a gas while **Y** is a solid at standard condition.

D $\mathbf{X^{2-}}$ and $\mathbf{Y^{2+}}$ are isoelectronic.

Ans: B
Since **X** and **Y** are elements in the first three periods and their valence electronic configurations consist of s and p subshells, there are likely to be in period 2 or period 3.

X has the valence shell electronic configuration $ns^2\ np^4$ so it is a Group 16 element and it can be in Period 2 or Period 3. **X** can be O or S.
Y has the valence shell electronic configuration of $(n+1)s^2$ and it should be in Period 3. **Y** can be Mg.

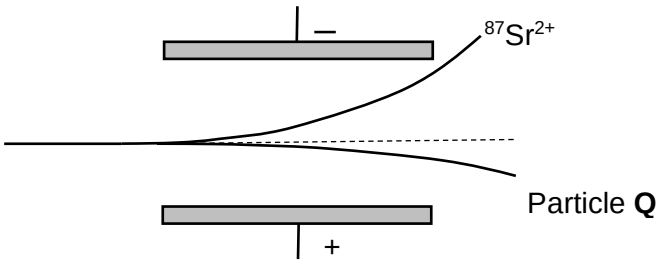
Option A: Since **Y** is Mg, X can have a smaller or larger proton than **Y**, depending on whether X is O or S

Option B: **X** would have 2 unpaired electrons while **Y** has no unpaired electrons.

Option C: **X** can be oxygen which is a gas but it may also be sulfur which is a solid at standard condition.

Option D: If **X** is S, S^{2-} is not isoelectronic with Mg^{2+}.

4 In an experiment, a sample of gaseous $^{87}Sr^{2+}$ was passed through an electric field. The angle of deflection for $^{87}Sr^{2+}$ was observed to be 2°.



The experiment was repeated with gaseous sample of particle **Q**.

Which of following could be **Q**?

A $^{74}As^{3-}$ **B** $^{19}F^{-}$ **C** $^{79}Se^{2-}$ **D** $^{127}Te^{2-}$

Ans: D

Angle of deflection = k(charge/mass)

k = 2 x 87/2 = 87

Angle of deflection of $^{74}As^{3-}$ = 87(3/74) = 3.5°

Angle of deflection of $^{19}F^{-}$ = 87(1/19) = 4.6°

Angle of deflection of Se^{-} = 87(2/79) = 2.2°

Angle of deflection of Te^{2-} = 87(2/127) = 1.4°

5 $BeCl_2$ reacts with CH_3NH_2 to form compound **Z** (M_r = 142.0).

Which of the following statements are correct?

1 The hybridisation state of N in **Z** is sp^3.

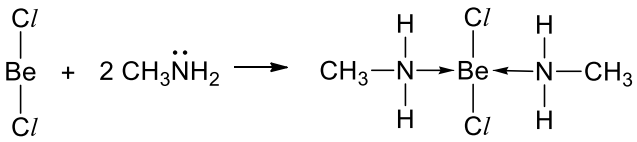
2 Hydrogen bonds exist between molecules of compound **Z**.

3 1 mol of compound **Z** is formed from 1 mol of $BeCl_2$ and 2 mol of CH_3NH_2.

A 1, 2 and 3 **B** 1 and 2 only

C 1 and 3 only **D** 3 only

Ans: C

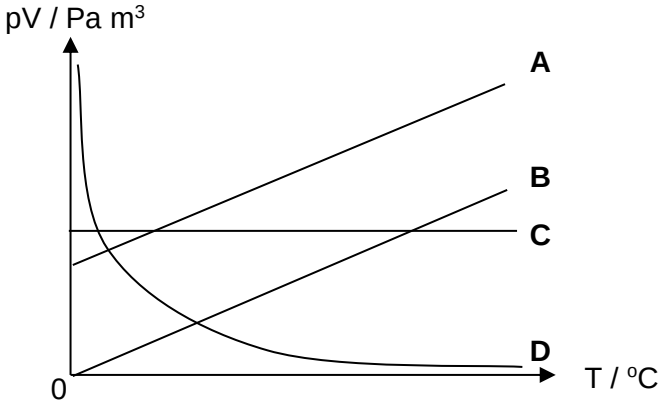


Option 1 is correct as N has a sp^3 hybridisation state and hence tetrahedral shape around N in compound **Z.**

Option 2 is wrong since there is no lone pair on the N after bonded to Be, hence between the molecules, H-bond no longer exist.

Option 3 is correct as Be in $BeCl_2$ has only 4 electrons and it can accommodate another 4 electrons to react octet configuration.

6 Which of the following graphs correctly describes the variation of pV with temperature for a fixed amount of an ideal gas?



Ans: A

pV = nRT. For an ideal gas, pV α T, hence straight line.

But since the scale is in ^oC, pV = 0 only when T = -273 ^oC.

7 The conversion of graphite into diamond is an endothermic reaction.

$$C(graphite) \longrightarrow C(diamond)$$

Which of the following statements are correct?

1 The carbon-carbon bonds in graphite are stronger than that in diamond.

2 The activation energy of the conversion of graphite to diamond is larger than that of the reverse reaction.

3 The enthalpy change of atomisation of diamond is less endothermic than that of graphite.

4 The enthalpy change of combustion of diamond is less exothermic than that of graphite.

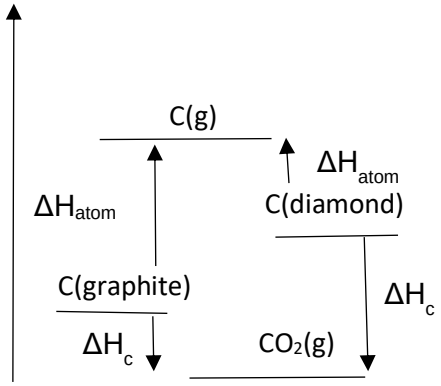
A 1 and 2 only **B** 1 and 3 only

C 1, 2 and 3 only **D** 1, 2 and 4 only

Ans: C

Option 1 is correct. Since ΔH > 0, C-C bond energy in graphite is higher than the C-C bond energy in diamond.

Option 2 is correct. Since ΔH > 0, the E_a of forward reaction is larger than that of backward reaction.



Option 3 is correct. ΔH_{atom} of diamond is less endothermic than that of graphite

Option 4 is incorrect: ΔH_c of diamond is more exothermic than that of graphite

8 Given the following enthalpy changes:

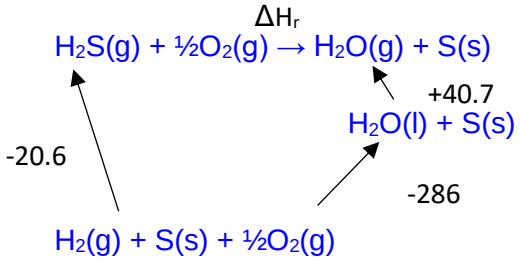
	ΔH / kJ mol^{-1}
Enthalpy change of formation of $H_2S(g)$	–20.6
Enthalpy change of formation of $H_2O(l)$	–286.0
Enthalpy change of vaporisation of $H_2O(l)$	+40.7

What is the enthalpy change (in kJ mol^{-1}) of reaction for the following reaction?

$$H_2S(g) + ½O_2(g) \rightarrow H_2O(g) + S(s)$$

A –224.7 **B** –265.4 **C** –306.6 **D** -347.3

Ans: A



ΔH_r = –286 + 40.7 + 20.6 = –224.7

9 Which equation corresponds to the enthalpy change stated?

A $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$ $\Delta H^{\theta}_{neutralisation}$

B $Na^+(s) + aq \rightarrow Na^+(aq)$ $\Delta H^{\theta}_{hydration}(Na^+)$

C $Al_2O_3(s) \rightarrow 2Al^{3+}(g) + 3O^{2-}(g)$ $\Delta H^{\theta}_{lattice\ energy}(Al_2O_3)$

D $O_2(g) \rightarrow 2O(g)$ $2\Delta H^{\theta}_{atomisation}(O_2)$

Ans: D

Option A: $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$ $2\Delta H^{\theta}_{neutralisation}$

Option B: $Na^+(g) + aq \rightarrow Na^+(aq)$ $\Delta H^{\theta}_{hydration}(Na^+)$

Option C: $2Al^{3+}(g) + 3O^{2-}(g) \rightarrow$ $Al_2O_3(s)$ $\Delta H^{\theta}_{lattice\ energy}(Al_2O_3)$

10 A chemical plant illegally dumped some radioactive waste in a landfill. This waste composed of two radioactive isotopes **X** and **Y**. The half-life of **X** is 4 days whereas that of **Y** is 2 days. The authorities found out about this illegal dumping only when the waste had been in the landfill for 8 days. They did an immediate analysis on a sample of the waste and found equal amounts of **X** and **Y**.

Considering that the decay of radioactive isotopes follows first-order kinetics, what is the initial molar ratio of **X** to **Y** if the waste had been in the landfill for 4 days?

	X	:	**Y**
A	1	:	2
B	1	:	4
C	2	:	1
D	4	:	1

Ans: A

Day	0	1	2	3	**4**	5	6	7	8
X	4x				**2x**				x
Y	16x		8x		**4x**		2x		x

X:Y = 2x: 4x = 1x : 2x =1:2

11 Hydrogen reacts with nitrogen monoxide to form nitrogen and steam only. The rate equation for this reaction is rate = $k[NO]^2[H_2]$.

Which could be the mechanism for this reaction?

A

$NO + 2H_2 \xrightarrow{slow} NH_2 + H_2O$

$NH_2 + NO \rightarrow N_2 + H_2O$

B

$$2NO \xrightarrow{\text{slow}} N_2 + O$$

$$2H_2 + O \rightarrow 2H_2O$$

C

$$2NO + H_2 \xrightarrow{\text{slow}} N_2 + H_2O_2$$

$$N_2 + 2H_2 \rightarrow N_2H_4$$

D

$$2NO + H_2 \xrightarrow{\text{slow}} N_2O + H_2O$$

$$N_2O + H_2 \rightarrow N_2 + H_2O$$

Ans: D

$$2NO + H_2 \xrightarrow{\text{slow}} N_2O + H_2O$$

$$N_2O + H_2 \rightarrow N_2 + H_2O$$

Overall: $2NO + 2H_2 \rightarrow N_2 + 2H_2O$

Rate: $k\,[NO]^2[H_2]$

Option A is wrong since Rate = $k\,[NO][H_2]^2$

Option B is wrong since rate= $k[NO]^2$

Option C is wrong since the products formed are N_2H_4 and H_2O_2 instead.

12 The table below shows the values of the ionic product of water, K_w, at two different temperatures.

Temperature / °C	K_w / mol^2 dm^{-6}
25	1.00×10^{-14}
60	1.00×10^{-13}

Which of the following statements is correct for pure water?

A The ionic dissociation of water is an exothermic process.

B At 60 °C, the pH is less than 7.

C At 60 °C, the pH is more than the pOH.

D At 60 °C, the solution becomes more acidic.

Ans: B

As K_w increases with increasing temperature, the rate constant of forward reaction increases more than the rate constant of the backward reaction, hence the forward reaction is endothermic and not exothermic. Option A is wrong.

pK_w at 60°C = -log K_w = 13
Hence, pH + pOH = 13, hence pH = 6.5
Option B is correct.

13 The numerical value of the equilibrium constant, K_c, for the following reaction at 25°C is 1.2×10^5.

$$CO\,(g) + 2H_2(g) \rightleftharpoons CH_3OH\,(g) \qquad \Delta H^{\ominus} < 0$$

Which statements about the reaction is correct?

1 The units for K_c is $mol^{-1}dm^3$.

2 $\Delta G^{\ominus}$ is less than zero.

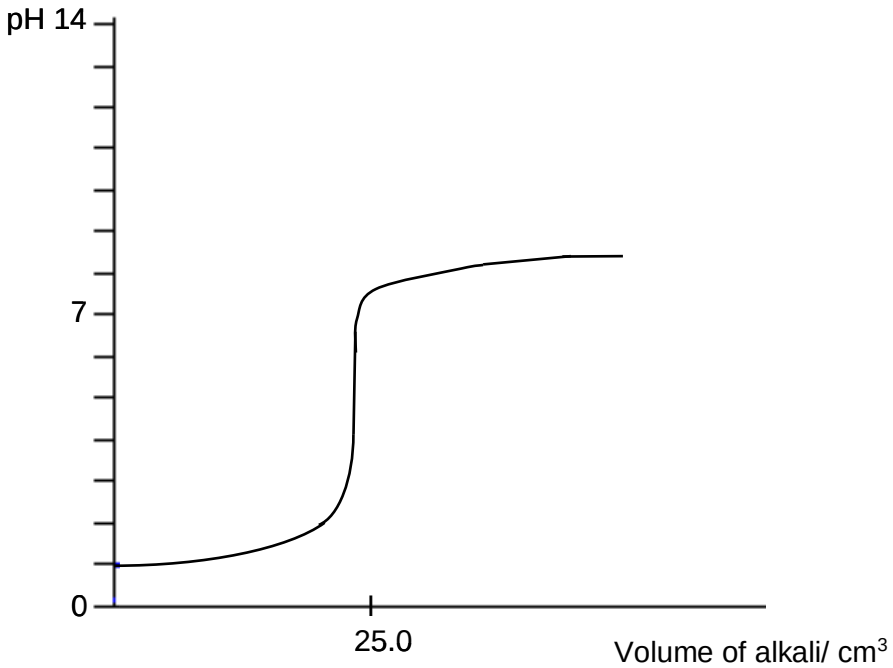
3 The equilibrium position shifts when an inert gas is added at constant volume.

A 1 and 3 only **B** 2 only

C 2 and 3 only **D** 1, 2 and 3

Ans: B
Option 1 is wrong since the units is $mol^{-2}dm^6$.
Option 2 is correct. $K_c >> 1$, hence $\Delta G^{\ominus} < 0$ (Correct)
Or $\Delta G^{\ominus} = -RT\ln K = -(8.31)(298)\ln(1.2X10^5) = -29$ kJ mol^{-1}.
Option 3 is wrong. At constant volume, the addition of an inert gas DOES NOT AFFECT the partial pressure of the reacting gases, even though the total pressure increases. Hence there is NO shift of the equilibrium position.

14 The graph shows the change in pH when an alkali is gradually added to 25 cm^3 of an acid.



Which of the following statements about the titration is correct?

A Acidic buffer is formed after the equivalence point.

B Both phenolphthalein and methyl orange can be used as the indicator for this titration.

C This is a titration between 0.10 mol dm^{-3} of HC*l*(aq) and 0.10 mol dm^{-3} of NH_3(aq).

D The maximum buffer capacity occurs when 12.5 cm^3 of alkali is added.

Ans: C

Option A: Basic buffer occurs after the equivalence point.

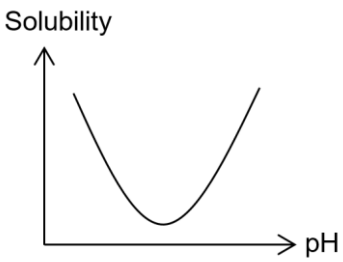
Option B: Only methyl orange is suitable for a strong acid- weak base titration.

Option C: Strong acid-weak base titration leads to an acidic salt.
pH of equivalence point is less than 7. (Correct)

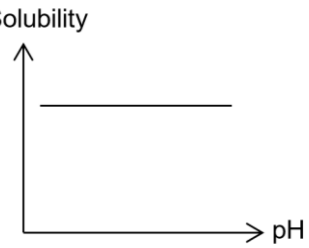
Option D: Since this is a SA-WB titration, MBC occurs at $2V_{equilvalence}$ instead of $½V_{equivalence}$.

15 CaF_2 is a sparingly soluble salt and is added to a weakly acidic solution of HF. The pH of the solution is adjusted by adding NaOH. Which diagram shows how the solubility of CaF_2 will vary with the pH of the solution at constant temperature?

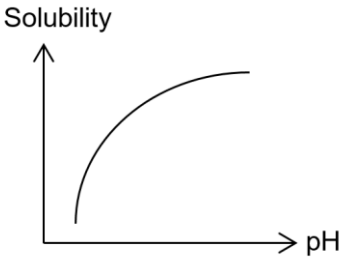
A



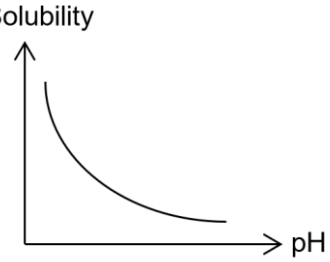
B



C



D



Ans: D
CaF_2 (s) $\rightleftharpoons$ Ca^{2+} (aq) + $2F^-$(aq) ----Eqm 1
HF (aq) $\rightleftharpoons$ H^+ (aq) + F^-(aq) ---- Eqm 2
When pH is very high, the H^+ is neutralised by the OH^-, hence eqm 2 is shifted to RHS to produced more F^-. This will cause the POE of Eqm 1 to shift to LHS, reducing the solubility of CaF_2 (s).

16 Why is ethanoic acid a stronger acid in liquid ammonia than in aqueous solution?

A Ammonium ethanoate is completely ionised in aqueous solution.

B Ammonium ethanoate is strongly acidic in aqueous solution.

C Ammonia is a stronger base than water.

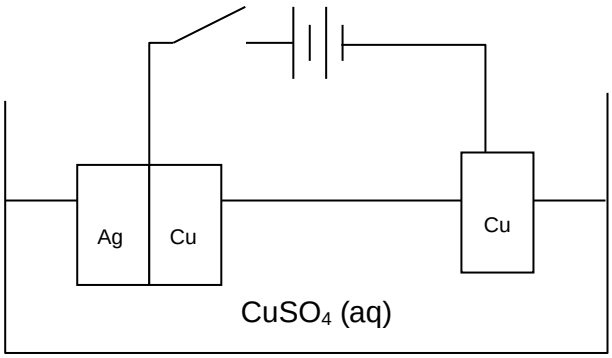
D Liquid ammonia is more polar solvent than water.

Ans: C

A more basic solvent is able to extract the H^+ more readily and therefore increase the strength of the acid.

17 Use of *Data Booklet* is relevant to this question.

The following circuit with a switch was set up as shown in the diagram:



Which electrode reactions will occur when the switch is closed?

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

Ans : B

Cu has a more negative $E^{\ominus}$ value than Ag would oxidise preferentially to form Cu^{2+};

Cu^{2+} has a more positive $E^{\ominus}$ value than H_2O, would be preferentially reduced to form Cu.

18 Some relevant redox half-equations are given below:

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$ $\quad E^{\ominus} = +1.33$ V

$S + 2H^+ + 2e^- \rightleftharpoons H_2S$ $\quad E^{\ominus} = +0.14$ V

Which of the following statements are true when hydrogen sulfide is bubbled into acidified aqueous sodium dichromate(VI)?

1 The solution turns orange to green.

2 White precipitate is observed.

3 The reaction has a positive entropy change.

A 1 only **B** 1 and 2 only

C 1, 2 and 3 **D** None of the statements are true

Ans: A

$E^{\ominus}_{cell}$ = +1.33 – (+0.14) = +1.19 V
Since $E^{\ominus}_{cell}$ > 0 V, the reaction between acidified aqueous sodium dichromate(VI) and hydrogen sulfide is thermodynamically feasible.
Option 1 is correct

Option 2 is wrong since S appears as yellow solid.

Option 3 is wrong since there is a decrease in number of gas molecules and hence entropy change should be negative.

19 Elements **X**, **Y** and **Z** are in Period 3 of the Periodic Table.

- The oxide of **X** gives an aqueous solution of pH less than pH 7.
- The oxide of **Y** reacts with both strong acids and strong alkalis.
- The oxide of **Z** gives an aqueous solution which is strongly alkaline.

What is the order of increasing atomic radius for these elements?

A **X** < **Y** < **Z**

B **X** < **Z** < **Y**

C **Y** < **Z** < **X**

D **Z** < **Y** < **X**

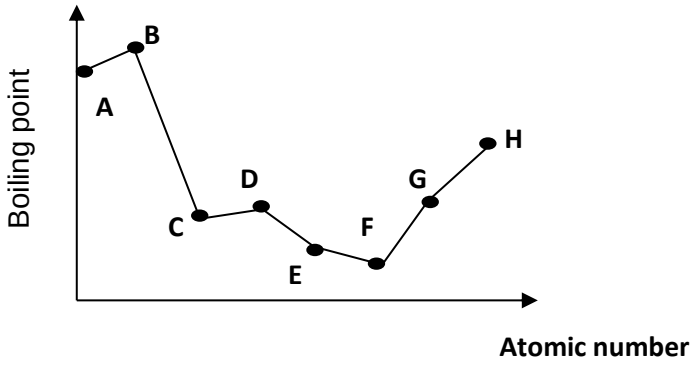
Ans: A

X could be phosphorus(0.110)/sulfur(0.104)

Y is aluminum (0.143nm)

Z is sodium (0.186 nm)

20 The graph below shows the variation in the boiling points for eight consecutive elements in the Periodic Table, all with atomic number between 10 and 20.



Which of the following statements is correct?

A Element **G** does not conduct electricity.

B Element **D** forms only one acidic oxide.

C Element **A** and beryllium are in the same group

D Element **C** forms a chloride which hydrolyse readily to give a strongly acidic solution.

Ans : D

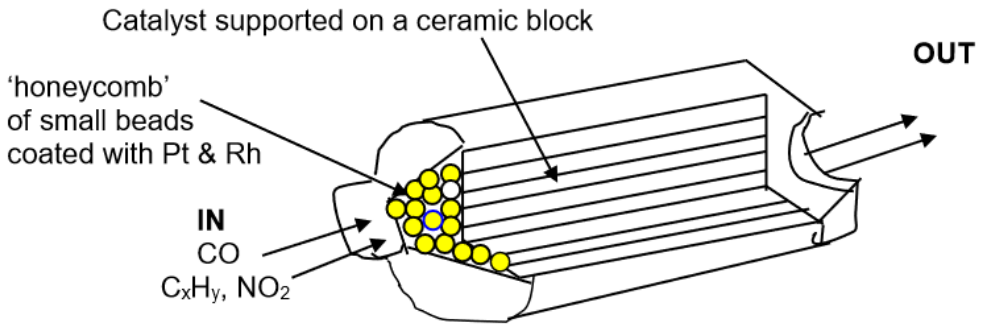
Option A: Element G is potassium, it can conduct electricity.

Option B: Element D is sulfur, it forms more than one acidic oxide (SO_2, SO_3).

Option C: Element A is aluminium, it is in Group 13.

Option D: Element C is phosphorus, its chloride hydrolyse completely to give HCl and H_3PO_4.

21 A catalytic converter is part of the exhaust system in modern cars.



Which of the following statements are true concerning the reactions and processes in the catalytic converter?

1 $CO_2 + NO \rightarrow CO + NO_2$

2 $2CO + 2NO \rightarrow 2CO_2 + N_2$

3 $C_xH_y + (2x + \frac{y}{2})NO \rightarrow xCO_2 + \frac{y}{2}H_2O + (x + \frac{y}{4})N_2$

4 Platinum and rhodium catalyse the reactions

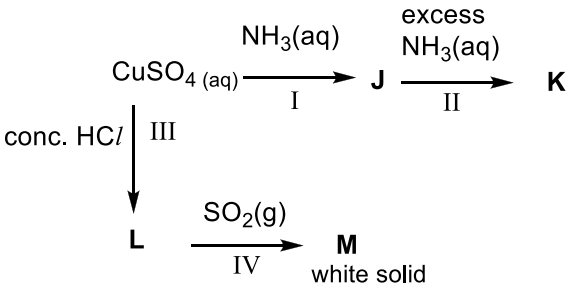
A 1, 2, 3 and 4 **B** 1 and 2 only

C 2 and 3 only **D** 2, 3 and 4 only

Ans: D

Option 1 is wrong as CO and NO_2 are pollutants.

22 Copper(II) sulfate solution reacted as shown in the scheme below.



Which of the following statements are correct?

1 NH_3 functions as a ligand in reaction I.

2 The coordination number of complex **L** is 4.

3 The oxidation number of Cu in **M** is +1.

A 1, 2 and 3 **B** 1 and 2 only

C 1 and 3 **D** 2 and 3 only

Ans: D

Option 1 is incorrect as NH_3 acts as a base.

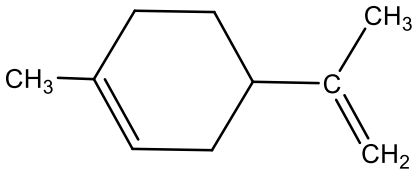
Option 2 is correct as metal complex in **L** $[CuCl_4]^{2-}$,coordination number 4.

Option 3 is correct.

$2[CuCl_4]^{2-} + SO_2 + H_2O \rightarrow CuCl\,(s) + 6Cl^- + SO_4^{2-} + 4H^+$

White solid is CuCl.

23 Limonene is an oil formed in the peel of citrus fruits.

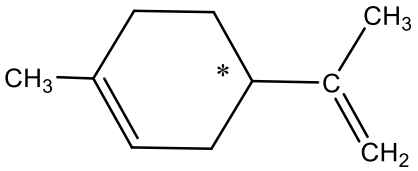


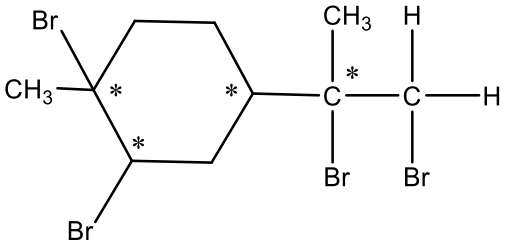
Limonene

When limonene reacts with excess bromine at room temperature in the dark, how many **more** chiral centers than limonene does the product molecule have?

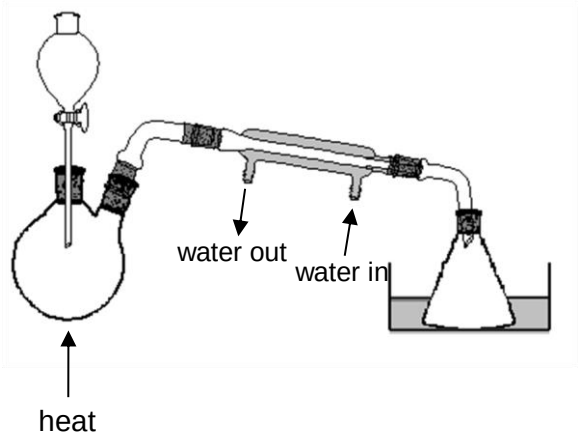
A 2 **B** 3 **C** 4 **D** 5

Ans: B





24 The diagram below shows some laboratory apparatus.



Which preparations could this apparatus be used for?

A 1,2-dibromoethane from ethene and bromine

B ethanal from ethanol, sodium dichromate(VI) and sulfuric acid

C propanone from propan-1-ol, sodium manganate(VII) and sulfuric acid

D butan-2-ol from butanone, lithium aluminum hydride in dry ether

Ans : B

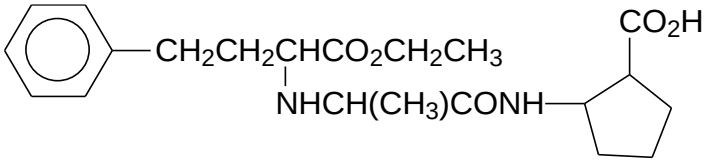
Option A is wrong since ethene is a gas, could not be prepared by heating under reflux.

Option B is correct ethanal could be prepared by heating under reflux with ethanol followed by distillation of ethanal which has a lower boiling point than ethanol.

Option C is wrong since propanone should be prepared from propan-2-ol instead of propan-1-ol,

Option D is wrong since butan-2-ol has a higher boiling point than butanone and would not be distill out first.

25 A prodrug is a molecule that can be converted into its active form in the body. An example is *Enalapril*, as shown below. The active form of *Enalapril* can be formed when enzymes in the body hydrolyse the esters found on the molecule.



Enalapril

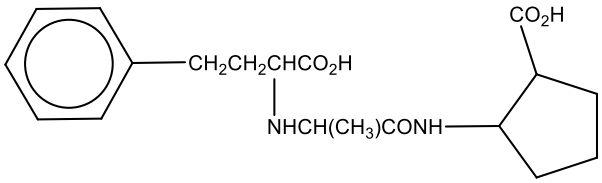
Which of the following is **not** true about *Enalapril*?

A *Enalapril* turns orange aqueous $K_2Cr_2O_7$ green when heated in an acidic medium.

B *Enalapril* does not react with 2,4–dinitrophenylhydrazine.

C *Enalapril* reacts with two moles ethanoyl chloride.

D The active form of *Enalapril* has the structure



Ans: C

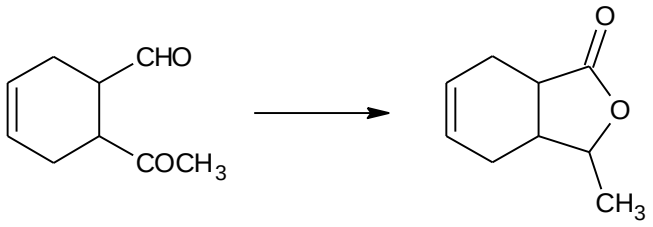
Option A: The ester in Enalapril can be hydrolysed when heated with acid and ethanol formed will be oxidised to ethanoic acid by $K_2Cr_2O_7$

Option B: No carbonyl group present.

Option C: There is only one amine group present hence it requires only 1 mol of ethanoyl chloride to react with to form amide.

Option D: The active form of *Enalapril* can be formed when enzymes in the body hydrolyse esters to form the above structure.

26 Compound **V** can be converted to compound **W** in three stages.



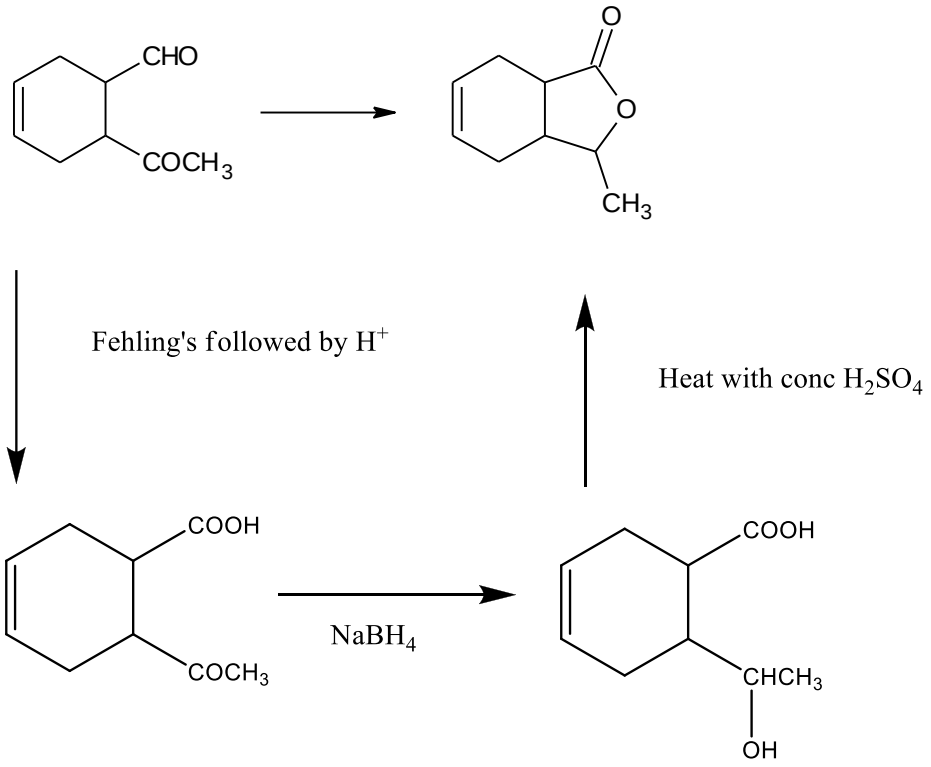
Compound **V** Compound **W**

Which sequence of reagents and conditions can be used to carry out this conversion?

	Stage 1	**Stage 2**	**Stage 3**
A	hot acidified $KMnO_4$	H_2 with Pt catalyst	heat with dilute H_2SO_4
B	hot acidified $K_2Cr_2O_7$	$NaBH_4$ in ethanol	heat with dilute H_2SO_4

C	hot Fehling's reagent, followed by acidification	$NaBH_4$ in ethanol	heat with a few drops of conc. H_2SO_4
D	hot Tollens' reagent, followed by acidification	LiA/H_4 in dry ether	heat with a few drops of conc. H_2SO_4

Ans: C

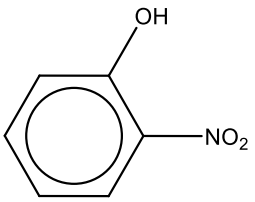


Note that $KMnO_4$ cannot be used in stage as it will oxidise alkene. LiA/H_4 will reduce carboxylic acid as well hence it cannot be used in stage 2. H_2SO_4 must be in conc form for the ester to form.

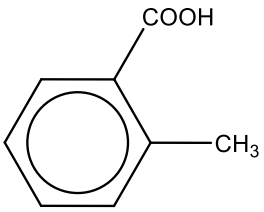
27 Phenol has a pK_a of 10.0.

Which one of the following has a higher pK_a value than phenol?

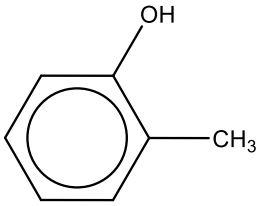
A



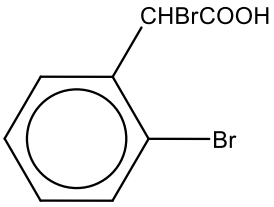
B



C



D

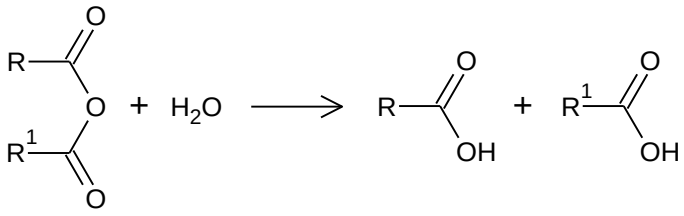


Ans: C

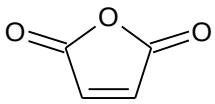
Higher pK_a implies less acidic than phenol and C is has an electron-donating $–CH_3$ group and hence the negative charge on O of the phenoxide conjugate base would be dispersed to a lesser extent.

The conjugate base is less stable, hence compound C is less acidic than phenol.

28 An acid anhydride is a carboxylic acid derivative that undergoes hydrolysis in water similar to acyl chlorides and esters. A mixture of carboxylic acids is produced in the case of the anhydride.



Based on the information above, which of the following can be deduced when maleic anhydride undergoes hydrolysis in the presence of water labelled with the ^{18}O isotope?



maleic anhydride

A The resulting product is non-planar.

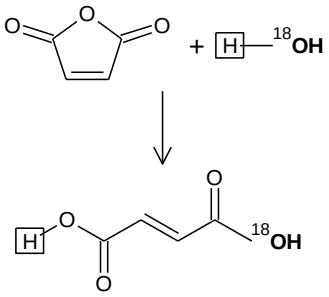
B The product is labelled with the ^{18}O isotope.

C Two carboxylic acid molecules are produced for every molecule of maleic anhydride.

D The reaction is faster than when maleic anhydride undergoes hydrolysis in the presence of water labelled with the ^{16}O isotope.

Ans: B

Option B: One ^{18}O atom from heavy water is inserted into every product molecule of maleic anhydride hydrolysis.



Option C is wrong since a single dicarboxylic acid molecule is produced for every molecule of maleic anhydride hydrolysed.

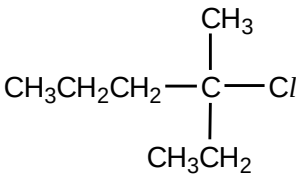
Option A is wrong as the resulting product is planar since the C are all sp^2 hybridised.

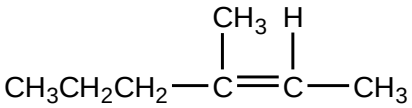
Option D: not enough information is given to deduce that.

29 Which of the following reactions will **not** form a racemic mixture of products?

A CH_3COCH_3 with HCN in trace amounts of NaOH

B $CH_3CH_2CH_2COCH_3$ with HCN in trace amounts of NaCN

C  with KOH(aq), heat under reflux

D  with HBr(g)

Ans: A

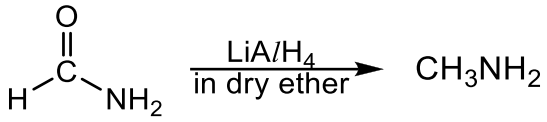
Option A: Product formed does not have chiral carbon.

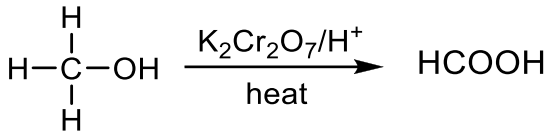
Option B: Nucleophile can attack the trigonal planar carbonyl carbon from either side.

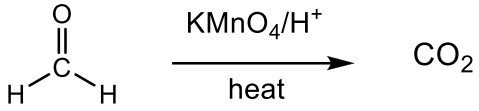
Option C: S_N1 reaction so a trigonal planar intermediate formed as it is a 3° alkyl halide

Option D: Carbocation intermediate is trigonal planar so Br^- can attack from the top or front

30 In which reaction will the oxidation number of carbon change by 4?

1 

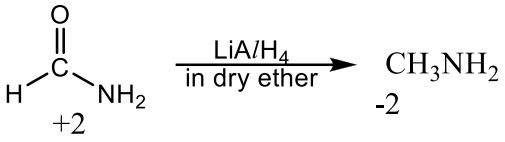
2 

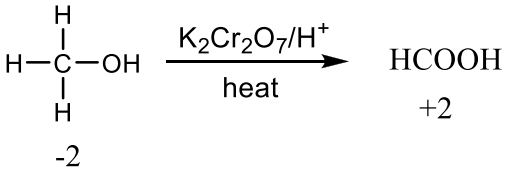
3 

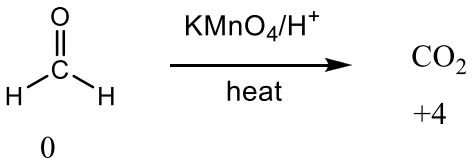
A 1, 2 and 3 **B** 2 only

C 1 and 3 only **D** 1 only

Ans: A







End of Paper