Class Adm No

Candidate Name: _____

H

millennia institute

2025 Preliminary Examination
Pre-University 2

H1 CHEMISTRY **8873/01**
Paper 1 Multiple Choice **17 September 2025**

1 hour

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and admission number in the spaces provided at the top of this page and on the Multiple Choice Answer Sheet provided.

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 Multiple Choice Answer Sheet provided.

Read the instructions on the Multiple Choice 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 question paper.
The use of an approved scientific calculator is expected, where appropriate.

FOR EXAMINER'S USE	
TOTAL (30 marks)	

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

1 Which of the following statements about 1 mol of a gas is always correct?

A It has the same mass as any gas with 6.02×10^{23} molecules.

B It has the same number of atoms as 1 mol of hydrogen gas.

C It occupies the same volume as 1 mol of H_2S gas under the same conditions.

D It contains the same number of particles as $\frac{1}{12}$ g of ^{12}C.

C

- 1 mol of any gas occupies the same volume as each other, under the same conditions.

X Option A

- 6.02×10^{23} gas molecules ≡ 1 mole gas ≡ molar mass of the gas
- different gases have different molar masses.

X Option B

- the gas may exist as monatomic ⇒ has 6.02×10^{23} atoms
- H_2 gas consists of diatomic molecules ⇒ 1 mol H_2 gas ≡ 2 x 6.02×10^{23} atoms.

X Option D

For the 1 mol gas:

- if it were a monatomic gas ≡ 6.02×10^{23} atoms

- if it were a diatomic gas ≡ 2 x 6.02×10^{23} atoms

- if it were a tri-atomic gas ≡ 3 x 6.02×10^{23} atoms

Whereas:

$\frac{1}{12}$ g of $^{12}C \equiv \frac{1}{12} \div 12$ mol of ^{12}C

⇒ $\frac{1}{12}$ g of $^{12}C \equiv 0.00694$ mol of ^{12}C

⇒ 0.00694 mol of $^{12}C \equiv 0.00694$ x 6.02×10^{23} atoms of ^{12}C atoms

2 In an experiment, 50 cm^3 of a 0.1 mol dm^{-3} solution of a metallic salt reacts exactly with 25 cm^3 of 0.1 mol dm^{-3} aqueous sodium sulfite, Na_2SO_3. The half-equation for the oxidation of the sulfite ion is shown below:

$$SO_3^{2-}(aq) + H_2O(l) \longrightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$$

If the original oxidation number of the metal ion for the metallic salt is +3, what is the new oxidation number of the metal ion?

A +1 **B** +2 **C** +4 **D** +5

Amount of SO_3^{2-} = 25/1000 x 0.1 = 0.0025 mol
Amount of electrons lost by SO_3^{2-} = 0.0025 x 2 = 0.005 mol
Amount of electrons gained by metal = 0.005 mol
Amount of metal present = 50/1000 x 0.1 = 0.005 mol
Mole ratio of metal : electrons gained = 1:1
Every one mole of metal gained one mole of electron.
Final oxidation number of metal = +3 + (-1) = +2

3 A carbon-containing macromolecule contains a large amount of carbon, mainly of isotopes ^{12}C and ^{13}C. It was found that the relative atomic mass of carbon in the molecule is 12.2.

What is the ratio of ^{12}C to ^{13}C in the molecule?

A 3:1 **B** 4:1 **C** 3:4 **D** 1:4

Let the % abundance of ^{12}C be x.
Therefore, the % abundance of ^{13}C is (100-x).

12.2 = [12x + 13(100-x)] / 100
X = 80
Therefore ratio of ^{12}C to ^{13}C = 80:20 = 4:1

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

What does the ion $^{31}P^{3-}$ have in common with an ^{40}Ar atom?

A They have isoelectronic structures.

B Both have more neutrons than electrons.

C The electronic configuration of their valence electron shell is $2s^2\ 2p^6$.

D Both particles are deflected to the same extent when passed through an electric field with the same strength.

A

$^{31}P^{3-}$ ion has a total of (15+3) electrons = 18 electrons

^{40}Ar atom has a total of 18 electrons

$\Rightarrow$ $^{31}P^{3-}$ ion and ^{40}Ar atom have isoelectronic structure as each other.

X B

$^{31}P^{3-}$ ion has 18 electrons and 16 neutrons (31-15 = 16)

$\Rightarrow$ $^{31}P^{3-}$ has less neutrons than electrons $\Rightarrow$ B is incorrect.

X C

$^{31}P^{3-}$ ion and ^{40}Ar atom are Period 3 elements, their valence electron shell would be principal quantum shell 3 and not 2, i.e. valence shell electronic configuration is $2s^2\ 2p^6$.

X D

$^{31}P^{3-}$ ion is negatively charged and ^{40}Ar atom is electrically neutral, they will be deflected differently in an electric field. ^{40}Ar atom will not be deflected.

5 Elements **X** and **Y** have successive ionisation energies as shown:

	ionisation energies / kJ mol^{-1}						
	1st	2nd	3rd	4th	5th	6th	7th
X	787	1577	3232	4356	16091	19805	23780
Y	1310	3400	5300	7500	11000	13300	20300

What could be the formula of the compound of these two elements?

A $\mathbf{X_2Y_3}$ **B** $\mathbf{X_3Y_2}$ **C** **XY** **D** $\mathbf{XY_2}$

D

Element X: Group 14 element (4 valence e);
Element Y: Group 16 element (6 valence e)
$\therefore$ mole ratio X : Y = 1 : 2 $\Rightarrow$ formula is XY_2

6 What is the electronic configuration of an element with its first ionisation energy higher than each of the elements before and after it in the Periodic Table?

A $1s^2 2s^2 2p^2$

B $1s^2 2s^2 2p^3$

C $1s^2 2s^2 2p^4$

D $1s^2 2s^2 2p^5$

B
- All the electronic configurations given in the options, suggest the element is in Period 2 and they are in consecutive order, i.e. A Group 14, B is Group 15, C is Group 16 and D is Group 17.
- 1st IE of atoms will increase across Period 2 due to increase nuclear charge and insignificant change in electron shielding effect ⇒ effective nuclear charge causes stronger forces of attraction between the nucleus and the valence electron ⇒ higher 1st IE across Period 2 ⇒ 1st IE of Option A < 1st IE of Option B. 16 and D is Group
- 1st IE of Option C will be less than Option B because in C, there is greater inter-electronic repulsion than B ⇒ 1st IE of Option C < 1st IE of Option B.
- ∴ 1st IE Option A < 1st IE Option B > 1st IE Option C
⇒ Option B has higher 1st IE than either side of the elements beside it in the PT.

7 An element **R** has a giant molecular structure.

Which statements are true of **R**?

1 It has strong covalent bonds between the molecules.

2 It has high melting point.

3 It is insoluble in water.

4 It can conduct electricity in the solid state.

A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 3 and 4 only

C

X Option 1
- the strong covalent bonds in R, are between atoms and not molecules since R is an element.

√ Option 2
- melting involves breaking the strong covalent bonds between the atoms in R.
- Since R has extensive covalent bonds between the atoms, large amount of energy is required to break the covalent bonds ⇒ mp increases.

Alkene functional group undergoes addition reaction with H_2 in the presence of platinum catalyst.

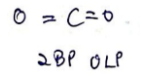
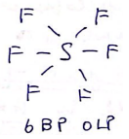
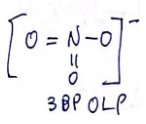
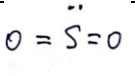
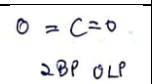
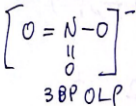
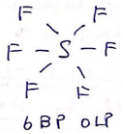
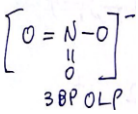
√ Option 3
- all macromolecular substances are insoluble in water.

X Option 4
- Element R is unknown, hence unable to determine if it can conduct electricity.

8 In which pair of chemical species, is the bond angle of I smaller than that in II?

	I	II
A	CO_2	SF_6
B	NO_3^-	SO_2
C	CO_2	NO_3^-
D	SF_6	NO_3^-

D

	I			II		
	Species	e⁻ domains	Shape & bond angle	Species	e⁻ domains	Shape & bond angle
A	CO_2		linear 180°	SF_6		octahedral 90°
B	NO_3^-		trigonal planar 120°	SO_2		bent < 120° (~117.5°)
C	CO_2		linear 180°	NO_3^-		trigonal planar 120°
D	SF_6		octahedral 90°	NO_3^-		trigonal planar 120°

9 The following are two observations made of cyclohexane, C_6H_{12}:

I	Cyclohexane is often used as a solvent for many organic compounds.
II	Cyclohexane is immiscible in H_2O.

Which of the following statements explain either of the above observations?

1 The C–H bonds in cyclohexane are stronger than the O–H bonds in H_2O

2 There are strong instantaneous dipole – induced dipole interactions between C_6H_{12} and the organic compounds.

3 The forces of interactions between C_6H_{12} and H_2O molecules are weaker than the hydrogen bonds in H_2O.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3 only

C

X Option 1
- strengths of the covalent bonds in C_6H_{12} and in H_2O have no impact on the use of C_6H_{12} as a solvent for organic compounds or C_6H_{12} miscibility in H_2O.

√ Option 2
- with strong id-id interactions between C_6H_{12} and organic compounds, makes C_6H_{12} a good solvent.

√ Option 3
- strong hydrogen bond interactions between H_2O molecules, means H_2O molecules will tend to “stick” to each other
- weak forces of interaction between C_6H_{12} and H_2O means these two substances do not mix well.

10 Which reaction is correctly represented with the stated type of standard enthalpy change of reaction?

	Reaction equation	Type of enthalpy change
A	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$	Enthalpy change of combustion
B	$H_2SO_4(aq) + Ca(OH)_2(aq) \rightarrow CaSO_4(s) + 2H_2O(l)$	Enthalpy change of neutralisation
C	$C(s) + O_2(g) \rightarrow CO_2(g)$	Enthalpy change of reaction
D	$\frac{1}{2}N_2(g) \rightarrow N(g)$	Bond energy

C

X A	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$	For ΔH_c^θ, should be $H_2O(l)$, liquid state at standard conditions, i.e. temp 298 K.
X B	$H_2SO_4(aq) + Ca(OH)_2(aq) \rightarrow CaSO_4(s) + 2H_2O(l)$	For ΔH_n^θ, there should be in 1 mol H_2O produced and not 2 mol H_2O.
√ C	$C(s) + O_2(g) \rightarrow CO_2(g)$	For ΔH_c^θ of C, all state symbols in the equation are correct, at temp 298 K.
X D	$\frac{1}{2}N_2(g) \rightarrow N(g)$	BE is the breaking of 1 mol covalent bond in 1 mol gaseous molecule.

11 The lattice energies, cationic and anionic radii in KF and CaO are given as follows:

	Lattice energy / kJ mol^{-1}	Ionic radius of cation / nm	Ionic radius of anion / nm
KF	-830	0.138	0.136
CaO	-3530	0.099	0.140

Which statement best explains the difference in their lattice energies?

A The forces of attraction between the ions in KF is stronger than that in CaO.

B The inter-ionic distance in KF is larger than in CaO.

C Both KF and CaO have the same total number of electrons in one mole of the compound.

D KF has a higher degree of covalent character than CaO.

B

- Lattice energy (strength of ionic bond) $\propto \left|\frac{q_+ q_-}{r_+ + r_-}\right|$

- LE (KF) $\propto \left|\frac{1 \text{ x } 1}{0.138+0.136}\right| \Rightarrow$ LE (KF) $\propto \left|\frac{1}{0.274}\right|$

LE (CaO) $\propto \left|\frac{2 \text{ x } 2}{0.099+0.140}\right| \Rightarrow$ LE (CaO) $\propto \left|\frac{2}{0.239}\right|$

$\Rightarrow \left|\frac{1}{0.274}\right| < \left|\frac{2}{0.239}\right| \Rightarrow \therefore$ LE (KF) < LE (CaO)

X A
- the stronger the attractive forces between the ions $\Rightarrow$ more exothermic LE
- from the data given:
  LE (KF) = - 830 kJ mol^{-1}; LE (CaO) = - 3530 kJ mol^{-1}

$\Rightarrow$ LE (KF) less exothermic than LE (CaO)

Lattice energy (strength of ionic bond) $\propto \left|\frac{q_+ q_-}{r_+ + r_-}\right|$

- in KF: $|(q+) \text{ x } (q-)| = 1$
  in CaO: $|(q+) \text{ x } (q-)| = 4$

$\Rightarrow$ strength of ionic bonds in CaO (doubly charged ions) is 4x that of singly charged ions in KF.

X C
- both 1 mol KF and 1 mol CaO have a total (28 x L) no. of electrons in them; is a fact but does not explain magnitude of LE.

X D
- charge density of Ca^{2+} > charge density of K^+ ion and
- O^{2-} electron cloud size > electron cloud size of F^-

$\Rightarrow O^{2-}$ ion more easily polarised than F^- ion $\Rightarrow$ CaO has greater covalent character.

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

A student carried out an experiment to determine the enthalpy change of combustion of ethanol (M_r = 46.0). It was found that the combustion of 1.00 g of ethanol raises the temperature of 100 g of water by 43 °C.

Given that the enthalpy change of combustion of ethanol is –1370 kJ mol^{-1}, what is the percentage efficiency of the heat transfer process?

A 97 % **B** 81 % **C** 60 % **D** 46 %

C

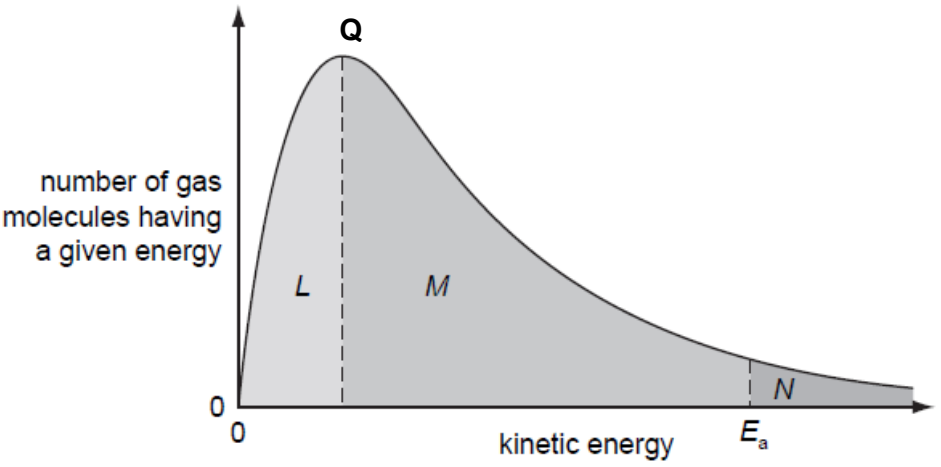
M_r Ethanol (CH_3CH_2OH; C_2OH_6)) = (2x12) + 16 + 6 = 46

Experimental Enthalpy change of combustion = $-\frac{q}{n} = -\frac{m \text{ x } c \text{ x } \Delta T}{n}$

$= -\frac{(100)(4.18)(43)}{(\frac{1}{46})} = -828.2$ kJ mol^{-1}

Efficiency = $\frac{(828.2)}{(1370)} \times 100 = 60.4\% = 60\ \%$

13 The Maxwell-Boltzmann Energy distribution graph shows the number of molecules having a particular kinetic energy at constant temperature.



Which statement is correct?

A As temperature decreases, the total area under the curve remains the same.

B At a higher temperature, area *N* decreases.

C At lower temperature, the proportion of molecules in *L* and *M* increases and E_a becomes higher.

D As temperature increases, the maximum point **Q** shifts to the left.

A

- Area under the curve in the Maxwell-Boltzmann graph, represents the no. of reacting molecules present. This total no. of molecules will not change with changing temperature, or decreasing temperature.

X Option B

- at higher temperature, more molecules have greater KE, area under N **increases**

X Option C

- at lower temperature, more molecules have lower KE, thus proportion of molecules in L and M increases But, ***E*$_a$ does not change**. E_a is affected by presence of catalyst.

X Option D

- at higher temperature, the maximum point **Q** shifts to the right.

14 Platinum is a material used as a catalyst in a catalytic converter. It is used in the form of nanoparticles. These nanoparticles can exhibit enhanced chemical reactivity, making them useful in catalysis and other chemical processes.

Which statement about the platinum catalyst is correct?

A Less sites are available for catalysis to occur in spherical nanoparticles with a smaller diameter.

B Nanoparticles of platinum are used since they have a large surface area to volume ratio.

C Platinum nanoparticles react with nitrogen oxide to form nitrogen and platinum oxide.

D The platinum catalyst helps to remove pollutants such as carbon dioxide gas from the exhaust.

B

Reactions in Catalytic Converter:

$2NO(g) + 2CO(g) \rightarrow 2CO_2(g) + N_2(g)$

$NO_2(g) + 2CO(g) \rightarrow 2CO_2(g) + ½\ N_2(g)$

$CO(g) + ½O_2(g) \rightarrow CO_2(g)$

$C_xH_y(g) + (x + \frac{y}{4})O_2 \rightarrow xCO_2(g) + \frac{y}{2}H_2O(g)$

X Option A

- Smaller particles have a larger surface area to volume ratio and hence larger surface area and more active sites for the reactants to be adsorbed / catalysis to occur.

X Option C

- Nitrogen oxide reacts with CO and is reduced to harmless nitrogen gas.
- Pt particles are the catalyst and do not chemicall react with NO.

- solid Pt metal catalysts provide sites for adsorption of chemicals, they should remain chemically unchanged by the end of catalysis after products desorb.

X Option D

- Carbon dioxide is not removed from the catalytic converter. But it is produced during the catalysis reaction.
- Carbon dioxide though is a greenhouse gas and harmful to environment, it is less toxic than the carbon monoxide in untreated exhaust gas.

15 Hydrogen peroxide reacts with acidified iodide ions and produces iodine according to the equation shown.

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

The following results were obtained.

	initial concentrations of reactants / mol dm^{-3}			initial rate of formation of I_2 / mol dm^{-3} s^{-1}
Experiment	$[H_2O_2]$	$[I^-]$	$[H^+]$	
1	0.010	0.010	0.10	2.0×10^{-6}
2	0.030	0.010	0.10	6.0×10^{-6}
3	0.030	0.020	0.10	1.2×10^{-5}
4	0.030	0.020	0.20	1.2×10^{-5}
5	0.020	0.020	0.020	unknown

What is the initial rate of formation of I_2, in mol dm^{-3} s^{-1} for Experiment 5?

A 6.4×10^{-11}

B 3.2×10^{-9}

C 1.6×10^{-7}

D 8.0×10^{-6}

D

- From expt 1 and 2, when $[H_2O_2]$ triples, keeping concentration of other reactants constant, the rate of reaction triples. Hence order of reaction wrt $[H_2O_2]$ is 1.
- From expt 2 and 3, when $[I^-]$ doubles, keeping concentration of other reactants constant, the rate of reaction doubles. Hence order of reaction wrt $[I^-]$ is 1.
- From expt 3 and 4, when $[H^+]$ doubles, keeping concentration of other reactants constant, the rate of reaction remains constant. Hence order of reaction wrt $[H^+]$ is 0.
- overall rate equation: rate = $k[H_2O_2][I^-]$, i.e. overall is second order.

- Using data from expt 1,
rate = $k[H_2O_2][I^-]$
$2.0 \times 10^{-6} = k(0.010)(0.010)$
$k = 0.02$ mol^{-1} dm^3 s^{-1}

- When $[H_2O_2]$, $[I^-]$ and $[H^+]$ are 0.020 mol dm^{-3} respectively,
rate = $k[H_2O_2][I^-]$
$= 0.02 \times 0.020 \times 0.02$
$=$ **8.0×10^{-6} mol dm^{-3} s^{-1}**

√ Option D
- When $[H_2O_2]$, $[I^-]$ and $[H^+]$ are 0.020 mol dm^{-3} respectively,
rate = $k[H_2O_2][I^-]$
$= 0.02 \times 0.020 \times 0.02 = 8.0 \times 10^{-6}$ mol dm^{-3} s^{-1}

16 Which statement about the reversible reaction, **S** ⇌ **T**, is correct when the system is at equilibrium?

A The concentrations of **S** and **T** are constant.

B The rates of the forward and reverse reactions are equal to zero.

C The rate constants of the forward and reverse reactions are equal.

D The concentrations of **S** and **T** are equal.

A

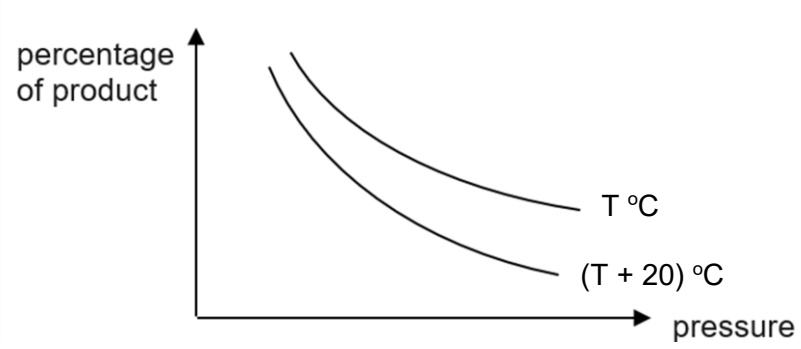
- At dynamic equilibrium, concentrations of reactants, **S**, and products, **T**, remain constant.

X Option B
- At dynamic equilibrium, rate of forward reaction equals to rate of backward reactions remain constant and is not zero. Zero rate of reaction means the reaction has stopped.

X Option C
- the rates of forward reaction and reverse reaction are equal but the rate constants need not be equal.

X Option D
- At dynamic equilibrium, concentrations of reactants and products remain constant. But the concentrations of reactants and products need not be equal.

17 The graph below shows how the percentage of product present at equilibrium varies with temperature and pressure for a reaction.



Which reaction could be represented in the graph above?

A $2NO_2(g) \rightleftharpoons N_2O_4(g)$ $\Delta H = -57$ kJ mol^{-1}

B $2C(s) + O_2(g) \rightleftharpoons 2CO(g)$ $\Delta H = -222$ kJ mol^{-1}

C $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$ $\Delta H = +107$ kJ mol^{-1}

D $NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$ $\Delta H = +176$ kJ mol^{-1}

B

- From the graph, when temp increases, equilibrium shifts left, because % products decreases ⇒ reaction is exothermic. ⇒ Options A or B are correct.

- From the graph, when pressure increases (with reference to either T °C or (T+20) °C graph), % product decreases
⇒ total mol of gaseous product > total mol gaseous reactants. ⇒ Option B correct.

18 The rate constant, *k*, of a reversible reaction are as shown below.

$$\text{reactants} \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} \text{products} \qquad \Delta H < 0$$

Which change(s) would cause both rate constants, k_1 and k_{-1} to be increased?

1 Increasing the concentrations of the reactants.

2 Increasing temperature of the equilibrium mixture.

3 Adding a catalyst.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

C

X Option 1, increasing concentrations of the reactants will increase only k_1.

√ Option 2, when the rxn reaches equilibrium, increasing temperature increases both forward and backward rates of rxn, because all chemical species gain kinetic energy, and will increase frequency of effective collision resulting in rates of both forward and backward rxns; (otherwise increase in temp before equilibrium is reached of a reversible reaction, will increase forward rxn of an endothermic reaction).

√ Option 3, presence of catalyst, speeds up the rate at which equilibrium is reached.

19 Which of the following underlined species is acting as a Brønsted base?

A $\underline{HSO_4^-} + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$

B $NH_3 + \underline{H_2O} \rightleftharpoons NH_4^+ + OH^-$

C $H_3PO_4 + \underline{CH_3NH_2} \longrightarrow H_2PO_4^- + CH_3NH_3^+$

D $\underline{HNO_2} + HCO_2^- \longrightarrow NO_2^- + HCO_2H$

C

Brønsted base is a proton acceptor.

$\underline{CH_3NH_2}$ accepts a proton to become $\underline{CH_3NH_3^+}$

All other options, A, B and D, the underlined substances, behaves as Bronsted acids. i.e. proton donors.

20 Human plasma is buffered mainly by dissolved CO_2 which has reacted to form carbonic acid.

The equation shows the dissociation of carbonic acid in human plasma:

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$$

The pH of human plasma is usually 7.4.

Which statement is correct?

A The pH of human plasma increases when the equilibrium of the dissociation reaction shifts to the right.

B With the slight surge in acidic materials in the human plasma, there will be an immediate decrease in concentration of the conjugate base, HCO_3^- in the plasma.

C The pH of human plasma tends to increase when it is diluted with large amount of water.

D This buffer system can be prepared by mixing varying amounts of sodium carbonate and potassium carbonate.

B

X Option A

As pH increases, i.e. pH > 7.4,

$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$

$\Rightarrow$ $[H_3O^+]$ decreases, $\Rightarrow$ POE shifts left

√ Option B

$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$

Surge in acidic materials, the conjugate base, $HCO_3^-(aq)$ will react with the acid to neutralise it, and maintain pH of plasma to be relative constant. This is how the buffer system of H_2CO_3/HCO_3^- works.

X Option C

When the buffer mixture is added with large amount of water, POE will shift to the right $\Rightarrow$

$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$ (favours forward rxn)

The overall $[H_3O^+]$ increases, pH will decrease.

X Option D
Addition of two weak bases, carbonate salts, will not give rise to the buffer solution.

21 Period 3 elements exhibit trends in their properties.

Which trend in the following properties is **true** across the period?

A Electronegativity decreases.

B Covalent character in their chlorides decreases.

C Electrical conductivity increases.

D First ionisation energy increases.

D

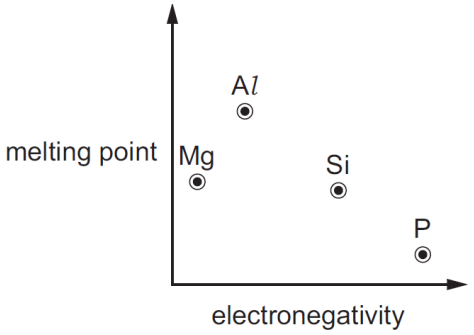
√ Option D
- Across period, nuclear charge increases, electron shielding effect insignificant increase, thus effective nuclear charge increases
⇒ stronger electrostatic forces of attraction between valence electron and nuclear charge (protons in nucleus) ⇒ higher energy is needed to remove the first mole electrons, i.e. 1st IE increases across the period.

X Option A; Option C
Across the period, elements change from being metallic to non-metallic
⇒ electronegativity increases across the period; and
⇒ non-metallic elements are poor electrical conductors.

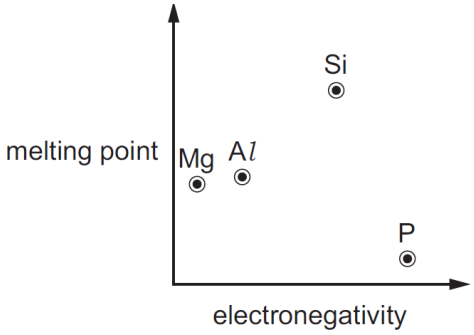
X Option B
Metal chlorides are ionic in character but $AlCl_3$ is covalent in character and non-metallic chlorides are covalent in nature
⇒ covalent character of chlorides increases across the period 3.

22 Which graph correctly shows the relative melting points of the elements Mg, Al, Si and P plotted against their relative electronegativities?

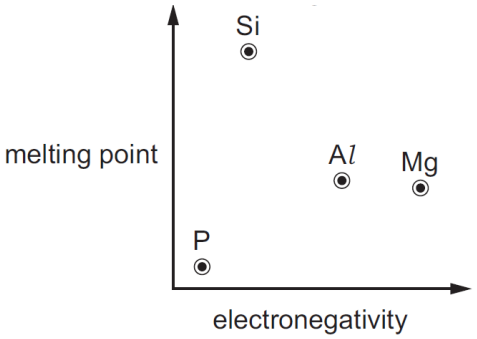
A



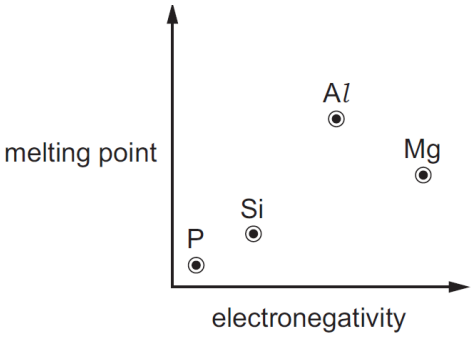
B



C



D



B

Electronegativity: Mg < Al < Si < P
(increased nuclear charge but approximately constant electron shielding across period)
⇒ Options A or B.

Melting point: P_4 < Mg < Al < Si
- melting in P_4, involves overcoming id-id intermolecular forces of attraction;
- melting Mg and Al, involves overcoming metallic bonding; Al has more delocalised electron for every 1 mole Al atom compared to Mg ⇒ mp Al > mp Mg.
- melting Si, involves overcoming strong exgtensive covalent bonds in Si macromolecular structure.
- comparing mp: P4 < Mg < Al < Si ⇒ Option B.

(melting phosphorus involves overcoming id-id interactions between P_4 molecules, which require significantly less energy than for the metallic bonds in Mg and Al. Si has the highest melting point due to its strong covalent bonds between Si atoms in the giant molecular structure)
⇒ reject option A.

23 Astatine is the element below iodine in Group 17 of the Periodic Table.

Which statements about astatine are correct?

1 Astatine is less electronegative than iodine.

2 Astatine can oxidise chloride ion to chlorine molecules.

3 The bond length of H−I is longer than H−At.

4 Thermal decomposition of HAt requires lower energy than HC*l*.

A 1 and 4 only

B 2 and 3 only

C 1, 2 and 3 only

D 3 and 4 only

A

√ Option 1
Down group 17,
- nuclear charge and shielding effect increase.

As the number of electronic shells increases,
- distance between the nucleus and the bonding electrons increases,
- electrostatic attraction between the nucleus and the bonding electrons decreases.
- hence electronegativity decreases.

Since astatine is below iodine in Group 17, hence, Astatine is less electronegative than iodine.

X Option 2
At_2 lower down in group 17,
- more difficult for At_2 to gain electrons to form its anion
- more difficult for At_2 to be reduced
- oxidising power (reactivity) of At_2 decreases

⇒ astatine is below chlorine in Group 17, astatine cannot oxidise chloride ions to chlorine.

X Option 3
Down Group 17,
- there is less effective orbital overlap between the 1s orbital of hydrogen and the valence p orbital of the halogen (as the size of the halogens gets bigger and the valence orbital used for bonding is more diffuse).
- bond length HI < HAt

√ Option 4
Ease of thermal decomposition of the hydrogen halides (HX) is related to the H–X bond strength and its bond length, the longer the bond length ⇒ easier to thermally decompose i.e. requires less energy.

bond strength: H–C*l* > H-At
bond length: H–C*l* < < H-At
⇒ energy needed for thermal decomposition HAt < HC*l*

24 Which of the following is the IUPAC name for the compound, $C(CH_3)_3OH$?

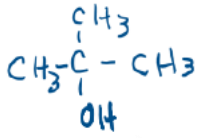
A 1,1-dimethylethanol

B 1,2-dimethylethanol

C 2,2-dimethylethan-2-ol

D 2-methylpropan-2-ol

D

$C(CH_3)_3OH$	 Name: 2-methylpropan-2-ol

25 A reaction occurs when a sample of 1-chloropropane is heated under reflux with sodium hydroxide dissolved in ethanol.

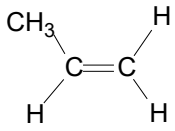
Which row is correct?

	type of reaction	name of product
A	elimination	propan-1-ol
B	elimination	propene
C	substitution	propan-1-ol
D	substitution	propene

B

Difference in the solvent results to different type of reaction occurring to halogenoalkanes.

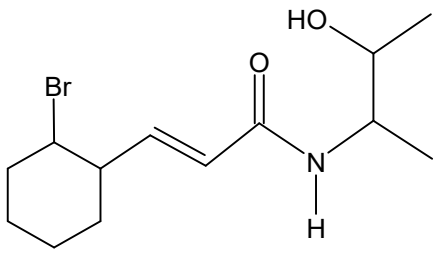
In ethanolic NaOH: Elimination reaction takes place to form alkene.

Elimination $CH_3CH_2CH_2Cl \xrightarrow[\text{heat}]{\text{NaOH/ethanol}}$ 

In aqueous NaOH: substitution reaction takes place to form alcohol.

Substitution $CH_3CH_2CH_2Cl \xrightarrow[\text{heat}]{\text{NaOH(aq)}} CH_3CH_2CH_2OH$

26 Compound **L** has the following structure.



L

Which statements about compound **L** are correct?

1 It can undergo addition with H_2, with platinum as the catalyst.

2 It undergoes hydrolysis when heated with aqueous NaOH.

3 It undergoes reduction with $NaBH_4$.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

A

√ Option 1
Alkene functional group undergoes addition reaction with H_2 in the presence of platinum catalyst.

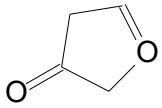
√ Option 2
Amide functional group is hydrolysed with aq NaOH with heat to form an amine and a carboxylic acid compounds.

X Option 3
Absence of ketone or aldehyde functional group that can be reduced by $NaHB_4$.

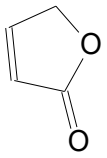
27 When $CH_2(OH)CH=CHCO_2H$ is warmed with a little concentrated sulfuric acid, a cyclic compound is formed.

What is the skeletal formula of the cyclic compound?

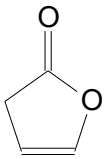
A



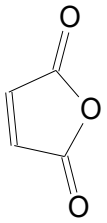
B



C

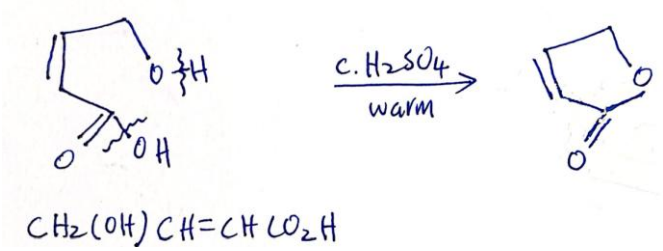


D



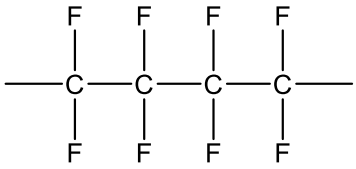
Answer: B

The presence of carboxylic acid and alcohol will result in condensation reaction in the presence of warm conc H_2SO_4.



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

A short section of the chain in the addition polymer Teflon™ is shown.

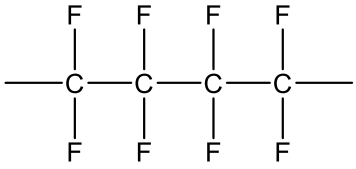


The M_r of a typical molecule of Teflon™ is approximately 200 000.

How many carbon atoms are joined together to make this typical polymer molecule?

A 2000 **B** 2800 **C** 4000 **D** 8400

C

From the structure:  it is deduced the monomer is 1,1,2,2-tetrafluoroethene $CF_2=CF_2$.

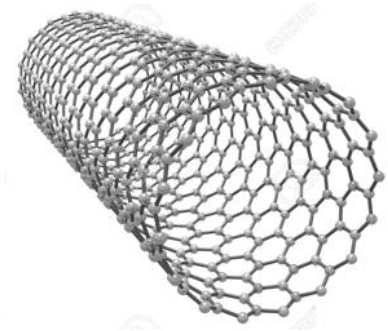
M_r of monomer $CF_2=CF_2$ = (2x12.0) + (4x19.0) = 100

M_r of TeflonTM = 200 000

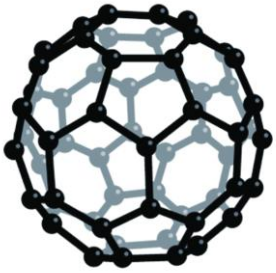
Amount of monomer $CF_2=CF_2$ = $\frac{200\ 000}{100}$ = 2000 mol

Each monomer $CF_2=CF_2$ molecule has 2 C atoms
$\Rightarrow$ total no. of C atoms = 2000 x 2 = 4000

29 Carbon nanotubes are produced by rolling graphene sheets that are used to generate electricity in solar panels. Another allotrope of carbon, buckminsterfullerenes, are spherical football-like structures that are used in lubricants.



carbon nanotube



buckminsterfullerene

Which of the following properties explains the uses of each allotrope?

	carbon nanotube	buckminsterfullerene
A	delocalised electrons	strong covalent bonds within each molecule
B	delocalised ions	strong covalent bonds within each molecule
C	delocalised electrons	weak forces of attraction between molecules
D	delocalised ions	weak forces of attraction between molecules

C

- to be able to generate electricity, and carbon nanotubes are formed from graphene, a macromolecular substance which is made of atoms of the same element, covalent bonds between the atoms, the electrical conductivity has to be due to delocalised electrons and not mobile ions.
⇒ Options A or C.

- to be used as a lubricant, there would be weak forces between molecules that can be overcome, so that the layers or molecules could slide over each other.
⇒ Option C.

30 Which statement is **not** true?

A Graphene is a nanomaterial.

B Nanoparticles exhibit chemical properties different from its bulk material.

C Nanomaterials have all three dimensions from 1 to 100 nm.

D Due to the small particle size, nanoparticles are used as materials to deliver medication in humans.

C (not true statement)
- Nanoparticles have dimensions of 1 to 100 nm while nanomaterials is considered as the bulk material of the nanoparticles

Option A (True statement)

Option B (True statement)
- Nanoparticles have high surface area to volume ratio, thus nanoparticles exhibit different chemical properties from its bulk material.

Option D (True statement)
- Due to the small particle size, nanoparticles can travel in the blood stream, hence is used to deliver medication in humans.

END OF PAPER

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