NATIONAL JUNIOR COLLEGE
SH2 TIMED PRACTICE
Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY **9476/01**
Paper A Multiple Choice **16 July 2026**
1 hour

Additional Materials: Optical Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.

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.

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.
The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

Instructions on how to fill in the Optical Mark Sheet
Shade the index number in a 5 digit format on the optical mark sheet:
2nd digit and the last 4 digits of the Registration Number.

Example:

Student	Examples of Registration No.	Shade:
	2505648	**55648**

This document consists of **14** printed pages.

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

Which sample of gas contains twice the number of atoms as 4 g of helium gas, He?

A 4 g of hydrogen, H_2

B 8 g of methane, CH_4

C 12 g of steam, H_2O

D 22 g of carbon dioxide, CO_2

Answer: C

	Molar mass / g mol^{-1}	Moles	No. of atoms per molecule	total moles of atoms	
4 g of He	4	$\frac{4}{4} = 1$	**1**	1	Twice the no.of He atoms = **2 moles of atoms**.
A. 4 g H_2	**2**	$\frac{4}{2} = 2$	**2**	$2 \times 2 = 4$	✗
B. 8 g CH_4	**15**	$\frac{8}{16} = 0.5$	**5**	$0.5 \times 5 = 2.5$	✗
C. 12 g H_2O	**18**	$\frac{12}{18} = \frac{2}{3}$	**3**	$\frac{2}{3} \times 3 = 2$	☑
D. 22 g CO_2	12 + 32 = 44	$\frac{22}{44} = 0.5$	**3**	$0.5 \times 3 = 1.5$	✗

2 The isotope of an element has a nucleon number of 112. It forms an ion with a charge of +2 with the electron configuration [Kr]$4d^{10}$.

How many protons, neutrons, and electrons are present in this ion?

A 46 protons, 66 neutrons, 44 electrons

B 46 protons, 66 neutrons, 46 electrons

C 48 protons, 64 neutrons, 46 electrons

D 48 protons, 64 neutrons, 44 electrons

Answer: C

[Kr] $= 36$ electrons, plus $4d^{10} = 10$ electrons → ion has 46 electrons.

- Charge $+2$ → neutral atom has 48 electrons → atomic number (proton no.) 48 (cadmium).
- Nucleon number 112 → neutrons = $112 - 48 = 64$.
- Ion electrons = 46 (as above).

3 An element **R** consists of four isotopes. The table below shows the percentage abundance of the isotopes.

Relative isotopic mass	Percentage abundance /%
90.0	50.0
91.0	10.0
92.0	20.0
94.0	20.0

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

A 91.00 **B** 91.30 **C** 91.75 **D** 92.00

Answer: B

Relative atomic mass of **R** = $90\left(\frac{50}{100}\right) + 91\left(\frac{10}{100}\right) + 92\left(\frac{20}{100}\right) + 94\left(\frac{20}{100}\right) = 91.30$

4 An element **X** has the following successive ionisation energies.

	1st	2nd	3rd	4th	5th
Ionisation energy /kJ mol^{-1}	786	1580	3230	4360	16000

Given that the oxide of **X** is acidic and is insoluble in water, which statement about **X** is correct?

A **X** is a gas at room temperature.

B **X** forms a chloride with a formula **X**Cl_5.

C The oxide of **X** has a linear shape with no dipole moment.

D The oxide of **X** has a giant covalent lattice with a high melting point.

Answer

D is correct.

- **From IE data:** A large jump after 4th IE (4360 → 16000) indicates that X has **4 valence electrons** → **Group 14**. Hence **option B** incorrect where **X** is in Group 15.

oxide data strongly points to Silicon (Si), whose oxide SiO_2 is:

  - Acidic (reacts with bases to form silicates)
  - Insoluble in water
  - Giant covalent lattice with high melting point

- **Option A** is incorrect as silicon is a **solid** at room temperature (metalloid, melting point 1414°C).

- **Option C** is incorrect as the oxide of silicon is **SiO_2**.
  - SiO_2 does **not** exist as discrete molecules. SiO_2 has a **giant covalent lattice**.
  - Therefore, it does not have a "linear shape" or "dipole moment".
  - (CO_2 is linear and non-polar, but CO_2 is soluble, so it's excluded by the oxide data.)

5 Which option correctly describes the shape and polarity of the species?

	species	shape	polarity
A	$AlCl_3$	trigonal planar	polar
B	SiF_4	square planar	non-polar
C	BrF_3	trigonal pyramidal	polar
D	$BeCl_2$	linear	non-polar

Answer: D

	species	shape	polarity
A	$AlCl_3$	trigonal planar (3 b.p.)	non-polar
B	SiF_4	tetrahedral (4 b.p.)	non-polar
C	BrF_3	T shaped (3 b.p. + 2 l.p.)	polar
D	$BeCl_2$	Linear (2 b.p.)	non-polar

6 When 10 cm^3 of a gaseous hydrocarbon was sparked with excess oxygen gas and cooled to room temperature, the gaseous mixture contracted by 30 cm^3. When the residual gas was passed through aqueous potassium hydroxide, there was a further contraction of 40 cm^3.

What is the hydrocarbon?

A C_3H_8

B C_4H_8

C C_4H_6

D C_4H_{10}

Answer: B

$$C_xH_y + \left(x + \frac{y}{4}\right) O_2 \rightarrow x\ CO_2 + \frac{y}{2} H_2O$$

Second contraction (40 cm^3) = volume of CO_2 absorbed by KOH

CO_2 volume = 40 cm^3 = **(10x)** cm^3 of hydrocarbon

x = 4

First contraction (30 cm^3) = volume decrease after burning and cooling (H_2O, water condenses)

[V(C_xH_y) + $V(O_2)$] – [$V(CO_2)$ + $V(H_2O)$] = 30

[10 + $V(O_2)$] – [40 + 0)] = 30

$V(O_2) = 60$

hence $x + \frac{y}{4} = 6$

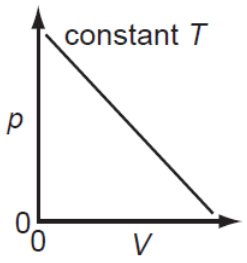
$4 + \frac{y}{4} = 6$

$\Rightarrow \boldsymbol{y = 8}$

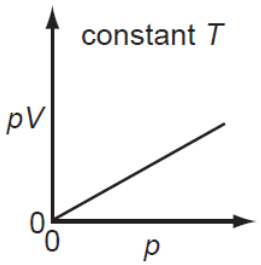
Formula: C_4H_8

7 Which diagram correctly describes the behaviour of a fixed mass of an ideal gas? (T is measured in K.)

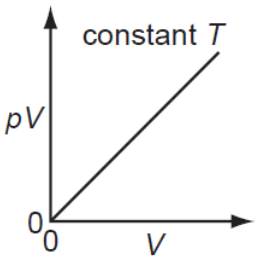
A



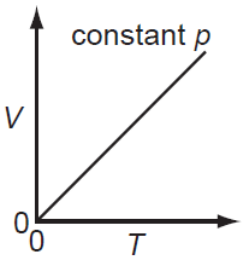
B



C



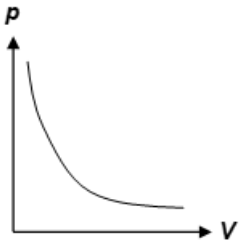
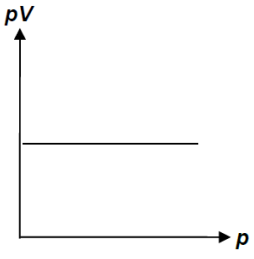
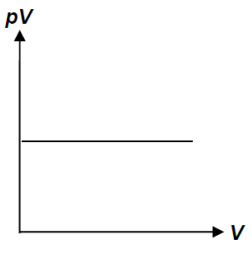
D



Answer: D

pV= nRT

for a fixed mass of an ideal gas, number of moles of gas is constant, n is constant

A	B	C	D
p = $\frac{nRT}{V} = \frac{constant}{V}$ since constant n, constant R, constant T → nRT = constant	pV= nRT = constant since constant n, constant R, constant T → nRT = constant		pV = nRT $V = \frac{nRT}{P} = \frac{nR}{P}T$ since constant n, constant R, constant P $V \propto T$
Correct graph 	Correct graph 	Correct graph 	Answer

8 Liquefaction can be defined as a process that turns a gas into a liquid by increasing the pressure at a constant temperature. In the liquefaction of CH_4 and NH_3, the pressure needed for NH_3 is less than CH_4.

Which reason best explains this observation?

A NH_3 has stronger intermolecular forces of attraction than CH_4.

B NH_3 has lower bond energy than CH_4.

C NH_3 molecules are bigger than CH_4 molecules.

D NH_3 molecules possess less kinetic energy than CH_4 molecules.

Answer: A

The process of liquefaction is making the gas molecules come closer together via pressurisation. If the intermolecular forces between the molecules are stronger, the pressure required would be less.
Since NH_3 has hydrogen bonds between molecules and is stronger than instantaneous dipole-induced dipoles interactions between CH_4 molecules, less pressure needed for NH_3 to undergo liquefaction.

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

Hexamine has an enthalpy change of combustion of –4288 kJ mol^{-1}.

12.4 g of hexamine tablets were burnt to heat up 850 g of water. Given that the process was 75% efficient and temperature of the water increased from 10°C to 90°C, what is the molar mass of hexamine?

A 124.7 g mol^{-1}

B 140.3 g mol^{-1}

C 187.1 g mol^{-1}

D 249.4 g mol^{-1}

Answer: B

Heat absorbed by water, $q = mc\Delta T = 850 \times 4.18 \times 80 = 284240$ J $= 284.24$ kJ
Heat actually released by burning hexamine = $\frac{284.24}{75} \times 100 = 378.99$ kJ
Moles of hexamine burnt, $n = \frac{378.99}{4288} = 0.08838$ mol
Molar mass of hexamine, $M = \frac{12.4g}{0.08838\ mol} \approx 140.3$ g mol^{-1}

10 *Use of Data Booklet is relevant to this question.*
Nitrous oxide, N_2O, commonly known as laughing gas, contains one N=N bond and one N=O bond per molecule. It burns in ethyne, HC≡CH, to produce water vapour, carbon dioxide and nitrogen gas as the only products.

$$5N_2O(g) + C_2H_2(g) \rightarrow H_2O(g) + 2CO_2(g) + 5N_2(g)$$

By making use of the following data:

	Bond energy / kJ mol^{-1}
N=N	418
N=O	686

Calculate the enthalpy change of the above reaction.

A +1930 kJ mol^{-1}

B +2260 kJ mol^{-1}

C –1680 kJ mol^{-1}

D –3980 kJ mol^{-1}

Answer: **C**

$$5N=N=O(g) + H–C≡C–H(g) \rightarrow H–O–H(g) + 2O=C=O(g) + 5N≡N(g)$$

ΔH

= [5BE(N=N) +5BE(N=O)+2BE(C–H) + BE(C≡C)] – [(2BE(O–H) + 4BE(C=O) + 5BE(N≡N)]

= [5(418) + 5(686) + 2(410) + (840)] – [(2(460) + 4(805) + 5(944)]

= – 1680 kJ mol^{-1}

11 Using the enthalpy changes below, calculate the standard enthalpy change of formation of gaseous hydrogen chloride.

	enthalpy change/ kJ mol^{-1}
$N_2(g) + 3\ H_2(g) \rightarrow 2NH_3(g)$	–92
$N_2(g) + 4\ H_2(g) + Cl_2\ (g) \rightarrow 2NH_4Cl\ (s)$	–629
$NH_3(g) + HCl\ (g) \rightarrow\ NH_4Cl\ (s)$	–176

A – 46.3kJ mol^{-1}

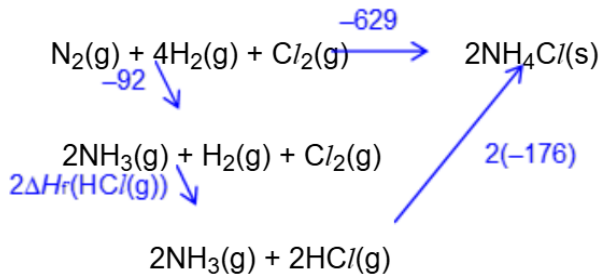
B – 92.5 kJ mol^{-1}

C –180 kJ mol^{-1}

D – 361 kJ mol^{-1}

Answer: B

Method 1: Draw energy cycle



$-629 = -92 + 2\Delta H_f(HCl(g)) + 2(-176)$

$\Delta H_f(HCl(g)) = -92.5$ kJ mol^{-1}

Method 2: Use formula

$$\Delta H_r = \sum \Delta H_f\,(products) - \sum \Delta H_f\,(reactants)$$

$\Delta H_r = \Delta H_f\,(NH_4Cl)\,) - [\Delta H_f\,(NH_3) + \Delta H_f\,(HCl)]$

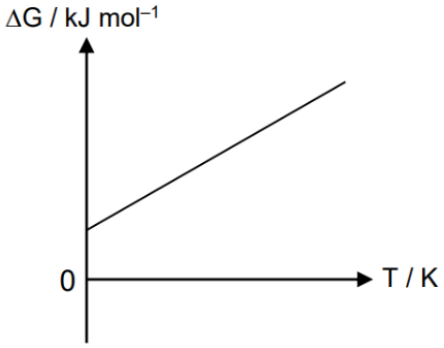
$-176 = ½\,(-629) - [\,½\,(-92) + \Delta H_f\,(HCl)]$

$\Delta H_f\,(HCl) = -92.5$ kJ mol^{-1}

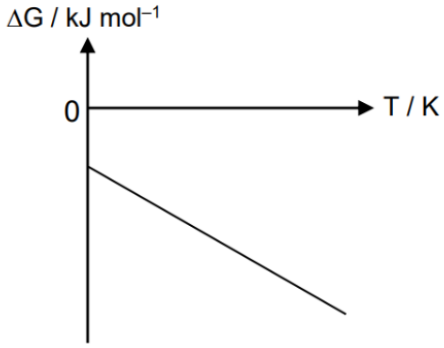
12 Which graph corresponds to the combustion of liquid ethanedioic acid, $(COOH)_2$ at increasing temperature (before the boiling point of water)?

$$(COOH)_2(l) + ½\ O_2(g) \rightarrow 2CO_2(g) + H_2O\ (l)$$

A



B



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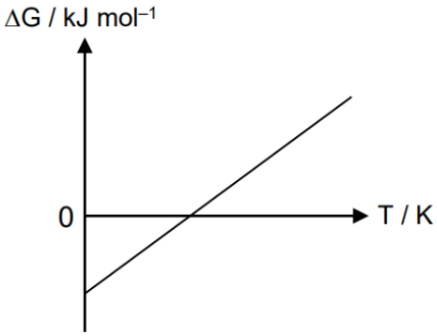
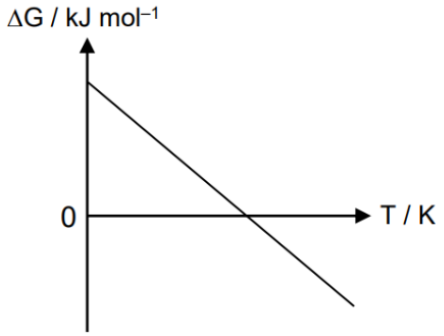


D



Answer: B

Combustion reaction is exothermic, ∴ $\Delta H < 0$.

$\Delta S > 0$ since there is increase in number of gas particles upon reaction.

i.e. 2 mol of gas products from ½ mol of gas reactant.

Since $\Delta G = \Delta H - T\Delta S$ and $\Delta H < 0$ and $\Delta S > 0$,

$\Delta G < 0$ for all temperatures as the physical states of $(COOH)_2(l)$ and $H_2O(l)$ remain unchanged with increasing temperatures (as stated in Question "before the boiling point of water").

$\Delta G = \Delta H - T\Delta S$ ➔ $\Delta G = -\Delta S\ T + \Delta H$

$$y = m x + c$$

hence gradient = $-\Delta S$ = negative (since $\Delta S > 0$)

y-intercept, c = ΔH = negative value (since $\Delta H < 0$)

13 The rate equation for a reaction is: rate = k[**P**]²[**Q**].
If the concentration of **P** is tripled and the concentration of **Q** is halved, what would be the new rate compared to the original rate?

A 1.5 times **B** 3 times **C** 4.5 times **D** 9 times

Answer: C

New rate = k([3**P**]² [½**Q**]) = k × 9[**P**]² × ½[**Q**]

= 4.5 × original rate.

14 Crotonaldehyde, $CH_3CH=CHCHO$, can be obtained by oxidising butadiene, $CH_2=CHCH=CH_2$, using air or oxygen. One method is to pass a mixture of butadiene and oxygen through a hot aqueous solution of palladium(II) ions, $Pd^{2+}(aq)$, which catalyses the reaction.

Which statements are correct about the action of the $Pd^{2+}(aq)$ ions?

1 Changing the concentration of $Pd^{2+}(aq)$ will have an effect on the rate of the reaction.

2 $Pd^{2+}(aq)$ increases the energy of the reacting molecules.

3 $Pd^{2+}(aq)$ lowers the activation energy for the reaction.

4 When $Pd^{2+}(aq)$ is used, the reaction proceeds by a different route.

A 1, 2 and 3 **B** 2, 3 and 4 **C** 1, 3 and 4 **D** All correct

Answer: C

Since $Pd^{2+}(aq)$ catalyses the reaction, $Pd^{2+}(aq)$ is involved in the rate determining step and in the rate law.

Option 1 correct. When conc of $Pd^{2+}(aq)$ is increased, rate of reaction increases.

Option 2 incorrect. $Pd^{2+}(aq)$ does not increase the energy of reacting molecules.

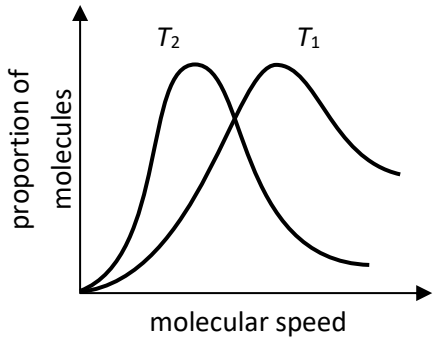
$Pd^{2+}(aq)$ provides an alternative reaction route (*option 4 correct*) and hence lowering the activation energy for the reaction (*option 3 correct*). Thus greater proportion of reacting molecules have energy greater than the (new) activation energy, frequency of effective collision increases. Rate of reaction increases.

15 Initially, there was 1 mol of neon gas at temperature T_1 in an enclosed system. 0.5 mol of neon gas was added and the temperature was increased to T_2.

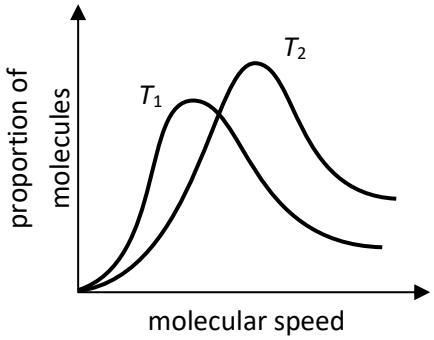
	Amount of neon gas/ mol	Temperature
Beginning	1	T_1
Final	1.5	T_2

Which diagram correctly represents the Boltzmann distribution of molecular speeds before and after the changes were made?

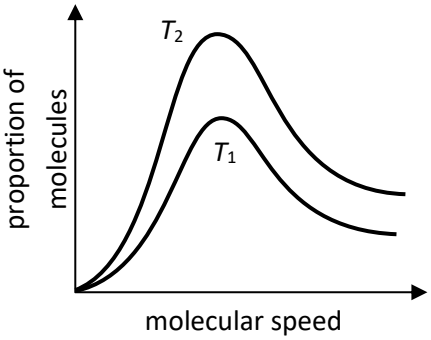
A



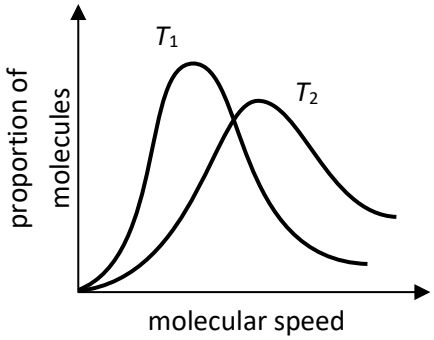
B



C



D

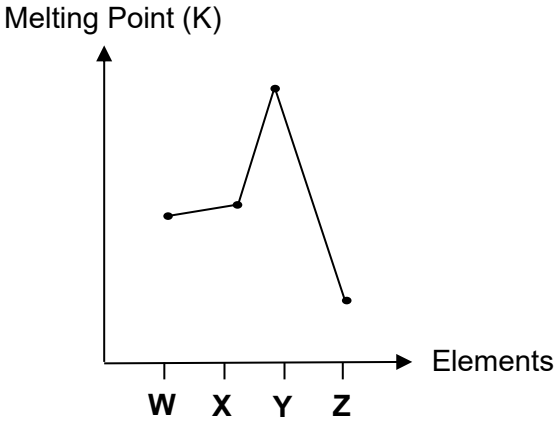


Answer: B

With the addition of 0.5 mol of gas, the area under the graph increases.

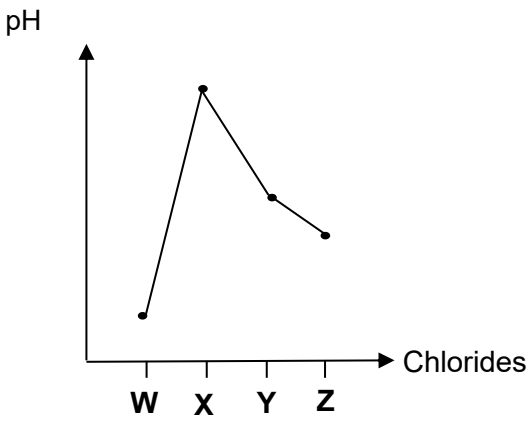
When the temperature increased, the Maxwell Boltzmann graph peak will be shifted to the right.

16 The graph below shows the melting points of four consecutive Period 3 elements **W** to **Z**.

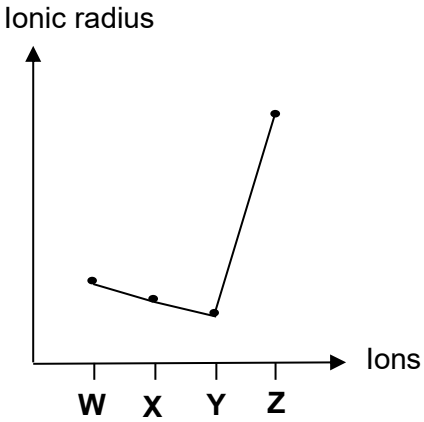


Which graph represents the correct trend of the stated property for **W** to **Z**?

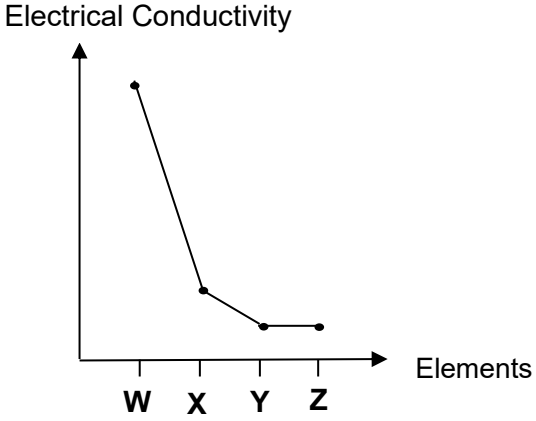
A



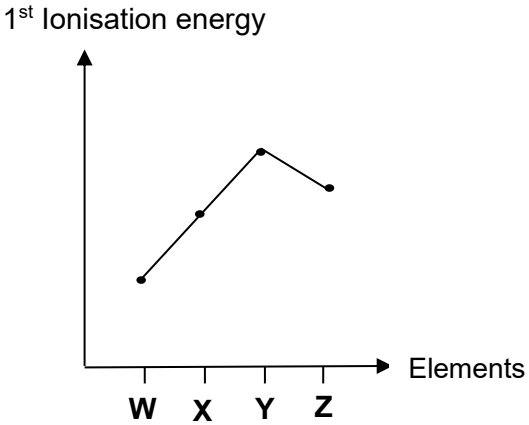
B



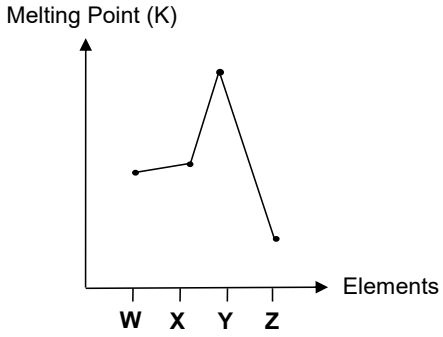
C



D



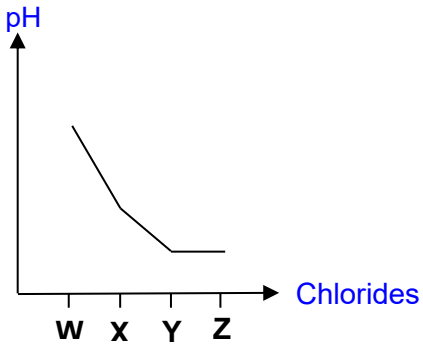
Answer: B

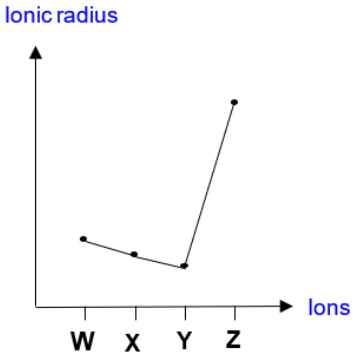


From the graph of melting point against elements, **Y** has the highest melting point. **Y** is Si as Si has the highest melting point among the Period 3 elements due to large amount of energy needed to overcome the extensive strong covalent bonds between Si atoms in the giant covalent/molecular lattice structure.

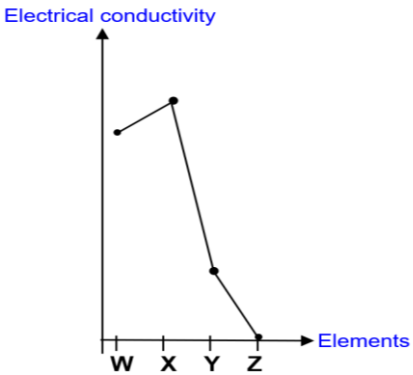
W – Mg, **X** – Al, **Y** – Si, **Z** – P.

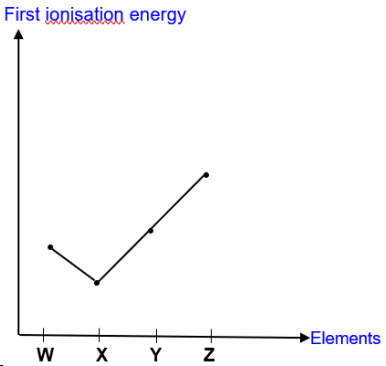
Graphs showing the correct trend of the stated property for **W** (Mg) to **Z** (P) are:





pH of $MgCl_2$ = 6.5 pH of $AlCl_3$ = 3.0 pH of $SiCl_4$ = 1.0 pH of PCl_5 = 1.0	Ionic radius of P^{3-} (**Z**) is much larger than that of Si^{4+}(**Y**)/ Al^{3+}(**X**)/ Mg^{2+}(**W**) due to the 1 addition electron shell. From Mg^{2+} (**W**) to Si^{4+} (**Y**), the ionic radii decrease due to more protons attracting same number of electrons.





Conductivity increases from Mg (**W**) to Al (**X**). Si (**Y**) is a semi–conductor. P (**Z**) is a non-conductor.	1st I.E increases from Al (**X**) to P (**Z**). 1st I.E decreases from Mg (**W**) to Al (**X**) because less energy is required to remove the higher energy 3p electron in Al than the 3s orbital in Mg.

17 **X**, **Y** and **Z** are three elements in Group 17.

- $\mathbf{X_2}$ has weaker covalent bonds than $\mathbf{Y_2}$.
- $\mathbf{X_2}$ has stronger instantaneous dipole–induced dipole interactions between its molecules than $\mathbf{Z_2}$.
- $\mathbf{Y_2}$ is a stronger oxidising agent than $\mathbf{Z_2}$.

What could be **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	I	C*l*	Br
B	I	Br	C*l*
C	C*l*	Br	I
D	Br	C*l*	I

Answer: A

For Group 17,

- strength of covalent bonds: C*l*–C*l* > Br–Br > I–I. Refer to Data Booklet for bond energies. OR As atomic radius increases from C*l* to I, the effectiveness of orbital overlap between the halogen atoms decreases, leading to weaker covalent bond between the halogen atoms.

- strength of instantaneous dipole–induced dipole interactions: $I_2 > Br_2 > Cl_2$. As M_r increases from Cl_2 to I_2, the larger electron cloud size has greater ease of electron cloud distortion and stronger instantaneous dipole–induced dipole interactions.

- strength of oxidising agent: $Cl_2 > Br_2 > I_2$.

The more positive the E^θ value, the greater the tendency to be reduced and the stronger the oxidising agent.

$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$ $E^\theta = +1.36V$ (Cl_2 is the strongest O.A.)

$Br_2 + 2e^- \rightleftharpoons 2Br^-$ $E^\theta = +1.07V$

$I_2 + 2e^- \rightleftharpoons 2I^-$ $E^\theta = +0.54V$ (I_2 is the weakest O.A.)

Hence, $\mathbf{X_2}$ is I_2 which has weaker covalent bonds than $\mathbf{Y_2}$ which is Cl_2. $\mathbf{X_2}$ (I_2) has stronger instantaneous dipole–induced dipole forces than $\mathbf{Z_2}$ which is Br_2. $\mathbf{Y_2}$ (Cl_2) is a stronger oxidising agent than $\mathbf{Z_2}$ (Br_2).

18 Solid sodium carbonate, Na_2CO_3, is added gradually added to a solution containing a mixture of Mg^{2+}, Ca^{2+} and Ag^+ ions, each at 0.002 mol dm^{-3}.

compound	K_{sp}
$MgCO_3$	3.6×10^{-8}
$CaCO_3$	2.8×10^{-9}
Ag_2CO_3	8.4×10^{-12}

What is the order of precipitation of the carbonates?

	first		last
A	$MgCO_3$	$CaCO_3$	Ag_2CO_3
B	$MgCO_3$	Ag_2CO_3	$CaCO_3$
C	Ag_2CO_3	$CaCO_3$	$MgCO_3$
D	$CaCO_3$	Ag_2CO_3	$MgCO_3$

Answer: D

For precipitation to occur, Ionic Pdt ≥ K_{sp}

$MgCO_3$	$CaCO_3$	Ag_2CO_3
Ionic Pdt = K_{sp} = $[Mg^{2+}][CO_3^{2-}]$ $3.6 \times 10^{-8} = (0.002)[CO_3^{2-}]$ $[CO_3^{2-}] = 1.8 \times 10^{-5}$ mol dm^{-3}	Ionic Pdt = K_{sp} = $[Ca^{2+}][CO_3^{2-}]$ $2.8 \times 10^{-9} = (0.002)[CO_3^{2-}]$ $[CO_3^{2-}] = 1.4 \times 10^{-6}$ mol dm^{-3}	Ionic Pdt = K_{sp} = $[Ag^+]^2[CO_3^{2-}]$ $8.4 \times 10^{-12} = (0.002)^2 [CO_3^{2-}]$ $[CO_3^{2-}] = 2.1 \times 10^{-6}$ mol dm^{-3}
Highest $[CO_3^{2-}]$ required for ppt ⇒ **Last to ppt**	Lowest $[CO_3^{2-}]$ required for ppt ⇒ **First to ppt**	**2nd**

19 Which pair is not a Brønsted–Lowry conjugate acid–base pair?

A HPO_4^{2-} and PO_4^{3-}

B H_2O_2 and HO_2^-

C NH_3 and NH_2^-

D H_2CO_3 and CO_3^{2-}

A Brønsted–Lowry conjugate acid–base pair is a pair of species that differ by **only** one proton, H^+. The acid donates one H^+ to form its conjugate base.

Species	Differ by only 1 H^+?	conjugate acid–base pair
HPO_4^{2-} and PO_4^{3-}	✓	✓
H_2O_2 and HO_2^-	✓	✓
NH_3 and NH_2^-	✓	✓
H_2CO_3 and CO_3^{2-}	No. Differ by 2.	X

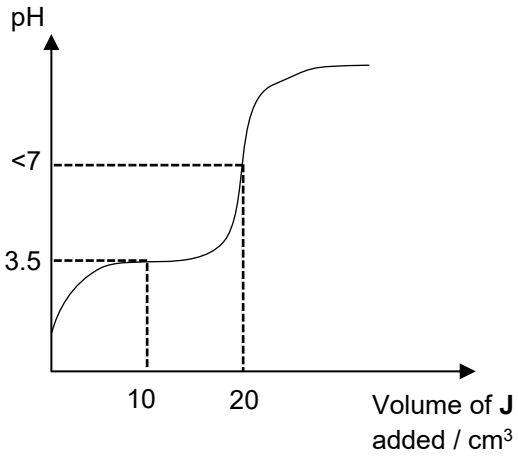
Answer: D H_2CO_3 and CO_3^{2-}

20 **J** is a monoacidic weak base with a pK_b of 3.5.

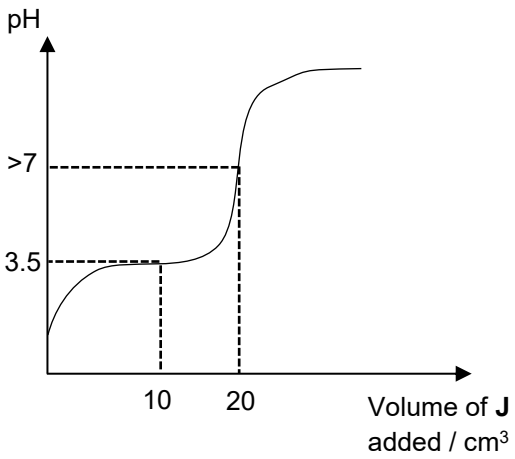
A total of 50 cm^3 of 0.1 mol dm^{-3} of **J** was added dropwise to 20 cm^3 of 0.1 mol dm^{-3} HNO_3.

Which pH curve correctly describes the changes in the pH of the resultant solution as **J** was added to HNO_3?

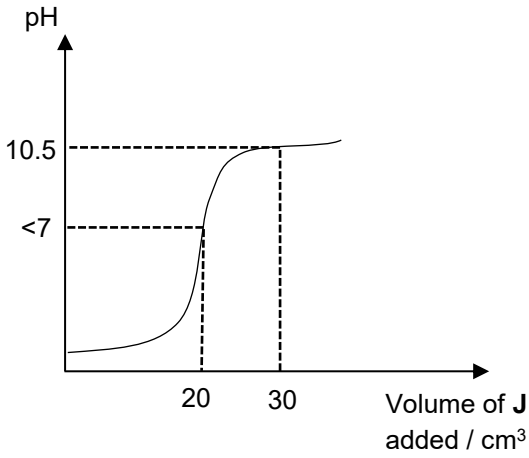
A



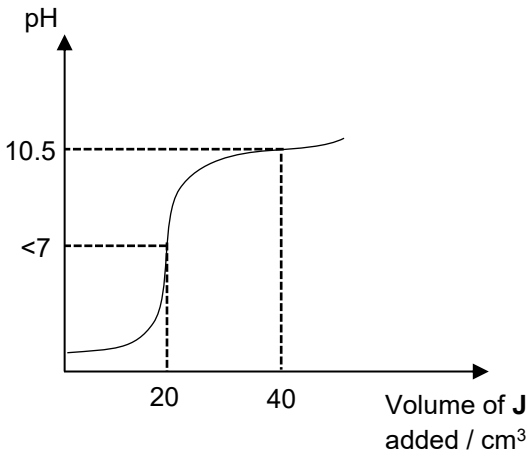
B



C



D



Answer: D

Weak base–strong acid titration:

- **At 0 cm^3 of J added:**
  Only strong acid (0.1 mol dm^{-3} HNO_3) is present → initial pH is low.

  pH of HNO_3 = – lg [H+] = – lg (0.10) = 1.0

- **At 20 cm^3 of J added (equivalence point):**
  20 cm^3 of 0.1 mol dm^{-3} HNO_3 required 20 cm^3 of 0.1 mol dm^{-3} monoacidic J for complete neutralisation. All acid has been neutralised → solution contains only the salt JH^+ (conjugate acid of the weak base J).
  Since JH^+ undergoes cationic hydrolysis, solution is acidic (pH < 7).

- **At 40 cm^3 of J added (twice the equivalence volume):**
  Solution contains equal moles of weak base J and salt JH^+ → maximum buffer capacity.
  Using Henderson–Hasselbalch: pH $= pK_a(JH^+) = 10.5$
  Recall= pK_a + pK_b =14. Since p*K*b = 3.5.

21 Which statements about the bonding in prop-2-en-1-ol, CH_2=CH–CH_2OH are correct?

1 All carbon atoms in the molecule are in the same plane.

2 The C–C bond in the =CH–CH_2OH is stronger than those in ethanol.

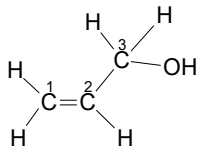
3 The molecule contains a π-bond formed by the side-on overlap of two 2p orbitals.

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

Answer: A (1, 2 and 3 correct)

Option 1 is correct:

- The two **sp^2 carbons** (C^1=C^2) and their attached atoms lie in one plane. The molecule is trigonal planar with respect to C^2 as the central atom which is sp^2 hybridised. Hence, all carbon atoms are in the same plane.



Although C^3 is sp^3 hybridised and hence atoms attached to it are tetrahedral about C^3 (non-planar), question is referencing the carbon atoms being on same plane and NOT the entire molecule.

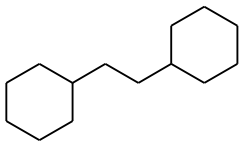
Option 2 correct:

- The C–C bond in the –CH–CH_2OH is a **σ-bond** formed from the **overlap of one sp^2 hybrid orbital of** C^2 and **one sp^3 hybrid** orbital of C^3.
- The **C–C bond** in ethanol, CH_3–CH_3 are formed from the overlap of **two sp^3 hybrid orbitals**.
- The **sp^2 hybrid orbital has greater 's' character than sp^3**, thus there is a **more effective overlap** of **sp^2 and sp^3** orbitals in the **C–C** of the –CH–CH_2OH in prop-2-en-1-ol are **stronger** than those in ethanol.

Option 3 is correct:

- Prop-2-en-1-ol contains a **carbon–carbon double bond** H_2C=CH–.
- A double bond consists of:
  - One **σ-bond** (head-on overlap of hybrid orbitals, e.g., sp^2)
  - One **π-bond** (side-on overlap of two unhybridised **2p orbitals**)

22 Compound **R**, $C_{14}H_{26}$, reacts with chlorine gas in the presence of UV light.



R

Which statement about this reaction is correct?

A The maximum number of mono-chlorinated structural isomers with formula $C_{14}H_{25}Cl$ is 5.

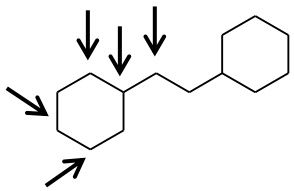
B $C_{28}H_{52}$ is present in small quantities in the product.

C Homolytic fission occurs only in the initiation step.

D HCl is formed in the termination step.

Answer: A

Option **A**: There are 5 positions on compound **R** that H atoms can be substituted by Cl to produce positional isomers. Substitution on other positions will also give rise to one of the 5 isomers.

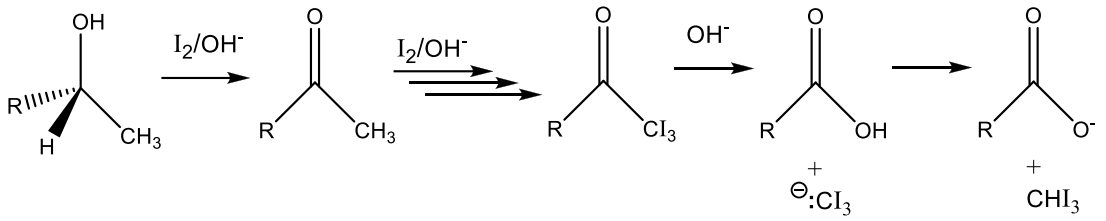


Option **B**: **Not correct.** The alkyl radical formed from the propagation step (a) is $\bullet C_{14}H_{25}$ since 1 H atom is being abstracted by Cl radical. Thus, the combination of 2 alkyl radicals in the termination step will produce $C_{28}H_{50}$ and not $C_{28}H_{52}$.

Option **C**: **Not correct.** Homolytic fission also occurs in the propagation step.

Option **D**: **Not correct.** $H\bullet$ is not formed in the reaction.

23 The reaction of methyl alcohols with alkaline aqueous iodine can be described by the simplified scheme as shown below:



Which reactions have taken place?

1 Oxidation

2 Acid-base reaction

3 Nucleophilic addition

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

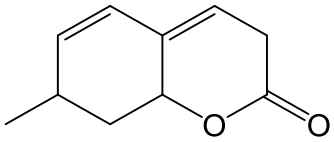
Answer: B

Statement 1: Iodoform test is an oxidation reaction. Alcohol is oxidised to a carboxylic acid (carboxylate).

Statement 2: Acid-base reaction occurs in the last step where CI_3^- acts as base to accept H^+ from OH in RCOOH (which acts as acid).

Statement 3: There is no nucleophilic addition reaction taking place.

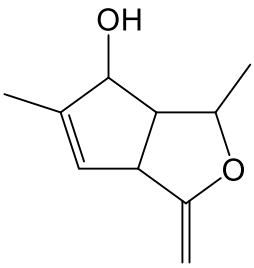
24 The diagram shows compound **M**.



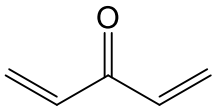
M

Which molecule has the same empirical formula as compound **M**?

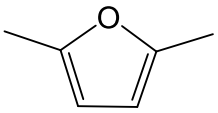
A



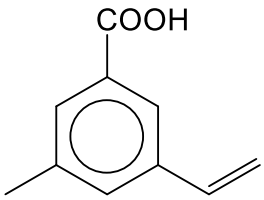
B

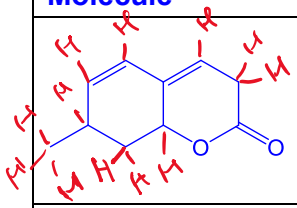
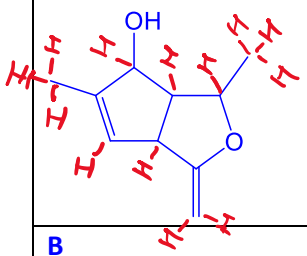
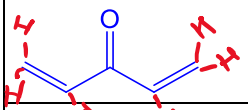
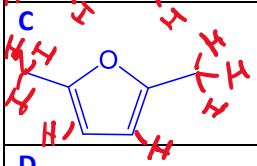
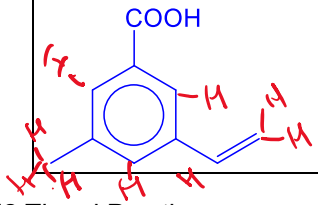


C



D



Molecule	Chemical Formula	Empirical Formula	Same as M?
	$C_{10}H_{12}O_2$	C_5H_6O	-
A 	$C_{10}H_{14}O_2$	C_5H_7O	X
B 	C_5H_6O	C_5H_6O	✓
C 	C_6H_8O	C_6H_8O	X
D 	$C_{10}H_{10}O_2$	C_5H_5O	X

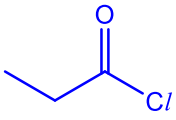
25 Which statement about propanoyl chloride is correct?

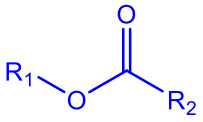
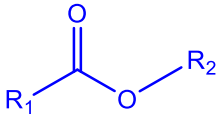
A It reacts with aqueous ammonia to produce $CH_3CH_2CONH_2$.

B It reacts with 2-methyl-propan-2-ol to produce $(CH_3)_3CCO_2CH_2CH_3$.

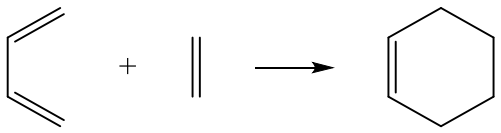
C It reacts with ethanol to produce $CH_3CH_2COCH_2CH_3$.

D It reacts with water to produce $CH_3CH_2CO_2H$.

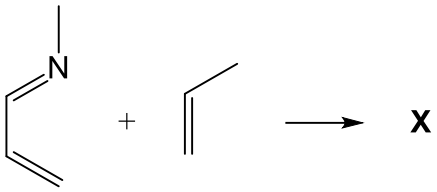
Structure of Propanoyl Chloride: 

Reactant	**Product**	**Reasoning**
NH_3***(aq)***	CH_3CH_2COOH	Acyl chloride is highly reactive and is **hydrolysed by the large amount of water** present rather than NH_3 present.
2-methyl-propan-2-ol, $(CH_3)_3COH$	$(CH_3)_3C\underline{\mathbf{O}}COCH_2CH_3$.	Check position of atoms in ester linkage. Ester OCO:  Ester COO: 
Ethanol, CH_3CH_2OH	$CH_3CH_2CO\underline{\mathbf{O}}CH_2CH_3$	
H_2O	$CH_3CH_2CO_2H$	Acyl chloride is highly reactive and is hydrolysed by water.

26 Buta-1,3-diene can react with ethene to form cyclohexene.

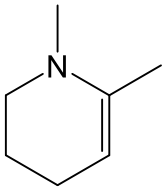


In a separate reaction, compound **X** can be made using similar method.

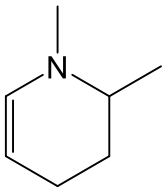


Which molecules are possible structure of compound **X**?

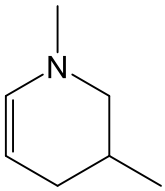
1



2



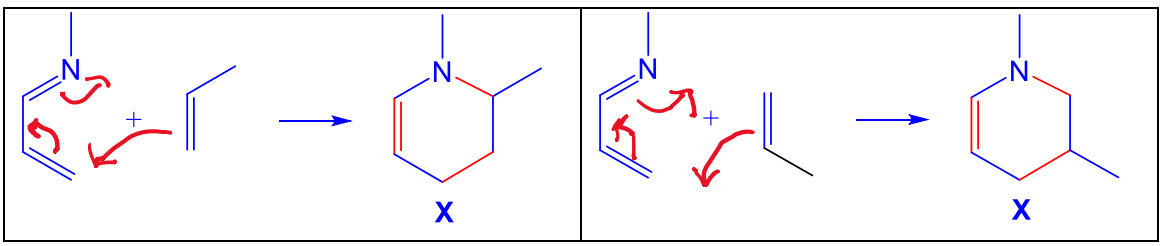
3



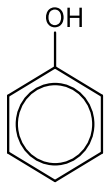
A 1 only **B** 2 only **C** 1 and 2 only **D** 2 and 3 only

Answer is **D** (**2** and **3**)

The alkene to make **X** can be positioned in 2 different orientations, providing different compounds for **X**.

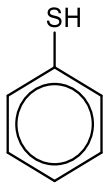


27 Thiophenol and phenol are both acting as weak acids in aqueous solutions.



phenol

pK_a = 10.0



thiophenol

pK_a = 6.50

Which statements are correct?

1 H^+ is less easily removed from thiophenol than phenol because the S–H bond is less polar than O–H bond.

2 The K_a value is smaller for phenol because the O–H bond is stronger than the S–H bond.

3 When pure liquid thiophenol and phenol are mixed together without water, the S–H bond in thiophenol is more likely to dissociate than the O–H bond in phenol.

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

	Answer: C (similar to TYS2022/P1/Q3) pK_a lower, means K_a higher From pK_a values, thiophenol is a stronger acid than phenol. 1: Incorrect. H^+ is more easily removed from thiophenol since it is the stronger acid. 2: Correct. The K_a value for phenol is smaller (10^{-10}) compared to thiophenol ($10^{-6.5}$). Furthermore O–H bond (460 kJ mol^{-1}) is stronger than S–H bond (347 kJ mol^{-1}), either refer bond energy value from *Data Booklet* or considering shorter O–H bond length due to smaller atomic radius of oxygen. 3: Correct. Given a smaller pK_a value of thiophenol, the acid dissociation of thiophenol occurs more likely than phenol.

28 Equal amounts of two organic compounds, **Y** and **Z**, were added to water and the pH values of both solutions were determined. It was found that the pH of the aqueous solution of **Y** is higher.

Which pairs of compounds could be **Y** and **Z**?

	Y	**Z**
1	$(CH_3)_2NH$	CH_3NH_2
2	$CH_3COCH_2NH_2$	$CH_3CH_2CONH_2$
3	$C_6H_5O^-Na^+$	$C_6H_5CO_2^-Na^+$

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

Answer: A

Higher pH means more basic. **Y** is more basic than **Z**.

Option 1: $(CH_3)_2NH$ is more basic than CH_3NH_2 as it has more electron donating alkyl group, increasing the availability of the lone pair on N to accept proton.

Option 2: $CH_3COCH_2\mathbf{NH_2}$ (amine) is basic while $CH_3CH_2CONH_2$ (amide) is neutral.

Option 3: C_6H_5OH is a weaker acid than $C_6H_5CO_2H$, hence its conjugate base ($C_6H_5O^-$) is a stronger base than $C_6H_5CO_2^-$.

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

Peroxodisulfate ions convert iodide ions into iodine slowly according to reaction **1**.

$S_2O_8^{2-}(aq) + 2I^-(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$ reaction **1**

The rate of the reaction can be increased by the addition of homogeneous catalysts such as aqueous iron(III) ions.

Step 1: $2Fe^{3+}(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2Fe^{2+}(aq)$

Step 2: $S_2O_8^{2-}(aq) + 2Fe^{2+}(aq) \rightarrow 2SO_4^{2-}(aq) + 2Fe^{3+}(aq)$

Which statements are correct?

1 $S_2O_8^{2-}$ is a stronger oxidising agent than Fe^{3+}.

2 The $E_{cell}^{\ominus}$ for step 2 is more positive than step 1.

3 Aqueous cobalt(II) ions can also be used as a homogeneous catalyst in reaction **1**.

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

Answer: D

	$E^{\ominus}$/V	
$Fe^{3+} + e \rightleftharpoons Fe^{2+}$	+ 0.77	---(1)
$S_2O_8^{2-} + 2e \rightleftharpoons 2SO_4^{2-}$	+ 2.01	---(2)
$I_2 + 2e \rightleftharpoons 2I^-$	+ 0.54	---(3)
$Co^{3+} + e \rightleftharpoons Co^{2+}$	+ 1.89	---(4)

Statement 1: True

$S_2O_8^{2-}$ has more positive reduction potential than Fe^{3+} (compare (1) and (2)). and Hence $S_2O_8^{2-}$ is more easily reduced and is a stronger oxidising agent than Fe^{3+}.

Statement 2: True

$E_{cell}^{\ominus}$ for step 1: 0.77 – 0.54 = +0.23 V (consider 1 and 3)

$E_{cell}^{\ominus}$ for step 2: 2.01 – 0.77 = +1.24 V **(consider 1 and 2)**

Statement 3: True

Step 1: $2Co^{2+}(aq) + S_2O_8^{2-}(aq) \rightarrow 2Co^{3+}(aq) + 2SO_4^{2-}(aq)$

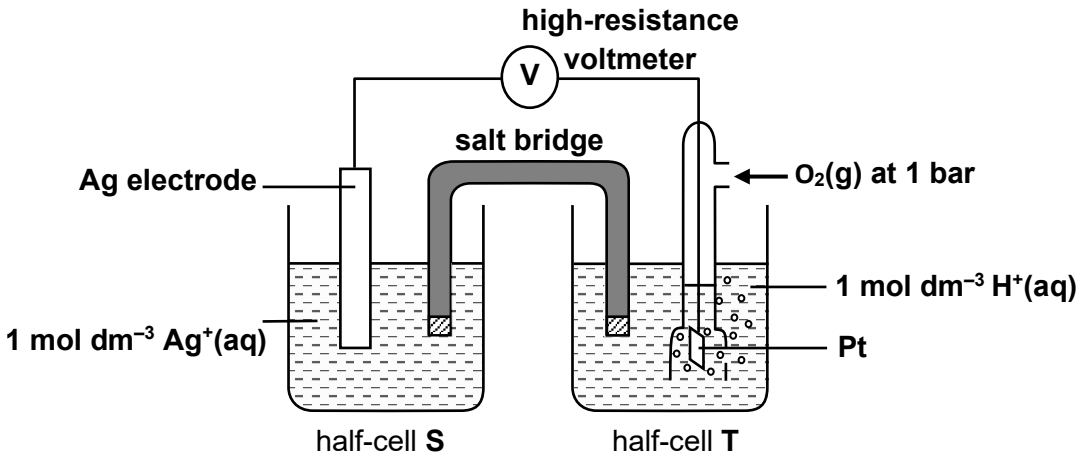
Step 2: $2I^-(aq) + 2Co^{3+}(aq) \rightarrow I_2(aq) + 2Fe^{3+}(aq)$

$E_{cell}^{\ominus}$ for step 1: 2.01 – 1.89 = +0.12 V > 0

$E_{cell}^{\ominus}$ for step 2: 1.89 – 0.54 = +1.35 V > 0

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

Which changes will result in a decrease in the cell potential for the following setup?



A Adding water to half-cell **S**.

B Adding potassium iodide to half-cell **S.**

C Adding water to half-cell **T**.

D Introduce O_2 (g) at 2 bar to half-cell **T**.

Ans: C

[O]: $Ag^+ + e^- \rightleftharpoons Ag$ $\quad E^\ominus = +0.80$ V

[R]: $O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$ $\quad E^\ominus = +1.23$ V

$E^\ominus_{cell} = E^\ominus_{red}(O_2/H_2O) - E^\ominus(Ag^+/Ag)$ $\quad = 1.23 - (+0.80) = +0.43$V

A : $[Ag^+] \downarrow$ due to dilution. By LCP, POE will shift left to increase $[Ag^+]$.
$\therefore E(Ag^+/Ag)$ decreases. E_{cell} increases (more positive).

B: $[Ag^+] \downarrow$ due to precipitation of AgI. By LCP, POE will shift left to increase $[Ag^+]$.
$\therefore E(Ag^+/Ag)$ decreases. E_{cell} increases (more positive).

C: $[H^+] \downarrow$. By LCP, POE will shift left to increase $[Ag^+]$.
E (O_2/H_2O) becomes less positive, E_{cell} decreases (less positive)

D: Higher P_{O2}. By LCP, POE will shift right to partially reduce partial pressure of O_2.
$E(O_2/H_2O)$ becomes more positive, E_{cell} increases (more positive)

Answer Key For MCQ

1	C	**11**	B	**21**	A
2	C	**12**	B	**22**	A
3	B	**13**	C	**23**	B
4	D	**14**	C	**24**	B
5	D	**15**	B	**25**	D
6	B	**16**	B	**26**	D
7	D	**17**	A	**27**	C
8	A	**18**	D	**28**	A
9	B	**19**	D	**29**	D
10	C	**20**	D	**30**	C

	Count
A	5
B	9
C	7
D	9
Total	30