

ANSWER SCHEME

1 C $pV = \frac{m}{M_r} RT$

$$(10^5 \times 5.7 \times 10^{-3}) = \frac{18.0}{M_r} (8.31)(273)$$

$$M_r = 71.6$$

Let a be the %mass of $^{35}\text{Cl}_2$

$$\left(\frac{a}{100} \times 70\right) + \left[\frac{1-a}{100} \times 74\right] = 71.6$$

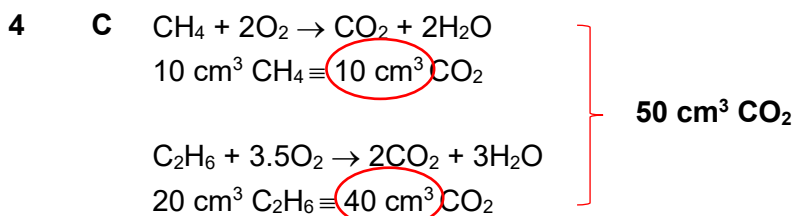
$$a = 60$$

- 2 B From the first 2 properties, **E** must be a main group metal.

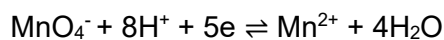
Hence, option C and D are incorrect.

Since it was obtained by removing electrons from the same orbital, **E** must be either a metal in Group 1 or 2.

- 3 A Since its shape is trigonal pyramidal, that must mean that around O there are 3 bp and 1lp.
The 3 bp are formed between one electron from F and 1 from O and the lp belongs to O.
With only 5 valence electrons around O than the usual 6, the entire ion is short of 1 electron and hence $n = 1$



5 B Amount of $\text{MnO}_4^- = \frac{37.5}{1000} \times 0.02 = 7.5 \times 10^{-4}$



Amount of MnO_4^- : amount of electrons: amount of **G** ion :

$$7.5 \times 10^{-4} : 3.75 \times 10^{-3} : 1.25 \times 10^{-3}$$

$$3 : 1$$

Given that ion of **G** is oxidised to GO_3^- , O.N. +5,
 Original O.N of ion of **G** is $+5 - 3 = +2$

6 B Assuming ideal gas behaviour (i.e. $pV = nRT$),

1) value of pV of L = $n_L RT_L = 3x$

value of pV of J = $n_J RT_J = x$

2) J deviates from Ideal gas behaviour more than L, indicating more significant/stronger intermolecular forces of attraction between J molecules than L

$$(i.e. \frac{n_L T_L}{n_J T_J} = 3)$$

$$\times 1: \frac{n_L T_L}{n_J T_J} = \frac{0.5 \times (273 + 50)}{0.5 \times (273 + 25)} = 1.08$$

✓2: J = NH_3 (stronger hydrogen bonds between NH_3 molecules)

L = CH_4 (weaker id-id attractions between CH_4 molecules)

$$\frac{n_L T_L}{n_J T_J} = \frac{1.5 \times (273 + 25)}{0.5 \times (273 + 25)} = 3$$

✗3: J = H_2 (weaker id-id attractions between CH_4 molecules)

L = SO_2 (stronger pd-pd bonds between NH_3 molecules)

$$\frac{n_L T_L}{n_J T_J} = \frac{0.75 \times (273 + 25)}{0.25 \times (273 + 25)} = 3$$

7 A K: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ Cl: $1s^2 2s^2 2p^6 3s^2 3p^5$

✓1: K has one more quantum shell, valence electrons are further away from nucleus. Increase in shielding effect by inner shell electrons outweighs the increase in nuclear charge hence, decreased attraction between nucleus and valence electrons / decreased nuclear attraction. Thus, the atomic radius of potassium is greater than atomic radius of chlorine atom.

✗2: Similarly, the 4s electron is further away from the nucleus, decreased nuclear attraction between nucleus and valence electrons, thus, less energy is required to remove an outermost/valence electron.

✗3 K⁺: $1s^2 2s^2 2p^6 3s^2 3p^6$

Cl⁻: $1s^2 2s^2 2p^6 3s^2 3p^6$

Both are isoelectronic, with potassium having a bigger nuclear charge. Hence, there is great nuclear attraction between nucleus and valence electrons. Thus the ionic radius of potassium is smaller than that of chlorine.

8 D reaction 1 $\text{Br}_2(\text{aq}) + 2\text{NaOH}(\text{aq}) \rightarrow \text{NaBr}(\text{aq}) + \text{NaOBr}(\text{aq}) + \text{H}_2\text{O}(\text{l})$

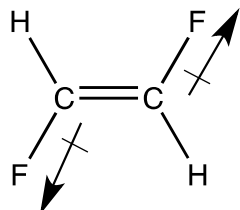
$$\text{reaction 2} \quad \underset{+1}{3\text{NaOBr(aq)}} \rightarrow \underset{-1}{2\text{NaBr(aq)}} + \underset{+5}{\text{NaBrO}_3\text{(aq)}}$$

Reaction 1: Br in Br₂ is oxidised to OBr⁻ and reduced to Br⁻

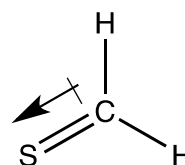
Reaction 2: Br in OBr^- is oxidised to BrO_3^- and reduced to Br^- .

Hence both are disproportionation reactions.

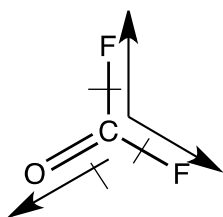
9 D A: Dipole moments cancel out.



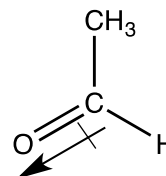
B: Dipole moment is smaller than that in D since S is less electronegative than O.



C: Dipole moment is smaller than that in D as the net dipole moment of C-F bonds reduces the dipole moment of C=O bond



D:



10 B

$$LE \propto \frac{q_+ \times q_-}{r_+ + r_-}$$

	sodium	magnesium	oxygen	bromine
Charge	+1	+2	-2	-1
Ionic size	0.186	0.160	0.140	0.195

	MgO	MgBr ₂	Na ₂ O	NaBr
LE _∞	13.33	5.63	6.13	2.62

Based on the above formula, MgO will be 2nd least exothermic

11 C $\Delta H = (5(\text{BE}(\text{N}=\text{N}) + \text{BE}(\text{N}=\text{O}) + 2\text{BE}(\text{C}-\text{H}) + \text{BE}(\text{C}\equiv\text{C})) - (2\text{BE}(\text{O}-\text{H}) + 4\text{BE}(\text{C}=\text{O}) + 5(\text{N}\equiv\text{N})))$
 $= (5(418 + 686) + 2(410) + (840)) - (2(460) + 4(805) + 5(944))$
 $= -1680 \text{ kJ mol}^{-1}$

- 12 C Since average IMF in water are much stronger than the average IMF in steam, and average IMF in ice are slightly stronger than the average IMF in water

✓1: The numerical value of ΔH_b is greater than ΔH_m

✗2 ($\text{H}_2\text{O}(l) = \text{H}_2\text{O}(g)$) ΔH_b is positive as the energy required to break stronger IMF in liquid water is more than energy released when forming IMF between steam molecules ($\text{H}_2\text{O}(s) = \text{H}_2\text{O}(l)$), ΔH_m is positive as the energy required to break stronger IMF in solid water is more than energy released when forming IMF between liquid water molecules.

✓3: The intermolecular forces in ice and water are similar – hydrogen bond

- 13 A Let the rate equation be $\text{rate} = k[\text{N}]^n [\text{P}]^q$.

Comparing Experiment 2 and 3, keeping $[\text{N}]$ constant,

$$\frac{6.4 \times 10^{-3}}{1.6 \times 10^{-3}} = \frac{k(0.006)^n (0.8)^q}{k(0.006)^n (0.4)^q} \Rightarrow q = \text{order of reaction w.r.t } [\text{P}] = 2$$

(correct; reject Option D)

Comparing Experiment 1 and 2,

$$\frac{1.6 \times 10^{-3}}{1.6 \times 10^{-3}} = \frac{k(0.006)^n (0.4)^1}{k(0.003)^n (0.4)^1} \Rightarrow n = \text{order of reaction w.r.t } [\text{N}] = 0$$

Since the order of reaction w.r.t $[\text{N}]$ is not one, the half-life of N is not constant.

(correct; reject Option C)

The rate equation is $\text{rate} = k[\text{P}]^2$ and hence, the units of $k = \text{mol}^{-1} \text{ dm}^3 \text{ min}^{-1}$.

(correct; reject Option B).

The rate equation implies that the rate-determining step involves 2 units of P only. Hence, this also implies that N is involved in other steps and thus, the reaction is not a one-step reaction.

- 14 D
- ✗A Reaction rate is defined as the speed at which a chemical reaction proceeds, defined as the change in concentration of a reactant or product per unit of time.
 - ✗B At higher concentration, particles are closer together per unit volume.
 - ✗C At higher concentration, the kinetics energy of the particles remain the same.
 - ✓D With more collisions per second, the rate will increase.

15 A

	ROH(l)	+	CH ₃ COOH(l)	=	CH ₃ COOR(l)	+	H ₂ O(l)
Initial amt	3		2		0		1
change	-0.5		-0.5		+0.5		+0.5
Eqm amt	2.5		1.5		0.5		1.5
Eqm []	$\frac{2.5}{V}$		$\frac{1.5}{V}$		$\frac{0.5}{V}$		$\frac{1.5}{V}$

$$K_c = \frac{[\text{CH}_3\text{COOR}][\text{H}_2\text{O}]}{[\text{CH}_3\text{COOH}][\text{ROH}]}$$

$$\checkmark A \quad K_c = \frac{\left[\frac{0.5}{V}\right]\left[\frac{1.5}{V}\right]}{\left[\frac{1.5}{V}\right]\left[\frac{2.5}{V}\right]} = 0.2$$

×B $\Delta H^\circ < 0$ i.e exothermic, When temperature decrease, POE will shift to the right, favouring the exothermic reaction to release heat. Hence, the [CH₃COOH] will reduce below 1.5 mol.

×C K_c has no units.

×D The equilibrium amount of ester is the not the same as the equilibrium amount of water. (See working above)

16 B $2 \text{ CO (g)} + \text{O}_2 \text{ (g)} \rightleftharpoons 2 \text{ CO}_2 \text{ (g)} \quad \Delta H < 0$

At time = t_1 , shape of graph shows a gradual increase in CO and decrease in CO₂, indicating POE shifts to the left.

Possible changes include

- increasing temperature as increasing temperature will favour endothermic reaction, i.e. backward reaction thus POE shifts left
- remove O₂ as removing O₂ will result in POE shifting left.

(Cancel A and D)

At time = t_2 , shape of graph shows a sharp increase in both CO and CO₂, indicates a decrease in the volume of system. When volume of system decrease, pressure of system increase. POE shifts to the right side with lesser mol to reduce the pressure.

(Cancel C)

Addition of catalyst will not result in any equilibrium shift.

Addition of an inert gas at constant volume will not result in any equilibrium shift as partial pressure of the other gases remains the same.

- 17 D Amount of $\text{NH}_4^+ = \frac{100}{1000} \times 0.10 = 0.01 \text{ mol (excess)}$
 Amount of $\text{OH}^- = \frac{40}{1000} \times 0.15 = 0.006 \text{ mol}$

In resulting solution,

Amount of NH_4^+ left $0.01 - 0.006 = 0.004 \text{ mol}$

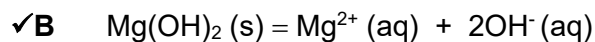
Amount of NH_3 formed $= 0.006 \text{ mol}$

$$\text{pOH} = \text{p}K_b + \lg \left(\frac{[\text{NH}_4^+]}{[\text{NH}_3]} \right)$$

$$\text{pOH} = 4.75 + \lg \left(\frac{0.004}{0.006} \right) = 4.57$$

$$\text{pH} = 14 - 4.57 = 9.43$$

- 18 B **×A** Since solubility of Group 2 hydroxides increases down the group, $[\text{M}^{2+}]$ and $[\text{OH}^-]$ increases, $K_{\text{sp}} = [\text{M}^{2+}][\text{OH}^-]^2$, value of K_{sp} increases down the group.



$$K_{\text{sp}} = [\text{Mg}^{2+}][\text{OH}^-]^2 = \text{X}$$

$$(\text{S}) (2\text{S})^2 = \text{X}$$

$$\text{S} = \left(\frac{\text{X}}{4} \right)^{\frac{1}{3}}$$

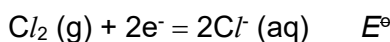
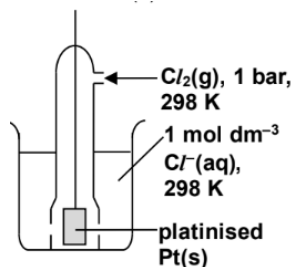
$$[\text{OH}^-] = 2 \text{S} = 2 \left(\frac{\text{X}}{4} \right)^{\frac{1}{3}} = (2\text{X})^{\frac{1}{3}}$$

$$\text{Thus pH} = 14 - (-\lg (2\text{X})^{\frac{1}{3}}) = 14 + \lg (2\text{X})^{\frac{1}{3}}$$

×C the solubility of magnesium hydroxide will decrease due to the common ion, Mg^{2+} , in $\text{Mg}(\text{NO}_3)_2$. Thus solubility will be lesser than **S**.

×D K_{sp} will not change unless there is a change in temperature.

- 19 B Reduction potential is measured under standard conditions of 1 mol dm^{-3} of any aqueous solution 298K and 1 bar.



×A Adding water will reduce $[\text{Cl}^-]$, and E^\ominus becomes more positive.

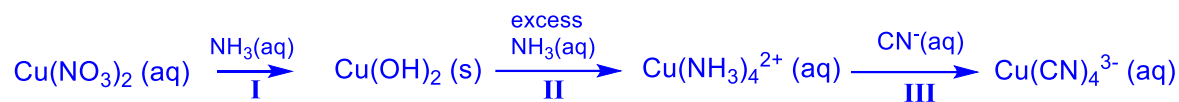
✓B Electrode potential depends on the nature of the electrode, temperature of

×C the solution and the concentration of metal ions in the solution. It does not depend on the size of the electrode.

×D Adding Ag^+ will result in the precipitation of AgCl , this reduces $[\text{Cl}^-]$, and E^\ominus becomes more positive.

20 A

21 A



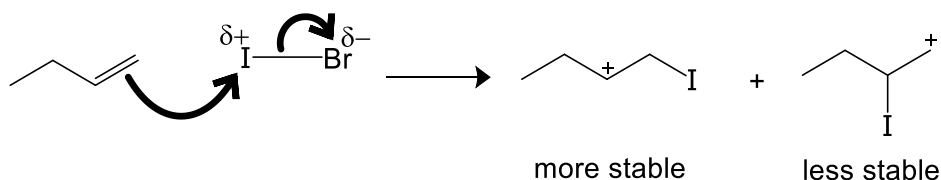
✓1 Step III involves both a ligand exchange where NH_3 has been displaced by CN^-
 ✓2 (indicating that CN is a stronger ligand than NH_3) and a redox reaction where Cu in $\text{Cu(NH}_3)_4^{2+}$ has been reduced from +2 to +1 in Cu(CN)_4^{3-} .

✓3 Step I shows the precipitation of Cu(OH)_2 solid.

22 D

23 D Type of reaction: electrophilic addition

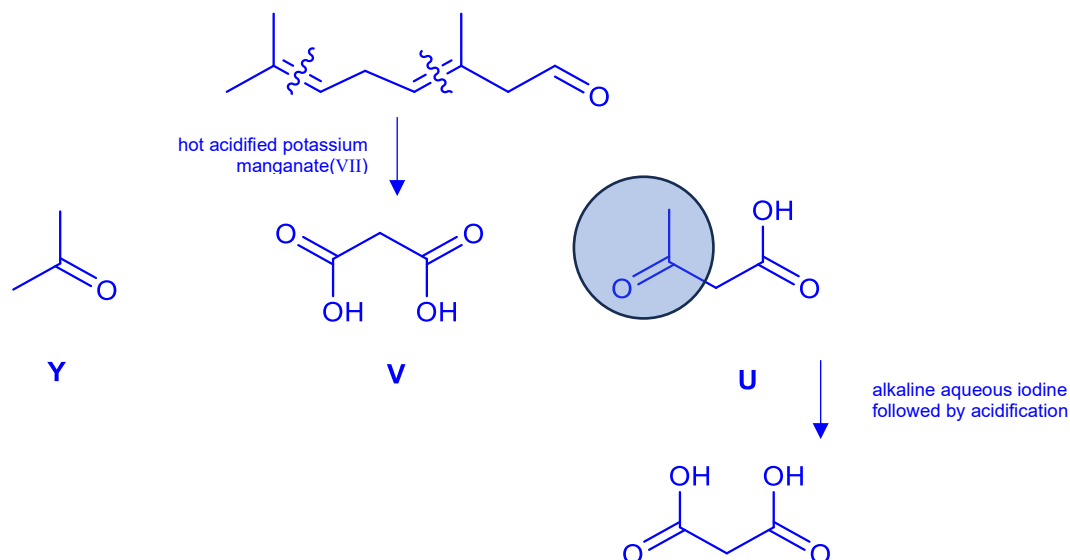
Since iodine is less electronegative than Br , iodine will bear the δ^+ charge and functions as the electrophile.



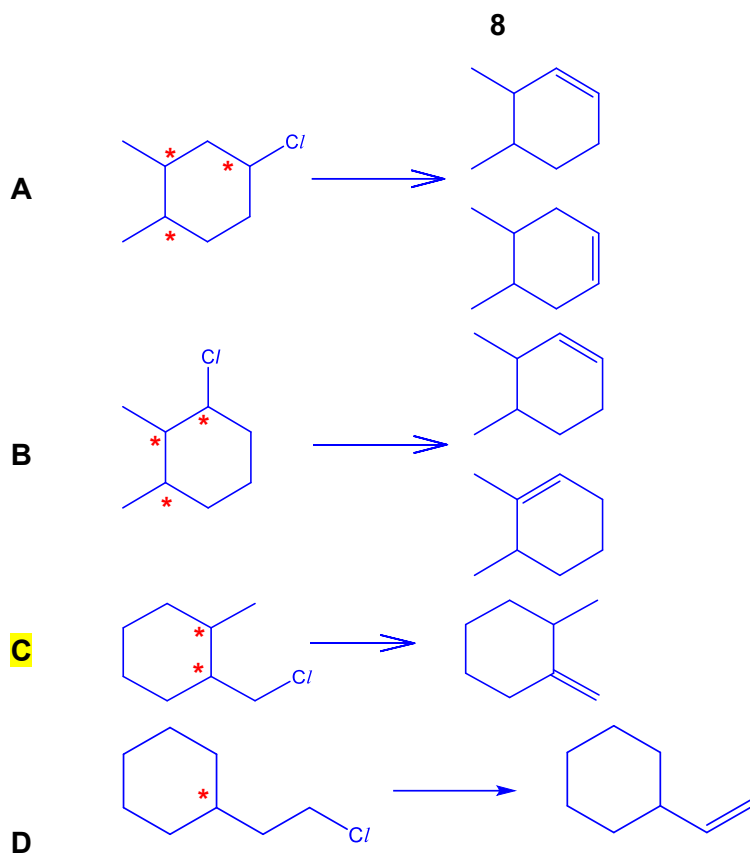
The product must contain I atom. (reject D)

Br^- and CH_3O^- can function as nucleophile to attack either carbocation to give the products in Option A to C.

24 A

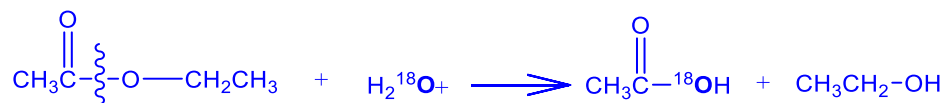


25 C



Starting compound has a plane of symmetry, thus cannot rotate polarised light

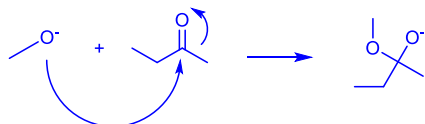
26 D



27 C

×1 Methanol acts as a Bronsted acid, i.e. donates H^+ , in step 1. It does not accept any lone pair from OH^- , hence, not acting as a Lewis acid.

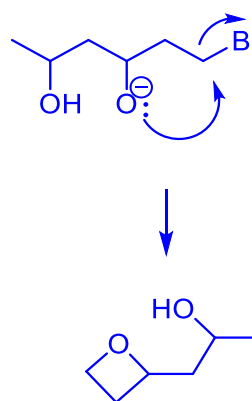
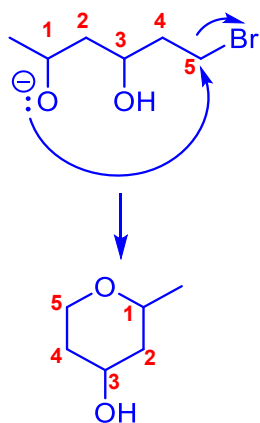
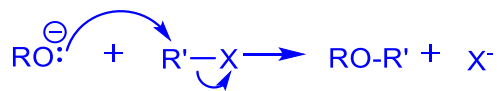
✓2 Step 2 is a nucleophilic addition reaction.



✓3 KOH is used as a catalyst in step 1 and regenerated in step 3..

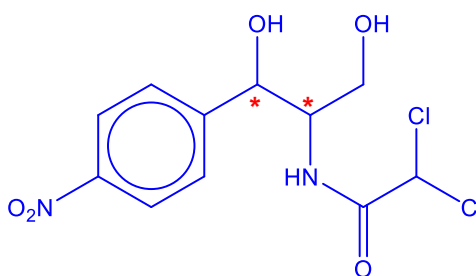
×4 Step 3 is not a redox reaction. It is an acid-base reaction.

28 B

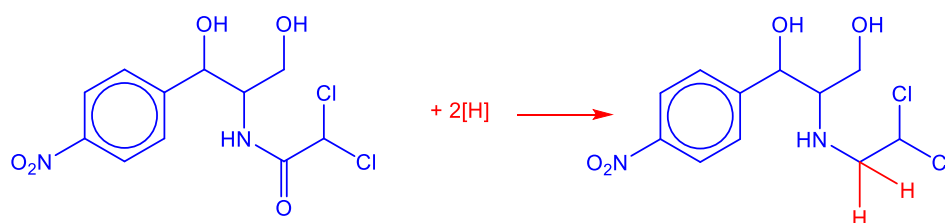


not stable due to ring strain

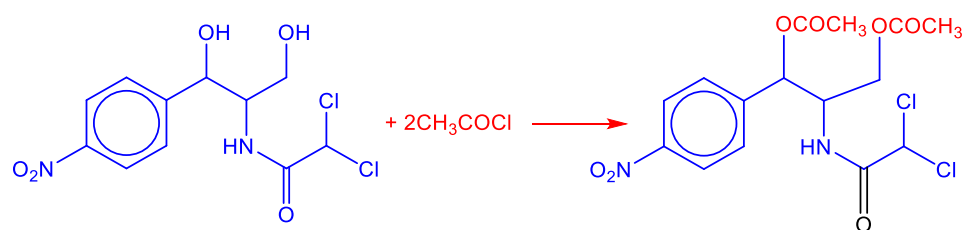
29 D



A: correct. It has 2 chiral carbon, hence 4 stereoisomers.



B: correct.



C: correct.

D: incorrect. No reaction.

- 30 C Since Z is a nonapeptide, it has the structure:
 (*N-terminus*) ____ - ____ - ____ - ____ - ____ - ____ - ____ - ____ - ____ (*C-terminus*)

Using the fragments obtained from the hydrolysis using the two enzymes:

Arg-Ile-

Arg-Ile-Ser-Lys-

Ser-Lys-Trp-Ile-

Trp-Ile-Lys-

Lys-Leu-Arg

Leu-Arg

Arg-Ile-Ser-Lys- Trp-Ile-Lys- Leu-Arg